Raw materials scoreboard

European Commission

European Innovation Partnership on Raw Materials

Raw Materials Scoreboard

GROW

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

Project coordination (European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs): Lie Heymans and Patrice Millet.

Main authors (European Commission, Joint Research Centre): Beatriz Vidal-Legaz, Lucia Mancini, Gian Andrea Blengini, Claudiu Pavel, Alain Marmier, Darina Blagoeva, Cynthia Latunussa, Philip Nuss, Jo Dewulf, Viorel Nita, Yildirim Kayam, Simone Manfredi, Armin Magyar, Patrícia Dias, Claudia Baranzelli, Evangelos Tzimas and David Pennington.

Comments and input can be sent by email to: GROW-EIP-RAW-MATERIALS@ec.europa.eu

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.

Luxembourg: Publications Office of the European Union, 2016

(print): ISBN 978-92-79-61699-0 doi:10.2873/85546 ET-04-16-759-EN-C
(pdf): ISBN 978-92-79-61700-3 doi:10.2873/686373 ET-04-16-759-EN-N

Cover picture: © APimages

Printed in Italy

Printed on recycled paper

European
Innovation
Partnership
on Raw
Materials

Raw Materials Scoreboard

Foreword

Raw materials are the lifeblood of the EU economy. Ensuring their secure supply is essential for the competitiveness of EU industries.

In view of the importance of raw materials to the EU economy, in 2008 the EU adopted the Raw Materials Initiative, the aim of which is to secure the supply of raw materials. Furthermore, the launch of the European Innovation Partnership (EIP) on Raw Materials in 2012 sent a signal that the EU considers the supply and use of raw materials a strategic challenge. The EIP is a stakeholder platform that brings together a strong raw materials community with representatives from the industry value chains, public services, academia and NGOs. Since its mission is to provide high-level guidance to the European Commission, Members States and private actors on innovative approaches to the challenges related to raw materials and to accelerate the take-up of innovations, the EIP has a strong role to play in the EU's raw materials policy framework.

We are pleased to present the first edition of the EU Raw Materials Scoreboard, an initiative of the EIP that was prepared in fruitful collaboration between DG Internal Market, Industry, Entrepreneurship and SMEs and the Commission's Science and Knowledge service, the Joint Research Centre. The Scoreboard provides an overview of challenges and opportunities along the entire raw materials value chain. It highlights the importance of raw materials to the EU economy and to jobs and growth in particular. For example, looking at the metals value chain the Scoreboard finds that more than 11 million jobs in sectors such as electronics manufacturing, automotive and machinery (equal to 40 % of the jobs and value added from the EU's entire manufacturing sector) depend on the secure supply of raw materials.

The Raw Materials Scoreboard presents relevant and reliable information that can be used in policymaking in a variety of areas. It will be also used to monitor progress towards a circular economy, the recently adopted Action Plan from the European Commission to boost global competitiveness, foster sustainable economic growth and generate new jobs via the use of resources in a more sustainable way. The Scoreboard is an integral part of the Raw Materials Information System, a cornerstone of the EU's knowledge base on raw materials.

In sum, the Raw Materials Scoreboard clearly demonstrates the continued relevance of EU raw materials policy. To ensure its security of supply the EU needs to keep investing in the diversification of supply, improve framework conditions for domestic production and stimulate the circular use of raw materials in the economy.

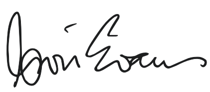
Brussels, July 2016

Vladimír Šucha

Director-General Joint Research Centre

Lowri Evans

Director-General DG Internal Market,
Industry, Entrepreneurship and SMEs



Contents

Executive summary

Introduction

The Raw Materials Scoreboard gives an overview of the challenges related to raw materials

The Raw Materials Scoreboard is **an initiative of the European Innovation Partnership (EIP) on Raw Materials**. Its **purpose** is to provide quantitative data on the EIP's general objectives and on the raw materials policy context. It presents relevant and reliable information that can be used in policymaking in a variety of areas. The Scoreboard will for example be used **to monitor progress towards a circular economy**, a crucial issue on which the European Commission recently adopted an ambitious Action Plan. The Scoreboard will be published **every two years**.

The Scoreboard consists of **24 indicators** grouped into **five thematic clusters** (see Figure 1). All indicators are based on best-available data and are considered to meet the 'RACER criteria', i.e. they are considered to be relevant, accepted, credible, easy to compute and understand and robust.

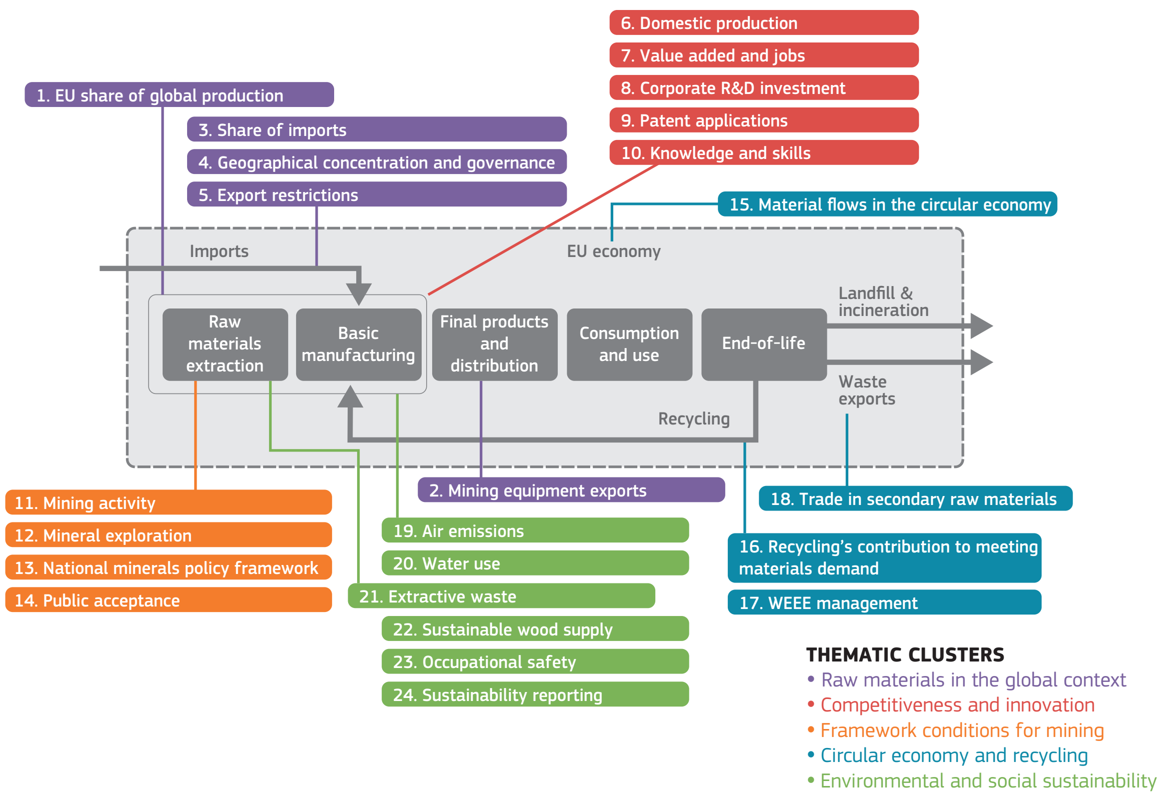
Throughout human history, raw materials have played an essential role in increasing human comfort

Raw materials are the **basic inputs** that are used to produce all possible objects. Throughout **human history**, from the Bronze Age through the Industrial Revolution to our current interconnected world, raw materials have played an essential role in **increasing human comfort**.

The **20th century** saw a shift from agrarian to industrialised societies, together with a growing world population and changing consumption patterns. This led to a significant **increase in global demand for raw materials**. Projections of **future trends** indicate that **resource use could double** between 2010 and 2030, mostly driven by demand in developing regions.

Raw materials are also essential for sustainable development. For example, **low-carbon technologies** are necessary for the EU to meet its climate and energy objectives. The production of these technologies is expected to see the demand for certain raw materials increase by a factor 20 by 2030.

Figure 1: The Raw Materials Scoreboard at a glance



Rising demand at global level has significant consequences for the security of supply in the EU

This rising demand for raw materials has significant **consequences for the EU economy's security of supply**. **Planning cycles** — the time between the exploration of a mineral deposit and the development of a mine — can take up to 10 years or more. Because of such **long cycles, raw materials supply cannot always be increased in the short term**. Similarly there are also limits to increasing raw materials production from **secondary raw materials**, as this depends for example, on the amount of products that reach their end of life and become available for recycling. As a result, **when demand exceeds supply, prices spike**. This drives up production costs for downstream industries. If, on the other hand, commodity prices drop, long-term investments are put on hold, which negatively affects future production capacity.

The EU is taking action to ensure the security of supply

In view of the importance of raw materials for the EU economy, in 2008 the EU adopted the **'Raw Materials Initiative'**. This policy strategy is based on sustainable sourcing of raw materials from global markets, sustainable domestic raw materials production, and on resource efficiency and supply of secondary raw materials.

The European Innovation Partnership on Raw Materials brings together a wide variety of stakeholders

In addition, the European Commission also launched **the European Innovation Partnership on Raw Materials**. This is a **stakeholder platform** that brings together representatives from industry, public services, academia and NGOs. It covers all non-energy, non-agricultural raw materials (i.e. metals, minerals and biotic materials) and provides high-level **guidance** on innovative approaches to the challenges related to raw materials.

Bringing together various players is important, because raw materials supply is characterised by **interlinked complex value chains**. Therefore raw materials production processes should not be considered in isolation. Even small regulatory changes can have an impact far beyond the process or market that was targeted.

Raw materials in the global context

Raw materials production is increasingly shifting to other regions

The European Union is the world's third biggest producer of industrial minerals, after Asia and North America. For roundwood the EU's share of global production is estimated to be close to 20 %. However, because of the growth of the global market **the EU's share of global production has decreased significantly**. **For metals production, this trend started in the middle of the 19th century**, when production began to move to other regions. In the 1850s, Europe accounted for more than 50 % of global production, but in 2009 its share was less than 5 % (Indicator 1).

Nonetheless, thanks to its long-standing mining history, **the EU is still one of the world's largest producers and net exporters of mining equipment**. Since the 2000s however, **China** has moved from being a net importer to a net exporter and has become a significant world player. This trend is driven by the nature of mine ownership, low production costs and the availability of knowledge and skills (Indicator 2).

The EU is highly import-dependent for certain raw materials, which poses a risk to its security of supply

The EU economy requires a wide variety of raw materials and not all of them can be produced domestically. While the EU is close to being **self-sufficient** for non-metallic minerals and wood, it is **highly dependent** on imports for metals, certain minerals and natural rubber.

Import dependency for certain materials considered to be critical for the EU economy is close to 100 % (Indicator 3). This dependency becomes problematic for raw materials for which the production is **highly concentrated in only a few countries**, especially when the quality of governance in these countries is low (Indicator 4). The increasing use of **export restrictions** has also highlighted how geographical concentration can lead to unexpected price hikes (Indicator 5).

Competitiveness and innovation

Domestic raw materials production provides a reliable supply of inputs to downstream manufacturing industries and creates EUR 280 billion of added value and more than four million jobs

Domestic production of raw materials is **an essential part of the EU economy.** It provides **a reliable supply of inputs to many downstream industries** (e.g. automotive, chemicals, and electronics manufacturing).

Domestic extraction of **construction minerals and harvesting of wood** has increased since the 1970s, allowing the EU to remain more or less self-sufficient. Domestic extraction of **industrial minerals** on the other hand stagnated in the 1980s, and for **metals** — in spite of an exponential increase in demand — it even decreased slightly. Further down the value chain data show that **the EU processes more raw materials than it extracts**. This difference can be explained by imports and recycling. Unfortunately **no comprehensive data exist on secondary raw materials production in the EU**, for which there are indications that the EU is in a strong position to become a global leader (Indicator 6).

More than 11 million jobs in manufacturing industries depend on the secure supply of raw materials

Taken together, raw materials industries in 2012 provided **EUR 280 billion of added value** and **more than four million jobs**. However, the economic importance of the raw materials sector goes far beyond the economic activities strictly related to the extractive and processing industries. Looking at the metals value chain alone, **the secure supply of raw materials is essential for jobs in downstream manufacturing sectors.** These include the production of fabricated metal products, electronics, and machinery and equipment. It is estimated that **more than 11 million jobs** are affected, equal to 40 % of the jobs and value added from the EU's entire manufacturing sector (Indicator 7).

While corporate R&D investment has doubled over a 10-year period, the EU's number of patent applications is in decline

Innovation is essential for the EU **to remain competitive internationally**. Despite being an industry of low R&D intensity, **top R&D investor companies in the raw materials sector have almost doubled their annual R&D expenditure since 2003**. Between 2003 and 2013, it grew more than twice as fast as public R&D investments (Indicator 8).

EU patent applications in the raw materials sector on the other hand show a **decreasing trend**. Nevertheless, in 2011, the EU still accounted for **36 %** of patent applications filed by the EU, Australia, Canada, Japan, Russia and the USA together (Indicator 9).

An increasing talent shortage may also threaten the EU's future ability to innovate

Finally, to be able to stay at the forefront of innovation, the EU needs the necessary **knowledge and skills** or skilled workforce. At global level, more than 90 % of **mineral processing graduates** are reported to be educated in Asia, Africa, and South and Central America. The figure for Western Europe is less than 1 %. Data also indicate that the number of **educational programmes** in the EU relevant to raw materials is in decline. The mining and minerals sector in particular is already reported to be suffering from a significant **talent shortage** (Indicator 10).

Framework conditions for mining

There is a significant potential to increase mining and exploration activities in the EU

Looking more closely at **metal mining,** it can be seen that **several metallic raw materials are mined in the EU**. Indeed, the EU has the potential to increase the current production or start new production units. Nevertheless, domestic extraction of metals is largely insufficient to meet the EU's raw materials demand (Indicator 11).

Looking at **mineral exploration activities**, data suggest that **the EU's minerals potential is under-explored and under-exploited**. Mineral exploration is an important step in the mining life cycle because it contributes to the discovery of potential new deposits and the opening of new mines. These activities also represent **a low level of investment**, in spite of the mineral potential in the EU. Furthermore, in recent years, **investment in metallic minerals exploration has steadily decreased**, both in the EU and globally (Indicator 12).

Inadequate national policy frameworks for minerals and low levels of public acceptance can put a brake on mining activities

Institutional framework conditions — national minerals policies, data on mineral endowments, environmental regulations, public acceptance etc. — can either **impede or expedite the development of mining operations.** The **policy framework and regulatory structure** in particular are important factors that affect the EU's **attractiveness to mining operations**. According to mining company managers, **the minerals policy framework of EU Member States varies widely**. The low scores received by some Member States can be attributed to uncertainties concerning the administration of current regulations, which makes long-term planning of mining operations difficult; lack of enforcement of existing regulations; and regulatory duplication (Indicator 13).

Public acceptance is another factor that greatly affects mining companies' operations. Data show that **public acceptance in the EU of extractive activities is low** as compared with other economic sectors. Compared with countries outside the EU, **the EU general public has little trust that extractive companies make efforts to behave responsibly** (Indicator 14).

Circular economy and recycling

The circular use of raw materials in the economy is relatively low, mostly due to technical limitations to recycling and because demand for raw materials to build infrastructure is higher than what can be met through recycling

Moving from the traditional, linear 'make, use, dispose' economy to a circular economy requires increased **reuse, remanufacturing and recycling of products.** This is an important aspect of the EU's strategy to ensure the **security of supply**. Data indicate that **the circular use of raw materials in the EU economy is relatively low** yet slightly higher than the global average. More than half of the EU's materials use consists of **construction materials**, which are used in **long-life, in-use stocks**. These stocks often provide value to the EU economy for decades and will only become available for recycling when they have reached their end of life.

Demand for raw materials, for example to make long-life products and to build infrastructure, exceeds the amount of materials that can be supplied from recycled materials, as raw materials are being added to productive stocks in larger volumes than what is being decommissioned. As long as this remains the case, **primary extraction will remain necessary**. Nevertheless, the circular use of raw materials in the EU economy could be improved by extending the life time of products – for example through repair and reuse – or by increasing end-of-life recycling rates for materials and products (Indicator 15).

Recycling rates for certain materials are relatively high (e.g. for some widely used metals). However, for most materials, **recycling's contribution to meeting materials demand is relatively low**. This is because **demand** is higher than what can be met by recycling, or because **high-quality recycling** is not yet technically or economically feasible (Indicator 16).

Differences in waste management across Member States indicate the potential to increase resource efficiency and to recover valuable raw materials

The **management of waste from electrical and electronic equipment (WEEE)** provides interesting insights into **the EU's potential to recover valuable raw materials**. Electrical and electronic waste is one of the fastest growing waste streams, with 9 million tonnes of waste generated in 2012. However, to date, only one third of it is officially reported as collected and made available for reuse and recycling. The fact that the levels of collection, reuse and recycling of waste from electrical and electronic equipment **vary considerably across the EU's Member States** indicates the **potential to improve resource efficiency** (Indicator 17).

A considerable amount of secondary raw materials leaves Europe and does not contribute directly to the circularity of the European economy

Cross-border movements of waste have increased significantly over the last decade. This arises because waste is increasingly being valued. Net exports of secondary raw materials have increased significantly over the last decade. Extra-EU exports of iron and steel waste amounted to almost 18 million tonnes and to almost 11 million tonnes for paper and cardboard.

Environmental and social sustainability

Monitoring the environmental pressures and impacts of raw materials production is an important aspect of the sector's environmental performance, yet relevant data are not always available at sector level

Data on air emissions suggest **a decoupling between raw materials production and air pollution and greenhouse gas emissions**. Between 1995 and 2009, emissions from the production of raw materials in the EU **decreased by 10-40 %**. Given that the raw materials industry is an **energy-intensive sector**, this decrease mainly reflects fuel switches and the increased uptake and effectiveness of air emission management systems in the EU (Indicator 19).

Water use is another important aspect of environmental sustainability. However, **no suitable data were found that would enable a fair and accurate comparison of water use** in the raw materials sectors. Ideally, an indicator on water use should provide insights into the **intensity of water use,** on **water reuse and recycling,** on **water discharges**, and on the local availability of water resources (Indicator 20). Likewise, no suitable data were found on **extractive waste management**. Better management and recovery of extractive waste has the potential to provide **additional supplies of raw materials** to the EU and further **reduce the environmental impact** of the extractive industry (Indicator 21).

Finally, with regards to sustainable wood supply, i.e. a constant supply of wood from sustainably managed forests, **the area and wood-growing stock of EU forests is rising** again, after centuries of deforestation. All Member States' felling rates are below 100 % and most are below 85 % (Indicator 22).

Social sustainability is an import factor to improve public acceptance of the raw materials sector

Occupational health and safety is important for **social sustainability**. While the raw materials sectors are relatively exposed to occupational hazards — accident rates are at the same level as those of other high-risk sectors such as construction — **accident rates have been decreasing since the middle of the 1990s** (Indicator 23).

Further, **the EU raw materials sector is a world leader in sustainability reporting.** About one third of the Global Reporting Initiative reports in the raw materials sector are filed by companies with their headquarters in Europe (Indicator 24).

Introduction

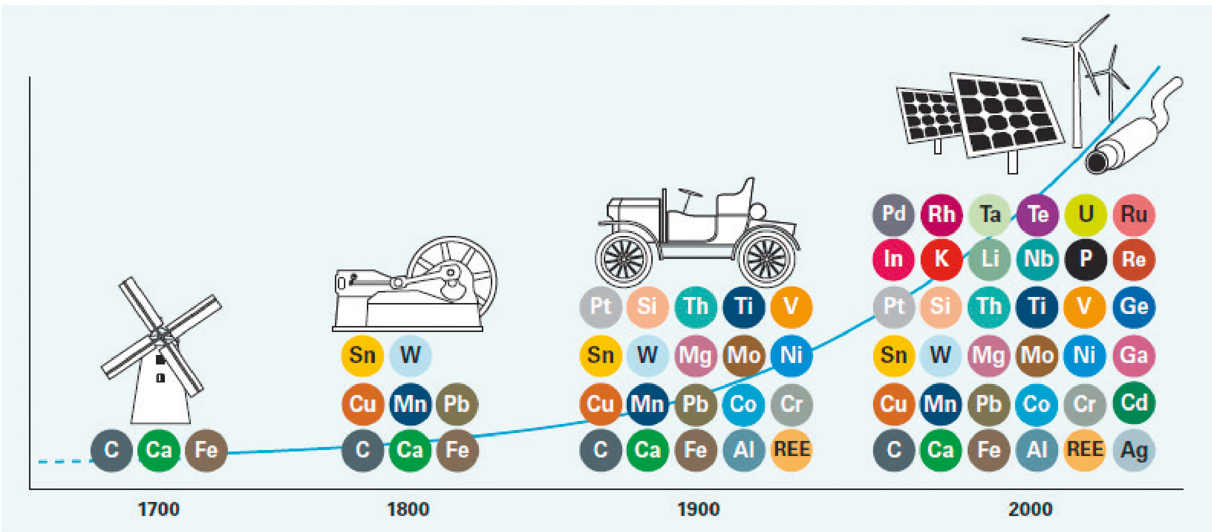
Raw materials in modern society

Raw materials throughout history

Raw materials are used to produce intermediate materials and final products. As such, they are the lifeblood of the economy. Put simply, they are what the objects all around us are made of.

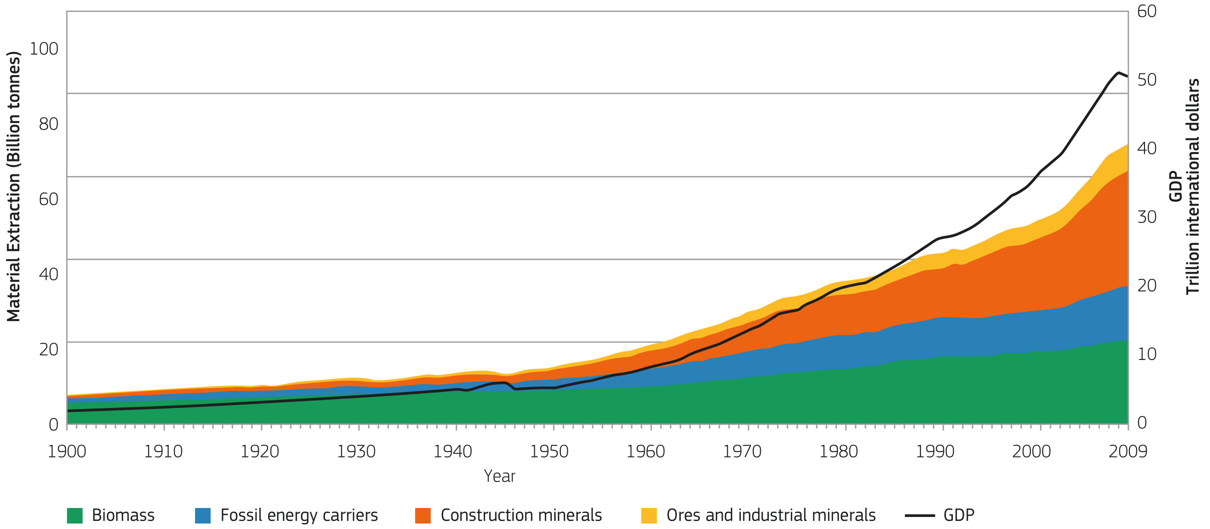
Raw materials have been at the heart of the remarkable progress made by human civilisation through the ages. From the use of wood, stone and ceramics in the Stone Age (before 6000 BC), to the discovery and use of copper, bronze, iron and steel and the invention of glass, paper and cement (between 3000 BC and 1000 AD), raw materials played an essential role in increasing human comfort. Since the industrial revolution (in the 18th century), technological advances have come in quick succession, requiring an increasing number of raw materials to produce ever more sophisticated technologies (see Figure 2 for an example on energy technologies). Today, critical sectors of the economy, such as the automotive and chemical industries and electronics manufacturing, depend on the secure supply of raw materials. Furthermore, many of the products we use in everyday life also contain a wide array of raw materials. A smart phone, for example, can contain up to 50 different metals.

Figure 2: Materials widely used in energy technologies (1700-2000)[1]



1 Volker, Z., Simons, J., Reller, A., Ashfield, M., Rennie, C. (BP), 2014, '*Materials critical to the energy industry — An introduction*'.

Figure 3: Global material extraction by resource type and GDP (1900-2009)[4]



Global material use

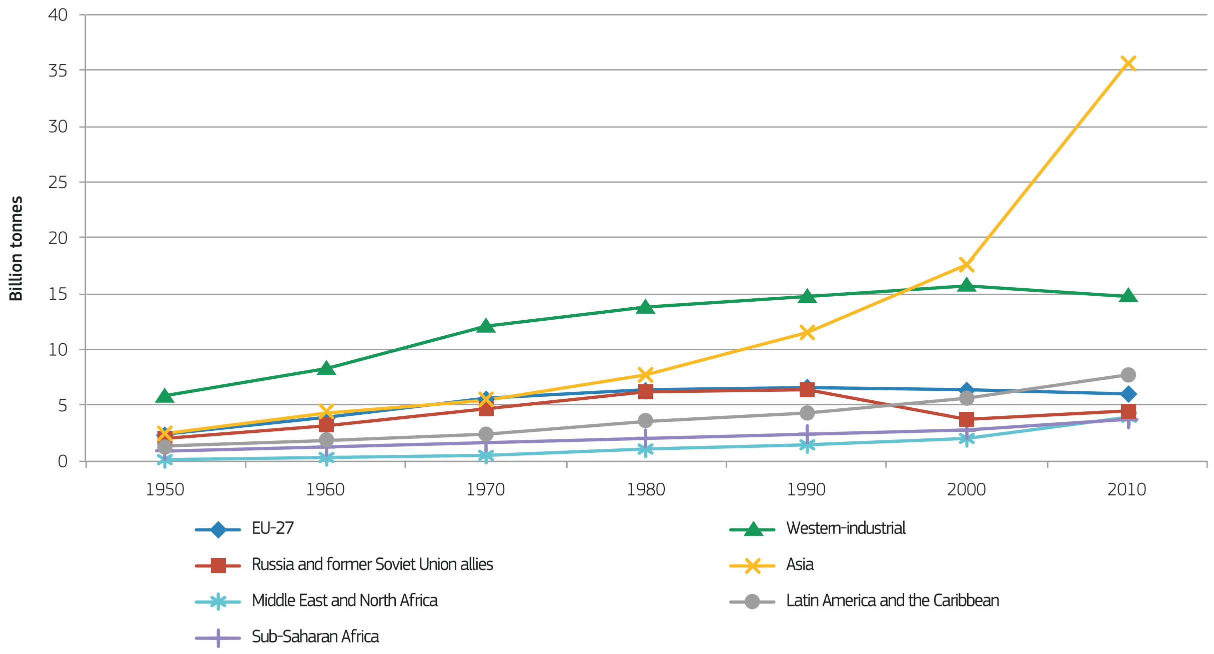
During the 20th century, rapid technological advances facilitated the transition from agrarian societies to industrialised economies. Together with the growing world population and changing consumption patterns, this change has led to a considerable increase in global demand for raw materials.[2] As a result, global material extraction is estimated to have grown from 7 billion tonnes in 1900 to 68 billion tonnes in 2009 — a tenfold increase (see Figure 3). The biggest increase in material extraction has been seen in construction minerals, where extraction has grown to more than 40 times the levels seen at the start of the 20th century. The next biggest increase was in ores and industrial minerals, which are now at 31 times their 1900 levels. The extraction of biomass was more stable, seeing a fourfold increase.[3] Figure 3 also shows that the change in global material extraction decoupled from economic growth. While global material extraction (left axis) grew to 10 times its 1900 level, global GDP (right axis) increased by almost 25 times.

The second half of the 20th century saw remarkable changes in different regions' domestic material consumption. Domestic material consumption measures a region's domestic extraction, plus its imports of materials, minus its exports of materials. When it is broken down by material category, it provides interesting insights into how materials are used in the economy (see Indicator 15 on material flows in the circular economy).

Figure 4 shows that while the consumption growth rate in the EU and other western economies stabilised from the 1970s onwards, with consumption more recently, from 2000 onwards, even decreasing, Asia, meanwhile, began to see exponential economic growth at the beginning of the 1980s, and has continued on this path. During this period China in particular experienced a period of rapid industrialisation and urbanisation, requiring a considerable amount of raw materials such as steel and concrete. As was the case in western industrial countries, demand for raw materials is expected to stagnate and then decrease once the demand for building up industrial stocks and infrastructure saturates.[5] Other regions, e.g. Latin America and North Africa, have seen moderate but steady consumption growth (see Figure 4). Projections of future trends indicate that developing regions will drive up global resource demand in the coming decades. Figures from the Sustainable Europe Research Institute suggest that world resource use could double between 2010 and 2030.[6]

2 EEA, 2015, '*Global Megatrends: Intensified global competition for resources*', State of the Environment Report, European Environment Agency.
3 UNEP, 2011, *'Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel'*, Fischer-Kowalski, M., Swilling, M., von Weizsäcker, E.U., Ren, Y., Moriguchi, Y., Crane, W., Krausmann, F., Eisenmenger, N., Giljum, S., Hennicke, P., Romero Lankao, P., Siriban Manalang, A., Sewerin, S.
4 Adapted from UNEP, 2011; and EEA, 2015 (see also methodological notes).
5 Schaffartzik, A., Mayer, A., Gingrich, S., Eisenmenger, N., Loy, C., Krausmann, F., 2014, '*The global metabolic transition: Regional patterns and trends of global material flows, 1950-2010*', Global Environmental Change, Vol. 26, pp. 87-97.
6 UNEP, 2011, *'Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel'*, Fischer-Kowalski, M., Swilling, M., von Weizsäcker, E.U., Ren, Y., Moriguchi, Y., Crane, W., Krausmann, F., Eisenmenger, N., Giljum, S., Hennicke, P., Romero Lankao, P., Siriban Manalang, A., Sewerin, S.

Figure 4: Domestic material consumption per region (1950-2010)[7]



A secure supply of raw materials to the EU economy

This rising demand for raw materials has significant consequences for the EU economy's security of supply[8]. This is due to the specificities of the raw materials markets. The time scales that these markets work on — the time between the exploration of a mineral deposit and the actual extraction of the first ores being potentially more than ten years — mean that the supply of raw materials cannot be increased from one day to the next. As a result, when demand exceeds supply, prices — which are set at global level — tend to spike, driving up production costs for the downstream industries (industries that use the raw material in question to produce other products). If, on the other hand, demand suddenly falls, prices will drop, which may put long-term investments in the raw materials markets at risk.

In view of the importance of raw materials to the EU economy (see text box 'Raw materials required for low-carbon energy technologies'), in 2008 the EU adopted the Raw Materials Initiative[9], the aim of which is to secure the supply of raw materials. The initiative is based on three pillars:

1. Fair and sustainable supply from global markets;
2. Sustainable supply of raw materials within the EU; and
3. Resource efficiency and supply of secondary raw materials.

In addition, the European Commission has also launched the European Innovation Partnership (EIP) on Raw Materials, which is a stakeholder platform that brings together representatives from industry, public services, academia and NGOs. Its mission is to provide high-level guidance to the European Commission, Members States and private actors on innovative approaches to the challenges related to raw materials.

The European Innovation Partnerships[10] (EIPs) are a new approach to EU research and innovation. By bringing together actors from across the entire value chain, they aim to streamline efforts and accelerate the market take-up of innovations that address the main challenges being faced in the EU.

The European Innovation Partnership (EIP) on Raw Materials covers all non-energy, non-agricultural raw materials, i.e. metals, minerals and biotic materials. Metals include iron, aluminium, copper, zinc, and nickel, which all have a wide range of applications, and a series of specialty metals, such as indium, cobalt, tellurium, palladium, ruthenium, magnesium,which are increasingly used in high-tech applications. Minerals include construction minerals such as sand, gravel and gypsum, and industrial minerals, such as silica, which is used for example in paints and plastics, glass, ceramics and filtration. Finally, biotic materials include natural rubber and wood that is not used for its energetic value. The EIP on raw materials covers the entire raw materials value chain, from the extraction of raw materials (exploration, mining, quarrying; wood harvesting) to the processing of raw materials to make intermediate materials (including recycling).

7 Schaffartzik et al, 2014. See also methodological notes.
8 Except the important demand for construction minerals outside the EU.
9 European Commission, 2008, '*The Raw Materials Initiative — meeting our critical needs for growth and jobs in Europe*', COM(2008) 699; European Commission, 2011, '*Tackling the challenges in commodity markets and on raw materials*', COM(2011) 25.

10 See http://ec.europa.eu/research/innovation-union/index_en.cfm?pg=eip

Raw materials used in low-carbon energy technologies

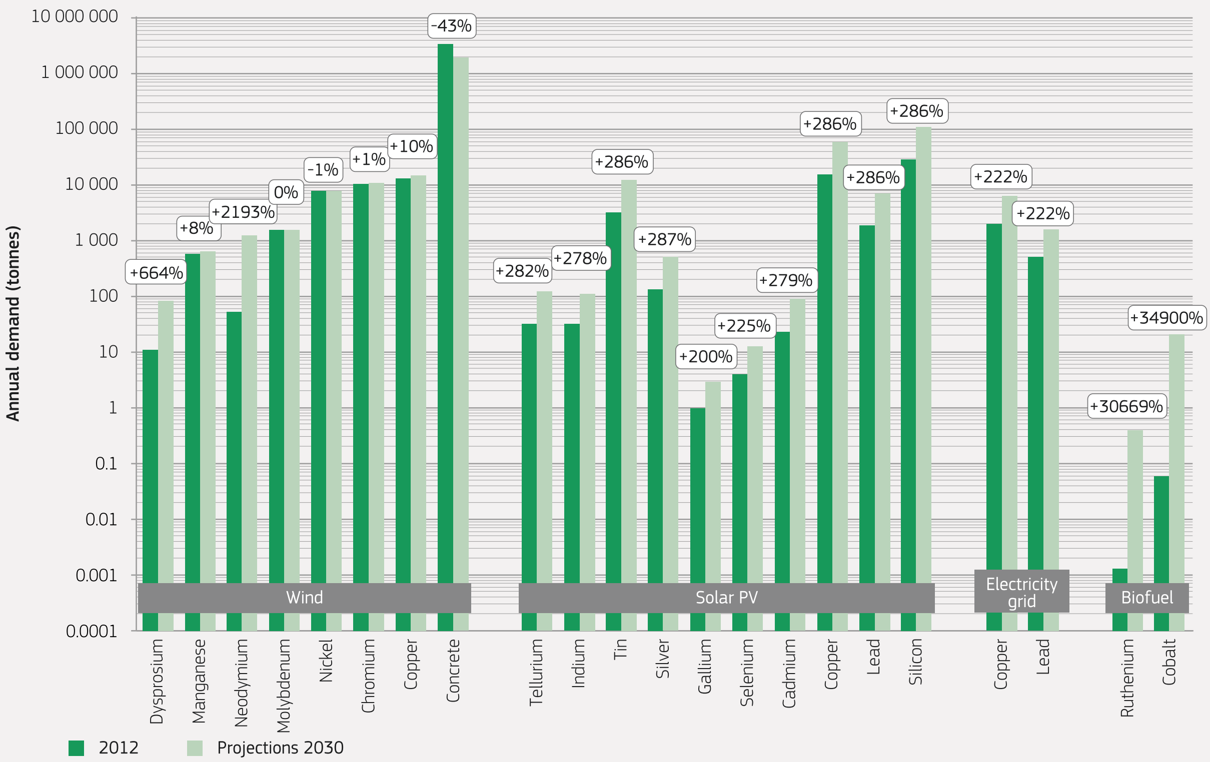
Low-carbon technologies play a fundamental role in the transition towards a clean, secure and sustainable energy system. They are essential for achieving both the EU's climate and energy targets and its policy objectives,[11, 12, 13] including the milestones set in the 2030 Framework for Climate and Energy[14] — to cut greenhouse gas emissions by 40 % compared to 1990 levels and to bring the share of renewable energy to 27 %.

European renewable energy businesses are a major part of the low-carbon energy sector. They have a combined annual turnover of EUR 129 bn and employ over a million people. EU companies hold 40 % of all patents for renewable technologies (compared to the EU's 32 % overall share in global patents). Whilst the EU is still a world leader in innovation and renewable energy, other parts of the world are fast catching up.[15]

Raw materials are indispensable for the development and large-scale deployment of low-carbon energy technologies. These technologies require significant amounts of steel, copper and aluminium and also a vast array of specialty metals.

Figure 5 shows the current demand and the projected demand for 2030[16] of the raw materials required in four low-carbon technologies, namely wind, solar photovoltaic (PV), electricity grid and bioenergy (biofuel). These technologies are identified as priorities in the EU's Strategic Energy Technology (SET) Plan,[17, 18] as are carbon capture and storage, nuclear fission and fuel cell and hydrogen technologies.

Figure 5: Current (2012) and projected (2030) annual demand of raw materials used for selected low-carbon energy technologies[19]



11 European Commission, 2007, '*Towards a low carbon future*', COM(2007) 723.
12 European Commission, 2011, '*Energy Roadmap 2050*', COM(2011) 885.
13 European Commission, 2015, '*A framework strategy for a resilient Energy Union with a forward-looking climate change policy*', COM(2015) 80.
14 European Commission, 2014, '*A policy framework for climate and energy in the period from 2020 to 2030*', COM(2014) 15.
15 European Commission, COM(2015) 80.
16 https://setis.ec.europa.eu/system/files/Critical%20Metals%20Decarbonisation.pdf. See methodological notes.
17 European Commission, 2009, '*Investing in the Development of Low Carbon Technologies (SET-Plan)*', COM(2009) 519.
18 European Commission, 2013, '*Energy Technologies and Innovation*', COM(2013) 253.
19 Source: JRC analysis based on European Commission, 2013, '*Critical Metals in the Path towards the Decarbonisation of the EU Energy Sector: Assessing Rare Metals as Supply-Chain Bottlenecks in Low-Carbon Energy Technologies*', JRC Science and Policy Reports

Demand for raw materials will increase significantly for all four technologies. Some of the raw materials needed for these technologies, including dysprosium, chromium, cobalt, gallium, indium, neodymium, silicon metal and platinum group metals are included in the 2014 EU critical raw materials list, in recognition of the fact that they are of high economic importance to the EU and that their supply is subject to a high level of risk.[20]

The annual demand for raw materials used in solar PV technology will, for example, increase on average by 270 % by 2030. For wind power, demand for dysprosium will increase by about 660 % and demand for neodymium by about 2 200 %, due to the increasing market share of rare earths-based generators in both onshore and offshore wind applications. Furthermore, to transmit electricity generated from remotely located offshore wind farms, a particular type of electricity system needs to be put in place, which involves installing submarine cables that require significant amounts of copper and lead. Biofuels offer a viable alternative to fossil fuels in the EU's transport sector, and will also help to reduce greenhouse emissions and to improve the security of fuel supply within EU. Sustainable biofuel production relies on specific catalysts, which contain cobalt and ruthenium metals. The demand for these metals is therefore expected to increase to more than 300 times its current level by 2030.

However, it may be difficult to meet this increase in demand, considering that many of these metals are often not mined on their own, but occur only as by-products from major metals. Indium for example is a by-product of zinc mining, gallium from aluminium and selenium and tellurium from copper. Because these by-products are often such small fractions of the host metal, it could prove difficult to increase their supply[21]. Current production ratios for indium to zinc for example are 50 g/tonne, for germanium it is 6.9 g/tonne. To increase the production of indium or germanium in line with projected demand would imply the production of zinc exceeding its demand between two and ten times. This would also generate significant amounts of waste[22].

In conclusion, whilst the EU is already on track to meet its 2020 target of 20 % renewable energy in its energy mix, there is still more to be done if it is to meet the 27 % target set for 2030. One crucial aspect of this is ensuring the secure supply of raw materials. For many raw materials, demand for use in low-carbon energy technologies will double or even triple by 2030.

A sector characterised by complex value chains

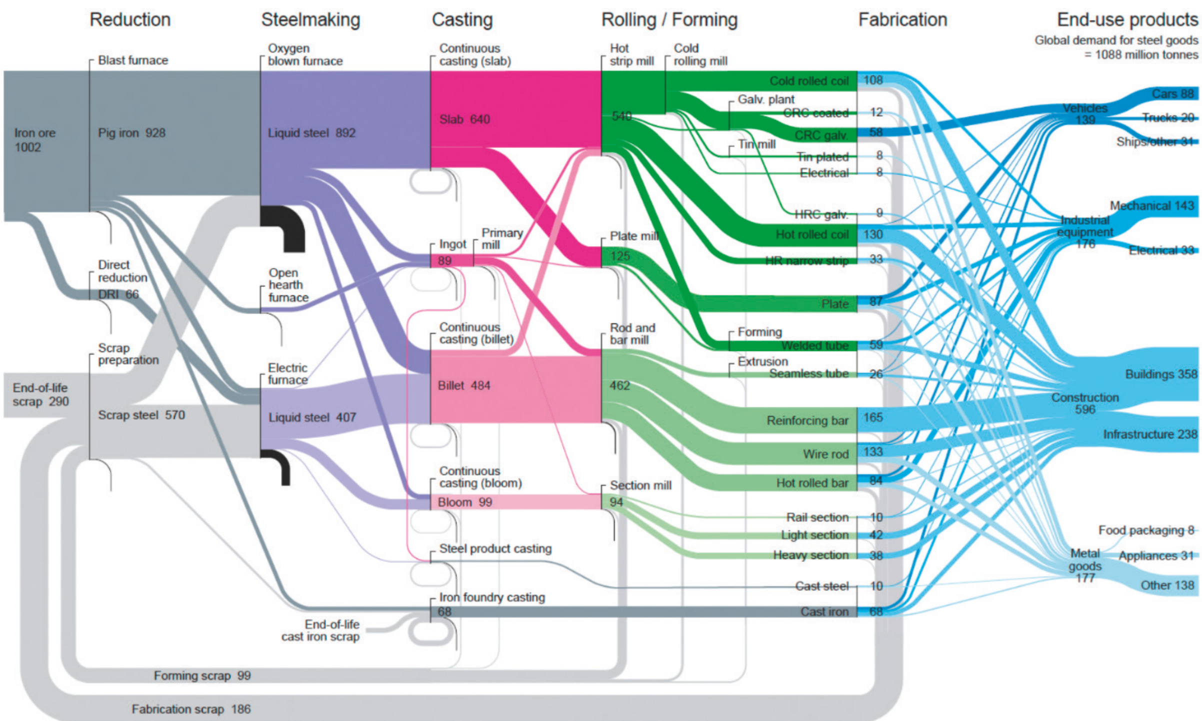
Raw materials are at the origin of all value chains. A prototypical example is provided in Figure 6, which shows the flow of steel along the global value chain from iron ore to end-use goods. As can be seen, material flows along the value chain are very complex and involve many interlinked steps. Once the iron ore has been mined and processed, it is melted in a blast furnace into pig iron. This is then cast and rolled into semi-products such as beams, bars, tubes and sheets, which can be used to manufacture end-use products, e.g. cars and buildings. Fabrication scrap and end-of-life scrap are also used in steel manufacturing.

Figure 6 shows that more than half of the world's steel is used in the construction of buildings and infrastructure, with the remainder shared roughly equally between vehicles, industrial equipment and metal goods. It also shows that two thirds of steel comes from iron ore and one third from recovered scrap.[23] The EU is the world's second largest producer of steel, after China. It produces 11 % of global output, equivalent to over 177 million tonnes of steel a year.[24]

Figure 6 provides a clear illustration of the interdependencies between the different stages of the value chain. Even if the different stages of production are being carried out in different locations, changes in conditions in one market can create ripple effects affecting other stages of production along the entire value chain, both upstream and downstream.[25] As many downstream sectors such as construction, chemicals, automotive, aerospace, machinery and equipment sectors depend on reliable access to raw materials, it is important to keep these interdependencies in mind.

What Figure 6 does not show, however, are the interlinkages with other raw materials sectors. There are two main reasons for these interlinkages. The first is that many different elements are needed in a particular raw materials production process. The steelmaking process, for example, requires significant amounts of coking coal, manganese, silicon, nickel, zinc and molybdenum. The second reason is that metallurgical industries, for example, exchange resources, intermediates and by-products so as to minimise the use of resources and the production of waste. As a result, the raw materials production processes are linked together via interdependent networks and should not therefore be considered in isolation.[26] This is an important point for policymakers to keep in mind, as it highlights how small regulatory changes can have an impact far beyond the element or process that was being targeted.

Figure 6: Global flow of steel from iron ore to end-use goods (in million tonnes, 2008)[27]



20 Ad hoc Working Group on defining critical raw materials, 2014, *'Report on critical raw materials for the EU'*, prepared for the European Commission, DG Enterprise and Industry (GROW).

21 Hagelüken, C., 2013, *'Recycling of precious and special metals'* in Michael Angrick, Andreas Burger and Harry Lehmann 'Factor X - Re-source - Designing the Recycling Society', Springer, pp. 221-241.

22 Elshkaki A. and T.E. Graedel, 2015, *'Solar cell metals and their hosts: A tale of oversupply and undersupply'*, Applied Energy 158 pp. 167–177.

23 Cullen J. M., Allwood J.M., Bambach M.D., 2012, *'Mapping the Global Flow of Steel: From Steelmaking to End-Use Goods'*, Environmental Science & Technology 46 (pp. 13048–13055).

24 European Commission, 2013, *'Action Plan for a competitive and sustainable steel industry in Europe'*, COM(2013) 407.

25 Low, P.,2013, *' The role of services in global value chains'* in *'Global value chains in a changing world*, ed. Deborah K. Elms and Patrick Low, World Trade Organisation.

26 Reuter, M.A., Boin, U.M.J., van Schaik, A., Verhoef, E., Heiskanen, K., Yang, Y., and G. Georgalli, 2005, *'The Metrics of Material and Metal Ecology — Harmonising the Resource, Technology and Environmental Cycles'*, Elsevier.

27 Cullen J. M., Allwood J.M., Bambach M.D., 2012, *'Mapping the Global Flow of Steel: From Steelmaking to End-Use Goods'*, Environmental Science & Technology 46 (pp. 13048–13055).

The search for suitable data ...

An ad hoc working group was set up to select the indicators to be included in the Scoreboard. The group was comprised of almost 30 experts representing a balanced range of interests, who considered close to 70 different indicators. To be selected, indicators were required to meet the "RACER" criteria[28], which set out that every indicator needs to be:

- Relevant
- Accepted (by all stakeholders)
- Credible (i.e. not from interest groups)
- Easy (to compute and to understand)
- Robust

During the selection process, it became apparent that the data and indicators available are subject to certain limitations, which are especially evident in the case of raw materials:

1) By definition, all indicators are imperfect proxies of complex phenomena. For example, the level of reporting on sustainability in a sector is measured by the number of companies adhering to the Global Reporting Initiative, while the level of innovation is assessed using data on the number of patent applications and on the level of corporate R&D investment.
2) Very few data sets can be perfectly disaggregated in such a way as to provide answers to specific policy questions. For example, very few data sets can be disaggregated to isolate non-energy, non-agricultural raw materials; very few data sets can give a complete picture of the entire secondary raw materials sector (i.e. beyond waste collection and treatment); and not all data sets make the distinction between energy and non-energy extraction.
3) Most data sets suffer from a certain degree of imperfection and incompleteness. Almost all data sets used for the Scoreboard have certain gaps (e.g. data for certain countries is missing), suffer from lack of harmonisation and/or are produced with significant time lags.

During the discussions with the ad hoc working group, it was agreed that these limitations are unavoidable (even commonly used indicators such as GDP are affected by these same issues), but that they can be partly overcome as follows:

1) By compiling a set of complementary indicators, each with their strengths and weaknesses. 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.
2) By explaining the data limitations clearly and providing the "story behind the data" in the accompanying text.

It was also found that, for some issues, there are no data available that meet the RACER criteria. Where this relates to important environmental or social impacts the decision was taken to provide a qualitative description of the issue or to use best-available data in the Raw Materials Scoreboard, with a view to replacing this with an indicator as and when suitable data become available. Several Commission services are in this regard working on the development of new data, or the improvement of existing data, which may be included in the future Raw Materials Scoreboards.

© apimages.com

28 European Commission, 2009, Impact Assessment Guidelines.

The Raw Materials Scoreboard

The Raw Materials Scoreboard is an initiative launched by the European Innovation Partnership (EIP) on raw materials.[29] It is part of the EIP's monitoring and evaluation scheme and will be published every two years. The Scoreboard's purpose is to provide quantitative data on the issues referred to in the EIP's objectives. The Scoreboard's purpose is not to measure the EIP's achievements, which will be assessed in the Strategic Evaluation Report.

The Scoreboard covers all aspects of the EIP's general objectives, the raw materials policy context and other criteria related to the competitiveness of the EU raw materials sector. As a result, it increases the visibility of the challenges related to raw materials and provides relevant and reliable information that can be used in policymaking in a variety of areas. The Scoreboard will for example be used to monitor progress towards a circular economy, a crucial issue on which the European Commission recently adopted an ambitious Action Plan[30].

The EIP on Raw Materials' objectives

[From the EIP's Strategic Implementation Plan Part I, Section 2.1 p. 13][31]

'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.'


© apimages.com

29 European Innovation Partnership on Raw Materials, 2014, *'Monitoring and evaluation scheme'.*

30 European Commission, 2015, '*Closing the loop — An EU Action Plan for the Circular Economy*', COM(2015) 614.

31 European Innovation Partnership on Raw Materials, 2013, '*Strategic Implementation Plan*'.

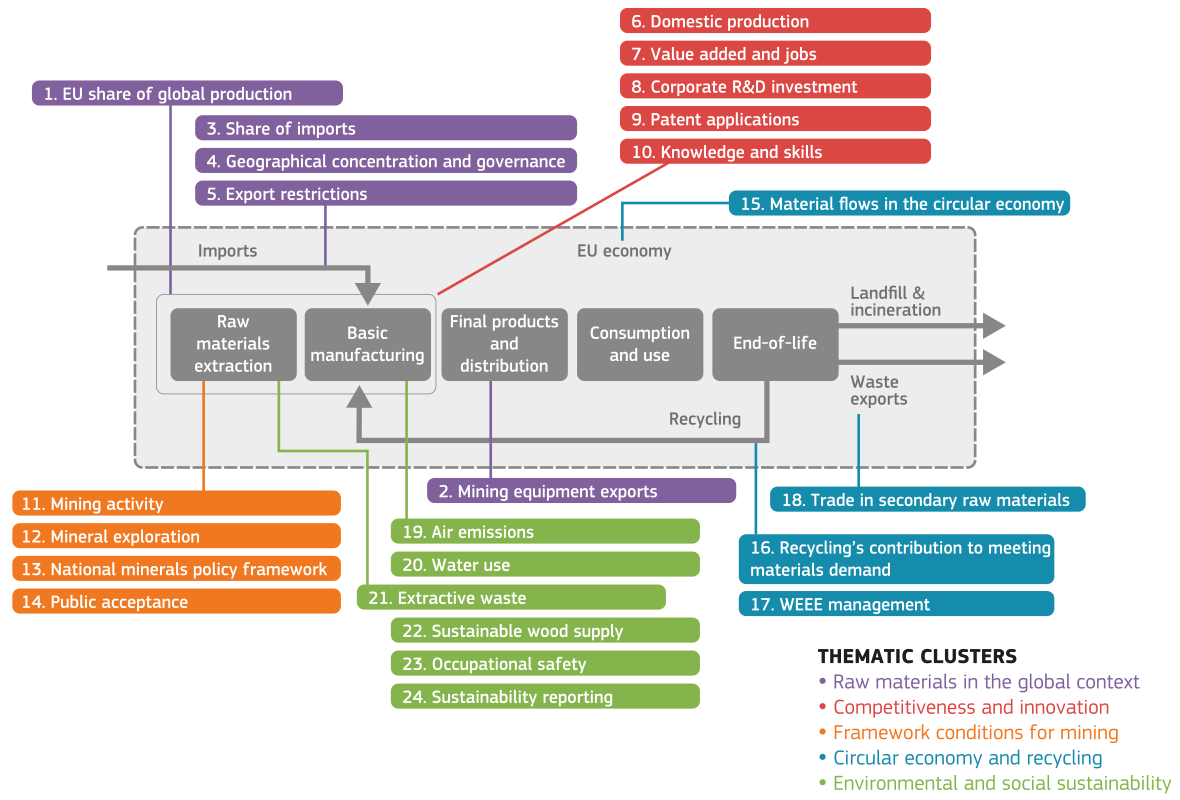
The Raw Materials Scoreboard at a glance …

The Raw Materials Scoreboard contains 24 indicators, which are grouped into five thematic clusters:

- Raw materials in the global context
- Competitiveness and innovation
- Framework conditions for mining
- Circular economy and recycling
- Environmental and social sustainability

Figure 7 provides an overview of how the indicators are linked to the EU economy.

Figure 7: The Raw Materials Scoreboard at a glance



Raw materials in the global context

>> Indicators:

1. EU share of global production
2. Mining equipment exports
3. Share of imports
4. Geographical concentration and governance
5. Export restrictions

1. EU share of global production

Key points:

- For industrial minerals the EU is the third biggest producer in the world, after Asia and North America. For roundwood the EU's share of global production is estimated to be close to 20 %
- The EU's mining production has mostly remained stable in absolute amounts during the last 20 years. However, due to the growth of the global market the EU's share of global production has decreased significantly.
- There was a shift in the production of metals in the 20th century, from Europe and the United States towards other regions of the world.

Overview and context

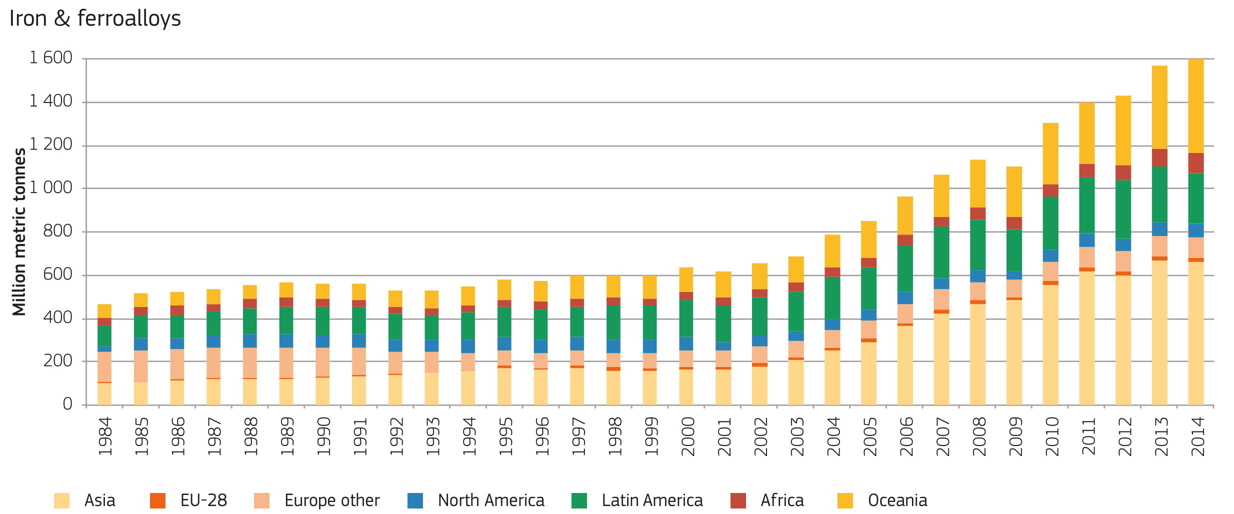
The secure and continued availability of raw materials is essential to any modern economy. The extractive industry provides many of the primary raw materials required by Europe's manufacturing and construction industries. As the amount of materials needed for common products is rising, the EU is increasingly dependent on the secure supply of a wide range of materials.

Even though the EU's share of global production is an indicator that is influenced by many different factors (including for example geological availability), it provides information on where the EU stands internationally, both in the recent past and from a longer-term perspective.

Facts and figures

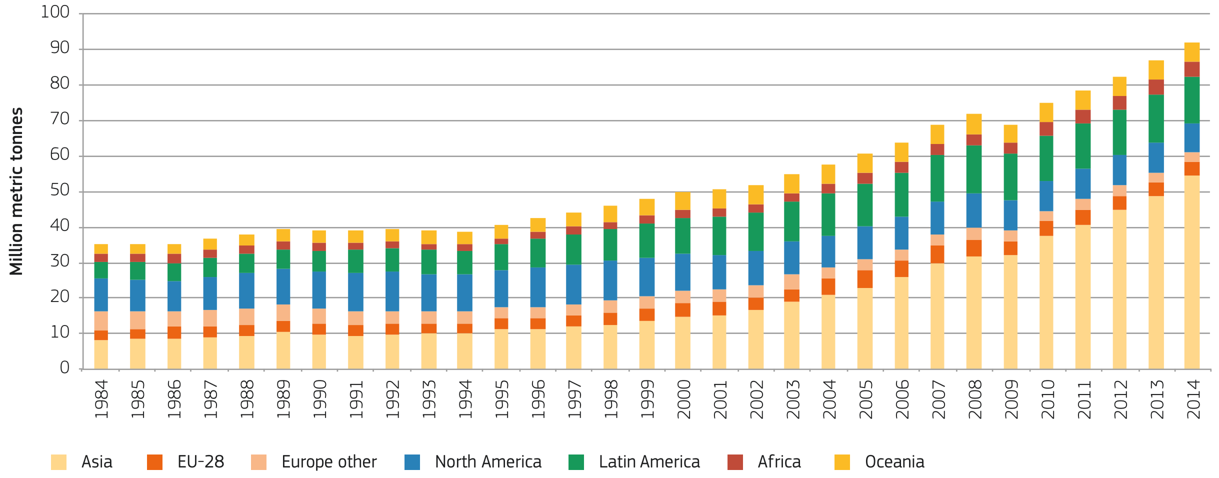
Figure 8 gives an overview of the EU's share of global production, between 1984 and 2014, of iron and ferroalloys, non-ferrous minerals, precious metals and industrial minerals. It shows that for all material categories the EU's mining production has mostly remained relatively stable in absolute amounts[32], a trend that can generally also be observed for North America. For industrial minerals, the EU is even the third biggest producer in the world, after Asia and North America.[33] For roundwood the EU's share of global production is estimated to be close to 20 %.[34]

Figure 8: World regions' share of global raw materials production (for different material categories, 1984-2014)[35]

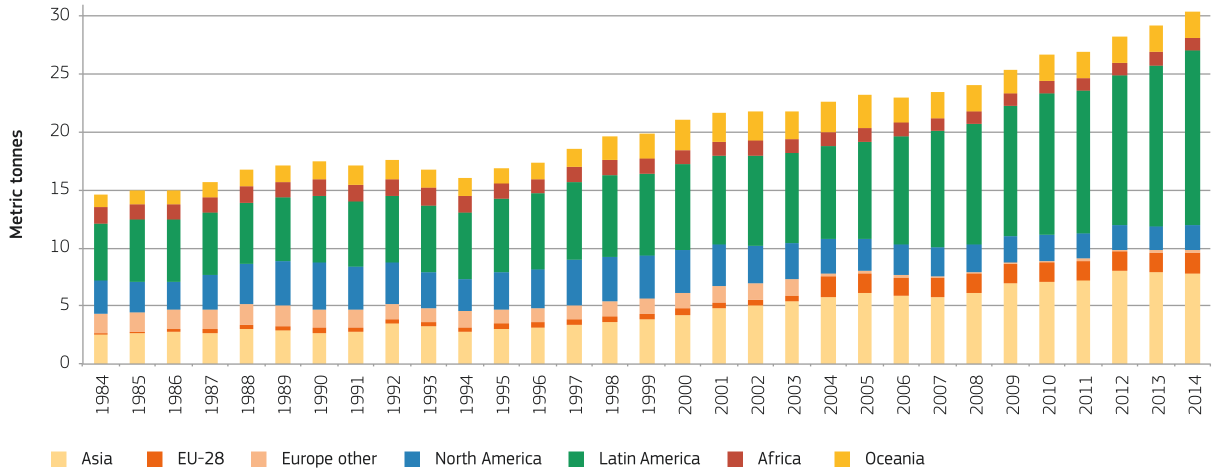


32 Taking into account changes due to the accession of new Member States.
33 Reichl, C., Schatz, M. and Zsak, G., 2015, 'World Mining Data 2015', Federal Ministry of Science, Research and Economy of the Republic of Austria
34 Eunomia, 2014, *Study on the competitiveness of the EU mineral raw materials sector: non-energy and extractive industries and recycling industries*, report to DG Enterprise and Industry.
35 Source: Reichl, C., Schatz, M. and Zsak, G., 2015, 'World Mining Data 2015', Federal Ministry of Science, Research and Economy of the Republic of Austria. See also methodological notes

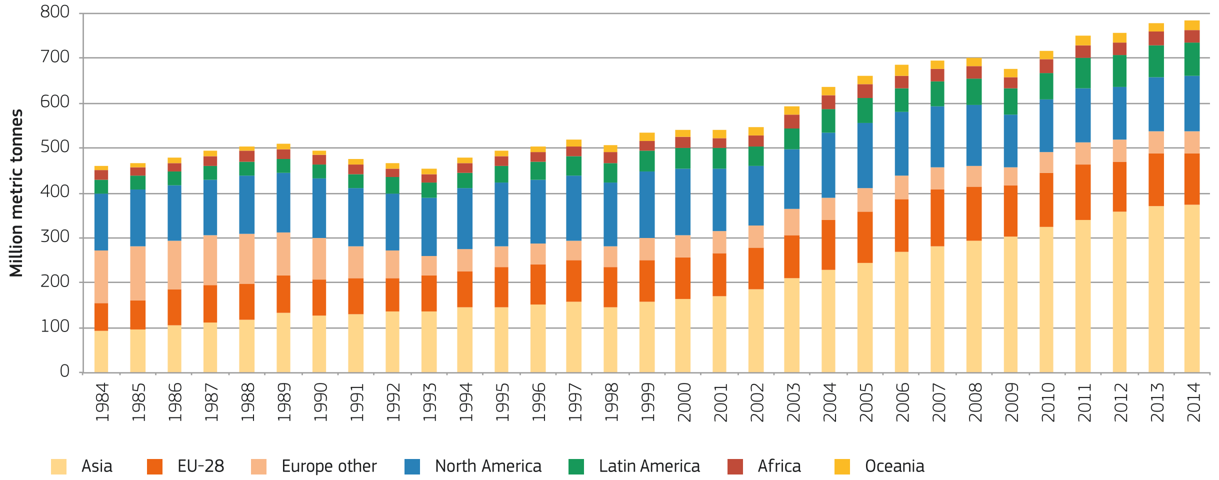
Non-ferrous minerals



Precious metals



Industrial minerals



Interestingly Figure 8 shows the significant growth of the global market, and especially how Asia and South America — and to a lesser extent Oceania and Africa — have significantly increased their share of global production.

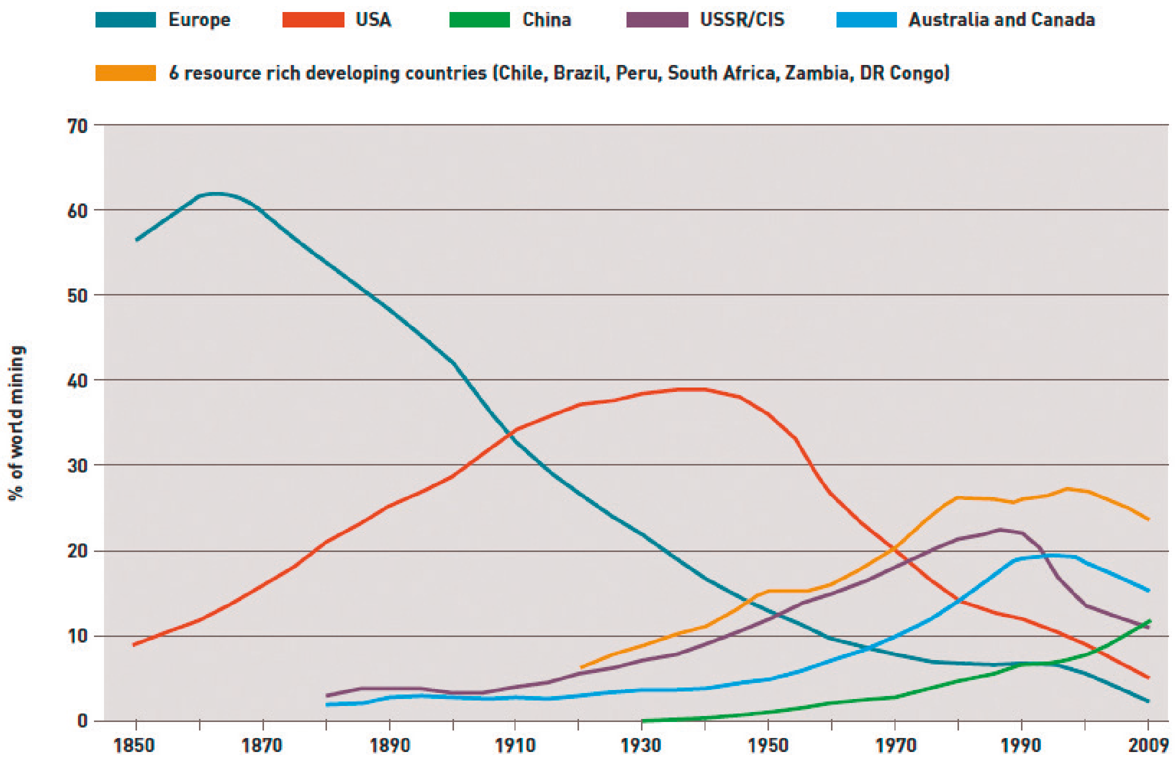
Figure 9 takes a more long-term view, showing the share of metals mining in different geographic regions between 1850 and 2009. It shows that by the middle of the 19th century metals mining was mostly concentrated in Europe, followed by the United States of America (USA). From this point on, the European share of production started to decrease, and American production surpassed European production in the first half of the 20th century. Furthermore, metals production started up in other parts of the world during this time — in China, Australia, Canada, the Soviet Union, Brazil, Congo, etc. – which led to a more diversified production scene. These trends in metals mining reflect the steady and rapid industrialisation in many economies outside of the USA and Western Europe and the move of exploration and mining from Europe and the USA to areas that were previously underexplored and underexploited.[36] Over the years, metals production in emerging economies continued to grow while the USA's share of metals mining steadily decreased. This led to the current situation, where Europe and the USA jointly produce less than 10 % of the world's metals.[37]

Conclusion

The EU's mining production has mostly remained stable in absolute amounts during the last 20 years. However, its share of global production has significantly decreased, mostly due to the growth of the global market. Taking metals mining as an example, it is clear that this trend already started in the second half of the 19th century when production began to move to other regions.

Despite this general trend showing a shift in raw material production, it should be noted that the situation differs between materials, with EU production for biomass and some non-metallic minerals still being significant at global level.

Figure 9: Share of world metals mining by world region (1850-2009)[38]



36 The Hague Centre for Strategic Studies, 2009, *'Scarcity of Minerals: A Strategic Security Issue'*, Kooroshy, J., Meindersma, C., Podkolinski, R., Rademaker, M., Sweijs, T.

37 Ibid.

38 ©ICMM, 2012, *'Trends in the mining and metals industry — Mining's contribution to sustainable development'*. Mining is measured as the produced metals' value at the mining stage.

2. Mining equipment exports

Key points:

- Mining equipment production and exports have grown since the 2000s, following the increased demand for raw materials.
- While the EU is one of the largest mining equipment exporters, emerging producers such as China are quickly gaining market share.
- Despite the EU's relatively low share in global mining production, EU mining equipment manufacturers are globally competitive. Taken together, EU mining equipment manufacturers account for 25 % of global sales.

Overview and context

In recent decades, mining techniques have advanced significantly, moving from labour-intensive to technology-intensive practices, and leading to a tremendous rise in mine productivity. The development of mining equipment has played a fundamental role in this process[39] and has been growing overall.

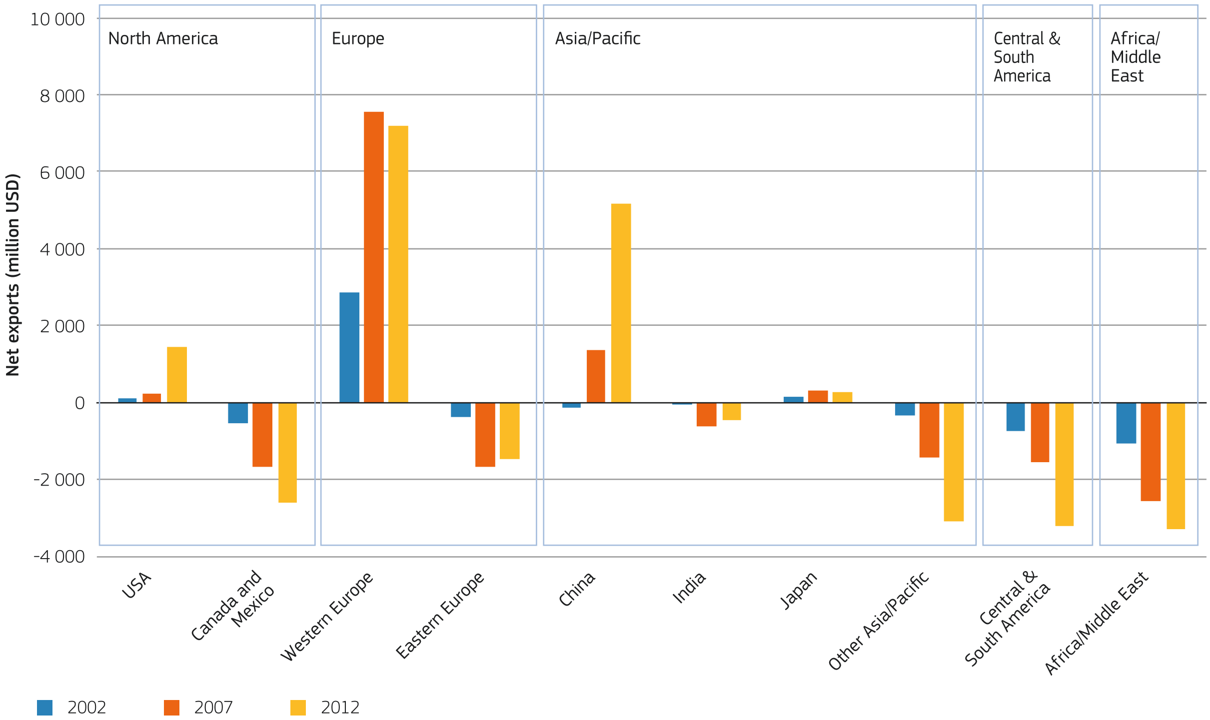
Mining equipment includes technologies used at various mining stages: crushing and screening units; drills and breakers; continuous mining and tunnelling machinery; underground load and haul equipment; and conveying, screening and separating machinery. Mining equipment is an essential technological input to mining activities. Therefore, its inadequate or untimely supply can become a bottleneck to mine production. During the 1980s and 1990s for example, mining equipment manufacturers cut back their investments, in line with low investment in the mining industry itself. When commodity markets started booming in the 2000s, longer lead times for the delivery of mining equipment are reported to have led to bottlenecks in the mining industry and to increased costs of production.[40]

Thanks to their long-standing mining tradition, the USA and the EU are the largest producers of mining equipment. Innovation in mining equipment relies heavily on the existence of mining activities: the need for tailored developments for specific mine conditions generally opens the path to new technologies that can then be further produced and commercialised. In view of the increased demand for metals and minerals and the shift in the location of mining activities, it is interesting to monitor the EU's global position compared with other regions.

© apimages.com

39 Farooki M., 2012, *'The diversification of the global mining equipment industry — Going new places?'*, Resources Policy 37, pp. 417–424.
40 Ibid.

Figure 10: Net exports of mining equipment (by mining region and country, for 2002, 2007 and 2012)[43]



Facts and figures

Figure 10 shows the level and progression of net exports of mining equipment[41] by world region between 2002 and 2012.

It shows a significant growth of mining equipment exports. This is linked to the general expansion of mining activities during this period. The figure also shows that only Western Europe, the USA, China and Japan have been — and continue to be — net exporters of mining equipment. Furthermore, it shows Western Europe's leading export position at global level, even though it saw its net exports fall after the financial crisis. The USA and China, on the other hand, kept increasing their net exports, with China moving from a net importer to a net exporter and becoming a significant world player. This reflects a shift in the production of mining equipment to China, driven by the nature of mine ownership — mining companies tend to source from companies they have done business with before — low production costs and the availability of knowledge and skills.[42] Figure 10 finally also shows that emerging mining regions such as Central and South America and Africa/ Middle East, but also Asia/Pacific and North America, significantly increased their net imports of mining equipment.

Looking at the market share of global mining equipment sales for the various regions, data[44] show that — taken together — EU mining equipment manufacturers[45] account for 25 % of global sales. The US accounts for 43 %, Japan for 14 % and China 9 %. Interestingly, three of the eight largest equipment manufacturers[46] worldwide[47] are based in the EU. These are all big multi-division enterprises. Their core business is capital goods production, with mining equipment often only a relatively small proportion of their total corporate sales. They have manufacturing plants located worldwide and — through acquisitions — have been expanding in terms of production size and distribution.

Conclusion

Even though the EU has a relatively low share of global raw materials production (see Indicator 1), it has a globally competitive mining equipment manufacturing sector. Over the years, due to the increase in demand for metals and minerals, mine production has increasingly shifted to new regions, and mining equipment flows have followed. China in particular has become a significant world player in recent years and is expected to catch up with Western Europe in the next decade.[48] Therefore, for the EU to maintain its competitive advantage in the raw materials sector the European Innovation Partnership on Raw Materials has planned several actions on innovative extraction and processing of raw materials,[49] some of which have also been covered by Horizon 2020, the EU's research and innovation programme.[50]

41 See methodological notes for details on the typology of mining equipment included.
42 Farooki M., 2012, *'The diversification of the global mining equipment industry — Going new places?'*, Resources Policy 37, pp. 417–424.
43 Source: JRC analysis based on Freedonia, 2015, *'World Mining Equipment — Demand and Sales Forecasts, Market Share, Market Size, Market Leaders'*. See methodological notes for further details.
44 Ibid.
45 I.e. Atlas Copco (Sweden), CNH Industrial (UK), FLSmidth (Denmark), Metso (Finland), Sandvik (Sweden), ThyssenKrupp (Germany) and Volvo (Sweden).
46 I.e. Sandvik (Sweden), Atlas Copco (Sweden) and Metso (Finland).
47 Out of a total of 25 companies considered.
48 Ibid.
49 European Innovation Partnership on Raw Materials, 2013, *' Strategic Implementation Plan'*,
50 See Societal Challenge 5 on 'Climate Action, Environment, Resource Efficiency and Raw Materials', https://ec.europa.eu/programmes/horizon2020/en/h2020-section/climate-action-environment-resource-efficiency-and-raw-materials.

3. Share of imports

Key points:

- The EU's production of non-metallic minerals and roundwood is sufficient to cover its needs.
- The EU is highly dependent on imports of many metal ores and natural rubber, but it is the security of supply (i.e. its diversification) that is crucial for a strong European industrial base.

Overview and context

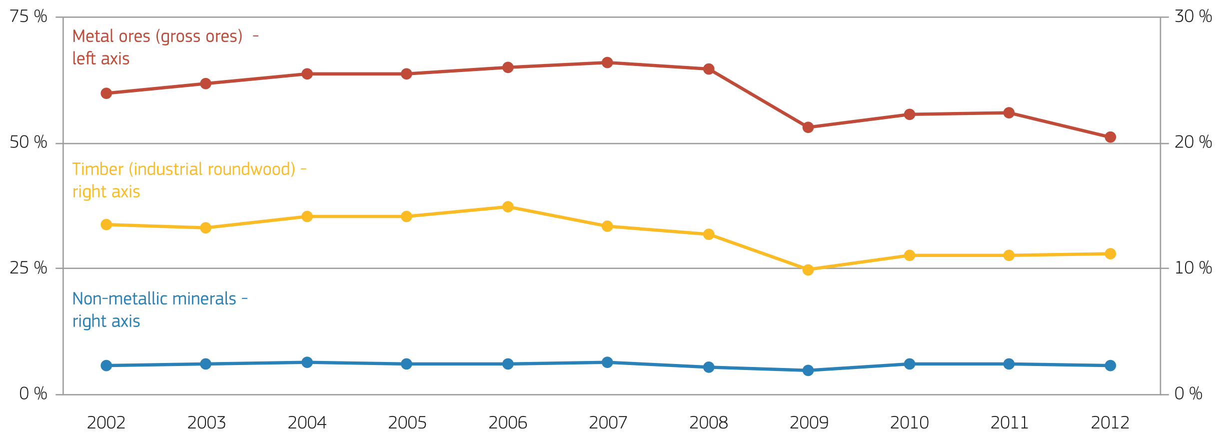
The EU's economy requires a wide variety of raw materials for its proper functioning and not all of them can be produced domestically. The EU's ability to satisfy its demand for raw materials domestically as against through imports is determined by natural and economic factors. First, natural resource endowment varies significantly across countries, with reserves of raw materials relevant to the EU economy often located in countries outside the EU. This applies to both abiotic and biotic materials, e.g. the climatic conditions required for growing rubber trees can be found mainly in tropical forests in South East Asia. Economic aspects also play a role, e.g. the costs of production for some raw materials are lower outside the EU than domestically. Additional limitations to raw material production and the exploration of new reserves are often posed by the competition for land, which is also needed for other uses such as agriculture or urbanisation.

This indicator looks at the share of imports in the EU economy's use of raw materials. To get a more complete picture of the EU's security of supply the Scoreboard also includes an indicator on diversification of supply sources (Indicator 4) and on recycling's contribution to meeting materials demand (Indicator 16).

Facts and figures

Figure 11 shows the share of imported raw materials used within the EU. Data on raw materials imports are compared to Direct Material Input[51] statistics, which quantify all materials that have an economic value and are used in production and consumption activities. This includes resources used for consumption within the EU and resources used to produce materials and goods being exported to countries outside the EU, but does not include secondary raw materials.

Figure 11: Share of imports in EU-28 compared to Direct Materials Input (2002-2013)[52]



51 Direct material input (DMI) measures the direct input of material into the economy. It includes all materials that are of economic value and which are available for use in production and consumption activities (domestic extraction plus imports).

52 Source: JRC analysis based on data from Eurostat's material flow accounts, from 9 November 2015, code *env_ac_mfa*, (http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_mfa&lang=en).

Figure 11 shows that the EU is almost self-sufficient as regards non-metallic minerals and roundwood, for which import reliance is always below 3 % and 11 %, respectively. Metals are the material group with the highest share of imports, always above 50 %. However, in recent years the share of metal ores imported has slightly decreased, which can probably be attributed to a reduction in the demand for metallic raw materials after the economic crisis which started in 2007/2008.

Figure 12 focuses on a number of raw materials for which the EU is largely dependent on imports. Data only includes primary production. For some materials included in Figure 12, production occurs in the EU but in a quantity that is not sufficient to fully satisfy EU demand (e.g. for copper, iron ore, and zinc). Import dependency for copper, for example, is above 50 %. Even though the EU produces copper, its global production share is only approximately 5 %. For other materials, such as iron (import share of 85 %) and bauxite, an aluminium ore (import share of 95 %), most mineral deposits are located outside the EU (in Australia and Brazil; also in China for iron).

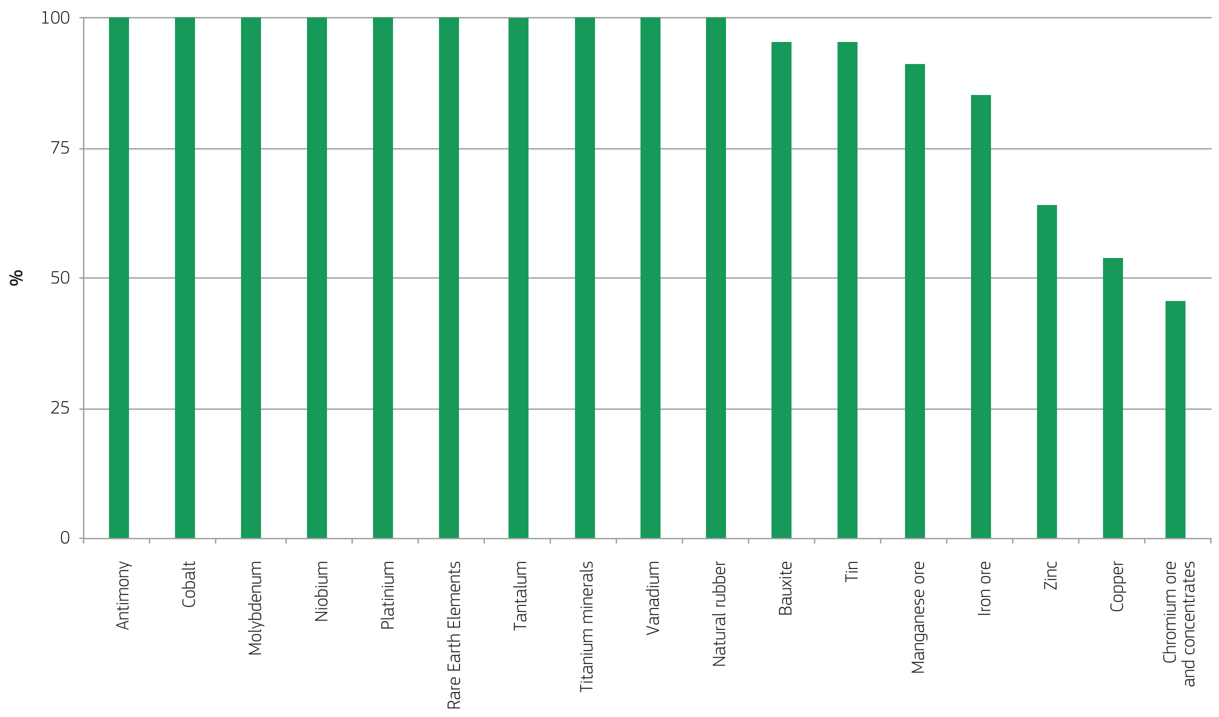
The share of imports reaches 100 % for many other metals, such as antimony, vanadium, and the rare earth elements that are important for a wide range of modern technologies. Imports are also the only source of natural rubber used in the EU, since the production of natural rubber relies on the cultivation of trees that are only grown in tropical climates. It should be noted, however, that when imported raw materials come from a diverse set of countries and production sites, a high import dependency does not necessarily translate into higher supply risk than for domestic extraction, especially for resources that come from countries with stable governance conditions (see also Indicator 4 on geographical concentration and governance).

Conclusion

The EU is close to being self-sufficient for many non-metallic minerals and for roundwood. However, it is highly dependent on imports of many other raw materials (especially metal ores and natural rubber). Having some level of import dependency is unavoidable in practically any economy, since the geological occurrence of mineral deposits and biotic materials varies across regions. This is the only factor that defines the EU's security of supply.

To increase the EU's security of supply, the EU's Raw Materials Initiative[54] focuses on raw materials diplomacy, trade and development policy, the promotion of domestic production and diversification of raw material sourcing through the improvement of resource efficiency and recycling or development of material substitutes.

Figure 12: Import dependence for selected raw materials[53]



53 Source: JRC analysis based on data from report of the Ad hoc Working Group on defining critical raw materials, 2010, *'Critical raw materials for the EU'*.

54 European Commission, 2008, '*The Raw Materials Initiative — meeting our critical needs for growth and jobs in Europe*', COM(2008) 699; European Commission, 2011, '*Tackling the challenges in commodity markets and on raw materials*', COM(2011) 25.

4. Geographical concentration and governance

Key points:

- The supply of critical and some non-critical raw materials to the EU is highly concentrated in a few non-EU countries that often show low levels of governance.
- Because the EU is highly import-dependent for certain raw materials this may lead to unexpected supply disruptions and thus put the EU's security of supply at risk.

Overview and context

Resource endowments, and consequently the production of primary raw materials, have a very uneven geographical distribution. Minerals such as nickel, silver, and zinc, for example, are mined in more than 30 countries, while for other minerals supply is highly concentrated in only a few countries. A good example is the platinum group metals (PGMs), which are mostly produced in South Africa and the Russian Federation.[55]

Because the EU is highly dependent on imports for certain raw materials (see Indicator 3), a high concentration of production in a few countries presents a risk to its security of supply, especially if the quality of governance in these countries is low.[56]

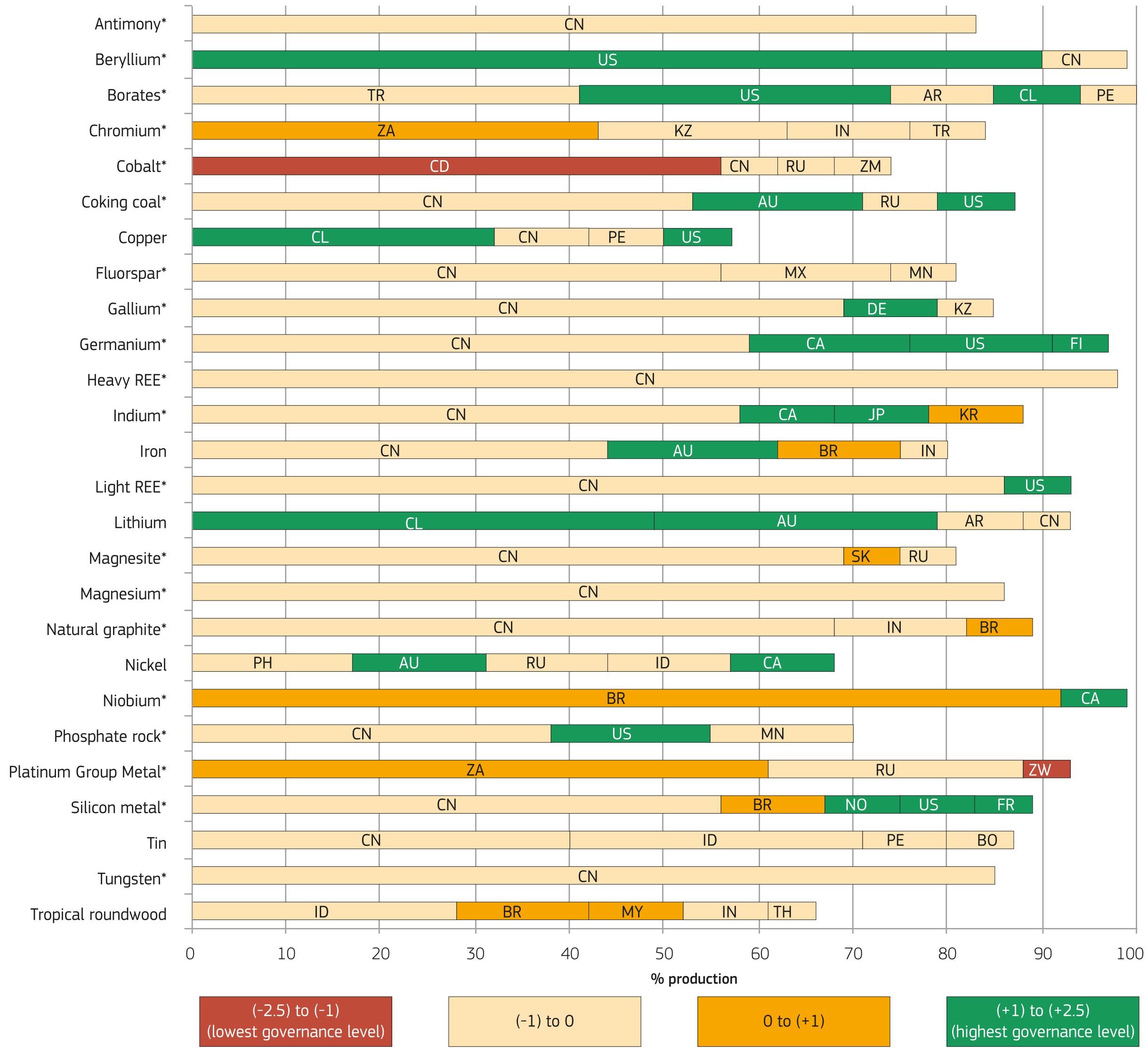
Facts and figures

Figure 13 shows the geographical concentration of supply for a selection of raw materials. It shows that a considerable amount of raw materials is produced by a rather limited number of countries. In addition, it includes an indication of the countries' level of governance, based on the Worldwide Governance Indicators (WGI).[57] The WGI are produced by the World Bank as a proxy of countries' political and economic stability, and are based on stakeholder perceptions of six governance dimensions: country voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law, and control of corruption.[58]

As can be seen in Figure 13, the production of a number of raw materials is concentrated in countries with rather low governance scores, which presents a potential supply risk. Rare earth elements (REE), for example, which are essential for the production of many of today's technologies such as high-strength permanent magnets, phosphors for lighting, catalysts, medical equipment, etc., are almost exclusively produced in China. Another example is cobalt, for which global production is largely concentrated in the Democratic Republic of the Congo (DRC), marked with the lowest WGI score because it has been struggling with internal conflicts and human rights abuses.[59] However, when production is concentrated in countries where governance is stable (e.g. beryllium), the supply risk is generally low.

55 OECD, 2014, *'Export restrictions in raw material trade: Facts, fallacies and better practices'*.
56 Ad hoc Working Group on defining critical raw materials, 2014, *'Report on critical raw materials for the EU'*,,and Ad-hoc Working Group on defining critical raw materials, 2010, 'Critical raw materials for the EU', both prepared for the European Commission, DG Enterprise and Industry (GROW). In these studies, country governance information was one of the factors determining potential supply risks.
57 The Worldwide Governance Indicators (WGI) project, http://info.worldbank.org/governance/wgi/index.aspx#home.
58 WGI scores in Figure 13 correspond to the average value of the six governance dimensions, ranging from -2.5 (the lowest quality of governance) to +2.5 (the highest level).
59 The Worldwide Governance Indicators, Country Data Report for Congo, http://info.worldbank.org/governance/wgi/pdf/c248.pdf.

Figure 13: Geographical concentration of raw material production and producer countries' governance levels[60]



* Critical[61] raw materials; REE stands for rare earth elements. 'Tropical roundwood' refers to non-coniferous tropical industrial roundwood.

Conclusion

The concentration of production in certain countries and these countries' levels of governance are two factors that affect the supply risk for raw materials. The data provided here shows that (primary) production is concentrated in only a few countries for a wide range of materials that are particularly important for EU industry. Many of these countries may also have low levels of political and economic stability. It is therefore important to put measures in place to reduce the possible impact of supply disruptions, including special trade agreements, research on substitute materials, the improvement of recycling systems and, where possible, development of domestic sources.

60 JRC analysis based on data from Chapman, A., Arendorf, J., Castella, T., Thompson, P., Willis, P., Tercero Espinoza, L., Klug, S. and E. Wichmann, 2013, *'Study on Critical Raw Materials at EU Level'*, prepared for the European Commission, DG Enterprise and Industry (GROW). Data corresponds to primary production, i.e. it does not include production from recycling. Data refer to years 2010-2012, depending on the material. WGI data is for 2011. Legend of producing countries; AU: Australia; BR: Brazil; CA: Canada; CL: Chile; CN: China; CD: Democratic Republic of Congo; FI: Finland; FR: France; DR: Germany; IN: India; ID: Indonesia; JP: Japan; KZ: Kazakhstan; KR: Republic of Korea; MY: Malaysia; MX: Mexico; MN: Mongolia; MA: Morocco; NO: Norway; PE: Peru; RU: Russian Federation; ZA: South Africa; SK: Slovakia; TH: Thailand; TR: Turkey; ZM: Zambia; ZW: Zimbabwe.

61 The term 'critical' refers to materials with high economic importance and a high potential supply risk. See Chapman, A., Arendorf, J., Castella, T., Thompson, P., Willis, P., Tercero Espinoza, L., Klug, S. and E. Wichmann, 2013, *'Study on Critical Raw Materials at EU Level'*, prepared for the European Commission, DG Enterprise and Industry (GROW).

5. Export restrictions

Key points:

- International commodity markets are increasingly distorted due to a growing trend in the use of export restrictions.
- Commodity market distortions are particularly relevant for raw materials for which the global market is dominated by a few exporting countries.

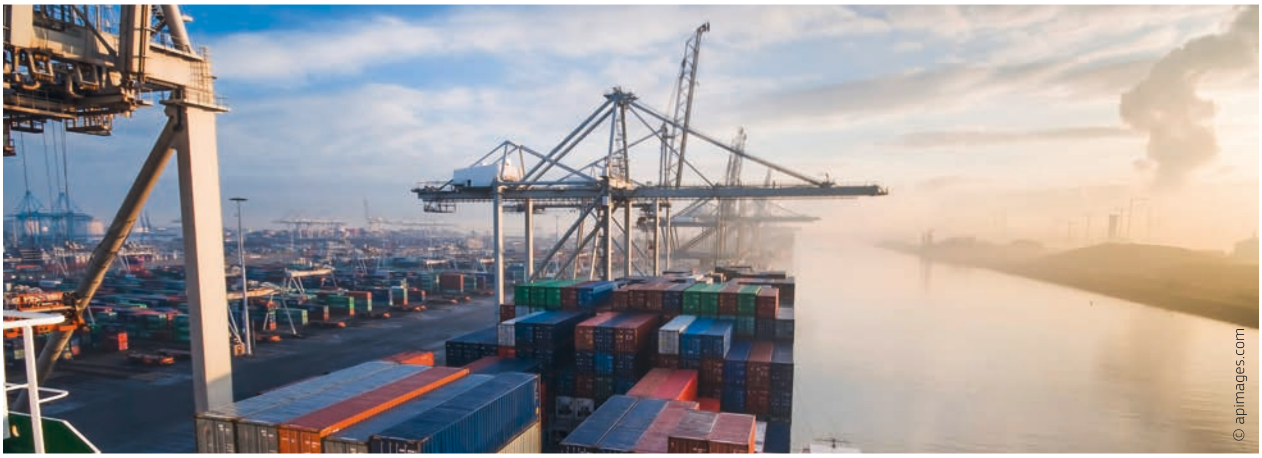
Overview and context

Global demand for raw materials steadily increased during the 20th century (see Figure 3 in the Introduction). Since the early 2000s, however, raw materials markets came increasingly under pressure due to the accelerated economic growth of emerging countries, leading to a significant increase in international trade.[62] For example, global mineral and metal exports have doubled since 2000.[63]

As a first reaction to a growing demand for raw materials in the global market, prices rose. This was followed by an increasing tendency of supplying countries to put in place export restrictions and trade barriers. Supplying countries used these restrictions to keep production outputs available domestically for use in their own downstream sectors, to raise revenue, or to conserve natural resources.[64] The increased use of these restrictive measures became an additional factor that pushed prices up and increased the volatility of raw materials markets.[65]

For several raw materials, such as antimony, lithium, platinum group metals, rare earth oxides, tin, and tungsten, more than 90 % of global supply is produced by five countries or fewer (see also Indicator 4 on geographical concentration and governance).[66] The case of China, which in 2011 introduced export restrictions on rare earth elements that led to sharp price increases, shows the impact on the security of supply of commodities that are supplied by only a few countries and for which there is a high demand from other countries.

62 OECD, 2014, *'Export restrictions in raw material trade: Facts, fallacies and better practices'*.
63 Ibid., based on data from UN Comtrade.
64 Schubert, S.R., Brutschin, E., Pollak, J., 2015, *'Trade in commodities: Obstacles to trade and illegal trade'*, prepared for the European Parliament, DG for External Policies.
65 OECD, 2014.
66 Ibid.



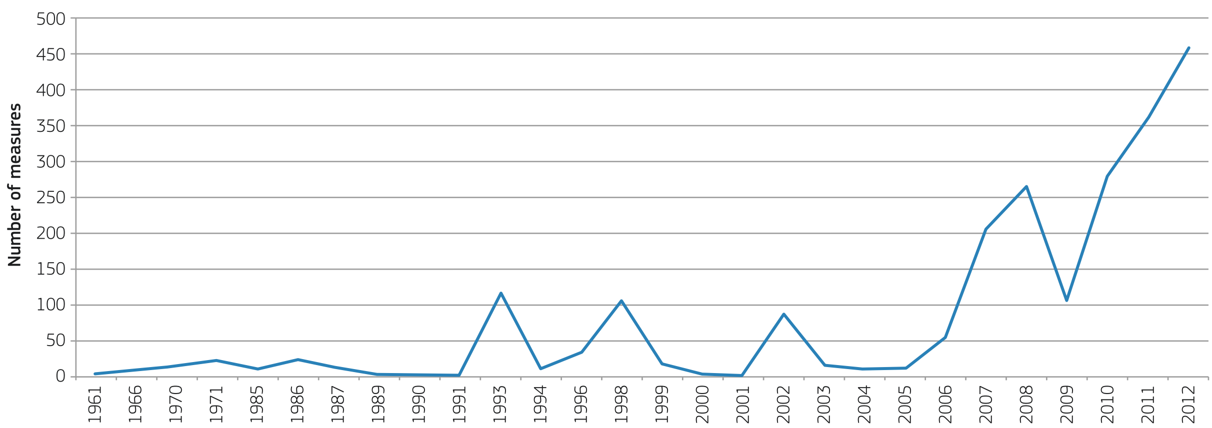
Facts and figures

Figure 14 shows the number of export restriction measures for raw materials which were introduced between 1961 and 2012 and which were still in place in 2012. It shows the number of export restrictions reported in the OECD Inventory of Restrictions on Trade in Raw Materials for minerals at HS 6 level,[67] adding up together the different types of restrictions — export taxes, export quotas, export prohibitions, license requirements, etc.

While some of these export restrictions have been in place for decades, Figure 14 shows that more than 50 % of the restrictions that were active in 2012 were introduced after 2009, and almost 25 % were introduced in 2012. Only 12 out of the 72 countries for which the OECD reported export restriction measures did not introduce any measures between 2009 and 2012,[68] while the other 60 countries introduced at least one restriction during this time.

Figure 15 shows the proportion of global supply subject to export restrictions for a selection of raw materials. This selection is based on Indicator 4 on geographical concentration and governance, and includes the so-called critical raw materials[69] and other materials essential for the EU economy. In this figure, production is considered to be subject to export restrictions if any of the main restrictive measures, i.e. export quotas, export taxes, or licensing requirements, were applied in the producing countries between 2009 and 2012.

Figure 14: Export restrictions affecting raw materials (data cover measures introduced per year and which were still present in 2012)[70, 71]



67 HS 6-digit level is the most detailed level used to define products as standard based on the World Customs Organisation's harmonised system.

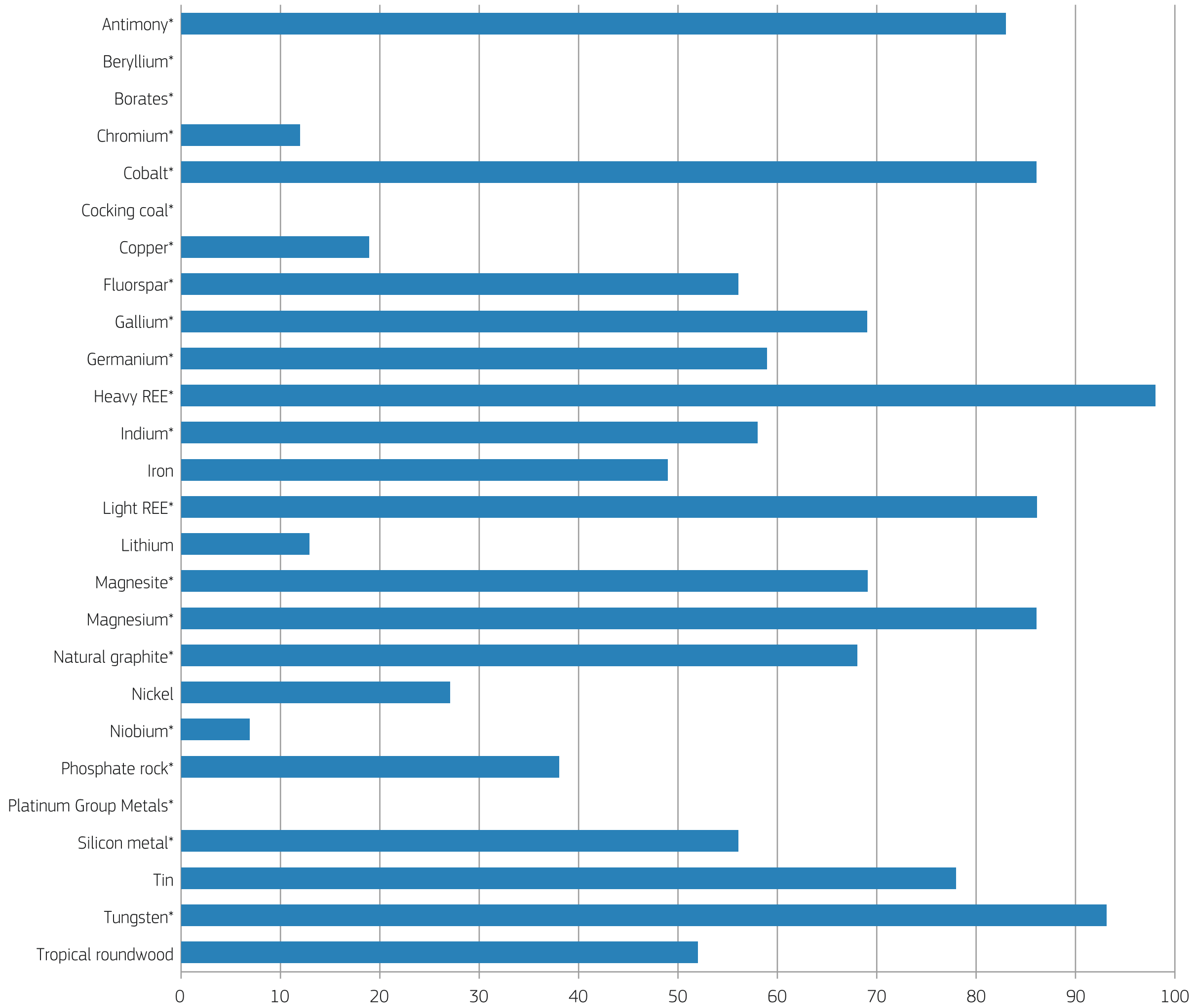
68 OECD, 2014.

69 The term 'critical' refers to materials with high economic importance and a high potential supply risk. See Chapman, A., Arendorf, J., Castella, T., Thompson, P., Willis, P., Tercero Espinoza, L., Klug, S. and E. Wichmann, 2013, *'Study on Critical Raw Materials at EU Level'*, prepared for the European Commission, DG Enterprise and Industry (GROW).

70 Data is based on the 2014 OECD report, which presents data from the Inventory of Restrictions on Exports of Raw Materials and includes export restrictions on metals, minerals and wood. The OECD inventory reports on the results of an extensive survey which covered: around 80 % of the world production of minerals, metals and wood at their primary state; and over 90 % of exports of metal waste and scrap. The inventory also covers a large share of raw materials global trade: 67 % of (2012) total value of primary materials' exports; and 45 % of total exports of primary and semi-processed materials combined. Restrictions removed and later reintroduced are counted as newly introduced.

71 It is important to note that values in Figure 14 are an approximation since there are many other types of measures that restrict exports, and since governments' use of export restrictions is often opaque.

Figure 15: Proportion of primary production subject to export restrictions, for a selection of raw materials (2009-2012)[73]



*Critical raw materials; REE stands for rare earth elements. 'Tropical roundwood' refers to non-coniferous tropical industrial roundwood.

One case that received a lot of media attention was the export restrictions on rare earths, tungsten, and molybdenum, for which the EU, USA, and Japan brought a case to the WTO's Dispute Settlement Body in 2012.[72] Following the WTO's ruling, China dropped its export restrictions in January 2015.

Aside from the materials included in Figure 15, it should be noted that since 2009 export restrictions have also considerably risen for commodities or products that are produced by many industrialised countries, such as iron and steel, metal waste and scrap, non-ferrous metals, and roundwood. For steel, for example, 38 countries accounting for almost 70 % of global production were recorded to have used export restrictions in 2012. For wood products, 11 out of 21 countries applied export restrictions between 2009 and 2012.

Conclusion

Export restrictions on raw materials have become more frequent in recent years. They cause higher prices and volatile market conditions and affect the security of supply. Although there are many ways to restrict raw material exports, the main restrictive measures are export quotas, export taxes, and licensing requirements. The impact of export restrictions on raw materials is stronger if the materials are supplied by only a few countries. There has been progress in some negotiations and bilateral and regional trade agreements to decrease the use of export restrictions.

72 See Dispute Settlement, Dispute DS431 'China — Measures Related to the Exportation of Rare Earths, Tungsten and Molybdenum' — https://www.wto.org/english/tratop_e/dispu_e/cases_e/ds431_e.htm.

73 Source: JRC analysis based on the OECD Inventory on Restrictions on Exports of Raw Materials. Export restrictions included are quotas, taxes, and licensing requirements.

Competitiveness and innovation

>> Indicators

6. Domestic production
7. Value added and jobs
8. Corporate R&D investment
9. Patent applications
10. Knowledge and skills

6. Domestic production

Key points:

- Domestic extraction of construction minerals and harvesting of wood increased significantly between 1970 and 2010, while domestic extraction of metals has fallen by almost 20 % since the 1970s.
- The EU processes and refines more raw materials than it extracts, using imported raw materials and scrap.
- Very little data are available on domestic production of secondary raw materials.

Overview and context

Domestic production of raw materials is an essential part of the EU economy. It creates EUR 280 billion of added value and more than four million jobs (see Indicator 7) and provides a reliable supply of inputs to many downstream industries (e.g. automotive, chemicals and electronics manufacturing —see Figure 6 in the introduction). Domestically produced raw materials are not subject to trade restrictions that could otherwise increase the likelihood of supply disruptions (see Indicator 5). Furthermore, domestic production of raw materials can result in shorter supply chains (if subsequent refining and manufacturing activities also take place within the EU), thereby decreasing supply chain complexity.

Raw materials production takes place over several stages. First, raw materials are extracted, after which they are processed and refined into materials to be used as input by manufacturing industries. This can take place on-site, but processing units are often located at long distances from extraction sites, so materials need first to be concentrated and then transported. Therefore, the EU's raw materials industries process not only domestically extracted raw materials but also those extracted in other parts of the world.

To be used as an indicator of competitiveness, domestic production needs to be seen in the right perspective. In the global context, it should be compared with global material use (see Figure 3 in the introduction), with the EU's share of global production (Indicator 1) and with the share of imports in the EU's consumption of raw materials (Indicator 3). Ideally, it should also be complemented with data on the cost of production, which is a complex factor for which very limited data are available. Data on the environmental and social performance of production (see the indicators included in the thematic cluster on social and environmental sustainability) should also be taken into account.

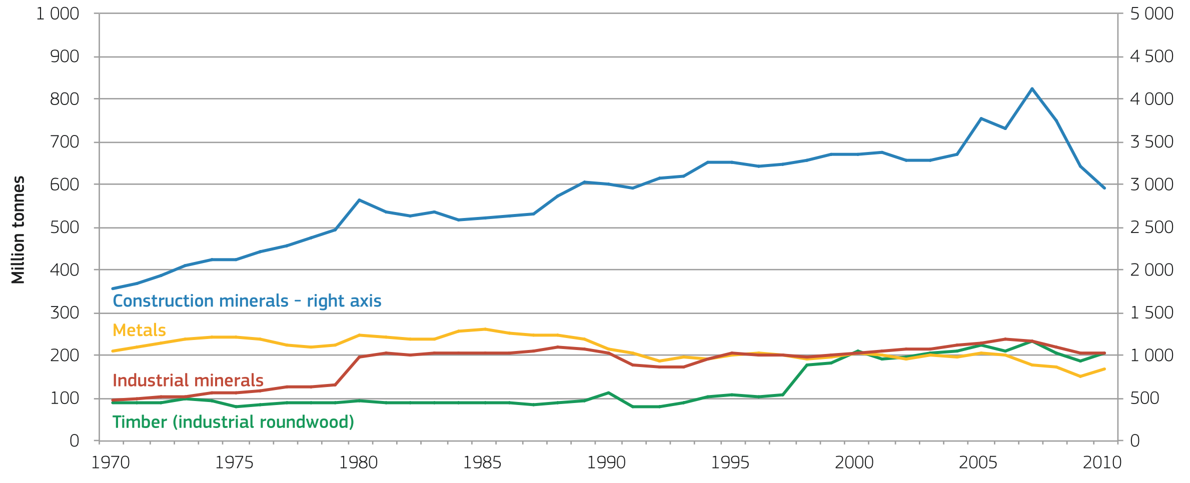
Facts and figures

Figure 16 gives an overview of the trends in domestic extraction for various raw materials since 1970. Domestic extraction refers to the amount of raw materials taken from the environment — from mining sites for metals and minerals, and harvested from forests or croplands in the case of biotic raw materials.

Figure 16 shows that, in terms of volume, domestic extraction is dominated by construction materials. These are the raw materials that are used most frequently in the EU (see Indicator 15 on material flows in the circular economy). Domestic extraction of construction materials steadily increased until the mid-1990s. It accelerated from the early 2000s and then dropped notably as from 2008 because of the financial crisis. The stagnating domestic extraction of construction minerals between 1995 and 2005 may also have been due to the lower demand for these materials for the building of long-lasting infrastructure. The extraction of industrial minerals and roundwood also increased significantly. As for metals, domestic extraction has fallen by almost 20 % since the 1970s. This may be due to mine production shifting to other countries (see Indicator 1) for various reasons, which are more closely discussed in the thematic cluster on framework conditions for mining.

These data are in line with the data on global and EU materials demand and on the share of imports in the EU's consumption of raw materials (Indicator 3). Over the years the EU has managed to be largely self-sufficient for construction minerals and wood. However, the EU's domestic production of metals did not follow the exponential increase in global demand for metals (see Figure 3 in the introduction).

Figure 16: Domestic extraction of raw materials (EU-28, 1970-2010)[74]



74 Source: UNEP (2016), *Material Flows and Resource Productivity* (forthcoming) Paris. See also methodological notes.

Figure 17 presents data on the production between 2004 and 2013 of a selection of raw materials. It shows how raw materials such as steel and aluminium — which are mostly used in sectors (such as construction or automotive) that are sensitive to economic cycles — experienced a sharp drop after the financial crisis of 2008. For aluminium, it can also be seen that the production of primary aluminium has fallen by almost 20 % since 2004. Indeed, since 2003, 11 out of 26 primary aluminium smelters closed down, mostly because of the high costs of electricity.[75]

Figure 17 also shows that — in terms of volume — the EU processes more raw materials than it extracts. This difference can be explained by the inputs to production coming from imports and recycling. Unfortunately, no comprehensive data exist on secondary raw material production in the EU, for which there are indications that the EU is in a strong position to become a global leader.[76] For copper and aluminium, global data indicate that secondary production has increased on average by a factor of 5 since the 1980s.[77] Data on recycling's contribution to meeting materials demand (Indicator 16) however indicate that this varies widely from material to material, ranging between 1 % and 30 %.

Conclusion

Domestic production of raw materials is an essential component of the EU's industrial system. Data on domestic extraction show that, since the 1970s, the EU has been able to meet its growing demand for construction minerals and roundwood domestically. For metals however, domestic extraction has remained relatively stable, in spite of an exponential growth in demand[78] during the 20th century. This reflects the shift of metal ores production to other world regions. At the same, time EU industry started to focus more on the production of secondary raw materials. Indeed, data on processing and refining of metals show that the EU processes more raw materials than it extracts, due to imports and recycling.

Figure 17: Domestic production of a selection of metals (2004-2013)[79]

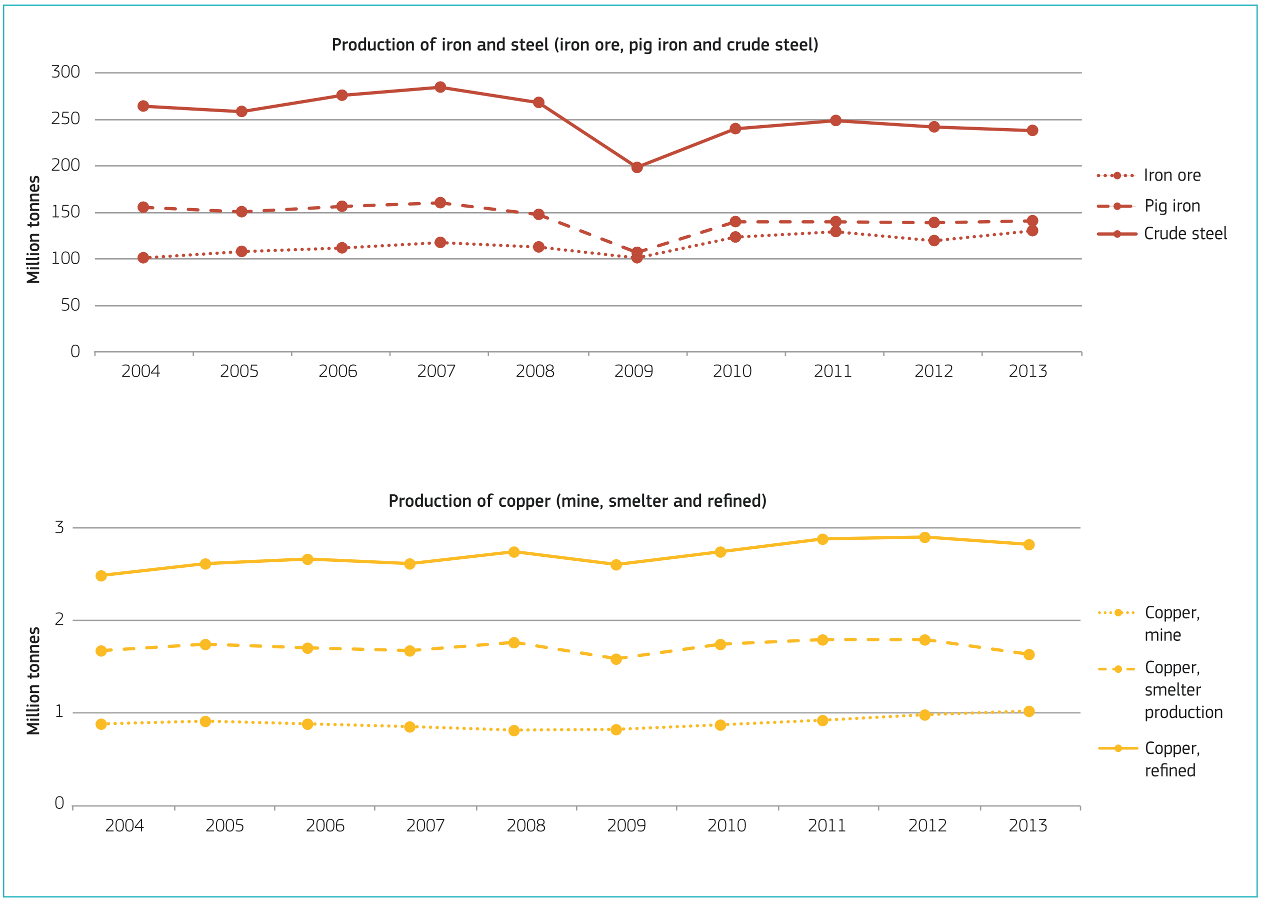
75 European Commission, 2013, '*The state of aluminium production in Europe*', MEMO/13/954.

76 Eunomia, 2014, *Study on the competitiveness of the EU mineral raw materials sector: non-energy and extractive industries and recycling industries*, report to DG Enterprise and Industry.

77 OECD, 2015, '*Material Resources, Productivity and the Environment*'.

78 UNEP, 2014, *'Decoupling 2: technologies, opportunities and policy options. A Report of the Working Group on Decoupling to the International Resource Panel'*, von Weizsäcker, E.U., de Larderel, J, Hargroves, K., Hudson, C., Smith, M., Rodrigues, M.

79 Source: JRC analysis based on data from the Minerals4EU project Yearbook (http://minerals4eu.brgm-rec.fr/m4eu-yearbook/theme_selection.html). Data retrieved February 2016. See also methodological notes.


Production of iron and steel (iron ore, pig iron and crude steel)
Million tonnes
300
250
200
150
100
50
0
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Iron ore
Pig iron
Crude steel
Production of copper (mine, smelter and refined)
Million tonnes
3
2
1
0
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Copper, mine
Copper, smelter production
Copper, refined


© apimages.com

7. Value added and jobs

Key points:

- In 2012, the raw materials sector contributed EUR 280 billion of added value and more than four million jobs to the EU economy.
- The economic importance of the raw materials sector goes far beyond the economic activities strictly related to the extractive and processing industries. Looking at the metals value chain alone, more than 11 million jobs in downstream manufacturing sectors depend on the secure supply of metals, equal to 40 % of the jobs and value added from the EU's entire manufacturing sector.

Overview and context

Raw materials are an essential building block of the EU's economy, with many downstream sectors relying on raw materials supply. Indeed, virtually all manufactured goods include some components that are made of non-energy, non-agricultural raw materials, or depend indirectly on raw materials for their production (e.g. industrial machinery used in the production of non-metal-containing goods).

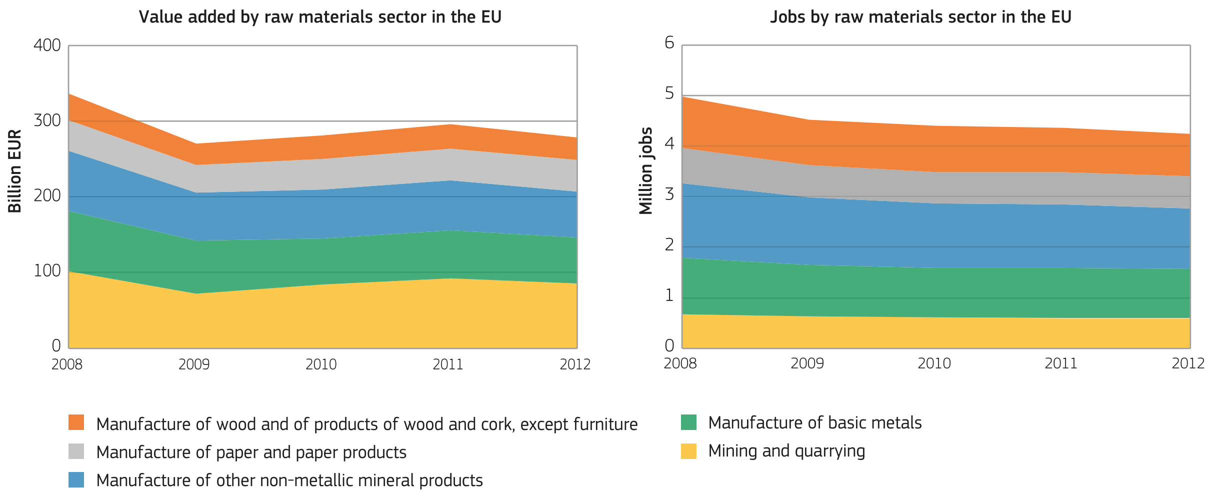
As can be seen in Figure 6 in the introduction on material flows across the value chain, raw materials extractive activities (mining, quarrying or harvesting) are the starting point of most value chains. They are followed by basic manufacturing industries (raw materials processing) and finally by industries responsible for the manufacturing of final products. To create added value and jobs, these industries rely fully on the supply from upstream sectors.

Facts and figures

Figure 18 displays the time trend of the value added (at factor cost) and the number of jobs[80] associated with a selection of raw materials extractive and processing subsectors for the EU between 2008 and 2012. Both of these are key economic indicators.

In 2012, the raw materials subsectors shown in Figure 18 contributed EUR 280 billion of added value and more than four million jobs in the EU. All sectors experienced a contraction after 2008 due to the effect of the economic recession. While value added partially

Figure 18: Value added at factor cost (left) and number of jobs (right) for a selection of raw materials economic sectors in the EU (2008-2012)[81]



80 See methodological notes.
81 Source: JRC analysis based on data from Eurostat, retrieved on 20 May 2015. *Value added at factor cost* from the *Annual detailed enterprise statistics for industry*, code *sbs_na_ind_r2.* Value added at factor cost represents the gross income from the economic activities after making an adjustment for subsidies and indirect taxes – but not taking depreciation into account. *Number of employees* from *Industry by employment size class* statistics (NACE Rev. 2, B-E), code *sbs_sc_ind_r2*. See also methodological notes.

recovered in recent years, the fall in the number of jobs continued (except in the mining and quarrying sector). This trend of a contraction followed by a partial recovery was in line with overall trends in most economic sectors in the EU.

To demonstrate the importance of raw materials to the rest of the economy, Figure 19 focuses on the metals value chain, covering the mining of metal ores, the manufacturing of basic metals and finally the manufacturing of final products such as motor vehicles, machinery, computers and electronic products. For each step of the value chain, it displays the related value added and jobs. It shows that the economic importance of the raw materials sector goes far beyond the economic activities strictly related to mining and quarrying.

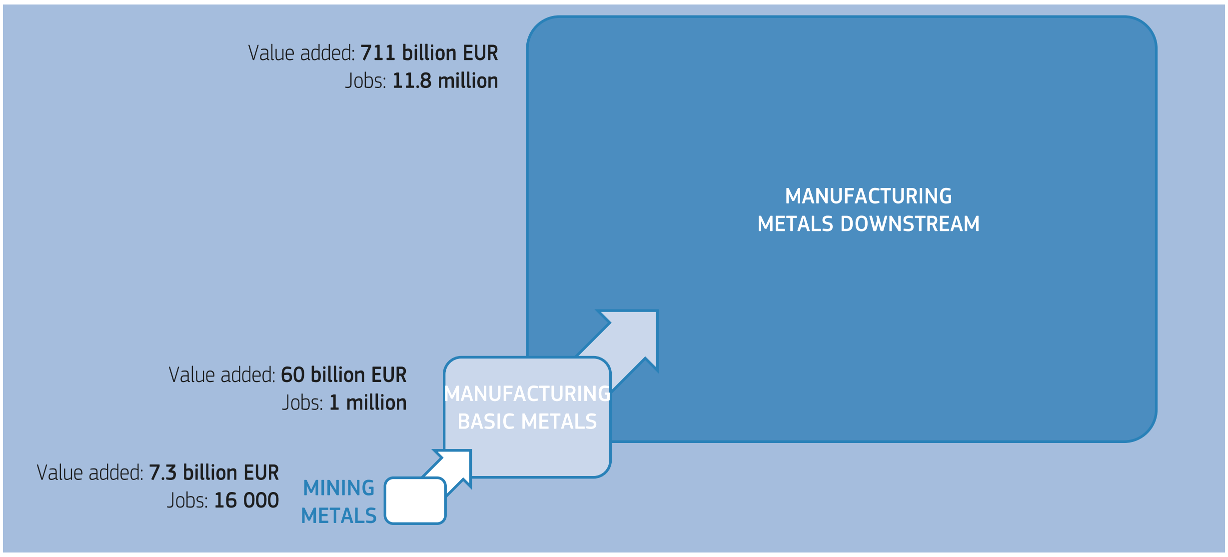
Indeed, the added value in the downstream sectors multiplies by a factor close to 10 when moving from the mining of metal ores (EUR 7.3 billion) to the manufacturing of basic metals (EUR 60 billion). Similarly, when moving from manufacturing of basic metals to the manufacturing of final products (e.g. the production of fabricated metal products, electronics, machinery and equipment), the added value increases to EUR 711 billion, which is more than 40 % of the total manufacturing value added.

A similar trend can be seen for jobs. While more than 16 000 jobs are associated with the mining of metal ores, almost one million jobs are generated by the manufacture of basic metals (4 % of the jobs associated with the whole manufacturing sector) and more than 11 million jobs in the downstream sectors (more than 40 % of jobs in the manufacturing sector).

Conclusion

Creating jobs and growth is the Juncker Commission's central priority. In 2012, the raw materials sector contributed more than EUR 280 billion of added value and more than four million jobs to the EU's economy. However, the economic importance of the raw materials sector goes far beyond the economic activities strictly related to the domestic extractive industries. Looking at the metals industry value chain alone, more than 11 million jobs in downstream manufacturing sectors depend on the secure supply of raw materials.

Figure 19: Value added and number of jobs associated with metals (mining, basic manufacture and downstream sectors) in the EU (2012)[82]



The search for suitable data ...

Given the high level of data aggregation, it is not possible to completely isolate non-energy, non-agricultural raw materials from other raw material types. Because the manufacture of rubber is aggregated with that of plastic, it was not included in the calculations. For similar reasons recycling activities were also not included. This is partly compensated by the fact that the data for mining and quarrying also includes the extraction of energy carriers (coal, lignite, natural gas). Therefore, the data included in Figure 18 should be seen as an approximation.

Furthermore, the data illustrating that the economic importance of raw materials goes far beyond extractive activities could only be calculated for metals (Figure 19) due to data limitations encountered for other types of material (e.g. data gaps for some countries and materials).

82 Source: JRC analysis based on data from Eurostat, retrieved on 10 June 2015. *Value added at factor cost* and *Number of employees* from the *Annual detailed enterprise statistics for industry* (NACE Rev. 2, B-E), code *sbs_na_ind_r2*. See also methodological notes.

8. Corporate R&D investment

Key points:

- Despite being an industry of low R&D intensity, top R&D investor companies in the raw materials sector have almost doubled their annual R&D expenditure since 2003, growing more than twice as fast as public R&D investments between 2003 and 2013.
- The biggest increase in corporate R&D investment is in the 'Construction and Materials' and 'Mining' sectors.

Overview and context

To remain competitive internationally, the EU needs innovative businesses that create added value. This requires investments, notably in R&D, to promote the development of new products and services, and thus drive growth and create high-quality jobs.

Innovation — the process of translating an idea or invention into a good or service that creates value or for which customers will pay — is difficult to cover by a single indicator. Therefore the Raw Materials Scoreboard brings together information on R&D investment, patent applications (Indicator 9) and knowledge and skills (Indicator 10).

Compared with high-tech industries, such as pharmaceuticals, biotechnology or technology hardware and equipment that have R&D intensities of 5 % or higher, the raw materials sectors generally have R&D intensities of 1 % or lower. This can be explained by the fact that the raw materials industries rely mostly on mature technologies provided by equipment manufacturers; they channel their investments to modernising their production facilities rather than to in-house research in breakthrough technologies. Nonetheless, it is important for the raw materials sectors to invest in R&D that can lead to process innovations so as to adapt to changing market conditions and to remain competitive at the international level.

Facts and figures

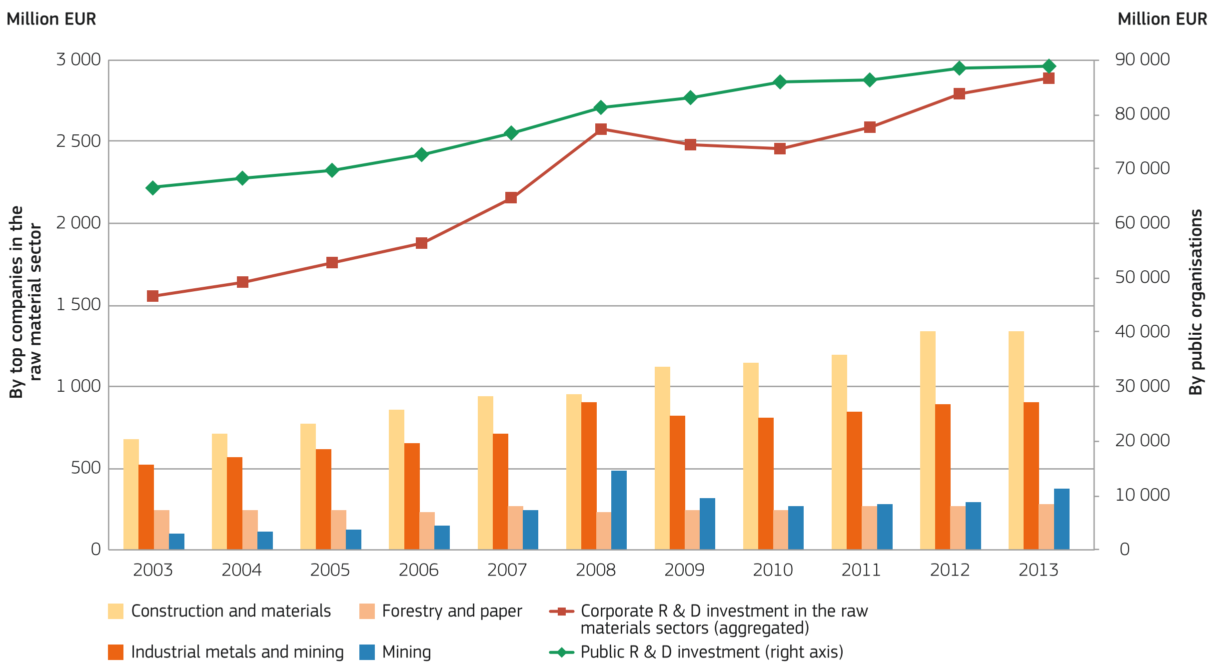
Figure 20 displays the aggregated R&D expenditures of 41 companies relevant to the field of raw materials that were consistently listed in the EU Industrial R&D Investment Scoreboard[83] between 2003 and 2013. The aggregated private investments by these companies are represented through four categories: 'Construction & Materials'; 'Industrial Metals & Mining' (covering manufacturers of non-ferrous metals and iron and steel); 'Forestry & Paper'; and 'Mining' (covering mining of coal, diamonds and gemstones, gold and other minerals).[84]

Overall, the aggregated R&D investment of the listed companies has grown by 86 % from roughly EUR 1.6 billion in 2003 to EUR 2.9 billion in 2013, at a compound annual growth rate of 6.4 %. This is twice as much as the increase in public R&D expenditure,[85] whose rate increased by 2.92 %.

The biggest growth rates in R&D investments were in the 'Construction & Materials' and 'Mining' categories, which experienced, respectively, 2 and 3.5-fold R&D expenditure increases from 2003 to 2013. The growth rate in 'Industrial Metals & Mining' (73 %) roughly corresponds to the overall average, while the growth rate of R&D expenditures was significantly lower in 'Forestry & Paper' — about 11 %.

83 EU Industrial R&D Investment Scoreboard, http://iri.jrc.ec.europa.eu/scoreboard.html.
84 See methodological notes for further details.
85 Government contributions to EU-28 gross domestic expenditure on R&D. Source: JRC analysis based on data from Eurostat, retrieved on the 30 August 2015. *GDP and main components (output, expenditure and income), code nama_10_gdp; Gross domestic expenditure on R&D (GERD), code t2020_20; Gross domestic expenditure on R&D (GERD) by source of funds, code tsc00031.*

Figure 20: Annual R&D investment (2003-2013) for companies with their headquarters in the EU[86]



Conclusion

The Europe 2020 Strategy sets the objective of devoting 3 % of EU GDP to R&D activities, more than half of which originates from the private sector. Even if the raw materials sector is considered of low R&D intensity, the average R&D investment of 41 relevant companies almost doubled between 2003 and 2013, growing more than twice as fast as public R&D investment. In view of the challenges ahead, such as increasing demand, global competitive pressure, increasing environmental standards and energy-efficiency requirements, it will be important for the sector to keep up its investment efforts. Especially given the recent fall in commodity prices, it will be interesting to see how this trend will develop.

86 EU Industrial R&D Investment Scoreboard, http://iri.jrc.ec.europa.eu/scoreboard.html.

9. Patent applications

Key points:

- Even though the EU proportion of patent applications in the raw materials sector is on a decreasing trend, it still accounted for almost 36 % of patent applications filed in the same sector by the EU, Australia, Canada, Japan, Russia and the USA altogether.
- The number of EU patent applications in the 'mining and mineral processing' sector increased by 35 % between 2000 and 2011.
- The overall number of patent applications in the other raw materials sectors (basic metals, biotic materials etc.) has declined since 2000, both in the EU and internationally.
- Patent applications are mainly filed by companies.

Overview and context

According to the OECD, patents can be defined as '*means of protecting inventions developed by firms, institutions or individuals, and as such they may be interpreted as indicators of invention*'.[87] By focusing on the marketable outputs of R&D activities, patents are mostly an indicator of technological innovation.[88] In the Raw Materials Scoreboard, this indicator is complemented by indicators on corporate R&D investments (Indicator 8) and on knowledge and skills (Indicator 10).

Facts and figures

Figure 21 shows the number of patent applications in the raw materials sector between 2000 and 2011 from the EU-28 Member States and a group of six major industrialised non-EU countries, named 'International reference countries', which comprises Australia, Canada, China, Japan, Russia and USA. The data were retrieved from the European Patent Office Worldwide Patent Statistical Database and are grouped into five industrial categories: 'basic metals'; 'biotic materials'; 'non-metallic mineral products'; 'recycling'; and 'mining and mineral processing'.[89]

In the EU, the overall number of patent applications in the raw materials sector fell by about 35 % from 2000 to 2011, while the selected international group of reference countries registered a fall of 15 % over the same period. For both groups, a marked drop in patent applications is evident after 2008, which is most likely a consequence of the global economic downturn.

The biggest contribution to the total number of patent applications in the raw materials sector comes from the 'basic metals' category. In the EU, this is followed by 'biotic materials', 'non-metallic mineral products', 'recycling' and 'mining and mineral processing'.

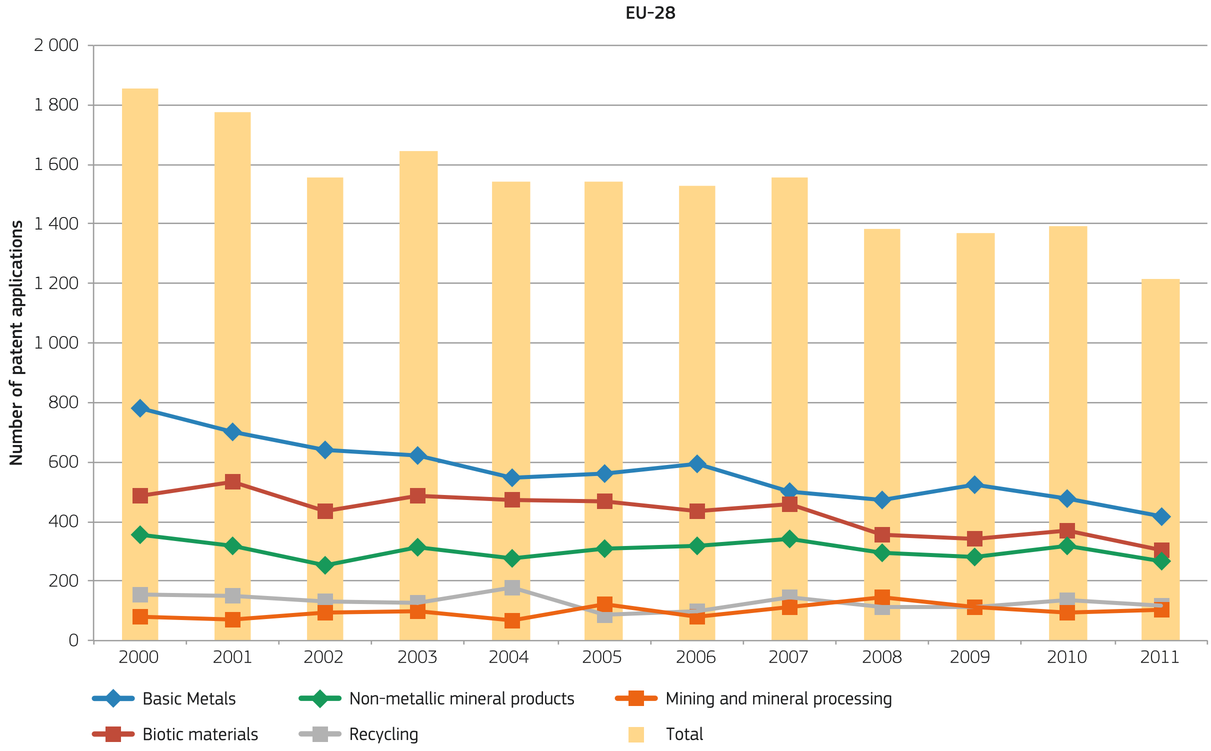
Between 2000 and 2011, the number of patent applications varied significantly across the individual categories. In the EU, for example, the 'basic metals' and 'biotic materials' categories saw a significant reduction in the number of patent applications, while 'non-metallic mineral products' and 'recycling' registered relatively moderate declines. In contrast, the number of patent applications in 'mining and mineral processing' increased by 35 % over the same period.[90] It has been observed that patent filing in this category follows the cyclical nature of mineral exploration investments, which are mainly driven by the commodity prices index.[91]

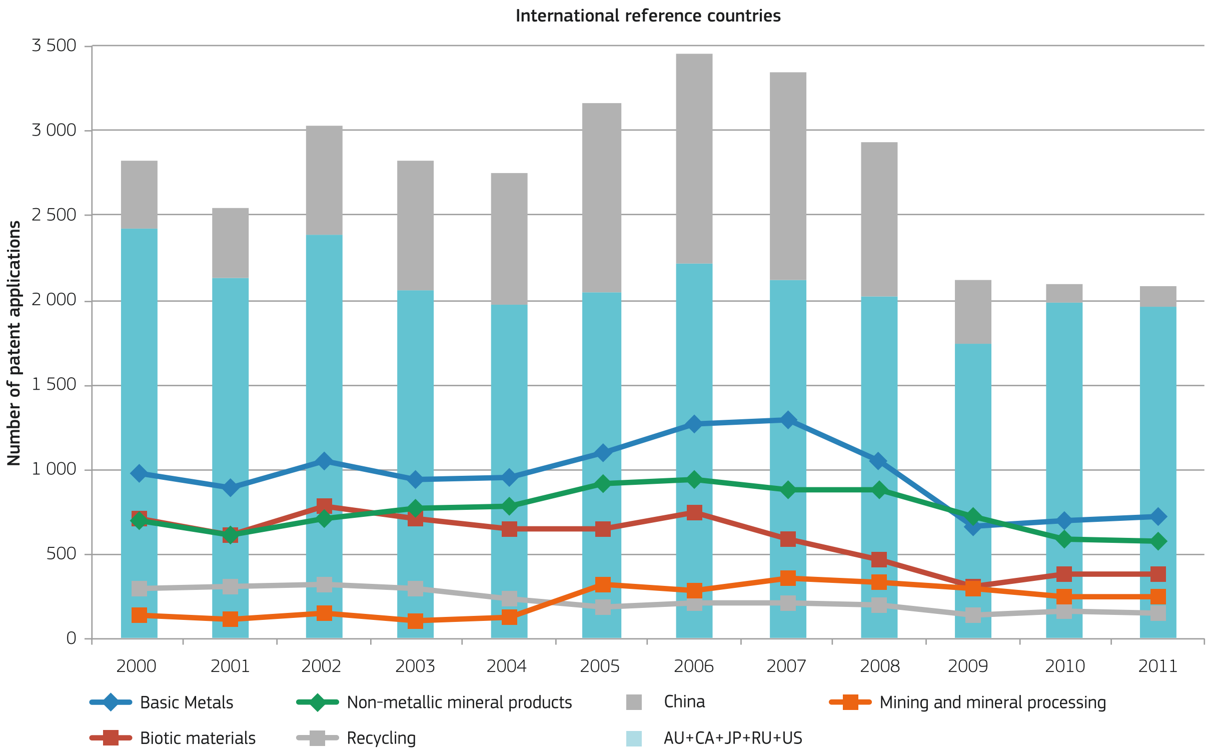
For international reference countries, from 2008 to 2009, patent filing by Chinese applicants fell dramatically (from 905 to 305, and even further to 109 in 2010). This is because, from 2009 onwards, the Chinese patent office did not communicate the country codes for Chinese applicants. By leaving China out of this analysis, the statistical trend of the remaining five international reference countries follows — to a certain extent — the one registered by EU-28.

Figure 22 shows that, between 2000 and 2011, patent applications were filed mainly by companies, up to 88 % in the EU and 75 % in the international reference countries. The proportion of universities in patent applications is much higher in the international reference countries (11 %) compared with the EU (2 %). This probably reflects the different structure of the R&D and innovation landscape. Patenting by universities in general leads to additional funding for research, spurring new start-ups.

87 OECD, 2009, '*Patent Statistics Manual*', ISBN 978-92-64-05412-7.
88 European Commission, 2013, '*Measuring innovation output in Europe: towards a new indicator*', COM(2013) 624.
89 See also methodological notes.
90 This increase might not be evident in the graph due to the low contribution of this category to the overall patents in the field of raw materials.
91 SNL Metals & Mining, 2014, '25th Annual Corporate Exploration Strategies study', (http://go.snl.com/Nonferrous-Mining-Exploration-Budgets-Request.html).

Figure 21: Number of raw materials patent applications from EU-28 Member States (top) and six international reference countries (bottom)[92]



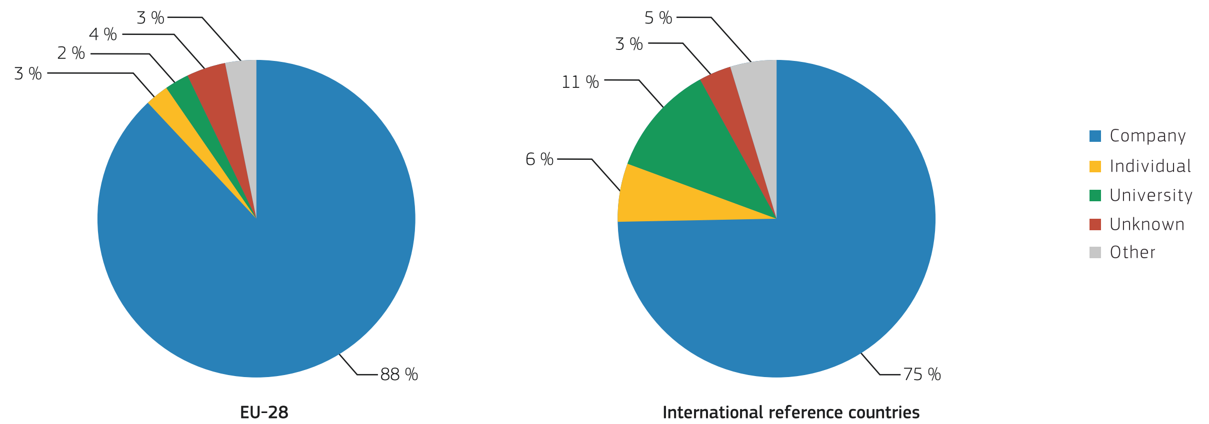


92 Source: JRC analysis of PATSTAT data. Country abbreviations — AU: Australia, CA: Canada, CN: China, JP: Japan, RU: Russia and US: USA. See also methodological notes.

Conclusion

Looking at the number of patent applications in the raw materials sector, it is once more demonstrated how challenging it is to measure innovation. Although R&D investor companies in the raw materials sector have almost doubled their annual R&D expenditure since 2003 (see Indicator 8), the number of patent applications over the same period has generally gone down, both in the EU and internationally. This could probably be explained by the fact that the raw materials sector relies on mature technologies and that, consequently, innovative activities do not necessarily give rise to patents. In addition, it is important to note that, due to technical limitations, patents in substitution of critical raw materials are not included in the analysis.

Figure 22: Proportion of patents by type of applicant in (EU-28 and international reference countries, 2000-2011)[93]



93 JRC analysis of PATSTAT data. Data are for all five categories related to the raw materials sector, aggregated between 2000 and 2011.

10. Knowledge and skills

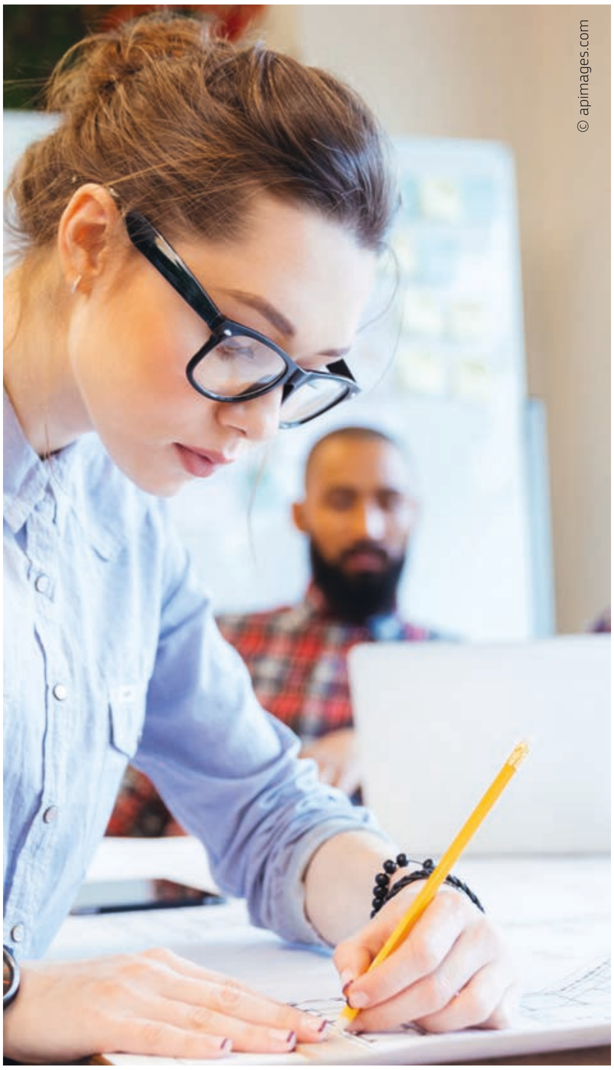
Key points:

- The mining and minerals processing sector is reported to be characterised by a talent shortage.
- There are indications that the number of educational programmes relevant to raw materials is in decline.
- Within the EU, countries with a strong mining industry and/or a long-standing mining history have in general more educational programmes related to raw materials.
- At global level, more than 90 % of mineral processing graduates are reported to be educated in Asia, Africa, South and Central America; the figure for western Europe is less than 1 %.
- The average level of workforce qualification increased between 2009 and 2013.

Overview and context

Knowledge and skills — the understanding of a subject, be it through training or lifelong learning — is key for innovation in firms. Skilled labour can contribute to innovation and growth by generating new knowledge, developing incremental innovations, supporting firms in the identification of business opportunities, helping companies adapt to changing environments, transferring knowledge to co-workers within the organisation, and adding to social capital.[94] To remain competitive, knowledge and skills need to be available in the required quantity and quality at the appropriate time and place.

The mineral exploration, mining and processing sector is reported to be characterised by a talent shortage.[95] It suffers from an ageing work force, and young graduates are often attracted to other sectors with equally high salaries[96] but with more attractive work locations. In addition, companies are reported to have underinvested in induction programmes and building talent within the organisation, which has contributed to the sector's declining productivity.[97]


© apimages.com

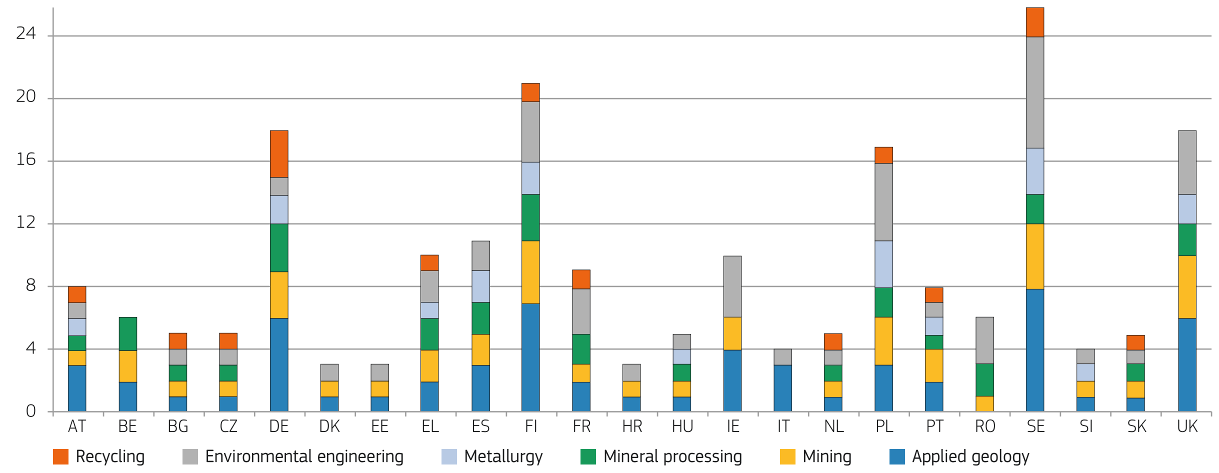
Facts and figures

Academic opportunities

Even though little quantitative data are available, there are indications that the number of educational programmes dedicated to the raw materials sector is declining in the EU.[98] Besides the cancellation of programmes, mergers with more general programmes

94 The Innovation Policy Platform (https://www.innovationpolicyplatform.org/).
95 Shillito, J., 2015, *'Talent wars — how the mining sector must dig deep for the right candidates'*, Industrial Minerals.
96 'Mining and quarrying' is in the top three sectors in terms of wages increase: over the last 10 years, wages in this sector increased by 45.6 %, to be compared with increases ranging from 25.5 % in 'Accommodation and food service activities' to 47.1 % in 'Financial and insurance activities' (Eurostat data).
97 Ernst & Young, 2014, *'Productivity in mining: now comes the hard part — A global survey'*.
98 McDivitt, J., 2002, *'Status of Education of Mining Industry Professionals'*, Mining, Minerals and Sustainable Development, report prepared for the Institute for Environment and Development (IIED).

Figure 23: Number of educational programmes related to raw materials by country (2012)[103]



(e.g. material science, civil engineering, chemical engineering or environmental technology) have been responsible for the declining number of specialised programmes. More recently, the drop in student enrolment and the restructuring of programmes resulting from the Bologna process[99] have also contributed to this trend. As a consequence, the availability of graduates specialised in fields of direct relevance to raw materials is decreasing, but is somewhat offset by the bigger number of graduates with broader knowledge. Mining engineers, mineral processing engineers and metallurgy engineers seem especially to be short in supply.[100]

Figure 23 shows the number of raw materials educational programmes for 23 Member States[101] in 2012. The number of educational programmes relevant to raw materials correlates with countries' involvement in mining (e.g. countries with a strong mining industry and/or a long-standing history in mining). In many cases, these countries have the necessary skilled teaching personnel and have established study programmes and close cooperation with the local industry.[102]

Qualifications and training

Figure 24 shows the trend for workforce qualifications and participation in education and training in the mining and quarrying sector in the EU between 2009 and 2013.[104] The average level of workforce qualification increased between 2009 and 2013. The proportion of employees with lower levels of education (levels 0-2 of the International Standard Classification of Education (ISCED),[105] i.e. up to lower secondary education) fell by 30 %, while the proportion with higher levels of education (levels 5-6, e.g. short-cycle tertiary education or bachelor's level) increased by 26 %. This trend might be explained by increasing use of IT and increasing levels of automation in the sector.

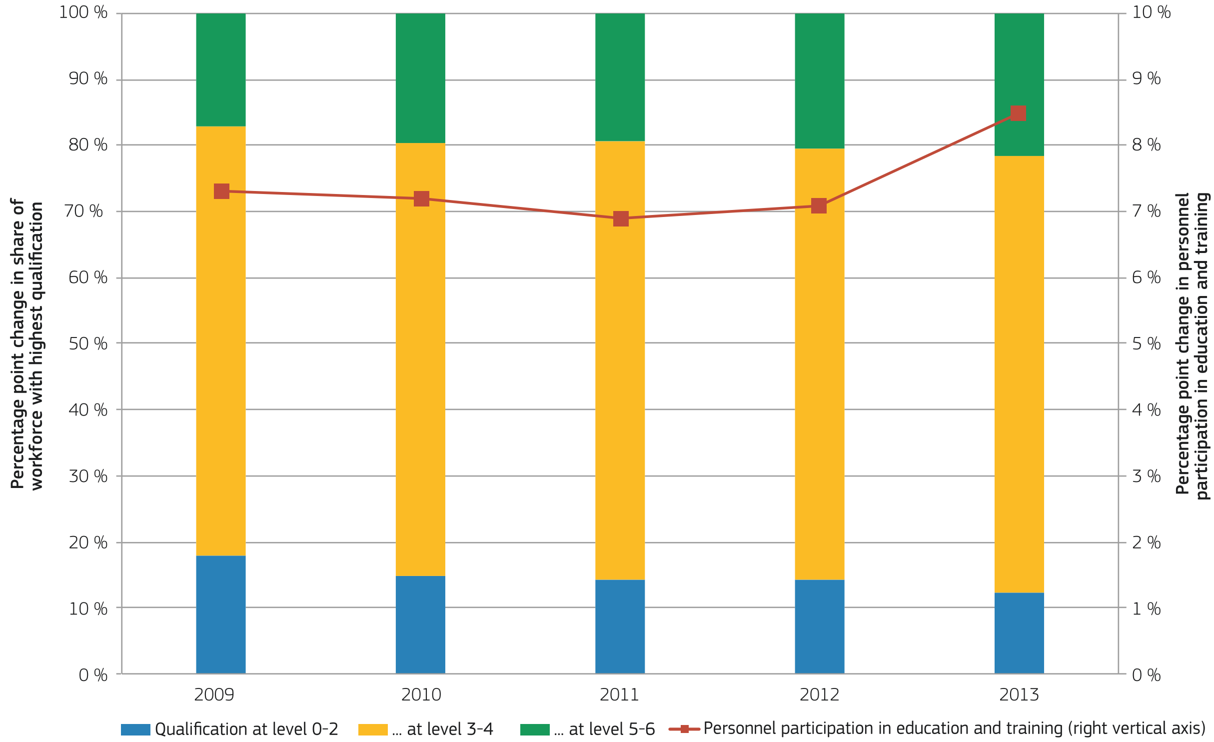
The search for suitable data ...

Measuring knowledge and skills is a complex issue. Although data are available on the number of students in science, technology, engineering and mathematical (STEM) education programmes, the data were found to be too coarse a proxy to represent knowledge and skills in the raw materials sector, because only a small fraction of STEM students may choose to work in the raw materials sector. Looking to the future, data on the number of students that are enrolled in raw materials specific study programmes may become available through the Knowledge and Innovation Community (KIC)[106] on Raw Materials. This was launched in 2015 as part of the European Institute of Innovation & Technology[107] and has planned the launch of a quality label for masters and PhD programmes.

99 Batterham, R. J., 2013, '*The Impact of the Bologna Model on Mineral Processing Education: Good, Bad or Indifferent*', in: Minerals Industry Education and Training, Cilliers, J., Drinkwater, D. and Heiskanen, K. (Eds.), New Concept Information Systems Ltd., New Delhi, ISBN 81-901714-4-5, pp. 29-36.
100 Shillito, 2015.
101 Sand, A., Rosenkranz, J., 2014, '*Education related to mineral raw materials in the European Union*', COBALT project "COmmunicating, Building of Awareness, Leadership competence and Transfering knowledge on sustainable use of raw materials" D3.1.
102 Ibid.
103 Source: JRC analysis based on Sand, A., Rosenkranz, J., 2014, '*Education related to mineral raw materials in the European Union*', COBALT project "COmmunicating, Building of Awareness, Leadership competence and Transferring knowledge on sustainable use of raw materials" D3.1. Educational programmes cover university-level educational programmes. Vocational training programmes are excluded, while programmes of applied sciences universities are included. The graph shows master's courses, bachelor courses and single course programmes that are not linked to research activities in their respective institutes. The graph only displays 23 EU countries as 5 did not report relevant educational programmes. Data for certain Member States may be incomplete.
104 The EU Skills Panorama provides data, information and intelligence on trends for skills and jobs across Europe: http://skillspanorama.cedefop.europa.eu/en.

105 ISCED fields of education and training 2013 (ISCED-F 2013), UNESCO Institute for Statistics, ISBN 978-92-9189-150-4 Ref: UIS/2014/INS/4 REV, DOI http://dx.doi.org/10.15220/978-92-9189-150-4-en.
106 KIC on Raw Materials (http://eitrawmaterials.eu/).
107 European Institute of Innovation and Technology (http://eit.europa.eu/).

Figure 24: Qualification levels and participation in education and training in the EU mining and quarrying sector (2009-2013)[108]



Conclusion

Knowledge and skills are important for the raw materials sector, both to sustain innovation and to maintain productivity. While talent shortage is recognised to be a significant problem in the raw materials sector, it is very hard to find reliable statistics on the number of graduates or the number of vacancies that cannot be filled. However, when looking at the number of educational programmes relevant to raw materials, the data show that countries with a rich mining tradition generally have a broader education supply, although there are indications that, in general, the number of educational programmes specifically on raw materials is decreasing.

This is alarming because, at global level,[109] more than 90 % of mineral processing graduates are now reported to be educated in Asia, Africa and South and Central America; western Europe accounts for less than 1 %.[110] Furthermore, projected trends see the gap widening; the number of graduates outside the EU is expected to rise by more than 15 % over the coming years, while in Europe the number is projected to remain static.

© apimages.com

108 The EU Skills Panorama provides data, information and intelligence on trends for skills and jobs across Europe: http://skillspanorama.cedefop.europa.eu/en.
109 Cilliers, J., 2013, *'The Supply and Demand of Minerals Engineers: A Global Survey'* in: Minerals Industry Education and Training, Cilliers, J., Drinkwater, D. and Heiskanen, K. (Eds.), New Concept Information Systems Ltd., New Delhi, ISBN 81-901714-4-5, pp. 3-13.
110 Sand, A., Rosenkranz, J., 2014, *'Education related to mineral raw materials in the European Union'*, COBALT project "COmmunicating, Building of Awareness, Leadership competence and Transfering knowledge on sustainable use of raw materials" D3.1.

Framework conditions for mining

>> Indicators:

11. National minerals policy framework
12. Public acceptance
13. Mining activity in the EU
14.. Minerals exploration

11. Mining activity in the EU

Key points:

- Several metallic raw materials are mined in the EU, including base, precious and specialty metals. The EU's mines are mainly concentrated in certain regions, a phenomenon that can mostly be explained by differences in natural endowments and national mining policy framework conditions.
- Even though the EU has the potential to increase the current production or start new production units, domestic extraction of metals is largely insufficient to meet the EU's raw materials demand.

Overview and context

Metals are ubiquitous in today's society. Their secure supply is a prerequisite for sustained economic development in the EU and elsewhere.

While the EU is close to being self-sufficient for construction minerals and most of the industrial minerals and roundwood (see Indicator 6 on domestic production), it is largely dependent on imports for metals (see Indicator 3). Despite existing European mineral deposits, there has been little metal extraction activity since the 1980s, with mine production shifting to other countries (see Indicator 1 on the EU's share of global production). The present indicator provides detailed information on active metal mines in the EU, which is essential to understanding the EU's current production potential. This information is complemented by Indicator 12 on minerals exploration, which highlights areas where mining activity could potentially be developed in the future.

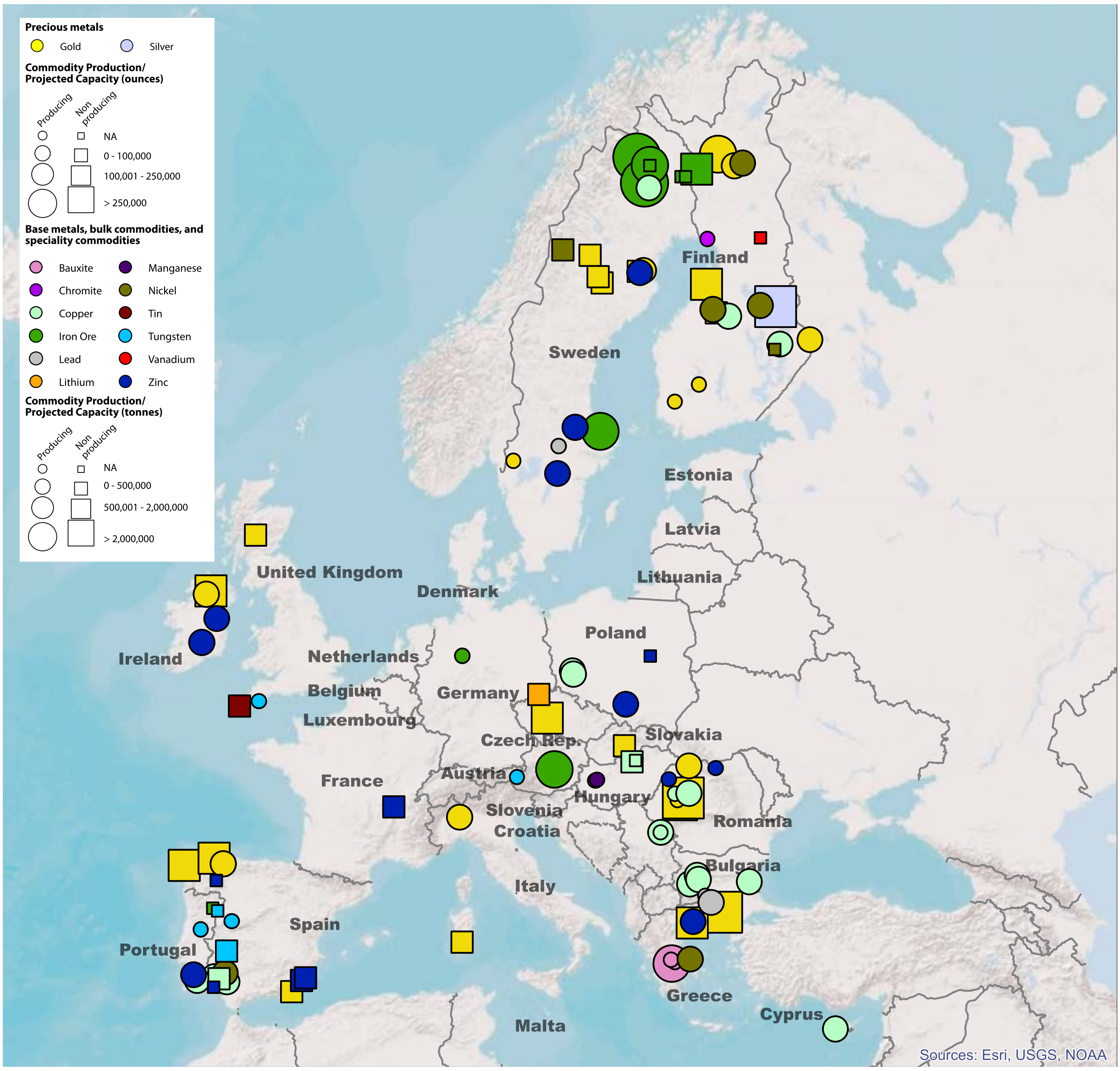
Facts and figures

Figure 25 provides information about the geographic location and approximate production size of metal mines in the EU, for 2014. It presents the main commodity mined in both producing and non-producing mines (e.g. mines at pre-production stage and mining projects undergoing feasibility studies).

The figure shows that the EU currently has several mines producing base metals, precious metals and critical raw materials. Interestingly, the mines are mainly concentrated in certain regions, a phenomenon that can mostly be explained by differences in natural endowments and national mining policy framework conditions (see Indicator 13).

For base metals, the EU produces bauxite, the main ore for aluminium, mostly in Hungary and Greece; copper and zinc, in various countries; and iron is mostly mined in Sweden. Other base metals mines in the EU include manganese in Hungary, nickel in southern and northern Europe, and lead, concentrated in Greece, Bulgaria and Sweden. Precious metals like silver and gold are also widely produced in the EU, although generally in small quantities. In addition, critical raw materials are also mined, for example chromite — the source of chromium – in Finland, and tungsten, mainly in southern Europe. Despite this mining production, the EU is — as shown by Indicator 3 — largely dependent on imports to meet its demand for metals.

Figure 25: Metal mine production in the EU (2014)[111]



Two observations can be made regarding the coverage of the map. The first is that it only shows primary commodities (i.e. the main material mined in each production site), when for many mines several other commodities are also mined as by-products. Second, the current production capacity of these mines might differ from the values displayed in Figure 25, given that mine production is particularly dependent on market prices, which tend to fluctuate as a function of economic cycles.

In addition to mines currently producing ores or metals — and as shown by the number of different projects at pre-production stage or undergoing feasibility studies — the EU has the potential to increase the current production or launch new production facilities.

Conclusion

Even though many metallic minerals are extracted in the EU, domestic production is not sufficient to meet overall demand. This is why improving the framework conditions for mining is a key component of both the EU's Raw Materials Initiative[112] and the European Innovation Partnership on Raw Materials.[113] Considering the many factors influencing the success rates of exploration and the long lead times, it is not to be expected that many new mines will be developed in the near future in the EU (see also Indicator 12 on exploration activities). Moreover, the currently relatively low commodity prices may have an additional impact on existing mines in the EU.

111 Source: © SNL Metals & Mining 2016. Data based on Esri, USGS and NOAA. See also methodological notes.
112 European Commission, 2008, '*The Raw Materials Initiative — meeting our critical needs for growth and jobs in Europe*', COM(2008) 699; European Commission, 2011, '*Tackling the challenges in commodity markets and on raw materials*', COM(2011) 25.
113 European Innovation Partnership on Raw Materials, 2013, ' *Strategic Implementation Plan*'.

12. Minerals exploration

Key points:

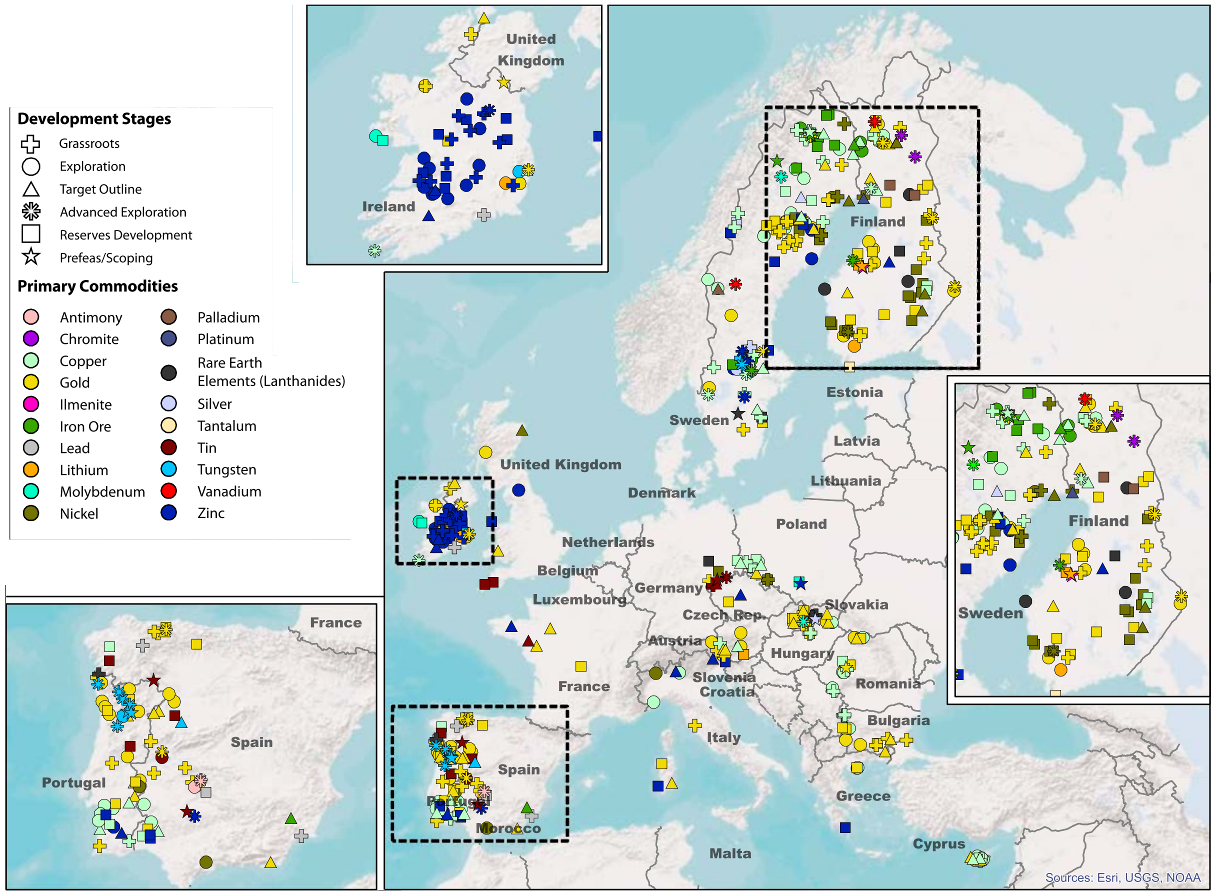
- Mineral exploration is an important step in the mining life cycle because it contributes to the discovery of potential new deposits and the opening of new mines.
- The EU's minerals potential is under-explored: the number of exploration projects is significantly low compared with the EU's estimated mineral potential. Several factors hamper minerals exploration in the EU, including social and economic constraints and limited geological knowledge.
- Exploration activities for metallic minerals in the EU and their related economic investment are relatively low compared with other world regions.
- Compared to the global level, investment in exploration activities in the EU is low. Due to the sector's sensitivity to economic cycles, investment in metallic mineral exploration has steadily decreased since the investment boom in 2011-2012, both in the EU and globally.

Overview and context

Mineral exploration is the process of finding mineral deposits that are economically profitable. It is a crucial step in the mining life cycle, involving a sequence of activities that begins with the early identification of a resource, its further quantification, and a feasibility assessment that leads to a decision about production.

In the EU's varied geology, mineral occurrences exist for a wide range of raw materials, including metals. However, many mineral occurrences of sufficient quality for mining activities are currently under-exploited in the EU, because their exploration and mining is hampered by various factors. These include limited geological knowledge, access to land or to under-sea areas, technological and economic feasibility of mine development, high and increasing costs for exploration, and in some cases the greater depths of mined and new deposits. In addition, mineral exploration is a capital-intensive activity that requires high-risk investments. It is therefore highly sensitive to business cycles: when prices are high, investments go up, but when commodity prices are low, investment in exploration plunges.

Figure 26: Metallic mineral exploration in the EU (2014)[114] per development stage[115]



Facts and figures

Figure 26 presents metallic mineral exploration activities in the EU for 2014. It shows activities taking place before the mine is set up[116], including early-stage exploration — which results in the initial quantification of resources – and late-stage exploration — which provides more detail on the initial resources quantification and a feasibility assessment.

The map shows that the locations of exploration activities are mostly concentrated in Ireland, Portugal, Finland and Sweden, which are considered to be attractive countries for investment in mining exploration (see Indicator 13 on national minerals policy frameworks), but also in Member States in central and south-eastern Europe. The target raw materials of these explorations are mainly base metals (such as copper, tin, iron, nickel and zinc), deposits of precious metals (e.g. gold) and rare earth elements.

Interestingly, the number of exploration projects is significantly lower than the number of identified mineral deposits[117], occurrences and showings as depicted in Figure 27. Currently, known deposits in Europe include several base metals, precious metals and critical raw materials. The comparison of Figures 26 and 27 suggests that the EU's metallic minerals potential is under-explored and therefore under-exploited.

114 Source: © SNL Metals & Mining 2016. Data based on Esri, USGS and NOAA. SNL's coverage includes all major commercially viable precious metals, base metals, bulk commodities and specialty commodities. Commodities classified as the main mine project product, i.e. primary commodity, are included. Mine projects for the following materials, not listed as primary commodities, are not displayed: cobalt, bauxite, alumina, chromium, manganese, niobium, titanium, rutile, zircon, scandium and yttrium. Alumina, chromium and titanium are typically associated with stand-alone processing facilities and this map displays mine projects and mine/mill combination projects only. Coal, phosphate, potash, diamonds, graphite and U308 (uranium oxide) were excluded. See also methodological notes.

115 Development stages: 1) *Grassroots* indicates claims have been staked on prospects; 2) *Exploration* indicates preliminary testing is underway, which may include mapping and sampling, geophysical and geochemical work and reconnaissance drilling; 3) *Target outline* indicates targets have been identified and more detailed surface and/or underground exploration and drilling is underway; 4) *Advanced exploration* involves drilling activities to add additional reserves/resources; 5) *Reserves development* indicates that an initial reserve/resource has been calculated; and 6) *Prefeas/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.

116 So not the mine-site exploration itself that takes place after the mine site is set up.

117 Deposits include not only sites where exploration projects are currently taking place but also all types of already-known mineral (metals) occurrences where concentration of minerals is high enough for the potential development of mining.

Figure 27: Mineral deposits, occurrences and showings in the EU-28[118] (2010)

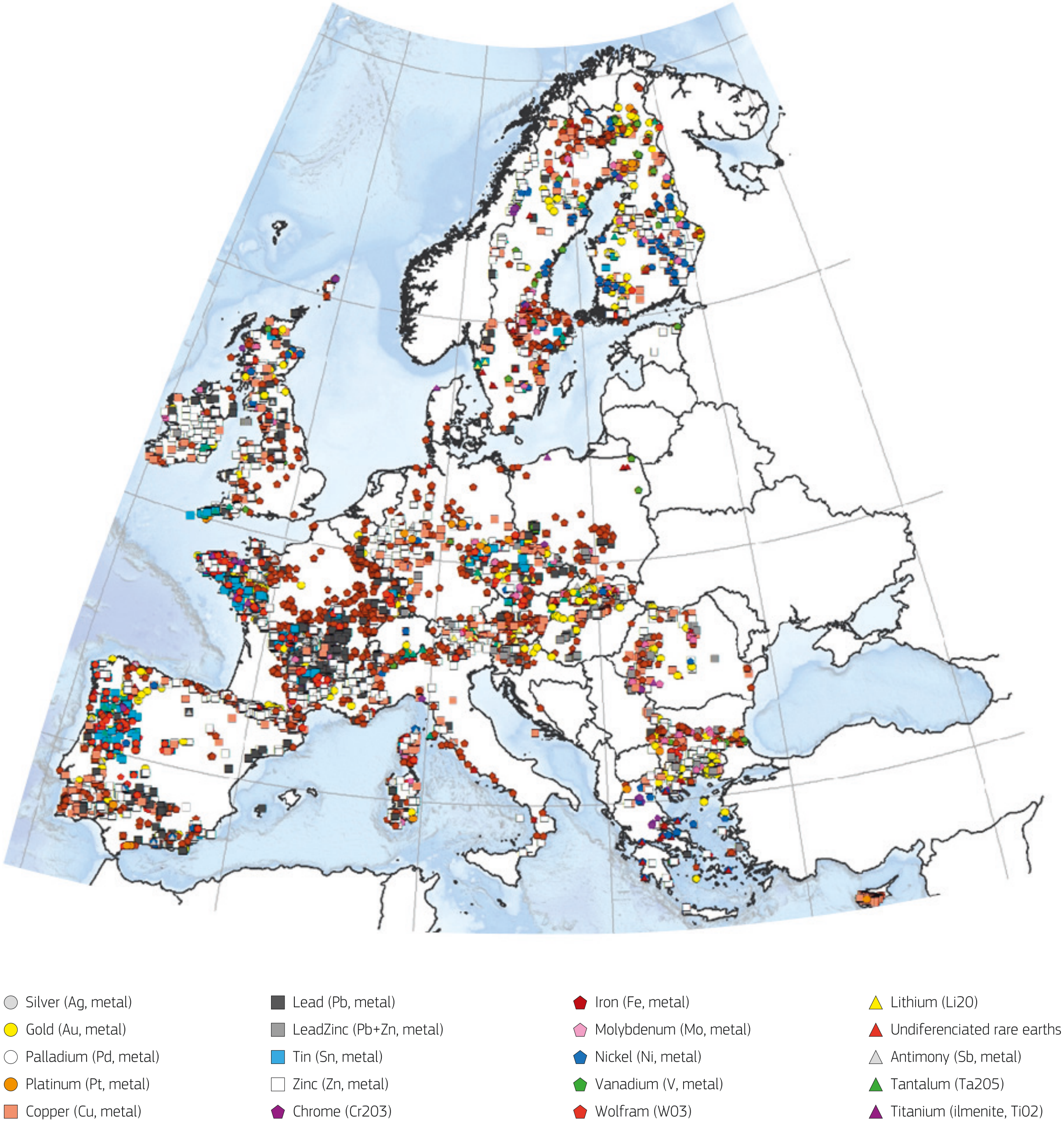


Figure 28A shows the budgets allocated to metallic mineral exploration between 1997 and 2015. It shows very clearly how investment in exploration is driven by commodity prices. At the end of 2002, commodity prices started rising because demand for raw materials from emerging economies exceeded short-run supply. This provided an incentive to mining companies to increase their investment in exploration. However, these budget increases are not maintained when prices decrease again. Between 2012 and 2015 for example, virtually all world regions experienced a fall of more than 60 % in exploration budgets for metals, a trend in line with minerals overall. In the EU, the decline was just below 60 %. This fall in exploration spending – with many companies simply stopping their exploration activities – can be explained by the low price of some commodities in the market[119].

Looking at exploration by region, Figure 28A shows that the highest percentage of investment in exploration takes place in Latin

118 Source: © BRGM 2016; G. Bertrand, D. Cassard, ProMine project, http://promine.gtk.fi/, retrieved January 2016.

119 Wilburn, D.R., K.A. Stanley and N.A. Karl (US Geological Survey (USGS)), 2014, '*Annual Review: Exploration Review*'.

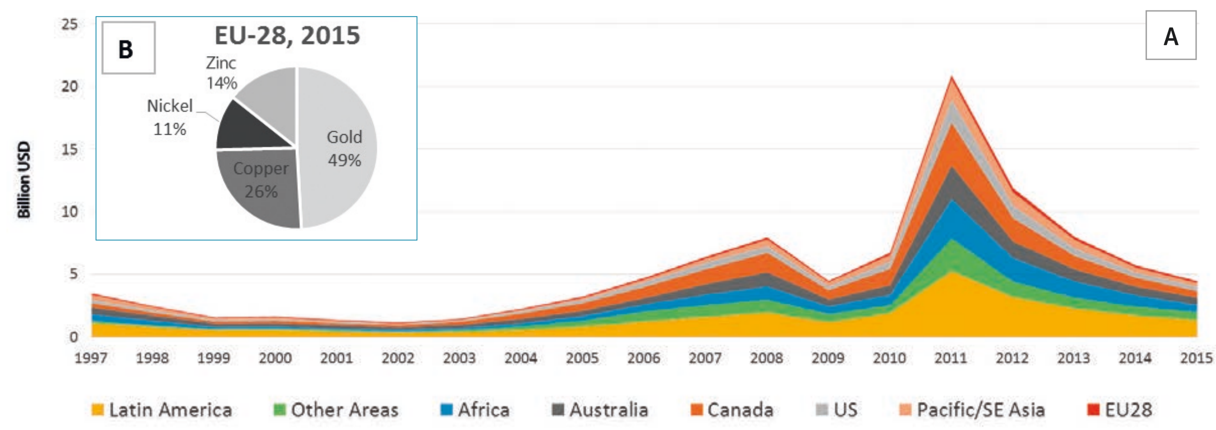
America, with 30 % of the global total in 2015. Africa (14 %), Australia (12 %) and Canada (12 %) follow. In comparison, the EU exploration budget is rather low at around 3 %. Remarkably, Latin America has been the leading region in mineral exploration since the middle of the 1990s, a trend that can probably be explained by its rich geological resources, benign mining policy framework, and successful historical record of mineral production and development.[120]

Figure 28B presents a breakdown of the EU exploration budget for various metallic materials in 2015. It shows that gold (49 %) had the biggest share of exploration budgets, followed by copper (26 %), zinc (14 %) and nickel (11 %).[121]

Conclusion

Mineral exploration is an important step in the mining life cycle because it contributes to the discovery of potential new deposits and the opening of new mines. In the EU, metal exploration activities are rather limited when compared with other world regions. These activities also represent a low level of investment, in spite of the mineral potential in the EU. Furthermore, in recent years, investment in metallic minerals exploration has steadily decreased, both in the EU and globally. Therefore, mineral exploration is a key component in the EU's strategy for increasing the supply of primary raw materials, both in the Raw Materials Initiative[123] and in the European Innovation Partnership on Raw Materials.[124]

Figure 28: Exploration budget by world mining region (1997-2015) (Figure A) and distribution of exploration budget allocation to various metals in the EU (2015)[122] (Figure B)



120 Ibid.
121 This breakdown of the exploration budget refers to the set of metals considered for the analysis (gold and three base metals — copper, nickel, zinc), and platinum group metals. Some metals were excluded from this analysis since exploration budget data was aggregated together with other minerals, so it was not possible to distinguish their specific contribution to metallic minerals exploration.
122 Source: JRC analysis based on exploration budget data provided by the SNL Metals & Mining exploration budget survey. Budget figures for a selection of metals (gold, copper, nickel, zinc, and platinum group metals), due to data availability. See also methodological notes for details.
123 European Commission, 2008, '*The Raw Materials Initiative — meeting our critical needs for growth and jobs in Europe*', COM(2008) 699; European Commission, 2011, '*Tackling the challenges in commodity markets and on raw materials*', COM(2011) 25.
124 European Innovation Partnership on Raw Materials, 2013a, ' *Strategic Implementation Plan*'.

13. National minerals policy framework

Key points:

- The minerals policy framework is a key determinant of the mining sector's performance, stability and sustainability.
- According to mining company managers, the minerals policy framework of the EU Member States varies widely. Low scores can be attributed to uncertainties concerning administration — which makes long-term planning of mining operations difficult — lack of enforcement of existing regulations, and regulatory duplication.
- Several of the major suppliers of raw materials of high importance to the EU economy are located in countries that lack attractive mining policies to encourage exploration. Even though the geological attractiveness of these countries results in a higher overall attractiveness for companies to invest, companies' perception of risk has played an increasing role in determining the allocation of exploration budgets.

Overview and context

The mining industry provides a large part of the material inputs to the European economy and is a significant contributor to employment and to government revenues. The policy framework and regulatory structure in mining countries can either impede or expedite the development of mining operations and thereby influence the overall security of raw materials supply. Key issues that determine the adequacy of minerals policies include the level of enforcement of existing mining policies, environmental regulation, regulatory duplication, political stability, and the state of the legal system.

Historically, a shift of mining activities from the EU to other regions of the world has happened (see Indicator 1 on the EU's share of global production). Furthermore institutional framework conditions in the EU — such as asymmetrical mining policies across Member States, missing information on mineral endowments, environmental regulations, public acceptance (see Indicator 14) — have also affected the EU's attractiveness to mining operations.

It is rather difficult to objectively quantify any of the issues that determine the EU's framework conditions for mining. Consequently, this indicator makes use of the *Fraser Institute Annual Survey of Mining Companies*.[125] This is based on the perceptions of mining company managers and executives on various policy areas affecting mining activities in the jurisdiction in which they operate or with which they are familiar. The survey has a global coverage of 112 jurisdictions, of which 11 are EU Member States.[126]

One indicator used in the Fraser Institute's survey is the Policy Perception Index. This assesses the public regulatory framework that affects investment, i.e. how government policy affects attitudes towards exploration investment in each mining jurisdiction, ranking jurisdictions based on survey respondents' views. The index takes account of 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 the quality of infrastructure.[127] The policy framework is not the only determinant of the performance of mining sectors and decisions on further investment. Consequently, the information provided by the Policy Perception Index is complemented by the Investment Attractiveness Index, which combines executives' perception of the policy framework with their perception of a jurisdiction's geological attractiveness.[128]

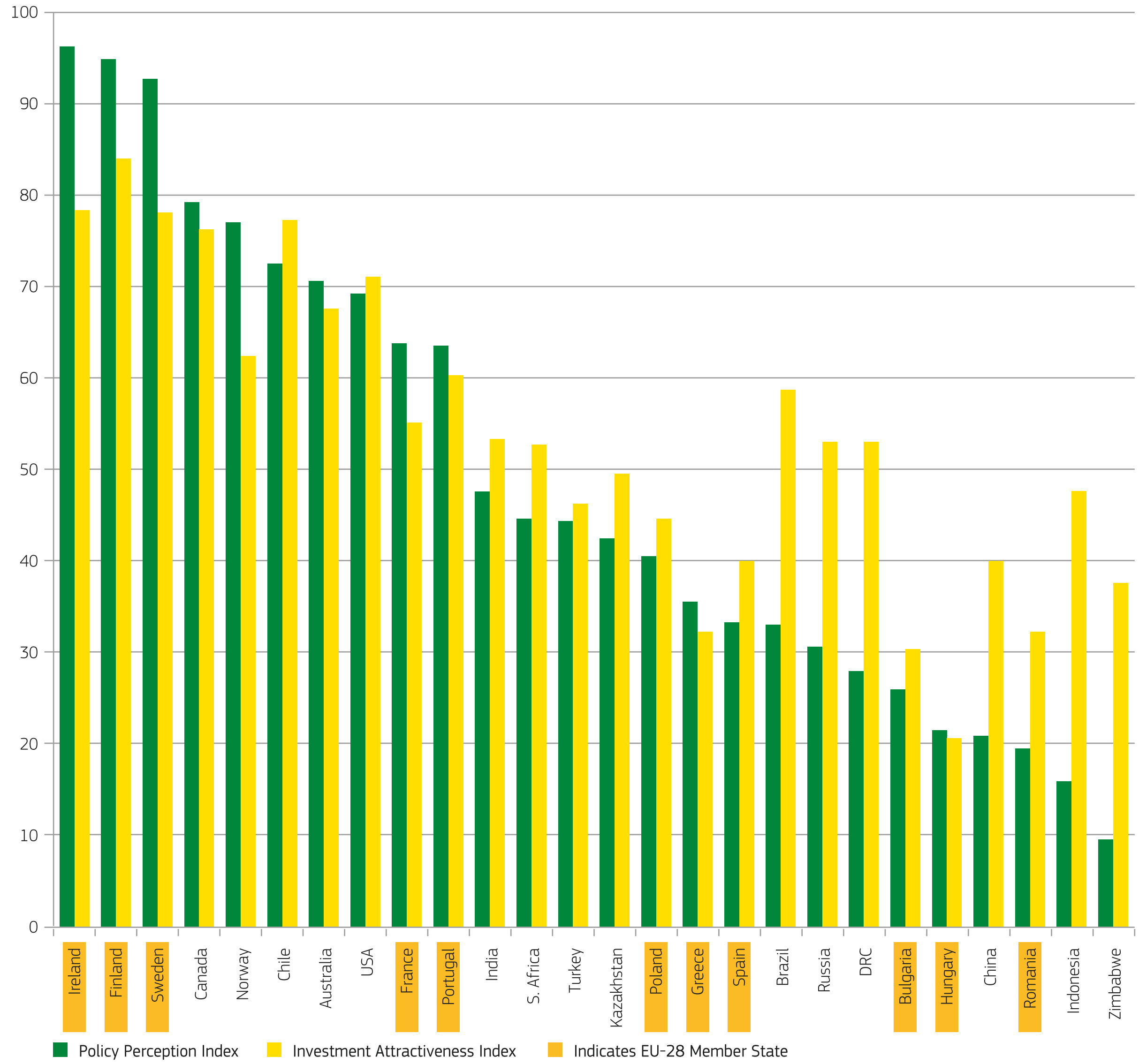
125 Jackson, T., 2014, *'Annual Survey of Mining Companies 2014'*, Fraser Institute

126 As is the case with all statistical data, the data used in this section are subject to certain limitations. Only 11 of the 28 Member States are covered, namely Bulgaria, Ireland, Greece, Spain, France, Hungary, Poland, Portugal, Romania, Finland and Sweden. (Survey responses for other Member States were insufficient to lead to reliable results). Because the list of survey respondents per country is not reported, it could not be assessed whether the surveys provide a representative sample of the mining companies in each country.

127 A full list of survey questions is given in the 2014 Fraser Institute Annual Survey of Mining Companies.

128 The Investment Attractiveness Index incorporates both the Policy Perception Index (40 % index weight) and the Best Practices Mineral Potential Index (60 % index weight), which rates jurisdictions on their geological attractiveness. Weights are based on survey responses.

Figure 29: Policy Perception Index and Investment Attractiveness Index (based on Fraser Institute *Annual Survey of Mining Companies, 2014*)[129, 130]



Facts and figures

Figure 29 shows the 2014 Policy Perception Index and Investment Attractiveness Index for major mining countries. All 11 EU countries (highlighted in orange) that are included in the Fraser Institute's survey are included in the figure.

The perception of policy framework conditions varies significantly in the major raw material supplier countries. Ireland, Finland and Sweden receive the highest scores (Policy Perception Index between 96 and 92) and Romania is among the least attractive countries (Policy Perception Index = 19). Interestingly, while Finland and Sweden have been consistently ranked at the very top of the list since 2010, Ireland rose from the 16th place in 2010 to first in only four years. At the other end of the spectrum, however, Romania, Bulgaria and several of the major suppliers of raw materials (China, Russia, Brazil and South Africa) are found at the lower end of the Policy Perception Index scale.

There are various possible reasons for the wide range in the Policy Perception Index scores. These include: uncertainties concerning the administration, which makes long-term planning of mining operations difficult; lack of enforcement of existing regulations; and regulatory duplication. In some cases, the geological attractiveness in the sourcing country results in a higher overall attractiveness for companies and governments to invest. This is seen in the Investment Attractiveness Index, which ranges from Finland's 84 (best score in the global list) to Hungary's 21. For example, Brazil, Russia, the Democratic Republic of Congo, China, Romania, Indonesia and Zimbabwe all have a relatively low Policy Perception Index but have a higher overall Investment Attractiveness Index due

129 Jackson, T., 2014, *'Annual Survey of Mining Companies 2014'*, Fraser Institute
130 Both indices are normalised to a maximum score of 100 (highest level of attractiveness to mining). S. Africa = South Africa. DRC = Democratic Republic of Congo.

to their geological availability of various raw materials. Nonetheless, since the economic crisis, which limited the possibility of raising new funds, companies' perception of risk has played an increasing role in determining the allocation of exploration budgets. Looking at the trend over the past three years, exploration budgets for high-risk countries, such as the Democratic Republic of Congo, Mali or Ecuador, have fallen by two thirds, from 28 % of global allocations in 2013 to 9 % in 2015 (see also Indicator 12 on exploration activities).[131]

Conclusion

A stable minerals policy framework is important in encouraging sustainable and continued mining developments. Because the EU imports a large proportion of raw materials, monitoring the policy framework in sourcing countries is also important to spot any potential supply risks. Many of the major producers of important raw materials, such as the rare earth elements, niobium and antimony, originate from countries that somewhat lack attractive mining policies (see also Indicator 4). The policy framework and geological attractiveness of the EU Member States vary widely and need to be further considered to encourage mining developments in the EU.


© apimages.com

131 Ferguson M. et al (SNL Metals and Mining), 2015, '*Corporate Exploration Strategies 2015 — Exploration Budgets by Location, 2015; Part 1: Overall Trends, Canada, Australia and United States*'.

14. Public acceptance

Key points:

- Public acceptance in the EU of extractive industries is low as compared with other economic sectors.
- The general public in the EU has little trust that extractive companies make efforts to behave responsibly. Trust in mining companies is generally higher in countries outside the EU.
- Significant efforts are needed to improve public awareness, acceptance and trust in the EU raw materials sector.

Overview and context

Public acceptance is a prerequisite for the development of any economic activity. It is linked to the 'social licence to operate'. This refers to the notion that companies need not only government permission to conduct their business but also society's permission based on the trust of the community in which they operate.

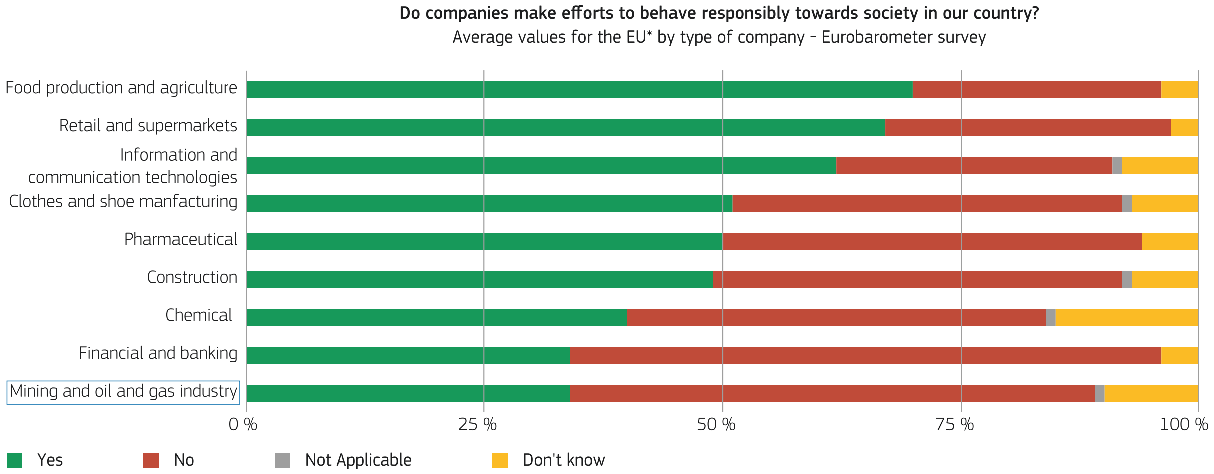
For the mining sector, public acceptance is a particular challenge, both for existing mines and for the development of new mining activities. The level of acceptance of extractive activities is difficult to quantify and is determined by many different factors. These include concerns about environmental impacts, highly publicised accidents and the 'Nimby ' effect (not in my backyard).

Facts and figures

Figure 30 shows the general public's trust in the commitment towards society of companies from various sectors. The graph is based on a comprehensive Eurobarometer survey about public perception of companies' behaviour, published in 2013.[132] More than 32 000 participants were consulted in this survey covering the EU Member States, Brazil, China, India, Israel, Turkey and the United States of America,.

The results show that, in comparison with other sectors, mining and oil & gas companies are perceived as making the least efforts to behave responsibly towards society: 55 % of respondents stated that companies working in mining and oil & gas do not make sufficient efforts to behave responsibly, while 34 % said that they do.

Figure 30: Public perception of the efforts of various types of company to behave responsibly towards society (2012)[133]



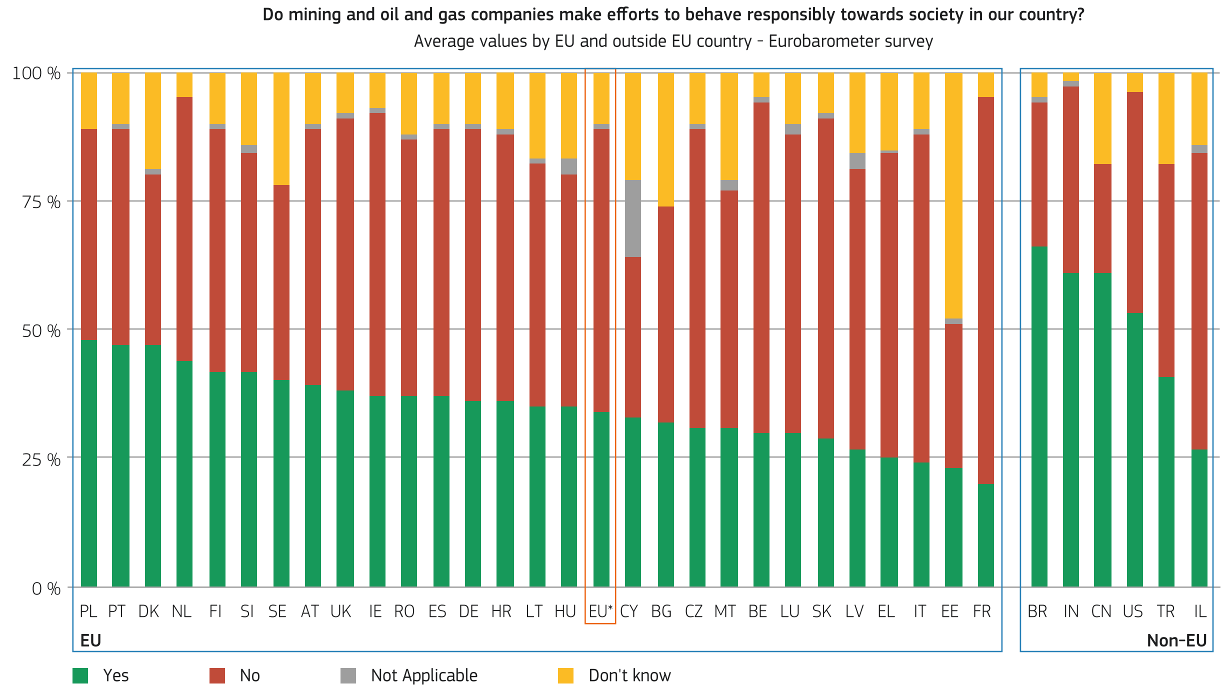
* EU average corresponds to EU-27 since the survey took place before Croatia joined the EU.

132 European Commission, 2013, *'How companies influence our society: citizens' view'*, Flash Eurobarometer 363.
133 Source: JRC analysis based on data from the (2013) Flash Eurobarometer 363. Data displayed relate to Question 6.5 of the report. Values were reported by country as well as average values for the EU — which corresponds to EU-27 since the survey took place before Croatia joined the EU.

Figure 31 provides a comparison of the various public perceptions towards the mining and oil & gas industry across EU countries and for a few countries located outside the EU. For all EU countries, less than half of those surveyed responded 'yes' to the question whether they consider that mining and oil & gas industry companies are making efforts to behave responsibly towards society. The lowest rate of 'yes' responses is found in France (20 %) and the highest in Poland (48 %), where mining activities are more prominent in the economy.

Similarly, in most EU countries, public perception towards the sector is low. France has the highest number of 'no' responses (75 %), followed by Belgium (64 %) and Italy (64 %). Estonia and Cyprus have the lowest, at 28 % and 31 %, respectively. Interestingly, this picture changes outside the EU-27. In most of the countries considered in this survey, the general public perceives a higher commitment to society from such companies. This is especially so in Brazil, India and China, but also in the US and Canada, where positive responses were significantly higher than in the EU.

Figure 31: Public perception by country about the efforts of mining and oil & gas industry companies to behave responsibly towards society (2012)[134]



* EU average corresponds to EU-27 since the survey took place before Croatia joined the EU.

The search for suitable data ...

The Eurobarometer survey covered economic sectors at a broad level of aggregation. Consequently, the information presented here corresponds not only to raw materials mining but also to other extractive activities for the production of oil and gas. Nonetheless, these results were considered relevant for the analysis of the mining sector's public acceptance. The results of future surveys would make it possible to monitor developments in public acceptance of the sector.

134 Source: JRC analysis based on data from the (2013) Flash Eurobarometer 363. Data displayed relate to Question 6.5 of the report. Country codes: PL= Poland; PT= Portugal; DK= Denmark; NL= Netherlands; FI= Finland; SI= Slovenia; SE= Sweden; AT= Austria; UK= United Kingdom; IE= Ireland; RO= Romania; ES= Spain; DE= Germany; LT= Lithuania; HU= Hungary; EU-27= European Union 27 Member States (excluding Croatia); CY= Republic of Cyprus; BG= Bulgaria; CZ= Czech Republic; MT= Malta; BE= Belgium; LU= Luxembourg; SK= Slovakia; LV= Latvia; EL= Greece; IT= Italy; EE= Estonia; FR= France; HR= Croatia; BR= Brazil; IN= India; CN= China; US= United States of America; TR= Turkey; IL= Israel.

Conclusion

Data on the general public's perception of various economic sectors underline the low level of public acceptance of the extractive industry in the EU when compared with other economic activities. The European public perceives companies operating in the mining and oil & gas sector to be the least responsible towards society compared with other sectors (e.g. food production, construction or chemicals). The data also show that while perceptions vary across Member States, overall trust towards the extractive industries is relatively low (below 50 %) compared with countries outside the EU. These low levels of public acceptance in the EU are probably one of the reasons why the EU raw materials sector is committed to corporate social responsibility and is an international leader on sustainability reporting (see Indicator 24). Acceptance by those communities most concerned by local developments is crucial. To this end, in addition to properly disseminating reliable and sound information, authorities concerned must ensure the full respect of EU rules on environmental impact assessments, public participation, etc.

Circular economy and recycling

>> Indicators:

15. Material flows in the circular economy
16. Recycling's contribution to meeting materials demand
17. WEEE management
18. Trade in secondary raw materials

15. Material flows in the circular economy

Key points:

- The circular use of raw materials in the EU economy is relatively low but slightly higher than the global average.
- A large part of the EU's materials use consists of construction materials, which are used in long-life, in-use stocks. These stocks often provide value to the EU economy for decades and will only become available for recycling when they have reached their end of life.
- As long as the demand for raw materials to make long-life products and to build infrastructure exceeds the amount of materials that can be supplied from recycled materials, primary extraction will remain necessary.
- The circular use of raw materials in the EU economy could be improved by extending the life time of products – for example through repair and re-use – or by increasing end-of-life recycling rates for materials.

Overview and context

A circular economy is an alternative to a (make, use, dispose) linear economy. In a circular economy, we keep the value in products and materials for as long as possible and minimise waste. When a product has reached the end of its life, resources are kept within the economy to be used again and again to create further value.[135] In this context, it is essential to understand an economy's 'societal metabolism',[136] i.e. to quantify the amount of materials flowing in and out of the economy and how they are used, and particularly to see how many materials are recycled and used again as an input.

On 2 December 2015, the European Commission launched a Circular Economy Package[137]. It aims to stimulate Europe's transition towards a more circular economy. The package includes an EU action plan with measures covering the entire product lifecycle — from production to consumption and ultimately to waste management and the market for secondary raw materials. The proposed measures aim at creating more value from product lifecycles through greater reuse and recycling. This is expected to boost the EU's global competitiveness, foster sustainable economic growth, and generate new jobs in Europe.

135 European Commission, 2015, *'Circular Economy Package: Questions & Answers'*.
136 The term 'metabolism', applied to natural systems, includes the transformations of inputs (sunlight, chemical energy, water, air, nutrients) needed by an organism to properly function, and related waste products. 'Societal metabolism', by analogy, refers to the flows of materials, energy, and waste in the economic system.
137 European Commission, 2015, '*Closing the loop — An EU Action Plan for the Circular Economy*', COM(2015) 614.

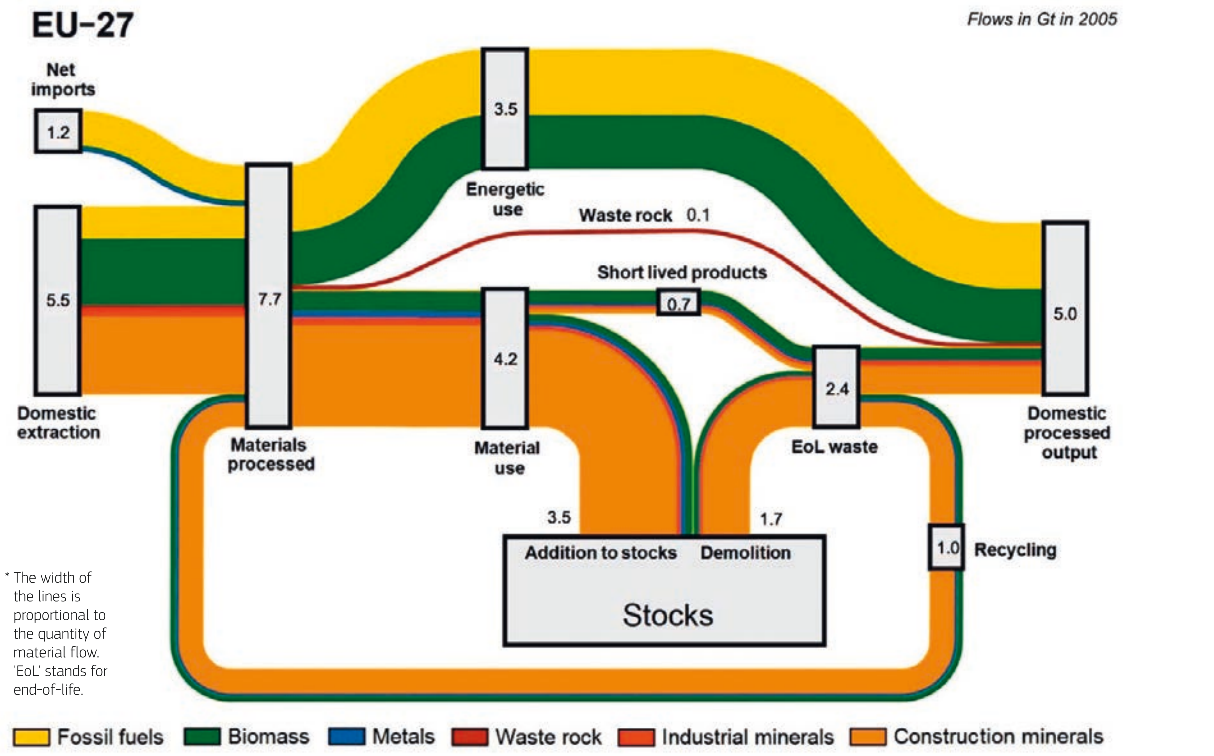
Facts and figures

Figure 32 depicts material flows through the EU-27 economy in 2005. Even if the data are relatively outdated — due to technical limitations — they still provide interesting insights into the order of magnitude of materials used in the EU economy, e.g. the amounts extracted, imported and recycled.

Figure 32 shows that more than 70 % of raw materials used in the EU originate from domestic extraction, 16 % from imports and 13 % from recycling. Of the 7.7 billion tonnes of materials that are processed annually in the EU economy, 3.5 billion tonnes (45 %) are used for energy and 4.2 billion tonnes (55 %) are used as materials as such. Among the latter, 3.5 billion tonnes, mostly construction minerals, are used as 'in-use stocks' — buildings, infrastructure and other long-life goods that remain part of the circular economy, but are only available for recycling once they have reached the end of their life. Once these stocks have reached their end of life, almost half of the materials they contain are recycled, thus offsetting the need to extract primary raw materials. Finally, the economy sees part of the materials transformed into emissions and residues that cannot be recycled to be used for their original purpose (domestic processed output).

Figure 32 also provides interesting insights on material use in the EU economy for the various material categories. *Non-metallic minerals* — including construction minerals and industrial minerals — represent around 70 % of the EU's material use. More than 90 % of these are bulk minerals such as sand, gravel, stone or clay used in the construction sector.

Figure 32: Material flows in the EU-27 economy (2005)[138]



Roughly one fifth of *biomass*, which mostly comes from domestic extraction, is used as material as such, of which wood is the largest proportion. Approximately 12 % of biomass is wood used for construction, for other durable wood products such as furniture, and for paper production. In the EU, approximately 44 % of wood used as material was recovered in 2005; of this, 64 % was recycled, 2 % was reused, and 34 % was used for energy generation. Some 17 % of the wood is used for paper production, for which recycling rates are above 40 %.

As for *metals*, while being of high economic importance, they represent only a minor proportion of EU material consumption in terms of mass. Overall end-of-life recycling rates[138] are estimated at 76 % but, due to the high flow of net additions to stocks the contribution of recycled materials to meeting materials demand is currently relatively low[139] (see also Indicator 16).

Overall, Figure 32 demonstrates that the circular use of raw materials in the EU economy is still limited. Of the 2.4 billion tonnes of end-of-life waste in 2005, 41 % (1 billion tonnes) was recycled.

The search for suitable data...

Due to the complexity of the issue and the need to combine various data sources, Sankey diagrams representing material flows in the economy are inevitably subject to certain limitations. The authors of the scientific article from which Figure 32 was extracted acknowledge that there are considerable uncertainties in the results presented. Due to the assumptions made, it is generally considered that the model overestimates the circular use of materials in the EU economy. Nonetheless, the authors conclude that the data reliability is sufficient to provide a rough but comprehensive assessment of the circularity of an economy at the level of material groups. In 2016, they envisage publishing a new study — based on 2012 data — which is expected to provide more up-to-date insights on the impact of the EU's recycling policies.

The European Commission has also published a study on material system analysis[141] and is continuing to work on harmonising and improving the quality of material flow data and data on waste management.

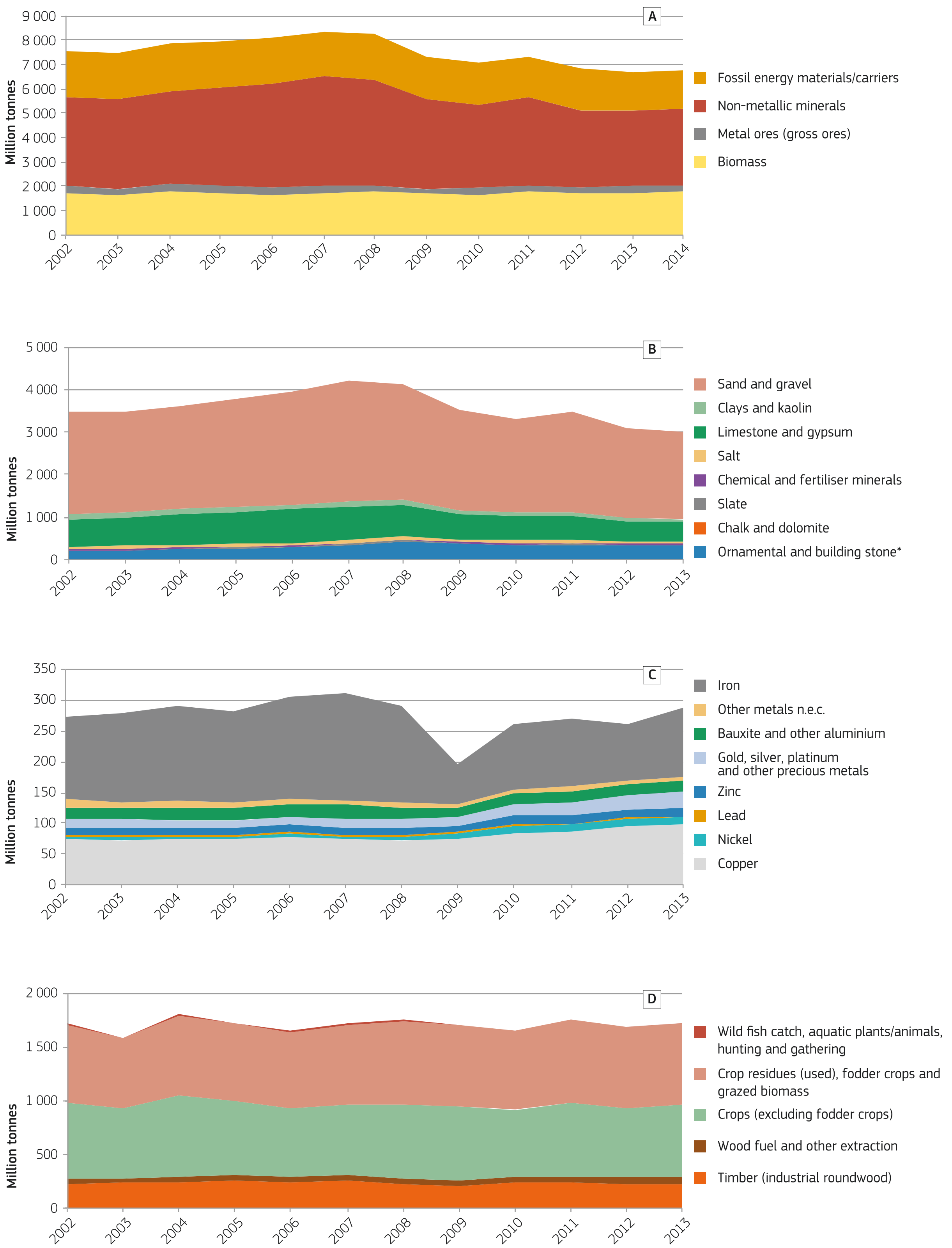
138 End-of-life recycling rates refer to recycling of waste originating from products that have reached their end of life, in contrast with waste that originates from fabrication or manufacturing processes.

139 Haas W., Krausmann F., Wiedenhofer D. and Heinz M., 2015, *'How Circular is the Global Economy?: An Assessment of Material Flows, Waste Production, and Recycling in the European Union and the World in 2005'*, Journal of Industrial Ecology.

140 Source: Haas W., Krausmann F., Wiedenhofer D. and Heinz M., 2015, *'How Circular is the Global Economy?: An Assessment of Material Flows, Waste Production, and Recycling in the European Union and the World in 2005'*, Journal of Industrial Ecology.

141 Bio by Deloitte, 2015, 'Study on Data for a Raw Material System Analysis: *Roadmap and Test of the Fully Operational MSA for Raw Materials'*, prepared for the European Commission, DG GROW.

Figure 33: Domestic material consumption by resource category (EU-28, 2002-2013)[142]
(A: Main raw materials groups; B: non-metallic minerals; C: metals; and D: biomass)



* Marble, granite, sandstone, porphyry, basalt, and other ornamental or building stone (excluding slate)

142 Source: JRC analysis based on data from Eurostat material flow accounts. See also methodological notes.

Figure 33 provides further detail on the EU-28's use of materials, presenting data on domestic material consumption[143] between 2002 and 2013. It shows that non-metallic minerals, which include construction materials (such as sand or gravel) and industrial minerals (such as fertilisers) are the biggest component of the EU-28's material consumption (close to 50 %), followed by fossil energy carriers (25 %), biomass (20-25 %) and, at the lower end, metals (4 %).

Figure 33A shows that domestic material consumption in the EU decreased by 10 % from 2002 to 2013. In the first part of the period (2002-2008), domestic material consumption experienced a steady increase of around 10 % overall, but then fell sharply (-18 %) between 2008 and 2013. This downward trend was temporarily reversed in 2011, on the back of an economic recovery, but then continued falling up to 2013. Over the whole period, the decreasing consumption of construction materials — a sector strongly affected by the economic crisis — was the primary cause of the fall in domestic material consumption.

Looking at the breakdown by material category, it can be seen that sand and gravel — together with limestone and gypsum — constitute the bulk of non-metallic minerals (Figure 33B). Interestingly demand for these materials is still about 20% lower than before the economic crisis. For metals (Figure 33C), iron and copper account for the biggest proportion of the EU's consumption. The trend for the various metals also shows how iron consumption was hit hard by the economic crisis, even though it slightly recovered in 2010, mostly due to demand from automotive and equipment manufacturing and the production of metal goods. On the other hand, the growing consumption of copper, gold, silver, platinum and other precious metals can be explained by the increasing demand for low-carbon energy technologies and high-tech applications. Finally, biotic materials, of which roundwood only represents a relatively small fraction, is the only category of materials that shows a constant trend (Figure 33D).

Conclusion

Mapping material flows in the circular economy is a challenge. Yet even though the best-available data are subject to certain limitations, they still provide us with interesting insights. It shows that a large part of the EU's material use consists of construction materials, many of which are accumulated in long-life, in-use stocks. The economy's circularity could be improved by increasing the reuse and recycling rates of materials (production processes and products). However, even if end-of-life reuse and recycling rates were to increase, primary resource extraction would still be needed to meet the EU's materials demand since materials contained in in-use stocks will only become available for recycling after decades or more.

To promote the transition to a circular economy, the European Commission has proposed a Circular Economy Package.[144] The package includes revised legislative proposals on waste to increase recycling and reduce landfilling, and several measures to 'close the loop'. These target market barriers in specific sectors or material streams, such as plastics, food waste, critical raw materials, construction and demolition, biomass and bio-based products. In addition, there are general measures in areas such as innovation and investment. The Circular Economy Package gives a clear signal to economic operators that the EU is using all the tools available to transform its economy, opening the way to new business opportunities and boosting competitiveness.

143 The indicator domestic material consumption (DMC) measures the total amount of materials directly used by an economy and is defined as the annual quantity of raw materials extracted within its territory plus all physical imports minus all physical exports (Eurostat Statistics Explained).

144 European Commission, 2015, '*Closing the loop — An EU Action Plan for the Circular Economy*', COM(2015) 614.

16. Recycling's contribution to meeting materials demand

Key points:

- Recycling keeps valuable materials within the economy and contributes to the security of raw materials supply.
- Recycling rates for certain materials are relatively high (e.g. for some widely used metals). Nevertheless, for most materials, recycling's contribution to meeting materials demand is relatively low. This is because demand is higher than what can be met by recycling or because high-quality recycling is not technically or economically feasible.
- The rate of recycling depends on several factors, including collection and treatment efficiencies of products at end of life, technical limitations in the recycling processes, the price of scrap compared with the price of primary raw materials, and whether products are designed for end-of-life recovery.

Overview and context

Recycling, or the production of secondary raw materials, has the potential to contribute to the security of supply of raw materials and to increase the circularity of the economy. It is also a key element for improving sustainability, due to the reduced environmental impacts arising from the reduced need to extract primary raw materials and the generally lower environmental footprint of recycling processes compared with primary production. Recycling is also expected to contribute to boosting EU competitiveness, as set out in the European Commission's Circular Economy Action Plan.[145]

Nonetheless, as can be seen from Indicator 15 on materials flows in the circular economy, the recycling of end-of-life products is relatively low. This is typically a consequence of three factors: the often limited efficiency of collection systems; recycling's (lack of) economic profitability; and technical limitations that prevent production of high-quality recyclates.[146] Often, an additional challenge to recycling is the design of products: the increasing complexity and design optimisation for mass automated production of many products and the use of many different materials, sometimes in very small quantities, can make recycling very difficult.

The most commonly quoted recycling statistics refer to the amount of end-of-life products that are collected and recycled (i.e. the end-of-life recycling rate). However, in order to monitor progress towards a circular economy, it is also necessary to have a look at recycling's contribution to meeting materials demand. In this regard, the 'end-of-life recycling *input* rate' (EOL-RIR) measures how much of the total material input into the production system comes from recycling of "old scrap".[147]

Facts and figures

Figure 34 shows the end-of-life recycling input rate (EOL-RIR) for a number of materials including metals (e.g. aluminium, tungsten), non-metallic minerals (e.g. borate and phosphate rock), rare earth elements that are used in specialised applications (e.g. erbium and dysprosium), and biotic materials (e.g. natural rubber, pulpwood).

Figure 34 reveals two interesting facts about recycling's contribution to materials demand. The first is that, in general, secondary raw materials represent a relatively small proportion of inputs to production processes. Very few materials have an EOL-RIR higher than 30 %: cobalt (35 %), pulpwood (54 %) and tungsten (42 %). The end-of-life recycling input rates for a number of bulk metals (e.g. iron, nickel) and a limited number of specialty metals (such as gold and silver) stand between 20 % and 30 %. Even though many of these materials have end-of-life recycling rates above 50 %, mostly because they are used in sufficiently large amounts in easily recoverable applications (e.g. steel in automobiles)[148] their end-of-life recycling *input* rates are much lower because demand for these materials is higher than what can be provided through recycling. The second observation is that for most specialty metals and rare earth elements, as well as for natural rubber, secondary production only represents a marginal proportion (often less than 1 %) in meeting materials demand. This is mostly because primary extraction is often more economic than recycling, because these materials are used in very small quantities (which makes their collection and separation

145 European Commission, 2015, '*Closing the loop — An EU Action Plan for the Circular Economy*', COM(2015) 614.

146 UNEP, 2011, '*Recycling rates of metals — A status report, A report of the Working Group on the Global Metal Flows to the International Resource Panel*',T.E. Graedel, J. Allwood, J.P Birat,. B.K Reck, S.F Sibley, G. Sonnemann, M.Buchert, C. Hagelüken.

147 Old scrap is an expression used to designate scrap that comes from products that have reached their end of life. Conversely, new scrap designates scrap that originates from fabrication or manufacturing processes.

148 UNEP, 2011, '*Recycling rates of metals — A status report, A report of the Working Group on the Global Metal Flows to the International Resource Panel*',T.E. Graedel, J. Allwood, J.P Birat,. B.K Reck, S.F Sibley, G. Sonnemann, M.Buchert, C. Hagelüken.

Figure 34: End-of-life recycling input rates (EOL-RIR) for a selection of raw materials[149]

> 30%	Cobalt, Pulpwood**, Tungsten
20-30%	Antimony, Chromium, Gold*, Iron*, Nickel*, Silver*
10-20%	Aluminium*, Copper*, Magnesium, Manganese*, Molybdenum*, Phosphate rock, Platinum, Tin*
1-10%	Aggregates, Borate, Germanium, Magnesite, Natural graphite, Neodymium, Palladium, Rhenium*, Rhodium, Sawn softwood**, Selenium**, Titanium*, Zinc*
< 1%	Beryllium, Dysprosium, Erbium, Gallium, Indium, Lithium, Natural rubber**, Niobium, Silicon

a costly undertaking) and/or because it is often difficult to recycle these materials at sufficient degrees of purity.

Conclusion

Recycling rates for certain materials are relatively high. However, for most materials, recycling is — for several reasons — far below the economy's demand for materials. In a world of increasing demand for raw materials, the use of secondary raw materials can help to improve the EU's security of supply and contribute to developing a solid circular economy. This requires measures to boost the market for secondary raw materials, for example, quality standards that increase trust as to the recycled materials' purity, as set out in the Circular Economy Action Plan.[150]

The search for suitable data...

The generally acknowledged limitations to recycling statistics also apply to the estimates provided here. These include: (1) the lack of appropriate data for many materials and materials applications, and (2) the use of estimates that are only applicable to certain regions (e.g. global vs country-specific data). In this context, Figure 34 displays global average EOL-RIR values for materials for which EU data were not available. The European Commission is currently working to simplify and harmonise recycling statistics, which in turn will support further research on raw materials flows.

149 Source: JRC analysis based on material flow data from Bio by Deloitte, 2015, 'Study on Data for a Raw Material System Analysis: Roadmap and Test of the Fully Operational MSA for Raw Materials', prepared for the European Commission, DG GROW. For materials for which no EU data are available, global values are displayed, taken from: 1) UNEP, 2011, *'Recycling rates of metals'* (marked with *) or 2) from Ad hoc Working Group on defining critical raw materials, 2014, *'Report on critical raw materials for the EU'*, prepared for the European Commission, DG Enterprise and Industry (GROW) (Annexes) (marked with **).

150 European Commission, 2015, '*Closing the loop — An EU Action Plan for the Circular Economy'*, COM(2015) 614.

17. WEEE management

Key points:

- Each year, substantial quantities of waste electrical and electronic equipment (WEEE), containing valuable raw materials, are generated.
- The levels of collection, reuse and recycling of WEEE vary considerably across EU Member States, indicating the potential to improve resource efficiency.

Overview and context

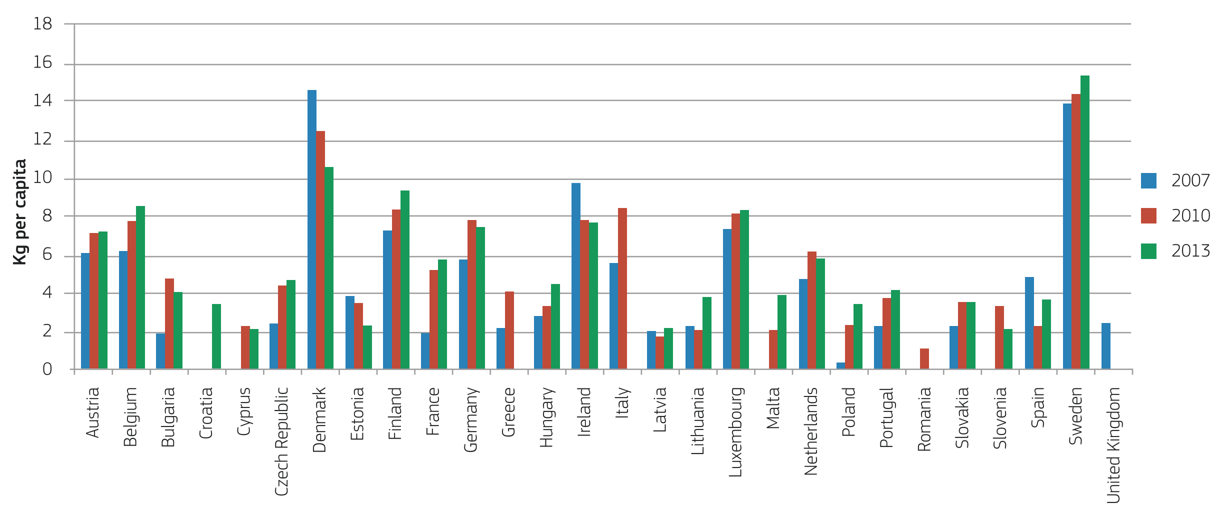
Waste of electrical and electronic equipment (WEEE), such as computers, televisions, fridges and cell phones, is one the fastest growing waste streams in the EU. Some 9 million tonnes were generated in the EU in 2012[151] and it is expected that this will grow to more than 12 million tonnes by 2020.[152] However, only about one third of this waste is officially reported as collected and made available for reuse and recycling.[153]

Compared with other waste streams, WEEE may not appear to be significant in terms of mass. However, it provides a good example of the untapped potential to recover valuable raw materials. WEEE — like many others — is a complex waste stream that contains significant amounts of valuable raw materials. It is estimated that up to 60 elements can be found in complex electronics, many of which could be recovered.[154] This highlights how further eco-design and improvements in systems to collect — and, subsequently, reuse or recycle — WEEE are key to reducing the losses of such valuable raw materials and to strengthen circularity in the European economy.

Facts and figures

Figure 35 presents the trend in WEEE reuse and recycling rates by Member State between 2007 and 2013. In most Member States, reuse and recycling increased considerably, but there are significant differences across countries.

Figure 35: Reuse and recycling of WEEE per capita (EU-28, 2007-2013)[155]



151 Eurostat Statistics Explained http://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics_-_electrical_and_electronic_equipment based on dataset http://ec.europa.eu/eurostat/en/web/products-datasets/-/ENV_WASELEE

152 EC, DG Environment: http://ec.europa.eu/environment/waste/weee/index_en.htm.

153 Huisman, J., Botezatu, I., Herreras, L., Liddane, M., Hintsa, J., Luda di Cortemiglia, V., Leroy, P., Vermeersch, E., Mohanty, S., van den Brink, S., Ghenciu, B., Dimitrova, D., Nash, E., Shryane, T., Wieting, M., Kehoe, J., Baldé, C.P., Magalini, F., Zanasi, A., Ruini, F., Männistö, T., and Bonzio, A., 2015, *Countering WEEE Illegal Trade (CWIT) Summary Report, Market Assessment, Legal Analysis, Crime Analysis and Recommendations Roadmap*, Lyon, France.

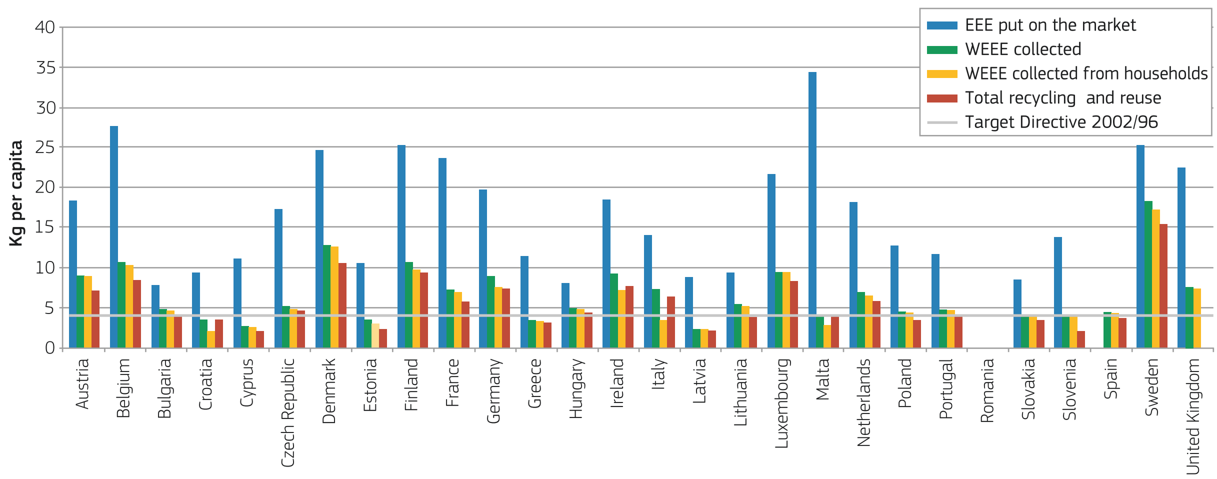
154 Baldé, C.P., Wang, F., Kuehr, R., Huisman, J., 2015, '*The global e-waste monitor — 2014*' — United Nations University, IAS — SCYCLE, Bonn, Germany.

155 Source: JRC analysis based on Eurostat data on WEEE, http://ec.europa.eu/eurostat/en/web/products-datasets/-/ENV_WASELEE. Data for some years for some countries are missing.

Figure 36 provides an overview of the amounts of WEEE that were collected and the amounts reused and recycled[156] in Member States in 2013. As a basis for comparison, Figure 36 also includes the amount of electrical and electronic equipment put on the market in the same year.

Figure 36 shows that the performance achieved in managing WEEE varies significantly across Member States. The best performing Member States collect waste quantities that correspond to nearly two thirds of the electrical and electronic equipment put on the market in the same year, and meet by far the agreed EU collection target of 4 kg per capita (from households) per year.[157] These Member States also reuse or recycle more than 90 % of the collected waste. However, to better reflect Member States' varying conditions, the revised WEEE Directive (2012/19/EU)[158] introduced progressive country-specific collection targets, which will become binding in 2016. Such targets are not laid down in absolute terms — as they were in the former WEEE Directive — but are based on the actual electrical and electronic equipment put on the market in each country.

Figure 36: Electrical and electronic equipment put on the market, WEEE collected, reused and recycled (2013)[159]



The search for suitable data…

Despite the EU's existing — and binding — WEEE collection target of 4 kg per capita, it is difficult to find out how much waste is actually collected and reused or recycled at national and EU levels. According to the results of work conducted under the project 'Countering WEEE Illegal Trade' (CWIT),[160] only 34 % of the waste generated in the EU is reported to be collected under extended producer responsibility schemes and subsequently reused or recycled. An additional 23 % is estimated to be recycled in, for example, mixed metal scrap waste streams. Some 7 % of WEEE is estimated to end up directly in waste bins and 2 % is documented to be exported as used electric and electronic equipment. The rest of the waste (about 34 %) is currently not accounted for and EU funded research estimates that more than 40 % of these unaccounted WEEE flows are exported, either legally or illegally[161].

Following up on the CWIT project, the currently ongoing ProSUM project[162] will update the CWIT data on WEEE stocks and flows. It will also characterise these WEEE flows by components and materials. This will contribute to providing a better picture of the secondary raw materials potential arising from WEEE across EU Member States.

156 Reused and recycled WEEE are the amounts of WEEE collected that are fed back to the market and used for example to produce new equipment. For the purpose if this indicator, reuse means that a given WEEE component is ready to be used again without any treatment, while recycling involves some kind of treatment to render the WEEE component ready for the same or similar use.

157 Established by the WEEE Directive (2002/96/EC), http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32002L0096 and valid until 2015. It refers to WEEE collected from private households.

158 Directive 2012/19/EU, http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32012L0019.

159 Source: JRC analysis based on Eurostat data on WEEE, http://ec.europa.eu/eurostat/en/web/products-datasets/-/ENV_WASELEE. Data for some indicators and/or some countries are missing.

160 Huisman et al., 2015 (CWIT project).

161 Huisman et al., 2015 (CWIT project).

162 http://www.prosumproject.eu/.

© apimages.com

Conclusion

Each year, growing quantities of waste electrical and electronic equipment, containing large amounts of valuable raw materials, are generated in Europe. However, the levels of WEEE collection, reuse and recycling vary across Member States. They can be improved substantially to prevent losses of these valuable resources. This could be further facilitated through improved eco-design and greater efficiency in recycling (for example, by targeting as many different materials as economically and technically feasible). While legally binding WEEE collection targets have not yet been met in some European countries, it is expected that the efficiency of WEEE management could be improved via the implementation of the revised WEEE Directive (2012/19/EU).

18. Trade in secondary raw materials

Key points:

- Net exports of secondary raw materials have increased significantly over the last decade.
- 'Iron and steel' is the most traded group of waste by mass. About 18 million tonnes are exported from the EU yearly (2011 data), about 25 million tonnes are traded among European countries, and about 3 million tonnes are imported into the EU.
- Total exports of 'copper, aluminium and nickel' waste have doubled between 1999 and 2011.

Overview and context

Many non-hazardous waste streams are regarded as valuable resources because they are an important source of raw materials.[163] Therefore, in order to provide an accurate picture of the European raw materials sector it is fundamental to keep track of the movements of raw materials originating from waste, i.e. secondary raw materials, crossing European boundaries both as imports and exports, as well as of intra-EU trade.

Overall, cross-border movements of waste have significantly increased over the last decade. A considerable amount of resources leaves Europe and does not contribute directly to increasing the circularity of the European economy.

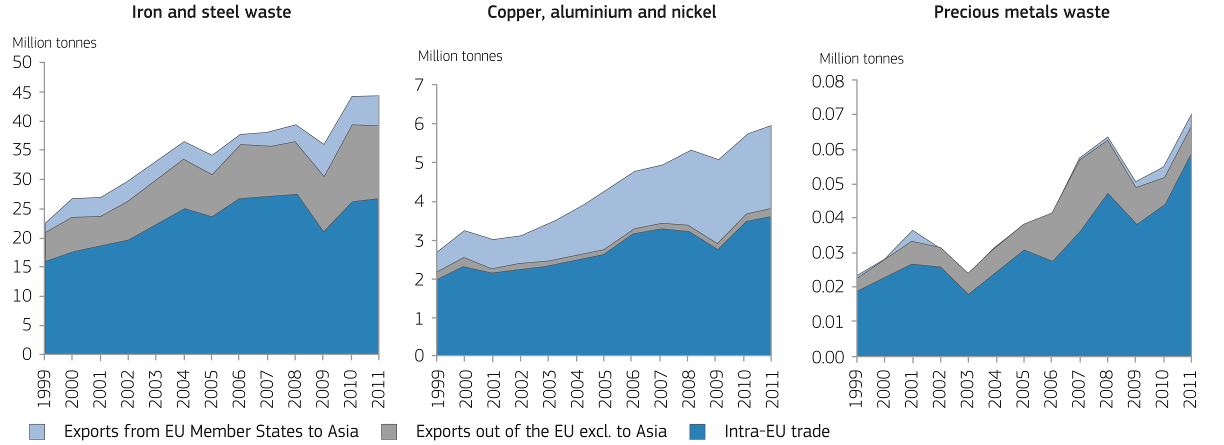
Facts and figures

Exports of secondary raw materials have grown significantly between 1999 and 2011

Figure 37 provides an overview of the amounts of waste of 'iron and steel', 'copper, aluminium and nickel', and 'precious metals' that were traded within the EU and exported outside the EU between 1999 and 2011.

In this time period, total EU waste material exports tripled for 'precious metals waste' and doubled for both 'copper, aluminium and nickel' and 'iron and steel'. A significant part of these exports is actually trade between EU Member States, especially for precious metals. For 'iron and steel', about 25 million tonnes were traded among EU countries, about 20 million tonnes were exported from

Figure 37: Gross exports of selected waste materials (1999-2011)[164]



163 EEA, 2012, *'Movements of waste across the EU's internal and external borders'*, European Environment Agency report No 7/2012.

164 Source: EEA, 2012, *'Movements of waste across the EU's internal and external borders'*, European Environment Agency report No 7/2012.

the EU (mostly to Turkey, Africa and the Middle East), and only about 3 million tonnes were imported into the EU.[165]

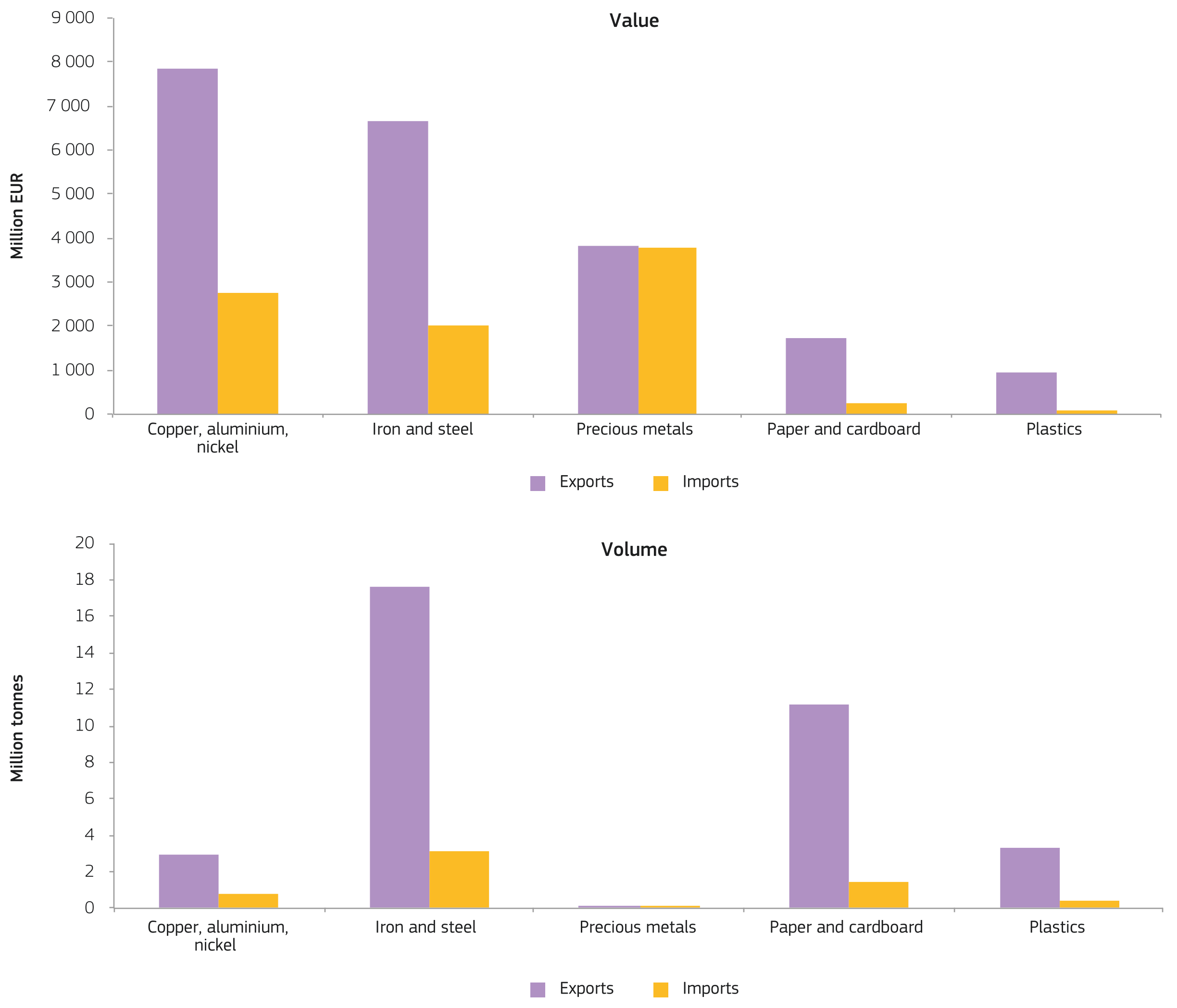
Figure 37 also suggests that for 'iron and steel' and 'copper, aluminium and nickel' the relative importance of extra-EU trade compared to the total exports of these metals increased substantially between 1999 and 2011. Asia was by far the largest destination for EU exports of 'copper, aluminium and nickel'.

This increase in exports is being driven by a number of factors, such as high prices for secondary materials in combination with low transportation costs, increasing external demand for materials, especially from Asia, uneven distribution of recycling capacity among EU Member States, and the recycling policies and targets set in EU waste directives.[166]

Exports of key secondary raw materials are much higher than imports

Figure 38 shows values and volumes[167] of the imports and exports of selected key waste materials traded across EU borders in 2011. It suggests that, with the exception of precious metals, 2011 waste exports were significantly higher than waste imports, both in terms of value and volume. For instance, about 18 million tonnes of 'iron and steel' waste were exported from the EU in 2011, while less than 4 million tonnes were imported into the EU, which means a net EU export of about 14 million tonnes.

Figure 38: Trade in selected waste materials to and from the EU (2011)[168]



165 Ibid.

166 Ibid.

167 Volumes are referred to as amounts, i.e. masses.

168 EEA, 2012.


© apimages.com

Conclusion

Recyclables are a significant source of raw materials for Europe, both in terms of value and volume. In order to provide an accurate picture of the European raw materials sector, it is thus important to quantify and monitor the movement of secondary raw materials. This includes tracking the amounts of secondary raw materials crossing EU borders both as external imports and exports and as intra-EU trade. Overall, movements of waste across Europe's borders have considerably increased over the last decade. A significant amount of resources are leaving Europe in the form of secondary raw materials.

Finally, it should be noted that this indicator covers only the legal exports of waste materials. Due to their nature, illegal waste shipments are by definition not tracked by official reporting systems, but there is extensive evidence that the amount of illegally exported waste is significant and, for some categories of waste (e.g. end-of-life vehicles or WEEE), perhaps even higher than the amount of legal exports.[169]

169 Ibid.

Environmental and social sustainability

>> Indicators:

19. Air emissions
20. Water
21. Extractive waste management
22. Sustainable wood supply
23. Occupational safety
24. Sustainability reporting

19. Air emissions

Key points:

- The raw materials sector has put particular efforts into reducing air emissions in recent years. Time trends suggest a decoupling between raw materials production and air pollution and greenhouse gas emissions, especially in the manufacturing subsectors included in this Scoreboard.
- Emissions of greenhouse gases and other air pollutant emissions from the production of raw materials in the EU decreased by 10-40 % between 1995 and 2009.
- This mainly reflects fuel switches and the increased uptake and effectiveness of air emission management systems in the EU.

Overview and context

As with many other economic activities, the raw materials industry is responsible for the emission of polluting substances to air. Emissions may occur across the entire life cycle of products: during clearing of land and extraction, during industrial processing and manufacturing of basic and final products, during the transport of materials and from waste management operations such as incineration.[170]

Given that the raw materials industry is an energy-intensive sector, air emissions originate to a large degree from fuel use in mining and quarrying and from subsequent production and manufacturing processes. Using energy and fuels leads to the emission of greenhouse gases (GHGs) such as carbon dioxide and methane. For example, the metals industry consumes around 8 % of global primary energy use per year.[171] The raw materials sector also contributes to emissions of particulate matter, of gases that form tropospheric ozone and (secondary) particulate matter and substances causing acidification and eutrophication, all of which have detrimental impacts on human health and ecosystems.

The Industrial Emissions Directive[172] is one of the pieces of EU legislation governing industrial emissions. The Directive requires the application of best available techniques (BAT) and sets limit values for the emissions of some specific substances. This framework covers the largest installations producing metals and minerals, and part of the wood sector, but not the extraction (quarrying and mining) of raw materials. In addition, emissions of certain pollutants to air from all human activities are regulated at EU level by the National Emission Ceilings (NEC) Directive[173], which is currently under review. This Directive determines the maximum overall emissions per Member State.

170 UNEP, 2013, 'Environmental Risks and Challenges of Anthropogenic Metals Flows and Cycles, A Report of the Working Group on the Global Metal Flows to the International Resource Panel', van der Voet, E.; Salminen, R.; Eckelman, M.; Mudd, G.; Norgate, T.; Hischier, R.
171 UNEP, 2013, *'International Resource Panel work on global metal flows'*.
172 Directive 2010/75/EU.
173 Directive 2001/81/EC.

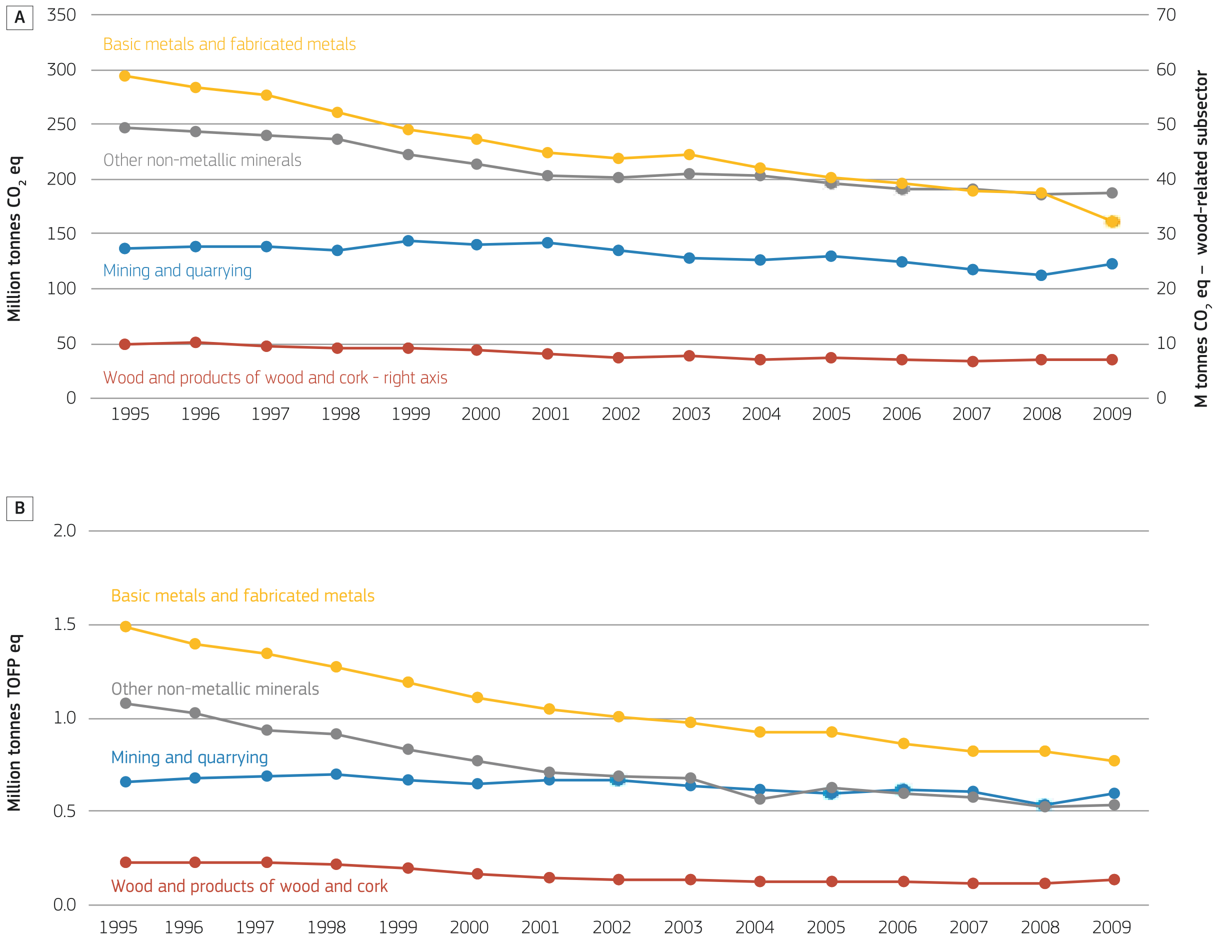
Facts and figures

Figure 39 presents a selection of production-corrected emissions to air[174] from economic subsectors within the raw materials industry[175] between 1995 and 2009 for the EU-27.[176] Greenhouse gas (GHG) emissions are shown in Figure 39A and gases that form tropospheric ozone (tropospheric ozone forming potential – TOFP) are shown in Figure 39B.

A significant decoupling of production and emissions of GHG and TOFP emissions can be observed for the raw materials subsectors in question, with the exception of the mining and quarrying sector. GHG and TOFP emissions from the production of metals decreased drastically — a 45 % reduction in GHGs and 50 % of TOFP, while for non-metallic minerals the reduction was 24 % for GHGs and 50 % for TOFP. These are the two subsectors responsible for most of the emissions. Emissions from the manufacture of wood products went down by 28 % for GHGs and by 42 % for TOFP, while a moderate 10 % decrease of emissions occurred in the mining and quarrying subsector.

174 Air emission values have been corrected by the production index, i.e. the ratio between the level of production each year and the first year of the time series. This makes it possible to show the real trend of changes in emissions. See methodological notes for more details.
175 World Input-Output Database (WIOD) classification codes of economic activities (subsectors here) slightly differ from the classification used in other indicators (NACE 2). This makes comparability of emissions with other data (e.g. value added and jobs in Indicator 7) more complex.
176 Data for Croatia not available.

Figure 39: Emissions of greenhouse gases (A) and gases with tropospheric ozone formation potential (B) (EU-27, 1995-2009)[177, 178]



Emissions from the wood-related subsector in Figure 39A refer to the secondary axis.

The search for suitable data...

After careful consideration, the Raw Materials Scoreboard opted to use data from the World Input-Output Database (WIOD),[179] because its time series starts in 1995, thus offering a more comprehensive overview of time trends. The WIOD also makes it possible to correct emissions to industry production levels, which in turn makes it possible to track real efficiency improvements in the sector. However, the WIOD data also have some limitations. For instance, they do not include emissions of particulate matter (PM_{10} and $PM_{2.5}$) and the latest data available are for 2009. Also, since the data are highly aggregated, the analysis of economic sectors has to be carried out at this same level of aggregation.

The significant decrease of emissions in the metals, minerals and wood-based industries can be attributed to changes in the fuels used, increased energy efficiency and the installation of abatement measures. The relatively lower decrease in the mining and quarrying sector may be explained by the fact that technological improvements may have been offset by increased energy demand. Increased energy demand is due to several factors such as lower ore grades and increasing ventilation requirements to access deeper mineral deposits.

177 Source: JRC analysis based on data from the WIOD: *Time series Air Emission Accounts*, http://www.wiod.org/new_site/database/eas.htm, and *Socio Economic Accounts*, http://www.wiod.org/new_site/database/seas.htm.

178 Data are displayed in production-corrected mass equivalent units. See also methodological notes.

179 WIOD combines data from Eurostat, which is based on the compilation of economic and environmental National Accounts, and data from the International Energy Agency (IEA).

Conclusion

The trends over time for air emissions suggest a decoupling between production and air pollution and greenhouse gas emissions, especially in the manufacturing subsectors included in this Scoreboard. Since 1995, raw materials industries in the EU have become more efficient at limiting direct environmental impacts caused by air emissions. Future updates of environmentally extended input-output databases such as WIOD would make it possible to investigate whether this trend continues.

20. Water

Key points:

- Water use is a key aspect of sustainability for the raw materials sector.
- No suitable data are readily available for a fair and accurate comparison of water use in the raw materials sector, which is typically affected by a wide range of factors.

Overview and context

The use and management of water is a major issue for all sectors of the raw materials industry. Even though the sector may be a relatively small water user compared with, for example, agriculture or some other types of industry, the raw materials sector requires significant volumes of water, especially in the extraction and processing phases.

Pressures on water availability are growing, making numerous industries vulnerable to water limitations throughout their operations and supply chains. These pressures can even directly threaten the feasibility of a company's activity: they can affect production levels, profit margins and even a company's capacity to operate, especially in water-stressed areas.[180]

Water quality is also a major issue in the raw materials industry.[181] Waste produced during extraction and processing of raw materials can potentially put surface and groundwater at risk, for example through seepage from tailing dams or run off of contaminated water. Careful management of runoff water can be critical to reducing potential negative impacts of large mining sites.[182]

In order to assess the sector's capacity to maintain the supply of raw materials, we need to look at the following key issues: Are water resources scarce? Is the sector using water in an efficient manner? How is the sector managing wastewater to limit negative environmental and health impacts?

Unfortunately, no data have been found that meets the Scoreboard's quality requirements. This is because of the complexity of factors involved in water use in the raw materials sector, which differ among production sites, management schemes and among types of mineral commodities. Ideally, indicators should provide insights into the intensity of water use, i.e. how much water is used relative to production, including data on water reuse and recycling at production sites and data on water discharges. Indicators on the local availability of water resources would also make it possible to assess the importance of water issues for the sustainability of production.

© EDM

180 Barton, B., 2010, *'Murky Waters? Corporate Reporting on Water Risk: A Benchmarking Study of 100 Companies'* Ceres Report.
181 UNEP, 2013, 'Environmental Risks and Challenges of Anthropogenic Metals Flows and Cycles, A Report of the Working Group on the Global Metal Flows to the International Resource Panel', van der Voet, E.; Salminen, R.; Eckelman, M.; Mudd, G.; Norgate, T.; Hischier, R.
182 Ibid.

The search for suitable data...

Addressing water use in the raw materials sector in a comprehensive and accurate manner is a complex task, made harder by limited data availability. Although no specific data sources have yet been selected to cover this topic, several sources were considered. Some of these might be potentially used in the future.

1) Data sources considered for the 2016 Scoreboard:

- Water use by supply category and economical sector:[183] this indicator, which reports water use (volume) for the mining and quarrying and the manufacturing subsectors, could be jointly used with the available data on production in all those subsectors to calculate the intensity of water use in production. However, data are not available for a significant number of countries, sometimes for confidentiality reasons.
- Water productivity:[184] this indicator shows how much economic output is produced per water cubic metre. It does so using national values for water abstraction and GDP. Since data are not disaggregated by economic sector, the indicator cannot be used to monitor changes in the raw materials sector.
- Water exploitation index (WEI):[185] this index, reported at country level, gives the percentage of total abstraction of fresh water relative to the long term average available water.[186] Data are only available at country level and do not distinguish between different economic sectors' use of water. However, the index WEI is currently being reviewed to develop an improved 'WEI +' index that can better describe how water scarcity affects different parts and basins of each Member State.
- Water intensity based on water abstraction and added value: water abstraction,[187] which reports abstraction of water by source and sector, can be divided by the added value of each sector[188] to obtain water use intensity. Both indicators are available from Eurostat. However, data for raw materials sectors are available only for the manufacturing industry and for mining and quarrying and lack the necessary detailed information on subsectors. In addition, complete times series data for the manufacturing sector are missing for some countries, while for the mining and quarrying sector, complete data series are available only for a limited number of EU countries. Also, abstraction of water is sometimes a limited proxy of water use, since it is not fully metered by Member States and it does not account for water reuse and recycling in the reduction of water demand.
- Environmentally extended input-output tables from the World Input Output Database (WIOD): this database reports data on use of blue water (from surface and groundwater resources), green water (from rainwater, useful mostly for crops) and grey water (freshwater required to assimilate the load of pollutants) by economic sector and country. Data availability for the raw materials sector is, however, as yet very limited (e.g. missing data for mining and quarrying and for many countries) and often faces similar problems as the indicators above.
- Generation and discharge of wastewater[189] (in volume): this Eurostat data source focuses on urban activities and does not provide data broken down by sectors.
- European Pollutant Release and Transfer Register (E-PRTR):[190] this data source contains among others annual data on the release of pollutants to water for 28 000 industrial facilities, including some raw materials sectors (e.g. mineral industry, production and processing of metals, paper and wood production and processing). However, this information cannot be used to assess changes in water quality. Such an assessment would require monitoring concentration of pollutants in water.

2) Potential data sources in the coming future:

In the future, some existing and emerging approaches for water accounting may become suitable to be used as an indicator for water use. These include:

- The ISO standard on water footprint:[191] released in 2014 and based on a life cycle approach, this standard requires computing the water footprint inventory, i.e. the water flows (considering inputs, recycle/reuse and discharges) associated with production, not only by product but also by organisation. This includes water quantity and quality, whenever relevant.
- Life cycle data: although this approach is restricted to specific products (rather than sectors), it could be used to identify and analyse key processes in terms of water consumption in the raw materials production chain. This could be used to compare water intensity between products.
- Other indicators derived from water accounting following the UN approach (System of Environmental-Economic Accounts for Water, SEEAW)[192].

Finally, to get a complete picture of water use in the raw materials sector, the information on water use and water discharges should be complemented with background information on water scarcity to reflect the differential impact of water use under different water availability conditions.

183 http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_wat_cat&lang=en.
184 http://ec.europa.eu/eurostat/tgm/table.do?tab=table&plugin=1&language=en&pcode=t2020_rd210.
185 http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tsdnr310&plugin=1.
186 For renewable fresh water resources, it also reports data with on surface water and groundwater separately.
187 Annual freshwater *abstraction by source and sector, available at* http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_wat_abs&lang=en. Value added at fa*ctor cost, extracted from the Annual detailed enterprise statistics for industry, indicator sbs_na_ind_r2, available at* http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sbs_na_ind_r2&lang=en.
188 Value added at factor cost, Annual detailed enterprise statistics for industry by Eurostat, http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sbs_na_ind_r2&lang=en.
189 http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ww_genv&lang=en.
190 http://prtr.ec.europa.eu/pgDownloadDataSet.aspx.
191 ISO 14046:2014 Environmental management — Water footprint — Principles, requirements and guidelines.
192 Several pilot projects on water accounts have been completed in various Member States, and a Guidance document on water asset accounts (water balances) has been published by the Commission http://ec.europa.eu/environment/water/blueprint/balances.htm.

21. Extractive waste management

Key points:

- Extractive waste raises important issues for the EU raw materials sector, both from an environmental and an economic point of view.
- Its improved management and recovery has the potential to provide additional supplies of raw materials to the EU and further reduce the environmental impact of the extractive industry.

Overview and context

Extractive waste, which includes waste from the extraction and processing of minerals, is one of the largest waste streams in the EU. This type of waste is significant from an environmental perspective because it can contain a variety of substances with widely differing pollution potentials, ranging from inert materials that would not have any significant environmental impact to heavy metals, which can be toxic in the environment.

The risk associated with mining waste substances also varies greatly from site to site, depending on the materials being produced and the storage and treatment systems used. Therefore, even if some operations are able to produce less waste per unit of output, differences in the levels of the toxicity of substances present in the waste stream must also be considered.

To minimise potential environmental impacts, extractive waste management is regulated in the EU by Member State Mining and/or Waste Codes, the EU Directive on the management of extractive industries waste (the Mining Waste Directive, 2006/21/EC), and, where applicable, by the Seveso-III Directive, which also puts the focus on minimising the risk of accidents. In addition, a best available techniques reference document on management of tailings and waste-rock was published in 2009[193] and is currently being revised.

From an economic point of view, extractive waste can also be seen as a potential source of valuable materials as it contains many raw materials that are currently often not recovered. This includes materials that are considered critical for the EU economy[194] such as rare earth elements used in many high-tech applications such as hybrid cars and cell phones, and rhodium, which is widely used in the chemical industries.

Increasing the recovery of raw materials from extractive waste through recycling could have a two-fold positive effect: first, it could reduce the need for treatment and storage of extractive waste and their associated environmental impacts; second, it could reduce the need for primary extraction, which often has higher environmental impacts compared with secondary production.

Limited data are available on recycling from extractive waste to date, which is estimated to be rather low, since recycling is not always economically profitable or because suitable technologies do not always exist.

193 See http://eippcb.jrc.ec.europa.eu/reference/mmr.html.

194 The term 'critical' refers to materials with high economic importance and a high potential supply risk. See Chapman, A., Arendorf, J., Castella, T., Thompson, P., Willis, P., Tercero Espinoza, L., Klug, S. and E. Wichmann, 2013, *'Study on Critical Raw Materials at EU Level'*, prepared for the European Commission, DG Enterprise and Industry (GROW).

The search for suitable data…

To date there is insufficient data that would allow for a comprehensive and accurate analysis of extractive waste generation and its environmental and economic implications..Listed below are some data sources that did not fully meet the demands of the Scoreboard and some potential options for waste generation and on recovering materials from extractive waste that could be used in the near future.

1) Data sources that were considered for the 2016 Scoreboard:

- Waste generation reported by Eurostat:[195] this data source reports data supplied by the Member States on the generation of hazardous and non-hazardous waste, classified by country and sector. The data source includes mining and quarrying activities and the manufacturing of metals and non-metallic minerals. This data could be analysed relative to the industry production volumes (also available in Eurostat). However, the main limitation of this data source concerning extractive waste is that different countries are known to use different reporting methods. This means that data are acknowledged as not being fully consistent. Furthermore, as extractive waste generation varies intrinsically per type of production site and per type of raw material extracted, a comparison of waste generation among countries on the basis of such data might be misleading.

2) Potential data sources in the coming future:

- The Minerals4EU[196] project: this project has collected data on mining waste (location, volume and included commodities). However, the consistency of this data with other sources, as needed for the analysis, is not yet fully certain.
- Extractive waste facilities per Member State: in 2016 the European Commission intends to propose that Member States provide basic information on extractive waste facilities (based on the data collected for permits granted). This could include detail on the type of activity and raw materials extracted.
- Data could become available in the future from the European Geological Surveys[197] or EU-funded research projects such as ProSUM[198] and SmartGround,[199] which are intended to provide sound information on mineral deposits, including mining waste. Such data might make it possible to analyse the location and size of major mining waste deposits, which could serve as a basis for estimating the recovery potential of raw materials from extractive waste. However, such an analysis will most probably face significant limitations, since the supply of data by the Member States and economic operators might not be always guaranteed, either for confidentially reasons or due to lack of data.

195 http://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics.
196 http://minerals4eu.brgm-rec.fr/m4eu-yearbook/theme_selection.html.
197 http://www.eurogeosurveys.org/.
198 http://www.prosumproject.eu/
199 http://www.smart-ground.eu/

22. Sustainable wood supply

Key points:

- After centuries of deforestation, the area and wood-growing stock of EU forests has been increasing over many decades. All Member States' felling rates are below 100 % of annual growth and most are below 85 %. Overall, they tend to range between 40 % and 90 %, with an average of about 60 %.
- Over 90 % of the raw wood processed into materials and products each year by EU forest-based industries comes from EU forests.
- Like other forest products and services, a sustainable supply of wood raw materials to competitive forest-based industries depends on healthy, dynamic and resilient forest eco-systems. The EU's forests are all subject to sustainable forest management (SFM) requirements to protect their ecological, social and economic functions.
- Wood demand from conventional forest-based industries and the rapidly growing bio-energy and bio-based products sectors is set to grow very significantly. Thus, greater efforts will be needed to ensure adequate, sustainable wood supplies from forests in the EU and elsewhere.

Overview and context

Wood is an essential renewable raw material in the EU, for conventional wood-based products, innovative bio-based products and bio-energy. Over 90 % of the raw wood processed into materials and products by EU industries is taken from EU forests, with small volumes of specific species and qualities imported – mostly from Russia, some from North America and a very small amount from tropical countries.[200] The EU's wood-processing industries provide thousands of products, including sawnwood and panels for construction and furniture, paper for writing and printing, packaging and a wide range of personal hygiene goods.

Demand for wood raw material is expected to grow.[201] The increase will probably be moderate for existing wood-based materials and products, but may be significant for innovative and bio-based products, such as bio-textiles and bio-medicines. EU demand for woody biomass for energy has already risen under Member States' programmes to meet EU renewable energy targets (some of which involve subsidies) and the trend is expected to continue.[202] To date, wood-based energy in the EU has been generated largely from biomass from industrial wood-processing residues, thus competing with biomass demand from the pulp and wood-based panels sectors. In the future, however, much of the growth in bio-energy demand is likely to be satisfied by low-grade forest residues, increased forest harvests and imports, e.g. of wood pellets.

200 European Commission, 2013, '*A blueprint for the EU forest-based industries (woodworking, furniture, pulp & paper manufacturing and converting, printing)*', SWD(2013) 343.

201 Indufor, 2013, '*Study on wood raw material supply and demand for the EU wood-processing industries*',prepared for the European Commission, DG Enterprise and Industry (DG GROW).

202 European Commission, 2014, '*State of play on the sustainability of solid and gaseous biomass used for electricity, heating and cooling in the EU*', SWD (2014) 259; European Commission, 2015, '*A framework strategy for a resilient Energy Union with a forward-looking climate change policy*', COM(2015) 80.

Overall, EU wood removal rates (ratio of annual wood removal to annual wood growth) are expected to increase[203] to help meet the increasing demand for biomass. Understanding sustainable forest management (SFM) and dynamics is essential to monitoring forests' capacity to continue to provide a range of functions and benefits, including wood-based and non-wood products and services. Simply put, SFM means not only day-to-day protection of functions, but also the long-term safeguarding of forest genetic potential. Therefore, SFM cannot be measured solely by the ratio of wood removal to net forest growth. Maintaining overall felling at or below incremental production is a necessary condition for sustainability, but it is far from sufficient; optimum harvesting levels are only one part of sustainable forest management which, overall, depends on many other economic, social and environmental factors.

In the long term, sustained wood supply also depends on an overall balance as regards the ages of trees (young, medium-aged, mature, over-mature, etc.). Many forest areas protected under Natura 2000 or comparable national schemes may undergo limited harvesting and so become over-mature and can have low/negative growth and net carbon loss. As a result, they may be more prone to catastrophic biotic and abiotic damage. Nonetheless old forests may have high biodiversity values. In addition, there is significant untapped wood supply potential in the many small, fragmented private forests belonging to owners who increasingly do not live locally and are often unaware of and/or unmotivated by the need to harvest wood.

All EU Member States are signatories of the Forest Europe Resolutions and other declarations on SFM (such as the Convention

203 European Commission, 2013, '*A new EU Forest Strategy: for forests and the forest-based sector*', COM(2013) 659.

on Biological Diversity or the Sustainable Development Goals) and the respect of the Sustainable Forest Management Principles is required in all Member States by national laws. Sustainable forest management is a complex and multifaceted issue. It covers the ecological, social and economic aspects of forestry and is essential to ensuring a sustainable supply of wood. However, while keeping felling below forests' net biomass production is necessary for sustainability, it is not sufficient. EU Member States and other European countries have developed common ecological, social and economic SFM criteria under the Forest Europe process. Since it is not yet possible to map EU forest areas covered by SFM certification schemes[204] or to measure how much wood comes from them, the Raw Materials Scoreboard has opted to concentrate on felling rates.

Maintaining healthy forest ecosystems is essential to retain their bio-diversity so they can fulfil their diverse environmental, social and economic functions and thus be sustainable, including as a source of all kinds of woody biomass satisfying current and anticipated demand. This involves forests being not only productive, but also resilient in the face of biotic and abiotic disruption from the effects of pests, disease and wind, snow or fire damage, etc.

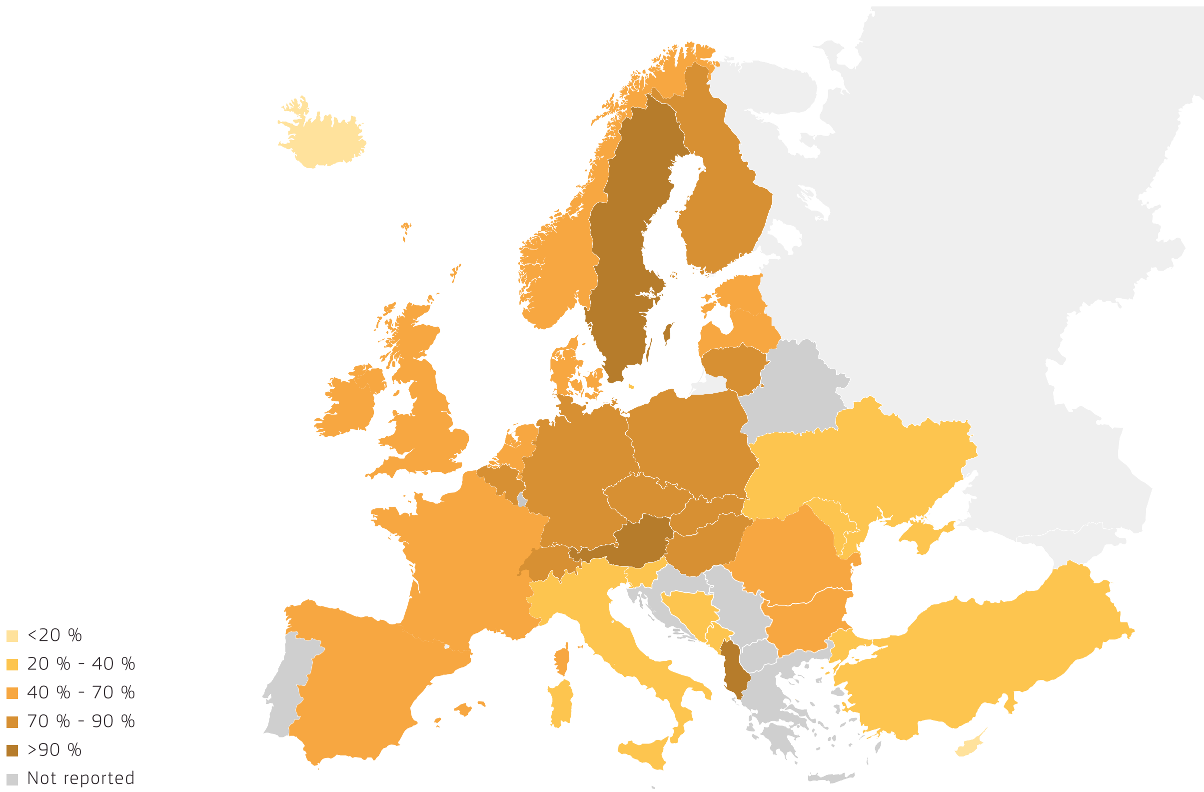
Facts and figures

Figure 40 gives an overview of the proportion of wood cut down in Member States' forests — felling rates — as a percentage of the net yearly wood growth of the forest (net annual increment).

After centuries of deforestation, the area and wood-growing stock of EU forests is rising. All Member States' felling rates are below 100 % and most are below 85 %. Overall, they tend to range between 40 % and 90 %, with an average of about 60 %. About 80 % of the raw wood is used by industry; the rest is used for fuel. Sweden and Austria have relatively high felling rates, based on their high total standing wood volumes and intensive planned wood use. Austria has a particularly high average standing wood volume per hectare.

Over 90 % of the raw wood processed by EU industry comes from EU forests, but rates vary significantly between Member States. There is a lot of trade within the EU, often from countries with high forest cover and low populations to countries where the opposite applies.

Figure 40: Geographical distribution of felling rates (% of net forest increment, 2010)[205]



204 Proprietary forest certification schemes are a tool commonly used by forest owners to acknowledge SFM, based on national or other SFM standards and criteria. Chain-of-custody certification is a monitoring, tracing and labelling mechanism, which certifies SFM claims along given value chains.

205 Forest Europe, 2015, '*State of Europe's forests 2015*'. The figure shows values for 2010 for EU countries for which data were available, plus Albania, Belarus, Bosnia and Herzegovina, Iceland, Moldova, Montenegro, Norway, the Russian Federation, Switzerland, Turkey and Ukraine.

Conclusion

Ensuring a sustainable supply of raw wood materials to competitive forest-based industries depends on the sustainability of healthy, dynamic and resilient forests. The current volume of wood biomass harvested in the EU is less than net forest growth. As long as this remains the case, supply of this raw material which is so essential for the EU economy will not be at risk, and provided the felling rate is kept below 85 % there should be no undue negative environmental impacts.

However, wood demand, both from existing industries and from the rapidly growing bio-energy and bio-based products sectors, is set to grow very significantly in the coming decades. Therefore, greater efforts will be needed to safeguard forest health and resilience on the basis of ecological, social and economic SFM principles, while ensuring adequate wood supplies. Accordingly, more intensive quantitative and qualitative monitoring is needed to give us a better understanding of forest dynamics as a basis for continued sustainable management so that forests continue to fulfil their important functions while also meeting increasing demands for wood.

23. Occupational safety

Key points:

- Although the raw materials sector in the EU meets or exceeds the strict safety standards, it is relatively exposed to occupational hazards and related work accidents.
- Raw material activities have relatively high rates of non-fatal accidents, at approximately the same level as other high-risk sectors such as fishing, construction and sports activities and recreation.
- Accident rates in the raw materials sectors have been decreasing since the middle of the 1990s.

Overview and context

Occupational safety and health (OSH) at work is important in the context of the social sustainability of any economic sector. When referring to the raw materials industry, a safe and healthy working environment is an important determinant of the level of acceptance or approval of an industry and its operations by local communities and stakeholders. OSH is also essential for a productive and competitive economy.[206]

OSH constitutes one of the areas where strict safety standards exist and where EU policies have had a large impact in recent years. Significant decreases have been achieved in virtually all economic sectors in both the number of workplace accidents and the overall incidence rate[207] (i.e. the number of accidents relative to the number of people employed in a sector).

In the raw materials sector, specific hazards include the exposure of employees to chemicals, noise and high temperatures. Proper management of work-related risks and hazards, which is the joint responsibility of the employer and the employee, can help to minimise employees' exposure to risk factors and in this way support a safe and healthy work environment. Sound risk management may include employing operators with adequate skills and levels of expertise, having the proper protective equipment and establishing risk management systems at the production site.

In order to monitor the social sustainability of economic activities, employers are asked to report accidents that occur at the production site to the responsible authorities. As a result, incidence rate statistics for work-related accidents are reported for the different economic activities. This makes it possible to compare the incidence of accidents across sectors and to view trends over time.

Facts and figures

Figure 41 shows the incidence rate for non-fatal accidents[208] occurring at the working place in raw materials and other economic activities in the different sectors of the economy, i.e. for extractive activities (primary sector), basic manufacturing (secondary sector) and service activities (tertiary sector). For comparability purposes, the average incidence rate level in the whole EU economy and incidence rates of each of the three economic sectors are also shown.

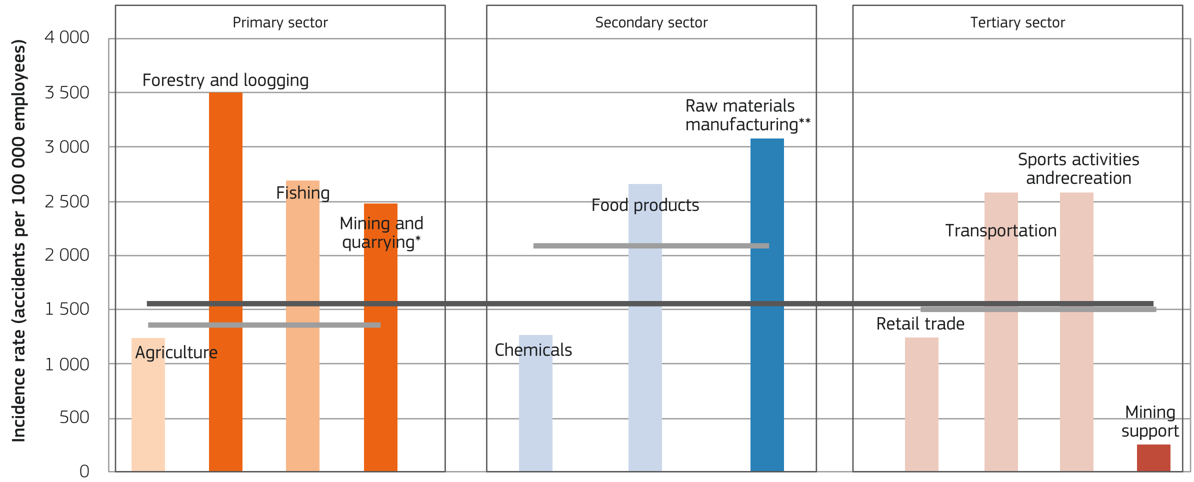
The figure suggests that the raw materials sector is relatively exposed to hazards leading to non-fatal accidents, but not more so than other high-risk sectors such as fishing, construction or sports and recreation activities. For example, within the primary sector, the incidence rate of mining and quarrying accidents is above the average for the sector, but below other activities such as fishing. By contrast, accident rates for forestry and logging activities are higher. Accident rates observed for raw materials manufacturing activities are higher than for other activities in the secondary sector (e.g. food products and chemicals) and approximately similar to the rates for the construction sector.

206 European Commission, 2014, '*An EU Strategic Framework on Health and Safety at Work 2014-2020*', COM(2014) 332.

207 European Commission, 2008, '*Causes and circumstances of accidents at work in the EU*', Directorate-General for Employment, Social Affairs and Equal Opportunities.

208 Non-fatal accidents are accidents that result in more than three days' absence from work without fatal consequences.

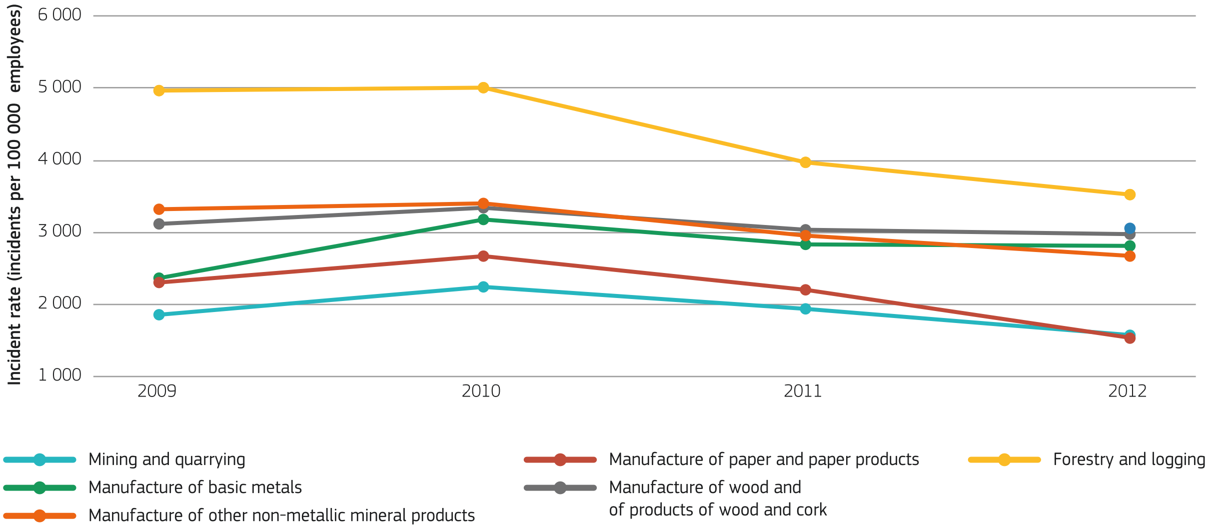
Figure 41: Incidence rate of non-fatal accidents for a selection of economic sectors (EU-28, 2012, raw materials displayed in darker colours)[209]



* Oil and gas extraction activities excluded ** Average of a selection of non-food, non-energy raw materials manufacturing activities. The average incidence rates for the whole EU economy and for each of the economic sectors are displayed as benchmarks (horizontal lines)

Figure 42 shows the trend over time for the incidence rate of non-fatal accidents for selected raw materials industries between 2009 and 2012. It shows that the incidence rate has decreased for all raw materials sectors. Historic data indicate that this trend can be observed since at least the middle of the 1990s. For the mining and quarrying sector, the data also indicate that the accident rates decreased faster than the average rate in the EU: the current incidence rate of mining and quarrying is below the values found for construction, whereas in the early 2000s it used to be above this level.[210]

Figure 42: Incidence rate of non-fatal accidents of selected raw materials sectors (2009-2012)[211]



209 Source: JRC analysis based on data from Eurostat, *Non-fatal accidents at work by economic activity and sex*, code *hsw_n2_01*, *incidence rate*, http://ec.europa.eu/eurostat/en/web/products-datasets/-/HSW_N2_01, retrieved in December 2015.

210 European Commission, 2008, *'Causes and circumstances of accidents at work in the EU'*, Directorate-General for Employment, Social Affairs and Equal Opportunities.

211 Source: JRC analysis based on data from Eurostat: Non-fatal accidents at work by economic activity and sex, code hsw_n2_01, incidence rate, http://ec.europa.eu/eurostat/en/web/products-datasets/-/HSW_N2_01, retrieved in December 2015.

The search for suitable data…

The data on accidents at work shown here are provided by Eurostat. The data are mainly taken from the European Statistics on Accidents at Work (ESAW), which collects statistics on accidents at work in the EU that are declared to specific public or private insurance schemes or to national authorities. The average values for the EU might be not fully consistent with the data available at national level as reporting systems may differ among countries. For example, for some countries the data refer to workers insured, while for others the data refer to employees. In addition, the definition of an accident may differ from one country to another.

The Raw Materials Scoreboard opted to present data on non-fatal accidents rather than on fatal accidents. This was because the number of non-fatal accidents is higher and may therefore provide a more robust comparison across sectors and activities. No data were found that would allow for an adequate international comparison outside the EU. This is because data are missing for many countries and because reporting methodologies differ significantly among countries and are therefore not comparable. Also, often data cannot be disaggregated for the raw materials sector.

Moreover, the analysis provided does not include details on accident typologies. Such detail could provide further insight into the severity of the accidents occurred.

Conclusion

Raw material activities have relatively high rates of non-fatal accidents, with rates at the same level as other high-risk sectors such as fishing or construction. The current EU policy framework strongly encourages establishing preventive and protective measures to improve health and safety at work. Regular reporting on rates of incidence of accidents and the understanding of the causes of accidents will help to achieve a continuing improvement in health and safety at work in the raw materials industry, which is an essential component of the sector's social sustainability.

24. Sustainability reporting

Key points:

- The EU raw materials sector is a world leader in sustainability reporting, which supports transparency and corporate social responsibility.
- About one third of the Global Reporting Initiative reports for the raw materials sector are filed by companies with their headquarters in Europe.
- Raw materials companies are increasingly publishing sustainability reports and their rate of increase is higher than for other sectors, such as agriculture, textiles and chemicals.

Overview and context

Sustainability reporting is an important step in making corporate social responsibility a central management topic for a company. Sustainability reporting is used by companies to measure, disclose and be accountable to internal and external stakeholders and the public with regard to their environmental, social, economic and organisational performance.[212] Sustainability of companies is the focus of the Global Reporting Initiative (GRI), an initiative formed in 1997 with the support of the United Nations Environment Programme (UNEP). The GRI has developed sector-specific guidelines that cover the specific sustainability challenges faced by different sectors. For example, the sector-specific guidelines for the mining and metals sector cover issues such as biodiversity management, indigenous people's rights during exploration phases and the resettlement of local communities.[213]

Facts and figures

Figure 43 shows the number of companies that have joined the GRI in different raw materials sectors, namely mining, metals products, forest and paper products, and construction materials. The top part of Figure 43 shows a comparison of sustainability reporting companies in the different world regions (in 2014). It shows Europe's leading position in sustainability reporting, with more than one third of raw materials companies participating in the GRI initiative located in Europe. Europe's leading position may be a consequence of companies taking active measures to improve the overall low levels of public trust in the sector, as demonstrated by Indicator 14.

The trend for GRI sustainability reporting in Europe in recent years (2000-2014) is shown in the bottom part of Figure 43. It shows a steady increase of reporting by European companies for all raw material sectors considered, although it should be noted that the number of GRI reports at the global level rose even faster (see values on the right-hand axis). This upward trend in GRI reporting in the raw materials sector, both globally and for Europe, was above the average increase rates for other economic sectors such as agriculture, chemicals and textile production. This shows the commitment of the raw materials sectors to transparency.

Globally, the biggest share of companies that have joined the GRI is among large and multinational enterprises[214] responsible for the biggest share of raw materials production (more than 90 % for construction materials and forest and paper products and nearly 100 % for metals and mining companies). This is because small and medium-sized enterprises cannot so easily afford the costs associated with participating in the initiative. Nonetheless, the GRI guarantees a sufficiently broad coverage of the industry.

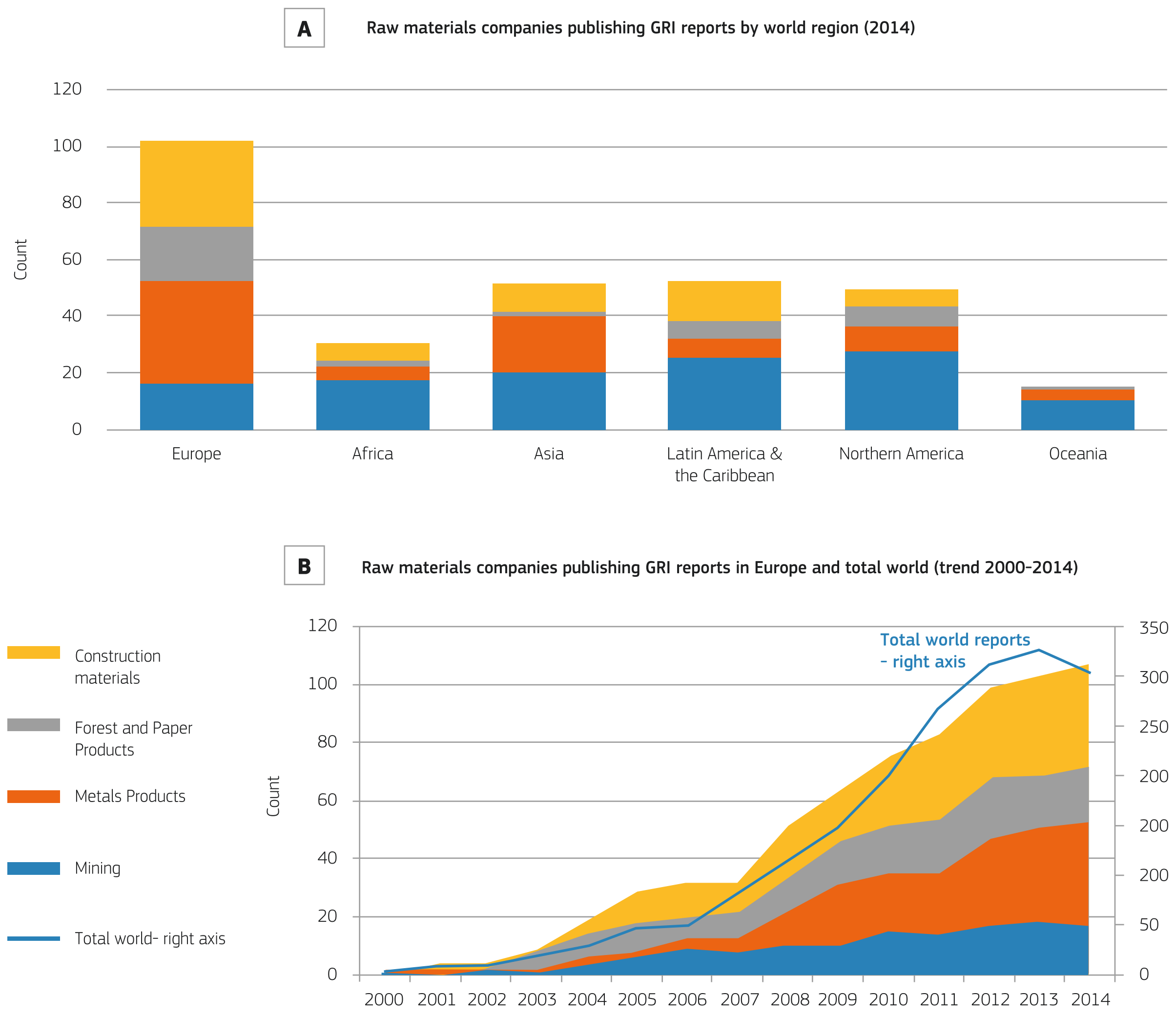
© apimages.com

212 Wensen K., Broer W., Klein J., Knopf J., 2011, *'The state of play in sustainability reporting in the EU'*, prepared for the European Commission to support the High Level Group on Corporate Social Responsibility.

213 https://www.globalreporting.org/Pages/default.aspx.

214 GRI classifies companies as SMEs (small and medium-sized enterprises, having less than 250 workers and not more than EUR 50 million in turnover), large (more than 250 workers and more than EUR 50 million in turnover) and MNE (Multinational enterprises, large companies that are also multinational).

Figure 43: Number of companies that have joined the Global Reporting Initiative, by world region (A, 2014) and for Europe (B, 2000-2014)[215]



Conclusion

The graphs above demonstrate that the EU raw materials sectors are taking public concerns about environmental impacts and community relations seriously and are committed to improving their transparency and corporate social responsibility. The leading position of EU raw materials companies is all the more impressive given that a bigger share of large and multinational raw materials companies may be located outside of Europe.

215 Source: JRC analysis based on data from the Sustainability Disclosure Database. Reports have been included that fit with GRI guidelines (therefore excluding non-GRI and GRI-Ref reports). Companies are counted as European if their headquarters are located in a European country. Where local branches or similar entities exist, the country refers to the location of the reporting entity. Europe includes EU countries plus other countries (e.g. Norway, the Russian Federation, Serbia, Switzerland, Ukraine, etc. depending on which companies join the initiative each year).

References

Ad hoc Working Group on defining critical raw materials, 2014, *'Report on critical raw materials for the EU'*, prepared for the European Commission, DG Enterprise and Industry (GROW) (http://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical/index_en.htm)

Ad hoc Working Group on defining critical raw materials, 2010, 'Critical raw materials for the EU' prepared for the European Commission, DG Enterprise and Industry (GROW) (http://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical/index_en.htm)

Baldé, C.P., Wang, F., Kuehr, R., Huisman, J., 2015, '*The global e-waste monitor — 2014*' — United Nations University, IAS — SCYCLE, Bonn, Germany.

Barton, B., 2010, *'Murky Waters? Corporate Reporting on Water Risk: A Benchmarking Study of 100 Companies'* Ceres Report (http://www.ceres.org/resources/reports/corporate-reporting-on-water-risk-2010/).

Batterham, R. J., 2013, '*The Impact of the Bologna Model on Mineral Processing Education: Good, Bad or Indifferent'*, in: Minerals Industry Education and Training, Cilliers, J., Drinkwater, D. and Heiskanen, K. (Eds.), New Concept Information Systems Ltd., New Delhi, ISBN 81-901714-4-5, pp. 29-36.

Bio by Deloitte, 2015, '*Study on Data for a Raw Material System Analysis: Roadmap and Test of the Fully Operational MSA for Raw Materials*', prepared for the European Commission, DG GROW (https://ec.europa.eu/growth/tools-databases/msa/content/home).

Chapman, A., Arendorf, J., Castella, T., Thompson, P., Willis, P., Tercero Espinoza, L., Klug, S. and E. Wichmann, 2013, *'Study on Critical Raw Materials at EU Level'*, prepared for the European Commission, DG Enterprise and Industry (GROW) (http://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical/index_en.htm)

Cilliers, J., 2013, *'The Supply and Demand of Minerals Engineers: A Global Survey'* in: Minerals Industry Education and Training, Cilliers, J., Drinkwater, D. and Heiskanen, K. (Eds.), New Concept Information Systems Ltd., New Delhi, ISBN 81-901714-4-5, pp. 3-13.

Cullen J. M., Allwood J.M., Bambach M.D., 2012, '*Mapping the Global Flow of Steel: From Steelmaking to End-Use Goods'*, Environmental Science & Technology 46 (pp. 13048–13055).

EEA, 2012, *'Movements of waste across the EU's internal and external borders'*,European Environment Agency report no 7/2012 (http://www.eea.europa.eu/publications/movements-of-waste-EU-2012).

EEA, 2015, '*Global Megatrends: Intensified global competition for resources'*, State of the Environment Report, European Environment Agency (http://www.eea.europa.eu/soer-2015/global/competition).

Elshkaki A. and T.E. Graedel, 2015, *'Solar cell metals and their hosts: A tale of oversupply and undersupply'*, Applied Energy 158 pp. 167–177 (http://dx.doi.org/10.1016/j.apenergy.2015.08.066).

Ernst & Young, 2014, *'Productivity in mining: now comes the hard part — A global survey'* (http://www.ey.com/Publication/vwLUAssets/EY-productivity-in-mining-now-comes-the-hard-part/$FILE/EY-productivity-in-mining-now-comes-the-hard-part.pdf).

Eunomia, 2014, *Study on the competitiveness of the EU mineral raw materials sector: non-energy and extractive industries and recycling industries*, report to DG Enterprise and Industry (http://ec.europa.eu/growth/tools-databases/newsroom/cf/itemdetail.cfm?item_id=8237&lang=en&title=Study-on-the-Competitiveness-of-the-EU-Primary-and-Secondary-Mineral-Raw-Materials-Sectors

European Commission, 2007, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: *Towards a low carbon future*, COM(2007) 723 (http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52007DC0723&from=EN).

European Commission, 2008, *'Causes and circumstances of accidents at work in the EU'*, Directorate-General for Employment, Social Affairs and Equal Opportunities.

European Commission, 2008, Communication from the Commission to the European Parliament and the Council: *The Raw Materials Initiative — meeting our critical needs for growth and jobs in Europe*, COM(2008) 699 (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0699:FIN:en:PDF).

European Commission, 2009, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: *Investing in the Development of Low Carbon Technologies (SET-Plan)*, COM(2009) 519 (http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52009DC0519&from=EN).

European Commission, 2009, Impact Assessment Guidelines (http://ec.europa.eu/smart-regulation/impact/commission_guidelines/docs/iag_2009_annex_en.pdf)

European Commission, 2011, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: *Tackling the challenges in commodity markets and on raw materials*, COM(2011) 25 (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0025:FIN:en:PDF).

European Commission, 2011, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: *Energy*

Roadmap 2050, COM(2011) 885 (http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0885&from=EN).

European Commission, 2013, '*How companies influence our society: citizens' view*', Flash Eurobarometer 363, (http://ec.europa.eu/public_opinion/flash/fl_363_en.pdf).

European Commission, 2013, '*The state of aluminium production in Europe',* MEMO/13/954 (http://europa.eu/rapid/press-release_MEMO-13-954_en.htm).

European Commission, 2013, *'Critical Metals in the Path towards the Decarbonisation of the EU Energy Sector: Assessing Rare Metals as Supply-Chain Bottlenecks in Low-Carbon Energy Technologies'*, JRC Science and Policy Reports (https://setis.ec.europa.eu/system/files/Critical%20Metals%20Decarbonisation.pdf).

European Commission, 2013, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: *Energy Technologies and Innovation*, COM(2013) 253 (https://ec.europa.eu/energy/sites/ener/files/comm_2013_0253_en.pdf).

European Commission, 2013, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: *A blueprint for the EU forest-based industries (woodworking, furniture, pulp & paper manufacturing and converting, printing),* SWD(2013) 343, (http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013SC0343&from=EN).

European Commission, 2013, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: *Action Plan for a competitive and sustainable steel industry in Europe*, COM(2013) 407 (http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013DC0407&from=EN).

European Commission, 2013, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: *Measuring innovation output in Europe: towards a new indicator*, COM(2013) 624 (http://ec.europa.eu/research/press/2013/pdf/indicator_of_innovation_output.pdf).

European Commission, 2013, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: *A new EU Forest Strategy: for forests and the forest-based sector*, COM(2013) 659 (http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52013DC0659).

European Commission, 2014, *'2013 Technology Map of the European Strategic Energy Technology Plan: Technology Descriptions'*, JRC Science and Policy Reports (https://setis.ec.europa.eu/sites/default/files/2013TechnologyMap.pdf).

European Commission, 2014, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: *A policy framework for climate and energy in the period from 2020 to 2030*, COM(2014) 15 (http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014DC0015&from=EN).

European Commission, 2014, *'State of play on the sustainability of solid and gaseous biomass used for electricity, heating and cooling in the EU'*, SWD (2014) 259, http://ec.europa.eu/energy/sites/ener/files/2014_biomass_state_of_play_.pdf.

European Commission, 2014, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions *on an EU Strategic Framework on Health and Safety at Work 2014-2020,* COM(2014) 332 (http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014DC0332&from=EN).

European Commission, 2015, *'Circular Economy Package: Questions & Answers'* (http://europa.eu/rapid/press-release_MEMO-15-6204_en.htm).

European Commission, 2015, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, the Committee of the Regions and the European Investment Bank: *A framework strategy for a resilient Energy Union with a forward-looking climate change policy*, COM(2015) 80 (http://eur-lex.europa.eu/resource.html?uri=cellar:1bd46c90-bdd4-11e4-bbe1-01aa75ed71a1.0001.03/DOC_1&format=PDF).

European Commission, 2015, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: *Closing the loop — An EU Action Plan for the Circular Economy*, COM(2015) 614, (http://ec.europa.eu/environment/circular-economy/).

European Innovation Partnership on Raw Materials, 2013, *' Strategic Implementation Plan'*,https://ec.europa.eu/growth/tools-databases/eip-raw-materials/en/content/strategic-implementation-plan-sip-0

European Innovation Partnership on Raw Materials, 2014, *'Monitoring and evaluation scheme'*

Farooki M., 2012, *'The diversification of the global mining equipment industry — Going new places?'*, Resources Policy 37, pp. 417–424 (http://dx.doi.org/10.1016/j.resourpol.2012.06.006).

Ferguson M. et al (SNL Metals and Mining), 2015, '*Corporate Exploration Strategies 2015 — Exploration Budgets by Location, 2015; Part 1: Overall Trends, Canada, Australia and United States'*.

Forest Europe, 2015, '*State of Europe's forests 2015'* (http://www.foresteurope.org/docs/fullsoef2015.pdf).

Freedonia, 2015, *'World Mining Equipment — Demand and Sales Forecasts, Market Share, Market Size, Market Leaders'*.

Haas W., Krausmann F., Wiedenhofer D. and Heinz M., 2015, *'How Circular is the Global Economy?: An Assessment of Material Flows, Waste Production, and Recycling in the European Union and the World in 2005'*, Journal of Industrial Ecology (doi: 10.1111/jiec.12244).

Hagelüken, C., 2013, *'Recycling of precious and special metals'* in Michael Angrick, Andreas Burger and Harry Lehmann 'Factor X - Re-source - Designing the Recycling Society', Springer, pp. 221-241.

Huisman, J., Botezatu, I., Herreras, L., Liddane, M., Hintsa, J., Luda di Cortemiglia, V., Leroy, P., Vermeersch, E., Mohanty, S., van den Brink, S., Ghenciu, B., Dimitrova, D., Nash, E., Shryane, T., Wieting, M., Kehoe, J., Baldé, C.P., Magalini, F., Zanasi, A., Ruini, F., Männistö, T., and Bonzio, A., 2015, *Countering WEEE Illegal Trade (CWIT) Summary Report, Market Assessment, Legal Analysis, Crime Analysis and Recommendations Roadmap*, Lyon, France (http://www.cwitproject.eu/).

ICMM, 2012, *'Trends in the mining and metals industry — Mining's contribution to sustainable development'*, International Council for Metals & Mining (https://www.icmm.com/document/4441).

Indufor, 2013, *'Study on wood raw material supply and demand for the EU wood-processing industries'*,prepared for the European Commission, DG Enterprise and Industry (DG GROW).

Jackson, T., 2014, *'Annual Survey of Mining Companies 2014'*, Fraser Institute (https://www.fraserinstitute.org/sites/default/files/survey-of-mining-companies-2014.pdf).

Low, P.,2013, *' The role of services in global value chains'* in *'Global value chains in a changing world*, ed. Deborah K. Elms and Patrick Low, World Trade Organisation, (https://www.wto.org/english/res_e/booksp_e/aid4tradeglobalvalue13_e.pdf).

McDivitt, J., 2002, *'Status of Education of Mining Industry Professionals'*, Mining, Minerals and Sustainable Development, report prepared for the Institute for Environment and Development (IIED) (http://pubs.iied.org/pdfs/G00953.pdf).

OECD, 2009, *'Patent Statistics Manual'*, ISBN 978-92-64-05412-7.

OECD, 2014, *'Export restrictions in raw material trade: Facts, fallacies and better practices'* (http://www.oecd.org/tad/benefitlib/export-restrictions-raw-materials-2014.pdf).

OECD, 2015, *'Material Resources, Productivity and the Environment'*.

Reuter, M.A., Boin, U.M.J., van Schaik, A., Verhoef, E., Heiskanen, K., Yang, Y., and G. Georgalli, 2005, *'The Metrics of Material and Metal Ecology — Harmonising the Resource, Technology and Environmental Cycles'*, Elsevier.

Sand, A., Rosenkranz, J., 2014, *'Education related to mineral raw materials in the European Union'*, COBALT project "COmmunicating, Building of Awareness, Leadership competence and Transferring knowledge on sustainable use of raw materials" D3.1 (http://www.cobalt-fp7.eu/pdf/deliverables/D3.1-Report%20on%20available%20study%20programmes%20and%20existing%20skill%20shortages.pdf).

Schaffartzik, A., Mayer, A., Gingrich, S., Eisenmenger, N., Loy, C., Krausmann, F., 2014, *'The global metabolic transition: Regional patterns and trends of global material flows, 1950-2010'*, Global Environmental Change, Vol. 26, pp. 87-97 (doi:10.1016/j.gloenvcha.2014.03.013).

Schubert, S.R., Brutschin, E., Pollak, J., 2015, *'Trade in commodities: Obstacles to trade and illegal trade'*, prepared for the European Parliament, DG for External Policies (http://www.europarl.europa.eu/RegData/etudes/STUD/2015/534996/EXPO_STU(2015)534996_EN.pdf).

Shillito, J., 2015, *'Talent wars — how the mining sector must dig deep for the right candidates'*, Industrial Minerals (http://www.indmin.com/Article/3452041/Talent-warshow-the-mining-sector-must-dig-deep-for-the-right-candidates.html).

SNL Metals & Mining, 2014, '25th Annual Corporate Exploration Strategies study', (http://go.snl.com/Nonferrous-Mining-Exploration-Budgets-Request.html)

The Hague Centre for Strategic Studies, 2009, *'Scarcity of Minerals: A Strategic Security Issue'*,Kooroshy, J., Meindersma, C., Podkolinski, R., Rademaker, M., Sweijs, T.,

U.S. Geological Survey, 2013, *'Mineral Commodity Summaries, Rare earths'*, (http://minerals.usgs.gov/minerals/pubs/commodity/rare_earths/mcs-2013-raree.pdf).

UNEP, 2011, *'Recycling rates of metals — A status report, A report of the Working Group on the Global Metal Flows to the International Resource Panel'*,T.E. Graedel, J. Allwood, J.P Birat, B.K Reck, S.F. Sibley, G. Sonnemann, M.Buchert, C. Hagelüken (http://www.unep.org/resourcepanel/Portals/24102/PDFs/Metals_Recycling_Rates_110412-1.pdf).

UNEP, 2011, *'Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel'*, Fischer-Kowalski, M., Swilling, M., von Weizsäcker, E.U., Ren, Y., Moriguchi, Y., Crane, W., Krausmann, F., Eisenmenger, N., Giljum, S., Hennicke, P., Romero Lankao, P., Siriban Manalang, A., Sewerin, S. (http://www.unep.org/resourcepanel/decoupling/files/pdf/Decoupling_Report_English.pdf).

UNEP, 2013, *'International Resource Panel work on global metal flows'* (http://www.unep.org/resourcepanel/Portals/50244/publications/UNEP_Synopsis_131008.pdf).

UNEP, 2013, 'Environmental Risks and Challenges of Anthropogenic Metals Flows and Cycles, A Report of the Working Group on the Global Metal Flows to the International Resource Panel', van der Voet, E.; Salminen, R.; Eckelman, M.; Mudd, G.; Norgate, T.; Hischier, R. (http://www.unep.org/resourcepanel/Portals/24102/PDFs/Environmental_Challenges_Metals-Full%20Report.pdf).

UNEP, 2014, *'Decoupling 2: technologies, opportunities and policy options. A Report of the Working Group on Decoupling to the International Resource Panel'*, von Weizsäcker, E.U., de Larderel, J, Hargroves, K., Hudson, C., Smith, M., Rodrigues, M.

UNEP, 2016 (forthcoming), '*Material Flows and Resource Productivity',* Paris.

Wensen K., Broer W., Klein J., Knopf J., 2011, *'The state of play in sustainability reporting in the EU',* prepared for the European Commission to support the High Level Group on Corporate Social Responsibility.

Wilburn, D.R., K.A. Stanley and N.A. Karl (US Geological Survey (USGS)), 2014, *'Annual Review: Exploration Review'* (http://minerals.er.usgs.gov/minerals/mflow/exploration-2014.pdf).

Volker, Z., Simons, J., Reller, A., Ashfield, M., Rennie, C. (BP), 2014, '*Materials critical to the energy industry — An introduction*'.

Methodological notes

Introduction

Global material use

>> Figure 3: Global material extraction by resource type and GDP

- Data on material extraction and GDP, 1900-2005: UNEP, 2011b
- Data on material extraction, 2006-2009: EEA, 2015 — this source uses data on material use, which is almost equal to material extraction when considered at global level
- Data on GDP, 2006-2009:;the Maddison Project database, http://www.ggdc.net/maddison/maddison-project/home.htm

>> Figure 4: Domestic material consumption per region

The data represent the average per decade.

- 'Western-industrial' includes the following countries: Albania, Australia, Austria, Belgium-Luxembourg, Bosnia and Herzegovina, Canada, Croatia, Cyprus, Denmark, Finland, former Yugoslav Republic of Macedonia, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Malta, Netherlands, New Zealand, Norway, Portugal, Serbia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States of America.
- 'Russia and former Soviet Union Allies' includes the following countries: Armenia, Azerbaijan, Belarus, Bulgaria, Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Republic of Moldova, Poland, Romania, Russian Federation, Slovakia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan.

A secure supply of raw materials to the EU economy

>> Text box: Raw materials used in low-carbon energy technologies

- Projected demand is based on the energy market scenario outlined in the EU Energy Roadmap 2050 (under which 2030 represents a milestone) and the JRC report *2013 Technology Map of the European Strategic Energy Technology Plan*. Estimates of demand for these raw materials are based on an established methodology, which uses a bottom-up approach for the identification and quantification of materials in each technology.
- See also:
    - o *Critical metals in strategic energy technologies: assessing rare metals as supply-chain bottlenecks in low-carbon energy technologies*, JRC report 2011 (https://setis.ec.europa.eu/system/files/CriticalMetalsinStrategicEnergyTechnologies-def.pdf).
    - o *Critical metals in the path towards the decarbonisation of the EU energy sector*, JRC report 2013 (https://setis.ec.europa.eu/system/files/Critical%20Metals%20Decarbonisation.pdf).

Raw materials in the global context

1. EU share of global production

>> Figure 8: World regions' share of global raw materials production

Raw materials per category:

- Iron and ferroalloy metals: iron, chromium, cobalt, manganese, molybdenum, nickel, niobium, tantalum, titanium, tungsten, vanadium.
- Non-ferrous metals: aluminium, antimony, arsenic, bismuth, cadmium, copper, gallium, germanium, lead, lithium, mercury, rare earth minerals, rhenium, selenium, tellurium, tin, zinc.
- Precious metals: gold, platinum-group metals (palladium, platinum, rhodium), silver.
- Industrial minerals: asbestos, baryte, bentonite, boron minerals, diamond (gem/industrial), diatomite, feldspar, fluorspar, graphite, gypsum and anhydrite, kaolin (china-clay), magnesite, perlite, phosphates (including guano), potash, salt, sulfur, talc (incl. steatite and pyrophyllite), vermiculite, zircon.

Mineral raw materials and ore bodies with significant variations in valuable mineral content have been calculated to obtain the actual useable mineral content.

2. Mining equipment exports

>> Data source:

Data presented here comes from a private data provider, based on a selection of mining equipment typologies and a limited number of mining equipment companies. The data reported are based on Eurostat and Comtrade data, yet no access was given to the precise methodology.

Products covered by the report are the following: surface and underground mining machinery, mining drills and breakers, crushing, pulverising, and screening equipment used in mining applications, mineral processing and other miscellaneous mining machinery, and mining machinery parts and attachments.

>> Country coverage

'Western Europe' includes Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom. 'Eastern Europe' includes Albania, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Kosovo, Latvia, Lithuania, Macedonia, Moldova, Montenegro, Poland, Romania, Serbia, Slovakia, Slovenia and Ukraine.

Competitiveness and innovation

6. Domestic production

>> Figure 16: Domestic extraction of raw materials

The data used presents results from the International Resource Panel (IRP) of the United Nations Environment Programme (UNEP), which aims at harmonising material flow accounts globally. The data are available for the period 1970-2010. UNEP's data allow for a comprehensive analysis, covering a total of 233 separate accounts including all EU Member States.

The raw materials categories have been aggregated from 42 raw materials sub-categories. Construction minerals consist of non-metallic minerals — primarily construction — while the industrial minerals category comprises other mining and quarrying products, chemical and fertiliser minerals, salt, and clays and kaolin. Metals represent an aggregate figure of usable ores extracted.

>> Figure 17: Domestic production of a selection of metals

Mining stages (bauxite, iron ore, mine copper and mine zinc) include only domestic, primary production. Bauxite and iron ore production are provided in gross weight irrespective of the metal content, while mine copper and zinc figures are given as metal content of domestic ores and concentrates. Next stages (alumina, pig iron and smelter copper) include primary production from both domestic and imported ores. Finally, crude steel, refined copper and slab zinc include primary and secondary (i.e. scrap) production, domestically sourced or imported. Primary aluminium might come also from imported sources but not from secondary materials.

7. Value added and jobs

>> Definitions

Value added at factor cost represents the gross income from economic activities after adjustment for subsidies and indirect taxes — but not taking depreciation into account.

Jobs are the number of employees, which includes people having a contract of employment or an economic remuneration – wage, salary, fee – from the raw materials industry.

The sectors for which values are displayed are classified according to NACE codes – a pan-European classification system that groups similar business activities: http://ec.europa.eu/competition/mergers/cases/index/nace_all.html.

>> Figure 18: Value added at factor cost and number of jobs for a selection of raw materials economic sectors in the EU

Values correspond to the following sectors, according to NACE classification: sector B for mining and quarrying; C16 for manufacture of wood products; C17 for manufacture of paper products; C23 for manufacture of other non-metallic minerals; and C24 for manufacture of basic metals.

For value added, data correspond to EU-27. EU data correspond to EU-27, since data for Croatia was not available for the first years of the data series. The number of employees does not include Malta and Luxembourg because data are missing.

>> Figure 19: Value added and number of jobs associated with metals (mining, basic manufacture and downstream sectors) in the EU

Values correspond to the following sectors: sector B07 for mining; sector C24 for manufacturing of basic metals; and sectors C25-C30 for manufacturing of downstream metals. The size of sectors represents the total of their respective value added.

8. Corporate R&D investment

>> Raw materials companies in the EU Industrial R&D Scoreboard

The EU Industrial R&D Scoreboard ranks companies among the top R&D investors. It lists two sets of companies (and their subsidiaries wherever they are located): firstly, 2 500 companies worldwide and secondly, 1 000 with headquarters located in the EU, each company investing more than EUR 15.5 and EUR 5 million, respectively, in R&D on an annual basis. The 2 500 companies listed in the worldwide version of the Scoreboard account for more than 90 % of business enterprise expenditure on R&D.

The EU Industrial R&D Scoreboard aggregates companies at sector level by the Industry Classification Benchmark.[216] This is an industry classification relying on four levels of classification: industries; super-sectors; sectors; and subsectors. Four sectors (hereinafter 'categories' to avoid confusion with the raw materials sector) relevant to raw materials are the following:

- 'Construction & Materials': producers of building materials & fixtures and heavy construction;
- 'Industrial Metals & Mining': manufacturers of aluminium, non-ferrous metals and iron & steel;
- 'Forestry & Paper': producers and operators of forestry and paper-related activities;
- 'Mining': companies engaged in coal, diamonds & gemstones, general mining (other minerals not defined elsewhere within the mining category) and gold mining.

>> Raw materials companies included in the Raw Materials Scoreboard

To ensure consistency throughout the time series, the Raw Materials Scoreboard restricted the companies that are taken into account to those that were consistently included in the R&D Scoreboard between 2003 and 2013, or for a shorter period of time in the case that they were absorbed by or created from other companies consistently included on the R&D Scoreboard between 2003 and 2013.

- The Construction & Materials category includes: Acciona; Assa Abloy; Bouygues; BPB (purchased by Saint-Gobain in 2005); Cardo (purchased by Assa Abloy in 2010); Chicago Bridge & Iron; Deceuninck; FLSmidth; Heidelbergcement; James Hardie Industries; Kingspan; Lafarge; RHI; Rockwool International; Saint-Gobain; Tarkett; Trevi Finanziaria Industriale; Uponor; Villeroy & Boch.

216 Industry Classification Benchmark: http://www.icbenchmark.com/.

- The Industrial Metals & Mining category includes: Aurubis (appears as Norddeutsche Affinerie in 2013 and before); Bekaert; Bohler-Uddeholm (purchased by Voestalpine in 2007); Eramet; Heraeus; Hoganas; Outokumpu; Salzgitter; Thyssenkrupp; Umicore; Voestalpine.
- The Forestry & Paper category includes: Metsaliitto; Mondi (demerged from Anglo American in 2007); SCA (appears as Svenska Cellulosa in 2004 and before); Sodra; Stora Enso; UPM-Kymmene.
- The Mining category includes: Anglo American; BHP Billiton; Boliden; LKAB; Rio Tinto.

The above-mentioned restrictions reduce the number of companies taken into account in the Raw Materials Scoreboard from 71 to 41. This reduction is less significant in term of investments in R&D: in 2013, the 41 companies accounted for EUR 2.9 billion, while the additional 30 companies only spent EUR 0.7 billion.

Finally, for the 2015 Raw Materials Scoreboard, it has not been possible to include all equipment manufacturers in the statistics, as most of them are spread across different categories in the R&D Scoreboard. For mining, R&D investment may partly include investment in exploration.

>> R&D investment peak in 2008

Figure 20 shows linear progressions between 2003 and 2013 for Forestry & Paper and Construction & Materials. For the categories Mining, and Industrial metals and Mining, R&D investments peaked in 2008. These variations related primarily to significant changes for seven companies:

- Acciona, Lafarge, Chicago Bridge & Iron, Rio Tinto[217] acquired, respectively, (part of) Endesa, Orascom, Lummus and Alcan. Since the purchased companies were not considered in the early version of the EU R&D scoreboards, including them through the acquisitions artificially changes the geometry of the EU raw materials sector.
- For Eramet, Salzgitter and BHP Billiton, the volatile economic situation at the end of 2008 seems to be the main reason for the significant variations.
- Further inconsistency relates to the reported R&D investment of Lafarge: figures reported in 2008 and before relates to 'part of the research costs', while the figures reported as from 2009 are a broader 'spending for product innovation and industrial process improvement'.

9. Patent applications

>> Overview of the categories

(i) Basic metals includes techniques, equipment and processes related to metallurgy such as casting and refining of metals, working of metallic powder and manufacture and treatment of metals and alloys.
(ii) Biotic materials includes the manufacture of rubber products, wood, products of wood and cork, paper and paper products.
(iii) Non-metallic mineral products includes the manufacture of clay and other ceramic compositions, cement, lime and plaster.
(iv) Recycling includes recovery and regeneration of waste, scrap and residues containing metals, minerals and biotic materials.
(v) Mining and mineral processing includes drilling methods and equipment, quarrying and underground mining methods and safety devices, mineral separation and concentration methods (including comminution, physical and chemical sorting and concentration).

These categories take into account the International Patent Classification (IPC) and the concordance scheme between IPC codes and the NACE Rev. 2 nomenclature of economic activities (EUROSTAT: Concordance IPC V8 — NACE REV.2).

>> PATSTAT and relevant keywords

The Worldwide Patent Statistical Database (PATSTAT) (http://www.epo.org/searching/subscription/raw/product-14-24.html) is run by the European Patent Office.

A patent application is a request filed by an applicant (e.g. an inventor) with an authorised body (patent office) with all necessary documents and fees. For instance, a European patent application consists of a request for the granting of a patent, a description of the invention, claims, drawings (if any) and an abstract. The patent office conducts an examination to decide whether to grant or reject the application.

217 See 2008 and 2009 annual reports of the said companies.

The patent applications relevant to the raw materials sector were retrieved from the spring 2015 edition of PATSTAT according to a specific methodology, which used customised queries based on specific IPC codes and relevant keywords for each technology category. The queries were designed to analyse patent applications by priority, earliest date and applicant country. It is to be noted that: (i) updated data on patents is not available for 2012-2015; and (ii) the number of patent applications might be underestimated since some applications in the database are not classified by applicant country.

Framework conditions for mining

11. Mining activity in the EU

>> Figure 25: Metal mine production in the EU

Commodities classified as the main mine product, i.e. primary commodity, are included. The production of the following materials, not listed as primary commodities in the mines, is not shown: platinum, palladium, cobalt, molybdenum, alumina, chromium, antimony, niobium, tantalum, titanium, ilmenite, rutile, zircon, lanthanides, scandium and yttrium. Alumina, chromium and titanium are typically associated with stand-alone processing facilities and this map displays mine projects and mine/mill combination projects only. Coal, phosphate, potash, diamonds, graphite and U3O8 (uranium oxide) were excluded from this analysis.

The map includes properties that are in feasibility, pre-production and production development stages, as defined by SNL. Feasibility stage indicates that a bankable feasibility study is underway or has been completed; pre-production stage indicates that a go-ahead decision has been made and the project is being advanced to production; and the production stage indicates that commercial production has been achieved. Production stage operations can include varying levels of production, including fully operational, mines undergoing expansion, and limited and or/residual production.

12. Minerals exploration

>> Figure 26: Metal exploration in the EU

Data limitations:

As is the case with all statistical data, the data used in this section are subject to certain limitations. For example, survey data are not available for all commodities and all countries involved in the mining business. Only 18 Member States were covered by the survey data shown above. The budget values (provided in US dollars) are not corrected for inflation.

>> Figure 28: Exploration budget by world mining region (1997-2015) and distribution of exploration budget allocation to various metals in the EU (2015)

Geographical classification follows SNL world mining regions, where 'Latin America' includes South America, Central America, Mexico, and the Caribbean; and 'Pacific/Southeast Asia' includes Cambodia, Fiji, Indonesia, Japan, Laos, Malaysia, Myanmar/Burma, New Caledonia, New Zealand, Papua New Guinea, Philippines, Solomon Islands, Thailand and Vietnam. 'Other areas' includes non-EU European countries, the former Soviet Union and Middle East countries, and most of mainland Asia.

Eighteen countries are covered by EU-28: Bulgaria, Czech Republic, Germany, Ireland, Greece, Spain, France, Italy, Cyprus, Hungary, Austria, Poland, Portugal, Romania, Slovakia, Finland, Sweden and the United Kingdom.

Regions are ordered based on 2015 values. The US dollar figures were not corrected for inflation. Other metals were excluded from this analysis since exploration budget data was aggregated together with other minerals; this does not enable the distinction of their specific contribution to metallic mineral exploration. Data on budget exploration for 2015 reflect budgeted expenditures rather than actual spending.

Circular economy and recycling

15. Material flows in the circular economy

>> Figure 33: Domestic Material Consumption by resource category

Material categories:

Fossil energy materials also include 'Other products' and 'Waste for final treatment and disposal'. The category 'Other metals' comprises 'Uranium and thorium' and 'Tin'. For biomass, Animals and animal products also include aquatic plants.

Indicator definition:

Domestic material consumption (DMC) is one of the indicators that can be derived from Economy-wide Material Flow Accounts (EW-MFA). DMC equals, for the aggregated EU economy: domestic extraction + extra-EU imports – extra-EU exports.

It should be noted that DMC includes the following components with different underlying measurement concepts: domestic extraction (DE) and trade (imports and exports). Domestic extraction is measured in tonnes of gross ore (or gross harvest) whereas imports and exports are measured as the mass weight of products as they cross country borders. However, the weight of a traded product does not represent the domestic extraction of materials that was necessary to produce the traded product.

Social and environmental sustainability

19. Air emissions

1) Emissions in Figure 39 account for:

- greenhouse gases (GHGs): CO_2, CH_4 and N_2O;
- tropospheric ozone formation potential (TOFP): CO, non-methane volatile organic compounds (NMVOCs) and NOx.

2) Emissions not included in the graph. Acidifying gases are not displayed in Figure 39 since they are not so relevant in terms of mass. Although emissions of particulate matter (PM_{10} and $PM_{2.5}$) might be relevant due to their potential damage to human health, data availability limitations did not allow for their inclusion in this analysis.

3) Data transformation. Emission data as expressed here have been transformed from the original sources as follows:

- Mass equivalent units. GHG and TOFP emissions are expressed in mass units using CO_2 equivalents and TOFP equivalents respectively. This means that conversion factors have been applied to 'translate' the original mass of the emissions into the potential of each gas to contribute to an impact category (GHGs or TOFP). This conversion is done using CO_2 as reference gas for GHG emissions and NMVOCs for TOFP emissions. GHG conversion factors have been taken from the IPCC Second Assessment Report (time horizon of 100 years); TOPF conversion factors have been taken from *de Leeuw, F.A.A.M.* (2002), 'A set of emission indicators for long-range trans-boundary air pollution', *Environmental Science & Policy*, Vol. 5, pp. 135-145.
- Production-corrected emissions. Emissions are displayed in *production-corrected* mass units. This means that emission values have been referenced to the production level of the industry each year (which may vary across years) in order to reflect the actual trend in emissions as if production was stable. This means that emissions have been divided by an index (*gross output volume indices 1995=100* as in the original WIOD dataset) that consists of the ratio between production each year and production in the reference year of the data series i.e. 1995. Using this correction, emissions will appear higher compared with other years only if the emission increase for that year was higher than the increase in production. The correction index considers the monetary value of the output, inflation corrected.

Emission data	Conversion of emissions to equivalent units (multiplying by conversion factors) and aggregation into GHGs and TOFP	Correction considering the production level (dividing by production index)
(Million tonnes)	(Million tonnes equivalent)	(Million tonnes equivalent production monetary value-corrected)

23. Occupational safety

Primary sector: agriculture (NACE A01), forestry and logging (A02), fishing (A03) and mining and quarrying (B07 and B08). Secondary sector: manufacture of chemicals (C20), manufacture of food products (C10), construction, raw materials manufacture (C16 and C23-C25). Tertiary sector: retail trade (G47), transportation and storage (H), sport activities and recreation (R93) and mining support service activities (B09).

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). The incidence rate for (manufacture of) raw materials was obtained as the weighted average of manufacture of basic metals (NACE C24), fabricated metals (C25), other non-metallic mineral products (C23) and wood and wood products (C16). Weights in both cases reflect the number of employees in each activity.

The average incidence rate for all economic activities is shown as a line cutting across sectors. The average for primary activities corresponds to agriculture, forestry and fishing (NACE A), while for secondary activities the average corresponds to manufacturing (C). Due to data limitations, the average for the services sector is the weighted average of NACE activities G-J and L-N.

HOW TO OBTAIN EU PUBLICATIONS

Free publications:

- one copy:
  via EU Bookshop (http://bookshop.europa.eu);
- more than one copy or posters/maps:
  from the European Union's representations (http://ec.europa.eu/represent_en.htm);
  from the delegations in non-EU countries (http://eeas.europa.eu/delegations/index_en.htm);
  by contacting the Europe Direct service (http://europa.eu/europedirect/index_en.htm) or
  calling 00 800 6 7 8 9 10 11 (freephone number from anywhere in the EU) (*).

(*) The information given is free, as are most calls (though some operators, phone boxes or hotels may charge you).

Priced publications:

- via EU Bookshop (http://bookshop.europa.eu).

ET-04-16-759-EN-N

Publications Office

ISBN 978-92-79-61700-3
doi:10.2873/686373