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- Global challenges like water scarcity and water pollution are also becoming increasingly prevalent in Germany
- One major problem is nutrient pollution from agriculture, which increases the drinking water supply cost
- Expanding organic farming can contribute to reducing nitrate pollution



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- Economic policymakers and companies recognize the need for action, but swift implementation of measures is needed, ideally on a European level

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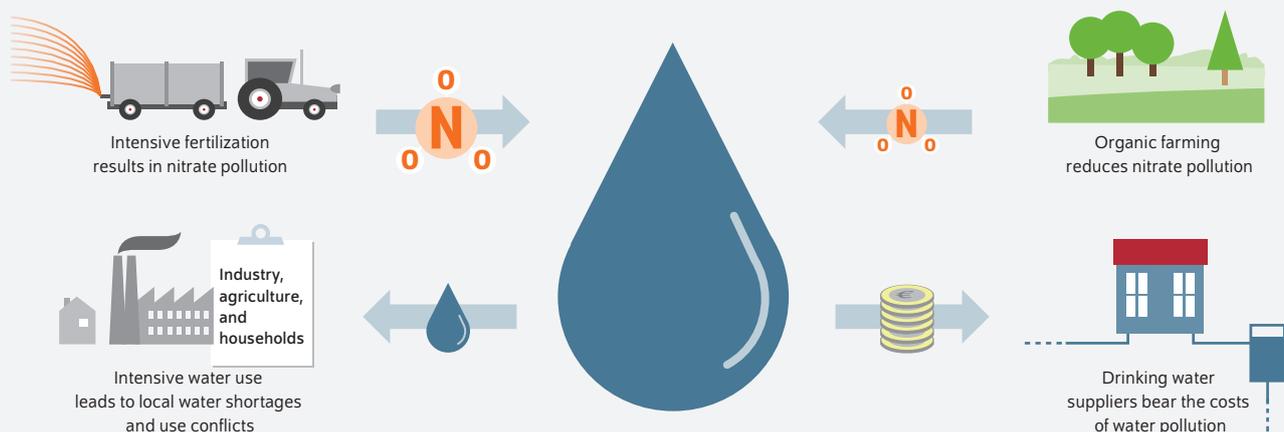
AT A GLANCE

Water resources in Germany: Increasingly polluted and regionally overused

By Astrid Cullmann, Greta Sundermann, Nicole Wagner, Christian von Hirschhausen, and Claudia Kemfert

- Global challenges like water scarcity and water pollution are also becoming increasingly prevalent in Germany
- One major problem is nutrient pollution from agriculture, which increases the drinking water supply cost
- Expanding organic farming can contribute to reducing nitrate pollution
- Sanitary innovations can help improve water quality
- More transparency in the distribution and pricing of water abstraction is also important

Water treatment costs rise due to nitrate pollution: Organic farming can reduce nitrate pollution—intensive fertilization leads to nitrate pollution



Source: Authors' depiction.

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FROM THE AUTHORS

“Even here in Germany, water resources are coming under increasing pressure. In particular, groundwater nitrate pollution due to intensive agricultural fertilization results in high ecological and social costs and drives up drinking water treatment costs.”

— Astrid Cullmann —

MEDIA



Audio Interview with Astrid Cullmann (in German)
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Water resources in Germany: Increasingly polluted and regionally overused

By Astrid Cullmann, Greta Sundermann, Nicole Wagner, Christian von Hirschhausen, and Claudia Kemfert

ABSTRACT

The effects of the climate crisis are worsening water shortages, not only in the Global South but also in Europe, for example in the Berlin-Brandenburg region. Due to inadequate pricing of surface and groundwater abstraction and a lack of regulatory instruments, water overuse is occurring in some regions of Germany. Overuse is especially an issue for industry, which has contractually secured high volumes of water withdrawals at very low cost. In addition, there is extensive water pollution as a result of contaminants released into water bodies by households, industry, sewage treatment plants, and agriculture, which further reduces the clean water supply. In particular, nitrate pollution due to intensive fertilization in agriculture is an increasing problem. As a consequence, households and businesses must bear the additional costs, for example due to increasing costs for drinking water treatment. Organic farming can improve water quality; sanitary innovations such as urine-diverting dry toilets (UDDTs) can also contribute. This Weekly Report summarizes current research results and contributes to the German National Water Strategy, a series of measures to be taken by 2030 to address the inter-generational challenges of water management.

Water is vital to human existence, an integral part of the ecosystem and cultural landscapes, and serves as a habitat for a variety of plants and animals. Access to clean water was recognized as a human right by the United Nations in 2010.¹ Water is also indispensable to industry, agriculture, and the energy sector. Careful management, effective conservation, and sustainable use of water are key prerequisites for preserving biodiversity and protecting ecosystems.² Clean water and sanitation are integral parts of sustainable development and universal access to both is one of the 17 UN Sustainable Development Goals (SDGs) to be achieved by 2030. This SDG is closely connected with other sustainability goals, especially those relating to health, education, the economy, and the environment.³

The climate crisis will further deplete global water resources.⁴ The issue of water scarcity is reinforced by water pollution stemming from increasing urbanization, industrialization, and intensive agriculture—globally and also in Germany. Given these challenges, the subject of water, and water pollution in particular, receives surprisingly little attention in economic research, especially when compared to air pollution.⁵ Opinion polls confirm that the general population is concerned about water shortages: A survey from the Center for Responsible Research and Innovation at Fraunhofer IAO reveals a pronounced awareness of the problem among

¹ United Nations, *Resolution adopted by the General Assembly on 28 July 2010* (available online; accessed on November 20, 2022. This applies to all other online sources in this report unless stated otherwise).

² Markus Siehlow, Georg Meran, and Christian von Hirschhausen, *Water: Economics and Management of a Key Resource* (Berlin: German Institute for Economic Research, 2012).

³ United Nations, *The 17 Sustainable Development Goals* (United Nations Department of Economics and Social Affairs, 2015) (available online).

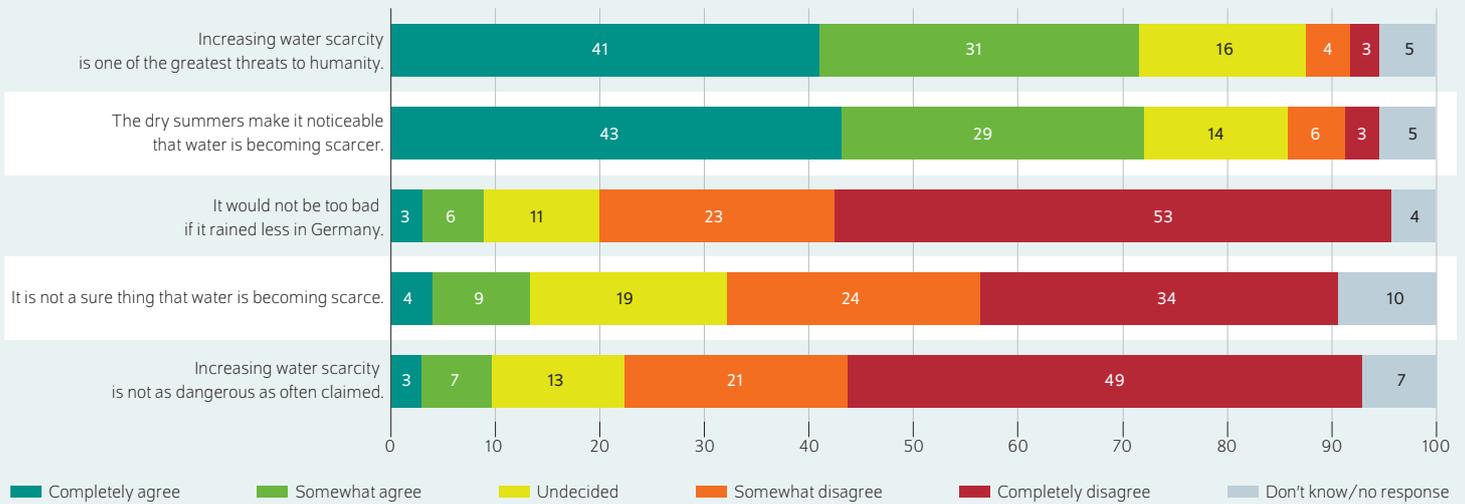
⁴ Water scarcity and water pollution are worsened by climate change. This is due, for example, to higher water temperatures, melting glaciers, the intensification of the hydrological cycle, and an increase in floods and droughts. Water scarcity and water pollution, conversely, affect climate change: For example, human nutrient accumulation in lakes leads to methane emissions, cf. John A. Downing et al., "Protecting local water quality has global benefits," *Nature Communications* 1, no. 12 (2021): 2709 (available online).

⁵ Cf. David A. Keiser and Joseph S. Shapiro, "US Water Pollution Regulation over the Past Half Century: Burning Waters to Crystal Springs?" *Journal of Economic Perspectives* 33, no. 4 (2019): 51–75.

Figure 1

Awareness of the water scarcity issue in Germany

Agreement in percent



Note: The figure depicts to what extent the respondents agree with statements about water scarcity in Germany. The evaluation scale has six categories ranging from "completely agree" to "completely disagree" and also has a "no response" option. From August 4 to 9, 2022, 2,046 respondents were surveyed via the YouGov platform.

Source: Representative survey from the Center for Responsible Research and Innovation at Fraunhofer IAO.

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The majority of the respondents view water scarcity and droughts in Germany to be a problem.

German residents (Figure 1),⁶ Surveys conducted in other countries, such as the USA, also show that water pollution is one of the top environmental concerns.⁷

Germany has extensive water resources. However, due to a lack of incentives for efficient use of water, there have been local shortages in recent years. In addition, there is nationwide pollution of surface and groundwater bodies by nutrients such as nitrate and phosphorus as well as various other substances, which endangers the ecological status of the water bodies. Moreover, it makes the treatment of drinking water complex and expensive.

Moreover, nutrients in wastewater remain largely unused. Through effective nutrient recovery using productive sanitation systems, human excreta can be processed into fertilizer, closing material cycles in a regional, climate-friendly, and safe way.

Within the context of political efforts in Germany—such as the 2050 National Water Strategy, which envisions fundamental changes in how water is handled to achieve sustainable water management—current research findings on the causes and effects of water pollution are discussed below and proposed solutions are outlined (Box 1).

Water shortages in Brandenburg

Water use conflicts—between households’ drinking water supply, industrial and commercial use, and agricultural irrigation—have so far been limited to water-scarce regions of the world. However, with climate change and increasing average temperatures and heatwave frequency, these conflicts become more relevant in Germany.⁸ Questions of water distribution are predominantly dealt with administratively: For example, the amount of water new customers may obtain is capped and watering open spaces during the summer months is prohibited.⁹ In contrast, industrial users mostly secure their water via long-term contracts covering high withdrawal volumes at low prices.¹⁰ For example, the chemical company BASF in Schwarzeide, Brandenburg, extracts 3.3 million cubic meters of water per year.¹¹ In Grünheide,

⁸ Government agencies, agriculture, and industry are fighting more and more often over water in court. One sample shows that the number of legal conflicts has drastically risen in 11 of 16 federal states over the past ten years. For example, the number of lawsuits in Bavaria increased by nearly 50 percent, cf. Correctiv, *Ausgetrocknet – Deutschland kämpft um Wasser*. Correctiv *Recherchen für die Gesellschaft* (2022) (in German; available online).

⁹ Cf. Wasserverband Strausberg-Erkner, *Amtsblatt* no. 3, vol. 4 (2021) (in German; available online).

¹⁰ According to the Federal Water Act, industrial abstraction requires a permit or authorization, with more extensive regulations set forth in state water laws and state ordinances. Permission is granted by the relevant local authorities, usually on a first come, first served basis, cf. Alexandra Lux, "Handelbare Wasserentnahmerechte als Ergänzung der ordnungsrechtlichen Vergabepolitik?" *netWORKS – Papers* (Deutsches Institut für Urbanistik: 2005) (in German; available online).

¹¹ BASF Schwarzeide GmbH, *Umwelterklärung – Daten und Fakten 2021* (2022) (in German; available online).

⁶ Cf. Hannah Bergmann, *Akzeptanzbefragung zu Trockentoiletten in Deutschland im Rahmen des BMBF-geförderten Projekts zirkulierBAR* (2022) (in German).

⁷ Cf. Keiser and Shapiro, "US Water Pollution Regulation over the Past Half Century."

Box 1

National Water Strategy

The Federal Ministry for Environment, Nature Conservation, and Nuclear Safety (*Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz*, BMUV) presented a draft of its National Water Strategy in June 2021.¹ This draft discusses water management challenges and creates an action program for a joint transition to sustainable water management by 2050. The National Water Strategy aims to ensure that sufficient high-quality and affordable drinking water will continue to be available at all times everywhere in Germany in 30 years, that bodies of water (groundwater, lakes, streams, rivers, and seas) become cleaner, that further overexploitation and overloading of water resources will be avoided, that wastewater disposal will continue to function excellently, that the costs will be causally and equitably distributed, and that water management and users will adapt to the consequences of the climate crisis and the changes in demographics.

The National Water Strategy sets targets and measures to be gradually taken by 2030. It focuses on ten strategic points: 1) Raising awareness of water as a resource; 2) Working together to conserve global water resources in a sustainable manner; 3) Conserving, restoring, and permanently safeguarding the near-natural water supply, preventing conflicting objectives; 4) Implementing water agreements and land use in rural and urban areas adapted to climate change; 5) Further developing sustainable water management; 6) Limiting risks from substance inputs; 7) Further developing water infrastructure; 8) Linking water, energy, and substance cycles; 9) Strengthening efficient administration, improving data flows, optimizing regulatory frameworks, and securing funding; 10) Protecting marine areas [North Sea and Baltic Sea] more intensively against substance inputs from land.

This Weekly Report mainly focuses on points 1, 3, 6, 8, and 9.

¹ Cf. BMUV, *Nationale Wasserstrategie* (Bonn: 2021) (in German; available online).

Brandenburg, Tesla applied for extraction of nearly 3.8 million cubic meters per year.¹² The LEAG open-cast lignite mine in Jänschwalde, Brandenburg, required over 100 million cubic meters of groundwater per year, of which only 42 million were officially approved.¹³ This high water con-

¹² Following a lawsuit filed by environmental associations, the permit to increase extraction volumes from 1.3 to 3.8 million cubic meters, which had been approved by the *Landesamt für Umwelt Brandenburg* in 2020, was rejected by the Frankfurt/Oder Administrative Court in 2022, cf. *Verwaltungsgericht Frankfurt/Oder, Urteil vom 04.03.2022 – VG 5 K 469/21* (2022) (in German; available online).

¹³ Since 2017, LEAG has extracted around 240 million cubic meters more groundwater than legally permitted. As a result of an urgent application by *Deutsche Umwelthilfe* and the *Grüne Liga*, the open-cast mine was shut down in May 2022, cf. *Verwaltungsgericht Cottbus, Entscheidung 3 L 381/21* (2022) (in German; available online).

sumption places an additional burden on the hydrological system: Intensive use of groundwater resources coupled with low groundwater recharge leads to falling groundwater levels. For example, the average groundwater level in the state of Brandenburg has decreased by a half meter since the 1970s (Figure 2). This will further intensify local water shortages of some regions in Brandenburg, and thereby endanger the regional drinking water supply.¹⁴

It is already apparent today that the needs of industry are being met preferentially and at the expense of citizens. This is facilitated not only by a lack of transparency and oversight in water extraction but also arbitrary pricing. As of 2022, water abstraction fees are only levied in 13 of 16 federal states. In the states that do levy fees, there are many exceptions. Mining and agriculture are frequently exempted, for example. In Berlin, Hamburg, and the Saarland, fees are only levied on groundwater extraction, not surface water extraction. Some federal states earmark the collected funds for water conservation measures, while others do not. Overall, prices for extraction vary widely between the federal states. For example, prices for agricultural water extraction range between 0.5 and 31 cents per cubic meter and between 6 and 31 cents per cubic meter for mining.¹⁵

Water pollution amplifies the problems

Water pollution is a serious, multi-faceted problem that leads to a scarcity of available clean water. It originates from a wide variety of substances (nutrients such as nitrate and phosphorus, trace substances like pesticides and pharmaceutical residues, and pathogens or heavy metals) from different sources such as agriculture, industry, or urban settlements. This results in surface and groundwater pollution, with groundwater pollution usually being irreversible and endangering drinking water supplies. In high-income industrialized economies, water pollution from trace substances and nutrients from fertilizers and wastewater treatment plant discharges poses the biggest problem.¹⁶

Agriculture is the main driver of nitrogen emissions

Intensive agriculture is usually the main source of these nutrient inputs, which enter the environment via the use of nitrogen fertilizers on agricultural land. Due to overfertilization, i.e., supplying plants with more nutrients than they need, nitrogen accumulates in the soil. There it undergoes biochemical processes that transform it into nitrate, which

¹⁴ In Germany, over 70 percent of drinking water comes from groundwater, cf. UBA, *Grundwasser: Nutzung und Belastung* (2022) (in German; available online).

¹⁵ Cf. BUND, *Die Wasserentnahme der Länder. Kurzgutachten* (Bund für Umwelt und Naturschutz Deutschland e.V.: 2019) (in German; available online).

¹⁶ Cf. European Commission, *Report from the Commission to the Council and the European Parliament on the implementation of Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources based on Member State reports for the period 2016–2019* (2021) (available online); cf. Bijay-Singh and Eric Craswell, "Fertilizers and nitrate pollution of surface and ground water: an increasingly pervasive global problem," *SN Applied Sciences* 3, no. 518 (2021).

is then washed out by rain or seeps into the ground, thereby polluting ground- and surface waters. The process is additionally amplified by a years-long practice of using purely synthetic mineral fertilizer and poor humus management that results in agricultural soils being less able to retain water and nutrients. In Germany, nitrate pollution in many groundwater bodies exceeds the EU limit value of 50 milligrams per liter, in some cases even by over 700 percent.¹⁷ In the past, these limit exceedances, in combination with insufficient countermeasures, led to an infringement proceeding against Germany by the European Commission.¹⁸ In the short term, the EU threatened fines in the millions of euros, which were ultimately avoided by repeatedly revising the fertilizer ordinance and designating nitrate-vulnerable and eutrophic areas.¹⁹ However, the most recent figures from the 2021 nitrate report show that the groundwater quality has not improved.²⁰ Nitrate pollution has a far-reaching impact on biodiversity (through water eutrophication, for example), the climate (due to increasing greenhouse gas emissions via eutrophication, for example), and human health (such as diseases caused by methemoglobinemia).²¹ Thus, nitrate pollution is associated with significant ecological and social costs, which have either not or only partially been empirically quantified.²²

High nitrate levels increase drinking water costs

The high nitrate levels in groundwater do not only have negative environmental effects, but also impact the cost of drinking water treatment. Drinking water companies must take measures to maintain the nitrate concentration in drinking water²³ in accordance with legal requirements to avoid damaging consumer health. For this purpose, they blend polluted and unpolluted raw water, relocate wells to deeper or less polluted groundwater bodies, and carry out technical separation processes or biological denitrification.²⁴ These

¹⁷ Cf. Greta Sundermann et al., "Nitrate Pollution of Groundwater Long Exceeding Trigger Value: Fertilization Practices Require More Transparency and Oversight," *DIW Weekly Report*, no. 8/9 (2020): 61-72 (available online).

¹⁸ Cf. Ruling of the European Court of Justice (Ninth Chamber) of June 21, 2018 (available online).

¹⁹ Eutrophic areas are surface waters with high nutrient levels that excessively stimulate the growth of algae and other aquatic plants. Cf. Bundesrat, *Verordnung zur Änderung der Düngerverordnung und anderer Vorschriften*, Drucksache 98/20 (2020) (in German; available online) and Bundesrat, *Allgemeine Verwaltungsvorschrift zur Ausweisung von mit Nitrat belasteten und eutrophierten Gebieten*, Drucksache 275/22 (2022) (in German; available online).

²⁰ Cf. Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit and the Bundesministerium für Ernährung und Landwirtschaft, *Nitratbericht 2020* (Berlin: 2020) (in German; available online).

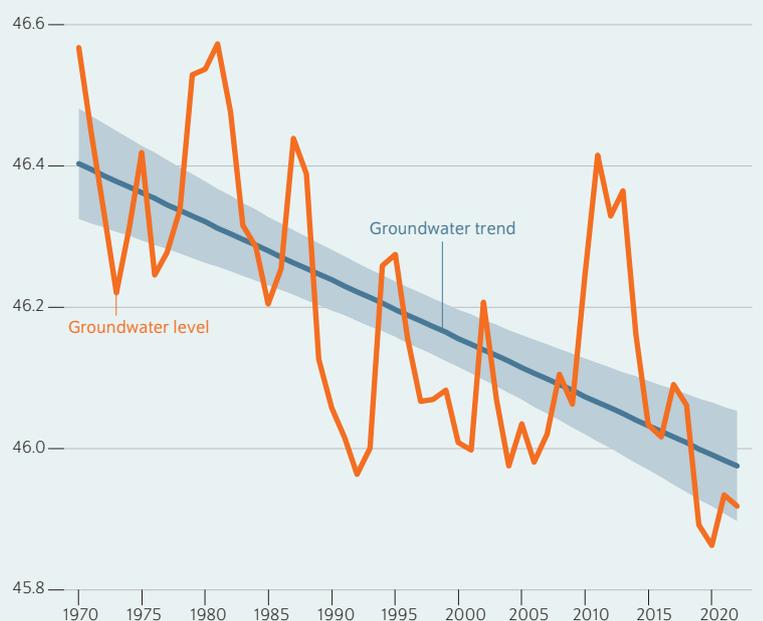
²¹ The danger posed to humans results from nitrate in food or in the human body. Nitrate can be converted to nitrite during digestion by bacteria or enzymatic processes, which inhibits the transport of oxygen in the blood, cf. Sundermann et al., "Nitrate pollution of groundwater long exceeding trigger value."

²² Alexandra Evans, "Agricultural water pollution: Key knowledge gaps and research needs," *Current Opinion in Environmental Sustainability* 36 (2018): 20–27.

²³ The nitrate trigger value for drinking water was set in the *Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption* (available online) and the *Ordinance on the Quality of Water Intended for Human Consumption (Trinkwasserverordnung)* (in German; available online).

²⁴ Separation processes make it possible to separate nitrate and water. German drinking water suppliers use the CARIX process or reverse osmosis for this purpose. Denitrification is a microbiological process that separates nitrate from water and decomposes it to gaseous nitrogen.

Figure 2
Annual groundwater levels of selected groundwater monitoring wells in Brandenburg from 1970 to 2022
 In meters above standard elevation zero



Note: The figure represents the average annual groundwater levels in Brandenburg. The annual averages are based on individual measurements at 244 groundwater monitoring wells that have had at least one reading per year since 1970, i.e., have been observed continuously over the years. To calculate the linear trend (blue), the annual groundwater levels were regressed on time in years. The shaded area shows the 95 percent confidence interval of the linear regression.

Source: Authors' calculations based on data from the Landesamt für Umwelt Brandenburg.

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Groundwater levels in Brandenburg have been decreasing since 1970.

measures lead to cost increases, for example due to higher energy or procurement costs for operating supplies. Using new data on drinking water companies and nitrate pollution, empirical analyses at DIW Berlin demonstrate the cost-driving effect of nitrate pollution in the drinking water sector (Box 2). According to estimates, a 10 milligram per liter increase in nitrate pollution increases overall costs by nearly 110,000 euros per year for the average drinking water company with around 50,000 customers.²⁵ These additional costs are potentially passed on to consumers in the form of higher water prices, such that consumers carry the cost of agricultural overfertilization.

Organic farming could reduce the nitrate problem

To reduce nitrate pollution in ground and surface waters, the nitrogen surpluses from agricultural fertilization must be reduced in the long term. Organic farming, which uses

²⁵ Cf. Greta Sundermann, Nicole Wägner, and Astrid Cullmann, "Organic farming, water quality, and drinking water supply cost – an empirical analysis for Germany," (lecture, International Interdisciplinary Conference on Land Use and Water Quality, Maastricht, 2022).

Box 2

Econometric estimation of the influence of groundwater nitrate concentrations on the costs of drinking water supply

The relationship between groundwater nitrate contamination and total costs of drinking water companies was examined using multivariate regressions. The analysis uses company data from the Federal and State Statistical Offices of Germany as well as data from the German Environment Agency's nitrate monitoring network covering 2008 to 2016. In addition, control variables were derived from the regional statistics of the Federal Statistical Office. Descriptive statistics on the variables used are presented in Table 1.

The effect of average nitrate levels at the locations of companies' water abstraction sites was estimated using a total cost model based on microeconomic theory. The company's total costs were the dependent variable (Table 2), while input prices (labor and capital), output quantities (total volume of drinking water sup-

plied, number of residents served), nitrate concentration, and other control variables (share of groundwater abstraction, share of water supplied to private households, population density of the water company's supply area) were considered explanatory variables. All variables have been logarithmized, such that the point estimates represent percentage changes. In addition, company-specific dummy variables controlled for unobserved, time-invariant effects.

Table 1

Descriptive statistics on drinking water companies and groundwater nitrate concentrations
Annual average per drinking water company analyzed

	Average
Total costs [1,000 euros]	16,794.28
Total water abstraction [1,000 m ³]	3,052.09
Water purchases [1,000 m ³]	567.16
Volume of drinking water delivered [1,000 m ³]	3,619.25
Number of residents supplied	53,415.56
Share of groundwater of water abstracted in percent	73.25
Population density [inhabitants/km ²]	352.16
Nitrate concentration in raw water [mg/l]	29.48

Note: The observation units are 342 drinking water companies that abstract and treat groundwater. The data cover the years 2008 to 2016.

Source: Authors' calculations using data from the German Environment Agency, regional statistics from the Federal and State Statistical Offices, and the Research Data Center of the Federal and State Statistical Offices.

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Table 2

Effects of various influencing factors on total cost of drinking water supply

Percentage change in total costs of drinking water companies given a one-percent change of variables

Independent variables	Change in percent
Nitrate concentration in raw water	0.018*
Contract price per hour	0.733***
Quantity of drinking water delivered	0.840***
Number of residents supplied	0.236
Share of groundwater of water abstracted	0.040
Share of household customers of total customers	-0.024
Population density of the municipalities supplied	-0.058
Number of observations	1,846
Number of companies	342

Note: Results are based on a multivariate regression accounting for company and year fixed effects and estimated by the ordinary least squares (OLS) method. The observation units are drinking water companies that extract and treat groundwater. Data cover the years 2008 to 2016. Standard errors are clustered at the company level. Asterisks denote the significance level, which indicates the statistical precision of the estimate. The more asterisks, the lower the probability of error: ***, **, and * indicate significance at the one-, five-, and ten-percent levels, respectively.

Legend: A one-percent increase in nitrate pollution results in a 0.02-percent increase in the total costs.

Source: Authors' calculations using data from the German Environment Agency, regional statistics from the Federal and State Statistical Offices, and the research data center at the Federal and State Statistical Offices.

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a sustainable farming system, can contribute to this reduction.²⁶ Unlike other methods of farming, especially conventional ones, organic farms must achieve as closed an operational nutrient cycle as possible, increase or maintain soil fertility, and adhere to proper welfare conditions for farm

animals.²⁷ Thus, organic farming must fulfill higher standards for environmental protection and animal welfare. They are not allowed to use synthetic pesticides or mineral fertilizers, for example, and livestock farming is restricted and space dependent. Several field studies indicate that organic farming systems could reduce nitrogen leaching by up to 64 percent.²⁸ Less nitrogen leaching could reduce the nitrate

²⁶ According to the European Green Deal, organic farming systems in particular are of crucial importance for the transition to sustainable agriculture, cf. European Parliament, "European Parliament resolution of 15 January 2020 on the European Green Deal," *Official Journal of the European Union* C270/2 (2020): 2–20 (available online). As part of its Farm to Fork Strategy, the EU aims to expand organic farming land to 25 percent by 2030, cf. European Commission, *Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system* (2020) (available online); European Parliament and the Council of the European Union, Regulation (EU) 2018/848 of the European Parliament and of the Council of 30 May 2018 on organic production and labelling of organic products and repealing Council Regulation (EC) No 834/2007 (2018) (available online).

²⁷ Cf. Bundesministerium für Ernährung und Landwirtschaft (BMEL), *Ökologischer Landbau in Deutschland* (Bonn: 2022) (in German; available online).

²⁸ Christian Schader, Matthias Stolze, and Andreas Gattinger, "Environmental performance of organic farming," in *Green Technologies in Food Production and Processing*, eds. Joyce I. Boye and Yves Arcand (Springer: 2012): 183-210. Various studies show that both nitrogen input intensities and nitrate leaching per unit area are generally lower in organic farming than in conventional farming, but this effect does not necessarily apply to nitrogen leaching per unit product, cf.

Box 3

Econometric estimation of the impact of organic farming on groundwater nitrate concentrations

The impact of organic farming on groundwater nitrate concentrations was estimated using regional data and location-specific nitrate measurements for 2008 to 2018 (Table). Annual averages of nitrate concentrations at groundwater monitoring sites, provided by the German Environment Agency, were used as the dependent variable. The explanatory variable is the share of organically farmed agricultural land (relative to total utilized agricultural area) in the county where the monitoring site is located; the data on organic farming were taken from the regional statistics of the Federal and State Statistical Offices. The relationship was estimated using an autoregressive regression model. It was assumed that the nitrate concentration of the observation year depends not only on the share of organically farmed land, but also on the nitrate concentration of the previous year, as the process of nitrate formation is relatively persistent over time. In addition, a number of other influencing factors were controlled for, such as high mineral fertilizer use (> 100 kilograms per hectare), land use in the vicinity of the monitoring site (shares of agricultural, viticultural, orchard, grassland, and forest land within a 500-meter radius of the monitoring site), and weather influences, which were pooled from various sources (regional statistics from the Federal and State Statistical Offices, CORINE Land Cover Database, German Weather Service).¹ In addition, fixed effects were used to control for hydrogeologic features at the monitoring site that were invariant over time and for year-specific influences. The generalized method of moments according to Blundell and Bond² was used for the estimation, which instrumented the previous year's nitrate values with nitrate values from the past.

Table

Effects of agricultural land use and weather on nitrate concentrations in groundwaters

In milligrams per liter for a one-unit increase in the variable

Variables	In milligrams per liter
Share of organic farming	-0.298***
Mineral fertilizer	1.598*
Share of agricultural land	0.134***
Share of viticultural land	0.411**
Share of orchard land	0.049
Share of grasslands	-0.041*
Share of forest land	-0.058***
Average temperature	1.086*
Total precipitation	0.001
Average precipitation	0.563
Nitrate concentration of the previous year	0.550***
Number of observations	7,311
Number of monitoring wells	1,323

Note: Results are based on a multivariate regression accounting for company and year fixed effects and estimated using the generalized method of moments. The observation units are groundwater monitoring wells. Data are for 2008 through 2018, and standard errors were clustered at the monitoring well level. Asterisks denote the significance level, which indicates the statistical precision of the estimate. The more asterisks, the lower the probability of error: ***, **, and * indicate significance at the one-, five-, and ten-percent levels, respectively.

Legend: A one-percentage point increase in the share of organically farmed agricultural land is associated with a nitrate concentration reduction of about 0.3 milligrams per liter.

Source: Authors' calculations based on data from the German Environment Agency, the regional statistics of the Federal and State Statistical Offices, the CORINE Land Cover Database, and the German Weather Service.

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¹ Cf. Uwe HäuBermann et al., *Stickstoff-Flächenbilanzen für Deutschland mit Regionalgliederung Bundesländer und Kreise – Jahre 1995 bis 2017. Methodik, Ergebnisse und Minderungsmaßnahmen* (Dessau-Roßlau: German Environment Agency, 2019).

² Cf. Richard Blundell and Stephen Bond, "Initial conditions and moment restrictions in dynamic panel data models," *Journal of Econometrics* 87 (1998): 115–143.

inputs in groundwater, but there is not yet any empirical evidence of this.

Results from an econometric analysis at DIW Berlin show that an increasing share of organic farming relative to total utilized agricultural area is accompanied by decreasing nitrate concentrations in the surrounding groundwater bodies. The regression results show that a one-percent increase in organic farming area is associated with a 0.3-milligram reduction in the nitrate concentration. The results represent an approximation of the actual effect, as the data on organically farmed land are only available at the county level and

Hanna Tuomisto et al., "Does organic farming reduce environmental impacts? A meta-analysis of European research," *Journal of Environmental Management* 112 (2012): 309-320.

thus are not small-scale enough to model hydrogeologic conditions (Box 3).

Sanitary innovations can contribute to improving water quality

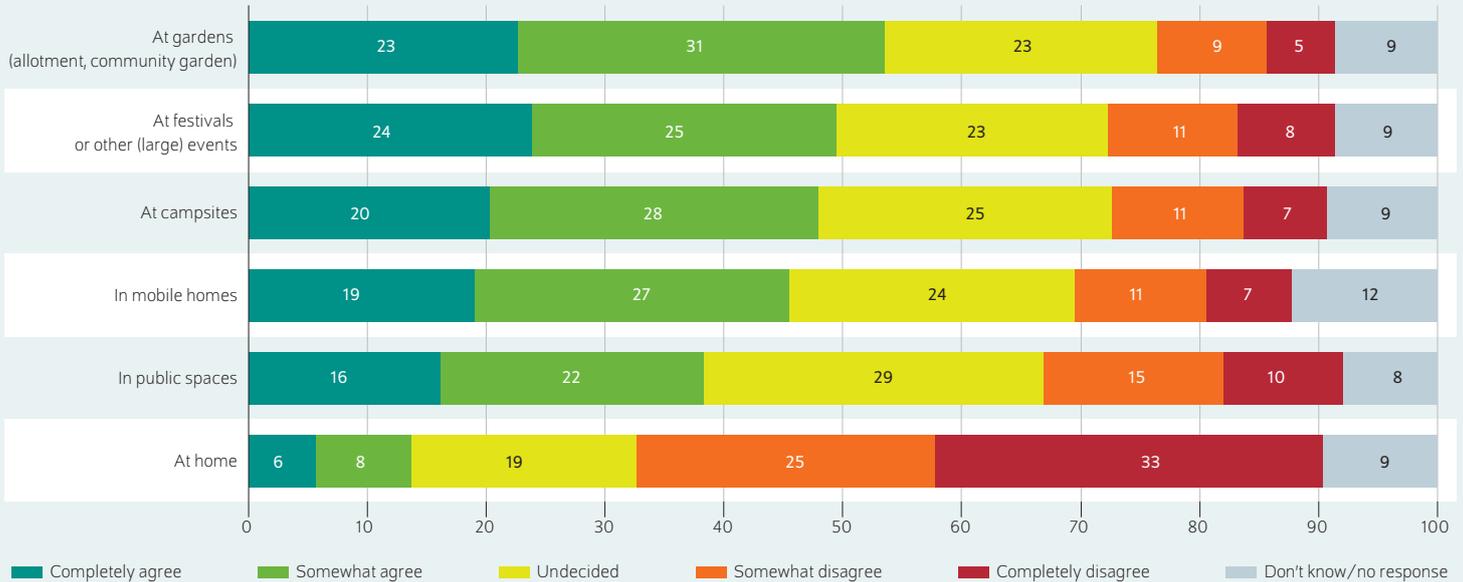
In regard to water pollution, wastewater-based sanitation is also a challenge for sustainable water supply.²⁹ For example, large amounts of fresh water are used to transport human excreta and are subsequently contaminated with nutrients

²⁹ Our current sanitation system promotes a linear, non-sustainable, and inefficient use of resources and is associated with process-related environmental emissions that are damaging to the environment and human health, cf. Ariane Krause et al., *Ressourcen aus der Schüssel sind der Schlüssel. Diskussionspapier zur Sanitär- und Nährstoffwende. Wertstoffe zirkulieren, Wasser sparen und Schadstoffe eliminieren* (2021) (in German; available online).

Figure 3

Evaluation of the use of dry toilets

Agreement in percent



Note: The figure depicts to what extent the respondents agree with statements about the use of dry toilets. The evaluation scale has six categories ranging from "completely agree" to "completely disagree" and includes a "no response" option.

Source: Representative survey of the population from the Center for Responsible Research and Innovation at Fraunhofer IAO.

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The majority of respondents positively evaluate the use of urine-diverting dry toilets at garden plots and community gardens. In contrast, the willingness to use them at home is low.

and trace substances such as pharmaceutical residues and hormones. In addition, wastewater can be contaminated with other pollutants, such as heavy metals like cadmium or quicksilver from road drains, when it mixes with rainwater. While the energy-intensive treatment processes remove much of these residues, the wastewater treatment plant discharges to surface waters are far from harmless. For example, despite state-of-the-art technology, wastewater treatment plants are considered one of the main sources of nutrient emissions³⁰ and potentially pathogenic germs in surface waters.³¹

Resource-oriented and circular sanitation management is one possible solution. This type of management is based on the technical approach of wastewater separation at the source. Separate collection (such as via UDDTs) and treatment of different wastewater streams, such as urine, feces

and rainwater, keeps the water and nutrient cycles technically separate. In this way, individual groups of substances are neither diluted nor mixed or cross-contaminated with each other, enabling more targeted and efficient treatment. Pathogens are killed and remaining nutrients are safely and sustainably returned to the cycle. In addition, the water and energy saved by using this process reduces the pressure on natural resources.³²

In this way, recycling the contents (urine and feces) of UDDTs into hygienically safe, nutrient-rich, and low-pollutant recycled fertilizer for agriculture can also contribute to sustainable water management and the strategic goals of the National Water Strategy.³³ Results of a representative survey from the Center for Responsible Research and Innovation at Fraunhofer IAO indicate that the societal acceptance barriers

30 Nearly 22 percent and 33 percent of the overall nitrogen and phosphorus inputs in surface waters are from communal wastewater treatment plants and urban sewer systems, cf. German Environment Agency, *Stickstoff- und Phosphoreinträge aus Punktquellen und diffusen Quellen in die Oberflächengewässer in Deutschland (2020)* (in German; available online).

31 Cf. German Environment Agency, *Antibiotika und Antibiotikaresistenzen in der Umwelt – Hintergrund, Herausforderungen und Handlungsoptionen* (Dessau-Roßlau: Umweltbundesamt, 2018) (in German); German Environment Agency, "Erarbeitung anspruchsvoller Standards für die mittelfristige Fortführung der bodenbezogenen Verwertung von Klärschlämmen aus Abwasserbehandlungsanlagen mit kleiner Ausbaugröße Bakterielle Resistenzen in Klärschlamm," *Umwelt & Gesundheit 3* (2022) (in German).

32 By using water-saving and UDDTs, an average of nearly 15 to 30 cubic meters of drinking water could be saved annually per person, cf. Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e. V., *Neuartige Sanitärsysteme. Begriffe, Stoffströme, Behandlung von Schwarz-, Braun-, Gelb-, Grau- und Regenwasser, Stoffliche Nutzung* (Bauhaus-Universitätsverlag Weimar: 2015) (in German). More information on the effects of wastewater-based sanitation systems and the benefits of nutrient separation can be found here (in German).

33 Results are from the research project *zirkulierBAR: Interkommunale Akzeptanz für nachhaltige Wertschöpfung aus sanitären Nebenstoffströmen*, funded by the BMBF as a part of the REGION.innovative funding measure. Together with municipalities, future-oriented companies, universities, and research institutes, the project creates a laboratory for a sustainable and regional circular economy.

for UDDTs and fertilizer made from human excreta are lower than expected, especially for use at gardens or festivals (Figure 3). In addition, over half of the respondents positively evaluate the use of UDDTs to collect human waste to be further processed into fertilizer. While most people generally are unaware of what the food they purchase was fertilized with, 44 percent of respondents are willing to eat vegetables grown with fertilizer made from human excreta.³⁴ In contrast, there is a lack of political acceptance for a broad implementation of this innovative technology: Unlike sewage sludge, manure, or organic waste, the current regulatory framework does not provide for the use of fertilizer from human excreta collected separately from wastewater. This represents a diffusion barrier for sanitary innovations. In order to enable the establishment of alternative sanitation systems, laws on waste and fertilizer regulation need to be revised.³⁵

Conclusion: Improve water quality, solve use conflicts

Water resources are coming under increasing pressure in Germany. In addition to the challenges caused by climate change, water pollution from nitrates, phosphorous, and other nutrients endangers the ecological status of water bodies and increases the costs of extracting and treating drinking water. Moreover, water use conflicts between industry, households, and agriculture are becoming more and more frequent in Germany.

To avoid future conflicts of water use, targeted measures for sustainable water abstraction for industry should be implemented, such as efficient water use as a prerequisite for

abstraction permissions. In particular, industry's preferential treatment, a sector that currently consumes large quantities at very low prices, should be ended to create incentives for efficient use.

To reduce nitrate inputs, the implemented regulations for agricultural fertilization must be enforced consistently, especially in nitrate-vulnerable zones. Organic farming can also contribute to reducing overfertilization and its expansion should continue, as is planned in the EU Farm to Fork Strategy.³⁶

Implementing resource-based and circular sanitation using wastewater separation at the source and UDDTs saves water and reduces pressure on natural resources. Energy, water, and nutrient cycles should be linked in terms of content, but technically separated. Sanitary innovations offer the possibility of effectively recovering nutrients from human excreta and closing material cycles in a regional, climate-friendly, and safe way. However, the current legal framework does not provide for producing fertilizer from human excreta that is collected separately from wastewater. The relevant laws should be revised and expanded on to effectively disassemble diffusion barriers.

A prerequisite for dealing with water use conflicts in a forward-looking manner is a comprehensive database on water supply and water demands. Currently, data collection is mostly the responsibility of regional authorities; for example, no nationwide data are available on groundwater levels. Such a high-quality, public database could contribute to intensifying environmental economic research in this area and is called for in the National Water Strategy.

³⁴ Cf. Bergmann, *Akzeptanzbefragung zu Trockentoiletten in Deutschland*.

³⁵ Cf. Krause et al., *Ressourcen aus der Schüssel sind der Schlüssel*.

³⁶ Cf. European Commission, *Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system*

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JEL: Q15, Q53, Q58

Keywords: Water, resources, pollution, nitrate concentration, water prices

AT A GLANCE

Germany can increase its raw material import security of supply

By Lukas Menkhoff and Marius Zeevaert

- Germany and the EU often import mineral raw materials from less democratic countries
- The partially extreme dependency on these raw material imports should be limited in the short and long term
- Analysis of individual critical raw materials as well as of supplier countries shows potential for action
- Greater diversification, better recycling, more domestic production, and technical innovations should be complemented by a mandatory reserve and joint EU purchasing
- Economic policy makers and companies have recognized the need for action; now it is a matter of swift—ideally Europe-wide—implementation

Appropriate measures can reduce heavy dependency on critical raw materials

High import dependency on **critical countries** calls for ...

... a domestic package of measures for each individual raw material ...

... to increase the **raw material supply security**.



Source: Authors' depiction.

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FROM THE AUTHORS

“The production of critical raw materials is concentrated in some cases up to 80 or even over 90 percent in individual countries. This means there is a very large market concentration that needs to be counteracted by short- and long-term measures.”

— Marius Zeevaert —

MEDIA



Audio interview with Marius Zeevaert (in German)
www.diw.de/mediathek

Germany can increase its raw material import security of supply

By Lukas Menkhoff and Marius Zeevaert

ABSTRACT

Over 90 percent of Germany's raw materials supply is imported and many of these imports come from only a small handful of producer countries. Often, these producer countries tend to be less democratic. In this respect, supply risks are extremely high in some cases, including for mineral raw materials such as rare-earth elements, lithium, and magnesium. To increase raw material import security of supply, various economic policies can be undertaken. European customers could bundle their procurement of raw materials to counter the market power of the few suppliers and more diversification potentials in imports could be used. Raw material storage should also be reconsidered and supplemented by a mandatory minimum reserve. In the long term, raw material imports can be reduced by recycling more and expanding domestic mineral raw material production. Finally, technical innovations should be initiated to replace raw material imports. These measures should be coordinated at a European level as much as possible.

For decades, two separate worlds seemed to exist in parallel: the world commodities markets and international politics. For example, the Soviet Union reliably sold raw materials to their enemy in the West during the Cold War. However, it has become clear throughout 2022 that the availability of raw materials is being used to exert political pressure. A reliable supply is not guaranteed, so government and business leaders are aware that more efforts must be made to secure raw materials.

Well over 90 percent of all the raw materials used in Germany are imported. Thus, raw material security of supply means the import of a specific raw material is guaranteed in the short term. Most of these raw materials are imported from different regions of the world, including from countries that are not considered reliable supplier countries from a European perspective. Over the course of the 2022 Russian war on Ukraine, this unreliability has become clear in the case of natural gas and oil. However, this applies even more to mineral raw materials when measured by import share.¹

EU Commission has evaluated supply security of many raw materials as critical

Since 2011, the European Commission has published a list of "critical raw materials" every three years.² A raw material is considered critical when two criteria are fulfilled: It must be of high importance to the economy and high risk must be associated with its supply.³ Raw materials are primarily important when they are indispensable for modern technology (semiconductors, battery technology, space flight). The supply risk considers the willingness of countries to supply, the means and routes of transportation, or the lack of competition between suppliers.

¹ There are other dependencies in Europe and Germany in addition to energy source materials and mineral raw materials, for example on electronic and medical primary products.

² European Commission, *Study on the EU's List of Critical Raw Materials – Final Report* (Brussels: 2020) (available online; accessed on November 28, 2022). This applies to all other online sources in this report unless stated otherwise). All raw materials that are neither an energy source material nor an agricultural raw material are considered.

³ European Commission, *Methodology for Establishing the EU List of Critical Raw Materials* (2019) (available online).

Thirty of the 83 observed raw materials are considered critical. The rest are not unimportant, but simply less critical. For example, gold is considered uncritical in both dimensions, while silver is important but its supply is low risk. Teak is subject to supply risk but considered less economically important. The critical group includes the rare-earth elements in particular, but for instance also magnesium, lithium, cobalt, and bauxite.

EU and German government preparing measures for more raw material security

In response to the new global economic environment, the EU Commission announced an action plan for critical raw materials for spring 2023. It will likely be more specific than previous recommendations and go further than previous starting points, including on import diversification. The German Federal Government is also considering national measures, both long and short term (Box).⁴

Short-term measures assume that imports of critical raw materials will continue to be necessary, suppliers will fundamentally remain the same, and volumes may even increase, for example to cope with the energy transition. In the short-term, three different measures are possible: One option is bundling demand to counteract the market power of a few suppliers. Another measure is a greater diversification of supplier countries, which tends to reduce the power of individual suppliers and also cushions import declines in the event of a supplier default. Finally, a mandatory minimum reserve to temporarily ensure the security of supply can be required.

In the long term, raw material security can be increased by partially replacing raw material imports with three measures. One of them is improved recycling, which can be reached through stricter legally binding recycling quotas, for instance.⁵ Furthermore, countries can make greater use of their own production facilities, and, finally, promote technical innovations that reduce the use of or completely replace critical raw materials.⁶

Coordinated European approach and joint procurement of raw materials are advantageous

For all six measures mentioned, it would be beneficial for Germany if other EU Member States cooperated. This becomes very clear when comparing the raw material import dependency between Germany and the EU. Both Germany and Europe are 100-percent import dependent regarding 14 of 27 critical raw materials from the EU list. For three others, they are each over 95 percent dependent on imports

⁴ Such as using subsidies and loan guarantees to secure raw materials, cf. Julia Löhr, "Ein Gesetz für die Rohstoffsicherheit," *Frankfurter Allgemeine Zeitung*, October 17, 2022 (in German; available online).

⁵ Sachverständigenrat für Umweltfragen, *Umweltgutachten 2020: Für eine entschlossene Umweltpolitik in Deutschland und Europa* (2020) (available online).

⁶ For example, a large battery that is made without critical materials, cf. Marcus Theurer, "Die grüne Mega-Batterie aus Franken," *Frankfurter Allgemeine Zeitung*, November 13, 2022 (in German; available online).

Box

Raw materials strategy of the EU and the German Federal Government

As early as 2008, the European Commission launched a Raw Materials Initiative (RMI). Accordingly, the EU is striving to diversify supplier countries, to recycle raw materials, and to achieve greater material efficiency. A study on critical raw materials has been produced every three years since 2011, and the latest edition from 2020 is used to define critical raw materials in this Weekly Report.¹ The number of raw materials considered has increased with each issue, most recently to 83 raw materials. Of these 83 raw materials, 30 are considered "critical," meaning they are both important to Europe and have a high supply risk.

Germany first drew up a raw materials strategy in 2010. As a result, the *Deutsche Rohstoffagentur* (DERA) was founded as a part of the Federal Institute for Geosciences and Natural Resources (*Bundesanstalt für Geowissenschaften und Rohstoffe*, BGR), which itself is an agency of the Federal Ministry for Economic Affairs and Climate Action (*Bundesministerium für Wirtschaft und Klimaschutz*, BMWK). The DERA gathers information on mineral raw materials and energy commodities, evaluates them, and advises German companies. The raw materials strategy was last updated in 2020 and mentions, among other things, "having the possibilities of additional state measures for securing raw materials examined in a commissioned study."² This study has been available since August 2022.³

¹ EU Commission, *Critical raw materials* (2020) (available online).

² Cf. Bundesministerium für Wirtschaft und Klimaschutz, *Rohstoffstrategie der Bundesregierung* (2020) (in German; available online).

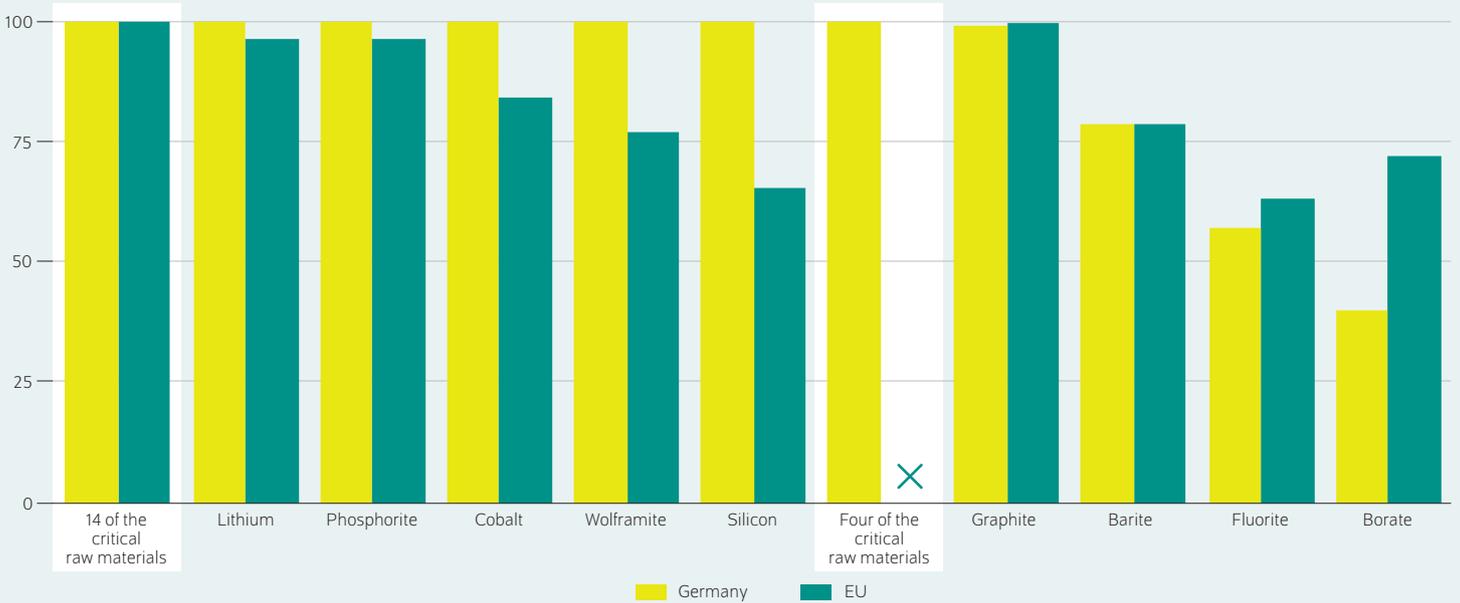
³ Cf. Ernst & Young, *Staatliche Instrumente zur Erhöhung der Versorgungssicherheit von mineralischen Rohstoffen*.

(Figure 1). In addition, there are seven raw materials on which Germany is completely import dependent, while the EU is only up to 80 percent dependent. Both Germany and the EU import 50 to 80 percent of two raw materials. Only when it comes to borates does Germany have a lower import dependency than the EU. Overall, the EU is more independent than Germany in seven cases, and vice versa Germany only in one case. This asymmetry applies to most other EU countries on a similar level, which creates a strong incentive for European cooperation.

European cooperation could begin with joint purchases of imported raw materials to counteract the market power of the few suppliers of critical raw materials. When including individual rare-earth elements (like cerium and dysprosium), the number of critical raw materials on the EU Commission list increases from 30 to 44. For all 44 raw materials, the largest supplier country in each case already has a significant

Figure 1

Share of imports of mineral raw materials used in the EU and in Germany
In percent



Notes: There is complete dependency on imports of antimony, beryllium, bismuth, gallium, germanium, natural rubber, niobium, phosphorus, platinum metals, the rare-earth elements, tantalum, titanium, vanadium, and magnesium. Germany is fully dependent on hadnium, indium, coking coal, and strontium imports, while the EU is independent. For data reasons, only 27 of the 30 critical raw materials are included.

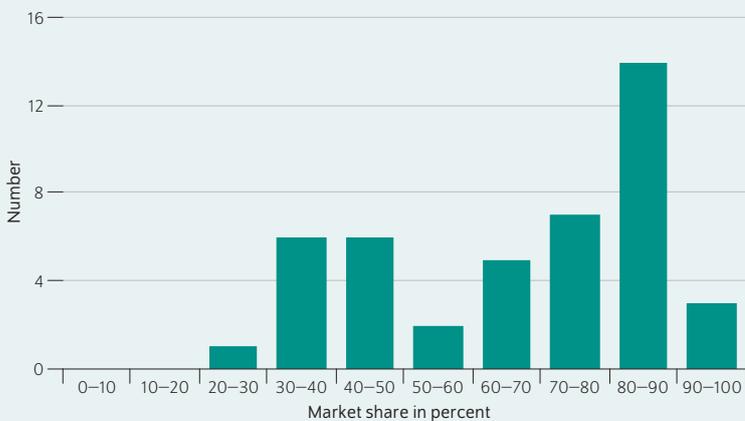
Sources: Eurostat; World Mining Data; UNFAO; EU Commission; US Geological Survey; British Geological Survey; authors' calculations.

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In many cases, Germany is more dependent on imports of critical raw materials than the EU.

Figure 2

Market concentration of critical raw materials
Number of raw materials; market shares of the most important supplier country globally in percent



Note: Thirty critical raw materials including subcategories (for example, the rare-earth elements) were observed.

Source: EU Commission (2020).

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The largest supplier country has immense market power for many raw materials.

market share. The smallest share of global production is 28 percent, while the largest is 93 percent (Figure 2). The median is 74 percent.

Diversification can increase security of supply

Diversifying imports so as not to depend on the whims of one or a few suppliers is a helpful measure. However, the short-term diversification potential for a major consumer, like the EU Member States, is limited when one single supplier dominates the world market by up to 74 percent.

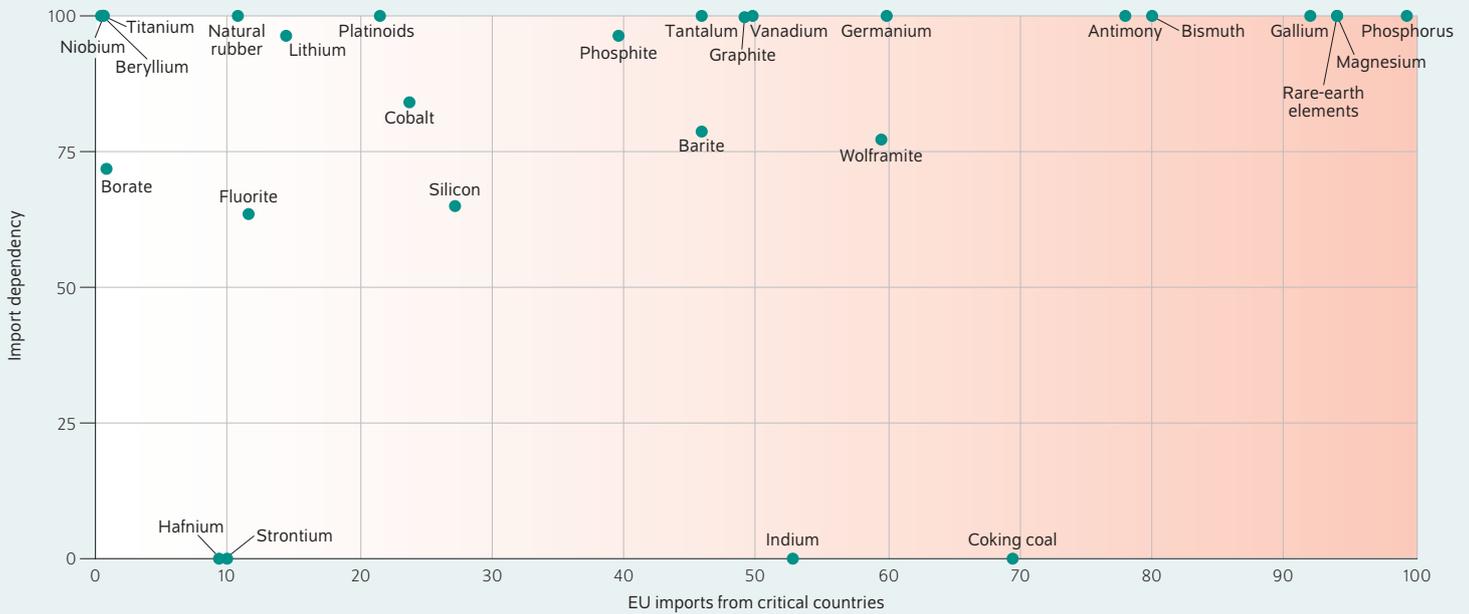
In addition to the economic dimension, there is also a political dimension when important supplier countries are also considered politically unreliable (Figure 3).⁷ The World Bank's Voice and Accountability Index is used to classify countries as critical supplier countries. Countries are considered critical if their score is worse than that of Turkey, which has the lowest score among all OECD members by far. Many of the critical raw materials imported are almost entirely from countries with little democracy, particularly

⁷ The World Bank provides a Voice and Accountability Index for almost all countries in the world over long periods of time, providing good coverage in terms of content and geography. Cf. World Bank, *Worldwide Governance Indicators* (2022) (available online).

Figure 3

Import dependency of critical countries

Share of EU imports in percent¹



¹ Share of total imports of a raw material from countries with a Voice and Accountability Index score lower than Turkey's.

Sources: Eurostat; World Mining Data; UNFAO; EU Commission; US Geological Survey; British Geological Survey; World Bank.

A high share of EU imports of many raw materials are from especially critical countries.

from China.⁸ In such cases, one starting point could be to attract other producer countries as suppliers.

However, the potential to import less from countries whose Voice and Accountability Index score is lower than Turkey's is limited in the short term. This can be illustrated by the difference between EU import shares from critical countries and their shares of global production (Figure 4).⁹ Accordingly, there are only a few mineral raw materials that Europe imports disproportionately large amounts of from less democratic countries (positive range). For these minerals, there is a short-term potential for diversification by importing more from democratic countries. Conversely, it can be seen that large amounts of many raw materials are imported disproportionately from democratic countries (negative change), and thus the potential for changing the supplier countries is lower.

More raw material extraction in Europe remains controversial

The most secure area to obtain raw materials from is the EU itself. For example, of the 30 critical raw materials considered, twelve are currently produced in the EU, but often only in very small quantities.¹⁰ Five other raw materials have deposits that have not yet been exploited in the EU. For three other raw materials, EU deposits are expected, but have not yet been quantified.

However, there is resistance to any kind of raw material extraction and environmental exploitation, which cannot be avoided even with a climate-friendly energy transition. As understandable as this resistance may be from the perspective of those affected, it is incompatible in macroeconomic terms with the goal of reducing dependency on critical raw material imports. Society must consider how best to balance the three goals of high income (as a high-tech location), raw material security (through less dependence on non-democratic countries), and protection of its domestic environment

⁸ Cf. Melinda Fremery and Thomas Obst, "Globalisierungskrise: Welche Abhängigkeiten bestehen bei kritischen Gütern und Rohstoffen aus China?" *IW-Kurzbericht* 48 (2022) (in German; available online).

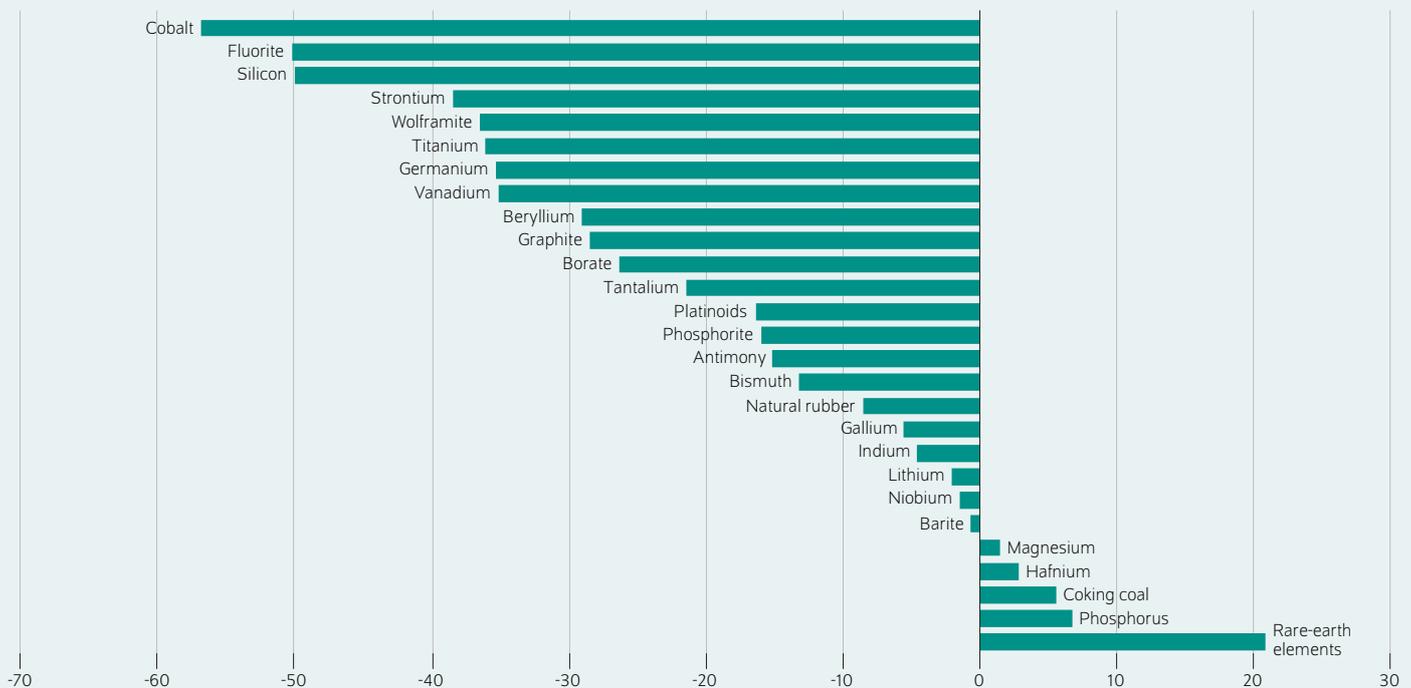
⁹ Cf. Lisandra Flach et al., *Wie abhängig ist Deutschland von Rohstoffimporten?* (Munich: Ifo-Institut, 2022) (in German; available online).

¹⁰ U.S. Geological Survey, *Mineral Commodity Summaries* (2022) (available online); Austrian Finance Ministry, *World Mining Data* (2022) (available online); Minerals4EU, *European Minerals Yearbook* (2022) (available online); EU Commission, *Critical Raw Materials Factsheets* (2020) (available online).

Figure 4

Short-term diversification potential

Difference between EU import and global production shares of critical countries, in percentage points



Legend: A positive difference for a raw material means that the share that the EU imports from critical countries is higher than their share of global production.

Sources: Eurostat; World Mining Data; UNFAO; EU Commission; US Geological Survey; British Geological Survey.

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The short-term diversification potential is often limited.

(by avoiding raw material extraction) (Figure 5). These conflicting goals can be mitigated (through recycling, for example), but choices must be made.

The current stance of the German Federal Government as formulated in the raw materials strategy remains insufficient, as it seems very passive considering the current situation: “The German government will support initiatives of the European Commission aimed at reviving the primary extraction of necessary metallic raw materials for e-mobility and the energy transition, such as copper, lithium, and nickel, in the member states of the European Commission.”¹¹

Situation of each raw material is unique

For all critical raw materials, it makes sense to bundle demand, to introduce mandatory minimum reserve requirements, to recycle, and to promote substitution through innovation. However, whether and how a diversification of imports and domestic production can be employed, differs

between the raw materials. This can be seen using the rare-earth elements, magnesium, and lithium as examples.

The 17 **rare-earth elements** are used in numerous key technologies and are especially vital in the construction of electric vehicles and wind turbines. The EU is almost completely dependent on imports of these raw materials: Ninety-four percent of EU imports come from especially critical countries, led by China (Figure 6).

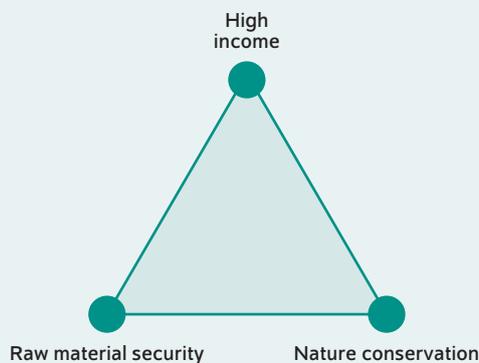
A short- to medium-term diversification of rare-earth elements will be difficult for the EU. In addition to China, Myanmar, the USA, and Australia produce large amounts of rare-earth elements, but their exports are low because they primarily serve domestic customers.¹² Thus, it will be expensive or impossible for European customers to purchase American and Australian rare-earth elements. Apart from China, only one country, Thailand, has a significant surplus

¹¹ Bundesregierung, *Rohstoffstrategie der Bundesregierung, Sicherung einer nachhaltigen Rohstoffversorgung Deutschlands mit nicht energetischen mineralischen Rohstoffen* (Berlin: 2020) (in German; available online).

¹² For trade data on rare-earth elements, see Eurostat, *EU Handel seit 1988 nach HS2-4-6 und KN8* (in German; available online) and UN Comtrade, *Trade Data* (2022), for production and reserves data, see U.S. Geological Survey, *Mineral Commodity Summaries*. Since different data sources were used in this case as well as for other raw materials, the delineations of the respective raw materials are sometimes different. The respective shares are therefore only comparable to a limited extent.

Figure 5

Conflicting goals in achieving a raw material supply



Source: Authors' depiction.

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The goals of a high income, secure raw material supply, and nature conservation must be balanced.

of rare-earth elements and could help the EU diversify in the medium term. However, the International Energy Agency forecasts that global demand for rare-earth elements just to meet the Paris climate goals is expected to increase seven-fold by 2040.¹³ Thus, for long-term raw material diversification, production expansion in democratic supplier countries is crucial.

In addition to the critical countries of China, Russia, and Vietnam, Brazil, India, and Australia, in particular, have large reserves of rare-earth elements (Figure 6). Therefore, it is in Europe's interest to strengthen the expansion of production capacities in these countries to secure long-term raw material supply security. To this end, the EU should examine the extent to which it can provide concrete support for exploration projects in these countries and should reduce trade barriers with them.

A further option for decreasing dependency on raw material imports is to begin or expand production in the EU. For example, some critical raw materials, such as fluorite, are already being produced in Germany or other EU countries, but extracting a significantly larger amount would be geologically possible. One example is **magnesium**, which is currently used in the manufacture of transmission housings for cars, among other things, because of its material properties. Since magnesium is also needed for fuel cells that can convert hydrogen into electricity, it plays an important role in achieving climate targets.¹⁴

China produces 90.7 percent of magnesium globally and 93.3 percent of EU imports are from China (Figure 7).¹⁵ When magnesium production fell in 2021 due to energy-saving requirements in China, EU dependency led to a tense supply situation and the threat of plant closures in the automotive industry.¹⁶ This dependency is unnecessary, as there is an extraordinarily high number of magnesium deposits globally. While there are no precise estimates of reserves per country, this is because magnesium can be extracted from seawater, dolomite rock and other minerals. However, there have been initial efforts from companies to mine magnesium in EU countries, and the EU should consider providing more support for these projects. For magnesium and some of the other 30 critical raw materials, the high costs of domestic production are the reason for strong import dependency, not a lack of deposits in the EU.

Despite the focus on raw materials from critical countries, EU dependencies on democratic countries should also be addressed, as these countries can also use their market power to fetch higher prices or completely stop exports, as the example of Indonesia showed for nickel in 2020.

Lithium is also one of the 30 especially critical raw materials according to the EU. Lithium is used in electric car batteries and is thus particularly important for achieving the climate targets. Accordingly, the International Energy Agency is forecasting that the global demand for lithium could increase by over 40-fold by 2040 if a sustainable development scenario is followed.¹⁷ It is therefore concerning that the EU sourced 63 percent of its lithium imports from Chile in 2020. Such a high share gives the country significant market power. One look at the global export countries shows that Australia, China, and Argentina are also potential supplier countries (Figure 8). However, in addition to Chile, only China exports large amounts of lithium. Because more Chinese imports would not make raw material imports more secure, the focus should be on increasing cooperation with other potential suppliers. Moreover, lithium production can be increased in Europe, too, such as in Spain.¹⁸ There are also large deposits of lithium in Germany in the Upper Rhine Rift, although the area is considered earthquake prone. If modern, environmentally-friendly methods can be utilized to mine lithium there safely, German import dependency could be markedly reduced.¹⁹

¹⁵ The data refer to (further) processed and recycled magnesium.

¹⁶ Deutsche Rohstoffagentur, *Rohstoff-Engpass: Chinas Magnesium-Metallexport eingebrochen – Versorgung auf dem Weltmarkt bleibt angespannt* (2021) (in German; available online).

¹⁷ International Energy Agency, *The Role of Critical Minerals in Clean Energy Transitions*

¹⁸ Linda Osusky, "Spanische Mine könnte bald ans Netz gehen," *Tagesspiegel*, November 9, 2022 (in German; available online).

¹⁹ In various scenarios of rising lithium demand, the German Mineral Resources Agency estimates that Europe could at best supply itself with around 30 percent from domestic production by 2030, plus a few percentage points from recycling, so that the overwhelming majority of lithium would still have to be imported. Cf. Deutsche Rohstoffagentur, "DERA stellt Ergebnisse der Rohstoffbewertung Lithium vor: Hohe Angebotskonzentration bei Lithium – Schlüsselrohstoff und limitierender Faktor für die Verkehrswende und Speicherung regenerativer Energie," press release from June 24, 2022 (in German; online verfügbar).

¹³ International Energy Agency, *The Role of Critical Minerals in Clean Energy Transitions* (Paris: IEA, 2021) (available online).

¹⁴ EU Commission, *Critical Raw Materials for Strategic Technologies and Sectors in the EU – A Foresight Study* (2020) (available online).

Figure 6

Diversification of the rare-earth elements, magnesium, and lithium

Share of countries of EU imports, global exports, global production, and reserves known worldwide, in percent



Sources: Eurostat, UN Comtrade, British Geological Survey, US Geological Survey, World Mining Data.

The rare-earth elements, magnesium, and lithium offer various possibilities for reducing dependency.

Learning from other countries

Countries such as Japan and South Korea are in a largely comparable situation to Germany. They have already taken wide-reaching measures: For example, both countries require mandatory minimum reserves of critical raw materials. In Japan, the minimum reserve must cover 180 days of use. South Korea recently founded a state-owned commodities company to support exploration. Both countries have targeted recycling support and subsidize research relevant to critical raw materials substitution.²⁰

The United States supports its domestic production of rare-earth elements with state investments and tax incentives for refineries and production sites. As a result, production was able to increase from zero tons in 2017 to 39,000 tons in 2020, or about 15 percent of global production. The EU could implement these types of measures for critical raw materials with their own European reserves, for example magnesium. Support will be more difficult for raw materials for which the EU does not have reserves. In such cases, investments in new mines and refineries in countries considered reliable could be considered. Strategic partnerships similar to energy partnerships should also be considered.²¹

²⁰ Cf. these and other examples in Ernst & Young, *Staatliche Instrumente zur Erhöhung der Versorgungssicherheit von mineralischen Rohstoffen. Bericht an das BMWK (2022)* (in German; available online).

²¹ See Bundesministerium für Wirtschaft und Klimaschutz, *Jahresbericht 2020 (2021)* (in German; available online).

Conclusion: Quick and Europe-wide coordinated action necessary

Policymakers have recognized the clear pressure to take action to secure the raw material supply. Even if no major supplier country of the raw materials under consideration, first and foremost China, stops or cuts exports to Europe, the extreme concentration of suppliers combined with the import requirements of the German and European economies is a vulnerable combination. Because measures such as recycling expansion occur over a long period of time, it seems reasonable to use all available measures simultaneously.

Three measures in particular are available in the short term that will not reduce the import need: One, bundling demand at a national, or better, European, level. Two, systematic information on suppliers and, based on this, the use of current diversification potentials. Third, a government-initiated and centrally coordinated build-up of minimum reserves to ensure emergency supplies, similar to energy commodities.

At the same time, it is worth considering reducing the import demand for raw materials in the long term. To this end, recycling can be promoted more strongly. A further measure, especially for indispensable raw materials, would be expanding European production, in which Germany, as the largest industrialized country in Europe, should participate appropriately. Finally, technologies that do not require or require fewer imported raw materials should be supported.

There are clear benefits to implementing these measures in a coordinated manner at a European level. However, the processes required to do so are often protracted, if they are even realistic in the first place. In this respect, it is advisable to not only focus on European cooperation but to also begin to implement measures at a national level as quickly as possible.

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