Deutsche Bank
Research

Europe

Economics

Focus Germany

Date
18 September 2023

Supply bottlenecks: Obstacles to growth and energy transition

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- **External shocks such as the coronavirus pandemic or the war in Ukraine have caused supply chain disruptions and material shortages on a historic scale in recent years.** The shocks were felt globally and in many sectors at the same time and have not completely subsided to this day.
- **The megatrends of decarbonisation (climate protection), digitalisation and demographics, as well as trends towards deglobalisation, could cause structural supply bottlenecks in the 2020s (and beyond).** They are likely to come along with relative growth losses and higher prices.
- **For raw materials such as copper, cobalt, nickel or lithium, global demand is likely to rise faster than supply, mainly due to the energy transition and the transformation of the transport sector.** Risks for supply security also result from a regional concentration of the extraction and processing of raw materials (China). Trade conflicts or the high energy and water requirements for raw material extraction also harbour risks.
- **To increase security of supply, imports of raw materials should be more regionally diversified. This is a major trade policy challenge for the EU and Germany.** It is also important to expand the domestic mining and processing of raw materials, although this is likely to be more expensive than imports. Recycling technologies must be improved.
- **The availability of labour is also increasingly becoming an obstacle to economic development.** By 2035, the number of people of working age in Germany is likely to shrink by 1.6-4.8 million, depending on net immigration. In China, the number of people between the ages of 15 and 64 could fall by over 50 million by 2035.
- **Furthermore, there is a risk of supply bottlenecks in the physical infrastructure in Germany. For example, the pace of expansion of renewable energies or electricity grids must be increased if the goals of the energy transition are to be achieved.** In addition, new H2-ready gas-fired power plants are needed to enable the phase-out of coal-fired power generation. An enormous need for investment meets financial restrictions from the state and companies.
- **In our view, the supply bottlenecks are likely to contribute to potential growth in Germany being closer to the 0.5% than to the 1% mark in the coming years and to the inflation rate being above rather than below the 2% target.** Technological progress is the main source of hope for the coming years, which can make it possible to achieve climate-compatible economic growth with a social balance.

Disruptions to global supply chains reached historic dimension

Supply chain disruptions or material shortages have always been part of economic activity. They can be triggered by external shocks, market-based imbalances between supply and demand or government regulation. In recent decades, however, such disruptions have been temporary and regionally limited or have affected only individual sectors or products.

A look back: Escalation through COVID-19 and other external shocks

In contrast, since the beginning of 2020, the coronavirus pandemic triggered disruptions in supply relationships that were felt globally and across many sectors at the same time, and which even today have not fully subsided. Due to the crisis of historic proportions, it is worth taking a look back: as recently as the first weeks of 2020, the business community in Europe or the USA was primarily focused on the regulatory measures to contain COVID-19 in China. At first, people feared a local supply shock, i.e. production interruptions and thus supply difficulties for consumer or intermediate goods from China. Only a short time later, however, it became obvious that COVID-19 would spread pandemically – i.e. across the globe. Lockdowns, quarantines, and other coronavirus measures then led to a simultaneous supply and demand shock in many countries around the world.

As a result, there were imbalances in logistics, for example because ships and containers were not in the right location or because land transport in Europe was delayed due to stricter border controls. These imbalances continued even as the economy began to recover from the initial shock. Furthermore, demand shifted between sectors. For example, the automotive industry significantly reduced its orders for intermediate products because it had to reckon with shrinking demand for new vehicles. The best-known example is probably that the industry cancelled orders for semiconductors. At the same time, demand for electronic consumer goods (laptops & co.) increased because millions of private households had to equip themselves to work from home or to prepare for home schooling. This increased the demand for semiconductors enormously, which is why semiconductor production became a bottleneck.

Another example of shifts in demand was seen in leisure activities: because holiday trips or visits to restaurants or cultural events were not possible or made more difficult by coronavirus measures, many people used the freed-up budget for renovation measures in their houses and flats or the purchase of bicycles and fitness equipment. The higher demand gave individual sectors (e.g., DIY stores or bicycle dealers) a boom.

As the general economic recovery from the initial coronavirus shock solidified in early 2021 with progress on vaccination, order books filled up in many sectors. At the same time, value chains were far from running smoothly again, as the coronavirus easing measures took place globally asynchronously. Moreover, the shortage of inputs and skilled labour was exacerbated by the shifts in demand. For example, when the auto industry started ordering more semiconductors again, global production was practically at full capacity due to higher demand from other sectors. This was compounded by other external shocks such as weather extremes (e.g., cold late winter in the US in early 2021, drought in parts of Latin America) or the temporary blockade of the Suez Canal in 2021. Restrictions at factories or individual ports in China led to local business interruptions well into 2023. With the mixture of rising demand for goods and external supply shocks, the wave of

inflation set in, affecting Western industrialised countries from 2021 onwards.

War in Ukraine exacerbated energy and commodity shortages – weather extremes hit power sector

At the beginning of 2022, there were signs of an easing of supply problems in individual sectors. However, Russia's war against Ukraine and the subsequent mutual sanctions between Russia and the EU exacerbated the shortages, especially in energy supplies. In addition, the markets for other raw materials (ores, metals, agricultural commodities) were hit hard because Russia and Ukraine are important suppliers here. Immediately after the invasion, there were significant jumps in energy and other commodity prices. These have since fallen again, not least because of the onset of the global economic slowdown. Nevertheless, many prices are still well above pre-crisis levels because Russia is unable to redirect the full amount of energy and other raw materials supplied to Europe before the war to other sales markets in the short term. In the case of oil, the most important energy raw material globally, the low production of the OPEC countries prevents a stronger price decline.

Figure 1: Raw material prices at a high level in a long-term comparison

Source : HWWI

During the summer months of 2022, weather extremes in Europe also caused shortages and thus rising prices on the electricity market. The persistent drought and high temperatures led to low water levels and high water temperatures in the rivers of Central Europe. This made it less possible to cool thermal power plants. Even the performance of hydro power plants in Norway was affected by the lack of precipitation. In addition, the supply of coal to coal-fired power plants in Germany was disrupted by low water levels on the Rhine because cargo ships could not be fully loaded. Finally, many French nuclear power plants had to be temporarily taken off the grid for maintenance and other disruptions. Low water levels on rivers in Central Europe caused concern again in the early summer months of 2023.

Indicators of supply chain disruptions reached all-time highs – but a lull has since set in

All in all, the last three years have been characterised by a string of many external shocks. The Global Supply Chain Pressure Index (GSCPI) of the Federal Reserve Bank of New York (NY Fed) can be used as a global indicator for the disruption of supply chains. It is calculated on the basis of various international indicators that allow statements about the current state of supply chains. These include the level of order backlogs and delivery times in individual countries or indices for international transport costs. The NY Fed developed the GSCPI in January 2022 and calculated it back to the end of 1997. If the indicator is positive (measured in standard deviations from the mean), supply chains tend to be tight. If it is negative, supply chain disruptions do not play a major role.

Figure 2: Supply chain problems have eased

Source : Federal Reserve Bank of New York

Before the coronavirus pandemic, the peak in the time series was recorded at 1.5 standard deviations from the mean in April 2011, i.e., immediately after the tsunami in Japan and the Fukushima nuclear disaster. As early as August of the same year, however, the GSCPI fell back into negative territory. In March 2020, when almost all industrialised countries had taken measures to curb infection, the indicator then reached a value of 2.5. The GSCPI initially declined in the course of 2020 due to the recession. In 2021, however, it averaged 2.9 and peaked at 4.3. A decline of the indicator also occurred in the course of 2022 due to the economic slowdown. However, the long-term average, which by definition is 0, was always exceeded until the beginning of 2023. Only in the last few months did the economic slowdown in Europe and the USA, the associated falling transport costs and order backlogs, and the end of the coronavirus measures in China cause the GSCPI to slip back into

negative territory.

In Germany, the ifo index for shortages of intermediate goods in manufacturing also rose to unimagined heights as a result of supply chain disruptions. From 1991 to 2019, only a good 5% of all companies reported material shortages on average. The peak before 2019 was 20%. The new peak in the latest supply chain crisis was reached in December 2021 with 82% (!). The index exceeded 60% for six quarters in a row and was still close to 30% at the beginning of Q3 2023. Unlike the GSPCI, the ifo index continues to signal a tense situation in the supply of materials. Capital goods manufacturers are particularly affected: as recently as August 2023, the share of companies suffering from material shortages was between 30% and 50% in the automotive industry, mechanical engineering, and electrical engineering. The order backlog in manufacturing is also still close to record levels because orders could not be processed promptly due to the bottlenecks. In the meantime, however, the weaker economy is making itself felt, so that the peak in order backlogs has now been passed.

The material bottlenecks had a dampening effect on growth, as the example of German industry shows: While new orders in the manufacturing sector expanded by almost 18% on an annual average in 2021, domestic production only rose by just under 5%.

Megatrends point to structural supply bottlenecks

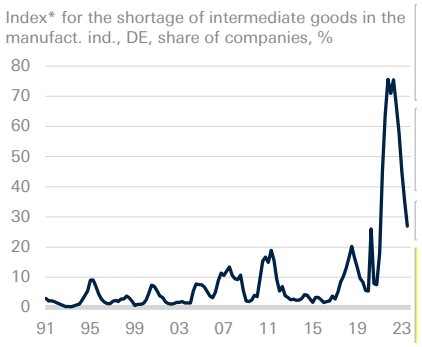
In view of the accumulation of external shocks in the last three years or so, it may sometimes be forgotten that markets in the past have always been characterised by a certain “return to equilibrium”. The influence of shocks on market events always decreases over time. This is true even if such shocks have triggered permanent changes in individual sectors in individual cases. For example, after the terrorist attacks of 11 September 2001, global air transport returned to its previous growth path after only a few months, although some security regulations in the industry introduced after 09/11 remain in place today.

The aforementioned "return to equilibrium" can also be justified by the fact that markets react to scarcity and price signals. If prices are permanently high, this leads to a decrease in demand. At the same time, it becomes more lucrative for suppliers to increase supply. Both developments cause prices to fall. As already mentioned, the cyclical decline in demand for some commodities has already led to declining world market prices. Even the end of the coronavirus measures in China has not supported global demand for commodities because the economic recovery in China is much less dynamic than expected. Private households are showing a high propensity to save, companies are holding back on investments and the construction sector is struggling with overcapacity. The relative economic weakness in China naturally has an impact on international commodity prices.

Decarbonisation, digitalisation, demography, deglobalisation

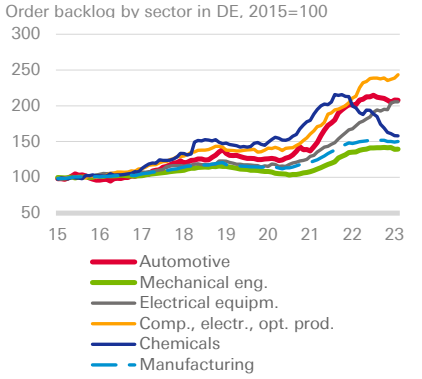
Despite the decline in prices after the peak of 2022, some megatrends can be identified that could also cause shortages in the supply of certain products in the medium to longer term, i.e. for the coming decade. The three most important megatrends are decarbonisation (climate protection), digitalisation and demography. In addition, tendencies towards deglobalisation have become

Figure 3: Easing of shortage of materials is likely to continue



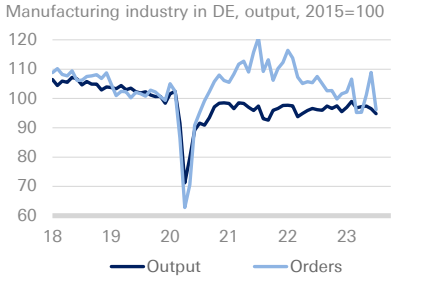
** Quarterly values. Q3 2023 = July-August*
Source: ifo

Figure 4: Capital goods producers still register a high order backlog



Source : Federal Statistical Office

Figure 5: German industry: Gap between output and orders is closed again



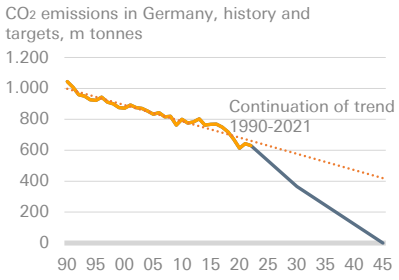
Source : Federal Statistical Office

apparent in recent years.[1] In the 2020s (and beyond), they could cause structural supply shortages with relative growth losses, higher prices for certain raw materials and intermediate products, and more strongly rising wages in individual sectors or regions.

1. **Decarbonisation:** To curb climate change, many industrialised countries are pursuing the goal of phasing out the use of fossil fuels by the middle of this century. Initially, coal, the energy source with the highest CO_2 intensity, is to be pushed back. Oil and natural gas are to follow in the future. This development is to be achieved through various climate and energy policy instruments. These include the pricing of CO_2 (via taxes or emissions trading) or regulatory law (e.g., bans on certain technologies, rules, quotas). Such policies should lead – all other things being equal – to a reduction in energy supply and to higher prices for fossil energy sources. Since in many cases private households and businesses cannot switch from fossil fuels to lower CO_2 or CO_2-free technologies in the short term (see the heating debate in Germany or switch to electric mobility), they will have to bear higher energy costs or consume less energy for a transitional period. At the same time, for reasons of sustainability, higher environmental and social standards are likely in the coming years, as well as stricter corporate governance requirements for the development of new oil and gas fields. Such stricter ESG guidelines (ESG = Environmental, Social, Governance) can also tighten supply or make it more expensive.[2]

   At the same time, not only industrialised countries but also developing and emerging countries are investing more in the expansion of renewable energies and climate-friendly technologies. According to the International Energy Agency (IEA), installed power generation capacity based on renewable energies will more than double to about 7.7 terawatts by 2030 if the countries implement their current expansion targets. Subsidies or other support regimes will continue to play a role in the future. As a result, the global demand for metallic and other raw materials needed for such climate-friendly technologies will increase (Clean Energy Minerals and Metals). Decarbonisation requires greater electrification in the heating market, in the transport sector or in industrial processes. It also requires investments in electricity grids. This also increases the demand for individual metals. Rising demand here is often likely to meet a rather rigid supply in the short to medium term, as it takes time to develop new mines and many high-yield deposits have already been tapped. In addition, stricter ESG requirements (occupational health and safety measures, energy consumption) are likely to lead to higher costs. Another risk is that deposits for such raw materials or industrial plants for the further processing of ores are often regionally concentrated. China is a global leader in the first processing stage of metals (see below). Should trade conflicts arise here, the supply of such metals is at risk. China's recent export restrictions on gallium and germanium are an example of this risk. Finally, demand will also increase for end products that are classified by policymakers as climate-friendly and are financially supported (e.g., renewable energies, electric cars, charging infrastructure, electric heat pumps, hydrogen technology). Here, too, supply is quite rigid in terms of the short-term availability of intermediate products, production facilities and skilled labour.

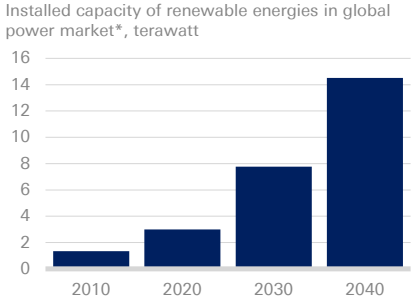
Figure 6: Germany aims to become climate-neutral by 2045



** CO_2 equivalents*

Source : Federal Environment Agency, Deutsche Bank Research

Figure 7: Steady expansion of renewable energies



** Announced Pledges Scenario 2022*

Source : IEA

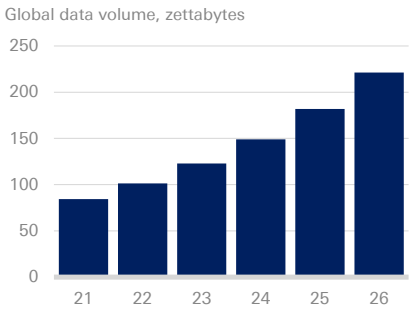
1 Cf. for example IW Köln (2021). Gleichzeitig. Wie vier Disruptionen die deutsche Wirtschaft verändern. Herausforderungen und Lösungen.
2 See Hubbard, James et al. (2023). ESG for the oil and gas sector. Deutsche Bank Research.

2. **Digitalisation:** Digitalisation is the second technological megatrend of our time. Most countries around the world want to expand the performance of their digital infrastructure. Private households are demanding more digital services, from streaming to digital working from home to smart homes. Companies use online conferencing and are continuously developing new digital technologies for private end customers or commercial applications. Artificial intelligence, Industry 4.0 and blockchain are just a few of the buzzwords. According to estimates, the global data volume is growing by more than 20% per year. This requires constant investment in the necessary hardware (data centres, routers, networks, etc.), although technical progress (software routers, more powerful chips, optimised routing through artificial intelligence) will dampen the relative use of raw materials per computing unit. The increasing demand for mobile devices goes hand in hand with an increased demand for battery raw materials. The trend towards more digital technologies and applications is not primarily stimulated by government requirements or subsidies but is based primarily on market forces. This makes it more independent of the respective state budgets, although the expansion of digital infrastructure in rural areas often requires state subsidies. Ultimately, the digitalisation of society and the economy leads to an increase in demand for metals and – ceteris paribus – to higher energy consumption. According to estimates, the energy consumption of digital applications already causes about 4% of global CO_2 emissions.[3]

3. **Demography:** Demographic developments in many countries will lead to a relative shortage of labour. In its 15th coordinated population projection from the end of 2022, the Federal Statistical Office calculated that by 2035 there will be about 4 million more people living in Germany who are 67 years or older. At the same time, the number of people of working age will shrink by 1.6-4.8 million by then, depending on net immigration. If the actual adjusting screws of the pension system (retirement age, pension contributions and pension levels) are not adjusted to this shift in the age cohorts, the state budget will face additional expenditure. At the same time, the declining labour force potential means a major challenge for the labour market, which is not likely to be mastered by more automation, the use of artificial intelligence or higher labour force participation alone. The shortage of skilled workers will increase in many sectors. Other EU countries are also facing a declining labour force. In China, too, demographic structures will shift in the coming years. When the country joined the WTO at the end of 2001, hundreds of millions of fairly cheap workers were automatically integrated more closely into the world market. The additional supply on the global labour market dampened wage growth in the industrialised countries and thus also the inflation rate. In the future, the opposite development will be observed. The number of people of working age in China has already been falling for several years. China's long-standing one-child policy will continue to leave its mark on the labour market. According to UN forecasts, the number of people aged 65 and over in the country could increase by more than 130 million by 2035 (compared to 2020). At the same time, the number of people between the ages of 15 and 64 could fall by more than 50 million. In other emerging countries (ASEAN, Latin America), too, the share of the labour force in the total population is likely to shrink in the future.

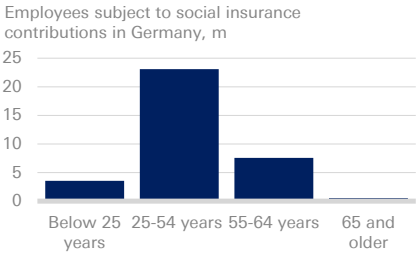
4. **Deglobalisation:** The last decade was marked by little progress in global free trade at WTO level, "my nation first" policy approaches, Brexit and an increase in bilateral trade conflicts. This had an impact on world trade and thus globalisation. While the average growth rate of world trade from 1990

Figure 8: Rising global data volume



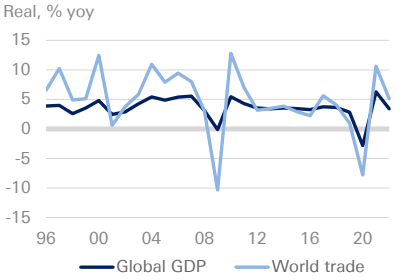
Source: IDC

Figure 9: Nearly 8 million employees are approaching the retirement age



Source: Federal Employment Agency

Figure 10: Global GDP and world trade: Similar growth rates since 2012



Source: IMF

3 Cf. Climate Impact Partners (2021). The carbon footprint of the internet.

to 2011 was more than double that of global GDP (6.5% versus 2.9% according to IMF data), the average growth rate of world trade since 2012 has been 2.8%, only just above the growth of global GDP (+2.5%). For an export-oriented and open economy like Germany, times of deglobalisation are particularly challenging. It is difficult to find a balance when dealing with important trading partners whose political system does not correspond to the Western understanding of democracy. This is exemplified by Germany's China strategy, which leaves "de-risking" primarily to the companies. An economic disengagement from China is not sought by politics or business and could also cause significant economic damage. Overall, however, restrictions on world trade and restrictions on trade in certain raw materials (e.g., gallium and germanium) and finished goods can exacerbate supply bottlenecks.

Critical raw materials: Global demand likely to grow faster than supply

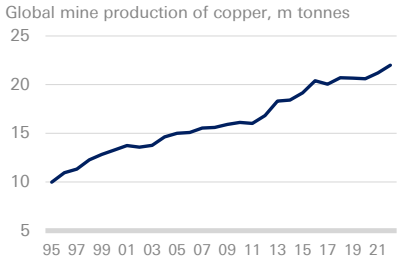
We have outlined that the global trends towards decarbonisation (electrification) and digitalisation will structurally lead to higher demand for many metallic raw materials. In the following, we take a more detailed look at the metals most affected.[4]

Copper: Structural excess demand ahead for the multi-talent

Fields of application: Copper is a multi-talent due to its very good electrical conductivity, thermal conductivity, corrosion resistance and formability and is generally considered the most important industrial metal. It is used in practically all electronic fields of application and can hardly be substituted on a large scale.

Supply: According to the German Federal Institute for Geosciences and Natural Resources (BGR) and the latest US Geological Survey (USGS) from early 2023, global mine production of copper has more than doubled from about 10 million tonnes in 1995 to about 22 million tonnes (2022). The most important producing countries last year were Chile, ahead of Peru, the Democratic Republic of Congo (DRC) and China. They account for slightly more than half of global mine production. It is striking that production in Chile, the largest producing country, has hardly increased for several years and fell in 2022. There is no physical scarcity in the sense of depleted resources for copper. According to the USGS, the secured copper reserves worldwide are 890 million tonnes.[5] The static range (i.e., the ratio of secured reserves to current annual consumption) is thus more than 40 years. Nevertheless, it is always uncertain how quickly and to what extent the reserves can be exploited.

Figure 11: Mine production of copper grows quite steadily



Source : BGR, DERA, USGS

Demand trend: The energy transition and the transformation of the transport sector as well as digitalisation will fuel demand for copper in the coming years. The International Energy Agency (IEA) states that more than twice as much copper is needed for an electric car than for a conventional vehicle. Wind turbines or photovoltaics also require many times more copper per megawatt hour of installed capacity compared to coal- or gas-fired power plants. Our colleagues from Commodity Research expect that demand from the electromobility and renewable energy sectors alone will reach about 5 to 7 million tonnes of copper per year by

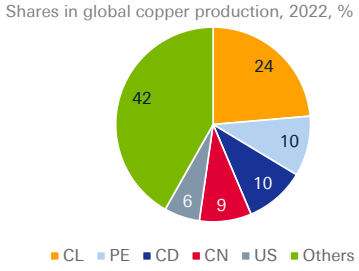
4 A comprehensive overview of many other commodities can be found in: DERA (2021). Rohstoffe für Zukunftstechnologien. A more compact overview can be found in: ifo Institut (2022). Wie abhängig ist Deutschland von Rohstoffimporten? Eine Analyse für die Produktion von Schlüsseltechnologien.
5 Cf. USGS (2023). Mineral Commodity Summaries.

2030.[6] In their latest Commodities Outlook, they speak of a "multi-year deficit", even if copper consumption per vehicle is likely to fall in the future due to technical progress.[7] The share of "clean energy technologies" in total copper demand is likely to rise from a good 20% in 2020 to at least 30% by 2040. The faster the expansion of renewable energies takes place, the higher this share will be.[8]

Recycling: Copper can be recycled without restriction and without loss of functionality. According to the BGR, the share of secondary material in global refined metal production is 17% (41% in Germany). Recycling is likely to become more important globally. However, it will not be enough to close the gap between supply and demand because many applications of copper have a long lifetime (e.g., in the building sector). Once installed, copper will therefore be withdrawn from the market for years or even decades in many cases. On the positive side, according to the BGR, the energy required to recycle copper is about 30 to 80% lower than in primary production.

Risks: Our colleagues from Commodity Research expect a structural supply deficit for copper from the middle of the decade. The IEA expects the gap between global copper demand and expected production from existing and planned new mining projects to widen from the second half of the 2020s. By 2030, the gap could be 5 million tonnes (i.e., a scant quarter of today's global primary production). The global processing of copper ores (refining) is highly concentrated regionally. China dominates here with a share of 42%, ahead of Chile with 8%. China consumes a large part of the domestically processed copper itself (and about 50% of the global refined copper production). Indirectly, however, it exports processed copper to other countries (e.g., as a component of electric cars, consumer electronics, solar modules, batteries). The USA accounts for less than 4% and Germany for just under 2.5% of global refined copper production (data for 2022). If the targets for renewable energies, e-mobility or digital infrastructure are to be achieved, Germany and other industrialised countries are directly or indirectly dependent on imports of copper. For example, Germany aims to quadruple its installed photovoltaic capacity by 2030 (compared to 2020). This will not be possible without higher imports of corresponding equipment (solar modules, inverters, etc.) from China. It is also foreseeable that Germany will import more electric cars directly from China in the future because some German car manufacturers have announced that they will produce individual electric cars exclusively in China and because Chinese manufacturers themselves are increasing their export efforts. According to a press release by the Federal Statistical Office, a good 28% of all electric cars imported into Germany came from China in Q1 2023.[9] Disruptions in trade relations between the EU and China would worsen the supply situation. Finally, supply risks or higher costs can result from stricter ESG requirements in the extraction of copper ores (energy, land and water consumption as well as environmental damage during ore mining, working conditions, child labour or corruption in individual mining countries, etc.). According to the IEA, energy costs account for almost 20% of the

Figure 12: Chile accounts for almost a quarter of copper production



Source : USGS

Figure 13: Legend ISO Codes

Country	ISO
Argentina	AR
Australia	AU
Brazil	BR
Canada	CA
Congo	CD
Chile	CL
China	CN
Indonesia	ID
India	IN
Madagascar	MG
Mozambique	MZ
New Caledonia	NC
Norway	NO
Peru	PE
Philippines	PH
Russia	RU
USA	US

Source : ISO

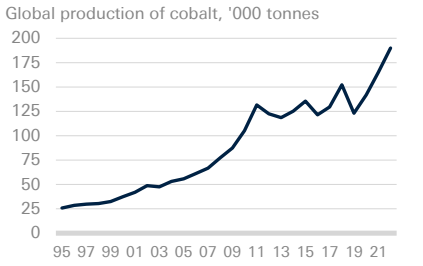
6 See Fitzpatrick, Liam et al. (2023). Recession risks mask structural tightness. Deutsche Bank Research. Commodities Outlook. See also: Fitzpatrick, Liam et al. (2023). Green shoots for base and precious metals. Deutsche Bank Research. Commodities Outlook.
7 See Fitzpatrick, Liam et al. (2023). Demand headwinds to persist as supply recovers. Deutsche Bank Research. Commodities Outlook.
8 Cf. IEA (2022). The Role of Critical Minerals in Clean Energy Transitions. Revised version. The IEA uses a broad definition of "clean energy technologies", which includes not only all renewable energies but also nuclear energy, electricity grids, electromobility, batteries and hydrogen technologies.
9 Cf. Federal Statistical Office (2023). Außenhandel mit China im 1. Quartal 2023 um 10,5% gegenüber dem Vorjahresquartal gesunken. Press release No. 182 of 12 May 2023.

total costs in the extraction of copper ore. Fossil fuels are predominantly used in this process.

Cobalt: Particularly high regional concentration in processing

Fields of application: Cobalt is mainly used for battery applications (cobalt as cathode material in lithium-ion batteries). The raw material is therefore indispensable for the expansion of electromobility or generally for the construction of batteries (both stationary battery storage and batteries for small-scale consumer electronics such as mobile phones or laptops). Cobalt is also needed for areas such as robotics or fuel cells. Cobalt is much less relevant for the expansion of renewable energies.

Figure 14: Production of cobalt increases sharply recently



Source : BGR, DERA, USGS

Supply: Cobalt is usually extracted as a by-product of mining other commodities such as copper or nickel. Global mine production of cobalt has increased quite steadily since the mid-1990s. According to the BGR, about 25,000 tonnes of cobalt were mined in 1995. Since 2010, production has exceeded 100,000 tonnes. The latest USGS report puts cobalt mine production in 2022 at 190,000 tonnes – a new record. By far the most important producing country is the DR Congo. The country accounts for 68% of global production. Congolese cobalt production comes mainly from the copper mines there. Indonesia, Russia, and Australia follow far behind (shares in 2022 according to USGS: 5.3%, 4.7% and 3.1% respectively). The German Mineral Resources Agency (DERA) and other market observers agree that the DR Congo will remain the most important producing country for cobalt for the foreseeable future or is even likely to expand its position.[10] As with copper, there are no physical shortages of global cobalt deposits. The USGS estimates that there are 8.3 million tonnes of proven reserves. Due to the exploration of new deposits, the proven reserves have even increased recently: Two years ago, they were only 7.1 million tonnes, according to the USGS. The static range is currently about 44 years.

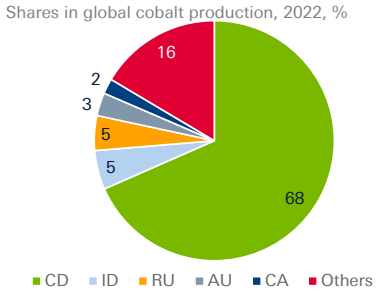
Demand trend: With the trend towards electromobility in large car markets or, more generally, with the increasing use of batteries as electricity storage devices, the demand for cobalt will rise significantly in the coming years. Depending on the market penetration of e-mobility, the IEA expects a demand of at least more than 200,000 tonnes of cobalt by 2030, which could even reach 400,000 tonnes in a more ambitious scenario. DERA estimates demand in 2030 at 315,000 tonnes. Fitch Ratings sees even greater growth, expecting the threshold of 300,000 tonnes to be exceeded as early as 2026.[11] The actual demand will strongly depend on the regulatory treatment of electric cars in the major car markets (China, USA, EU), because this is crucial for the acceptance of electric cars by end customers. In many countries, subsidies support the purchase of electric cars. Also important for the acceptance of the technology will be how fast the technical progress of electric cars progresses and how quickly the public charging infrastructure is expanded. Thanks to increasing economies of scale in production, the price competitiveness of electric cars should improve compared to vehicles with internal combustion engines. According to the IEA, "clean energy technologies" will account for at least 40% of global cobalt demand in 2040, up from less than 20% in 2020.

Recycling: The recycling of cobalt does not yet play a major role. The BGR estimates that recycling contributes about 10% to the total supply of cobalt. For the time being, the additional demand will therefore have to be met primarily through

10 Cf. DERA (2021). Batterierohstoffe für die Elektromobilität.
11 See Fitch Ratings (2022). Energy transition means more metals.

additional primary production. Again, once cobalt is used, it is withdrawn from the market for several years. In the case of batteries in electric cars, there could even be a secondary use of the batteries as stationary power storage units after the electric car has reached the end of its service life. Nevertheless, it is important to push ahead with the technical progress of recycling technologies in order to reduce the costs even for small batteries. The USGS data for the US show that recycling can become more significant in the future. Here, recycled material accounted for about 24% of total cobalt consumption in 2022.

Figure 15: Congo is the key player in global cobalt production in 2022



Source : USGS

Risks: It is very likely that future demand will exceed the production of cobalt that is expected for the coming years. According to the IEA, there will be a deficit in cobalt supply in the second half of the 2020s even in a less ambitious climate protection path. This will be all the greater the more batteries are needed for electric cars, consumer electronics or as stationary power storage. Fitch Ratings expects an undersupply as early as 2025, estimated at just under 8% for 2028. It is true that cobalt can be partly replaced by nickel in batteries. However, this is at the expense of the lifetime and thermostability of the batteries. In the short term, this substitution option is therefore unlikely to play a major role. Ultimately, the availability of cobalt may become a limiting factor for the market ramp-up of e-mobility. The market supply of cobalt is characterised by a particularly high concentration on the supply side. Not only mine production (almost 70% is accounted for by the DR Congo) is dominated by just one country, but also refining. Here China leads with a share of about 65%, followed by Finland (about 10%) and Belgium (5%). China is the largest producer of batteries for electric cars and also of electric cars themselves. According to the USGS, China uses about 80% of the cobalt for battery production. As with copper, there are also direct or indirect supply dependencies on China for cobalt if the production of electric cars is to be ramped up in Germany and Europe. Germany and the EU are therefore striving to significantly expand battery cell production in Europe in order to reduce supply dependencies. However, this requires a secure supply of cobalt. This also calls for politicians to conclude corresponding supply agreements with producing countries, because a supply from European deposits will not be able to cover the demand. In terms of ESG risks, the problems of cobalt mining are almost identical to those of copper mining, as cobalt is often mined as a by-product of copper (environmental and water pollution, land, energy and water consumption). Particular ESG risks result in the primary production of cobalt from the fact that in the DR Congo, according to the BGR, around 10% of production is based on small-scale mining. This is problematic in terms of working conditions (occupational safety, child labour).[12] This results in considerable reputational risks for mining companies and their customers. In addition, the processing of cobalt is very energy-intensive and is largely based on fossil fuels in China. According to the IEA, the CO_2 emissions per tonne for the processing of cobalt are in some cases many times higher than the values for other materials (e.g., about twice as high as for the already energy-intensive processing of aluminium). It is therefore also true for cobalt that large amounts of fossil energy must be used for mining and processing before cobalt can be used for climate-friendly technologies.

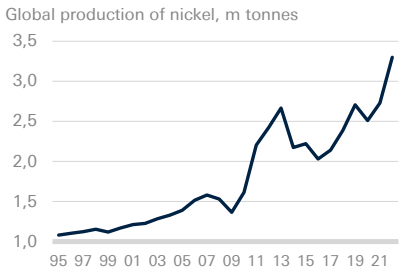
Nickel: Change of the draught horses in demand

Fields of application: Nickel is traditionally used primarily as an alloying metal and is needed, for example, for the production of stainless steels (high-grade steel). In 2021, according to the BGR, 73% of the global demand for nickel was for the

12 Cf. BGR (2021). Kobalt. Informationen zur Nachhaltigkeit.

production of stainless steels. Nickel also plays a major role in non-ferrous alloys (share of global demand: 6%). The use of nickel for battery production has recently gained significantly in importance (share in 2021: 11%). Basically, the nickel market can be divided into three product areas: high-purity nickel metal (Class I nickel; nickel share over 99%) with a 30% share of global refined nickel supply, nickel chemicals (especially nickel sulphate) with about 5% of supply and so-called Class II nickel (nickel share below 99%), which accounts for 65% of the supply of primary nickel. We will come back to this distinction.

Figure 16: Production of nickel picks up speed



Source : BGR, DERA, USGS

Supply: Nickel mine production has increased in recent decades. In 1995, it was just under 1.1 million tonnes per year, reaching about 3.3 million tonnes in 2022 (new record), according to the USGS. Intermittent setbacks in primary production were explained by economic cycles or temporary export bans on nickel ores from Indonesia (initially from 2014 to 2017 and from 2020), the largest mine producer of nickel. The country accounted for a good 48% of mine production in 2022, ahead of the Philippines (10%) and Russia (6.7%). Indonesia and the Philippines in particular are focused on mining ores for the production of Class II nickel. However, with the export ban on nickel ores, Indonesia pursued the goal of strengthening the nickel processing industry in the country. This has been crowned with success. Chinese companies in particular have invested in nickel processing factories in Indonesia in recent years. In the course of this development, stainless steel production capacity has also grown in the country. The WTO has declared the export ban illegal (the EU had filed a complaint). However, Indonesia appealed against the ruling. Ultimately, the country has expanded its position in the global nickel market in terms of quantity and quality, not least because of investments by Chinese companies.[13] In the future, this is likely to include the production of nickel sulphate, which is needed for the manufacture of batteries. According to the IEA, China has so far ranked first in total refined nickel production with a global market share of about 35%, ahead of Indonesia (15%). The export ban on nickel ore from Indonesia and the investments of Chinese companies in Indonesia in the processing of nickel should narrow the gap between the two countries.

For Germany, the import of high-purity nickel metal has been particularly significant so far. The most important producers of nickel metal in 2021 were China (market share: 20.4%), ahead of Russia (15.6%), Canada (13.1%) and Australia (12.7%). In Europe, Norway and Finland are also important producing countries. The most important importing country for Germany was Russia, with a share of more than 40% for nickel metal in 2021.[14] Initially, Russia's war against Ukraine had not changed this dominant position, as Russian nickel producers were not subject to sanctions. According to the foreign trade statistics of the Federal Statistical Office, German imports by weight from Russia in the product group "nickel and goods made from it" (i.e., not only nickel metal) even increased by 0.7% in 2022. However, imports in this product group from Russia fell by almost half in the first half of 2023 yoy. Obviously, a certain diversification has been achieved in the meantime.

According to a DERA study from 2021, there were more than 2,000 exploration projects and mining operations for the extraction of primary nickel. About 300 of these were in production or at an advanced stage of development. There are uncertainties for the time projection because, on average, more than 15 years elapse between the start of exploration and actual production. Mine production of

13 Cf. GTAI (2022). Welthandelsorganisation kippt Ausfuhrverbot für Nickelerz.
14 Cf. BGR and DERA (2022). Der globale Nickelmetallmarkt – zwischen Legierungselement und Batterierohstoff. Commodity TopNews 68.

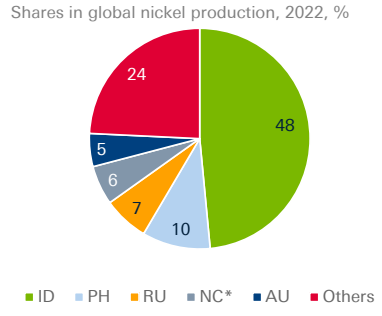
nickel is expected to increase further in the coming years, especially in Indonesia and Australia. With regard to nickel refining, besides Indonesia and Australia, additional capacities are likely to be created in the US, Brazil, China, Finland, or Turkey.[15] Chinese companies will continue to play an important role in the Indonesian market. Thus, China could increase its own supply security for nickel for both stainless steel and battery production. Possible nickel shortages could be more a question of allocating the desired nickel products and qualities than a question of absolute quantitative availability. Depleted resources are not expected for nickel. The USGS estimates that there are more than 100 million tonnes of proven reserves.

Demand trend: In the coming years, stainless steel production will remain the most important driver of nickel demand in terms of volume. Much of the new capacity in Indonesia is geared towards this. Nevertheless, the use of nickel for battery production (especially electromobility) will increase much faster in the coming years. According to Fitch Ratings, an electric car requires about 30 times as much nickel as an internal combustion engine car. BGR and DERA expect an annual growth rate of 5% for stainless steels. In view of the energy transition, nickel and stainless steel are needed, for example, for the construction of electrolysis plants.[16] However, the growth rate for the use of nickel for the production of batteries is estimated at 20% to 30% per year. This requires nickel sulphate, which is mainly obtained from high-purity nickel metal. It is true that production processes using Class II nickel are also possible for battery production. However, these are more expensive and involve higher energy demand. In addition to e-mobility, nickel is also needed for the expansion of wind power. According to the IEA, the share of "clean energy technologies" in total nickel consumption could rise from less than 10% in 2020 to more than 30% in 2040 and even up to 60% if e-mobility takes off quickly. The exact nickel demand depends not least on which battery technologies will prevail in the course of the coming years, because there are also nickel-free batteries. In most of the technologies currently in use, however, nickel is an essential component of the battery.[17]

Recycling: Recycling of nickel already plays an important role today. According to DERA, secondary raw materials accounted for about 30% to 35% of the total demand for nickel in recent years. This is mainly because stainless steel scrap is directly recycled back into stainless steel production. Outside of China and Indonesia, where there is not enough scrap, secondary raw materials account for about 70% of stainless steel production (in China it is estimated at 25%). In the future, recycling of batteries will become more important for nickel supply. At the end of the last decade, the production of nickel sulphate as a precursor for battery production was based on secondary raw materials for about 15%. The share is expected to increase with a rising market penetration of electric cars and the expected technical progress in recycling technologies for batteries. For the time being, however, recycling will not be able to cover the additional demand due to increasing battery production.

Risks: For the coming years, the IEA and Fitch do not expect a physical undersupply of nickel globally – despite rising demand. Possible nickel shortages could, as already mentioned, rather affect the desired nickel products and qualities. The regional concentration of mining (Indonesia) and processing (China and Indonesia)

Figure 17: Indonesia tops the list of nickel-producing countries by far in 2022



** Overseas Territory of France*
Source : USGS

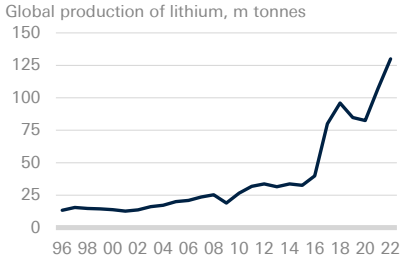
15 Cf. DERA (2021): DERA Rohstoffinformationen. Risikobewertung – Nickel.
16 Cf. SWP (2022). Elektrolyseure für die Wasserstoffrevolution. SWP-Aktuell Nr. 58.
17 Cf. DERA (2021). Batterierohstoffe für die Elektromobilität.

is also a significant risk regarding nickel supply. For Germany, the great importance of imports from Russia results in a risk for the supply of nickel, as supply relationships could be disrupted by mutual sanctions as a result of the war in Ukraine. If battery production is to be expanded in Germany and Europe, the supply of nickel must be guaranteed. The Indonesian export ban on nickel ores shows that the free movement of goods is anything but a matter of course. Depending on the mining method of nickel (above ground or underground), there are different ESG risks (land and water consumption, energy consumption and use of fossil fuels, working conditions). The mining and processing of nickel causes about five times as high CO_2 emissions per tonne as iron and steel production. The long lead times in the development of new nickel mines entail the risk of temporary imbalances between supply and demand.

Lithium: Battery production creates particularly dynamic demand

Fields of application: Lithium is already predominantly used for the production of (rechargeable) batteries, for which the metal is the eponym (lithium-ion batteries). Already in 2020, about 67% of the global demand for lithium was for batteries (consumer electronics, electromobility).[18] This share is likely to have increased in the meantime. In addition, lithium is used in the ceramics and glass-ceramics industry, where it serves to prevent the products in question from expanding with temperature fluctuations (e.g. glass-ceramic cooktops). In batteries, lithium is not the most important component in terms of weight or value, but it functions as the dominant cathode material in modern batteries. Prior to this, the further processing of lithium into lithium carbonate or lithium hydroxide is required.[19]

Figure 18: Rising demand for batteries leads to higher production of lithium



Source : BGR, DERA, USGS

Supply: In the mid-1990s, a good 13 million tonnes of lithium were mined worldwide. In the years that followed, mine production increased quite steadily. There was a sharp increase of about 100% in 2017, which was mainly made possible by a massive expansion of lithium extraction in Australia. In 2022, according to the USGS, mine production was already 130 million tonnes, a tenfold increase compared to 1995. The most important producing country is Australia with a global market share of 47% (2022). In Australia, lithium is mainly extracted from solid rock and then shipped as concentrate to China for further processing. Chile follows in second place in terms of production with a market share of 30%. In Chile, the extraction of lithium on the basis of lithium-containing brines dominates. In contrast to Australia, much of the processing in Chile takes place locally. China is in third place in terms of extraction (share: 15%) and also processes the lithium in its own country. The three largest producing countries thus account for 92% of the world market share. There is also a high regional concentration in the processing of lithium. According to the IEA, China has a 58% share of the world market, ahead of Chile (29%) and Argentina (10%). The primary supply of lithium will continue to increase in the coming years. In view of the growing importance of electromobility, existing mines are being expanded and new projects are being launched.[20] For an expansion of the supply, it is advantageous that lead times for the development of new mining projects are quite short compared to other raw materials. According to the IEA, they are about 4 years in Australia and about 7 years in Chile. This means that supply can react more quickly to rising demand than is the case with copper or nickel, for example. Lithium is not a scarce commodity from a geological point of view. According to the USGS, the secured global reserves in 2022 were 26 million tonnes (static range: about 200 years). Formally reported

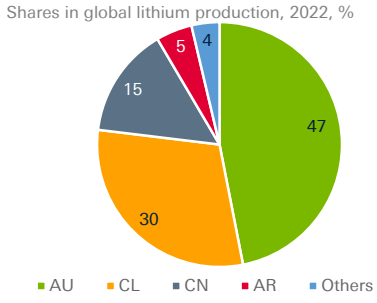
18 Cf. DERA (2023). DERA Rohstoffinformationen. Risikobewertung – Lithium.
19 Cf. DERA (2021). Battery raw materials for electromobility.
20 An overview can be found in DERA (2023). DERA Rohstoffinformationen. Risikobewertung – Lithium.

reserves will increase in the coming years as more lithium deposits are developed through a variety of exploration projects. In 2020, reported reserves were only 21 million tonnes. According to the USGS, the identified resources[21] of lithium in 2022 were about 98 million tonnes (2020: 86 million tonnes). Even in Germany (Upper Rhine Graben) there are identified resources of a good 3 million tonnes. However, a sufficiently high supply of mining capacity is not synonymous with a sufficient supply of lithium chemicals for battery production. For this, the capacity for further processing of lithium must also be expanded.[22]

Demand trend: The demand for lithium in the coming years will be driven predominantly by the trend towards electromobility. In China and Europe in particular, the share of battery electric vehicles (BEVs) in sales and new registrations is rising sharply. The share of BEVs in 2022 was 21% in China and 14% in Europe (EU+EFTA+UK). In the US, demand for electric cars is mainly concentrated in the state of California. However, the US Inflation Reduction Act provides incentives for the production and sales of electric cars in the US.[23] The IEA even says that the demand for lithium will grow fastest among all important raw materials for "clean energy technologies" until 2040. Even with a moderate ramp-up of electric mobility, lithium demand would increase by a factor of 13 by 2040 compared to 2020. In its study, DERA outlines various scenarios according to which the demand for lithium will expand between 2020 and 2030 in the range of just under 16% per year to a good 22% per year. In absolute terms, this corresponds to a range of a good 316,000 tonnes to 559,000 tonnes. According to the IEA, the share of "clean energy technologies" in lithium demand was around 30% in 2020. This may seem surprisingly low. However, it must be taken into account that the demand for batteries in the field of consumer electronics does not count as "clean energy technologies". Depending on the dynamics of electromobility, this share could increase to 75% to 90% by 2040. In this respect, the future demand for lithium depends not least on technical progress as well as government regulation of electromobility in important car markets (subsidies for electric cars, restrictions on vehicles with combustion engines, etc.). Lithium is of little relevance for other climate-friendly technologies such as renewable energies or hydrogen production plants.

Recycling: According to DERA, recycling does not yet play a major role in the overall supply of lithium globally. Reasons for this include the still low recycling volumes (e.g., few electric cars that have reached the end of their service life) and the higher costs compared to the cheap primary extraction of lithium. In the coming years, however, recycling will become more important. This is supported not least by regulatory requirements for the recycling of batteries. According to the USGS, at the end of 2022 there were already 44 companies in the US and Canada and 47 companies in Europe that recycle lithium-ion batteries or are pursuing such plans. Due to the low return of spent batteries, DERA expects that the volume of new scrap (scrap from current production) will remain more important than the volume of spent batteries for many years to come.[24] However, from 2030 and beyond, the volume of spent batteries will become more important. In its 2023 report, DERA outlines various scenarios for the supply of lithium from the recycling of spent

Figure 19: Lithium production is concentrated in only a few countries



Source : USGS

21 According to the USGS, for identified resources, the location, quality and quantity of the raw material deposits are known or can be estimated on the basis of geological findings. This also includes deposits that could already be economically developed today.
22 Cf. (DERA 2022). Rohstoffrisikobewertung – Lithium 2030. Update.
23 Cf. Heymann, Eric and Jule Mau (2023). Electromobility: Competition for market share intensifies. Deutsche Bank Research. Germany Monitor.
24 Cf. DERA (2022). Chart des Monats. November 2022.

batteries. Depending on the market ramp-up of e-mobility and the achievable recycling rates, between 9,000 and almost 56,000 tonnes could be added to the market from recycled batteries in 2030. Compared to the expected development of demand, it becomes clear that recycling of spent batteries will only make a contribution in the (low) single-digit percentage range to the total supply in 2030. As for all sectors, it is nevertheless true that investments in the technical progress of recycling methods are necessary to improve the supply situation. For example, a recent study by RWTH Aachen University in cooperation with PwC predicts that battery recycling is likely to increase tenfold between 2030 and 2040 because more used batteries will then be generated from the e-mobility sector. By 2035, the study estimates the investment volume in recycling capacities in the EU at EUR 9 billion.[25]

Risks: In the very short term, neither DERA, Fitch Ratings nor the IEA expect physical supply shortages of lithium. From the second half of the 2020s, however, there could be a shortfall in supply if demand for electric cars were to rise rapidly. Ultimately, however, the market ramp-up would be slowed down by a lack of lithium availability. According to DERA, such scenarios are not unlikely even if the global supply of mining capacity were to rise sharply. Even then, with very strong growth in demand for electric cars, there could be a gap of up to 200,000 tonnes in 2030. In addition to primary production, bottlenecks could also occur in the processing of lithium. Such imbalances between supply and demand would also result in price risks for lithium and lithium-ion batteries. Currently, the high concentration of lithium production and processing (the latter mainly in China) poses a risk. According to the Federal Statistical Office, in the first quarter of 2023 a good 39% of the lithium-ion batteries imported into Germany came from China. Not least because of the high importance of the supply of lithium for the transformation of the German and European automotive industry, Germany and Chile signed a cooperation agreement on the German-Chilean Partnership for Mining, Raw Materials and the Circular Economy at the beginning of 2023. From an ESG perspective, it is particularly relevant in the extraction of lithium that today more than 50% of lithium deposits are extracted in regions with "extremely high" water scarcity and that water consumption for lithium extraction is very high. Should climate change have a negative impact on the local water supply in the areas concerned, this would negatively affect lithium extraction. We had explained that Germany has significant deposits of lithium. For some time now, it has been investigated how these deposits can be exploited. The basic idea is to extract lithium with the help of geothermal processes, which would contribute to the generation of heat and electricity. In principle, the state government of Baden-Württemberg has signalled support for lithium extraction. It is also necessary to weigh up economic interests against resistance from the local population to such projects, which is justified by the fact that the Upper Rhine Graben is one of the regions at risk of earthquakes.[26] It is an example that ESG risks can also be relevant for national projects.

Other commodities at a glance: Availability and price risks

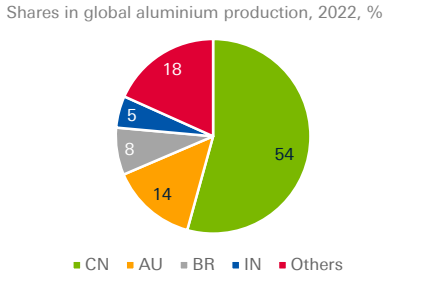
For many other commodities, demand is likely to grow faster than supply in the coming years. Together with a regional concentration on the supply side as well as stricter ESG requirements and generally high energy costs for extraction and

25 See RWTH Aachen and PwC (2023). The EU recycling market – a viable and sustainable business.
26 Cf. tagesschau.de (2022). Lithiumförderung am Rhein. Zwischen Erdbebengefahr und Goldgräberstimmung.

processing, this results in availability and price risks:

- **Aluminium** is one of the most important industrial metals worldwide because of its low weight and wide range of applications. For the expansion of electricity grids, the demand for aluminium will increase in the coming years. Its importance is likely to increase further in vehicle construction or the building sector. Aluminium is also needed for the expansion of photovoltaics and for consumer electronics. The extraction of bauxite, the basic raw material for aluminium, is quite diversified regionally. The largest producing country is Australia (market share in 2022 according to USGS: 26%), ahead of China (24%), Guinea (23%), Brazil (9%), and Indonesia (just under 6%). In actual aluminium production, however, China dominates with a share of 54%, ahead of Australia (14%). Our colleagues from Commodity Research see little potential for an increase in aluminium production in China due to government regulations. They therefore expect further price increases (from 2025) or a permanently high price level. This is also due to the fact that the production of metallic aluminium, which is extracted from bauxite ore, is very electricity-intensive (electricity costs account for almost 40% of total costs, according to the IEA). Fitch Ratings expects a structural supply deficit for aluminium from 2030. On the positive side, there is an established recycling market for aluminium in many countries. This can contribute to security of supply in the countries where aluminium is used. According to the BGR, the share of secondary feedstocks in aluminium production in Germany has been above 50% for years.[27]

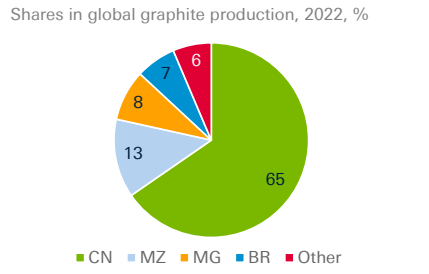
Figure 20: China accounts for more than half of aluminum production



Source: BGR, DERA, USGS

- **Graphite** is a mineral that is used in many areas because of its positive properties (resistance to oxidation and thermal shock, high thermal and electrical conductivity, good lubricating properties). A distinction must be made between natural and synthetically produced graphite. So far, there are only a few substitution possibilities or competing applications between the two types of graphite. Natural graphite is mainly used for refractory products, batteries and foundry products. The application areas for synthetic graphite are mainly electrodes (e.g., for electric steel production and steel recycling), carburising materials (e.g., for better qualities in the steel industry) or high-grade lubricants. In the future, the trend towards electromobility will become the main driver of demand for graphite, which dominates as an anode material in lithium-ion batteries. This affects both types of graphite, whereby natural graphite must first be processed to achieve the necessary qualities for use in batteries, while synthetic graphite can be used directly for battery production. With annual growth rates in demand from e-mobility of around 20%, batteries will be the most important application area for graphite in 2030.[28] Whether this will increase demand for natural or synthetic graphite faster depends on prices and battery technologies. Synthetic graphite is more expensive, but can be used directly. However, "high-energy" batteries may perform better with a higher share of natural graphite.[29] Many countries have extensive reserves of natural graphite. Nevertheless, supply risks can result from the fact that production is currently concentrated in only a few countries (USGS data for 2022: China 65% world market share, Mozambique 13%, Madagascar 8.5%, Brazil 7%). In the production of synthetic graphite, China is also in first place with a market share of over 50%, ahead of Japan and the US.[30] According to Baker Steel, there are few projects outside China to process

Figure 21: China has a large market share in the graphite production



Source : USGS

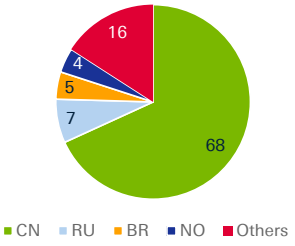
27 Cf. BGR (2022). Deutschland – Rohstoffsituation 2021.
28 Cf. DERA (2021): DERA Rohstoffinformationen. Rohstoffrisikobewertung – Graphit.
29 Cf. Baker Steel Capital Managers (2022). Graphit – Der Rohdiamant im Zentrum der Batterierevolution.
30 Cf. BGR (2022). Natürlicher und synthetischer Graphit. Rohstoffwirtschaftliche Steckbriefe.

graphite to produce grades for use in batteries. 95% of this processing currently takes place in China. High energy costs for graphite processing, the use of fossil fuels in China and working conditions in the mines pose price and ESG risks.

- **Silicon** is – apart from its importance for the semiconductor industry – particularly important for the global expansion of photovoltaics. According to DERA, photovoltaics accounted for just under 17% of global demand for silicon in 2020.[31] According to the IEA, the global installed capacity of photovoltaics will increase from just under 900 gigawatts (GW) in 2021 to at least 3,000 GW by 2030. A new area of application for silicon may arise in lithium-ion batteries. Here, silicon leads to a higher energy density when it is used as anode material instead of graphite. However, the production of these "high-energy" batteries is technologically demanding and not yet fully developed. The US company Amprius has announced that it will start manufacturing such batteries in 2025.[32] With an increasing market share in battery production, the demand for silicon would be additionally fuelled. To sum up, rising demand for silicon also coincides with currently highly concentrated production (market share of China in 2022 according to USGS: 68%, ahead of Russia with 7%). On the positive side, silicon (bound in various silicate rocks) is the second most common element in the earth's crust and the production of silicon could thus be diversified.
- **Rare earths** comprise a group of 17 metals that are needed not only for climate technologies but also for many other industrial products. In terms of quantity, rare earths play only a small role in the individual products compared to other raw materials. However, they are necessary for certain product properties and qualities and are difficult to substitute. Of the climate technologies, wind power is particularly dependent on rare earths. According to the IEA, global installed capacity for wind power will grow by 120% by 2030 and by more than 240% by 2040 (both yoy 2021), even in the most conservative scenario.[33] Demand for rare earths is expected to triple by 2040 in this conservative scenario. Higher growth rates are likely. As is well known, rare earths are actually not rare, but rather quite widespread in the earth's crust. The main supply risk is that, according to the IEA, China has a market share of 87% in the processing of rare earths (followed by Malaysia with 12%). In this respect, there are global supply dependencies on China.
- **Gallium** and germanium are current examples of metals where trade policy conflicts can affect security of supply. China announced in early July 2023 that companies wishing to export gallium and germanium products must apply for a licence to do so. Gallium and germanium are important for chip manufacturing, for example. China's decision is likely to be related to the fact that previously the US had restricted the export of high-performance chips to China. It remains to be seen whether the stronger export controls will actually lead to physical restrictions on exports from China.

Figure 22: China dominates global production of silicon

Shares in global silicon production, 2022, %



Source: USGS

Supply and price risks not limited to raw materials

We have so far focused on potential supply and price risks for commodities, which can result from rapid demand growth with supply-side risks (regional concentration, time needed to develop new deposits, higher ESG requirements). China in particular is the dominant supplier for raw material extraction and – even more so – for the further processing of raw materials. The high energy and water demand for the extraction of raw materials is also a risk that is likely to increase due

31 Cf. DERA (2022). Chart des Monats. April 2022.
32 Cf. elektroauto-news.net (2023). Amprius fertigt in Colorado Batterien mit Silizium-Anode.
33 Cf. IEA (2022). Word Energy Outlook 2022.

to climate policy and climate change (restriction of the use of fossil energies, intensification of regional water shortages). Russia is also an important player on the world market for many raw materials. The war in Ukraine thus poses considerable supply risks for deliveries from Russia.[34] The EU has not concluded a free trade agreement with China. The geopolitical tensions between China and the US as well as a readjustment of trade relations between the EU and China could therefore affect trade in commodities.

However, such risks are not limited to raw materials, but also apply to intermediate and end products for the production of which these raw materials are used in China, for example, and which are subsequently imported from there. For example, according to the IEA, the country is the largest producer of battery cell components and battery cells (world market share of around 75% each). In addition, China's share in the manufacturing stages in the photovoltaic sector is over 80%. Although Germany has some production facilities for solar modules or inverters, it imports solar technologies mainly from China. In 2022, China accounted for 87% of all German imports of photovoltaic systems, according to the Federal Statistical Office. We had already mentioned China's high shares in German imports of electric cars and lithium-ion batteries in Q1 2023.

Labour and skills shortages: No comprehensive solutions in sight in the short and medium term

The shortage of skilled workers in Germany has been a limiting factor for economic development for many years. It is noticeable in many sectors. This is shown, for example, in a current analysis by the Federal Employment Agency (BA), according to which there are bottlenecks in 200 out of 1,200 assessed occupational fields.[35] The shortage of skilled workers is also reflected in the number of vacancies in Germany, which stood at just under 740,000 in August 2023 (seasonally adjusted). Although this is a decrease of 112,000 compared to August 2022 – due to the weaker economic development – it is still a high number in a long-term comparison. While the BA only reports officially registered vacancies, the data of the Institute for Employment Research (IAB) is based on representative surveys of companies. This means that vacancies that are not reported to the BA are also included here. According to the IAB, the number of job vacancies in Germany in the second quarter of 2023 was just under 1.74 million, which is a decline from the peak of 1.98 million in the fourth quarter of 2023.

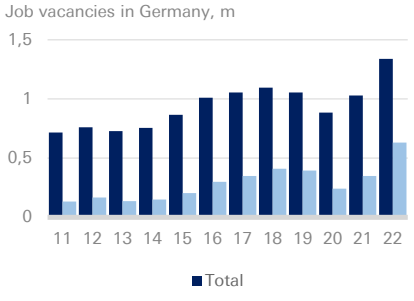
According to the latest DIHK business survey from early summer 2023, the shortage of skilled workers continues to be a major business risk for companies. This affected 53% of companies in trade, 62% in services, 63% in industry, and as many as 70% in construction. In industry this is an all-time high. Only the high energy and commodity prices were named more frequently as a major business risk across all sectors.

In many occupational fields, the shortages have been known for many years. Particularly worthy of mention are skilled workers in the health care sector, in childcare or among truck drivers. In addition, the energy and transport transition as well as digitalisation are also hampered by the persistent shortage of skilled

Figure 23: Number of job vacancies declining, but still at a high level

Source : Deutsche Bundesbank

Figure 24: Lack of skilled labour



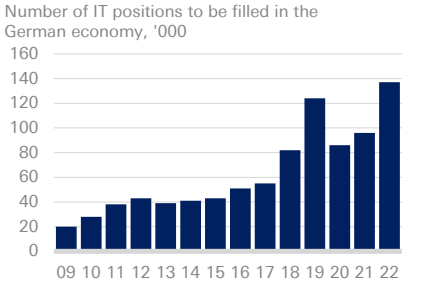
Source : KOFA

34 Cf. IW Cologne (2022). Rohstoffabhängigkeiten der deutschen Industrie von Russland. IW-Kurzbericht Nr. 31/2022.
35 Cf. Federal Employment Agency (2023). Fachkräfteengpassanalyse 2022.

workers:

- According to a study by the Centre of Competence for Securing Skilled Workers (Kompetenzzentrum Fachkräftesicherung, KOFA) from 2022, there is a skilled worker gap of more than 216,000 people for the wind and solar energy sector (annual average 2021/2022). Many of these vacancies cannot be filled because there are currently no unemployed people with the appropriate qualifications.[36]
- According to a joint press release by several industry and trade associations as well as IG Metall from 2022, there is a shortage of up to 190,000 skilled workers for energy-efficient building refurbishment.[37]
- The German Sanitation, Heating and Air Conditioning Association (Zentralverband Sanitär Heizung Klima, ZVSHK) states that the goal of installing around 6 million heat pumps in residential buildings in Germany by 2030 will result in an additional demand for 60,000 fitters.[38]
- The trade association Bitkom stated in a 2022 press release that there is a shortage of 137,000 IT professionals across all sectors.[39] This represents an increase of almost 43% compared to 2021.
- According to Deutsche Bahn, about half of the employees will leave the company by 2030, mainly due to age. At the same time, the company wants to double the number of passengers in long-distance transport and increase the share of rail in freight transport (transport volume) from 18% to 25%. The company therefore wants to hire 100,000 new employees in the next few years.[40] This is ambitious in view of the scarce labour supply.
- Shortages of skilled workers are not only noticeable in companies. Public administration is also increasingly affected. According to the Federal Statistical Office, 37% of employees in the housing, urban planning, regional planning and municipal community services sector were aged 55 or older in 2021. Most of these will leave public service over the next ten years due to age. Only just under 17% of the employees in this area of the administration (including the building authorities important for planning and approval) were under 35 years old in 2021. Thus, concerns about attracting enough young talent are inevitable, especially since the rather rigid remuneration system in the public sector is unlikely to be attractive to many talented people compared to earnings opportunities in the private sector. Bottlenecks in public administration are likely to lead even more frequently to delays in planning and approval procedures in the future, which are already a bottleneck factor today.

Figure 25: High demand for IT professionals



Source: Bitkom

Immigration helps, but only to a very limited extent in the short term – matching problems make it difficult to fill vacancies

The demographic development in Germany will lead to a declining labour force potential in the coming years, even with quite high net immigration. The demographic factor will therefore tend to exacerbate the shortage of skilled workers. Immigration is necessary to cushion the demographic burdens on the labour market in the coming years. However, the shortage of skilled workers often

36 Cf. KOFA (2022). Energie aus Wind und Sonne. Welche Fachkräfte brauchen wir?
37 Cf. IG Metall et al. (2022). Erfolgreiche Klimawende braucht leistungsfähiges Handwerk. Join press release.
38 Cf. ZVSHK (2022). Klimaschutz braucht Klimahandwerk. Fachkräfte gewinnen = Klimaziele erreichen.
39 Cf. Bitkom (2022). Trotz Krieg und Krisen: In Deutschland fehlen 137.000 IT-Fachkräfte. Press release. See also Bitkom (2022). Closing the Gap: Empfehlungen für einen zukunftsfähigen IT-Fachkräftestandort Deutschland. Position paper.
40 Cf. Deutsche Bahn (2023). Deutschland braucht eine starke Schiene.

concerns occupational profiles with special qualifications. There is unlikely to be a systematic surplus abroad. In addition, Germany competes with other countries for global talent. Language barriers (German as a less international language compared to English) and bureaucratic hurdles in the immigration of highly qualified people show that the influx of people with the desired qualifications to Germany is anything but a foregone conclusion. For rather unqualified immigrants to Germany (including refugees), language training and other education and training measures usually have to be taken first before they can be integrated into the labour market. This often takes several years and incurs costs. In order for immigration to help alleviate labour market bottlenecks, it would have to be managed in a more targeted way.

Better utilisation of the existing domestic labour potential could help to alleviate the shortage of skilled workers. However, there are also matching problems here in regional, sectoral and qualification terms. For example, it is likely that production capacity in energy-intensive sectors such as the chemical or metal industry will be structurally reduced, thus releasing workers with a time lag. However, these employees cannot easily be deployed directly in sectors where there is a shortage of skilled workers because the requirement profiles do not fit or because this would mean relocating the people concerned. Increased labour mobility and training measures would help to reduce matching problems.

Physical infrastructure: High investment needs meet financial and time restrictions

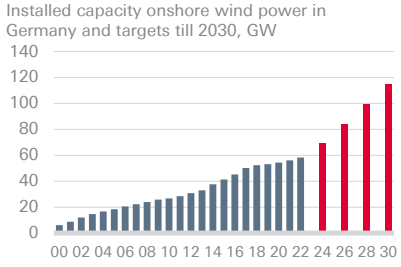
In order to achieve the energy, climate and transport policy goals, massive investments will have to be made in the physical infrastructure in the coming years. For example, by 2030, 80% of gross electricity generation in Germany is aimed to be based on renewable energies (2022: 44%). To achieve this goal, the German government has set significant expansion targets for renewables. In a report from the beginning of the year, we showed how ambitious these expansion targets are.[41] Some of the results are summarised here:

- The installed capacity of onshore wind energy is to increase to 115 gigawatts (GW) by 2030. This corresponds to an average addition of around 7 GW per year from 2023 to 2030, about 2 GW above the historical peak of 2017. In the area of photovoltaics, the government is aiming for an installed capacity of 215 GW by 2030. This corresponds to an average of 18.4 GW of gross capacity to be added annually between 2023 and 2030. The previous maximum of newly-installed PV capacity was 8.2 GW in 2012.
- The targets for offshore wind (30 GW by 2030 compared to 8 GW today), electric heat pumps (6 million by 2030 compared to 1.5 million today), electric cars (15 million by 2030 compared to 1 million today) or charging stations (1 million by 2030 compared to 80,000 at the beginning of 2023) are also very ambitious. Many bottlenecks are currently hindering a rapid ramp-up for the individual sub-segments, although the addition of photovoltaics has been quite dynamic so far in 2023 (+5 GW installed capacity in the first five months).

Expansion of H2-ready gas-fired power plants envisaged

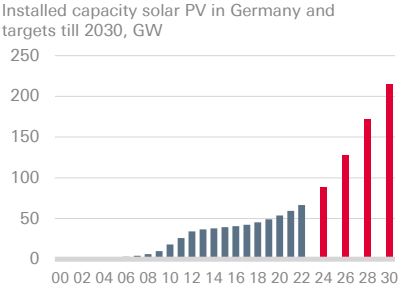
Germany aims to phase out coal-fired power generation (ideally by 2030). The last

Figure 26: Onshore wind power: Installed capacity to rise to 115 GW by 2030



Source : BMWK, Federal Network Agency

Figure 27: Solar PV: More than tripling of capacity by 2030 intended



Source : BMWK, Federal Network Agency

41 See Heymann, Eric and Marion Mühlberger (2023). Energy Transition Monitor #1 – what, when and how. Deutsche Bank Research. Germany Blog.

three nuclear power plants were taken off the grid in mid-April 2023. The federal government is counting on new hydrogen-capable gas-fired power plants to bridge those times when there is too little wind and/or the sun is not shining. Such power plants are also necessary to replace the secured installed generation capacity based on coal and nuclear energy (in mid-2022 this was 40 GW, which corresponds to about 50% of the peak load). It has been discussed that 25 GW of new gas-fired power plants are needed, which corresponds to about 50 power plant units.

There are currently no signs that enough new gas-fired power plants will be built. The Federal Network Agency only expects an additional secured electricity generation capacity of 3.3 GW by 2025. At the same time, electricity demand is expected to increase by at least 20% by 2030 compared to 2022 (more electric heat pumps, e-mobility, electrification of industrial processes, digitalisation, etc.). If the gap cannot be closed in the coming years, some of the coal-fired power plants are likely to run longer than until 2030 or remain in a kind of safety reserve. The basic problem is that no cost-effective electricity storage technologies on a large industrial scale are in sight (the potential for pumped storage power plants in Germany has been exhausted). Germany will therefore continue to rely on traditional backup power generation capacity, even if the average utilisation decreases with the addition of renewable power generation capacity.

Since hydrogen is to play a greater role in energy supply in the future, investments must also be made here. This includes electrolysers, the transport and distribution infrastructure for hydrogen as well as investments in those sectors in which hydrogen is to be used more in the future (e.g. steel industry). It is clear that most of the hydrogen to be used in Germany will have to be imported in the future. The BMBF lists projects in the field of green hydrogen that are being funded nationally and internationally.[42] Extensive investments will also have to be made abroad for this.

Massive expansion of the electricity grids necessary

In the course of the energy transition, the electricity grids in Germany must be upgraded. The generation centres for wind power are mainly located in the north of Germany. However, many large power consumers are located in the south. A draft strategy of the transmission grid operators from the end of March 2023 shows an investment requirement for the transmission grid of EUR 198 bn by 2037. In addition, the distribution grid must be physically expanded and more intelligently controlled, as decentralised electricity generation through renewables and decentralised electricity demand (e.g., heat pumps, charging stations) will increase in the future. In the absence of such measures, the distribution grid is likely to become a bottleneck regionally for the electrification of the heating market and the transport sector. In 2021, the Federal Network Agency had estimated the need for investment in the electricity distribution grid at EUR 47 bn by 2030. Since then, the figure is likely to have risen due to higher prices and requirements.[43]

Rail infrastructure remains bottleneck for the time being

In order for rail transport volume to increase as targeted in the coming years, the rail network and other infrastructure (e.g. terminals for freight transport) must be expanded. Deutsche Bahn itself says that currently about 5% of the network is

42 Cf. BMBF (2023). Green hydrogen: Grüner Wasserstoff: Welche nationalen Projekte fördert das BMBF? Further: BMBF (2023). Grüner Wasserstoff: Welche internationalen Projekte fördert das BMBF?
43 Cf. Heymann, Eric (2023). Costs of electricity generation: System costs matter. Deutsche Bank Research. Germany Monitor.

overloaded. This has an impact on 70% of long-distance passenger traffic.[44] However, the expansion of the network is by and large progressing slowly. The association "Die Güterbahnen" (The Freight Railways) noted in 2022 that only 67 kilometres of new railway lines were connected to the network in Germany during the last legislative period.[45] In addition, the association criticises the increase in planned funds for the new construction and expansion of the rail network in the federal budget as being not large enough.[46] At the same time, it is unclear whether significantly higher funds could also be fully used for sensible projects in the short term in view of long planning and approval procedures.

There is also fundamental criticism of the financing of the railways. New construction and expansion measures are largely financed by the federal government through so-called construction cost subsidies, which the network operator does not have to pay interest on or repay. If neither interest nor depreciation has to be earned when operating the network, there is a danger that the infrastructure may be driven to wear and tear.[47]

As is so often the case with infrastructure projects, the expansion of rail networks is often delayed by local citizen protests. There are many small-scale examples of this, but also a number of nationally relevant ones. One example is the Y route, which has since been rejected and was supposed to connect Hamburg and Bremen with Hanover. The alternatives to this route are only in the planning phase. Another example would be the Brenner North Access, which, among other things, is supposed to enable a greater shift of transalpine freight traffic to the railways. This project has also given rise to local resistance and is only likely to be finally realised once the Brenner Base Tunnel has already been opened.

Recommendations for action: More supply, more efficiency, more recycling

The extent of the actual and potential supply bottlenecks shows that policymakers and companies will have to take many measures to prevent supply shortages and reduce price risks. However, they will not be entirely avoidable. With regard to the supply of raw materials, three pillars are essential:

- When products are scarce, it is important to expand the supply. The first pillar of this is diversification in the countries from which raw materials or processed metals are sourced. We have shown that, globally, many raw materials are not scarce in the physical sense, but that extraction or processing are highly concentrated regionally. Trade and commodity partnerships with countries that can expand their production of critical raw materials should be intensified. An economic incentive could exist for these countries if they were to enter into further processing in addition to raw material extraction.
- In view of the extremely ambitious energy and climate policy goals in the EU and Germany, stronger domestic production of raw materials must not be a political and economic taboo as a second pillar. Europe and Germany are in large parts more densely populated than many regions in America,

44 Cf. Deutsche Bahn (2023). Deutschland braucht eine starke Schiene.
45 Cf. Die Güterbahnen (2022). Schienengipfel 2022 muss der Wendepunkt für klimafreundlichen Güterverkehr sein – Handout der Güterbahnen.
46 Cf. Die Güterbahnen (2023). Verkehrshaushalt: Wieder nicht der große Wurf für die Schiene.
47 Cf. Eisenkopf, Alexander (2023). Schieneninfrastruktur: wenig Mut zu radikalen Reformen. In: Wirtschaftsdienst 2023, Heft 5.

Africa, Asia, or Australia. However, it is difficult to argue that people prefer to import the urgently needed raw materials because they do not want to accept the negative ecological side effects of raw material extraction at home. Therefore, political courage is needed to explain the need for more domestic extraction. One disadvantage of stronger domestic raw material extraction is that it is more expensive (not least because of higher energy costs in Germany and Europe) than in many developing and emerging countries. While higher costs are negative, security of supply would improve. However, a 100% self-sufficiency of Europe and Germany with domestic raw materials and processed metals is not in sight anyway. Therefore, the first pillar is clearly more important.

- The third pillar concerns the efficiency of raw material use in extraction (efficient mining machinery), during the production process (e.g., minimising waste), in the finished product (e.g., lightweight construction, substitution between materials depending on scarcity) and at the end of the product life cycle. Especially the strengthening of the circular economy and the technical progress of recycling technologies should improve the security of supply.

In addition to these three pillars, it seems sensible to examine whether a larger national reserve stock should be organised for certain raw materials. This could serve to stabilise value chains in the event of supply shortfalls of particularly critical raw materials or to avoid production stoppages. Our colleagues from the corporate bank have fleshed out the idea of how a "strategic raw materials reserve" could be structured.[48]

Use of artificial intelligence should mitigate bottlenecks

To improve security of supply, it is important to identify, develop and ultimately exploit the opportunities that result from the use of artificial intelligence (AI) and other digital technologies. They can provide better results in the exploration and development of raw material deposits, in the efficiency of resource use, in the management of supply routes and warehousing, the optimal distribution of the raw materials required, recycling or the replacement of skilled workers.

EU Critical Raw Materials Act and national raw materials strategy address the problems

Politicians at national and European level have recognised the problem and are endeavouring to take precautions. The EU's Critical Raw Materials Act is an example of this.[49] The three pillars are reflected in it. It stipulates that from 2030 onwards "not more than 65% of the EU's annual consumption of each strategic raw material at any relevant stage of processing [may come] from a single third country". In addition, by 2030, 10% of annual demand is to be secured through extraction in the EU, 40% through processing in the EU and 15% through recycling. It is debatable how meaningful such concrete quotas are, especially since the processing of raw materials is also to be strengthened in partner countries. Nevertheless, the fundamental goal of greater diversification and autonomy is to be welcomed.

The Federal Government is also working on expanding and adapting the national

48 Cf. Deutsche Bank AG (2023). Energie- und Rohstoffsicherheit in Einklang bringen. Schlüssel für eine erfolgreiche Transformation des Wirtschaftsstandorts Deutschland.
49 For an overview, see EU Commission Factsheet (2023). European regulation on critical raw materials.

raw materials strategy,[50] which was already presented at the beginning of 2020. At the beginning of 2023, the BMWK presented a key issues paper on raw materials supply.[51] Here, three priorities are set: (1) circular economy, resource efficiency and recycling, (2) diversification of raw material supply chains, and (3) ensuring a fair and sustainable market framework. In this respect, the German government emphasises ESG standards in raw material extraction, which is also becoming more important from our point of view, as we have pointed out in the discussion of individual raw materials.

The bottom line regarding the future supply of raw materials is that first of all, a great deal of responsibility lies with politicians to conclude trade agreements with potential supplier countries. After that, the responsibility lies primarily with companies to secure their own concrete raw material needs through contracts with raw material and trading companies.

Shortage of skilled workers and infrastructure development: Well-known measures only have an effect with a time lag

A lot of measures have been propagated for many years in the fight against the shortage of skilled workers. These include better early childhood, school and university education as well as a lower dropout rate, especially in school education. According to the Bertelsmann Foundation, for years about 6% of a cohort have left school without a diploma.[52] Furthermore, the advanced training of employed people and career jumpers must be strengthened in order to address matching problems in the labour market. A further increase in labour force participation, e.g., of women or older people, would also help to fill vacancies. In terms of immigration, a focus on skilled workers is needed to relieve the German labour market. In the skilled trades, attempts are being made to increase attractiveness with image campaigns. In view of the shortage, however, higher wages in certain craft areas would be more effective. In any case, it is to be expected that wages in particularly sought-after craft occupations will rise faster than the average for all occupations.

With regard to the expansion of physical infrastructure, faster planning and approval procedures have been on the list of demands for years. How quickly and whether the "new Germany speed" proclaimed by Chancellor Scholz can be achieved remains to be seen. The construction of floating LNG terminals to cope with the acute energy crisis of 2022 took place very quickly. However, delays in infrastructure projects are expected to remain the order of the day for some time.

A permanently higher allocation of public budgets for infrastructure investments would increase the willingness of the implementing sectors (e.g., construction industry and building trades) to increase capacity accordingly, although this is not trivial in view of the shortage of skilled labour in the sectors concerned. However, short-term and temporary government investment programmes – for example to support the economy – tend to lead to rising prices and not to an adjustment of capacity. In any case, construction prices have risen sharply in recent years. For example, the construction price index for road construction in Q2 2023 was almost 30% higher than in Q2 2021. Ultimately, it comes down to political prioritisation of tasks: If more funds are made available for consumption purposes and the national

50 Cf. BMWi (2020). Raw materials strategy of the Federal Government. Securing a sustainable supply of non-energy mineral raw materials for Germany.
51 Cf. BMWK (2023). Eckpunktepapier: Wege zu einer nachhaltigen und resilienten Rohstoffversorgung.
52 Cf. Bertelsmann-Stiftung (2023). Anteil der Jugendlichen ohne Schulabschluss seit zehn Jahren auf hohem Niveau.

debt is not to rise, fewer funds remain – relatively speaking – for investment purposes. Although this correlation is generally known, politicians have found it difficult for decades to make a substantial shift away from consumptive to investment spending. According to the Federal Ministry of Finance, the social benefit ratio (share of social expenditure in total federal budget expenditure) was 50% in 2022; it is likely to remain high in the medium term.

The possible measures mentioned are not new. Politicians also regularly declare their commitment to more spending on education, better managed immigration or higher investment in infrastructure. However, the reality shows a divergence between announcement and implementation or at least a significant time lag between implemented measures and a noticeable impact. In this respect, quick and serious improvements in the areas of skilled labour and infrastructure development are not to be expected at present.

Final remarks: Risk of status quo bias, but growth and inflation negatively affected

As we stated at the beginning of the report, the last few years have been marked by supply chain disruptions on an historic scale. This imprint carries the risk that the judgement of future development is distorted by a status quo bias. So it may be that we are overestimating the danger of structural supply bottlenecks because we underestimate the steering effect of price signals or the innovative power of people or do not trust "politics" enough to quickly improve the framework conditions, e.g., for a secure supply of raw materials. After all, times of crisis can be the seedbed for innovation. When the Club of Rome proclaimed the "limits to growth" a good 50 years ago, such a status quo bias influenced the view of the future. Ultimately, technical progress, which pushed back the limits to growth, was misjudged at the time. However, the status quo bias is contrasted by a certain availability bias, which refers to possible future scarcities that we do not (or cannot) recognise today.

All in all, technical progress remains the main source of hope for the coming years, which can enable climate-friendly economic growth with a social balance. In view of the (potential) structural supply bottlenecks described in this report, however, technical progress would have to accelerate on a broad front and probably be promoted much more strongly by politics than has been the case so far. However, we consider this unlikely, especially since it is unclear with which instruments policy-makers should succeed in significantly boosting technical progress in a fairly foreseeable period of time.

Given the many unknowns, it is difficult to quantify the impact of structural supply constraints on trend growth and inflation. However, in our view they should contribute to potential growth in Germany being closer to the 0.5% than the 1% mark in the coming years and to inflation being above rather than below the 2% target.

We would like to thank Christoph Tauscher-Köstler for his valuable contribution.

Appendix 1

Important Disclosures

*Other information available upon request

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