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Improving the climate impact of raw material sourcing

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Key messages

- Raw material extraction and processing activities account for around **18 % of the total greenhouse gas (GHG) emissions** associated with the EU's consumption of all goods and services. This report assesses the potential to reduce the emissions from the extraction and processing of a selected group of raw materials that are consumed in high volumes in the EU, are associated with significant levels of GHG emissions from their production and are sourced both within and outside the EU.

- **Climate-friendly sourcing practices,** interpreted as a set of requirements that final users of raw materials can impose on their suppliers, span various types, including the adoption of life cycle thinking and the use of associated tools, the use of resource and energy efficiency measures, the use of renewable energy sources, increasing use of secondary raw materials, and the implementation of transparency and cooperation frameworks.

- To maximise their climate change mitigation potential, climate-friendly sourcing practices should focus on the **raw material processing stage**, which is responsible for a relatively larger share of GHG emissions from raw material sourcing than the extraction and trade stages.

- Climate-friendly sourcing is a way that allows the final consumers of raw materials in the EU, in either the private or public sector, to use their **decision-making power** to influence the way that raw materials are extracted and processed both within and outside the EU.

- Instruments such as **public procurement** or provisions in **international trade agreements** are examples of vehicles for promoting and/or requiring the application of climate-friendly sourcing globally.

Executive summary

The extraction and processing of raw materials are associated with potentially significant environmental impacts, including contributing to approximately half of the greenhouse gas (GHG) emissions globally. In the EU, non-energy, non-agricultural raw materials, although a small subset of all raw materials and natural resources, account for 18 % of GHG emissions associated with EU consumption. In the context of the EU's commitment to reducing its share of global GHG emissions, as well as the European Green Deal's aspiration to achieve a climate-neutral continent by 2050, mitigating climate impacts from raw material production has a central role to play in the EU's climate agenda.

Climate-friendly sourcing practices are a set of requirements that final consumers of raw materials can impose on their suppliers with the aim of reducing the GHG emissions linked to extracting and processing the raw material. Such requirements include adopting life cycle thinking and the use of associated tools such as life cycle assessment, promoting resource and energy efficiency, focusing on renewable energy sources, strengthening demand for secondary raw materials and using transparency and cooperation frameworks. The sourcing practices can be directed to one or more of the different operators across the different stages of raw material production, such as extraction, processing and trade.

This report demonstrates the potential for climate change mitigation that climate-friendly sourcing practices can bring. It focuses on a selected group of raw materials that are consumed in high volumes in the EU, are associated with significant levels of GHG emissions from their production and are sourced both within and outside the EU. The list includes copper, iron, gold, limestone and gypsum, bauxite and aluminium, timber, chemical and fertiliser minerals, and salt.

Climate-friendly sourcing practices need to be specific enough to address particular technological processes involved in specific raw material production. This report has identified examples of practices for all eight selected categories of raw materials listed above. These examples mainly aim to reduce the energy required to produce the raw material or replace non-renewable energy sources with renewables, as energy consumption is the part of the process that contributes most to GHG emissions from raw material extraction and processing. Practices identified include adopting novel energy-efficient techniques in metal processing, requiring operators to participate in voluntary commitments, roadmaps and third-party certification schemes aiming to achieve climate change mitigation, creating demand for recycled content in available raw materials, and adopting best available techniques in the supply chain.

The EU's consumption of the selected group of raw materials is responsible for the emission of 620 million tonnes of carbon dioxide equivalent (CO_2e) annually. These emissions arise from processes taking place inside the EU but also from external countries when raw materials are imported to satisfy EU demand. The practices identified have the potential to reduce these emissions significantly by intervening in the way the supply chain operates both within and outside EU borders. It should also be noted that sustainable sourcing, a broader concept than climate-friendly sourcing, can be applied to tackle other, equally important, impacts associated with raw materials by applying the same principles outlined in this report.

The increase in the uptake of climate-friendly sourcing practices depends on initiatives taken both by final consumers of raw materials individually and by governments employing policy mechanisms that facilitate their uptake. Final consumers, when procuring raw materials, have a decision-making power that can be used to favour a supply less harmful to the climate. Final consumers can set these requirements for raw materials in such a way that all supply chain operators are mobilised. An example is aligning the existing due diligence processes with climate-friendly sourcing objectives.

Equally importantly, policymakers have a responsibility to develop mechanisms that promote climate-friendly sourcing. First of all, public procurement instruments can transform public sector sourcing into climate-friendly sourcing by including several of the practices identified in this report. Public sector sourcing constitutes a significant part of raw material consumption, and changes there could influence the way that raw materials are produced in general through 'leading by example'. Another example of a policy instrument is incorporating climate-friendly sourcing in international trade agreements, thereby influencing the increasingly globalised raw material supply chains.

Sourcing concerns that are related to economic considerations, such as the potential changes in raw material pricing due to sourcing requirements, are not addressed. However, before climate-friendly sourcing is fully implemented, a full investigation of such concerns should be undertaken.


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1 Introduction and methodology

1.1 Raw materials and sustainable development

Natural resources such as metals and minerals are fundamental to almost every aspect of our modern life and society, and they enable, among other things, farming, healthcare, communications, water and energy supply, transport and construction. However, the extraction and processing of natural resources requires energy and the use of auxiliary materials. As a result, the International Resource Panel (IRP) has estimated that extraction and processing of natural resources, ranging from minerals to energy carriers and food, is responsible for **around half** of global greenhouse gas (GHG) emissions and for **over 90 %** of impacts associated with water stress and biodiversity loss (International Resource Panel, 2019). According to the same source, however, there is some good news in that increasing demand for all types of natural resources does not lead to an equal increase in the related impacts, indicating a relative decoupling of environmental impacts from the demand for natural resources. On the other hand, projections of demand for raw materials indicate that this will **more than double** by 2060, compared with the demand in 2011, rising from 79 to 167 Gt (OECD, 2019), meaning that, unless absolute decoupling is achieved, the impacts associated with raw material extraction and processing are expected to increase at a global level.

The extent of the climate impact of extraction, and especially processing, of natural resources indicates that the focus of climate mitigation should target this sector if global GHG emissions are to be curbed. For example, according to the International Council on Mining and Metals, mining companies can contribute to addressing climate change by reducing their carbon footprint and by engaging in dialogue with stakeholders to enhance adaptive capacities and integrate climate change measures into policies and strategies. Pursuing opportunities for energy efficiency and substituting carbon-intensive sources with renewables, measuring and reporting direct, indirect and product-related emissions, and collaborating with partners to develop effective mitigation technologies are identified enablers for minimising the negative impacts of this sector on Sustainable Development Goal 13 (ICCM, 2020).

1.2 Raw materials in EU policymaking

In 2019 the European Commission released a new growth strategy, the **European Green Deal**, that 'aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use' (European Commission, 2019). As an essential building block of this strategy, in March 2020 the Commission released a new industrial strategy for Europe together with a new circular economy action plan (CEAP). To reduce the environmental impact associated with European production and consumption, the CEAP presents a list of interrelated initiatives to establish a consistent product policy framework (see Box 1.1) relying on the improvement of existing instruments such as the EU green public procurement (GPP) criteria. The Commission explains that ''public authorities' purchasing power represents 14 % of EU GDP (gross domestic product) and can serve as a powerful driver of the demand for sustainable products' but that currently 'in fact, there is no comprehensive set of requirements to ensure that all products placed on the EU market become increasingly sustainable and stand the test of circularity' (European Commission, 2020a). In parallel, and as demand for raw materials is projected to double by 2050, the Commission explains that 'industry will need a secure supply of clean and affordable energy and raw materials' (European Commission, 2020b).

The European Green Deal is the vehicle for Europe to take the lead in becoming a climate-neutral continent based on sustainability, green energy and the circular economy. This ambitious goal will require significant changes in the EU's economies and supply chains, and this includes raw material supply chains. The EU needs to ensure a secure and sustainable supply of raw materials to meet the needs of clean and digital technologies, and this is part of the industrial strategy of March 2020 ([1]), which is to be updated in 2021 taking into account developments in the political context, including the COVID-19 pandemic.

([1]) https://ec.europa.eu/info/sites/info/files/communication-eu-industrial-strategy-march-2020_en.pdf

This secure and sustainable supply of raw materials will need to be addressed by rethinking the way that resources are consumed, by becoming more circular and by ensuring that new extraction/mining and refining activities are carried out as sustainably as possible. The 2020 criticality list ([2]), the action plan on critical raw materials (CRMs) of 2020 and the corresponding foresight report ([3]) set out concrete steps to achieve these goals. Ten actions are presented to develop resilient EU value chains, be more circular, increase sustainable sourcing and processing in the EU, and diversify supply with sustainable and responsible sourcing from third countries. Although focusing on CRMs, the main parts of the action plan can also be considered valid for base metals and minerals.

Given the policy context calling for more sustainable management of raw materials, and because of elevated European consumption patterns and the high global climate impact associated with extraction and processing of natural resources, it is becoming essential to understand the role and apply the principles of public and private sustainable sourcing of raw materials to achieve these defined European objectives as part of a transition towards a carbon-neutral economy.

1.3 Background information and scope

The aim of this report is to identify sourcing practices that various operators in the raw material extraction and processing supply chain can be required to adopt to reduce the associated GHG emissions. To fulfil this objective, the report:

1. provides context on the links between the consumption of raw materials in the EU and GHG emissions;
2. selects a small group of raw materials to demonstrate concrete sourcing practices;
3. includes a literature review that identifies different types of raw material sourcing practices for each of the selected materials;
4. reflects on the potential for GHG savings by applying climate-friendly sourcing practices on raw materials consumed by citizens and industry in the EU.

Box 1.1 Sustainable products initiative

Production, consumption and waste linked to products are responsible for around 40 % of global greenhouse gas emissions. The sustainable product policy aims to set, at EU level, appropriate minimum sustainability and/or information requirements for specific groups of products, giving priority to addressing product groups identified in the context of the value chains featuring in the action plan, such as electronics, information and communications technology (ICT) and textiles, but also to furniture and high-impact intermediate products such as steel, cement and chemicals.

The sustainable product policy initiative aims to correct the following market and regulatory failures:

1. Product-related externalities are not fully internalised: the linear production and consumption pattern of 'take-make-use-dispose' does not provide producers with sufficient incentives along the supply chains to make their products more sustainable. The average lifespan of many products has become shorter over recent decades. Many products break too quickly, many cannot be easily and safely reused, repaired or recycled, and many are made for single use only. Furthermore, there are concerns over the environmental impact of materials and products and the working conditions in which materials are sourced and/or products produced.
2. EU initiatives and legislation only partially address the sustainability aspects of products, on either a mandatory or a voluntary basis. The Ecodesign Directive successfully regulates energy efficiency and some circularity features of energy-related products covered by implementing measures. At the same time, instruments such as the EU Ecolabel or EU green public procurement are broader in scope but have reduced impact because of the limitations of voluntary approaches. In fact, there is no comprehensive set of requirements to ensure that all products placed on the EU market become increasingly sustainable.
3. The lack of reliable information on sustainability along value chains related to many products placed on the EU market de facto reduces the ability of economic operators upstream in the value chain to offer more sustainable products and the ability of consumers and procurers to choose products with the lowest environmental footprint.

Source: European Commission (2020e).

([2]) https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0474

([3]) https://ec.europa.eu/docsroom/documents/42881

This report aims to inform both policymakers in the public domain and private procurers of raw materials about the options available to apply sourcing practices that have the potential to reduce GHG emissions from the extraction and processing of raw materials.

The following sections provide detailed information on the goal and scope of the report.

1.3.1 Sustainable and responsible sourcing

In the context of the present analysis, the notion of 'sustainable' is restricted to the **environmental dimension of sustainability**, meaning that responsible sourcing practices, a term that refers to the social and economic aspects of sustainability, are outside its scope. Analogously, although mining and processing operations can have negative impacts on the environment in diverse direct and indirect ways, our study is dedicated to practices that target a **reduction in GHG emissions**. In this way, although sustainable sourcing refers to the full spectrum of environmental impacts derived from raw material consumption, this report focuses only on climate change, and thus on **climate-friendly sourcing**. The authors acknowledge the need for further work on the topic of sustainable sourcing so that other, equally important, environmental impacts are addressed (see Box 1.2).

Box 1.2 Major potential environmental impacts from extraction of raw materials

1. **Acid mine drainage:** this poses a serious threat to water resources and is acknowledged to be the mining industry's top environmental problem. The sulphuric acid formed dissolves heavy metals, such as arsenic, cadmium, mercury or lead, and can contaminate groundwater and soil if no restraining systems are installed.
2. **Water contamination:** several factors can cause severe groundwater contamination, since mining often penetrates the Earth' surface to depths that reach the water table. This allows groundwater to flow into the mining pit, which may contaminate local groundwater. Leakages from tailing ponds can lead to high concentrations of toxic reagents and heavy metals in groundwater. Toxic components originate from the chemical reagents used and by-elements in ore.
3. **Dam bursts and flooding:** tailings deposits are stored in large ponds or dams known as tailing storage facilities (TSFs). In climates with heavy rainfall and in tectonically active regions, a TSF has a higher risk of failure.
4. **Waste production:** mineral extraction is the largest global waste producer, particularly copper, zinc, bauxite and nickel mining. Depending on the specific ore grades and the degree of overburden, the ratio of waste-to-metal mined is large. For example, to mine seven grams of gold, on average a tonne of waste material must be mined, not including the overburden. Other hazardous waste generation that requires special treatment includes smelting residues produced during ore processing.
5. **Air pollution:** all mining stages can affect air quality, since fine particles and dust are often produced and dispersed by the wind. Volatile reagents, such as mercury in gold mining, volatile organic compound (VOC) emissions from flotation reagents or nitrogen oxide (NO_x) emissions from diesel-powered engines can pollute the air.
6. **Soil erosion and contamination:** land conversion due to mining and its infrastructure destroys or contaminates the soil cover in many cases, which constitutes a long-term or even total loss of agricultural potential.
7. **Water availability:** the mining industry's demand for water can exacerbate existing competition for water with agriculture and consumers in regions where water availability is low or water consumption is too high. Lowering groundwater levels to allow mining further aggravates water stress.
8. **Ecosystem destruction:** mining, particularly large-scale open-pit mining, can cause complete or partial destruction of ecosystems and agricultural land.
9. **Radiation:** this can arise from radioactive elements embedded in the ore, which are contained in the tailings.
10. **Submarine/riverine tailings disposal:** mining sites close to bodies of water often dispose of tailings directly into rivers or the sea.

Source: Dolega et al. (2016); text amended for clarity.

Box 1.3 Examples of responsible and sustainable sourcing practices

Responsible sourcing practice — out of scope
An example of a private responsible sourcing practice is Umicore's sustainable procurement framework for cobalt — inspired by the 2013 *OECD Due diligence guidance for responsible supply chains of minerals* — which has obtained external validation for its ethical approach to cobalt procurement. The framework aims to 'minimize the risk of any connection between the cobalt in its supply chain — and subsequently that of its customers — and human rights abuses or unethical business practices'.

Sustainable sourcing practice — in scope
In 2017, the Dutch Ministry of Defence procured towels and overalls, with the requirement that the goods contained at least 10 % recycled post-consumer textile fibres. The award criteria also recognised and awarded those offers that significantly exceeded the technical specifications (i.e. achieved over 30 % or 50 % recycled content). Contracts were awarded for 100 000 towels and 10 000 cloths with a 36 % recycled content and for 53 000 overalls with a 14 % recycled content. Taken together, the contracts resulted in savings of 15 252 kg of cotton, 68 880 kg of CO_2, 23 520 MJ of energy and over 233 million litres of water.

Source: European Commission (2017); Umicore (2020).

Box 1.3 illustrates the distinction between sustainable and responsible sourcing with examples of public and a private practice.

In the context of this study, a 'sourcing' practice refers to **procurement requirements**, set by raw material final consumers, for raw material immediate (tier 1 ([4])) suppliers. The requirements are applicable to preceding stage(s) in a product's value chain, always addressing and evaluating upstream activities. Thus, all existing practices should in some sense address the raw material production stage, such as mining, quarrying and harvesting, either directly, as required by the procurer of ores, minerals or logs, or via the sourcing requirements of purchasers that can be carried on by the immediate suppliers further downstream the supply chain. These 'sustainable' requirements are intended to reduce the environmental impacts generated upstream over the entire raw material supply chain.

By applying requirements that specifically aim to improve the sustainability of their upstream providers, global brand owners and manufacturing companies can meet the growing expectations of their clients and stakeholders, which demand that producers explicitly take responsibility for managing the environmental risks and impacts associated with the materials and products procured (Lambrechts, 2020). The same logic applies to the requirements set by public authorities, such as government departments, regional and local authorities or bodies governed by public law. In other words, the climate-friendly sourcing practices aim to use the **decision-making power** of the final consumers of raw materials to influence the way that suppliers operate along the supply chain.

According to their position in the supply chains, the nature of the **climate-friendly sourcing requirements** placed on these suppliers, whether they supply raw materials, intermediate products or consumer goods, is diverse and can include:

- Requirements to incorporate life cycle thinking in procurement. Life cycle thinking allows us to identify the full consequences of decisions taken in one life cycle stage that affect other life cycle stages of a product. This avoids shifting the burden from one part of the supply chain to another and potentially reduces the overall impacts of an economic activity or a product.

- Criteria for resource and energy efficiency, recyclability and using renewable resources during the raw material production process. These refer to specific quantitative requirements that consumers of raw materials can impose on their suppliers.

- Requirements promoting the use of secondary raw materials. For example, mandatory recycled content requirements, which are expected to have lower GHG emissions than their virgin alternatives.

- Requirements on transparency and cooperation in global supply chains. The flow of robust data and information among stakeholders in a supply chain can help monitor and benchmark progress on potential GHG reductions.

Climate-friendly sourcing practices should be implemented by both the private and public sectors, as final consumers of raw materials can be found in both. In this report, the scope of mapping such practices therefore includes both sectors, drawing from the literature on good practice from

([4]) Suppliers of raw materials can be ordered in the supply chain preceding the final consumer. The immediate supplier is defined as a tier 1 supplier. A tier 1 supplier purchases less finalised raw material from a tier 2 supplier, and so on.

individual private companies (i.e. 'bottom-up approach') and from practices and strategies laid down by governments and other public bodies (i.e. 'top-down' approach). However, climate-friendly sourcing practices are not the same as policy instruments that address the sustainability of raw material supply, such as trade agreements and GPP. The practices refer to concrete requirements that raw material consumers can impose on their suppliers, while relevant policy instruments are designed to promote such practices.

The geographical scope of this study is the 27 EU Member States (EU-27) and the climate-friendly sourcing analysis focuses on the consumption of raw materials reported for this geographical area. The study addresses both private and public sector consumption of raw materials.

The topic is approached by focusing on environmental and climate issues, but the proposals for adopting climate-friendly sourcing practices, if implemented, might have significant consequences in the cost value chain of raw materials. Issues related to competition and externalities related to raw material producers would be particularly affected. Such an analysis is not conducted in this report.

1.3.2 Non-agricultural, non-energy, non-critical primary and secondary raw materials for EU consumption

The primary raw materials within the scope of this study refer to non-energy, non-agricultural mineral raw materials, such as iron and ferro-alloys, non-ferrous metals, precious metals and industrial minerals, but exclude energy carriers. Except for timber (5), biomass is also excluded from the scope, as are raw materials that are energy carriers such as fuels. CRMs are also excluded, with the exception of bauxite and titanium: these were added to the list of CRMs for the EU in 2020 (European Commission, 2020d). CRMs have been well investigated in the EU context (6) and they are excluded from the present analysis because of the relatively small quantities consumed in the EU and their varying essential and unique functions in the EU economy, including their key role in the transition to climate neutral energy sources.

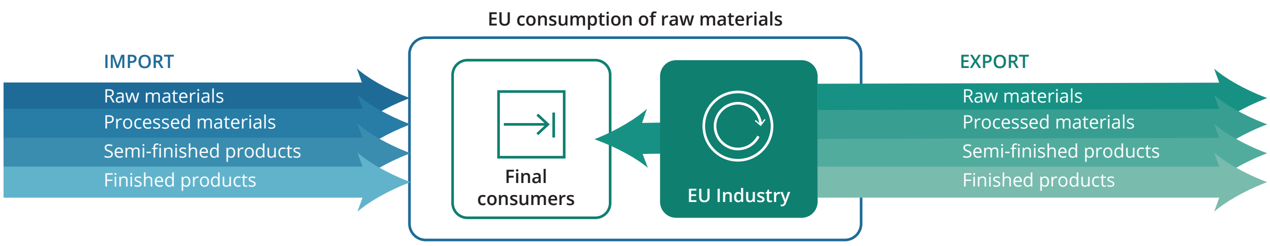
The raw materials investigated relate to raw materials consumed in the EU, and the quantities of these materials refer to both consumers and industry (see Figure 1.1). The demand covering this consumption includes all domestically extracted and imported raw materials that are (1) further processed in EU industrial installations into materials and/or (semi-)finished products for internal consumption or for export; (2) embedded in imported and domestically produced final products that are consumed in the EU. The raw materials associated with EU consumption can be sourced internally or globally. In the latter case, the required raw materials — whether in the form of processed materials or (semi-)finished products — are imported into the EU.

Climate-friendly sourcing practices that can be applied by EU consumers refer exclusively to raw material extraction and processing. Two options exist:

1. Procurement of raw materials. In this case the climate-friendly sourcing practices may address all upstream activities.

2. Procurement of (semi-)finished products. In this case, the sourcing practices address the activities upstream that exclusively concern extraction and processing of raw materials. Further processing and assembly of materials to produce final products (e.g. in a manufacturing plant) are excluded from the scope of the sourcing practices mapped in this study. The sourcing requirements might be imposed by purchasers on their immediate suppliers (e.g. to the manufacturing plant) with the aim that the requirements are carried over by the immediate suppliers further down the supply chain where the extraction and processing of raw materials take place.

Figure 1.1 Mass flow of EU raw material consumption



Source: EEA.

(5) Timber, although a biomass material, which is outside the scope of the study, is included in the selection, as it differs from other types of biomass in that it is used in similar applications as minerals (e.g. in construction).

(6) https://ec.europa.eu/jrc/en/news/jrc-assesses-critical-raw-materials-europe-s-green-and-digital-future

The processes involved in the extraction and processing of raw materials require the input of energy and auxiliary material resources, and will thus be associated with environmental impacts, such as GHG emissions. However, GHG emissions resulting from further manufacturing, transport and the production of finished products are outside the scope of the present analysis. The product value chain stages at which practices to reduce GHG emissions are of interest here are as follows:

1. Mining, quarrying and harvesting of primary raw materials
At the very beginning of a product's supply chain, metal ores and industrial minerals are extracted from mines and quarries, and wood is harvested from natural forests and forest plantations.

2. Refining and processing of primary raw materials
Extracted ores and minerals, as well as harvested wood, cannot be readily used as feedstocks for product manufacturers:

- Wood logs are subject to a series of processes such as scanning and sorting, debarking, sawing, stacking, drying, jointing, planing and packaging.

- Metal ores are converted into tradeable intermediate or semi-fabricated products through complex metallurgical processes that often involve resource-intensive smelting and refining steps. This processing is generally referred to as the manufacture of basic metals, and it includes industrial activities such as the manufacture of iron, steel and ferro-alloys and of basic precious and non-ferrous metals. Basic metal production also comprises the first processing stages of metal manufacturing (such as the manufacture of tubes, bars, strips, wires and sheets of metal, as well as casting). The resulting basic metals are then converted into fabricated metal products covering the production of structural metal products; boilers, metal containers and steam generators; forging, pressing, stamping and roll forming of metal; the treatment and coating of metal and general mechanical engineering (such as turning, milling or welding); the manufacture of cutlery, tools and general hardware; and the manufacture of other fabricated metal products (such as metal drums, metal packaging, wire products and household articles of metal) (Eurostat, undated).

- Extracted industrial minerals also have to undergo processing to refine the crude mineral ore into a processed grade or series of grades for sale to downstream industries such as foundries and glass, ceramics, paper, paint, plastic and steel manufacture.

3. Transport and trade of raw materials
Since no single country is self-sufficient in every raw material, ores, timber, minerals, basic metals, semi-fabricated products and consumer goods must be exchanged between countries and continents in considerable volumes. Therefore, geographically, suppliers of the primary and secondary raw materials needed to sustain EU consumption can be located anywhere on the globe.

4. Secondary raw materials
The EU has defined 'secondary raw materials' as 'recycled materials that can be used in manufacturing processes instead of or alongside virgin raw materials' (European Commission, 2020c). The source of secondary raw materials can only be waste.

1.4 Review of climate-friendly sourcing types

An obvious example of a policy area for promoting climate-friendly sourcing is GPP, defined as 'a process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that would otherwise be procured' (European Commission, 2008). GPP can incorporate multiple climate-friendly sourcing practices in the form of instruments that promote climate-friendly sourcing.

Fortunately, many more **sourcing types** are available for enabling the inclusion of climate-friendly sourcing requirements and for verifying and/or validating compliance with them (see Figure 1.2). Although the applicability of some existing practices can be more transversally applicable, for example including them in GPP, other instruments can be more targeted to specific product value chain stages.

1.4.1 Sourcing types for reducing GHG emissions from raw material production

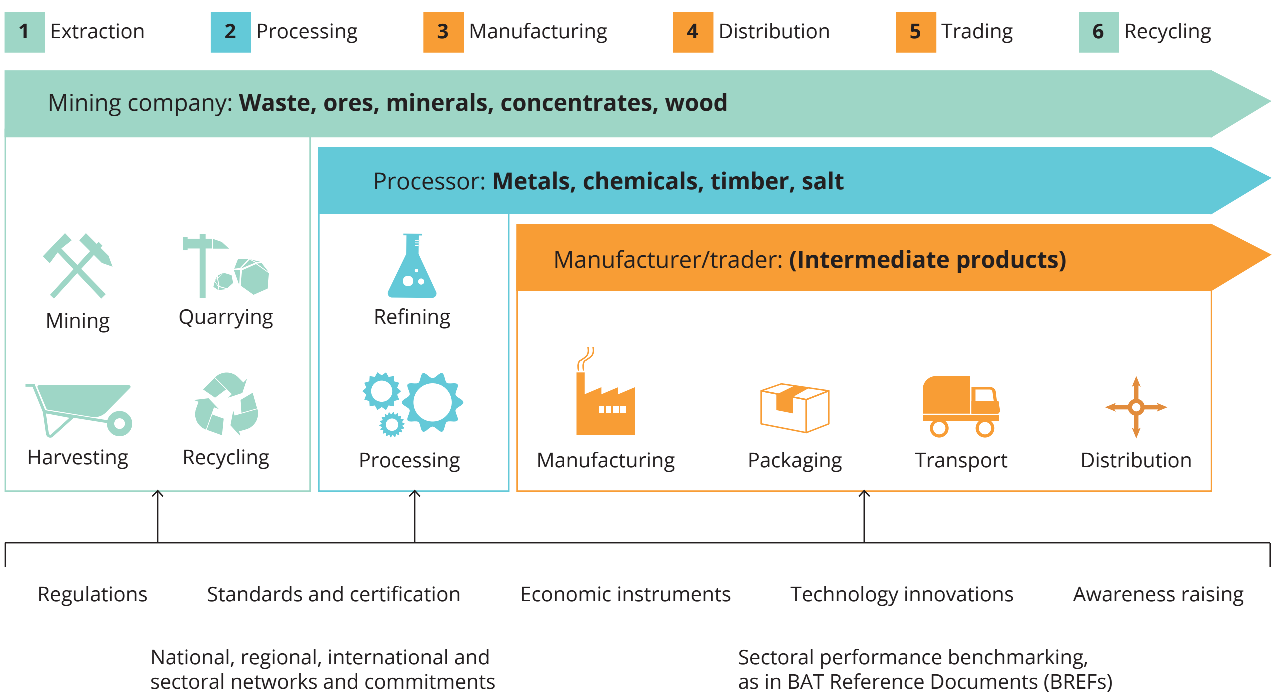
The available sourcing types that can be applied to limit energy demand from mining and timber harvesting operations include **economic instruments** that foster investment in energy-efficient mining technologies, as well as the voluntary application of standards and certification schemes that consider the monitoring and reduction over time of the energy consumption per unit of output. In the EU Member States, **national and regional raw material strategies** are often expected to improve the sustainability of specific, national industries — a country's mining and quarrying sector being the most obvious and recurrent one. This means that the majority of countries with such strategies in place have defined objectives that explicitly aim to improve the sustainability of their national mining and quarrying industries (EEA, 2020). Raw material consumers might prefer to source materials from countries that have targeted sustainability strategies in place.

1.4.2 Sourcing types for reducing GHG emissions from industrial processing of raw materials

Sourcing practices aiming to reduce emissions from processing should aim to foster the supply and prioritise the procurement of those raw materials, intermediate products and finished goods that are the result of industrial processing and manufacturing activities with the lowest emissions and environmental impacts. Climate-friendly sourcing at these stages of a product's value chain thus requires the identification of suppliers that can demonstrate that (1) their emissions and impacts comply with stringent **voluntary environmental and energy efficiency standards** and/or (2) are lower than their benchmarks. Among those standards used to verify and validate compliance with the procurement criteria are, for instance, ISO 14040 compliant life cycle analyses, the certification of credible sustainability standards, such as those advanced by the International Social and Environmental Accreditation and Labelling Alliance (ISEAL), and the verification of technologies using procedures such as those employed by the EU environmental technology verification (ETV) programme, which allow independent assessment and validation of the manufacturer's claims on the performance and environmental benefits of a technology (European Commission, 2016b).

The Industrial Emissions Directive (IED; 2010/75/EU), currently under review, is the main EU legislation covering the most polluting industrial activities in the territory. It establishes the main principles for permitting and controlling large industrial installations based on an integrated approach and the application of **best available techniques** (BATs). The IED covers various sectors, including some that are related to extraction and processing of raw materials, but not mining. The IED establishes that the environmental permits issued to installations under the scope of the Directive have to be integrated (covering air, water, soil, waste management and energy consumption) and apply BATs as they are described in the **BAT reference documents** (BREFs). These are sectoral technical documents describing the characteristics of each sector and establishing BATs and their BAT-associated emission and environmental performance levels. A chapter called 'BAT conclusions' adopts air, water and soil emission limits as well as other BATs as legally binding via a Commission Decision. Although some industrial sectors, such as the extractive sector, are not covered by the IED, BREFs might be developed for them, without having the same legal basis (e.g. the mining BREF ([7])).

Figure 1.2 Climate-friendly sourcing types available per value chain stage of raw material production



Source: EEA and CSCP, based on a discussion with the ETC task team (2021).

([7]) https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/best-available-techniques-bat-reference-document-management-waste-extractive-industries

Although the IED aims to tackle all environmental aspects, the focus of the quantitative limits in the BAT conclusions is generally air and water emissions. On the one hand, the sustainable processes and use of raw materials is mentioned qualitatively or, for example, by means of establishing an environmental management system. On the other, GHG emissions are only tackled indirectly via certain BATs focusing on energy efficiency, given that permits from installations also covered by the EU Emissions Trading System (EU ETS; Directive 2003/87/EC) cannot include limit values for GHG emissions. In fact, the evaluation of the IED (Ricardo E&E, Milieu, Umweltbundesamt, 2020) highlights that the IED has not been effective in promoting a circular economy and sustainable use of resources, not least because the IED was drafted and adopted before the Commission shifted towards circular economy policies.

BAT conclusions still can refer to measures targeting improved energy efficiencies, which often will have a positive, though indirect, effect on the installation's GHG emissions. Overall, in the context of this study, the BATs and BREFs are a source of information on clean technologies that might have an indirect effect on mitigating GHG emissions associated with a sector.

1.4.3 Sourcing types for reducing GHG emissions from transport and trade

Although trade volumes are well known and well monitored ([8]), the associated environmental impacts are poorly documented and the corresponding information difficult to retrieve. Often, when a raw material finally arrives for product manufacturing, its original sources are already obscured (van den Brink et al., 2020). For this reason, available sourcing types for reducing GHG emissions considered in the context of the present study are those that aim to increase transparency, environmental information exchange and cooperation. Subsequently applicable practices used in trade agreements and other areas that refer to transport and global trade include the use of **international environmental standards, certification schemes**, such as cradle-to-cradle schemes, and **certifications of origin**. Strategies from intergovernmental organisations, such as the initial GHG strategy adopted by the United Nations International Maritime Organization, can be considered as instruments Member States can use for reducing GHG emissions from international shipping (International Maritime Organization, 2018).

1.4.4 Sourcing types for promoting the use of secondary raw materials

Mandatory recycled content existed only as a public procurement tool, but the new EU CEAP suggests **mandatory requirements** for recycled plastic content in areas such as packaging, construction materials and vehicles. The Commission has also proposed a revision of the Construction Product Regulation, which may include recycled content requirements for certain construction products. In addition, a new regulatory framework for batteries includes sustainability requirements, such as the level of recycled content in new batteries (European Commission, 2020a).

A 2017 study on the ecodesign of electronics concluded that **voluntary instruments** appear to perform better than mandatory ones for optimising the use of recycled material and are more acceptable to manufacturers (RDC Environment, 2017). This suggests that in some sectors like electronics voluntary requirements might be more effective. **Labels and standards** are mentioned as the most common instruments. The study also mentions other instruments — such as modulation of eco-fees (eco-modulation), financial incentives, recyclers and product labels, and standards — being useful to structure product value chains and initiate a dialogue between recyclers, manufacturers and public authorities.

([8]) The IRP provides an authoritative database including time series of global materials extraction and materials trade, presenting 'direct and consumption-based material flow indicators for seven world regions and for more than 185 countries, covering total usage, per capita use, and material use per US dollar. It also provides details for different groups of materials' (International Resource Panel, 2020).

1.5 Objectives and methodological approach

The aim of this report is to identify the links between the sourcing of raw materials for EU consumption and the **climate impacts** that their consumption causes. Moreover, the report will attempt to map **climate-friendly sourcing practices** that can be implemented by both the private and the public sector and that have the potential to significantly reduce the **GHG emissions** associated with the extraction and processing of raw materials necessary for EU consumption.

The analysis considers the following methodological steps, which are described and properly justified in Chapters 2 and 3:

- First, the **raw material demand** associated with EU consumption related to both final consumers and industry was quantified.
- Guided by the quantified raw material demand, a selection of **non-agricultural, non-energy** raw materials and raw material groups was made, to focus on those few raw materials that are most important, in terms of volume, for satisfying EU consumption. Different criteria were used for quantifying the demand.
- Next, existing **climate-friendly sourcing practices** were identified that specifically target the reduction in GHG emissions associated with the previously selected raw materials, and with the materials and (semi-)finished products made thereof.
- Finally, by analysing each of the inventoried practices using a bottom-up approach, the **GHG reduction potential** of climate-friendly sourcing practices, with reference to the raw materials that are most important for satisfying EU consumption, is estimated qualitatively as far as is possible.

2
Selection of relevant raw materials for EU resource consumption

To be able to estimate the climate mitigation potential of applying the principles of climate-friendly sourcing and transitioning towards a European carbon-neutral economy, we need to select specific raw materials so that the application of climate-friendly sourcing practices can be demonstrated practically. In this chapter, such a list of raw materials is compiled by reflecting on their relevance both for European consumption and for climate mitigation.

For this reason, data are presented on the input of resources into the European economy, from a consumption perspective. Most of the data are consolidated for large commodity groups, such as metallic minerals and non-metallic minerals. Nevertheless, where available, higher resolution figures for specific categories or classes of minerals and metals, as well as timber, have been included. In addition, the climate impact of extracting and processing raw materials is considered so that both of these groups of data can be used to help select **relevant** raw materials.

2.1 Criteria for selecting raw materials and raw material groups

As stated in Chapter 1, the aim of this study is to map climate-friendly sourcing practices that have the potential to significantly reduce greenhouse gas (GHG) emissions associated with the extraction and processing of raw materials. To demonstrate the effectiveness of the practices identified, we needed to focus on a list of specific non-energy, non-agricultural raw materials.

A set of criteria was developed for selecting materials **relevant** for this type of exercise:

1. **Volumes** of EU domestic consumption. These include all raw materials required to satisfy the demand for goods for both EU final consumers and industry, as illustrated in Figure 1.1 ([9]). This criterion is selected so that the list of selected materials includes those materials of greatest volume that are consumed in the EU. The GHG emissions of raw material consumption are a product of the volume consumed and the unitary emissions associated with raw material production.

2. Volumes of direct raw material imports to the EU. This criterion includes materials for which the EU is highly dependent on **imports** to identify climate-friendly sourcing practices that can be applied to extraction and processing occurring outside the EU. This type of practice demonstrates that EU sourcing can influence processes and GHG emissions occurring in global supply chains.

3. **GHG footprint** of raw materials. This criterion indicates the GHG intensity associated with raw material extraction. Materials making a considerable contribution to climate change should be selected so that the climate-friendly sourcing practices identified have the potential to significantly reduce GHG emissions associated with the extraction and processing of raw materials, regardless of where the emissions occur. The GHG emissions of raw material consumption are a product of the volume consumed and the unitary emissions associated with raw material production.

([9]) For example, in the case of a passenger car produced in an EU Member State, it considers all raw materials that were used somewhere in the car production chain, including the raw materials that were required for producing those parts and components imported from outside the EU.

4. Contribution of **recycled** materials ([10]) to the EU raw material demand. This criterion is included to take into account the contribution that secondary sources make to covering the EU demand for raw materials.

Annex 1 presents the data and methodology used to apply these criteria in selecting the most crucial materials for the analysis.

2.2 Selection of relevant raw materials for EU consumption

As described above, to focus the mapping and analysis of climate-friendly practices in Chapter 3, it is important to select a manageable number of non-energy, non-agricultural and non-critical raw materials. Table 2.1 presents the final selection of raw materials and their contribution to each of the selection criteria.

Table 2.1 Overview of raw material input, import reliance and climate impact data for selected raw materials

Selected raw materials	EU raw material input, 2018 (kt)	Import reliance 2018 (%)	Climate change impact (kg CO_2e/ tonne produced)	EOL recycling input rate, 2016 (%)
Bauxite and other aluminium	90 897		18 396	12
Bauxite		87		
Aluminium		59		
Chemical and fertiliser minerals	54 290		741	n.d.
Sulphur		-35		
Potash		27		
Copper	331 402	44	5 059	55
Gold	92 077	n.d.	15 226 146	n.d.
Iron	292 383	72	1 764	24
Limestone and gypsum	140 874		2	58
Limestone		5		
Gypsum		-25		
Salt	65 003	n.d.	135	n.d.
Timber (industrial roundwood)	276 716	n.d.	37	n.d.

Note: EOL, end of life; n.d., no data.

([10]) https://rmis.jrc.ec.europa.eu/?page=scoreboard2018#/ind/16

In Box 2.1, the final list of those non-energy, non-agricultural, non-critical raw materials that were found to be most relevant to sustaining EU consumption is presented, together with a description for each material summarising the key aspects that motivated the selection.

Box 2.1 Selected raw materials relevant for EU consumption

1. **Copper** is the single most used raw material contained in products for EU consumption. Direct imports of copper ore are indeed modest, but the amount of copper ore that is required for producing the ore concentrates, semi-finished and finished copper products, and products with copper that are imported to the EU is massive. The contribution of recycled copper in European raw material demand is higher than primary copper.

2. **Iron** ore is supplied in significant volumes by mining activities located within the EU and, at the same time, it accounts by far for most of the direct material imports. In addition, the amount of iron ore required for the production of steel and steel products that are imported for consumption in the EU, the so-called raw material footprint, is only surpassed by the tonnage of copper ore for the import of copper-containing products. The contribution of recycled materials to meet iron raw material demand is also significant.

3. The extraction of **gold** is known to be environmentally burdensome. Even when there are no significant imports of gold, and the domestically extracted volumes are extremely low, the material footprint of the gold that is embedded in imported products is very high.

4. Domestic extraction of **limestone and gypsum** is a relevant source for satisfying the EU consumption needs for this industrial mineral, although significant amounts are found to be embedded in imported products. The contribution of recycled limestone to meet demand for this raw material is the highest recycling input rate in the European economy.

5. The mining of **bauxite** ore and the chemical processing to produce **aluminium** oxide are very resource intensive. Although there is aluminium production based on domestic extraction in a few Member States, most of the bauxite and aluminium oxide is imported, as a raw material or embedded in imported products.

6. **Timber** is, in terms of weight, by far the single most produced raw material in the EU, which makes this material extremely well-performing with regard to self-reliance. The significant domestic production, concentrated in high-income countries, probably has led to the implementation of successful sustainable sourcing practices within the EU territory. These might be illustrative or exemplary for other raw materials sourced in the EU or elsewhere. At the same time, direct imports of timber, mainly from low-income countries, are also significant.

7. **Chemical and fertiliser minerals** are third on the list of direct imports of raw materials, only preceded by iron ore and timber. These raw materials are also at the base of long and extended value chains, involving chemical and manufacturing industries in the EU, as well as agricultural production.

8. The last raw material proposed for selection is **salt**. Similar to chemical and fertiliser minerals, salt is converted into products like chlorine, caustic soda and soda ash, which are basic resources for the EU chemical industry. The volume of domestically extracted salt is sourced from 18 European countries, and is almost double that imported to the EU under the form of semi-finished and finished products.

3
Mapping of climate-friendly sourcing practices

3.1 Identification and categorisation of climate-friendly sourcing practices applicable to selected raw materials

In Chapter 2, a selection of raw materials considered most crucial for EU consumption was made. In the next step, a literature review was performed, supported by direct contact with relevant European associations ([11]), that contributed to the identification of climate-friendly sourcing practices targeting operators in the aluminium, copper, iron, gold, limestone and gypsum, timber, chemicals and fertiliser minerals, and salt supply chains.

With the objective of estimating their potential to reduce greenhouse gas (GHG) emissions, practices were categorised based on (1) the position of the possible **adopter(s) of the practice** in the product's supply chain and (2) the **type of practice(s)** employed (see Chapter 1). Nonetheless, most types of practices are not exclusive to a single value chain operator or stage. Similarly, practices can target several supply chain operators and may not be specific to only one adopter. It should be also noted that a series of environmental benefits resulting from the adoption of a practice can be realised by different operators in the supply chain and does not therefore necessarily target (only) direct climate mitigation impacts realised by the immediately preceding value chain operator. Finally, the readiness of a practice to be immediately adopted by the raw material supply chain is not taken into account in this report.

Once categorised and indexed accordingly, individual identified practices were described and referenced following a specially prepared template. This mapping exercise yielded 44 climate-friendly sourcing practices from all over the world. The approach and individual practice profiles are further described in Annex 1.

3.2 Overview of identified climate-friendly sourcing practices

The aforementioned identification and categorisation exercise resulted in an inventory of 44 climate-friendly sourcing practices. Those practices are mapped in Table 3.1, according to their categorisation. Each of those individual practices,for instance 'A7' (identified practice number 7 applicable to aluminium) or 'C3' (identified practice number 3 applicable to copper), is described and can be found in Annex 2. It is important to note that this mapping exercise is a **non-comprehensive inventory**: it aims to **illustrate the diversity of practices** rather than list all existing ones. It also means that practices assigned to specific materials (e.g. C5 and A6, applicable to copper and aluminium, respectively, and relying on 'National, regional, international & sectoral networks & commitments') could be identified for other raw materials. Identified and categorised practices from this overview (Table 3.1) are further described in the following sections.

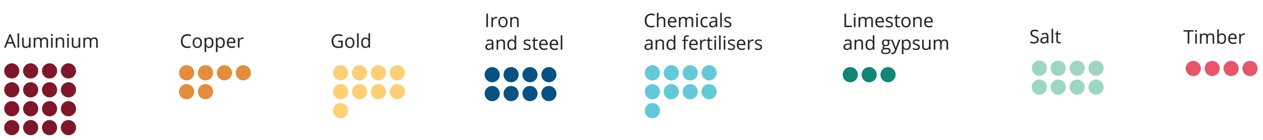
([11]) EUsalt, Eurometaux, European Aluminium, Fertilizers Europe.

Table 3.1 Overview of identified and categorised climate-friendly sourcing practices applicable to selected raw materials

Type/Supplier of raw materials, intermediate products or finished goods	Requirements addressing raw material: Products	Processors or manufacturers	Traders
Regulations	A9, L1	A9, G3, F6	A9
Standards and certification	A5, C1, G4, I2, S1, T1, C3, I5, S6, T2	A5, C3, G3, I2, F7, S6, T2, A7, G4, I3, A8, G5, I4, I5	A5, G4, F7, S6
Commitments to voluntary roadmaps	A6, C5	A6	A6
Sectoral performance benchmarking		C2, G3, F5, S3, S4	
Technology innovations	A4, G1, I1, F1, L1, S2, G2, F4, L2	A1, C4, I1, F2, S5, A2, F3, A3	
Economic instruments	A10	T3	
Awareness raising		F8	

Aluminium · Copper · Gold · Iron and steel · Chemicals and fertilisers · Limestone and gypsum · Salt · Timber

Overview of number of requirements addressed per material



The following sections outline the practices listed in Table 3.1 and describe the procurement requirements addressing the different suppliers of raw and processed materials and goods, including requirements addressing raw material producers (Section 3.2.1), processors or manufacturers (Section 3.2.2), traders (Section 3.2.3) and users of secondary raw materials (Section 3.2.4). The indexed practices (e.g. 'G1') can be found in Annex 1.

3.2.1 Identified practices with requirements addressing raw material producers

Procuring raw materials from **certified raw material producers** complying with standards established by not-for-profit multi-stakeholder membership organisations was observed to be a common climate-friendly sourcing practice among selected supply chains. Compliance with GHG emission-related requirements established in those standards is certified by an accredited independent third party. Aiming to establish responsible — including ethical, social and human rights aspects — business practices through entire supply chains (and thus also applicable to Sections 3.2.2 and 3.2.3), these environmental practice examples also target mining, quarrying and harvesting activities:

- **Gold** mining companies adhering to the Responsible Jewellery Council's code of practice should, for instance, and where applicable, reduce GHG emissions and increase the energy efficiency of their operations (G4).
- **Iron ore** producers should comply with GHG emission-related requirements of the ResponsibleSteel certification programme (I5).
- Similarly, the programme for the endorsement of **forest** certification certifies harvesting companies encouraging practices contributing to climate change mitigation in management operations, such as reducing GHG emissions and efficient use of resources (T1).

More generically, procurement requirements for raw material producers that voluntarily apply **certified energy-management systems**, such as through the ISO 50001 standard (e.g. certifying the continuous improvement of energy use in salt production — S1), or from organisations that can provide product-specific certificates, for example the **Forest Stewardship Council** certificate (which requires the organisation to avoid, repair or mitigate negative environmental impacts), have also been identified as existing practices (T1).

The International Copper Alliance, which aims to positively contribute to society's climate-friendly development goals, has defined an objective to use only renewable energy at copper mining sites as part of its strategy. In addition to raising awareness in the copper industry, research and other dedicated initiatives have been conducted to implement the strategy.

Procuring copper ore and concentrates from adopters of research and initiatives carried out by this alliance has been listed as a climate-friendly sourcing practice (C5).

Procuring raw materials from mining companies that have demonstrably invested in **technological solutions** for improving the energy efficiency of their operations is a transversal practice identified for different product value chains:

- Several **gold** and **potash** mines have already reduced the GHG emissions associated with their energy consumption by transitioning towards lower carbon energy sources for their power supply. One practice identified also describes a supplier's investment in a 'ventilation-on- demand' system using sensors that monitor real-time air quality, vehicle use and personnel movement, permitting ventilation of only specific potash mine areas rather than ventilating the entire mine, leading to substantial energy savings (G1, F1).
- Procuring **ores** from mines that have committed to replacing their diesel fleet with electric and hybrid electric vehicles is a practice that can also be adopted for reducing GHG emissions. Some mining companies have also invested in innovative and energy-efficient loader and haulage systems (G2, F1).
- In extractive activities other than mining, it is worth mentioning a sea **salt producer** that has invested in a solar photovoltaic system and also recovers heat from a neighbouring company to reduce emissions associated with drying the salt (S2).

3.2.2 Identified practices with requirements addressing raw material processors

Procuring raw materials from **certified raw material processors** complying with standards established by not-for-profit
multi-stakeholder membership organisations was already identified as a common practice addressing raw material producers (see Section 3.2.1):

- In addition to the supply chain-specific certification schemes mentioned in Section 3.2.1, another good practice example could be procuring **aluminium** from processors certified by the Aluminium Stewardship Initiative standards, which implies that certain GHG emission levels are not exceeded during the smelting process (A5).
- Compliance with a standardised product stewardship programme is also requested of **fertiliser** producers that are members of the European industry association Fertilizers Europe (F7).

Similarly, procuring from raw material processors voluntarily applying **certified environmental management systems**, such as through the ISO 14001 standard, has also been identified as a common practice targeting raw material processors:

- An example is the certification of the continuous monitoring and reduction of GHG emissions during **steel** production (I3).

Some manufacturers are requesting **third-party verified certificates** from their suppliers, guaranteeing the use of renewable energy sources in upstream production stages:

- Examples can be found among **aluminium manufacturers** (A8).
- For several of the raw material-intensive supply chains studied, such as **wood** (T2) and **copper** (C3), individual private operators have implemented their own business partner code of conduct, defining the specific environmental requirements to be met by their suppliers.

Sectoral industry associations have agreed on **voluntary sustainability targets** that their members commit to for mitigating climate change. One association, Fertilizers Europe, is also raising awareness among its industry members by rewarding best performers using a voluntary benchmark that aims to measure the sector's progress and encourage investment in efficiency improvements, in this case for **ammonia** production (F8).

Procuring raw materials from processing plants applying **best available techniques** (BATs) ([12]) and performing according to the associated environmental performance levels (BAT-AEPLs) is a common practice in the different raw material-intensive supply chains selected. The corresponding installations often apply specific techniques for reducing energy consumption, mitigating energy losses, or lowering CO_2 and N_2O emissions, all contributing to a reduction in GHG emissions of industry-specific processes and/or sub-processes.

- An example of such practice is the improvement in energy efficiency of the electrolysis process by using specifically recommended membranes in chlor-alkali production, one of the main **salt** processing industries (S3).

Procuring raw materials from processing companies that have demonstrably invested in **technological solutions** for improving energy efficiency, thereby reducing the GHG emissions of their operations, is a practice applicable to all selected raw material sectors:

- Scaling up the development and deployment of low-CO_2 electrification of the heat required (e.g. in **chlor-alkali** (S5) and **aluminium** (A2) production) and the continued electrification of production processes (e.g. in **chemical** (S5) and **steel** (I1) production) are considered future enablers of sustainable procurement.
- The **steel-making** industry (I1) and **ammonia** producers (F4) are also investigating low-carbon sources of hydrogen. Procuring raw materials from those frontrunners is identified as a practice to be adopted in the near future.
- Several raw material processors, particularly **ammonia** (F2, F3) and **lime** producers (L2), have invested in carbon capture and use technologies for valorising CO_2. One specific practice describes the opportunities for capture and use of CO_2 and for its permanent storage.

Several industrial facilities operating within the selected raw material-intensive supply chains for this study are covered by the EU Emissions Trading System (ETS) Directive. The EU ETS operates in all EU countries plus Iceland, Liechtenstein and Norway, and it seeks to limit emissions from more than 11 000 heavy energy-using installations (such as power stations and industrial plants) and airlines operating between these countries, covering around 40 % of the EU's GHG emissions (European Commission, 2016a). As the EU ETS includes the emissions associated with the production and industrial processing of raw materials, the procurement of raw materials from **plants subject to the EU ETS Directive** is considered a relevant practice (F6, G3).

3.2.3 Identified practices with requirements addressing raw material traders

In line with what has been described in Sections 3.2.1 and 3.2.2, procuring raw materials from **certified traders** complying with standards established by not-for-profit multi-stakeholder membership organisations is an identified practice applicable to different parts of raw material supply chains:

- Traders are listed as supply chain partners that have to comply with requirements as, for instance, set by the Responsible Jewellery Council's code of practice (G4) or the **fertiliser** product stewardship programme (F7).

Requiring the application of voluntary **certified environmental management systems**, such as through the ISO 14001 standard, addressing transport aspects and, subsequently, their continuous monitoring and improvement, is also an identified practice that can be adopted by traders (S6).

([12]) The BAT approach is not exclusive to the EU but is used for permitting industrial operations at national or even regional level, both in EU Member States and internationally. Examples of how the information exchange for, and the drafting of, BAT reference documents (BREFs) are organised in South Korea, United States, Russia, China and the region of Flanders (Belgium) can be found in OECD (2020).

3.2.4 *Identified practices with requirements addressing users of secondary raw materials*

Referring to metal manufacturing activities, some **gold** (G5) and **aluminium** manufacturers (A7) are requesting third-party verified certificates from their suppliers guaranteeing the percentage of secondary raw material content.

Investments in **technological innovations** targeting increased valorisation of waste streams is likely to increase the supply of high-quality secondary raw materials, allowing innovative companies to respond to green (public) procurement tender documents that include requirements on recycled content:

- One practice identifies techniques that increase the sorting efficiency by separating non-metallic constituents and metals other than **aluminium**, subsequently providing scrap of sufficient quality to enable secondary aluminium production (A4).

Following the same logic, to increase the quality of secondary raw materials, as well as the recovered quantities:

- Procuring from companies that are part of national and/or regional extended producer responsibility schemes, has been listed as a practice. Members of an **aluminium** producer responsibility organisation need to comply with collection rules and are certified that their materials will be recycled by qualified companies (A9).
- **Aluminium** recyclers can procure post-consumer scrap collected through deposit return systems (A10).

4
Estimation of climate mitigation potential

4.1 Greenhouse gas emissions associated with the supply of raw materials for EU consumption

4.1.1 GHG footprint of the final use of raw material-intensive products in the EU-27

The greenhouse gas (GHG) footprint is a measure of the amount of CO_2 that is emitted throughout the full production chain of a material or product that ends up in the EU for final consumption or investment, irrespective of the industry or country where the actual CO_2 emissions occurred (see Box 4.1). These emissions are sometimes referred to as emissions 'embodied' in EU consumption, although they are not literally included in the processed materials or final products. Domestically produced or imported materials and products can be purchased by end-consumers, such as households, retailers and industries, but may also be added to existing 'stocks' that include infrastructure and investment goods or may be (re-)exported. The underlying modelling usually assumes that the production technology in the rest of the world's economy is the same as it is in the EU. GHG footprints are thus estimated from the perspective of the final product and where it ends up, and are therefore also referred to as consumption-based accounts (Eurostat, 2020).

Box 4.1 Greenhouse gas reporting versus footprinting

The greenhouse gas (GHG) footprint estimations account for GHG emissions from the perspective of final consumption. This means that the footprint associated with the EU consumption of products includes GHG emissions embedded in products consumed in the EU, but the actual emissions might take place outside the EU (e.g. when the raw materials needed for the product consumed are extracted outside the EU). Therefore, the GHG emissions associated with EU consumption are not all reported by the EU under the United Nations Framework Convention on Climate Change (UNFCCC) reporting. The reporting structure takes into account emissions actually taking place in EU territory. This could create an incentive for the EU to outsource the emissions associated with its consumption. From a sustainable sourcing point of view, the focus on sustainable sourcing practices by EU final consumers of raw materials that address raw material producers outside the EU have no benefits for the EU reporting on GHG emissions and progress towards the EU climate targets. One could therefore argue that the EU final consumers of raw materials do not have very much incentive for adopting sustainable sourcing practices for their EU-external suppliers, as the GHG benefit would appear on the EU-external GHG inventory. The use of consumption-based GHG footprinting methods would assign the responsibility for GHG emissions to the final consumer of products irrespective of where the emissions take place and incentivise the final consumers to put sustainable sourcing requirements on to their suppliers.

However, policymaking and target setting is justifiably based on GHG accounting methods that refer to emissions taking place within national (or EU) borders. The EU does not have control over emissions taking place outside its sovereign borders and therefore cannot include those in its target setting. Consumption-based footprinting can be a valuable instrument, complementary to GHG accounting for understanding impacts related to EU consumption.

For the present analysis, the carbon footprint corresponding to consumption in the 27 Member States of the EU (EU-27) of all raw material-intensive products indicated in Table 4.1 was considered. The listed product categories typically require relevant volumes of non-agricultural, non-energy and non-critical raw materials obtained from mining and quarrying and forestry, as well as products obtained from the processing and refining of these raw materials, such as basic metals, timber and paper. Table 4.1 looks at the GHG emissions embodied in the final use of the selected products, which were either purchased by final consumers (households and industries) within the EU territory or exported. This means that all GHG emissions that have occurred in the entire supply chain of the domestically purchased or exported products are included, irrespective of the countries where actual emissions took place. The sum of GHG emissions that are embedded in the products that typically require the raw materials included in the scope of this report for their production amount to 838 million tonnes, or **approximately 18 %** of the total GHG footprint of EU consumption and exports. It is important to note that these emissions are higher than the emissions due to the extraction and processing of the product's raw material content, since manufacturing activities, such as product assembly, industrial processing, and distribution and transport of materials, product parts and (semi-)finished goods, also emit GHGs.

The GHG emissions associated with the use of raw materials in the EU economy still is in the order of magnitude of hundreds of millions of tonnes. Tackling these emissions by **climate-friendly raw material sourcing practices** is thus expected to contribute substantially to the EU's ambitions on climate change, expressed in the European Green Deal.

To further complement the information on the GHG emissions associated with raw material extraction and processing for EU consumption and export, the GHG contributions of the individual raw materials are assessed in Section 4.1.2.

Table 4.1 Emissions of GHGs (tonnes) from final use in the EU of classes of products by activity (CPA), 2018

	Final consumption and capital formation	Exports of goods and services	Total final use
Total CPA products	**3 092 590 523**	**960 160 306**	**4 052 750 829**
Products of forestry, logging and related services	3 648 037	206 991	3 855 028
Mining and quarrying	10 846 738	19 940 476	30 787 214
Wood and products of wood and cork, except furniture	4 758 353	4 257 587	9 015 940
Paper and paper products	11 209 856	14 252 239	25 462 095
Chemicals and chemical products	34 070 003	101 419 169	135 489 173
Basic pharmaceutical products	17 895 410	28 299 903	46 195 313
Rubber and plastic products	10 208 562	14 893 083	25 101 644
Other non-metallic mineral products	20 792 437	29 610 618	50 403 055
Basic metals	918 065	65 513 666	66 431 731
Fabricated metal products, except machinery and equipment	28 244 970	17 702 413	45 947 383
Computer, electronic and optical products	28 072 259	26 115 651	54 187 910
Electrical equipment	23 823 859	25 026 324	48 850 183
Machinery and equipment not elsewhere classified	51 730 840	59 153 110	110 883 950
Motor vehicles, trailers and semi-trailers	91 680 325	54 048 668	145 728 993
Other transport equipment	20 473 824	19 676 273	40 150 097
Furniture and other manufactured goods	34 977 951	16 008 373	50 986 324
Total for raw material intensive products	**358 373 538**	**480 116 171**	**838 489 709**
Total CPA products plus direct emissions by private households	**3 863 252 373**	**960 160 306**	**4 823 412 679**

Source: Eurostat (2020).

Table 4.2 GHG emissions associated with raw material demand for EU consumption

Raw material		EU raw material input (kt) ([a])	Metal in gross ore (%) ([b])	Metal input for EU	kg CO_2e/tonne mineral/ metal/ timber ([c])	EU raw material input (t CO_2e)
		A	B	C = A × % B	D	D × C (metals) or D × A (non-metals)
Metals	Copper	331 402	1.04	3 447	5 058.51	17 434 549
	Iron	292 383	43.32	126 660	1 764.14	223 446 423
	Gold	92 077	0.00021	0.193	15 226 146.00	2 944 160
	Bauxite and other aluminium	90 897	18.98	17 252	18 395.54	317 364 222
Non-metallic minerals	Limestone and gypsum	140 874			2.49	350 776
	Chemical and fertiliser minerals	54 290			741.03	40 230 865
	Salt	65 003			135.44	8 804 006
Biomass	Timber	276 716			36.99	10 235 733
Total						**620 459 958**

Note: Tables 4.1 and 4.2 are not directly comparable owing to the very different nature of the methodologies and assumptions involved in the data behind the calculations.

Sources: ([a]) Eurostat Material flow accounts in raw material equivalents — modelling estimates (env_ac_rme); World mining data (Reichl et al., 2018);
([b]) Eurostat economy-wide material flow accounts, Handbook, 2018 edition (Eurostat, 2018);
([c]) Ecoinvent (2021) — calculations based on Environmental Footprint Method 2.0.

4.1.2 Greenhouse gas emissions associated with the selected raw materials

In Table 2.1, an overview was provided of the volumes of selected raw materials that are supplied to satisfy EU consumption needs by both final and intermediate (industry) consumers of raw materials. This supply is also referred to as the raw material input to the EU-27 (see Annex 1). These required input volumes can then be combined with the CO_2 equivalent (CO_2e) emissions per raw material category to provide an estimate of the total GHG emissions associated with the total raw material demand for satisfying EU consumption, independent of the geographical origin of the raw materials. The results are shown in Table 4.2 for the selected raw materials addressed in this report.

The total GHG emissions from the extraction and processing of the selected raw materials required to produce the goods that are used in production and consumption activities within the EU amounts to about 620 million tonnes. This is a product of the quantity of each raw material needed to satisfy EU use, on the one hand, and the raw material-specific unitary GHG emission factor of the material, on the other. With average GHG emissions of 8.7 tonnes of CO_2e per capita in 2018 in the EU-27 (Eurostat, 2021b), the global emissions related to the mining, quarrying, harvesting, processing and refining of the selected raw materials to be used in the EU is equivalent to the emissions of those of an average area in Europe with about 71 million inhabitants.

As well as the 838 million tonnes estimate for the contribution of GHG emissions associated with the **EU consumption or export** of those final products that typically require metals, minerals and timber for their production, the 620 million tonnes estimate for the CO_2e emissions from **extraction and processing** of the EU raw material input is an overestimation. After all, especially in the case of metals, not all raw materials originate from ore but some are derived from the recycling of waste and end-of-life products in the form of secondary raw materials. The use of scrap metal as a substitute for primary metals from ore hence constitutes a core strategy for tackling raw material-related GHG emissions (see Section 4.2.2).

The CO_2e emissions are dominated, in absolute terms, by metals, mainly aluminium and iron. Large quantities of raw material input do not always translate into high total GHG emissions, as for example for limestone and gypsum, because of the relatively small unitary GHG emission factor (column D of Table 4.2).

Climate-friendly practices that aim to reduce global GHG emissions associated with the raw material demand from EU consumption should preferably target the procurement of bauxite and aluminium, iron, chemical and fertiliser minerals, and copper.

4.2 Greenhouse gas emissions from different stages of relevant raw material-intensive value chains

The following sections describe the main sources of GHG emissions throughout the production and supply chain of selected raw materials most in demand for European consumption. Information is presented for larger commodity groups.

4.2.1 Harvesting and industrial processing of timber

The carbon footprint of sawn timber in 2020 is estimated to be 35 kg CO_2e/m^3, of which 50 % originates from forest management, harvesting and wood hauling, about 17 % from transport of raw material to sawmills and the rest from the operations at sawmills. The average shares of the carbon footprint of the sawmill industry is presented in Figure 4.1.

4.2.2 Extraction and industrial processing of selected metal ores

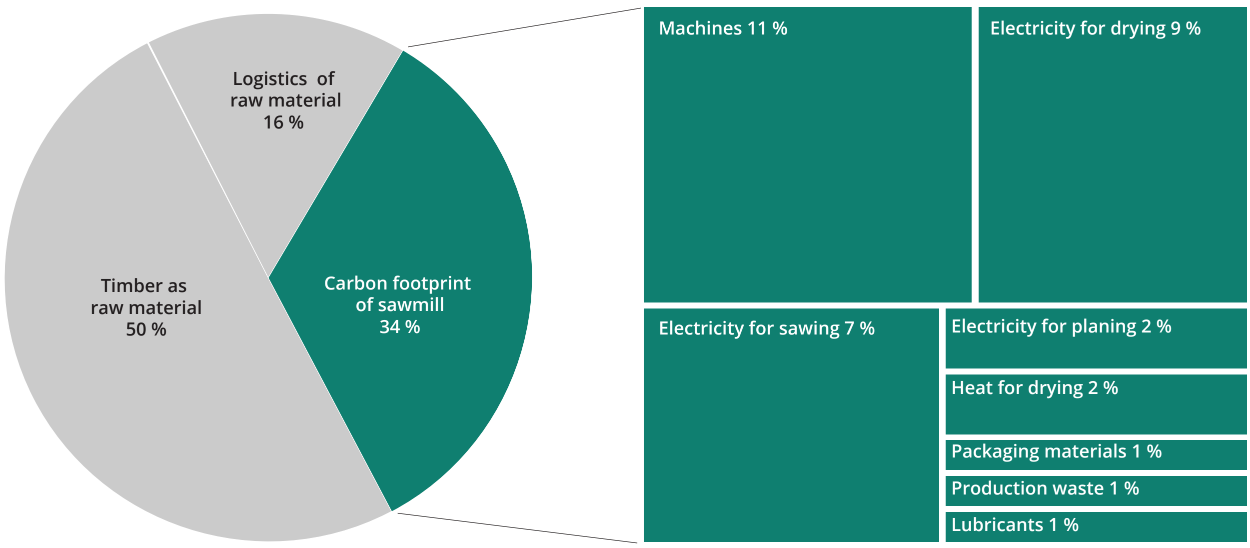
As briefly described in Section 2.1, the production of primary **metals** typically includes ore mining and concentrating, smelting or separation, and then refining to obtain the element in its metallic form, with a variety of processing routes available. At each life cycle stage, impurities and by-products are separated and the concentration of the metal in the final product increases. To obtain sufficient purity levels, metal refining usually requires energy-intensive and precisely controlled melting stages, currently often based on fossil fuel inputs, either directly as a reductant or indirectly as a source of heat and electricity (Nuss and Eckelman, 2014).

As reflected in Figure 4.2, specifically for those metals that were selected for the present study (aluminium, iron, copper) in their metallic form — either as pure metals or as metal alloys — the main sources of GHG emissions are the purification (i.e. smelting) and refining stages required to obtain the corresponding basic metals.

Gold, as well as other precious metals, generally occurs at very low densities, requiring complex and resource-intensive mining operations. As a consequence, the extraction of gold metal requires the sorting and processing of large amounts of mined material through energy-intensive smelting and electrolysis.

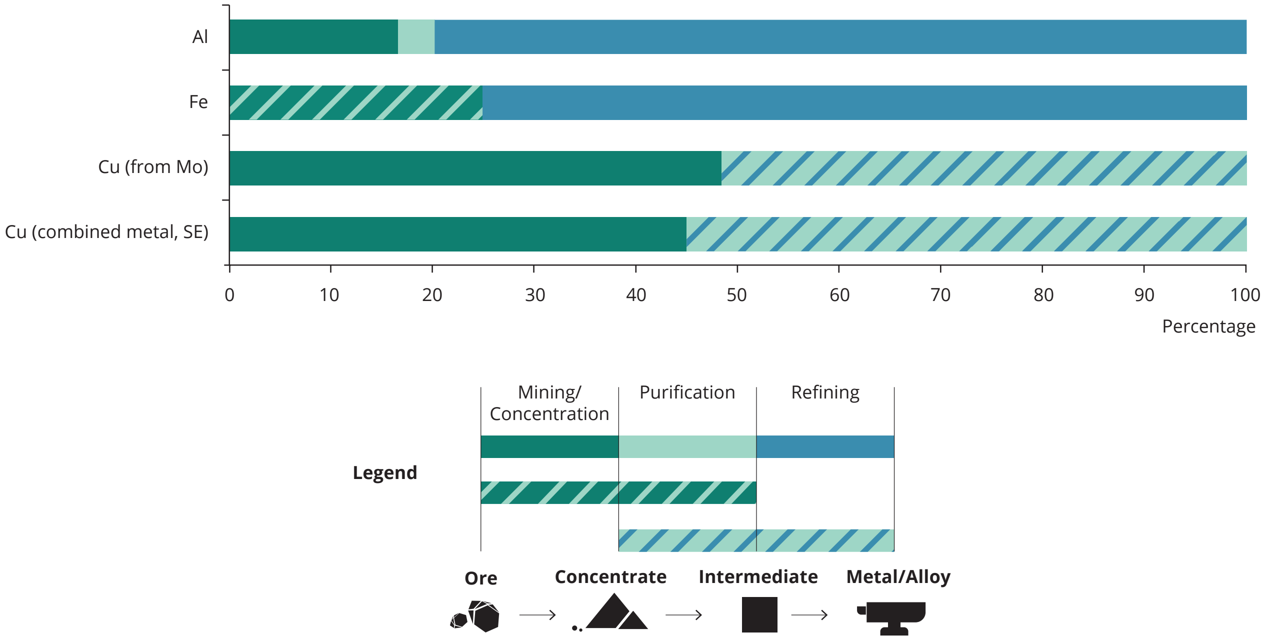
By avoiding the mining and concentration stages, the **production of metals from scrap** requires significantly less energy than production from ores. According to the European Aluminium Association, **secondary aluminium** requires 95 % less energy and emits approximately 95 % less GHGs as than primary production of aluminium (European Aluminium, 2015). A study discussing the environmental benefits of recycling reports GHG emission savings of up to 65 % and 58 % for **secondary copper** and **ferrous metals**, respectively, compared with their primary production (Grimes et al., 2008).

Figure 4.1 Average share of the carbon footprint of the sawmill industry



Source: Based on data from the Finnish Sawmill Association (2020).

Figure 4.2 **Global warming potential per life cycle stage of selected metals (aluminium, iron, copper)**



Note: Elements in brackets indicate the host metal from which the metal is obtained as a co-product. SE means Sweden, as the data inventory comes from a single plant.

Source: Reproduced from Nuss and Eckelman (2014). Modified and reproduced under the terms and conditions of Creative Commons attribution licence CC BY 4.0 (https://creativecommons.org/licenses/by/4.0/).

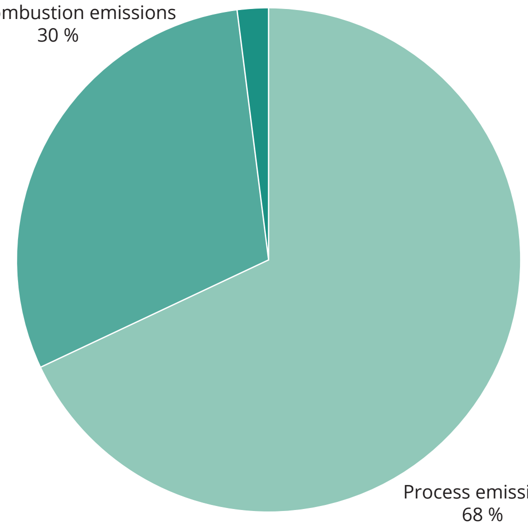
4.2.3 Extraction and industrial processing of selected industrial minerals

Table 2.1 shows that calcium-based materials obtained from minerals such as dolomite and limestone rank third regarding GHG emissions from the production of primary mined materials. **Lime** production is carbon intensive; however, it is different from many other carbon-intensive industries. Only one third of emissions come from burning fuel to heat kilns; the bulk of emissions come from a chemical reaction in the production process in which CO_2 is released from the carbonate fraction. Since close to two thirds of emissions are linked to this chemical reaction, options to mitigate these emissions without capturing the carbon are limited. Smaller amounts of indirect CO_2 emissions are generated during other parts of the production process, such as the mining of **limestone**, but they are insignificant compared with the emissions associated with heat production and calcination processes. The average shares of CO_2 emissions from the manufacture of lime are illustrated in Figure 4.3.

The production of **nitrogen fertilisers** has a high carbon intensity due to the use of fossil fuels, mainly natural gas, both as fuel and feedstock. As the main technology for producing ammonia, steam methane reforming is a source of CO_2 emissions. Nitrous oxide (N_2O) emitted during nitric acid production also contributes to GHG emissions from the production of nitrogen-based fertilisers. Concerning potassium-based fertilisers, mining and processing of potash ore is also energy intensive. Potash is typically mined underground, hoisted to the surface, and crushed and purified using electrically powered equipment before being dried. According to one main producer, electricity to power equipment for potash processing represents approximately 15 % of its potash production costs (Nutrien Ltd, 2020). Another global producer of ammonia reports that 87 % of the total energy consumption associated with the production process is consumed as feed or fuel (Yara, 2019). Although average GHG emissions were used in Table 2.1 the carbon footprint varies widely, according to the different fertiliser types and the location of production sites. Indicative and illustrative values for the global average carbon footprint associated with the production of urea, ammonium nitrate, muriate of potash (potassium chloride) and sulphate of potash (potassium sulphate) are given as 5.00 kg CO_2e/kg, 9.47 kg CO_2e/kg, 0.69 kg CO_2e/kg and 0.23 kg CO_2e/kg, respectively (Kool et al., 2012).

The forced evaporation of brine to obtain vacuum **salt** (using solution mining) represents the main source of primary energy consumption of the different salt production processes. Using the German electricity mix, values of 93 kg CO_2/tonne of vacuum salt produced, compared with 12 kg CO_2/tonne for rock salt and 3 kg CO_2/tonne for sea salt, have been estimated and reported (Vidovic, 2018). In Europe, the chlor-alkali and synthetic soda ash industries are the main

Figure 4.3 **Average share of CO_2 emissions from the manufacture of lime**



Source: Based on data from the European Lime Association (EuLA, 2019).

procurers and consumers of salt, representing 53 % of the demand. The chlor-alkali industry sector produces chlorine, caustic soda and hydrogen through electrolysis of brine. This is an energy-intensive industry that, particularly during the electrolysis process, consumes large amounts of electricity. Additional energy, in the form of steam or electricity, is necessary for auxiliary processes, the nature of which depend on the cell technique used. In 2010, the total electricity consumption of the chlor-alkali sector in the EU-27 and European Free Trade Association (EFTA) countries amounted to 35 TWh. This was then equivalent to 1 % of the total final energy consumption in the form of electricity in this region, to 3 % of all industry sectors' consumption and to 17 % of the chemical and petrochemical industry's consumption (Joint Research Centre, 2014). Almost all CO_2 emissions in the chlor-alkali industry originate from steam generation that occurs in the various combined heat and power installations. Three main production methods exist: membrane electrolysis, mercury-based cell electrolysis and diaphragm electrolysis. The quality of the salt feedstock influences the energy consumption of the electrolysis process itself.

As reflected in previous sections, mining and quarrying operations are often not the main sources of GHG emissions in the supply chains that build on the selected raw materials. While it is acknowledged that other major environmental concerns are associated with mining and quarrying activities (see Box 1.1), mining companies increasingly recognise that sustainable development is an essential part of risk management in mining operations and should consider factors such as increased water and energy scarcity (Buxton, 2012). In addition, it is currently observed that lower ore grade mining is leading to a higher energy demand and thus to potentially more GHG emissions per tonne of extracted ores (Dold, 2014).

4.3 Climate impact reduction potential of climate-friendly sourcing practices

Based on the bottom-up identification and successive mapping of climate-friendly sourcing practices (Chapter 3), supported by the understanding of the main sources of GHG emissions in selected raw material supply chains, this section provides a qualitative and relative ranking of practices applicable to the selected supply chains, according to their potential for reducing GHG emissions. When available, these descriptions are supported and illustrated by quantitative information on the climate mitigation potential of one or a few individual sourcing practices. Such practice-related, quantitative information can be found in Annex 1.

4.3.1 GHG emissions reduction potential of identified climate-friendly sourcing practices for timber

Growing trees will sequester CO_2, and therefore it is important to safeguard the capacity of forests to store carbon in the medium and long term by balancing harvesting and growth rates, using appropriate silvicultural measures, and employing techniques that minimise adverse impacts on forest resources. Forest management, harvesting and wood hauling represent about 50 % of the sawmill industry's carbon footprint; procuring wood from third-party certified suppliers complying with specific industry standards (obviously depending on the requirement level) is thus considered to have the highest mitigation potential (T1). The carbon footprint of sawn **timber** is already low; nonetheless, procuring wood from suppliers that have improved their logistical operations and the associated GHG emissions at the sawmill site (e.g. by electrification or the use of biofuels) can still lead to additional GHG savings. Carbon is captured in wood products for the whole of their life cycle, providing opportunities for the construction industry to significantly reduce its carbon footprint by increasing the use of timber in urban development (T3).

4.3.2 GHG emissions reduction potential of identified climate-friendly sourcing practices for metals

As discussed in Section 4.2.2, GHG emissions in the production and supply of selected metals mainly occur during the **purification and refining stages** (which account for roughly between 50 % and 80 % of the total metal production emissions; see Figure 4.3). Subsequently, sourcing practices that aim to mitigate emissions occurring at those production stages can be considered to have the highest climate mitigation potential for **aluminium, iron and copper**.

Although the **mining and beneficiation stages** account for a more limited share of the impacts for iron and aluminium, the greater relevance of emissions at these specific production stages for **copper and gold** offers more significant mitigation potential.

It is also clear that for all selected metals, practices that promote the **use of secondary metals** can lead to major savings in GHG emissions.

Identified sourcing practices mitigating GHG emissions from aluminium, iron and copper processors

Individual practices identified reflect that procuring aluminium from processing companies that invest in **energy-efficient technologies** can mitigate emissions associated with fossil fuel energy consumption:

- The novel electric arc furnace can improve the efficiency of the bauxite refinement process from 3 % to 13 % (A1).
- New electrolysis technology is being developed, theoretically using 15 % less energy for aluminium production (A2).

Procuring from production plants that have invested in the implementation of **low-carbon energy sources** to power their activity can also mitigate GHG emissions:

- To achieve its target of reducing the CO_2 intensity of its primary copper production plants by 40 % by 2030, a private company has made agreements with wind power developers to build wind farms close to its smelting operations, in order to secure a long-term supply of renewable energy (C3).
- In addition to converting the blast furnace into an electric arc furnace to reduce its CO_2 emissions by 25 % in 2025, a global high-strength steel producer has joined forces with an iron ore producer and an electricity producer to set up a pilot plant for fossil fuel-free steel production, subsequently aiming to produce steel with virtually no carbon footprint (I1).

Requirements that are established in standards promoted by not-for-profit multi-stakeholder membership organisations can lead to significant reductions in GHG emissions, especially if they specifically target the **purification and refining** stages:

- The Aluminium Stewardship Initiative Performance Standard includes two smelter-specific criteria. Smelters starting production after 2020 must achieve a level of direct and indirect GHG emissions below 8 tonnes CO_2e/tonne of aluminium produced. Existing aluminium smelters that were in production before 2020 must achieve this level by 2030 (A5).

Similarly, procuring from metal processors that voluntarily apply certified **environmental management systems** and/or requiring their compliance with specific certification schemes can lead to significant savings:

- An aluminium manufacturer certifies that its products have a carbon footprint 25 % lower than the global average by requesting that its suppliers comply with the ISO 14064 ([13]) standard and mainly use renewable energy sources to power the production processes upstream of bauxite mining (A8).

As several industry associations are setting **sustainability targets**, the procurement of metals from members that voluntarily initiated actions to enable the industry reach those targets can also lead to reduced GHG emissions:

- The International Copper Alliance explains that, in theory, moving towards 100 % renewable energy could cut CO_2 emissions down to 21 %, and it supports its members that are committed to this transition (C5).
- The objective of the European Aluminium Industry Association is to reduce energy consumption by 10 % per

([13]) Specification providing guidance at the organisation level for quantification and reporting of GHG emissions and removals.

tonne of aluminium produced or transformed throughout the whole value chain, by 2025. Like the copper example, above, reducing emissions from European power generation to 92 % has the potential to deliver a 79 % reduction in the sector's direct and indirect emissions throughout the whole value chain by 2050 (A6).

Without providing quantitative numbers on potential savings, procuring metals from processing plants that apply **BATs and BAT-AEPLs**, for instance by reducing the energy consumption of certain sub-processes and/or mitigating energy losses, also has some mitigation potential.

Identified sourcing practices mitigating GHG emissions from gold and copper producers

As described in Section 4.2.2, the extraction of the gold metal requires the sorting and processing of large amounts of mined material through energy-intensive smelting and electrolysis. Fuel and electricity consumption associated with open-pit and underground mining processes are also considered major sources of GHG emissions from copper production. It is noted that, for copper, surface mining is estimated to be about four times more GHG emission intensive than underground mining (Azadi et al., 2020).

Procuring gold from mining companies that have **decarbonised their power supply** can subsequently lead to savings in GHG emissions:

- A gold mine previously powered by diesel fuel installed two gas powered plants (a total of 62 MW) and thereby reduced its GHG emissions by 20 % (35 400 tonnes CO_2e) (G1).
- A gold mine that installed an 8 MW solar panel system and a 2 MW backup battery, to support the mine's existing gas engines to supply electricity for the underground gold mine, processing plant, camp and other facilities, reduced its GHG emissions by 10 % (9 500 tonnes CO_2e) (G1).
- A gold mine that intends to install a new 56 MW hybrid energy microgrid, combining wind, solar and gas energy sources and battery storage, to supply power to the mine's operations intends to reduce GHG emissions by 50 % (40 700 tons CO_2e) (G1).
- A gold mine that installed a solar power plant and a 6 MW backup battery reduced its GHG emissions by 12 959 tons CO_2e (G1).

Procurement from gold mining companies that have invested in **energy-efficient technologies** can be highly beneficial. According to a study that presents the maximum cumulative reduction in GHG emissions achievable in the Canadian gold mining sector through technological innovations — new alternative haul truck powertrain technologies, improving haul truck operating mode, advanced haul truck thermal management system, high-pressure grinding rolls technology, adding pebbles during grinding, ventilation on demand — which could concurrently be implemented by 2050, would yield a reduction of 10 Mt CO_2e, 20 % of the sector's emissions (Kumar Katta et al., 2020). The following individual practice identified provides quantitative information on the reduction potential of technological innovations:

- Electrifying the vehicle fleet for open-pit and underground gold mining, such as deploying battery electric vehicles in underground mines, can reduce the need for ventilation by up to 50 % compared with a mine with diesel-operated vehicles (generation of diesel particulate matter is avoided, reducing the need for ventilation) (G2).

Following the same logic as that described above for practices relying on similar instruments but adopted by different producers, procurement from copper and gold producers that apply certified environmental management systems, and/or are compliant with specific certification schemes, can lead to significant savings.

As mining, concentration and purification activities 'only' represent about 20 % of GHG emissions from steel production, identified practices with procurement requirements addressing iron ore producers are considered to have a slightly lower mitigation potential than requirements that address (pig) iron processors or steel manufacturers. Kumar Katta et al.'s study (2020) also found that the maximum cumulative GHG reduction achievable in the Canadian iron ore mining sector through **technological innovations** that could be concurrently implemented by 2050 results in 8 Mt of CO_2e, which is 10 % of the sector's emissions.

Identified sourcing practices mitigating GHG emissions by promoting secondary metals production

As previously discussed, secondary metals production from scrap has a high GHG emissions reduction potential compared with primary production. With regards to aluminium production, primary production emits considerably more direct CO_2 than secondary production. This is because secondary aluminium production requires a lower temperature and thus uses far less energy than primary production. It is considered that recycling 1 kg of aluminium saves up to 8 kg of bauxite ore and 4 kg of other chemical products (Wyns and Khandekar, 2020) ([14]). By procuring aluminium scrap from metal recovery plants that have implemented efficient sorting technologies that increase the scrap quality, secondary aluminium producers have an opportunity to further reduce the carbon footprint of aluminium production:

- The application of improved sorting and separation techniques allows improved selection of feed raw materials for the melting process. This in turn will reduce energy use in secondary aluminium production. It is estimated that an increased quality of secondary feedstock results in a reduction of 12 % in energy use relative to current methods of secondary production (A4).

By requesting their suppliers to comply with a **minimum recycled content**, producers can reduce the carbon footprint of their metal products:

- Based on a recycled content certification scheme, an aluminium alloy producer certifies a carbon footprint below 2.3 kg CO_2/kg aluminium produced (A7).

- Similarly, a refiner and manufacturer of precious metals certifies the use of 100 % recycled gold. For the same type of product produced, it is estimated that using recycled gold has 99 % less environmental impact than using primary, mined gold (G5).

4.3.3 GHG emissions reduction potential of identified climate-friendly sourcing practices for industrial minerals

GHG emissions reduction potential of identified climate-friendly sourcing practices for limestone and gypsum

As described in Section 4.2.3, two thirds of GHG emissions released during the **production of lime from limestone** occur during the calcination reaction at high temperature, compared with 'only' one third from the burning of fuels in a kiln. Procuring limestone-based products from plants that have invested in the development and implementation of **carbon capture and storage technologies** therefore presents the highest GHG emissions mitigation potential. New process concepts and technologies are still needed and currently being developed for CO_2 separation and concentration. Such technologies might specifically include indirect heating of limestone, for example by electrification of the lime kiln and oxy-combustion. Possible options for using separated CO_2 include sellable liquid CO_2 when purified and compressed; use in paper filler production; conversion to sellable CO; synthesis to synthetic natural gas; or synthesis to Fischer-Tropsch products:

- An EU-funded research project, Leilac, will 'develop, build, operate and test a 240 tonne per day pilot plant next to the Heidelberg Cement's plant at Lixhe, Belgium, demonstrating that over 95 % of the process CO_2 emissions could be captured (60 % of total CO_2 emissions) from cement production (or lime) without significant energy or capital penalty' (Leilac project, 2017) (L2).

GHG emissions reduction potential of identified climate-friendly sourcing practices for chemical and fertiliser minerals

Fertiliser production accounts for about 1.2 % of global energy consumption and 1 % of annual worldwide GHG emissions. Ammonia production is responsible of approximately 90 % of this energy use (International Fertilizer Association, 2015). Identified practices clearly indicated that the procurement of green ammonia is a main lever for mitigating GHG emissions associated with the EU consumption of nitrogen-based fertilisers. Around 4 million tonnes of nitrogen-based fertilisers were imported to the EU in 2018, representing around 30 % of EU fertiliser consumption (Fertilizers Europe, 2020). For procuring ammonia and/or nitrogen-based fertilisers outside the EU, selecting suppliers that invest in **energy-efficient technologies** and/or valorise CO_2 through **carbon capture and storage technologies** has high climate mitigation potential:

- A non-European nitrogen fertiliser producer has implemented carbon capture and use technologies at its own ammonia production sites to reduce GHG emissions. This involves compressing the CO_2 into a near-liquid state and injecting it into a pipeline to be sold and transported to an oilfield for enhanced oil recovery. In 2019, one of its ammonia facilities started capturing previously vented CO_2. This producer reports that captured and sold CO_2 diverted more than 1.2 Mt of CO_2 from the atmosphere in 2019 (F2).

- A fertiliser company has set up a symbiotic collaboration for valorising residual heat and CO_2 from gas burners used in ammonia production, which are supplied to the adjacent facility. Now, 60 kt of CO_2 are used annually in horticulture through this practice and the use of the residual heat avoids the emission of another 135 kt of CO_2 annually (F3).

([14]) All activities associated with the collection of waste materials destined for recycling, as well as their pre-treatment and processing, also require energy and material resources, which will lead to GHG emissions. Especially for metals however, the contribution of collection and recycling systems to the net GHG emissions from metal recycling, represents only a fraction of the emissions saved by avoiding the use of primary metals. Turner et al. (2015) conclude that in the case of aluminium cans from households, gross emissions from collection and recycling amount to 1.113 kg of CO_2/tonne of aluminium, whereas the net emission from aluminium recycling is -8.143 kg/tonne.

Industries are making efforts to promote and certify sector-specific, **GHG emission-reducing practices**:

- Fertilizers Europe has established a mandatory programme providing a structure for establishing a product stewardship programme for its member companies. Quantitative information on the climate mitigation potential associated with this programme has not been reported; however, it guides and promotes the adoption of energy-efficient and abatement (CO_2 and NO_2 emissions) techniques for certified producers, as well as compliance with regulations such as REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) (F7).

The procurement of ammonia- and/or nitrogen-based fertilisers within Europe from plants that apply BATs and BAT-AEPLs has significant climate mitigation potential, especially because of EU standards for reducing N_2O emissions levels:

- A European producer of ammonium nitrate concluded that procuring ammonia and nitric acid from plants using BATs resulted in total emissions of 3.6 kg CO_2e/kg of ammonium nitrate produced. The implementation of such abatement technology for N_2O emissions led to a reduction in emissions of around 50 % (compared with a similar plant not having implemented this technology) (F5).

Investment in technologies and scaling up pilot projects to enable ammonia producers to procure hydrogen with a low carbon footprint, provides the highest mitigation potential for mitigating GHG emissions associated with European production of fertilisers:

- Although no plants using electrolysis to produce ammonia are currently operational (they are still at a pilot level in the EU) and the use of electrolysis is dependent on the intensity of GHG emissions of electricity generation, its climate mitigation potential could reach more than 80 % (compared with current operations) (F4).

Although the GHG emission-saving potential associated with the production of potassium-based fertilisers is probably considerably lower than that of nitrogen-based fertilisers, procurement from European and/or non-European suppliers that use **energy-efficient** loaders, haulage systems and ventilation systems in potash mines can contribute to GHG emissions savings:

- By using a belt transport system instead of truck haulage in a non-European potash mine, a feasibility study estimated that CO_2 emissions are reduced by factors in the range 1.2-1.4 kg/tkm, resulting in a potential saving of about 300 000 tonnes per year (F1).
- Implementing automated ventilation control systems, including controlled recirculation and dynamic operation mode, results in 36 % savings in energy consumption in a Belarus underground potash mine (F1).

GHG emissions reduction potential of identified climate-friendly sourcing practices for salt

Identified practices revealed that all types of **salt** require energy for their extraction, purification and transport. The energy consumption will vary with the extraction techniques used, as well as with the means of transport and the distance from the salt source to the processing plant:

- Procuring salt from energy-efficient mining operations and evaporation techniques, especially by selecting suppliers that have implemented environmental management systems, subsequently providing a certified framework for continuous improvement, can lead to GHG emissions savings (S1).
- As solar salt uses the renewable energy from the sun for the evaporative step, procuring solar salt from energy- efficient drying operations and optimised logistics, can lead to minor GHG emissions savings (S2).

However, the highest mitigation potential in the salt supply chain (and included within the scope of this study) appears to be at the processing stage in the different industrial sectors that use salt in very diverse applications. Some 53 % of salt extracted is used for chlor-alkali production, an energy-intensive industry. Procuring chlorine and caustic soda from plants **applying BAT techniques and observing BAT-AEPLs** has significant climate mitigation potential, because of the reduced energy consumption from the electrolysis process:

- Conversion to asbestos-free diaphragms at two plants from the same company in France (chlorine capacity of diaphragm cell unit 150 kt/year and 175 kt/year) also involved the replacement of anodes and cathodes with expandable anodes and better performing cathodes, resulting in an overall reduction in electricity consumption for electrolysis of 3-4 % (S3).

Investments in **innovative technologies** might enable the chlor-alkali industry to use low-carbon energy sources and reduce direct emissions. Investment in electric boilers has considerable climate mitigation potential and offers opportunities to purchasers of products such as chlorine and caustic soda:

- Based on the research carried out by the Midden project, small-scale implementation of biomass and electric boilers was able to support three production plants located in the Netherlands (producing roughly 850 kt of chlorine, 950 kt of caustic soda and 24 kt of hydrogen, per year) to meet the thresholds for direct emission reductions stipulated by the EU ETS. The necessary investments in electrifying steam generation were assessed as relatively minor (EUR 150 000) while reducing direct GHG emissions by more than 20 kt of CO_2 per year by 2030 (S5).
- Although the chlor-alkali industry's direct GHG emissions are not lowered by the 'zero-gap technology', it has a significant influence on its electricity use, and thus helps to reduce indirect emissions. Since the indirect emissions of the chlor-alkali industry are considerably higher than the direct emissions, this alternative technology seems promising in reducing the net emissions of the Netherlands as a whole. One plant in the Netherlands that implemented this technology reported a reduction in the energy consumption of its chemical processes of 10 % (S5).

5 Conclusions and enabling factors

5.1 Conclusions

In a transition to a low-carbon economy, applying the principles of public and private climate-friendly sourcing becomes increasingly important for mitigating the climate change impacts associated with the demand for raw materials generated by EU consumption.

Limiting the scope of this study to sourcing practices aiming to mitigate greenhouse gas (GHG) emissions associated with the extraction and processing of raw materials, a list of available instruments that enable the inclusion of sustainable procurement requirements, and that can verify and/or validate compliance with these, has been provided (Chapter 3).

In view of estimating the climate mitigation potential of existing practices relying on the use of these instruments, it was essential to first understand which non-energy, non-food material resources are currently most in demand for satisfying EU consumption. Different criteria, such as volumes of raw material input to the EU and the share of the demand that is satisfied by secondary raw materials, were used to perform a mass-based selection of relevant raw materials and raw material groups currently needed to satisfy this European demand. Aluminium, copper, iron, gold, limestone and gypsum, timber, chemicals and fertiliser minerals, and salt were the raw materials selected (Chapter 2).

Referred to as a mapping exercise, we carried out a non-comprehensive, bottom-up inventory of climate-friendly sourcing practices with sourcing requirements addressing the supply chain operators typically purchasing the selected raw materials, as well as the corresponding processed metals, minerals and timber, and the final products made thereof. The 44 identified practices were then categorised based on the position of the possible adopter(s) of the practice in the product's value chain and the type of instrument(s) employed (Chapter 3).

There is a very relevant distinction to be made between raw material extraction (harvesting) and processing. Extraction (mining, quarrying and harvesting) of raw materials contributes very marginally to global GHG emissions. Other environmental impacts, however, are indeed more relevant for mining and extraction, namely those listed in Box 1.2**.** However, these other impacts are outside the scope of this report. It is key to stress that, to reduce material-related GHG emissions, metal processing should be targeted rather than raw material extraction activities. The contribution of mining and quarrying in the EU Member States is between 0.4 % and 4.7 % of national GHG emissions, including petroleum, coal, lignite and natural gas extraction (Fugiel et al., 2017). Most of the raw material requirements for EU production and consumption are, however, sourced outside the EU. This extra-EU sourcing is particularly relevant for those raw materials for which high volumes need to be extracted or processed to satisfy EU production and consumption needs and/or for which extraction and processing is most carbon intensive. This means that the emissions associated with their extraction and processing will generally not be accounted for in EU GHG emission statistics. Table 4.1, however, highlights the relevance of the emissions that occur in the first, raw material-sourcing steps of the supply chains of those products that will be used and consumed in Europe, irrespective of the countries where the extraction and processing, and the corresponding actual emissions, took place. Table 4.2 demonstrates that, for only those raw materials that were selected for the analysis of climate-friendly sourcing practices, the total GHG emissions associated with their extraction and processing to produce goods that are consumed in the EU amounts to about **620 million tonnes**.

With average per capita GHG emissions of 8.7 tonnes of CO_2 equivalent in the 27 Member States of the EU (EU-27), this level of emissions is equivalent to the average emissions of an area in Europe with more than 71 million inhabitants. Therefore, the potential scope of the climate-friendly practices analysed in this report is very significant and can substantially contribute to the EU's climate change aspirations, as expressed in the **European Green Deal**.

5.2 Enabling factors

Based on this analysis, this report underlines the significant potential for reducing GHG emissions associated with the extraction and processing of raw materials through the deployment of climate-friendly sourcing practices. GHG emissions (and hence potential savings) are always case specific and defined by, for example, the applied industrial process technologies, the nature and quality of the (raw material) feedstock, the energy source used, resource and product transport distances and modes, and the local geographical and environmental conditions at the mining, quarrying and harvesting sites. It is precisely this diversity of influencing factors that permits the design of a series of different sourcing practices that effectively reduce GHG emissions at the different stages of the supply of products that satisfy the demand created by EU consumption.

Therefore, climate-friendly practices should be designed for specific supply chains and for specific technologies. However, this report has demonstrated and quantified that reducing GHG emissions by an order of **at least 10 %** is possible for a number of processes inherent in the extraction, but mainly processing, of raw materials. This demonstration has been applied to a limited number of raw materials, but as already stated in Chapter 4, the principles of climate-friendly sourcing can easily be upscaled to cover the sourcing of other raw materials and from other groups of natural resources.

To harness this significant potential, final consumers of raw materials, either private or public, should use their **decision-making power** to influence the way that raw materials are extracted and processed upstream and throughout the entire supply chain. This influence can be exerted through requirements (or climate-friendly sourcing practices) that aim to transform existing processes in the supply chain or replace them with alternative, more climate-friendly, ones. Private sector final consumers can, for example, incorporate elements of climate-friendly sourcing into their due diligence processes.

The identified climate-friendly sourcing practices can be applied by both private and public final consumers of raw materials. However, given the significant share of demand for raw materials from the public sector, it can lead by example by integrating climate-friendly sourcing requirements in its **public procurement**, for example through the green public procurement instrument. The first step in this process is that public procurement embraces **life cycle thinking** so that the full spectrum of consequences of procuring products is identified throughout the product's life cycle.

Public authorities and the EU also have other instruments to enable climate-friendly sourcing, not only by the public but also the private sector. **International trade agreements** can include climate-friendly sourcing elements for raw materials sourced from territories outside the EU, so that raw materials with a low level of embedded carbon are favoured. Another example, which is already in the pipeline of EU policymaking, is the carbon adjustment border tax that is designed to avoid carbon leakage and to incentivise reducing GHG emissions from industries operating outside the EU.

When examining the identified climate-friendly sourcing practices in more detail, it is evident that a large part of them is related to mitigating the impacts from energy consumed during the extraction and processing of raw materials. Therefore, replacing fossil fuel-based energy sources with **renewables** is at the centre of many climate-friendly sourcing practices. This type of sourcing requirement is aided by the EU's (and many other parts of the world's) rapid decarbonisation of the energy sector due to an ambitious clean energy agenda and the aspiration for a climate-neutral EU by 2050. However, from the opposite perspective, implementing climate-friendly sourcing has, in turn, the potential to reinforce and expedite, to a certain extent, this decarbonisation.

Although in this report, we did not investigate the **economic** relevance of climate-friendly sourcing, it is expected that the application of climate-friendly sourcing practices would have an impact on the prices of natural resources, also affecting final consumers. Policy can address the economic effects of climate- friendly sourcing through price regulation, taxes or other economic instruments. On the other hand, final consumers of natural resources or even final products can also be involved by being offered choices of products with different degrees of climate-friendly sourcing. Transparent information about the carbon embedded in materials in products and accurate and easy to understand **labelling** can help final consumers make informed choices.

Regarding economic instruments, the EU Emissions Trading System (**EU ETS**) is the main EU economic instrument designed to reduce GHG emissions. A cap is established that limits the total amount of certain GHGs that can be emitted by installations covered by the system. The cap is reduced over time so that total emissions fall (European Commission, 2016a). More economic sectors will be included in the ETS. In addition to the ETS, the European Commission recently proposed a 'carbon border adjustment mechanism' as a way of avoiding carbon leakage and protecting EU industry. The carbon border adjustment imposes a carbon price on imports of certain goods from non-EU companies operating abroad, unless these companies also commit to reducing their GHG emissions. This should prevent EU companies moving production abroad to countries with less ambitious climate policies. Therefore, there is an apparent interrelation between the climate-friendly sourcing concept and the implementation of the EU ETS. Economic sectors related to the extraction and processing of raw materials within the EU, if included in the ETS, can make use of climate-friendly sourcing practices to reduce their own GHG emissions.

With respect to broader EU policy developments, several key actions and initiatives announced in the European Green Deal directly target the raw materials and selected supply chains scrutinised in this study. This new growth strategy sets the objective of creating new markets for climate-neutral and circular products from energy-intensive industries such as **steel, cement** and **basic chemicals**. For that, the EU needs novel industrial processes and cleaner technologies to reduce costs and improve market readiness:

- The Commission will, for instance, support clean steel breakthrough technologies leading to a **zero-carbon steel-making process**.
- Europe also aims to address the **sustainability of construction products** and improve the energy efficiency and environmental performance of built assets. A more sustainable built environment is said to be essential for Europe's transition towards climate neutrality.

In the context of the 'A clean planet for all' strategy, it has already been acknowledged that industry transformation has a relevant role in the reducing GHG emissions (European Commission, 2018). While several identified sourcing practices currently relying on technical innovations by producers and processors have already shown some benefits upstream in the value chain, most practices categorised under this topic are heavily dependent on the actual development and implementation of innovative technologies (see Box 5.1).

Box 5.1 Examples of industry efforts towards climate neutrality

A roadmap commissioned by the **steel industry** reports possible reductions in greenhouse gas (GHG) emissions ranging between 10 % and 36 % by 2050 compared with 2015, but without the use of carbon capture and storage (CCS) and carbon capture and use (CCU). The inclusion of CCS and CCU could further increase the reductions to 60 %, under certain limiting assumptions.

In the **non-metallic minerals sector**, such as the cement and lime industry, it is believed that the use of today's best available techniques offers a limited potential for mitigating GHG emissions, including energy efficiency and switching to less carbon-intensive fuels. As a consequence, in these sectors, breakthrough technologies are essential to achieve the necessary reductions, in combination with circular measures (resource, material and product efficiency) and CCS or CCU.

Overall, studies on the **non-ferrous sector** (including aluminium, copper and gold) seem to point to limited potential for reducing GHG emissions. Nevertheless, two **aluminium** producers have recently announced the world's first 'carbon-free' aluminium smelting process, called 'Elysis'. A new joint venture for larger scale development and commercialisation of this emerging technology, expected to become commercially available around 2024, has been launched. The measure that probably offers the highest potential for reducing emission from both aluminium and copper production, complementing the reduction that can be achieved in primary production, is the shift to more secondary production through further recycling and reuse.

Abbreviations

BAT	Best available technique
BAT-AEPLs	Best available techniques and associated environmental performance levels
BREF	BAT reference document
CEAP	Circular economy action plan
CO_2e	Carbon dioxide equivalent
CPA	Classes of product by activity
CRM	Critical raw material
EEA	European Environment Agency
EOL-RIR	End-of-life recycling input rate
ETC	European Topic Centre
ETS	Emissions Trading System
EU-27	27 Member States of the EU
GHG	Greenhouse gas
GPP	Green public procurement
NO_x	Nitrogen oxides
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RMI	Raw material input

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Annex 1 Methodology for selecting relevant raw materials

The demonstration of applicable climate-friendly practices has been performed using a selected list of relevant raw materials, as these are some key materials for EU consumption and are also associated with significant imports from outside the EU and with high greenhouse gas (GHG) emissions for their extraction and processing. The following sections describe how this list of selected raw materials was determined, with reference to the criteria set out in Chapter 2 of the report.

A1.1 EU domestic raw materials consumption

Climate-friendly sourcing practices applied from an EU perspective have the potential to influence all of the raw material consumption regardless of whether the raw material is extracted and/or processed in EU territory. To select materials relevant according to criterion (1) in section 2.1, this section examines quantities of raw materials produced in the EU and quantities imported to the EU. All data presented in this section are extracted from Eurostat (2020), which describes the terms and data collection methods in detail.

The EU's consumption of raw materials is represented as the total raw material extraction that was required to produce all products that in a certain year are consumed within the geographical boundaries of the EU, both by final consumers and industries. The consumed products may consist of (1) raw materials, such as metal ores and ore concentrates; (2) processed materials, such as steel and copper wire; (3) semi-finished products, for example automotive parts and kraft paper rolls; and (4) finished products, such as industrial equipment, cars and consumer electronics. The modelling of the raw material consumption, through the so-called EU raw material equivalent (RME) model, considers **all consumed products**, whether produced domestically or imported from outside the EU, and accounts for **all raw materials** that were needed for their production, regardless of the geographic location of the mining, quarrying or harvesting activities (Eurostat, 2020).

Since some of the raw materials will be either consumed as process inputs during the production process of the product, for example fossil energy carriers, or lost as production residues, and because only part of the metal ore mass consists of metals, the mass of extracted mineral, wood or ore that is required to produce a certain product will **always** exceed the weight of that product, except when the imported product consists of unprocessed, gross ores.

The domestic extraction, imports, exports and consumption of major non-fuel, non-agricultural and non-critical raw materials is shown in Table A1.1. The table also contains the raw material input (RMI) to the economy of the 27 Member States of the EU (EU-27) (last column), accounting for both domestic extraction and imports. RMI consists of the total amount of raw materials required to produce the goods that are available for use in production and consumption activities of the EU economy ([15]). It includes the total global extraction of metal ores, minerals and wood needed for EU production and consumption. For the purposes of this study, the relevance of raw materials for EU consumption is indicated by the RMI column of Table A1.1, as these quantities need to be sourced to satisfy the demand posed by both final consumers of raw materials and industry.

([15]) https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Material_flow_indicators

Table A1.1 Summary of raw material volumes supplied to satisfy EU-27 demand, according to sourcing method, 2018 (in thousand tonnes)

Material/Indicator	Domestic extraction	Imports in raw material equivalents	Exports in raw material equivalents	Raw material consumption (RMC)	Raw material input (RMI)
	A	B	C	A + B - C	A + B
Total all raw materials	5 367 826	3 550 348	2 409 917	6 508 258	8 918 174
Biomass					
MF131 — Timber (industrial roundwood)	230 676	46 040	56 127	220 589	276 716
Metal ores (gross ores)					
MF21 — Iron	*(19 385)*	272 998	133 744	no data	292 383 ([f])
MF221 — Copper	*(912)*	330 490	221 154	no data	331 402 ([f])
MF222 — Nickel	21 826	28 213	29 525	20 514	50 039
MF223 — Lead	3 364	5 163	3 961	4 566	8 527
MF224 — Zinc	17 411	22 523	20 953	18 981	39 934
MF225 — Tin	57	20 004	7 740	12 321	20 062
MF2261 — Gold	*(32)*	92 045	72 393	no data	92 077 ([f])
MF227 — Bauxite and other aluminium ([a])	*(3 902)*	86 995	39 664	no data	90 897 ([f])
MF2294 — Titanium ([b])	0	68 727	34 638	34 089	68 727
MF2295 — Manganese	2	7 526	3 313	4 215	7 528
MF2296 — Chromium	513	5 614	2 653	3 475	6 128
Non-metallic minerals					
MF31 —Marble, granite and other stone	311 257	39 331	55 764	294 824	350 588
MF32 — Chalk and dolomite	56 622	29 000	22 744	62 878	85 622
MF34 — Chemical and fertiliser minerals ([c])	28 331	25 959	22 392	31 899	54 290
MF35 — Salt	45 034	19 969	22 043	42 960	65 003
MF36 — Limestone and gypsum	*(26 051)*	114 823	145 978	no data	140 874 ([f])
MF37 — Clays and kaolin ([d])	72 636	18 454	17 090	74 001	91 091
MF38 — Sand and gravel	2 063 172	256 878	325 446	1 994 604	2 320 050
MF39 — Other non-metallic minerals ([e])	*(14 285)*	19 032	16 872	no data	33 317 ([f])

Notes: Domestic extraction data in italic and between brackets refer to World Mining data for EU-28 for 2018 ([16]).
([a]) Bauxite, aluminium.
([b]) Titanium has recently been included in the EU list of critical raw materials (European Commission, 2020d).
([c]) Sulphur, potash, phosphates, baryte, fluorspar, perlite.
([d]) Kaolin, bentonite.
([e]) Feldspar, magnesite, diatomite, graphite, talc.
([f]) Authors own calculation, not included in Eurostat (Eurostat, 2020).

Source: Eurostat material flow accounts in raw material equivalents — modelling estimates (env_ac_rme); World mining data (Reichl et al., 2018).

([16]) This data, referring to 2018, includes the United Kingdom, which is no longer a member of the EU. Although data for the EU-27 would result in lower quantities, this is not judged to affect the conclusions regarding the relevance of raw materials for EU consumption.

A1.2 Global production and imports to the EU

From a climate-friendly sourcing perspective, it is important to understand the position of the EU in terms of its share of global production. It has been observed that in particular raw materials embodied in the final products consumed in the EU are increasingly extracted outside Europe, specifically in different parts of Asia, where local environmental conditions of mining activities have historically been worse than in Europe, while increasing transport emissions. Such increased reliance on international supply networks might render it more difficult to compensate for a continued growth of raw material demand in the EU by boosting material efficiency only. The growing internationalisation also implies reduced control over the material implications of the EU's final demand and a diminished effect of domestic material-related efforts (Pfaff, 2020).

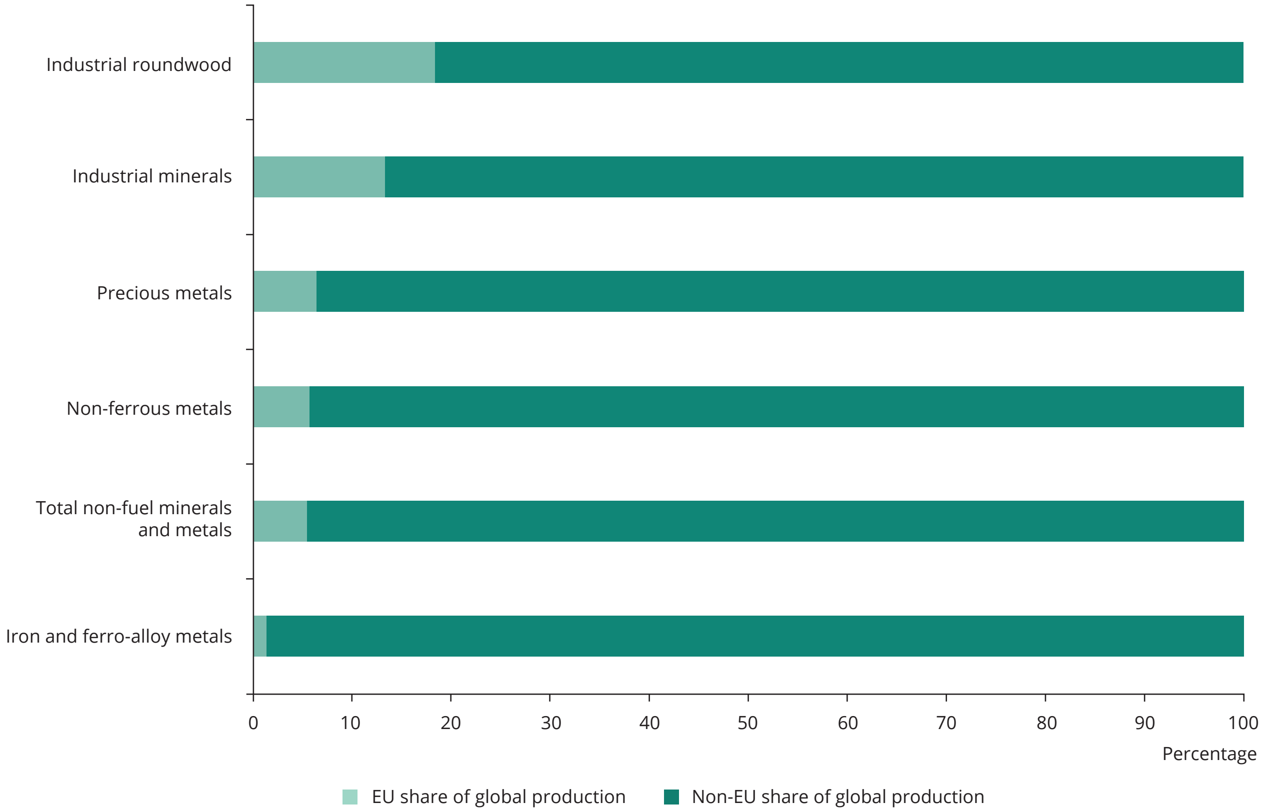
At the same time, it is safe to assume that it will be far easier to implement effective sourcing practices targeting raw materials that are to a significant extent extracted, processed and/or consumed within the EU. Deepening the knowledge base on the mechanisms for, barriers to and difficulties of addressing GHG emissions from internally sourced raw materials will contribute to the necessary development of practices targeting materials and products from outside the EU, accompanied by a higher potential for GHG emission reduction. The share of EU-27 production is presented in Figure A1.1. The category of 'non-fuel minerals and metals' refers to the aggregated production volume of iron and ferro-alloy metals, non-ferrous metals, precious metals and industrial minerals.

It is observed that, for all large commodity groups, the EU share of global production is below 20 %. The EU, however, accounts for a relevant part of the world's industrial roundwood production, which offers interesting perspectives for designing, testing, implementing and benchmarking climate-friendly sourcing practices applicable to this material category. At the other extreme are the iron and ferro-alloy metals, of which 98.7 % of the global supply originates outside the EU territory.

The EU's small share in global production of specific resources indicates that the EU is relying on imports to satisfy its needs for raw materials. The EU is not self- sufficient in most raw materials and thus must rely on the supply of materials and goods provided on international markets. This implies that climate-friendly sourcing practices should be applicable and applied to resources sourced from outside the EU. Table A1.2 presents the EU **import reliance** (IR) at the level of specific raw materials. The indicator that was developed for measuring IR takes into account the global supply risk that exists for a certain raw material, as well as the risk based on actual EU sourcing. This methodology accounts for the fact that, for many raw materials, those countries that are relevant for supplying raw materials to the EU do not coincide with the mix of global suppliers, resulting in different supply risks. For example, although China is the main global producer of phosphate rock, Morocco is the main source of the EU supply (European Commission, 2020c). The IR indicator measures the share of net imports per tonne of domestically produced raw material. For assessing the criticality of raw materials, supply risks due to IR have been considered at two successive stages of the supply chain: the mining or extracting stage and the processing or refining stage. For the purposes of this study, high IR at either of the two stages makes a raw material relevant for climate-friendly sourcing, because such practices have the potential to influence the climate impact of extraction and processing of raw materials not only in the EU territory but also in external territories.

The IR of major non-fuel, non-agricultural and non-critical raw materials is presented in Table A1.2, both for the mining or extraction stage (stage I) and for the processing or refining stage (stage II). By monitoring the EU economy's dependence on the import from international markets of raw materials in the initial stage of their value chain, Table A1.2 shows that levels of IR are highly variable for the different raw materials consumed in the EU, even within the same raw material group.

Figure A1.1 EU share of global production for large commodity groups, 2018



Note: EU-26 (EU-27 excluding Luxembourg).

Source: World mining data (Reichl et al., 2018), all groups except for industrial roundwood; Faostat, industrial roundwood.

Table A1.2 Import reliance for major non-fuel, non-agricultural and non-critical raw materials in the EU, 2018

Raw material (group)	IR EU-27, stage I (%)	IR EU-27, stage II (%)
Bauxite and other aluminium ([a])		
Bauxite	87	
Aluminium		59
Chalk and dolomite	n.d.	n.d.
Chemical and fertiliser minerals ([b])		
Sulphur		-35
Potash	27	
Clays and kaolin ([c])		
Kaolin	*20*	
Bentonite	*15*	
Copper	44	0
Gold	n.d.	n.d.
Iron	72	4
Limestone and gypsum		
Gypsum	-25	
Limestone	5	
Marble and other ornamental or building stone	n.d.	n.d.
Nickel	28	67
Other non-ferrous metals ([d])		
Manganese	90	20
Rhenium		22
Cadmium		-178
Selenium		9
Arsenic		32
Selenium		9
Tellurium		-14
Other non-metallic minerals ([e])		
Feldspar	34	
Magnesite	0	
Diatomite	-1	
Graphite	98	
Talc	13	
Salt	n.d.	n.d.
Sand and gravel	1	
Timber (industrial roundwood)	n.d.	n.d.
Tin	0	64
Titanium ([f])	100	100
Zinc	60	-2

Notes: ([a]) Bauxite, aluminium.
([b]) Sulphur, potash, phosphates, baryte, fluorspar, perlite.
([c]) Kaolin, bentonite.
([d]) Manganese, cobalt, rhenium, cadmium, selenium, arsenic, lithium, indium, germanium, gallium, selenium, tellurium.
([e]) Feldspar, magnesite, diatomite, graphite, talc.
([f]) Titanium has recently been included in the EU list of critical raw materials (European Commission, 2020d).

Source: Study on the EU's list of critical raw materials (European Commission, 2020d). "n.d." means not determined.

A1.3 Greenhouse gas emissions from harvesting, extraction and processing raw materials

In the previous sections of this Annex, a quantitative insight into the volumes of raw materials that have to be sourced for satisfying the material needs derived from EU consumption was provided for aggregated groups of materials.
The activities associated with the harvesting, quarrying, mining and processing of these raw materials inevitably will generate GHG emissions. Overall and as introduced above, the extraction and processing of natural resources, including raw materials, accounts for approximately half of global GHG emissions (IRP, 2019). However, the accounting conducted by the International Resource Panel (IRP) has a different scope from this study: it includes more material groups, such as food and fuels, and more stages in the natural resources' value chains, such as manufacturing. Therefore, the GHG emissions that correspond to the scope of this study, which considers only non-metallic minerals, metals and timber, and only their extraction and initial processing, represent a small fraction of the GHG emissions as calculated by the IRP. However, the approach presented by this report can easily be transferred to other raw material groups and the logic of climate-friendly sourcing applied to raw material consumers of these other groups. Therefore, overall, climate-friendly sourcing can be a powerful climate change mitigation tool across the spectrum of raw material consumption in the EU.

The total GHG emissions embodied in EU consumption and in exports of goods produced in the EU ([17]) amounted to approximately 4.8 billion tonnes in 2018 (Eurostat, 2020). However, only part (**about 18 %**) of these emissions can be attributed to those final products that are typically using significant volumes of the raw materials in the scope of the present analysis, such as metal ores, non-metallic minerals and timber (see Chapter 4.1).

Table A1.3 presents the GHG emissions associated with the harvesting, quarrying, mining and processing of the previously analysed large raw material streams. The figures are provided per unit of weight, and represent the average estimates of total emissions resulting from the entire sequence of processes needed to produce one tonne of basic metal, non-metallic mineral and timber ([18]). For metallic ores, the GHG emissions associated with the extraction of one tonne of ore is provided in a separate column.

The data presented here are deemed robust, but might not be fully representative: average GHG emission factors are presented that might differ not only across countries but also across different mining areas or processing plants. These considerations create uncertainty around the data presented, but this uncertainty is not judged to be substantial enough to erase the validity of our analysis.

Generally, the most important contributor to the carbon footprint of beneficiated ores is energy use. The direct emissions depend mainly on the type of energy (fossil fuels or renewable sources). Also relevant are the production of explosives for blasting, chemicals used and infrastructure (all indirect emissions). The share of these depends on the metal considered. For the refined metals, in addition to the input of beneficiated ore, the energy consumption is the principal contributor, while chemicals and infrastructure have relatively small contributions to the carbon footprint. For copper, the production of oxygen to inject in the blast furnace also has a relevant contribution to the carbon footprint.

For non-metallic minerals, similar to metal ores, the most important contributor to the carbon footprint is energy use. The direct emissions depend mainly on the type of energy (e.g. from fossil fuels or renewables). Also relevant are the production of explosives for blasting and infrastructure (all indirect emissions). The share of these depends on the mineral considered. For the more processed minerals, such as fertilisers, chemicals also make a relevant contribution to the carbon footprint.

For timber, the carbon footprint is mainly determined by energy use, more specifically diesel for clefting and skidders and petrol for sawing. Thus, these are primarily direct emissions.

([17]) Refers to EU-27 GHG emissions from final consumption expenditure (P3), gross capital formation (P5) and exports (i.e. goods and services sold to other economies in the rest of the world) (P6).

([18]) Calculations based on the Ecoinvent dataset used to estimate climate impact data. The calculation method is the environmental footprint (EF) method, which is the impact assessment method applied in the context of the European Commission Environmental Footprint initiative. The implementation is based on EF method 2.0.

Table A1.3 Greenhouse gas emissions from the production of raw materials and the extraction of metallic ores

Raw material	kg CO_2e/tonne refined metal produced	kg CO_2e/tonne ore extracted ([e])	Geography
Metals			
Copper	5 058.51	924.16	RoW ([f])
Iron	1 764.14	5.78	GLO ([g])
Gold	15 226 146.00	69.50	RoW
Bauxite and other aluminium	18 395.54	12.54	RoW (refined aluminium), GLO (bauxite)
Titanium ([a])	30 514.69	1 149.99	GLO (refined titanium), RoW (rutile)
Nickel	12 109.34	1 110.39	GLO (refined nickel), CA-QC (beneficiated ore)
Zinc	5 099.60	405.29	RoW (refined zinc), GLO (concentrate)
Tin	23 632.11		RoW
Non-metallic minerals			
Sand and gravel	4.31		RoW
Limestone and gypsum	2.49		RoW
Chemical and fertiliser minerals ([b])	741.03		Mix of RoW, RER ([h]) and GLO
Salt	135.44		RER
Clays and kaolin ([c])	106.78		RoW
Chalk and dolomite	40.88		RoW
Other non-metallic minerals ([d])	195.96		RoW
Biomass			
Timber (industrial roundwood)	36.99		CH

Notes: CA-QC, Canada, Québec; CH, Switzerland.

([a]) Titanium has recently been included in the EU list of critical raw materials (European Commission, 2020d).

([b]) Including sulphur, potash, phosphates, baryte, fluorspar, perlite.

([c]) Including kaolin, bentonite.

([d]) Including feldspar, magnesite, diatomite, graphite, talc.

([e]) Including beneficiation processes up to the point where the (concentrated) ore leaves the mine.

([f]) Rest-of-the-World (RoW) is a geographical area in Ecoinvent, referring to the rest of the world that is not represented in other geography-specific datasets.

([g]) Global (GLO) datasets in Ecoinvent represent world averages.

([h]) RER datasets in Ecoinvent represent European averages.

Source: Ecoinvent (2021), calculations based on Environmental Footprint Method 2.0.

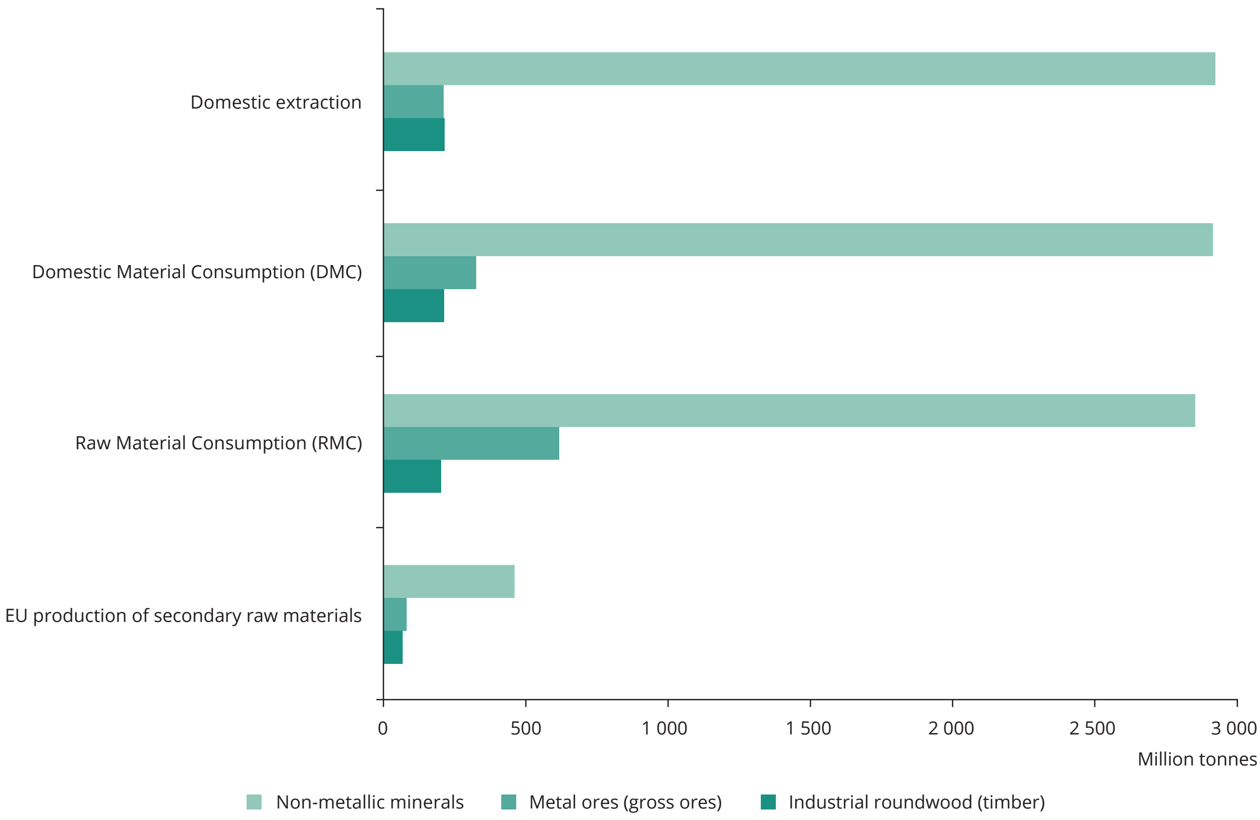
A1.4 Contribution of secondary raw materials

EU production of raw materials also includes the production of secondary raw materials, that is to say, raw materials obtained from the recycling of end-of-life products and production residues that are categorised as waste (European Commission, 2007).

To provide context for interpreting the secondary raw materials production data, Figure A1.2 gives an overview of the EU production and consumption data for the large commodity groups. Consumption data refer both to direct domestic raw material consumption (DMC) and consumption that includes the raw materials embedded in traded products (RMC).

To calculate end-of-life recycling input rates (EOL-RIR) (Directorate-General for Internal Market, 2018), an indicator was proposed that measures, for a given raw material, how much of its input into the production system comes from recycling of 'old scrap', that is scrap from end-of-life products. The EOL-RIR does not take into account scrap that originates from manufacturing processes ('new scrap'). Based on this indicator, bars on the right in Figure A1.2 show the absolute quantities of secondary raw materials used as inputs into the EU economy per large commodity group in 2017. A considerable weight, about half a billion tonnes of non-metallic minerals, is currently being recycled in the EU. It is assumed that this volume largely consists of recycled building materials from the demolition of buildings and infrastructure.

Figure A1.2 Secondary raw materials production as a material source for EU consumption



Note: EU-27; secondary raw material production corresponding to industrial roundwood (timber), is an estimate based on the share of primary timber in the total 2010 EU timber demand.

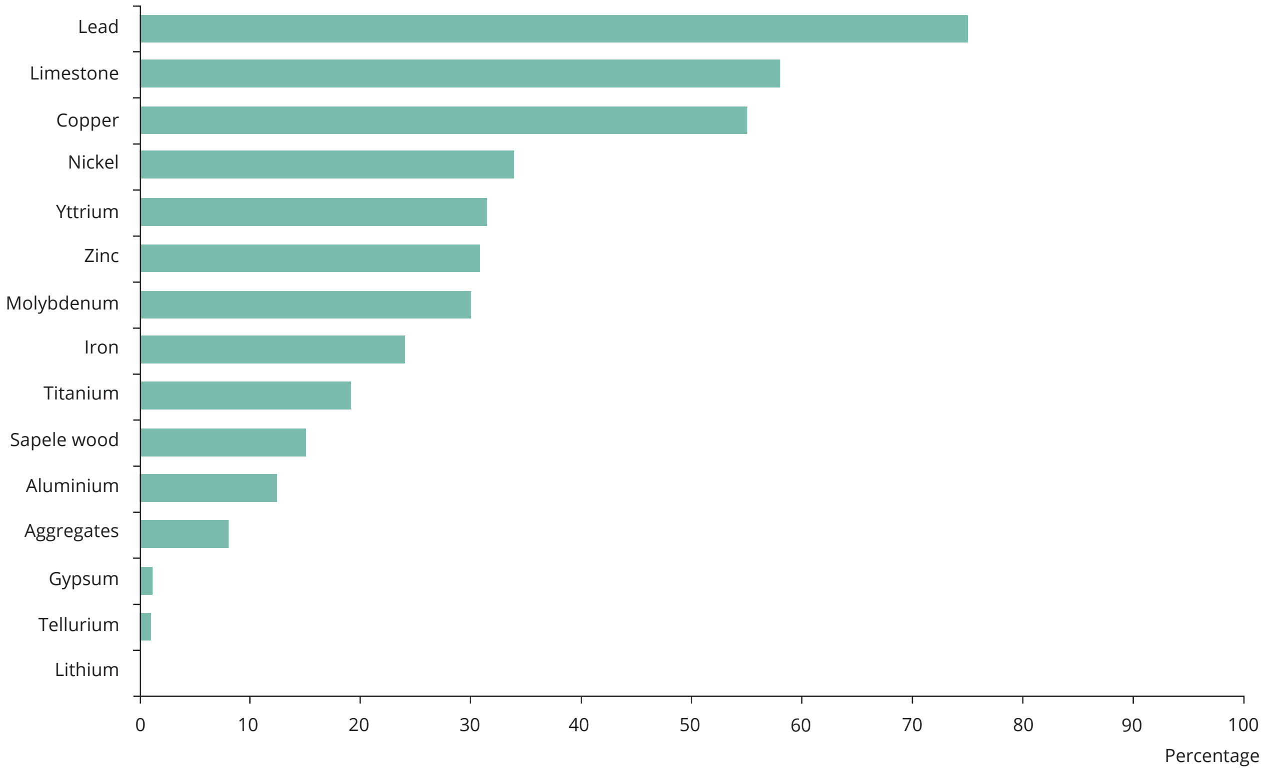
Source: Eurostat (2021c); Eurostat (2021a).

For timber, in 2010, about 31 % of the EU timber demand of 800 Mm^3, or about 559 kt, would be met by recycled timber (O'Brien, 2016) .

It is evident that, despite the huge volume of recycled non-metallic minerals shown on the right in Figure A1.2, the actual proportion relative to the consumption (RMC) remains fairly modest, representing about 16 %. This means that, although the substitution of primary raw materials by recycled materials is important for increasing the sustainability of production and consumption, a major share of the EU materials need will still require the sourcing of mined, quarried and harvested raw materials for many years.

Since most of the figures presented above refer to aggregated, large commodity groups only, and in consideration of the very different weight shares and enormous diversity of materials in each group, data on the relative contribution of recycling to the demand for individual raw materials, both metals and industrial minerals, are presented in Figure A1.3.

Figure A1.3 Relative contribution of recycled materials in EU raw materials demand, 2016



Note: EU-28 ([19]); excluding critical raw materials as identified in the report on critical raw materials and the circular economy (Directorate-General for Internal Market, 2018).

Source: Eurostat (2021a).

([19]) It has not been possible to retrieve data for the EU-27, so data for EU-27 and the UK is used here. This is not expected to result to a significant difference in the contribution of recycled materials in EU raw materials demand.

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