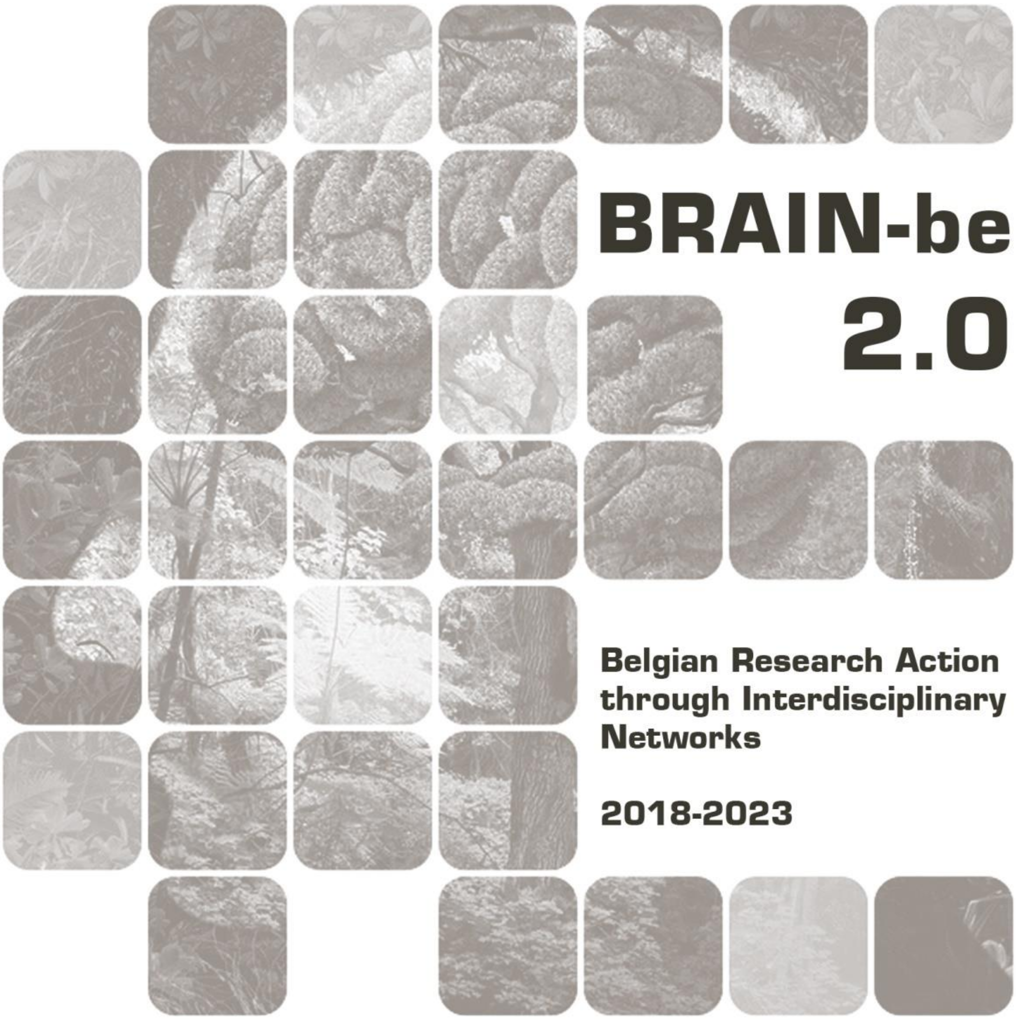

CAMBIUM

CirculAr Material flows in BelgIUM

WP1: State of the art of methodology and results for Belgium

Final report on the State-of-the-Art

Louise Noël - Alizé Carême - Marco Orsini (ICEDD)
Maarten Christis - Jana Deckers (VITO)

Pillar 3: Federal societal challenges

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NETWORK PROJECT

CAMBIUM

CirculAr Material flows in BelgIUM

Contract - B2/223/P3/CAMBIUM

WP1: State of the art of methodology and results for Belgium

Final report describing the state of the art

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1 INTRODUCTION

The state-of-the-art of the material flow framework is a part the Work Package 1 within the CAMBIUM project. WP1 is designed to support the improvement of the Belgian material indicators set in aspects relating to sustainable production and consumption with a focus on the progress towards self-sufficiency, resilience, and circularity. This work package has two primary objectives:

1. To provide a structured overview of existing indicator and blind spots in existing indicator sets to monitor material footprint and circularity of material flows, while identifying any gaps or shortcomings.
2. To investigate and develop several new indicators specific to the Belgian context, aiming to address some of the identified gaps.

The state-of-the-art serves the first objective by providing a structured overview of existing indicators and methodologies. To fulfil this objective, the paper is structured into several sections. The first section seeks to establish clear definitions for the concepts of self-sufficiency, resilience, and circularity. The second section gives an overview of policies related to self-sufficiency, resilience, and circularity, both in the European context and within Belgium. Given Belgium's federal structure, where regions have specific competencies related to the circular economy, resilience, and self-sufficiency (for instance, while product regulation falls under federal jurisdiction, waste management is a regional competence), the paper delve into the various regional policies. Subsequently, the paper proceeds with a comprehensive review of the current state of literature on methodologies for material flow frameworks. Methodologies typically consist of frameworks composed of individual indicators. This part aims to understand what currently exists to monitor the material footprint as well as circularity of material flows and their scope of measurement. Each of the reviewed methodologies in this state-of-the-art literature is documented in annex in the form of a standardized sheet. Next, the paper conducts a state-of-the-art review of region-specific indicators that assess various aspects of regional circularity and the material footprint.

2 DEFINITIONS

2.1 CIRCULAR ECONOMY

There is currently no universally accepted definition of a circular economy, but various definitions used by countries, international institutions, and NGOs share common elements. Key among these is the concept of material circularity. Several authors have presented definitions and interpretations that focus on resources, emphasizing the importance of establishing closed loops for material flows and decreasing the utilization of virgin resources to mitigate their adverse environmental effects (CEPS, 2017). These definitions also typically encompass the objective of reducing the demand for specific natural resources and the materials and products derived from them (UNECE, 2021). According to the United Nations Economic Commission for Europe, “a circular economy and a linear economy differ from each other in the way in which value is created or maintained. In a linear economy, materials are extracted, processed, used, and become waste at the end of their life. Value is created by producing and selling as many products as possible. A circular economy seeks to:

- maximise the value of the materials, products, and other resources (e.g., water, energy) that circulate in the economy by maintaining them in the economy for as long as possible, and
- minimise the consumption of materials – paying particular attention to virgin materials and hazardous substances – and the generation of waste.

A CE further seeks to minimise negative environmental impacts along the life cycle of materials. In practice, businesses, industries, and economies act on a spectrum of linear vs. circular activity, and the relatively circular activities are more efficient with respect to waste (less waste per output).” (UNECE, 2021).

In addition, the Ellen MacArthur Foundation outlines three fundamental principles that form the foundation of the circular economy concept. These principles are as follows:

- Design out waste and pollution: This principle underscores the importance of considering the environmental impacts of production and consumption during the design phase, thereby minimizing the use of virgin raw materials and waste generation.
- Keep products and materials in use: The second principle aims to extend the lifespan of products and materials. This can be accomplished through practices such as reuse, repair, and remanufacturing, which contribute to prolonging their life cycle.
- Regenerate natural systems: The third principle advocates for going beyond mere environmental preservation and instead actively seeking to improve the state of the environment and restore valuable nutrients to ecosystems.

The Ellen McArthur Foundation furnishes an illustration of circular economy with the butterfly diagram. The butterfly diagram, also known as the circular economy system diagram, visually represents the ongoing flow of materials within a circular economy. It consists of two primary cycles: the technical cycle and the biological cycle. In the technical cycle, the focus is on maintaining products and materials in circulation through various processes such as reuse, repair, remanufacturing, and recycling. These activities ensure that resources are utilized efficiently, and waste is minimized. The biological cycle, on the other hand, involves the return of nutrients from biodegradable materials back to the Earth. Through natural processes like composting or anaerobic digestion, these materials break down and contribute to the regeneration of nature's resources (Ellen MacArthur Foundation, 2023).

2.2 RESILIENCE

The EC defines resilience (Regulation (EU) 2021/241) as the ability to face economic, social, and environmental shocks or persistent structural changes in a fair, sustainable, and inclusive way. It is the ability of an individual, a household, a community, a country, or a region to withstand, cope, adapt, and quickly recover from stresses and shocks such as violence, conflict, drought, and other natural disasters without compromising long-term development.

2.3 SELF-SUFFICIENCY FOR RAW MATERIALS

A wide variety of industrial sectors depend on the secure supply of raw materials, typically in a diversified mix of domestic extraction, recycling, and imports. Self-sufficiency means that the EU is independent from the rest of the world for several raw materials. The concept should be considered in a broader context considering potential disruption of supply in the context of economically sensitive key areas. Self-sufficiency for raw materials, in combination with an analysis of the source countries for these materials, can help assessing supply risks for these materials.

The EU will never be self-sufficient in supplying such raw materials and will continue to rely on imports for a majority of its consumption. One of the objectives of the new Critical Raw Material Act is to improve the self-sufficiency and to diversify the supply. International trade is essential to supporting global production and ensuring diversification of supply. The EU will need to strengthen its global engagement with reliable partners to develop and diversify investment and promote stability in international trade and strengthen legal certainty for investors.

3 OVERVIEW OF POLICIES RELATED TO THE CIRCULAR ECONOMY, RESILIENCE AND SELF-SUFFICIENCY

3.1 THE EUROPEAN LEVEL

In December 2015, the European Commission took a significant step by adopting the first circular economy action plan. This marked the EU's initial comprehensive strategy to transition towards a circular economy. The plan aimed to promote resource efficiency, waste prevention, and recycling, laying the foundation for subsequent circular economy initiatives (EC, 2015). On 11 December 2019, the European Commission adopted the European Green Deal, a visionary plan that sets the EU's goals and roadmap for achieving climate neutrality by 2050. The European Green Deal encompasses various areas, including the circular economy, as it seeks to transform Europe into a sustainable and resource-efficient economy (EC, 2021).

3.1.1 The European Grean Deal (EGD)

The European Green Deal (EC, 2019) is the EC's overarching sustainable development strategy of the European Commission to 2030/2050. It aims to transform the EU into a resource-efficient and competitive economy which will be climate neutral by 2050, and in which economic growth is decoupled from natural resource use. Achieving this requires changes to the way in which Europeans produce and consume in the coming decades, with the Green Deal implying alterations in material and recycling flows including a rapid reduction of fossil fuels in view of the 2030/50 climate targets, increasing recycling, material efficiency, and circularity across EU industries, more intensive use of existing buildings and vehicles, and food waste reduction targets. (ETC-CE, 2023)

The Green Deal aims to enable Europe to become a climate-neutral, resource-efficient, and competitive economy by:

- reducing greenhouse gas emissions by at least 55 % by 2030 (the Fit for 55 package) and by becoming climate neutral by 2050 – i.e., to strongly reduce fossil energy carriers by 2050; and
- decoupling economic growth from resource use, especially through policies targeting the energy transition, mobilising industry for a circular economy, introducing sustainable and smart mobility, the farm-to-fork strategy, and encouraging sustainable and energy-efficient buildings, thereby gradually increasing materials efficiency across the whole economy.

3.1.2 The Circular Economy Action Plan (CEAP)

Building upon these efforts, on 11 March 2020, the European Commission adopted a new circular economy action plan. This updated plan aligned with the goals of the European Green Deal and focused on specific actions and measures to accelerate the transition to a circular economy (EC, 2021). The plan emphasized sustainable product design, waste prevention, recycling, and the use of secondary raw materials. In February 2021, the European Parliament passed a resolution calling for additional measures to be implemented in the new circular economy action plan. The resolution emphasized the importance of achieving a carbon-neutral, environmentally sustainable, toxic-free, and fully circular economy by 2050. The Parliament specifically highlighted the need for stricter recycling rules and binding targets for materials use and consumption to be set by 2030. Subsequently, in March 2022, the European Commission unveiled the first set of measures aimed at accelerating the transition to a circular economy, as part of the circular economy action plan.

Under the CEAP sustainable product policy framework, "the (European) Commission will consider establishing sustainability principles and other appropriate ways to regulate the following aspects" (Chapter 2 of the CEAP): improve product durability, reusability, upgradability and reparability; increase recycled content in products; enable remanufacturing and high-quality recycling (i.e., reducing material consumption through longer lasting products and using less material by design, and enhanced end-of-life recycling).

Under the CEAP's enhanced waste policy proposal, the Commission aims to, for example, significantly reduce total waste generation and halve the amount of residual (non-recycled) municipal waste; … put forward waste reduction targets for specific waste streams; … and ensure high quality recycling through, for example, separate waste collection systems (Chapter 4 of the CEAP) – i.e., enhanced end-of-life recycling and waste prevention. For example, the CEAP 2020 states "*the Commission will propose a target on food waste reduction, as a key action under the forthcoming EU Farm-to-Fork Strategy, which will address comprehensively the food value chain*". Furthermore, the Commission aims to significantly reduce total waste generation and halve the amount of residual (non-recycled) municipal waste by 2030. (ETC-CE, 2023)

3.1.3 The Waste Framework Directive

The Waste Framework Directive[1], a fundamental element of European Union waste management policy, establishes a comprehensive framework for managing waste with the aim of promoting sustainability and resource efficiency. Key provisions within this directive encompass several crucial aspects of waste management. As its core, the directive introduces the waste hierarchy, a prioritization framework emphasizing waste prevention as the top choice, followed by waste preparation for re-use, recycling, other forms of recovery, and, as a last resort, disposal. Additionally, the directive sets specific recycling targets for various types of waste materials. For example, by 2020, recycling and preparing for re-use of household waste materials, including paper, metal, plastic, and glass, should reach a minimum overall weight of 50%. Recognizing the heightened environmental and health risks associated with hazardous waste, the directive enforces stricter control measures. Specifically, it prohibits the mixing of hazardous waste with other categories of hazardous or non-hazardous waste, ensuring a higher level of safety and environmental protection.

Moreover, the directive provides criteria to determine when certain waste materials cease to be waste and attain the status of products or secondary raw materials. Currently, end-of-waste criteria have been established for priority waste streams, including iron, steel, and aluminium scrap, glass cullet, and copper scrap. Furthermore, integrated into the Waste Framework Directive, the Extended Producer Responsibility (EPR) concept represents a pivotal shift in waste management responsibility. It transfers the responsibility for managing certain waste streams from consumers to producers. Producers are now legally obligated to take extended responsibility for their products throughout their entire lifecycle, including proper waste management. EPR applies to various waste streams (household packaging waste, household and professional waste electrical and electronic equipment, edible oils and fats, old tyres, non-food oils, end-of-life vehicles, batteries, accumulators and torches, lead starter batteries, expired and unused medicines, non-household packaging waste). In line with the EU Strategy for Sustainable and Circular Textiles, the European Commission has proposed an amendment to the directive addressing textile waste. The amendment includes mandatory and harmonized EPR schemes for textiles across EU member states, with financial contributions based on circularity and environmental performance.

[1] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain directives.

3.1.4 The Critical Raw Material Act (CRMA)

On 16 March 2023, the EC published a communication (COM(2023) 165 final) and a proposed regulation (COM(2023) 160 final) called the Critical Raw Material Act (CRMA). Both describe a proposal for a series of measures to ensure access to and supply of critical raw materials. The measures aim at reliability, diversification, affordability, and sustainability. The Council and the European Parliament reached a preliminary political agreement on the CRMA on 13 November 2023. On 12 December 2023, the Parliament gave the final green light to the CRMA. The legislation must now be formally adopted by the Council before publication in the Official Journal for it to enter into force in early 2024.

Achieving the EU's green and digital objectives ('twin transition') and strengthening its strategic space (and aerospace) and defence sectors requires unhindered access to raw materials. Although demand for critical raw materials is expected to increase dramatically, Europe is heavily dependent on imports for this, often from third-country suppliers with near monopoly. The EU needs to mitigate the risks to supply chains associated with such strategic dependencies to increase its economic resilience.

The communication, together with the proposed regulation, on critical raw materials draws on the strengths and opportunities of the single market and the EU's external partnerships to diversify and make the EU's critical raw materials supply chains more resilient. The critical raw materials legislation aims to improve the EU's capacity to monitor and mitigate the risk of supply disruptions and improves circularity and sustainability.

The Raw Material Initiative (COM(2008) 699 final), the Circular Economy Action Plan '(CEAP) 2020 and the REPowerEU plan all already address increasing the resilience of the European economy and include concrete actions to ensure access to critical raw materials (CRM). The CEAP addresses resilience directly to a lesser extent. It describes actions towards more sustainable products that have an impact on resource availability, admittedly broader than critical raw materials. Nevertheless, the 2023 communication recognises that we need to do more. Both broadening and accelerating actions are needed, both for the supply of primary and secondary raw materials in Europe. Addressing the demand side for raw materials is also discussed. The focus includes resource efficiency and circular economy. The circular economy focuses on eco-design, recycling, and substitution. The communication recognises that complete self-sufficiency is not feasible, and that Europe will continue to depend on imports for most of its consumption. Building and improving international trade relations therefore remains high on the agenda.

The communication [COM(2023) 165 final] is structured around three pillars. Each of these pillars is supported by a series of actions.

- Developing the value chain for critical raw materials in the EU;
    - The proposed regulation (COM(2023) 160 final) sets the overall objective of ensuring the EU's access to a secure and sustainable supply of critical raw materials and includes measures to strengthen the EU's capabilities across the value chain, mining, production capacity and recycling as well as diversification of imports with benchmarks in each case. To ensure that the measures set out in the regulation focus on the most relevant materials, a list of critical and strategic raw materials has been established (this list will be updated at least every four years). A first step in developing an internal capacity in the EU is to gain a better understanding of available resources by developing exploration programmes and updating geological knowledge at least every five years in the EU.

    - Strategic projects to strengthen the value chain of SRMs, for which support should be given to speed up the permitting processes with specific deadlines, a single point of contact for the permitting process and support in finding the necessary funding. In addition to projects considered strategic, member states are encouraged to increase their permitting efficiency for all SRM projects.
    - Member States are also invited to adopt national programmes to increase the circularity of critical raw materials value chains, with a focus on those not yet subject to European obligations and including the recovery of critical raw materials from mining waste.
    - Raising awareness and acceptance among the general public.
    - Coordinating and facilitating the potential creation of strategic stockpiles of SRMs.
    - Coordinating the monitoring of the CRM supply chain and stress tests on the supply of SRMs.
    - Financial support (InvestEU, taxonomy regulation, state aid) to co-support significant investments in new and additional production capacities of critical raw materials.
    - The development of European standards for the exploration, extraction, refining and recycling of critical raw materials. In addition, technical requirements for processing, including recovery, recycling and preparation for re-use of critical raw materials should be supported through standardisation (from Chapter II.3, COM(2023) 165 final).
    - Actions on the need for a workforce equipped with the right skills for the green and digital transition.
    - Research and innovation in the critical raw materials value chain is essential for the development of knowledge, innovative solutions and highly sustainable processes for exploration, extraction, processing, refining, recycling, substitution, and design for resource efficiency. Each of these parts of the value chain has its challenges related to geological availability, mineralisation characteristics, chemical properties, applications and energy, environmental and social performance. Research on these challenges is needed for critical and non-critical raw materials to address supply-related hurdles and curb rising demand in the EU. The EIT Raw Materials' mission closely aligns with this.
- Promote diversification of supply sources and establish mutually beneficial partnerships to support global production; and
    - Wide range of tools to facilitate trade, investment, and cooperation to create global opportunities to increase security of supply and affordability of critical raw materials.
    - Establish a critical raw materials club, bringing together consuming and resource-rich countries. The EU should work with partners (including through sustainable investments) in promoting a reliable, commercially based, transparent and environmentally friendly supply of critical raw materials.
- Promote sustainable supply chains and circularity.
    - Increase efforts to reduce any negative impacts, both within the EU and in third countries, on labour rights, human rights, and environmental protection.
    - As most critical raw materials are metals, they can be recycled. This offers opportunities to move to a truly circular economy in the context of the green transition.
    - Promote sustainability and circularity.
    - Low recycling rates for most critical raw materials. At least in the medium term, increasing recycling rates of waste containing critical raw materials, as well as promoting efficient use and substitution of critical raw materials, offers great potential to reduce

dependencies, build value chains and create local jobs (e.g., in the recycling industry, research on substitution, in repair shops).

Given the complexity and transnational nature of CRM value chains, uncoordinated national measures to promote a secure and sustainable supply of CRM could lead to competitive distortions and fragmentation of the internal market. A common EU framework serves to jointly address this challenge. Actions from Flanders cannot go against the basic principles of the European single market. We also need to co-assess the embedding and impact of Flemish actions on European value chains. A reinforcing effect should therefore also be aimed at from a European standpoint. Beyond economic interests, social and environmental perspectives also need to be addressed.

The objectives of the proposed regulation are:

- Strengthening the different steps in the European value chain around CRM;
- Diversifying the import of SRM;
- Improving monitoring and resilience to (risks of current and future) supply problems for SRM; and
- Ensuring free trade of CRM and products containing CRM in the single European market, while improving circularity and sustainability.

The Council and the European Parliament reached a provisional political agreement on the CRMA on 13 November 2023. This agreement sets **benchmarks** for internal capacity across the strategic raw materials supply chain and to diversify the EU's supply by 2030 at the latest as follows:

- At least 10 % of the EU's annual consumption of strategic raw materials will come from extraction within the EU, as far as Union supplies allow;
- At least 40 % of the EU's annual consumption of strategic raw materials comes from Union processing capacity;
- At least 25 % of the EU's annual consumption of strategic raw materials comes from recycling within the Union;
- No more than 65% of the annual consumption of each strategic raw material in the Union at any relevant stage of processing comes from one third country (imports).

3.2 THE BELGIAN LEVEL

Belgium published in 2021, **the Federal Action Plan for a Circular Economy (2021-2024)**, which outlines several key initiatives to accelerate the transition towards a circular economy in Belgium. One of these initiatives is the establishment of an intra-Belgian platform on the circular economy, which aims to facilitate collaboration and ensure coherence among regional and federal administrations. The platform focuses on addressing barriers related to financing and identifying legislative, technical, and financial challenges in the transition to a circular economy in Belgium (SPF Environnement, 2021).

The Federal Action Plan includes various measures, such as improving the recyclability of products, promoting repairability through mandatory labelling indicating the repairability index, developing a reliable certification system for recycled content, defining a public policy strategy with partners for substituting hazardous chemicals to enhance product circularity, phasing out certain single-use products and promoting reusable alternatives, and supporting the development of an efficient digital system for tracking material flows to increase transparency and ensure high-quality and safe recycling (SPF Environnement, 2021).

In July 2020, the European Council agreed on the implementation of a recovery plan for Europe, called "Next Generation EU" to address the socio-economic consequences of the COVID-19 crisis (European Council, 2020). As part of this plan, Belgium submitted **its Recovery and Resilience Plan (PRR)** to the European Commission in April 2021, outlining projects from various entities in the country. The PRR includes public investment projects and structural reforms aligned with the European Semester's country-specific recommendations and national energy and climate plans (European Parliament, 2022). Within this framework, the federal government will implement **the "Belgium Builds Back Circular" investment project**, aiming to finance projects in eco-design, substitution of hazardous chemicals, and raising awareness among SMEs about the circular economy (SPF Economie, 2023).

In 2024, the creation of the **knowledge cell resources** is planned. An initiative from the Cabinet Khattabi is behind the establishment of the knowledge cell within the Federal Institute for Sustainable Development (FIDO/IFDD). The aim of the knowledge cell, through analysis, evaluation, and advice, is to

- make Belgian society as independent as possible from the availability of primary raw materials for the products it produces and consumes; the ultimate goal is to achieve "raw material neutrality";
- preparing Belgian society for resource shortages by reducing the negative economic, social, and environmental consequences of this resource shortages; and
- mitigate the negative domestic and global social and environmental impacts of current and foreseeable resource consumption by Belgian production and consumption to a minimum (due diligence).

3.3 AT THE REGIONAL LEVEL

3.3.1 Wallonia

In Wallonia, several plans and strategies emphasize the importance of circularity and aim to promote a transition towards a circular economy. The **Walloon Plan for Resources and Waste** sets ambitious objectives to reduce waste generation and increase circularity through measures such as waste avoidance, reuse, sorting, and recycling (SPW, 2023a). **Circular Wallonia**, the region's first circular economy deployment strategy, focuses on key sectors like construction, water, metallurgy, textiles, plastics, and food. It aims to monitor and foster the development of the circular economy in Wallonia (SPW, 2023b).

The 2030 Air, Climate, and Energy Plan serves as Wallonia's roadmap for meeting European and international obligations. It includes the objective of promoting a circular and functional economy while reducing energy and resource waste. The Smart Specialisation Strategy (S3) targets priorities and challenges specific to the region, with one of the competitive poles being resource efficiency (SPW, 2019). Additionally, the **Climate-Employment-Renovation Alliance (ACER)** was established to facilitate energy renovation in buildings through partnerships and the implementation of the Long-Term Renovation Strategy (SPW, 2021).

3.3.2 Flanders

On 25 March 2016, the Government of Flanders approved the transversal policy framework **Vision 2050**, which sets out a long-term strategy for the region. It aims to create an open, social, resilient, and international region that combines prosperity and well-being in a smart, innovative, and sustainable manner. One of the seven explicitly defined transition priorities in Vision 2050 is the circular economy (Vlaanderen, 2018). In 2017, **Circular Flanders (Vlaanderen Circulair) was established as the hub and**

inspiration for the circular economy in Flanders. It operates as a partnership between the government, private sector, civil organizations, and knowledge institutions under the coordination of OVAM (the Public Waste Agency of Flanders). The current government of Flanders has reaffirmed its commitment to transforming the region into a circular economy leader in Europe by 2030. To achieve this, it aims to decouple the material footprint of Flemish consumption from economic growth and reduce it by 30% by 2030 (Vlaanderen Circulair, 2023).

Within the framework of Circular Flanders, various strategic agendas and action plans have been developed to address specific sectors and challenges. **The Circular Construction Strategic Agenda**, led by the Confederation of the Construction Industry and OVAM, focuses on advancing circular practices in the construction sector. Other initiatives include the **Flemish Action Plan for Circular Food Loss** and **Biomass Residues 2021-2025**, **the Bioeconomy Policy Plan**, and **the Flemish Implementation Plan for Plastics 2020-2025**. These plans aim to promote circularity and sustainable resource management in their respective sectors (Vlaanderen Circulair, 2023).

3.3.3 Brussels

In the Brussels Capital Region, two primary plans and strategies incorporate elements related to the circularity of material flows as well as resilience towards resource efficiency. The **Resource and Waste Management Plan (2018-2023)** legally implements regional waste policy. The idea behind the Plan is to go from and “end-of-pipe” perspective to a “cradle-to-cradle” one. As such, the general objectives are to anchor a transformation towards more sustainable and circular consumption practices; to maximise the preservation and recovery of materials, locally where possible and to encourage the supply side of the economy to adopt circular practices (Bruxelles Environnement, 2023a).

The **Shifting Economy** is the Brussels-Capital Region's Economic Transition Strategy and is defined as "the gradual transformation of the Brussels activities to contribute to local and global social and environmental challenges, as well as to the creation and maintenance of quality employment for the people of Brussels”. One of the cross-functional policies of the Shifting Economy is the “access to resources, local production and logistics”. This policy is aimed at reducing direct and indirect environmental impacts and boost business productivity by selecting raw materials with a high level of environmental quality, increasing the rate of use of sustainable resources in production activities and by supporting ecosystem so that supply is available and accessible, through reuse, sorting of materials at source remanufacturing, upcycling, and recycling (The Shifting Economy, 2023).

4 STATE-OF-THE-ART METHODOLOGIES

4.1 EU MONITORING FRAMEWORK FOR THE CIRCULAR ECONOMY

The European Union monitoring framework for the circular economy, developed by the European Commission, plays a vital role in tracking the progress of circular economy initiatives within the EU. The monitoring framework focuses on key indicators and tools used to measure the transition towards a more circular and resilient economy. Indeed, by measuring various aspects of production, consumption, waste generation, waste management, secondary raw materials, competitiveness and innovation, and global sustainability resilience, the framework offers insights into the effectiveness of circular and resilient economy policies and identifies areas for improvement (Eurostat, 2023a). The EU Monitoring Framework includes a total of 27 individual indicators, which are detailed in the annex. It is worth noting that most of these indicators are accessible not only at the EU level but also for individual Member States.

Additionally, the EU Monitoring Framework comprises three crucial components that are particularly relevant for discussion in this research paper due to their significance in measuring circularity, resilience, and self-sufficiency. The first component is **the Sankey diagram**. This visual tool provides a clear representation of material flows within the economy. The diagram depicts the flow of materials from extraction to production, consumption, and ultimately, their fate as residuals or their reintroduction into the economy. The data for these diagrams are categorized into biomass, metal ores, non-metallic minerals, and fossil energy carriers/materials. The second key element is the **Circular Material Use Rate** (Eurostat, 2023a), which indicates the circularity of materials in the economy and refers to the share of the total amount of material used in the economy that is accounted for by recycled waste. The third component comprises a **set of indicators related to material footprints**. These indicators quantify demand for material extractions triggered by consumption and investment by households, governments and businesses (Eurostat, 2023d).

4.2 CIRCULARITY METRICS LABS

The European Environment Agency's Circularity Metrics Labs (CML) employs a diverse range of data sources, including European datasets, national statistics, surveys, and innovative data flows, to offer insights into the advancement of the circular economy. Its primary purpose is to complement existing monitoring frameworks by presenting supplementary evidence regarding circularity. While the material flows cluster primarily relies on the EU Monitoring Framework, other clusters within CML encompass various facets of the circular economy. These additional aspects encompass elements related to business innovation, such as Ecolabel certification in each Member State, eco-innovation, circular economy lending and financing, and more (EEA, 2023).

4.3 MAYER'S MONITORING FRAMEWORK

Mayer and colleagues developed a monitoring framework that aims to provide tools for monitoring material flows in a circular economy at a macro level. The goal is to capture system-wide effects and assess the achievement of absolute reductions in resource use and waste flows (Mayer et al., 2018). The framework builds upon previous studies conducted (Haas et al., 2015), which focused on system-wide assessments of a circular economy at the global and European levels. The study describes certain indicators that are currently absent from the EU monitoring framework (especially the Sankey diagram) and incorporating these indicators would provide valuable insights into the evaluation of Belgium's circularity. In fact, the authors present the **circularity rates**, which evaluate the cycling of resources in relation to input and output flows (Mayer et al., 2018). They identified three categories of circularity rates: socioeconomic cycling, ecological cycling potential (EC), and non-circularity (NC). Processed materials in an economy can be broken down into different categories, like biomass, non-metallic minerals, fossil carriers, and metal ores. Cycling indicators help us understand how much secondary materials are contributing to these processed materials and their output flows (SC). They also tell us about the role of primary biomass in the DMC and its presence in processed materials (EC). Together, these indicators give us an idea of how circular a country's economy is. Anything not covered by these circularity rates is considered non-circular (NC). It is important to distinguish these circularity rates from **scale indicators**, which measure the overall size of the socioeconomic system (as described by O'Neill in 2015).

Furthermore, Mayer's research introduces an aspect not addressed by the EU Monitoring Framework. In the framework, waste is categorized solely based on material use, without distinguishing whether it originates from short-lived items (throughput materials) or stock-building materials. This distinction highlights different circularity-driven approaches to waste reduction. Indeed, one approach focuses on extending the lifespan of existing stocks (product lifetime extension), while the other centres on more efficient resource utilization. Examining these aspects over time can shed light on the integration of reuse within the economy. Mayer’s et al. approach offers a method for calculating the proportion of waste arising from these two material use categories.

4.4 AGUILAR-HERNANDEZ’S INDICATOR

Following Mayer's Monitoring Framework, a complementary indicator known as the **Circularity Gap (CG)** enhances the assessment of a country's economic circularity. The aim is to pinpoint waste that remains unrecycled and is available for potential material circularity improvements (Aguilar-Hernandez et al., 2011).

4.5 CIRCULARITY GAPS REPORTS

Circle Economy has pioneered a methodology for producing Circularity Gap Reports, which have gained recognition in several countries, including Austria, the Netherlands, Norway, Sweden, Poland, Northern Ireland, Scotland, Switzerland, and the UK (Circle Economy, 2023). These reports introduce a fresh perspective on circularity assessment, offering several improvements. Indeed, they employ a Sankey Diagram like the one of the EU Monitoring Framework, albeit with notable distinctions. One key difference is in distinguishing between imports based on physical weight and the actual material import footprint. This distinction is important because it recognizes that imported volumes may result from manufacturing processes conducted elsewhere before arriving in the country. A similar approach is applied to exports. Additionally, like the Sankey diagram in the EU Monitoring Framework, these reports categorize material flows into key categories such as biomass, fossil fuels, non-metallic minerals, and metal ores. However, they go beyond this by meticulously tracking how these material flows are strategically allocated to meet various societal needs, spanning sectors like housing, communication, mobility, healthcare, consumables, nutrition, and more. Furthermore, the reports identify the sources of waste and classify them as originating from either short-lived products or existing stocks. Another noteworthy aspect introduced is the consideration of re-exports and net imports in the Sankey diagram.

4.6 ECONOMY-WIDE ASSESSMENT IN FLANDERS

Following the material flow analysis conducted for Flanders during the period 2002-2018, which was published by the Circular Economy Policy Research Centre in June 2020, the centre released another study in 2021 (CE Center, 2021). This study aimed to establish a connection between the inflow and outflow of materials in the Flemish economy and the internal material flows. The primary objective of the report was to gain a comprehensive understanding of the physical material flows within Flanders, assess its current circularity status, monitor its progress, and explore strategies to further enhance circularity. The study employs previously discussed indicators, with the aim of delving deeper into the circularity aspects of the region. For example, it distinguishes between scale indicators and circularity rates within the Flemish material flow economy, in addition to calculating the circularity gap. Notably, the study challenges the validity of the CMUR developed by Eurostat and proposes alternative indicators utilized by other methodologies. Furthermore, to refine the assessment of circularity within the region, the study suggests an enhanced framework for material flows based on Mayer's et al. Sankey diagram. This novel framework introduces a unique element within the Sankey diagram known as the Waste Management System (WMS). Through this system, waste imports and exports (as well as waste destined for recycling) can be identified, providing a more detailed view of waste flows, and isolating them from conventional imports and exports.

4.7 THE EU'S RAW MATERIAL SCOREBOARD

The Raw Materials Scoreboard, initiated by the European Innovation Partnership (EIP) on raw materials, is a critical source of monitoring data. It serves government authorities, industry stakeholders, and aligned parties in line with EIP's objectives. The Scoreboard offers a comprehensive view of the raw materials supply chain through 26 key indicators in six clusters: EU raw material supply, global context, circular economy and recycling, competitiveness and innovation, environmental and social dimensions (EIP, 2021).

In the circular economy and recycling cluster, several indicators are derived from the EU Monitoring Framework. While these indicators may not offer alternative perspectives, other clusters hold value in assessing raw material resilience, particularly. For instance, some indicators provide valuable insights into minerals exploration, mining production projects encompassing 25 primary commodities, and production trends for selected metals within the EU. It sheds light on the EU's contribution to global production, its dependence on imports, and the status of critical raw materials subject to export restrictions. This resource plays a crucial role in identifying key countries with monopolies or significant involvement in the extraction or processing of critical raw materials. Import reliance indicators are particularly noteworthy, focusing on essential raw materials like cobalt, copper, platinum, and rare earth elements (while the EU Monitoring Framework focuses on the four main flow categories). Concerning the circular economy aspect, the Scoreboard utilizes Sankey diagrams to visually represent the movement of materials into and out of the economy for individual critical raw materials within the EU, based on the list of identified critical raw materials (EIP, 2021).

4.8 RESOURCE PANEL DATA BASE

The Global Material Flows Database created by the UNEP provides data to assist governments, policy researchers, and interested stakeholders in understanding and tracking the connections between economic growth and the use of raw materials. The database is built upon authorized and publicly accessible international data sources whenever possible, coupled with the most recent methodologies for establishing material flow accounts. It spans the period from 1970 to 2019, covering over 200 countries and reporting on the extraction and direct trade of raw materials, indirect trade flows (including material footprints), and the derived intensities from these material measurements (UNEP, 2023).

The database offers a detailed granularity of material flows, in contrast to the EU Monitoring Framework's Sankey diagrams, which primarily cover four flows (biomass, metal ores, non-metallic minerals, and fossil fuels). In the Global Material Flow Database, six additional categories are included for manufactured materials and waste. Four of these categories pertain to "products mainly from..." manufactured for each of the main categories of raw materials, while another category covers complex/mixed manufactured items, and one last category deals with internationally traded waste. Furthermore, an additional category, "excavated earthen materials (including soil)" is included as a placeholder to record material flows that have not traditionally been included in direct material flows (UNEP, 2023).

5 STATE-OF-THE-ART REGIONAL DATA SOURCES AND METRICS

There are various data sources available at different levels of aggregation: regional, federal, European level.

At European level ESTAT publishes material flow related data in mainly the themes international trade, energy, material flows and resource productivity, and waste. The data on **material flows and resource productivity** collects the following material flows variables, based on economy-wide material flow accounts (which exclude water and air):

- domestic extractions of materials, broken down by material categories (biomass, metal ores, non-metallic minerals and fossil energy materials/carriers)
- imports and exports of materials
- domestic processed outputs and emissions to the air

Some indicators which are derived from the economy-wide material flow accounts are:

- domestic material consumption (DMC): It measures the total amount of materials directly used by an economy. It is defined as the annual quantity of raw materials extracted from the territory of a country, plus all physical imports and minus all physical exports.
- resource productivity: It is the gross domestic product (GDP) generated per unit of domestic material consumed (DMC). GDP is a measure of economic production and wealth; DMC is a measure of natural resources extracted. Their ratio indicates the ability of our economies to create wealth with fewer extractions of natural resources, or to create more wealth with the same amount of extractions. This is called 'decoupling' whenever we break the link between environment extractions and economic growth.
- material footprint: This is also called raw material consumption (RMC). It measures the worldwide demand for material extractions triggered by consumption and investment in the European Union.

Regular statistics on waste generation and treatment for the whole economy and on specific waste streams are published under the **waste** theme. Statistics are compiled on the following topics:

- Waste generation and treatment
- Management of waste
- Shipment of waste between countries
- Key waste streams:
    - Batteries
    - End of life vehicles
    - Hazardous waste
    - Municipal waste
    - Packaging and packaging waste
    - Annual consumption of lightweight plastic carrier bags
    - Waste electrical and electronic equipment
    - Waste excluding major mineral wastes.

The European Environment Agency (EEA) indicators are designed to support all phases of environmental policy making, from designing policy frameworks to setting targets, and from policy monitoring and evaluation to communicating to policymakers and the public. The indicators linked to the theme of resource efficiency and waste are:

- Circular material use rate in Europe
- Diversion of waste from landfill in Europe

- Europe’s consumption footprint
- Europe’s material footprint
- Waste generation in Europe
- Wate recycling in Europe

The **EEA's Circularity Metrics Lab** (CML) uses a range of sources such as European datasets, national statistics, surveys, and novel dataflows to provide insights on progress towards the development of the circular economy. It is intended to complement other monitoring frameworks by presenting additional evidence on circularity, including metrics focussed on the implementation of circular principles and practices.

Also, EU-funded project results are also of interest. Examples are:

- **FutuRam**: FutuRaM will develop the Secondary Raw Materials knowledge base on the availability and recoverability of secondary raw materials (SRMs) within the European Union (EU), with a special focus on critical raw materials (CRMs). The project research will enable fact-based decision making for the recovery and use of SRMs within and outside the EU, and disseminate the data generated via an accessible knowledge base developed in the project.
- **CE-RISE**: CE-RISE will develop and pilot an integrated framework and an ensuing resource information system to identify optimal solutions for the effective reuse, recovery, and/or recycling of materials.
- **WEEE-NET9**: WEEE-NET sets up a novel e-waste (WEEE) recycling business ecosystem by introducing an innovative mixture of gravitational, hydro- and bio-metallurgical technologies. Beneficiaries of this innovative technology are WEEE recycling plants, collectors, and sorters as well as territorial waste management public authorities.
- **DiCE**: Electronic waste (e-waste) from digital health devices is a complex and growing problem requiring a holistic solution. E-waste from healthcare products may pose biological or chemical contamination, leading to its incineration, with or without energy recovery. This means that all items are destroyed. DiCE was created to bring key stakeholders together to address challenges associated with the growing use of digital healthcare products and increasing demand for raw materials to manufacture new electronic devices and other equipment.
- **GRINNER**: The GRINNER project aims at commercialising an autonomous AI-enabled robotic sorting system capable of detecting and removing waste containing batteries from current waste streams before they enter inhospitable-to-battery machines that crush and consolidate waste. The system will comprise the fastest Energy-resolved X-Ray detectors in the market, an ML-enabled software module that will analyse X-Ray data and effectively detect waste containing batteries while passing through the waste flow and vision-based pick-and-place robot(s) that will remove the flagged WEEE.
- **CircThread**: CircThread wants to swiftly increase appliance lifespan, repairability and reuse, and products to be properly recycled when they are no longer repairable. The objective is to interconnect the information along the life of a product, from concept to retirement, so that it can be easily accessed and shared. This will allow you and others to make decisions at all stages to shift to a circular economy. To make this information available, we will develop, test, and share our open-source software platform within the next four years. It will enable digital exchanges of data across the extended product life cycle.

At Federal level the trade statistics and the household budget survey are available, and some dedicated datasets like, for example, the building stock.

The following sections will describe this data sources at regional level and mainly concern the waste generation and treatment as these are regionalised powers in Belgium. The following data sources have been identified as relevant to the scope of the CAMBIUM project.

5.1 WALLONIA

Industrial waste generation and management: The data is derived from a survey conducted among approximately 400 industrial units, and then extrapolated to encompass the entire industrial sector in the Walloon region. This dataset includes information on both waste generation and waste management. Regarding waste generation, it compiles data on the quantities generated based on NACE and EWC classifications. As for waste treatment, it provides information on the quantities treated for each type of treatment. In addition to waste-related data, the survey also offers insights into various other aspects within the sampled industries, such as energy production and consumption, air emissions, water usage, wastewater discharges, and environmental expenditure. This comprehensive dataset is available on an annual basis.

Cetra survey on household waste statistics: The survey gathers data on the collection, recovery, and disposal of household waste generated by each municipality within its respective territory. This data is collected by waste management companies operating at the intermunicipal level. Specifically, the following information is available on an annual basis: quantities of waste collected, categorized by the type of waste, which is further divided based on the various fractions present in recycling centres (1); quantities of waste collected based on their source of origin, which includes municipal waste, recycling centres, flood-related waste, waste from public cleanliness efforts, door-to-door collection, and "bulles" (community recycling bins) (2). This data is collected for each intermunicipal management company individually and can also be aggregated to provide a total for the Walloon Region. Additional details include : the initial destination of the collected waste; subsequent waste streams after the initial destination, which includes the type of outgoing waste, the destination it is sent to, and the type of treatment it undergoes; annual quantities of waste that are incinerated.

Fedem survey on statistics and fees for separate collection of household waste: the survey collects information on the collection, recovery and disposal of waste by the recycling centres and the intermunicipal waste management companies. The data set available on a yearly basis is the following: quantities of waste by type of collection; the quantities by type of waste; total quantities by type of waste.

Coditax survey on the tax declaration concerning landfilling, incineration, co-incineration and the subsidiary tax on waste collection and management: the yearly available data through this survey is the following: movements of waste into a landfill, incineration or co-incineration facility with a description of the waste, the waste code from the Walloon waste catalogue, the quantity of waste treated, the tax code.

Energy balances of the region: the energy balance of the region gives useful information about the energy consumption by type of source (nuclear, natural gas, renewable sources, solid fuels, and petroleum products) and by sector (industry, transport, tertiary sector, housing, agriculture).

Social economy enterprises data: social enterprises receive grants and subvention from the region, they have to send back to the regions the following information every year: the geographical area covered by their collection; the number of tons collected, sorted, processed and put back on the market annually; the number of tons reused annually in the Walloon Region, by type of waste and product or product component, for which the reuse company is authorised; the nature, quantity and destination of the waste, products or product components that are not reused; the manner in which and the place where the goods are put back on the market; a statement describing the different costs that have been incurred annually by the re-use company in the framework of the activities related to its approval.

Material flows report: Every five years, the Directorate for Environmental State within the Department for the Study of the Natural and Agricultural Environment of DGARNE publishes a report on the state of the environment in Wallonia. The primary goal of this report is to offer a critical, evolving, and forward-looking assessment of various facets of the Walloon environment. These reports include an analysis of the impacts of human activities and an evaluation of existing management strategies. In line with a similar report for Flanders, the main objective of this report is to gain a comprehensive understanding of the physical material flows within Wallonia.

5.2 FLANDERS

Industrial waste generation and management: The *Integraal Milieujaarverslag* (IMJV) collects data on the production of industrial waste in Flanders at a selection of companies. Based on this sample of reporting data from companies, the total production of industrial waste in Flanders is estimated per sector and size class. From production year 2012, an overview of the secondary raw materials produced can also be made.

The 'Report on industrial waste and secondary raw materials' describes the methodology used and shows the evolution of the most important indicators since 2004, together with several conclusions. This concerns the production of industrial waste, the decoupling of waste production from economic growth, the amount of industrial residual waste and the share of waste that is given a second life.

The Excel file 'Data on industrial waste and secondary raw materials' consists of several tabs and contains more detailed figures, per sector, per waste stream and per processing method.

Household waste: The total amount of household waste collected by or on behalf of municipalities. These figures also include comparable industrial waste collected by or on behalf of the municipalities.

Trade in waste: The series 'import and export of waste' represents the waste export from the Flemish Region and the waste import to the Flemish Region based on the notifications about waste transports that OVAM has approved.

European rules apply to the cross-border shipment of waste, laid down in European Regulation 1013/2006/EC (European Waste Shipment Regulation or EVOA for short).

Mapping the cross-border transport of waste is important for several reasons. Not only is there a legal obligation (from EU and Basel legislation) in the context of the environmentally responsible processing of waste worldwide, but it also offers opportunities in our transition to a circular economy.

This indicator therefore does not reflect all waste imports and exports to and from the Flemish Region, but only those for which a notification has been granted.

The European Waste List (EURAL) is a harmonized list for coding waste in the European Union.

Key waste streams: data on packaging waste includes the ratio of the amount of recycled packaging waste compared to the amount of packaging placed on the market in Belgium. Waste from electrical and electronic equipment (WEEE) figures indicate the collection percentage and processing results of WEEE for Belgium. The collection percentage is calculated in accordance with the European WEEE Directive (2012/19/EC) by dividing the Out Of Market (OOM) by the average Put On Market (POM) of the 3 previous years. The processing percentages are obtained by dividing the quantities that are reused and recycled and have a useful application (= reuse + recycling + incineration with energy recovery) by the total quantity of WEEE collected from year X. The figures for discarded vehicles indicate the recycling percentages for the processing of vehicles collected at recognized centres in the Flemish Region. This only concerns discarded passenger cars and light vans up to 3.5 tons (category M1 and N1).

Material Consumption data: The material consumption by the economy (Domestic Material Consumption, DMC) describes the material use of an economy's domestic production and consumption, but also considers the export of materials. The DMC measures the total amount of materials directly used by an economy (classified into the material categories biomass, metal ores, fossil energy carriers and non-metallic minerals). By reducing the Direct Material Input or DMI with all exports of goods (EXP), the consumption indicator DMC is obtained: Domestic material consumption (DMC) = Direct material input (DMI) - Physical export (EXP).

The materials footprint (Raw Material Consumption, RMC) describes the total of primary raw materials that are extracted worldwide for the final consumption of goods and services in the Flemish Region. These primary raw materials are classified into 4 material categories: non-metallic minerals, fossil energy carriers, biomass and metals. The RMC provides a picture of the global impact of the needs of the Flemish Region and describes not only the actual quantities of products traded when they cross land borders, but also the indirect raw materials extracted upstream during the entire production chain of these traded goods and services.

The RMC is based on the Economy-Wide Material Flow Accounts (EW-MFA), which are required to be reported by each Member State of the European Union to the European statistical office Eurostat. The physical import flows (IMP) and export flows (EXP) are converted into raw material equivalents (IMP-RME & EXP-RME) using European aggregated RME coefficients. Eurostat annually estimates the RME coefficients for almost 190 European product groups based on a European model.

Raw Material Consumption (RMC) = Domestic Extraction Used (DEU) + Imports in raw material equivalents (IMP-RME) – Exports in raw material equivalents (EXP-RME)

Energy balance: The energy balance of the region gives useful information about the energy consumption by type of source (nuclear, natural gas, renewable sources, solid fuels and petroleum products) and by sector (industry, transport, tertiary sector, housing, agriculture). The Flemish Energy Balances in GWh and in PJ provide insight into the evolution of gross domestic energy consumption in Flanders, and the energy flows per energy carrier from 1990 onwards.

CE-monitor Flanders[2]: The Flemish CE Center is working together with numerous transition partners on a Flemish monitor for the circular economy. The current monitor bundles together more than 100 indicators, supplemented with some analyses of these indicators.

Monitor groene economie[3]: The *monitor groene economie* of the Vlaams Departement Omgeving maps out how sustainable the transition of the Flemish economy is. The indicators used are based on the OECD's Green Growth Indicators Framework and indicate how our economy is greening.

Monitoringsysteem Duurzaam Oppervlaktedelfstoffenbeleid (MDO): Data over primaire delfstoffen en alternatieve grondstoffen in Vlaanderen. Het MDO kwantificeert en volgt de evolutie van de minerale grondstoffen stromen in Vlaanderen.

5.3 BRUSSELS

BRUDAWEB mandatory waste report for registered or accredited collector, dealer or broker of waste or an operator of a licensed facility for the collection or treatment of waste: this waste report gives the following information on a yearly basis: information on the owner of the waste, the company in which the waste is sent and the waste itself: EURAL code, description of the waste, quantity and applied treatment.

Data on household and assimilated waste: the data is based on two sources. First, each year waste analysis is carried out and extrapolated to the entire region. This study is applied to residual waste (white bag), PMC (blue bag), and paper and cardboard (yellow bag). The second source of data is the measures of the total tonnage of household waste for all collections (collection by Brussels Propreté of residual waste and selectively sorted waste, glass bubbles, drop-off points for chemical waste (Proxy Chimik), collections by recycling parks, by neighbourhood composts, (e.g., take-back obligations, social economy) and household waste generated per inhabitant. Based on these two sources, the following data are derived yearly: quantities of household waste collected, and quantities of assimilated waste collected.

Data on streams collected in the social economy: social enterprises receive grants and subvention from the region, they must send back to the regions the following information every year: quantities of waste collected per category (DEEE, textiles, second-hand goods, IT) and total quantities of waste reused/recycled/eliminated.

Data on waste prepared for reuse and recycling: this data is derived based on the waste that is collected selectively. The assumption is the following: if a waste is collected selectively, the aim is to prepare it for reuse or to recycle it. The following information is available yearly: categories of waste prepared for reused and recycling and the percentage of waste prepared for reused and recycling There is no distinction in the dataset between the waste being prepare for reuse and the waste being recycled.

Construction/demolition waste and professional waste: for those two sectors studies, respectively from 2012-2013 for construction waste and from 2014 for professional waste are available. The data available in those studies is the following: quantities of construction waste per waste type and indicative percentage of recycling and sorting for construction/demolition waste; quantities of professional waste

[2] https://cemonitor.be/en/about/
[3] https://indicatoren.omgeving.vlaanderen.be/onderwerpen/monitor-groene-economie

per waste type and treatment/destination of professional waste per waste type. Data on those two streams are also available through BRUDAWEB.

6 CONCLUSION

In conclusion, while the EU Monitoring Framework provides a strong foundation for a comprehensive assessment of material flows, circularity, self-sufficiency, and resilience, it is evident from the literature that several studies have ventured further to enhance the analysis. Indeed, some methodologies have introduced additional categories than the conventional categorisation by material type (UNEP, 2023) or have focused on specific flows, particularly in the context of waste (plastics, wood, ferrous and non-ferrous metals), allowing for a more precise granularity of material flows (Eurostat, 2023a). Furthermore, some studies have gone beyond more quantification by tracking how material flows are strategically allocated to serve diverse societal needs across sectors like housing, communication, mobility, healthcare, consumables, and nutrition (Circle Economy, 2020). These same studies have also explored representing an economy in terms of material footprint rather than just physical weight, offering a deeper understanding of resource use. Moreover, certain studies have delved into distinguishing between different types of material use, classifying materials into stock-building materials and throughput materials, and examining the waste originating from each category. Additionally, other studies have also shifted the focus from the simple consideration of waste destined for recycling centres to domestic recycling capabilities or the specific outputs of the recycling process (Circle Economy, 2020). While the EU Monitoring Framework lays a solid groundwork, these endeavours have advanced the field by introducing additional methodologies and dimensions to comprehensively evaluate Belgium's circularity and material footprints.

As part of the WP1, the current state-of-the-art enables us to anticipate the next step in the study, which involves identifying gaps and shortcomings. While this will be elaborated upon in the following phase, we can already highlight a few gaps. Indeed, the standardized sheets provide an indication of whether the methodologies can be applied to Belgium and whether the necessary data is available. For certain specific methodologies, further examination is required. But, when it comes to the concept of the circular economy, a significant gap lies in the fact that incorporating indicators and methodologies that more precisely capture and evaluate reuse efforts would provide a more comprehensive picture. The subsequent step of the study could draw from the Lansink ladder to see what is covered by the various methodologies and what is not. The Lansink ladder is the waste hierarchy emphasizing waste prevention as the top choice, followed by waste preparation for re-use, recycling, other forms of recovery, and, as a last resort, disposal. We already know that the aspect of reutilization is not adequately addressed. Another gap is that some regions, particularly Flanders, have been able to calculate the waste used by businesses as raw materials, depending on whether it is pre-consumer or post-consumer waste. However, it appears to be challenging to calculate this on a national scale for all of Belgium. Nevertheless, this is crucial in order to focus not only on waste intended for recycling, regardless of where it is sent worldwide. This differentiation allows for an evaluation of recycling efficiency by distinguishing between waste collected for recovery and the utilization of secondary materials obtained from waste. Furthermore, it seems that some indicators and metrics are already available at all three levels, but others are only used at the regional level, even though they could address other aspects of the Lansink ladder not currently addressed.

The gap analysis performed by the ETC-WMGE (2021) confirmed that the value retention strategies, encompassing reuse, repair, refurbish, remanufacture and repurpose, are the least covered by indicators in existing monitoring frameworks. Given the fact that the EU definition of CE is “an economy where the value of products, materials and resources is maintained for as long as possible”, the need for more value retention indicators is clear. Following the gap analysis, the exploratory work concentrated on indicators related to the value retention – or the inner circle – strategies.

The study of the CE CENTER – Circular Economy (2021) assessing circular in Flanders adds some points of attention to the CMUR-indicator that calculates the waste generated by domestic consumption, thus primarily reflecting the country's efforts in waste collection for recycling. The numerator of the indicator represents the circular use of materials and is estimated by the quantity of waste recycled in domestic recovery plants minus imports of waste adding exports of waste. It ideally consists of two components. Firstly, residual material that is legally declared as waste, recovered, and reintroduced into the economy after treatment through the legally demarcated waste management system. This component is approximated using waste statistics, which capture the flow of materials that have been legally defined as waste and are subsequently recovered and reintegrated into the economy, thus avoiding the need for primary materials. Only waste flows directed towards "recovery-recycling" are considered, excluding energy recovery and backfilling. Secondly, residual material that falls outside the legal waste management system, such as by-products of production processes. These materials are either internally recycled within the same processes (intra) or sold and processed by external entities through economic transactions. Official statistics do not capture this flow, and therefore, it is not included in the numerator. Moreover, as the CMUR-indicator focuses on the country's efforts to collect waste for recovery, waste collected abroad and imported should be excluded, while waste collected domestically but exported for treatment should be included. According to the study of the CE Center, there is another perspective, which emphasizes the domestic use of secondary material recovered from former waste, is also possible and is called the alternative CMU-rate (CE Center, 2021).

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8 ANNEX 1: DOMESTIC AND RAW MATERIAL CONSUMPTION INDICATOR

DMC AND RMC (OR MATERIAL FOOTPRINT)

The **domestic material consumption** (DMC) is a derived indicator from the economy-wide material flow accounts and is estimated via the formula: domestic extraction (DE) plus imports (IMP) minus exports (EXP).

$$\mathrm{DMC} = \mathrm{DE} + \mathrm{IMP} - \mathrm{EXP}$$

The development of the economy-wide material flow accounts is coordinated by Eurostat and regulated by Regulation (EU) No. 691/2011 (European environmental economic accounts). Eurostat provides a handbook with compilation guidelines and support to the MS to develop their accounts.

The EW-MFA classification of materials for DE are restricted to the material categories MF1 to MF4: biomass, metal ores, non-metallic minerals, and fossil energy materials/carriers. Material categories MF5 (other products) and MF6 (waste for final treatment and disposal) are added in the description of IMP and EXP. A more detailed classification into classes, groups and sub-groups is also available (up to 51 raw material categories).

DMC measures the total amount of materials that are directly used in a national economy, i.e. by resident units. DMC is the amount of materials that become part of the material stock within the economy or are released back to the environment (DPO).

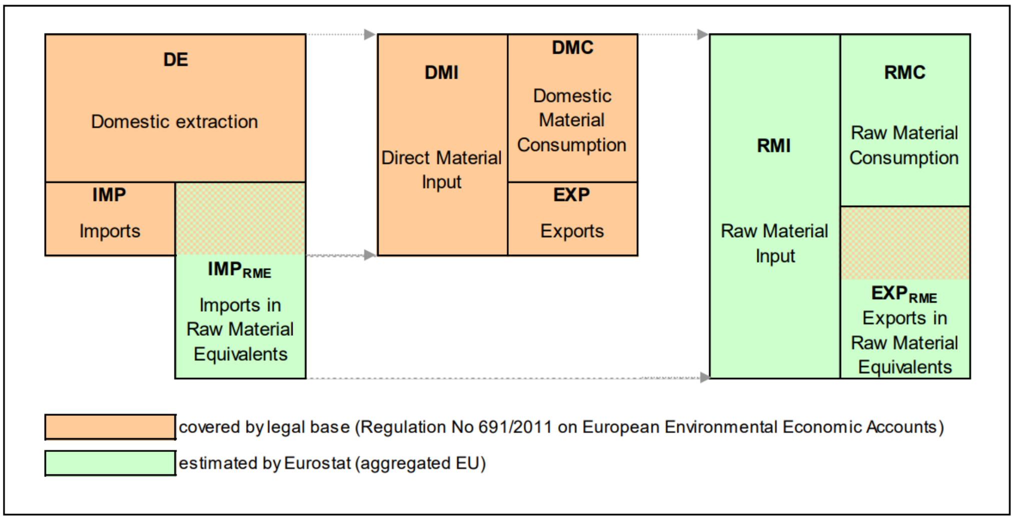


Figure 1: Eurostat's economy-wide material flow indicators and raw material equivalent extensions.

The currently established EW-MFA framework can be extended to enrich the picture of the demand for material resources by national economies. A possible extension is the material flow accounts in raw material equivalents (MFA-RME). MFA-RME account for products in terms of the amount of material extraction necessary to produce them, irrespective of where the material was extracted (sometimes referred to as 'material footprints'). Extending the current framework by compiling MFA-RME enhances the analytical potential of the EW-MFA framework, however, the estimation of MFA-RME requires modelling leading to higher levels of uncertainty.

A feature of the indicators DMI and DMC is that their components DE on the one hand and physical trade (IMP and EXP) on the other hand are measuring two different things, although in the same unit, i.e. tonnes. The former measures the weight of amounts of virgin materials as extracted from the environment while the latter measure the weight of products as crossing borders. This asymmetry is sometimes perceived as a shortcoming.

The weight of a traded product does not represent the extraction of materials that was necessary to produce the traded product. The material extractions needed to produce a product will always be higher than its simple mass weight (as far as no secondary materials were used in production).

Almost all products go through different stages of manufacturing, starting from raw products followed by further processing and assembling into semi-manufactured products and finally into finished products. At each stage the resulting products becomes relatively lighter in terms of actual weight compared to the material extractions needed to produce that product. Not all material inputs into the manufacturing process necessarily become part of the product. For example, products may require energy-intensive processing for which fossil energy carriers need to be extracted, but these are not part of the actual weight of the product itself.

A country may reduce DE, e.g. the mining of metal ores, by increasing the imports of products, e.g. metal concentrates or even further manufactured (semi-)finished metal products in order to meet the same demand as before. Due to the measurement asymmetry between DE and physical trade this country would significantly reduce its DMI and/or DMC, even though the worldwide demand for material resources associated with its production and consumption activities does not change.

The conceptually different measurement of DE and physical trade also hampers comparability of DMI and DMC across countries. Some countries are endowed with material resources which tend to result in comparably higher domestic material extractions whilst other countries do not have exploitable material deposits and need to import raw products or (semi-) manufactured and finished products, which are relatively lighter. Resource-rich countries tend to have a higher DMI and/or DMC compared to resource-poor countries, which must rely on imports to meet the demand for material resources.

In order to overcome the different measurement of components of DMI and DMC, traded products (imports and exports) can be converted into equivalents of DE – called raw material equivalents (RME).

Expressing material flows in RME captures consistently the amount of extracted material needed to produce a certain (set of) product(s); all traded products are converted into the (virtual) amount of material extractions needed to produce it. Extraction of raw materials throughout the product’s entire production chain is considered, irrespective of whether the material extraction took place domestically or in the rest of the world.

Compiling MFA-RME effectively implies allocating material extraction (domestic extraction as recorded in EW-MFA) to products at the stage of their final use. As such MFA-RME provide a consumption-based view of material requirements.

The MFA-RME consists of the components DE, IMP in RME and EXP expressed in RME. They are used to derive the raw material input (RMI), raw material consumption (RMC) and the physical trade balance in RME (RTB). The material categories are equal to those used to describe DE.

Raw material consumption (RMC) represents the domestic final use of products in terms of RME. In other words, RMC captures the amount of domestic and foreign extraction of materials needed to produce the final products used by households, governments or non-profit institutions serving households, or used for gross capital formation. The indicator RMC – also known as 'material footprint' – takes a domestic consumption perspective by excluding exports in RME from the RMI. Broken down by product group, RMC can be used to analyse which final products have the largest impact on material extraction, and hence the largest 'material footprint'.

At the moment, the compilation of the IMP in RME and EXP in RME is on voluntary basis. Eurostat does publish these voluntary submissions and in addition published an EU-estimate.

Depending on the calculation method used, the components of MFA-RME can also be broken down by product group and, in addition, RMC can be broken down in types of final uses (final consumption, gross capital formation, exports). The RME estimates are published in Eurostat's database in two datasets:

- Material flow accounts in raw material equivalents - modelling estimates (online data code: env_ac_rme), which contains indicators in RME by material; and

- Material flow accounts in raw material equivalents by final uses of products - modelling estimates (online data code: env_ac_rmefd), which contains raw material consumption estimates by material, by final product and by type of final use.

The DMC indicator inherently bears two major asymmetries:

- The imports and export are measured in a different "unit" than the domestic extraction (DE). The latter is measured in virgin raw material extraction (e.g. tonnes of gross iron ore which is much heavier than the resulting steel). Trade is measured in simple product weight only (e.g. tonnes of steel).
- The composition of imports and exports can differ leading to a further asymmetry. For the EU, one knows that products with a rather low degree of processing, like metal ores or primary energy carriers, dominate the imports. These raw or semi-manufactured products have a relatively low value of tonne RME per tonne of product in comparison to more finished products. EU exports are rather dominated by finished products, like cars, machinery etc. The weight of the finished products usually represents only a fraction of the weight of raw materials that were originally extracted for their manufacturing. This means that 1 million tonnes of imported products –measured in simple product weight – have a significant lower RME than 1 million tonnes of exported products.

The RME concept overcomes these asymmetries by considering the imports and exports measured in raw material equivalents, which represent the same "unit" as domestic extraction (DE). However, the estimation of MFA-RME requires modelling leading to higher levels of uncertainty.

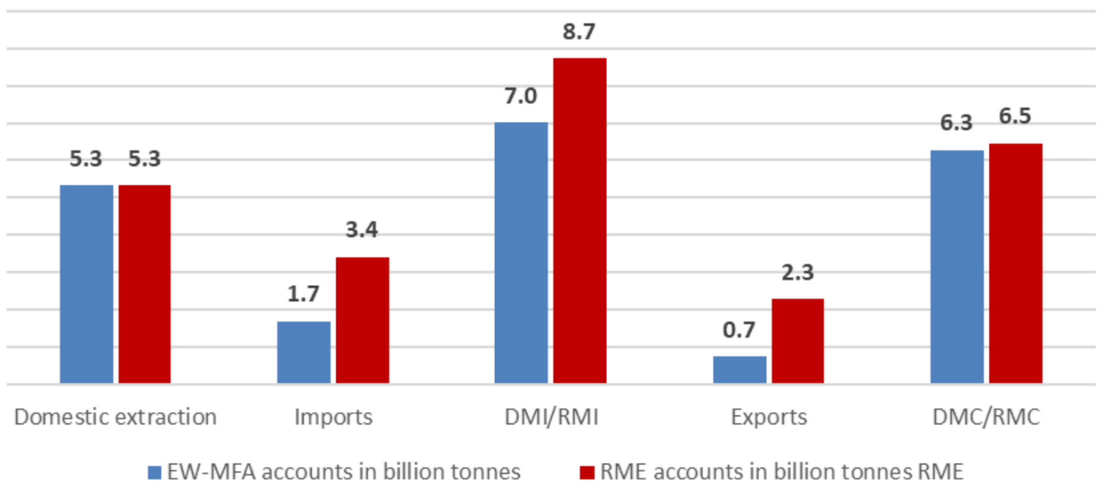


Figure 2: Comparison of EW-MFA and MFA-RME, 2019, EU27_2020, unit: 10^9 tonnes.

The DMC can only be disaggregated to the level of aggregated raw material categories (biomass, metal ores, non-metallic minerals and fossil energy resources) as semi-finished and finished imported and exported products can only be lumped together into rather broad material categories such as “products mainly from biomass” or “products mainly from metals”. It is an important property of the RME accounting system that the accounting identity is not only valid for total materials, but also at the level of individual raw material categories. This implies that the RMC (and RMI) indicator can be broken down to the more detailed material classes, groups and sub-groups. A detailed disaggregation by material flow categories accounts for the fact that different raw material categories can have extremely different characteristics in terms of their environmental impact. The disaggregation is therefore a precondition for a meaningful ecological analysis and interpretation of material flows.

Another advantage is the possibility to establishing an economic link by relating the direct and indirect demand for raw materials by 51 material flow categories to the final use of products by 182 product groups. Further, the underlying IOT establishes a link between the final use of products and the direct economic production and consumption activities. That link is essential for embedding the material flow indicator into an environmental-economic context that is able to relate the demand for raw materials to the economic driving forces.

EU-level reference results of the MFA-RME framework are presented in Chapter 4 of this Eurostat's report (including the raw material productivity).

DMC/GDP (RESOURCE PRODUCTIVITY) - TOTAL RAW MATERIAL PRODUCTIVITY AS (GDP + MONETARY VALUE OF IMPORTS)/RAW MATERIAL INPUT (RMI)

DMI and RMI are so-called input indicators. DMI represents materials supply into the economy. It measures the direct input of materials for use, i.e. all materials that are of economic value and are used in production and consumption activities; DMI equals domestic extraction used plus imports. RMI is defined as the sum of DEU and imports expressed in RME. It measures the global use of resource linked to the input into the domestic economy by converting the import into RME. By including the indirect flows of import, the RMI is robust against outsourcing.

The so-called efficiency or productivity indicators relate economy-wide indicators (as a measure of material input: DMI or RMI, and material footprint: DMC or RMC) to economic output (e.g. GDP). They are a measure of the material productivity or intensity of an economy or sector: the ability to produce the same output or meet the same consumption needs with less material indicates an improvement in environmental and economic performance (and therefore competitiveness).

INDICATORS 6, 8, 12 FROM THE RAW MATERIAL SCOREBOARD

The European raw material scoreboard indicators:

- **Indicator 6: domestic production**
    - Comparison between domestic extraction and domestic consumption to estimate the self-sufficiency.
- **Indicator 8: import reliance**
    - Import reliance both at mining and refinement stage
- **Indicator 12: material flows in the circular economy**
    - Framework allowing an estimate of the level of circularity
    - Closely related to the circular material use rate

Important characteristics of the indicators in relation to policy questions:

- **DMC (per material type) with or without a graph on import reliance**
    - Difficult to link DMC with import reliance:
        - Import reliance is based on the EC's criticality methodology, and is available on the level of 83 individual materials.
        - DMC is at a maximum level of the four broad material categories and can't be more disaggregated. Because of the issue with allocating complex imported products (e.g. car) to one of the more specific 51 material sub-groups.
    - DMC focusses on the domestic use of materials. It shows the materials that 'remain' within the territory. Indicator 12 of the RMS shows, in addition, information on the domestic use of these input flows: it makes the link between input and domestics uses/stocks.
    - In comparison to indicator 12 of the RMS, we believe the indicator 12 is superior as it gives a broader picture, including the domestic use. Indicator 12 is closely linked with the Eurostat Sankey diagram of material flows (with link CMUR).
- **DMC/GDP (resource productivity)**
    - This ratio indicator is just linking two macro-economic indicators. The added value of this ratio is that it allows to assess relative or absolute decoupling.
    - GDP might be influenced by growth in the tertiary sector, while domestic material use might be more correlated with manufacturing activities. For this reason, this indicator might give an incorrect indication of productivity (or efficiency).
    - Other macro-trends than GDP might be of interest, like population size.
    - The same remarks apply for the link between RMC or others.
- **Total raw material productivity as (GDP + monetary value of imports)/raw material input (RMI)**

- One issue with RMI is re-exports (they do not involve European activities). If re-exports are important, the RMI indicator might give an incorrect indication. I don't know, by hearth, how large re-export is in Europe.
- Remark: in RMI the export is not subtracted from the total. The RMC indicators does exclude export.
- GDP and import value are all strongly correlated with price fluctuations. This may lead to an increasing ratio indicator due to price increases, which in case of stable RMI gives an incorrect indication of the productivity trend.
- RMI (and DMI) focus on the need for materials for our economy (not for our (final) consumption).

- **RMC or material footprint**
  - By definition both are the same, although the calculation methodology can be different. RMC is typically calculated via the MFA-RME accounts, while the material footprint uses an input-output methodology.
  - RMC is available from Eurostat for the EU as a whole. MS can on a voluntary basis estimate their RMC (and RMI) indicators. Currently 12 or 13 MS results are available on Eurostat website.
- **Indicators 6,8 and 12 from the raw material scoreboard:** https://op.europa.eu/en/publication-detail/-/publication/eb052a18-c1f3-11eb-a925-01aa75ed71a1
  - Indicator 12 is not really an indicator, as in it does not generate one number. It requires an assessment of all numbers on the overview to know if the trend goes in the positive or negative direction. This give more a macro-economic picture of material flows in the economy. Advantage is that it includes linkages between life cycle stages (extraction to product use to waste to feedback loop) and comprehensive. Stocks are not included (only net additions to stocks).

9 ANNEX 2: STANDARDISED SHEETS

#	Methodology name	Reference
1	**EU Monitoring Framework for the Circular Economy**	**Eurostat (2023a).** EU Monitoring Framework for Circular Economy. Retrieved from https://ec.europa.eu/eurostat/web/circular-economy/monitoring-framework
2	**Mayer et al.: A Monitoring Framework for Economy-wide Material Loop Closing**	**(Mayer et al. 2018)** Mayer, A., Haas, W., Wiedenhofer, D., Krausmann, F., Nuss, P., Blengini, G.A. (2018). Measuring Progress towards a Circular Economy: A Monitoring Framework for Economy-wide Material Loop Closing in the EU28. Journal of Industrial Ecology, 22(4), 727-739. https://doi.org/10.1111/jiec.12809
3	**The Circularity Gap of Nations - A Multiregional analysis of waste generation, recovery and stock depletion**	**Aguilar-Hernandez et al., (2011)** Aguilar-Hernandez, G.A., Sigüenza-Sanchez, C.P., Donati, F., Merciai, S., Schmidt, J., Rodrigues, J.F.D., Tukker, A. (2019). The circularity gap of nations: A multiregional analysis of waste generation, recovery, and stock depletion in 2011. Resources, Conservation and Recycling, Volume 151, 104452. https://doi.org/10.1016/j.resconrec.2019.104452 .
4	**Economy-wide assessment in Flanders**	**CE Center (2021).** CE Center Circular Economy (2021). An economy wide circularity assessment in Flanders, OVAM.
5	**Circularity Gap Report: the Circularity Gap Metric**	Circle Economy (2020). The Circularity Gap Report: The Netherlands – Methodology document. https://www.circularity-gap.world/netherlands
6	**3rd Raw Materials Scoreboard 2021 – European Innovation Partnership on Raw Materials**	**EIP (2021).** 3rd Raw Materials Scoreboard – European innovation partnership on raw materials. Publications Office. https://data.europa.eu/doi/10.2873/567799
7	**Expanding the knowledge base on intra-EU waste movements in a circular economy**	**Trinomics et al. (2021).** Expanding the knowledge base on intra-EU waste movements in a circular economy. European Environnement Agency.
8	**Circularity Metrics Label (CML)**	**European Environnement Agency. (2023).** Measuring Europe's circular economy – Circularity Metrics Label (CML). https://www.eea.europa.eu/en/topics/in-depth/circular-economy/measuring-europes-circular-economy
9	**Global Material Flows DataBase**	**UNEP (2023).** Global Material Flows Database. https://www.resourcepanel.org/global-material-flows-database

9.1 METHODOLOGY #1

Methodology #1
EU Monitoring Framework For the Circular Economy

Short description

The European Union monitoring framework for the circular economy, developed by the European Commission, plays a vital role in tracking the progress of circular economy initiatives within the EU. The monitoring framework focuses on key indicators and tools used to measure the transition towards a more circular and resilient economy. By measuring various aspects of production, consumption, waste generation, waste management, secondary raw materials, competitiveness and innovation, and global sustainability resilience, the framework offers insights into the effectiveness of circular and resilient economy policies and identifies areas for improvement. The EU Monitoring Framework comprises a total of 27 individual indicators.

In the context of circularity, resilience and self-sufficiency and especially material flows, the EU Monitoring Framework contains three key components: the Sankey diagram, the Circular Material Use Rate and a set of indicators related to material footprints.

Eurostat (2023a). EU Monitoring Framework for Circular Economy. Retrieved from https://ec.europa.eu/eurostat/web/circular-economy/monitoring-framework

Methodology overview

Category overview

Circular Economy	X
Self-sufficiency	X
Resilience	X

Purpose

Macro-overview	X
Specific indicators measurement	X

Geographical coverage

International	
EU aggregates	X
EU member states individually	X
Specific country development	
Belgium	X
Brussels	
Wallonia	
Flanders	

Sub-category covered features

Self-sufficiency	X
Material footprint	X
Waste	X
Recovery (recycling)	X
Secondary raw materials	X

Data sources

Waste statistics, international trade in goods statistics, and economy-wide material flow accounts (EW-MFA).

Period

Variable depending on the indicators.

Indicators overview	
Sankey diagram	• **materials extracted** to make products or be used as a source of energy; • **products flowing in and out** of our society; • **materials and products discarded into the environment** as residuals, e.g. landfilled waste or air emissions, or recovered and fed back into the economy; this latter part closes the loop in the circular
Circularity material use rate	The circularity rate measures the share of material recycled and fed back into the economy in overall material use — thus reducing the extraction of primary raw materials. The indicator includes flows of materials, fossil fuels and energy products, but not flows of water. Correspondingly, the circularity rate (CMU) is defined as the ratio of the circular use of materials (U) to an indicator of the overall material use (M): $CMU = \frac{U}{M}$
Monitoring framework (27 indicators)	1) **Production and consumption** : ○ Self-sufficiency of raw materials for production in the EU ○ Green public procurement ○ Waste generation ○ Food Waste 2) **Waste management** : ○ Recycling rates ○ Specific waste streams **3) Secondary raw materials** ○ Contribution of recycled materials to raw materials demand ○ Trade of recyclable raw materials between the EU MS and with the rest of the world. **4) Competitiveness and innovation** ○ Private investments, jobs and gross value added ○ Patents related to recycling and secondary raw materials as proxy for innovation **5) Global sustainability and resilience**

Full methodology description 1 – the Sankey diagram

Data sources

Waste statistics, international trade in goods statistics, and economy-wide material flow accounts (EW-MFA).

Period

Presented time series starts in 2010.

Material flow streams

Biomass, metal ores, non-metallic minerals and fossil energy carriers.

Description

A crucial component of the monitoring framework the Sankey diagram to visualize material flo throughout the circular economy. The diagram depi the flow of materials from extraction to productio consumption, and ultimately, their fate as residuals their reintroduction into the economy.

Geographical coverage

EU aggregate and EU member states individually.

Applicability to Belgium

Yes, data available on Eurostat's website.

The Eurostat Sankey diagram of material flows provides a comprehensive view of material quantities extracted, imported, recycled, or disposed of, along with associated emissions. The following components are depicted in the diagram:

1. **Direct Material Input (DMI)**

Direct Material Input (DMI) is a crucial component in understanding the material flows within an economy. It encompasses two main sources: imports and natural resources. Imports represent the flow of products from the global economy into the domestic economy, including waste destined for treatment. On the other hand, natural resources refer to the materials extracted from the environment by resident production units, also known as domestic extraction (DE). The DMI combines these two sources and represents the direct input of materials into the economy. It includes all materials of economic value that are utilized in production and consumption activities, playing a significant role in shaping resource use and environmental impacts.

2. **Processed Materials (PM)**

Processed materials refer to the combination of direct material input (DMI) and secondary material input, which includes materials obtained through recycling and backfilling. Processed materials can be either exported or used domestically. The portion that is not exported is referred to as domestic material consumption (DMC).

3. **Outputs from the Economy**

The outputs from the economy, as illustrated in the Eurostat Sankey diagram, include the exports of products (the mass weight of products that are exported), emissions to air and water, dissipative flows (to materials that are dispersed into the environment as residuals).

After being used, materials can be either incinerated, landfilled, backfilled, or recycled. However, in the Sankey diagram, only recycling and backfilling are considered to close the loop. The recycling rate measures the proportion of recycled waste out of all the waste treated.

Full methodology description 2 – Individual monitoring indicators

Data sources

Waste statistics, international trade in goods statistics, and economy-wide material flow accounts (EW-MFA).

Period

Presented time series starts in 2010.

Material flow streams

Variable depending on the indicator.

Description

The EU Monitoring Framework comprises a total of individual indicators.

Geographical coverage

EU aggregate and EU member states individually.

1. **Production and consumption**

1.1. Material footprints (RMC)

Raw material consumption indicator (RMC) is a measure of material footprints. It represents the amount of material in terms of Raw materials equivalent (RME) needed (or, the amount of extraction, domestic and abroad, required directly and indirectly) to produce the products consumed in the reference area. It is calculated as Raw material input (RMI) minus exports in RME (calculated at the aggregate product level, by material). The indicator RMC gives insight into the quantity and type of materials required to meet the EU's demand for products.

Details

Measures : Tonnes per capita	**Period** : 2008-2020
Geopolitical entity : EU countries individually and EU aggregate	**Source** : Economy-wide material flow accounts (EW MFA)
Material flow streams : Minerals, metal ores, biomass, fossil energy materials	**Belgium applicability** : Yes, see Eurostat's website.

1.2. Resource productivity

The indicator is defined as the gross domestic product (GDP) divided by domestic material consumption (DMC).

DMC measures the total amount of materials directly used by an economy. It is defined as the annual quantity of raw materials extracted from the domestic territory of the local economy, plus all physical imports minus all physical exports. It is important to note that the term 'consumption', as used in DMC, denotes apparent consumption and not final consumption.

Details

Measures : Index, 2000 = 100	**Period** : 2000-2022
Geopolitical entity : EU countries individually and EU aggregate	**Source** : Economy-wide material flow accounts (EW MFA)
Material flow streams : None	**Belgium applicability** : Yes, see Eurostat's website.

1.3. Green Public Procurement

No available information.

1.4. Total waste generation per capita

The indicator is defined as total waste generated in a country including major mineral wastes (all NACE activities plus households), divided by the average population of the country.

Details

Measures : Kilograms per capita	**Period** : 2004, 2006, 2008, 2010, 2012, 2014, 2016, 2018, 2020.
Geopolitical entity : EU countries individually and EU aggregate	**Source** : Statistical Office of the European Union (Eurostat) based on data reported by the countries: Generation of waste by waste category, hazardousness and NACE Rev. 2 activity (env_wasgen) collected on the basis of the Waste Statistics Regulation (EC) No 2150/2002.
Material flow streams : Total waste	**Belgium applicability :** Yes, see Eurostat's website.

1.5. Generation of waste excluding major mineral wastes per GDP unit

The indicator is defined as all waste generated in a country (in mass unit), excluding major mineral wastes (extracting and processing mineral resources), per GDP unit (in euro, chain linked volumes (2010)). The ratio is expressed in kg per thousand EUR.

Details

Measures : Kilograms per thousand euros	**Period** : 2004, 2006, 2008, 2010, 2012, 2014, 201 2018, 2020.
Geopolitical entity : EU countries individually and EU aggregate	**Source** : Regulation on waste statistics (EC) N 2150/2002, amended by Commission Regulation (EU No. 849/2010
Material flow streams : Total waste, excluding major mineral wastes	**Belgium applicability** : Yes, see Eurostat's website.

1.6. Generation of municipal waste per capita

Generation of municipal waste per capita (kg per capita) : The indicator measures the waste collected by or on behalf of municipal authorities and disposed of through the waste management system. It consists to a large extent of waste generated by households, though similar wastes from sources such as commerce, offices and public institutions may be included.

Details

Measures : Kilograms per capita	**Period** : 2004, 2006, 2008, 2010, 2012, 2014, 201 2018, 2020.
Geopolitical entity : EU countries individually and EU aggregate	**Source** : Regulation on waste statistics (EC) N 2150/2002, amended by Commission Regulation (EU No. 849/2010
Material flow streams : Total waste, excluding major mineral wastes	**Belgium applicability** : Yes, see Eurostat's website.

1.7. Food waste

The indicator is defined as the amount of food waste generated per year divided by the average population of the country. Food waste is measured as fresh mass all along the food value chain, including production sites, processing and manufacture, retail and distribution, restaurants and food services and households.

Details

Measures : Kilograms per capita	**Period** : 2020
Geopolitical entity : EU countries individually and EU aggregate	**Source** : Food waste and food waste prevention b NACE Rev. 2 activity - tonnes of fresh mas [ENV_WASFW]

Material flow streams : Food waste	**Belgium applicability :** Yes, see Eurostat's website.

1.8. Generation of packaging waste per capita

'Packaging' in this context means all products made of any materials of any nature to be used for the containment, protection, handling, delivery and presentation of goods, from raw materials to processed goods, from the producer to the user or the consumer. 'Non-returnable' items used for the same purposes shall also be considered to constitute packaging.

Details

Measures : Kilograms per capita	**Period** : 2004-2020
Geopolitical entity : EU countries individually and EU aggregate	**Source** : 'Packaging waste' means any packaging c packaging material covered by the definition of wast in the Waste Framework Directive 2008/98/E excluding production residues (Art.3(1): 'waste' mear any substance or object which the holder discards c intends or is required to discard).
Material flow streams : Packaging	**Belgium applicability :** Yes, see Eurostat's website.

1.9. Generation of plastic packaging waste per capita

This indicator includes plastic packaging waste.

Details

Measures : Kilograms per capita	**Period** : 2004-2020
Geopolitical entity : EU countries individually and EU aggregate	**Source** : 'Packaging waste' means any packaging c packaging material covered by the definition of wast in the Waste Framework Directive 2008/98/E excluding production residues (Art.3(1): 'waste' mear any substance or object which the holder discards c intends or is required to discard).
Material flow streams : Plastic	**Belgium applicability :** Yes, see Eurostat's website.

2. Waste management

2.1. Recycling rate of municipal waste

The indicator measures the share of recycled municipal waste in the total municipal waste generation. Recycling includes material recycling, composting and anaerobic digestion. The ratio is expressed in percent (%) as both terms are measured in the same unit, namely tonnes.

Details

Measures : Percentage	**Period** : 2000-2021
Geopolitical entity : EU countries individually and EU aggregate	**Source** : Definition and concepts of municipal waste statistics are fixed by the Waste Framework Directiv (Directive 2008/98/EG). The definition of municip waste is regulated in article 3 (2b) and in recital 10 th Directive (EU) 2018/851 amending Directiv 2008/98/EC on waste.
Material flow streams : Municipal waste	**Belgium applicability :** Yes, see Eurostat's website.

2.2. Recycling rate of all waste excluding major mineral waste

The indicator is calculated as recycled waste (RCV_R) divided by total waste treated excluding major mineral wastes (TRT), multiplied by 100. It is expressed in percent (%) as both terms are measured in the same unit, namely tonnes.

Recycled waste is waste treated, which was sent to recovery operation other than energy recovery and backfilling (for simplification referred to as recycling).

Details

Measures : Percentage	**Period** : 2010, 2012, 2014, 2016, 2018 and 2020.
Geopolitical entity : EU countries individually and EU aggregate	**Source** : Waste treated is based in Waste Statisti Regulation and the imports and exports of wastes a based on Foreign Trade Statistics and reporte according to the Combined Nomenclature (CN-codes The indicator covers both hazardous (hz) and no hazardous (nh) waste from all economic sectors an from households, including waste from wast treatment (secondary waste) but excluding mo mineral waste.
Material flow streams : Hazardous and non-hazardous	**Belgium applicability :** Yes, see Eurostat's website.

2.3. Recycling rate of overall packaging

The indicator is defined as the share of recycled plastic packaging waste in all generated plastic packaging waste. Packaging waste covers wasted material that was used for the containment, protection, handling, delivery and presentation of goods, from raw materials to processed goods, from the producer to the user or the consumer, excluding production residues.

Details

Measures : Percentage	**Period** : 2004, 2006, 2008, 2010, 2012, 2014, 201 2018 and 2020.
Geopolitical entity : EU countries individually and EU aggregate	**Source** : The reporting methodology and details o packaging and packaging waste are laid down i Commission Decision 2005/270/EC of 22 March 200 establishing the formats relating to the databas system pursuant to Directive 94/62/EC on packagir and packaging waste.
Material flow streams : Packaging (total), plastic packaging, wooden packaging, metallic packaging and glass packaging).	**Belgium applicability :** Yes, see Eurostat's website.

2.4. Recycling rate of plastic packaging

The indicator is defined as the share of recycled plastic packaging waste in all generated plastic packaging waste. Packaging waste covers wasted material that was used for the containment, protection, handling, delivery and presentation of goods, from raw materials to processed goods, from the producer to the user or the consumer, excluding production residues.

Details

Measures : Percentage	**Period** : 2004, 2006, 2008, 2010, 2012, 2014, 201 2018 and 2020.
Geopolitical entity : EU countries individually and EU aggregate	**Source** : The reporting methodology and details o packaging and packaging waste are laid down i Commission Decision 2005/270/EC of 22 March 200 establishing the formats relating to the databas system pursuant to Directive 94/62/EC on packagir and packaging waste.

Material flow streams : Plastic	**Belgium applicability :** Yes, see Eurostat's website.

2.5. Recycling rate of WEEE separately collected

The indicator is calculated by dividing the weight of waste of electrical and electronic equipment (WEEE) that enters the recycling/preparing for re-use facility by the weight of all separately collected WEEE (both in mass unit).

Details

Measures : Percentage	**Period** : 2011-2020
Geopolitical entity : EU countries individually and EU aggregate	**Source** : The indicator is calculated by dividing th weight of WEEE that enters the recycling/preparing fo re-use facility by the weight of all separately collecte WEEE (both in mass unit) in accordance with Artic 11(2) of the WEEE Directive 2012/19/EU
Material flow streams : Electric and electronic equipment	**Belgium applicability :** Yes, see Eurostat's website.

3. Secondary raw materials

3.1. Circular Material Use Rate (CMUR)

The indicator measures the share of material recycled and fed back into the economy - thus saving extraction of primary raw materials - in overall material use. The circular material use, also known as circularity rate is defined as the ratio of the circular use of materials to the overall material use. The overall material use is measured by summing up the aggregate domestic material consumption (DMC) and the circular use of materials. The circular use of materials is approximated by the amount of waste recycled in domestic recovery plants minus imported waste destined for recovery plus exported waste destined for recovery abroad.

Details

Measures : Percentage	**Period** : 2010-2021
Geopolitical entity : EU countries individually and EU aggregate	**Source** : Waste recycled in domestic recovery plan comprises the recovery operations R2 to R11 - a defined in the Waste Framework Directive 75/442/EE The imports and exports of waste destined for recyclin - i.e. the amount of imported and exported wast bound for recovery – are approximated from th European statistics on international trade in goods.
Material flow streams : Total for specific streams : minerals, metal ores, biomass, fossil energy materials	**Belgium applicability :** Yes, see Eurostat's website.

3.2. End-of-live recycling input rates (EOL-RIR), aluminium

The indicator measures, for a given raw material, how much of its input into the production system comes from recycling of "old scrap" i.e. scrap from end-of-life products. The 'end-of-life recycling input rate' (EOL-RIR) does not take into account scrap that originates from manufacturing processes ("new scrap").

Details

Measures : Percentage	**Period** : 2013, 2016; 2019, 2022.
Geopolitical entity : EU aggregate only.	**Source** : Few data are available at the European an international level on the amount of secondary ra materials produced. Available data sources for th calculation of the EOL-RIR have been ranked based o the following cascade approach:

	A) Material System Analysis for the EU B) International reports C) Industry data and scientific publications
Material flow streams : Aggregate, aluminium, beryllium, bismuth, cobalt, copper, dysprosium, gallium, germanium, etc.	**Additional information :** More info on the methodology found here : https://ec.europa.eu/eurostat/cache/metadata/en/cei_srm010_esmsip2.htm

3.3. Recyclable raw materials

The indicator measures the quantities of selected waste categories and by-products that are shipped between the EU Members States (intra-EU) and across the EU borders (extra-EU). Five classes have been selected: plastic; paper and cardboard; precious metal; iron and steel; copper, aluminium and nickel. The indicator includes the following variables:

• Intra EU trade of selected recyclable raw materials (measured as the Imports from EU countries).

• Imports from non-EU countries and exports to non-EU countries of selected recyclable raw materials (as regards extra-EU trade).

The indicator is based on International Trade in Goods Statistics (ITGS) published by Eurostat.

Details

Measures : Percentage	**Period** : 2004-2021
Geopolitical entity : EU countries individually and EU aggregate	**Source** : The scope of the “recyclable raw materials” measured in terms of relevant product codes from th Combined Nomenclature used in International Trade i Goods Statistics (see list of codes selected).
Material flow streams : Total, paper and carboard, plastics, rubber, wood, textiles, glass, organic, mineral, metal-ferrous, metal non-ferrous (precious metal), metal non-ferrous (copper, aluminium and nickel), metal non-ferrous (other), not specified.	**Additional information :** Imports extra-EU, impor intra-EU, exports extra-EU. **Belgium applicability :** Yes, see Eurostat’s website.

4. Competitiveness and innovation

4.1. Private investments

The indicator includes “Gross investment in tangible goods” and “Value added at factor costs” in the following three sectors: the recycling sector, repair and reuse sector and rental and leasing sector.

Details

Measures : Million euros or percentage of GDP	**Period** : 2012-2021
Geopolitical entity : EU countries individually and EU aggregate	**Source** : The indicator is calculated in three steps a follows: -Conceptual framework. The delineation of econom activities related to the circular economy wa determined by means of a sector classification based o the purpose of each sector. -The relevant activities were identified and matche against the integrated system of econom classification, drawing upon existing lists of goods an services for the environmental sector.

	-Produce the estimates based on official statistics, in particular structural business statistics, PRODCOM, national accounts, the Labour Force Survey and others.
Material flow streams : None.	**Belgium applicability :** Yes, see Eurostat's website.

4.2. Persons employed

The indicator measures "number of persons employed" in the following three sectors: the recycling sector, repair and reuse sector and rental and leasing sector.

Details

Measures : Percentage of total employment or in number of persons employed.	**Period** : 2009-2021
Geopolitical entity : EU countries individually and EU aggregate or Full Time Equivalent.	**Source** : Eurostat initiated a project to develop methodological approach that allows deriving ke economic variables on the economic activities relate to circular economy. In essence, the approach can b summarised as follows: -Building a conceptual framework. A suitable an widely accepted overall definition of the environment policy subject based on an international body serves a a starting point; The boundaries of the scope wer defined; The criteria for the delineation of relate economic activities was established by means of sector classification by purposes (e.g. the 10 framework for Circular Economy). -Mapping relevant activities and matching against th integrated system of economic classification. Drawin upon existing lists of goods and services. This li presents the list of identified economic activitie including the corresponding NACE, CPA and PRODCOI codes as well as a suitable estimation procedure fo each code. -Delineation and data compilation. The estimatic procedure and methods to compile the variables can b found in the report included in the annex of this file..
Material flow streams : None.	**Belgium applicability :** Yes, see Eurostat's website.

4.3. Gross value added

The indicator includes "Gross investment in tangible goods" and "Value added at factor costs" in the following three sectors: the recycling sector, repair and reuse sector and rental and leasing sector.

Details

Measures : Million euros or percentage of GDP	**Period** : 2012-2021
Geopolitical entity : EU countries individually and EU aggregate	**Source** : The indicator is calculated in three steps a follows: -Conceptual framework. The delineation of econom activities related to the circular economy wa determined by means of a sector classification based o the purpose of each sector. -The relevant activities were identified and matche against the integrated system of econom classification, drawing upon existing lists of goods an services for the environmental sector.

	-Produce the estimates based on official statistics, in particular structural business statistics, PRODCOM, national accounts, the Labour Force Survey and others.
Material flow streams : None.	**Belgium applicability :** Yes, see Eurostat's website.

4.4. Patents related to waste management and recycling

The indicator measures the number of patents related to recycling and secondary raw materials.

Details

Measures : Number of per million inhabitants	**Period** : 2000-2019
Geopolitical entity : EU countries individually and EU aggregate	**Source** : The attribution to recycling and secondary ra materials was done using the relevant codes in th Cooperative Patent Classification (CPC) (list of CP codes selected).
Material flow streams : None.	**Belgium applicability** : Yes, see Eurostat's website.

5. Global sustainability and resilience

5.1. Consumption footprint

The indicator consumption footprint estimates the environmental impacts of EU and Member States consumption by combining data on consumption intensity and environmental impacts of representative products. The indicator covers five areas of consumption: food, mobility, housing, appliances, and household goods. Consumption intensities are calculated based on consumption statistics.

Details

Measures : Index, 2010 : 100, Planetary Boundary, per inhabitant.	**Period** : 2000-2019
Geopolitical entity : EU countries individually and EU aggregate	**Source** : The Consumption Footprint is a set of 16 LCA based indicators (also available as a single score) whos purpose is to quantify the environmental impacts c consumption at EU and Member State level. Joir Research Center.
Material flow streams : None.	**Additional information :** Single weighed scor acidification, climate change, ecotoxicit eutrophication (freshwater and terrestrial), huma toxicity (non-cancer and cancer), land use, ozor depletion, particulate matter (human health photochemical ozone formation, resource use (fossil resource use (minerals and metals), water use.
Belgium applicability : Yes, see Eurostat's website.	

5.2. GHG emissions from production activities

This indicator presents greenhouse gas emissions of all production activities undertaken in the EU economy. Notably, this indicator includes emissions from international air transport undertaken by EU resident airlines and excludes emissions by private households.

Details

Measures : Kilograms of CO2 equivalents per capita	**Period** : 2008-2021

Geopolitical entity : EU countries individually and EU aggregate	**Source** : European Statistical System (ESS). Air emission accounts based on Regulation (EC) No. 691/2011 on European environmental economic accounts (EEEA) Data provider: Statistical Office of the European Union (Eurostat) based on data reported by the countries. Air emissions accounts by NACE Rev. 2 activity [ENV_AC_AINAH_R2]
Material flow streams : None.	**Belgium applicability :** Yes, see Eurostat's website.

5.3. Material import dependency

This indicator provides the ratio of imports (IMP) over direct material inputs (DMI) in percentage. The term 'material import dependency' shows the extent to which an economy relies upon imports in order to meet its material needs. Material import dependency cannot be negative or higher than 100%. Values equal to 100% indicate that there are no domestic extractions during the reference year.

Details

Measures : Percentage	**Period** : 2008-2022.
Geopolitical entity : EU countries individually and EU aggregate	**Source** : Details Measures : European Statistical System (ESS Economy-wide material flow accounts (EW-MFA) base on Regulation (EU) 691/20.
Material flow streams : None.	**Additional information :** Belgium applicability : Yes, se Eurostat's website.

5.4. EU self-sufficiency for raw materials

The Self-sufficiency (SS) indicator measures how much the EU is independent from the rest of the world for several raw materials (23 raw materials).

The indicator has been calculated based on actual yearly quantity data for domestic production, exports and imports, using the formula: Self-sufficiency = 1 - (net) Import Reliance, where Import Reliance (IR) is defined in the EU Critical Raw Materials methodology as Net imports / (Net imports + Domestic Production).

The computations of Self-sufficiency indicator have been conducted at the first two stages of the value chain: extraction (E) and processing (P) for most of the materials.

Data accessible here. Available for the EU-28 countries only. Limits : Data available for 7 out of the 23 raw materials.

Details

Measures : Percentage	**Period** : 2008-2022.
Geopolitical entity : EU aggregate only.	**Source** : Joint Research Center (JRC).
Material flow streams : Aluminium, borate, cobalt, copper, dysprosium, europium, fluorspar, gallium, germanium, indium, iron, limestone, lithium, magnesium, molybdenum, natural graphite, neodymium, phosphorus, platinum, silicon, tantalum, vanadium, yttrium.	**Additional information :** Available for extraction o processing.
Belgium applicability : No, EU aggregate only.	

9.2 Methodology #2

Methodology #2
Mayer et al. : A Monitoring Framework for Economy-wide Material Loop Closing

Short description

This article aims at contributing to the establishment of monitoring tools of material flows in a CE at the macro level, with the premise that a more circular economy should contribute to the reduction of environmental pressures instigated by resource use. Our proposal is to go beyond the level of individual products, substances, or industrial symbiosis but monitor progress towards a CE from an economy-wide perspective at the national or higher scale. They develop a comprehensive approach including all biomass,
metals, non-metallic minerals, and fossil energy carriers and, second, by reconciling officially available datasets published by EUROSTAT.

(Mayer et al. 2018) Mayer, A., Haas, W., Wiedenhofer, D., Krausmann, F., Nuss, P., Blengini, G.A. (2018). Measuring Progress towards a Circular Economy: A Monitoring Framework for Economy-wide Material Loop Closing in the EU28. Journal of Industrial Ecology, 22(4), 727-739. https://doi.org/10.1111/jiec.12809

Methodology overview

Category overview

Circular Economy	X
Self-sufficiency	
Resilience	

Sub-category covered features

Self-sufficiency	
Material footprint	
Waste	X
Recovery (recycling)	X
Secondary raw materials	X

Purpose

Macro-overview	X
Specific indicators measurement	

Geographical coverage

International	
EU aggregates	X
EU member states individually	X
Specific country development	X
Belgium	
Brussels	
Wallonia	
Flanders	

Data sources

The study based the assessment as far as possible on statistical data from the official environmental reporting system of the EU and systematically mass-balanced material inputs with waste flows reported in the different statistical sources.

Period

/

Indicators overview	
Circular Economy Monitoring Framework	The accounting framework traces materials by main material groups from their extraction to major uses within the socioeconomic system and towards discard and either material recovery or deposition to nature as wastes and emissions.
Scale indicators	Scale indicators provide measures for the overall size of the socioeconomic metabolism (DMC, RMC, DPO, interim ouputs and PM).
Cycling indicators	The authors present the circularity rates, which evaluate the cycling of resources in relation to input and output flows (Mayer et al., 2018). Mayer et al. (2018) have identified three categories of circularity rates: socioeconomic cycling (SC), ecological cycling potential (EC), and non-circularity (NC). • **Socioeconomic Cycling (SC)** measures the contribution of secondary materials in PM and in output flows. To illustrate, on the input side, the SC rate measures the proportion of secondary materials used in production compared to the total quantity of processed materials consumed. • **Ecological cycling potential** (EC) is evaluated through two rates. The first measures the proportion of primary biomass that is utilized in the production of processed materials. On the other hand, the second assesses the share of processed output derived from primary biomass in the output flows. • **Non-circularity (NC)** is decomposed into the input non-circularity rate and the output non-circularity rate. They are determined based on the proportion of fossil energy carriers used in the production and consumption stages, respectively. These rates measure the portion of material flows that do not contribute to socioeconomic and ecological loop closing.

Full methodology description 1 – CE Monitoring Framework

Data sources

EW-MDA and assumptions from Mayer et al.

Period

2014

Material flow streams

Biomass, metal ores, non-metallic minerals and fossil energy carriers.

Description

The accounting framework traces materials by main material groups from their extraction to major uses within the socioeconomic system and towards discard and either material recovery or deposition to nature as wastes and emissions.

Geographical coverage

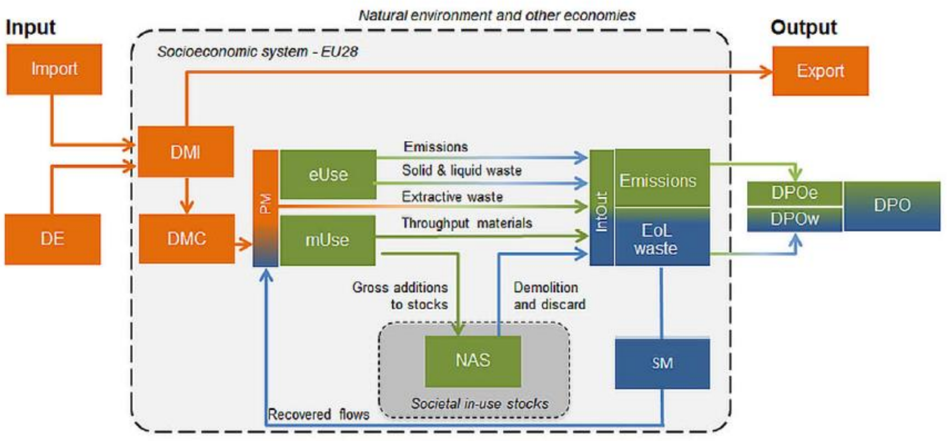
EU-28

Belgium applicability

Yes.

Secondary materials refer to materials recovered through all forms of recycling, reuse, and remanufacturing but also downcycling (e.g., backfilling) or cascadic use (while in the EU monitoring framework, only recycling and backfilling are considered to close the loop). We built upon a systems and material perspective of the economy, and as a substantial advancement, we based the assessment as far as possible on statistical data from the official environmental reporting system of the EU (Eurostat 2017c, 2017b) and systematically mass-balanced material inputs with waste flows reported in the different statistical sources. While recovered materials were reported in waste statistics and could be directly quantified, this was not possible for other CE strategies like extending product lifetimes, reusing and remanufacturing, or sharing. In our framework, these strategies would result in an increase of the service lifetime of in-use stocks and potentially a stabilization of in-use stock growth, as indicated by the net additions to stocks (NAS; figure 1).

The CE Monitoring Framework is represented as follows :



DE = Domestic extraction; DMI = Direct material inputs; DMC = Domestic material consumption; PM = Processed material; eUse = Energetic use; mUse = Material use; NAS = Net additions to stocks; IntOut = Interim outputs; EoL waste = End-of-life waste; SM = Secondary materials; DPOe = Domestic processed output of emissions; DPOw = Domestic processed output of wastes; DPO = Domestic processed output

The accounting framework traces materials by main material groups from their extraction to major uses within the socioeconomic system and towards discard and either material recovery or deposition to nature as wastes and emissions.

Direct material input (DMI) into the socioeconomic system comprises materials that were extracted from the domestic environment **(domestic extraction [DE])** and **imports** of raw materials and manufactured products.

Exports to other economies were deducted to calculate **domestic material consumption (DMC).** Processed materials (PMs) were defined as the sum total of DMC and secondary material (SM) inputs.

PMs were allocated to either **energetic** or **material use**.

Energetic use (eUse) not only comprises materials used to provide technical energy (fuel wood and biofuels) but also feed and food, the primary energy sources for livestock and humans. The majority of all fossil energy carriers were allocated to eUse with the exception of, for example, petrochemical feedstock.

All other materials were assigned **to material use (mUse).** mUse comprises all metal ores and metals and non-metallic minerals, as well as those fractions of fossil and biomass materials not used for energy provision. The biomass fractions assigned to material use include industrial roundwood, crops for uses other than food, and feed including seeds and most harvested crop residues.

mUse was split into extractive waste, materials used for **stock building** (i.e., gross additions to in-use stocks of materials [GAS]), and **throughput materials**.

Extractive waste refers to waste material that occurs during early stages of the processing of domestically extracted ores and directly goes from PM to **interim output (IntOut)**.

Stock building materials comprise all materials that accumulate in buildings, infrastructures, or durable goods with a lifetime of more than one year (e.g., concrete, asphalt, or steel). The share of stock-building materials in mUse was estimated based on information from industry and production statistics, results from material flow studies and assumptions.

Throughput materials comprise materials that do not accumulate in in-use stocks, and can be split into two types of materials: first, materials used deliberately in a dissipative way such as salt or fertilizer minerals, and losses that occur during material processing (wastage, not reported in waste statistics); and second, short-lived products such as packaging or newspaper, manufacturing wastes, and food waste (reported in waste statistics).

All materials that are neither added to stocks nor recycled are converted into gaseous, solid, or liquid outputs within the year of extraction. Together with demolition and discard from in-use stocks that have reached the end of their service lifetime, these outflows were denoted as interim outputs (IntOut) in figure 1.
IntOuts were split into emissions, comprising all gaseous emissions (e.g., carbon dioxide [CO2], sulfur dioxide [SO2], methane [CH4]) including water vapor and into EoL waste, including all solid (and liquid) outputs.

Emissions cannot be recycled and go straight into domestic processed output (DPO). A fraction of total EoL waste, reported as RCV B – (recovery other than energy recovery—backfilling) and RCV O (recovery other than energy recovery—except backfilling) in Eurostat (2017b) waste statistics, is reentering socioeconomic processes as secondary materials. Note that imported or exported secondary materials (e.g., scrap, waste paper) were not explicitly accounted for as secondary materials but included in trade flows; they are therefore also not reflected in circularity indicators. The remaining EoL waste (after subtracting SM) is returned to the environment as DPO waste and either landfilled, incinerated, or deliberately applied (e.g., manure, fertilizer). DPO emissions and DPO waste together are DPO.

To close the material balance between input and output flows we combined data from statistical reporting (i.e., from ew-MFA and waste statistics) with modeling. This was done separately for eUse and for the mUse components in two balancing calculations. The following equations summarize the mass balancing for eUse (equation 1) and mUse (equation 2).

DPO emissions = *eUse − solid and liquid wastes (1)*
Demolition and discard = EoL waste from mUse −throughput materials in waste (2)

mUse Balancing : Due to a lack of knowledge of actual in-use stocks, we used the following approach to close the material balance: In a first step, a consistent split of total EoL waste from mUse into waste flows resulting from discard and demolition and throughput materials was required. Total EoL waste from mUse was derived from waste statistics. While waste statistics report information on construction and demolition waste, this waste flow was not fully consistent with EoL waste from discard and demolition, which also contains waste flows from discarded long-living products such as furniture, cars, or electric appliances. In a second step, we calculated the amount of discard and demolition as the difference between EoL waste from mUse reported in waste statistics and the fraction of throughput materials (i.e., materials with a life span < 1 year) in mUse (e.g., waste from packaging, paper, food waste, etc.). In a third step, NAS were calculated as the difference between additions to stocks and discard and demolition. Closing the mass balance in this way implies that all inaccuracies in statistical data and assumptions that result in inconsistencies between input and output flows for mUse accrue in demolition and discard flows as residual flow category, and consequently in the value for NAS. Since no information on NAS in the EU28 was available, a cross-check with independent data was not possible.

Full methodology description 2 – Scale and cycling indicators

Data sources

Based on EW-MFA principles and build on proposals from previous research.

Period

/

Material flow streams

Processed materials.

Description

Based on this general definition, we developed a set of six indicator pairs, which allows us to measure progress towards a CE in terms of closing material cycles (table 1).

Geographical coverage

/

Adaptability to Belgium

Need for deeper examination for scale indicators.

We distinguished between **scale indicators**, which provide measures for the overall size of the socioeconomic metabolism (O'Neill 2015), and **circularity rates**, which measure socioeconomic and ecological cycling relative to input and output flows. Providing independent measures for flows on both the input and output sides is necessary because of the delaying effect that in-use stocks of materials have on output flows.

Table 1 Mass-based circular economy indicators for the EU28 in 2014 where scale indicators measure the absolute size of input and outputs flows in tons and circularity rates measure socioeconomic and ecological cycling relative to input and output flows in percentage[1]

	Dimension	*Input-side indicator*	*Output-side indicator*
Scale indicators (t)	In- and output flows	*Domestic material consumption* **DMC**	*Domestic processed outputs* **DPO**
	Consumption based perspective	*Raw material consumption* **RMC**	*n.a.*
	Interim flows	*Processed materials* **PM** = DMC + secondary materials	*Interim outputs* **IntOut** = EoL waste + DPO emissions
Circularity rates (%)	*Socioeconomic cycling* SC	*Input socioeconomic cycling rate* **ISCr** = Share of secondary materials in PM	*Output socioeconomic cycling rate* **OSCr** = Share of secondary materials in IntOut
	Ecological cycling potential EC	*Input ecological cycling rate* potential **IECrp** = Share of DMC of primary biomass in PM	*Output ecological cycling rate* potential **OECrp** = Share of DPO biomass in IntOut
	Non-circularity NC	*Input non-circularity rate* **INCr** = Share of eUse of fossil energy carriers in PM	*Output non-circularity rate* **ONCr** = Share of eUse of fossil energy carriers in IntOut

Note: n.a. = not applicable.

The indicators proposed in this context have been developed to identify and monitor economy-wide improvements and trade-offs related to economy-wide circularity. Since specific materials or material categories are interconnected, enhancing circularity for one material can affect the usage of other materials and energy. For materials like plastics, construction minerals, or metals, recycling can require significant energy investments in recycling operations, infrastructure, and transportation. As a result, increasing recovery rates, such as those for plastic waste, may reduce overall circularity due to higher energy consumption. Therefore, we have employed the proportions of socioeconomic, ecological, and non-circular flows within Product Material (PM) and Input-Output (IntOut) as circularity indicators capable of monitoring the system-wide consequences of circularity initiatives.

Illustration of the indicator in the CE Monitoring Framework :

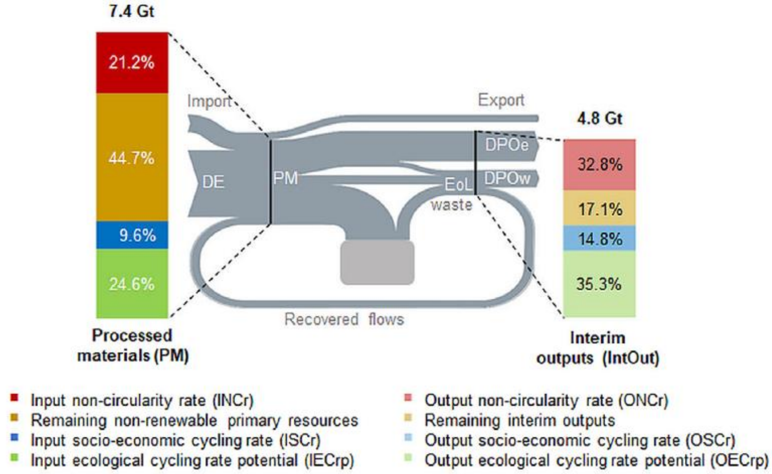


Figure 5 Input- and output-side CE indicators. Left bar depicts processed materials; right bar depicts interim outputs. Percentage denotes the share in relation to processed materials (left bar) and interim outputs (right bar).

9.3 METHODOLOGY #3

Methodology #3
The Circularity Gap of Nations - A Multiregional analysis of waste generation, recovery and stock depletion

Short description

When past studies are taken into consideration, it can be noticed that the current analysis of material circularity is mostly focused on how much waste is recovered in an economy as shares of primary material inputs. Furthermore, the current metric of circularity gap does not distinguish between the amount of materials that are emitted, added to stocks, or disposed as waste from previous in-use stocks. This last aspect limits the capacity to identify the actual waste available for circularity because the current measurement accounts for waste materials that are not available to be recovered in the present.

To enhance the circularity gap calculation, they propose a metric that focuses on the amount of unrecovered waste that can be reintegrated into the economy as materials or products. A key difference between the approach and the previous studies is that we make an explicit mathematical distinction between those materials that are added to stocks, and dispersed in the environment as dissipative emissions or other combustion and biomass residues. This allows us to identify the actual fraction of waste for material circularity in a specific period. We consider the quantity of waste generated and recovered in a period, and the old goods removed from stock and durable products disposed, defined as stock depletion. Thus, the **circularity gap (CG)** of a nation can be defined from these parameters as the waste generation, plus stock depletion, minus recovered materials. Such a CG metric can be seen as measure of the waste materials that are theoretically available for circularity.

(Aguilar-Hernandez et al., 2011) Aguilar-Hernandez, G.A., Sigüenza-Sanchez, C.P., Donati, F., Merciai, S., Schmidt, J., Rodrigues, J.F.D., Tukker, A. (2019). The circularity gap of nations: A multiregional analysis of waste generation, recovery, and stock depletion in 2011. Resources, Conservation and Recycling, Volume 151, 104452. https://doi.org/10.1016/j.resconrec.2019.104452 .

Methodology overview

Category overview

Circular Economy	X
Self-sufficiency	
Resilience	

Sub-category covered features

Self-sufficiency	
Material footprint	
Waste	X
Recovery (recycling)	X
Secondary raw materials	

Purpose

Macro-overview	
Specific indicators measurement	X

Geographical coverage

International	
EU aggregates	
EU member states individually	
Specific country development	X
Belgium	
Brussels	
Wallonia	
Flanders	

Data sources

/

Period

/

Full methodology description 1 – The Circularity Gap

Data sources	Description
To visualize the input-output flows of materials and CG worldwide, they created a Sankey diagram based on the Economy-wide Material Loop Closing framework (Mayer et al., 2018).	The circularity gap (CG) of a nation can be defined from these parameters as the waste generation, plus stock depletion, minus recovered materials. Such a CG metric can be seen as measure of the waste materials that are theoretically available for circularity.
Period	**Geographical coverage**
/	/
Material flow streams	**Applicability to Belgium**
Biomass, metal ores, non-metallic minerals and fossil energy carriers.	Need for deeper examination.

A generic diagram of the material flows in an economy has been created by the researchers. In the diagram, the following activities (represented as solid boxes) are considered: intermediate activities and final demand (I&C), waste treatment sectors (T), and rest of the world economy (RoW).

Material stocks (presented as solid circles) are considered: stock of natural resources (N), material inuse stocks (S), and the stock of nature from domestic processed outputs (DPO).

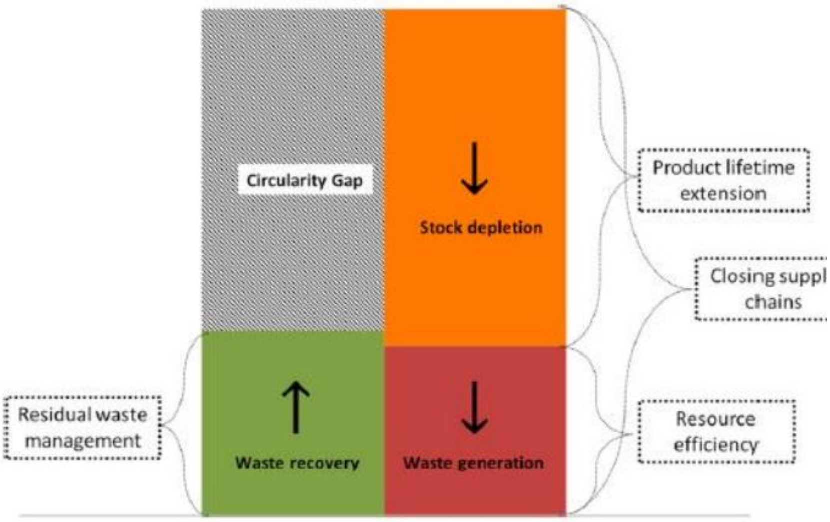
The last one comprises all material wastes that are disposed into the environment as dissipative emissions or other combustion and biomass residues (e.g. ashes and slag from fossil fuels combustion, and biomass waste from humans and livestock), as well as waste solid landfilling and incineration. The following flows (represented as solid lines) are considered: imports (m), domestic resource extraction (r), recovered or secondary materials (wrec), exports (e), waste generation (wsup), additions to stocks (sadd), stock depletion (sdep). Finally, the flow of dissipative emissions, and other combustion and biomass residues caused by intermediate activities and final demand (bI C &), and waste treatment (bT) are represented as dashed lines. Waste treatment is considered as a defensive expenditure that can be required to mitigate the potential impacts of waste disposal on the environment (EC, 2000).

Circularity gap calculation
For a specific period, there are three main outflows related to the amount of waste materials that can be potentially recovered as physical products: waste generation, stock depletion, and waste recovery.

The circularity gap (CG) quantifies the amount of waste materials available for material circularity is defined as the following :

$$CG = Waste_{sup} + Stock_{dep} - Waste_{rec}$$

Aguilar-Hernandez et al. (2019) gives the following definitions of each part of the equation :
$Waste_{sup}$ is waste generation which are material outflows of human activity which require further treatment to be disposed of outside the technosphere.
$Stock_{dep}$ is the amount of waste resulting from materials accumulated previously, which includes the old materials depleted from stock and durable products disposed from previous years.
$Waste_{rec}$ refers to all waste that reprocessed or recycled into products or materials that are used by the economy.
This, the CG corresponds to all waste that is generated from $Waste_{sup}$ and $Stock_{dep}$excluding the recovered waste. Visually, the CG can be represented as below



It is important to notice that CG represents a simplification of the time dimension and material losses. Regarding the temporal aspect, waste recovery consists of waste materials from the same period as well as those released as waste from preview years due to stock depletion. In this study, it is assumed that waste generation, stock depletion, and recovery take place in the same year, and future waste supply is the result from additions to stocks. In addition, this approach does not recognize material losses, quality, or recycling efficiency rates.

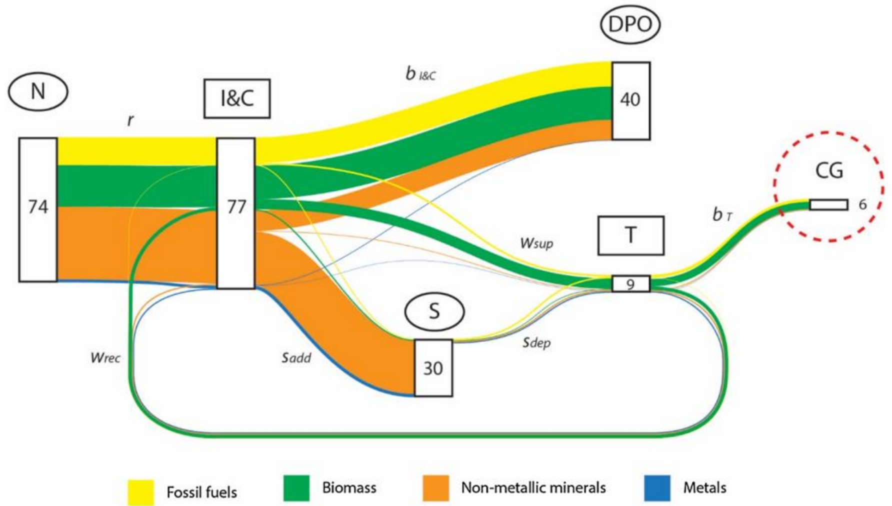


Fig. 2. Sankey diagram of global ma traction, waste, and emission flows Numbers indicate the size of Gigatonnes (Gt). Solid blocks indi nomic activities of: I&C = Intermedia and final demand; T = waste treatm ities. Solid circles indicate resource N = Natural resources; S = Materi stocks; DPO = Domestic processed Colored lines indicate flows of: r = extraction; w_{rec} = waste recovery; s_{ad} additions; s_{dep} = stock depletion, w_{sup} generation; $b_{I\&C}$ = dissipative e others combustion and biomass resid intermediate activities and final den b_T = dissipative emissions and oth bustion and biomass residues fro treatment. Dashed circle denotes c gap (CG). Note: RoW, m, and e are not this figure because physical trade bal not appear in the global material flov

There are three ways to reduce a country's CG: **increasing waste recovery**, **decreasing waste generation**, and **reducing stock depletion**. In order to change the material flows related to CG reduction (i.e. generated waste, depleted stocks, and recovered materials), specific circular economy strategies that aim to retain materials in a closed-loop economic system should be implemented. Such a set of strategies, also called circularity interventions, have been categorized in four groups: residual waste management, closing supply chains, resource efficiency, and product lifetime extension.

1) **Waste recovery** can be increased through residual waste management. This intervention type is focused on strategies at the end-of-life of products, in which materials are disposed outside the economic system. An increase of waste recovery would imply the replacement of landfill and incineration processes with recycling activities. This can contribute to material circularity in countries with a low degree of waste recovery, which is particularly the case of middle, upper lower and lower income economies.
2) **Closing supply chains** are the strategies of re-integrating materials at different levels of the supply chain after their initial use phase. This intervention category is implemented by: using a product one more time for the same purpose (product reuse), taking reusable components and rebuilding a new product (component reuse), substituting or repairing major parts in order to return a product to its working condition (refurbishment), and material reuse as material recycling.

3) **Resource efficiency** refers to actions that improve material flows through the use of less resources per unit of total output, which can contribute to waste reduction in specific
4) **The decrease or delay of waste from previous stocks can be achieved through product lifetime extension**. Such an intervention focuses on the design for longevity and maintenance of durable goods. It is expected that a significant amount of future waste will be generated due to the depletion in-use stocks from building and infrastructure activities, especially in high and upper high income countries, where there is a high degree of stock additions every year. Instead of interventions addressing material flows, delaying stock depletion should be focused on stock management, in which extending product lifetime will prevent the erosion of durable products.

9.4 METHODOLOGY #4

Methodology #4
Economy-wide assessment in Flanders

Short description

This study introduces the link between the material flows in and out of the Flemish economy and the material flows within the Flemish economy. The scope of this report is the understanding of physical flows of materials in Flanders, the assessment of the current circularity, the monitoring thereof and how they can be made more circular.

The economy-wide circularity assessment is acknowledged to be an effective tool to provide a high level overview and understanding of the socio-economic metabolism of our economic system.

CE Center, (2021). CE Center Circular Economy (2021). An economy wide circularity assessment in Flanders, OVAM.

Methodology overview

Category overview

Circular Economy	X
Self-sufficiency	
Resilience	

Sub-category covered features

Self-sufficiency	
Material footprint	
Waste	X
Recovery (recycling)	X
Secondary raw materials	X

Purpose

Macro-overview	X
Specific indicators measurement	X

Geographical coverage

International	
EU aggregates	
EU member states individually	
Specific country development	
Belgium	
Brussels	
Wallonia	
Flanders	X

Data sources

OVAM

Period

2018

Full methodology description 1 –

Data sources

EW-MFA, waste and emission data and mass-balanced modelling.

Period

2018

Material flow streams

Biomass, metal ores, non-metallic minerals and fossil energy carriers.

Description

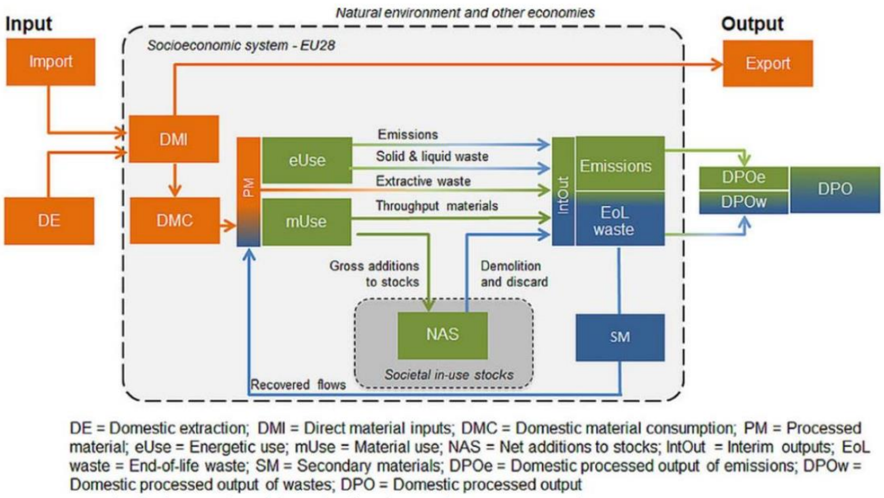
Following the study on the material flow analysis for Flanders in the period 2002-2018, which is published by the Circular Economy Policy Research Centre in June 2020, this study introduces the link between the material flows in and out of the Flemish economy and the material flows within the Flemish economy. The scope of the report is the understanding of physical flows of materials in Flanders, the assessment of the current circularity, the monitoring thereof and how they can be made more circular.

Geographical coverage

Flanders

1. Economy-wide assessment of circularity

The economy-wide circularity assessment is acknowledged to be an effective tool to provide a high level overview and understanding of the socio-economic metabolism of our economic system. In this report, the framework and accompanying methodology developed by Mayer et al. (2019) was used, which is presented in Figure 1. The framework builds upon existing scale indicators for material flow accounting and for statistics on waste flows and emissions, and it is extended with additional indicators that require specific modelling and can't be derived directly from macro-economic statistics.



The actual material flows are domestic extraction used (DE), import, export, emissions, throughput materials (including dispersed and dissipated materials), stock additions, stock depletions (i.e. demolition and discard), supplied or generated waste (EoL waste), secondary materials (SM) and lost waste (DPOw). Next to the actual materials flows, there are virtual material flows including the raw material equivalents of import and export flows. Physical stocks include natural stocks of resources (preceding DE), socioeconomic stocks of products (societal in-use stocks) and domestic processed output (DPO).

The colours in Figure above indicate data sources that could be used to compile the framework:

- Orange: based on data from the economy-wide material flow accounts;
- Blue: based on waste and emission data; and
- Green: mass-balanced modelling (i.e. no data source available). A shift from green to blue colour indicates a combination of statistical data and modelling.

2. The economy-wide circularity applied to Flanders

A first set of economy-wide indicators is based on Mayer et al. (2019). All the indicators they describe in this set are derived from the framework presented in Figure 1. These authors distinguish between:

- **scale indicators**: which provide measures for the overall size of the socioeconomic metabolism;

- **circularity rates**: which measure socioeconomic and ecological cycling relative to input and output flows.

Providing independent measures for flows on both the input and output sides is necessary because of the delaying effect that in-use stocks of materials have on output flows.

Results can be illustrated here :

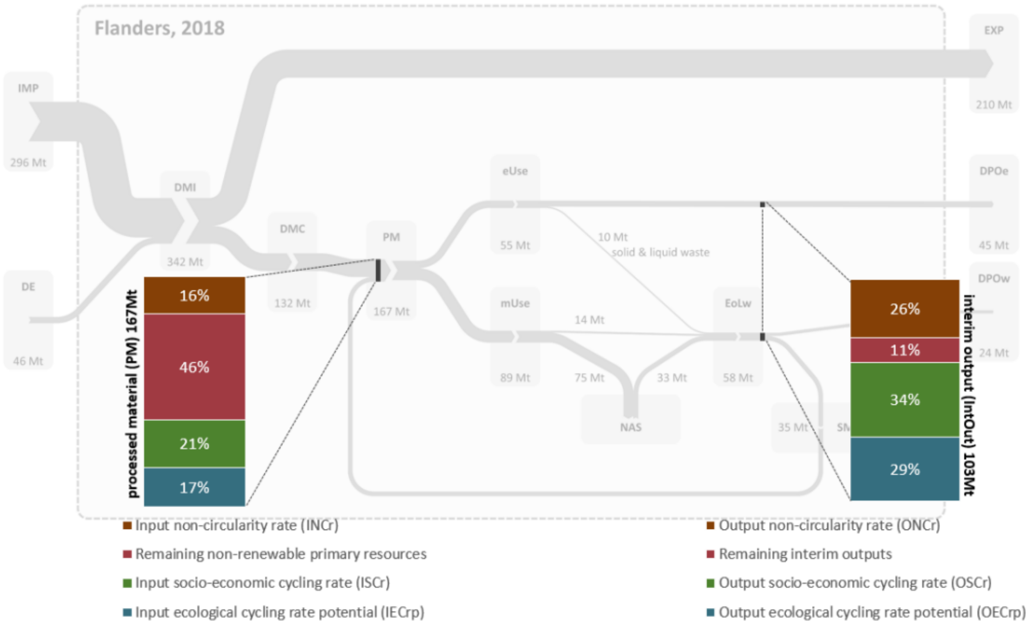


Figure 8: Input- and output-side CE-indicators. The left bar depicts the processed materials (PM), and the right bar depicts interim outputs (IntOut). The percentages denote the share in relation to the PM (left bar) and the IntOut (right bar). Based on Mayer et al. (2019).

An alternative indicator is the circularity gap presented by Aguilar-Hernandez et al. (2019).

The indicator is defined as the generated waste plus old materials removed from stocks and durable products disposed minus recovered waste.

The circularity gap (CG) can be interpreted as the measure of waste materials that are theoretically available for material circularity. From the framework presented in Figure 1, the stock depletion, waste generation and waste recovery are represented by -Stock, EoLw and SM, respectively. Also, in this framework the CG is represented by DPOw.

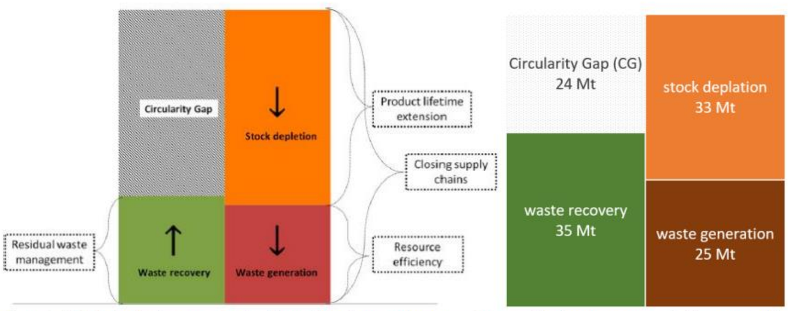


Figure 9: (left) A circularity gap reduction through four intervention types. Green, red and orange squares indicate material recover, waste generation, and stock depletion, respectively. The grey area depicts the circularity gap. Upward arrows indicate an increase of materials flows, and a downward arrow indicates a decrease or delay of the flow. (right) The estimated circularity gap for Flanders, 2018.
Source: Aguilar-Hernandez et al. (2019).

3. Refining the economy-wide circularity framework

3.1. Adding trade in waste and trade in secondary materials to the framework

Extending the existing framework with trade, both import and export, of waste and secondary materials will further improve the understanding of the framework and will increase the possibilities for reading/deriving indicators directly from the framework. In this part, the trade of waste and secondary materials are made visible in the Sankey diagram, starting from the framework presented in Figure 1 and completed for Flanders in Figure 4.

Classifications of waste, trade flows of waste and secondary materials need to be clearly agreed upon and visualized separately on the Sankey in order to improve consistency. Improved data on the production and trade of secondary raw materials is therefore required, as well as a good insight in the waste statistics. **The goal is to end up with an extended framework which will improve the interpretation of the SM/PM indicator by visualizing the individual components of the indicators.**

The extended version of the economy wide material flow framework should include, in addition to Figure 1, **the trade in waste and secondary raw materials**. Both flows should explicitly be visible.

Imported waste is added to the domestic EoL waste. However, in order keep domestic EoL waste visible the imported waste is only added to a 'new step' which is called the waste management system (WMS). The WMS processes both the domestic waste and imported waste.

Part of this volume might be exported (with or without processing in Flanders). Adding imported secondary raw materials and subtracting exported secondary raw materials results together with the domestic provision of secondary materials in the volume of secondary raw materials being feedback into the domestic economy. The import and export are still present, but (in theory) no longer include the trade in waste and secondary materials. In practice, the trade in products containing secondary materials are still included.

The trade in secondary materials is based on a list of CN-codes developed by Eurostat and extended for use in this study. Secondary materials outside these CN-codes or products outside these CN-codes containing secondary materials are still included in the original trade flows of import and export.

3.2. Improved framework

The material flow diagram presented in Figure 11 shows the improved framework of material flows through the Flemish economy in the year 2018. This figure shows a Sankey diagram the width of the arrows is proportional to the size of material flows. The numbers show the size of the material flows in million tons per year. The green flows are trade flows of either products, waste or secondary materials. The trade in waste and secondary materials are excluded from the 'traditional' import and export flow. The flows between the Flemish domestic economy and the environment are presented by blue arrows. On the input side it shows domestic extraction; on the output side it shows domestic processed output of emissions and waste. Remind that controlled landfills are considered as part of the domestic economy (stock). The domestic flows are visualised by orange flows.

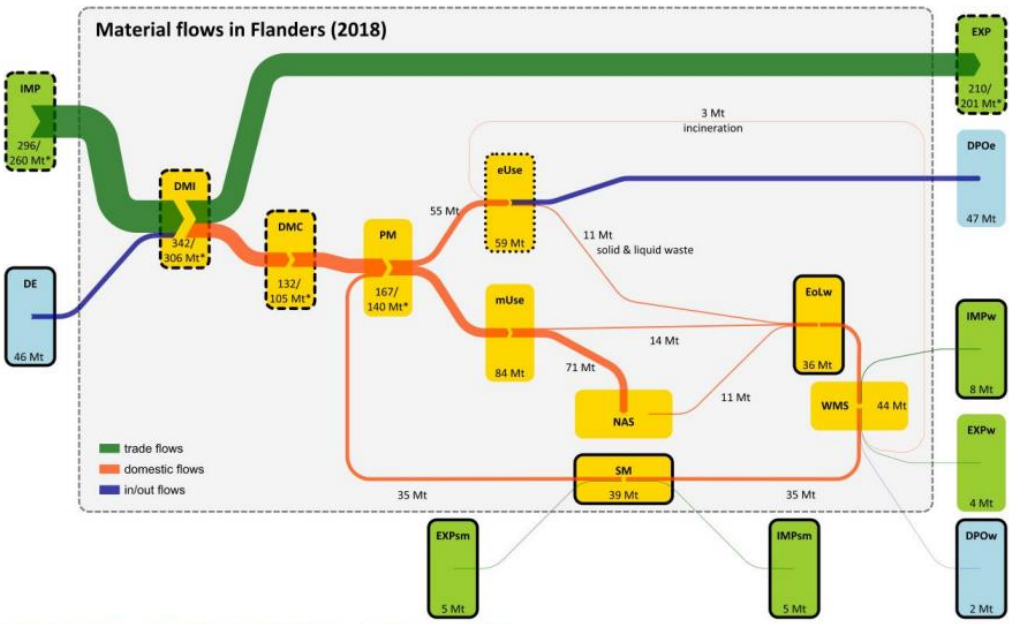


Figure 11: Material flows through the Flemish economy in 2018.
**Numbers according to the EW-MFA/numbers according to Energiebalans Vlaanderen.*

3.3. Effect of circular strategies on the indicator

The aim was investigate the effect of circular strategies on the circularity rate indicator as currently calculated for Flanders, to better interpret what is captured by this indicator and what not. As explained previously, the circularity rate is defined as:

$$\frac{SM}{PM} = \frac{SM}{DMC + SM} = \frac{SM}{DEU + IMP - EXP + SM}$$

Recycle - Recover

The Flemish circularity rate indicator, like the CMUR and the NCI, takes a consumption perspective, not a "production" perspective.

This is reflected by the use of the indicator DMC for the denominator, only the materials used for consumption in Flanders are included so the exported products are not considered in this indicator .

If the circularity indicator follows the perspective of collection of waste (instead of use of secondary materials) the materials, also secondary materials, which are extracted/recovered or processed in products in Flanders but exported, are not included.

A consequence of this perspective is that the use of secondary material by Flemish companies in products which are exported is not awarded.

The use of secondary materials by Flemish companies is only awarded for the share of products that are consumed in Flanders. In this case the circularity rate doesn't credit the complete use of secondary materials in Flemish industry. If the perspective of use of secondary materials from waste is applied for the circularity indicator, the secondary materials used in Flanders are included in the SM flow regardless of the fact that they are used for products consumed in Flanders or exported.

An option is to define a complementary indicator which starts from the production perspective of a country and uses e.g. the DMI as a measure for total material use. However, this leads to double counting of some import and export flows for different countries. The choice between an indicator from a consumption or production perspective is also related to the choice where to put the responsibility of improving circularity of a country: to the country as a producer or as a consumer?

In a case where additional fossil fuels are required (e.g. for transportation, sorting) to increase the collection of waste for recovery/recycling (SM), the trade-off between on the one hand the increase in DMC due to extra fossil fuel use and on the other hand the increase in SM determines whether the circularity rate SM/PM improves. If too much fossil fuels are needed for too little additional waste collected for recovery/recycling, the indicator will decrease. It is good that the indicator captures this effect. Distinguishing the circularity indicator for the different material types helps even more to have insight in the different elements of this scenario.

Reduce – Rethink – Refuse

The example related to the use of plastic bags, can be used to illustrate the effect of reducing the amount of plastic bags used by consumers. This reduces the DMC, but has no effect on the SM as in Flanders the waste for energy recovery is not included in the SM. The circularity rate indicator would thus increase.

A similar reasoning can be followed for drinking water bottled in plastic PET-bottles. If Flemish households would increase the use of tap water at the expense of PET bottled water, the DMC would decrease (less PET-bottles), the waste going to recycling would decrease with a similar absolute amount (assuming that close to 100% of PET-bottles are collected for recycling) but the relative decrease of the numerator is higher than the denominator. This would lead to a lower circularity rate, which is opposite to what you would expect. This illustrates the importance of not only using the circularity rate as the one single indicator for monitoring circularity. It is important to put this next to other indicators, for example at micro or meso-level. In this example the DMC would decrease, which is also what you want to achieve with circular economy. It may not only be the objective to increase the circularity rate, an important objective should be to use less material (primary and secondary together) for meeting our consumption needs.

With regard to biomass, e.g. for food, some circular strategies are reflected in the circularity rate indicator but other are not. For example, additional valorisation of food waste causes the circularity rate indicator to increase because the SM increases. Switching to a more high-quality valorisation is not reflected in the indicator if the total amount of SM remains equal. A shift from animal to vegetal food products is only accounted for in the circularity rate indicator if the value chain is located in Flanders. If these products are imported, they represent an equal amount (tonne) of imported products thus the DMC doesn't change, although less biomass is required to produce the vegetal products.

Reuse – Repair – Remanufacture

Reuse, repair and remanufacture are CE strategies that aim at reducing the useful life of products. Referring to the Sankey diagram (see Figure 11) the Net Addition to Stock (NAS) part creates a time gap between the input and output of materials. Materials in mUse will eventually flow to EoLw, but there is a time gap between both. Reuse, for example, will extend the time a 'material' remains mUse until it becomes EoLw. The issue with the Sankey and the related indicators is that the stock is not presented, only the flows going in and out of the stock are. Increased reuse will lead to a smaller flow going out of the NAS, but also a smaller inflow, while the (unknown) stock remains the same.

9.5 METHODOLOGY #5

Methodology #5
Circularity Gap Report : the Circularity Gap Metric

Short description

In the Circularity Gap Report, the Netherlands' assessed the circularity using our measurement: the Circularity Gap Metric. In the first edition of the global Circularity Gap Report, in 2018, they launched the Circularity Metric on a global level, but this current analysis adapts the metric to suit a country profile. Measuring the Netherlands' circularity should also provide an answer to how the Dutch economy is progressing towards its ambition to be fully circular by 2050. By measuring circularity in this way, businesses and governments can track their circular performance over time and put trends into context, as well as engage in uniform goal-setting and guide future action in the most impactful way.

Circle Economy (2020). The Circularity Gap Report: The Netherlands – Methodology document. https://www.circularity-gap.world/netherlands

Methodology overview

Category overview

Circular Economy	X
Self-sufficiency	
Resilience	

Sub-category covered features

Self-sufficiency	
Material footprint	X
Waste	X
Recovery (recycling)	X
Secondary raw materials	X

Purpose

Macro-overview	X
Specific indicators measurement	

Geographical coverage

International	
EU aggregates	
EU member states individually	
Specific country development	X
Belgium	
Brussels	
Wallonia	
Flanders	

Data sources

EW-MFA technique, for RME, COMEXT.

Period

2017-2020

Full methodology description 1 –

Data sources

EW-MFA technique, for RME, COMEXT.

Period

2017-2020.

Material flow streams

Biomass, minerals, ores, fossil energy carriers and cycled materials.

Description

The material footprint of the Netherlands.

Geographical coverage

The Netherlands.

1. Material flows and footprints

The below figure provides a schematic depiction of the material footprint of the Netherlands. It essentially details the amounts of materials in **physical weight** (excluding water and air) that are available to the economy. The left side shows four resource groups—minerals, ores, fossil fuels and biomass—that are the result of domestic extraction.

We also see on the left the volume of resources entering the national economy through import. Because the imported volumes are manufactured elsewhere and transported to the country, **the actual material import footprint exceeds the amount of direct imports as shown in the shaded colour**. Together, the domestic extraction and the import comprise the total material input into the national economy.

Within the national economy, the materials undergo a set of processes to convert them into end products. Beginning with the extraction, the resources are processed—such as metals from ores—and are manufactured into products in the produce stage. The finished products provide satisfaction to societal needs such as Nutrition and Healthcare, or they are exported. Of these materials entering the national economy every year, the majority are utilized by society as short-lived **Products that Flow**—reaching their end-of-use typically within a year, such as an apple or a pair of jeans. Their end-of-use resources are typically either lost or cycled back into the economy. The remaining aforesaid materials enter into long term stock—referred to as **Products that Last**. These products are namely capital equipment, buildings and infrastructure.

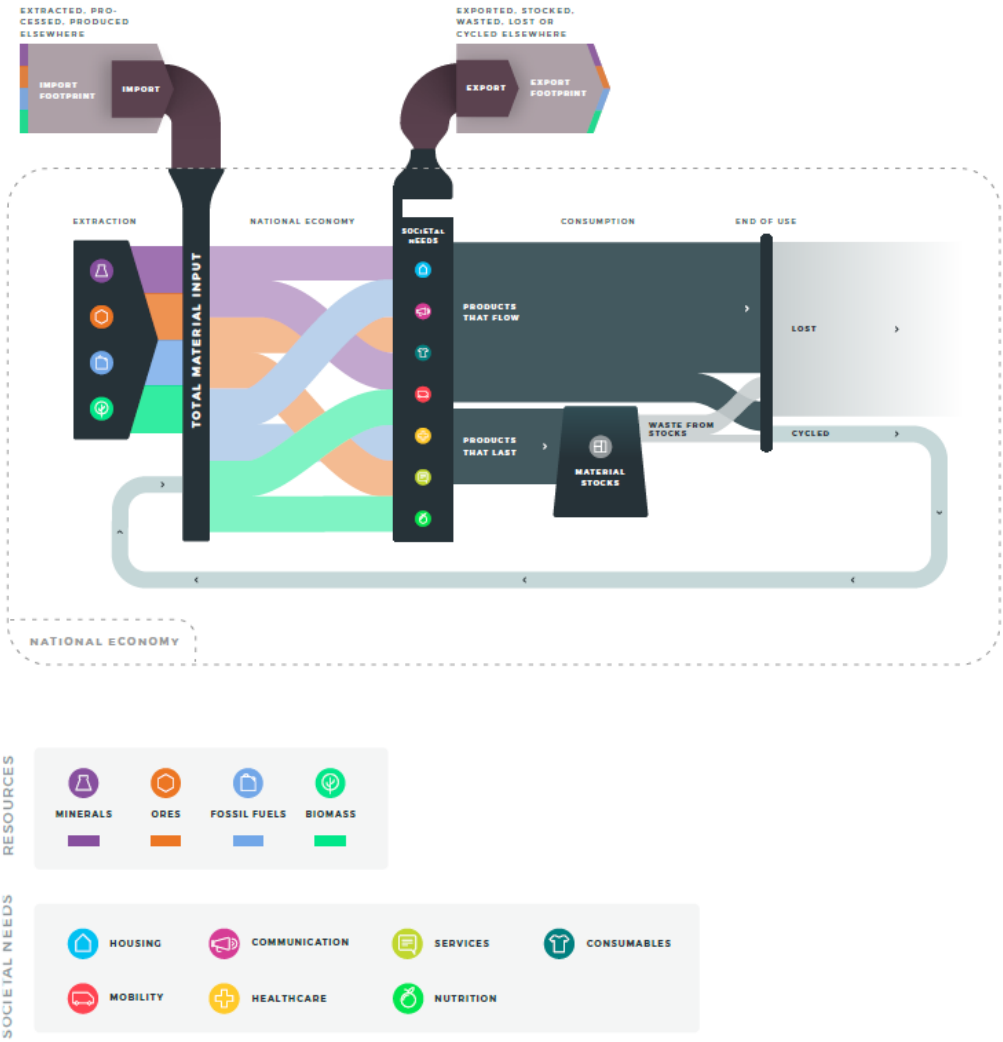


Figure 1 A schematic overview of the material footprint of a country. Note: material stock and cycled material flows are not scaled to proportion.

The Circularity Metric Explained

The National Circularity Index (NCI) follows from the Global Circularity Metric defined by Circle Economy and published annually in the Circularity Gap reports since 2018. While the Global Circularity Metric takes a global perspective, the NCI is developed for monitoring on a national and regional scale.

Global Circularity Metric is defined as the share of cycled materials as part of total material inputs into the global economy every year. Total material inputs includes:

- Cycled materials = materials classified as waste which are cycled (=to water treatment, to land application, to biogasification, to recycling and to composting)
- Extracted resources = all resources globally (except water).

The National Circularity Index (NCI) starts from a Sankey diagram which is based on MFA. Some important differences can be seen in the Sankey diagram compared to the traditional Sankey as presented by Eurostat;

- The flows are not only visualizing the direct material inputs, but are expressed in tons of Raw Material Equivalents (RME) and thus include the indirect use of raw materials (i.e. the rucksack of materials required in the production of the product. The RME-coefficients are estimated by combining national and Eurostat data.
- The Sankey shows explicit flows of imported resp. exported cycled materials.

The ratio of the NCI is the same as for Eurostat i.e. it is defined as the share of cycled materials as part of the total national material consumption. An important difference is the perspective used for the cycled materials.

The NCI applies the perspective of a country that recycles the secondary materials putting emphasis to the recycling process within the national economy, thus not a country's efforts to collect waste for recycling (as is used in Eurostat's CMU rate). The indicator distinguishes 4 key resource groups i.e. biomass, metals, non-metallic minerals and fossils. The type of material flows accounted for is different to the Eurostat CMU rate indicator i.e. backfilling material is included, as well as material send to energy recovery if it has a Combined Heat and Power (CHP) efficiency of more than 65%.

The NCI is defined by the following formula: NCI = $A = \frac{(SMC+WU)}{(RMC+SMC+WU)}$

The numerator distinguishes two flows:

- The waste reused domestically without pre-processing (wu): It is assumed that short-lived, low-value and bulky recyclable waste (e.g. non-metallic mineral waste such as aggregates, rubble and composting material) is only consumed within the national economy and thus not imported nor exported. This flow is known from the waste statistics.
- The secondary materials consumed domestically (smc): This includes the secondary materials domestically cycled plus imported, minus the secondary materials exported. These flows are not captured by statistics and need to be calculated using proxies and assumptions.
- Secondary materials imported (smi): Approximated by applying the Global Circularity Metric per resource group to the net direct imports (aggregated by resource group using shares of RME per resource group).
- Secondary materials consumed domestically rather than being exported: Assumed that the share of secondary materials in the total consumption of raw materials equals the share of imported and domestically cycled secondary materials in total input of raw materials.

The denominator uses the Raw Material Consumption (RMC) as a measure for the total national material consumption. The RMC is not available for all European countries (in Eurostat statistics), but is calculated by combining MFA data with RME-coefficients from Eurostat and national Input-Output modelling data.

The four strategies we can use to achieve these objectives are :

- **Strategy one—Slow flows**: The utilisation of stocks is optimised by, for example, extending the functional lifetime of products and buildings. Long-life products are designed using durable materials;
- **Strategy two—Narrow flows**: Material use efficiency is optimised by deploying circular design strategies that aim to minimise material use in delivering a product or service, it also increases the usage rate of products;
- **Strategy three—Regenerate flows**: Fossil fuels and toxic materials are replaced with regenerative sources. The natural capital of ecosystems is maintained and increased in the process;2
- **Strategy four—Cycle flows**: Material cycling for reuse is optimised. This includes improving the collection of materials used in infrastructure, and the wide-scale adoption of best-available technologies for (re)processing of resources, such as optimised cascading, which uses residues and recycled materials for extending biomass.

When we measure the combined effect of the above strategies, the cycling of materials comes to the fore as crucial. If we effectively deploy strategies focussed on slowing, narrowing and regenerating the flow of materials, we require fewer materials to provide similar needs, materials used by the economy have a longer lifespan, can be reused more effectively and take longer to become wasted. So, for our Circularity Metric to capture this crucial process, we thereby define it as measuring the share of cycled materials as part of the total material inputs into a national economy every year. We capture circularity in one number; the Circularity Metric. The value of this approach is that it allows us to track changes over time, measure progress and engage uniform goal-setting, as well as benchmark countries' circularity against the global rate and each other.

Firstly, in assessing a country, we can either take a production or consumption perspective. In a production perspective, we consider all the materials involved in any sort of processing of production activity, regardless of whether they are exported or consumed domestically. In a consumption perspective, we can only consider the materials that are consumed domestically. Whether we apply the metric to a consumption or production perspective will yield different results. In this study, we take a consumption perspective in a bid to generate actionable insights for the economy and consumption on the ground

Secondly, when considering what Dutch citizens consume to satisfy their needs, we must apply a nuanced lens to the direct imports; meaning we work out the full material footprints of the products. To account for the material footprint of raw materials is straightforward, but this is not the case with semifinished and finished goods. A motor vehicle, for example, may weigh 1 tonne when imported, but, all the materials used to produce and transport it can be as much as 3.4 tonnes. To represent actual material footprints in imports and exports, we apply so-called raw material equivalents (RMEs) in this study.

Thirdly, the Circularity Metric considers all secondary materials as adding to a country's level of circularity. These secondary materials can be part of those cycled within the country, as well those that are imported or exported, either as waste destined for recycling or as secondary materials embedded in traded products. However, estimating the shares of traded secondary materials is a difficult undertaking, so we introduce two important assumptions. First, to estimate the volume of secondary materials imported, we apply an average global share of secondary materials per resource group that is equal to the global Circularity Metric, to all imports. We further assume that some low-value, recyclable waste (mainly non-metallic minerals waste such as aggregates and rubble) is only consumed within the national economy. In our global Circularity Metric, these low-value resources were included in the total figure of 8.6% (there are no imports or exports in a global perspective); without them, that figure would be 2.8%. To understand the amount of secondary materials that are consumed domestically, rather than are exported, we make our second assumption. This is that the share of secondary materials in the total consumption of raw materials is equal to the share of imported and domestically cycled secondary materials in the total input of raw materials.

7 societal needs & wants

Societies need to not only survive, but thrive, and resources are needed to fuel the living. Here we describe the 7 key societal needs and wants and which products and services they include, as well as the volume of materials it takes to fulfil them in the Netherlands. Since various products can be allocated differently, here we make our choices explicit. For example, "radio, television and communication equipment" can be classified either as part of the societal need "communication", or as "consumables". We decided to subsume it under "communication".

- Housing and infrastructure
- Consumables
- Nutrition
- Healthcare
- Mobility
- Services
- Communication

The figure on the next page builds on the schematic material footprint diagram in figure one on page 14. It dives into the material footprint of the Netherlands; linking how four resource groups (minerals, metal ores, fossil fuels and biomass) satisfy the seven key societal needs

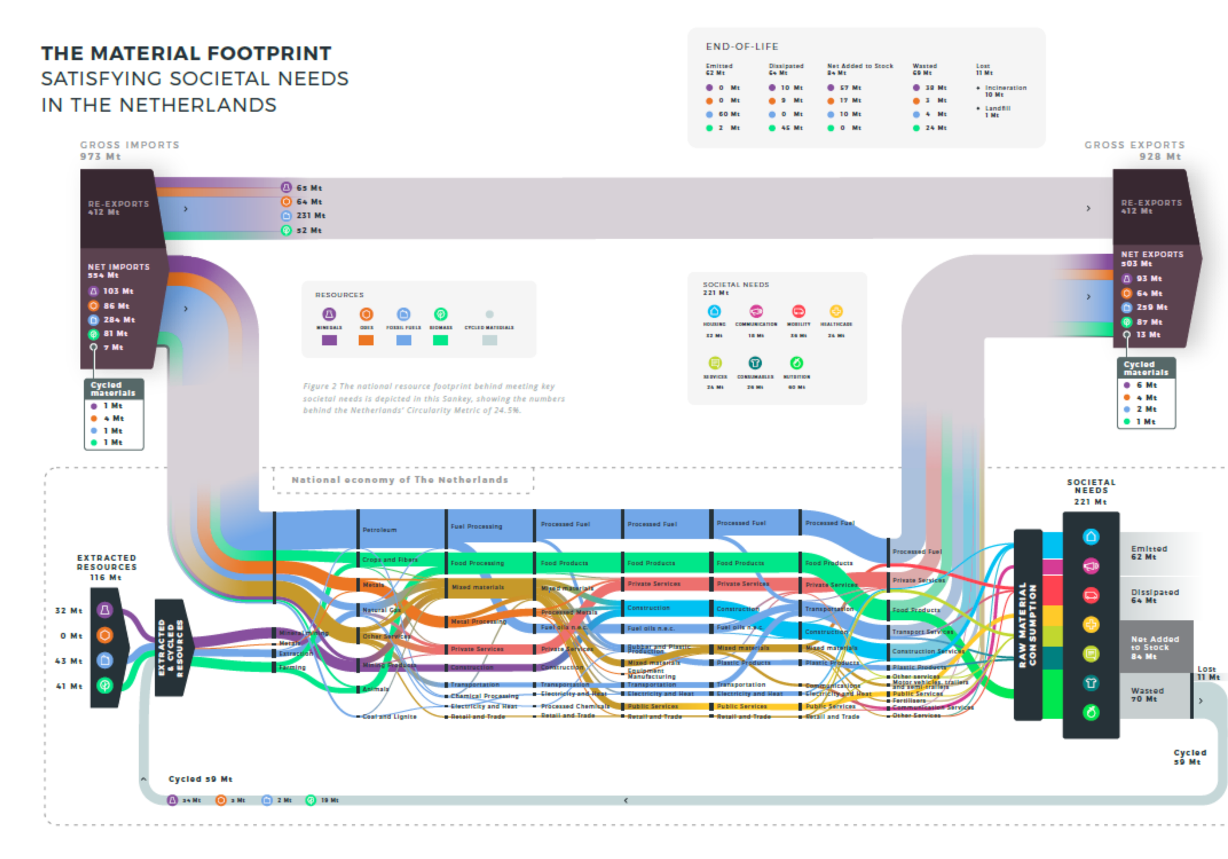


Figure 2 The national resource footprint behind meeting key societal needs is depicted in this Sankey, showing the numbers behind the Netherlands' Circularity Metric of 24.5%.

9.6 METHODOLOGY #6

Methodology #6
3rd Raw Materials Scoreboard 2021 – European Innovation Partnership on Raw Materials

Short description

The Raw Materials Scoreboard is an initiative of the EIP (European Innovation Partnership) on raw materials. It presents relevant and reliable monitoring information that informs government, industry, and other stakeholders inline with the overarching objectives of this EIP. The Scoreboard is published every two years.
It provides an overview of the raw materials supply chain. It takes a closer look at markets and trade, and presents the flow of materials through the EU economy. The Raw Materials Scoreboard comprises 26 indicators divided into 6 clusters:

1. Raw Material Supply in the EU
2. Raw Materials in the global context
3. Circular Economy and recycling
4. Competitiveness and innovation
5. Environmental dimension
6. Social dimension

EIP (2021). 3rd Raw Materials Scoreboard – European innovation partnership on raw materials. Publications Office. https://data.europa.eu/doi/10.2873/567799

Methodology overview

Category overview

Circular Economy	X
Self-sufficiency	X
Resilience	X

Purpose

Macro-overview	X
Specific indicators measurement	X

Geographical coverage

International	
EU aggregates	X
EU member states individually	X
Specific country development	X
Belgium	
Brussels	
Wallonia	
Flanders	

Sub-category covered features

Self-sufficiency	X
Material footprint	
Waste	X
Recovery (recycling)	X
Secondary raw materials	X

Data sources

Data sources vary depending on the indicator.

Period

Period vary depending on the indicator.

Full methodology description 1

1) Introduction : The Raw Materials Scoreboard

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

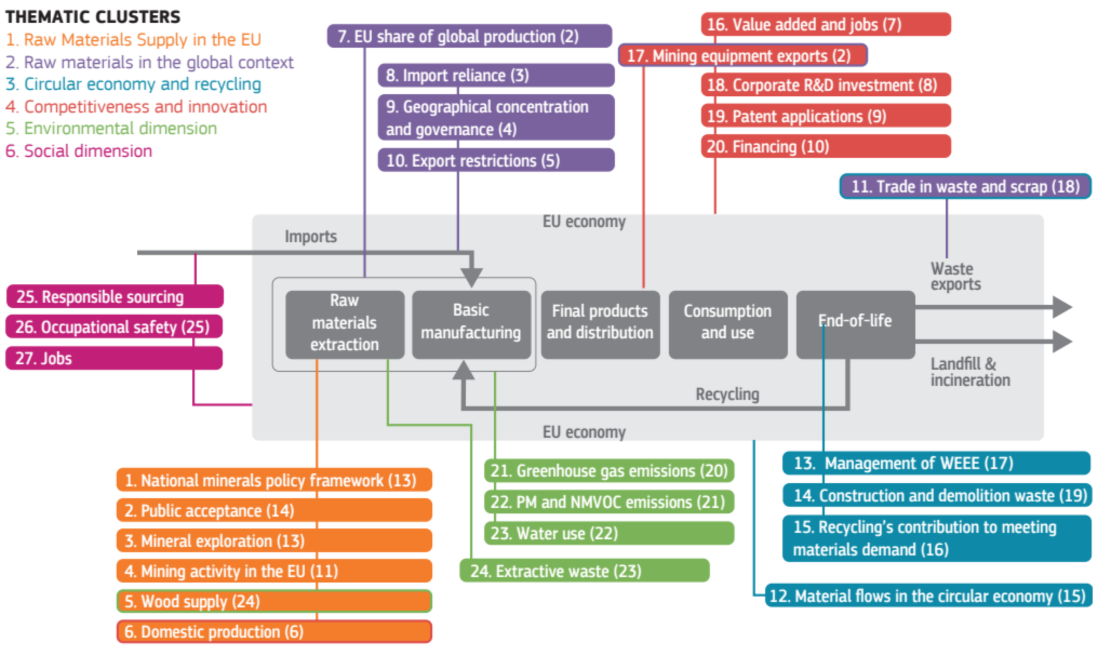
The indicators within the Scoreboard look at a range of raw materials – often grouped into **metals**, **minerals** and **biomass**, but also sometimes individually. While most indicators provide data at EU level, in certain fields they look through the lens of Member State performance.

Table 1 shows the materials covered by the **Scoreboard.**

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

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

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



2) Raw materials supply in the EU

2.1. National minerals policy framework

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

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

The indicator present the **PPI (Policy Perception Index)** and the **IAI (Investment Attractiveness Index (IAI)** for selected major mining EU and non-EU countries in 2010-2019.

The PPI takes into account policy-relevant factors such as burdensome regulations, regulatory duplication, uncertainty concerning the administration of current regulations, the legal system, disputed land claims and socioeconomic agreements, environmental regulation, taxation levels, and infrastructure.

The IAI complements the PPI, combining the perception of the policy with geological attractiveness. The PPI and IAI annual surveys have a global coverage of around 100 jurisdictions, covering also some EU countries.

Measures : 0 to 100 (with 100, high policy-relevance or investment attractiveness).	**Period** : 2010-2019
Geopolitical entity : EU : Finland, Ireland, Sweden, Portugal, Spain and Poland. Non-EU : China, Russia, Australia, Canada, Brazil, Chile, USA, South Africa and DR of Congo.	**Source** : Two index datasets published by the *Frase Institute Annual Survey of Mining Companies*. Thes report on managers' perceptions of various aspec related to framework conditions. First, *the poli perception index (PPI)* is used as a proxy for th perceived adequacy of the policy framewor Therefore, information on the *investme attractiveness index (IAI),* which combines perceptic of the policy framework with perception of geologic attractiveness, is also considered here.

Material flow streams : None.	**Applicability to Belgium :** Need to establish contact with the team associated with the Fraser Institute Annual Survey of Mining Companies.

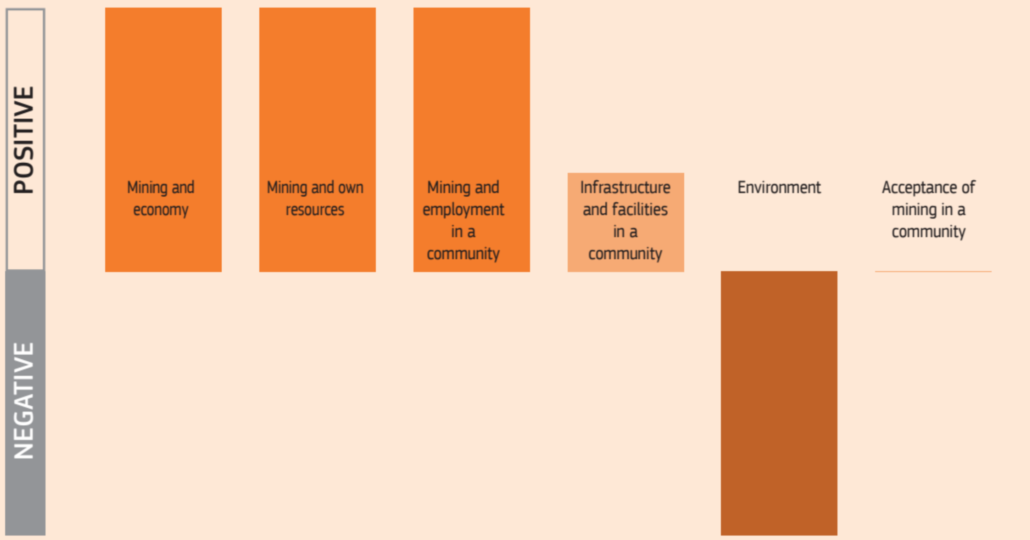
2.2. Public acceptance

Description : Public acceptance is an overarching indicator for upstream and downstream activities, as well as for primary and secondary raw materials, especially in a broader context when awareness and sustainable consumption are taken into account. It therefore also impacts on the success of the circular economy, e.g. through influencing collection rates or recycling activities.

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

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

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



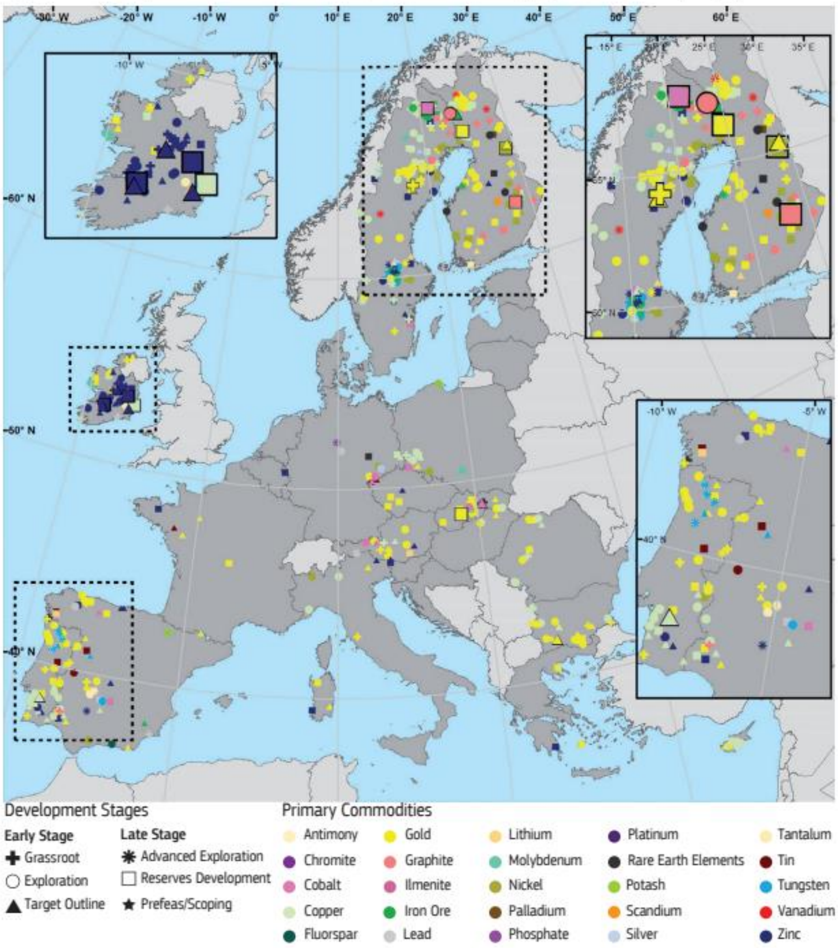
Measures : Binary (positive vs. negative).	**Period** : Not specified.
Geopolitical entity : Germany, Spain and Finland.	**Source** : INFACT – Horizon 2020 project
Material flow streams : Mining and mineral exploration.	**Applicability to Belgium :** If a similar investigation conducted, or in reference to the 2016 edition of th Scoreboard where the indicator utilized was Eurobarometer survey gauging public perception corporate behaviour.

2.3. Minerals exploration

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

Mineral exploration is considered a high-risk business, with one successful mine in 1 000 geological projects. Mineral prices and future metal demand are the main drivers of exploration activities.
Figure 3.1 shows that mineral exploration activities in the EU in 2019 remained concentrated in Ireland, Spain, Portugal, Sweden and Finland, countries regarded as attractive for investment in exploration. Gold, copper and zinc are still the main target commodities. It shows significant differences among Member States in terms of mineral exploration activities, similarly to the 2018 Scoreboard.

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

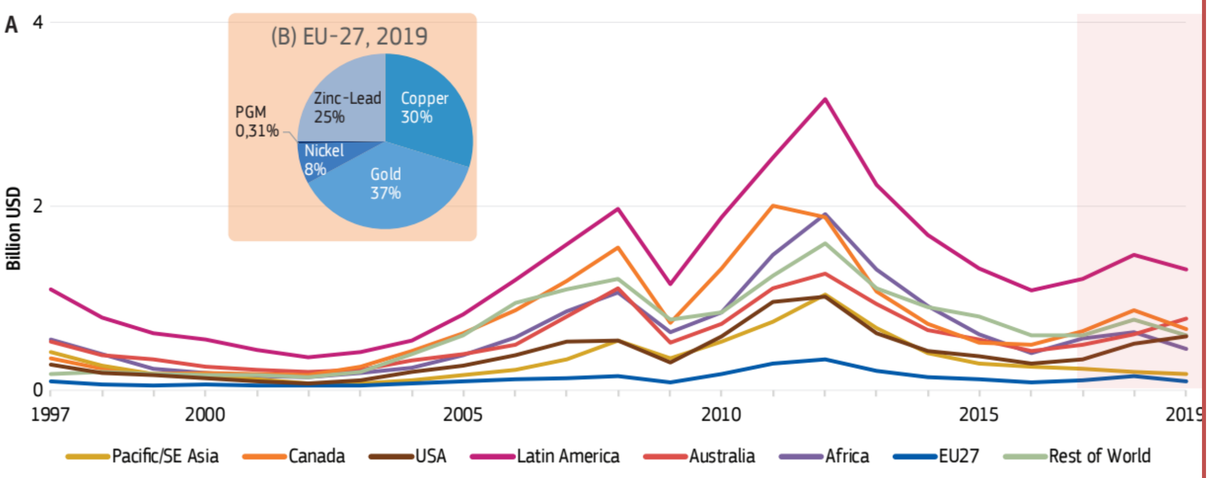


Measures : Visual.	**Period** : 2019
Geopolitical entity : EU member states.	**Source** : EIP.
Material flow streams : Mining and mineral exploration (see list of primary commodities).	**Applicability to Belgium :** Data available for Belgium.

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

Figure 3.3 presents the total budget allocated to exploration activities by world region over time. The coverage of the data source means that the exploration budget in the figure is limited to copper, gold, nickel, platinum group metals (PGM), and zinc-lead. The highest investment amounts allocated to exploration were still seen in Latin America, Canada and Australia. The Figure shows how since 2012, declining market prices for metals have led to a drop in exploration budgets.

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



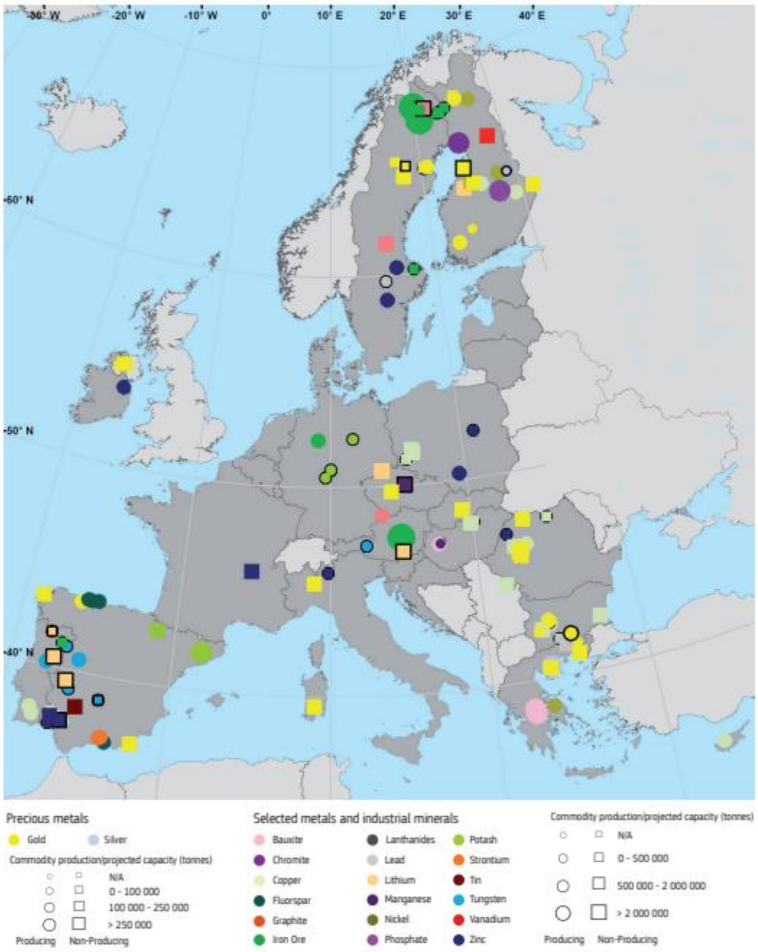
2.4. Mining activity in the EU

The figure refers to the *main commodity* targeted by each activity, which implies that all other co- or by-products are not shown on the map (i.e. a copper mine may also produce zinc, silver, lead and gold).

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

Measures : Visual.	**Period** : 2019
Geopolitical entity : EU member states.	**Source** : EIP.
Material flow streams : Metal and selected industrial minerals (see selected commodities).	**Applicability to Belgium :** Data available for Belgium.

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

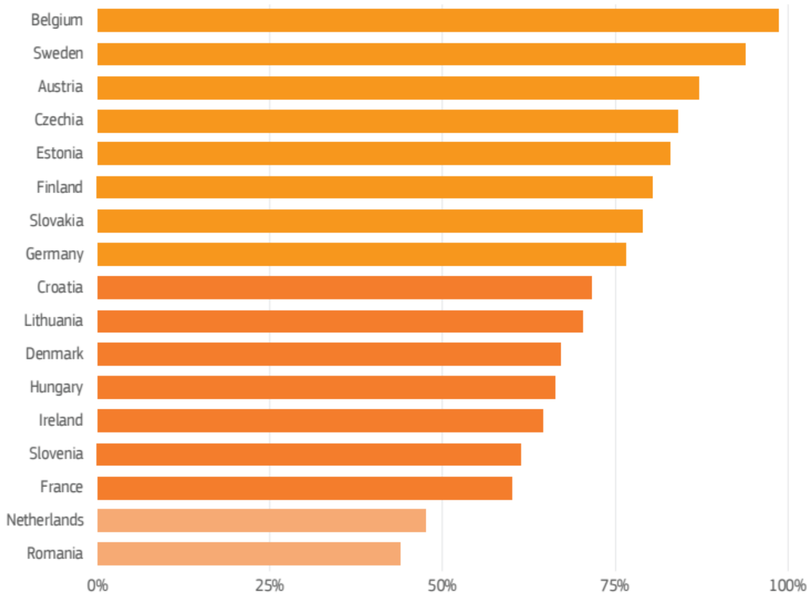


2.5. Wood supply

EU forests produce close to 20% of the industrial roundwood in the world, with some EU countries among the world's top-10 producers. The EU's wood-based upstream sectors generated EUR 98 billion of valued added in 2017. Over 56% of wood supply to the EU comes from domestic removals, around 19% from wood by-products of the wood industries, and 4% from post-consumer wood. While the net trade balance, imports minus exports, of wood with non-EU countries was less than 2%, volumes of intra-EU trade are high since the northern EU region produces more that it uses.

Figure 5.1 gives an overview of felling (utilisation) rates – i.e. the proportion of wood cut down in EU forests – as a percentage of the net annual increment – i.e. net yearly wood growth of the forests. This indicator belongs to the updated set of pan-European indicators for SFM criteria under the Forest Europe process, developed by EU Member States and other European countries.

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

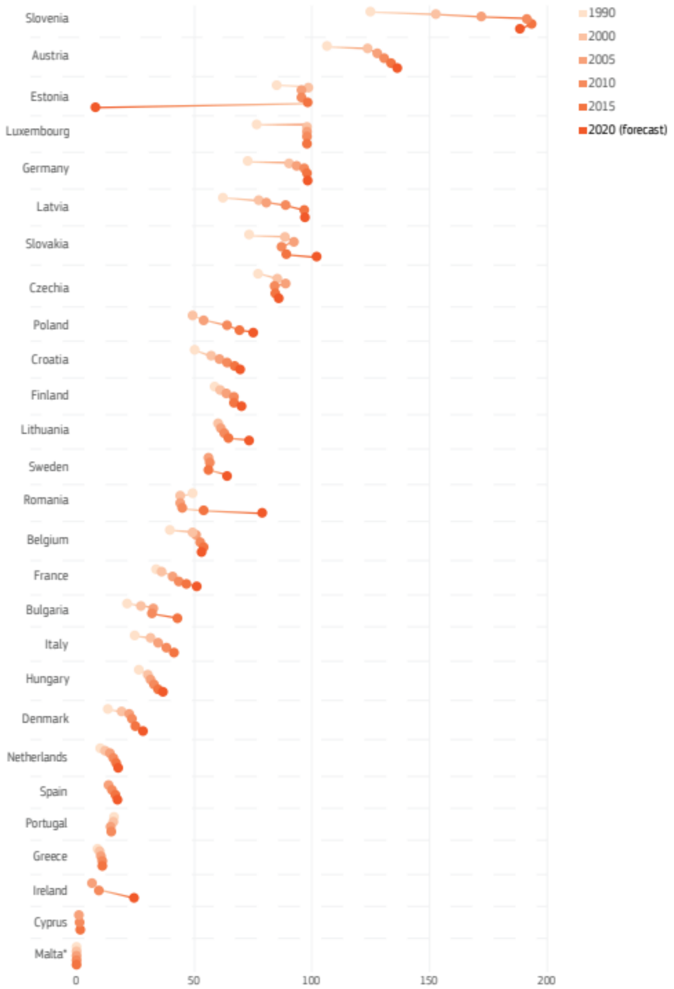


Measures : Percentage (felling rates as a percentage of net annual wood net increment).	**Period** : 2015.
Geopolitical entity : EU member states.	**Source** : SFM criteria under the Forest Europe.
Material flow streams : Wood	**Applicability to Belgium :** Data available for Belgium.

Figure 5.2 presents the EU's forest growing stock in forest available for wood supply from 1990 to 2020. The growing stock represents the volume of living trees, and is a combined effect of the increase of forest area and of growing stock per area unit. Growing stock shows whether forest stocks are expanding or shrinking, their potential wood supply and helps to estimate carbon stocks.

To help compare countries, growing stock values are presented relative to country areas. Data for 2020 are forecasts, since the Forest Europe report was released in 2020.

Figure 5.2: Wood growing stock in forest available for wood supply per country area (m³/ha) (EU-27, 1990-2020)[147]. Data for 2020 are forecasts. Countries are ordered according to 2015 values.



Measures : Wood supply per country area (m³/ha).	**Period** : 1990-2015.
Geopolitical entity : EU member states.	**Source** : Forest Europe report.
Material flow streams : Wood	**Applicability to Belgium :** Data available for Belgium.

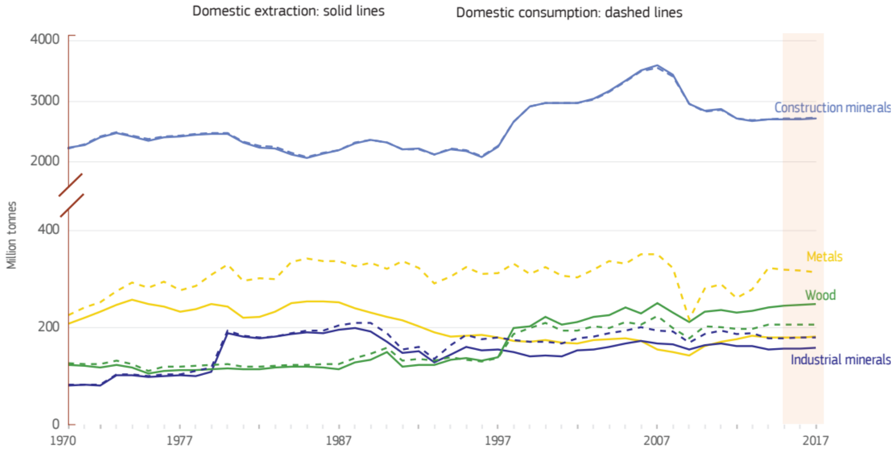
2.6. Domestic production

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

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

Figure 6.1 presents EU trends in domestic extraction (solid lines) by category of raw materials, and as compared to domestic material consumption (dashed lines) from 1970 to 2017. The figure on extraction cannot be directly compared with results in the 2018 Scoreboard, due to changes in materials grouping.

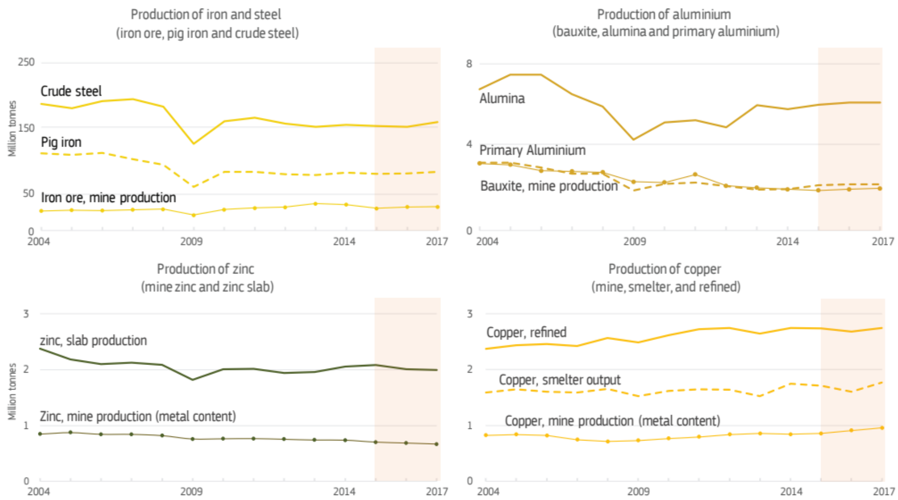
Figure 6.1: Domestic extraction (solid lines) and domestic consumption (dashed lines) by raw material category (EU-27, 1970-2017)[155].



Measures : Million tonnes.	**Period** : 1970-2017.
Geopolitical entity : EU aggregates.	**Source** : Eurostat.
Material flow streams : Construction minerals, metals, wood, industrial minerals.	**Applicability to Belgium :** Data available for Belgium a it refers to Domestic Extraction (DE) and Domest Material Consumption (DMC).

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

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



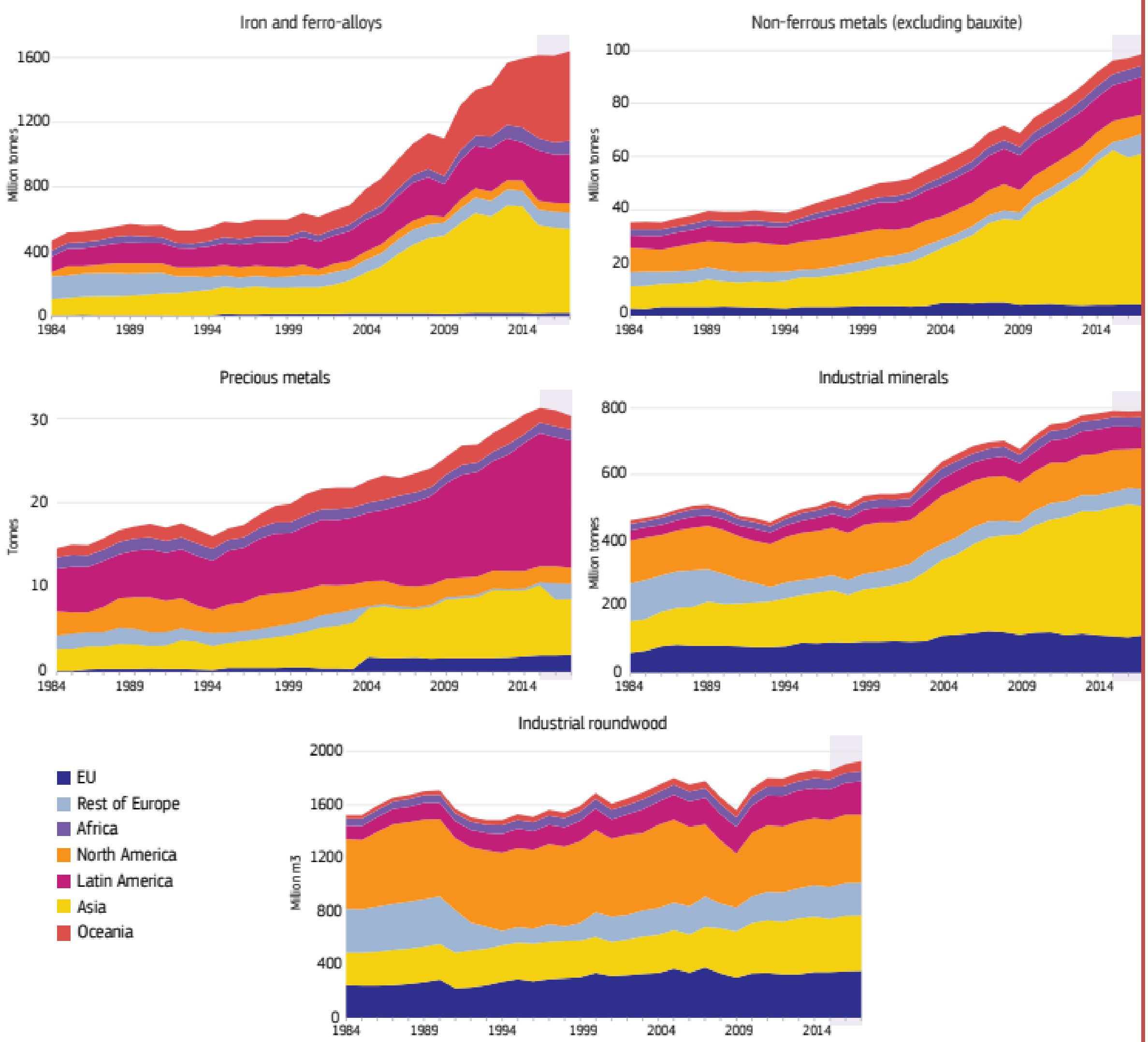
Measures : Million tonnes.	**Period** : 2004-2017.
Geopolitical entity : EU aggregates.	**Source** : Source: JRC elaboration based on Britis Geological Survey
Material flow streams : Iron and steel (1); aluminium (2); zinc (3); copper (4).	**Applicability to Belgium :** Need for examination.

3) Raw Materials in the Global Context

3.1. EU share of global production

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

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



Measures : Million tons.	**Period** : 1984-2017.
Geopolitical entity : EU, Rest of Europe, Africa, North America, Latin America, Asia and Oceania.	**Source** : Source: JRC elaboration, using data fro World Mining Data, WMD (2019) and from the UN Foc and Agriculture Organization database, FAOSTA (2019).
Material flow streams : Iron and ferro-alloys, non-ferrous metals, precious metals, industrial minerals, industrial roundwood.	**Applicability to Belgium :** Need to establish conta with the Joint Research Center regarding the potenti for data disaggregation at the national level in Belgiur

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

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

Material	Stage	Production	World	*EU27*	*Australia*	*Africa*	*Canada*	*China*	*Latin America*	*United States*	*Top 3 producing countries****
Bauxite	Extraction	% (kilotonnes)	**100% (281 124)**	1% (2 009)	**28% (80 092)**	9% (24 449)	-	**20% (56 110)**	**18% (51 938)**	0% (228)	Australia (28%) China (20%) Brazil (13%)
*Chromium***	Processing	% (kilotonnes*)	**100% (6 158)**	4% (273)	-	**30% (1 817)**	-	**37% (2 300)**	2% (108)	-	China (37%) South Africa (28%) Kazakhstan (14%)
Copper	Extraction	% (kilotonnes*)	**100% (18 700)**	4% (792)	5% (969)	**9% (1 672)**	4% (666)	**9% (1 726)**	**44% (8 248)**	7% (1 328)	Chile (30%) China (9%) Peru (9%)
Iron ore	Extraction	% (kilotonnes)	**100% (2 038 750)**	2% (36 368)	**35% (707 335)**	5% (101 102)	2% (44 413)	**10% (197 100)**	**21% (435 702)**	2% (49 960)	Australia (35%) Brazil (18%) China (10%)
Lead	Extraction	% (kilotonnes*)	**100% (5 100)**	4% (223)	**12% (631)**	2% (91)	-	**49% (2 518)**	**12% (615)**	7% (353)	China (49%) Australia (12%) United States (7%)
Nickel	Extraction	% (kilotonnes*)	**100% (2 271)**	2% (47)	11% (258)	5% (116)	10% (228)	4% (96)	**18% (403)**	1% (19)	Indonesia (18%) Philippines (17%) Australia (11%)
Zinc	Extraction	% (kilotonnes*)	**100% (13 330)**	5% (726)	**11% (1 409)**	1% (161)	3% (402)	**37% (4 925)**	**20% (2 624)**	6% (797)	China (37%) Australia (11%) Peru (10%)
Industrial roundwood		% (thousand m³)	**100% (1 851 139)**	**18% (336 937)**	1% (25 743)	4% (73 502)	8% (149 874)	9% (160 777)	**12% (230 313)**	**19% (354 018)**	United States (19%) Russia (10%) China (9%)

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

Measures : Kilo tonnes	**Period** : 2004-2017.
Geopolitical entity : EU aggregates, Australia, Africa, Canada, China, Latin America and the US.	**Source** : Source: JRC elaboration, based on data fro European Commission, Study on the EU's list of Critic Raw Materials (2020) and for industrial roundwoc production data from FAOSTAT.
Material flow streams : Material, bauxite, chromium, copper, iron ore, lead, nickel, zinc and industrial roundwood.	**Applicability to Belgium :** Need to establish conta with the Joint Research Center regarding the potenti for data disaggregation at the national level in Belgiun

3.2. Import reliance

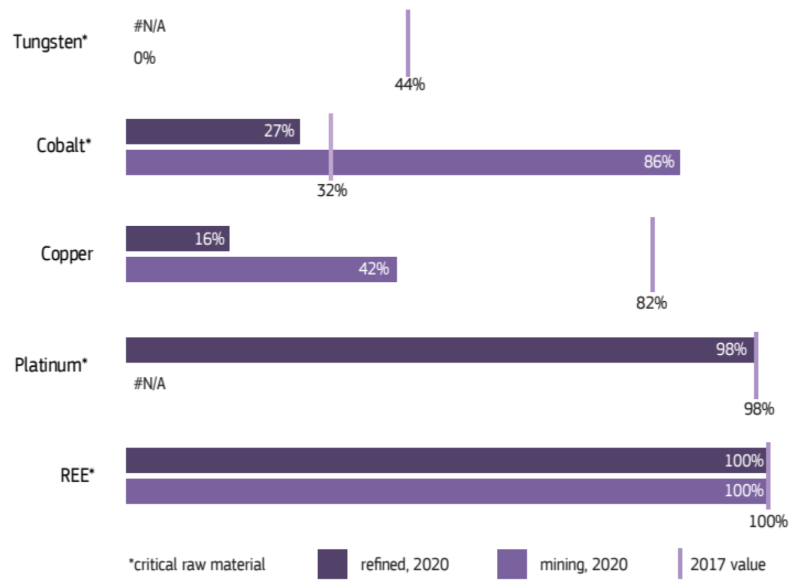
Measures : Percentage.	**Period** : 2000-2018.
Geopolitical entity : EU aggregate, Australia, Africa, Canada, China, Latin America and the US.	**Source** : Eurostat (EU Monitoring Framework).
Material flow streams : Industrial roundwood, metal ores, non-metallic minerals.	**Applicability to Belgium :** Yes, data available (E Monitoring Framework for Circular Economy).

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

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

In addition to the EU Monitoring Framework indicator, figure 8.2 presents the EU import reliance for five raw materials: tungsten, cobalt, copper, platinum and the rare earth elements (REE) group.

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

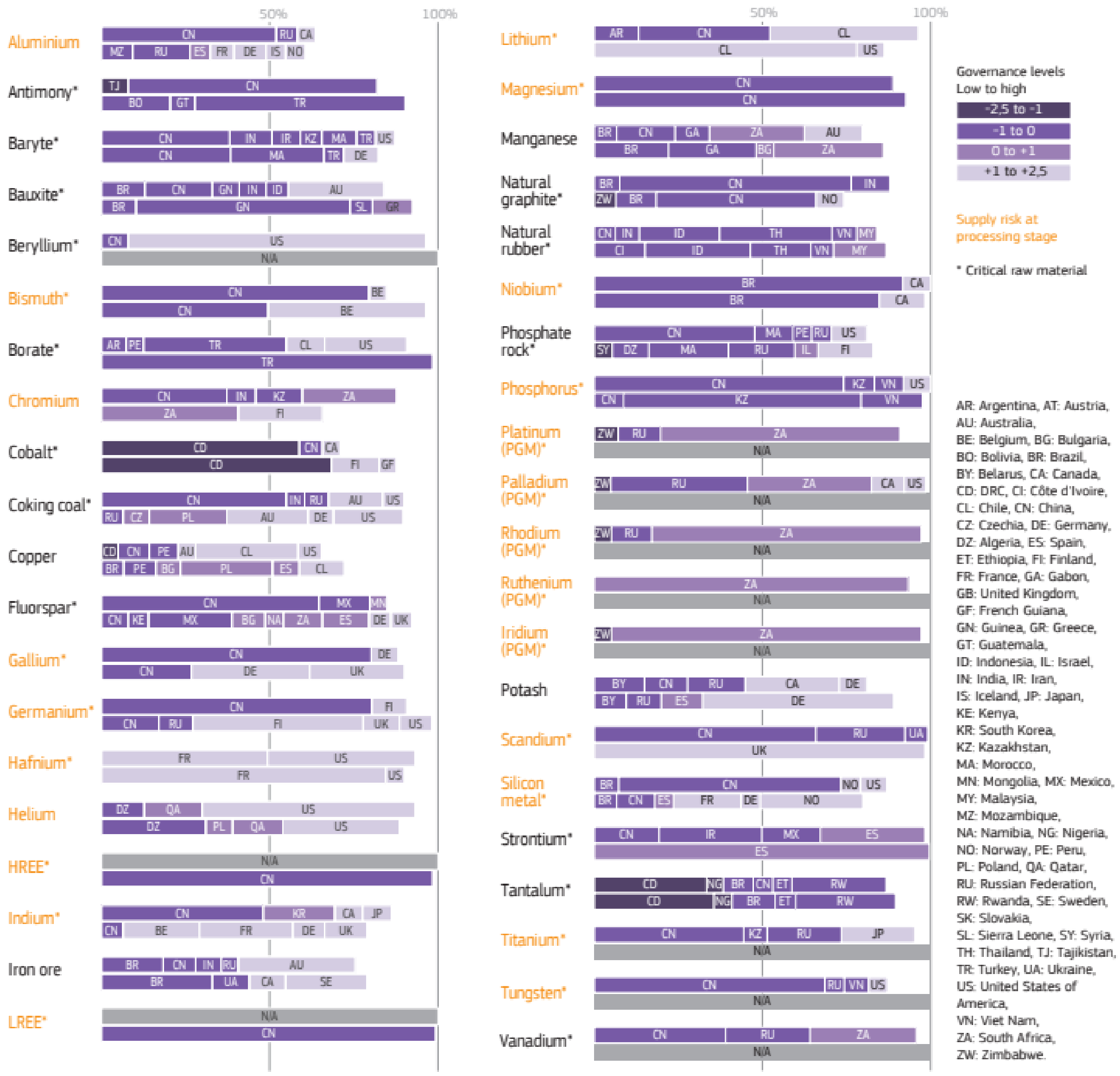


Measures : Percentage	**Period** : 2017-2020.
Geopolitical entity : EU aggregates	**Source** : JRC, based on data from the Europea Commission, Study on the review of the list of Critic Raw Materials (2017), except for the import reliance c copper, which has been updated.
Material flow streams : Tungsten, cobalt, copper, platinum, REE.	**Applicability to Belgium :** No but would be as an outpu of this research study.

3.3. Geographical concentration and governance

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

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

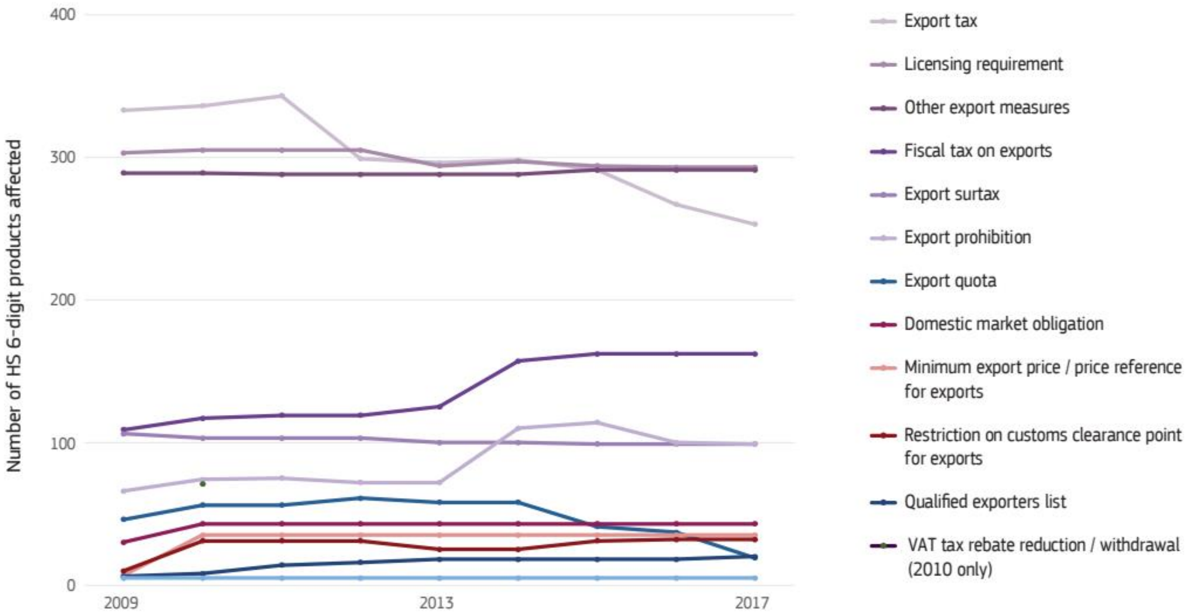


Measures : Percentage – The percentage represents the countries responsible for production and those in need of supply.	**Period** : 2016.
Geopolitical entity : See figure for concerned countries.	**Source** : Worldwide Governance Indicators (WGI).
Material flow streams : Critical raw materials.	**Applicability to Belgium :** Yes.

3.4. Export restrictions

Supplier countries of raw materials can impose restrictions on exports of minerals and metals to meet various political objectives : promoting their domestic processing industries; generating tax revenues; reducing depletion of natural resources, etc. Figure 10.1 presents the number of industrial commodities affected by worldwide export restrictions by type of restriction over the period 2009-2017. The annual figures are calculated by counting the commodities (identified by HS 6-digit) affected by each of the 13 types of measure that were imposed in a certain year by the 73 countries covered in the OECD's Inventory of Export Restrictions on Industrial Raw Materials. Except for some limited product or country exemptions, most export restrictions have a global reach.

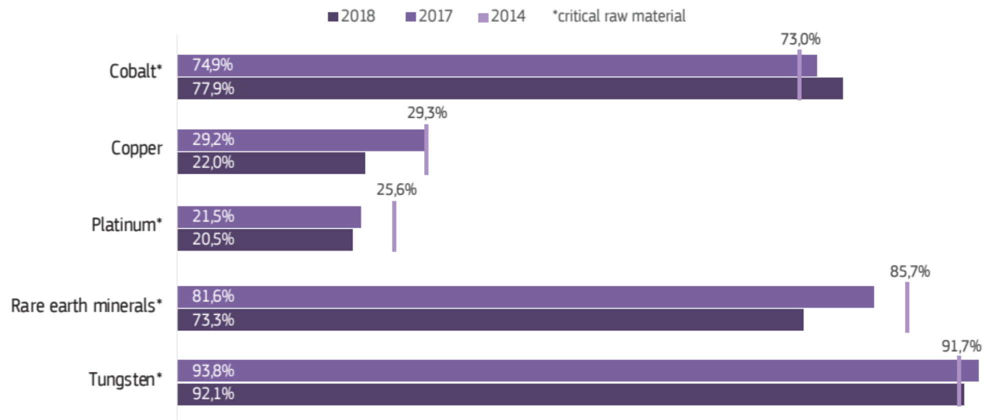
Figure 10.1: Total number of (HS 6-digit) industrial commodities affected by export restrictions worldwide, by year and type of measure (2009-2017)[197].



Measures : Number of HS-6 digit products affected.	**Period** : 2009-2017.
Geopolitical entity : Worldwide.	**Source** : OECD's Inventory of Export Restrictions o Industrial Raw Materials.
Material flow streams : HS 6-digit industrial commodities.	**Applicability to Belgium :** No.

Figure 10.2 presents the proportion of global production subject to export restrictions in 2017 and also in 2014 (i.e. the reference year in the 2018 Scoreboard), 2017 and 2018 for a selection of primary raw materials. A raw material is considered subject to export restrictions if at least one of the 13 export-restricting measures taken into account was in place in the producing countries. The selected materials are identified as strategic to the EU, and include cobalt, copper, platinum, rare earths and tungsten. For each of these materials, only the commodities corresponding to the first processing stage – i.e. metal ores and minerals – were taken into account. As shown in Figure 10.2, the share of global production affected by export restrictions was higher than 70% for cobalt, rare earth elements and tungsten. In 2018, China applied export restrictions on three out of five of the selected materials: platinum, rare earth minerals and tungsten ores and concentrates.

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



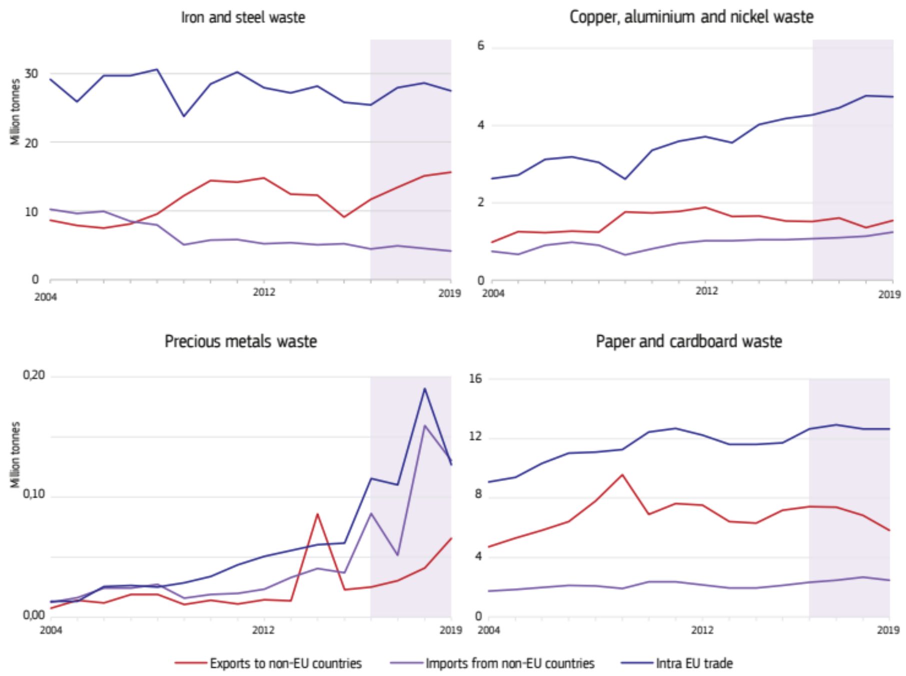
Measures : Percentage – Proportion of global production subject to export restrictions.	**Period** : 2014, 2017 and 2018.

Geopolitical entity : Worldwide.	**Source** : OECD's Inventory of Export Restrictions on Industrial Raw Materials.
Material flow streams : Cobalt, Copper, Platinum, Rare earth minerals, Tungsten.	**Applicability to Belgium :** No.

3.5. Trade in waste and scrap

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

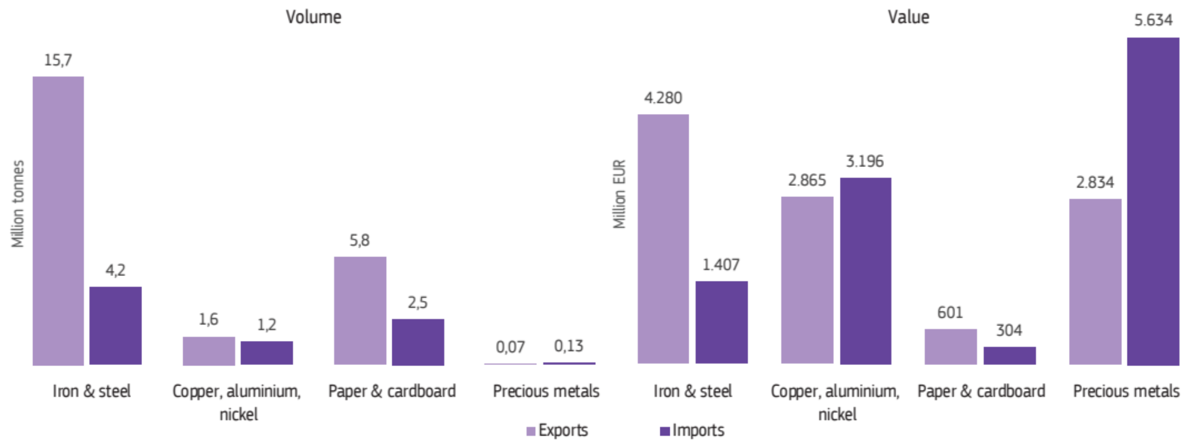
Figure 11.1: Trade of selected waste and scraps — 'iron and steel', 'paper and cardboard', 'copper, aluminium and nickel' and 'precious metals' (EU-27, 2004-2019)[207].



Measures : Million tons	**Period** : 2004-2019.
Geopolitical entity : EU-27	**Source** : International Trade in Good Statistics.
Material flow streams : Iron and steel waste; copper, aluminium and nickel waste, precious metals waste; precious metals waste; paper and cardboard waste.	**Applicability to Belgium :** Yes, using ITGS.

Figure 11.2 presents trade in selected types of waste and scraps in 2019, measured by trade volume and value. 'Iron and steel' waste was the most traded material, by both volume and value of exports. However, while 'precious metals' were negligible in terms of mass flows, they were the most important flow in terms of import value, and very relevant even in terms of exports.

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



Measures : Million tons	**Period** : 2004-2019.
Geopolitical entity : EU-27	**Source** : International Trade in Good Statistics.
Material flow streams : Iron and steel waste; copper, aluminium and nickel waste, precious metals waste; precious metals waste; paper and cardboard waste.	**Applicability to Belgium :** Yes.

4) Circular economy and recycling

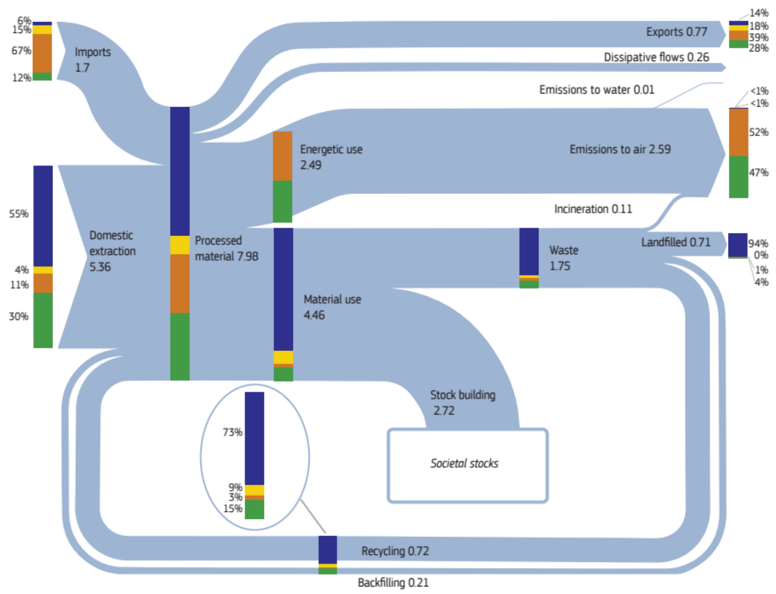
4.1. Material flows in the circular economy

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

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

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

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

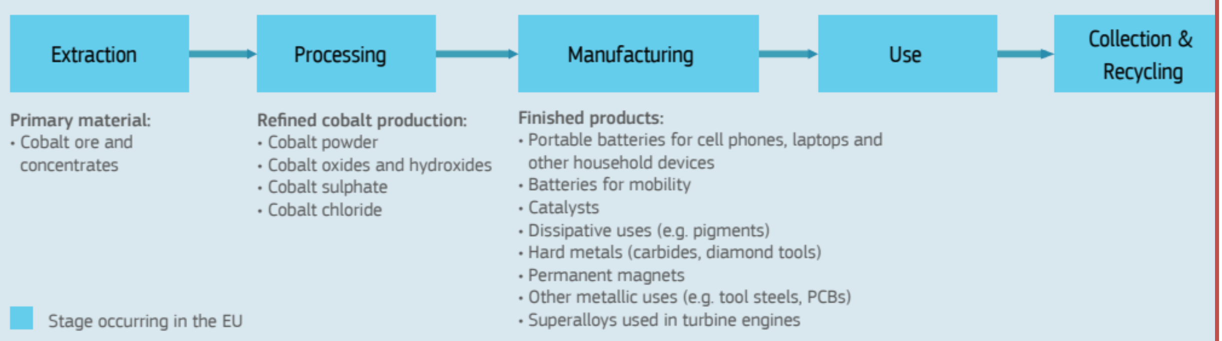


Measures : Million tons	**Period** : 2017.
Geopolitical entity : EU-27	**Source :** Eurostat (EW-MFA) and available in the E Monitoring Framework.
Material flow streams : Non-metallic minerals, metal ores, fossil energy materials and biomass.	**Applicability to Belgium :** Yes.

Material system analysis of relevant critical raw material

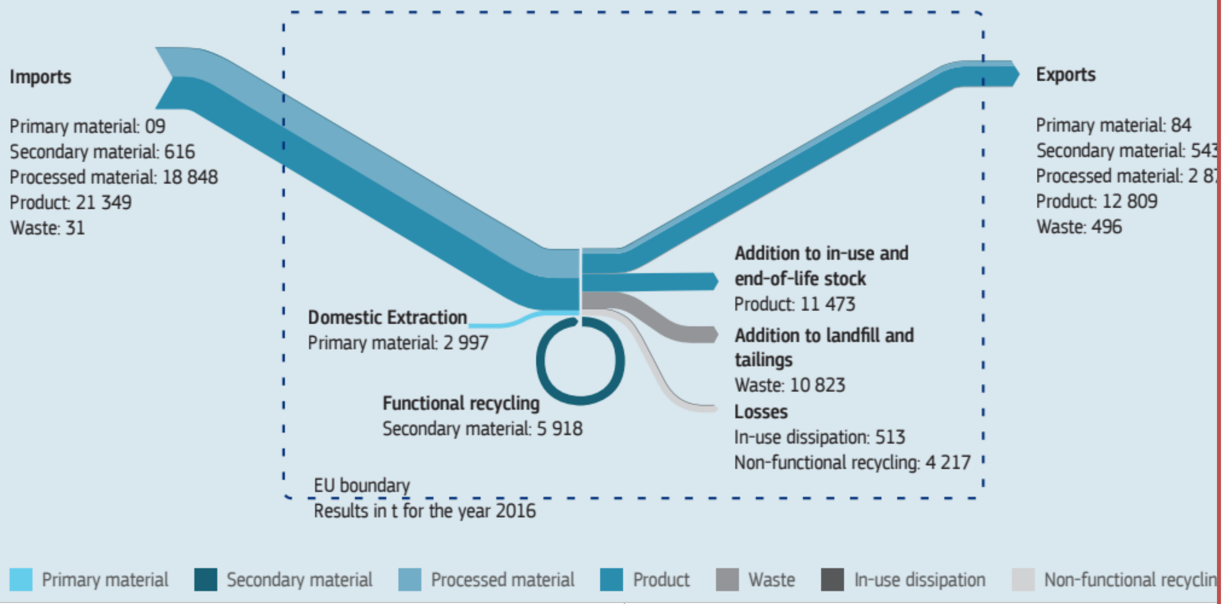
This box summarises the material flows of cobalt for the EU in 2016, calculated following the Commission's material system analysis (MSA) methodology. This MSA study investigates the stocks and flows of cobalt through the EU economy along the overall supply chain, from extraction until end-of-life management.

Figure 12.3: Value chain of cobalt[221]



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

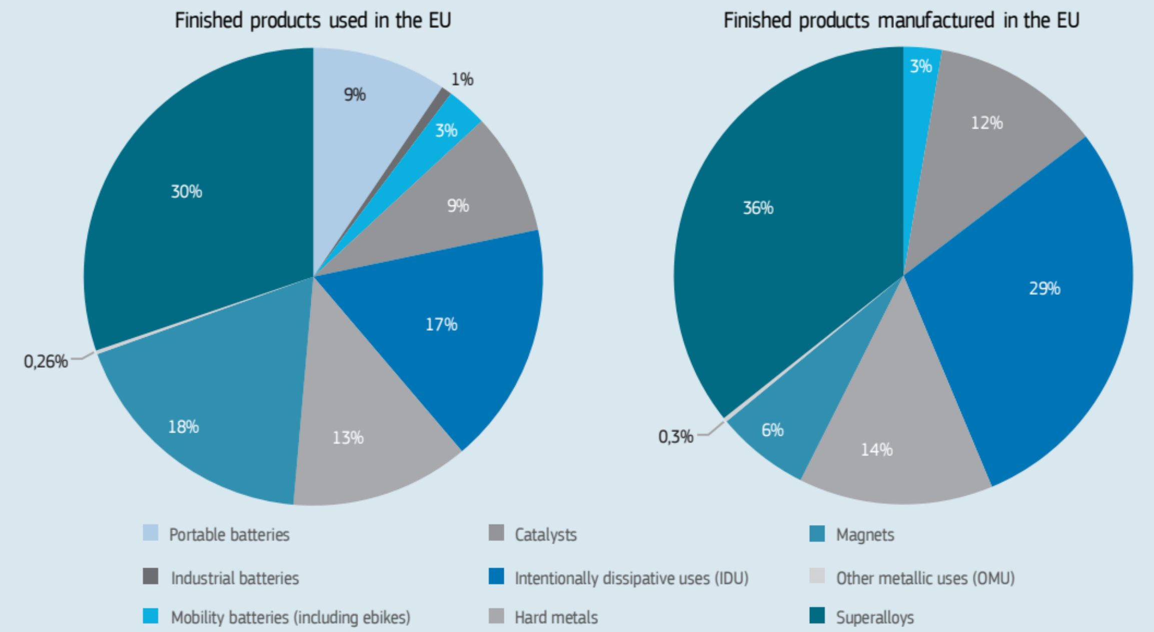
Figure 12.4: Simplified Sankey diagram of the flows of cobalt in the EU (without the UK); imports of processed materia include 10.3 kt of semi-processed material and 8.5 kt of processed material[222]



Measures : Kilo tons.	**Period** : 2016.
Geopolitical entity : EU-27	**Source** : MSA methodology.
Material flow streams : Cobalt.	**Applicability to Belgium :** Need for examination of th MSA methodology and data available for Belgium.

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

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



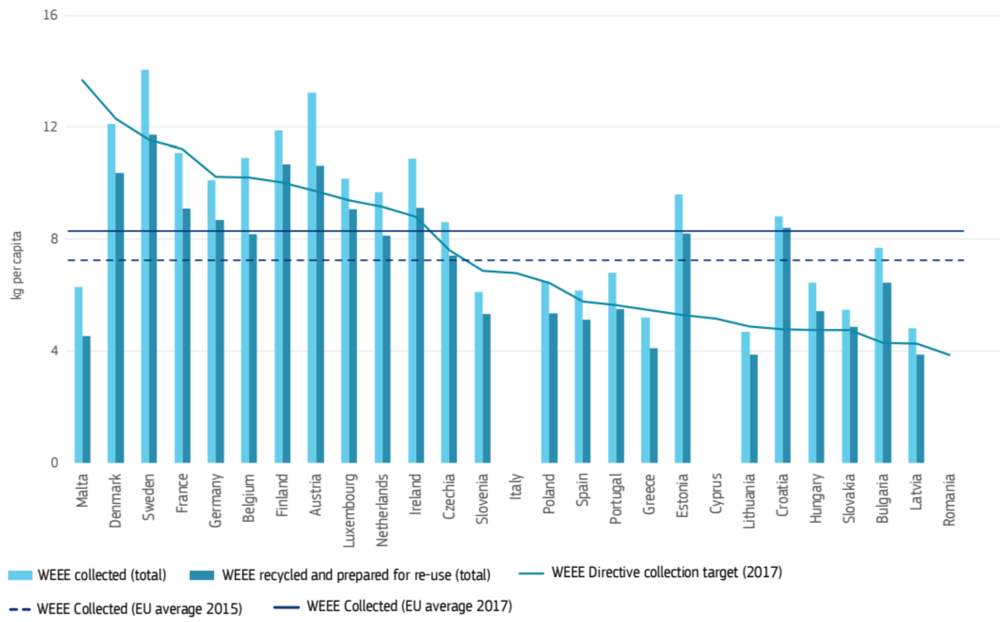
Measures : Shares of finished products containing cobalt manufactured in the EU.	**Period** : 2016.
Geopolitical entity : EU-27	**Source** : MSA methodology.

Material flow streams : Cobalt.	**Applicability to Belgium :** Need for examination of the MSA methodology and data available for Belgium.

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

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

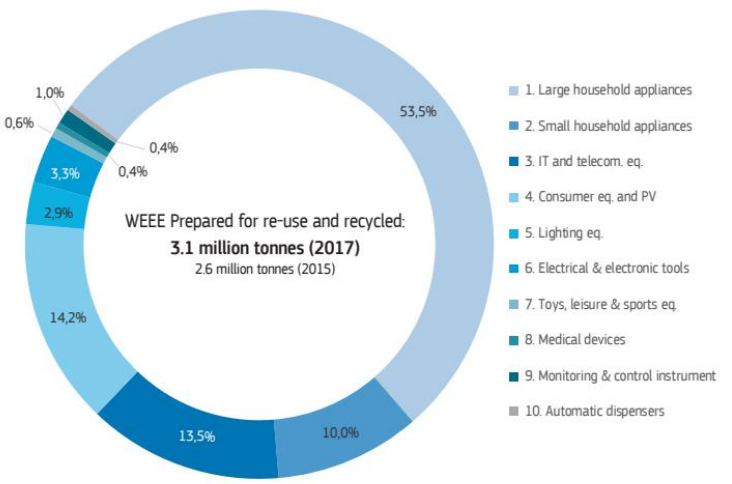
Figure 13.1: WEEE officially reported as collected and WEEE prepared for re-use and recycled (amounts per capita) and collection targets of WEEE for EU countries (EU-27, 2017)[248]. Average WEEE collected in the EU (in 2015 and 2017) are displayed as horizontal lines.



Measures : Kg in capita.	**Period** : 2017.
Geopolitical entity : EU-27 and EU member states individually.	**Source :** Eurostat (waste Statistics)
Material flow streams : Electric and electronic equipment (EEE).	**Applicability to Belgium :** Yes.

Figure 13.2 shows the total amount of WEEE 'prepared for re-use and recycled' and the share by WEEE category (type and numbering as set by the WEEE Directive).

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

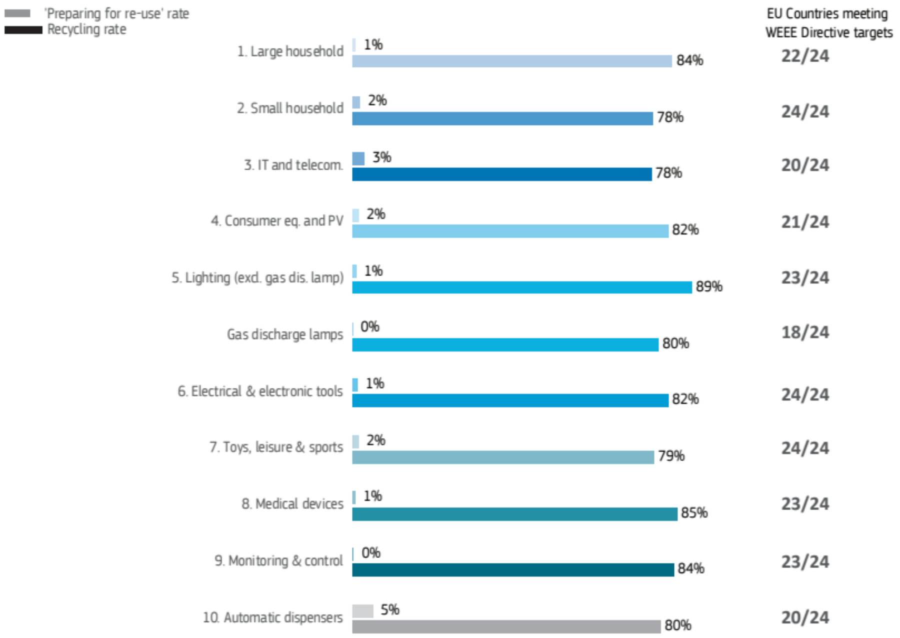


Measures : Total amount of WEEE prepared for re-use and recycled and the share by WEEE.	**Period** : 2017.

Geopolitical entity : EU-27	**Source** : Eurostat (waste Statistics)
Material flow streams : Electric and electronic equipment (EEE).	**Applicability to Belgium :** Yes.

Figure 13.3 shows the disaggregated rates of WEEE 'prepared for re-use' and 'recycled', per WEEE category (average percentages for the EU in 2017). Although the WEEE Directive refers to an aggregated target for both WEEE prepared for re-use and WEEE recycled, Figure 13.3 presents the re-use and recycling rates separately to better illustrate the contribution of both activities.

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

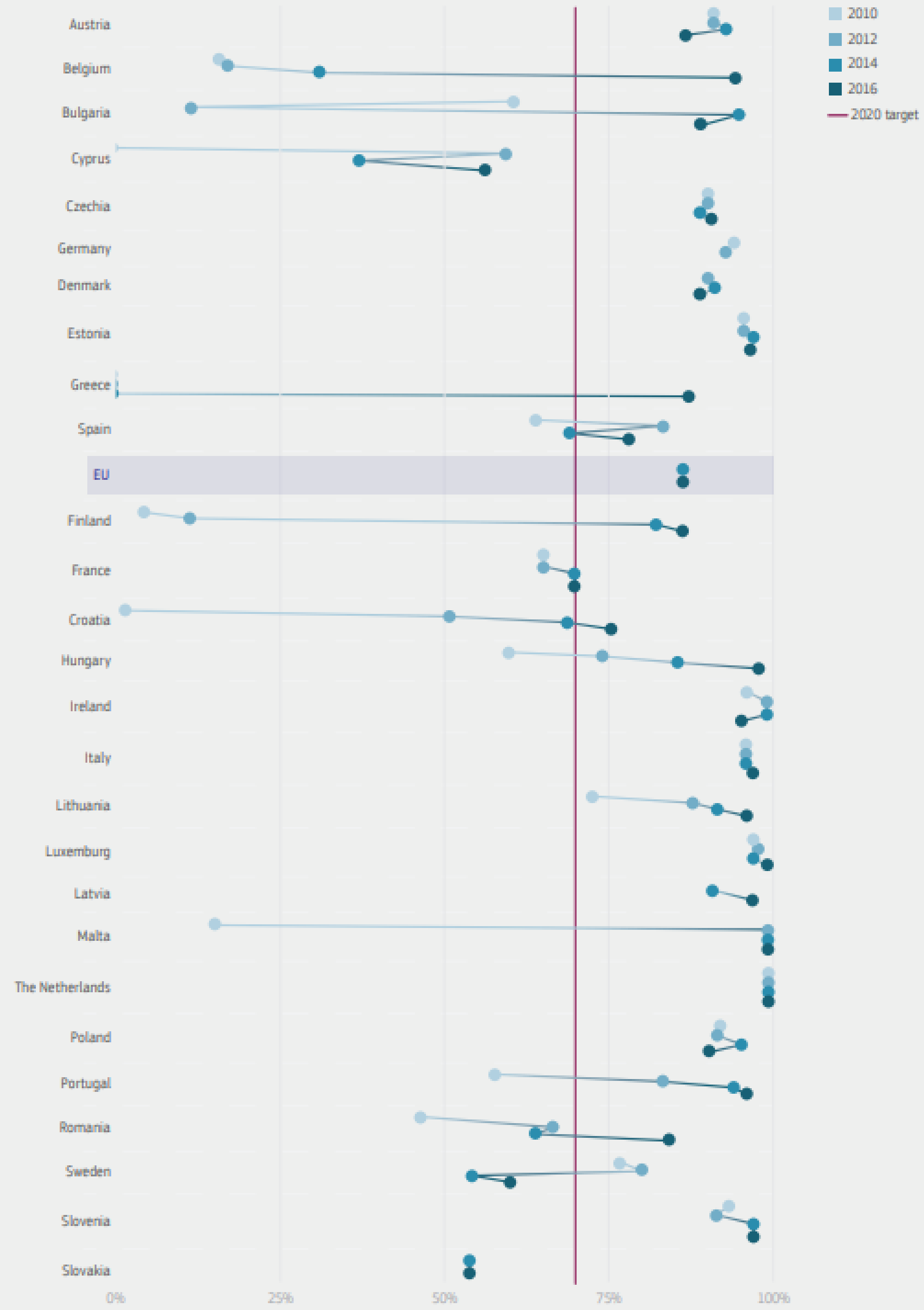


Measures : Preparation for re-use and recycling rate per WEEE category.	**Period** : 2017.
Geopolitical entity : EU-27	**Source** : JRC, based on Eurostat data. The number o EU countries reporting reuse and recycling data was 2 (since data from Cyprus, Italy and Romania were no available in May 2020).
Material flow streams : Electric and electronic equipment (EEE).	**Applicability to Belgium :** Yes, but need to establis contact with the Joint Research Center regarding th availability of data.

4.3. Construction and demolition waste

Data on 'mineral waste from construction and demolition' are currently available in Eurostat and collected every two years in accordance with Regulation (EC) No 2150/2002 on waste statistics. Based on this dataset, the CDW 'recovery rate' can be calculated for each EU country and monitored over time (see Figure 14.1). This indicator, which covers only the non-hazardous fraction of waste, is included within the set of indicators of the circular economy monitoring framework. The CDW recovery rate can be expressed as the ratio between the mass recovered (including recycling and backfilling operations) divided by all CDW collected and treated. As shown in Figure 14.1, several EU Member States reached very high CDW recovery rates in 2016, with the average EU rate of about 87%.

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

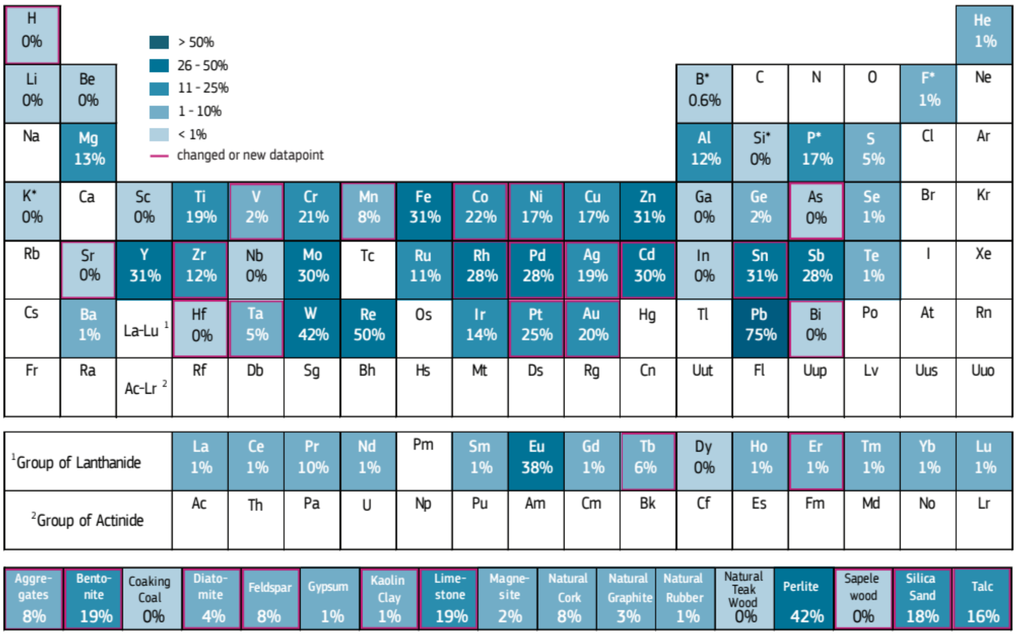


Measures : Recovery rate of construction and demolition waste in the EU.	**Period** : 2010-2016.
Geopolitical entity : EU-27 and EU member states.	**Source** : Eurostat (waste Statistics)
Material flow streams : Construction and demolition waste.	**Applicability to Belgium :** Yes.

4.4. Recycling’s contribution to meeting materials demand

Figure 15.1 shows end-of-life recycling input rates (EOL-RIR) for the 83 candidate raw materials assessed in the EU 2020 criticality assessment. The figure updates the values presented in the 2018 edition of the Scoreboard in line with the latest available data from the EU material system analyses.

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

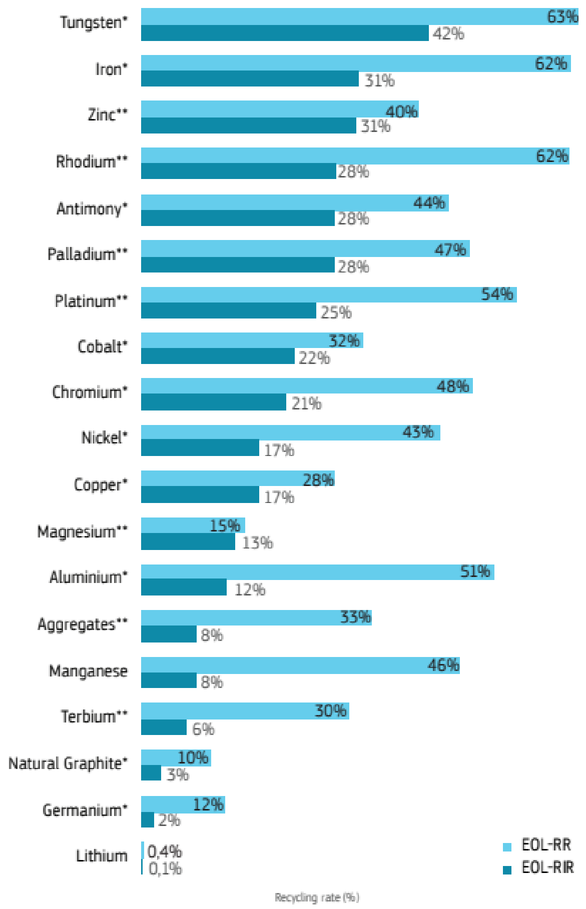


* F = Fluorspar, P = Phosphate rock, K = Potash; Si = Silicon metal, B = Borates.

Measures : End-of-life recycling input rates (EOL-RIR).	**Period** : 2020.
Geopolitical entity : EU-27 and EU member states.	**Source** : Eurostat.
Material flow streams : 83 candidate raw materials assessed.	**Applicability to Belgium** : No. Methodolog encompassing a wide range of assumptions (not bottom-up methodology but rather a top-down), se EU Monitoring Framework.

Figure 15.2 shows that, despite several materials contained in end-of-life products having recycling rates (EOL-RR) above 40% or 50%, recycling’s contribution to overall demand for these materials (EOL-RIR) is lower.

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



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

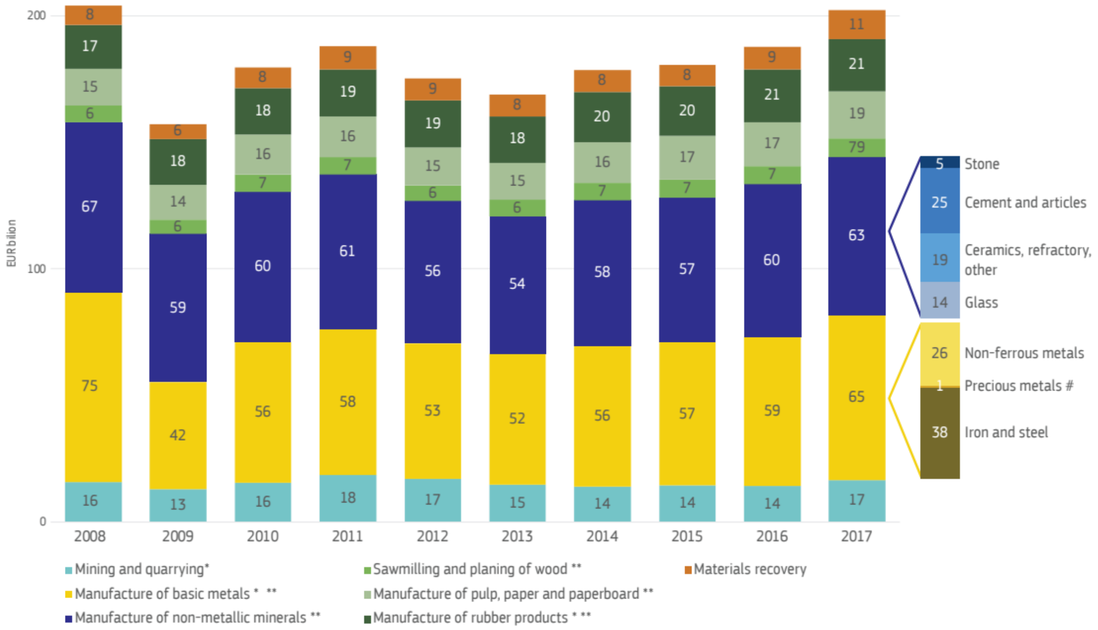
Measures : End-of-life recycling input rates (EOL-RIR) and End-of-life-recycling rates (EOL-RR).	**Period** : 2020.
Geopolitical entity : EU-27 and EU member states.	**Source** : Eurostat.
Material flow streams : 83 candidate raw materials assessed.	**Applicability to Belgium** : No. Methodolog encompassing a wide range of assumptions (not bottom-up methodology but rather a top-down).

5. Competitiveness and innovation

5.1. Value added

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

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

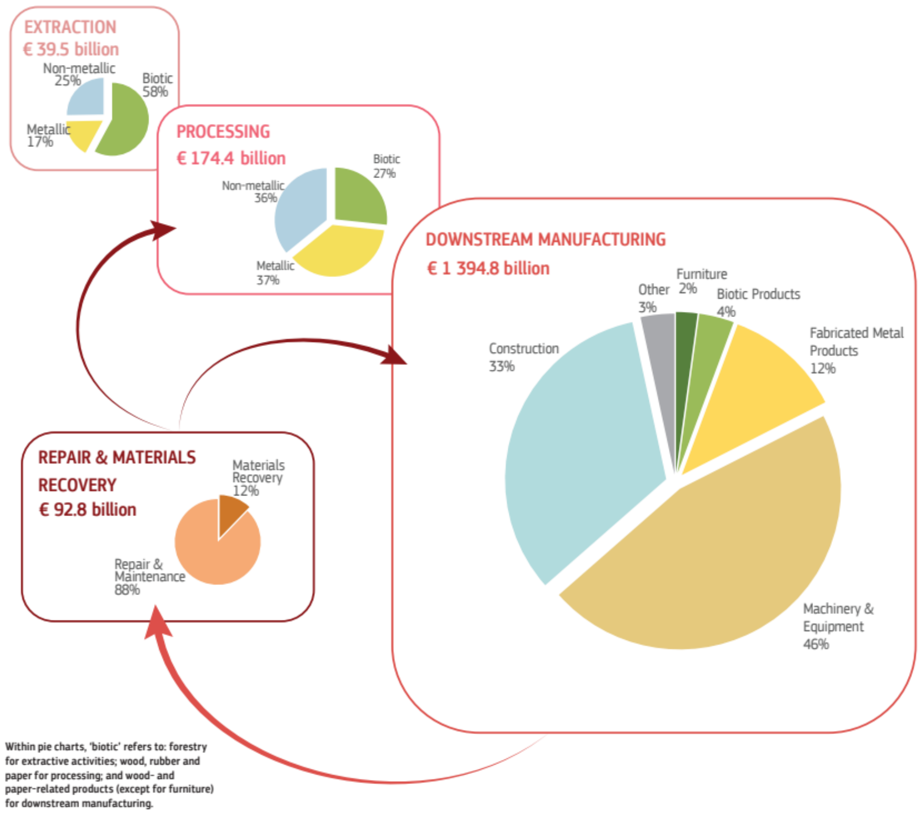


Data for 2008-2010 refer to the EU without Croatia; data for 2011-2017 refer to the EU-27 (EU without UK).
* Some data are missing due to confidentiality.

Measures : Value added (EUR billion).	**Period** : 2008-2017.
Geopolitical entity : EU-27.	**Source** : Source: JRC, based on data from Eurostat annual detailed enterprise statistics for industry (NAC Rev. 2, B-E) ´sbs_na_ind_r2´
Material flow streams : Non-energy, non-agricultural raw materials sectors.	**Applicability to Belgium** : Need to establish conta with the Joint Research Center regarding the availabili of data.

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

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



Measures : The contribution of the raw materials sectors within each stage of the value chain, from the upstream to the downstream sectors and to repair and materials recovery.	**Period** : 2017.
Geopolitical entity : EU-27.	**Source** : Source: JRC, based on data from Eurostat annual detailed enterprise statistics for industry an construction, and additional Eurostat statistics fo forestry and logging.
Material flow streams : /	**Applicability to Belgium** : Need to establish conta with the Joint Research Center regarding the availabili of data.

5.2. Mining equipment exports

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

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

Measures : Evolution of net exports of mining equipment.	**Period** : 2013-2017.
Geopolitical entity : Worldwide.	**Source** : Official trade statistics.
Material flow streams : /	**Applicability to Belgium** : No.

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

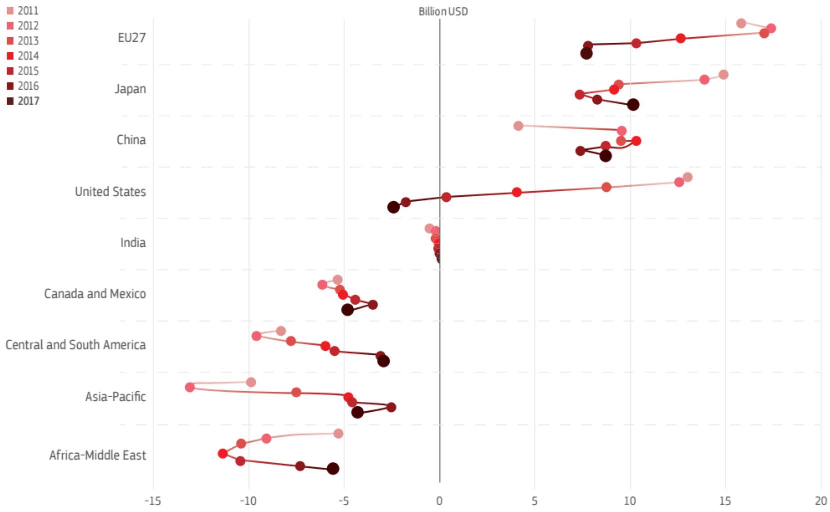
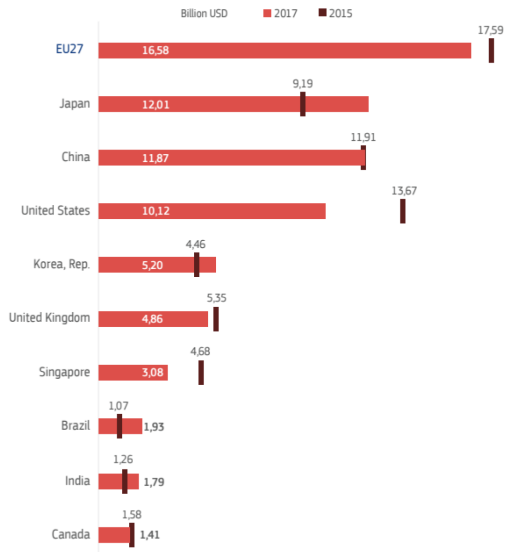


Figure 17.2 shows the export value of the top 10 global exporters of mining equipment in 2017 compared to 2015 (year covered by the 2018 edition of the Scoreboard).

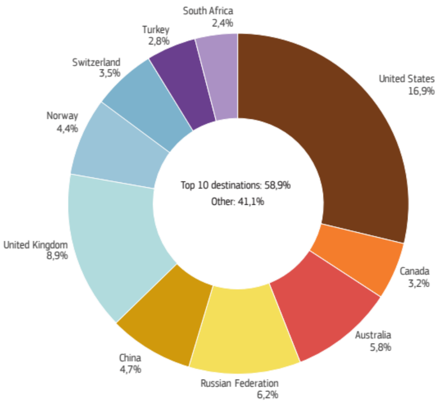
Figure 17.2: Export value of top 10 global exporters of mining equipment (EU-27 as trading bloc, excluding UK, 2015 and 2017)[333].



Measures : Export value of top 10 global exporters of mining equipment.	**Period** : 2015 and 2017.
Geopolitical entity : Worldwide.	**Source** : Official trade statistics.
Material flow streams : /	**Applicability to Belgium** : Yes.

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

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

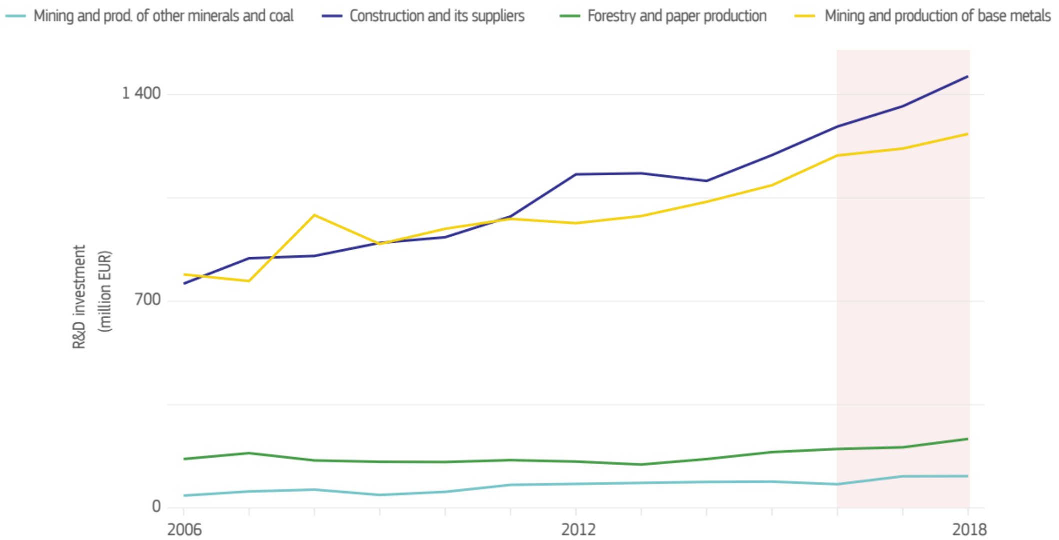


Measures : Top-10 destinations of EU.	**Period** : 2017.
Geopolitical entity : Worldwide.	**Source** : Official trade statistics.
Material flow streams : Mining equipment.	**Applicability to Belgium** : Yes.

5.3. Corporate R&D investment

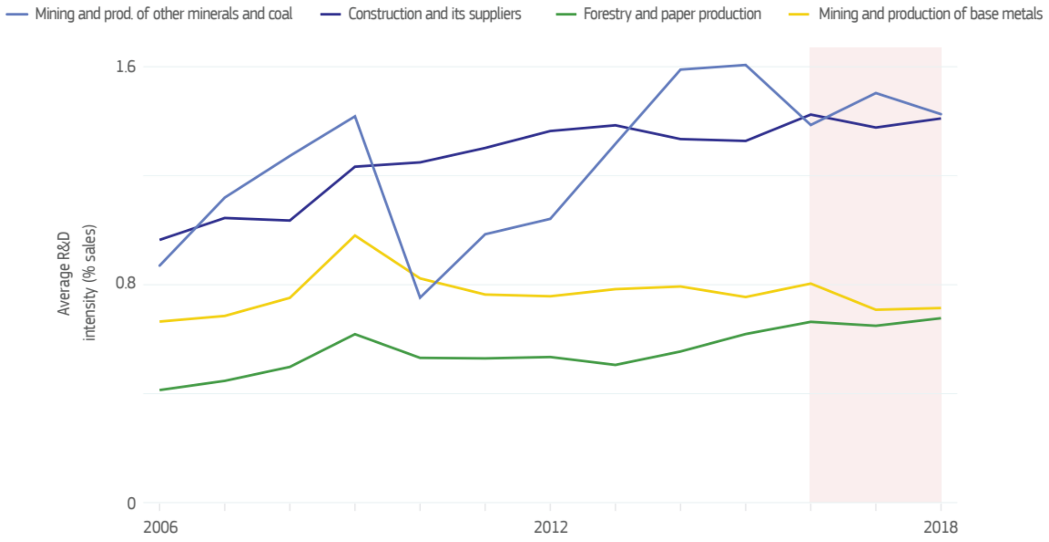
Figure 18.1 shows the R&D investment in absolute (monetary) terms by raw materials sector. To give an idea, in Europe a top 10 investing company in these sectors invests between EUR 150 and 450 million a year in R&D. Data comes from the EU Industrial R&D Investment Scoreboard.

Figure 18.1: Annual R&D investment by top EU-based investing companies, by raw materials sector group (EU-27, 2006-2018)[34



Measures : Million euros – R&D investment in absolute terms by raw material sector.	**Period** : 2006-2018
Geopolitical entity : EU aggregates	**Source** : EU Industrial R&D Investment Scoreboard
Material flow streams : Mining and production of other minerals and coals; construction and its supplies; forestry and paper production ; mining and production of base metals.	**Applicability to Belgium** : Need examination of the E Industrial R&D Investment Scoreboard.

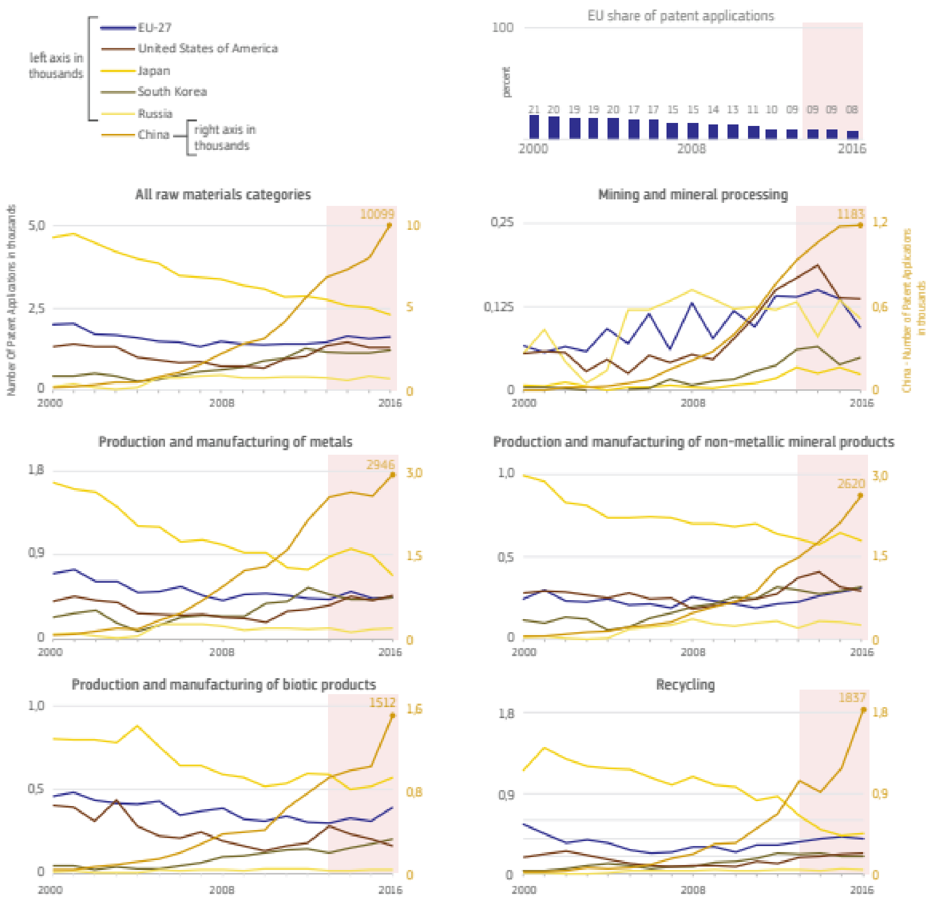
Figure 18.2: Annual average R&D intensity of top EU-based investment companies, by raw materials sector group (EU-27, 2006-2018)[343].



5.4. Patent applications

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

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

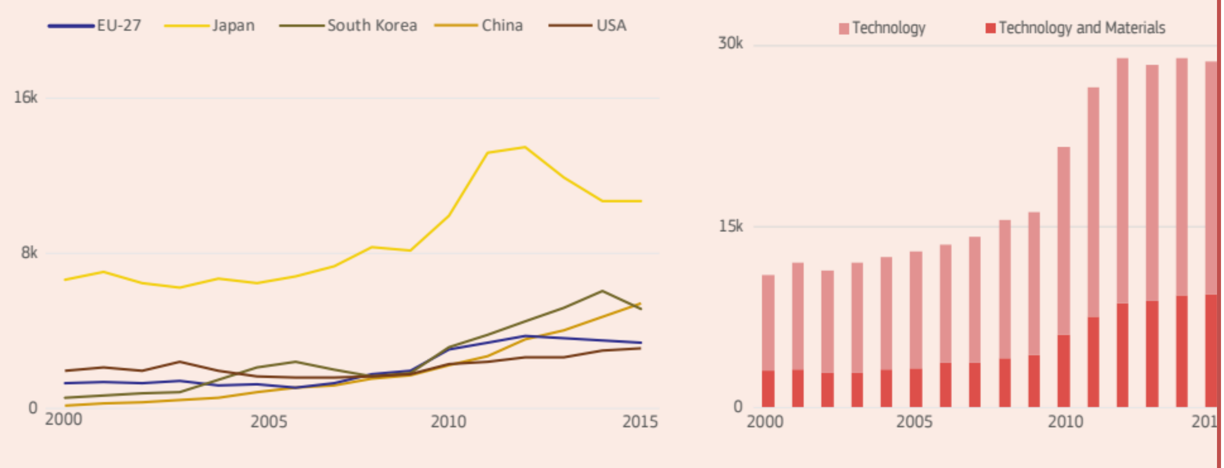


Measures : Number of patents applications.	**Period** : 2000-2016.

Geopolitical entity : EU aggregates and worldwide.	**Source** : JRC analysis of PATSTAT data.
Material flow streams : Mining and mineral processing, production and manufacturing of metals, production and manufacturing of non-metallic products, production and manufacturing of biotic products, recycling.	**Applicability to Belgium** : Need for examination with PATSTAT data but patents related to recycling and secondary raw materials already available in the EU Monitoring Framework.

Patent application trends in selected dual-use technologies – the case of lithium-ion batteries
The data reported here illustrate one of those specific examples, which is the case of lithium-ion batteries355. Figure 19.2 shows the number of patent applications for lithium-ion batteries from applicants based in the EU and worldwide (left), as well as the number of applications that could be associated with specific key materials for the development of that technology (aluminium, cobalt, copper, graphite, lithium, manganese, nickel) (right).

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

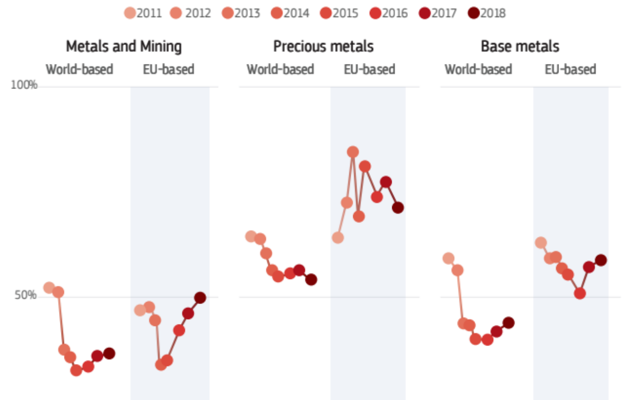


Measures : Patents application by country.	**Period** : 2000-2015.
Geopolitical entity : EU aggregates and worldwide.	**Source** : JRC analysis of PATSTAT data.
Material flow streams : Lithium-ion batteries.	**Applicability to Belgium** : Need for examination wit PATSTAT data.

5.5. Financing

Figure 20.1 shows the evolution of the share of total equity in total assets over the 2011-2018 period, of both worldwide and EU-based companies operating in the metals and mining sector and in its two sub-sectors, i.e. basic metals and precious metals. This indicator provides information about shareholders' contribution to the companies' assets and is a proxy for investment attractiveness. The geographical base of companies refers to the location of the official headquarters, not the location of their activity (i.e. company divisions and branches might be located elsewhere). Data reflects the EU-27 composition.

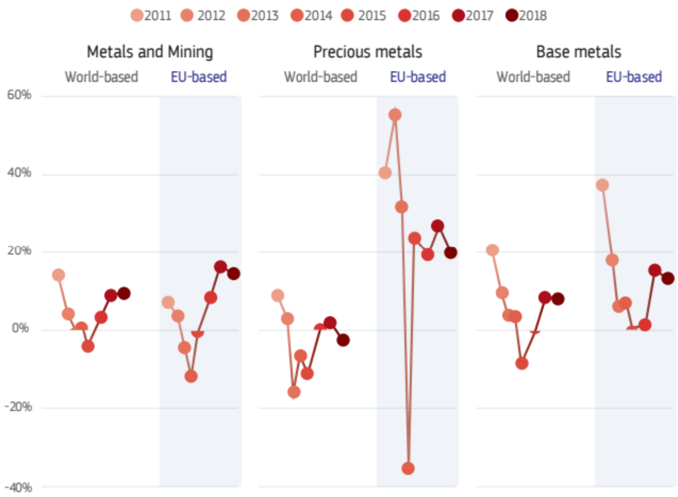
Figure 20.1: Share of total equity in total assets of companies from the metals and mining sector and two of its sub-sectors (world and EU-27-based company aggregates[360], 2011-2018)[361].



Measures : Share of total equity in total assets of companies.	**Period** : 2011-2018
Geopolitical entity : EU aggregates and worldwide.	**Source** : JRC, based on the S&P Market Intelligenc Industry Trends & Statistics.
Material flow streams : Metals and mining ; precious metals ; base metals.	**Applicability to Belgium** : No.

Figure 20.2 shows the evolution of the return on average equity for capital investments in the metals and mining sector and its two sub-sectors, base metals and precious metals. Return on average equity provides information about the investors' earnings, and could potentially explain the evolution of the indicator in Figure 20.1 (share of total equity in total assets).

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



Measures : Return on average equity.	**Period** : 2011-2018
Geopolitical entity : EU aggregates and worldwide.	**Source** : JRC, based on the S&P Market Intelligenc Industry Trends & Statistics.
Material flow streams : Metals and mining ; precious metals ; base metals.	**Applicability to Belgium** : No.

5) Environmental dimension

5.1. Greenhouse gas emissions

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

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

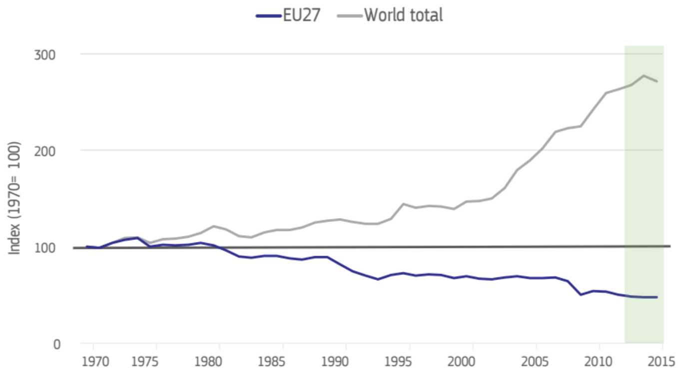
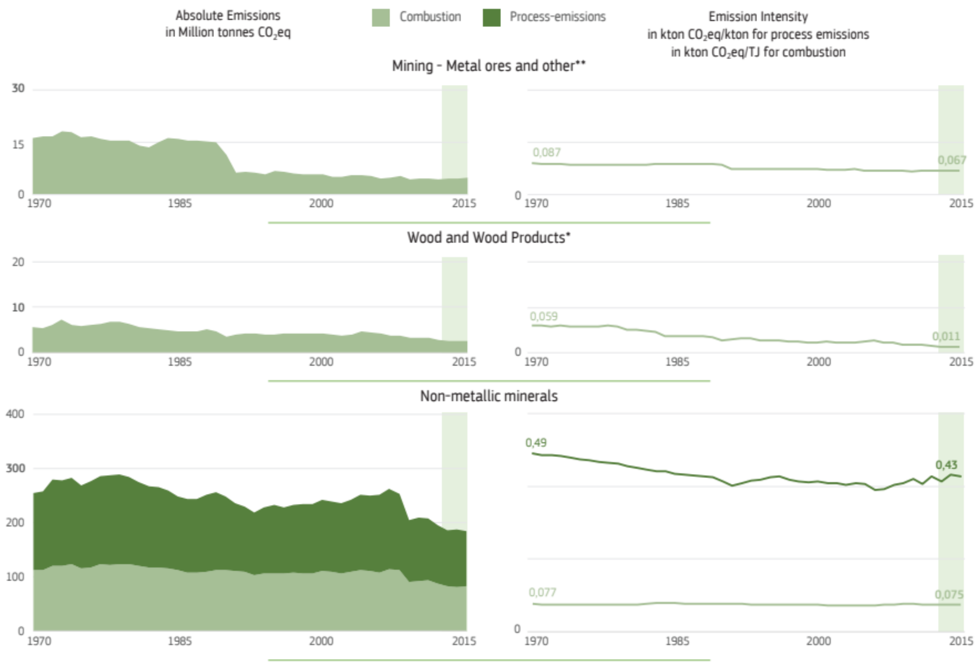
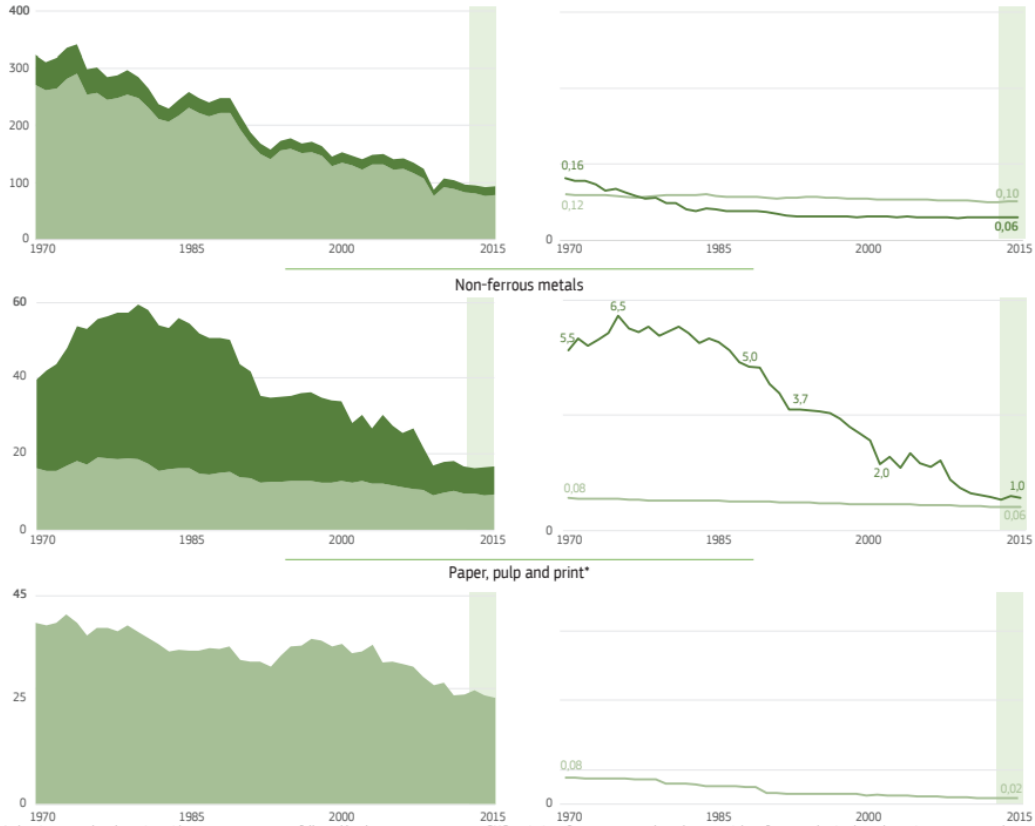


Figure 21.2 provides a breakdown of absolute direct GHG emissions in the EU by raw materials industry and provides data on the industries' emission intensities, i.e. the amount of emissions per unit of production. Absolute emissions provide information about industry's impact on climate, whereas emission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

Measures : Absolute direct GHG emissions by raw materials industry (index 1970 = 100).	**Period** : 1970-2015.
Geopolitical entity : EU and the wold total.	**Source** : JRC, based on EDGAR data
Material flow streams : Industrial facilities in the raw material sectors.	**Applicability to Belgium** : Need examination of EDGA data.

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





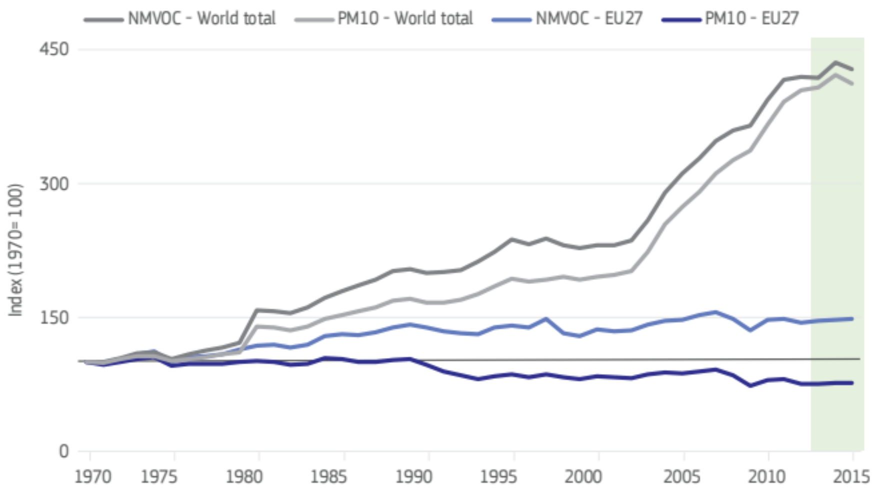
Industries are ordered starting with upstream processes, followed by downstream processes. GHG emissions from some metals and paper might refer to production based on primary resources, but also on secondary materials. * For the paper and wood industries, GHG process emissions are considered null, since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

Measures : Absolute direct GHG emissions by raw materials industry (index 1970 = 100).	**Period** : 1970-2015.
Geopolitical entity : EU and the world total.	**Source** : JRC, based on EDGAR data
Material flow streams : Industrial facilities in the raw material sectors.	**Applicability to Belgium** : Need examination of EDGA data.

5.2. <u>Particulate matter and NMVOC emissions</u>

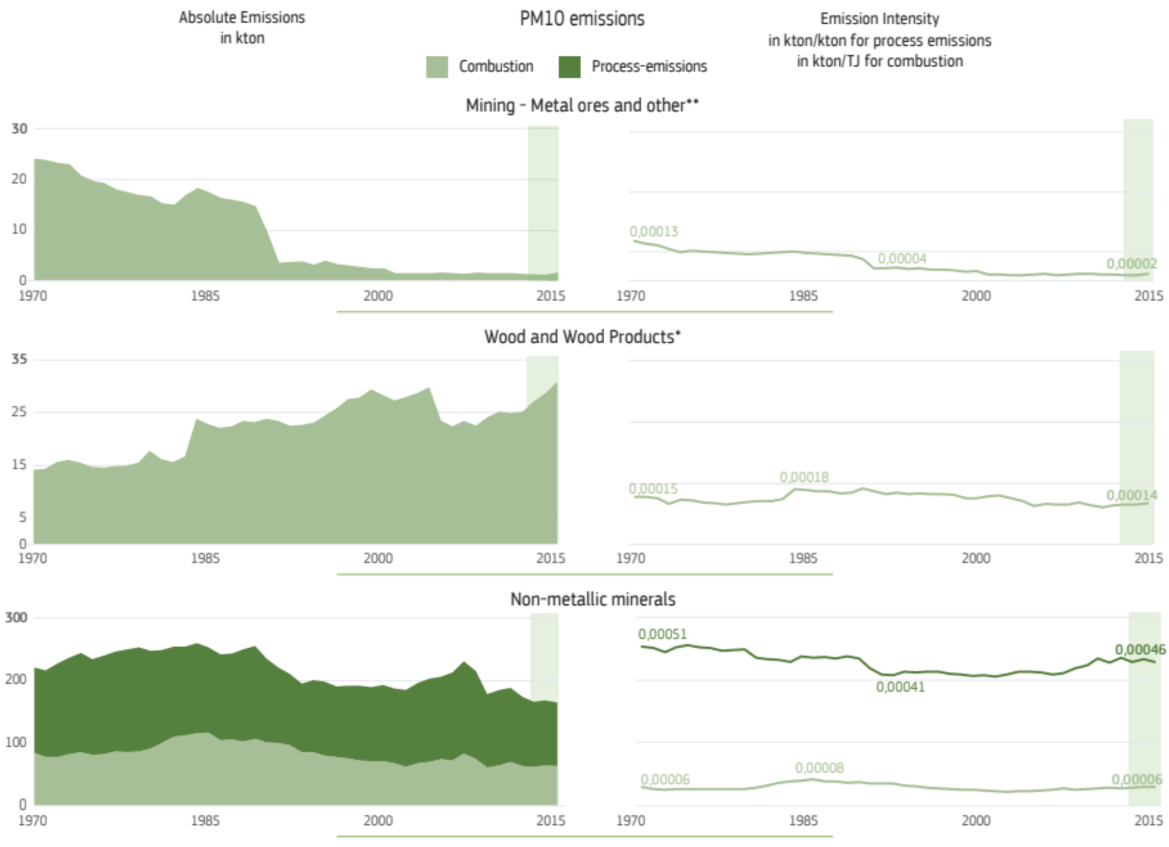
Figure 22.1 presents the trend of emissions of the two main air pollutants, particulate matter (measured in terms of PM10) and non-methane volatile organic compounds (NMVOC), from the raw materials industry in the EU and globally. Data are presented normalised relative to absolute emissions of 1970. Data cover emissions from mining, the production of iron and steel, non-ferrous metals, non-metallic minerals, pulp, paper and print, and wood and wood products. Data include emissions from fuel use (combustion) and process emissions. Production in some industries is based also on secondary materials.

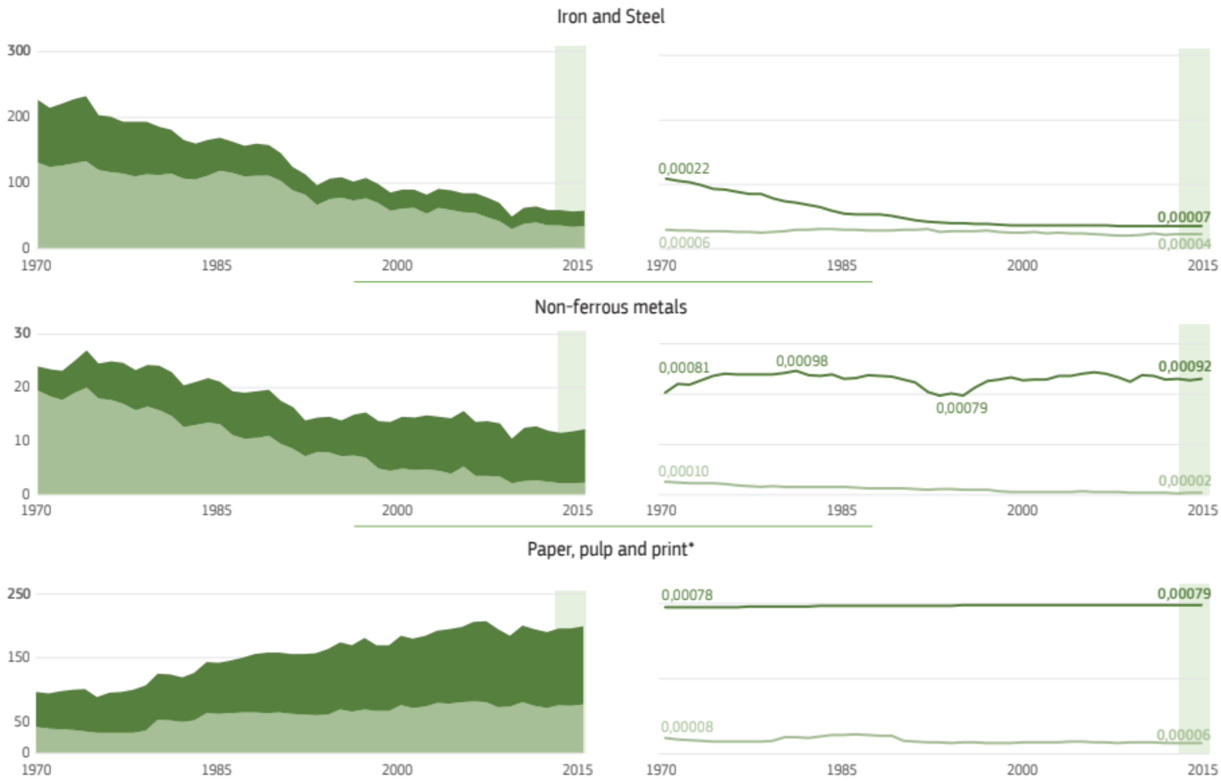
Figure 22.1: Index (related to 1990) of absolute direct PM_{10} and NMVOC emissions from the raw materials sector (EU-27 an world total, 1970 - 2015)[431].



Measures : Absolute direct PM10 and NMVOC emissions by raw materials industry (index 1970 = 100).	**Period** : 1970-2015.
Geopolitical entity : EU and the world total.	**Source** : JRC, based on EDGAR data
Material flow streams : Industrial facilities in the raw material sectors.	**Applicability to Belgium** : Need examination of EDGA data.

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





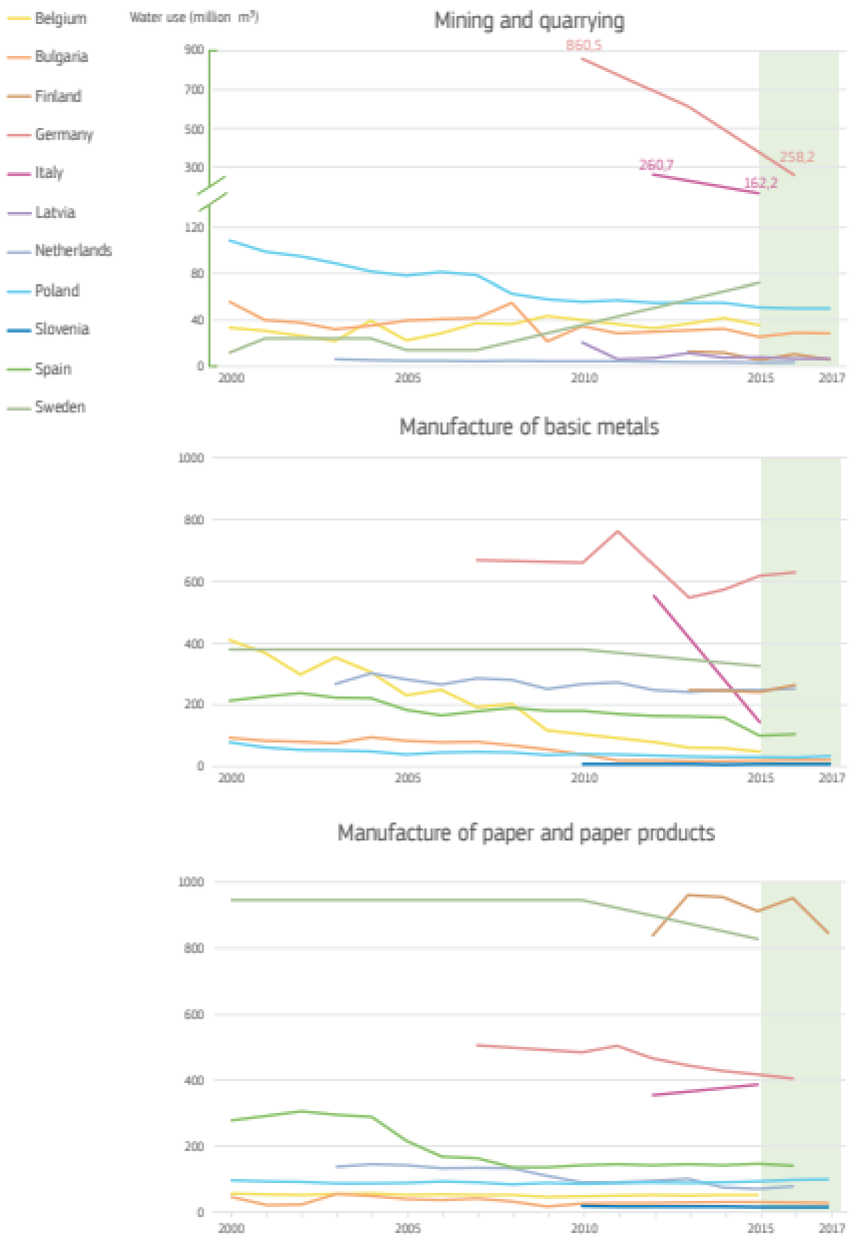
Industries are ordered starting with upstream processes, followed by downstream processes.
Emissions from some metals and paper might refer not only to the production based on primary resources but also to production based on secondary materials. Note the varying y-axes units.
* For the 'wood and wood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

Measures : Absolute direct PM10 and NMVOC emissions by raw materials industry (index 1970 = 100).	**Period** : 1970-2015.
Geopolitical entity : EU and the world total.	**Source** : JRC, based on EDGAR data
Material flow streams : Industrial facilities in the raw material sectors.	**Applicability to Belgium** : Need examination of EDGA data.

5.3. Water

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

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



Measures : Water use by raw materials sector.	**Period** : 2000-2017.
Geopolitical entity : Specific EU member states.	**Source** : Country-based data.
Material flow streams : Mining and quarrying; basic metals ; paper and paper products.	**Applicability to Belgium** : Yes, data already available.

5.4. Extractive waste

The extractive industry generates the second largest waste stream in the EU after construction and demolition waste, representing 25-30% of the total waste volume (2016 data). Extractive waste generation is linked directly to minerals production; however, the overall objective is to decouple this volumetric correlation. Volumes and characteristics of extractive wastes vary significantly across commodity groups. About 2% of the bulk volume is hazardous. Metallic minerals extraction poses the highest environmental risk through surface disposal of sulfidic waste rocks, which generate acidic leachates when exposed to surface waters.

Available data show that the generation of extractive waste in the EU has been decreasing since 2012. However, a longer time series of data is required to support more profound conclusions on volume and quality trends. Similarly, there is a lack of EU-wide data on backfilling and of recycling of, and recovery from, extractive waste, with the exception of some countries such as Portugal and Hungary. In general, the data indicate that the Extractive Waste Directive is working and waste management practices are improving in the sector. No comparable datasets are available on extractive waste volumes and quality that would make it possible to assess performance on a global or EU scale.

6) Social dimension

6.1. Responsible sourcing

Given the many voluntary supply chain due diligence initiatives in place, the European Commission has developed a methodology and criteria for assessing and recognising supply chain due diligence schemes in order to facilitate compliance. The exact number of existing due diligence initiatives and the number of companies adhering to them is hard to calculate. A review published by the German Federal Institute for Geosciences and Natural Resources (BGR) identifies 19 sustainability schemes for mining and metals, though some of them are not strictly related to responsible sourcing but have a more general scope covering sustainability-related aspects. Of the reviewed schemes, two focus on gold only; six address 3TGs, diamonds and aluminium; and two cover coal and natural stone.

6.2. Occupational safety

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

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

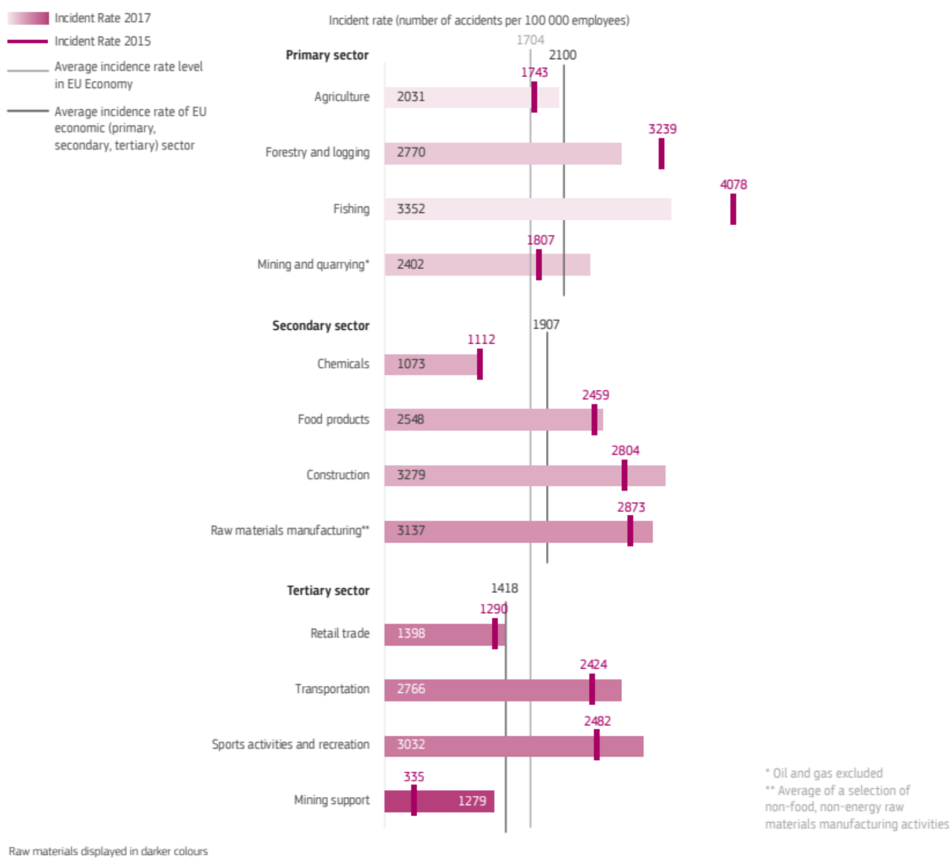
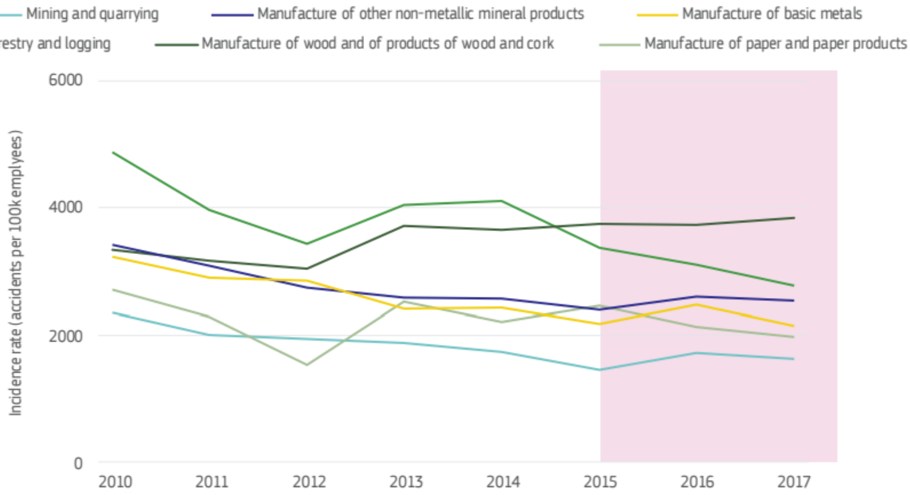


Figure 26.2 presents the 2010 – 2017 incidence rate of non-fatal accidents for selected raw materials industries. From 2015 (the last year included in the 2018 Scoreboard), the trend was almost stable for the manufacture of basic metals (-1%) and the manufacture of wood (2%).

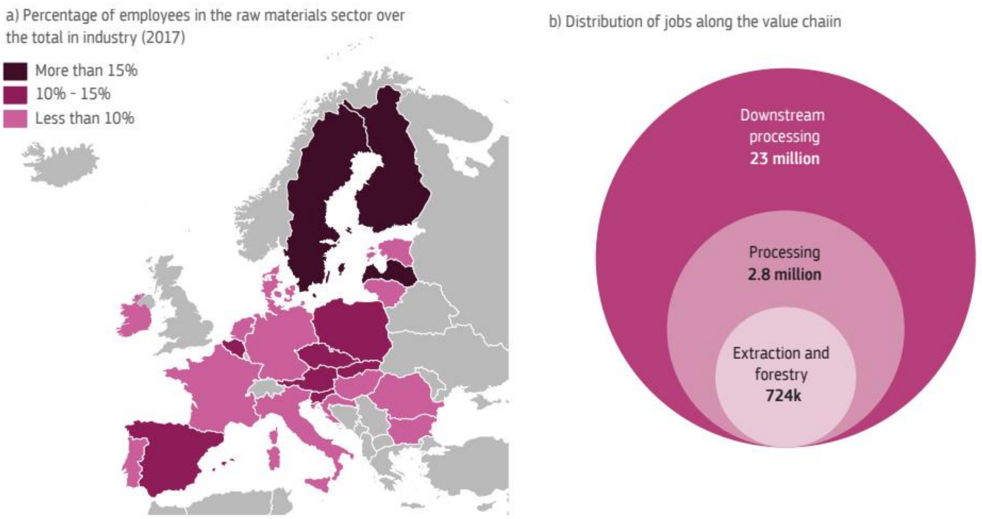
Figure 26.2: Incidence rate of non-fatal accidents of selected raw materials sectors (EU-27, 2010-2017)[541].



6.3. Jobs

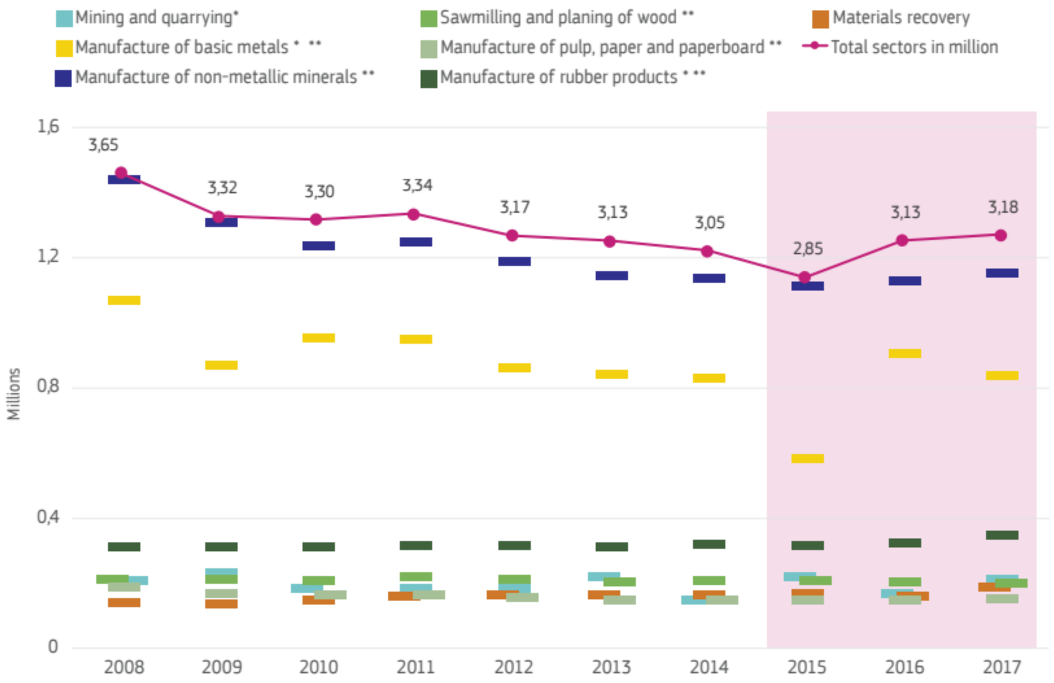
Figure 27.1 shows the share of jobs in the raw materials sectors compared with total jobs in industry.

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



Measures : Share of jobs in the raw materials sectors.	**Period** : 2017
Geopolitical entity : Specific EU member states.	**Source** : JRC elaboration, based on data fro Eurostat's annual detailed enterprise statistics fo industry (NACE Rev. 2, B-E) ´sbs_na_ind_r2´.
Material flow streams : Raw materials sector.	**Applicability to Belgium** : Yes, data already available.

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



Measures : Trend in number of employees by raw material sector.	**Period** : 2008-2017.
Geopolitical entity : EU aggregate.	**Source** : JRC elaboration, based on data from Eurostat's annual detailed enterprise statistics for industry (NACE Rev. 2, B-E) ´sbs_na_ind_r2´.
Material flow streams : Raw materials sector.	**Applicability to Belgium** : See with JRC.

9.7 Methodology #7

Methodology #7
Expanding the knowledge base on intra-EU waste movements in a circular economy

Short description

The core of the method is to use the outcomes of the model using COMEXT trade statistics developed by Wood for the current WSR IA project work for the European Commission. This model uses **a stream by stream approach**, and provides a suitable basis for categorising waste (which includes what might be classified as 'tradeable secondary raw materials - that would not be picked up as waste (in waste statistics), because they are accepted as meeting 'end of waste criteria') movements and movement of waste between MS for the period 2016-2019.

The purpose of this study is to improve the understanding of the movements of waste between EU Member States by broadening the knowledge base, describing the dynamics and the drivers behind these movements and assessing the overall environmental benefit and risks that the movements bring to the overall EU waste management system. The work can be structured under the following three questions:

1. What can the available data tell us about the intra EU shipments of Waste?
2. What drives and constrains these waste movements?
3. What are the environmental benefits of these waste movements?

Trinomics et al. (2021). Expanding the knowledge base on intra-EU waste movements in a circular economy. Agence européenne pour l'environnement (EEA).

Methodology overview

Category overview

Circular Economy	X
Self-sufficiency	
Resilience	

Purpose

Macro-overview	
Specific indicators measurement	X

Geographical coverage

International	
EU aggregates	X
EU member states individually	X
Specific country development	
Belgium	
Brussels	
Wallonia	
Flanders	

Sub-category covered features

Self-sufficiency	
Material footprint	
Waste	X
Recovery (recycling)	X
Secondary raw materials	X

Data sources

COMEXT trade statistics developed by Wood for the WSR IA project work for the European Commission.

Period

2016-2019

Full methodology description

Intra-EU waste movements by weight

The study presents the volumes of weights of non-hazardous wastes against the categories of plastic, glass, textiles, non-ferrous metals, ferrous metals, paper and cardboard and totals of these wastes combined. These have been presented as it is considered that these are the materials of greatest interest to the European Environment Agency – given their relevance to the circular economy (i.e. they are recyclable).

Analysis of the flows of identified high volume waste types between EU Members States.

1. Movements by weight

It is apparent that transboundary shipments remain a small percentage of total waste generated, indicating that, in general, 98% of wastes generated are treated within the Member States themselves, with transboundary movements representing a small percentage by total volume.

The nature of the countries plays an important role in their exports of imports of waste. Countries such as BE, NL and LU are generally transport hub countries, LU as a result of its location amongst a number of large Member States and BE and NL as a result of the rail and port infrastructure in those countries that undertake a considerable share of transboundary shipments of waste both within the EU and between the EU and third countries. This is likely to account for their proportionally higher levels of exports of wastes than countries of a similar size in terms of population and economy.

Analysis of the patterns in the waste streams considered key to the circular economy, as they are the most resource rich (i.e. recyclable) revealed the following:

- **Plastic waste :** Some Member States (FR, DE and SE) consistently relying on exports whilst others appear to be expanding their imports (most notably CZ, and RO);
- **Glass waste**: Some Member States (BE, HU, EL, HU, NL, RO, SE and SI) consistently relying on exports, whilst others appear either to be expanding their imports of glass waste overall (most notably CZ) or are large destinations for glass waste overall (DE and PT);
- **Textile waste**: Some Member States (AT, BE, DE, FI, FR, PT and SE) consistently relying on exports, whilst others are generally net importers of textiles waste (most notably BG, ES, HU, IT, LT, NL, PL and RO);
- **Non-ferrous metals**: When considering the significant volume of shipments originating from or entering DE, the balance of imports versus exports is relatively small. DK, FR and NL are the largest Member States by volume that export more non-ferrous metal waste than they import, whereas the likes of AT, ES and IT show increasing trends of net volumes imported increasing over time;
- **Ferrous metals**: IT, BE, ES and LU appear to be the overall countries of destination for ferrous metal wastes from other EU Member States. DE, FR and FR appear to rely more heavily on exports to other Member States of their ferrous metal wastes. Imports into Italy are reported (industry interview) as being relatively high due to the high use of electric arc furnaces in iron and steel production in Italy, and these are capable of using a much higher proportion of waste material than blast furnaces (which are more common in German steel making plants). Germany appears to have the largest number of shipments by waste moving into and out of the country. Germany accounted for over 40M tonnes of crude steel in 2019 (25% of crude steel production in the EU). With net exports of just under 3.5M tonnes, exports of ferrous metal waste represent just under 10% of total production. When compared with FR, that accounts for 14.5M tonnes of crude steel production in 2019, net exports as a percentage of production in FR are 30% of total production. A similar proportion to FR in found in CZ;
- **Paper and cardboard**: AT, DE, ES, HU and NL appear to be the overall countries of destination for paper and cardboard wastes from other EU Member States. CZ, DK, FR and PL appear to rely more heavily on exports to other Member States of their paper and cardboard wastes;
- **Refuse derived fuel, other wastes from mechanical treatment and mixed municipal waste for energy recovery and incineration**: DE and SE are net importers of these wastes for R1 and D10 activities but that the proportions imported are a small fraction of the total wastes subject to these activities. However, for SK, imports are an important fraction of the total feedstocks for R1 and D10 capacity. Conversely, IE and to a lesser extent SI are heavily reliant on exports for the incineration of their wastes.

2. Final treatment

Data on the actual treatments at the point of destination are not always easily identifiable, if they exist at all. There are two main sets of data that can be interrogated for this, each with their benefits and shortcomings, including in relation to understanding final treatments applied:

- **Comext data provides a lot of detailed and reliable data on flows of materials and their reported values.** However, it does not include data on final treatment. Certain assumptions are made in relation to some CN code material identified as recyclable raw materials by waste (i.e. that it is assumed that it always crosses borders for recovery given its inherent value). Whilst this may, in general, be correct, it is almost certain that at least a fraction of the materials transferred across borders are not recycled or reused but may be recovered in energy from waste facilities or disposed of (i.e. sorting residues);
- **Eurostat waste shipment data generally contains a significant amount of information on the waste treatments applied to the wastes shipped**. However, the dataset is far less encompassing of recyclable raw materials by waste because not all such wastes are subject to notification and reporting under the relevant waste statistics Regulation.

9.8 METHODOLOGY #8

Methodology #8

Expanding the knowledge base on intra-EU waste movements in a circular economy

Short description

The EEA's Circularity Metrics Lab (CML) uses a range of sources such as European datasets, national statistics, surveys, and novel dataflows to provide insights on progress towards the development of the circular economy. It is intended to complement other monitoring frameworks by presenting additional evidence on circularity, including metrics focussed on the implementation of circular principles and practices.

The circularity metrics are grouped in four categories:

1. Enabling framework
2. Business
3. Consumption
4. Materials and waste

European Environnement Agency. (2023). Measuring Europe's circular economy – Circularity Metrics Label (CML). https://www.eea.europa.eu/en/topics/in-depth/circular-economy/measuring-europes-circular-economy

Methodology overview

Category overview

Circular Economy	X
Self-sufficiency	
Resilience	

Sub-category covered features

Self-sufficiency	
Material footprint	
Waste	X
Recovery (recycling)	X
Secondary raw materials	X

Purpose

Macro-overview	X
Specific indicators measurement	X

Geographical coverage

International	
EU aggregates	X
EU member states individually	X
Specific country development	
Belgium	X
Brussels	
Wallonia	
Flanders	

Data sources

Data sources vary depending on the indicator.

Period

Period varies depending on the indicator.

Full methodology description

1) Enabling framework assessment

1.1. National circular economy policies

20 / 27 EU member states have published national circular economy policy documents by September 2022. These plans guide national efforts towards the development of a circular economy.

Measures : Countries with national adopted CE Strategies.	**Period** : 2015-2022.
Geopolitical entity : EU aggregates.	**Source** : ETC/WMGE, 2019, Eionet, European Environment Agency.
Material flow streams : None.	**Applicability to Belgium :** Yes, by calculating all the CE Strategies within the country.

1.2. Circular economy lending and financing

€2.7Bn of lending was made available by the European Investment Bank for circular economy projects over the period 2016-2020. Targeted financing is a key measure to steer economic development towards more sustainable production and consumption patterns.

Measures : Circular economy related lending by the European Investment Bank. In billion EUR.	**Period** : 2014-2020.
Geopolitical entity : EU aggregates.	**Source** : Annual Circular Economy Overview, 2021, European Investment Bank; Annual Circular Economy Overview, 2020, European Investment Bank.
Material flow streams : Energy, urban development, mobility, water management, waste management, agriculture and bioeconomy, industry and services.	**Applicability to Belgium :** Yes, by assessing circular economy related lending by Belgium's public authorities.

1.3. Scientific articles on circular economy

3,033 articles were published in scientific journals concerning circular economy innovations in the EU27 during 2021. This increased activity suggests there is a growing level of innovation in this area.

Measures : Number of scientific articles concerning circular economy.	**Period** : 2010-2021.
Geopolitical entity : EU aggregates.	**Source** : Web of Science.
Material flow streams : /	**Applicability to Belgium :** Yes, by assessing all articles related to circular economy published by Belgium's universities and research institutes.

1.4. Circularity in green public procurement

26% of Belgian public procurement included some considerations for sustainability. Public authorities offers a high potential for driving the circularity transition through government purchasing power.

Measures : Percentage of public procurement notices in Belgium that consider sustainability aspects.	**Period** : 2011-2016.
Geopolitical entity : Belgium.	**Source** : Grandia and Kruyen, 2017, Erasmus Universiteit Rotterdam.

Material flow streams : /	**Applicability to Belgium :** Belgian data available already.

1.5. Economic incentives for circularity

€988m of tax deductions in 2020 for home renovations, conversions and extensions in Sweden. The transition to a circular economy requires systemic changes, such as economic measures, that incentivise actions aligned with circularity objectives.

Measures : Amount deducted from taxes on repair activities.	**Period** : 2016-2020.
Geopolitical entity : Sweden.	**Source** : Grandia and Kruyen, 2017, Erasmus Universiteit Rotterdam.
Material flow streams : /	**Applicability to Belgium :** Need for examination, but collaboration with SPF/FOD on all the economic incentives linked to circularity.

2) Business

The development of the circular economy requires a transformation in the operating models of companies to provide goods and services with reduced resource consumption. From a business perspective, the new circular economic paradigm offers benefits by decoupling profit from the downside risks of natural resource depletion, pollution and climate change, while also delivering improved competitiveness and responding to changing customer demands

2.1. Eco-Innovation scoreboard outcomes

A 21% increase is reported for positive outcomes on the eco-innovation scoreboard across in the EU, with an increasing trend observed for most Member States.
The Eco-innovation Index is calculated as a unweighted average of a series of innovation-related metrics, covering eco-innovation inputs, activities and outputs, as well as resource efficiency and socio-economic outputs:

1) Eco-innovation inputs
- Governments environmental and energy R&D appropriations and outlays
- Total R&D personnel and researchers
- Total value of green early-stage investments

2) Eco-innovation activities
- Implementation of resource efficiency actions among SME
- Implementation of sustainable products among SMEs
- Number of ISO 14001 certificates

3) Eco-innovation outputs
- Eco-innovation related patents
- Eco-innovation related academic publications
- Eco-innovation related media coverage

4) Resource efficiency outcomes
- Material productivity;
- Water productivity (GDP/total fresh water abstraction);
- Energy productivity
- GHG emissions productivity

5) Socio-economic outcomes
- Exports of environmental goods and service sector
- Employment in environmental protection and resource management activities
- Value added in environmental protection and resource management activities

Measures : Eco-Innovation Index (the maximum score is the highest score found across all years ithin all countries).	**Period** : 2012-2021

Geopolitical entity : EU aggregates and Member States individually but a range of EU countries not included.	**Source** : Eco-Innovation Index, 2022, European Commission.
Material flow streams : /	**Applicability to Belgium :** No available data for Belgium

2.2. Certifications to European ecolabel

A 39% increase was recorded in European ecolabel product certifications between 2010 and 2021. Paints and varnishes are the products with the highest number of ecolabels.

Although not displayed in the graph, data on the number of Ecolabels is also available by Member State and by product group. Most licenses are awarded in Spain (21%), Italy (16%), France (10%) and Germany (9%). The product groups having the highest number of products Ecolabel award, as for data for 2022 (March) are paints and varnishes (39%), tissue paper and tissue products (17%), textiles (9%) and hard coverings (9%). Absorbent hygiene products, furniture, and indoor cleaning services showed the highest increments.

Measures : Number of EU Ecolabel products (goods and services) in the EU.	**Period** : 2010-2021.
Geopolitical entity : EU aggregates and Member States individually but a range of EU countries not included.	**Source** : Eco-Innovation Index, 2022, European Commission.
Material flow streams : /	**Applicability to Belgium :** Already data available for Belgium.

2.3. Circular business ranking and performance

Measuring and disclosing companies' circularity can accelerate the transition to a more circular economy. Globally, 1,884 companies have signed up to the Ellen MacArthur Foundation's Circulytics tool which gauges the extent to which a company has achieved circularity across its entire operations, with European companies dominating this cohort.

Measures : Headquarter region of companies with completed Circulytics assessments.	**Period** : 2020-2022.
Geopolitical entity : EU aggregates and worldwide.	**Source** : Ellen MacArthur Foundation
Material flow streams : /	**Applicability to Belgium :** Yes but not relevant given EU's reporting compliance.

2.4. Production and consumption of chemicals

After some decreasing trends, production and consumption of chemicals has been rising in recent years. Recycling of products that contain hazardous chemicals can lead to impacts on human health and the environment and so are detrimental to circularity.

Measures : European chemical production and consumption.	**Period** : 2011-2020
Geopolitical entity : EU aggregates and worldwide.	**Source** : Eurostat, 2022.
Material flow streams : /	**Applicability to Belgium :** Yes.

2.5. Corporate communications on circular activities

In order to measure the transition towards a circular economy, it is important to monitor circular activities in the economy. 5% of Dutch companies have reported undertaking circular economy activities.

No data available.

2.6. Investments, jobs and gross value added

Measures : Private investment, jobs and gross value added related economy sectors.	**Period** : 2015-2019.
Geopolitical entity : EU aggregates	**Source** : Eurostat, 2022.
Material flow streams : Jobs, value added, gross investments.	**Applicability to Belgium :** Yes, indicator of the EU Monitoring Framework.

2.7. Products evaluated for repairability

1,201 products have been scored by the French Repairability Index. Smartphones are the product category for which more products have been scored, obtaining very variable scoring results.

Measures : Private investment, jobs and gross value added related economy sectors.	**Period** : 2015-2019.
Geopolitical entity : France	**Source** : Indice de réparabilité, 2022.
Material flow streams : Smartphones, front leading washing machine, land mowers, televisions, laptops.	**Applicability to Belgium :** When the Belgian's Reparability Index will be created.

2.8. SMEs offering green products or services

32% of SMEs in the EU offer green products or services, with a further 11% planning to do so in the next two years. Focussing on green products and services will allow European businesses to evolve to more sustainable business models.

Measures : SME offering green products or services	**Period** : 2012-2021.
Geopolitical entity : EU aggregates.	**Source** : Flash Eurobarometer 342, Flash Eurobarometer 426, Flash Eurobarometer 456, Flash Eurobarometer 498.
Material flow streams : Smartphones, front leading washing machine, land mowers, televisions, laptops.	**Applicability to Belgium :** No.

3) Consumption

3.1. Europe's consumption footprint

8.4 % decrease in Europe's consumption footprint between 2012 and 2020, although levels continue to exceed planetary boundaries. The EU must achieve a sustained reduction in the overall level of consumption while increasing the use of products that have less impact on the climate and environment.

Measures : Europe's consumption footprint.	**Period** : 2010-2020.
Geopolitical entity : EU aggregates	**Source** : EEA, 2022.
Material flow streams : Clothing and footwear, mobility, household goods, direct impact from households, services, gross capital formation, food, housing.	**Applicability to Belgium :** Need examination with EEA.

3.2. Consumer environmental activities

Consumers are showing mixed responses to sustainability, with increasing action for purchasing local and second-hand products and worsening behavior towards energy and water use reported between 2014 and 2019.

Measures : Responses to question : "Have you done any of the following in the past 6 months?"	**Period** : 2014, 2017, 2019.

Geopolitical entity : EU aggregates	**Source** : Eurobarometer, 2014; Eurobarometer 2017; Eurobarometer 2020.
Material flow streams : Separated most of your waste for recycling ; avoided single plastic goods other than plastic bags; bought local products, cut down your energy consumption, repaired a product instead of replacing it; avoided buying over-packaged products, etc.	**Applicability to Belgium :** No.

3.3. Consumer food waste in Europe

55% of food waste comes from households, which generated on average 70 kg of food waste per inhabitant in 2020. Data varies significantly across Member States.

Measures : Tonnes of fresh mass	**Period** : 2020.
Geopolitical entity : EU aggregates	**Source** : Eurostat 2022.
Material flow streams : Total food waste, households, processing and manufacturing, primary production, restaurants and food services, retail and other distribution.	**Applicability to Belgium :** Yes, Eurostat.

3.4. Number of members of car sharing schemes

Car sharing is an example of circularity measures that helps moving from an ownership model to a service model. 49% of survey respondents have used a collaborative platform for transport. Usage varies across the Member States, from more than 80% in Lithuania to 20% in Hungary.

Measures : Percentage	**Period** : 2018.
Geopolitical entity : EU aggregates and EU member states.	**Source** : Eurobarometer 2018.
Material flow streams : /	**Applicability to Belgium :** Yes, data available.

3.5. Citizens who have chosen alternates to new products

35% of survey respondents reported buying a remanufactured product instead of a new product. Choosing alternatives to buying new products results more circular than the traditional linear (and individual) consumption model, since products are used for longer time and are more intensively.

Measures : Percentage of citizens who have chosen alternatives to buying new products.	**Period** : 2018.
Geopolitical entity : EU aggregates and EU member states.	**Source** : Eurobarometer 2018.
Material flow streams : Used sharing schemes; leased or rented a product instead of buying it, bought a remanufactured product.	**Applicability to Belgium :** Yes, data available.

3.6. Household expenditure on repair and maintenance

20-30% decrease of budget allocated to repair and maintenance of many appliances and equipment categories, and increase for furniture.

Measures : Consumption expenditure per household on repair, hire and maintenance by product group.	**Period** : 2005-2015.
Geopolitical entity : EU aggregates.	**Source** : Eurostat 2015.
Material flow streams : Maintenance and repair of personal transport equipment, maintenance and repair	**Applicability to Belgium :** No.

of the dwelling, repair of furniture, furnishings and floor coverings, spare parts and accessories for personal transport equipment, repair of audio-visual, photographic, and information processing equipment, repair of household appliances; cleaning, repair and hire of clothing; maintenance and repair of other major durables for recreation and culture; repair and hire of footwear.	

4) Materials and waste

4.1. Waste generation

4.2% less waste was generated per capita by EU citizens between 2010 and 2020. However this improvement occurred during the economic slow-down caused by the COVID-19 pandemic, and this figure masks a steady upward trend in waste generation in the EU.

Measures : Waste generation millions tons	**Period** : 2005-2020.
Geopolitical entity : EU aggregates	**Source** : Eurostat.
Material flow streams : /	**Applicability to Belgium :** Yes, see Eurostat.

4.2. Circular Material Use Rate (CMUR)

4.2% less waste was generated per capita by EU citizens between 2010 and 2020. However this improvement occurred during the economic slow-down caused by the COVID-19 pandemic, and this figure masks a steady upward trend in waste generation in the EU.

Measures : CMUR in %	**Period** : 2010-2020.
Geopolitical entity : EU aggregates	**Source** : Eurostat.
Material flow streams : /	**Applicability to Belgium :** Yes, see Eurostat.

4.3. Waste recycling

46% of overall waste in the EU is recycled. This ratio between total waste generated (excluding major mineral wastes) and the quantities managed through recycling has remained steady for some years, but actually declined slightly in the period 2018-2020.

Measures : Recycling rates in %	**Period** : 2004-2020.
Geopolitical entity : EU aggregates	**Source** : Eurostat.
Material flow streams : Packaging, municipal waste, WEEE, all.	**Applicability to Belgium :** Yes, see Eurostat.

4.4. Renewable energy

Over 22% of EU energy consumption is met from renewable sources. An increasing share of EU energy demands are being met from renewable sources, however the share of renewable energy in the EU grew by only 0.1 percentage points, from 22.1% in 2020 to 22.2% in 2021.

Measures : Share of gross final energy consumption from renewable sources	**Period** : 2005-2020.
Geopolitical entity : EU aggregates	**Source** : Eurostat.
Material flow streams : /	**Applicability to Belgium :** Yes, see Eurostat.

4.5. Europe's material footprint

6.1Bn tonnes of material extracted from nature, both inside and outside the EU, to manufacture or provide the goods and services consumed by EU citizens. The total EU material footprint is above the global average and exceeds the planet's 'safe operating space' for resource consumption.

Measures : EU material footprint, expressed in million tonnes of RME.	**Period** : 2010-2020.
Geopolitical entity : EU aggregates	**Source** : Eurostat.
Material flow streams : Non-metallic minerals, metal ores, fossil energy materials, biomass.	**Applicability to Belgium :** Yes, see Eurostat.

4.6. Diversion of waste from landfill

280kg/person of waste is landfilled by EU citizens each year. The amount of waste landfilled is reducing but it remains a significant route for waste management resulting in loss of materials and significant pollution risk.

Measures : Amounts of waste deposited in landfills.	**Period** : 2010-2020.
Geopolitical entity : EU aggregates	**Source** : EEA.
Material flow streams : /	**Applicability to Belgium :** Yes, see Eurostat.

4.7. Residual waste generation

774 Mtonnes of Europe's waste was considered as residual and so was sent to sent to landfill or incineration in 2020. Waste treated via these processes loses its resource value and this can considered as a failure of circularity.

Measures : Amounts of waste deposited in landfills.	**Period** : 2010-2020.
Geopolitical entity : EU aggregates	**Source** : EEA.
Material flow streams : /	**Applicability to Belgium :** Yes, see Eurostat.

4.8. Resource productivity

2.1€/kg worth of production activity is generated for every kilogramme of material consumed in the EU economy. Resource productivity reached above 2 €/kg in 2015 and has remained above 2 €/kg since.

Measures : Resource productivity.	**Period** : 2010-2020.
Geopolitical entity : EU aggregates	**Source** : Eurostat.
Material flow streams : /	**Applicability to Belgium :** Yes, see Eurostat.

9.9 METHODOLOGY #9

Methodology #9
Global Material Flows DataBase

Short description

The Global Material Flows Database provides data to help governments, policy researchers and interested stakeholders understand and trace the linkages between economic growth and raw material usage. Such information is basic for the development of effectively targeted sustainable consumption and production strategies. It also builds a strong quantitative basis upon which the success or failure of those strategies in lowering resources use can subsequently be assessed.
The database is based on authoritative, publicly accessible international data sources wherever possible, combined with the most recent methodologies for establishing material flow accounts. It covers the period 1970-2019, for more than 200 countries and reports extraction and direct trade of raw materials, indirect trade flows (including material footprints), as well as intensities derived from these material measures.

UNEP. (2023). Global Material Flows Database. https://www.resourcepanel.org/global-material-flows-database

Methodology overview

Category overview

Circular Economy	X
Self-sufficiency	X
Resilience	

Purpose

Macro-overview	X
Specific indicators measurement	

Geographical coverage

International	X
EU aggregates	X
EU member states individually	X
Specific country development	
Belgium	X
Brussels	
Wallonia	
Flanders	

Sub-category covered features

Self-sufficiency	
Material footprint	X
Waste	X
Recovery (recycling)	X
Secondary raw materials	

Data sources

UNEP

Period

1970-2019

Full methodology description

There are six modules mooted for a comprehensive material flows accounting framework, outline in the database:

1. Direct, gross physical domestic extraction (DE) of materials from the environment within a nation's territory, direct physical imports (IM) and direct physical exports (EX). These basic flows are further combined to produce further "territorial" metrics given in this data set. To be counted as DE, the extracted material must be used for some economic activity or at least further transformed. For example, all of a metal ore is counted, as it is generally all processed postextraction.

2. Embodied material flows associated with imports and exports, i.e., the raw material equivalents of imports (RMEIM) and exports (RMEEX). These are then used to calculate material footprint (MF), which provides a view of a nation's material consumption that, unlike DMC, fully accounts for extraction in other countries used for local consumption, and for DE ultimately used for consumption in other countries.

3. Deals with the output side of the material flow account and reports domestic processed output (DPO), i.e., flows of waste and emissions and the gateways through which they leave the economy towards the environment (landfill, soil, water and air).

4. Measures net additions to stocks (NAS) and may contain a stock account of in-use stock (Stock) and allows for closing the material flow balance by linking inputs to outputs and by introducing a set of balancing items.

5. Deals with unused extraction that occurs in a country's territory, often associate with DE in module 1. Things such as waste rock / overburden in mining and unused crop residues would be accounted for here rather than module 1, as they do not enter into further economic activity / transformation.

6. This module would focus on the material flows of different economic sectors and would create a true material flow satellite account and is related to the creation of physical input output tables.

Table 1 Material flows covered in the Global Material Flows Database

INDICATOR	
DE	Domestic extraction
IM	Physical imports (direct, territorial)
EX	Physical imports (direct, territorial)
DMI	Direct material input = DE + IM
PTB	Physical trade balance = IM - EX
DMC	Domestic material consumption = DE + IM - EX
RME_{IM}	Raw material equivalent of imports
RME_{EX}	Raw material equivalent of exports
MF	Material footprint = DE + RME_{IM} - RME_{EX}

The publicly available online database presents direct material flows data for four main material categories which are directly extracted from the environment (biomass, metal ores, non-metallic minerals and fossil fuels).

An additional six categories to accommodate manufactured materials and waste are provided at the most aggregated level, but these will not have data for DE, as they generally make no sense in the context of DE, where they would involve double counting of materials. They are included mainly for international trade, where double counting is not a concern. Four of these categories accommodate "products mainly from…" manufactures for each of the main DE categories, and one covers complex/mixed manufactures, and one (internationally traded) waste.
One further additional category, "Excavated earthen materials (including soil) nec," is included as a placeholder, as it is already reportable for some jurisdictions material flows, notably the EU, but may in practice be used to record material flows which have not traditionally been included as DE. Notable examples include much "cut and fill" material in construction, and mining overburden. Introducing it as a separate category now enables it to be recorded, but also quarantined from DE estimates going forward. There is also an intermediate detail system, where the four main DE categories are disaggregated further into 13 sub-categories, matching earlier versions of this database. There are also additional sub-categories for non-wild animals, while the "products mainly from fossil fuels" category is split into two sub-categories, one covering refined fuels, and the other all other fossil fuel derived products. This split was introduced to facilitate a level of backwards comparability with earlier versions,

where refine fuels were included in the trade accounts (and so PTB and DMC calculation), while other fossil fuel-based products were mainly excluded.
This results in two systems of 11 and 22 categories respectively, compared to the previous database's four and 13 category systems. These shown in table 2, labelled MFA4Plus and MFA13Plus, with the additional trade related categories for the 2021 version in blue.

Table 2 Augmented aggregate categories used for this update of GMFD (new, trade-related categories in blue)

MFA4Plus	MFA13Plus
Biomass	Crops
Biomass	Crop Residues
Biomass	Grazed biomass and fodder crops
Biomass	Wood
Biomass	Wild catch and harvest
Products from biomass	Non-wild animal products
Products from biomass	Products mainly from biomass nec.
Fossil Fuels	Coal
Fossil Fuels	Petroleum
Fossil Fuels	Natural Gas
Fossil Fuels	Oil shale and tar sands
Products from fossil fuels	Other products mainly from fossil fuels e.g., plastics
Products from fossil fuels	Refined fossil fuels mainly for fuel e.g., LPG gasoline diesel
Metal ores	Ferrous ores
Metal ores	Non-ferrous ores
Products from metals	Products mainly from metals nec.
Non-metallic minerals	Non-metallic minerals - construction dominant
Non-metallic minerals	Non-metallic minerals - industrial or agricultural dominant
Products from non-metallic minerals	Products mainly from non-metallic minerals
Excavated earthen materials (including soil) nec	Excavated earthen materials (including soil) nec
Mixed and complex products nec.	Mixed / complex products nec.
Waste for final treatment and disposal	Waste for final treatment and disposal