Global Material Resources Outlook to 2060

Economic drivers and environmental consequences

HIGHLIGHTS

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Global Material Resources Outlook to 2060

Economic Drivers and Environmental Consequences

"Growth in materials use, coupled with the environmental consequences of material extraction, processing and waste, is likely to increase the pressure on the resource bases of our economies and jeopardise future gains in well-being. This Outlook can help decision makers understand the direction in which we are heading and help to assess which policies can support a more circular economy."

Angel Gurría, OECD Secretary-General

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Key messages

The economic drivers...

- In the coming decades, growing populations with higher incomes will drive a strong increase in global demand for goods and services.
- Global gross domestic product (GDP) is projected to quadruple between 2011 and 2060, according to the central baseline scenario projected with the OECD ENV-Linkages model. By 2060, global average per capita income is projected to reach the current OECD level (around USD 40 000).
- Production and consumption are shifting towards emerging and developing economies, which on average have higher materials intensity.
- The growing share of services in the economy will reduce the growth in materials use as the sector is less materials intensive than agriculture or industry.
- Technological developments will help decouple growth in production levels from the material inputs to production.

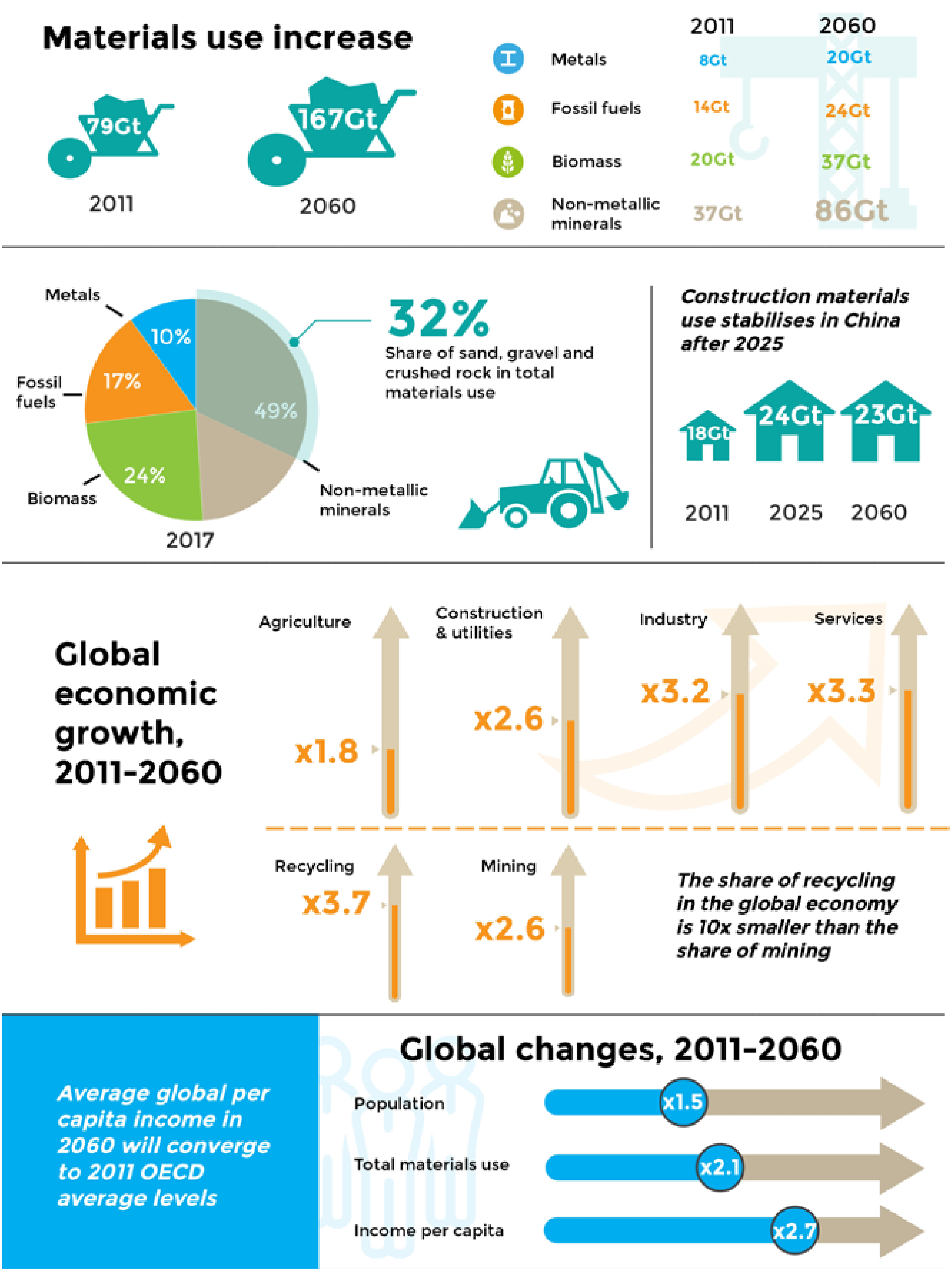
...of materials use

- Global materials use is projected to more than double from 79 Gt in 2011 to 167 Gt in 2060. Non-metallic minerals, such as sand, gravel and limestone, represent more than half of total materials use.
- The materials intensity of the global economy is projected to decline more rapidly than in recent decades — at a rate of 1.3% per year on average — reflecting a relative decoupling: global materials use increases, but not as fast as GDP.
- Recycling is projected to become more competitive compared to the extraction of primary materials.
- The strong increase in demand for materials implies that both primary and secondary materials use increase at roughly the same speed.

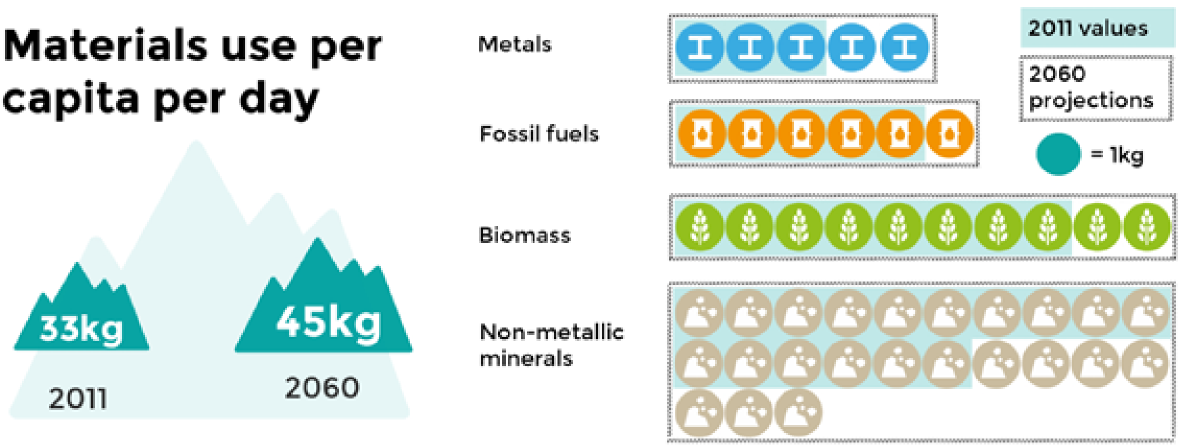
…and its environmental consequences

- More than half of all greenhouse gas (GHG) emissions are related to materials management activities. GHG emissions related to materials management will rise to approximately 50 Gt CO_2-equivalents by 2060.
- Fossil fuel use and the production of iron & steel and construction materials lead to large energy-related emissions of greenhouse gases and air pollutants.
- Metals extraction and use have a wide range of polluting consequences, including toxic effects on humans and ecosystems.
- The extraction and use of primary (raw) materials is much more polluting than secondary (recycled) materials.

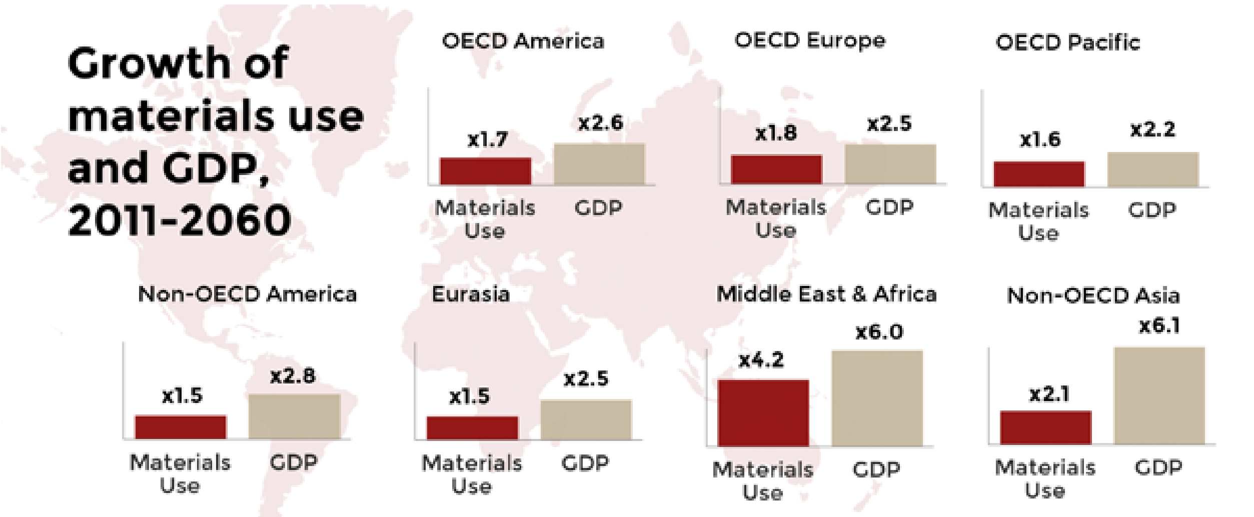
Key facts and projections from the OECD Global Material Resources Outlook to 2060



Materials use per capita per day



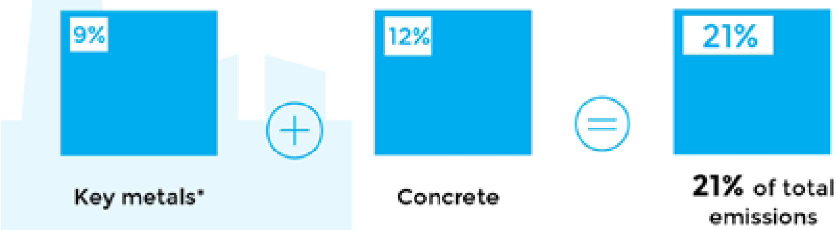
Growth of materials use and GDP, 2011-2060



Material intensity decrease

-1.1% 1980-2017 ▶ **-1.3%** 2017-2060

Greenhouse gas emissions in 2060 from materials extraction and processing



**The key metals are Al, Cu, Fe, Mn, Ni, Pb, Zn*

Primary copper and primary nickel have the highest *cradle-to-gate* environmental impacts per kg

1 The global economy is on course to quadruple by 2060

The world has seen strong economic developments in recent decades. Global growth of GDP has been largely driven by fast-growing emerging economies like China and India. The coming decades are expected to bring further shifts in the geographical balance of the global economy.

Global population growth is projected to slow down, but nonetheless, another 3 billion people are projected to be added to the 2011 total of 7 billion by 2060. At the same time, living standards are gradually converging across economies: per capita growth rates are higher in emerging and developing economies than in the OECD region (see Figure 1). By 2060, the global average gross domestic product (GDP) per capita is projected to reach the current level of the OECD.

Population growth and income convergence together drive growth of the global economy. The projected increase in population and tripling of global per capita income levels combine to a quadrupling of global GDP (see Figure 2). Large populations and rapid catching up of living standards in the People's Republic of China (hereafter China), and to a lesser extent in India and the rest of Southeast Asia, will drive global growth the most.

But global growth is projected to be lower than in the past. The annual global GDP growth rate is projected to stabilise below 2.5% per year, a full percentage-point below the average at the turn of the century. A key driver of this is the decline in the growth rate of China, which is only partially offset by strong growth in other emerging economies such as India, followed by high growth in large parts of Sub-Saharan Africa.

The economic projections are also characterised by changes in the structure of the economy. The main change is the shift of demand from manufacturing and agricultural goods towards services. At the global level, the share of services is projected to increase from 50% to 54%. This is driven by income growth, digitalisation, and ageing. This servitisation trend holds for both industrial and final demand.

Box 1. **A BASELINE SCENARIO APPROACH**

Creating a global outlook to 2060 for future materials use at the sectoral and regional level for 61 different materials consists of three main steps:

1. **Projecting trends in the economic drivers of materials use.**

   A comprehensive global general equilibrium model is developed, representing the complex dynamics between economic activities across sectors and regions.

2. **Linking materials use to the most relevant economic activity.**

   Biomass resources are linked to agricultural production activities; fossil fuels to fuel extraction sectors. Metals and non-metallic minerals are linked to the input of mining products into the processing sectors, including metals processing and construction.

3. **Linking economic activities and materials use to environmental pressures.**

   Emissions of greenhouse gases are linked to materials management and other economic activities. A wider range of life-cycle impacts are connected to extraction and processing of metals and construction materials.

These projections are made with the OECD ENV-Linkages model under the assumption of no new policies, thus reflecting the implemented policy landscape of 2017. The baseline scenario describes one possible future development and is not a prediction.

Figure 1. **Living standards are projected to gradually converge**

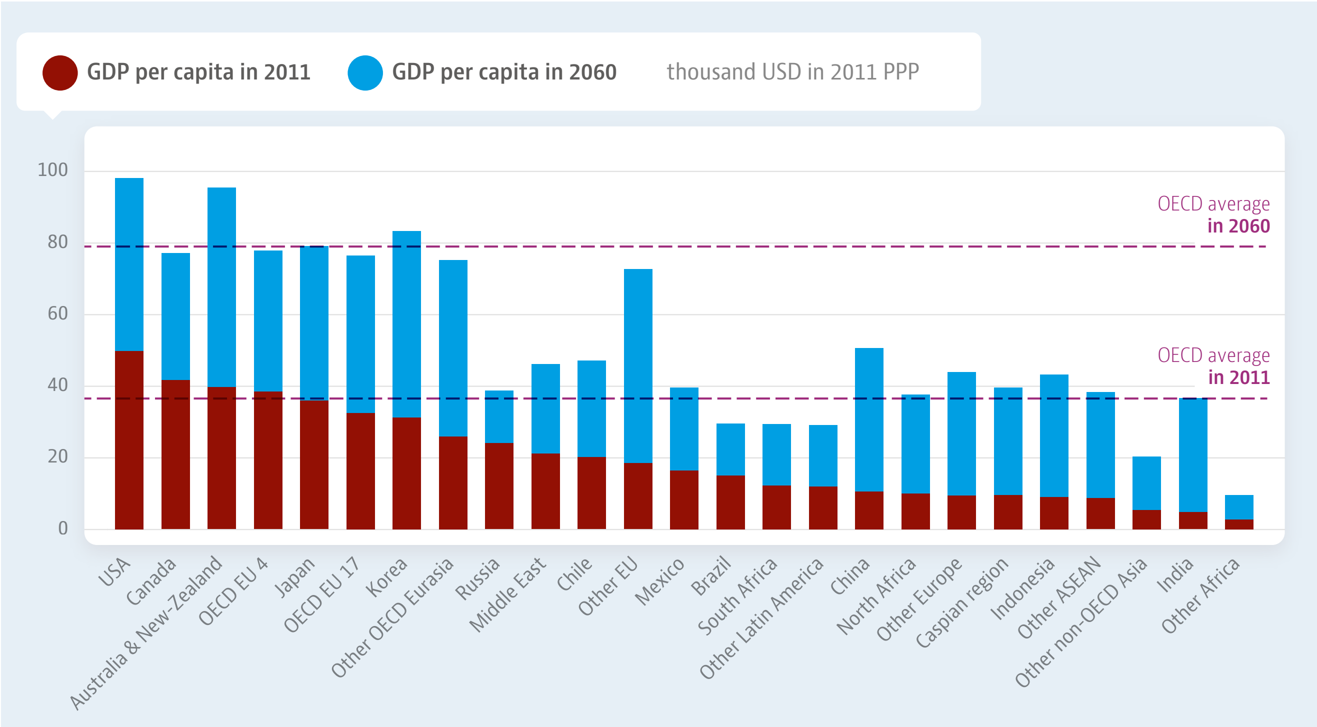
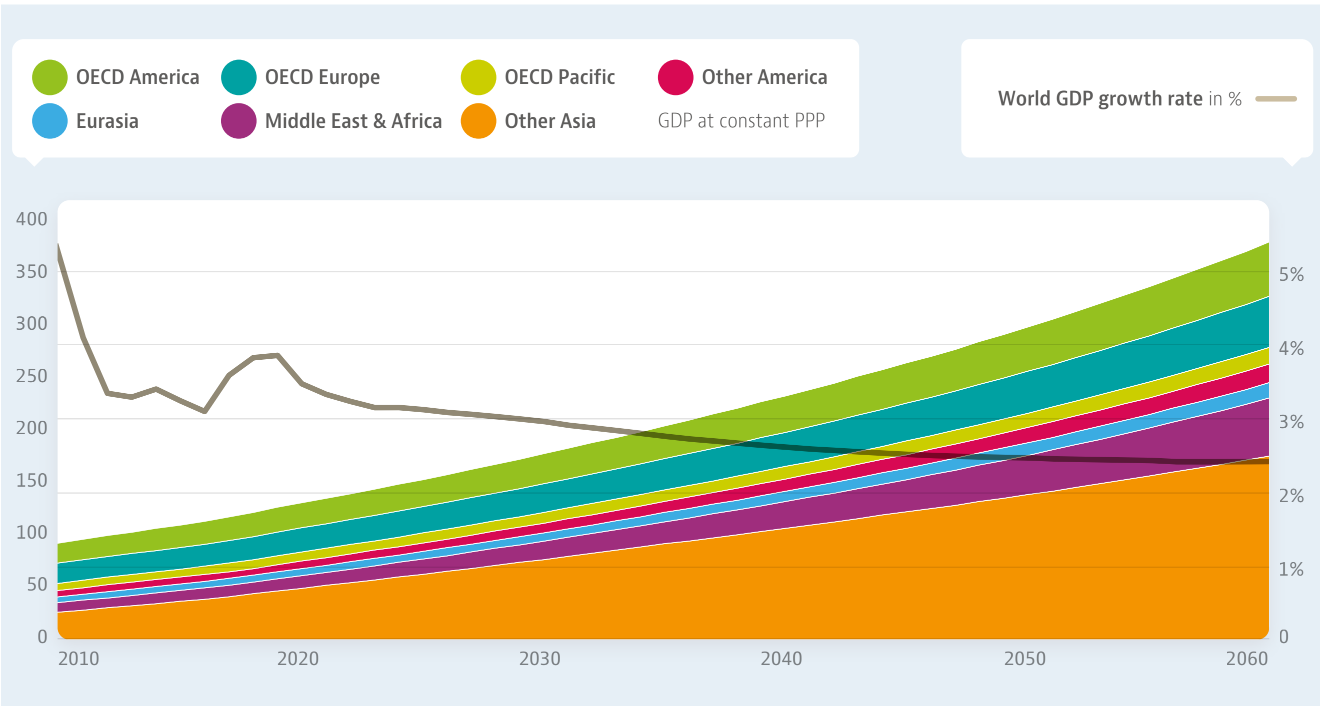


Figure 2. **Emerging economies drive the projected global GDP growth**



2 Socioeconomic and technological trends drive future materials use

The projections in the Global Material Resources Outlook to 2060 build on three key socioeconomic trends that affect materials use. A detailed understanding of the evolution of the global economy and how different economic activities link to the use of different materials is essential for an understanding of future materials use.

Income convergence

Strong links between economic growth – and especially convergence in income levels across countries – and investment, infrastructure and construction drive a solid increase in global materials use. As the economies of fast-growing countries mature and develop infrastructure, their use of non-metallic minerals and metals increases strongly. This has been occurring in China in the past two decades, and is projected to happen for many Asian and African countries in the coming decades, as shown in Figure 3. As China's construction boom gradually comes to an end, its demand for construction materials may stabilise below 25 Gt per year after 2025.

Structural change

The demand for services by firms, government and households, which is projected to increase faster than the demand for agricultural or industrial goods – leads to structural change in the economy.

As the services sectors have lower materials intensity (materials use per unit of output) than agriculture and industry, the global materials intensity of the economy is likely to decrease by 2060. The high output growth rates and low materials intensity for the services sectors are shown in Figure 4. Motor vehicles and electronics have low total materials intensities, but are relatively large users of metals, and so drive the fast increase in metals use.

Technology improvements

Technology improvements slow the growth in future materials use despite production growth. These reductions in materials intensity are projected to occur in all major sectors of the economy, albeit at widely varying rates, as shown in Figure 4. Together, income convergence, structural change and technology developments are projected to lead to a relative decoupling of primary materials use globally.

Figure 3. **Economic growth drives construction materials use**

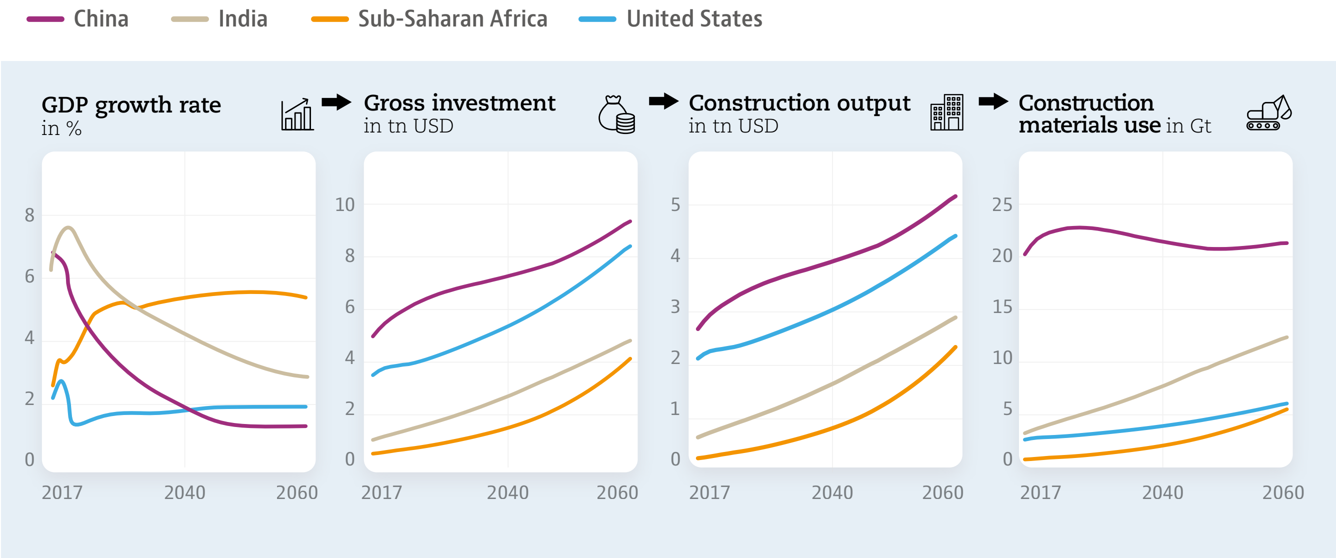
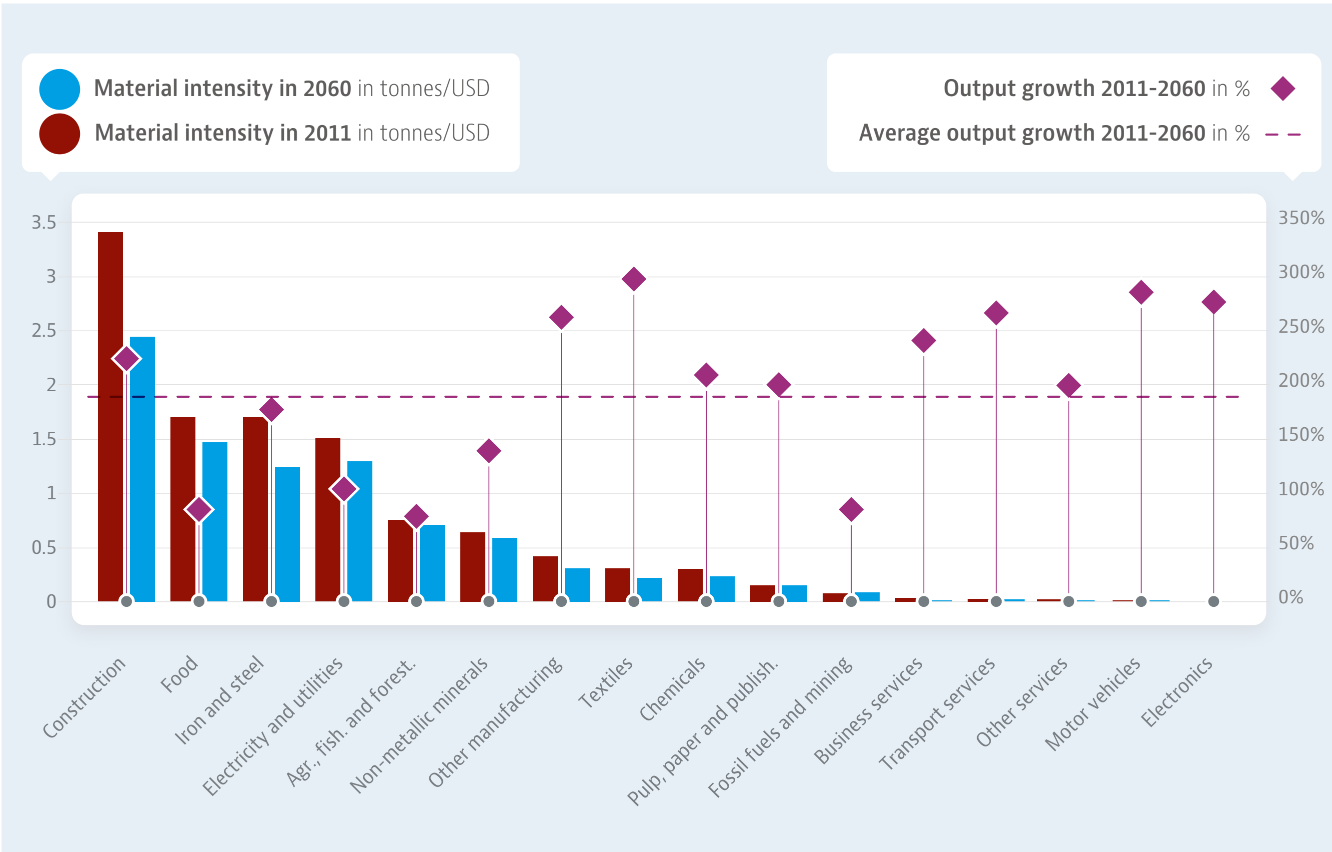
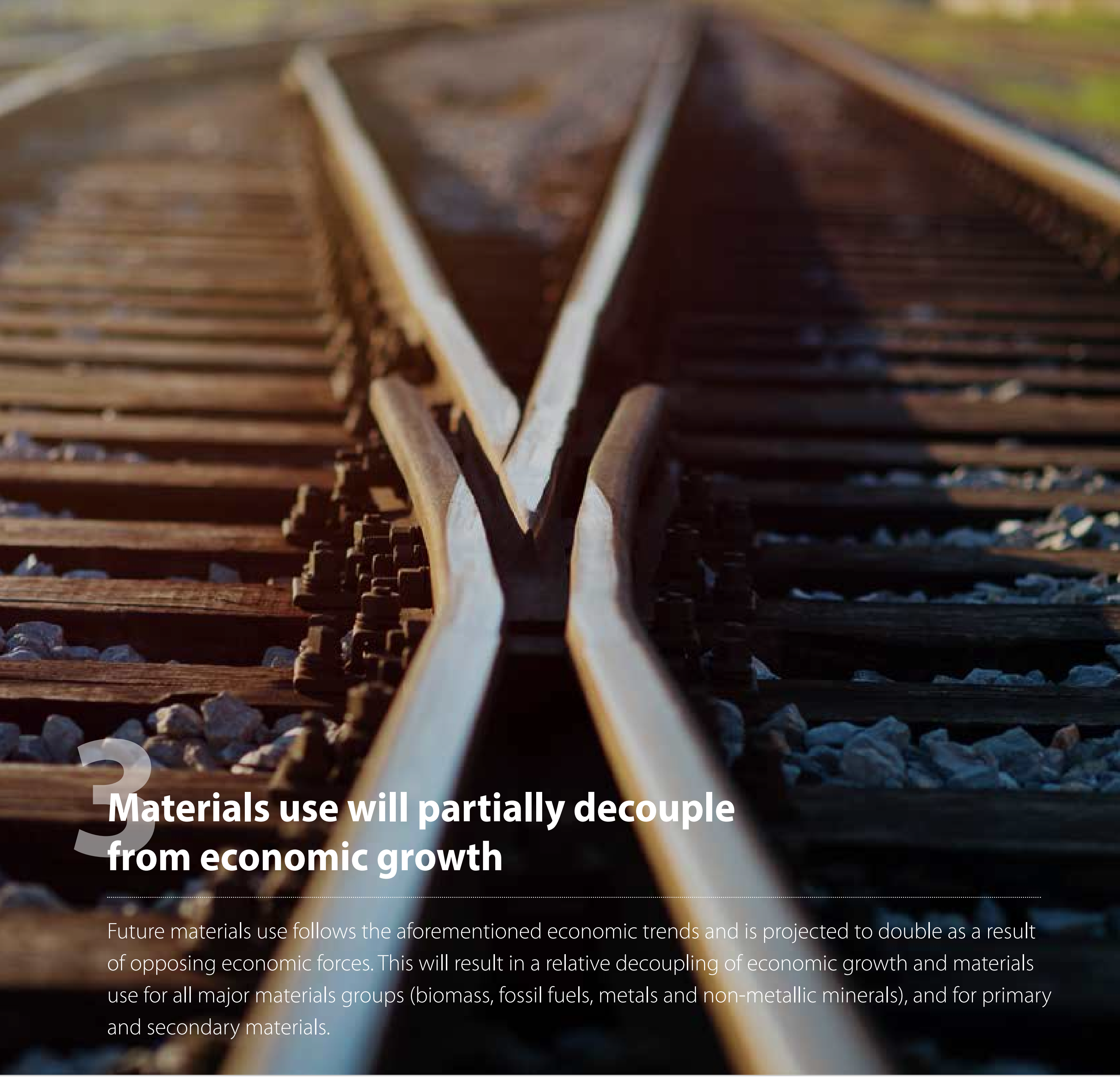


Figure 4. **Structural change and technology developments will reduce global materials intensity**





3 Materials use will partially decouple from economic growth

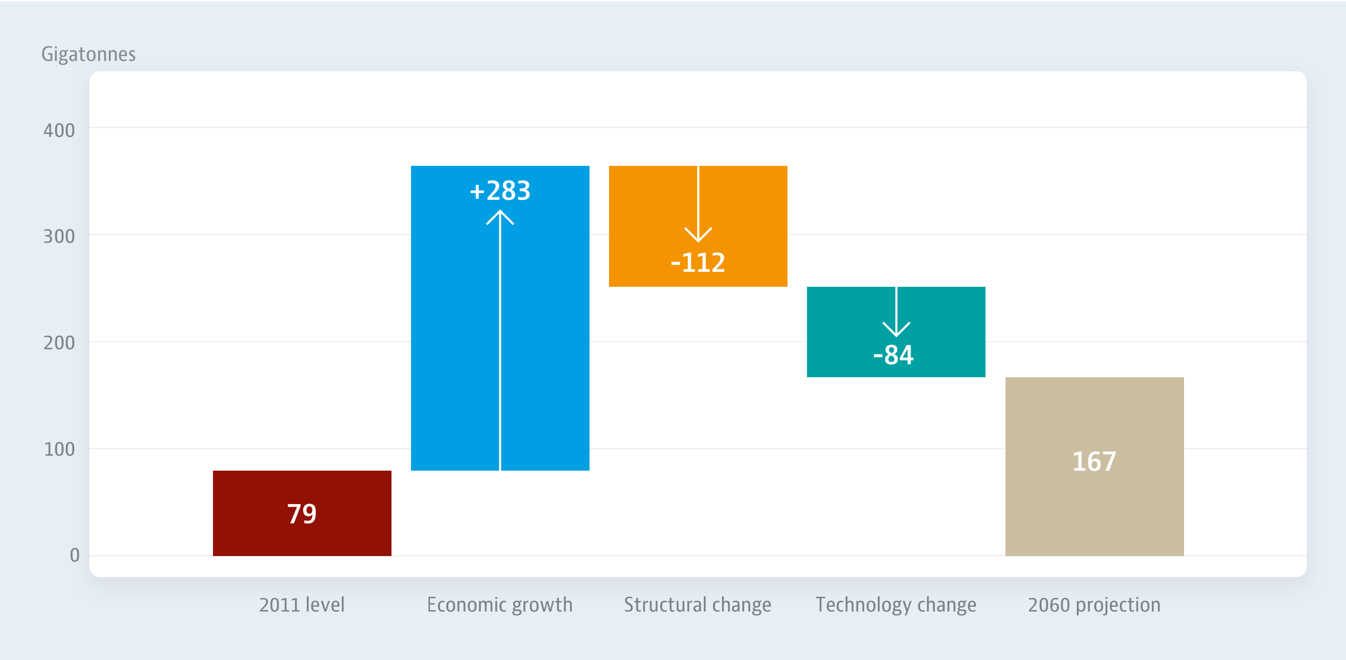
Future materials use follows the aforementioned economic trends and is projected to double as a result of opposing economic forces. This will result in a relative decoupling of economic growth and materials use for all major materials groups (biomass, fossil fuels, metals and non-metallic minerals), and for primary and secondary materials.

Global materials use is projected to double

Global primary materials use, and thus global primary materials extraction, is projected to double in the coming decades in the central baseline scenario (from 79 GT in 2011 to 167 Gt in 2060). As Figure 5 shows, this is the net effect of three major trends:

1. If materials use were to keep up with economic growth (measured as growth of gross domestic product) total materials use would surpass 350 Gt in 2060.
2. Taking into account the effects of structural change, including servitisation of the economy, slows the growth of materials use relative to global GDP growth, and would lead to 250 Gt total materials use by 2050.
3. Further decoupling (projected at 84 Gt by 2060) comes from changes in technology, including efficiency improvements in production. Together, all these effects imply a central baseline scenario where materials use roughly doubles.

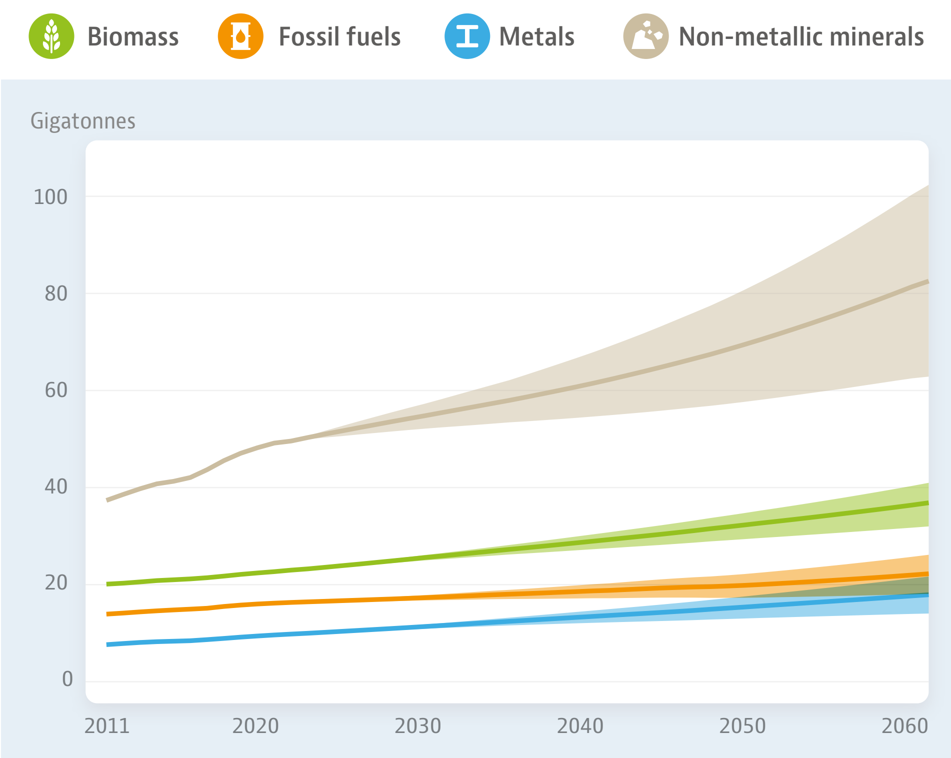
Figure 5. **Global materials use is projected to double**

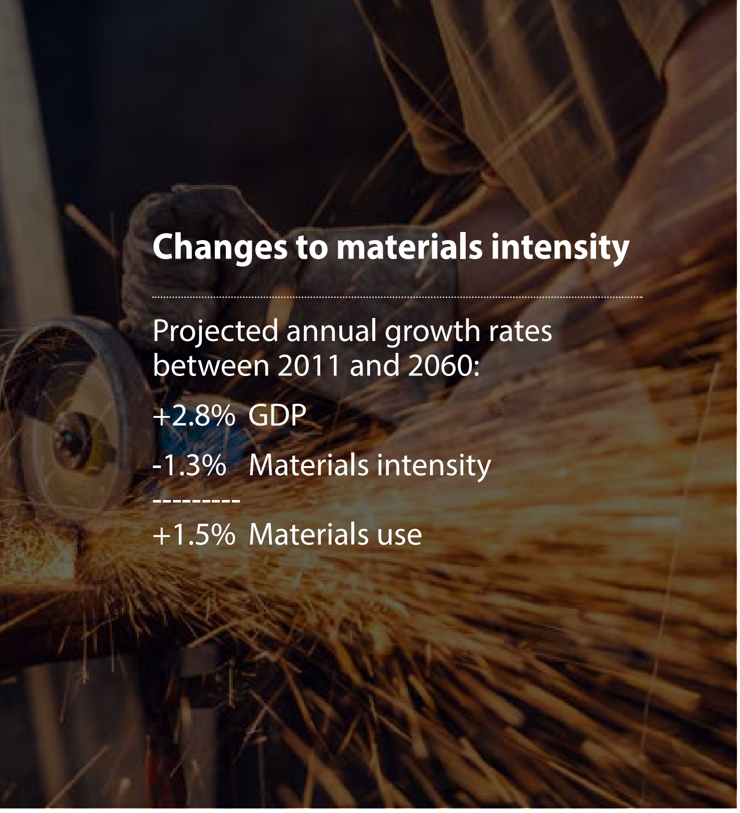


Materials use will grow under a range of population and economic growth scenarios

Varying the assumptions about population growth and the rate at which countries catch up in income levels introduces an uncertainty range of around 20% on either side of the central baseline scenario. In all cases, however, global materials use is still projected to grow over time (Figure 6). Faster economic convergence implies higher materials use, especially for construction materials and metals. Similarly, faster population growth boosts materials use as long as these two are not fully decoupled. Changes in sectoral and technology developments will also affect materials use but could not be quantified.

Figure 6. **Growth in materials use depends on population and economic growth assumptions**





Changes to materials intensity

Projected annual growth rates between 2011 and 2060:

+2.8% GDP

-1.3% Materials intensity

+1.5% Materials use

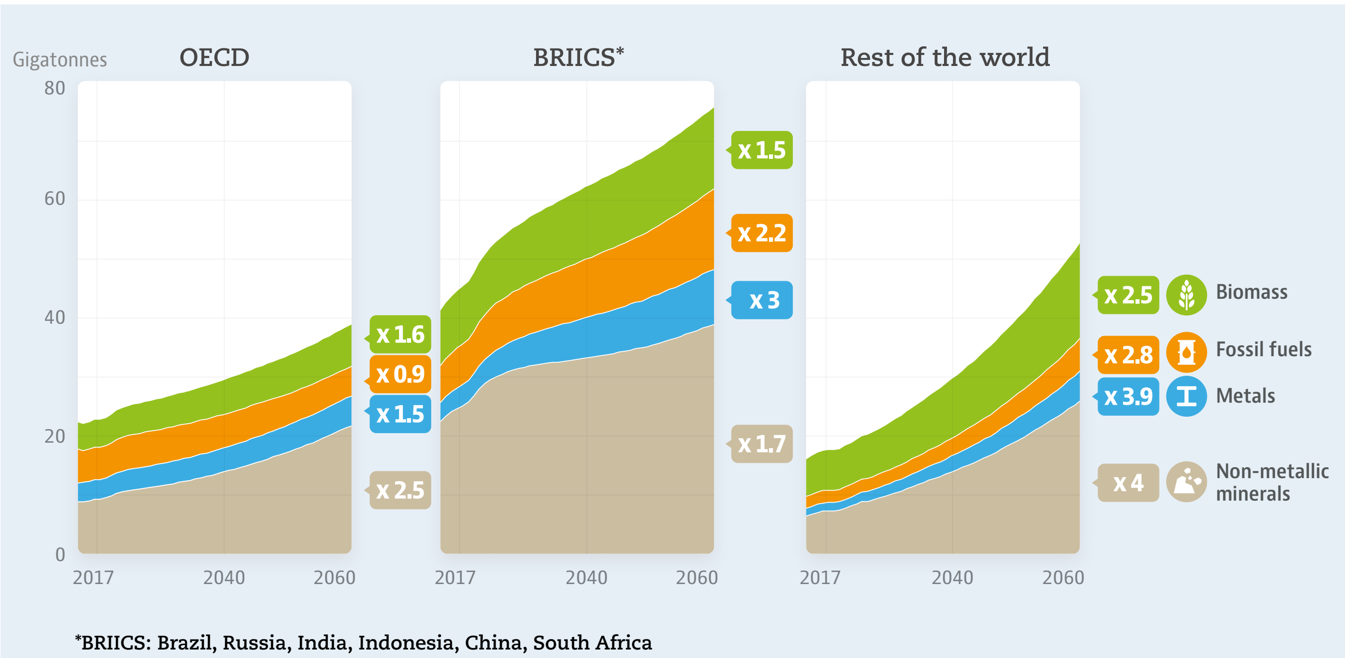
Materials intensity is projected to decrease

In parallel to the growth in materials use, materials intensity is projected to gradually decrease over time. While global GDP is projected to grow on average by 2.8% annually between 2011 and 2060, global primary materials use is projected to grow by 1.5% per year. The materials intensity of the global economy is thus projected to decrease by 1.3% per year on average, with improvements occurring mostly after 2025 as the economy orients towards more services globally and the construction boom in emerging economies (especially China) is projected to slow down.

Not all materials grow equally fast, as they are linked to different economic activities

- Metals are projected to grow the fastest. Over the period to 2060, metals are projected to increase from 7 to 19 Gt per year (see Figure 7). The rapid increase holds for both primary and secondary (recycled) metals, and for Brazil, Russia, India, Indonesia, China, South Africa (hereafter BRIICS), as well as for developing countries.
- Non-metallic minerals such as construction materials are projected to grow rapidly from 35 Gt in 2011 to 82 Gt in 2060. Their use will grow especially rapidly in the short run, given their strong links to investment and construction needs and a lack of high-value recycling.
- The strongest rise in non-metallic minerals is projected for developing countries, while China faces a saturation in construction materials demand. In OECD countries, growth of non-metallic minerals is also likely to be stronger than for other materials groups.
- Global extraction (and thus use) of biomass resources is projected to not quite double over the period, i.e. will remain well below the average economic growth rate, reflecting the low income elasticity of food demand.
- Fossil fuel use follows projected trends in energy efficiency and will not quite double by 2060.

Figure 7. **Materials use rises for all material groups**



The evolution of recycling and secondary materials use

Recycling will gradually become more competitive than mining of minerals thanks to projected technological developments and changes in relative prices of production inputs. This leads to growth in the recycling sector outpacing growth in mining (see Figure 8), as well as growth in GDP, albeit less strongly.

Nonetheless, the central baseline scenario projects a mild decrease by 2060 in the share of secondary non-ferrous metals. A key driver for this is that the increase in total demand for materials can only be easily met through increasing both primary and secondary materials use. The relatively high labour costs for secondary production methods also hampers further penetration of secondary non-ferrous metals in the central baseline projection.

Did you know?

In 2017, in most countries mining activities represented less than 1% of GDP, and recycling less than 0.25% of GDP.

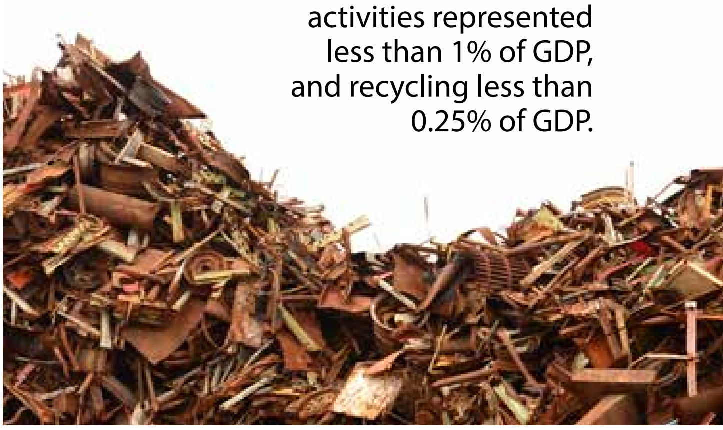
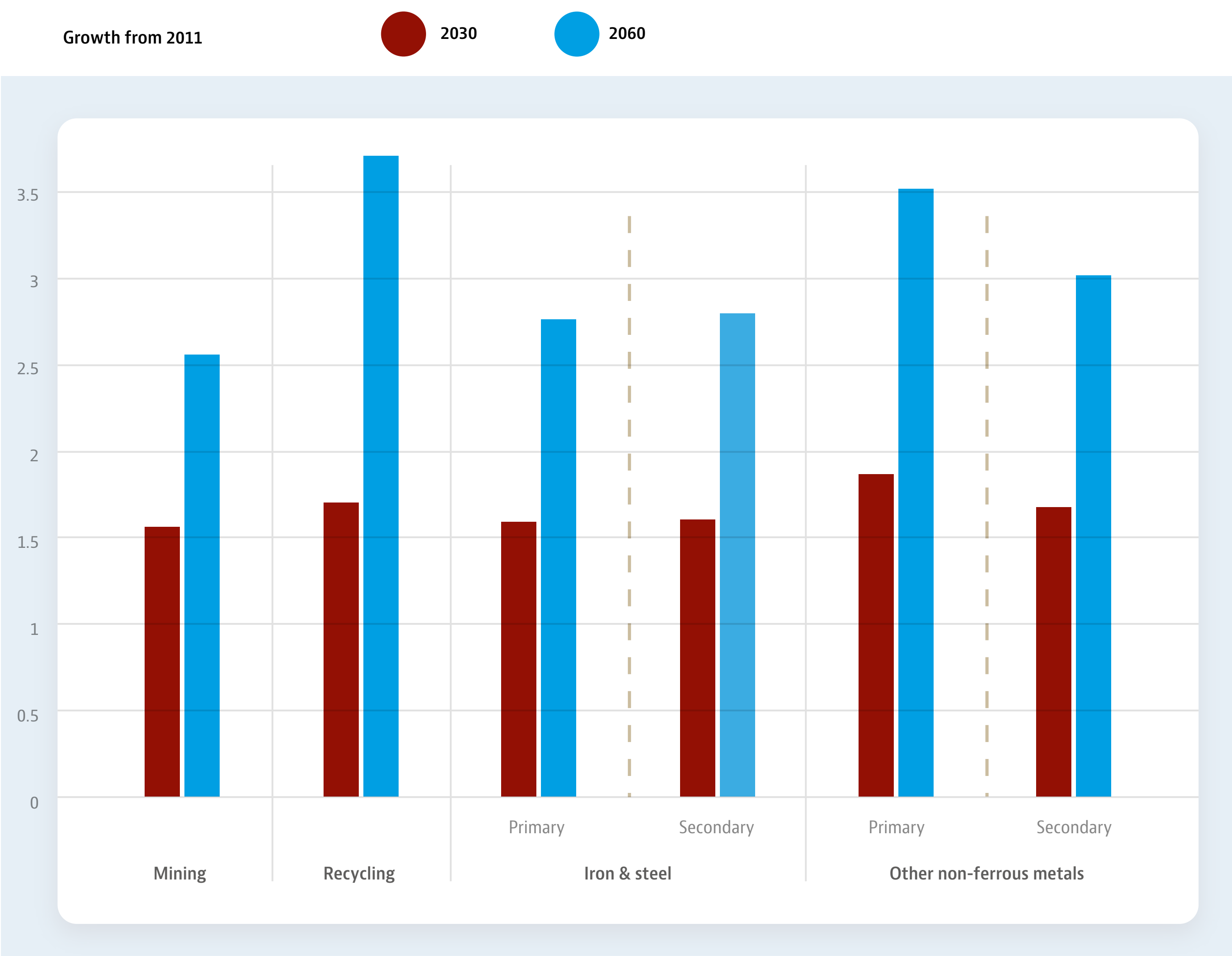


Figure 8. **Recycling is projected to grow faster than mining or materials use**



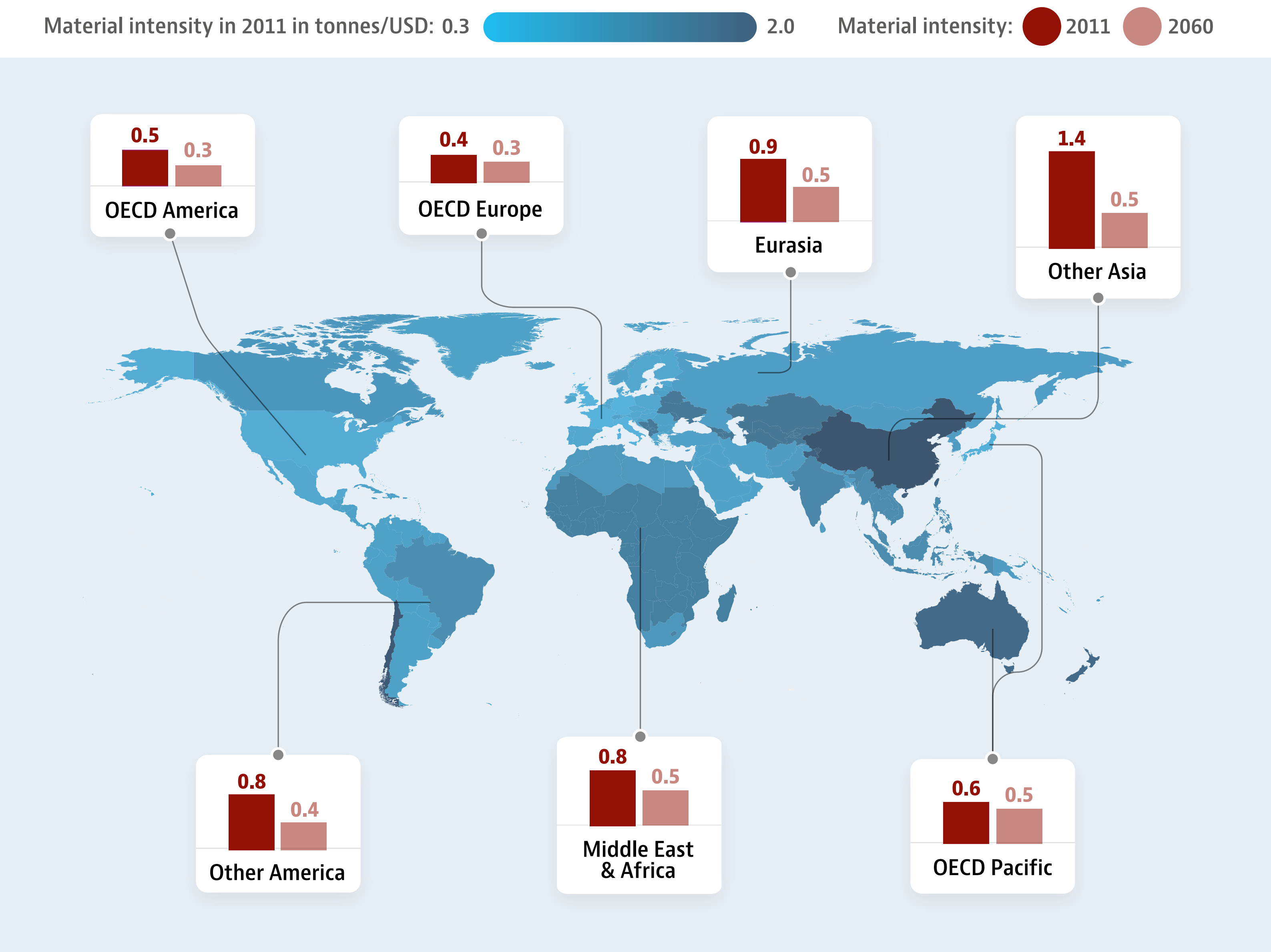
The regional patterns of materials use are shifting significantly

The strongest growth in materials use is projected to be in emerging and developing economies that are likely to ramp up their economic growth rates in the coming decades. The trends in the OECD region are fairly stable in comparison: relatively slow population and income growth and a continued trend of relative decoupling lead to an increase in materials use levels from 22 Gt in 2011 to 39 Gt in 2060. Materials intensity in the OECD declines from 0.5 to 0.3 kg/USD between 2011 and 2060 (Figure 9).

Materials intensity is projected to decline most in China and India, where the infrastructure boom is coming to an end. Even so, as economic activity levels remain high, materials use levels in 2060 are projected to rise to 38 Gt in China and 23 Gt in India, from 2011 levels of 27 Gt and 6 Gt, respectively.

The projected trend in the developing countries is much more one of acceleration of both economic activity and materials use, with less room for decoupling. Overall, non-OECD countries, excluding China and India, are projected to increase their materials use from 24 Gt in 2011 to 67 in 2060.

Figure 9. **Materials intensity is projected to decrease by 2060**

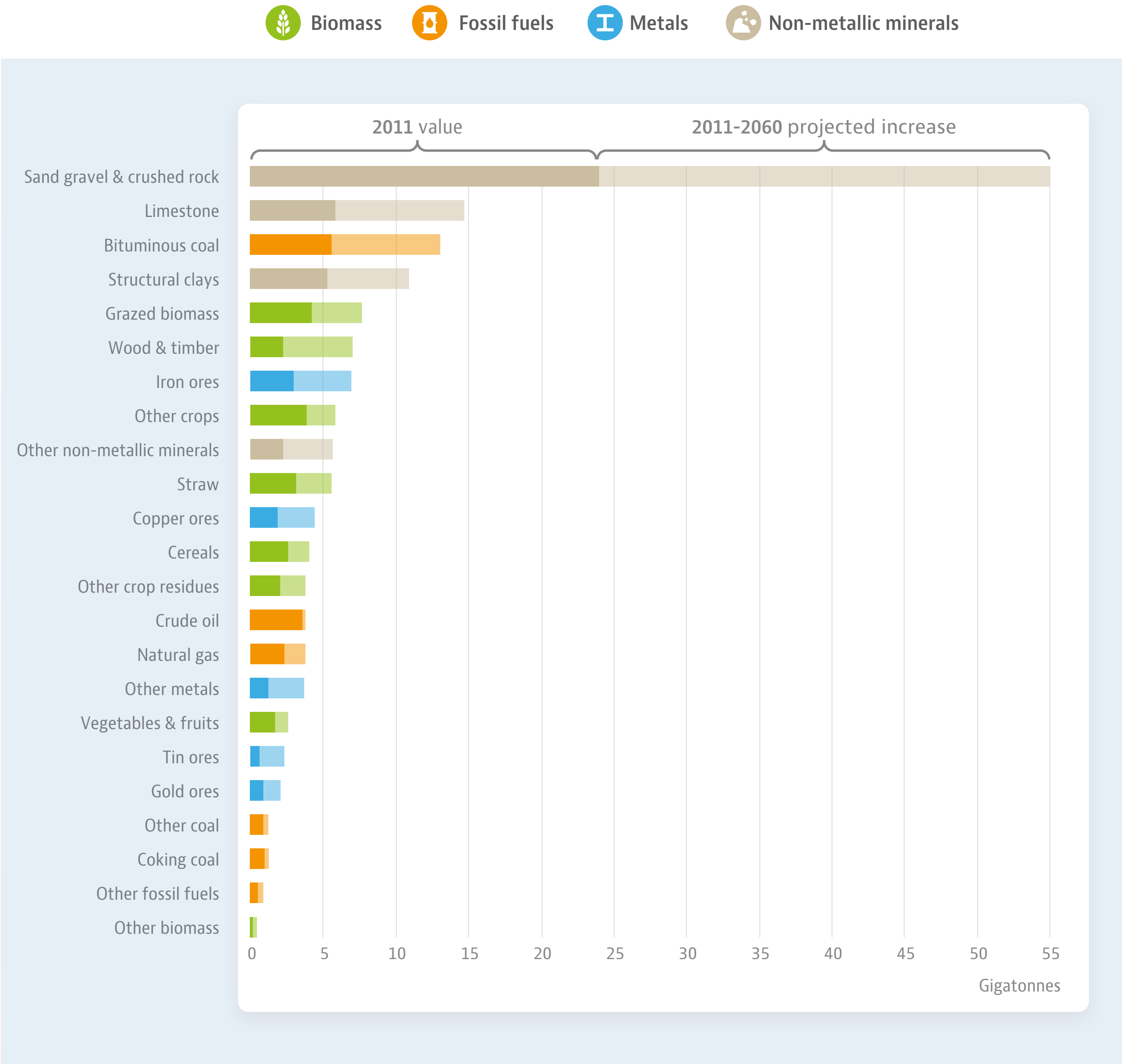


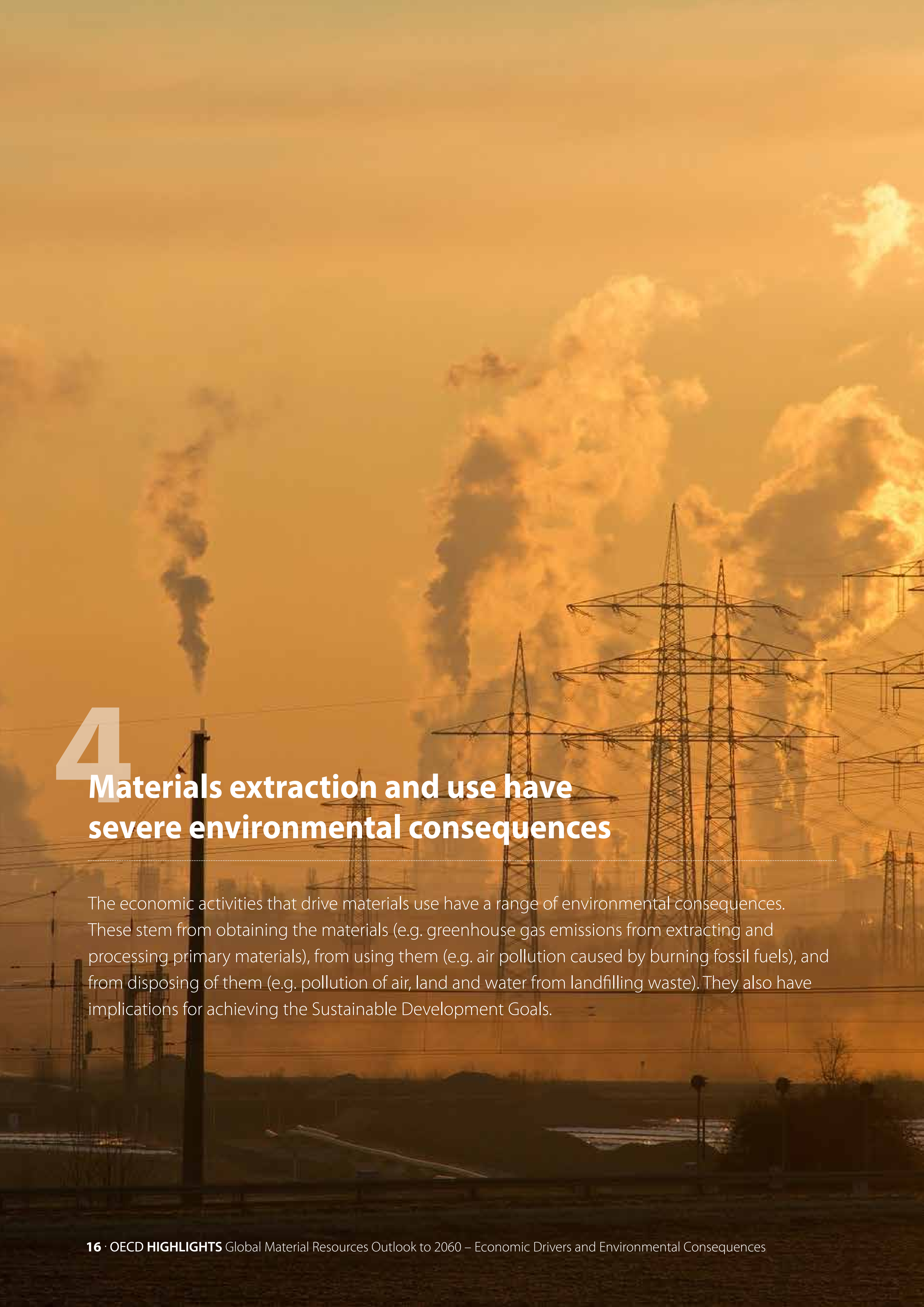
Linking material flows to economic flows

Material flows are linked to the economic flows at the detailed sectoral level. The dataset on physical material flows from the International Resource Panel (UNEP, 2018) is used as the basis for the projection of primary material extraction.

The basic principle for linking is that physical flows (materials use in tonnes) for each of the 61 materials is attached to the corresponding economic flow (materials demand in USD). A coefficient of physical use per USD of demand is calculated and used to project materials use to 2060.

Figure 10. **Construction materials dominate total materials use in 2011 and 2060**





4 Materials extraction and use have severe environmental consequences

The economic activities that drive materials use have a range of environmental consequences. These stem from obtaining the materials (e.g. greenhouse gas emissions from extracting and processing primary materials), from using them (e.g. air pollution caused by burning fossil fuels), and from disposing of them (e.g. pollution of air, land and water from landfilling waste). They also have implications for achieving the Sustainable Development Goals.

Box 2. **MATERIALS USE AND THE LINKS TO THE SUSTAINABLE DEVELOPMENT GOALS**

The development of the economic and environmental variables in the baseline scenario have a mixed effect on achieving the targets defined by the UN Sustainable Development Goals (SDGs) for 2030.

Some of these targets, like the doubling of agriculture productivity as targeted by SDG2, are projected to be almost reached without the aid of new policies, although the sustainability of agricultural practices that underlie this productivity increase remains problematic.

For other targets, the baseline projection is further off track. For instance, income per capita growth rates for developing economies are projected to be around 4% per year for the period 2015-2030, well short of the 7% growth rate targeted in SDG8. Nonetheless, this projected income growth will help to halve the proportion of people living in poverty, as targeted by SDG1.

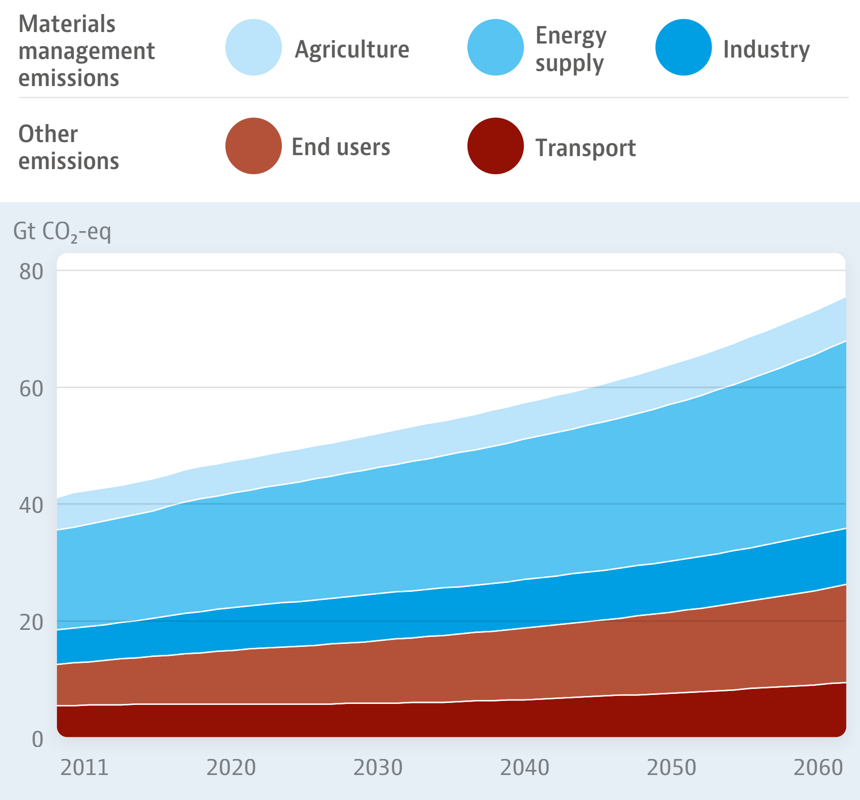
Absolute decoupling of materials use and environmental degradation from GDP growth is targeted in SDG 8.4; however, the baseline projections show only limited progress. Similarly, SDG 12.2 directly aims at the sustainable management and efficient use of natural resources, yet the baseline projection of increased primary materials use highlights the need for more ambitious policies to decouple economic activity and materials use.

Materials use contributes heavily to climate change

A large share of greenhouse gas (GHG) emissions is directly or indirectly linked to materials management (see Figure 11). These come from the combustion of fossil fuels for energy, from agriculture, from manufacturing, and from construction. The increased extraction and use of materials contributes to a global increase in GHG emissions, even if their contribution to overall emissions is projected to decrease relative to emissions not related to material management. Total emissions are projected to reach 75 Gt CO_2-eq. by 2060 of which materials management would constitute approximately 50 Gt CO_2-eq.

The ambitions of the Paris Accord, including the Nationally Determined Contributions (NDC) and the "well below two degrees" objective, would not be met in the central baseline scenario. Additional policy efforts are required to meet these goals, such as including policies aimed at reducing emissions of GHGs in a comprehensive resource management policy package.

Figure 11. **Materials management is a key driver of the increase in GHG emissions**



The global environmental impacts of metals are severe and diverse

Life-cycle analysis of global extraction and production of seven metals (iron, aluminium, copper, zinc, lead, nickel and manganese) and two construction materials (concrete, and sand and gravel) shows a wide range of environmental consequences linked to materials use, including significant impacts on acidification, climate change, cumulative energy demand, eutrophication, human toxicity, land use, ozone layer depletion, photochemical oxidation, and aquatic and terrestrial ecotoxicity (see Figure 12). Despite ongoing efficiency improvements that reduce environmental impacts per unit of production, the global environmental impacts of using these metals are projected to more than double and in some cases even quadruple by 2060. This analysis excludes impacts during the use phase, as these are highly product-specific.

In general, copper and nickel tend to have the greatest per-kilo environmental impacts, while iron and steel have the highest absolute environmental impacts due to the large volumes used. Regional differences can, however, be large.

While secondary metals also have environmental impacts, these are generally one order of magnitude lower than primary production.

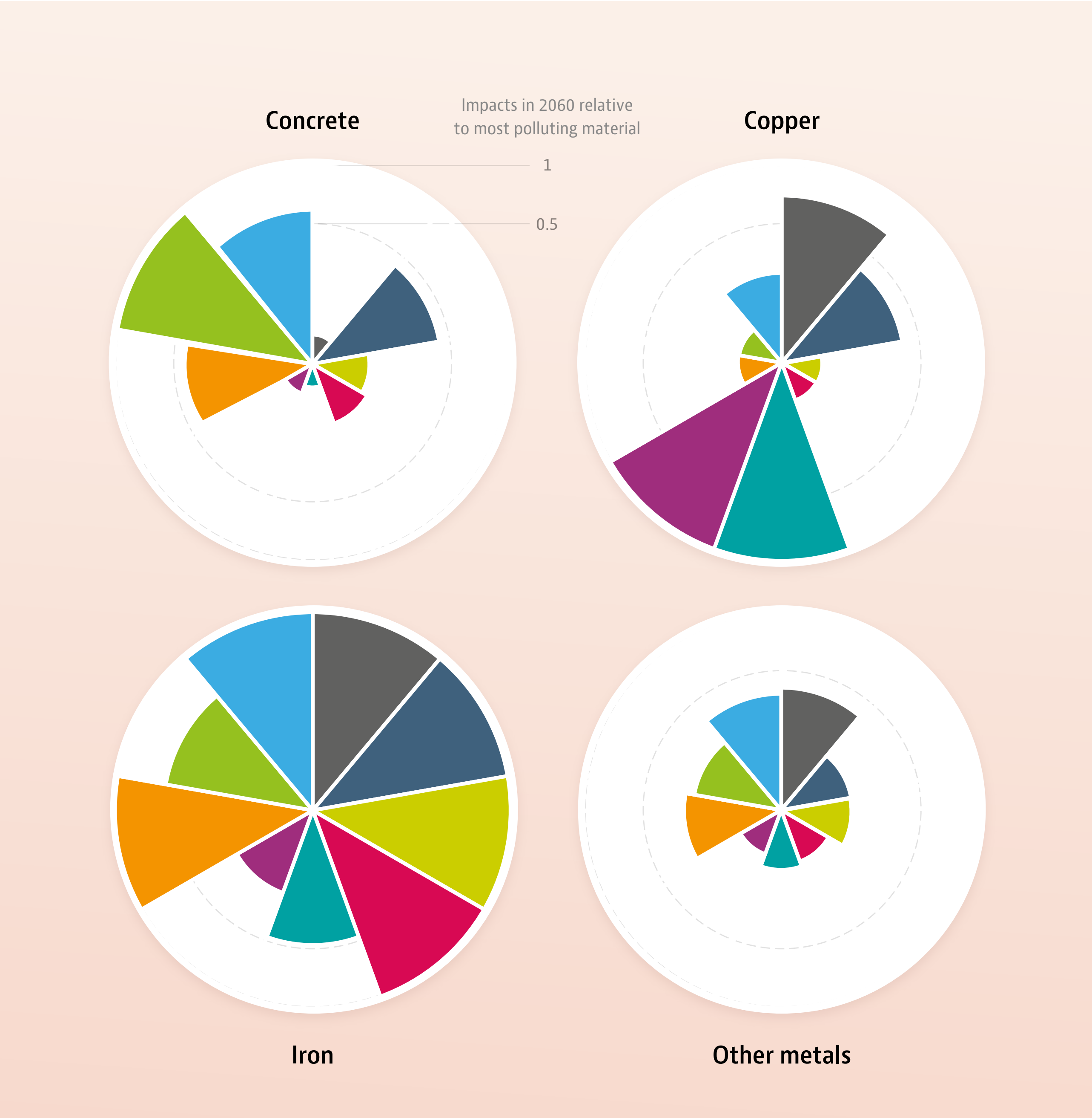
In comparison to metals, concrete, sand and gravel have much smaller impacts per kilo, but their volume of use is huge. These materials are especially associated with climate change impacts (for concrete), and photochemical oxidation, which has severe health impacts.

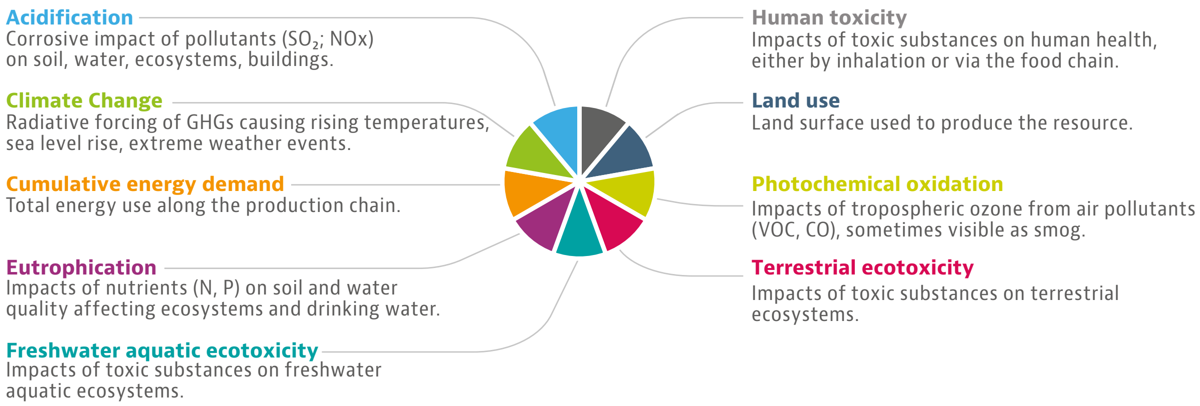
The seven metals and two construction materials together represent almost a quarter of all GHG emissions and one-sixth of cumulative energy demand.

Did you know?

Today, concrete is responsible for 9% of total greenhouse gas emissions and 7 metals – iron, aluminium, copper, zinc, lead, nickel and manganese – are responsible for 7%.

Figure 12. **Global environmental impacts differ significantly across materials**





5 Different materials require tailored policy responses

Policy priorities should be determined by considering the links between the use of a specific material and its economic drivers, as well as its impacts on the environment and the criticality of its supply. The opportunities for substituting secondary for primary materials are also important in determining policy responses.

Macroeconomic indicators of materials productivity cloud the picture and obscure insights into what drives materials use. Countries at different levels of development use different material resources and have different opportunities to decouple materials use from economic growth. A granular approach is needed to understand which policy interventions may improve resource efficiency at the sectoral level, and how major environmental consequences can be avoided. An effective resource policy thus hinges on a detailed understanding of the economic drivers of materials use, and the environmental consequences.

The objectives of resource efficiency and circular economy policies are manifold: increasing recycling, increasing the share of secondary resources, reducing waste streams, boosting economic growth, boosting employment, avoiding environmental impacts, et cetera. This multitude of policy objectives requires a carefully balanced policy mix. The OECD Policy Guidance on Resource Efficiency (OECD, 2016), provides some generic recommendations.

To move towards more detailed and operational policy insights, quantification of the main linkages between economic activity, materials use and environmental pressures is needed. Baseline scenario projections as presented here are an essential first step. A numerical assessment of the policies needed to transition to a more resource-efficient and circular economy can shed light on which policies may be most effective in reaching the various policy objectives.

Did you know?

In Slovenia, the prime minister's office coordinates the circular economy transition.

Box 3. OECD POLICY GUIDANCE ON RESOURCE EFFICIENCY

Resource efficiency policies can help to counteract current trends of continued material resource consumption and generate significant positive impacts for the economy and the environment.

Yet, to realise these benefits, resource efficiency policies need to be further developed and mainstreamed. When designing policy, governments should focus on the following:

- Applying mixes of policy instruments that ensure a coherent set of incentives for resource efficiency along the product value chain.
- Implementing policies that promote resource efficiency across the lifecycle of products.
- Treating resource efficiency as an economic policy challenge and integrating it into cross-cutting and sectoral policies.
- Strengthening policy development and evaluation through better data and analysis.

As the globalisation of our economies continues and value chains stretch across multiple jurisdictions, there is also an increasing need for co-ordinated approaches at the international level. Governments should strengthen international co-operation, with particular focus on the following issues:

- Supporting businesses in their supply chain management efforts. As it is difficult for national governments to influence the way supply chains are managed due to their limited jurisdictional reach, this can be done more effectively at the international level.
- Alleviating barriers to trade and investment in environmental goods and services to ensure the diffusion of the best available environmental technologies.
- Mainstreaming resource efficiency into official development assistance more systematically.
- Harmonising environmental labels, information schemes and mutual recognition, reducing their duplication and associated costs across international markets.
- Improving resource efficiency data and indicators of resource efficiency challenges and policies, and making economic analysis of these more robust.

Source: OECD (2016), Policy Guidance on Resource Efficiency.

The OECD RE-CIRCLE Project

The OECD's RE-CIRCLE project aims to identify and quantify the impacts of policies that could support a more circular economy. There are two main streams of work. The first uses global environment-economy modelling to project the impacts of continued resource use, and the effect of policy interventions. The second applies qualitative analysis to a set of selected topics in order to guide policies to further the transition to the circular economy.

The Global Material Resources Outlook to 2060 falls in the first stream of work. It builds on a literature review of the macroeconomics of the circular economy transition. The next step in this stream of work is to assess the macroeconomic consequences of stylised policy packages to improve resource efficiency and stimulate the transition to a more circular economy.

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Further reading

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This report presents global projections of materials use and their environmental consequences, providing a quantitative outlook to 2060 at the global, sectoral and regional levels for 61 different materials (biomass resources, fossil fuels, metals and non-metallic minerals). It explains the economic drivers determining the decoupling of economic growth and materials use, and assesses how the projected shifts in sectoral and regional economic activity influence the use of different materials. The projections include both primary and secondary materials, which provides a deeper understanding of what drives the synergies and trade-offs between extraction and recycling.

The report projects a doubling of global primary materials use between today and 2060. Population and converging per capita income growth drive the growth in materials use. However, structural change, especially in non-OECD countries, and technology improvements partially dampen that growth. Metals and non-metallic minerals are projected to grow more rapidly than other types of materials.

For further reading see the following publication on which these Highlights are based:
OECD (forthcoming), *Global Material Resources Outlook to 2060 – Economic drivers and environmental consequences*, OECD Publishing, Paris.
oe.cd/materials-outlook

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