The Use of Natural Resources

Report for Germany 2016

For our environment

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The Use of Natural Resources

Report for Germany 2016

Foreword

Maria Krautzberger
President of the German Federal Environment Agency

Dear readers,

Humans use ever increasing amounts of natural resources. Driven by global population growth and increasing economic performance, mineral raw materials and fossil fuels are being extracted in ever greater quantities, while the agricultural production system continues to expand.

This has profound environmental consequences, such as the destruction of ecosystems and habitats, or air, water and soil pollution. Furthermore, the dependency of many industrialised countries on resources from other world regions has grown, and international competition for increasingly scarce resources is intensifying.

Because of this, the issue of resource conservation has gained significantly in importance in the past years, both in economic and political terms, which led among other things to the adoption of the German Resource Efficiency Programme (ProgRess) and its update in March 2016 by the German Federal Cabinet.

With this report on “The Use of Natural Resources – Report for Germany 2016”, the Federal Environment Agency (UBA) sheds light upon the current situation regarding resource use in Germany. The report focuses on renewable and non-renewable raw materials, and the themes covered range from raw material extraction and trade to the use of raw materials in the German economic system and raw material consumption. Other resources, such as water, land or flow resources, are the focus of a separate chapter. In order to provide a comprehensive picture, the report includes an in-depth account of aspects such as dependency on direct and indirect imports, thereby also addressing implications for supply security.

This new UBA resource report is written for everyone interested in the subject of sustainable use of natural resources – addressing both readers with and without expert knowledge. It provides insights for environmental policy and awareness raising and is a reference work for all relevant target groups and multipliers in this thematic area.

“The Use of Natural Resources – Report for Germany 2016” is the result of a UBA research project, which investigates the interconnections between resource use and resource demand as well as economic development and consumption in Germany. A second report focusing on new key areas is planned for 2018.

I wish you an interesting reading.

9.5
billion litres

Beer production
2014

4.9
million tonnes

Meat consumption
2014

387
million

Sold books
2014

2.0
million

Flight activities
2015

147,304

Permissions for
new buildings
2015

3.2
million

Registrations
of new cars
2015

20.4
million

Sold computers
2014

24.1
million

Sold
smartphones
2014

Germany's consumption is based on natural resources

403
million tonnes

Fossil fuels

602
million tonnes

Minerals

272
million tonnes

Biomass

25
million tonnes

Metal ores

Data sources: ↘ page 80

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Key Figures

1.1 billion tonnes
Used domestic extraction 2013

page 12

1.9 billion tonnes
Unused domestic extraction 2013

The national perspective: Domestic raw material extraction

Every second, 24 tonnes of renewable and non-renewable raw materials are mined or harvested, processed and used in the German economy. Domestic extraction thereby amounts to more than one billion tonnes per annum, although the overall trend currently shows a slight decrease. The process of extracting and harvesting these raw materials also creates large quantities of materials, which are not used by the economy, but still associated with impacts on the environment – so-called unused material extraction.

1.7 billion tonnes
Direct and indirect imports 2010

page 24

1.5 billion tonnes
Direct and indirect exports 2010

The international interdependencies: Germany's global raw material trade

Each year, about one billion tonnes of goods are either imported into Germany or exported to other countries. In addition to these "direct trade flows", "indirect flows" also hold great environmental significance. The latter term refers to those raw materials, which were required along the value chain beyond Germany's national borders in order to produce the traded goods. With regard to some raw materials, for example metals, Germany is highly dependent on imports, which has implications regarding supply security.

page 34

1.3 €/kg
Total raw material productivity 2010

The role of the economy: Value creation from raw materials

Raw material intensity, i. e. the volume of raw material required for each Euro earned, varies significantly between individual sectors of the German economy. Raw material intensity is highest in agriculture and lowest in the retail and distribution sector. From both an environmental and an economic perspective, the aim must be to decouple economic development from raw material use and related environmental impacts. One of the most important strategies to achieve this goal is to increase the raw material productivity of the German economy.

16.2 tonnes
Per-capita raw material consumption 2011

page 44

The demand side: Raw materials for consumption

A significant quantity of Germany's demand for raw materials is required for fulfilling private consumer needs. They hold a share of around half of the final demand for raw materials. The consumption areas of housing and food contribute most to this amount. Consumption also has a global dimension. To satisfy consumer needs, more raw materials are required than the amount being mined or harvested within Germany.

page 56

3,300 litres
Daily water footprint per capita 2013

Resource use: A complementary viewpoint

In Germany, alongside raw materials, other natural resources are also used and these are often closely interrelated. Apart from raw materials such as minerals, biomass and fossil energy carriers, water and land area provide an especially important basis for the economy. Germany also uses increasing amounts of flow resources, such as wind and solar energy.

Data sources: page 80

Methodological background

What are natural resources?
Natural resources include all components of the natural world. These comprise renewable (biotic) and non-renewable (abiotic) raw materials, physical space, area/land, environmental media i. e. water, soil and air, flow resources such as geothermal energy, wind power, tidal and solar energy, and all living organisms.

What is the focus of this report?
This report observes and analyses data relating to extraction of used and unused materials from the environment and their subsequent use in the economic system; i. e. their processing, trade and their significance for final demand in Germany. The report focuses on raw materials such as biomass, fossil energy sources, minerals or metal ores. The use of other natural resources such as water or land area are the subject of a separate chapter.

By what means are raw materials obtained?
On one hand, raw materials are extracted from the natural environment as primary raw materials. Examples of this are the harvesting of cereals, the excavation of sand, gravel or coal, or the extraction of oil or gas from reserves. On the other hand, raw materials can also be obtained in the form of secondary raw materials from existing products through recycling. This lessens the need for primary raw materials, which in turn reduces pressures on natural systems.

How can we quantify the amounts of raw material extraction?
In Germany, the Federal Statistical Office (Destatis) collects data on raw material use in the framework of the environmental economic accounts – analogous to the system of national accounts, which depicts the monetary flows within an economy. Data on raw material use are published by Destatis in different degrees of detail – up to 35 raw material groups. The most recent raw material data currently available refer to 2013.

How can we determine the ways in which these raw materials are used?
The Federal Statistical Office compiles input-output tables, which depict the economic interdependencies between production and consumption in a very detailed form, expressed as monetary values (i. e. in Euros). This allows identifying which economic sectors exchange products between them and what role is played by final demand. Extracted raw materials are recorded in physical units (i. e. tonnes) and then assigned to those sectors that are responsible for their extraction – for example, minerals to the mining sector, wood to the forestry sector, etc. By looking at the economic interdependencies in monetary terms, raw material inputs can be related to individual supply chains and to final demand. Tracing physical raw material flows with monetary data can cause inaccuracies, for which reason "hybrid" forms of input-output tables are increasingly used, in which monetary values are partly replaced by physical values.

What is the purpose of analysing data on raw material use?
Raw materials provide an important basis for the functioning of our economy and for satisfying our needs. Yet the deposits of non-renewable raw materials on the planet are finite. In addition, the extraction of raw materials is connected to a diverse range of negative environmental impacts. Because of this, the importance of developing robust indicators for interpreting raw material use has increased steadily in recent years. The aim is to achieve a better understanding of which raw materials and in what quantities economic activities require and where these originate from. The analysis of data and the interpretation of these indicators holds particular relevance for three areas: (1) scientific policy advice and the development of concrete policy measures, (2) the economically and environmentally sustainable management of raw material use, and (3) the identification of new areas of research.

Indirect use of raw materials: how is international trade accounted for?
To provide a comprehensive depiction and analysis of raw material use in Germany, it is essential not only to look at those raw materials that are extracted within Germany's borders but also to consider those which are extracted and used along the international trade and production chains that create the products consumed in Germany. In the last ten years, various methodological approaches have been developed for quantifying material demand at the national level. These include models based on national economic and sector-specific data, such as input-output analysis. A second method employs the use of data from life cycle analysis (LCA) at product level. The third approach, known as the "hybrid" method, combines information from LCA with input-output models for a specific country. The various approaches have different advantages and disadvantages and also provide different results. At the international level, initiatives have been started aiming to harmonise these to a greater degree. "Raw Material Consumption" or RMC is an important indicator for quantifying the sum of direct and indirect raw material flows for final demand in Germany.

What data sources are used to account for the indirect use of resources?
This report draws upon data on indirect raw material flows from two sources. The first of these is Destatis, which calculates raw material consumption for Germany on the basis of a hybrid input-output calculation model. The results provided by this model are currently available for the period from 2000 to 2011 and in part only for 2010. The second source are results of own calculations carried out for this project using Exiobase, a global input-output model (www.exiobase.eu; Tukker et al., 2013). Exiobase was developed in the context of European research projects and is characterised by its high level of complexity. The model distinguishes 200 product groups, 49 countries and country groups and currently provides data for a time series from 1995–2011.

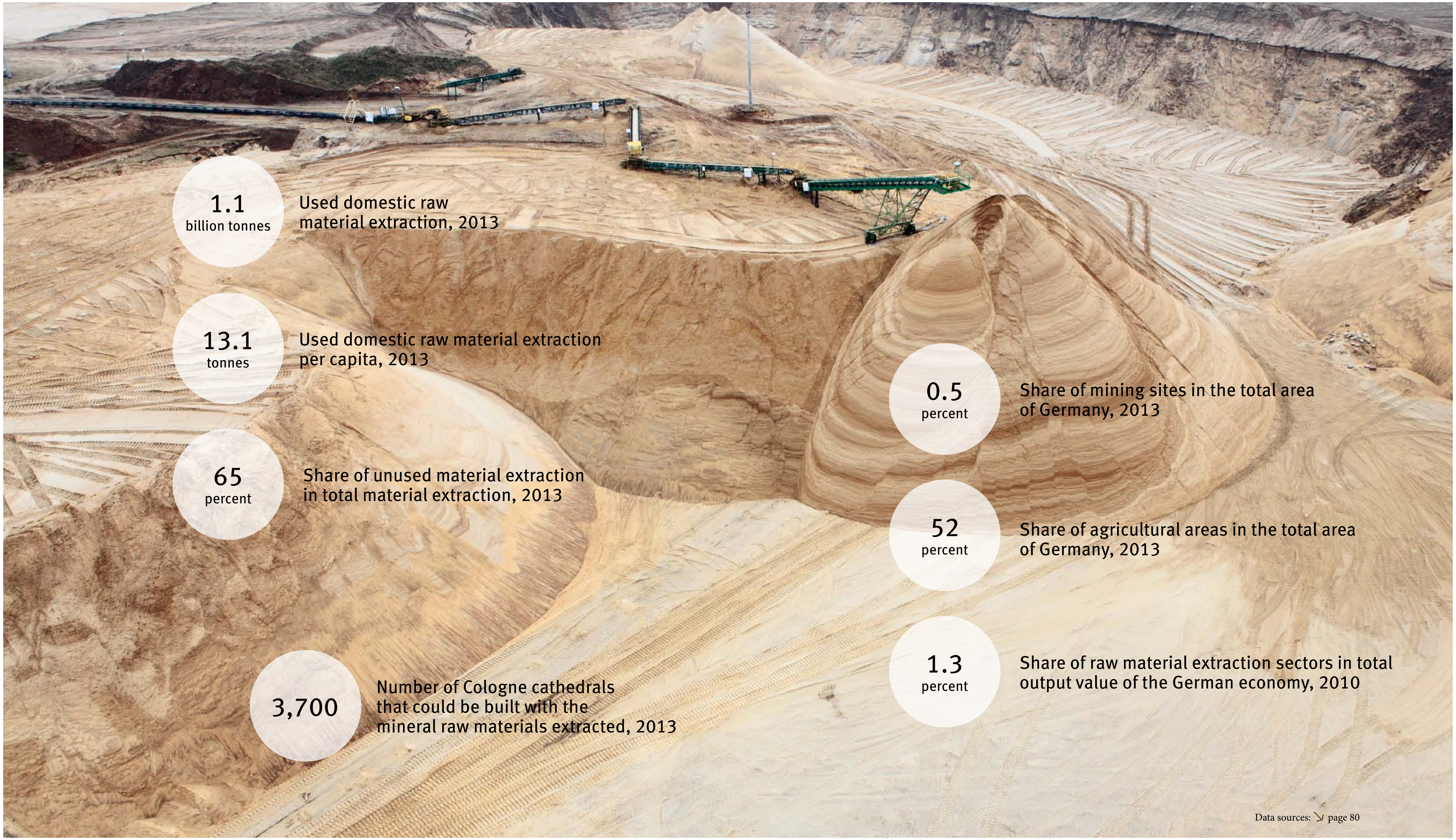
On one hand, data from Destatis can be regarded as more robust, in particular regarding linkages between domestic production sectors, as they are based on highly detailed supply and use tables for Germany. On the other hand, the use of Exiobase allows performing complementary analyses, which would not be realisable based on available data from Destatis. These include examinations of the geographical origin of imported raw materials or analyses of single categories of German final demand, such as private or public consumption.

Which base year is used for this report?
In this report, data regarding both used and unused material extraction and direct trade are taken from the most recent version of the environmental accounts produced by Destatis. The most recent yearly data are available for 2013. However, calculations from Destatis regarding indirect raw material flows are only available up to 2010 or 2011. 2011 is also the most recent available year for the international comparison of indirect raw material flows, for which the Exiobase model is used.

How reliable are the reference data?
Data published by national statistical offices generally enjoy a high degree of public confidence regarding their quality – this is the case for the data supplied by the system of national accounts and the environmental economic accounts (see above). In order to map domestic raw material extraction and associated physical trade flows, the method of material flow analysis (MFA) has become the standard approach and has also been progressively harmonised in recent years through the publication of handbooks by Eurostat, the European Statistical Office. A distinguishing German feature is the high level of detail of the data on raw material use in the individual German federal states, which has been collected and made available by the statistical offices of the German federal states. Where calculation models come into play, the precision of results decreases. The data used here, however, come from the most advanced available current models and thus provide a reliable representation of existing (international) interdependencies.

How are issues of raw material scarcity considered?
Raw material scarcities have become a heavily debated topic in raw material policy and economics. These debates result less from the foreseeable global depletion of certain raw materials, but rather from a combination of geological, technical, structural as well as geopolitical, socio-economic and environmental factors concerning the supply of raw materials in the context of a country-specific situation of raw material demand – in the case of this report of Germany. By applying criticality analyses, ratios of relative scarcities are determined, which occur in cases in which demand for raw materials cannot be met by supplies in temporal, spatial or organisational terms. Such analyses consider the importance and adaptability (vulnerability), for example through substitution in case of disruptions of raw material supply. On the European level a list of crititcal raw materials for the European economy is identified on a regular basis (European Commission, 2014). In Germany a comprehensive and well-documented assessment approach for raw material criticality for various parts of the economy (for example the national economy, sectors, companies) has been developed within the VDI standard 4800 (VDI, forthcoming). The criticality of raw materials and associated specific actions for efficiency improvements, substitution and recycling cannot be covered in-depth in this report. Only one selected aspect – the import dependence for selected raw materials – is being addressed in the chapter on trade.

The national perspective: Domestic raw material extraction



1.1 billion tonnes
Used domestic raw material extraction, 2013

13.1 tonnes
Used domestic raw material extraction per capita, 2013

65 percent
Share of unused material extraction in total material extraction, 2013

3,700
Number of Cologne cathedrals that could be built with the mineral raw materials extracted, 2013

0.5 percent
Share of mining sites in the total area of Germany, 2013

52 percent
Share of agricultural areas in the total area of Germany, 2013

1.3 percent
Share of raw material extraction sectors in total output value of the German economy, 2010

Data sources: ↘ page 80

Domestic extraction: Non-renewable raw materials

Raw material extraction in Germany refers to the extraction of coal from surface mining, harvesting of cereals or excavation of sands and gravels. In 2013, more than one billion tonnes of natural raw materials were extracted from natural systems in Germany; this represents 36 kilogrammes per capita per day. Non-renewable raw materials, such as minerals, fossil fuels and metal ores, constitute the largest share of domestic extraction at almost 75 %.

In 2013, Germany's used domestic extraction used amounted to 1,058 million tonnes (13.1 tonnes per capita). Of this total, more than 56 % (596 million tonnes) belonged to the category of mineral raw materials. Total biomass extraction in 2013 comprised 260 million tonnes (26 %) and fossil fuels a little over 19 % at 202 million tonnes (↘ page 68, Table A 1). Due to limited reserves within Germany, metal ores were almost entirely imported during the same period (⇢ Box, ↘ page 24, "International interdependencies: Germany's global raw material trade").

Where domestic extraction of non-renewable – or abiotic – raw materials is concerned, minerals and fossil fuels in particular have a role to play. Minerals are divided into construction and industrial minerals. A total of 535 million tonnes of construction minerals alone were extracted in 2013. The majority of these – approximately two-thirds – comprised pebbles and gravels, almost one-quarter concerned sands and the remainder were limestone, gypsum and other categories. These construction minerals are used on one hand for the expansion and maintenance of infrastructure in Germany: For example, Germany has one of the most densely developed and longest (almost 13,000 kilometres) motorway networks in Europe. On the other hand, the construction of buildings requires large quantities of these raw materials. In 2013 more than 194,000 new buildings were constructed in Germany. Although industrial minerals are less significant in terms of quantity, representing only 6 % of total abiotic extraction, special sands and clays, salts and fertilizer minerals nonetheless play an important role in areas such as the glass and ceramics industry, the chemicals industry and in agriculture.

In addition to this, 202 million tonnes of fossil fuels were extracted in 2013, 90 % of which comprised lignite, 4 % coal and 4 % natural gas. In 2013, Germany produced 183 million tonnes of lignite, making the country the largest producer of lignite worldwide. By way of comparison, this quantity means that Germany extracted almost 110 million tonnes more lignite than the world's second-largest producer, Russia.

Used raw material extraction in Germany, 2013

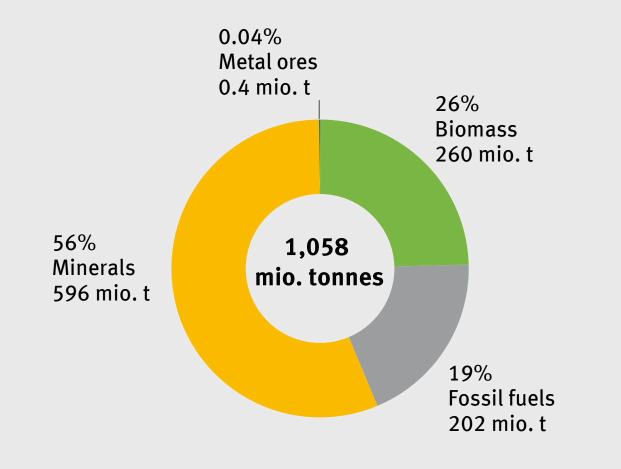


Figure 1 Source: Destatis, 2015 a

Used extraction of non-renewable raw materials in Germany, 2013

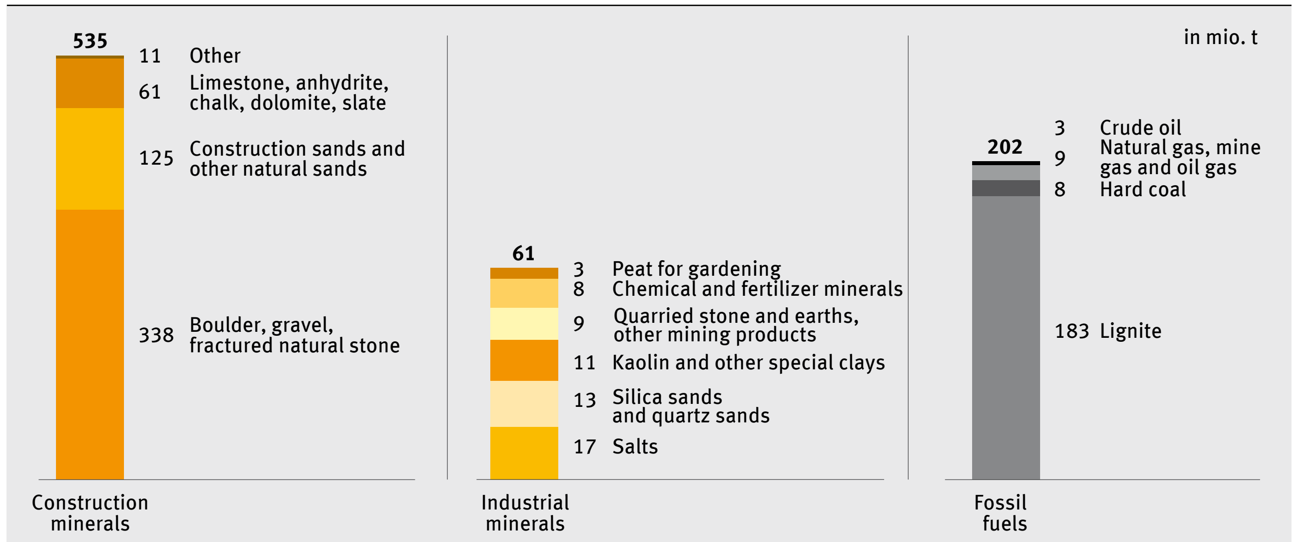


Figure 2 Source: Destatis, 2015 a

Comparison of fossil fuel extraction by selected countries, 2013

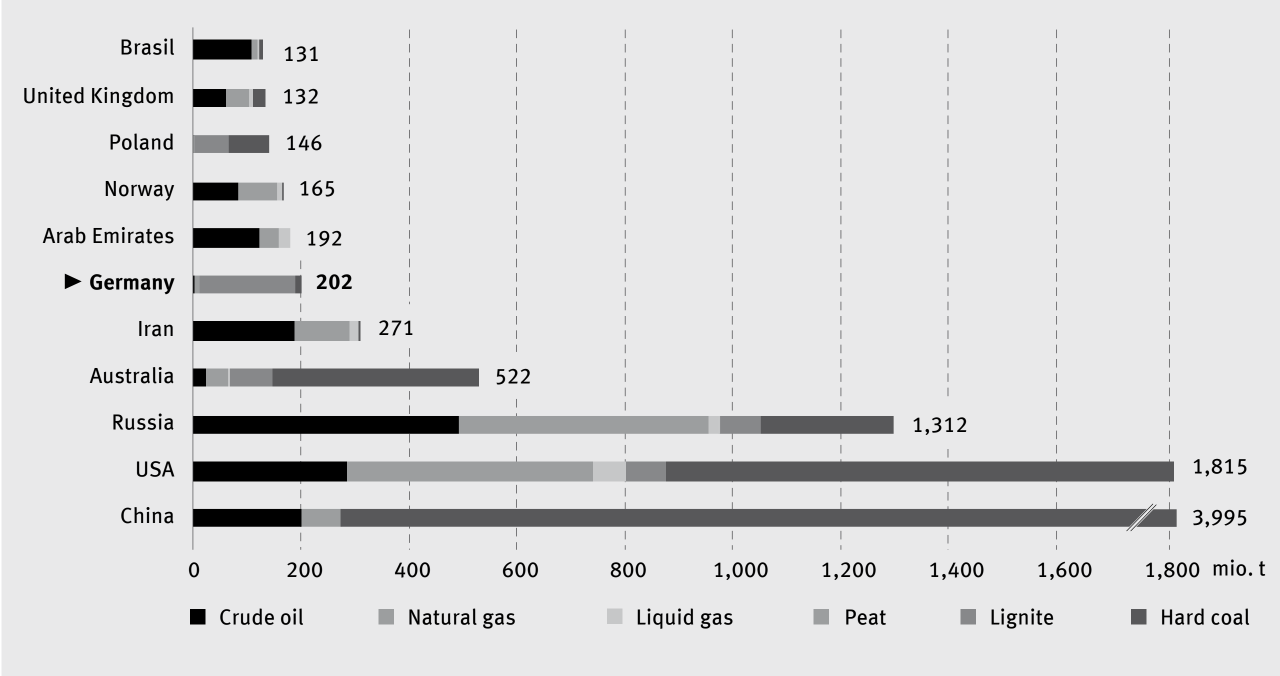


Figure 3 Source: WU, 2016 b

At 7.5 million tonnes, hard coal extraction within Germany in 2013 was significantly lower than the figure for lignite. Falling prices on the global markets and difficult mining conditions have meant that hard coal extraction in Germany has long been unable to compete internationally and domestic production has fallen drastically. The last working colliery in Germany is scheduled to close in 2018, whereupon the country's coal requirements will have to be met exclusively through imports.

The example of coal mining illustrates the high degree to which extraction of raw materials is dependent upon the availability of deposits. Accordingly, the extraction of oil and natural gas is very limited in Germany. In contrast, large reserves are to be found in Russia, the United Arab Emirates and Norway, which has specialised in these extractive industries (⇠ Figure 3). The distribution of reserves across the world has an important geopolitical dimension that is not only related to energy sources, since individual raw materials are often only extracted within a few countries. For importing countries, dependencies may occur as a result (↘ page 30, "Dependency on raw material imports"). The negative environmental impacts resulting from the use of fossil fuels, particularly relating to climate change, are fuelling debate regarding a transition to renewable energy sources and an absolute reduction in energy use. Furthermore, concerns about supply security and balances of power are also cited in arguments favouring this transformation.

In response to the challenge posed by high import dependency in the area of metal ores, support has been growing for the concept of the circular economy and increased recycling activities (↘ page 42, "Recycling as an alternative source of raw materials"). By these means, the input of new raw materials and therefore the dependency on imports from other countries can be significantly reduced. This is all the more important because there are only very few accessible reserves remaining in Germany today and exploiting them would be difficult and expensive to achieve, given high population density, other forms of use, and environmental protection legislation.

Metal ore mining is of only marginal importance in Germany

While a significant proportion of non-metallic raw materials, particularly potash and rock salt, and most quarried stone and earth is supplied by domestic extraction, Germany is almost entirely dependent on imports for the supply of primary metallic raw materials. 489,000 tonnes of iron ores were extracted in Germany in 2011, whereas total requirements amounted to around 826 million tonnes (Destatis, 2015 b).
Iron ore is an important basic material for the production of steel. The steel industry is a core industry, which provides key materials for the car manufacturing and engineering industries, for plant engineering and for the construction industry. In 2013, more than 87,000 people were employed in almost 90 companies within the German steel production sector. However, the sole extraction site for iron ore in North Rhine-Westphalia possesses a low iron concentration of around 10.5 %. Because of this, the iron ore coming from this source is only used as an aggregate material in the construction sector. The steel industry relies exclusively on imported iron ore, particularly from Brazil (BGR, 2014).

Domestic extraction: Renewable raw materials

Renewable raw materials such as cereals, forage crops or fish form the basis for our food supply. In 2013, 260 million tonnes of these renewable (biotic) raw materials were extracted from the environment in Germany – approximately one-quarter of total domestic extraction of all raw materials. Covering almost two-thirds of the total area of Germany, agriculture and forestry shape the German landscape.

If one were to take a bird's eye view of Germany, one thing would quickly become apparent: the cultivation and use of land for agriculture and forestry plays a central role. The quantities of biomass thereby obtained are impressive. In 2013, a total of 260 million tonnes of biogenic raw materials were extracted. Of this total, 48 % comprised fodder crops, 21 % were cereal crops, and 14 % comprised pulses and root crops, together with fruits and vegetables (↘ page 68, Table A 1). These raw materials were used for the production of food and animal feed, as well as fuels and construction materials. Only approximately one-tenth of total biomass extracted – almost 28 million tonnes – comprised hardwood and softwood together with bark mulch, produced by the forestry industry.

The statistics also record fishing and hunting as a part of domestic "extraction". In terms of volume, however, biomass from fishing (221,000 tonnes) and hunting (51,000 tonnes) are of low importance. After France, Germany is the second largest producer of biomass in the EU and the third largest timber producer after Sweden and Finland.

In 2013, more than half (186,193 km²) of Germany's total area of 357,340 km² was used for agriculture and almost one-third (108,162 km²) was woodland used primarily for forestry (↘ page 60, "Area"). Approximately one million people are involved in the cultivation of land used for agriculture, working in more than 285,000 businesses. More than one-quarter of the arable land is used for the cultivation of wheat crops (Destatis, 2014).

The cultivation of arable land in Germany has undergone great changes over recent decades. Whereas a century ago a farmer could provide for the nutritional needs of four people, 65 years ago this number rose to ten and it has risen today to 144 (Brand Eins, 2015). Multiple factors play a central role in this development: on one hand, increasing mechanisation of agriculture and the associated increase in energy input have made it possible for each farmer to cultivate a far greater area of land. Linked to this on the other hand, yields per hectare have also risen significantly in recent decades (⇢ Figure 5), a result also achieved through the increased use of machines and fertilizers. Thus wheat production more than doubled between 1980 and 2013 to

Used renewable raw material extraction in Germany, 2013

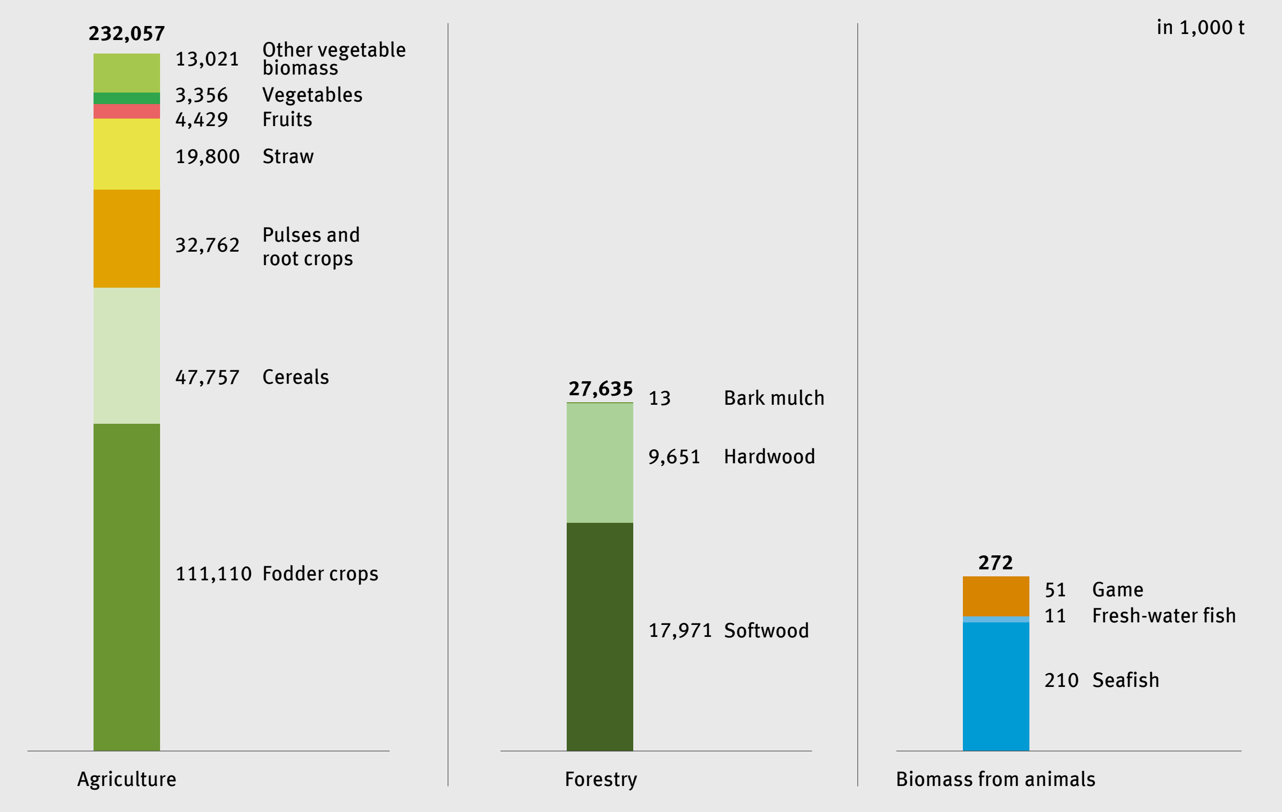


Figure 4 — Source: Destatis, 2015 a

Development of yields for selected cereals in Germany, 1965–2013

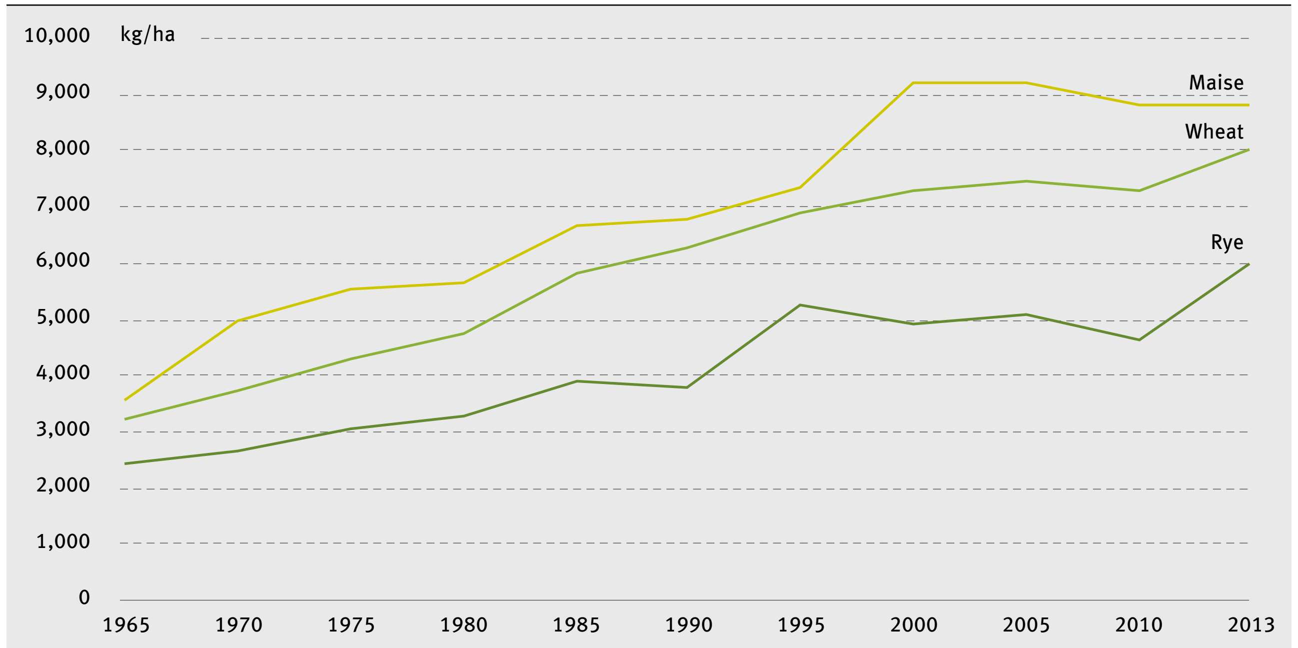


Figure 5 — Source: FAOSTAT, 2015

reach 25 million tonnes in 2013, although the area used for wheat cultivation only increased to an insignificant extent in the same period.

Particularly in the context of increased yields and the raw material inputs required to achieve these (e. g. for pesticides and fertilizers) as well as the related environmental impacts, there is debate about the extent to which industrialised agriculture needs to develop in the direction of more environmentally friendly farming methods. Organic farming operates in largely closed nutrient cycles, arable and livestock farming are coupled at farm level or at least regionally, and the use of chemical synthetic pesticides and mineral fertilizers is avoided.

Livestock farming in Germany 2014 / 2015

Kind of livestock	Stock (mio.)
Cattle	12.6
Pigs	27.7
Sheep	1.6
Laying hens	39.6

Table 1 — Source: Destatis, 2015 c

Intensive resource use in livestock farming in Germany

The statistics on domestic extraction do not include livestock such as cattle, pigs or sheep, because they are regarded as products of our economic system. Nonetheless, their "production" requires the extraction of biogenic raw materials in the form of animal feed, particularly protein-rich imported feedstuff such as soya, together with silage, hay etc.

In total, livestock farming in Germany involves more than 40 million cattle and pigs. In addition to these, there are roughly the same numbers of laying hens and 1.6 million sheep (⇠ Table 1). The larger the animal, the greater is the investment of resources required to maintain its existence. Approximately half of all the biomass extracted in Germany is used as animal feed while the residues are used to a lesser extent as litter for livestock farming (Fischer et al., 2016). In addition to this, large quantities are imported material, for example, Brazil or Argentina, which are often linked with ecological problems, such as deforestation, or social problems, such as the forced displacement of indigenous peoples (SERI et al., 2013).

These facts and figures illustrate the high degree of resource intensity involved in the production of animal products. In this context it has therefore been argued for some time already that we should address human nutrition with a greater level of awareness, which would not only have a positive effect on health but could also significantly reduce the resource requirements of providing food supplies. It should be noted that in addition to the raw material requirements for meat production, there is an additional need for other resources, such as land and water (↘ page 56, "Resource use: A complementary viewpoint").

Trends in raw material extraction

In recent decades, global economic growth has produced a strong upward trend in the extraction of raw materials worldwide. Consequently, reserves are increasingly being exhausted or newly exploited, with corresponding impacts on the environment and on supply for raw materials on the world markets. In Germany, however, a trend running counter to these developments is evident: raw material extraction in Germany is decreasing overall. Raw material extraction in 2013 was almost 21 % less than in 1994. While the share of non-renewable raw materials is decreasing, there has nonetheless been a strong increase in recent years in the extraction of renewable raw materials from agriculture and forestry.

In the period from 1994 to 2013, raw material extraction in Germany decreased from 1.3 billion tonnes to 1.06 billion tonnes; this represents a reduction of nearly 21 %. A particularly significant decrease is seen in the extraction of construction and industrial minerals, 29.5 % less than in 1994. Fossil fuels too have shown an almost continual downward trend from almost 280 million tonnes in 1994 to 202 million tonnes in 2013 – a reduction of more than one-quarter. Only biomass has shown a significant increase of 23 % (↘ page 68, Table A 1).

There are multiple reasons for these developments. On one hand, the economy has managed to use raw materials with increasing efficiency, as well as reducing the input of primary raw materials through recycling (↘ page 42, "Recycling as an alternative source of raw materials").

On the other hand, a process of relocation to other countries is evident. Raw materials are extracted or processed more cheaply abroad than in Germany, and they are in many cases imported from other countries as a consequence (↘ page 28, "Indirect import and export flows"). Where biomass is concerned, the increase is related to the growing demand for feedstuff and for biomass for material use and energy production (↘ page 20, "Raw material extraction by the federal states"). This trend is also a reflection of the current German energy strategy. A move away from fossil fuels and towards renewable sources of energy does however have impacts on a country's raw material requirements, since the production of wind turbines and solar panels also requires the input of a range of raw materials (↘ page 62, "Flow resources").

Trends in used raw material extraction in Germany, 1994 – 2013

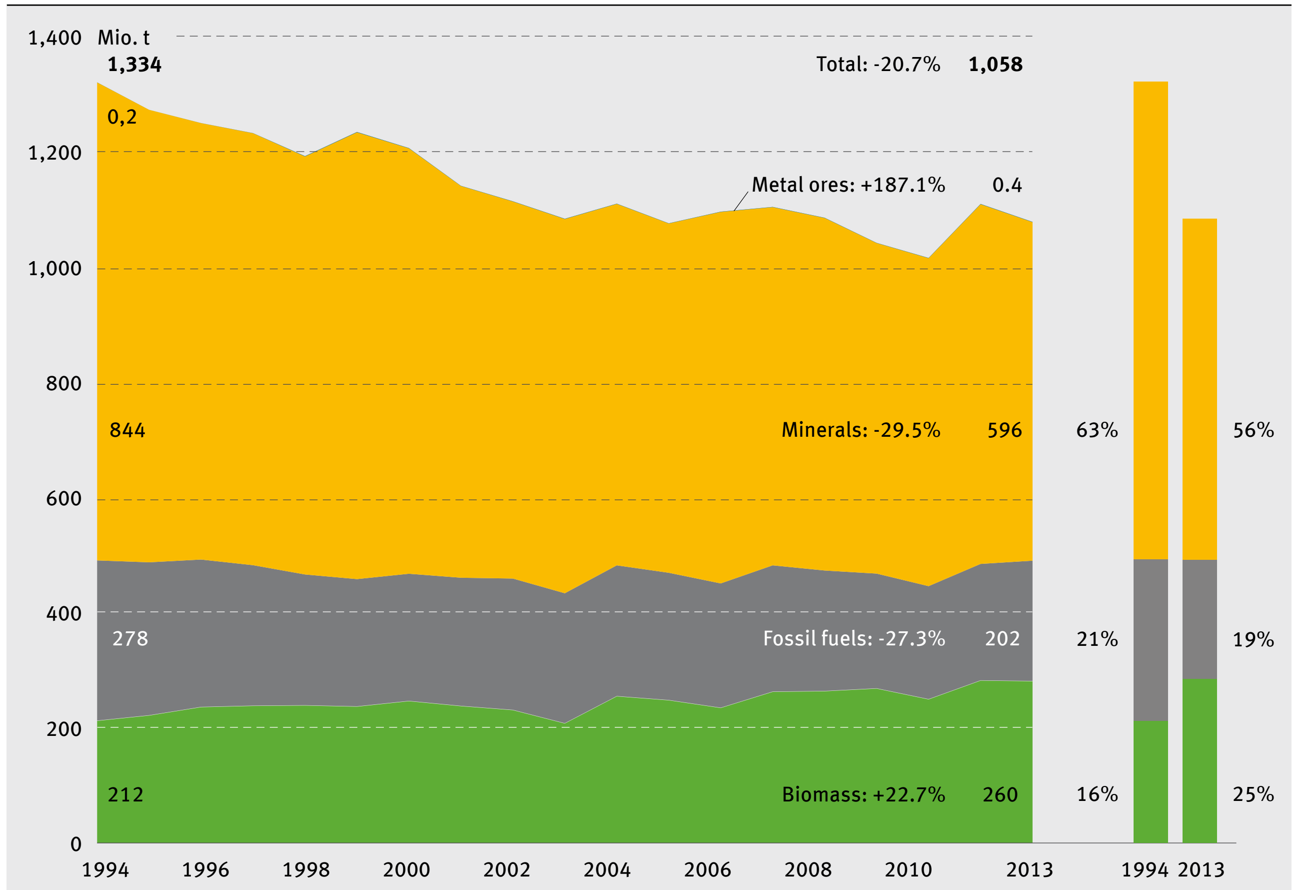


Figure 6 Source: Destatis, 2015 a

Trends in the extraction of selected minerals, fossil fuels and renewable raw materials, 1994 – 2013, indexed to 1994

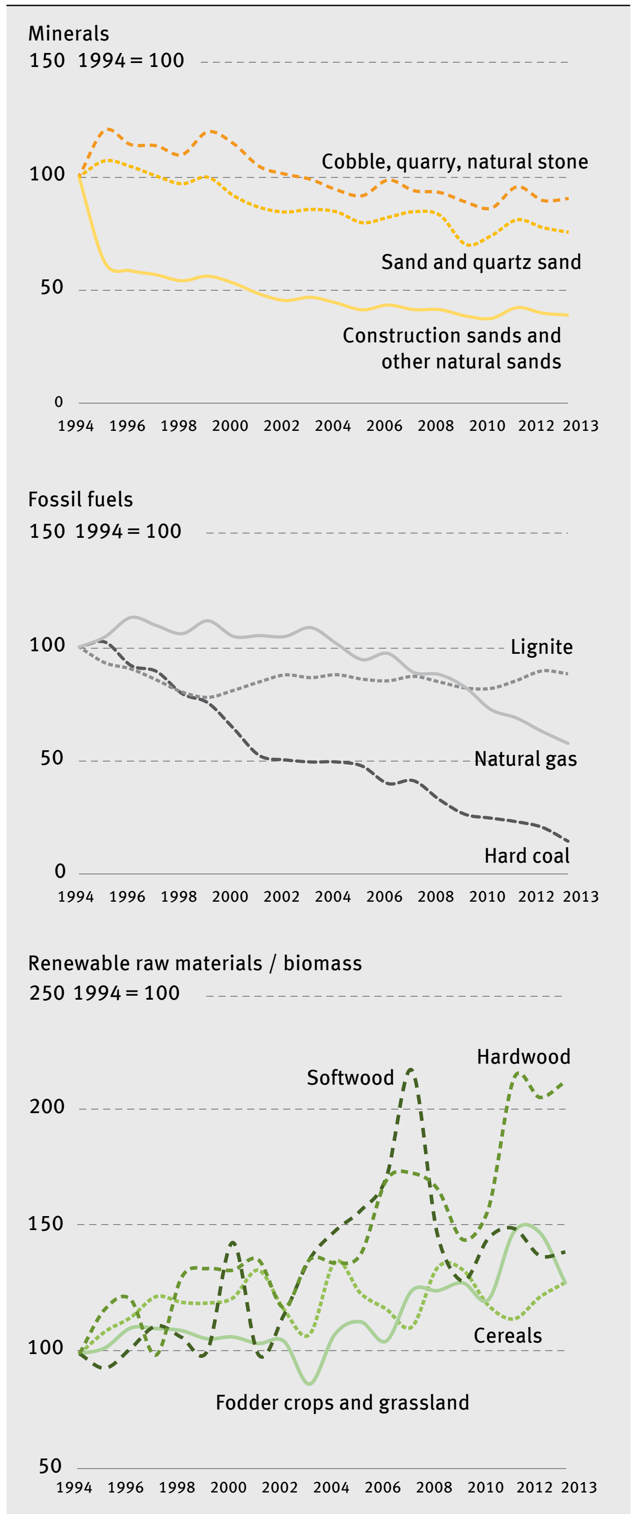


Figure 7 Source: Destatis, 2015 a

Price fluctuations on global markets – and the competitiveness of domestic raw material industries related to these – can exert great influence over extraction rates in Germany. This is particularly evident in the case of hard coal. Providing cheaper forms of energy, oil and natural gas as well as lignite, which is cheaper to obtain through surface mining, and nuclear energy have replaced hard coal in numerous areas of application. Furthermore, transportation and logistics have advanced, bringing their costs down. Since extraction costs are often lower abroad, even when transport costs are factored in (↖ page 14, "Domestic extraction: Non-renewable raw materials"), almost 45 million tonnes less hard coal was mined in Germany in 2013 than in 1994 (⟵ Figure 7). At the same time, however, imports rose by around 36 million tonnes.

Where domestic extraction alters because of political changes, fluctuating world market prices or other factors, this also has indirect effects on other sectors in turn. Thus the number of those working in lignite mining in Germany fell from around 150,000 people in 1980 to just over 21,000 in 2014 (www.kohlenstatistik.de). At the same time, the numbers of those working in the wind energy sector has been rising (BWE, 2016; ↘ page 62, "Flow resources").

In the biomass sector, almost twice as much hardwood was harvested through forestry in 2013 as was the case ten years previously. Equally, over 40 % more softwood was obtained. In this respect, 2007 was an exceptional year with a timber harvest of almost 28 million tonnes. This was attributed to Hurricane Kyrill, which caused great damage to forested areas in Germany.

Cereal production was consistently subject to small fluctuations. This is not surprising, since the harvest is strongly dependent on weather conditions. Thus, for example, 2008 and 2009 were record years, whereas 2003 witnessed heavy losses (⟵ Figure 7). Changes in harvest quantities as well as climatic conditions are also reflected in the level of fertilizer input.

These trends in raw material extraction also have consequences for other types of resources. For example, agriculture are sectors that make intensive use of both land and water resources. Moreover, the exploitation of new reserves for non-renewable resources or expansion in the use of new energy forms requires large quantities of raw materials, land and water (↘ page 56, "Resource use: A complementary viewpoint").

Raw material extraction by the federal states

Raw material extraction in Germany is unequally distributed across the federal states. This variation is determined by factors such as the availability of raw materials, the size of federal states in terms of area, population density and economic performance. In absolute figures, the four states of North Rhine-Westphalia, Bavaria, Lower Saxony and Baden-Württemberg together account for approximately 60 % of Germany's total domestic extraction. In per capita terms, however, the figures for domestic extraction of raw materials in Brandenburg and Saxony-Anhalt are significantly higher than in other federal states.

Germany is one of only a few countries in Europe in which statistical data on the extraction of and trade in raw materials is collected not only at national level but also for the individual federal states. The fact that such data is available allows for the identification of variations in the extraction of the different raw material groups and for these data to be related to other key figures such as GDP and population size or density.

Both natural environmental and economic factors exert great influence over the quantities of raw materials that are extracted within each of the federal states. Reserves of non-renewable raw materials, such as fossil fuels and mineral raw materials are unequally distributed among the federal states because of geological conditions. Where the extraction of biotic raw materials is concerned, the size and cultivation intensity of forested and agricultural areas are decisive factors.

If figures for all raw material categories are considered together, it becomes clear that the highest levels of raw material extraction occur in the federal states with the largest area, a high level of GDP per capita and a large population in absolute terms. This is particularly the case for North-Rhine Westphalia, Bavaria, Lower Saxony and Baden-Württemberg. Almost 60 % of all domestic extraction in Germany takes place in these four federal states (↘ page 69, Table A 2).

An entirely different picture emerges when the focus is placed upon per-capita extraction. Brandenburg and Saxony-Anhalt recorded far higher levels of extraction, with values above 31 tonnes per capita in 2013, than in other federal states. By way of comparison: the federal average for the same year was 13 tonnes per capita. The population density in these federal states was lower by a factor of 5–6 than that of North Rhine-Westphalia, which – apart from Berlin, Hamburg and Bremen – has the highest population density in Germany. In North Rhine-Westphalia, per capita extraction in 2013 was 15 tonnes. The lowest values for per-capita extraction in 2012 were those for Hessen and Saarland, which also show very high levels of population density (↘ page 69, Table A 2).

The extraction of fossil fuels in the German federal states relates largely to lignite mining (↖ page 18 ,"Trends in raw material extraction"). Almost 90 % of the total extraction of fossil fuels takes place in only three federal states: North Rhine-Westphalia, Brandenburg and Saxony.

Per capita raw material extraction in the German federal states (excluding federal city-states), 2013

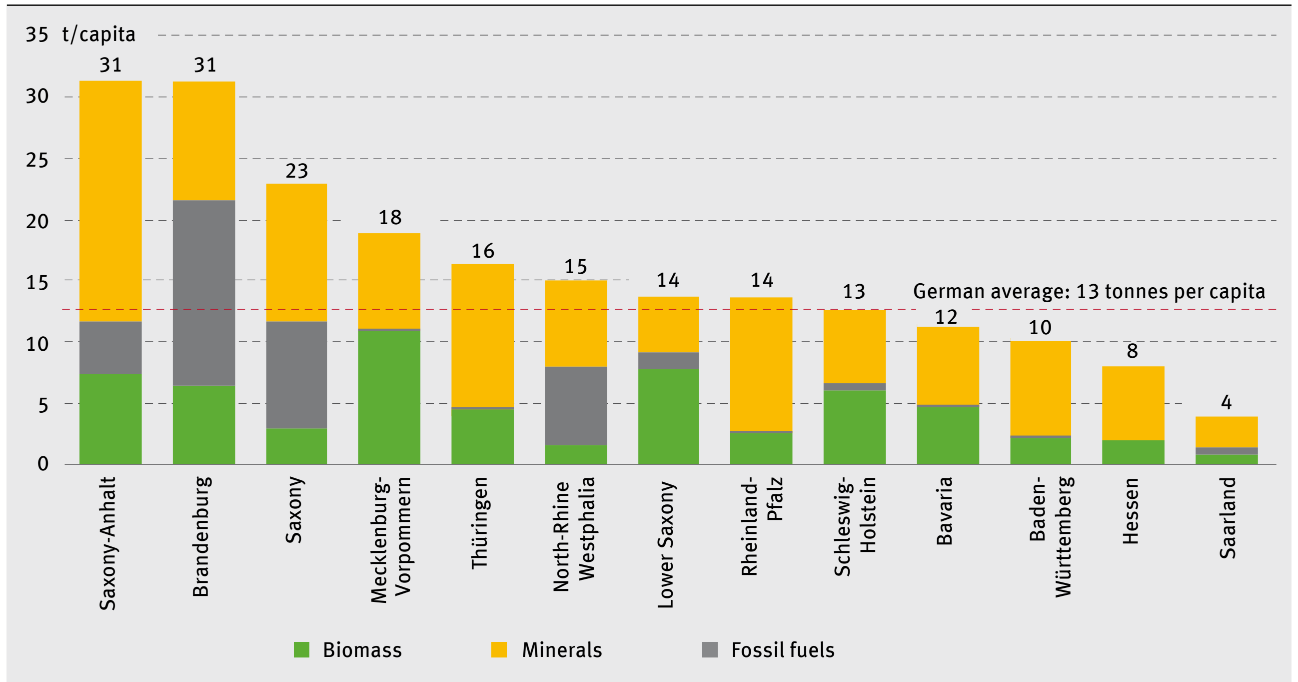


Figure 8 Source: Statistische Ämter der Länder, 2015

Raw material extraction in the German federal states (excluding federal city-states), 2013

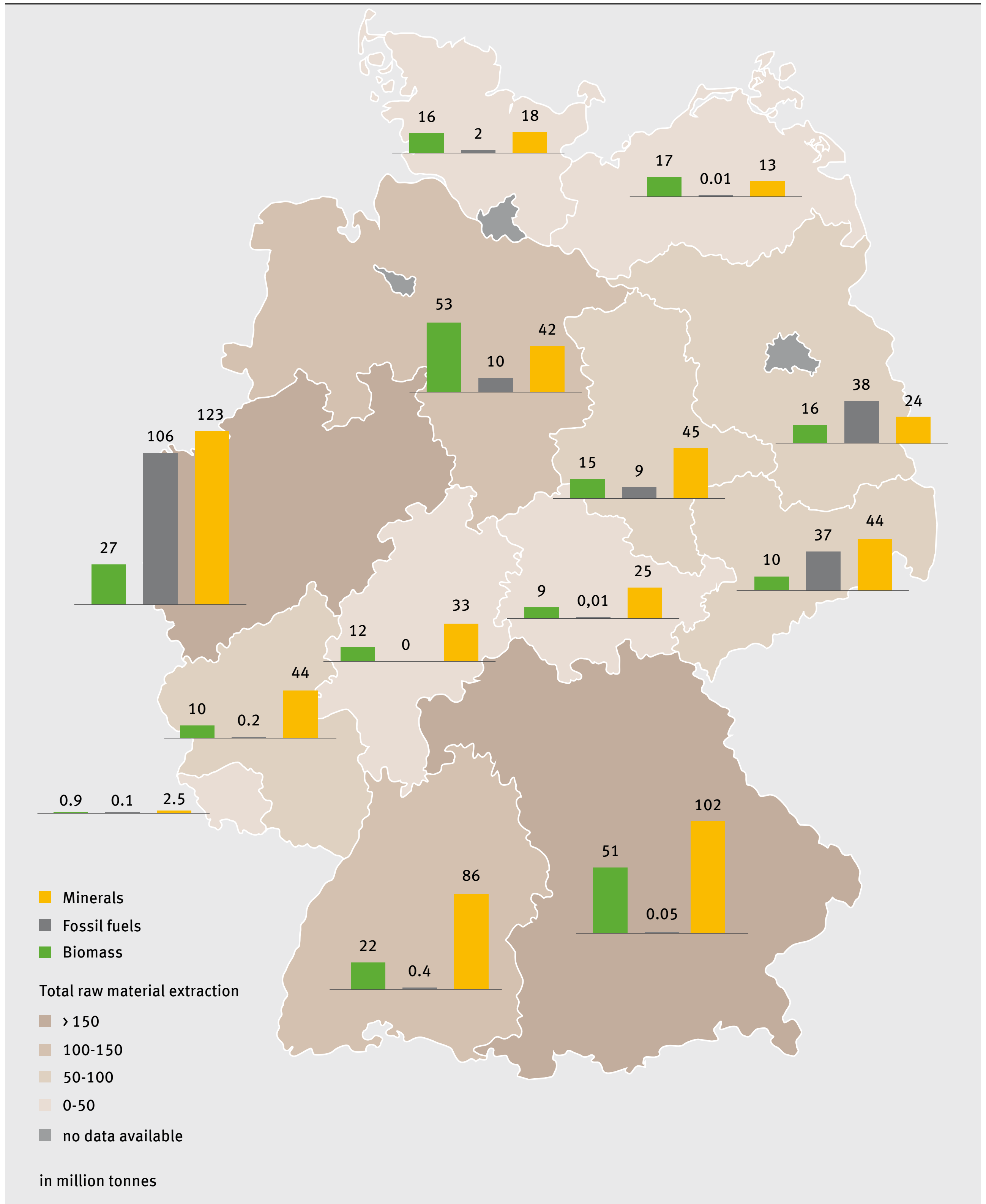


Figure 9 Source: Statistische Ämter der Länder, 2015

Extraction of biotic raw materials has been increasing in all German federal states over the past 20 years. The federal states of Schleswig-Holstein, Brandenburg and Mecklenburg-Vorpommern have shown the strongest increases, with an overall growth of more than 70 % during the period 1994–2013. In all three of these federal states, growth was particularly linked to increased cultivation of forage crops and the harvesting of biomass from grassland. The latter is used particularly as feed for the dairy industry, and increasingly as a raw material for the production of biogas. A similar trend can be observed in Bavaria and Lower Saxony, the two largest producers of biomass in quantitative terms. Since cattle stocks in Germany are falling, it may be assumed that the share of biomass used for energy will increase further in the future.

Unused material extraction

Not all materials that are extracted or harvested in Germany are exploited economically. Significant quantities – almost two-thirds – of the total quantity of materials extracted comprise e. g. overburden from mining or harvest residues from agriculture. This unused domestic extraction renders the overall magnitude of material extraction, since gaining access particularly to extraction of non-renewable energy sources often requires the displacement of large quantities of soil, rock and sand.

Extraction of raw materials involves the displacement of large quantities of materials, which cannot be exploited economically and therefore remain in the environment after extraction. According to the method of material flow analysis, these are recorded as "extraction without economic value" or "unused extraction". This includes, for example, certain components of the tailings and overburden from mining, excavated soil from building construction and engineering, harvest residues from agriculture and forestry and bycatch from the fishing industry. The quantities of unused extraction are determined by multiple factors: the accessibility of raw materials, the efficiency of extraction and the extent to which they are subsequently used within the economic system. Particularly with regards to mining it makes a considerable difference whether materials are obtained by open pit or deep mining and which amounts of excavation are required to reach the raw material in an open pit.

Unused material extraction is also of great relevance, as it illustrates the scale of additional human intervention in the natural environment. For example, lignite mining produces enormous amounts of overburden, as a result of which the landscape of entire regions is altered and habitats destroyed (⇢ Boxes). Great efforts are also being made, however, to recultivate these portions of land and to restore them to their original state – potentially creating new habitats (also for humans). How successful such a recultivation is realised depends essentially on the governance structure in the extraction regions. Another example of the impacts of unused extraction may be found in the fishing industry. Current common fishing practices mean that tonnes of marine creatures that cannot be used to create economic value die in fishing nets and are therefore thrown back into the sea. This bycatch can amount to 20 kg for each kilogramme of caught fish (WWF, 2016). This appears particularly problematic when one considers that the majority of the fish stocks in European waters have been regarded for years as over-exploited.

Share of used and unused material extraction in Germany, 2013

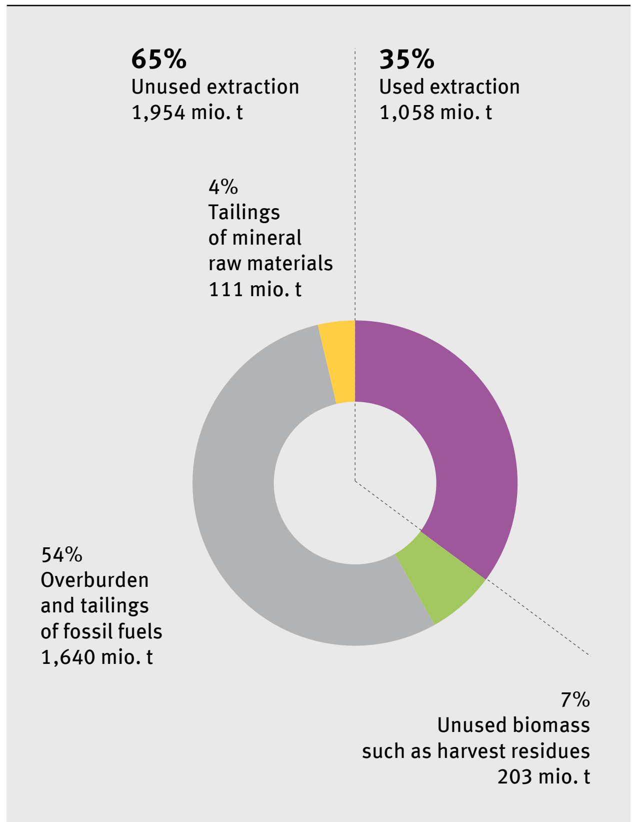


Figure 10 Source: Destatis, 2015 a

The environmental impacts of lignite mining in Germany

Lignite is currently almost exclusively extracted through surface mining. This requires the removal of entire strata, since deposits are often located several hundred metres below the earth's surface. Thus a further eight tonnes of overburden must be removed and transported on average for each tonne of lignite extracted (UBA 2016 a). At the same time, the so-called coal seams often lie below the water table, which makes it necessary for this level to be lowered, affecting the water balance of the surrounding regions. In 2009 in the Lusatia region of Saxony, 230 million cubic metres of groundwater were pumped out (Grüne Liga 2013), which represents one and a half times the entire annual water requirement of the inhabitants of Berlin (BWB, 2016). As a result, stream levels fall and wetlands dry out, soil structure alters and widespread soil subsidence over a radius of several kilometres can occur.

The landscape's appearance and land use are fundamentally altered in mining areas and in many cases, local populations are displaced. At the same time, land that has provided high agricultural yields over decades becomes no longer available for its original use. The significant external environmental costs (e. g. emissions, air pollution, and soil degradation) that accrue due to these extraction activities are not accounted for in the price of the coal thus obtained (BUND, 2016).

In addition to the large quantities of raw materials that are extracted annually and are used within the economic system (↸ page 20, "Raw material extraction by the federal states"), a further quantity of materials that is more than double this amount is extracted yet remains unused. In 2013 this amounted to almost 2 billion tonnes of unused materials. By far the largest share – 1.6 billion tonnes – comprised overburden and tailings produced through the extraction of fossil fuels (↘ page 68, Table A 1). The quantity of unused material produced per tonne of used extraction is closely linked to the type of raw material (⇢ Figure 11).

Total unused extraction in the period from 1994 to 2013 fell by 13 %, from around 2.2 to 1.95 billion tonnes, which development may be ascribed primarily to the fall in coal production in Germany during that period. At the same time, more than one additional tonne of overburden is produced for each tonne of used raw material in comparison with the mid-1990s. This means that the ratio of unused to used extraction in the extraction of fossil fuels has shifted. The trend by which the share of residual materials increases as exploitation of raw material reserves progresses is not only evident in Germany but also in many other countries.

Where mineral raw materials are concerned, the ratio is very different: per tonne of exploited mineral raw material, "only" approximately 200 kilogrammes of mine tailings were accrued in 2013. This is partly due to the fact that reserves of gravels, sands and industrial minerals are generally easier to access than those of fossil fuels.

While the quantity of used harvest in the period 1994–2013 rose by as much as a quarter, the quantity of unused biomass thereby accrued only rose by approximately 1 % and in 2013 amounted to a total of 203 million tonnes. The development thus shows clearly that biomass has been utilised more efficiently in general in recent years and that less residues accrued per tonne of harvested material. In absolute figures, the largest quantities of unused biomass are produced by the cultivation of forage crops, sugar beet and potatoes. The cultivation of grain and forage crops produce large quantities of straw, part of which remain on the field and are incorporated into the soil. In the case of forestry, the proportion of unused residues is lower, although in 2013, two-thirds more wood was extracted than in 1994, as a result of which the quantity of unused extraction also increased. Specific parts, such as crown material or branches, typically remain in forested areas after logging.

Used and unused raw materials extracted in Germany, 1994 and 2013

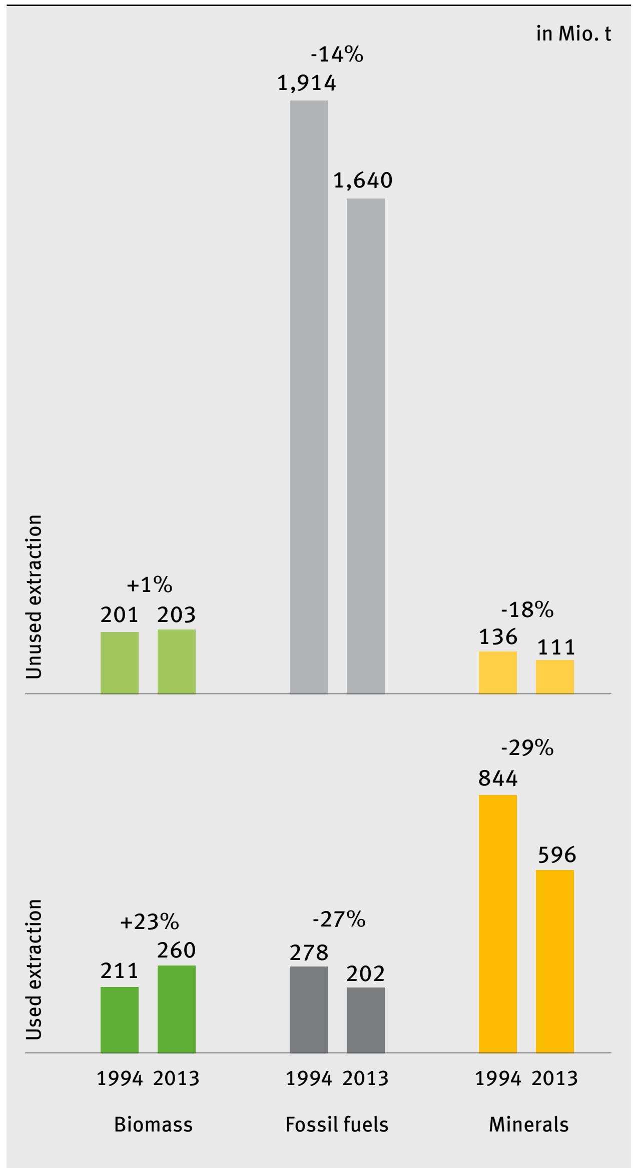


Figure 11 Source: Destatis, 2015 a

Recultivation and ecological land restoration measures

After ceasing mining operations, the land thus occupied needs to be assigned a subsequent use through recultivation, and the self-regulation of the water balance must also be restored. In Germany, this strategy is regulated by the Federal Mining Act and by the legal provisions for each federal state. This recultivation is accomplished by several means: through afforestation, agricultural use, the establishment of nature conservation areas or through flooding, thereby creating artificial lakes and recreation areas. Prominent examples of this approach in Germany include the Ville lakes in the Rhineland lignite mining region, the Neuseenland area south of Leipzig in the central German lignite mining district and the Lusatia lakes district (LMBV, 2009, 2014).

The international interdependencies: Germany's global raw material trade

1.1 billion tonnes
Used domestic extraction, 2013

0.6 billion tonnes
Direct imports, 2010

99.7 percent
Share of imports in total demand for metal ores, 2010

248 billion tonnes
Export surplus, 2015

40 percent
Share of exports in GDP, 2015

1.7 billion tonnes
Direct and indirect imports, 2010

1.5 billion tonnes
Direct and indirect exports, 2010

78 percent
Share of goods transported by road in total physical goods transport, 2014

24,110
Number of containers loaded/unloaded daily in Hamburg, 2015

Data sources: ↘ page 80

Direct imports and exports

A significant share of raw materials required by the German economy is not extracted in Germany itself but is imported from elsewhere. These raw materials are used to produce a broad range of products for domestic consumption as well as for export. International trade plays a very important role for Germany: 40 % of GDP is created through the export of products and services, and the trend is rising. The role of the manufacturing industry is significant here. While Germany imports many raw materials and goods with a low level of processing, exports are comprised largely of high value goods.

The German economy's demand for raw materials is supplied from two sources: from domestic extraction (↖ page 12, "National perspective: domestic raw material extraction") and from imports coming from other countries. Imports include raw materials and goods that are either not available within the country or that can be more cheaply extracted or produced elsewhere. Domestic extraction amounted to 1.06 million tonnes in 2013, while 624 million tonnes of raw materials and goods were imported (↘ page 70, Table A 3). This figure refers to the actual (net) weight of traded raw materials and products recorded in foreign trade statistics, which do not account for the inputs required along the product chains outside Germany (↘ page 28, "Indirect import and export flows").

If one compares direct physical imports with exports, it becomes apparent that Germany imports almost 60 % more raw materials and goods than it exports. Where imports are concerned, finished metal products also play an important role (also 9 %). Shares of exports exhibit a more even distribution between the various stages of processing, although finished products made from metals (e. g. automobiles or machinery) constituted the largest single category, at 19 % of total physical exports in 2013 (↘ page 70, Table A 3).

If physical values are compared with monetary values, the great importance of trade for the German economy and society – not only in terms of the supply of raw materials but also in its role as the driver of economic growth – becomes evident. In 2013 the German economy achieved an export surplus for the industrial sector (raw materials, semi-finished products, finished products) of almost 220 billion Euros (this figure reached almost 250 billion Euros by 2015), generated largely by finished products (92 % of total monetary exports). In contrast, there was an import surplus in the case of raw materials and semi-finished products. Whereas imports of raw materials and semifinished products are largely of high mass yet comparatively low value, the monetary trade balance shows that it is primarily finished products with a lower weight but higher value that are exported. This emphasises the scale of value creation within Germany. While, for example, intermediate products such as automotive or machinery components are imported, the most important export goods in monetary terms in 2015 were automobiles, followed by machinery and chemical and metal products (Destatis, 2016 a).

The growing trade in raw materials and products goes hand in hand with the globalisation of the economic system; it is both its driver and its result. Thus a significant increase in trade flows has occurred over the last 20 years. In the case of Germany, physical imports rose between 1994 and 2013 by 35 %, and exports by as much as 72 %. Oil represented more than half of all imports of fossil fuels in 2013, although this share remained constant through the entire period, while imports of coal and gas rose by 155 % and 115 % respectively. Where exports were concerned, the quantity of finished products doubled, while their share in total exports rose from 37 % to 44 % (↘ page 70, Table A 3).

Measured in physical units, almost two-thirds of total direct imports into Germany in 2013 came from only ten countries. These included countries outside the EU, in particular Russia (the import of fossil fuels, primarily natural gas), Brazil (the import of biomass, particularly feedstuff and metallic raw materials) and the US. Almost 70 % of Germany's physical exports were also supplied to ten countries, all of these within the EU, apart from China (with a share of a little over 2 %). The Netherlands, due to the location of Europe's largest port at Rotterdam, constitutes Germany's most important intermediary trade partner, both in terms of direct imports and of direct exports (⟶ Figure 14).

Physical and monetary aspects of Germany's direct trade flows, 2013

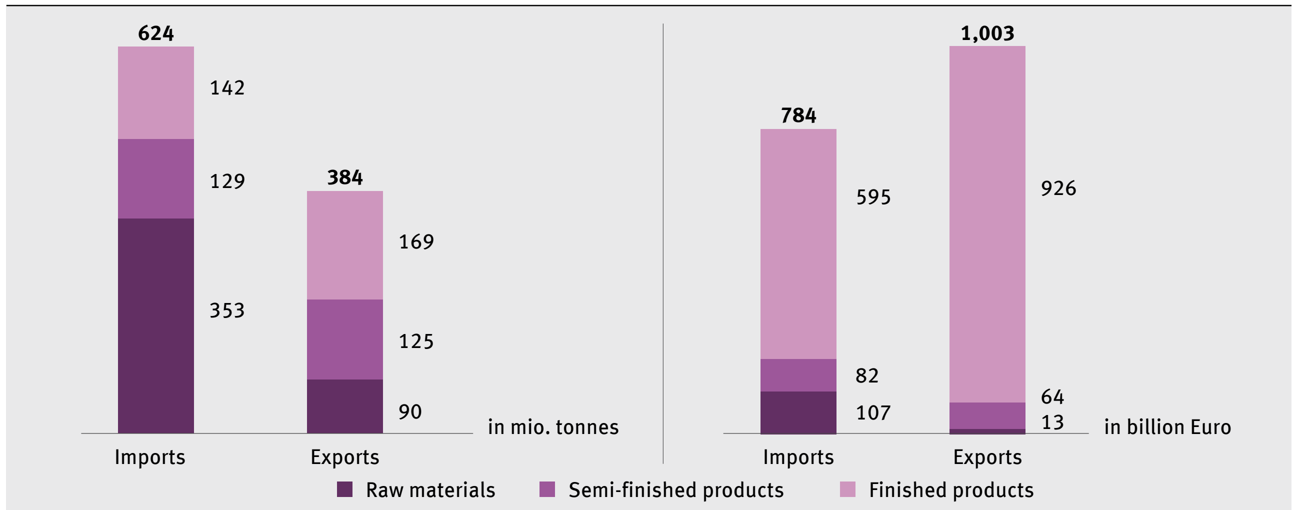


Figure 12 Sources: Destatis, 2015 a, d

Trends in Germany's physical imports and exports, 1994 and 2013

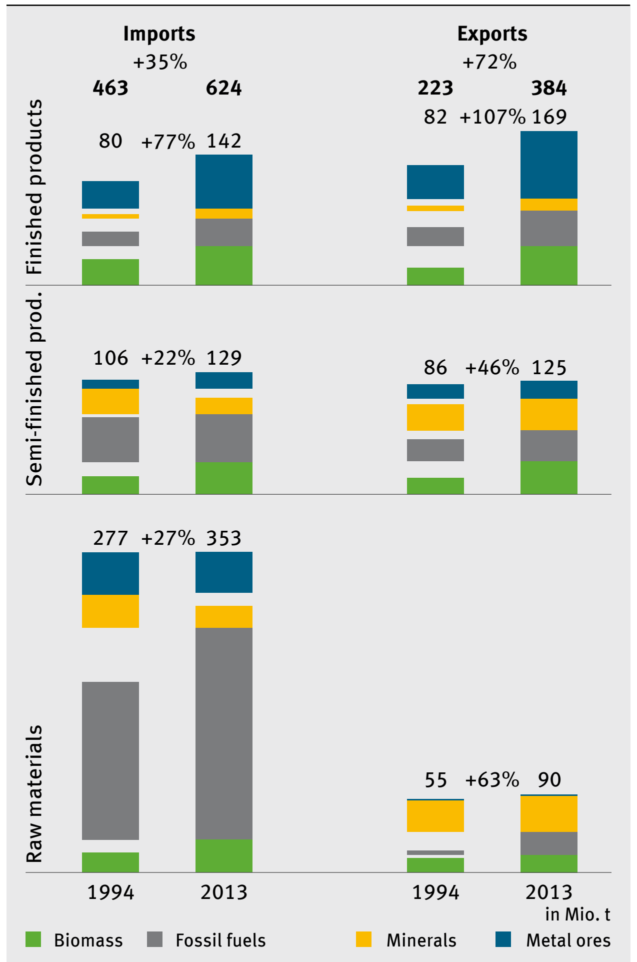


Figure 13 Sources: Destatis, 2015 a, d

Germany's major trade partners for physical imports (above) and exports (below), 2013

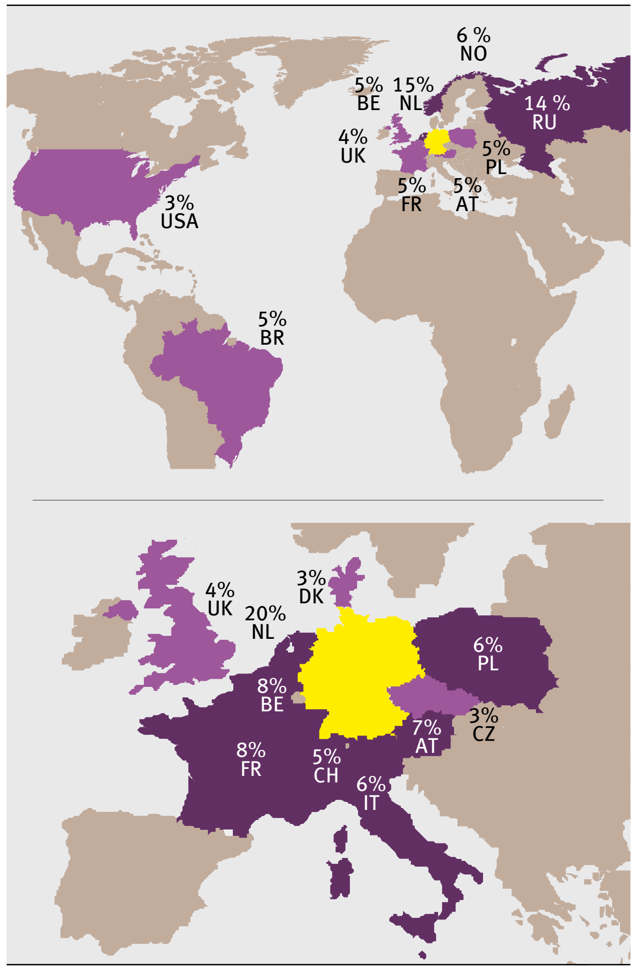


Figure 14 Sources: Destatis, 2015 a, d

Global raw material flows behind an everyday product: The example of "hazelnut spread"

Hazelnut-chocolate spread provides a good example of the extent to which globalised supply chains also form the background to everyday products. While some of the contents, such as skimmed milk, are sourced locally, the long journey taken by other components can be traced back to their originating countries. The hazelnuts come from countries such as Turkey, the palm oil from Malaysia or Indonesia, the cocoa from e. g. Nigeria, the sugar largely from Brazil, and the vanilla flavouring from China. This example explains why it is so important to consider the international dimension when analyzing the resource use of a single country. (OECD, 2012)

Indirect import and export flows

Raw materials and products, which are imported to Germany from other countries, have a previous history, since significant quantities of raw materials are often additionally required as inputs along their production chains. In the case of a few raw materials, particularly metal ores, these so-called "indirect flows" are approximately six times larger than the direct trade flows involved. Since the production of many of these traded raw materials and products are linked to negative environmental impacts in other countries, the indirect flows reveal Germany's shared responsibility for global environmental problems.

Production and value creation chains are becoming increasingly complex. Along the way from the original extraction of the raw materials to the production of finished consumer goods, they often involve numerous processing steps that cross many national boundaries. Each of these processing phases requires inputs of new ingredients or components. The consumer product eventually created thus has a previous history in terms of the raw material inputs involved; these are referred to as "indirect flows". In addition to the recorded figures on ↖ page 26 on direct imports and exports, for indirect flows, the components of a product are converted into their so-called "raw material equivalents" (RME). Thus an automobile imported into Germany is accounted for not in terms of its actual net weight but in terms of gross weight i. e. the weight of all the raw material inputs along the entire production chain (including steel from iron ore, plastics from oil, etc.). The sum of these raw material equivalents provides the indirect flows of a product and can be calculated for all internationally traded products, to arrive at a comprehensive picture of the global impacts of Germany's international trade.

Comparison between net weight and indirect flows for Germany's imports and exports, 2010

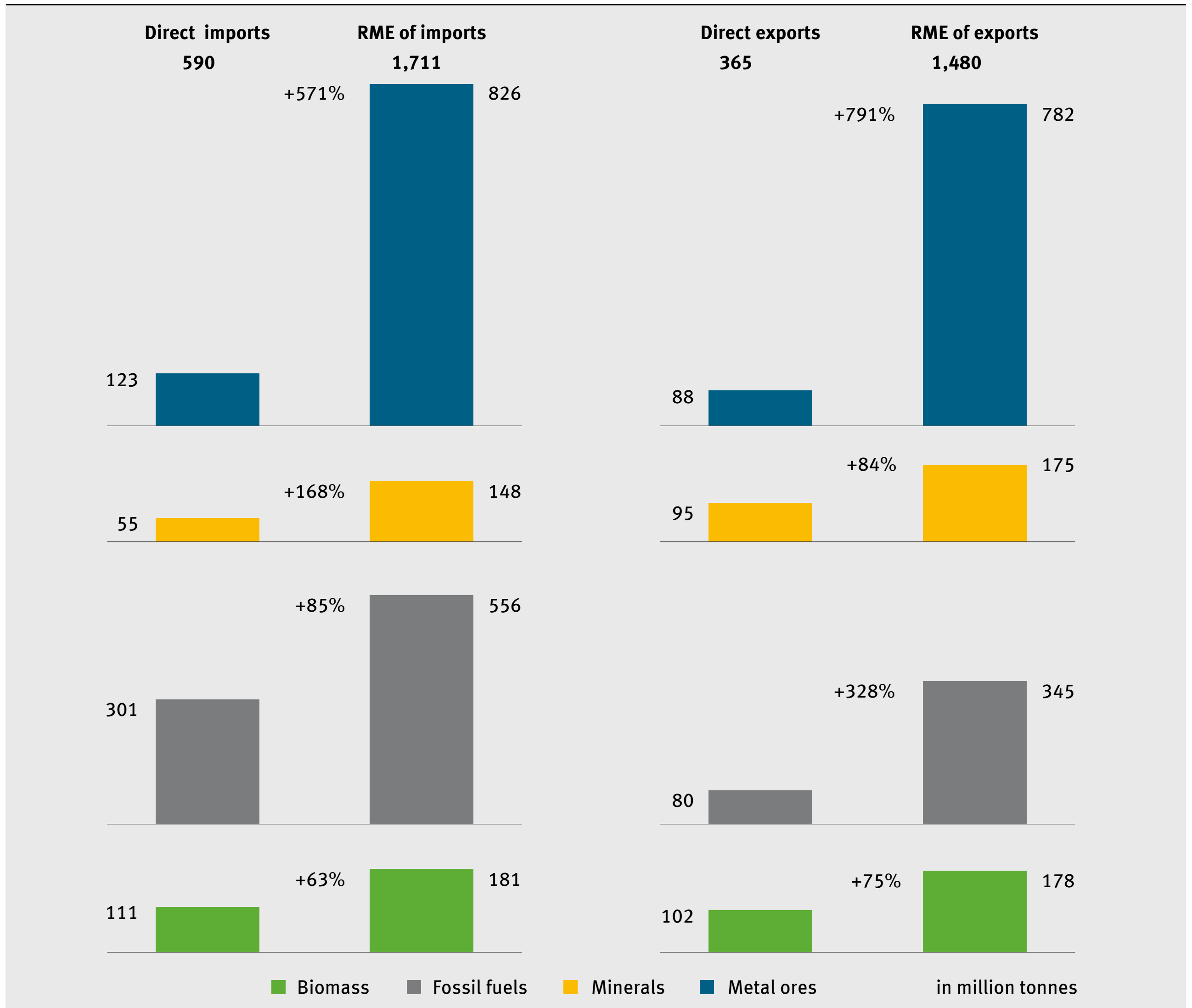


Figure 15 Source: Destatis, 2015 a

Analysis of the raw material equivalents in 2010 as the most recent calculation year (↖ page 10, "Methodological background") shows that far more raw materials were indirectly imported than were extracted within Germany itself. In 2010, net imports of indirect flows, i. e. imports (1,711 million tonnes) minus exports (1,480 million tonnes), amounted to 231 million tonnes (← Figure 15). This amount represents a little more than one-fifth of domestic extraction in the same year (↖ page 18, "Trends in raw material extraction"). In other words, Germany is also a net importer of raw materials in terms of indirect flows. The largest net imports comprise the raw material category of fossil fuels, at more than 211 million tonnes (imports: 556 million tonnes, exports: 345 million tonnes). For metal ores and biomass too, Germany's indirect imports are greater than the indirect exports. Only in the case of minerals is there a net export figure of 27 million tonnes (← Figure 15).

The ratio between indirect and direct flows in 2010 was 3:1 for imports and 4:1 for exports. Within this, large differences between individual raw material groups are discernable. There are more indirect flows within the exports of products from metals and fossil fuels than within imports for these groups. This makes clear that raw materials and semi-finished products are imported to undergo further processing as components of various export goods (↖ page 26, "Direct imports and exports"). The German export industry is also particularly energy-intensive, since exports contain almost two and a half times as many fossil fuels and one-third more metal ores than are found in imports. By contrast, in the case of biomass there is hardly any difference of this kind between imports and exports, and the relationship is reversed where minerals are concerned; Germany's imports require one-third more mineral resources than its exports.

The upstream requirements for raw materials can also be accounted for in the case of individual products, by incorporating indirect flows. This is usually undertaken with the help of a life cycle assessment (LCA). These analyses show that the overall requirements for raw materials are many times larger than the actual weight of a product. Thus an average car weighs around 1,500 kilogrammes, yet the upstream raw material input required to produce it may amount to as much as 70 tonnes (→ Table 2).

Comparison between net weight and total material input for selected products

Product	Net weight (kg)	Weight of the ecological backpack (kg)
Motorbike	150	3,300
Car (S-Class)	1,500	70,000
Computer-Chip	0.00009	20
Music-CD	0.015	1.6
Laptop	2.8	434
Gold ring	0.005	2,700

Table 2 Source: Schmidt-Bleek, 2008

Why is it important to consider indirect flows?

The interconnectedness of the global economic system is becoming increasingly complex, with production and consumption becoming ever more detached from one another in geographical terms. If one wishes to assess the external economic, environmental and social effects abroad that are associated with final demand for products and services in Germany, it is essential to take the upstream flows along the global value chain – known as "indirect flows" of "raw material equivalents" – into account, because increasing imports of resources are often accompanied by negative impacts in the environmental or social spheres. An example of this may be found in the extraction of ores from rainforest areas. Extraction of a range of raw materials that are commonly found in humid and tropical regions requires large-scale deforestation. This brings with it profound negative consequences not only for the local populations but also for the rainforest as a carbon sink and as an ecosystem with a very high biodiversity. The raw materials are further processed, exported and used for the production of high value finished products. As a manufacturing economy and through the consumption practices of its population, Germany shares responsibility for the negative impacts resulting from the original extraction of these resources.

Dependency on raw material imports

Germany is a net importer of raw materials and products. The functioning of the economy and the maintenance of existing lifestyles for Germany's population are thus in a direct and indirect sense highly dependent on imports from abroad. Where oil and natural gas are concerned, import dependency is higher than 90 %. In the case of many metallic raw materials, this situation is even more pronounced, with 100 % dependency upon sources of raw materials located in other countries. This has consequences for the supply security of the economy as a whole.

Reserves and accessibility of raw materials are unequally distributed among the countries of the world. The reasons for this are primarily geological. In the case of certain raw materials, reserves from which extraction is economically viable are only found in a few regions worldwide. By way of example, relevant copper reserves are currently only to be found in thirteen countries (USGS, 2015).

The greater the quantities imported in relation to the domestic extraction of raw materials, the more pronounced the dependency upon other producer countries. Germany lacks domestic reserves particularly in the case of metallic raw materials such as iron and non-ferrous metal ores, as well as fossil fuels such as oil and natural gas, and the economy is almost 100 % dependent on supply sources abroad (⟶ Figure 16). Metal ores are of crucial importance in the mechanical engineering and electronics sectors – two of the most important sectors for the German economy as a whole. Oil and natural gas play an essential role as energy sources

Domestic and foreign share of Germany's raw material requirements by primary raw materials, 2010

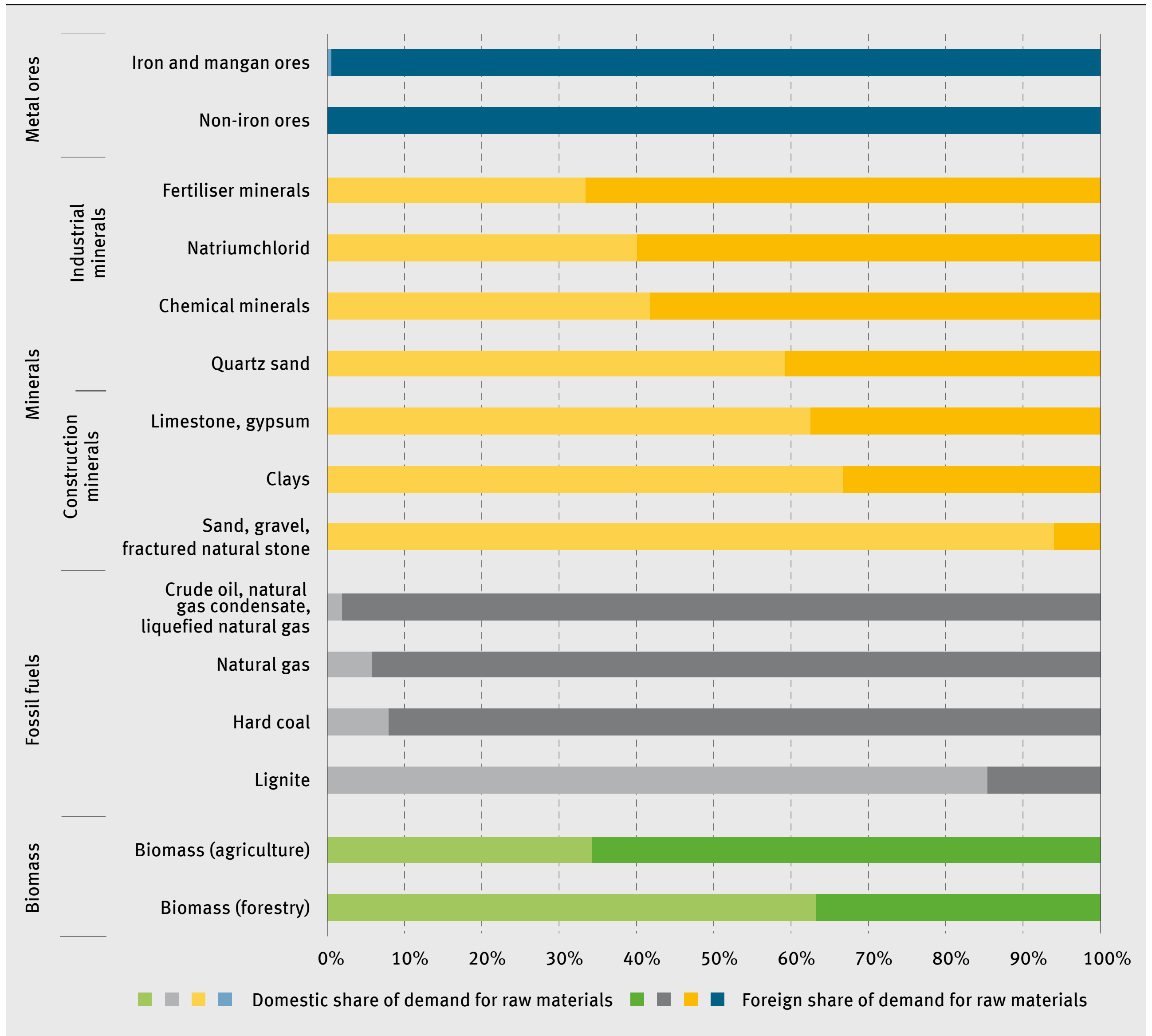


Figure 16 Source: Destatis, 2015 a

for production, transport and heat generation. Dependency on supply from abroad is not just a cost factor but also has profound consequences for the supply security of the economy. Thus China, which has a 90 % market share as the world's largest producer of rare earths, introduced export quotas in 2010 for these metallic raw materials, which play a central role in the production of electronic equipment in particular. Following long negotiations with major economies such as the EU, the US and Japan, the quotas were eventually removed again in 2015. By then, however, industrialised countries had already experienced partial supply shortages and competitive disadvantages as a result. Such risks can be reduced by intensified recycling of materials – as far as technically possible (↘ page 42, „Recycling as an alternative source of raw materials"). In particular, this is the case for metals, but also for industrial minerals, such as phosphorus, which plays a central role for the German agriculture and domestic food production. In contrast to fossil fuels and metal ores, the major share of construction mineral requirements (approximately 86 % in total) were supplied by domestic extraction in 2010. In the biomass sector (agriculture and forestry) the larger share, or 58 % of the total quantity used, is produced within Germany.

Both in terms of raw material requirements for production processes and also for final demand, Germany is among those industrialised countries that obtain a large share of their raw material requirements from other countries. The share of imports in Germany's raw material consumption (RMC), at more than two-thirds, is almost at the level of Japan or the United Kingdom (⟶ Figure 17). Compared to these countries, however, in Germany more extracted raw materials are also directly or indirectly exported (↘ page 28, „Indirect import and export flows"). In contrast, several other industrialised countries with relatively large national territories are in a position to supply their own final demand to a far greater extent from domestic reserves, for example, the US and Australia. China is a special case in this respect: Although the share required from abroad to cover domestic demand for raw material consumption is low, at 20 %, there is nonetheless a high import requirement for raw materials to supply China's export industries.

Import dependency of Raw Material Consumption (RMC) by country, 2010

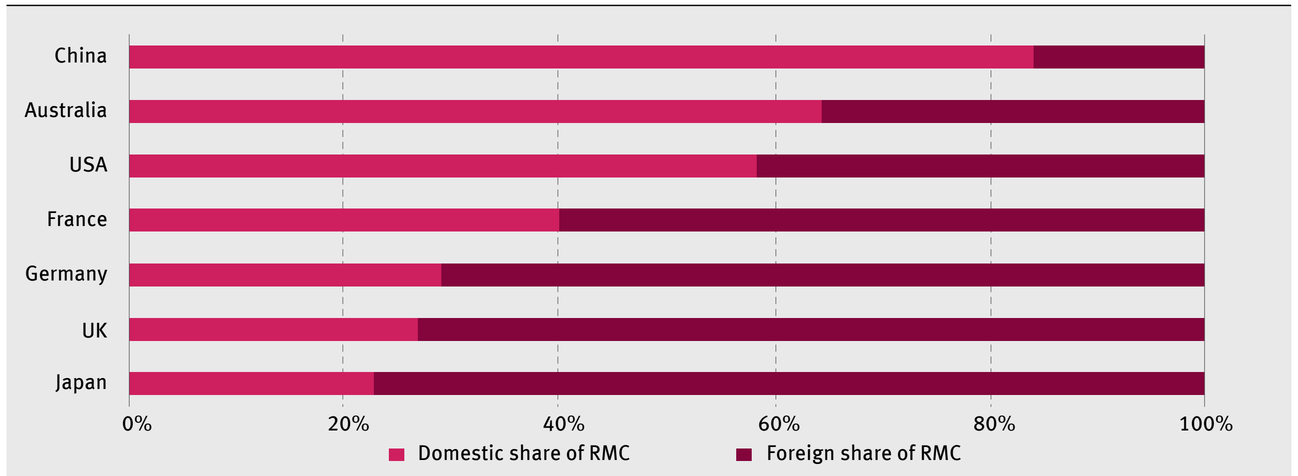


Figure 17 Source: WU, 2016 a

High import dependency: Metal ores for the German economy

According to the Federal Institute for Geosciences and Natural Resources (BGR), Germany obtains certain metals and their ores from only a few countries. One example concerns the metal niobium, which in 2013 was imported from Brazil at a rate of 97 % and is primarily used as an alloying additive for stainless steel and for non-ferrous alloys. A similar case is that of rare earths and antimony, which are imported from China at rates of 90 %. The former are primarily used in key technologies such as magnetic materials for electric motors or generators, as electrode materials in batteries or fluorescent materials in energy-efficient LEDs, while the latter is an essential flame retardant. Furthermore, bulk metals such as iron, copper and tin are produced by a relatively small number of countries. With increasing concentration of reserves and production to only a few countries, the risk of restrictive trade policies and protective trade measures rises, i. e. the abuse of market power by the respective supplying countries. Such oligopolistic supply structures can have considerable impacts on the quantities of global supply and trade of raw materials. In the case of politically unstable, insecure, repressive or undemocratic countries, interruptions along supply chains can arise due to military or political conflicts. The World Bank has categorised some countries from which Germany sources large quantities of metal ores and metal products as countries with inadequate governance as well as significant unreliability as trading partners (DERA, 2014). In order to reduce those risks and dependencies, specific economic policy strategies are being developed at both the national and EU level; one example is the EU Commission's communication on "Commodity Markets and Raw Materials" (BGR, 2014).

The geographical origin of raw materials

In the case of some of the raw materials sourced from around the world by Germany, specific regions and countries have acquired an important role. The Asian continent stands out particularly in this respect. 62 % of the fossil fuels required by the German economy and extracted internationally along the value chain and as much as 73 % of the minerals required are extracted and used in Asia. Beyond this, Latin America, North America and Africa play an important role where specific raw materials are concerned. Thus Latin America, for example, is an important producer region supplying metal ores to Germany.

EITI – Extractive Industries Transparency Initiative

The Extractive Industries Transparency Initiative (EITI) is an international initiative with participants comprising numerous non-governmental organisations, companies and states that is dedicated to furthering transparency regarding all revenue of developing countries that stems from the extraction of raw materials.

Governments and their subordinate authorities, companies from the extractive industries, service companies, multilateral finance organisations, shareholders and NGOs are all represented in EITI as a multi-stakeholder group. The members of the initiative have undertaken an obligation to a minimum level of transparency regarding payments in company reports and revenue recorded in government reports. This involves, for example, disclosure of state revenue generated from extractive industries and the disclosure of all relevant payments from oil, gas and mining companies to the state.

Unrestricted access to all the relevant data (Open Data) is to be guaranteed in the interests of open government. A further goal is to promote public awareness and debate and to demonstrate responsibility in the context of a globalised economy. Germany is currently a candidate for membership in the EITI (EITI, 2016).

Germany's consumption of raw materials in 2011 was around two-thirds dependent on imports (↖ page 30, "Dependency on raw material imports"). In most cases, only a few countries or regions played a central role as suppliers of raw materials. The Asian continent in particular, and once again China, occupied a prominent place among suppliers for all raw material groups. Among the imports required to satisfy German consumption of raw materials in 2011, approximately half of the biomass, more than half of the fossil fuels (including Russia, but excluding the Middle East), more than a third of the metal ores and more than two-thirds of the minerals had been originally extracted in Asia. In the case of the latter category, more than half of the raw material imports came just from China alone. This can be explained by the fact that for many years, large quantities of raw materials have been required in China for the expansion of infrastructure for the Chinese export industry, such as buildings, roads, ports and power stations.

If we look at the metal ores required for German raw material consumption, it becomes clear that apart from supplies from Asia, approximately one-third of the total quantity (almost 50 million tonnes) was extracted in Latin America. The largest share of these imports came from Brazil, which possesses large reserves of iron, aluminium, copper, gold, manganese, niobium and zinc ores.

Geographical origin of Germany's raw material basis, by raw material groups and world regions, 2011

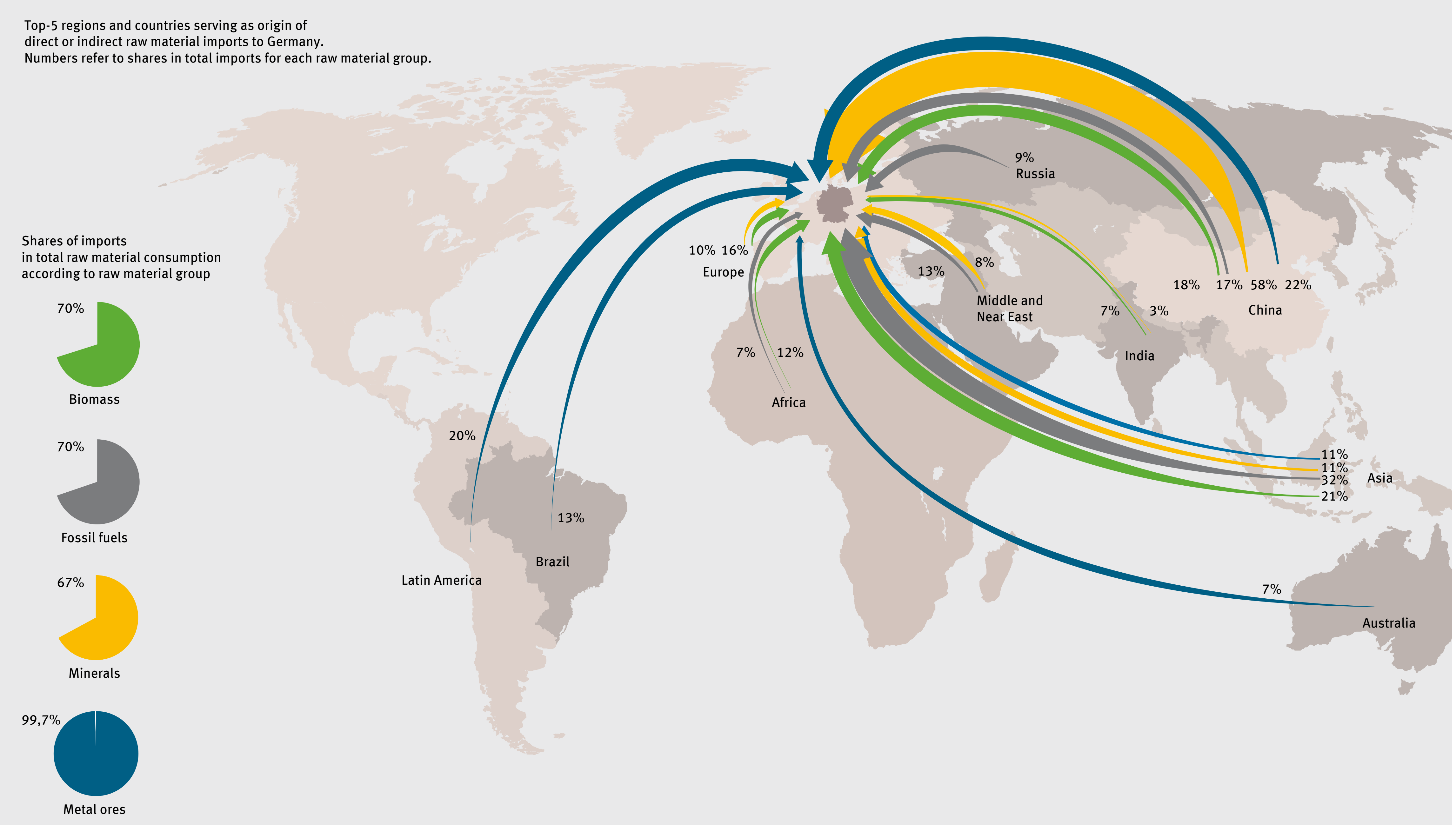


Figure 18

Source: WU, 2016 a

The role of the economy: Value creation from raw materials

1.9 billion tonnes
Raw material requirements for final demand goods produced in Germany, 2011

20 percent
Share of products from biomass in total raw material consumption, 2011

1.3 Euro
Value added per kg of raw material input, 2011

48.3 percent
Increase in raw material productivity, 1994 – 2013

46 percent
Share of secondary raw materials in crude steel production, 2013

79 percent
Overall recovery rate from total wastes, 2014

Data sources: ↘ page 80

Raw material consumption by economic sectors

Many different sectors contribute to Germany's economic performance. These use raw materials to varying degrees. Raw materials may be used directly in production activities but may also be required indirectly through the use of machinery and intermediate products. In addition, the value added that is generated from raw materials varies considerably from sector to sector, ranging between 30 cents per kilogramme in agriculture and 180 Euro per kilogramme in sales and retail trade.

Germany is the fourth-largest economy in the world. In 2011, 1.9 billion tonnes of raw materials were directly or indirectly used in the production of goods and services, which were delivered to final demand in Germany and other countries (⇖ page 28, "Indirect import and export flows"). These quantities of raw materials are not distributed evenly across the different economic sectors. Thus the manufacture of products from biomass involves the consumption of more than 380 million tonnes of raw materials, while the sales and retail sector accounted for only 647,000 tonnes (⇢ Figure 19, contained in the category "Other", ⇘ page 72, Table A 5). Different quantities do not indicate per se that one sector operates more inefficiently than another. A comparison of the absolute quantities recorded for different sectors can nonetheless provide important indicators of where the so-called "hotspots" requiring policy measures for reducing raw material use are to be found. A comparison between the intensities of the same sectors in different countries, on the other hand, makes it possible to define benchmarks for best practice.

Raw material requirements for final demand goods produced in Germany, 2011

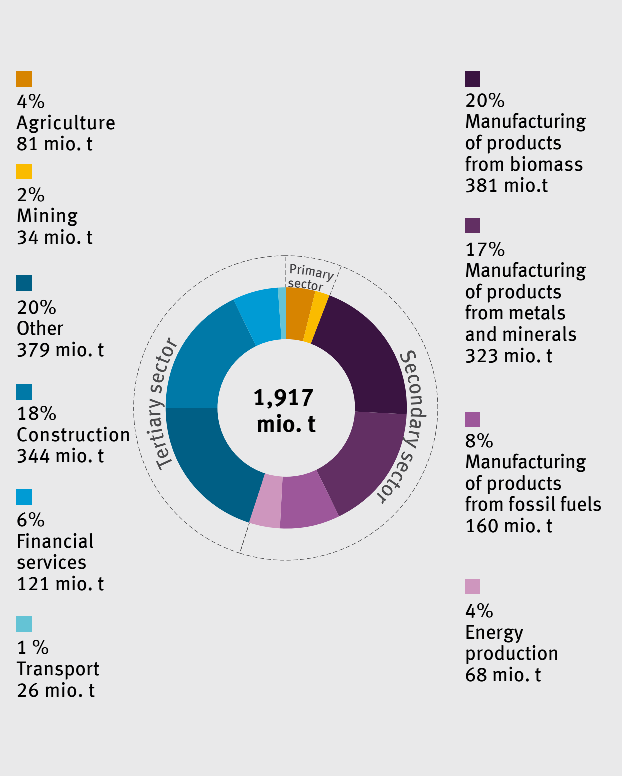


Figure 19 Source: WU, 2016 a

Alongside the biomass sector, the construction industry and the manufacture of products from metals and minerals also require particularly significant quantities of raw materials in absolute terms in order to satisfy domestic and international final demand for products. They are respectively responsible for 20 %, 18 % and 17 % of the German economy's total raw material requirements for final demand goods (⇢ Figure 19). These sectors have a high requirement for primary raw materials such as construction minerals or biomass, and of processed products that involve a comparatively high level of raw material-intensive input upstream, such as metal components or machinery. In contrast, the sales and retail or transport sectors makes use of a far smaller share. These sectors, taken together, account for only 2 % of total raw material requirements. The relatively small requirements of these sectors consist largely of indirect flows of raw materials (⇖ page 28, "Indirect import and export flows"), which primarily arise through upstream services relating to infrastructure. The low consumption of the primary sectors, on the other hand, can be attributed to the fact that they produce comparatively little for (national and international) final demand.

Levels of raw material intensity – i. e. the quantity of raw materials that are used per Euro generated are as varied as the absolute quantities of raw materials used. In the case of agriculture, this figure is 3 kg / €, whereas in sales and retail, the figure is only 10 g / € (⇢ Figure 20). These variations may be caused by a number of different factors. On one hand, the share of primary raw materials used plays an important role. Thus large quantities of sand and gravel are used by the construction industry, yet they have a relatively low price per unit of mass, which produces a high level of raw material intensity for the mining sector of 2.3 kg / € (⇘ page 70, Table A 5). An additional factor is the degree to which the traded product undergoes further processing, since processed products tend to have a higher sales price. Service sectors often have correspondingly very low raw material intensities. Ultimately, the applied technology and thus the raw material efficiency of a specific manufacturing process can also influence raw material intensity. Innovative processes can help to enhance efficiency potentials and thus also to reduce both the absolute input and the intensity of raw material use. Moving the economic system away from manufacturing industry towards the service industries might increase the value added while achieving lower intensities, yet it can only partly reduce the absolute quantities of raw requirements

Raw material intensities of sectors of the German economy, 2011

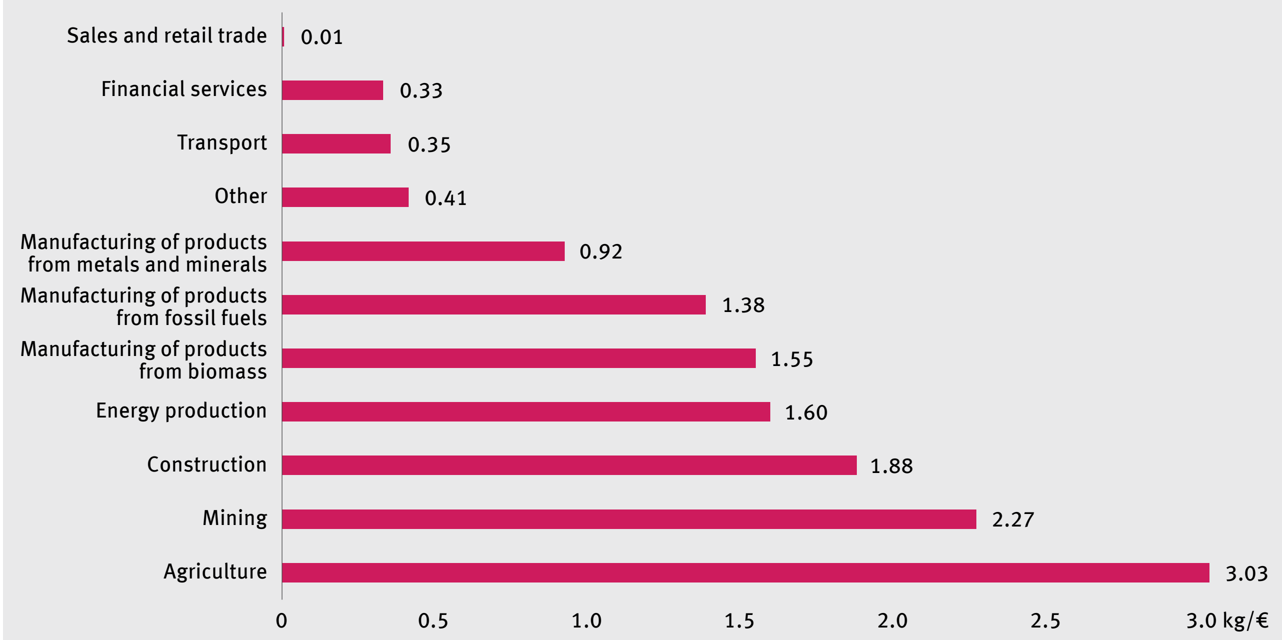


Figure 20 Source: WU, 2016 a

consumption, since these are still contained in the indirect flows upstream. The demand of individual sectors for raw materials is supplied either directly or indirectly by domestic or international sources (⇖ page 28, "Indirect import and export flows"). The share of total raw material consumption constituted by upstream raw material inputs abroad in the case of a particular sector is closely linked to the major raw material groups required for processing by that sector. While agriculture depends largely upon biomass (and thus upon raw materials extracted in Germany), fossil fuels and metal ores generally constitute a large share of the raw material requirements of manufacturing sectors (i. e. primarily raw materials originating from outside Germany) (⇢ Figure 21). The fact that the majority of primary raw materials in the area of minerals and biomass are generally obtained from domestic sources, while fossil fuels and metal ores come largely from imports thus influences the degree to which sectors in the German economy are dependent upon raw materials coming from abroad (⇖ page 30, "Dependency on raw material imports").

Raw material requirements of sectors of the German economy by material group, 2011

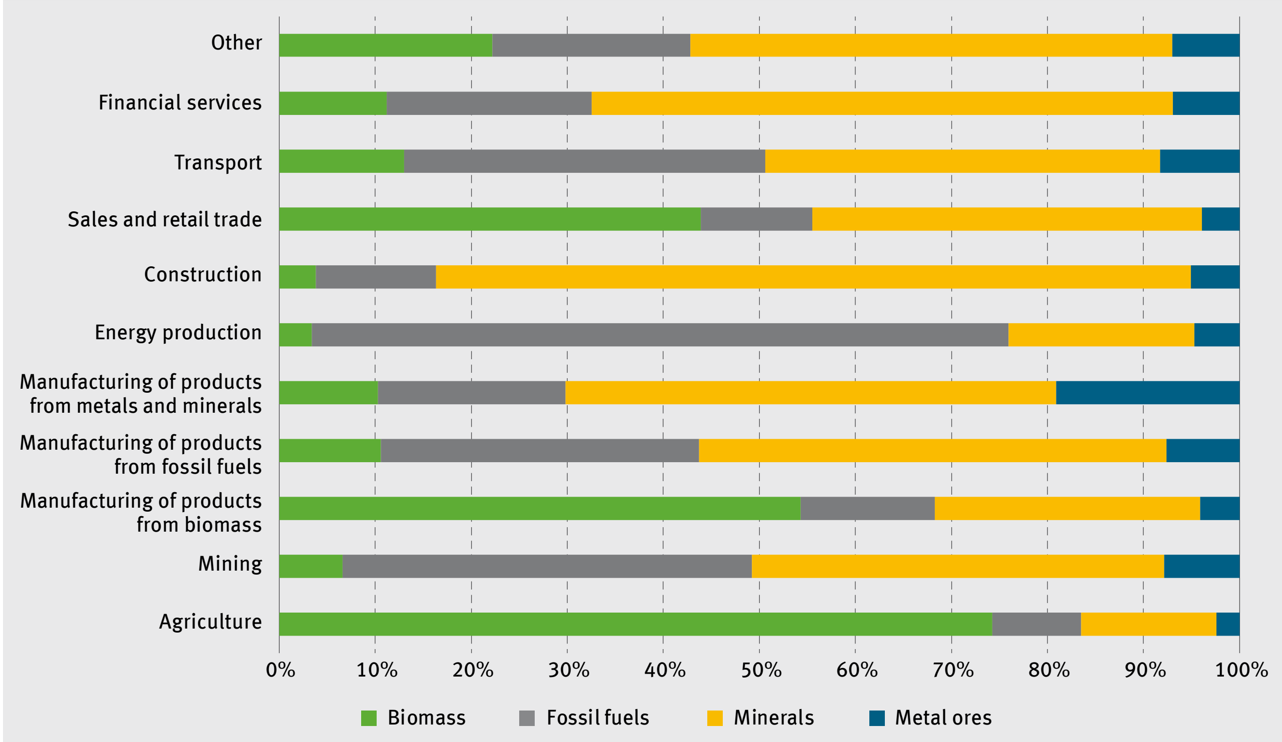


Figure 21 Source: WU, 2016 a

Economic growth and raw material use

In Germany, the decoupling of economic growth from raw material use is an environmental and economic policy goal. The consideration of whether such a decoupling is indeed taking place and how observable trends should be interpreted is, however, dependent on which aspects of material use are considered and whether a production-based or consumption-based perspective is adopted. In general, Germany has increased its raw material productivity in recent years and has thus achieved decoupling.

At the global level, raw material consumption doubled in the period from 1980 to 2011, as a consequence of which environmental pressures increased significantly. The concept of decoupling aims to detach a positive trend – economic growth, which is commonly regarded as the most important driver for employment and prosperity – from raw material use.

Where a country manages to increase its economic performance at a higher rate than its raw material use, this is referred to as relative decoupling. Absolute decoupling refers to cases in which economic growth is accompanied by decreasing raw material use. Both cases entail an increase in productivity in raw material use, but only the latter reduces the pressure on the environment.

It is precisely for industrialised countries such as Germany that absolute decoupling is a necessary (and also a political) goal, to relieve pressure on the environment on one hand and to allow for an increase in raw material use by developing countries on the other hand. The primary goal set out in Germany's Strategy for Sustainability Development was to double raw material productivity between 1994 and 2020, a target that has been only partly met thus far (German Federal Government, 2002) (↘ Page 73, Table A 6).

Similar patterns are evident for raw material productivity and for total raw material productivity (⇢ Box): Both abiotic direct material input (DMI_{abiot}) and primary raw material input (RMI) declined sharply in 2009 – the year of the global economic crisis – although, whereas RMI had remained in the preceding years at above the level attained in 2000, DMI_{abiot} had shown a continual reduction since 2000. From 2010, the trend in terms of quantities nonetheless resumed development from the point at which it had been interrupted in 2008. DMI_{abiot} had declined so markedly during the crisis because of its profound effect upon the construction industry, which forms a very important share of DMI_{abiot}. Since other sectors (outside Germany) also play a significant role in levels of indirect raw material consumption, RMI had also shown a sharp decrease during this period. A similar trend was observed where GDP and imports were concerned. Steady economic growth was abruptly interrupted in 2009, only to resume a strong upward trend in 2010 – albeit at a lower level than before the crisis (↘ Page 73, Table A6).

These developments meant that raw material productivity in 2011 fell back strongly from its high point in 2010, although an improvement of 20% was evident when compared with figures for 2000. Total raw material productivity also declined in 2010, yet was able to re-establish an upward trend in 2011, approximately in line with that attained in 2009. For the period from 2000 to 2011, it therefore showed an overall increase of 17%.

If DMI_{abiot} and GDP are considered, analysis reveals an absolute decoupling for the period 2000–2011. This can be attributed to the fact that DMI_{abiot} fell by 6 %, while GDP rose in the same period by 13 %. A comparison of RMI with the sum of GDP plus imports, however, shows only a relative decoupling for that period. The aim of reducing primary raw material input was not achieved, given the 5 % increase in RMI in absolute terms (↘ Page 73, Table A6).

At the international level (e.g. EU or the UN environmental programme, UNEP), the indicators RMC (raw material consumption, with indirect flows) and DMC (domestic material consumption, without indirect flows) are used for analysis instead of DMI_{abiot} and RMI, which represent the production perspective. These consumption indicators are compared with GDP – for example, in the "Roadmap to a resource-efficient Europe" from the EU Commission.

In international comparisons using the indicators GDP/RMC (⇠ Figure 23) it becomes clear that Germany, with a converted value of 1.74 USD per kilogramme, is in the same range as other industrialised countries such as France or the US, while Japan is the international leader. At the same time, Germany is at a level that is more than double that of China or Australia. The reasons for this are, in the case of China, that it has a relatively low level of income in relation to its extremely high level of raw material consumption; where Australia is concerned, this reflects the economy's focus upon raw material-intensive sectors, which leads to low productivity rates despite the high level of GDP.

The use of this indicator also shows that during the period 2000–2011, Germany was able to increase its productivity by more than 30 % on the one hand, while on the other, clearly achieved an absolute decoupling. In other words, while progress is evident relating to final demand, the corresponding indicators reveal potential for improvement on the production side.

Development of raw material productivity (left) and total raw material productivity (right) in Germany, 2000 – 2011

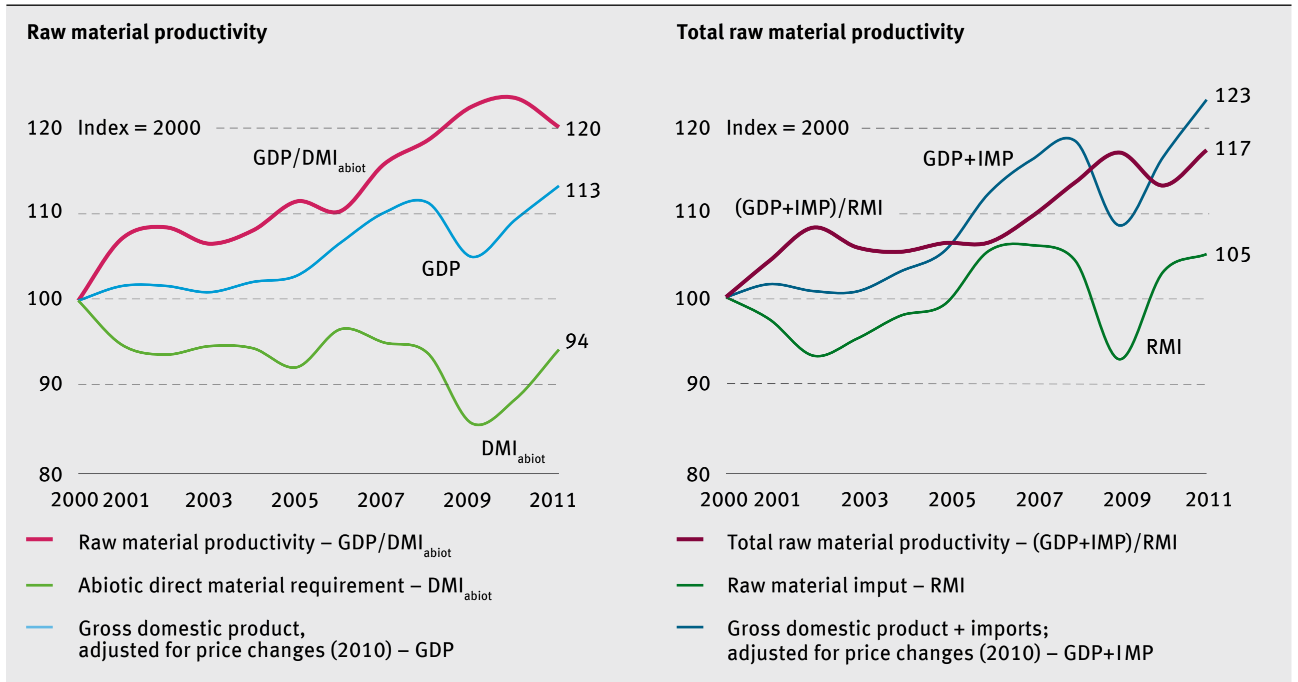


Figure 22 — Source: Calculations by WU Vienna based on Destatis, 2015 a, e, g

Relationship between GDP and RMC for selected countries, 2011

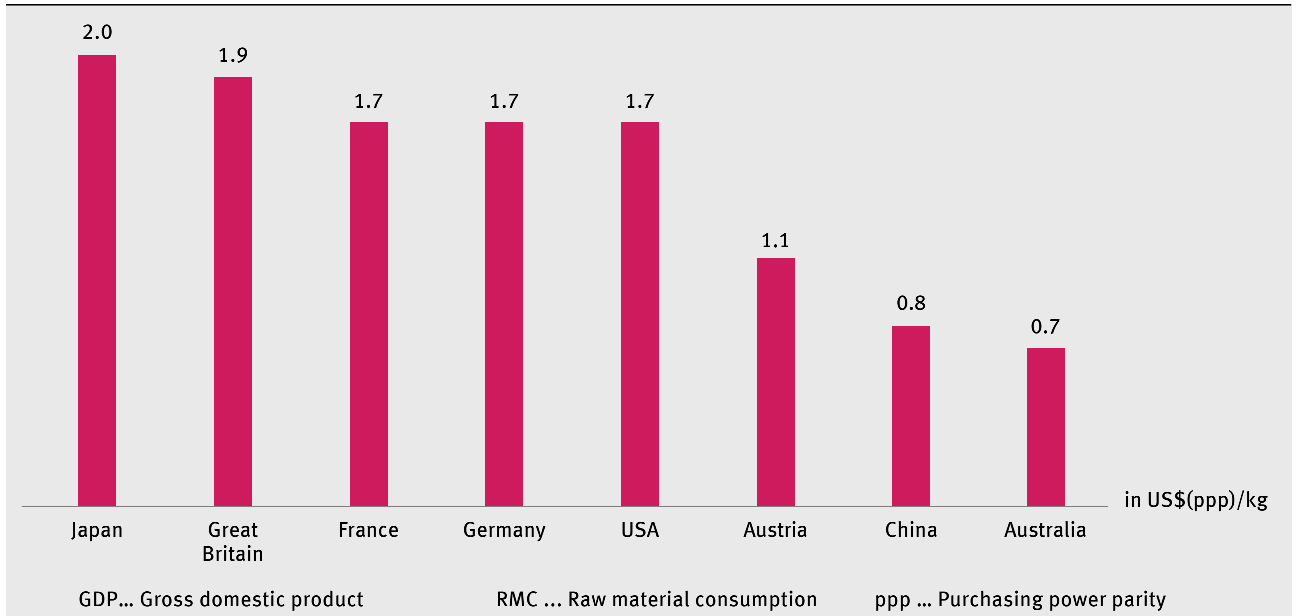


Figure 23 — Source: WU, 2016 a

Calculating raw material productivity

Various indicators can be used to investigate whether economic performance and raw material use have been decoupled. In Germany, the indicators direct material input (DMI; domestic extraction plus direct imports) and raw material input (RMI; domestic extraction plus direct and indirect imports) are used to calculate raw material use. In the German strategy for sustainable development, the focus lies with abiotic direct material input (DMI_{abiot}), i.e. biomass is explicitly excluded (Deutsche Bundesregierung, 2002).

DMI_{abiot} can be directly compared with GDP, and thereby raw material productivity (GDP/ DMI_{abiot}) calculated. To make a comparison with RMI, the sum of GDP plus the value of imports must be taken, in order to compare indicators with the same system boundaries. This enables total raw material productivity to be calculated (GDP+IMP/RMI) (⇠ Figure 22).

Economic efficiency potentials

Not only the development and application of technologies but also the way in which products are used plays an important role in increasing the resource efficiency of the economy. In this respect, even small technological advances and changes in the awareness and behaviour of people can produce wide-ranging and sustained impacts across the entire system. Sectors including construction, transport, food and (tele)communications therefore have a key role to play in increasing economy-wide resource efficiency.

In any endeavor to decouple economic growth from raw material use from one another, the economy – that is, the different branches, with their enterprises and products – plays a central role. Sectors differ widely from one another in terms of their raw material intensity, depending upon the uses of different raw materials (with different prices) or their position in the value chain (⇖ page 38, “Economic growth and raw material use”). Partly because of this, the scale of the potential contribution they may make to decoupling also varies. Some economic sectors may play a key role in increasing resource efficiency, either because they account for a particularly large share of total raw material use or because they can help to significantly reduce the demand for raw material intensive products or technologies.

Furthermore, efficiency improvements are also an important economic factor as resource efficiency is an opportunity to save costs and achieve competitive advantages. Innovations within companies play a crucial role and can be supported by the state through appropriate instruments (⇢ Box). At the same time, it is important to limit rebound effects. Because increased resource efficiency, by creating cost savings, can lead to increased demand, which in turn allows consumption to rise in absolute terms. In this way, measures may give rise to effects that run counter to the aims of the original policy (⇖ page 38, “Economic growth and raw material use”).

In the updated German Resource Efficiency Programme (Deutsche Bundesregierung 2016 a), increasing resource efficiency in production is also identified as a key approach. Three areas of action have been defined with a view to achieving this goal: (1) the development and dissemination of resource-efficient production and manufacturing processes (2) the expansion of efficiency consulting for businesses (3) the creation of incentives for using energy and environmental management systems. Targeted measures range from the continuation and expansion of funding programmes for material- and energy-efficient technologies and processes to the further development of resource efficiency consulting and strengthening infrastructure for training business consultants, through to the coupling of government support to implementation of energy and environmental management systems.

German Raw Material Efficiency Prize

The German Raw Material Efficiency Prize granted by the Federal Ministry for Economics and Technology provides a further incentive for improving resource efficiency. Under the expert management of the Germany Mineral Resources Agency (DERA), prizes are awarded to outstanding examples of raw material-efficient and material-efficient products, processes or services and to applied research results.

www.deutsche-rohstoffagentur.de/DERA/DE/Rohstoffeffizienzpreis/rep_node.html

Fine-particle surplus minerals

One of the winners of this prize has been Dr. Krakow RohstoffConsult GmbH, which has long specialised in the marketing of fine-particle surplus minerals from the mining and quarrying industries. The prize was awarded in recognition of the company’s successes in answering the question of what a partial decoupling from the primary raw material base could look like. In this context, the aim is to find sources of secondary raw materials and to answer a number of questions: can clay minerals for example only be found in identified clay deposits or also in other types of reserves? Can anthropogenic sources of raw materials substitute primary brick clays while matching product quality? To what extent could a transition to secondary raw materials be associated with technical or monetary advantages?

www.dr-krakow-labor.de/ressourcen

Environmental innovation programme of the Federal Ministry for the Environment

Resource efficiency and material savings also constitute a funding and support focus within the environmental innovation programme of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), which fosters demonstration projects with a large-scale technological basis in Germany. Outstanding projects are supported, which advance the technological state-of-the-art within a particular field and in some cases even function across different fields as “showcase projects” with exemplary impact. Both economy and environment stand to benefit, since innovative businesses can reduce their resource and energy inputs and lower their costs.

www.umweltinnovationsprogramm.de

Innovative process: Moulding technique instead of milling technique

An example from the innovation programme concerns the company TITAL GmbH, which produces premium-grade investment castings from titanium and aluminium alloys for the aerospace industry. The milling and machining techniques traditionally used were associated with a high level of material use of up to 10 kilogrammes per kilogramme of titanium finished component, as well as with a high level of energy input. Through the development of an innovative vacuum arc casting furnace with a capacity of up to 500 kilogrammes of titanium or titanium alloy, large titanium components up to a size of 1,500 millimetres can be produced using gravity casting, thereby saving up to 75 % in terms of material use.

http://www.umweltinnovationsprogramm.de/erfolgsgeschichten#project_11_main

Changing the printing technology

The company Ritter GmbH produces plastic and packing technologies, e. g. cartridges or building materials (such as grass protection mesh). Where the energy-, raw material- and time-intensive cartridge printing process is concerned, the company has worked to replace the traditional screenprinting process with digital printing. In comparison with the existing screenprinting method, this project is able to achieve savings amounting to three tonnes of paint and up to 210 tonnes of plastic for cartridge production. In addition, around 15 tonnes less hazardous waste is produced and other waste materials such as paint residues, ink residues and alkaline solutions can be reduced by up to 2.4 tonnes annually. Further to this, the annual energy saving is estimated at 450,332 kilowatt hours, which is linked to a reduction in CO_2-emissions of around 270 tonnes. Of course all these savings are also an important cost factor, since the costs of waste management and materials are also reduced accordingly.

www.ritter-online.de

VDI Center of Excellence for Resource Efficiency

In the framework of the national climate protection initiative of the BMUB, the Centre for Resource Efficiency of the VDI (Association of German Engineers) brings together all available technical know-how about the more efficient use of materials and energy and provides sector-specific expertise to interested companies.

www.ressource-deutschland.de

Alternative manufacturing of films

An example of increased material efficiency is provided by a company working in the area of film manufacturing, a branch of industry with material costs that are almost 60 % higher than the average for manufacturing industry in Germany. Through measures such as reducing waste, improving production planning, lowering inventory stocks, transparent production reporting and an increased recovery rate in recycling processes, annual cost savings of over 700,000 Euros have been achieved – with a turnover of just below 50 million Euros. Material efficiency rose by roughly 1.8 % of total use.

www.ressource-deutschland.de/instrumente/gute-praxis-beispiele

Recycling as an alternative source of raw materials

There are a range of environmental, economic and social arguments in favour of increasing the use of secondary raw materials obtained through recycling processes. Recycling rates in Germany for some materials are already very high. For example, since many years, more of the aluminium used has come from secondary production than from primary production. This has led to a reduction of approximately 90 % in the emissions relating to aluminium production.

Many raw materials that are processed for products, buildings, transport infrastructure and other facilities can be recovered through corresponding preparation for reuse as secondary raw materials. The limited availability of many abiotic raw materials and Germany's high degree of import dependency (↸ page 14, "Domestic extraction: Non-renewable raw materials", ↸ page 30, "Dependency on raw material imports") highlight the importance of such an approach. Increased use of secondary raw materials also results in a reduction in demand for primary raw materials and thereby lessens the environmental and parts of the negative social consequences of resource extraction. In addition to the reduction in extraction, the use of recycled raw materials in Germany also leads to decreasing quantities of waste materials, thereby saving emissions and reducing the space required for landfills.

Recovery rates in Germany are already very high for most types of wastes, both in energetic and in material form – either through incineration to generate energy or through recycling. In 2013 the overall recovery rate across all waste types was 79 % on average. Rates were particularly high, at 89 %, in the case of construction and demolition wastes, for which almost all materials could be recovered and nearly entirely in material form. In the case of municipal wastes (primarily from private households), secondary wastes (those that are produced during waste recovery processes) and industrial wastes, a comparatively small proportion entered landfill. For many materials recycling is thus already the norm. Well-known examples are glass and paper, for which the fraction of municipal waste has been subject to recycling rates of nearly 100% over the last ten years (Destatis, 2016 c). The recycled glass finds numerous applications. For the production of glass bottles, for example, an average of 60 % of materials already come from recycled glass and only 40 % is new glass. This implies that since 1970, raw material use has been reduced by more than 40 million tonnes of quartz sand and several million tonnes of carbonates, feldspar and soda (BGR, 2014). One type of recovery whose exploitation is increasingly being enforced, is the recovery of phosphorus from sewage sludge. More than 12% of the 150,000 tonnes of phosphorus being used as mineral fertilizer each year can be obtained this way, in addition to the already more established recovery from wastewater (UBA, 2014).

The available quantity of secondary raw materials for industrial purposes varies according to the material and depends on different factors, for example economic costs, recoverability, process losses, feasibility of sorting or

Waste disposal and recycling in Germany by waste type, 2013

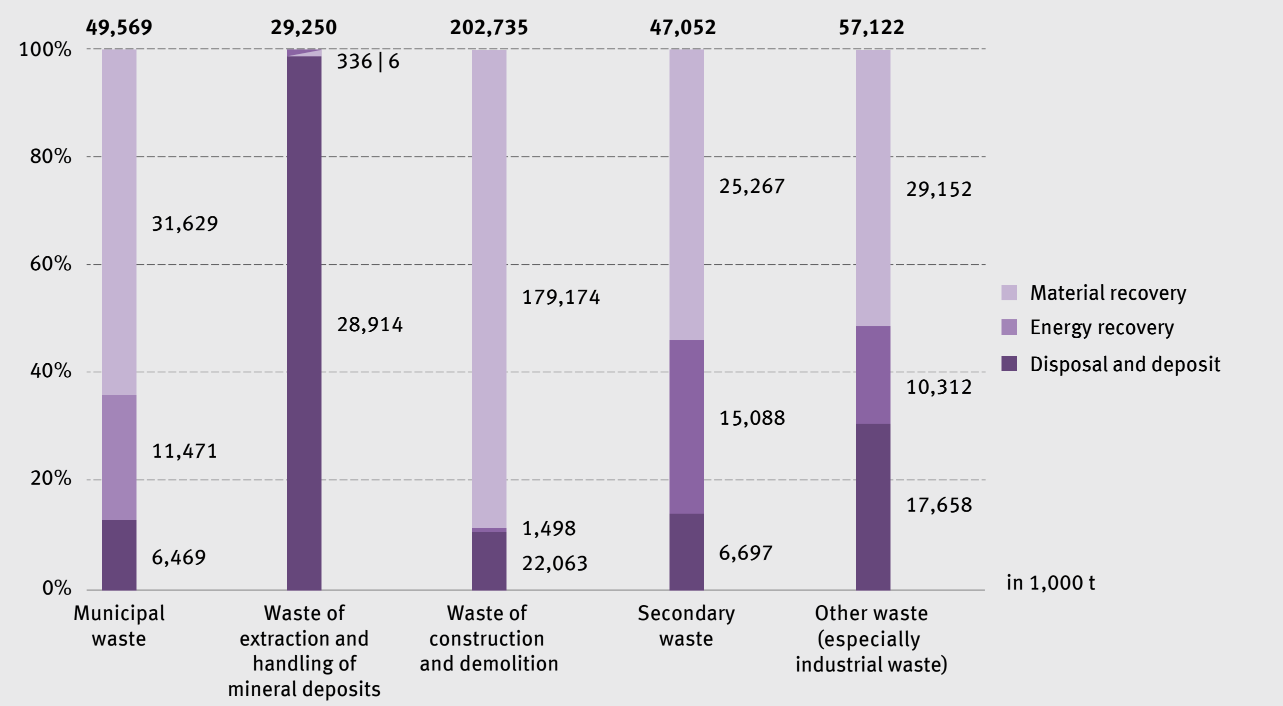


Figure 24 Source: Destatis, 2016 c

Share of secondary raw materials in the production of selected metal ores in Germany, 2013

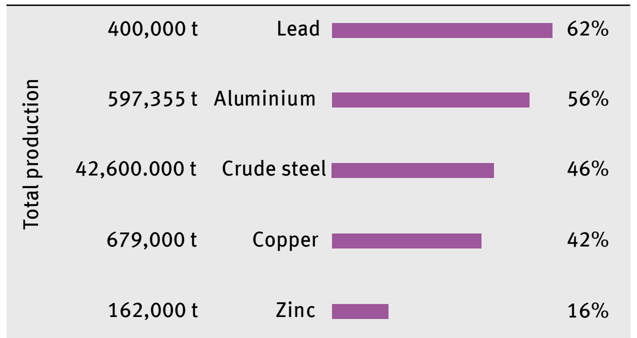


Figure 25 Source: BGR, 2014

Potential CO_2-savings through recycling, 2008

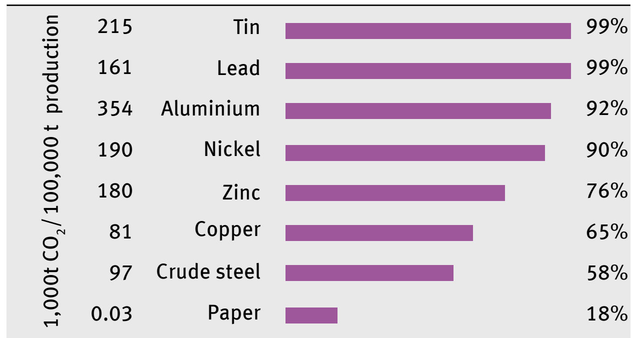


Figure 26 Source: BIR, 2009

collection rates. Of the 42.6 million tonnes of steel produced in Germany in 2013, 45.5 % came from secondary production. In the case of lead and aluminium, secondary production contributed more materials than primary production, with shares of 62 % and 55.5 % being recycled metal (↸ Figure 25). These rates had been even higher in some of the preceding years, when raw material prices were high. The largest share at times also came from secondary production in the case of copper. These proportions fluctuate, however, according to market prices and the resultant economic viability of recovery.

Recycling enables large savings to be made in terms of energy and consequently also of related CO_2-emissions. This is particularly relevant for metals, such as in the case of steel scrap, which can be recycled as many times as desired. This is an important consideration, given the fact that Germany was the seventh largest steel producer in the world in 2013. Recycling aluminium reduces the relevant CO_2-emissions by around 92 %. In the case of aluminium production for 2013, this was comparable to the annual carbon sequestration of an area of mixed forest the size of Berlin. The recycling of other raw material types, including that of paper, waste wood and plastics, such as polyethylene (PE) and polyethylene terephthalate (PET), also saves on emissions.

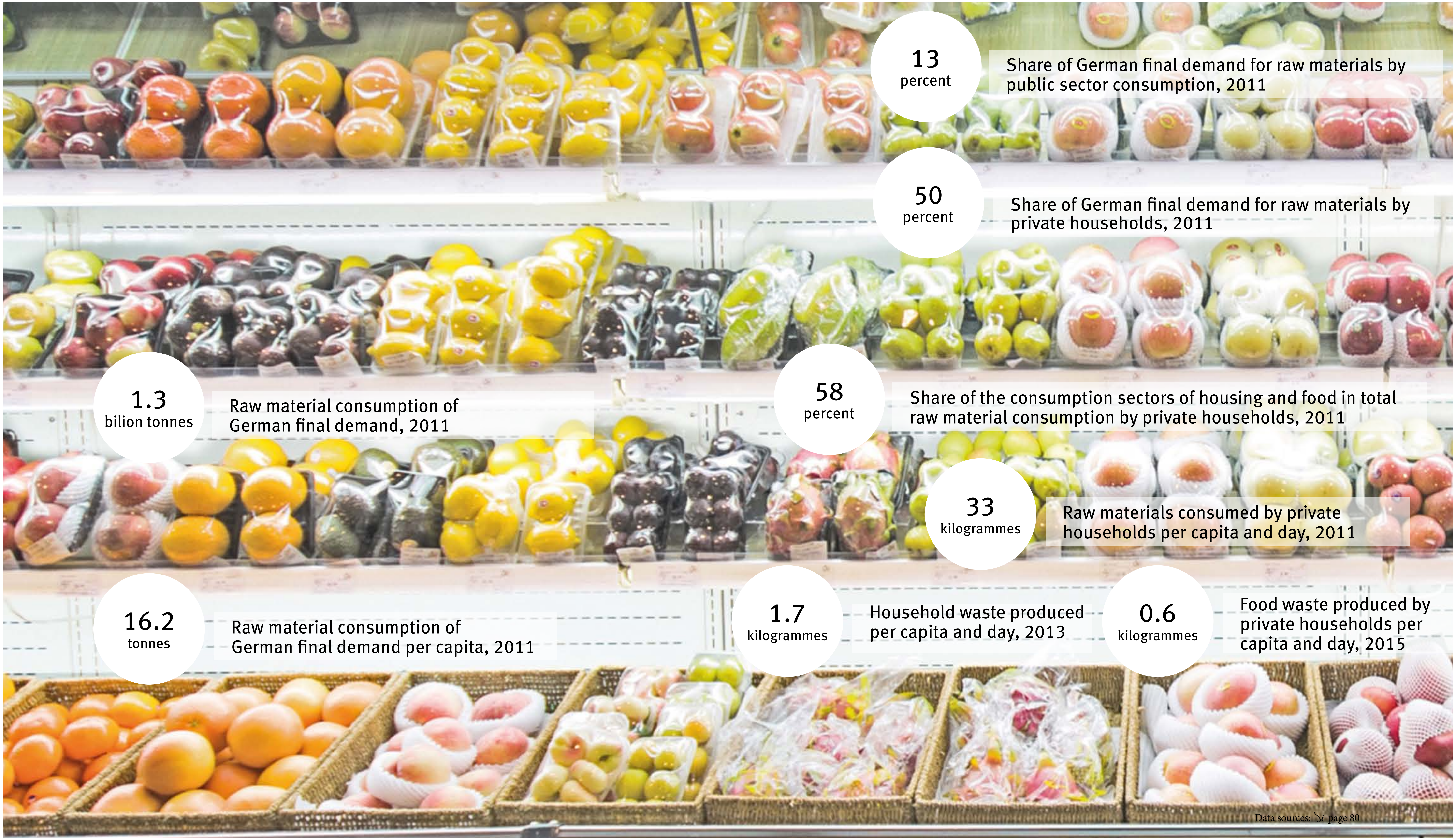
However, not all materials can be recycled as easily as the previously mentioned examples suggest. On one hand, the requirements in some industrial processes can be higher than the quality of not adequately recycled materials. On the other hand, the recovery of some materials from certain types of waste is only realisable with high economic costs – since they either cannot be isolated from composite materials or their chemical properties have been altered during manufacturing processes. Although metal scrap is largely recyclable, some non-metallic raw materials in specific cases are not. Brick clay once fired to make bricks cannot be returned to clay again and limestone used for cement production cannot be recovered again in its original form. However, usually they can still be reused as substitutes for certain primary raw materials, such as construction minerals, in the economic cycle (BGR, 2014). In general, the recycling potential of a material and its economic viability is determined by the degree to which a material is altered during production processes. For example, aluminium in the form of beverage cans is easier to recover than aluminium contained in a mobile phone. Hence, product designs with focus on recyclability and appropriate treatment processes are of high relevance to increase the recoverability of complex composite materials.

Recycling as a component of Germany's resource efficiency programme (ProgRess)

The first German Resource Efficiency Programme of the Federal Government produced in 2012 already presented the increased use of secondary raw materials and the development of the circular economy in Germany – as one of four key ideas – as priorities. In general terms, important foundations and framework conditions have been established in the last two decades, through the 1994 Closed Substance Cycle and Waste Management Act (KrW-/AbfG), the 2012 Circular Economy Act and further legal regulations. These include numerous specific regulations, such as those dealing with the management of particular forms of hazardous waste, packing materials or the production responsibilities of manufacturers. Furthermore, incentive measures included in the 2013 waste prevention programme also contributed to this.

Also in the second German Resource Efficiency Programme adopted in 2016, strengthening the circular economy is accorded a correspondingly high priority as one of four core ideas. The primary aim is to build further upon existing measures and targets and to improve recycling rates for bio- and green wastes. As highlighted by the first programme, future anthropogenic raw material stocks – i. e. secondary raw materials, which are embedded in the built environment, infrastructure and durable goods – should be appropriately recovered and the systematic recording and collection of these materials should be advanced further (Deutsche Bundesregierung, 2016 a). ProgRess II should thus also be seen as closely related to the new and updated action plan on the circular economy from the European Commission. This similarly identifies a range of opportunities to take action, among which recycling is one of the most prominent.

The demand side: Raw materials for consumption



Raw material consumption in Germany

At 1.3 billion tonnes, raw material consumption in Germany in 2011 was 18 % higher than domestic extraction. Per-capita raw material consumption (RMC) of 16.2 tonnes per person and year places Germany at the same level as other EU states such as France or Great Britain, however far ahead of countries including China and India or other emerging economies.

To maintain the economy, the living standards of the population and the functioning of public sector institutions, Germany requires vast quantities of raw materials. If raw material consumption is to be comprehensively analysed, all raw materials required to produce the goods and services consumed in Germany must be included. Therefore in addition to the raw materials obtained through domestic extraction, those that are required outside Germany along the entire supply and value chain must also be accounted for (↸ page 24, “International interdependencies: Germany’s global raw material trade”). If the extraction in Germany is examined (↸ page 18, “Trends in raw material extraction”) it becomes clear that 1.1 billion tonnes of raw materials are mined or harvested within the country each year. The total raw material consumption (domestic plus international), however, amounted to approximately 1.3 billion tonnes (↘ page 74, Table A 7).

Mineral raw materials were the most important category and constituted 46 % of total consumption in 2011, followed by biomass at 31 % and fossil fuels at 21 %. Metal ores were recorded at 25.5 million tonnes or 2 % of the total, and as such formed a relatively small share. The trend in raw material consumption in Germany is declining and has fallen by approximately 15 % since 2000, whereby the consumption of metals and mineral raw materials has shown the greatest decline in absolute terms. During the same time period, biomass consumption has risen by at least 16 % (→ Figure 27).

In the case of Germany, the consumption of many products, such as electronic goods or household equipment, is based to a large extent on raw materials that are extracted in other countries. This means that increasing international trade has resulted in raw material extraction moving beyond the country’s borders. In 2011 the share of raw material consumption accounted for by materials extracted abroad had already reached 71 %, with the upward trend still pre-vailing (↸ page 30, “Dependency on raw material imports”).

Germany’s per-capita consumption in 2011 was 16.2 tonnes and thus very high in global comparison. Great Britain and France exhibit similar values, whereas figures for Japan are approximately 30 % below those of Germany. The US, in contrast, shows a consumption level that is almost 30 % higher than that of Germany, and Australia consumes three times as much. This shows that such high per-capita consumption values are generally associated with comparatively large domestic raw material stocks combined with lifestyles that make intensive use of raw materials (← Figure 28).

Despite rapidly growing demand for raw materials, per-capita raw material consumption in emerging economies such as China or India remains comparatively low. In 2011, it amounted to only half or even one-fifth that of Germany. Even if these countries have closed the gap in the intervening years (and the difference between China and India has narrowed), increasing efficiency and decreasing raw material consumption for Germany and the European Union is without doubt necessary; on one hand because of the resultant reduction in environmental pressures, and on the other as part of a world in which access to raw materials is “fairly” distributed and global conflicts due to resource scarcity might be avoided (↸ page 38, “Economic growth and raw material use”). In emerging economies such as Brazil or India, biomass forms the raw material category with the largest share of total consumption. These countries are currently undergoing industrialisation processes and the agricultural sector is traditionally very important for the domestic market. As development into a highly diversified and industrialised economy gathers pace, the importance of the agricultural sector – and thus also of biomass as a basic raw material – is declining. Developing industry and (transport) infrastructure is then reflected in the high share of consumption accounted for by mineral raw materials. China is the best example of this development – almost 60 % of consumption is accounted for by mineral raw materials. Depending on availability and the chosen energy mix, fossil fuels account for a higher or lower share of total consumption. In Germany or Japan, this share amounts to approximately 20 %, in the US the share is 25 % and in Russia as much as 30 %. Countries with a strong nuclear energy or hydroelectric sector consume less fossil fuels. In France or Austria, these represent only approximately a 12 % share of total raw material consumption.

Development of raw material consumption (RMC) in Germany, 2000 – 2011

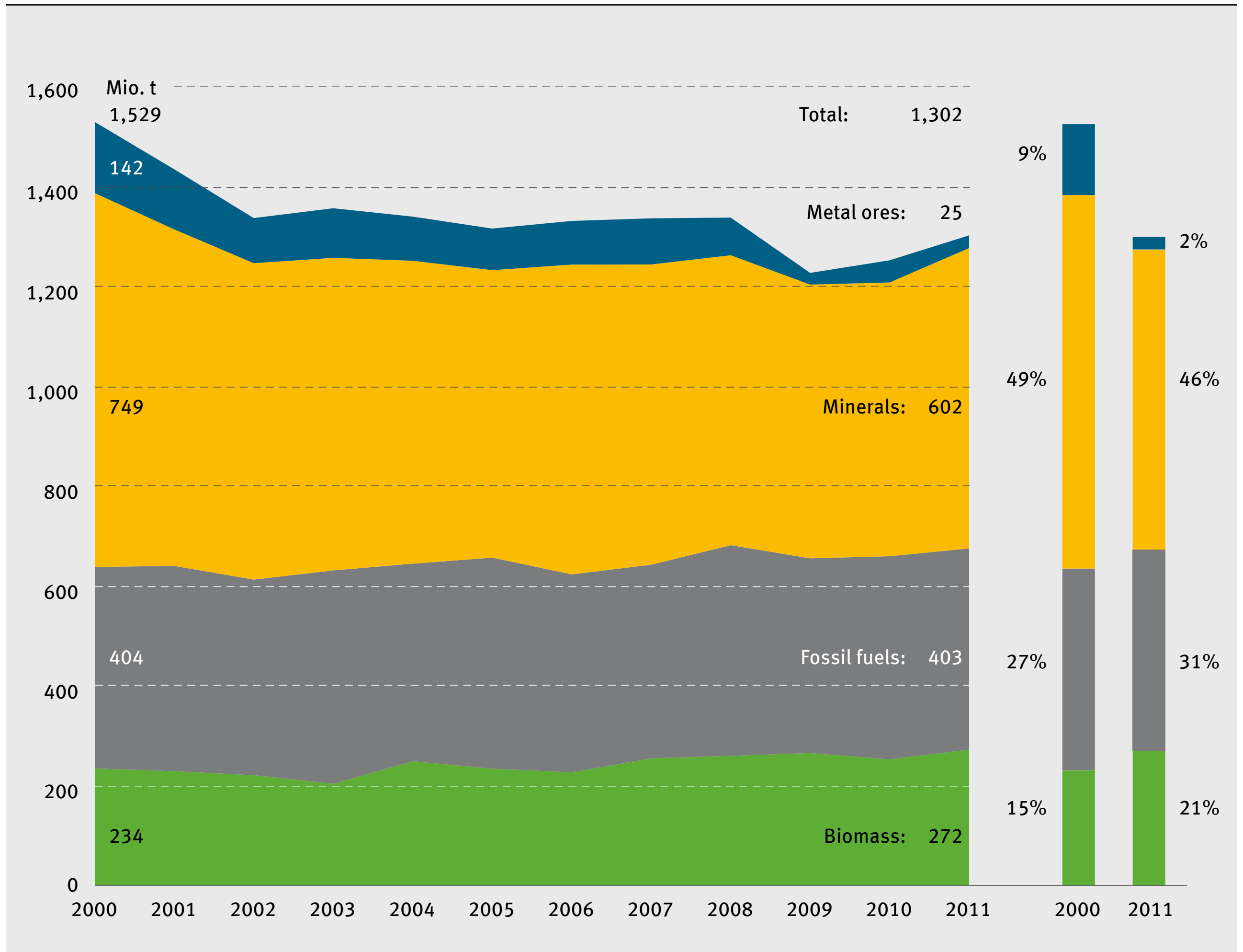


Figure 27 Source: Destatis, 2015 a

International comparison between per capita raw material consumption (RMC) and the global average, 2011*

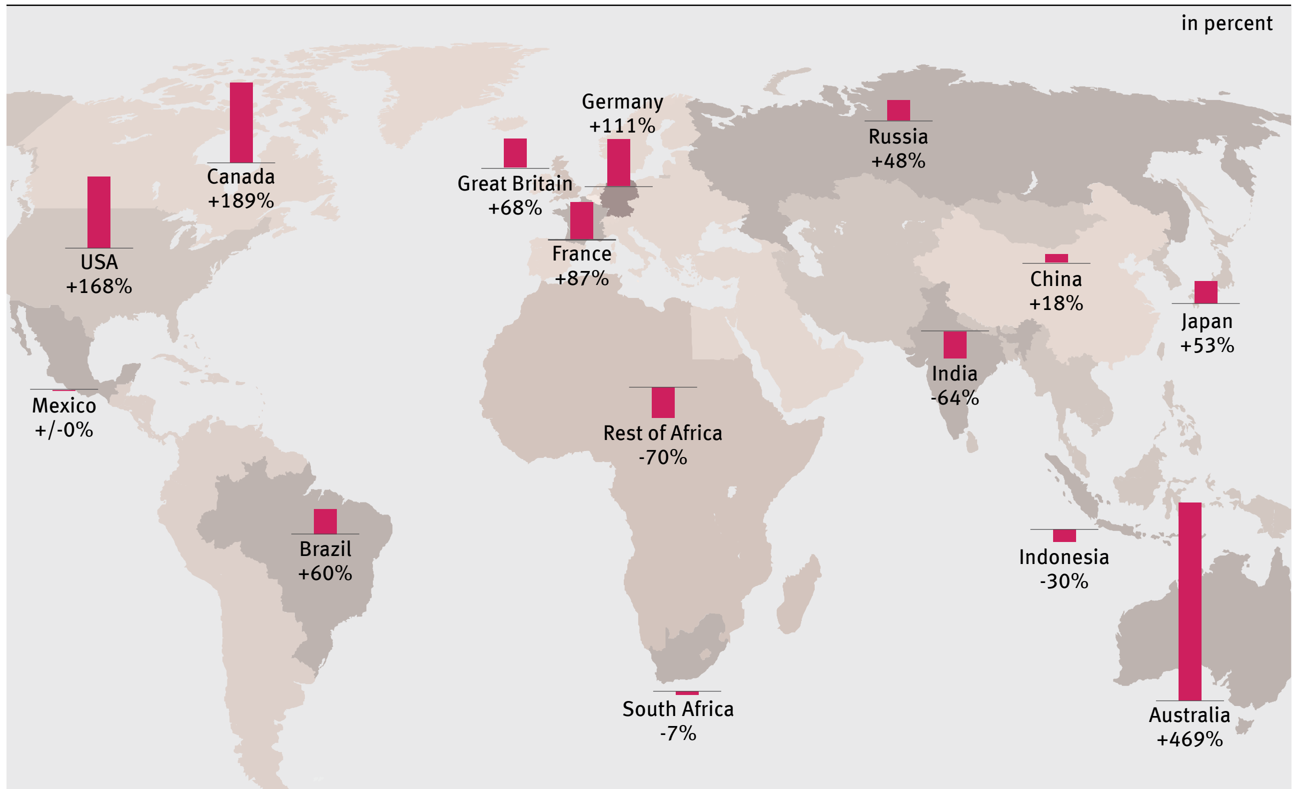


Figure 28 Source: WU, 2016 a

** Note: The figures for raw material consumption in this graph differ from the figures cited above because they have been calculated using a different data basis. (↸ page 10, “Methodological background”)*

Raw material consumption – from the domestic to the international perspective

The use of raw materials in Germany can be measured with different indicators. An exclusively national perspective produces far lower figures than are obtained when including the indirect and unused extraction along the production chains. The indicator which takes account of all aspect of material consumption – in short: TMC – produces a figure of almost 43 tonnes per capita and year. This is almost three times as high as the figure for domestic extraction. Depending on the thematic focus, different indicators are appropriate.

The thematic focus of decoupling (↖ page 38, “Economic growth and raw material use”) already revealed that the use and productivity of raw materials in Germany are assigned different values depending on the scope of the selected indicators. A common feature of all the indicators used is that they show a decrease in the last ten to fifteen years (⇢ Figure 30). This is true for domestic extraction used (DEU) and domestic material consumption (DMC) as territorial indicators and is equally true for raw material consumption (RMC) and total material consumption (TMC), which also take account of indirect extraction of raw materials along supply chains. TMC however also includes unused extraction both from within and outside Germany (↖ page 22, “Unused material extraction”). DMC and RMC per capita in 2010, the most recent year for which all the indicators mentioned are available, were similarly high, at 15.2 and 15.3 tonnes respectively (as they were in 2011, at 16.8 and 16.2). If the unused extraction is also accounted for, this value (TMC) is tripled (at 43.3 tonnes per capita). Since additional factors must be included from one indicator to another, the shares constituted by different raw material groups in the overall figures also shift (⇢ Figure 29). This is partly linked to the availability of different raw materials in Germany and internationally (↖ page 12, “National perspective: domestic raw material extraction”, ↖ page 24, “International interdependencies: Germany’s global raw material trade”). It is also connected to the fact that the various raw material groups exhibit different relationships

Different material flow indicators for Germany, 2010

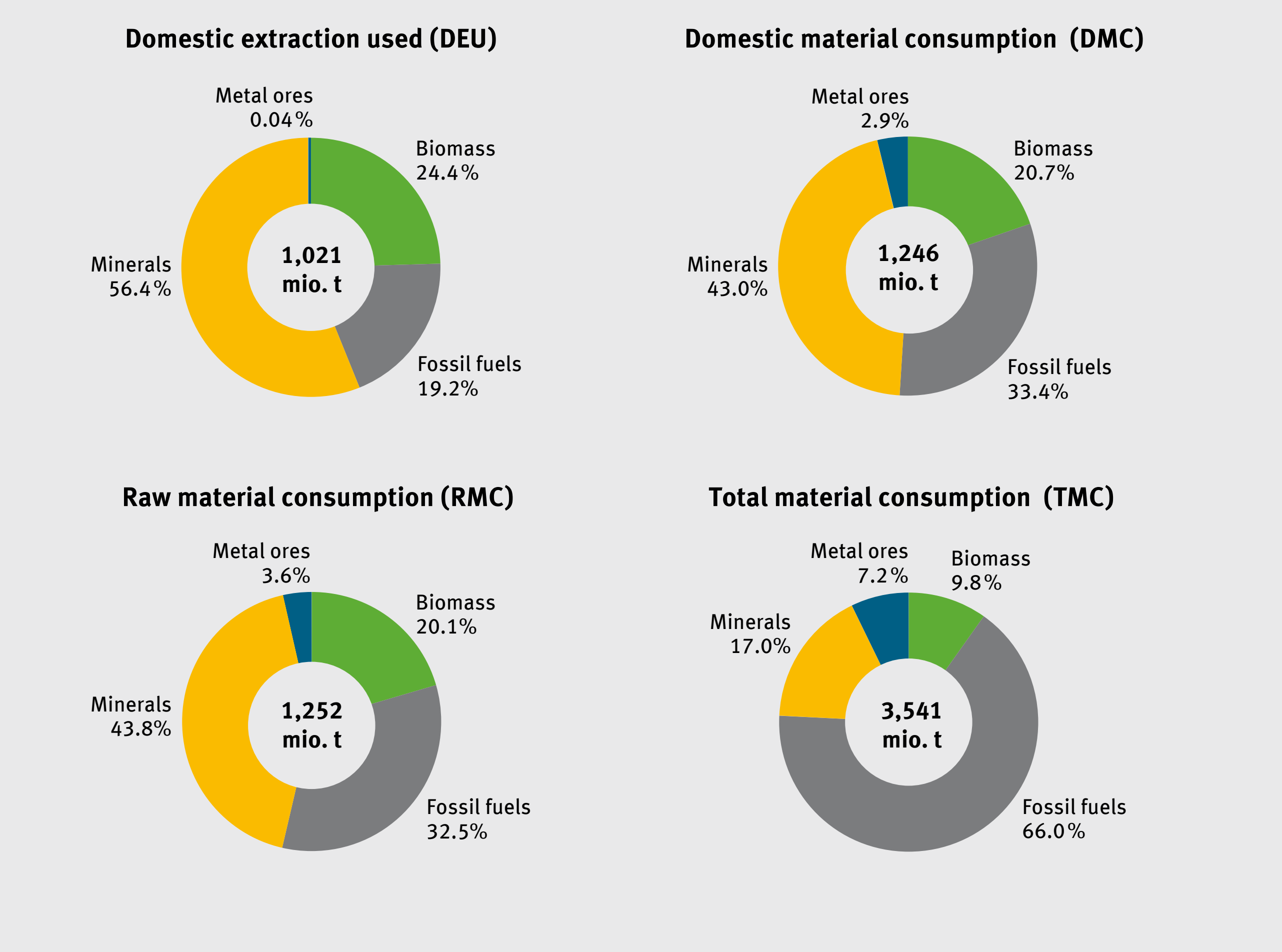


Figure 29 Sources: DEU, DMC, RMC: Destatis, 2015 a; TMC: OECD, 2015

Development of per-capita raw material use in Germany using different indicators, 2000 – 2010

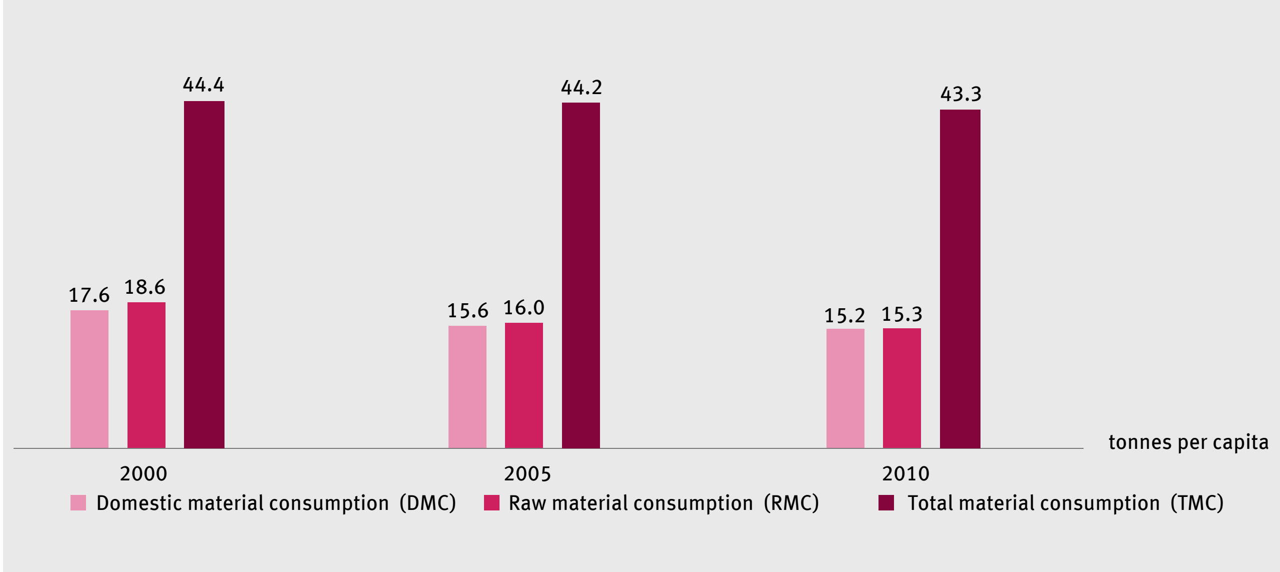


Figure 30 Sources: DMC, RMC: Destatis, 2015 a; TMC: OECD, 2015

between net weight and raw material equivalents or the unused extraction accrued (↖ page 28, “Indirect import and export flows”).

Thus metal ores, for example, only play a marginal role in domestic extraction (Indicator: Domestic extraction used, DEU), whereas mineral raw materials comprise the largest share (56 %). This clearly reflects the availability of different raw materials. If imports of raw materials are also included in the calculation and exports are subtracted (Indicator: Domestic material consumption, DMC), it is evident that the influence of mineral raw materials declines, while metal ores and particularly fossil fuels gain in importance. This picture changes little when indirect raw material flows are included (⇠ Figure 29). It also becomes clear that little progress has been made in recent years where the reduction of raw material use is concerned. In the case of DMC and RMC these comprise 13 % and 18 % respectively, and in the case of TMC, only 3 % (⇠ Figure 30).

Depending on which perspective or which indicator is used, varying conclusions may be drawn in relation to raw material management and environmental protection. While indicators such as domestic extraction and domestic consumption identify which raw materials are of particular importance for the German economy, raw material consumption (RMC) reveals what quantities of raw materials are extracted globally in order to facilitate domestic consumption. Total raw material consumption, in contrast, quantifies in which area large-scale environmental consequences occur as a result of unused raw material extraction.

Both the indicators RMC and TMC therefore bring the international dimension into consideration. This approach is critical in allowing an estimation of the social or environmental consequences associated with the consumption of particular products. Accordingly, the share of raw material originating outside Germany is also higher, since international supply chains are also taken into account where these indicators are used. The different indicators can therefore be employed to answer different questions and should be calculated and evaluated as the context requires.

European aluminium consumption as a cause of Amazonian rainforest clearance

In the global context, Brazil is the third largest producer of bauxite, which is used as a raw material in the production of aluminium. In parallel to global developments, aluminium production in Brazil has continually increased and reached almost 38 million tonnes in 2013. Aluminium production in Brazil is largely controlled by foreign multinational companies. Thus while the country generates income through the export of crude ore and primary goods produced from it, the largest share of value added is generated through further processing outside Brazil.

Bauxite extraction and the production of aluminium uses around 16,000 square kilometres of land area in Brazil. These figures are all the more alarming if one considers that bauxite deposits are located in the Amazon rainforest. Bauxite extraction is thus responsible for profound environmental damage, ranging from destruction of the rainforest to the pollution of soils and water. These impacts are robbing indigenous communities of their means of existence and such populations are forced to abandon their traditional ways of life. Since large quantities of the bauxite extracted in Brazil flow indirectly into European consumption, it is of critical importance that cooperation between producer and consumer countries should ensure sustainable supply chain management and thereby reduce the negative consequences for humans and the natural environment to a minimum. (SERI et al., 2013).

Final demand: Structure and trends

The consumption of raw materials in Germany is determined by different areas of so-called final demand, such as private households, the public sector or non-profit organisations. In Germany, private households account for around half of the raw material consumption. Most raw materials are used through the consumption of products based on biomass – for example, foodstuffs – followed by products made from metallic and mineral raw materials, and products from the construction sector.

While a part of the goods produced in Germany or imported into Germany are used as upstream inputs for production, the remainder are available to satisfy final demand. Final demand thus comprises those goods that are not further processed within the domestic economy but are consumed instead. In analysing the final demand of a particular country, expenditure is normally assessed in relation to type of use – private household expenditure, public sector expenditure, expenditure by private non-profit organisations, capital investments or exports – and according to different product groups. For an effective, goal-oriented management of raw material consumption, it is however sensible to consider not only financial expenditure but also the consumption of raw materials by product groups and final demand categories. This allows identifying the raw material intensity of different areas of consumption.

Three product groups in particular share responsibility for the raw material consumption of German final demand: Products based on biomass (e. g. food), products for the construction industry and further processed products based on metals and minerals. Taken together, these products comprise over 50 % of total raw material consumption. These three groups are significantly more raw-material intensive than products that are created directly in the agricultural or mining sectors and are made available to meet final demand, since these only constitute a small part of the total production in these sectors. Minerals and biomass in particular play an important role in all three product groups – both as direct raw material inputs and also via necessary upstream services, such as the construction of buildings in which foodstuffs are processed (⟶ Figure 31).

Raw material consumption of final demand in Germany by product group and raw material group, 2011

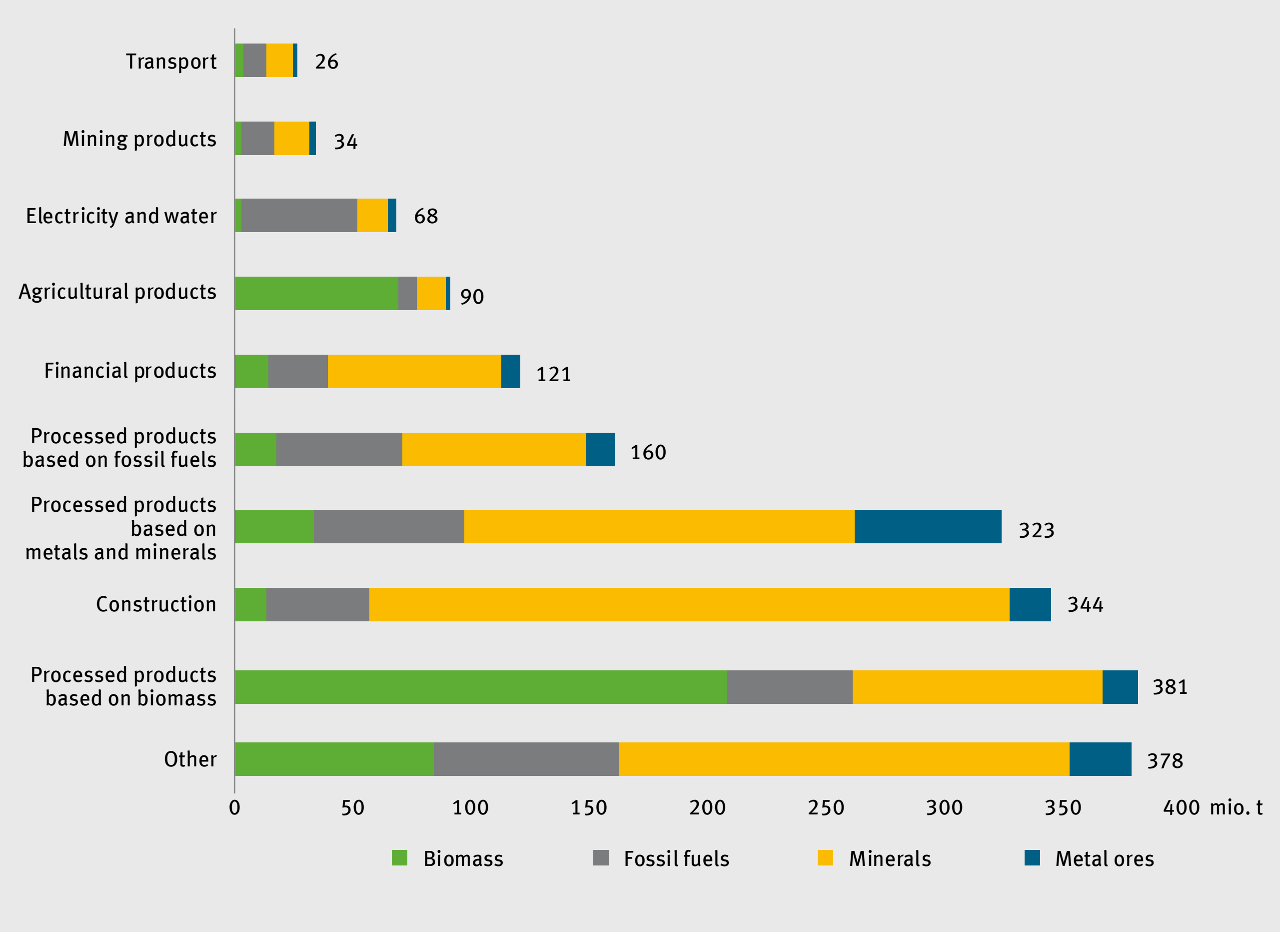


Figure 31 Source: WU, 2016 a

Raw material consumption in Germany by final demand category, 1995 and 2011

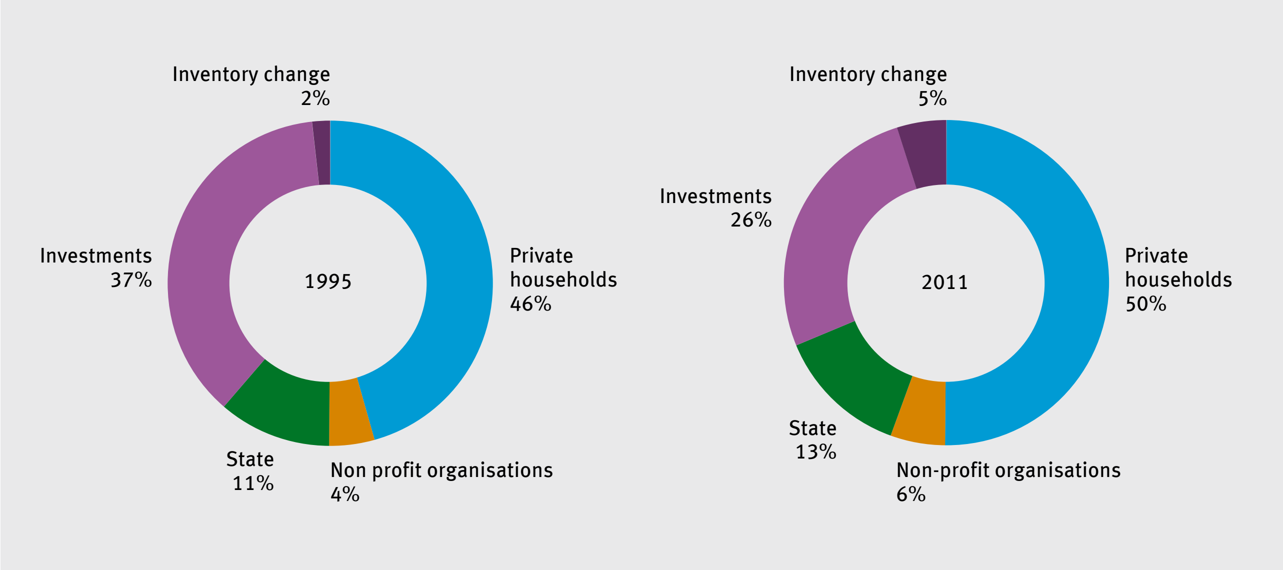


Figure 32 Source: WU, 2016 a

Just under half of the raw materials that are required both directly and indirectly (via upstream services) in order to produce the goods consumed in Germany are extracted in Asia (44 %). At least one-third of these raw materials originate within Germany or the EU, although North and South America and Africa also play an important role as raw material suppliers. In a world with ever more complex production chains, it is becoming more difficult to manage potential supply risks proactively, or to operate responsibly by taking account of the global impacts caused.

Service sectors also make use of raw materials. Thus, in the case of transport means such as rail or taxi travel, both the raw materials required for their creation are accrued, and also, for example, fossil fuels that are required for their operation. In the same way, a doctor, a library or a sports facility require particular equipment, buildings or other material goods, which rely on a particular raw material requirement. In Germany, many raw materials are also consumed via financial products, primarily related to property services (such as the granting of credit for building projects) (⟵ Figure 31). These are not accounted for as part of the infrastructure or construction business.

Due to the composition of different products and services, the raw material intensity of final demand varies significantly between private consumption, public sector consumption or investments. Public sector consumption (↘ page 52) and that of non-profit organisations are characterised by their high share of services, which require relatively fewer raw materials and thus show a lower level of raw material intensity. The development of capital investments, such as buildings or machinery, typically makes very intensive use of raw materials. Private consumption, with its mix of products and services (↘ page 54), lies in the mid-range where raw material intensity is concerned (⟶ Figure 33).

Trends in raw material intensity of different final demand categories in Germany, 1995 – 2011

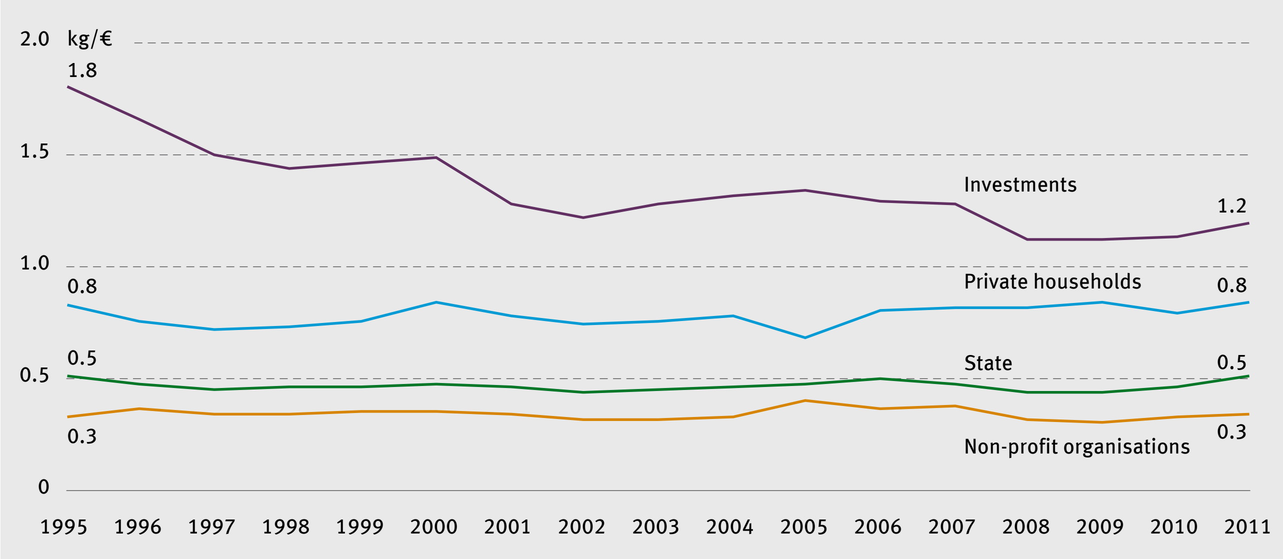


Figure 33 Source: WU, 2016 a

Public sector consumption

The high standard of living in Germany is based to a large extent upon an extensive system of publicly funded services. This too requires raw materials, since a wide range of products are used in sectors including health, education, defense or civil protection. Public procurement is therefore particularly well-placed to provide important momentum for the development and establishment of resource efficient, innovative products and technologies.

The public sector, with its diverse functions and services, plays a decisive role in German raw material consumption. In 2011 the public sector consumed more than 250 million tonnes of raw materials either directly or indirectly – that is, via upstream services. This represents 13 % of total utilisation of German final demand. Public procurement also accounts for 13 % of gross domestic product, and thus exerts a significant influence on demand for and the development of resource efficient products and services (⇢ Box).

Particularly intensive areas of public sector consumption in terms of raw material use include the three central public service sectors of public administration, defence, and social security (44 % of total raw material consumption by the public sector), health (30 %) and education services (8 %, ↘ page 76, Table A 9). In addition, the state also directly demands products such as further processed products from fossil fuels (15 %). The latter reflects the use of fuels for public transport, e. g. schoolbuses etc. and the public supply of products for private means, for example, regarding health care services (⇢ Figure 34).

The composition of raw material consumption by the public sector has changed little over time (↘ page 76, Table A 9). Nonetheless, services relating to health and social services are becoming ever more significant in material terms, which may be seen as representative of general developments in public spending.

In order for the state to provide all the services that fall within its core area of responsibility, an enormous quantity of upstream inputs involving a wide range of products is required. The most important supply industries for the public sector in quantitive terms are the mining and construction industries, since appropriate infrastructure is required for the provision of all public services. In 2011, this group of upstream products alone accounted for more than 100 million tonnes (⇢ Figure 35). The second most important product group in 2011 were biomass-based products (more than 45 million tonnes). These were either taken directly by the state from the agriculture or forestry sectors or procured via further processing industries, such as the food industry or the timber processing industry. Vast quantities of biomass are required for example in the area of state provision of food, e. g. in school or hospital canteens. State requirements for paper and paper products also fall within this category. Products from metals and minerals were in third place in 2011 (43 million tonnes). These include a range of products such as vehicles, machinery or IT products. At over 30 million tonnes, products from fossil fuels also contributed substantially to raw material consumption by the public sector in 2011. The generation of energy, particularly electricity, and transport services only played a minor role as upstream services for public consumption of raw materials.

German public sector consumption of raw materials – key product groups, 1995 – 2011

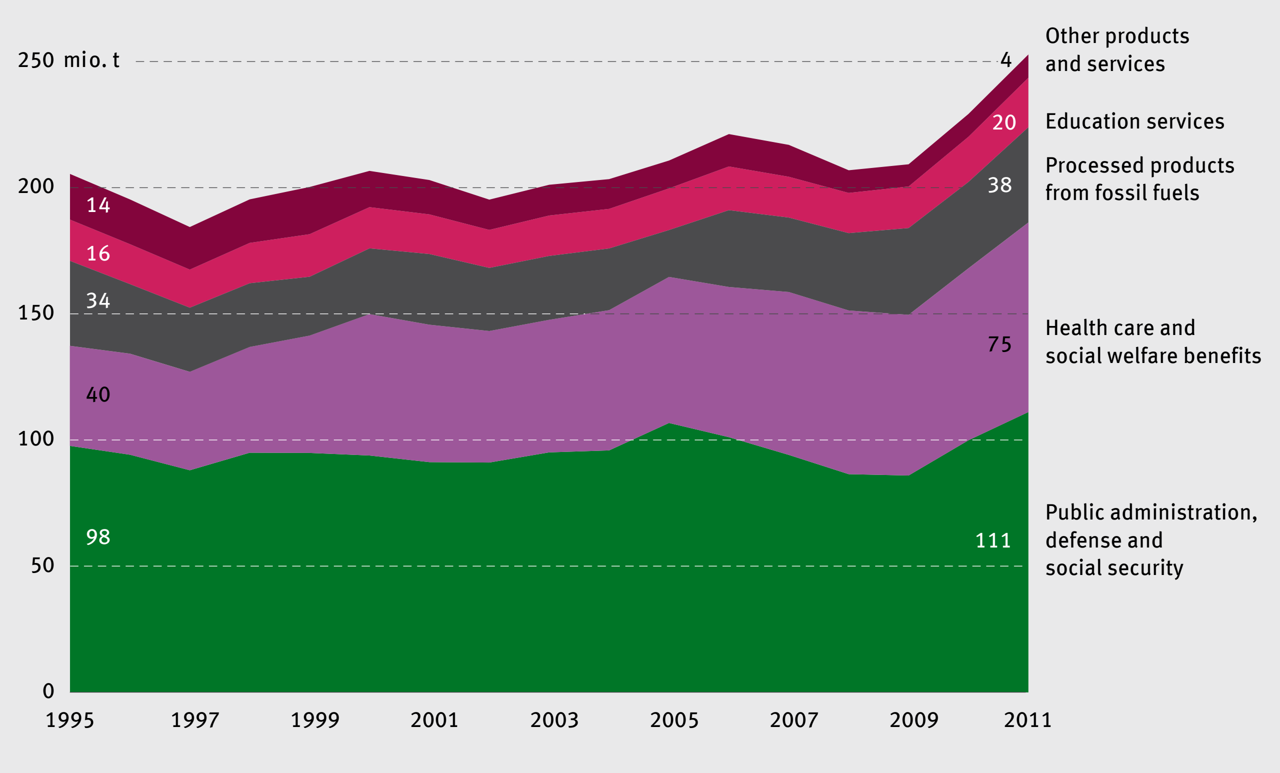


Figure 34 Source: WU, 2016 a

Intermediate inputs to raw material consumption by the German state, 2011

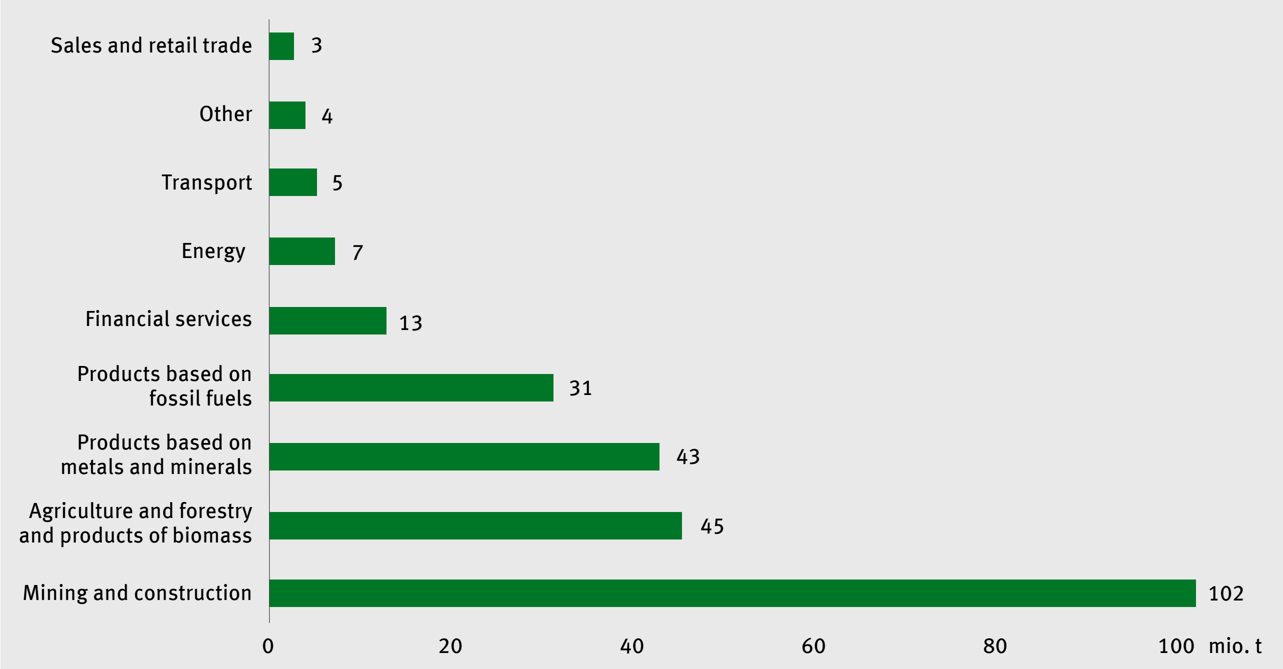


Figure 35 Source: WU, 2016 a

Raw material efficiency in public procurement in Germany

On 06.12.2010, the State Secretaries' Committee for Sustainable Development of the Federal Government adopted a paper on the implementation of sustainability measures in the public administration ("Nachhaltigkeit konkret im Verwaltungshandeln umsetzen – Maßnahmenprogramm Nachhaltigkeit") (Deutsche Bundesregierung, 2010). The measures set out in the document include, for example, the exclusive procurement of products of the highest energy efficiency category, the stipulation of appropriate environmental standards and labels (e. g. "Blauer Engel") in public tendering, the improvement of energy efficiency for vehicle fleets, and training in sustainable procurement for employees of commissioning bodies. This range of measures clearly demonstrates the federal government's determination to ensure that public procurement supports resource efficient products and services.

To develop further initiatives and measures, an expert working group on resource efficiency was founded within the alliance for sustainable procurement, to formulate recommendations for action and guidelines for procurement bodies at national, federal state, and municipality levels. Thus, for example, guidelines for the thematic area of recycled building materials or green IT have been developed and published on the website of the Competence Centre for Sustainable Procurement (KNB), the central point of contact for all federal government departments, federal states, municipalities and other public procurement departments in the framework of sustainable public procurement (www.nachhaltige-beschaffung.info).

Private consumption

Private consumption of products and services fulfils various purposes. Basic needs such as nutrition or housing are thereby met, but other requirements are also involved, including leisure activities, travel and entertainment. The areas of private consumption that show the highest raw material intensity are the three consumption areas of housing, food and leisure. 75 % of the raw material consumption of private households in 2011 was related to these three areas. Intelligent concepts and more informed behaviour can create substantial savings in the realm of private consumption.

At 50 %, private consumption constitutes by far the greatest share of domestic final demand for raw materials (⇖ page 50, "Final demand: Structure and trends"). During the period from 1995 to 2011, raw material consumption by private households in Germany rose by 16 %. Individual consumption fields that we wish to satisfy differ from one another in terms of their raw material intensity. The two major consumption fields of housing and food balance one another with 30 % of total private consumption. Meeting our basic needs – sufficient food and shelter – is therefore the most relevant issue concerning raw material requirements (⇘ page 76, Table A 9). However, leisure (almost 20 %) and mobility play an important role in Germany as they do in other highly developed countries (⇢ Figure 36). From the perspective of a sustainable management of raw materials, reducing per-capita consumption and a stronger focus on sustainable products and services are also necessary in the context of private consumption. This requires the cooperation of all actors, including those from the political and economic spheres and consumers.

The individual consumption fields consume different raw materials. Thus in the housing sector, minerals and fossil fuels play a more important role than biomass. The opposite is true in the area of food and nutrition. Interesting trends can also be identified over time. Thus in the area of housing between 1995 and 2011 the use of fossil fuels shows a sharp decline (of approximately 44 %), in part due to changes in the composition of electricity generation – moving away from coal. In the consumption area of leisure, the share of minerals has risen. Of relevance here is the fact that today more products originate in China (electrical goods, etc.), and because of the infrastructure expansion in China these bring with them a higher share of minerals as up-stream inputs (⇘ page 76, Table A 9). In the case of the diverse upstream inputs in the course of ever more complex supply chains in all consumption fields, all categories of raw materials are relevant, however. Thus we meet some of the requirements in the area of housing through the use of biomass, while the production of food also requires the use of minerals (⇢ Figure 36).

In order to achieve a reduction in raw material consumption by private households, it is useful to identify not only the consumption areas with the highest levels of raw material consumption but also the specific product groups that play an important role within each of the consumption fields. Thus the "hotspots" with the highest levels of raw material consumption and by association the priority areas for policy measures within each consumption field can be identified. In general, further processed products based on biomass, metals and minerals or fossil fuels play an important role.

Raw material consumption of private households in Germany by consumption areas and raw material categories, 1995 and 2011

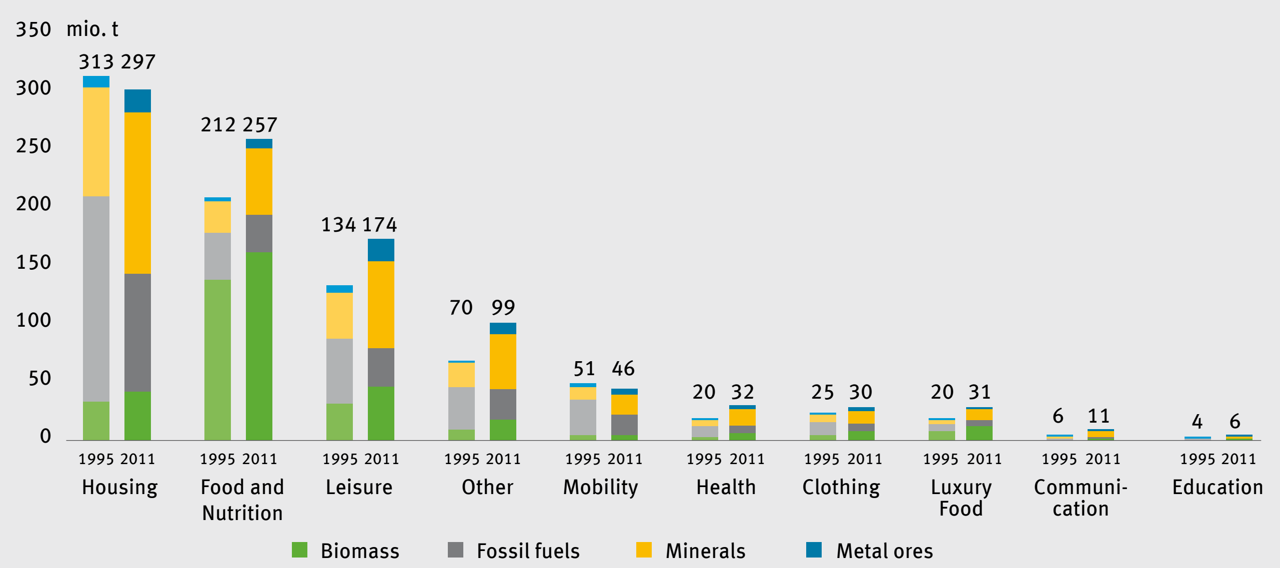
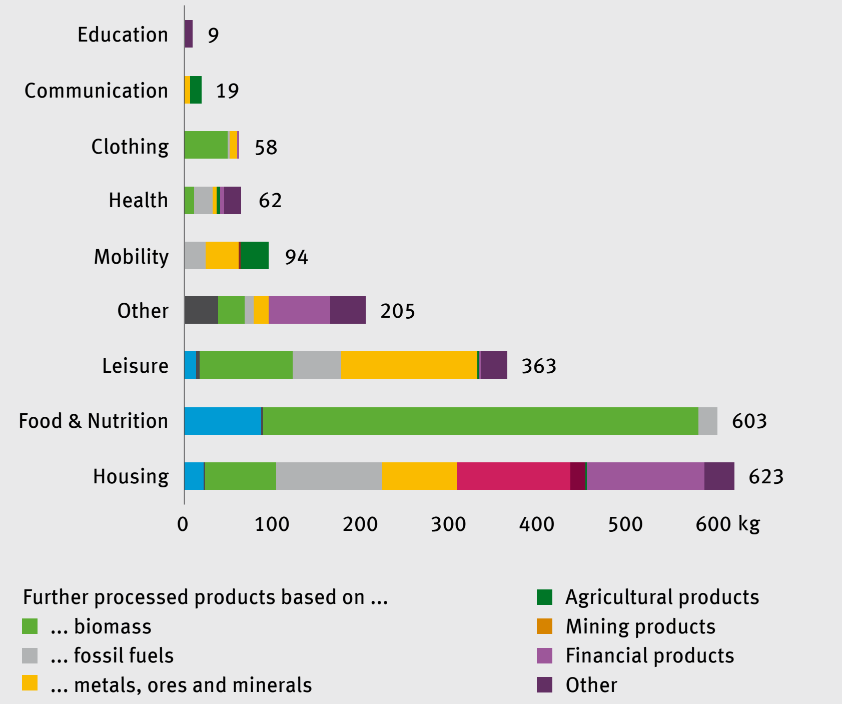


Figure 36 Source: WU, 2016 a

Monthly raw material consumption and expenditures per household by consumption areas and product groups, 2011



	Raw material consumption		Expenses	
	kg	percent	Euro	percent
Education	9	0	16	1
Communication	19	1	57	3
Clothing	58	3	104	5
Health	62	3	93	4
Mobility	94	5	319	14
Other	205	10	88	4
Leisure	363	18	244	11
Food & Nutrition	603	30	431	19
Housing	623	31	900	40

Figure 37 Sources: WU, 2016 a; Destatis, 2015 f

The first of these are, for example, foodstuffs such as meat or milk products. In the area of housing, energy for heating and electricity as well as the construction of buildings are key issues, and in the case of leisure, different vehicles or electronic products. The category "Other" comprises a range of goods and services, such as, for example, services in the areas of insurance and financial investments (⇠ Figure 37). Over time, the composition of raw material consumption by private households in relation to product groups has changed very little. Some consumption trends are only evident in the case of specific products.

Raw material consumption for the individual consumption areas is only reflected to a partial degree in the average monthly expenditures of German households. Thus – parallel to raw material consumption – by far the largest share (40 %) of spending is related to housing, whereas spending on mobility and food account for no more than a third. Savings in raw material consumption related to housing could therefore produce the largest savings in household spending and vice versa. In general, it is evident that in the areas of housing, food and nutrition, mobility and leisure, there are great potential savings to be made in terms of raw material consumption and the costs associated with this, and that exploiting these would lead to an economic and environmental win-win situation (⇢ Box).

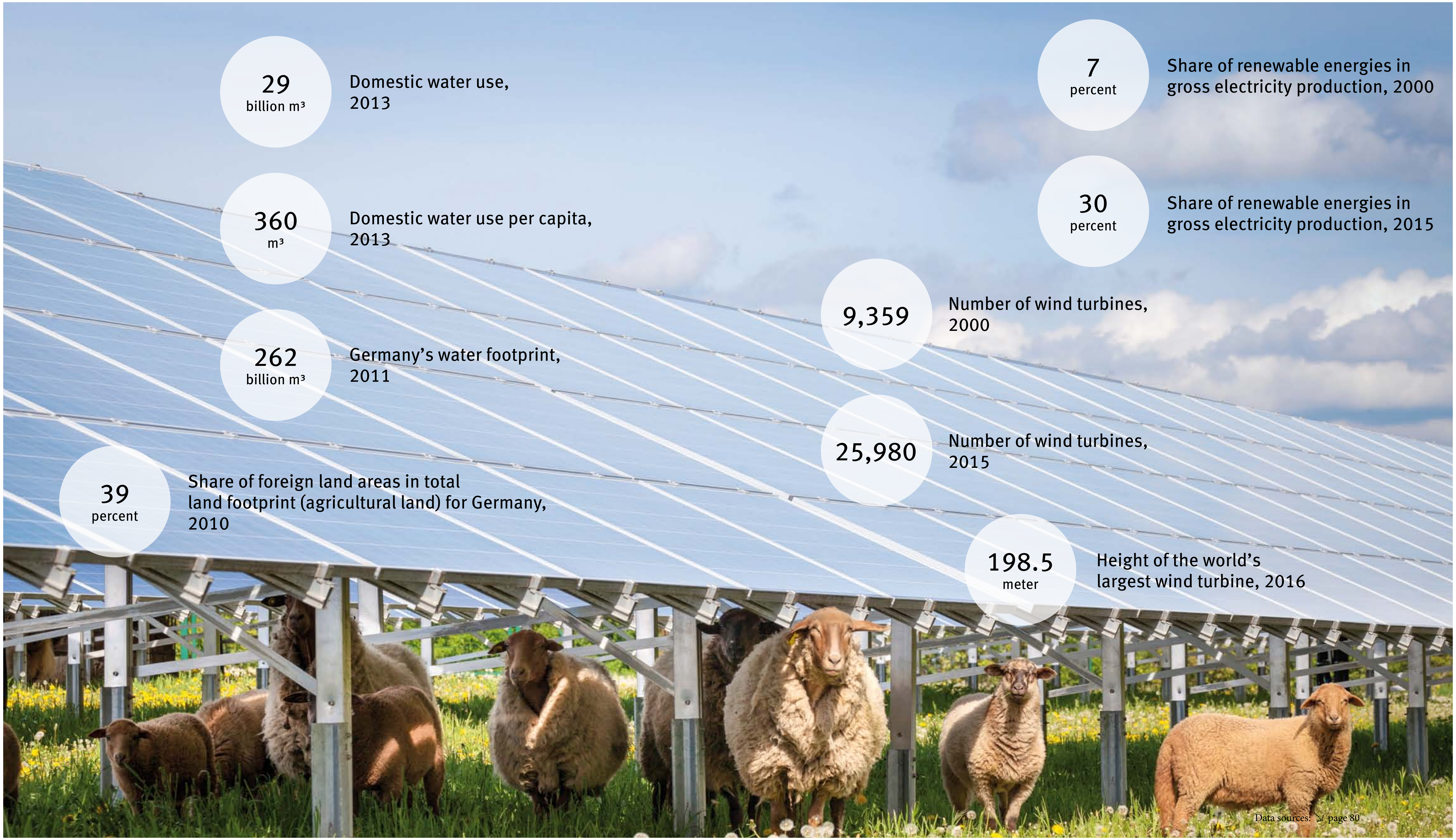
National programme for sustainable consumption

On 24.02.2016 the German Federal Government adopted a national programme to strengthen sustainable consumption. This envisages that particularly areas with a significant sustainable management potential, such as domestic life and housing, mobility, food and nutrition, workplaces and work, clothing, and tourism and leisure, should be systematically supported and developed.

In the programme, goals and measures for more sustainable consumption are identified and existing strategies, funding programmes and regulations are linked together and developed further. As a part of the overall sustainability strategy of the Federal Government, a platform for social dialogue on the future development of consumer behaviour is to be established.

In the public sector, sustainable consumption will be strengthened through the establishment of sustainable procurement in the context of the Federal Government's sustainability action programme (⇖ Box, Chapter "Public sector consumption"). In addition, a government working group is engaged in developing an indicator for sustainable consumption, which could be adopted within the National Sustainability Strategy. (Deutsche Bundesregierung, 2016 b)

Resource use: A complementary viewpoint



Water

The extraction, trade and economic utilisation of raw materials also require the use of other natural resources. Water is used during the extraction of raw materials, for example through irrigation of agricultural land or as a processing solution and coolant in mining operations. Equally, it is used in energy production and in almost all production processes as a coolant or cleaning agent. Water use in private households has declined around 16% since 1991. While direct water use in Germany has declined in recent years, indirect water flows, i. e. the water contained in products consumed, have increased.

Global stocks of available water are of critical importance for both society and the economy. Although water is a “renewable” resource, its availability can be limited, when considering the huge regional and temporal differences. Many regions worldwide suffer from water shortages – at least periodically – which results in the water table falling, rivers no longer transporting sufficient volumes of water and natural wetlands drying out. In the countries of central and northern Europe, which has a relative abundance of available water, the focus of water management strategies has long been upon water quality rather than the quantitative use of water. This has also been the case in Germany. Nonetheless, in Germany too, efforts have been made – both for economic and ecological reasons – to reduce the demand for water. As a result, water extraction for various sectors declined considerably since 1991, by about 47 % (⇢ Figure 38).

Also in the year 2013, the largest water withdrawal was required for energy supply, even though it had dropped by about 7 billion m³ compared to 2010. The water is required primarily for cooling processes in coal, gas or nuclear power stations. Further water withdrawals take place for public water supply, the manufacturing industries as well as the mining industry. Germany uses around 14% of the 188 billion m3 of potentially available water resources. 10 % of total water use is accounted for by private households, with every member of the German population using 121 litres per day for daily hygiene, washing machines, dishwashers or simply as drinking water (⇢ Figure 38).

With intensifying trade between states and continents, water is increasingly being used for the extraction, production and further processing of export goods. In many countries with relatively low freshwater reserves, a significant share of those reserves are being used for the production of goods to be exported to water-rich countries. If a consumer-oriented perspective is taken for the analysis of water use in Germany, then the water that is used to create imported goods must be correspondingly assigned to Germany’s water use. The resulting indicator is refered to as the water footprint. Germany’s water footprint has continually grown in recent years and roughly doubled in the period 1995–2011 to reach 260 billion cubic metres (3,245 m³ per capita) by 2011. In the course of this development, the share of Germany’s total water footprint constituted by water used outside Germany reached almost 75 % (WU, 2016 a). As the region of origin for water contained in products, an important role has been played by the Asian region, particularly China (around 20 bn. m³) and India (around 10 bn. m³) (⇠ Figure 39).

To develop a comprehensive and effective water management strategy, global interlinkages between resource use, trade, economic growth and social wellbeing must be taken into account, before changes in the economic and industrial management of (water) resources can be achieved. Local availability of water is a critical factor in evaluating direct and indirect water consumption. The water footprint concept can make the hidden water trade at the expense of water-poor countries more transparent. The aim is to identify policy options for regions in which water overuse due to the export of water-intensive products is resulting in negative environmental and social consequences, although trading partners of these regions should assume joint responsibility for these impacts.

Trend of water withdrawal for energy supply, mining and manufacturing industries and public water supply, 1991 – 2013

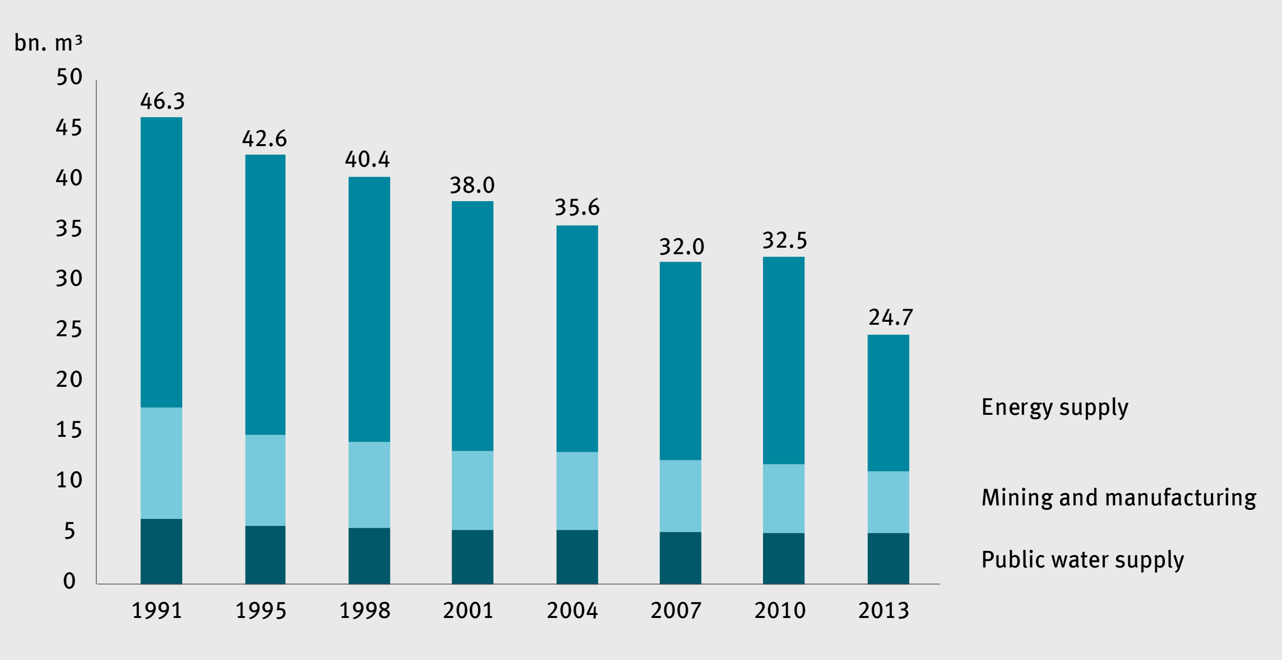


Figure 38 Source: Destatis, 2015 h, 2016 b

Germany’s net imports of blue and green water, top 10 countries of origin, 2011

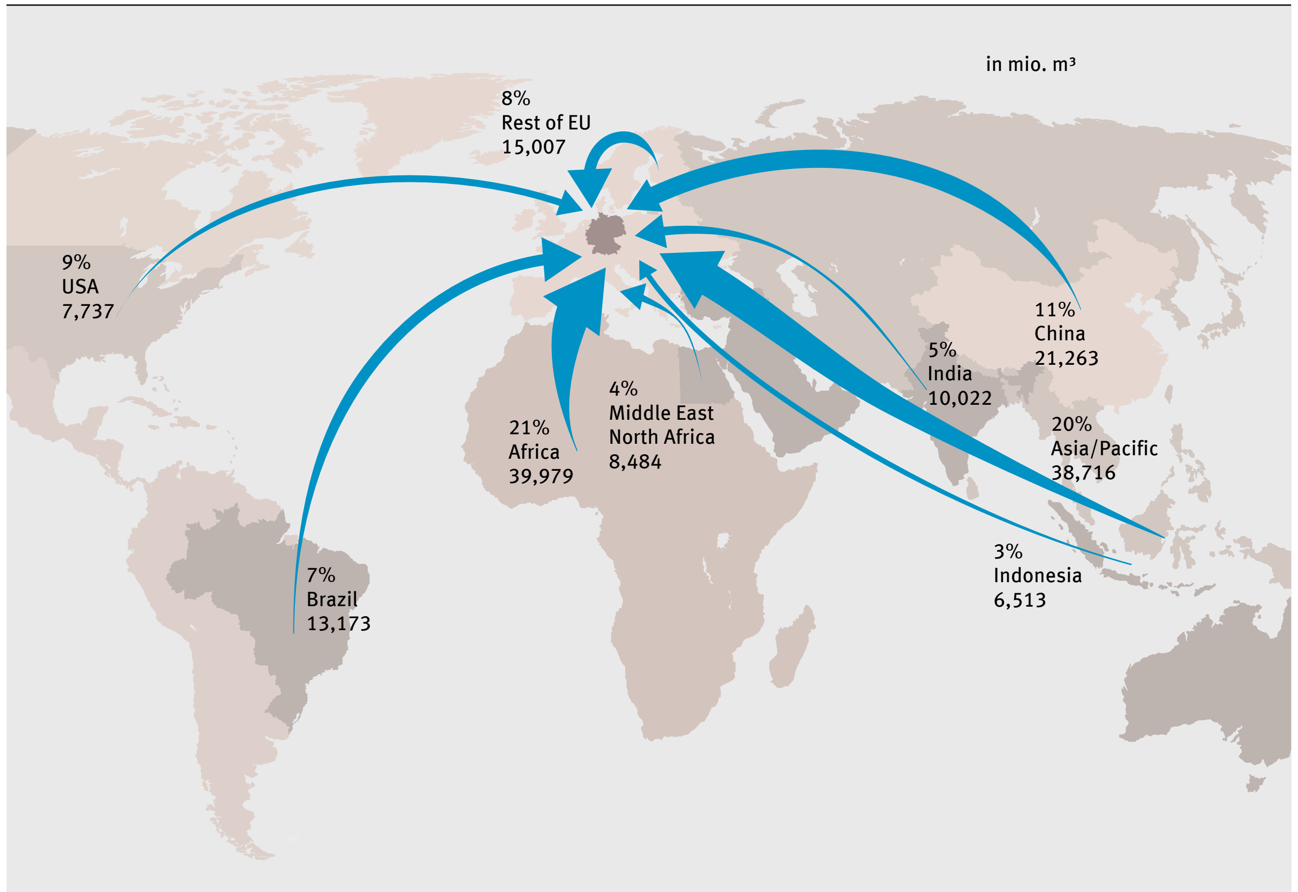


Figure 39 Source: WU, 2016 a

Relevant aspects for the analysis of water use

Direct and indirect water use: Direct water use refers to the use of water in production processes, for cooling processes, in households or as drinking water. Indirect use quantifies the amount of water that was required along the production chain to create a specific product. The sum of the indirect water use for a product or to satisfy the con sumption requirements of a person or a country is also termed the “water footprint”.

Three types of water are differentiated: “Blue water” is water from surface water bodies or groundwater, “green water” is rainwater, which – in contrast to groundwater – is stored in the upper soil layer from where it is absorbed by plants and evaporated. This is of particular relevance for agriculture. “Grey water” refers to waste water produced through production processes. Depending on the definition used, this either refers to the quantity of the waste water itself or to the quantity of water required in order to dilute waste water to a level at which it once again fulfils environmental standards.

Spatial, temporal and sectoral variations are particularly important for the analysis of water use and availability. In spatial terms, large differences can occur within a watershed or particularly between watersheds. In temporal terms, these differences appear according to the season and production cycle. Depending on the industrial sector and facility, very different water intensities can be observed.

Area

Alongside raw materials and water, a further category plays a central role in analysis of Germany's resource use: area. Agriculture and mining require area and subject it to alteration. At the same time, huge areas are required for business and industrial premises as well as for the trade and transportation of goods, for example for shopping centres or roads. The majority of Germany's area is used for economic purposes. Private uses, including housing and leisure activities, occupy a comparatively small share of the total. Since Germany is importing increasing quantities of goods, for the production of which area is required, both national and international aspects of land use management must be considered.

Similarly to raw materials and water, area, which includes both land area and water area, provides an essential basis for all life on earth. Forms of so-called land-cover vary widely – from woodland and arable land through to settlement areas and extractive areas. In addition, their uses are diverse and, depending on area availability, are in competition with one another. Alongside their significance in terms of environmental function, available areas are also an important basis for economic systems in a modern society and have great value as elements of the landscape.

Germany has a size of almost 360,000 square kilometres. Roughly half of this, i.e. 52 %, is used for agriculture, followed by forestry (30 %). Settlement areas and that used for transport infrastructure comprised almost 49,000 square kilometres in 2014 (13.7 % of the total area), although these areas are expanding by around 250 square kilometres per year (⇢ Figure 40). This annual expansion is the equivalent of roughly 35,000 football pitches or 69 hectares per day. Almost half of this area is sealed, i.e. built upon, concreted, paved or otherwise surfaced. Because of this, important soil functions, such as filter, storage and habitat functions are lost. In the framework of the national sustainability strategy, the Federal Government has set itself the goal of reducing the expansion of settlement areas and areas used by transport infrastructure by 30 hectares per day until 2020 (UBA 2016 b).

The extraction of minerals also requires area use. In 2014, approximately seven hectares per day were excavated, of which 3.6 hectares related to construction minerals, 2.2 hectares to lignite, 0.9 hectares for peat, and 0.3 hectares for industrial minerals (UBA 2016 c).

As an open national economy with intensive international trade activities, Germany imports increasing amounts of raw materials and products (⇱ page 24, "The international interdependencies: Germany's global raw material trade"). For the production of these traded goods, area in other countries is required. Germany thus possesses a "land footprint" (⇱ page 28, "Indirect import and export flows") beyond its national borders. Over the years, this has acquired significant dimensions. The share of Germany's total land footprint relating to agricultural land comprised of areas in other countries is currently two-thirds. Of this, the largest share is used for the production of animal products (around 50 %). A quarter (5.5 million hectares) of the global agricultural land required by German consumption is required for non-food materials (basic materials for industry, textiles, and bioenergy). This area also shows the fastest growth rates (Fischer et al., 2016).

Similarly to raw materials and water, it is also evident in the case of area that in an era of globalisation and strongly intertwined economic systems, the international dimension – that is, the footprint perspective – is becoming increasingly important. The growing competition for available areas threatens supply security both for local populations and also for those countries with large land imports. Beyond the quantitative aspects, the different intensities of area use together with the environmental consequences related to these must also be taken into consideration (⇢ Box). The issue of land use should therefore also occupy a more prominent position in responsible strategies on resource management and international trade.

Allocation of land use in Germany by use type, 2013

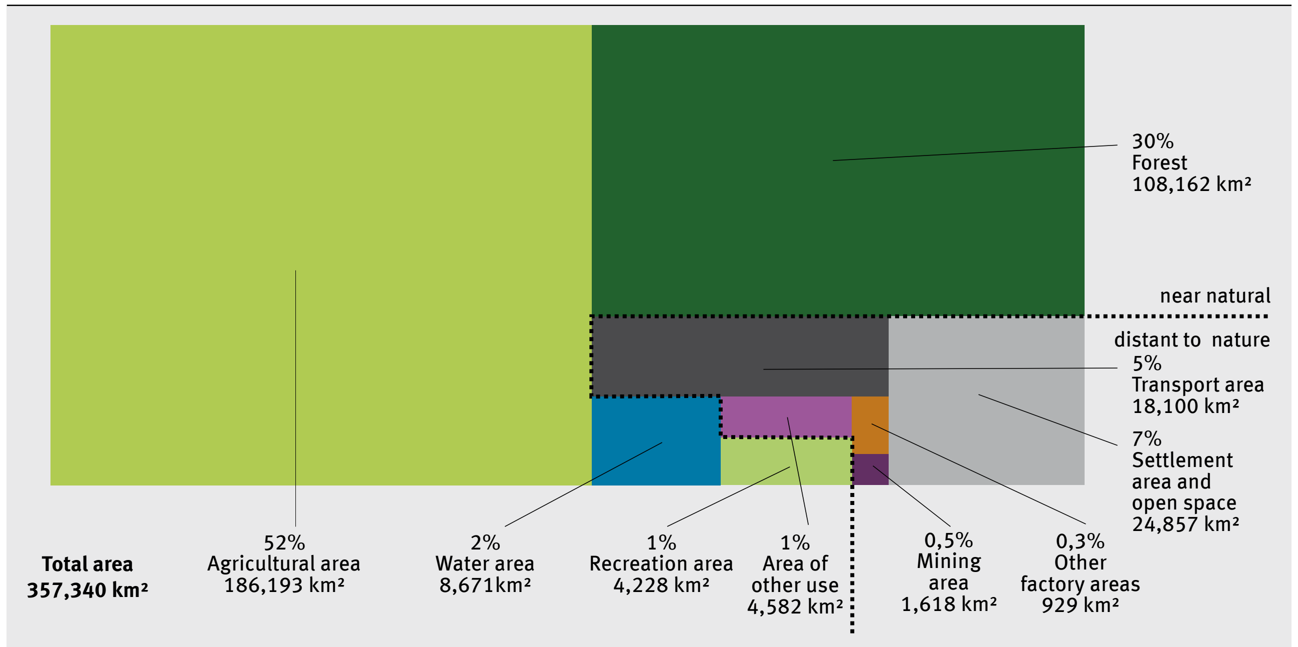


Figure 40 Source: Destatis, 2015 a

International land footprint (cropland) for food products consumed in Germany by region of origin, 2010

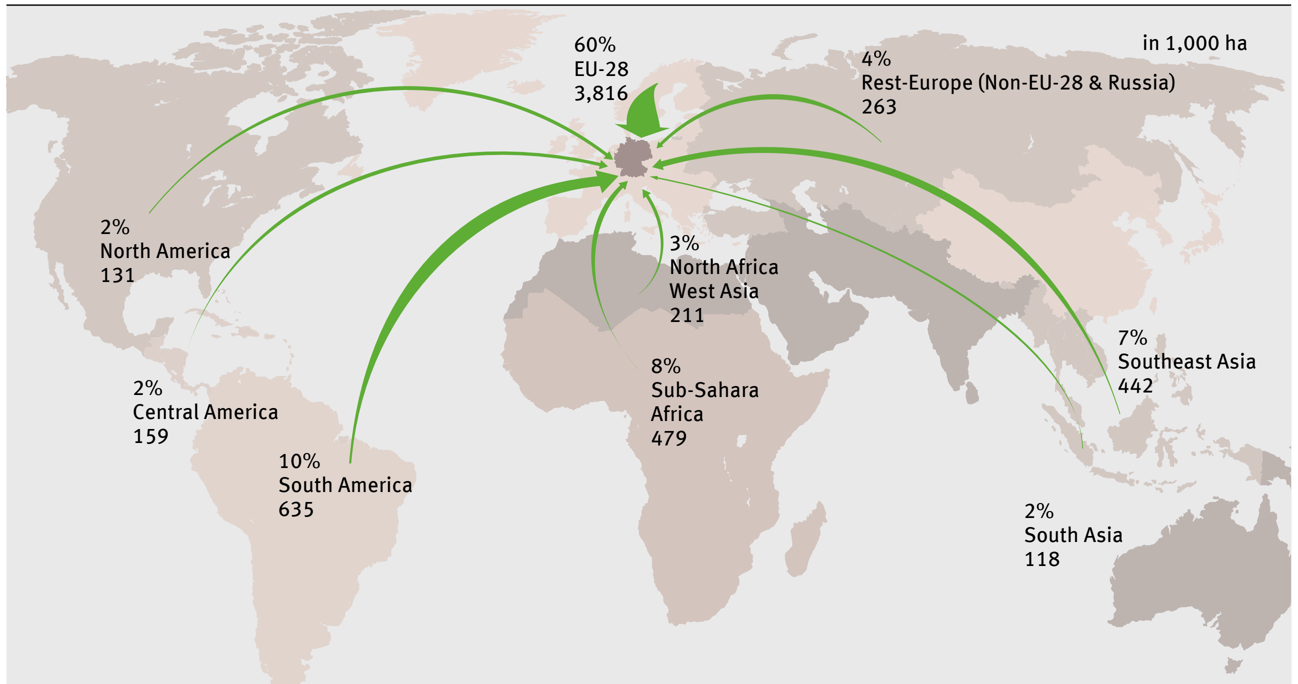


Figure 41 Source: Fischer et al., 2016

Land footprint and Ecological Footprint

The land footprint quantifies the scale of the area required both within a country and internationally, in order to produce the goods and services that are consumed in a country or region. It is expressed through the hectares or square metres of actual land utilised and can be calculated for individual countries or for sectors of the economy. Various categories of land use are differentiated – e.g. arable land, forestry area, grazing area or industrial area. The land footprint is thus also a basis for important extensions, such as weighting areas according to yield, biocapacity or other ecological, social or economic criteria (UBA 2013 a).

By contrast, the Ecological Footprint includes not only area requirements related to resource inputs and to the absorption of greenhouse gas emissions. It is defined as the sum of all bioproductive land and water areas that are required in order to produce the biotic raw materials consumed within a country, and that are required to absorb the greenhouse gas emissions. In contrast to the land footprint, the Ecological Footprint uses a weighting for different areas in accordance with biological capacity. This enables it to combine different categories of land use and greenhouse gas emissions in a single unit, termed the "global hectare". This indicator allows illustrating the degree to which inhabitants of individual countries utilise the regenerative capacity of the biosphere as a result of their consumption, and whether the national or global limits of ecosystems are exceeded (Global Footprint Network 2016).

Both indicators have different areas of application, based on the characteristics described above. The land footprint allows for real land use along the global production chains to be quantified. It is thus an important indicator for scientific research purposes and provides a basis for the design of policy measures. The Ecological Footprint on the other hand integrates different resource categories and environmental impacts within one figure, which makes communication easier. An example of the way in which this indicator is well-suited to communication purposes is the "Earth Overshoot Day", which shows the date in a given year on which the annual ability of global ecosystems to renew their biocapacity is exhausted – in 2015 this day occurred as early as 13 August. Ten years earlier, the date had been 20 October.

Flow resources

Flow resources, such as solar energy, wind or water flows, play an important role in particular as a replacement for fossil fuels. In 2015 the share of these energy sources in German electricity production already amounted to 30 %, even though electricity production had increased by 18 % since 1990. The largest contribution came from the use of wind energy, followed by photovoltaics. Especially at a time of increases both in energy consumption and climate-damaging emissions, conversion to this form of natural resource makes a vital contribution to climate protection. Nonetheless, expanding such infrastructure also requires the use of a wide variety of raw materials. This may in future lead to scarcity of these materials.

Solar energy, wind and geothermal energy or water flows all belong to the category of renewable resources. However, since they either cannot be collected or stored at all or only in a limited form, their flow characteristic is used as a source of energy. Approximately 30 % of electricity production in 2015 came from renewable energy sources. In comparison to this, around 42 % was obtained from lignite and coal, and 14 % from nuclear energy (AGEB, 2016).

In the light of Germany's overall climatic and topographical conditions, the focus lies primarily with exploiting wind energy and photovoltaics. Installed power in 2014 amounted to almost 40 gigawatts. This generated a total of 92 terawatt hours (TWh) of electricity (the majority of which came from wind energy). Although wind energy use has a long tradition in Germany, installed capacity increased sevenfold in the period 2000–2015, whereas photovoltaic installations as a new technology increased by a factor of 60 in the same period (see Figure 42). Hydroelectric potentials have practically reached their maximum capacity at 5.6 gigawatts, for which reason the electricity yield of about 20 TWh remained unchanged for a long period (BDW, 2016). Geothermal energy plays a minor role in the production of electricity, and is primarily used to generate heating energy. The absolute quantities produced and the distribution between different forms of renewable resources show strong variations between the individual federal states. Lower Saxony, North Rhine-Westphalia and Bavaria produce the most electricity from renewable sources in absolute terms. Mecklenburg-Vorpommern and Saxony-Anhalt have a high share of wind energy, while Bavaria produces a large share of its electricity through hydroelectricity (alongside solar energy), due to its topography (··· Figure 44).

In the context of a renewable energy potential analysis, the German Federal Environment Agency (UBA) examined the potential for land-based wind energy. Taking technical and ecological restrictions into account, potential was identified on 13.8 % of the land area of Germany. With the use of the selected reference facilities, this would represent a potential power generation of 1,200 gigawatts. Although the realisable potential, given resistance on the part of local populations or economic conditions in particular cases, is lower than this figure, this investigation shows that there is a great deal of room to expand land-based wind energy in Germany (UBA 2013 b).

The transition to flow resources such as wind energy is also an important factor for the economy. Thus the number of people employed in the German wind energy sector rose during the period 2000–2014 from 25,000 to almost 149,200 (BWE, 2016). Those employed in the solar energy sector in 2014 numbered 38,300 (BSW-Solar, 2016).

Gross electricity generation from renewable energies in Germany, 2000 – 2015

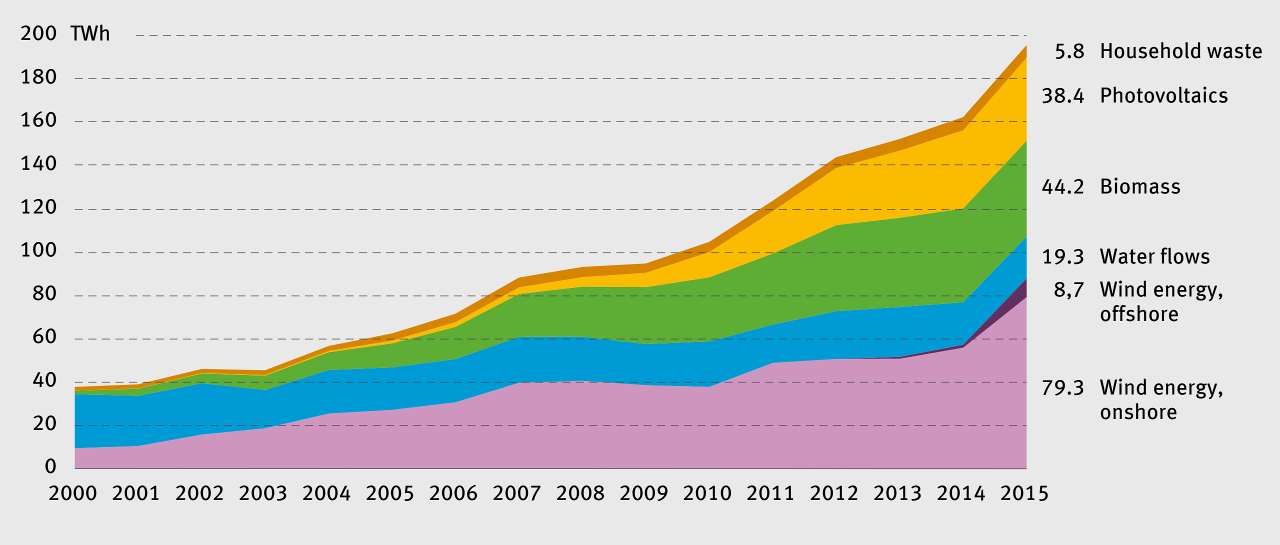


Figure 42 Source: AGEB, 2016

Despite numerous advantages when compared with fossil fuels, the use of renewable energies – particularly bioenergy, but also hydroelectricity – is nonetheless not entirely free of negative impacts on the environment, which can be taken into account and thus reduced through careful planning measures. Wind and solar energy use have significant requirements in terms of area and can thus affect ecosystems. Further to this, the installation of such power plants requires the use of large amounts of metallic and mineral raw materials, the production of which is sometimes associated with severe environmental impacts. In the case of wind power plants, this includes rare metal ores such as selenium or neodymium for the production of magnets, as well as large quantities of common metallic raw materials such as iron, aluminium or copper, and sands and industrial minerals to produce concrete or glass. A typical wind turbine with a generating capacity of 2.3 megawatts contains more than 2,000 tonnes of materials (··· Figure 43).

Raw material input for a wind turbine *

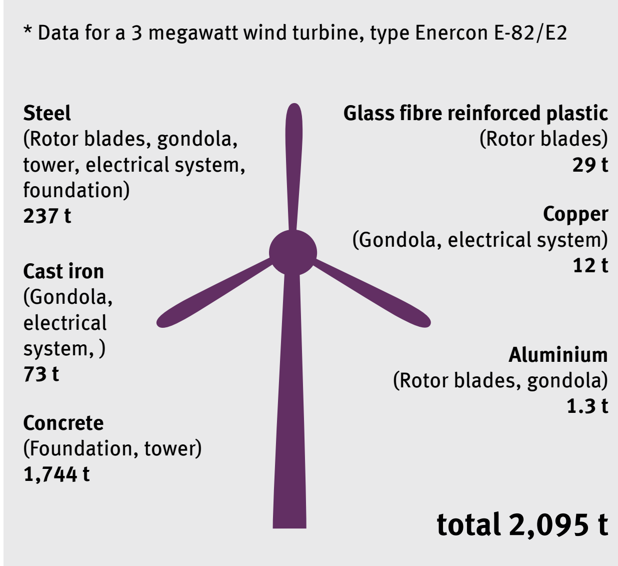


Figure 43 Source: Ingenieur.de, 2016

Gross electricity generation and distribution of renewable energies in the German federal states, 2013

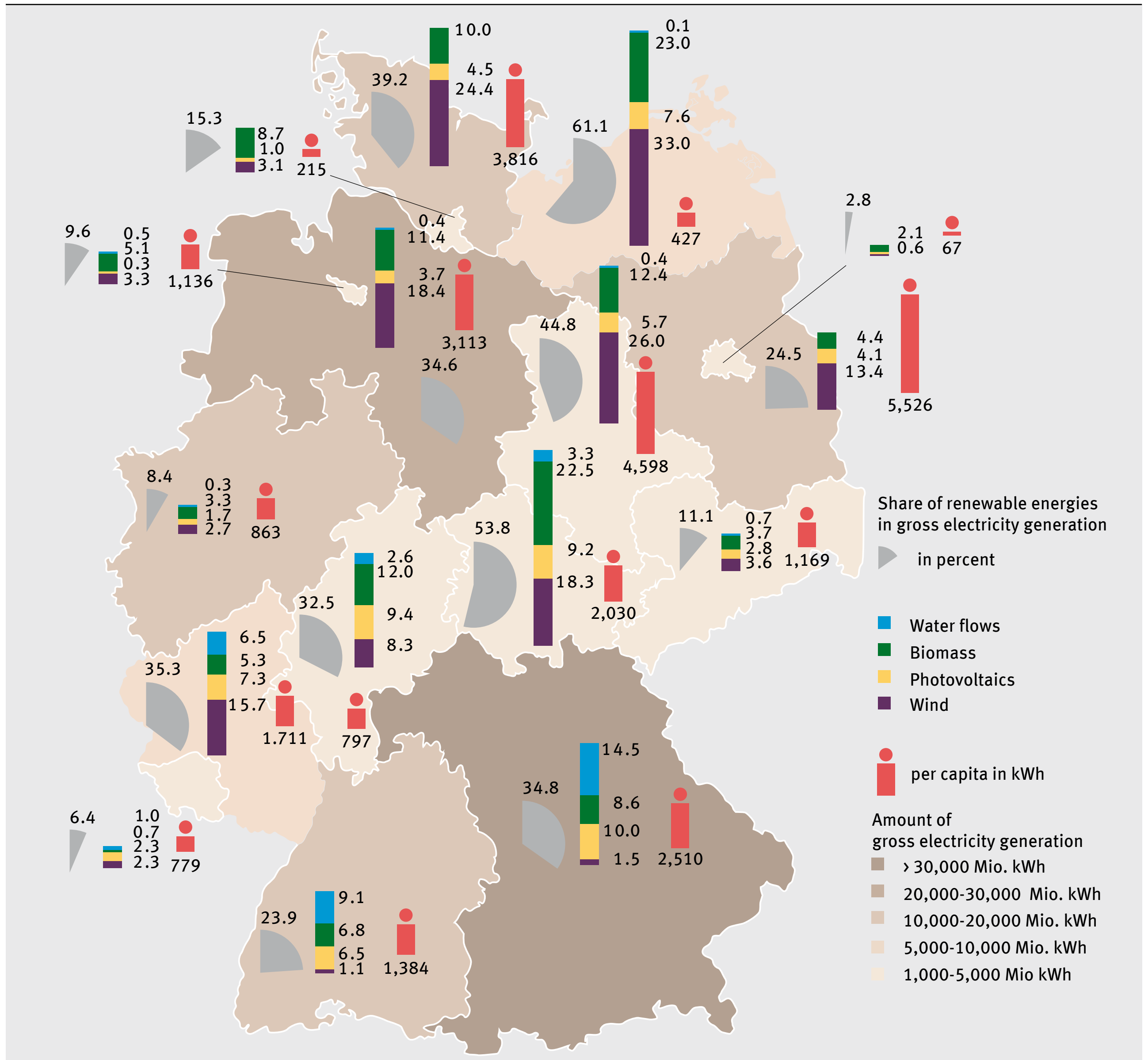


Figure 44 Source: AEE, 2013

The environment as a sink: Another resource category

The extraction and use of raw materials and other natural resources represent interventions in natural ecosystems. The environment as a natural resource provides two important types of functions: It serve as a source for a wide range of raw materials but particularly also as a sink, for example, for absorbing emissions or filtering waste water. Overusing this partially very scarce resource produces negative environmental consequences, such as, for example, the accumulation of nitrates in drinking water or climate changes due to the emission of greenhouse gases into the atmosphere. This impairs or even destroys the functioning of ecosystems.

The absorption of nutrients and pollutants from settlement areas, agriculture or industry is an important sink function of the environment. These substances can overburden the self-regulation capacities of ecosystems and irreversibly harm biocenoses. For example, intensive nitrate or phosphorus use in agriculture can lead to nutrient accumulation (termed eutrophication), reduce the oxygen balance of water bodies and result in algae blooms.

A large share of nutrients, particularly phosphates, enters surface water through run-off or the erosion of soil particles from arable and grazing land used in agriculture. The primary threat to groundwater comes through the leaching of nitrates from nitrogenous fertilisers. Since these types of emissions arise not at specific points but over large areas, they are referred to as “diffuse emissions”.

Breaches of the critical load limits for nitrogen in Germany, 2009

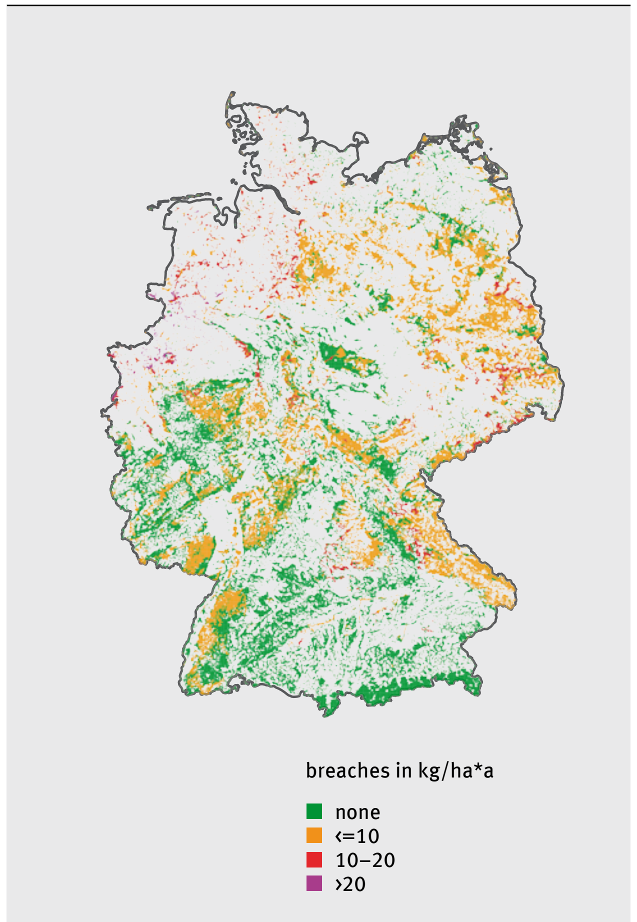


Figure 45 Source: Schaap et al., 2015

In recent decades, overall diffuse phosphorus and nitrogen loads in Germany have been halved, an achievement associated particularly with significantly reduced discharges from municipal and industrial wastewater treatment plants and the collapse of livestock farming in the former GDR after German reunification. Nitrogen inputs from agriculture declined to a much lesser extent in the period 1985–2011, by about 18 %. This means that in many areas of federal territory, permissible loads continue to be exceeded (⇠ Figure 45). In the case of phosphorus from agricultural activity, no decrease has been observed at all. In addition to this, improvements in the quality of watercourses as a result of limited nitrogen use only appear after a considerable time period (5–30 years). This is due to the fact that nitrogen is retained in aquifers over long periods of time.

To reduce diffuse nutrient and pollutant inputs from agricultural activities, it is thus important that farmers adhere to the key principles of good practice in agriculture and soil conservation, such as the stipulations of the fertiliser regulations, together with general measures to combat erosion, and drastically reduce their overall use of these substances.

The development of our society from a traditional agrarian to a modern industrialised society is closely linked to changes in the energy sources used. Whereas primarily biomass (particularly wood) was used in earlier times, the use of fossil fuels opened up entirely new opportunities for energy use, which found application in industry, transport and households. However, the release of greenhouse gas emissions is a consequence of the use of fossil fuels. These anthropogenic emissions, having increased greatly in recent decades, are now threatening the atmospheric balance and driving the rise in global temperatures. In 2014, almost 88 % of the greenhouse gases released in Germany comprised carbon dioxide from electricity and heat generation, from households and small-scale consumers, transport and industrial production. About 10 % were methane and nitrous oxide, primarily from agriculture and forestry and in particular, large-scale livestock farming. The remainder comprised fluorinated greenhouse gases. The latter three of these substances in fact have a greater potential greenhouse effect than carbon dioxide. Greenhouse gas emissions in Germany have been significantly reduced since 1990, falling by 27.7 % by 2014. After energy-related emissions, the agricultural sector is the second largest emitting sector with a share of around 7 % of total emissions. In this area, emissions fell between 1990 and 2014 by only 15 % (UBA 2016 d).

Germany’s net imports of greenhouse gas emissions, top 10 countries and regions of origin, 2011

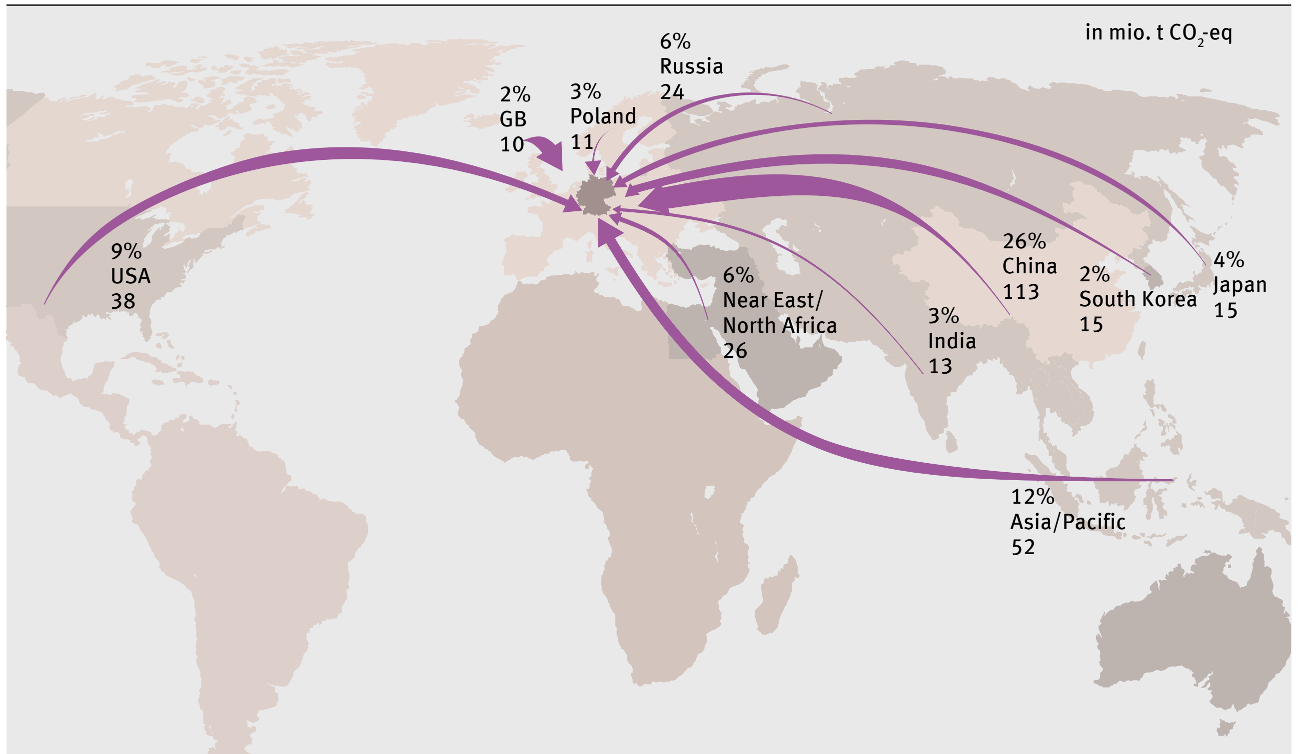


Figure 46 Source: WU, 2016 a

As with raw materials, water or area, a comparison between the greenhouse gas emissions produced in Germany with those produced outside the country during the production of goods and services for domestic consumption in Germany, i. e. the carbon footprint, is instructive. This reveals that Germany’s balance appears better when a consumption perspective is taken, since the carbon footprint lies some 10 % below the emissions level within Germany itself. The largest amount of indirect emissions are imported from China, the rest from the EU and the US. In the international context, Germany is ranked 17th, with a per-capita carbon footprint of 13 tonnes of CO_2-equivalents per capita. The country with the highest carbon footprint worldwide is Luxembourg (Exiobase 3.1).

As early as 2006, the former World Bank Chief Economist Nicholas Stern warned that a failure to respond to climate change would cost between 5 and 20 % of global annual GDP.

Such economic valuations consider those services and goods which humans directly or indirectly obtain from the natural environment and which are beneficial for societal wealth and well-being – among others the function as an environmental sink. Thereby ecosystem services are assigned with a monetary value. On the international level this has been realised in particular within the framework of the TEEB initiative (The Economics of Ecosystems and Biodiversity) and its associated studies. This work is currently continued in the project “Natural Capital Germany” (Naturkapital Deutschland – TEEB DE, 2012).

These valuations are to some extent subject to criticism in terms of focusing on ecosystem services and thereby neglecting economically less relevant aspects of nature such as biodiversity – which nevertheless deserve conservation efforts (BUND, 2010). It can be regarded as problematic to let market-based mechanisms and actors alone decide on environmental protection measures. However, economic valuation efforts pursue the objective of illustrating the often invisible and not sufficiently considered value of nature and of making this value available for political, corporate and private decisions by applying an economic rationale. In addition to ecological and ethical reasoning, this creates another opportunity to emphasise that wealth and well-being depend on services provided by nature.

It seems particularly noteworthy that in many cases nature conservation is less costly than the later reestablishment of essential environmental services. A relevant example for Germany is the conversion of meadows and pastures to farmland which is beneficial for individual farms, but causes future costs for the general public – such as for water treatment, for climate mitigation, or for the prevention of flood damages (Naturkapital Deutschland – TEEB DE, 2012).

Glossary

This glossary is based on the glossary of the German Resource Efficiency Programme (ProgRess II) (Deutsche Bundesregierung, 2016a) and the glossary on resource conservation of the Federal Environment Agency (UBA, 2012).

Biomass: Comprises all organic matter, which accrues or is produced by plants or animals. Where biomass is used to produce energy, a distinction is made between renewable raw materials (energy crops such as rape, maize or cereals) and organic residues and waste materials. (ProgRess II)

Circular economy: The achievement of zero waste or waste regeneration through recycling or reusing raw materials from wastes, as inputs for new production and consumption processes (see Secondary raw material). (UBA)

Decoupling – relative / absolute: The removal or reduction of a quantitative link between interdependent developments. The term is often used in situations in which the use of natural resources increases more slowly that economic growth, which is defined as "relative decoupling". "Absolute decoupling" refers to situations in which resource use remains the same or even falls as the economy continues to grow. (UBA)

Direct and indirect raw material flows: Direct raw material flows comprise the actual weight of extracted or traded raw materials or products. Indirect flows comprise the mass of all the input of raw materials along the entire value chain. A consideration of all direct and indirect flows required to satisfy domestic consumption is also termed "footprint".

Direct material input (DMI): A material flow indicator: The mass flow of materials directly entering a national economy, which are either further processed or consumed within it. DMI is the sum of the mass of domestically extracted raw materials together with that of imported raw materials, semi-finished or finished goods. (ProgRess-II)

Domestic extraction used (DEU): The extraction of raw materials from the natural environment or their geographical displacement within the environment as a result of human activities. DEU is a material flow indicator, which comprises the entire quantity of (1) harvested biomass, (2) mined minerals and metal ores, and (3) extracted fossil fuels that enter the economic system (and which are thereby assigned an economic value). Commonly used synonyms: "domestic extraction" or "extraction".

Domestic material consumption (DMC): Material flow indicator describing the mass flow of those materials that directly enter the domestic economic system for consumption within it. DMC is calcuated as the sum of domestic extraction plus the mass of directly imported raw materials, semi-finished and finished goods, minus the mass of directly exported raw materials, semi-finished and finished goods. (UBA)

Efficiency: The relationship between a particular use, product or service and the raw material input required to acquire this. (UBA)

Extraction: The extraction of raw materials from the environment or their displacement within the environment as a result of human activities. A distinction is made between utilised (or used) and unutilised (unused) extraction. Extraction is defined as used where the extracted material is exploited economically, for example as part of a treatment process. Unused extraction refers to extracted raw material that remains in the environment, e. g. deposited waste rock from coal mining. (UBA)

Final demand: Goods, which are not further processed in the domestic economy. These include goods for the consumption of private households, public investments or exports to other countries.

Flow resources : Wind, geothermal, tidal and solar energy. Although these resources cannot be exhausted, their use requires the input of other resources. Examples are the energy, raw materials and space required to construct wind turbines or photovoltaic cells. (ProgRess II)

Fossil fuels: Animal or plant-based raw materials used for energy found in deposits that have accumulated over geological periods and are therefore non-renewable. (ProgRess II)

Metal ores: A category in material flow analysis, which comprises all metallic raw materials.

Minerals: A category in material flow analysis, which comprises industrial minerals, such as clay, quartz or kaolin, and construction minerals such as sand, gravel, etc. These are referred to in the report as "mineral raw materials".

Natural resources: All components of the natural environment. These include biotic and abiotic raw materials, physical space (e. g. area), environmental media (water, soil, air), flow resources (e. g. geothermal energy, wind, tidal and solar energy) and all living organisms in their diversity. (ProgRess II)

Non-renewable primary raw materials: Raw materials that are obtained through extraction from the natural environment and that do not have the potential to regenerate within a particular time period. These comprise mineral, metallic and fossil raw materials. There is no standard measure of the time limit beyond which a raw material is no longer regarded as renewable. The dividing line between the definitions of "renewable" and "non-renewable" generally lies somewhere between 100 and 1,000 years. (UBA)

Overburden: Rock with no or very little value (waste rock), which must be excavated to obtain access to the raw materials from a deposit, yet which has no input into the economic system. (UBA)

Physical trade balance: A material flow indicator, calculated as the weight of imports minus the weight of exports. This shows the physical trade balance surplus or physical trade deficit of a national economy. (UBA)

Primary raw materials: Raw materials obtained through extraction from the natural environment. (UBA)

Raw materials: Substances or mixtures of substances in an unprocessed or unfinished state, which are used as inputs to a production process. A distinction is made between primary and secondary raw materials. (UBA)

Raw material consumption (RMC): A material flow indicator, which is calculated as the total mass of domestic extraction of primary raw materials and imported raw materials, semifinished and finished goods – expressed as raw material equivalents – minus exported raw materials, semi-finished and finished goods, expressed as raw material equivalents (ProgRess II). It thus represents the sum of direct and indirect raw material flows required for final demand in Germany. Synonym: Raw material requirements for domestic consumption and investments.

Raw material equivalents (RME): The RME of specific goods comprises the mass of all the raw materials used along the entire value chain to produce the goods. This calculation does not include unused extraction, such as overburden, tailings from mining activities, and excavated soil, which cannot be exploited economically. (ProgRess II)

Raw material input (RMI): A material flow indicator, calculated as the total mass of primary raw materials extracted domestically and of imported raw materials, semi-finished and finished goods, expressed as their raw material equivalents (RME). (ProgRess II)

Renewable energies: Forms of energy that are not produced from finite resources, such as, for example, energy from biomass, hydropower, geothermal energy, wind or solar energy.

Renewable primary raw material: Raw materials that are extracted from the natural environment and have the capacity to replenish within given time frames. These comprise primarily biotic raw materials. There is no standardised measure of the time frame beyond which a raw material is defined as non-renewable. The distinction between "renewable" and "non-renewable" generally lies somewhere between 100 and 1,000 years. (UBA)

Total material consumption (TMC): The total mass of direct and indirect material flows associated with domestic consumption into an economic system, including hidden material flows measured in mass units. In economy-wide material flow accounting TMC is defined as TMR minus the mass of exports and their indirect and hidden material flows. (UBA)

Total material productivity: Price-adjusted GDP together with price-adjusted expenditure for imports (GDP+IMP) divided by the mass of used domestic extraction of raw materials together with the mass of imports expressed in raw material equivalents (RME); serves as a production-related indicator for the raw material efficiency of the Germany economy. (ProgRess II)

Total material requirement (TMR): The total quantity of all direct and indirect material flows into an economic system, including hidden material flows measured in mass units. It includes all material flows of used and unused domestic extraction together with all used and unused material flows in other countries, which are necessary to provide imported goods. (UBA)

Reboundeffekt: This describes the effect by which cost savings produced as a result of efficiency savings do not lead to a comparable decrease in resource use, since these savings lead to an increase in demand and consumption. (UBA)

Recycling: Any recovery operation, through which waste materials are reprocessed into metal products, materials or substances – either for their original purpose or for another use. This includes the processing of organic materials, but excludes energy recovery and reprocessing into materials that are intended for use as fuels or for backfilling operations. (UBA)

Raw material use: An umbrella term for the use of raw materials by society. This includes the use of raw materials both for production and consumption.

Raw material productivity: This is defined in the national sustainability strategy as the quotient of the price-adjusted gross domestic product (GDP) and the abiotic direct material input ($DMI_{abiotic}$). The commonly used unit measurement is Euro per tonne. Abiotic primary raw materials include used domestic extraction of abiotic raw materials together with all imported abiotic materials (raw materials, semi-finished and finished goods). In the German Strategy for Sustainable Development it functions as an indicator for the raw material efficiency of the Germany economy. (ProgRess II)

Secondary raw materials: Raw materials that are recovered from wastes or production residues. (UBA)

Sink: Endpoint for material flows. In the context of natural resources sinks refer to the absorption capacity (e. g. for pollutants) of the natural environment. (UBA)

Unused domestic extraction (UDE): The mass of material that must be displaced in order to gain access to materials required for eventual use. Examples include overburden in the mining industry and by-catch in the fisheries sector. Unused extraction cannot enter the economic system and therefore has no monetary value.

Water footprint: The sum of the indirect water use for a product or to satisfy the consumption requirements of a person or a country.

Data Tables

Table A 1: Abiotic and biotic extraction in 1,000 t, tonnes per capita

Data sources: Used extraction:
Destatis, Umweltnutzung und Wirtschaft, Tabellen zu den Umweltökonomischen Gesamtrechnungen, Teil 4: Rohstoffe, Wassereinsatz, Abwasser, Abfall, Tabelle 5.1
Unused extraction:
Statistische Ämter der Länder, Umweltökonomische Gesamtrechnung der Länder, Tabellen 2.1.1–2.1.16

ABIOTIC EXTRACTION	1994	2000	2006	2011	2013	Change 1994–2013	Per-capita 1994	Per-capita 2013
USED EXTRACTION								
Fossil fuels	277,980	220,661	215,657	202,062	202,052	-27%	3.4	2.5
Hardcoal	52,405	33,591	20,882	12,059	7,566	-86%	0.6	0.1
Lignite	207,086	167,694	176,324	176,595	182,754	-12%	2.5	2.3
Crude oil	2,937	3,119	3,514	2,679	2,638	-10%	0	0
Natural gas	15,033	15,742	14,617	10,335	8,652	-42%	0.2	0.1
Other energy carriers	519	515	320	396	442	-15%	0.01	0
Minerals	829,934	739,001	645,405	631,433	595,934	-28%	10.2	7.4
Metal ores	**146**	**462**	**426**	**489**	**418**	**187%**	0	0
Construction minerals	765,934	679,201	580,780	566,752	534,537	-30%	9.4	6.6
Industrial minerals	63,854	59,338	64,200	64,191	60,979	-5%	0.8	0.8
TOTAL	**1,107.914**	**959,661**	**861,063**	**833,495**	**797,987**	**-28%**	**13,6**	**9,9**
UNUSED EXTRACTION								
Overburden and tailings of fossil fuels	1,913.656	1,560.748	1,690 881	1,703.194	1,639.825	-14%	23,5	20,3
Tailings of mineral raw materials	136,421	130,259	120,109	114,991	111,310	-18%	1,7	1,4
TOTAL	**2,050.077**	**1,691.006**	**1,810.991**	**1,818.185**	**1,751.136**	**-15%**	**25,2**	**21,7**

BIOTIC EXTRACTION	1994	2000	2006	2011	2013	Change 1994–2013	per capita 1994	per capita 2013
USED EXTRACTION								
Plant biomass from agriculture	194,912	221,375	204,202	252,515	232,057	19%	2.4	2.9
Cereals	36,329	45,271	43,475	41,920	47,757	31%	0.4	0.6
Pulses and root crops	36,684	42,685	31,609	41,920	32,951	-10%	0.5	0.4
Commercial crops	3,243	3,690	5,435	3,969	5,858	81%	0.04	0.1
Vegetables and fruits	7,047	9,024	8,048	8,267	7,606	8%	0.1	0.1
Catch crops	4,215	2,990	2,190	2,154	2,173	-48%	0.05	0
Fodder crops	106,844	117,172	112,855	153,763	135,213	27%	1.3	1.7
Other plant biomass	551	543	590	521	499	-9%	0	0
Plant biomass from forstery	16,802	24,503	29,800	28,993	27,635	64%	0.2	0.3
Hardwood	12,406	18,487	22,043	19,254	17,971	45%	0.2	0.2
Softwood and bark	**4,396**	**6,016**	**7,757**	**9,739**	**9,664**	**120%**	**0.1**	**0.1**
Animal biomass	**222**	**249**	**311**	**279**	**272**	**23%**	0.003	0
TOTAL	**211,936**	**246,127**	**234,313**	**281,786**	**259,963**	23%	2.6	3.2
UNUSED EXTRACTION								
Unused biomass	**201,378**	**209,382**	**208,595**	**202,782**	**203,031**	**1%**	**2.5**	**2.5**

Total domestic extraction	1994	2000	2006	2011	2013	Change 1994–2013	per capita 1994	per capita 2013
Used	1,319.850	1,205.789	1,095.376	1,115.281	1,057.950	-20%	16.2	13.1
Unused	2,251.455	1,900.389	2,019.586	2.020.967	1,954.166	-13%	27.7	24.2

Table A2: Extraction in the German federal states in 1,000 t, tonnes per capita

Data source: Statistische Ämter der Länder, Umweltökonomische Gesamtrechnung der Länder, Tabellen 2.1.1–2.1.16

		1994	2000	2006	2011	2013	Changes 1994–2013	per capita 1994	per capita 2013
Baden-Württemberg	Fossil fuels	384	340	322	397	442	15%	0.04	0.04
	Minerals	119,989	118,252	92,761	87,078	86,421	-28%	11.71	8.15
	Biomass	20,456	28,459	20,070	22,668	21,816	7%	2.00	2.06
	TOTAL	**140,829**	**147,051**	**113,152**	**110,143**	**108,678**	**-23%**	**13.74**	**10.25**
Bavaria	Fossil fuels	179	98	85	38	54	-70%	0.02	0.00
	Minerals	142,829	127,454	99,271	102,648	101,872	-29%	12.01	8.11
	Biomass	50,003	53,284	54,521	60,913	51,034	2%	4.21	4.06
	TOTAL	**193,012**	**180,835**	**153,876**	**163,599**	**152,960**	**-21%**	**16.23**	**12.18**
Brandenburg	Fossil fuels	47,692	40,329	39,055	35,682	37,606	-21%	18.81	15.35
	Minerals	27,388	27,568	25,975	26,026	23,458	-14%	10.80	9.58
	Biomass	9,243	11,047	11,407	14,599	15,861	72%	3.65	6.48
	TOTAL	**84,323**	**78,944**	**76,438**	**76,307**	**76,925**	**-9%**	**33.26**	**31.41**
Hessen	Fossil fuels	151	156	0	0	0	-100%	0.03	0
	Minerals	44,744	43,960	35,683	36,334	33,474	-25%	7.49	5.55
	Biomass	9,887	10,744	10,501	11,067	11,531	17%	1.66	1.91
	TOTAL	**54,783**	**54,860**	**46,184**	**47,401**	**45,005**	**-18%**	**9.17**	**7.46**
Mecklenburg-Vorpommern	Fossil fuels	27	12	5	5	5	-82%	0.01	0
	Minerals	22,173	13,802	16,540	15,649	13,409	-40%	12.07	8.39
	Biomass	9,921	13,932	13,641	17,148	17,165	73%	5.40	10.74
	TOTAL	**32,121**	**27,746**	**30,186**	**32,801**	**30,579**	**-5%**	**17.49**	**19.13**
Lower Saxony	Fossil fuels	18,786	20,109	15,843	11,998	9,982	-47%	2.45	1.28
	Minerals	61,166	52,980	40,216	43,073	42,360	-31%	7.97	5.44
	Biomass	39,514	45,898	43,869	59,730	53,388	35%	5.15	6.86
	TOTAL	**119,466**	**118,987**	**99,929**	**114,801**	**105,730**	**-11%**	**15.56**	**13.58**
North-Rhine-Westphalia	Fossil fuels	145,091	119,496	113,393	106,448	106,080	-27%	8.16	6.04
	Minerals	150,591	135,177	136,790	131,454	123,418	-18%	8.47	7.03
	Biomass	24,404	26,737	24,339	28,196	27,166	11%	1.37	1.55
	TOTAL	**320,086**	**281,409**	**274,522**	**266,098**	**256,664**	**-20%**	**18.00**	**14.61**
Rheinland-Pfalz	Fossil fuels	121	78	41	172	211	74%	0.03	0.05
	Minerals	49,566	53,640	48,210	46,602	43,583	-12%	12.59	10.92
	Biomass	8,867	9,638	9,893	10,111	10,313	16%	2.25	2.58
	TOTAL	**58,554**	**63,356**	**58,144**	**56,885**	**54,107**	**-8%**	**14.87**	**13.55**
Saarland	Fossil fuels	8,676	6,018	4,029	1,544	117	-99%	8.01	0.12
	Minerals	5,256	4,062	2,637	2,921	2,459	-53%	4.85	2.48
	Biomass	649	772	710	835	872	34%	0.60	0.88
	TOTAL	**14,581**	**10,853**	**7,376**	**5,300**	**3,448**	**-76%**	**13.46**	**3.47**
Sachsen	Fossil fuels	43,680	23,429	33,540	34,939	36,875	-16%	9.50	9.11
	Minerals	87,656	60,199	59,941	53,248	43,838	-50%	19.07	10.83
	Biomass	9,124	10,340	9,406	11,805	10,336	13%	1.99	2.55
	TOTAL	**140,460**	**93,969**	**102,887**	**99,992**	**91,049**	**-35%**	**30.56**	**22.49**
Saxony-Anhalt	Fossil fuels	12,468	9,010	6,314	9,007	9,111	-27%	4.50	4.05
	Minerals	60,535	57,677	48,781	49,143	45,258	-25%	21.86	20.10
	Biomass	11,693	13,743	12,182	16,598	15,335	31%	4.22	6.81
	TOTAL	**84,696**	**80,429**	**67,277**	**74,747**	**69,704**	**-18%**	**30.59**	**30.95**
Schleswig-Holstein	Fossil fuels	448	1,345	2,979	1,701	1,539	244%	0.17	0.55
	Minerals	14,309	15,484	16,528	17,445	18,292	28%	5.30	6.51
	Biomass	9,176	11,336	11,174	16,381	15,800	72%	3.40	5.62
	TOTAL	**23,933**	**28,164**	**30,681**	**35,527**	**35,631**	**49%**	**8.86**	**12.67**
Thüringen	Fossil fuels	53	41	22	20	13	-76%	0.02	0.01
	Minerals	40,980	36,145	33,018	28,375	24,636	-40%	16.23	11.38
	Biomass	8,165	8,698	9,066	9,763	9,282	14%	3.23	4.29
	TOTAL	**49,198**	**44,884**	**42,106**	**38,159**	**33,931**	**-31%**	**19.49**	**15.67**

Table A 3: Direct trade in 1,000 t

Data source: Destatis 2015, Umweltnutzung und Wirtschaft, Tabellen zu den Umweltökonomischen Gesamtrechnungen, Teil 4: Rohstoffe, Wassereinsatz, Abwasser, Abfall, Tabelle 5.2–5.3

	1994	2000	2006	2011	2013	Changes 1994–2013
IMPORTS						
TOTAL	**463,150**	**520,990**	**599,500**	**613,004**	**624,344**	**35%**
Raw materials	277,263	305,517	337,102	334,210	352,740	27%
Fossil fuels	172,460	194,532	232,577	222,254	244,772	42%
Metal ores	47,030	51,851	49,599	47,127	45,181	-4%
Minerals	35,689	34,110	26,593	28,956	23,286	-35%
Biomass	22,084	25,023	28,332	35,873	39.501	79%
Semi-processed products based on …	105,624	112,250	121,984	131,092	129.349	22%
… fossil fuels	48,514	53,506	54,729	56,759	58,104	20%
… metal ores	9,583	13,001	19,425	20,164	18,273	91%
… minerals	27,875	23,005	17,499	19,180	17,051	-39%
… biomass	19,653	22,737	30,331	34,989	35,921	83%
Processed products based on …	80,263	103,224	140,414	147,702	142,256	77%
… fossil fuels	15,532	20,263	28,391	30,469	30,962	99%
… metal ores	30,562	42,142	59,073	62,541	58,171	90%
… minerals	5,247	7,525	9,659	11,266	10,781	105%
… biomass	28,922	33,293	43,290	43,426	42,341	46%
EXPORTS						
TOTAL	**223,181**	**289,245**	**379,632**	**378,449**	**384,498**	**72%**
Raw materials	55,297	74,396	82,008	86,792	90,211	63%
Fossil fuels	4,967	13,424	11,412	21,705	30,900	522%
Metal ores	171	215	158	259	318	86%
Minerals	34,708	37,881	47,889	46,060	37,080	7%
Biomass	15,450	22,876	22,548	18,769	21,913	42%
Semi-processed products based on …	86,064	98,623	134,665	121,826	125,294	46%
… fossil fuels	23,814	26,945	39,949	27,737	35,520	49%
… metal ores	14,982	14,737	16,731	20,024	18,135	21%
… minerals	28,607	31,370	45,188	36,424	35,149	23%
… biomass	18,662	25,570	32,797	37,642	36,490	96%
Processed products based on …	81,819	116,226	162,959	169,831	168,993	107%
… fossil fuels	20,648	26,753	36,951	37.952	38,451	86%
… metal ores	36,763	52,537	72,733	74,967	72,890	98%
… minerals	5,525	9,188	12,978	14,254	14,269	158%
… biomass	18,883	27,749	40,297	42,657	43,382	130%

Table A 4: Indirect trade in 1,000 t

Data sources: Destatis 2015, Umweltnutzung und Wirtschaft, Tabellen zu den Umweltökonomischen Gesamtrechnungen, Teil 4: Rohstoffe, Wassereinsatz, Abwasser, Abfall, Tabelle 5.4
Globalisierungsindikatoren, Kennzahlen zur Außenwirtschaft
Imports:
https://www.destatis.de/DE/ZahlenFakten/Indikatoren/Globalisierungsindikatoren/Tabellen/36.html
Exports:
https://www.destatis.de/DE/ZahlenFakten/Indikatoren/Globalisierungsindikatoren/Tabellen/37.html

RME: Raw material equivalents

	2000	2002	2004	2006	2008	2010	2011	Changes 2000–2011
RME OF IMPORTS								
TOTAL	**1,443.000**	**1,351.000**	**1,481.000**	**1,697.000**	**1,677.000**	**1,712.000**	**1,675.000**	**16%**
Fossil fuels	454,000	471,000	505,000	587,000	580,000	556,000	551,000	21%
Metal ores	740,000	634,000	711,000	804,000	780,000	826,000	807,000	9%
Minerals	138,000	133,000	131,000	144.000	143,000	148,000	149,000	8%
Biomass	111.000	113,000	134,000	162,000	174,000	181,000	168,000	51%
RME OF EXPORTS								
TOTAL	**1,132.000**	**1,137.000**	**1,259.000**	**1,468.000**	**1,430.000**	**1,479.000**	**1,488.000**	**31%**
Fossil fuels	271,000	307,000	336,000	406,000	367,000	345,000	350,000	29%
Metal ores	598,000	544,000	623,000	717,000	705,000	782,000	782,000	31%
Minerals	140,000	163,000	160,000	175,000	180,000	175,000	178,000	27%
Biomass	123,000	123,000	140,000	170,000	178,000	178,000	178,000	45%

Table A 5: Raw material consumption and raw material intensity by sectors

Data source: Calculations by WU Vienna based on Exiobase 3.1, 2016, www.exiobase.eu

in 1,000 t	1995	2000	2005	2011	Changes 1995–2011
Agriculture	78,214	99,641	85,759	81,146	4%
Mining	49,257	27,569	24,809	34,001	-31%
Manufacturing of products from biomass	290,076	358,155	266,617	380,935	31%
Manufacturing of products from fossil fuels	184,992	134,197	104,857	160,194	-13%
Manufacturing of products from metals und minerals	229,280	296,275	186,837	322,643	41%
Energy production	75,150	57,737	64,228	67,631	-10%
Construction	530,441	417,583	352,390	343,867	-35%
Sales and retail trade	11,683	20,483	9,546	647	-94%
Transport	19,935	24,948	27,840	26,441	33%
Financial services	99,333	111,311	137,112	120,562	21%
Other	262,679	297,872	333,448	378,361	44%
TOTAL	**1,831,039**	**1,845.773**	**1,593.442**	**1,916.427**	**5%**

in kg/€	1995	2000	2005	2011	Changes 1995–2011
Agriculture	3,6	4,6	4,9	3,0	-15%
Mining	5,1	2,9	2,6	2,3	-55%
Manufacturing of products from biomass	1,4	1,7	1,6	1,5	13%
Manufacturing of products from fossil fuels	2,3	1,5	1,3	1,4	-41%
Manufacturing of products from metals und minerals	0,8	0,9	0,8	0,9	13%
Energy production	3,0	2,7	2,0	1,6	-47%
Construction	2,3	2,1	1,9	1,9	-19%
Sales and retail trade	0,1	0,2	0,1	0,0	-96%
Transport	0,4	0,4	0,4	0,4	-2%
Financial services	0,4	0,4	0,4	0,3	-9%
Other	0,4	0,4	0,4	0,4	1%

2011 in 1,000 t	Biomass	Metal ores	Minerals	Fossil fuels	Changes in total
Agriculture	60.272	1.945	11.432	7.497	4%
Mining	2.252	2.671	14.590	14.488	2%
Manufacturing of products from biomass	206.860	15.476	105.341	53.258	20%
Manufacturing of products from fossil fuels	16.967	12.176	77.943	53.108	8%
Manufacturing of products from metals und minerals	33.179	61.668	164.784	63.011	17%
Energy production	2.287	3.177	13.093	49.074	4%
Construction	13.231	17.423	270.203	43.009	18%
Sales and retail trade	284	25	263	75	0%
Transport	3.432	2.183	10.874	9.952	1%
Financial services	13.520	8.324	73.034	25.684	6%
Other	83.906	26.374	189.925	78.156	20%
TOTAL	**436.189**	**151.444**	**931.483**	**397.311**	**100%**

Table A 6: Decoupling in 1,000 t, mio. Euro

Data sources: Calculations by WU Vienna based on:
Destatis 2015, Umweltnutzung und Wirtschaft, Tabellen zu den Umweltökonomischen Gesamtrechnungen, Teil 4: Rohstoffe, Wassereinsatz, Abwasser, Abfall, Tabelle 5.1–5.4
Destatis 2015, Globalisierungsindikatoren, Kennzahlen zur Außenwirtschaft
Imports:
https://www.destatis.de/DE/ZahlenFakten/Indikatoren/Globalisierungsindikatoren/Tabellen/36.html
Exports:
https://www.destatis.de/DE/ZahlenFakten/Indikatoren/Globalisierungsindikatoren/Tabellen/37.html
Destatis, 2015, Volkswirtschaftliche Gesamtrechnungen, Inlandsproduktsberechnung

DMI: Direct Material Input
DMI_{abiot}: Abiotic Direct Material Input
DMC: Domestic Material Consumption
RMI: Raw Material Input
RMC: Raw Material Consumption

ABSOLUTE	1994	2000	2003	2006	2009	2011	2013
DMI	1.797.560	1.739.430	1.633.401	1.701.676	1.583.672	1.728.286	1.682.294
DMI_{abiot}	1.514.966	1.412.249	1.337.710	1.365.409	1.211.618	1.332.211	1.304.567
DMC	1.574.380	1.450.185	1.314.936	1.322.044	1.245.196	1.349.837	1.297.796
RMI		2.661.440	2.526.616	2.799.176	2.459.025	2.790.281	
RMC		1.529.440	1.357.616	1.331.176	1.227.025	1.302.281	

GDP (adj.): Gross Domestic Product, adjusted for price changes
GDP/DMI_{abiot}: Raw material productivity

TREND	1994	2000	2003	2006	2009	2011	2013
BIP/DMI_{abiot}	100.0	120.0	127.9	132.4	147.0	144.2	148.3

GDP+IMP: Gross Domestic Product plus imports
(GDP+IMP)/RMI: Total raw material productivity

TREND	2000	2002	2004	2006	2008	2010	2011
(BIP+IMP)/RMI	100.0	108.6	106.8	106.6	113.7	114.3	117.,1

Table A 7: Material consumption indicators in 1.000 t, tonnes per capita

Data sources: Calculations by WU Vienna based on:
DMC, RMC – Extraction, direct imports and exports:
Destatis UGR 2015, Teil 4, Tabelle 5.1-5.4
RMC – RME of imports/exports:
Destatis 2015, Globalisierungsindikatoren, Kennzahlen zur Außenwirtschaft
Imports:
https://www.destatis.de/DE/ZahlenFakten/Indikatoren/Globalisierungsindikatoren/Tabellen/36.html,
Exports:
https://www.destatis.de/DE/ZahlenFakten/Indikatoren/Globalisierungsindikatoren/Tabellen/37.html

DMC: Domestic Material Consumption
RMC: Raw Material Consumption

DMC	Biomass	Fossil fuels	Minerals	Metal ores	Total
2000	250,986	421,841	737,392	39,966	**1,450.185**
2001	242,522	427,084	665,631	30,423	**1,365.661**
2002	235,867	434,164	631,582	30,400	**1,332.013**
2003	218,200	445,271	620,745	30,720	**1,314.936**
2004	262,258	438,214	592,172	36,061	**1,328.704**
2005	250,006	438,595	564,557	33,512	**1,286.670**
2006	240,625	443,042	599,476	38,902	**1,322.044**
2007	273,443	430,710	571,090	43,492	**1,318.736**
2008	268,210	435,272	566,837	37,024	**1,307.343**
2009	275,027	412,797	536,768	20,603	**1,245.196**
2010	258,434	415,968	535,767	35,676	**1,245.846**
2011	297,007	424,151	593,608	35,071	**1,349.837**
Changes 2000–2011	18%	-19%	-12%	1%	**-7%**
Per capita 2000	3,1	5,1	9,0	0,5	**17,6**
Per capita 2011	3,7	5,3	7,4	0,4	**16,7**

RMC	Biomass	Fossil fuels	Minerals	Metal ores	Total
2000	234,127	403,661	749,191	142,462	**1,529.440**
2001	228,448	411,412	674,374	120,407	**1,435.641**
2002	220,554	391,883	634,032	90,419	**1,336.888**
2003	203,383	427,532	626,272	99,429	**1,357.616**
2004	248,468	395,859	607,064	88,412	**1,339.802**
2005	233,594	422,882	576,043	83,362	**1,317.881**
2006	226,313	396,657	620,780	87,426	**1,331.176**
2007	254,274	388,045	601,615	92,434	**1,336.368**
2008	259,353	422,050	581,059	75,463	**1,337.925**
2009	264,935	390,106	548,617	23,368	**1,227.025**
2010	252,214	407,064	548,598	44,394	**1,252.270**
2011	271,786	403,062	601,944	25,489	**1,302.281**
Changes 2000–2011	16%	0%	-20%	-82%	**-15%**
Per capita 2000	2,8	4,9	9,1	1,7	**18,6**
Per capita 2011	3,4	5,0	7,5	0,3	**16,1**

Table A 8: Raw material consumption of final demand by raw material group, in percent

Data source: Calculations by WU Vienna based on Exiobase 3.1, 2016, www.exiobase.eu

1995	Private households	Non-profit organisations	State	Investments	Inventory Change
Biomass	71%	4%	8%	16%	2%
Metal ores	51%	6%	11%	31%	1%
Minerals	25%	4%	11%	58%	2%
Fossil fuels	59%	6%	13%	21%	2%
TOTAL	**46%**	**4%**	**11%**	**37%**	2%

2011	Private households	Non-profit organisations	State	Investments	Inventory Change
Biomass	67%	6%	11%	7%	8%
Metal ores	45%	5%	12%	34%	5%
Minerals	40%	5%	14%	37%	3%
Fossil fuels	57%	6%	13%	20%	4%
TOTAL	**50%**	**5%**	**13%**	**26%**	5%

CHANGES IN ABSOLUTE QUANTITY 1995–2011	Private households	Non-profit organisations	State	Investments	Inventory Change
Biomass	29%	103%	95%	-36%	576%
Metal ores	176%	182%	219%	251%	1245%
Minerals	78%	55%	42%	-28%	103%
Fossil fuels	-39%	-35%	-35%	-39%	61%
TOTAL	**16%**	**27%**	**23%**	**-25%**	188%

Table A 9: Raw material consumption by the state and by private households, in 1,000 t

Data source: Calculations by WU Vienna based on Exiobase 3.1, 2016, www.exiobase.eu

PUBLIC CONSUMPTION	Biomass		Fossil fuels		Minerals		Metal ores		Total		Changes 1995–2011
	1995	2011	1995	2011	1995	2011	1995	2011	1995	2011	
Public administration, defense, and social secutriy	9,218	16,896	26,930	19,020	59,546	67,951	1,984	7,229	97,677	111,096	-23%
Health care and social welfare benefits	7,910	20,916	16,350	14,978	14,090	33,970	1,307	5,264	39,657	75,128	-5%
Further processed products from fossil fuels	2,939	4,403	21,115	10,058	8,474	20,486	1,127	2,789	33,655	37,735	-42%
Education services	2,283	4,190	8,171	5,412	5,420	8,550	483	1,461	16,357	19,613	-83%
Other products	1,101	671	2,682	774	3,073	966	211	310	7,067	2,720	-8%
Other services	1,371	1,271	4,928	1,828	4,336	2,883	393	511	11,027	6,493	2,192%
TOTAL	**24,823**	**48,347**	**80,176**	**52,069**	**94,939**	**134,805**	**5,504**	**17,563**	**205,442**	**252,785**	**-100%**

PRIVATE CONSUMPTION	Biomass		Fossil fuels		Minerals		Metal ores		Total		Changes 1995–2011
	1995	2011	1995	2011	1995	2011	1995	2011	1995	2011	
Food and nutrition	134,990	161,534	39,986	30,748	27,720	56,709	2,333	8,009	205,030	257,000	25%
Luxury food	7,154	12,096	6,631	4,992	3,716	9,906	449	1,583	17,950	28,576	59%
Clothing	5,227	8,003	9,747	5,337	7,160	12,215	865	2,171	22,999	27,726	21%
Housing	33,626	40,601	175,196	99,383	92,630	136,003	9,154	19,265	310,606	295,252	-5%
Health care	3,011	6,412	8,709	6,164	5,278	14,779	640	2,260	17,638	29,614	68%
Mobility	4,883	4,674	30,272	16,841	10,696	17,151	2,913	5,756	48,765	44,422	-9%
Communication	326	1,069	1,552	2,040	1,528	4,668	200	1,089	3,605	8,866	146%
Leisure	30,898	45,045	55,549	33,736	39,821	74,700	5,667	18,515	131,935	171,996	30%
Education	256	872	915	1,127	607	1,780	54	304	1,831	4,083	123%
Restaurants and hotels	2,396	168	2,508	44	1,892	154	124	14	6,921	380	-95%
Other	9,024	17,777	37,016	24,584	19,902	46,399	2,078	8,519	68,020	97,279	43%
TOTAL	**231,791**	**298,251**	**368,080**	**224,993**	**210,950**	**374,463**	**24,476**	**67,486**	**835,298**	**965,194**	**16%**

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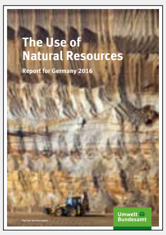

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