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A European circular single market for economic security and competitiveness

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Executive summary

IF THE EUROPEAN UNION is to achieve a sustainable net-zero economy, resources need to be used much more efficiently. Extraction from nature and processing of materials are the principal causes of biodiversity loss and are also major sources of pollution, water stress and greenhouse gas emissions.

RESOURCES ARE USED INEFFICIENTLY currently because market and government failures create a nexus of disincentives and barriers to firms and individuals, hindering them in making resource-efficient choices. The most prominent failure is the artificial cheapness of raw materials because the environmental and human costs of extraction are not including in their prices.

A POWERFUL WAY to improve resource efficiency is to increase circularity, so that fewer resources are used to meet the same level of human need. This can be done by extending the duration of use and reuse of materials, and by reducing resource demand from the start by designing products and systems for optimal efficiency.

A CIRCULAR SINGLE MARKET would allow faster de-risking from toxic dependencies and economic coercion by authoritarian regimes. It would increase resilience in the context of fragile supply chains while reducing instability from volatile commodity prices. Firm competitiveness would also be enhanced, given that European companies operate on a continent that is poor in energy and natural resources, and are thus very exposed to future scarcity of resources when climate impacts will make water and land scarcer. If firms were to optimise production and consumption systems for efficiency now, they would be ahead of the curve.

TO DEVELOP THE CIRCULAR ECONOMY FURTHER, the EU will need to spur investment. Public policy that sets common standards and a predictable regulatory framework would accelerate the development of markets for inputs such as recyclates and services such as repair, both in the EU and in trade partners. The EU has established a legislative framework for the circular economy but it needs scaling up in the forthcoming Circular Economy Act.

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1 Why resource efficiency matters

For many years, tackling climate change and environmental degradation lingered in the shadow of other policies as political leaders prioritised short-term economic issues. In terms of the former, the European Union's transition to a net-zero economy has been boosted by the supply side measures taken to end dependence on Russian gas following Putin's 2022 invasion of Ukraine. Carbon emissions are the focus of the international agenda on climate.

However, awareness remains low of the magnitude of human extraction from nature and the risks building up from breaching planetary environmental boundaries. This has led to the "*tragedy of the horizon*"[1] of longer-term consequences ignored as short-term concerns prevail, despite the threats to human life and well-being. In addition to the problem of time horizons for environmental impacts, there is a global public good problem: the loss of biodiversity and other environmental impacts create harm across countries but governments cannot agree on sufficiently effective measures to address them.

This Policy Brief gives an overview of the environmental and economic cases for Europe to improve resource efficiency, particularly by increasing circularity in the single market. Greater resource efficiency would reduce pressure on nature, enabling biodiversity improvements and lessening pollution and water stress, both in Europe and regions where Europe's imports come from. It would also improve the EU's economic security and financial stability, as well as the competitiveness of European firms in the medium term.

Resources include materials, land and water. Materials include everything extracted from the earth and initial processing, and can be categorised into biomass, fossil fuels, metals and non-metallic minerals. Materials can be transported to other regions, while the effects of land and water use and pollution are local. However, all of these resources can be accounted for as 'embedded' environmental impacts (such as emissions, water and pollution) in the raw materials and products that are transported and traded internationally.

The current economic system does not encourage resource efficiency on a large scale, even though companies and consumers would see efficiency gains from circularity if multiple market failures were removed. The most obvious market failure is that the impact on nature of the linear economy is largely unpriced and often unmeasured because the environmental and human costs of extraction and processing of materials, and of their end-of life disposal, fall mainly on local residents and on taxpayers.

Many ecosystem services delivered by nature cannot be substituted by human technology

Environmental degradation is a problem for the economy as well as for nature. Many of the ecosystem services delivered by nature – from pollination to fertile soil – cannot be substituted by human technology. Others – such as fresh water – are extremely expensive and difficult to provide at scale when ecosystems are disrupted.

In addition to the risks, the potential value of greater resource efficiency is also under-appreciated. This value includes opportunities to increase economic security, financial stability and competitiveness over the medium and longer terms.

The EU has an important role to play in promoting resource efficiency because of Europe's high levels of consumption and, on the positive side, its high quality of governance. The EU is a global leader in applying circularity principles. However, like other economies, the single market faces market failures of several kinds that prevent faster and more extensive moves to increase the efficiency of material use throughout value chains, in both production and consumption. Even when individual companies and consumers would benefit from efficiency gains from circularity, realising these gains requires public policy to set common standards and to create markets that can deliver inputs such as recyclates, and services such as repair.

We start with the scientific evidence on the environmental impact of global and European extraction and processing. We then show how resource efficiency would improve the EU's

1 This term is widely attributed to Mark Carney (Carney, 2015).

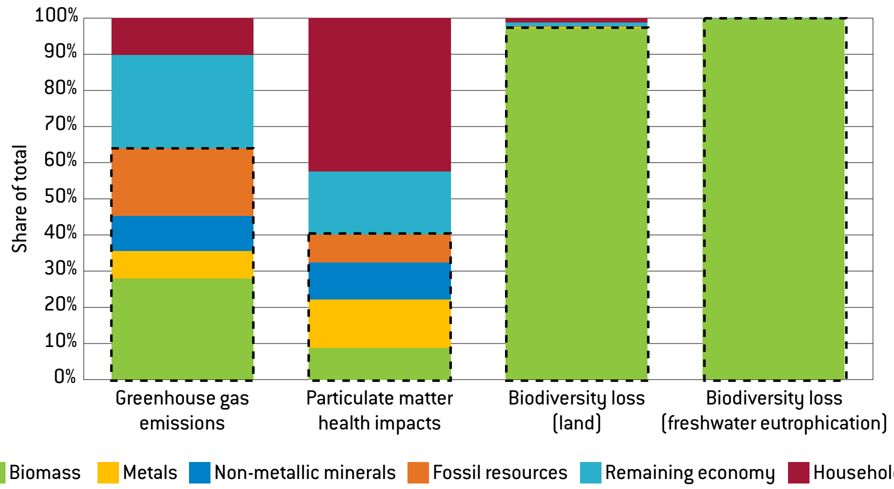
economic security and financial stability, as well as the competitiveness of European firms in the medium term, particularly through increased circularity in the single market. We then provide policy recommendations for achieving greater resource efficiency in the EU.

2 The environmental case for resource efficiency

2.1 The impact of resource over-use on the planet

It is a harsh reality that the unsustainable extraction of resources from nature is already well beyond several key planetary boundaries[2]. Biomass cultivation for food, forestry and textile production, mineral and fossil resource extraction, and processing of these primary materials are the principal drivers of the triple planetary crises of climate change, biodiversity loss and pollution (Figure 1). In 2022, these activities, including the fossil-fuel use that underpins them, were responsible for 64 percent of greenhouse gas emissions, 40 percent of air pollution health impacts, 98 percent of land biodiversity loss and nearly 100 percent of biodiversity loss from freshwater eutrophication[3].

Figure 1: Global environmental impacts of cultivation/extraction, processing and use of biomass, metals, non-metallic minerals and fossil resources, 2022



Source: Bruegel adapted from UNEP (2024), Figure 3.2. Notes: The dotted lines correspond to the impacts attributed to the cultivation/extraction and processing of materials, which are captured in four categories: biomass, metals, non-metallic minerals and fossil resources. See Annex 1 for definitions and an explanation of how economic activities are categorised.

The extent to which resource-related environmental impacts have already severely transgressed planetary boundaries (Figure 2) means there is a high risk of disruption of the natural systems that underpin the Holocene, the stable and favourable conditions in which human civilisations have developed over the last 11,700 years (Richardson *et al*, 2023). Despite often being treated as separate issues, the non-linear interactions between environmental impacts

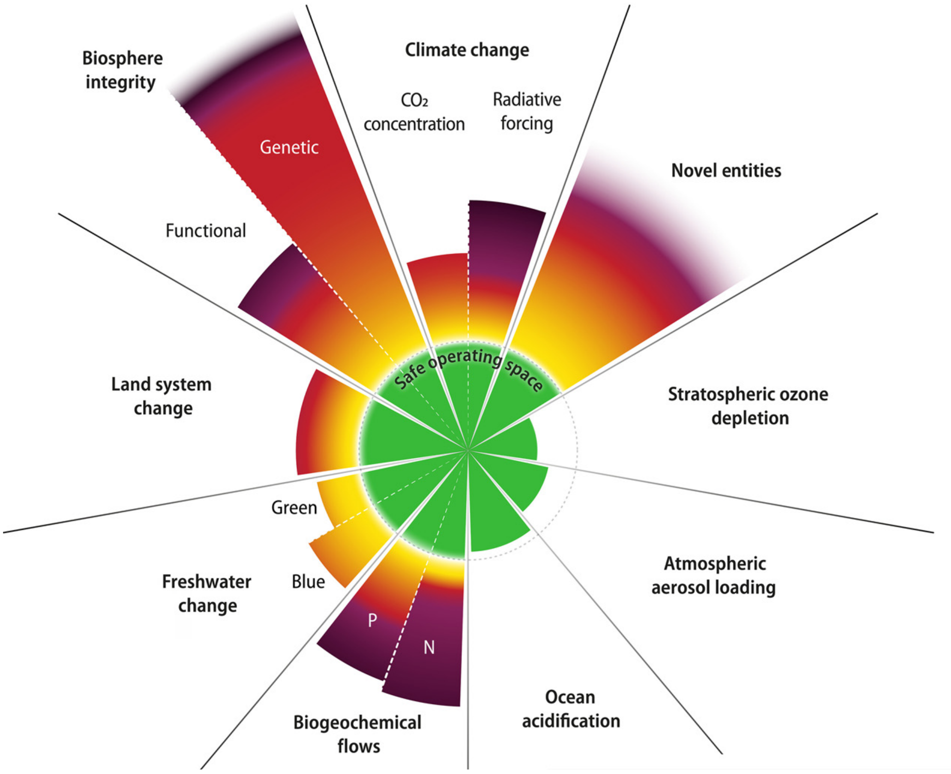
2 The planetary boundary framework "*identifies nine processes that are critical for maintaining the stability and resilience of the Earth system as a whole*", based on Earth system science (Richardson *et al*, 2023). It calculates the extent to which these processes are perturbed by human activities.

3 The primary cause of eutrophication (accumulation of nutrients in water, leading to algal growth and other effects) is overload of nitrogen and phosphorus from animal waste, human sewage and excess use of fertilisers.

mean that greater risks are building up from the aggregate effects of degradation of ecosystems (IPCC, 2022). This will have damaging and volatile impacts on economies, which are embedded in nature and rely on the services it provides (Dasgupta, 2021).

It is therefore worrying that the climate impacts and biodiversity loss driven by extraction and processing of materials are rising fast. Figure 3 shows that materials-related CO2 emissions have increased by 52 percent since 1995, reaching 26 gigatonnes in 2022. This alone exceeded by a factor of five the level of CO2 emissions that would enable the world to keep to the Paris target of a global temperature rise of no more than 1.5°C – and the chasm has widened despite measures to decarbonise economies. New annual species loss driven by land use change has consistently exceeded targets, increasing biodiversity loss. Annual species loss resulting from land-use change exceeded the international target by 35 times in 2022 (UNEP, 2024). Biomass cultivation and processing have driven the vast majority of land-based annual species losses historically.

Figure 2: Current status of the nine planetary boundaries

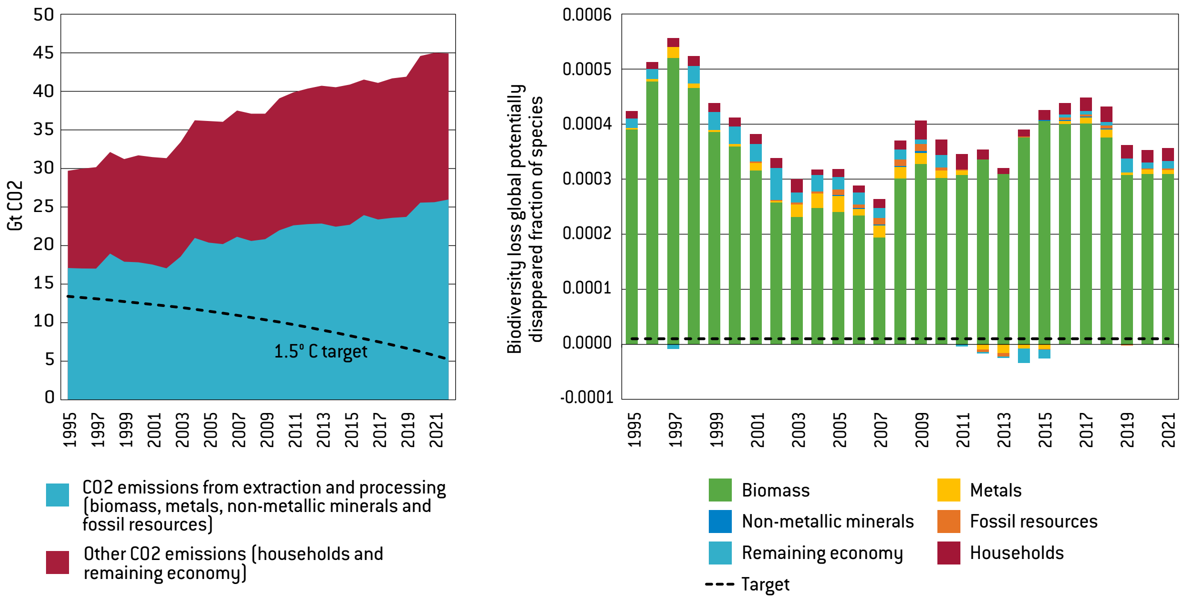


Source: Richardson *et al* (2023). Reproduced from https://www.science.org/doi/10.1126/sciadv.adh2458. Note: N = nitrogen, P = phosphorus.

The divergence of climate and biodiversity impacts from intergovernmental targets is driven by growing extraction and processing. Material extraction grew for the last five decades at an annual rate of 2.3 percent (UNEP, 2024), but material productivity[4] has hardly improved, unlike the other factors of production (Figure 4). Unlike emissions, these trends are only expected to speed up. The UN International Resource Panel forecasts resource use to increase by up to 60 percent by 2060 relative to 2020 levels if no significant action is taken (UNEP, 2024).

4 Material productivity is the ratio of GDP to total material requirement (TMR). The European Environment Agency defines TMR as the total mass of primary materials extracted from nature to support human activities.

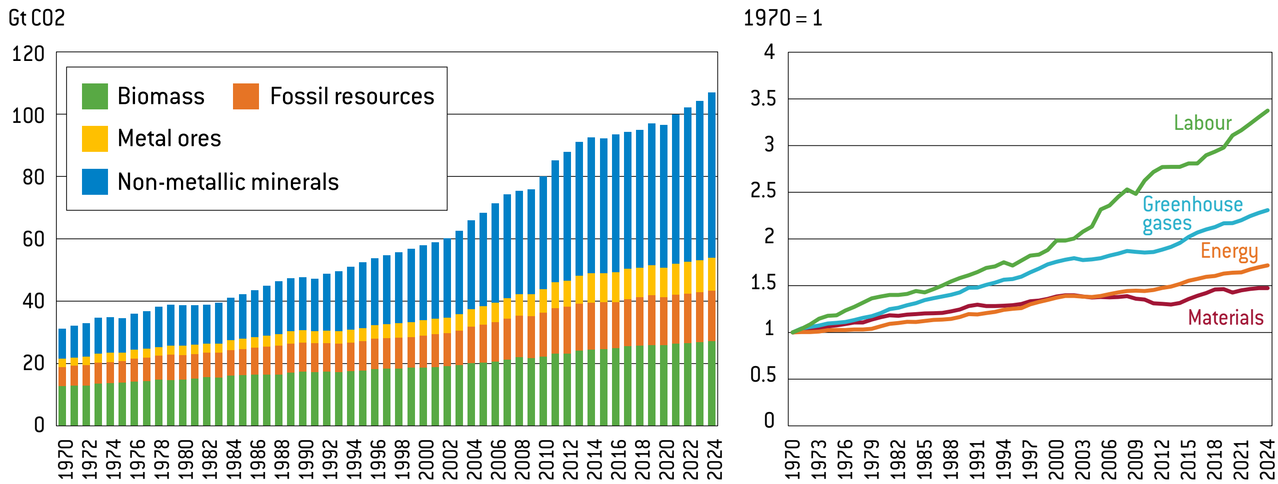
Figure 3: Global contribution of materials vs remaining economy and households to CO2 emissions and land-related biodiversity loss, 1995 – 2022



Source: Bruegel adapted from UNEP (2024), Figure 3.5. Notes: See Annex 2 for definitions and explanations of the targets.

Figure 4 shows limited improvement in material productivity since 1970, relative to improving productivity of energy, greenhouse gases and labour. Globalisation has contributed to this lag in the material productivity trend through the outsourcing of production to regions with lower material efficiency (UNEP, 2024). The energy crises of the 1970s and 2020s led to drives for energy efficiency, but there has been no systemic drive for similar increases in materials efficiency. This is despite relatively high material input costs in sectors such as manufacturing, which can be more than twice the labour and energy costs (VDI, 2016).

Figure 4: Global material extraction 1970 – 2024, and productivity of materials, greenhouse gases, energy and labour, 1970 – 2024



Source: UNEP (2024), Figures 2.9 and 2.23.

Demand for some materials is rising as a result of the decarbonisation of energy, transportation and other systems. The transition to renewable energy and electric vehicles presents a paradox: it is essential to reduce emissions and improve the outlook for climate change, but it is driving more extraction of certain critical raw materials in the short term, with uncertain but potentially profound environmental impacts (see, for example, Riofrancos *et al*, 2023; Watari *et al*, 2021; Sonter *et al*, 2020). Once decarbonisation has been largely achieved, it will reduce resource extraction because a functioning renewable energy system needs hardly any more materials, whereas a fossil-fuel system requires ongoing extraction of highly polluting hydrocarbons (ETC, 2023). Furthermore, once there are enough electric vehicles and other clean technologies in circulation, with an efficient re-use and recycling system, the secondary markets for materials will reduce demand for new extraction of critical raw materials (Karali and Shah, 2022).

2.2 The EU's high consumption of resources

The European continent's per-capita resource use is more than three times that of Africa

Europeans are responsible for a disproportionately large share of material extraction. The European continent's *per-capita* resource use is more than three times higher than that of Africa, for example (UNEP, 2024). The EU comprises 6 percent of the world's population, but its consumption accounts for between 70 percent and 97 percent of the 'safe operating space' across multiple planetary boundaries available for the entire planet (Sala *et al*, 2019; Nega-Watt *et al*, 2024).

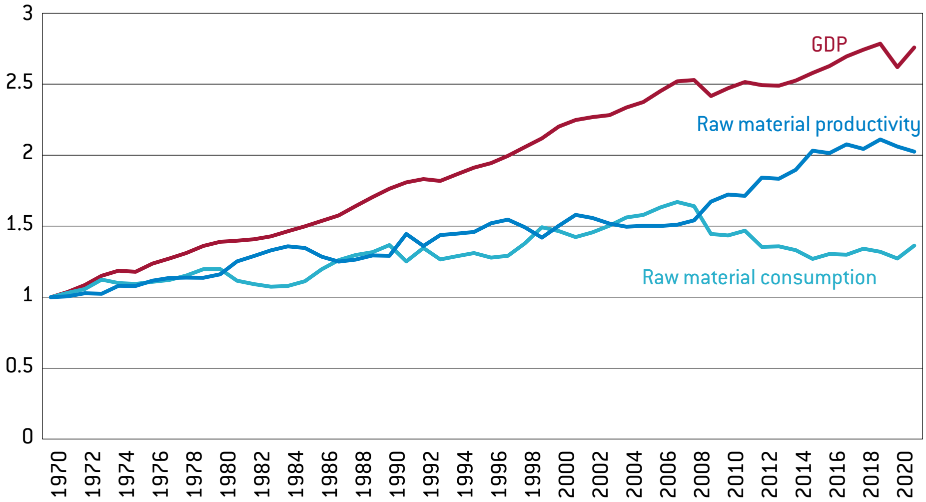
In 2021, EU domestic extraction of raw material amounted to 5.6 gigatonnes[5], the largest categories being non-metallic minerals (60.6 percent) and biomass (27.9 percent)[6]. Outside Europe, new material extraction generated by the EU's demand for imported goods was 3.1 gigatonnes in 2021[7]. The largest categories were fossil energy materials/carriers (46.3 percent) and metal ores (29.7 percent).

The EU's material use – the weight of products consumed in the EU – comprised just under 5 gigatonnes in 2022. Approximately 35 percent this, or 1.76 gigatonnes, became waste. The remaining 65 percent accumulated as stock, for example in buildings and machinery (EEA, 2024).

However, Figure 5 indicates a positive exception to the global trends of increasing resource use, as shown in Figure 4, and that the EU's circular economy policy might be having a tangible impact on resource efficiency. Although the EU's material consumption remains disproportionately high, it has improved in the last 15 years (Figure 5). In the 14 current EU countries that were already members before 2004 (EU14)[8], raw materials consumption[9] grew after 1970, albeit at a slower rate than GDP. Since 2007, however, there has been an absolute decoupling in those countries of resource use from GDP growth, and a resulting boost in raw material productivity. In 2021, the material footprint of the EU was the same as in 1998, and 18 percent lower than in 2007, despite a 9 percent increase in GDP over the same period. This absolute decoupling – as opposed to a relative decoupling – is significant even though overall material volumes remain high.

5 Billion tonnes or trillion kilogrammes.
6 Bruegel calculations based on Eurostat.
7 Models to calculate the raw material equivalent of traded goods are still under development and have high degrees of uncertainty (Eurostat, 2018), but these are the best available estimates for understanding the true global impact of the EU's material use.
8 We use the EU14 since data is available starting from 1970. However, we observe the same absolute decoupling in recent years when using data for the whole EU.
9 The material footprint, or raw materials consumption comprises domestic extraction plus total imports in raw material equivalent minus total exports in raw material equivalents. It therefore fully accounts for extraction in other countries for EU consumption.

Figure 5: Raw material productivity, raw material consumption and GDP, EU14, 1970 – 2021 (1970 = 1)



Source: Bruegel based on Global Material Flows Database. Note: EU14 = Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain and Sweden.

2.3 Defining the circular economy

The circular economy is an assembly of many different ideas and initiatives (Kovacic *et al*, 2020), but in essence it "*revolves around maintaining high product and material value while extending their lifespan within the economy and eliminating unnecessary material usage*" (Letta, 2024). More broadly, it is an alternative economic paradigm to the current mainly linear economy (ie extract-use-throw away), comprising a system that meets human needs[10] – including food, mobility, shelter and health – in the most resource-efficient way possible (Potočnik and Nohl, 2023).

In practice, the circular economy involves actions such as designing products or processes for least resource use, optimisation of material use (through circular business models such as providing goods as a service; Systemiq, 2021), recycling and turning used resources into new products (Kovacic *et al*, 2020; Bocken *et al*, 2016; Geissdoerfer *et al*, 2018; Allwood, 2014). Frameworks such as the '9 Rs'[11] or 'narrow-slow-close' (ie use less material, use it for longer and then reuse it) encapsulate the ethos of the circular economy.

The potential environmental benefits of a circular economy are great. For example, circular approaches in seven important sectors – including steel, construction, plastics and vehicles – could reduce annual EU industrial emissions by 34 percent by 2050 relative to 2018, with reductions in greenhouse-gas emissions within the next one to five years (Agora Industry, 2022). Material efficiency through redesigned industrial processes and products, substitution of materials and enhanced recycling are examples of the circular measures that can contribute to emissions reduction.

Circular economy interventions could also help halt biodiversity loss in the EU and even help it to recover to 2000 levels by 2035 (Forslund *et al*, 2022). Agriculture, forestry and other land use change (such as the draining of wetlands) are the principal drivers of biodiversity loss globally (UNEP, 2024). Circular measures that would support the recovery of biodiversity include reducing input requirements for livestock farming, extending the lifetimes of buildings and other products that use timber, land use techniques in forestry and agriculture such as regenerative agriculture, and recycling of textiles (Forslund *et al*, 2022).

10 Referred to as "*provisioning systems*" in UNEP (2024), these include food, built environment, energy, public mobility, household fuel use, private mobility, clothing, education, water, sewage and health.

11 9Rs = refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, recover.

2.4 The EU's progress towards circularity so far

The EU has fostered circularity for more than a decade through regulation. Two Circular Economy Action Plans (CEAP) in 2015 and 2020 have broadened the scope of EU policy from a focus on waste to a wider vision for circularity, introducing ecodesign and shifting towards legally binding measures (Watkins and Meysner, 2022). Key measures include the Batteries Regulation (Regulation (EU) 2023/1542), the Right to Repair initiative, the directive on empowering consumers for the green transition (Directive (EU) 2024/825) and the Ecodesign for Sustainable Products Regulation (ESPR, Regulation (EU) 2024/1781). A new European Packaging and Packaging Waste Regulation, to update rules from the mid-1990s, is also pending adoption, at time of writing. The 2020 CEAP also contained several ambitious targets including on decoupling economic growth from resource use, doubling the circular material use rate and halving the amount of non-recycled municipal waste by 2030 – although these are non-binding.

The most recent legislation aims to increase resource efficiency across the whole life-cycle of products. For example, the Batteries Regulation contains mandatory recycled content requirements for lithium, which could spur the creation of new markets for an element that is not widely recycled at present. The ESPR first working plan will ensure minimum ecodesign requirements in several high-impact intermediate and end-use products, including iron products, chemicals, furniture and textiles. These requirements could include resource efficiency, durability, level of recycled content and repairability[12].

To succeed, these measures will require many implementing regulations in the coming years to invigorate the so-far modest national application of circular principles.

Although all EU countries have national circular economy roadmaps or strategies, or are currently developing one, most of these remain generic (EEA, 2024). The European Court of Auditors found in 2023 that Commission action since 2015 has led to little progress in influencing circular activities beyond these generic strategies, that waste management has remained the focus of funding and that reaching 2030 targets looked unlikely given current progress (ECA, 2023). However, hopeful signs of progress towards resource efficiency at national level include targets for absolute decoupling of material use from growth set by three EU countries (Austria, Finland and the Netherlands), and the start of a decline in raw material use in the EU (Figure 5). The economic case for action by governments, municipalities and firms needs to be understood better to motivate Europeans to act faster to decouple resource use from growth.

3 The economic case for greater resource efficiency

Greater resource efficiency would make a significant contribution to the EU's major policy goals, most notably economic security and strategic autonomy, competitiveness and financial-system stability. This section discusses how resource efficiency through circular economy principles can support priorities at the top of the EU's agenda.

3.1 Economic security and strategic autonomy

Raising resource efficiency would be the fastest way to de-risk the European economy. It would reduce dependence on authoritarian regimes and fragile supply chains, and make the EU less vulnerable to volatile commodity prices (Letta, 2024; WEF, 2024). Circular solutions will become more important as energy infrastructure dependencies shift from imports of fos-

12 See Article 5, Regulation (EU) 2024/1781, for the full list of ecodesign requirements.

sil fuels (commodities) to the import of critical raw materials (CRMs; to create capital assets in renewable energy). This does not mean that the EU should aim to move to autarky and become a self-sufficient economy or introduce protectionist policies. Rather, the elimination of wasteful use of materials and energy has the potential to support the economic-security objectives of reducing import dependencies for critical products and deepening the single market and making it more flexible (Pisani-Ferry *et al*, 2024). A well-functioning circular single market would increase the EU's resilience against import shocks. Critical dependencies can be reduced by bringing down demand for imported virgin materials, by substituting them with local, re-used and recycled materials and by using fewer materials thanks to efficiency-by-design or repair opportunities.

In energy, the recovery of biodegradable waste could contribute significantly to supply diversification. Biogas and biomethane could meet 10 percent of natural gas demand by 2030[13], to which better food-waste collection and processing could contribute. Biogas production emits little carbon and prevents organic material from going to landfill. Given that organic waste accounts for up to 50 percent of municipal waste (ECN, 2022) and 10 percent of all greenhouse gas emissions (WWF, 2021), that would reduce environmental damage while contributing to energy security.

Even in the very short term, resource efficiency can offer a buffer to protect EU economic security

The next decades are likely to be characterised by supply bottlenecks as climate shocks proliferate, economies race to decarbonise and trade rivalries disrupt flows. But even in the very short term, resource efficiency can offer a buffer to protect the EU's economic security. For CRMs, supply deficits are already expected for 2024 (Stewart *et al*, 2023). In the medium term, there are forecasts of potential supply gaps for copper and lithium of up to 10 percent and 49 percent respectively in 2030 (ETC, 2023).

Commodity price volatility is another threat to economic security. Since 2020, the prices of critical minerals used in batteries underwent both dramatic increases and large declines (IEA, 2024). Certain battery-grade lithium compounds increased in price by 800 percent to 1000 percent in just over one year (Riofrancos *et al*, 2023). This volatility is likely to increase because of climate impacts, with 25 percent of mining executives expecting climate risks to be very significant in their operations in the next five years (KPMG, 2023).

To ensure that decarbonisation is not disrupted, the circular market for CRMs needs to expand faster. Through end-of-life recovery, design for materials efficiency and extended product lifetimes, more reliable markets for critical minerals can be developed that would improve economic security. According to one estimate, secondary materials could meet up to 91 percent of US demand for CRMs in low-carbon technologies by 2050 (Karali and Shah, 2022). Another example is Apple's calculation that from one metric ton of iPhone components, recyclers can recover the amount of gold and copper typically extracted from 2,000 metric tons of mined rock (Apple, 2024) – but users need incentives to return old devices and those devices need to be designed for easy materials recovery. The EU's Critical Raw Materials Act (CRMA, Regulation (EU) 2024/1252) sets targets for recycling to meet 25 percent of EU annual consumption of strategic raw materials by 2030.

The value embedded in disused electronic devices globally is around $57 billion[14]. The EU has room to increase from its current 39 percent recycling rate for waste electrical and electronic equipment (WEEE) (EEA, 2024). The contribution of recycled minerals to fresh inputs that are crucial for electronics is also very low: cobalt (22 percent), nickel (16 percent), neodymium (1 percent) and lithium (0 percent)[15], even though significant supply gaps are forecast for these transition materials (ETC, 2023). This is partly driven by low rates of recovery

13 See European Biogas Association news of 17 February 2022, 'A way out of the EU gas price crisis with biomethane', https://www.europeanbiogas.eu/a-way-out-of-the-eu-gas-price-crisis-with-biomethane/.

14 Kimberley Botwright and James Pennington, 'Will your next phone be made from recycled materials? These 6 tech giants are working on it', World Economic Forum, 24 September 2020, https://www.weforum.org/agenda/2020/09/will-your-next-phone-be-made-from-recycled-materials-these-6-tech-giants-are-working-on-it/.

15 See Eurostat, 'Contribution of recycled materials to raw materials demand - end-of-life recycling input rates (EOL-RIR)', dataset code: cei_srm010. Data is for 2022.

due to poor product design for end of life and the lack of well-established infrastructure for recovery of such minerals (Charles *et al*, 2020).

However, although end-of-life treatment is important, the high projected demand for CRMs suggests that recycling alone cannot meet all the EU's needs. One estimate suggests that globally, recycling may only start to play a substantial role in reducing virgin material extraction after 2040, once enough recyclable materials are in use (Peplow, 2023). To achieve economic security, end-of-life treatment must be pursued in conjunction with other measures to reduce the volume of CRMs needed further up the production chain.

Beyond CRMs, design of products so that they use less raw materials, and resource efficiency through repair and durability have great potential to contribute to economic security. Many household appliances are treated as obsolete far before their designed lifetimes are over, partly driven by a culture of constant upgrading to the latest model (EEA, 2024). Design also has a role to play in developing clean circular loops. This ensures that products are designed to minimise the use of substances of concern and other pollutants, to facilitate end-of-life recovery.

By reducing biodiversity loss, circularity would diminish bio-risks to health, such as epidemics

Circularity would contribute to other aspects of security. By reducing biodiversity loss, it would also diminish bio-risks to health, such as epidemics, and environmental disasters due to extraction, such as landslips. It would also reduce the drivers of armed conflict, as shown in the Environmental Justice Atlas[16], which maps how the extraction of resources and resource management drive conflict. These conflicts will proliferate with the increase in extraction for decarbonisation, given that 32 percent to 40 percent of this extraction is expected to occur in countries with weak to failing resource governance (Watari *et al*, 2021).

Resource efficiency would be a major contribution to security at an existential level – not only economic security but nature's support of life and every kind of human activity. Recent European debates have been dominated by external threats – from Russia and China to COVID-19 – but the environmental threats to security have not gone away and tipping-points are looming (Lenton *et al*, 2019).

3.2 Competitiveness

A circular single market (the term used in Letta, 2024) could boost European competitiveness in several ways. First, it would help eliminate inefficiencies in resource use in production and consumption that prevail under the linear economy, because of market and government failures such as cheap resources with prices that do not include environmental impacts, or lack of information about resource-efficient production methods (section 4). By increasing efficiency in how goods are produced and in how long they are used, the EU can achieve greater productivity that will enhance its competitiveness over the long term. At firm level, greater resource efficiency means lower input material costs. This allows firms to set lower prices and to invest in R&D or increase wages, all of which enhance competitiveness (Flachenecker and Kornejew, 2019).

A second issue is opportunity cost. Europe will further lose competitiveness if it misses out on the growth of new, green sectors – not only clean tech but also the major opportunities for Europe to develop competitive products and services around the circular economy (EEA, 2024). Material productivity improvements have been shown to generate spillover innovations, contributing positively to firms' successes (Rennings and Rammer, 2009). In a study of 52,000 firms in 12 EU countries, Flachenecker and Kornejew (2019) found that firms that developed eco-innovations to improve material productivity increased their market shares while reducing their CO2 footprints.

At macro level, a functioning circular economy needs well-functioning markets for secondary raw materials characterised by consistent price signals and standardised product-quality specifications (EEA, 2024). The Circular Economy Act proposed in the political guidelines for the 2024-2029 European Commission could foster world-leading waste and secondary materials markets, attracting global investments and expertise (von der Leyen, 2024).

For example, the European remanufacturing market's circular potential is projected to grow from its current value of €31 billion to €100 billion by 2030, creating half a million new jobs (World

16 See 'EJAtlas - Global Atlas of Environmental Justice', https://ejatlas.org/.

Bank, 2022). In Finland, the circular potential for textile fibres could yield €1.2 billion in investments and generate 17,000 new jobs[17]. In the agricultural sector, initiatives such as the Dutch 2018 circular agricultural plan, which includes practices such as local production, reusing waste flows and identifying symbiosis between the supply chains of arable, livestock and horticulture sectors, are likely to be in high demand globally as competition for land and biomass increases (King *et al*, 2023; Muscat *et al*, 2020).

The EU's circularity standards are likely to spread as other countries aim to go circular as well

Third, the EU's circularity standards are likely to spread as other countries aim to go circular as well. Europe is poor in resources but rich in human capital, and world-class in making regulations that create and lead markets (Bradford, 2020). Many governments around the world struggle with the problems of increasing volumes of waste (Kaza *et al*, 2018) and are creating circular economy plans[18]. As environmental regulation increases internationally, European companies – in the context of the EU setting global norms for ecodesign, repairability, durability and recyclability through its circular economy strategy – will be able to comply with this regulation more cost-effectively than other firms (Gunningham *et al*, 2004). European firms might also have a comparative advantage in developing the most energy- and resource-efficient products and services.

Fourth, European firms are more vulnerable to volatility in global markets for many materials than are Chinese producers which have long-standing vertical integration of their supply chains with extraction and processing. Through resource efficiency, European firms would reduce their exposures to material price fluctuations and insure themselves against supply shocks (Flachenecker and Kornejew, 2019). Furthermore, in the future, the cost of many raw materials may rise because climate change will make both land and water scarcer (IPCC, 2022), raising the costs of extraction and processing (which are often very water-intensive). This will be in addition to more governments starting to price pollution and emissions. Although regulation to increase circularity might increase costs in the short and medium terms, this is likely to be out-weighed by the longer-term benefits if it gives European companies an incentive to invest in resource efficiency. An analogy would be European standards on fuel efficiency (see Oki, 2021), which led to the creation of cars that were more competitive when oil prices went up.

3.3 Financial stability

Resource inefficiency causes excessive extraction of materials that degrades the natural assets that provide ecosystem services[19]. This poses systemic risks to the financial sector. The European Central Bank is among the financial institutions now calculating the exposure of financial institutions to ecosystem services. It has found that 75 percent of all corporate loan exposures in the euro area have a strong dependency on at least one ecosystem service (Boldrini *et al*, 2023). The ECB is also starting to measure the contribution of the financial sector to the degradation of natural assets, having calculated that corporate loans in the euro area have driven biodiversity loss globally equivalent to the loss of 582 million hectares of pristine natural areas (Ceglar *et al*, 2023).

The Dutch and French national banks have calculated exposure to biodiversity risks for their own financial institutions of €510 billion and 42 percent of the value of securities portfolios held respectively (van Toor *et al.*, 2020; Svartzman *et al.*, 2021). In the private sector, credit ratings agencies and insurers are developing their own methodologies for risk assessment around the costs of environmental degradation.

In addition to evaluating risk, valuation of natural assets is a powerful tool for fostering the circular economy. It puts a price on the degrading of ecosystem services, which reduces systemic risk to the financial sector and encourages value creation through means other than cultivation

17 Ali Harlin, 'The Finnish textile industry will be the most responsible and functional in the world in 2035 – investment opportunities of more than billion euros', VTT Technical Research Centre of Finland, 27 August 2021, https://www.vttresearch.com/en/news-and-ideas/finnish-textile-industry-will-be-most-responsible-and-functional-world-2035.

18 In 2022, over 70 countries were applying circular economy policies; see UNDP, 'Circular Economy', Chemicals and Waste Hub, undated, https://www.undp.org/chemicals-waste/our-work/circular-economy.

19 The benefits that nature provides to sustain human wellbeing, such as pollination, food production and water purification.

and extraction. Nature can be a high-value investment; the European Commission estimates that every euro invested in EU nature restoration adds €4 to €38 in benefits (European Commission, 2022). This attention to environmental and climate risks in the financial system is an important step forward in recognising and analysing previously uncalculated risks. However, central banks, financial regulators and credit agencies cannot introduce the policies and laws that would reduce these risks. Only governments and international institutions can lead the system change to a circular economy.

4 How to improve the circular single market: policy recommendations

We have described how resource efficiency can contribute to environmental and strategic goals and assessed the EU's progress towards a circular economy. However, current progress can be characterised as an incremental approach to resource efficiency within the context of a linear economy, rather than a deep transformation through which circular behaviour becomes the norm (European Commission, 2019). To reap the environmental and economic benefits, this transition needs to go much faster.

The linear economy exists because producers, consumers and waste managers have optimised systems and behaviour to match the prevailing linear incentive structure (European Commission, 2019). An extensive literature documents the market and governance failures and barriers to a fully-fledged circular economy, creating a nexus of disincentives to making resource-efficient choices. Some of these barriers prevent companies and consumers from taking what would otherwise be financially positive resource efficiency actions (Table 1, part a). Others are systemic economic barriers (Table 1, part b).

Table 1: Barriers to resource efficiency

(a) Barriers that inhibit pursuit of financially positive resource efficiency actions	
Information constraints	Consumers may not make rational economic and resource-efficient choices if they have incomplete information on efficiency, for example of energy-consuming appliances.
Financial barriers	Uncertain payoffs, competing conventional investment opportunities and inadequate credit markets may inhibit resource-efficient investment even if it would be financially positive.
Path dependency	Pre-existing habits, relationships, knowledge and therefore technical and managerial capacity may inhibit the identification of opportunities to increase resource efficiency.
Fiscal mismanagement	Subsidies or tax incentives for polluting inputs (for example fossil fuels), enforcement gaps or incoherent policy (for example landfill taxes) may create disincentives.
(b) Other barriers	
Absent or incomplete pricing of externalities	The negative impacts of emissions, biodiversity loss and resource depletion may carry no price or a low price, making virgin materials artificially cheap, so private actors do not have a strong financial interest to use resources efficiently.
Split incentives	Individual actors may lack an incentive to use resources efficiently, even if it is in the social interest to do so, if they are not exposed to the costs of waste disposal.
Infrastructure deficits	Actors may not have infrastructure to re-use resources to their maximum potential.
Market structures	Lack of competition, protected industries and trade protectionism discourage innovation, including in resource efficiency.

Source: Bruegel based on Ekins *et al* (2019) and Rentschler *et al* (2018).

Policy is essential to address these barriers and establish effective incentive structures to optimise resource efficiency. The next EU Circular Economy Act needs to ensure effective implementation of the current legislative tools at the right level of government. Some incentives might be more powerful if implemented in a more decentralised way (eg local or municipal level), such as incorporating circularity criteria into public procurement rules.

Our policy recommendations highlight measures that would yield the highest returns if implemented at EU level, presented from most to least ambitious[20].

Price materials according to their environmental cost

In many parts of the world, there is currently little or no financial price put on the negative environmental effects of material extraction and processing. That makes virgin raw materials often cheaper than secondary materials, reducing investments in circular infrastructure and hindering circular business models. Environmental taxation is crucial to create a level playing-field for secondary materials and prevent arbitrage. To achieve this, more work should be done to identify the costs of climate, biodiversity and pollution externalities. Research into resource taxes and their feasibility should be encouraged, since there are few real-world examples and little literature on this (UNEP, 2024).

Producers must internalise the costs of disposal in purchase prices

The burden of landfill and incineration taxes and 'pay-as-you-throw' systems usually falls directly or indirectly on the consumer and taxpayer. If more responsibility for materials throughout their lifecycles falls on producers, they might redesign products radically for easy recycling or remanufacturing, or develop different business models such as product-as-a-service. Extended Producer Responsibility[21] (EPR) should be strengthened and extended to other sectors with high impact, such as construction, where EPR schemes are not common.

Assess tax incentives throughout the economy

Environmental taxes are a major economic instrument to promote circularity, but are often countered by tax incentives in other sectors of the economy. Progress is needed to tackle the negative incentives created by fossil-fuel subsidies, which total €55 billion to €58 billion per year in the EU, and to shift more of the current high tax burden on labour, which in 2019 constituted 52 percent of EU tax revenues, onto pollution and resources, which constituted only 0.19 percent of tax revenues (World Bank, 2022).

Design whole systems for efficiency, not only individual products

In addition to designing individual products and services for efficiency, systems should be designed to meet human needs in the most resource-efficient ways. For example, Riofrancos *et al* (2023) found that continuation of the current US transport system with like-for-like replacement of current vehicles with electric vehicles, up to 2050, would create demand for three times more lithium than is currently available on the global market. However, this demand could be vastly reduced if the US were to encourage smaller car batteries, lighter vehicles and expansion of public transport.

Implement and harmonise regulatory measures

Effective implementation of sustainable product standards, requirements for recycled content and end-of-waste criteria are crucial for developing stable circular markets. They will foster steady streams of circular materials, while providing price signals and reliable, standardised information that will generate business confidence and economies of scale.

Implementation also has to be coherent in order to counter perverse incentive structures.

20 Mario Draghi's report crystallises ways of achieving some of these recommendations in the short and medium term (see Draghi, 2024).

21 Legislation which makes producers responsible for their products throughout the whole life-cycle.

For example, the EU's Waste Shipment Regulation (Regulation (EU) 2024/1157) makes it difficult for waste to cross borders in the EU, resulting in about 90 percent of waste being treated in the country where it was generated (EEA, 2021). However, recycling facilities need greater economies of scale to generate enough recovery of many materials to be profitable.

Incentivise investment

For the circular single market to achieve its potential in terms of boosting EU competitiveness, the 2024-2029 European Commission needs to build out the institutional and policy infrastructure to address the demand side, while framing it intelligently under the headings of the main strategic goals. This strategy will need to include materials efficiency, not only energy. Such an incentive structure would support the substantial investments that are necessary. Currently, projections of the economic benefits of the circular economy do not bring an equivalent scale of investment. For example, in plastics recycling alone, the European Investment Bank has estimated an investment gap of €6.7 billion to €8.6 billion to achieve EU targets (EIB, 2023). Policy needs to incentivise both public and private investment in the circular economy, which will be essential to the transformation from an inherently inefficient linear economic model (Letta, 2024).

Correct information asymmetries in the private sector

Firms are reluctant to share commercially sensitive information that might increase welfare but could reduce their competitiveness

Firms are reluctant to share commercially sensitive information that might increase welfare but could reduce their competitiveness. The EU could provide missing institutions, such as a neutral inter-firm mediator, to enable confidential or anonymised information exchanges to take place, allowing firms to identify resource synergies with firms in other sectors. One example is facilitated industrial symbiosis, which was successful in the United Kingdom in overcoming data and trust problems to allow firms to trade used materials to mutual benefit[22]. Such practices can lead to huge resource and financial savings, as demonstrated in the EU by the Kalundbourg eco-industrial park in Denmark[23]. For critical and valuable materials, firms will need communication and data-sharing along the value chain to avoid pollutants and preserve the recycling potential of materials.

Circular economy review

Although the Commission regularly monitors, reports and reviews the impact of circular economy legislation, the incremental approach to resource efficiency makes it unlikely the EU's 2030 targets on resource use will be met. This is exacerbated by a legislative framework that is dispersed across different parts of the European Commission. The Commission should launch a comprehensive review which assesses the whole European strategy on resources, similar to the 2001 'Strategy for a future chemicals policy' (European Commission, 2001) which led to the REACH chemicals regulation of 2006 (registration, evaluation, authorisation and restriction of chemicals, Regulation (EC) No 1907/2006). The 2001 review increased momentum around a complex issue, resulting in a paradigm-shifting approach to chemicals legislation in the EU (Engström, 2020). A review of resource use could be a powerful catalyst for bolder action that, like the chemicals review, could transform the EU's relationship with resources.

Leverage financing at EU level to enhance circularity

Lenders lack understanding of circular investments and of evaluating the benefits of circular models compared to linear models, the risks of which are also underestimated. An enhanced

22 See UK Parliament, 'Written evidence submitted by International Synergies Ltd', 1 September 2015, https://committees.parliament.uk/writtenevidence/57938/pdf/.

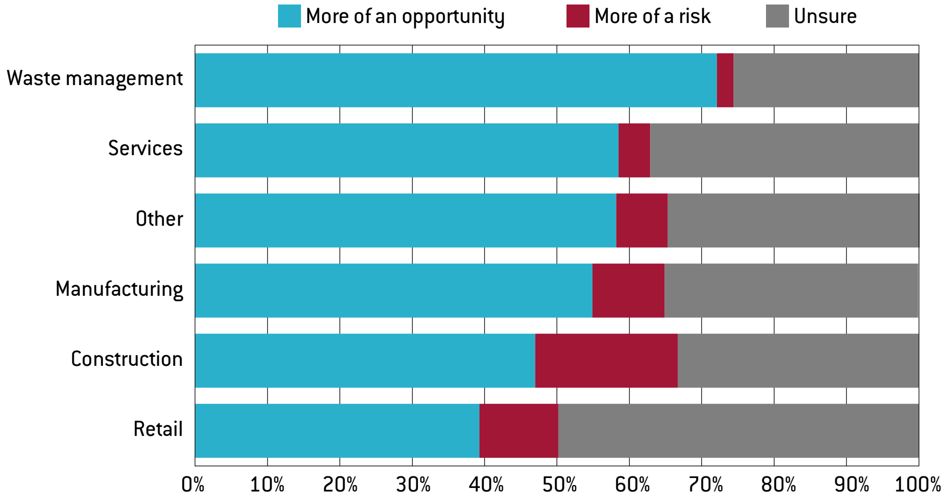
23 Ministry of Foreign Affairs of Denmark, 'Half a Century of Industrial Symbiosis', *Insight*, 24 October 2022, https://investindk.com/insights/half-a-century-of-industrial-symbiosis-denmark-offers-a-platform-for-success-in-biosolutions.

circular economy taxonomy would allow for investment and other financial tools, such as green bonds, to support circular businesses (EEA, 2024).

Make the business case for circularity

Support from European businesses may be greater than among politicians at present. For example, the German Chamber of Commerce showed that companies in most sectors see circularity as an opportunity rather than a risk (DIHK, 2024; Figure 6).

Figure 6: Corporate attitudes to the circular economy, Germany, 2024



Source: DIHK (2024). Note: The figure shows responses to the question: *Is the development towards a circular economy more of an opportunity or a risk for your company's current business model?*

Improve metrics

All of the policy recommendations we have listed require improved and standardised metrics – both estimates of the value of a circular economy in macro variables, such as growth and employment, and the measurement of risk, reward and externalities for calibrating and implementing the right incentives to spur the transition to a circular economy (Box 1).

Box 1: Circularity metrics

Although research demonstrates that greater resource efficiency can lead to higher economic growth, employment and improvements in other macroeconomic variables, there remains considerable variation in the size of these estimates and their underpinning assumptions. Modelling of circular-economy practices is at an early stage and needs development and standardisation to create robust metrics for use in policy.

One priority to make the case for a circular economy is job creation estimates. The ILO estimates that the circular economy could create a net total of 7 million to 8 million jobs globally by 2030 (ILO, 2019). In the EU, one estimate forecasts a net increase of 700,000 jobs by 2030 if circular economy policies are pursued (Cambridge Econometrics, ICF and Trinomics, 2018).

In the EU, current metrics mostly provide a macro-view of the circular economy, providing information on outcome variables such as waste collection and consumption of materials (World Bank, 2022). According to the World Bank, greater granularity on materials throughout value chains is needed, as is tracking of impacts of circular policies. Such data would be much more useful for application by business and policymakers.

A further area for development of metrics is avoided costs and disasters. The costs of environmental policies are widely discussed and calculated in terms of trade and competitiveness, but the costs of pollution and waste are not subject to the same denominators and are often not included in cost-benefit calculations. There is still no widespread understanding of either the near-term or longer horizon risks posed by losing the services that nature provides for free, such as pollination and carbon sequestration. Few metrics are available for valuing those services in monetary terms. Only rarely do calculations of the effect of lessening the pressure on nature appear in economic thinking, for example by using concepts such as sufficiency or *sobriété*, which would reduce the rate of extraction from nature thanks to demand reduction and/or greater resource efficiency.

These accounting challenges have long caused environmental objectives to lose out in the competition for investment, even relative to other aspects of the green transition. For example, risk assessments suggest that biodiversity collapse is a nearer-term threat than sea-level rise, but the potential costs, such as the economic impact of key pollinators becoming extinct, are little discussed in policy debates. The efficiency and value of circular solutions can only be properly understood once such metrics are standardised and implemented.

5 Resource efficiency and the EU's global green role

A more circular economy in Europe will have an impact on major EU trade partners, requiring attention to achieve a just transition. More EU circularity would to some extent correct the historical imbalance of European resource consumption relative to the rest of the world, but the EU will need to support trade partners that rely on European markets during the transition to circularity.

The predominant linear take-make-waste economic model causes over-extraction from nature in Europe and even more in other regions of the world that still have greater biodiversity (UNEP, 2024). If the EU reduced its imports of goods with high levels of embedded fresh water and pollution (not only emissions), that would reduce stresses on nature and societies on other continents. A drop in raw material imports would lessen the conflict drivers in resource-rich regions. For example, UNEP (2009) estimated that at least 40 percent of all intrastate conflicts have a link to the exploitation of natural resources.

Most estimates of Europe's environmental footprint do not take account of the environmental impact in other regions of the huge amounts of goods that the EU imports. The demand side of the green transition now needs attention, but progress will be harder politically than on the supply side. To ensure that environmental outcomes are met, the EU will need to integrate circularity more systematically into its external policies. This must also take into account energy security and independence, resilience in the face of climate-related disasters, and the value of ecosystem services. It should start with the EU's southern neighbourhood and enlargement countries.

The impact on other regions of Europe moving to a circular economy will be significant and have adjustment costs that need to be factored into EU external policies (see Grabbe *et al*, 2022; Repp *et al*, 2021). Countries with large numbers of people employed in industries producing goods for European markets will need help to develop other economic opportunities. An example is the garment industry in Bangladesh, which employs for 4 million people, with 56 percent of output destined for European markets (Berg *et al*, 2021; Razzaque and Rahman, 2019). The shift to a circular economy in textiles may result in up to 756,000 job losses in low- to upper middle-income countries, while EU employment would grow by up to 91,000 (Repp *et al*, 2021).

Exportable European expertise on circular solutions would also benefit development by reducing the cost of, and the environmental damage caused by, waste in developing countries. Urban waste management is expensive, often the single highest budget item for local administrations in low-income countries, where it comprises nearly 20 percent of municipal budgets, on average, and where the total quantity of waste generated is expected to increase more than three times by 2050 (Kaza *et al*, 2018). In addition to the budget savings, recovery of value from waste would bring greater efficiency and new resources to low-income countries.

6 Conclusion

Despite the enormous risks building up from over-extraction from nature – in terms of climate change, biodiversity and human health – the physical reality that Europeans will face in the longer term is quickly forgotten in EU and national debates about priorities and resources for the next one to five years. Moreover, the voices of those who benefit from the current economic system are loud – industries, farmers, coalminers – whereas the people and companies who will benefit from a green economy in the future cannot speak up because they are often unaware of these future benefits (or they are not yet born).

Circularity principles are an effective way to reduce inefficient resource use and its impact on climate change, biodiversity loss and pollution. But a circular single market would also contribute to the EU's strategic priorities in the short and medium terms.

The legislative framework set up at EU level has so far achieved modest results, and the opportunity to optimise it is substantial. For resource efficiency to become the norm would require policies that foster pricing of materials to account for their environmental costs, the filling of information gaps, implementation of the EU's regulatory framework and spurring of investment in resource-efficient business practices.

Circularity would support EU competitiveness by helping leading European companies in this field to deploy their expertise and services. Metrics to make this case are still lacking, and the impact of resource use on the EU's global role still needs to be integrated into its external policies.

The case for a structural change that favours circular economy principles needs to focus on how it links to the EU's major policy objectives, because that is where the power, money and political attention will be. Any environmental policy that is treated as a 'nice to have' will be quickly elbowed aside by other, more immediate priorities. To put the circular economy at the core of EU policies aiming at economic security, competitiveness and financial stability is a way to overcome the tragedy of the horizon.

References

Agora Industry (2022) *Mobilising the circular economy for energy intensive materials*, available at https://www.agora-industry.org/publications/mobilising-the-circular-economy-for-energy-intensive-materials-study

Allwood, J. M. (2014) 'Squaring the Circular Economy,' in E. Worrell and M.A. Reuter (eds) *Handbook of Recycling*, Elsevier, available at https://doi.org/10.1016/B978-0-12-396459-5.00030-1

Apple (2024) *2024 Environmental Progress Report*, available at https://www.apple.com/environment/pdf/Apple_Environmental_Progress_Report_2024.pdf

Berg, A., H. Chhaparia, S. Hedrich and K.-H. Magnus (2021) 'What's next for Bangladesh's garment industry, after a decade of growth?' McKinsey & Company, 25 March, available at https://www.mckinsey.com/industries/retail/our-insights/whats-next-for-bangladeshs-garment-industry-after-a-decade-of-growth

Bocken, N.M.P., I. De Pauw, C. Bakker and B. Van Der Grinten (2016) 'Product design and business model strategies for a circular economy', *Journal of Industrial and Production Engineering*, 33(5): 308–20, available at https://doi.org/10.1080/21681015.2016.1172124

Boldrini, S., A. Ceglar, C. Lelli, L. Parisi and I. Heemskerk (2023) 'Living in a World of Disappearing Nature: Physical Risk and the Implications for Financial Stability', *ECB Occasional Paper* 2023/333*,* European Central Bank, available at https://doi.org/10.2139/ssrn.4630721

Bradford, A. (2020) *The Brussels Effect: How the European Union Rules the World*, Oxford University Press, available at https://doi.org/10.1093/oso/9780190088583.001.0001

Cambridge Econometrics, ICF and Trinomics (2018) *Impacts of Circular Economy Policies on the Labour Market*, report for the European Commission, available at https://trinomics.eu/wp-content/uploads/2018/07/Impacts-of-circular-economy-on-policies-on-the-labour-market.pdf

Carney, M. (2015) 'Breaking the tragedy of the horizon - climate change and financial stability - speech by Mark Carney', Speech given at Lloyd's of London, 29 September, available at https://www.bankofengland.co.uk/speech/2015/breaking-the-tragedy-of-the-horizon-climate-change-and-financial-stability

Ceglar, A., S. Boldrini, C. Lelli, L. Parisi and I. Heemskerk (2023) 'The Impact of the Euro Area Economy and Banks on Biodiversity', *ECB Occasional Paper* 2023/335, European Central Bank, available at https://doi.org/10.2139/ssrn.4651049

Charles, R.G., P. Douglas, M. Dowling, G. Liversage and M.L. Davies (2020) 'Towards Increased Recovery of Critical Raw Materials from WEEE– evaluation of CRMs at a component level and pre-processing methods for interface optimisation with recovery processes', *Resources, Conservation and Recycling* 161:104923*,* available at https://doi.org/10.1016/j.resconrec.2020.104923

Dasgupta, P. (2021) *The Economics of Biodiversity: The Dasgupta Review*, London: HM Treasury, available at https://www.gov.uk/government/publications/final-report-the-economics-of-biodiversity-the-dasgupta-review

DIHK (2024) *Kreislaufwirtschaft als Chance?* Deutsche Industrie- und Handelskammer, available at https://www.dihk.de/resource/blob/117788/4847632a7db7d7cdf922f1dc55e6ac8a/dihk-circular-economy-report-2024-v3-data.pdf

Draghi, M. (2024) 'The future of European competitiveness', available at https://commission.europa.eu/topics/strengthening-european-competitiveness/eu-competitiveness-looking-ahead_en

ECA (2023) 'Circular Economy: Slow transition by member states despite EU action', *Special Report* 17/2023, European Court of Auditors, available at https://www.eca.europa.eu/en/publications?ref=SR-2023-17

ECN (2022) *Compost and Digestate for a Circular Economy*, European Compost Network, available at https://www.compostnetwork.info/policy/biowaste-in-europe/

EEA (2021) 'Linking cross-border shipments of waste in the EU with the circular economy', *Briefing*, European Environment Agency, available at https://www.eea.europa.eu/publications/linking-cross-border-shipments-of

EEA (2024) *Accelerating the Circular Economy in Europe: State and Outlook 2024*, EEA Report 13/2023, European Environment Agency, available at https://www.eea.europa.eu/publications/accelerating-the-circular-economy

EIB (2023) *Cutting plastics pollution: Financial measures for a more circular value chain*, European Investment Bank, available at https://www.eib.org/en/publications/20220248-cutting-plastics-pollution

Ekins, P., T. Domenech, P. Drummond, R. Bleischwitz, N. Hughes and L. Lotti (2019) *The Circular Economy: What, Why, How and Where*, background document for an OECD/European Commission workshop on 'Managing the transition to a circular economy in regions and cities', 5 July, available at https://discovery.ucl.ac.uk/id/eprint/10093965/1/Ekins-2019-Circular-Economy-What-Why-How-Where.pdf

ETC (2023) *Material and Resource Requirements for the Energy Transition*, Energy Transitions Commission, available at https://www.energy-transitions.org/publications/material-and-resource-energy-transition/

Engström, M. (2020) 'Sverige, EU-medlemskapet och kontrollen av farliga kemikalier', *Sieps* 2020:9, Svenska institutet för europapolitiska studier, available at https://www.sieps.se/globalassets/publikationer/2020/sieps-2020_9-web.pdf

European Commission (2001) 'Strategy for a future Chemicals Policy', *COM(2001) 88 final*, available at https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2001:0088:FIN:en:PDF

European Commission (2019) *Accelerating the Transition to the Circular Economy: Improving Access to Finance for Circular Economy Projects*, Publications Office of the European Union, available at https://data.europa.eu/doi/10.2777/983129

European Commission (2022) 'Impact Assessment Accompanying the Proposal for a Regulation of the European Parliament and of the Council on Nature Restoration', COM/2022/304 Final*,* available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022SC0167&%3Bqid=1686750707844

Eurostat (2018) *Economy-Wide Material Flow Accounts Handbook: 2018 Edition*, available at https://data.europa.eu/doi/10.2785/158567

Flachenecker, F. and M. Kornejew (2019) 'The Causal Impact of Material Productivity on Microeconomic Competitiveness and Environmental Performance in the European Union'. *Environmental Economics and Policy Studies* 21(1): 87–122, available at https://doi.org/10.1007/s10018-018-0223-z

Forslund, T., A. Gorst, C. Briggs, D. Azevedo and R. Smale (2022) *Tackling Root Causes: Halting Biodiversity Loss through the Circular Economy*, Sitra studies 205*,* available at https://www.sitra.fi/app/uploads/2022/05/sitra-tackling-root-causes.pdf

Geissdoerfer, M., S.N. Morioka, M.M. De Carvalho and S. Evans (2018) 'Business models and supply chains for the circular economy', *Journal of Cleaner Production* 190: 712–21, available at https://doi.org/10.1016/j.jclepro.2018.04.159

Grabbe, H., J. Potočnik and S. Dixson-Declève (2022) *International System Change Compass: The Global Implications of Achieving the European Green Deal*, Open Society, Systemiq, The Club of Rome, available at https://www.clubofrome.org/wp-content/uploads/2022/05/International-System-Change-Compass-main-report-compressed.pdf

Gunningham, N., R.A. Kagan and D. Thornton (2004) 'Social License and Environmental Protection: Why Businesses Go Beyond Compliance', *Law and Social Enquiry* 29(2): 307–41, available at https://doi.org/10.1111/j.1747-4469.2004.tb00338.x

IEA (2024) *Global Critical Minerals Outlook 2024*, International Energy Agency, available at https://www.iea.org/reports/global-critical-minerals-outlook-2024

ILO (2019) *Skills for a Greener Future: Key Findings*, International Labour Organisation, available at https://www.ilo.org/publications/skills-greener-future-key-findings

IPCC (2022) *Climate Change 2022: Impacts, Adaptation and Vulnerability*, Intergovernmental Panel on Climate Change, available at https://www.ipcc.ch/report/ar6/wg2/

Karali, N. and N. Shah (2022) 'Bolstering supplies of critical raw materials for low-carbon technologies through circular economy strategies', *Energy Research & Social Science* 88: 102534, available at https://doi.org/10.1016/j.erss.2022.102534

Kaza, S., L.C. Yao, P. Bhada-Tata and F. Van Woerden (2018) *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*, World Bank, available at https://doi.org/10.1596/978-1-4648-1329-0

King, R., T. Benton, A. Froggatt, H. Harwatt, D. Quiggin and L. Wellesley (2023) *The Emerging Global Crisis of Land Use*, The Royal Institute of International Affairs, available at: https://doi.org/10.55317/9781784135430

Kovacic, Z., R. Strand and T. Völker (2020) *The Circular Economy in Europe: Critical Perspectives on Policies and Imaginaries*, Routledge, available at https://www.econstor.eu/bitstream/10419/213905/1/978-0-429-06102-8.pdf

KPMG (2023) *2023 Global Mining and Metals Outlook*, available at https://assets.kpmg.com/content/dam/kpmg/xx/pdf/2023/06/2023-global-mining-and-metals-outlook-WEB.pdf

Lenton, T.M., J. Rockström, O. Gaffney, S. Rahmstorf, K. Richardson, W. Steffen and H.J. Schellnhuber (2019) 'Climate tipping points — too risky to bet against', *Nature* 575(7784): 592–95, available at https://doi.org/10.1038/d41586-019-03595-0

Letta, E. (2024) *Much more than a market: Empowering the Single Market to deliver a sustainable future and prosperity for all EU Citizens*, available at https://www.consilium.europa.eu/media/ny3j24sm/much-more-than-a-market-report-by-enrico-letta.pdf

Muscat, A., E.M. De Olde, I.J.M. De Boer, and R. Ripoll-Bosch (2020) 'The Battle for Biomass: A Systematic Review of Food-Feed-Fuel Competition', *Global Food Security* 25: *100330,* available at https://doi.org/10.1016/j.gfs.2019.100330

NegaWatt, CAN Europe, ECOS, European Environmental Bureau, European Youth Forum, Friends of the Earth Europe, Zero Waste Europe and Seas at Risk (2024) *Sustainable Resource Management in the EU*, available at https://eeb.org/library/white-paper-on-sustainable-resource-management-in-the-eu/

Oki, T. (2021) 'European fuel economy policy for new passenger cars: a historical comparative analysis of discourses and change factors', *International Environmental Agreements: Politics, Law and Economics* 21(2): 165–81, available at https://doi.org/10.1007/s10784-020-09510-7

Peplow, M. (2023) 'Lithium-ion battery recycling goes large', *Chemical & Engineering News* 101(38), available at https://cen.acs.org/environment/recycling/Lithium-ion-battery-recycling-goes/101/i38

Pisani-Ferry, J., B. Weder di Mauro and J. Zettelmeyer (2024) *How to de-risk: European economic security in a world of interdependence*, Paris Report 2, CEPR and Bruegel, available at https://cepr.org/publications/books-and-reports/paris-report-2-europes-economic-security

Potocnik, J. and R. Nohl (2023) 'Accelerated Circular Economy and Reduced Resource Use', *Reflection Paper*, Mistra, available at https://mistra.org/wp-content/uploads/2024/02/Mistra_RP_Accelerated_Circular_Economy_korr02.pdf

Razzaque, M.A. and J. Rahman (2019) 'Bangladesh's Apparel Exports to the EU: Adapting to Competitiveness Challenges Following Graduation from Least Developed Country Status', *International Trade Working Paper* 2019/02, Commonwealth Secretariat, available at https://www.researchgate.net/publication/333092701_Bangladesh's_Apparel_Exports_to_the_EU_Adapting_to_Competitiveness_Challenges_Following_Graduation_from_Least_Developed_Country_Status

Rennings, K. and C. Rammer (2009) 'Increasing Energy and Resource Efficiency Through Innovation - An Explorative Analysis Using Innovation Survey Data', *Discussion* No. 09-056, ZEW - Centre for European Economic Research, available at https://doi.org/10.2139/ssrn.1495761

Rentschler, J., R. Bleischwitz and F. Flachenecker (2018) 'On Imperfect Competition and Market Distortions: The Causes of Corporate under-Investment in Energy and Material Efficiency', *International Economics and Economic Policy* 15(1): 159–83, available at https://doi.org/10.1007/s10368-016-0370-2

Repp, L., M. Hekkert and J. Kirchherr (2021) 'Circular economy-induced global employment shifts in apparel value chains: Job reduction in apparel production activities, job growth in reuse and recycling activities', *Resources, Conservation and Recycling* 171: 105621, available at https://doi.org/10.1016/j.resconrec.2021.105621

Richardson, K., W. Steffen, W. Lucht, J. Bendtsen, S.E. Cornell, J.F. Donges … J. Rockström (2023) 'Earth beyond six of nine planetary boundaries', *Science Advances* 9(37), available at https://doi.org/10.1126/sciadv.adh2458

Riofrancos, T., A. Kendall, K.K. Dayemo, M. Haugen, K. McDonald, B. Hassan and M. Slattery (2023) *Achieving Zero Emissions with More Mobility and Less Mining*, UC Davis, available at https://www.climateandcommunity.org/more-mobility-less-mining

Sala, S., L. Benini, A. Beylot, V. Castellani, A. Cerutti, S. Corrado … E. Crenna (2019) *Consumption and Consumer Footprint: Methodology and Results: Indicators and Assessment of the Environmental Impact of European Consumption*, Publications Office of the European Union, available at https://data.europa.eu/doi/10.2760/98570

Sonter, L.J., M.C. Dade, J.E.M. Watson and R.K. Valenta (2020) 'Renewable energy production will exacerbate mining threats to biodiversity', *Nature Communications* 11(1), available at https://doi.org/10.1038/s41467-020-17928-5

Stewart, D., G. Crossan, A. Bucaille and C. Simons (2023) 'A raw deal: Will materials shortages, supply chain challenges threaten tech's future?', *Deloitte,* available at https://www2.deloitte.com/us/en/insights/industry/technology/technology-media-and-telecom-predictions/2024/e-waste-recycling-could-help-raw-material-shortage-for-tech-industry.html

Svartzman, R., E. Espagne, J. Gauthey, P. Hadji-Lazaro, M. Salin, T. Allen, J. Berger, J. Calas, A. Godin and A. Vallier (2021) 'A "Silent Spring" for the Financial System? Exploring Biodiversity-Related Financial Risks in France', *Working Paper 826*, Banque de France, available at https://publications.banque-france.fr/en/silent-spring-financial-system-exploring-biodiversity-related-financial-risks-france

Systemiq (2021) *Everything as a service Xaas: How businesses can thrive in the age of climate change and digitalization*, available at https://www.systemiq.earth/xaas/

UNEP (2009) *From Conflict to Peacebuilding: The Role of Natural Resources and the Environment*, United Nations Environment Programme, available at https://www.iisd.org/publications/conflict-peacebuilding-role-natural-resources-and-environment

UNEP (2024) *Global Resources Outlook 2024*, United Nations Environment Programme, available at https://www.unep.org/resources/Global-Resource-Outlook-2024

van Toor, J., D. Piljic, G. Schellekens, M. van Oorschot and M. Kok (2020) *Indebted to Nature Exploring Biodiversity Risks for the Dutch Financial Sector*, De Nederlandsche Bank, available at https://www.dnb.nl/media/4c3fqawd/indebted-to-nature.pdf

VDI (2016) 'Competitive Advantage: Resource Efficiency', VDI Zentrum Ressourceneffizienz GmbH, available at https://www.ressource-deutschland.de/fileadmin/user_upload/1_Themen/h_Publikationen/VDI-ZRE-competitive-advantage-resource-efficiency.pdf

von der Leyen, U. (2024) *Europe's Choice: Political Guidelines for the next European Commission 2024 - 2029*', available at https://commission.europa.eu/document/download/e6cd4328-673c-4e7a-8683-f63ffb2cf648_en?filename=Political%20Guidelines%202024-2029_EN.pdf

Watari, T., K. Nansai, K. Nakajima and D. Giurco (2021) 'Sustainable energy transitions require enhanced resource governance', *Journal of Cleaner Production* 312: 127698, available at https://doi.org/10.1016/j.jclepro.2021.127698

Watkins, E. and A. Meysner (2022) *European Circular Economy policy landscape overview*, Institute for European Environmental Policy, available at https://ieep.eu/wp-content/uploads/2022/11/European-Circular-Economy-policy-landscape-overview.pdf

WEF (2024) *The Global Risks Report 2024*, World Economic Forum, available at https://www3.weforum.org/docs/WEF_The_Global_Risks_Report_2024.pdf

World Bank (2022) *Squaring the Circle: Policies from Europe's Circular Economy Transition*, available at https://www.worldbank.org/en/region/eca/publication/squaring-circle-europe-circular-economy-transition

WWF (2021) *Driven to Waste: Global Food Loss on Farms*, available at https://wwf.panda.org/discover/our_focus/food_practice/food_loss_and_waste/driven_to_waste_global_food_loss_on_farms/

Annex 1

Global environmental impacts of cultivation/extraction, processing and use of resources: definitions (Figure 1)

Climate impacts include the impact of all greenhouse gases, with units are converted to CO2 equivalents taking into account their relative climate impacts.

Land-related biodiversity loss includes that from land occupation and land-use change only, measured in 'potentially disappeared fraction of species' (PDF). Biodiversity loss from drivers including climate change, terrestrial acidification and water stress are not included here, nor is marine biodiversity loss.

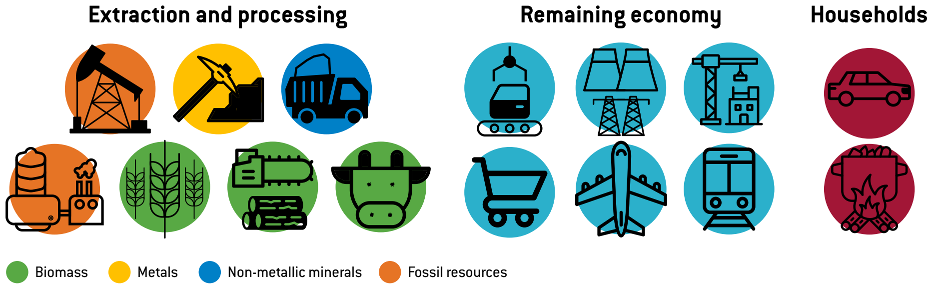
Particulate matter (PM) health impacts are impacts from primary emissions of PM and secondary formation from precursor gases SOx, NOx and ammonia. Health impacts are measured in disability adjusted life years, ie the number of life years lost or lived with a health impairment.

Understanding the categorisation of greenhouse gas emissions from materials extraction and processing

Greenhouse gas impacts in Figures 1 and 3 are categorised by economic activity and purpose rather than the more usual categorisation by sector (eg industry) or energy carrier (eg coal). If the purpose is the cultivation, processing or extraction of material, then all greenhouse-gas impacts resulting from that activity (eg from energy use) are categorised into one of biomass, metals, non-metallic minerals and fossil resources. If counted not for these purposes, the impacts are categorised under 'remaining economy or households'.

An economic activity's purpose is determined by where it sits in the value chain: cultivation, processing and extraction are all the activities up to the point where a usable material is delivered (eg natural gas, steel or animal products). These products are then distributed or become inputs into other processes. Figure A1 gives several examples of how economic activities are categorised.

Figure A1: categorisation of economic activities to extraction and processing vs remaining economy and households



Source: Bruegel based on Annex 2 to UNEP (2024).

Therefore, the calculation that 64 percent of climate impacts is attributable to materials processing and extraction does not suggest that fossil energy carriers are unimportant. On the contrary, they account for around 75 percent of emissions, but for our purposes greenhouse gas emissions from oil and gas are distributed throughout the six categories (see UNEP, 2024, Annex 2 for a complete mapping of economic sectors).

Annex 2

Materials-related CO2 emissions shown in Figure 3 correspond to emissions from the manufacturing and processing of materials (biomass, metals, non-metallic minerals and fossil resources).

For each year, the CO2 equivalent target corresponds to the total carbon budget to limit global warming by 20100 to 1.5 degrees Celsius with a 50 percent probability, divided by the number of years until 2100. For example, in 2022 the carbon budget was 410 gigatonnes (from IPCC, 2021) divided by 78, the number of years until 2100. This is why the curve declines: the CO2 budget reduces every year because of overshoot of annual targets.

The PDF biodiversity target in Figure 3 corresponds to a limit of 0.001 percent additional global species extinction per year. Both the target and the contribution of materials pertain to land-based biodiversity loss from land-use change. Biodiversity loss from climate change, terrestrial acidification and water stress are not included in Figure 3.