12. Material flows in the circular economy

Key points:

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

Overview and context

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

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

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

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

Facts and figures

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

Figure 12.1 shows that in 2017 more than 67% (5.36 billion tonnes - Gt) of the mass of raw materials processed in the EU

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

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

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

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

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

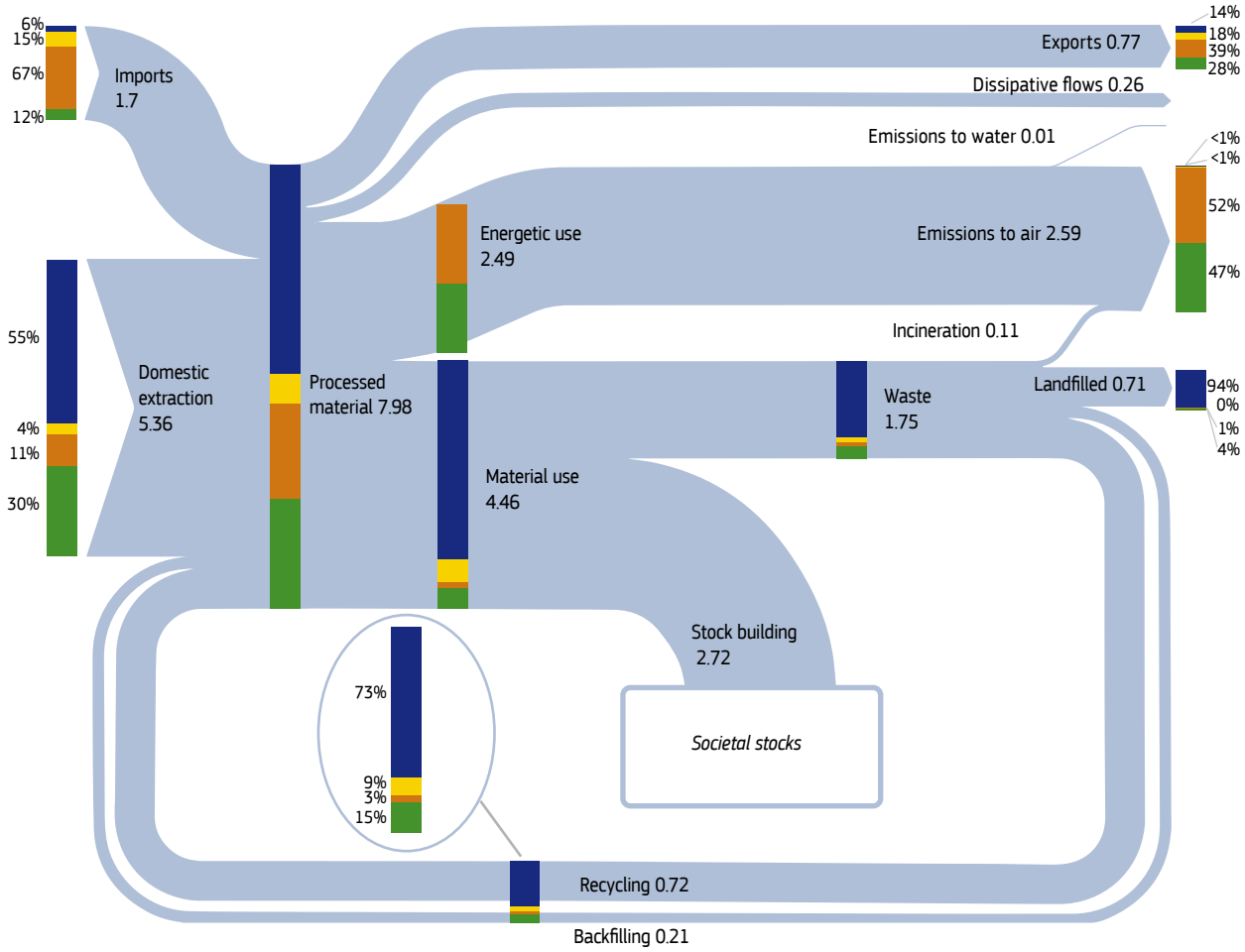
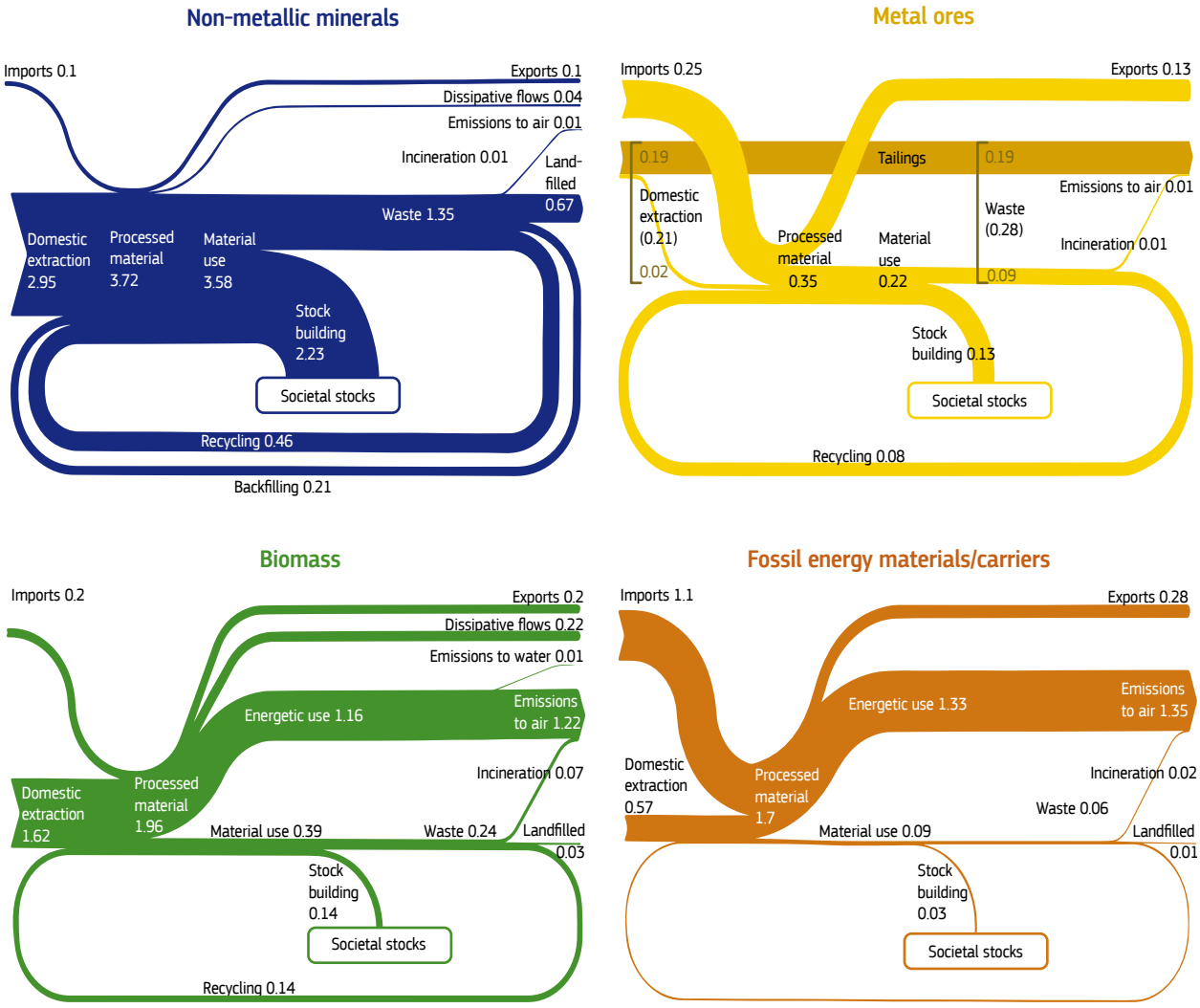


Figure 12.2: Material flows for single material categories in the EU economy (in billion tonnes/year) (EU-27, 2017)[217]



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

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

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

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

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

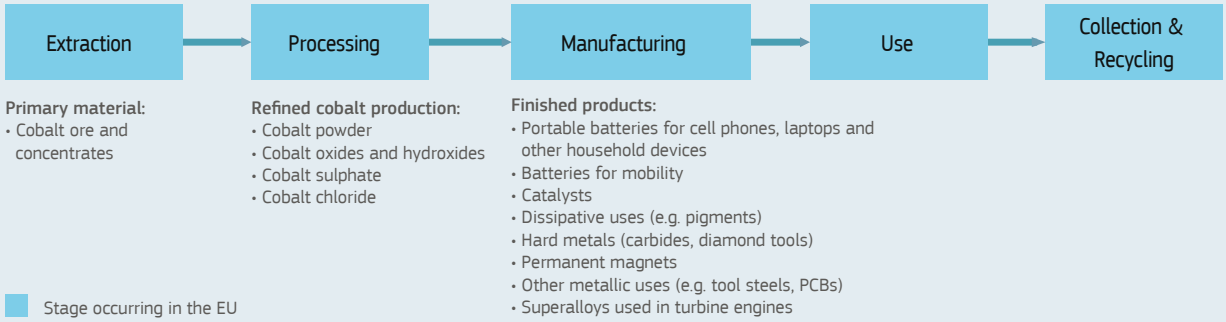
Material system analysis of a relevant critical raw material – cobalt

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

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

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

Figure 12.3: Value chain of cobalt[221]



Cobalt flows and stocks

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

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

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

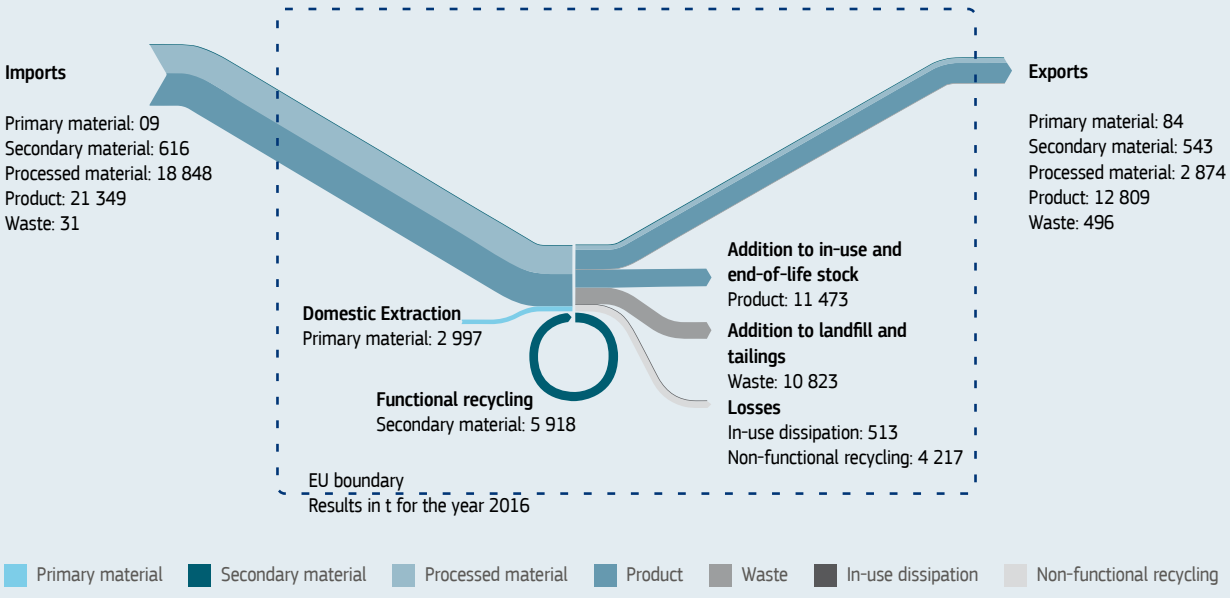


Figure 12.5: Shares of finished products containing cobalt manufactured in the EU (24 kt of Co) and other uses of cobalt in the EU manufacturing industry (left), and used in the EU (33 kt of Co) (right) [223]

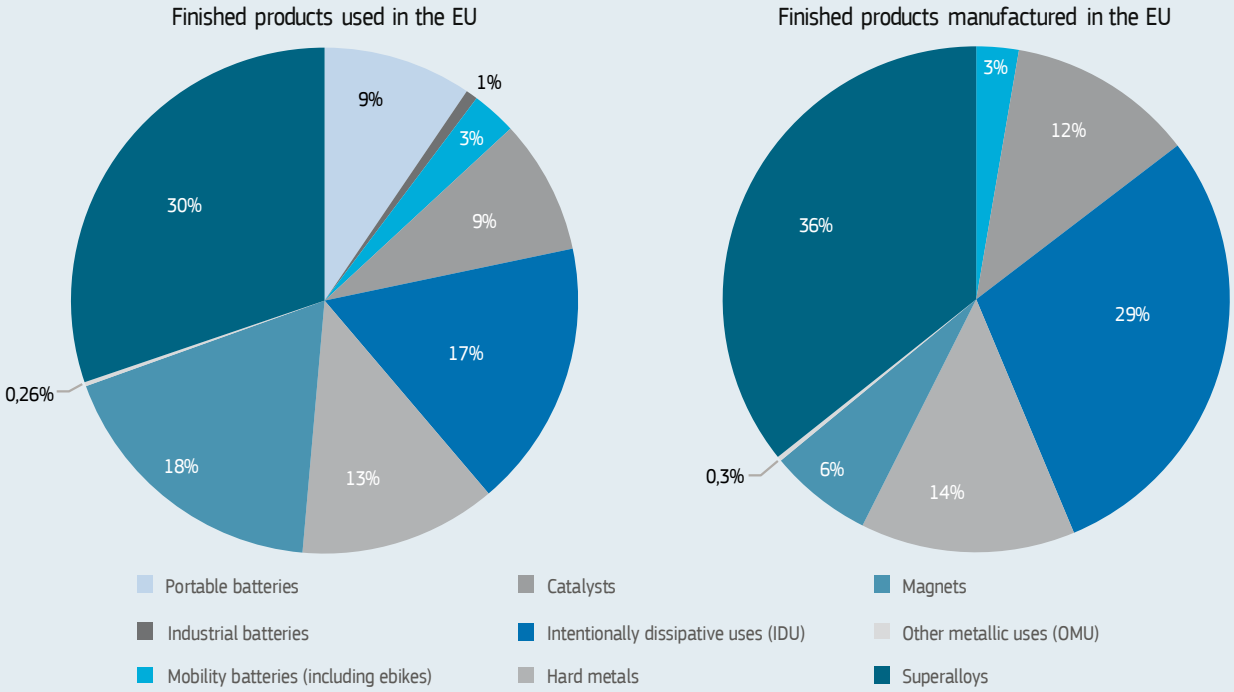


Figure 12.5 also shows that batteries account for 3% of EU manufacturing demand, mainly for the production of e-mobility batteries. In the use phase, 9% of cobalt consumed was embedded in portable batteries and smaller shares were used in mobility and industrial batteries (3% and 1%, respectively).

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

Cobalt circular economy

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

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

Conclusion

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

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

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

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