Vontobel

The quest for resources

How resource scarcity, geopolitics and globalization will impact your investments

3 **Foreword**

4 **Executive summary**

6 **Why should investors care about resource scarcity and geopolitics?**

14 **Where scarcity rules**
Understanding the resource spectrum: from essential to life-enhancing.

34 **Resource scarcity: The energy example**
How resource scarcity affects a country's independence and geopolitical actions.

38 **What happens when resources are restricted**
Understanding the impact of a country restricting access to resources.

42 **Fault lines**
Where future resource-related problems may arise.

46 **Vontobel's insights: A word from our investment teams**

54 **Connecting the dots for investors**

Click to navigate report

Our fiduciary duty as capital allocators is to invest in the best interests of our clients. To do so effectively, we thoroughly assess the many factors that affect investments and the environment that investment decisions are made in. At Vontobel, our aim is to map the true future of investing, helping ensure that we allocate capital in the most effective way to achieve the best returns.

As this whitepaper, written by Dr Reto Cueni, our Chief Economist, so clearly communicates, resources—and the quest for them—have a very strong impact on the financial markets and the economy. All signs are that this is set to continue, especially given current geopolitical concerns and, indeed, the climate crisis we are facing.

While it is one thing to discuss macroeconomics in whitepapers at a high level, raising all the important questions as we aim to future-proof investment solutions, it is another to see the dynamics of geopolitics and markets playing out on a daily basis.

Within our six investment boutiques we see understanding the fight for resources taking place across the globe as part of our work, and we share here some examples of the *realpolitik* of resources and investing. This paper lays out the state of the world's resources, what that means for the future and how investors should be thinking about resources to maximize their investment success.

Christel Rendu de Lint, PhD.
Head of Investments, Vontobel

Executive summary

What's important now?
What will matter in the future?
The need for and availability of resources can change drastically over time and are one of the main drivers of geopolitics (Criekemans 2021). Access to resources defines a nation's capability to survive, to keep, or to increase its living standards and limits its geopolitical sphere of influence.

For example, the shale oil revolution in the US enabled the country to become an energy exporter after 2020, having been a heavy energy importer in the decades before, triggering significant changes in US national security strategy and its focus in international relations (Butts 2015, Krane & Medlock 2018).

Similarly, Russia's invasion of Ukraine stoked Europe's ambition to finally implement its green transition in a quest to become more energy independent. This shift in strategy will lead to an increase in Europe's resource needs in other dimensions, such as minerals and metals (European Commission 2022).

This paper examines which resources are currently of geopolitical importance, which countries and regions have access to these resources, and how this system might shift over the next few decades, affecting and being affected by geopolitical considerations that impact the prices of resources and, hence, financial markets and investing.

To support you in navigating the situation and understanding the importance of the quest for resources, we both begin and end with a summary, designed to connect the dots for investors. And, as Christel mentions in her foreword, we include case studies from our investment boutiques to provide real-life examples from the daily work of our investment teams.

Seeking to future-proof investing requires an understanding of the world we operate in today and will inherit tomorrow. And resources, quite literally, shape that world.

"The story of resources is the story of investing."

Reto Cueni, PhD, Vontobel Chief Economist

Scarcity is here to stay
Resource scarcity will remain a key topic in geopolitics, substantially affecting financial markets and investing as geopolitical considerations disrupt economic principles of supply and demand.

Fault lines and the importance of global trade
Current complexities in global trade—built up over more than six decades—cannot be reversed quickly, thus globalization, although likely to have found a peak, is here to stay. Even the biggest countries must currently rely strongly on trade to secure access to vital resources for many industrial sectors of their economies. This dampens a fast break-up of fault lines as long as countries are aware of the economic risks that a stop in trade relations would entail.

Pricing pressures
However, trade partners will likely pay more attention to trading with geopolitical allies and this will lead to economic inefficiencies and elevated underlying price pressure for resources, since theses may no longer be accessed where they can be produced most cheaply.

Multipolarity: the rise of 'swing states' ...
Despite the current geopolitical leadership struggle between the US and China likely leading to a bipolar gravity, the distribution of resources and trade around the globe suggests that multipolarity will gain strength in the geopolitical power game.

Resource-rich 'swing states' will be able to leverage their assets under geostrategic alliances that can change quickly leading to a volatile geopolitical environment.

... and of proxy wars
This multipolarity with bi-polar gravity is set to lead to more proxy wars, particularly in resource-rich states that have weak governmental structures or are already hampered by intra-state conflicts—further increasing geopolitical uncertainty while leading to increased volatility in commodity markets and other resource-prone sectors of the economy.

Know-how: The resource to rule them all
From a resource point of view, the US, and its allies—including their military cooperation in the NATO—appear to still be in a good position, endowed with a solid set of resources, more ample than that of China.

On top of that, the West is globally still master of the development of know-how—the resource that rules all other resources. It is difficult to proxy know-how with numbers but it seems China is catching up, although still significantly distant from the West. Its potential geopolitical allies like Russia or Iran are even further behind.

Minerals and fossil fuel are needed for the green transition
The quest of many developed countries is to achieve a green transition and induce lower energy dependency from oil-exporting countries—the EU's aim to get rid of Russian energy being a case in point. However, a key element to understand is that such transitions will lead to a higher dependency on mineral-exporting countries, at least during the transitional period, which may take several decades.

During this period, fossil energy sources will still be in heavy demand and can only slowly be reduced, as renewable energy sources must first be built and installed, employing significant amounts of fossil energy.

Active investment captures the opportunity
The expected geopolitical multi-polarity we outline here—with its volatile alliances, friend-shoring strategies and investment programs to support the green transition and renewable energies—may lead to some distortion in the economic models of supply and demand usually used by investors to price resources and linked assets.

Capturing and harnessing the opportunities presented in such a complex, geopolitically driven environment is ideal ground for the expertise and flexibility of active investing.

Why should investors care about resource scarcity and geopolitics?

Global demand for the extraction of raw materials seems, if anything, to be growing over the century. Figure 1 highlights the demand placed on resources as extraction is expected to increase at an accelerated rate. The developed world has traditionally been the biggest consumer of raw materials; however emerging markets are catching up quickly.

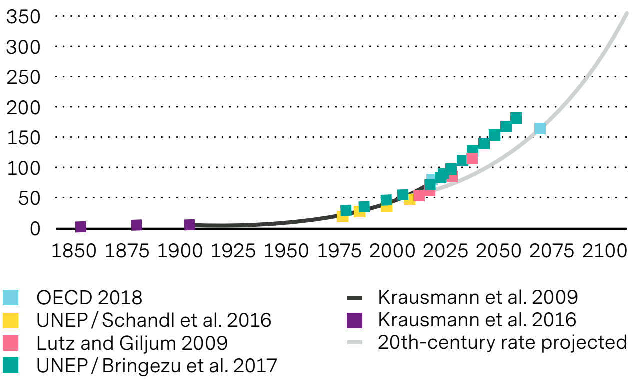
Competition for resources leads to scarcity, and population growth is a key driver here. By the end of this century, the world's population is expected to grow from eight to more than ten billion, according to the United Nations. And, while annual world population growth rates are on a downward trend—from a high of 2.3% in the 1960s baby boomer years, to the current level of 1%, to an expected level below zero by 2100—emerging economies are expected to consume a greater amount of resources as their living standards improve.

Some of these emerging economies will increase their population on an absolute level even until the end of this century and also increase their share of the world's population during the next decades—in contrast to almost all developed economies, which will see their populations decline (United Nations 2019).

As figure 1 shows, the OECD and UN are among those predicting that the consumption of materials globally will continue to increase in the decades ahead, which does not speak for any relaxation of the resource scarcity issues we currently face on the planet.

Figure 1: Global material extraction (including fossil energy carriers) is set to increase further

Billions of tonnes per year



Note: The 20th-century rate was projected by extrapolating the global material extraction between 1900 and 2000 as estimated by Krausmann et al. (2009/2016), forecasts based on external analysis; not guaranteed; and actual outcomes may differ materially.
Source: See the legend of the figure, e.g. OECD, UNEP, Krasusmann et al.

Scarcity and geopolitics
Scarcity and geopolitics are inextricably linked to modern-day resources, and so is investing. Resources only get a price when there is scarcity, and the interplay of demand and supply in defining the scarcity of a resource is key to economic models and investment decisions (Robbins 1932, Backhouse & Medema 2009).

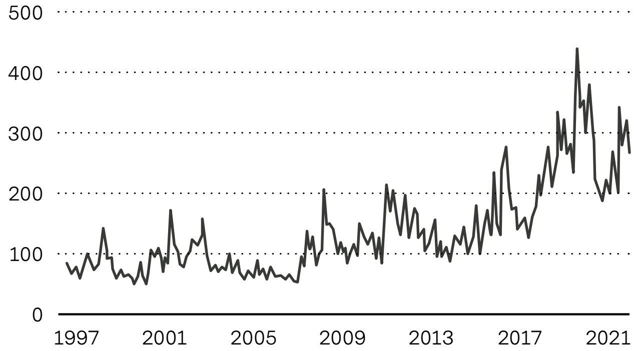
Scarcity is investors' bread and butter.
Investors are expertly able to gauge resource and raw material prices when the economic principles of supply and demand are at work. They have economic models at their disposal to estimate prices depending on current and future scarcity and the cost to produce, ship, and trade.

Distribution of resources plays an important role. A resource that is not scarce on a global scale can nevertheless mean that there is 'regional scarcity'. That is why trade is so important—between people, companies and countries—and why investors embedded trade in their models. If a resource can be mined and produced cheaper in another part of the world, investors expect companies to adapt their sourcing of that resource to improve costs.

For decades now, investors have lived in such a world where economic efficiency was increasing and constituted the guiding principle of international relations. This was a result of the reduction of global trade barriers since the 1970s and the inclusion of China in the global trade system in the 1980s. Global trade reached an all-time high just before the start of the global financial crisis (GFC) in 2008 (see figure 2). The maxim of ever more global trade and continuously increasing global economic efficiency will be challenged by major geopolitical forces.

Figure 3: Higher geopolitical uncertainty since 2007 GFC

Index points



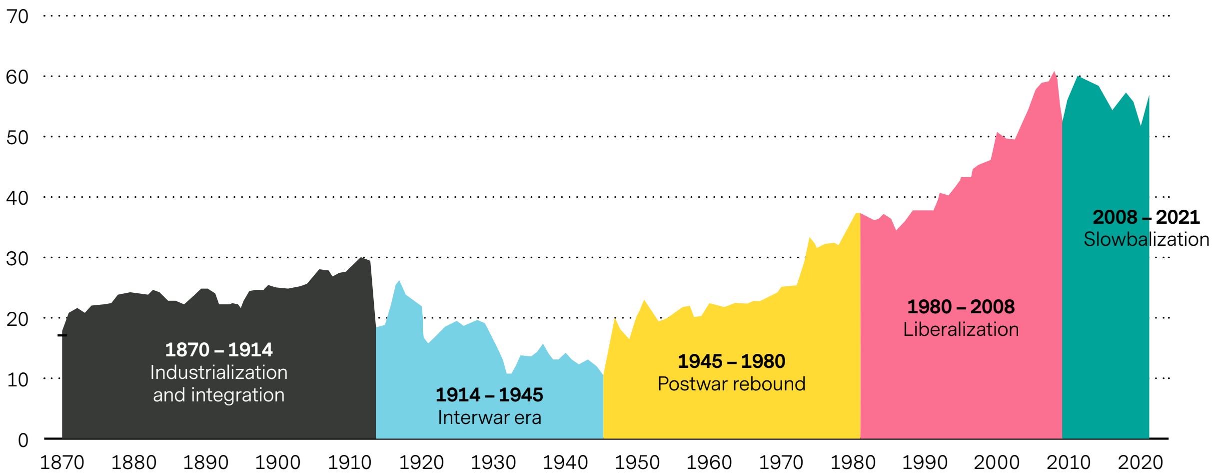
Source: Economic Policy Uncertainty Index (2022).

International trade relative to economic activity has stagnated since 2008 when the world has experienced an increase in global economic uncertainty after the GFC (see figure 3). It is no surprise that particularly during periods of major wars, when uncertainty reaches a maximum, global trade decreased most strongly, as can be seen during the two world wars (see figure 2).

Higher geopolitical uncertainty today raises investors' fears that geopolitics dictates decisions on access to resources (trade restrictions and other state interventions), leading to flawed or completely out-of-sync price mechanisms that mean investors struggle to gauge the true price of that resource. Therefore, it is important for investors to consider the current and future position of global natural resources and raw materials, including worldwide access and the trade environment for resources impacted by the geopolitical environment.

Figure 2: Globaliization is slowing down

Trade Openness Index



Note: The Trade Openness Index is defined as the sum of world exports and imports divided by world GDP. 1870 to 1949 data are from Klasing and Milionis (2014); 1950 to 1969 data are from Penn World Tables (10.0); 1970 to 2021 data are from the World Bank. Source: PIIE (2022), Our World in Data, World Bank (2023), Vontobel.

40%

of conflicts are linked to natural resources.

Resource scarcity increases geopolitical uncertainty

The most likely trigger for resource-related conflicts—be that an international dispute between states, or, more often, a civil conflict between different political, ethnic or geographic factions—is the scarcity (or potential scarcity) of the fundamental resources that are required for survival. In fact, 40% of conflicts are linked to natural resources, according to the UN. Investors and politicians alike need to be concerned about resources because access to them is required to prevent social unrest and political turmoil within a country but also between nations.

A recent IMF study highlights the detrimental impact of resource scarcity leading to a substantial price increase for water, food and energy on the political stability within a country but also on an international scale (Redl & Hlatshwayo 2021). Therefore, it's government leaders' first priority to maintain uninterrupted access to vital resources and to ensure prices for basic household needs are kept low. Any scarcity of such basic resources will immediately trigger social unrest and political turmoil.

Aside from this first set of vital resources, substantial changes to a country's resources needed for economic security and prosperity have likewise the potential to result in social unrest also impacting political stability, the government in power, and the country's elite. Usually, the population expects a current economic functioning and living standards to be maintained, at a minimum. Yet, particularly in developing countries, maintaining living standards is not enough and living standards that cease to keep up with an expected trend can trigger upheavals.

Of course, this second set of resources linked to economic security and well-being incorporates the first set of vital resources, but in a country with a high living standard, food is typically abundant and luxuriant, apartments do not just provide shelter and access to drinking water isn't a question. Additionally, more special materials and metals come into play, which are needed to provide us with today's advanced technologies. Higher living standards are also linked to higher energy consumption, as not only more complex goods are consumed but also a lot of energy-intensive services.

On the other hand, what do leaders need to achieve their geopolitical goals? Here, a third set of resources represent a means to demonstrate strength and power, benefiting domestic companies and citizens, and a gateway to implementing their vision on the geopolitical stage. Resources also pose a hard limit to leaders' preferences and ambitions, determining the possibility space in which a nation's geopolitics can operate. (Mearsheimer 2001, Papic 2020).

Again, in this third set of resources, the other two sets are partially included, and technology, which is a combination of know-how and all other resources, plays an even more important role in the geopolitical power game than for economic security and prosperity. The response time to scarcity in this third set of resources is usually protracted—besides in emergencies concerning the national security of a country—because it often involves long-term strategic power plays.

A geopolitical framework of resources

These three key groups of resources translate into a tripartite geopolitical framework for governments:

Trade as the gateway for geopolitics

Level 1: Vital resources

Scarcity in resources needed to survive.
Immediate reaction.

Scarcity in the set of resources that a population needs to survive immediately triggers social unrest and geopolitical actions. This set usually includes air, water, food and (heated / cooled) shelter (including also some form of energy).

Level 2: Resources for economic security and prosperity

Scarcity in resources needed to maintain economic security and prosperity.
Response time varies from fast to slow.

Scarcity in this second set of resources, those that help countries to keep their economies running and prosper, usually triggers social unrest and geopolitical actions by the government. Yet the response time ranges from immediately, in the case of an economic security emergency, to protracted, in the case of slowly withering economic prosperity.

Level 3: Resources for geopolitical aspirations

Scarcity in resources needed for a country's geopolitical aspirations.
Response time varies from emergencies to long-term strategic moves.

Scarcity of resources that endanger the geopolitical aspirations of leaders and populations can trigger social unrest and harsh government actions but the response time varies from national security emergencies to slowly evolving long-term strategic power plays, where the response time tends to be gradual.

Trade as the gateway for geopolitics
The importance of the trade of resources becomes evident in the context of geopolitics. This is simply because trade exhibits a dependency of two trading partners and identifies the leverage that the partners have, and which traded resources could be used as a pawn in any geopolitical power game.

Given how intertwined and complex supply chains have become, it is needless to say that trade is sensitive to geopolitical tensions and conflicts, while resources play a key role in every geopolitical power game. Humans have always fought and competed over resources and nations are often split into groups as allies and enemies (bloc formations) in times of war. This can quickly result in a resource becoming scarce if previous trading partners break off their trade relations or if access to a resource is suddenly lost (see, for example, the dispute over 'rare earth exports' between China and Japan, later in this paper on page 39).

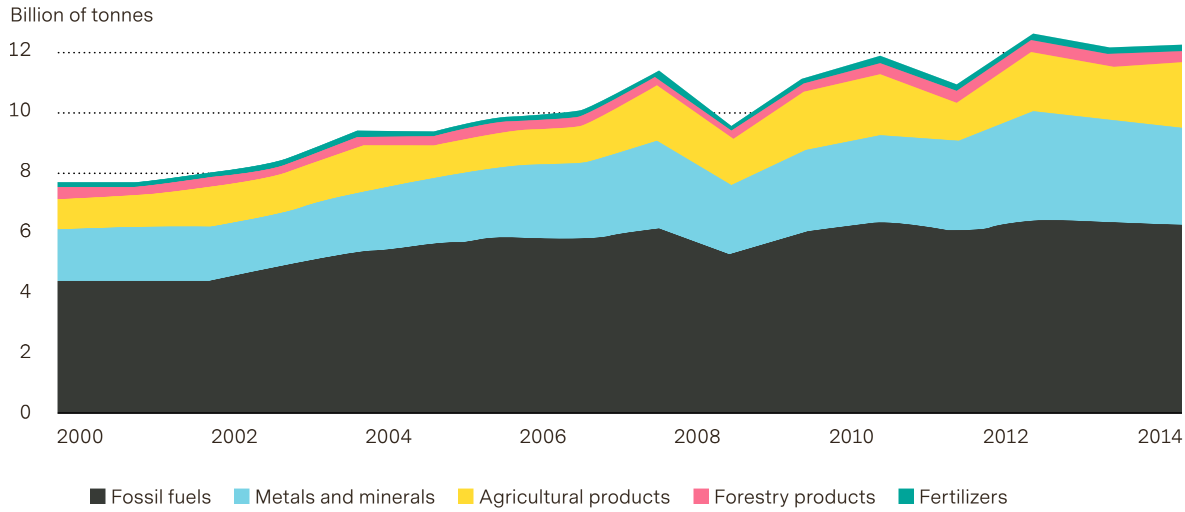
Due to energy's facilitating nature, for example, and the geographic imbalance of resources, it is not a surprise that energy in the form of fossil fuels remains the most heavily traded material (in terms of volumes, see figure 4). Thus, any country that must import a lot of energy is vulnerable from a geopolitical point of view and faces the challenge of securing the energy it requires for its economy and its population and maintaining or developing a capable nation, which includes military and political strength.

This necessitates networking and establishing political alliances to ensure a country is capable of securing future resources. As the Center for a New American Security (CNAS) stated in a report: "The […] access to fossil fuels influences US relations with key supplier nations around the world—Russia, Saudi Arabia, Iran, and major consumer nations such as China." (Parthemore & Rogers 2010, p. 25).

Figure 4 below shows that the second-most traded goods are metals and minerals, which mostly belong to level 2 and 3 of our framework, as they are key to retaining or improving our living standards and for technological aspirations, as well as for national security.

Last but not least, agricultural goods trade is also key when it comes to geopolitics and we need to dig deeper here to filter out which nations are depending substantially on food trade (and on the fertilizers to produce food).

Figure 4: The global economy trades mostly fossil fuels followed by metals and minerals



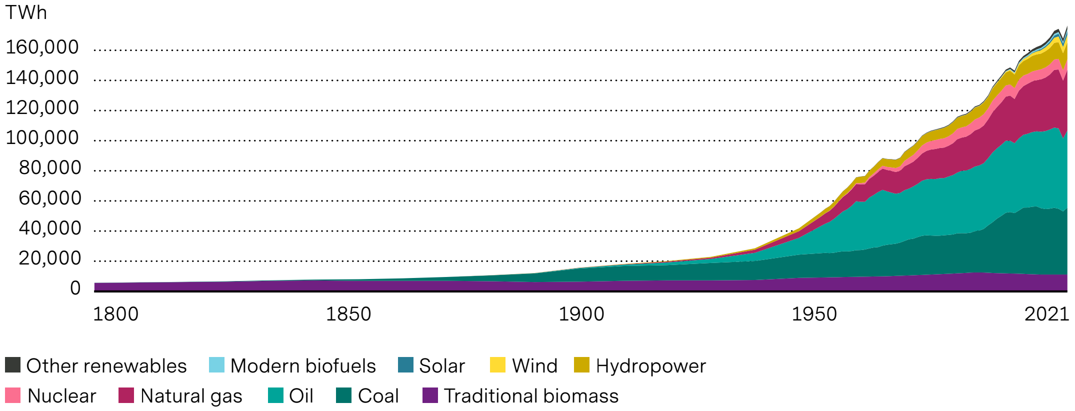
Note: Traded volumes of resources. Source: ResourceTrade.Earth (2023) – Chatham House database.

The geopolitical importance of energy
Take energy, as the most heavily traded material, and let's now consider why it has such a strategic significance from a resource perspective. The 'invention' of energy that does not stem from a muscle is a cornerstone of humankind's emergence: fire being utilized by humans for cooking, heating, and safety, is supposed to have secured our place as the most powerful species on Earth (Gowlett 2016, Harari 2015).

As the example of fire illustrates access to, and control of energy has a strong link to power dynamics. In its simplest form, when used directly, energy provides us with both security and comfort.

Yet there's more to energy than that. It's a so-called 'facilitator' resource and allows us to produce multiple other resources, such as facilitating the smelting of ore into metals and the cracking of stones to produce gravel—one that enables the production of goods and services. This facilitator function of energy underpins our modern world. A turning point was the invention of the steam engine in England at the beginning of the 18th century, which started the industrial revolution (see figure 5) and unleashed a huge increase in global energy usage. As late as 1850, still more than 80% of all useful kinetic energy on the planet came from animal and human muscles (Smil 2022).

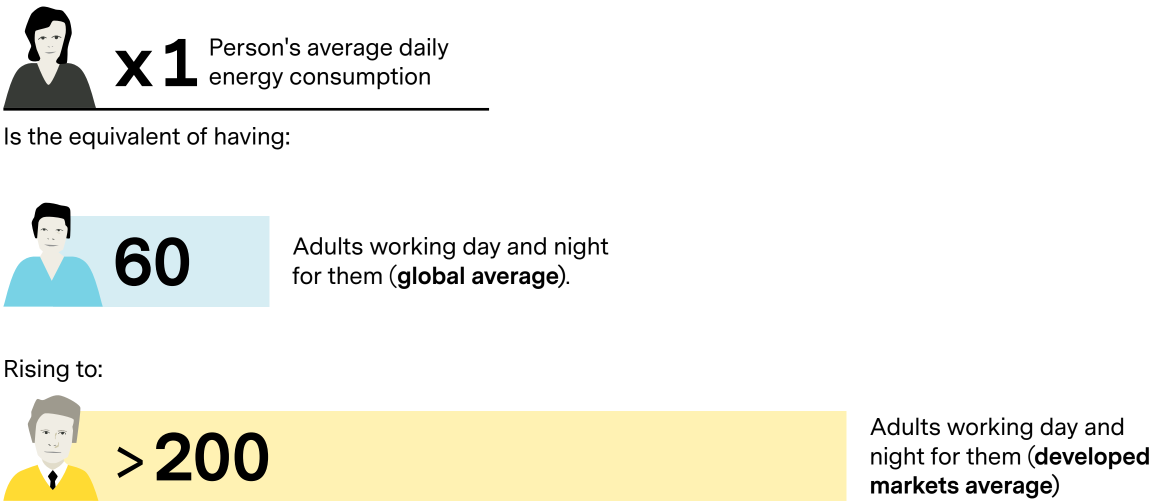
Figure 5: Since the 1850s global primary energy consumption is growing rapidly



Source: Our World in Data based on Vaclav Smil (2017) and BP Statistical Review of World Energy (2023).

> **"Prices [...] of food and fuel, seem to be particularly important [... among ...] other factors identified as predictive of [social] unrest. "**

IMF Study, Barrett & Chen 2021



Today, on an individual level, maintaining the daily lifestyle people are accustomed to, for both work and leisure, requires the constant consumption of energy. A person's average daily energy consumption could be compared to the equivalent of 60 adults working day and night for that person. This comparison even rises to between 200 and 240 for persons in developed countries, as they consume much more energy, and drops to almost one in very low-developed countries, since individuals there typically have no money to spare to consume energy or have only very limited access to energy that does not stem from living muscle power (Smil 2022).

Energy and material consumption to increase further

As the example shows, at a societal level, without enough energy to run the machines we built over the last centuries, today's global economy would collapse immediately and suddenly trigger social unrest and political turmoil. As our discussion of energy makes apparent, resources shape and drive geopolitical considerations. Any scarcity of energy is detrimental to every economy or country today and is still the key material resource focused on in today's geopolitical power game.

But as energy is mostly a facilitator, global demand for the extraction of other raw materials is also important, and this demand seems to be perpetual and, if anything, growing. Figure 1 highlights the demand placed on resources as extraction increases at an accelerated rate.

Why know-how is even more powerful than energy in the long run

So, from a geopolitical point of view, governments continuously attempt to reduce their reliance on other nations' resources. In the case of energy, they aim to achieve energy self-sufficiency. Shifts in energy dependency always represent a significant and influential development in the balance of geopolitical power. The shale oil revolution in the US, which we mentioned earlier, is not only a story about energy but also a reminder of the importance of another facilitator resource that is even more powerful than energy: know-how.

Geopolitics, trade and know-how

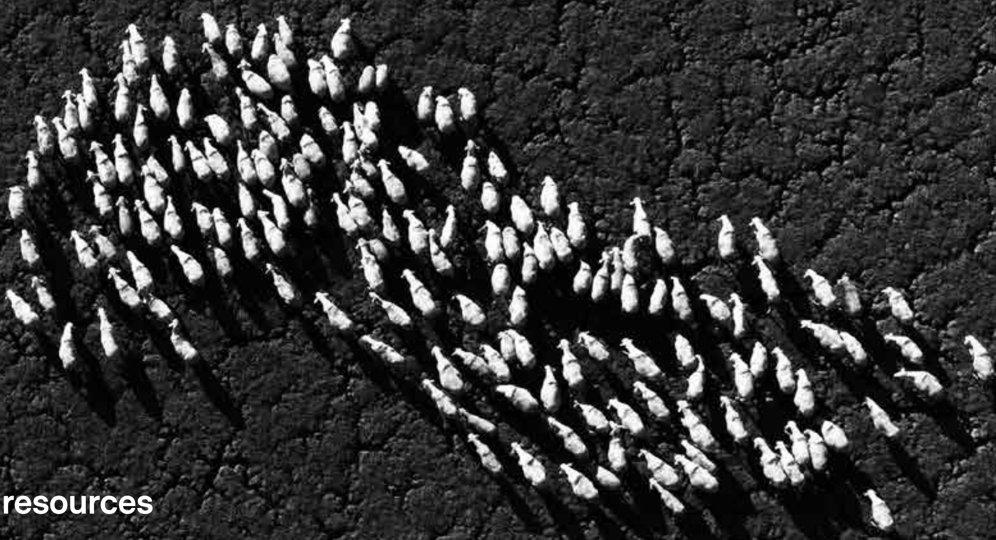
We will explain the importance of 'know-how' as a resource and the shale oil revolution in more detail towards the end of the next chapter, but highlight already the important link between know-how, trade and geopolitics.

Open trade also results in the transfer of know-how and helps to support a peaceful relationship between trading partners, as strong economic ties help to incentivize investments in a peaceful and economically sound relationship (Aslam et al. 2018). For example, if a country D trades with Switzerland, it is exposed to cultural elements that are important to Switzerland—e.g. timeliness and its advantages. Over time, country D is likely to adopt such elements if they can be used for its own advantage. Knowledge improves the way in which two parties trade with each other and share their know-how.

In the next section we delve into the various resources in more detail, guiding us from basic survival requirements to the needs for economic security and the resources needed for geopolitical aspirations.

Where scarcity rules

Understanding the resource spectrum: From essential to life-enhancing.



Trade as the gateway for geopolitics

Level 1: Vital resources

Scarcity in resources needed to survive.
Immediate reaction.

Level 2: Resources for economic security and prosperity

Scarcity in resources needed to maintain economic security and prosperity.
Response time varies from fast to slow.

Level 3: Resources for geopolitical aspirations

Scarcity in resources needed for a country's geopolitical aspirations.
Response time varies from emergencies to long-term strategic moves.

The spectrum of impact
In our geopolitical framework, we focus first on the basic resources required to survive, since any scarcity there would immediately trigger social unrest, domestic and ultimately geopolitical actions.

We put them in a pecking order of fast to less-fast lethality: air (oxygen), water, sunlight, food, shelter (heating). When you run out of oxygen, you die in a couple of minutes, but can normally survive around three days when running out of water. So the pressure to act is highest in the moment of scarcity for air. Fortunately, there is enough oxygen around to survive the next 1000 years plus, even if we burn all the fossil energy carriers on the planet (Smil 2022)—however, we might run into trouble due to polluted air.

Luckily, we are guaranteed even more years with sunlight. The most important source of energy on the planet is not expected to die out over the next billion years but it might shine so hot after the next 500 millions of years, that it would render our Earth uninhabitable (Scudder 2015). What is more pressing in this context is the expected global warming and the resulting migration away from regions that become uninhabitable to those more livable.

Beside these two vital resources, air and sunlight—that thankfully will not disappear over the next 1,000 years plus—water and food scarcities and shelter are the next point of concern, before then focusing on the other energy sources besides the sun. Losing access to these energy resources would virtually cease not only the production of most goods and services but also access to most of the basic resources needed to survive.

Particularly in more highly developed countries, households and firms can only access these basic resources with the help of energy as a facilitator resource. But even with just a tangible reduction in energy supply, standards of living drop almost immediately as people are less able to heat or cool homes, offices, or facilities and cannot prepare or store food.

As outlined earlier, many other materials are important to retaining today's living standards in most parts of the world. We do not focus on plastic, as this seems to be abundantly available but focus instead on minerals and metals. So we have included them in our geopolitical framework as the second set of resources.

Last but not least, special minerals and metals are also of high importance to geopolitical considerations around the globe as they enable key technologies needed for economic advantage as well as for national security and military aims of a country. They are therefore heavily important at the third and last level of resources in our geopolitical framework.

Finally, this section also includes know-how as the resource to rule all the other resources. Simply put, no other resource is useful unless you know how to use it. Know-how always comes first, be it to produce high-tech goods in combination with other highly specialized resources or just to know how to use a matchbox. It comes without saying that know-how has an important geopolitical dimension. We already touched on the example of know-how in form of the shale oil revolution and how it changed the global power balance between the United States and energy exporting countries and we will shed more light on know-how from a resource point of view towards the end of the section.

Vital resource No 1: Water

Water is life. And yet, without the help of natural gravity, water is a resource that is difficult to transport over long distances as we consume so much water on a daily basis.

While bottled drinking water is traded and shipped around the world, agricultural and industrial sectors require significant volumes of water that can only be accessed using pipelines or water canals used to redirect greater amounts of water.[1] These difficulties in trade, together with the geographical importance of lakes, rivers, and underlying water basins, mean that water is a resource that is a geopolitically sensitive subject. Water can trigger fierce conflicts among neighboring countries. Figure 7 displays the transboundary river basins and the current conflict zones due to water disputes.

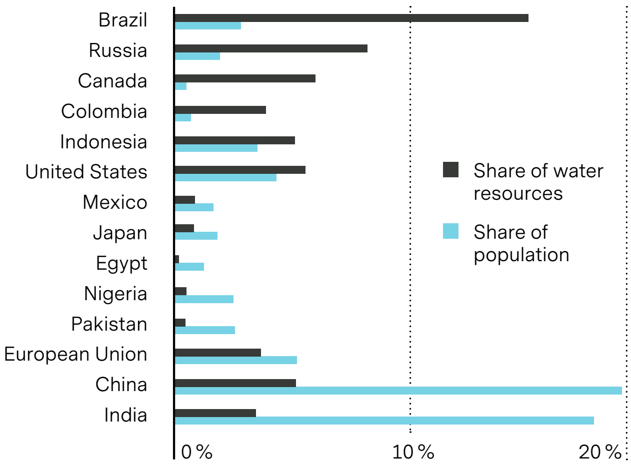
Another consideration is a country's share of the world's population compared with its share of global water resources (see figure 6). This highlights that, apart from the global issue of water scarcity, the distribution of water—regions with an abundant supply versus those that are drier—is a key geopolitical topic.

This is exacerbated by climate change, which appears likely to impact temporal discrepancies between periods of rainfall and dry periods. Spatial differences in rainfall and droughts are also likely to be impacted (Smil 2022 p. 187, Greve et al. 2018).

The most vulnerable regions are West and East Africa, the northern Middle East, and the areas bordering Central, East, and South Asia, according to a United Nations report (UN-FAO 2022). This last region entails potential future water basin conflicts involving globally important powers such as India, Pakistan and China.

Figure 6: Extreme water imbalances in India and China

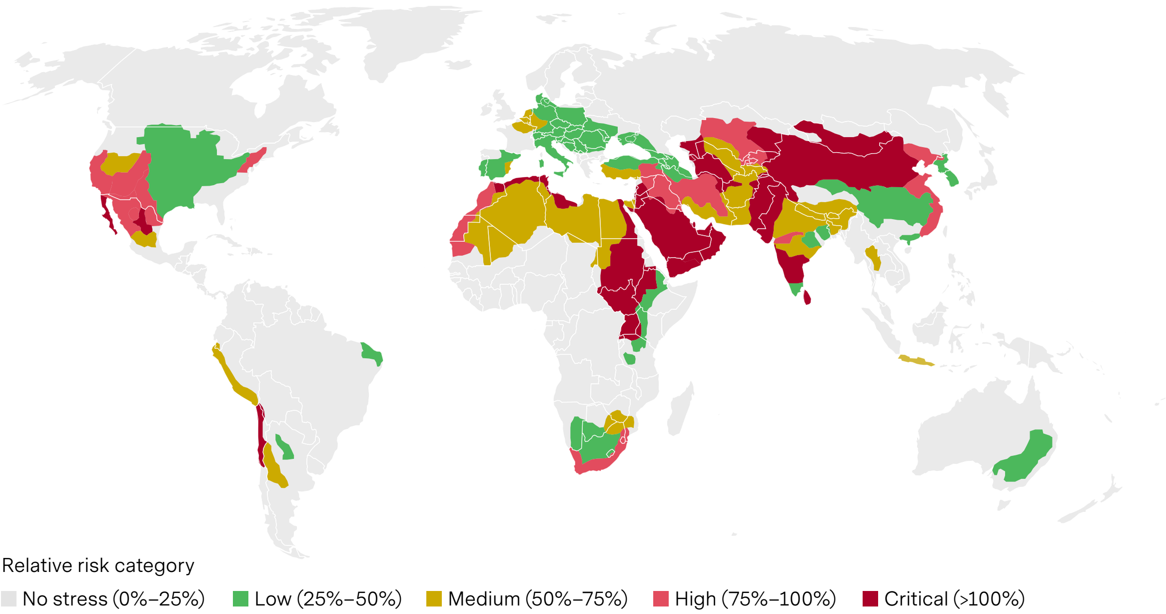
Brazil has the world's largest share of water resources



Source: World Bank data portal (2022), CIA World Fact Book (2020).

Figure 7: Northern Africa, Central Asia and the Middle East are the regions most prone to conflicts due to water scarcity in underlying water basins

Levels of water stress of all sectors by major basin



Source: UN-FAO (2022), Food and Agriculture Organization of the United Nations.

[1]Unless we talk about virtual water, e.g. water that is traded within a certain product (e.g. water used to produce grains that are then exported)—see the paragraph about food).

It appears also that the US has a substantial amount of territory that experiences water scarcity issues. However, most of these regions are within the country, and only a small portion is shared across borders with Mexico, which makes this issue less pressing for the U.S. from a geopolitical point of view.

Europe and the Latin America (LATAM) region seem to be mostly untroubled by such water scarcity issues. This is in line with a simple comparison between a country's share of population and its share of water resources. This also highlights the (problematic) issue of water in India, China, Pakistan, Nigeria, and Egypt and points to the positive situation in the US, Canada, and even more so in LATAM (Brazil), plus Russia as a whole.

Water: The building blocks of our world

Despite water being in abundance on our planet, many parts of the world are experiencing water stress. While 70% of the earth's surface is water, most of this is salt water. In fact, only 2.5% of the planet's water supply is freshwater suitable for agriculture and industry, with pollution rendering an even smaller amount suitable for human consumption.

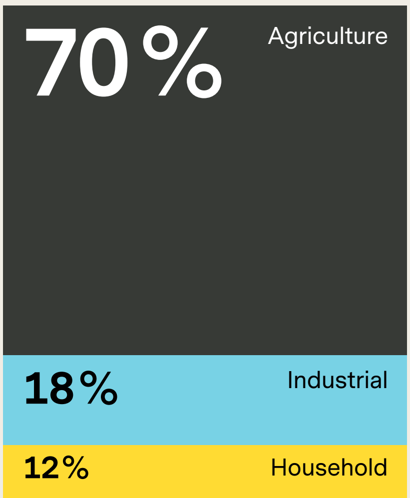
To complicate matters further, only about one-third of the freshwater suitable for human consumption is accessible on the surface or stored in groundwater, amounting to under 1% of the earth's total water resource (USGS 2019). Glaciers and ice caps contain all the remaining freshwater.

Water consumption is indispensable in today's world—we use and require water in every aspect of daily life. Of the world's freshwater, about 70% is used for agriculture, roughly 18% for industrial use, and 12% for domestic (household) consumption (World Bank data portal 2022).

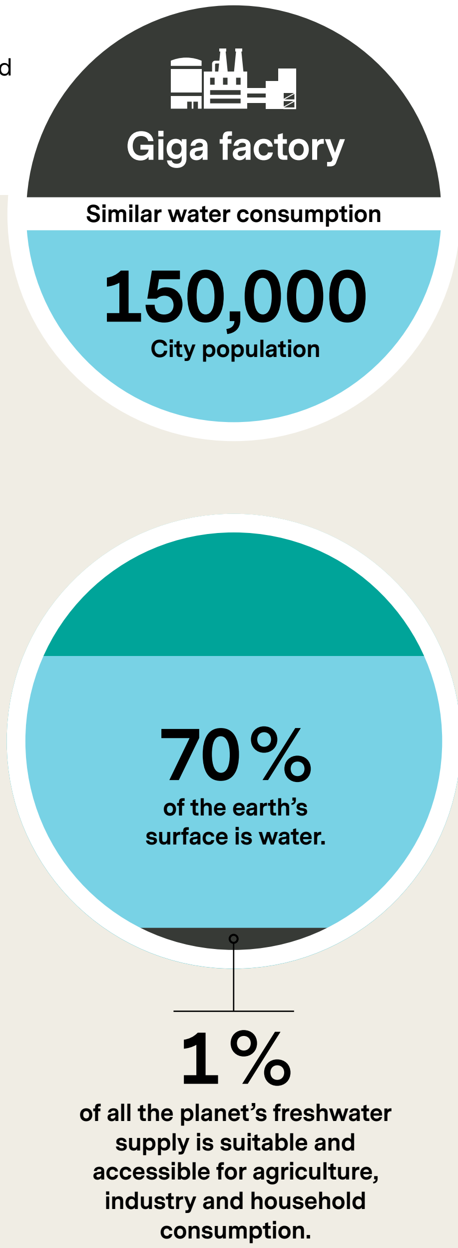
Think of the water required to produce concrete or consumed in semiconductor facilities— without this resource, agriculture, households, offices, and industry cannot function. And we also consume it at huge volumes: semiconductor giga factories consume water at a similar rate to a city with a population of 150,000 or more.

Given the limited supply of freshwater and our current consumption rates, water scarcity is a real issue. A recent study highlights that approximately 3.8 billion people currently experience water scarcity at least one month per year (Boretti & Rosa 2019). The 2018 edition of the UN's World Water Development Report estimates that nearly 6 billion people will suffer from clean water scarcity by 2050.

Global water consumption



Source: UN World Water Report (2018), Coin (2022), United States Geological Service (2019).



Vital resource No 2: Food

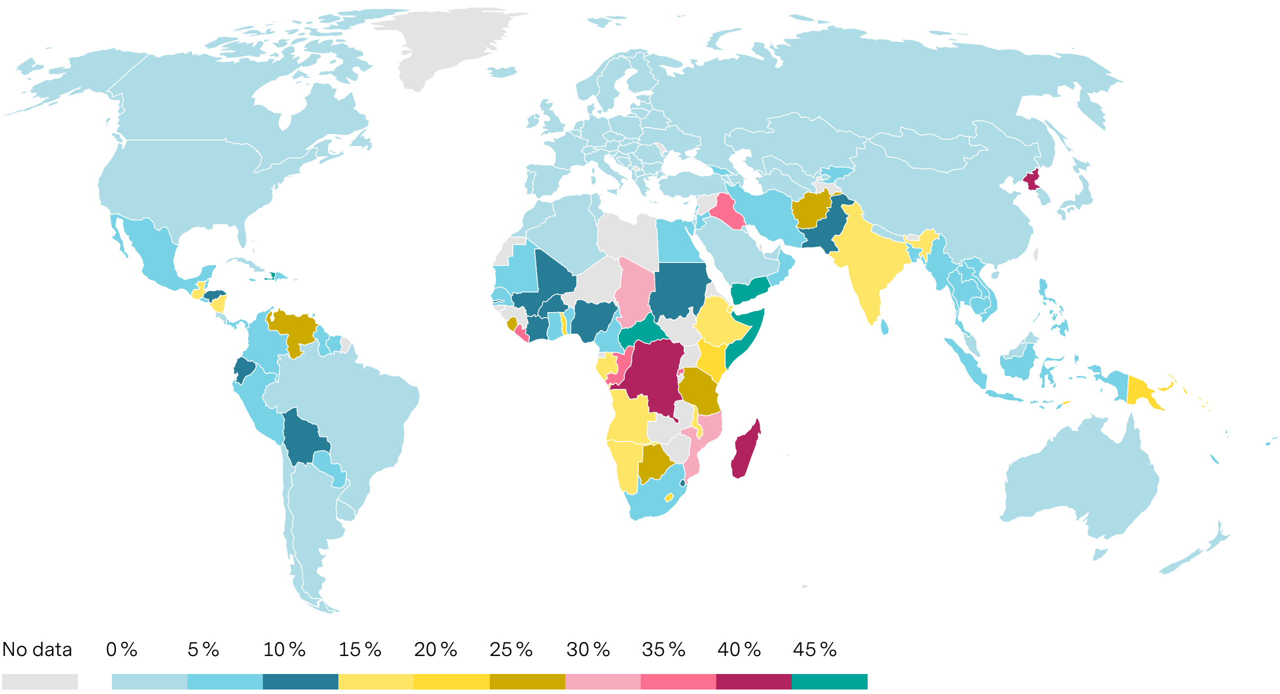
While we've come a long way from our hunter-gatherer era, food remains a significant topic. Taking the scarcity of food, fertilizers, and arable land into account, all scarcities add up to the geographic picture of undernourishment in figure 8.

Undernourished populations are mostly found in Africa, the Middle East, and East and Southeast Asia. Figure 8 also highlights India, Pakistan, and a lower proportion in Indonesia (approximately 6.5% of the population) as being subject to underfeeding. Mexico and several other western LATAM countries also partially exhibit dire levels of undernutrition, most prominently Venezuela (over 25% of its population).

On the other side are China, the US, and Europe, where less than 2.5% or even virtually zero percent of the population is undernourished. When we focus on food dependency, a similar picture in Africa and India emerges, but it's also clear that the Middle East is heavily dependent on food imports. In addition, parts of Europe and China import a substantial amount of their nutrition from foreign countries. Canada, the US, Russia as well as Brazil and Argentina are net exporters of food (see figure 9). The regions with an elevated degradation of land are in many parts of the globe congruent to regions with high water stress and food dependence (Coppus 2022).

Figure 8: Share of the population that is undernourished is highest in Africa, Southern and Western Asia

Share of individuals that have a daily food intake that is insufficient to provide the amount of dietary energy required to maintain a normal, active, and healthy life

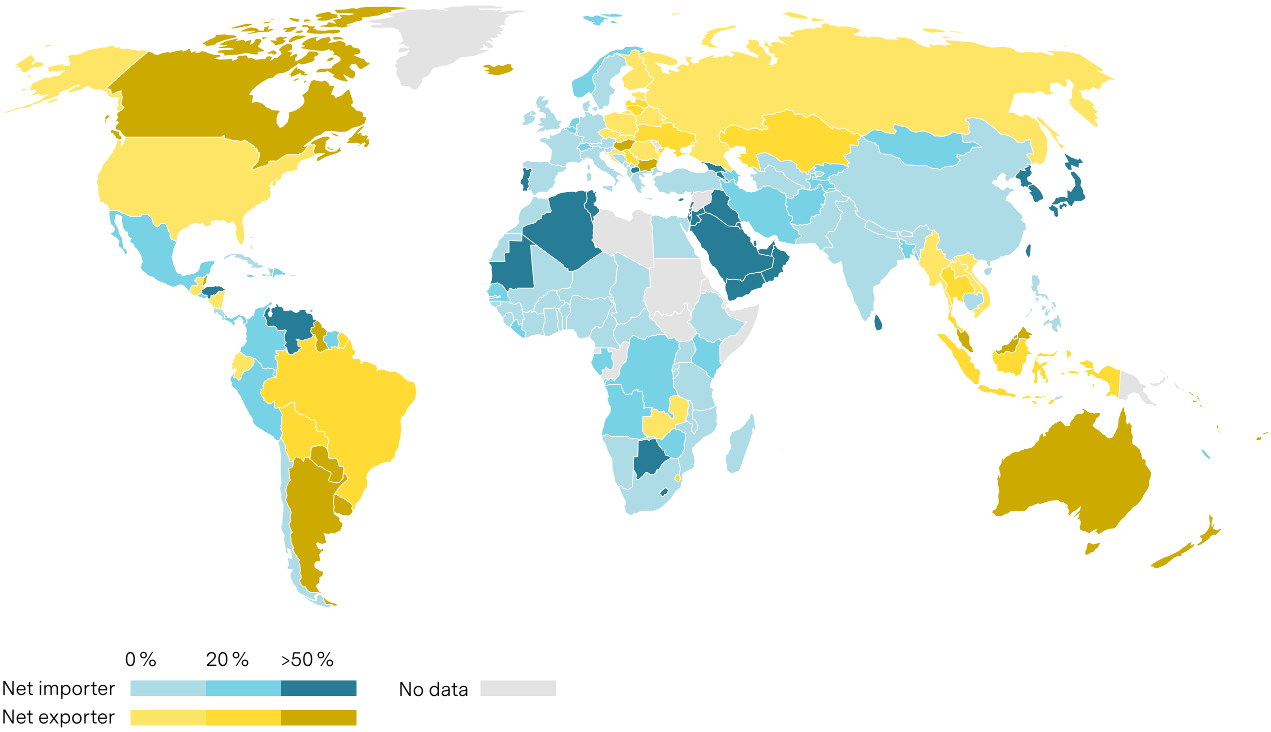


Source: IHME, Global Burden of Disease (2019)

More than 40% of the world's population could not be fed today without synthetic fertilizers.

Erisman et al. 2008, Smil 2022

Figure 9: Food dependence is highest in Africa, the Middle East, Japan and Korea
Trade as share of domestic food supply



Source: FAO (2018).

Fertilizer: Food's critical engine of growth
To achieve the enormous increase in crop yields, today's agriculture requires synthetic fertilizers, and estimates suggest that more than 40% of the world's population could not be fed today without these fertilizers. (Erisman et al. 2008, Smil 2002).

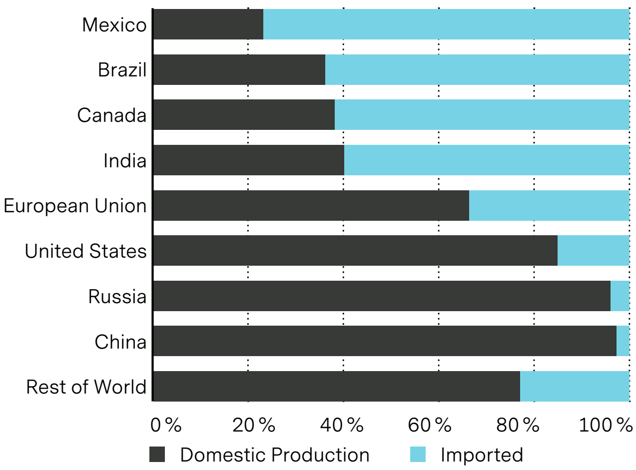
So, our dependence on fertilizer is crucial for today's food production. Figure 9 shows that several big exporters of food, such as Brazil or Canada, (compare to Figure 10) are strongly dependent on fertilizer imports.

The global share of most of the key ingredients required for today's agricultural fertilizers is regionally concentrated; Russia, Canada, the EU, China, and Belarus provide over 60% of total global exports (see figure 11).

The geographic concentrations of main ingredients, such as potassium and phosphorus, are more pronounced. For example, Canada is responsible for 35% of potassium exports, and China and Morocco account for 20% each of phosphorus exports. Morocco possesses more than 80% of phosphate reserves, the raw material to produce phosphorus fertilizer (USGS 2022).

To circle back to our special resource, energy, it also plays a key role in food production.

Figure 10: Share of imported and domestic produced fertilizer by country, 2019



Source: FAO (2022).

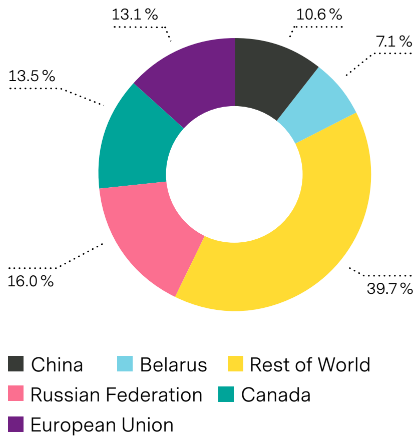
In relation to fertilizers, the IEA estimates (IEA 2021, Roadmap to Sustainable Ammonia) that the production of ammonia accounts for approximately 2 % of global total final energy consumption, virtually all of it from fossil fuels. The production of ammonia as a base material for nitrogen fertilizers, requires high temperatures in a reactor to trigger certain chemical processes. This is in addition to energy consumption in the agricultural sector, which amounts to approximately 4 % of global energy consumption either as a direct input or to facilitate work required on fields, farms, and barns.

The US Agricultural Department estimates that approximately 2 / 5 of total (indirect) energy input in the agricultural sector is from fertilizers and pesticides, and only 3 / 5 of inputs come from all the other actual work on farms.

Considering another side of food use, cooking represents a clear direct use of energy; the European Statistical Office (Eurostat) estimates that households require approximately 6 % of their total energy consumption for cooking.

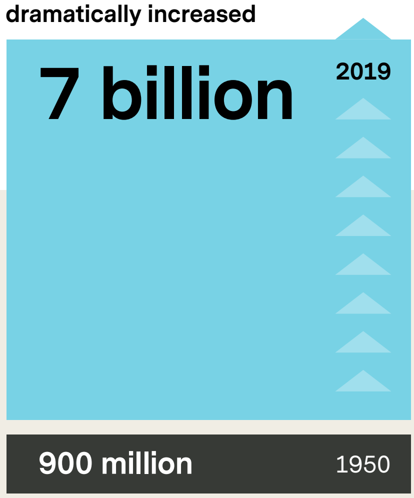
Additionally, more than 10 % of energy use relates to food storage for cooling (refrigerator and freezer use). Of course, if necessary, a typical household in a developed country could significantly reduce energy consumption by changing its diet and cooking habits. However, this discussion lies outside the scope of the current analysis. Nevertheless, it becomes clear how much the production and preparation of food relies on energy inputs.

Figure 11: Russia hast the highest share of global fertilizer exports



Source: US Foreign Agricultural Service (2022), 2017–2019 average

World food supply has dramatically increased



Food: The building blocks of our world

Food production requires other resources, including air (oxygen), soil, water, fertilizer, and both natural and manmade energy. As discussed earlier; the planet has enough oxygen and sun, at least for the next thousand years or more, and while water is a crucial resource, the global distribution of it—from wet to dry regions—is more important than the issue of global scarcity.

Improving efficiency
Additionally, it is encouraging to note that rates of water withdrawal in most developed and more developed emerging market countries remain constant even as the production of crop yield increases. This is because of the improving efficiency of agricultural water usage.

Furthermore, the types of crops that are employed require less water on average (see for example: USDA 2022).

The same can be said for the use of soil per crop. According to the History Database of the Global Environment (University of Utrecht and the PBL of the Netherlands), land use per person has significantly declined since the beginning of the 20th century.

As a result, arable land does not appear to be scarce on a global scale, despite significant population growth—due to strong technological progress. According to the UN food and Agricultural Organization (FAO) in 1950, the world was able to adequately supply food to about 900 million people. In 2019 that number was almost eightfold higher (FAO 2020): 7 billion!

Despite these positive developments, the degradation of land will remain a problem for certain countries and regions that already suffer water stress and have an elevated dependance on external supplies of food like India or parts of Africa, China and the Middle East (Coppus 2022).

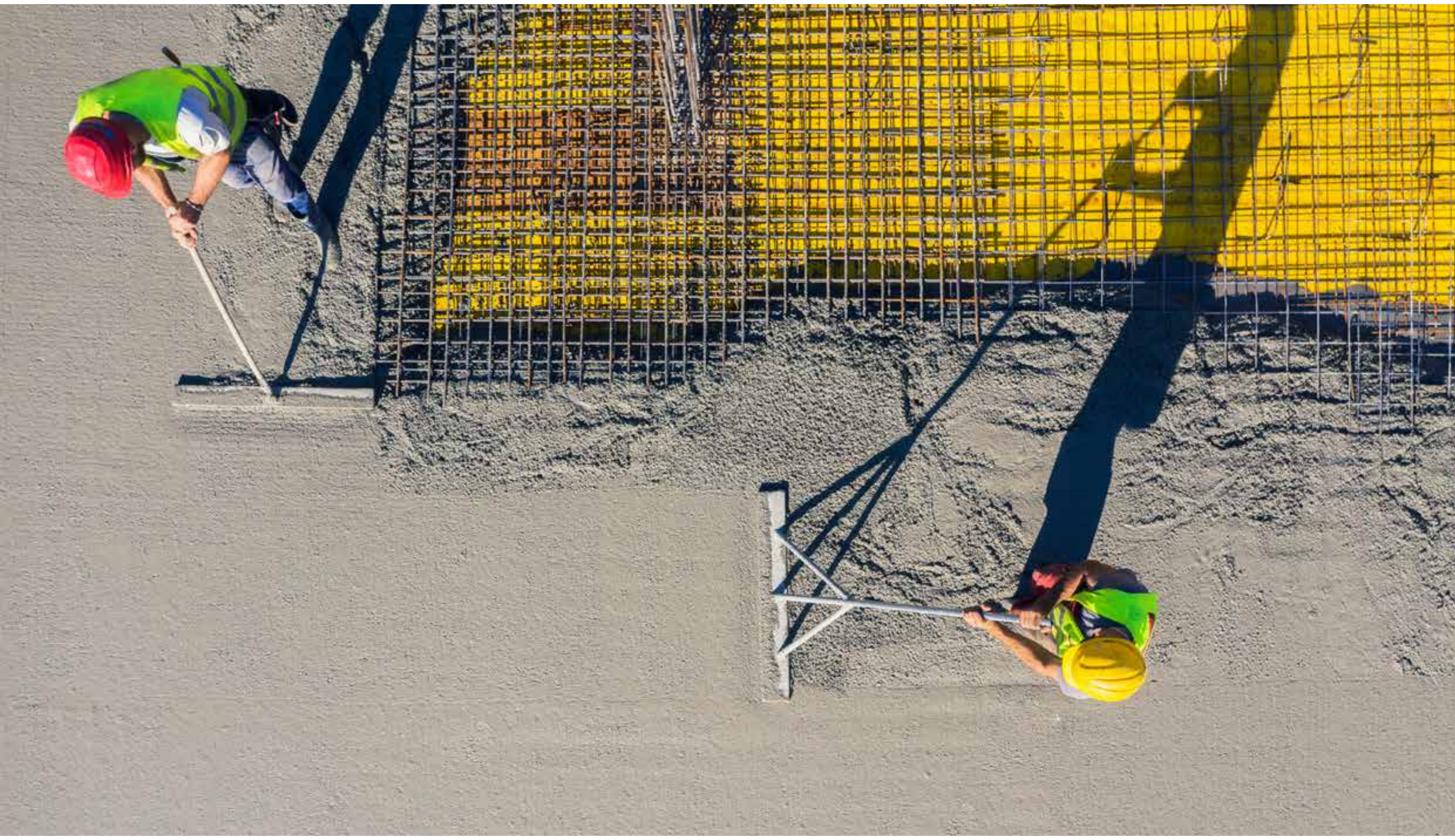
Vital resource No 3: Shelter and heating

Another clear direct use of energy, essential for survival, lies in the basic need to heat and cool our homes and places of work. This accounts for roughly 40 – 60 % of total household energy consumption in developed nations. However, these patterns can be very different across countries. In the EU, heating accounts for more than 60 % of total final energy consumption in the residential sector, but cooling only about 1 %, while in the US heating only uses about 30 % and cooling more than 10 % (see Eurostat 2022, EIA 2021).

The International Energy Association estimates that today, the residential sector accounts for roughly 20 % of total global energy consumption and the heating of residential space, about 11 % (IEA 2021).

In a vast majority of areas that actually have a mild climate, humans are still dependent on heating and shelter. But, the habitable area of the planet suitable for humans, is quite a narrow band around the globe with an annual average temperature of 11 to 15 degrees Celsius, which stretches from the US to Europe and smaller parts of central Asia to China. Countries outside this temperature range tend to have a high energy requirement, either for cooling or heating purposes, so a high dependency on energy becomes evident. (Xu et al. 2019).

Multiple resources are required in today's construction sector. A report on global material use estimates that of all sectors, housing has the highest material footprint— about 40 gigatons (one gigaton is equal to one billion tons) per year (Circle Economy 2022). According to an OECD report, the heavyweights among construction materials are quarry materials used mostly in concrete (sand, gravel, crushed rocks) and limestone (also used in the production of concrete) which seem not be subject to scarcity (OECD 2018).



In today's developed economies, concrete (primarily made of sand and cement) is the most widely used material, making up approximately 80% of total material weight. Metals (primarily steel) mostly account for less than 5% of total material weight in an average modern building (Griffiths et al. 2003, Crow 2008).

As is the case for food and fertilizers; steel, aluminum, and cement production require a substantial amount of energy within the construction sector. They add around 4% of the total contribution of 30% by the construction sector towards total global energy consumption and have a significant influence on price movements that occur in construction materials (IEA 2022a). Hence, it seems that the scarce factor in shelter and heating is energy rather than most of the raw construction materials itself. Of course, as we will see later in the section on minerals and metals, certain materials like aluminum could become scarce for shelter construction, but substitution is in most cases possible.

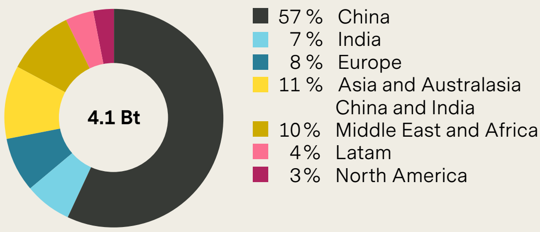
Shelter and heating: The building blocks of our world

Concrete: The hidden essential
Resources required to build shelters appear to be readily available when there is access to cement, water, and wood, together with the know-how for construction. The base element, cement, can be produced and shipped to any region if it can be used with water to create concrete. However, this is only valid if energy is available at a low price, given that cement production is very energy-intensive, like steel and aluminum.

Looking at global demand and production of cement, it is evident that China is by far the biggest consumer and producer, with more than 55% of global demand and supply (see figure 12). Because the materials required to produce cement are not scarce, it is more important to focus on energy as a resource in the areas of shelter and heating.

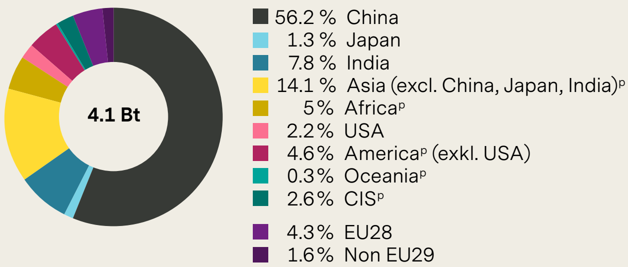
China produces more than 50% of global concrete while the second largest producer, India, produces 7%. China's demand for cement amounts to nearly 60% of that resource while demand from India and Europe is 7 to 8% (see figure 12; Cembureau 2019, 2020; International Cement Review 2022). Wood in most parts of the world, is not a scarce resource. We will look at scarcity in steel and iron ore (as a base material) below, under minerals.

Figure 12: China has by far the hightest cement demand



... and China has by far the hightest cement production

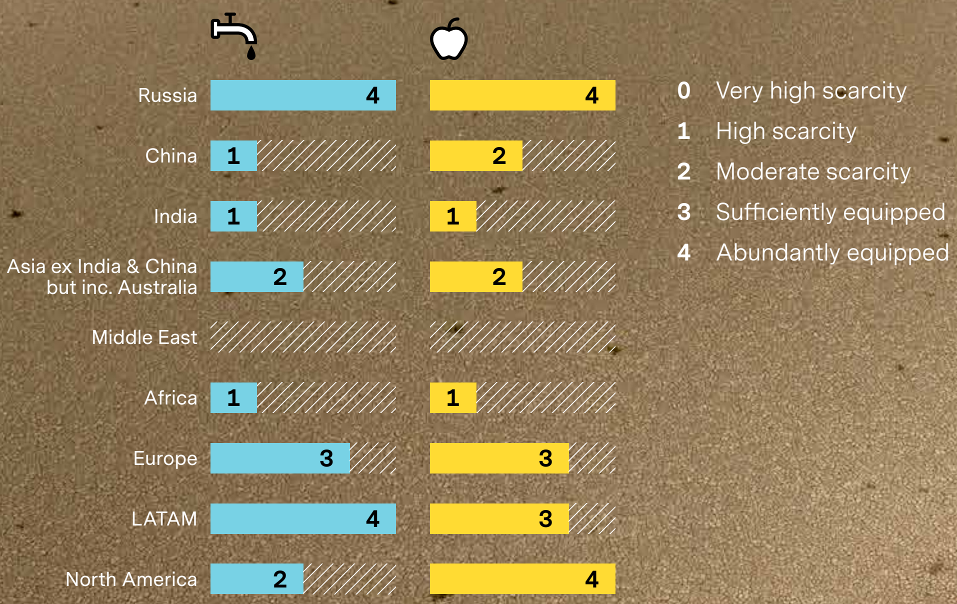
by region and main countries, % Estimations



Source: Cembureau (2019, 2020); International Cement Review (2022).

Level 1: Vital resources

Basic resource scarcities boil down to this simple chart, where we see that geopolitical heavyweights like India and China but also the Middle East and Africa exhibit quite some scarcity issues.



The facilitator resource—from basic to life-enhancing: Energy

Energy, our prime example as a universally crucial resource, directly fulfills a basic survival need; it's impossible to heat and to survive without it in the winter season in many parts of the world. Of course, the need for heating energy crucially depends on how isolated you are from the climatic environment around you; hence, shelter is a closely related kind of resource here.

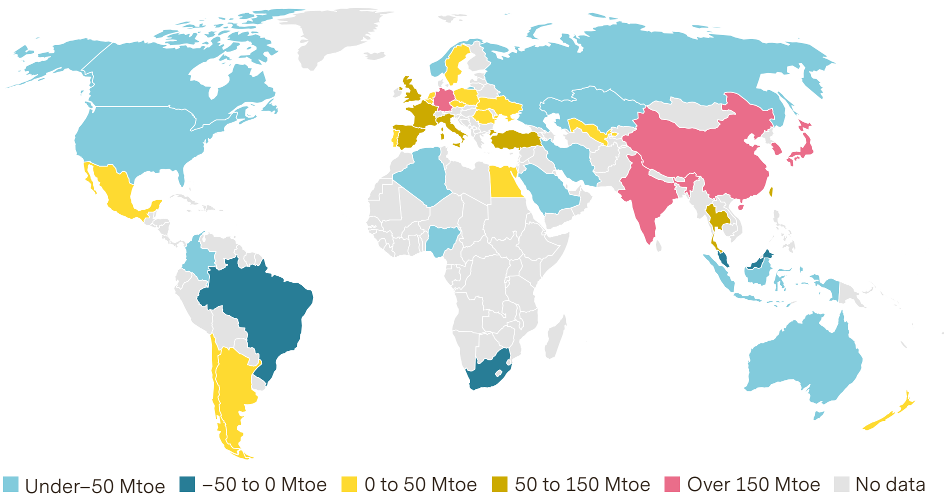
When also taking the indirect use of energy (as an enabler resource, see also the text box on energy) into account, Russia's invasion of Ukraine is a tragic reminder, especially for Europeans, that our overall dependence on energy can be a curse. This explains why achieving energy independence is so important in a geopolitical sense (EEA 2020, IRENA 2022).

For countries with more extreme climates global warming will have the greatest impact. These countries tend to have a high energy requirement, either for cooling or heating purposes, so a high dependency on energy is evident, and the issue of scarcity will be especially pertinent. Furthermore, these regions tend also to face the most challenges in regard to droughts, severe snowfall, and the effects of too much or too little precipitation on agriculture.

According to a recent study, the band of regions with milder climates will shift further north, while large parts of Africa and LATAM, but also in the Middle East and East Asia, will become even less suitable for humans as temperatures rise, creating annual average temperatures of 30 degrees and above (Xu et al. 2019).

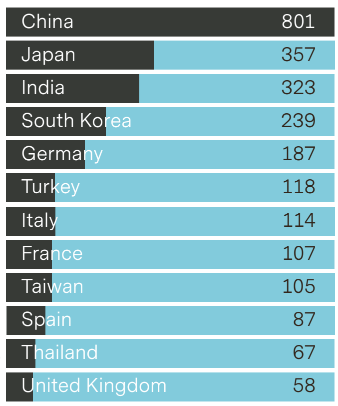
Figure 13: China, Japan, India, and South Korea are heavy energy importers, while Russia and Canda, Australia and the US are net exporters

Energy trade balance, in million tonnes of oil equivalent, Mtoe



Source: USGS 2022, UN Comtrade database (2022).

China imports much more energy than it exports



The primacy of energy
All net energy-importing nations need to constantly ensure that their access to the supply of energy is guaranteed for households, industry, and service sectors. China, Japan, India, South Korea, and Europe are net energy importers and are therefore heavily reliant on energy from other parts of the world (see figure 13).

Energy heavyweights such as Russia, the Middle East, several Latin American countries, Canada, and the US are net energy exporters. This picture is confirmed by looking at proven oil and energy reserves. In this regard, Europe appears to be in an even more vulnerable position.

This underpins the importance of the technological revolution in shale oil and gas production that saw the US become a net exporter of energy just before 2020, as discussed on page 31. This has not occurred in the EU, and as a result, it has opted to reduce energy dependency by increasing its share of renewable energy (Dobreva & Wilson 2019).

Unfortunately, the Russian invasion of Ukraine has hampered these ambitions, exposing Europe's energy dependency and endangering living standards through surging energy prices and supply restrictions for households and industry (European Commission 2022). At this stage, the discussion moves on to the topic of how such investment initiatives, following the warning to citizens and politicians, especially in Europe, can change the global power balance of the geopolitical quest for resources.

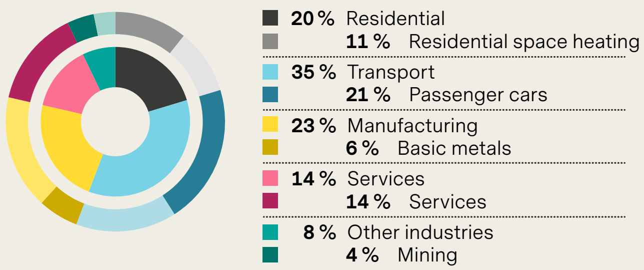
People have seen their living standards threatened, and politicians realize their positions as leaders are jeopardized.

Energy: The building blocks of our world

Energy is a fascinating resource that can be used both directly and indirectly. Examples of direct use include room heating, with approximately 11% of developed world energy consumption being used for residential heating and 6–8% being used for heating commercial and public spaces (see figure 14).

Given that the developed world consumes the most energy, these statistics reveal that the majority of energy consumption occurs indirectly, with energy being used as a facilitator resource to enable the production of goods and services. Examples of indirect energy consumption include its facilitation of transporting goods and people, the melting of ore and the processing of it into iron, or the production of nitrogen fertilizer out of ammonium (see food section pages 18-20).

Figure 14: Residential sector ranks third in terms of final energy consumption
Largest end uses of energy by sector in selected IEA countries, 2019



Source: IEA (2021b).

Economic security and fulfilling geopolitical aspirations: Minerals and metals

What resources do we need to produce all the engines, instruments, and vehicles to feed the world but also to reside, to drive, or, simply put, to live our daily lives? In a geopolitical sense, the question boils down to the following: Who extracts all the minerals and metals needed in today's economy and who consumes them?

A divergence of dependence
Focusing on the most traded resources, figure 4 highlighted that traded volumes (weight) are highest for fossil fuels—energy, which we just discussed—followed by metals and minerals, which makes them sensitive to global trade disruptions.

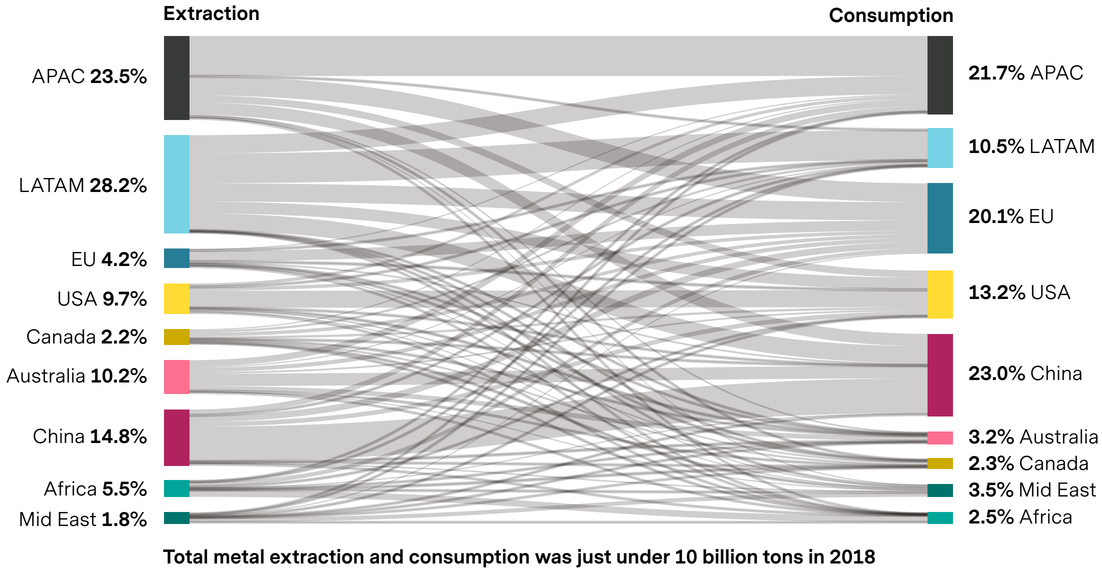
A comparison of the amount of extracted materials on the planet shows that the most extracted materials are not traded the most, as the majority of heavy construction materials—primarily sand, stones, gravel—are extracted and consumed locally. These construction materials are the major part of the 50 gigatons of non-metallic minerals, which are annually extracted from the planet, but which only account for approximately 1 gigatons in global trade weight.

For metals, the picture looks different. Here, although only 10 gigatons of metals are extracted, approximately 3 gigatons are globally traded, highlighting that metals are a significantly more geopolitically sensitive element within this group of materials since the traded share is much higher.

This becomes more apparent when considering the strong spatial imbalance between extracting regions and regions of consumption and processing of metals (see figure 15).

Here, the often highly concentrated deposits of metals in certain regions (including the strong resistance against any exploration and mining in most developed countries due to environmental and health reasons) and the advanced processing capacities or significant demand in other countries create an important interconnected global trade system. The EU for example, is more dependent than other regions on the external supply of metals to meet its demand, as it only extracts a small fraction relative to its consumption (see figure 15).

Figure 15: EU consumes more than the US but extracts far less metals



Note: APAC (Asia Pacific Region) is ex China and Australia, LATAM is Latin America. Source: Giljum and Lutter 2018.

Other countries such as the USA and China produce or extract almost half of their total metals consumption locally. The APAC and LATAM regions, Australia and Africa consume substantially less than the amount extracted locally. Hence, they perform an important role supplying these materials to other regions or countries, helping them meet their demand for the consumption of metals.

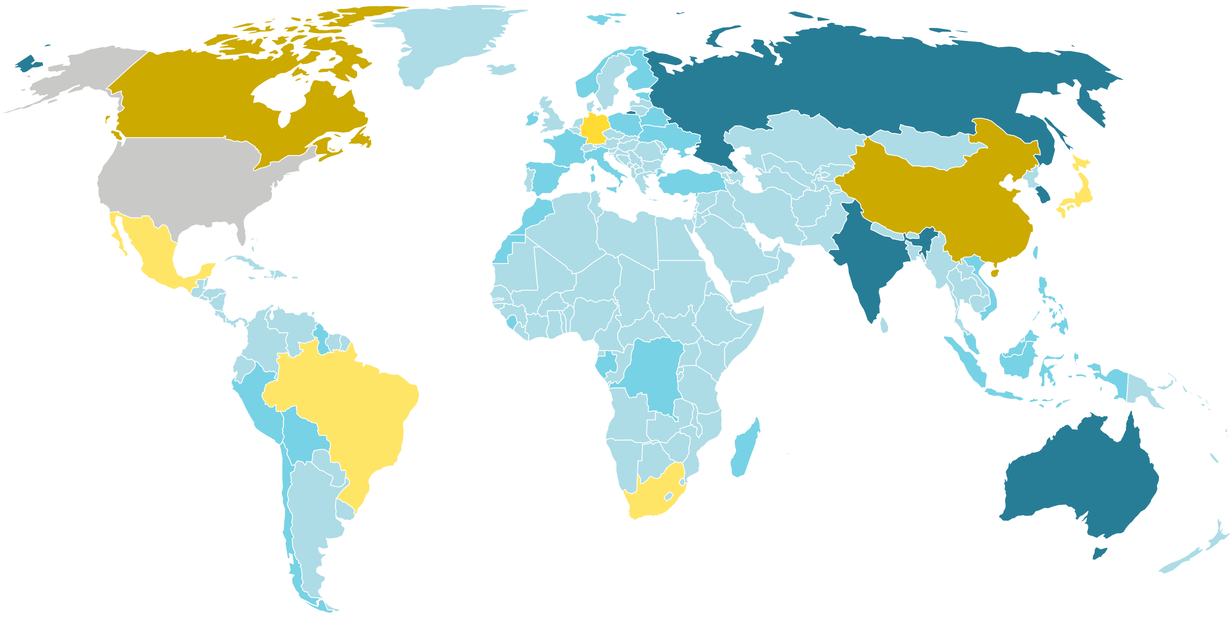
The importance of metals

The critical nature of the global trade in metals is evident when considering a list of essential raw materials required by the region that is most dependent on them—Europe. Twenty-three of the thirty names in the EU's critical raw material list for its strategic sectors and technologies are metals or metallic elements (e.g. rare earth elements) (European Commission 2020).

Similarly, in the essential minerals list relevant to the US, which entails 50 elements (or groups of elements), only two of the essential elements listed are neither a metal nor metallic element. This highlights the importance of geopolitics in the global trade in metals. The geographic position of exporters of these essential metals gives rise to the strongly dependent relationship the EU and the USA have with specific trading partners—first and foremost China and South Africa, including Canada, Brazil, and the DRC (see figure 16). The world will require more of these metals if the Green Energy Revolution takes off, which we will discuss in the next chapter.

Figure 16: The US is strongly dependent on China's supply of several critical minerals

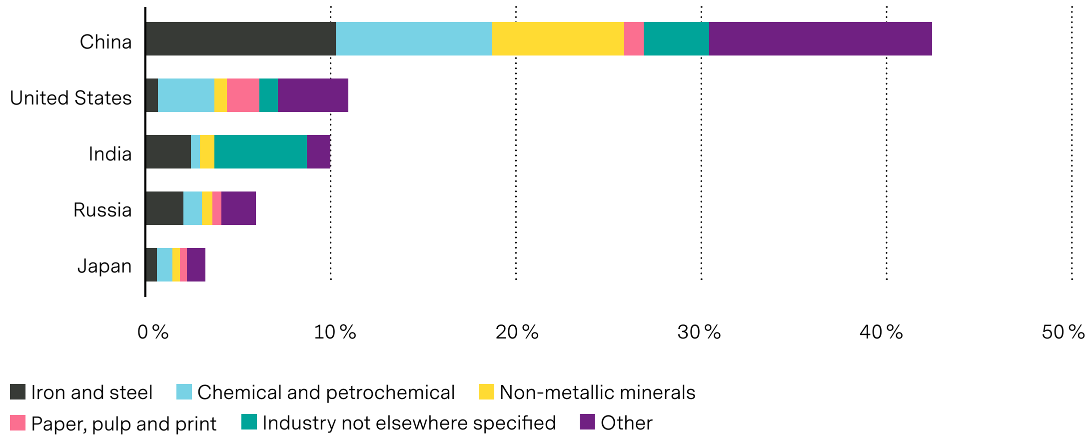
Numbers indicate how many critical metals and minerals a country supplies to the US



Source: USGS 2021 (US minerals net impot reliance in 2020).

Iron and steel (based on iron ore) are produced in greater amounts than any other metal, with an annual production of approximately 3 billion tonnes per annum. This is followed by aluminum, with only approximately 0.06 billion tonnes (USGS 2022). The volume of production in the iron and steel industry also highlights the fact that this sector is among the world's biggest energy consumers. China is the largest producer of iron and steel, and energy consumption in this subsector amounts to 10 % of the country's total amount (see figure 17).

Figure 17: Energy consumption by industry sub-sector of top five countries to total final domestic consumption



Source: IEA (2021b).

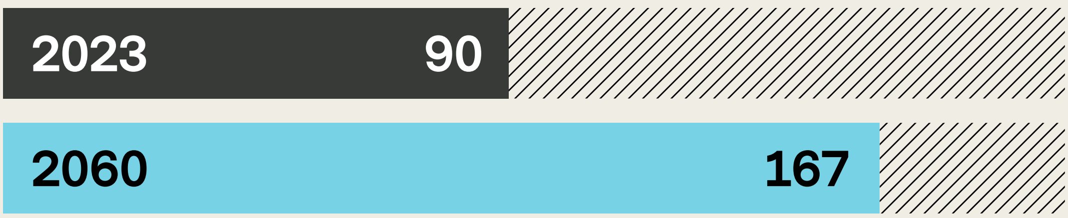
Materials: The building blocks of our world

Global material extraction is on the rise
Having increased almost tenfold in weight since the 20th century, today more than 90 gigatons (one gigaton is equal to one billion tons) of materials are extracted per year and this is expected to reach above 150 gigatons in 2050, according to the UN and OECD (see figure 4). This enormous surge in extraction is expected to continue at an unabated pace, with scarce materials set to remain an important topic for years to come.

Of these materials, the vast majority, approximately 50 gigatons, are non-metallic minerals such as the sand, stones, and clay used commonly for construction (see figure 17 and the earlier discussion on shelter and construction).

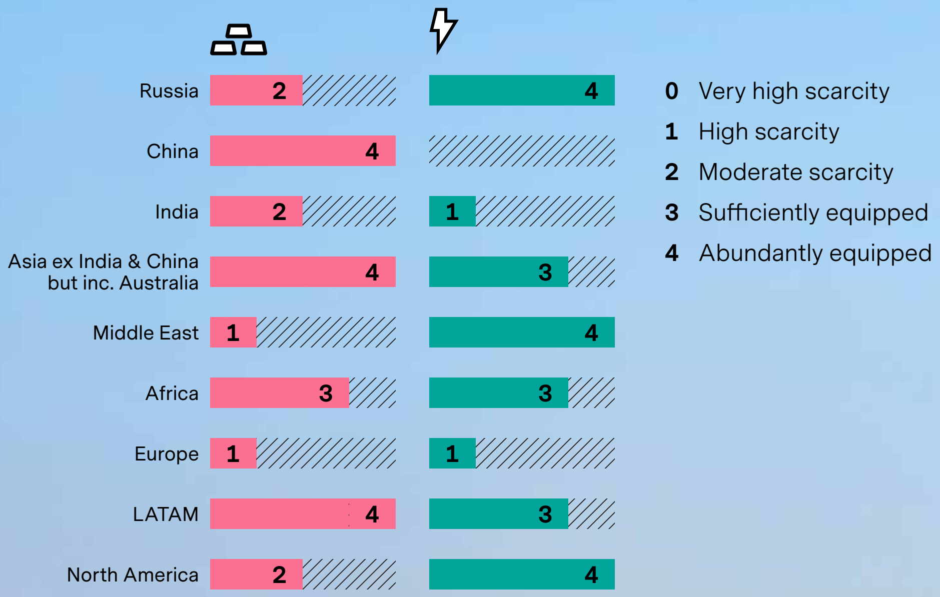
Metallic minerals (ores), fossil fuels and biomass resources make up the remaining half of the entire material world (Circle Economy 2022). Weighing in at only 10 gigatons, metallic minerals account for a smaller amount of extracted materials but are of critical importance, used in construction but mainly relied upon for the communications sector (lines, IT systems, servers, phones) and in mobility (machines, cars, ships, turbines). We have already discussed extracted biomass (about 25 gigatons) in the food (agriculture), shelter and heating (wood) segments and will look at fossil fuels (about 15.1 gigatons) in the discussion on energy.

Gigatons of materials extracted per year (estimated by OECD, 2018)



Level 2: Resources for economic security and prosperity

For our second set of resources—that span from those ensuring economic security and prosperity and, on a next level (3), to fulfilling geopolitical aspirations—we see that in terms of scarcity in critical minerals and metals and energy, Asia ex China and India but including Australia is doing best, while among the geopolitical heavyweights, the US and Russia rank before China. The latter is scarce of energy but rich in metals while the Middle East has the opposite set-up. Europe and India rank last in this view.



The ultimate geopolitical resource: Know-how

One resource to rule them all
The importance of know-how as a resource lies in the fact that it enables the use of all resources. It is also the resource that improves the use of other resources or leads to the creation of a new resource through technological innovation in combination of other resources.

Know-how is the resource that allows all other resources to become more or less important over time, to become scarce or abundant, and can even let them oscillate from one extreme to the other.

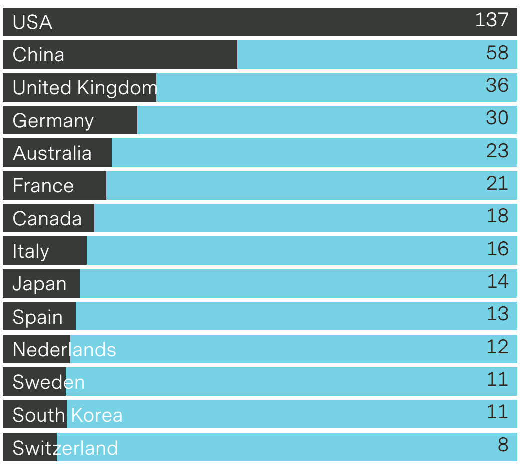
Know-how should not be considered a synonym for technology. The latter represents the interplay between know-how and other resources that create technological innovation. Therefore, know-how is a facilitator resource that enables the use of all other resources. Thus, know-how is the most important resource; it determines the scarcity of all resources based on its capacity to make resource utilization more efficient or even invent new resources.

We can think of the invention of petrol-driven lamps and later engines and the rise of the Middle East's strategic importance in the second half of the last century, which led to the energy-driven geopolitical strategy of the US and many other countries (see, e.g. Parthermore & Rogers 2010).

Measuring the availability, production, and consumption of know-how is difficult. However, it is possible to use certain broad indicators to gauge the availability or the supply a country has of the resource know-how.

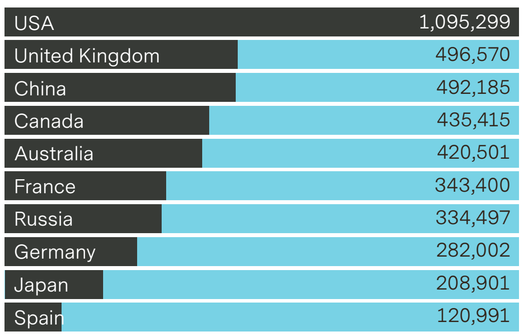
Education, research, and innovation are used around the globe as proxies for know-how. The US and Europe lead in terms of academic education and research. China, relative to its population, remains behind the US and Europe, but is catching up. The number of top 500 universities in the Shanghai International Universities Ranking, highlights a dominance of US institutions—137 out of the 500 in the US, followed by China with 58, the UK with 36 and Germany with 30 (see figure 18). Similarly, the US and Europe attract significantly more international students, reinforcing their appeal as knowledge hubs, while China currently attracts half the number of foreign students as the US (figure 19).

Figure 18: US dominates the Shanghai ranking for the 500 best universities globally



Source: Shanghai University Ranking (2022).

Figure 19: The US also hosts the highest number of foreign students within one country, but Europe leads as a region



Source: Project Atlas (2019), Institute of International Education.

Patents
In terms of another proxy for know-how—actual patent applications per residents—China is catching up with the US and has overtaken Germany. Japan and South Korea are still world leaders, with 2,000 or even 3,000 patents per one million people. Yet, this is a very rough approximation of the current distribution of know-how on the planet.

To detect more of the underlying factors in know-how, one must explore deeper. For example, China leads in the number of patent applications in the raw materials sector—four times as many applications (10,099) as Japan in 2020 and compared to approximately 2,500 applications in 2016 (European Commission 2021). This explains why China has not only built a strong ecosystem to lead the global production of important metals but also why it annually produces three times as many patents for the production and manufacturing of metals as any other nation.

That said, patent numbers may be misleading, as there are several indications that non-economic incentives in China distort the numbers. A higher number of Chinese patents seems to be associated with lower quality and poorer usage of the patent: while more than 1.6 million applications were released in China, several studies state that the quality of Chinese patents is between half and one-third of US or European patents, which would balance China's high patent numbers out with the US ones (Song & Li 2014, Boeing & Mueller 2019, Santacreu & Zhu 2018). Similarly, the Global Innovation index by the World Intellectual Property Organization (WIPO 2022a) ranks the US and 7 European countries among the top ten most innovative countries. China was ranked 11 in this index in 2022.

Applying the proxies for know-how as a resource (see figures 18, 19 and 21), it appears that the US and Europe remain ahead of China and other global players such as India or Russia.

The distribution of knowledge through the internet reduces the cost of accessing know-how and in certain areas, such as the raw material or photovoltaic sector, China has established a lead, shifting the know-how power balance from the US, Japan, and Europe to China.

How shale upended the oil hegemony

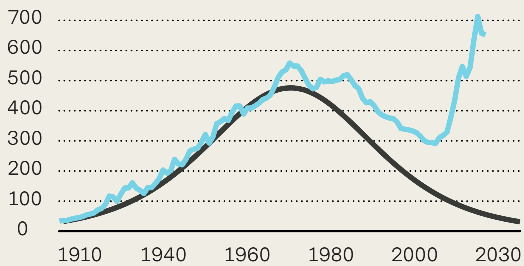
As the shale oil know-how in the US emerged, it has not only been a boon to the US but has also resulted in a reduction of the power and influence of oil exporting countries on the global hegemon. This outcome has dispelled the so-called Hubbert's peak prediction. Named after the American geophysicistM. King Hubbert, who laid the foundation for modeling the oil production curve under certain assumptions.

In 1956, Hubbert predicted that US oil production would peak between 1965 and 1970 and then decline almost as rapidly as it increased during the preceding decades. The projection appeared to be correct until the turn of the last century, when the technological advancement in the shale oil production method reversed the trend, resulting in a surge in US oil production.

Following this innovation, the US became a net exporter of energy by 2020. This illustrates how quickly know-how resulting in technological innovation can reverse a country's depleted resources, how strongly it can shift the geopolitical power game, and why investors usually recognize that identifying the next disruptive innovation of know-how is key.

Figure 20: Hubbert's peak prediction vs. actual oil production in the United States

million m³

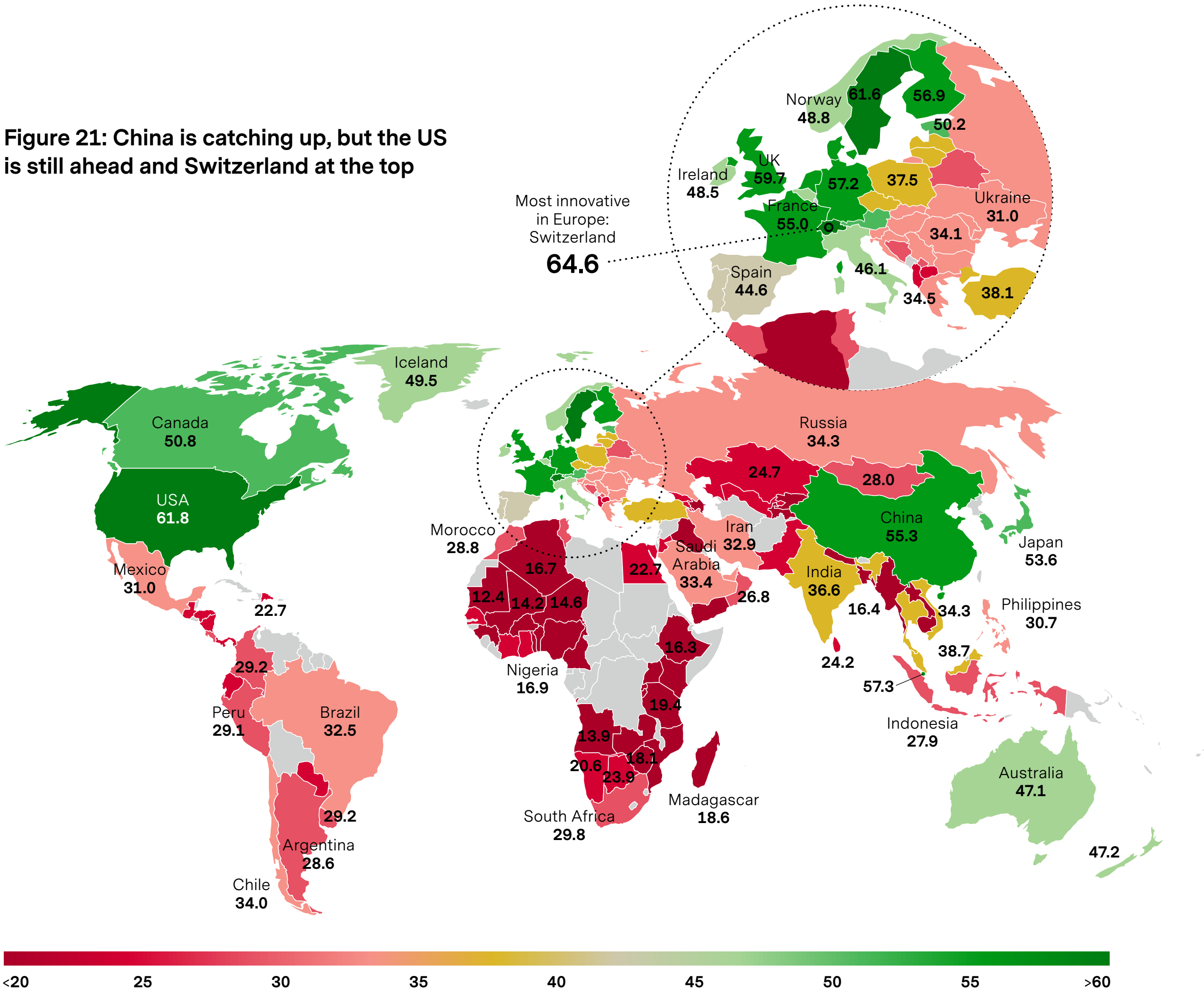


— Hubbert's prediction of the future US oil production (from 1956)

— Actual US oil production

Source: Hubbert (1965), Cavallo (2004), EIA (2022).

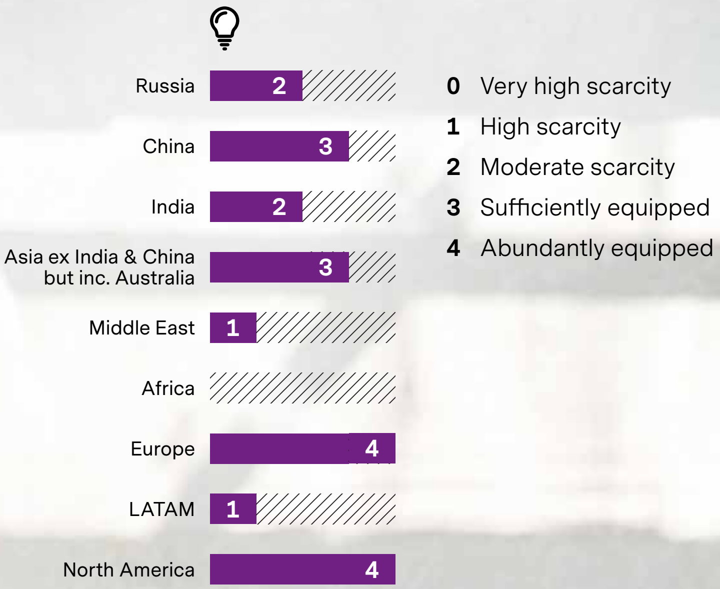
Figure 21: China is catching up, but the US is still ahead and Switzerland at the top



Source: WIPO (2022a), Global Innovation Index 2022.

Level 3: The ultimate resource for geopolitical aspirations

Know-how is the resource which is particularly key in securing the economic prosperity and in facilitating geopolitical aspirations of governments. Of course, all other resources are needed to become a global leader but without world-class know-how, all other resources alone are not enough. Africa is scarcest in know-how as a resource. LATAM and the Middle East are also weakly equipped. Asia ex China and ex India but including Australia as well as China itself seem equally strong but North America and Europe still dominates this resource to rule all other resources.



Know-how: The building blocks of our world

When considering a facilitator resource that enables us to produce other goods and services, we need to look at know-how or any form of knowledge that enables us to utilize any other type of resource. This means firstly, that we need to know which resource or group of resources is required to solve a problem, to satisfy a need and to produce goods and services.

In a similar manner to where energy as an enabler is used to melt an ore and process it to iron, we are required to have the necessary knowledge to perform this task, e.g. to know which resources are required to build a blast furnace or a whole foundry. Know-how alone is not sufficient. We always require another resource to perform a task. By the same token, know-how is always required to employ any other resource.

Figure 21, for example, shows a ranking of innovation criterion compiled to a Global Innovation Index by the World Intellectual Property Organization. Switzerland ranks first, and the US ranks second, Germany follows on the 7th place and China is in position 11.

Furthermore, comparing the number of international students within a country can provide an insight into where important know-how is available—it appears that people still view the US as the center of knowledge with more than 1 million students stemming from abroad, while the UK and China follow with almost 500,000 foreign students per year (data from 2019).

Therefore, the US remains the hotspot for know-how and knowledge while developed Europe and China rank second and third respectively.

It will be interesting to see how the rise of artificial intelligence changes the current pecking order of know-how of a country. China is generally said to be a leader in AI and also there, when looking at the crude patent numbers, they are even outpacing the US (see Beraja et al. 2023, WIPO 2019). Hence, when applying a more sophisticated measure, like taking into account if a patent is not registered in at least one other jurisdiction, or how many patents belong to a highly cited family of patents or if a patent got at least one grant, the US and Japan are AI patent leaders (WIPO 2019).

Similarly, some argue that China has more data on daily human behavior than any other country in the world, due to its extensive surveillance of its people.

But some doubt China's success in artificial intelligence, as particularly in the field of generative language processing (GLP, think of ChatGPT) since the country's censorship reduces the amount of available data and its isolation of the domestic internet prevents their GLP machines form learning from all the other (censored) data that is available on the planet (see, e.g. Roach 2023). In a diligent assessment of the digital competition between the US and China, in 2019, Vontobel wrote in co-operation with Eurasia Group a white paper about the next digital superpower, where we stated that particularly in the field of digital technology the clash between the two super-powers will continue and even aggravate during the running decade (see Eurasia-Vontobel 2019).

Resource scarcity: The energy example

How resource scarcity affects a country's independence and geopolitical actions.

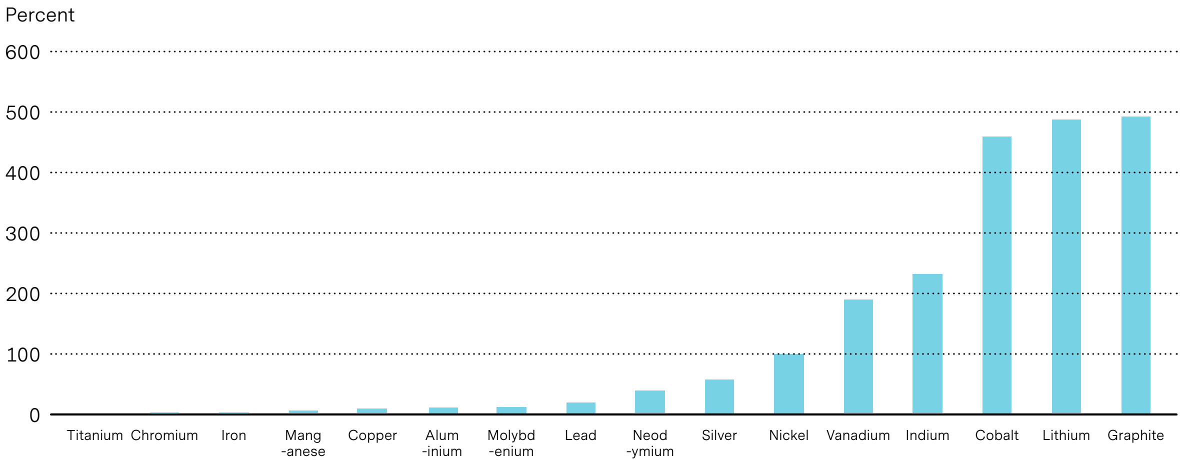
The quest for sustainable energy
The 'energy transition' is a term used to describe the shift in supply and consumption of energy, commonly used at present in association with the shift toward more sustainable energy. For the Paris Agreement to be successful in ensuring climate stabilization by limiting the global temperature rise to well below 2°C, as defined by the IEA Sustainable Development Scenario (SDS) for 2040, a surge in demand for certain metals and minerals is a prerequisite condition, according to the World Bank (World Bank 2020).

When large developed markets, such as Europe or the US, set their sights on achieving a higher consumption share of renewable energy in a short period of time, this creates a significant change in the demand for materials.

Such increases can, understandably lead to new shortages in materials, and this is set to increase if the IEA SDS for 2040 becomes reality, as it requires a quadrupling of demand for critical minerals for the so-called green energy transition.

As an alternative to the Paris Agreement, the IEA suggests a more moderate and therefore realistic scenario in which the world embarks on an energy trajectory where at least 50% of the cases achieve the Paris-2-degree-target by 2100. In this scenario (2DS), the World Bank estimates that global demand only from renewable energy technologies for certain key minerals could significantly exceed current production, e.g. for cobalt more than 4 times the current production (see figure 22).

Figure 22: According to the World Bank global demand for certain key minerals can massively exceed current production (base of 2018)



Note: 2050 projected annual demand from energy technologies as percentage of 2018 annual production (under the SDS scenario). Source: World Bank, 2020.

Here graphite, lithium and cobalt will be in the spotlight, with the World Bank study estimating they will experience the highest overdemand—an overdemand between four to five times today's production (e.g. of the 2018 global production numbers, see World Bank 2020, USGS 2022).

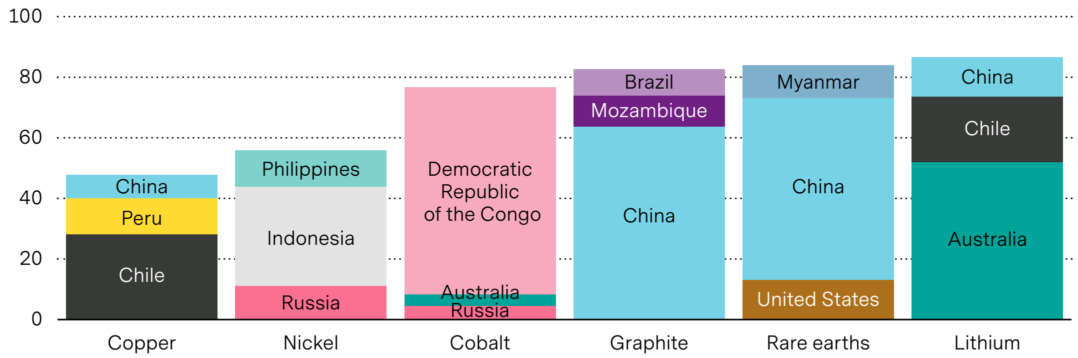
What these scenarios show us, is that we are poised to continue to face situations of resource scarcity within our economic system in the future, just as we experienced them in the past. Price movements over time clearly reflect scarcity levels. Consider metal prices, for example, whose price fluctuations can be mapped against the development of new technologies.

In 2000, copper was only a quarter as costly (in real terms) as it had been in 1900, while aluminum cost almost a tenth. In 2007, copper was again of a similarly high price (in real terms) than in 1900 but aluminum remained cheap.

The quest for independence
Even though certain materials are abundant on the planet, this does not necessarily equate to the required capacity for processing them. Furthermore, global abundance does not necessarily rule out the possibility of regional scarcity.

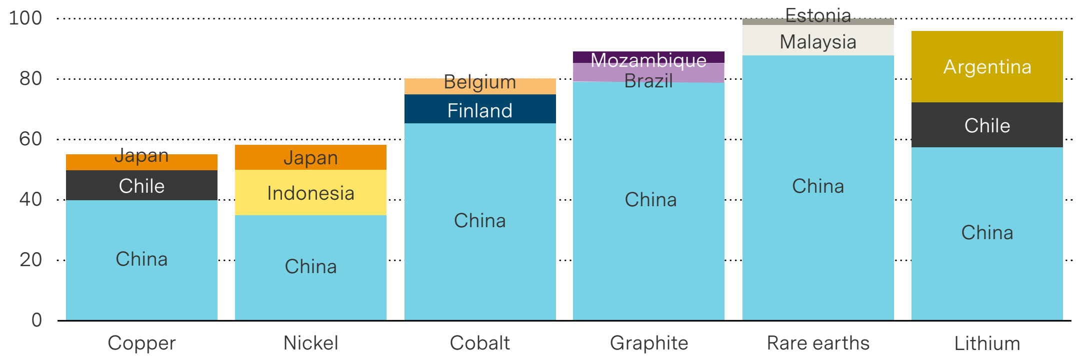
From a geopolitical perspective, while global scarcity need not become a problem, we need to consider both distributional scarcity, due to the geographical imbalance of resource extraction, and scarcity related to the fact that significant processing capabilities currently exist in only a few countries.

Figure 23: China, DR Congo and Australia dominate the mining of important minerals ...
Percent



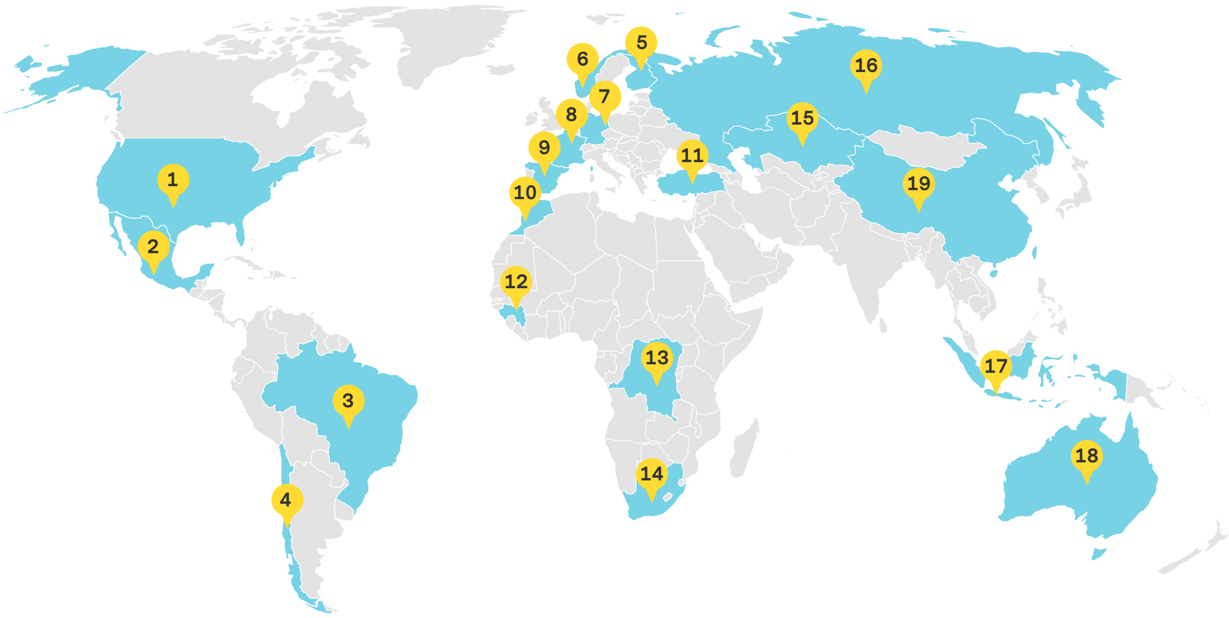
Note: Share of top producing countries in extraction of selected minerals, 2019. Source: IEA (2022c).

Figure 24: ... but China dominates the processing of these critical minerals almost alone
Percent



Note: Share of top producing countries in total processing of selected minerals, 2019. Source: (IEA 2022c).

Figure 25: Not only the US but also the EU is strongly dependent on China for a number of critical minerals



1 **United States**
Beryllium* 88 %

2 **Mexico**
Fluorspar 25 %

3 **Brazil**
Niobium 85 %

4 **Chile**
Lithium 78 %

5 **Finland**
Germanium 51 %

6 **Norway**
Silicon metal 30 %

7 **Germany**
Gallium 35 %

8 **France**
Hafnium 84 %
Indium 28 %

9 **Spain**
Strontium 100 %

10 **Morocco**
Phosphate rock 24 %

11 **Turkey**
Antimony 62 %
Borates 98 %

12 **Guinea**
Bauxite 64 %

13 **DRC**
Cobalt 68 %
Tantalum 36 %

14 **South Africa**
Iridium* 92 %
Platinum* 71 %
Rhodium* 80 %
Ruthenium* 93 %

15 **Kazakhstan**
Phosphorus 71 %

16 **Russia**
Palladium* 40 %

17 **Indonesia**
Natural rubber 31 %

18 **Australia**
Coking Coal 24 %

19 **China**
Baryte 38 %
Bismuth 49 %
Magnesium 93 %
Natural graphite 47 %
Scandium* 66 %
Titanium* 45 %
Tungsten* 69 %
Vanadium* 39 %
Light Rare Earths Eelements 99 %
Heavy Rare Earths Elements 98 %

*share of global production

Source: European Commission (2020), EU critical minerals list (2020).

Issues stemming from distributional- and processing-related scarcity issues are usually addressed via trade solutions or the creation of extraction facilities requiring considerable investment. The latter tactic needs significant time to become effective: The total time required to get new extraction and production facilities off the ground varies per material, but the IEA estimates that nickel and copper production takes 12 to 18 years while even lithium needs four to five years to build up from scratch (IEA 2022c).

Thus, friend-, near- or on-shoring of new production capacities takes time, and any hit to the current complex global trading of minerals and metals would lead to a shock in today's supply and production chains. This becomes very visible by looking at figure 25, which depicts the EU's heavy dependency on countries like China, South Africa or the Democratic Republic of Congo, that mine and produce metals and minerals (compare also Figure 16 on the US dependencies for critical minerals).

What happens when resources are restricted

Understanding the impact of a country restricting access to resources.

When a country blocks resource exportation
A meaningful example of geopolitical tensions impacting global trade occurred in 2010, when China cut its exports of rare earth elements (REE) by around 40% globally and ceased the export of REEs for two months to Japan. REEs metallic key ingredients for certain technologies such as robotics, chips, fuel cells, generators, and traction motors—all of which are also utilized in national security and military gear.

Geopolitical tensions between China and Japan were what sparked China to limit and block exports of REE. In this instance the countries were in disagreement over the ownership of inhabited islands and sea areas important for geostrategic reasons and fishery rights (see, e.g. Bradsher 2010, Lang 2010). Once Japan ended its opposition—because certain key industries required REEs to maintain production and because the US and EU lowered their support for Japan for the same reason—China resumed its REE exports.

Concentrated extraction and processing capacities are key issues in geopolitics
For certain resources, particularly those that are processed in a highly technical way or involve a large eco-system of suppliers, and occasionally where the processing is environmentally dangerous, one ends up with a high concentration in a small number of extracting and processing countries.

This is evident in figure 23, for example, with cobalt, where the DRC controls more than 2/3 of global extractions and is the clear leader, but China controls 65% of the global refinement of the metal. China has an even more substantial position as a processor for REE (as explained with the story above) and is strong in many other metals such as lithium (important for battery production) copper and nickel.

Critical dependencies
These considerations are important for the final reasons that explain why politicians and citizens concern themselves with the issue of resources: The quest for resources for military capacity and national security to fulfill their geopolitical aspirations.

The critical minerals list for the EU and US covers many metals that are identified as key resources for security and military technology, such as drones, high-tech weapons, ammunition, and cyber-security instruments (see figures 16 and 25, US and EU maps on critical minerals). This highlights the substantial dependence on certain critical metals by global powers such as the US and the EU on China's production capacities and on other smaller countries particularly for extraction.

This is the case even with heavily financed programs to reduce dependency, such as the Inflation Reduction Act (IRA) of the US government and the EU's REPower program and needs to be considered when assessing the impact on the geopolitical power balance.

We saw in figure 15 that the global trade in metals is complex—the EU is the region that is most dependent, while geopolitical heavyweights such as the US and even China are also dependent on metals imports for their consumption and production. On the other hand, LATAM, Australia, and Africa are the strongest net exporters of metals, according to this data.

Click to read our case study on the battery electric vehicle (BEV) value chain: From a global market back to a divided one.

Current stance and potential future of resource trading
Trading tangible resources helps distribute intangible resources more efficiently across borders. An IMF study shows that trade helps spread knowledge and technology across borders, which boosts the trading partners' productivity and contributes positively to global growth (Aslam et al. 2018). Restricting trade leads to less efficient global resource and production allocation and hinders the distribution of knowledge and potential productivity gains.

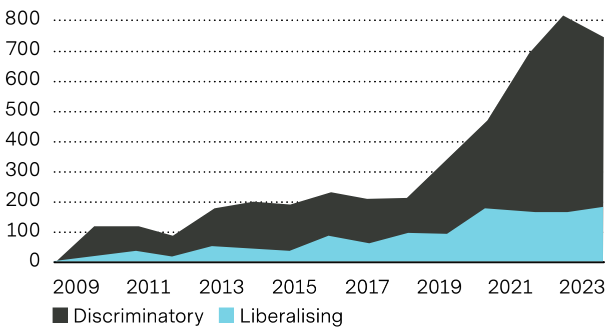
However, there are more direct ways to spread knowledge beyond the trade of goods and services. The Trump administration created the China Initiative to counter allegations of theft of American intellectual property rights by China and also began to target Chinese researchers and students in the US for their academic activities or their Research & Development (R&D) knowledge (Bradsher & Swanson 2018). Incentives were provided to foreign researchers to persuade them not to return to their home countries and thus prevent any technology transfer from the US to other countries.

The UK called for western military pilots not to be recruited by China, to avoid passing on any military know-how (Lovely 2017, Needham 2023). It should, however, not be forgotten that spying between nations for know-how, is a mutual activity (Sevastopulo & Leahy 2023).

Looking at tangible resources, it is evident that activities of several globally important governments are to some extent mutual, and the outcome is the same: more government intervention that is harmful to global trade. The Global Trade Alert (GTA) database counts the number of harmful and liberalizing state interventions (trade barriers, subsidies, quotas, other government interventions, ceasing exports) and provides a comprehensive picture of global developments in government actions affecting trade. The database figures clearly point toward a substantial increase in trade interventions since the onset of the Global Financial Crisis 2008 / 9 (see figure 26).

Figure 26: Many more discriminating interventions since 2018

Number of new interventions implemented each year



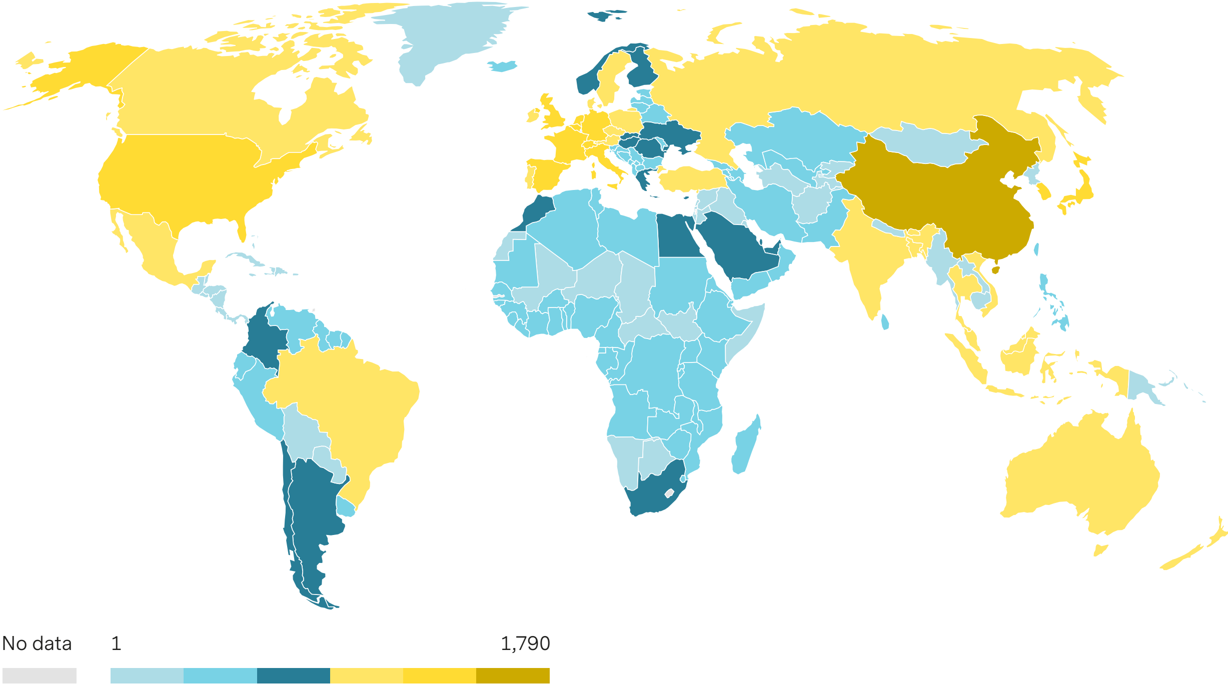
Source: Global trade alert database, GTA 2023.

As evidenced by Figure 3 at the start of this paper, global trade has improved since World War II and increased the efficiency of the global economy significantly, but this guiding principle on ever-increasing globalization has now come to a halt.

The intervention calculus
A look at figure 27 shows that in the current geopolitical situation, two important forces are at work: China and the US, and to a lesser extent, Russia and Europe. Finally, the GTA database provides suggestions about trade-battlegrounds, and discloses the sectors most affected by harmful interventions.'Products of iron and steel' are impacted the most,followed by 'basic organic chemicals', 'cereals' (think of food scarcity) and 'other fabricated metal products' (think of the critical minerals list).

State interventions in trade and the issue of scarcity of minerals and metals critical to renewable energies raise doubts about Europe's ability to shift from its significant dependence on Russian energy to energy self-sufficiency with renewable energy. Europe's energy strategy appears to be a choice between moving away from a dependence on Russian energy imports towards renewable energy technologies that are still vulnerable to potential restrictions for access to critical minerals and metals by China and other important producers (see figure 16).

Figure 27: China is affected by the largest number of harmful interventions



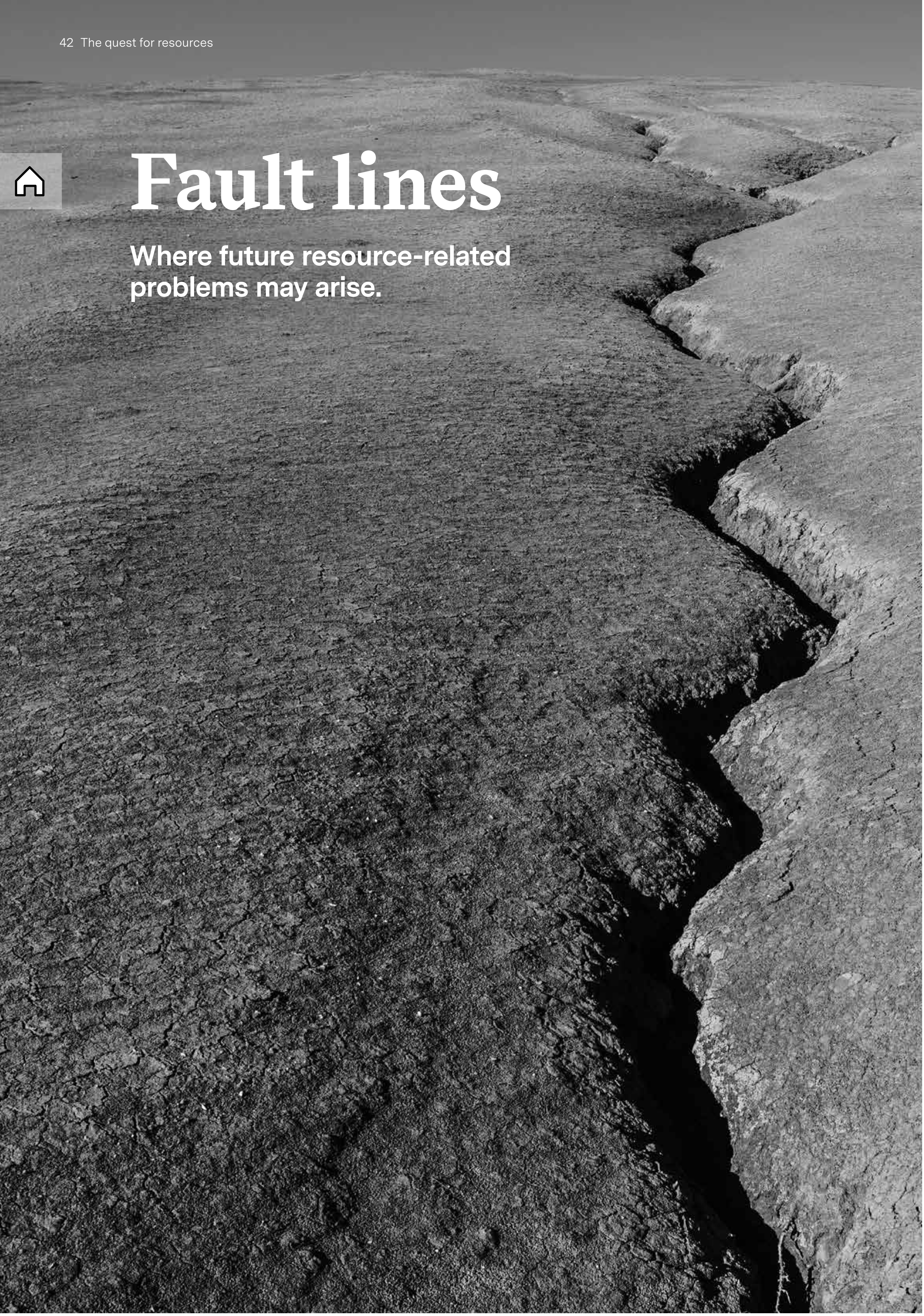
Source: Global trade alert database, GTA 2023.

Choose your trading partner wisely
European countries and other nations, particularly small open economies and more independent ones like Switzerland, must choose their trading partners wisely when barriers to trade and the exchange of know-how are erected. In this regard, trade data can be beneficial in attempting to separate a trading partner that is of high quality from those that are not.

The Global Trade Alert Institute has used the geopolitical shock of the Covid-19 pandemic, when many countries suddenly implemented stricter border controls or import and export embargoes, to analyze which countries kept their borders and trade channels open or even supported other countries by providing more liberalized access to certain resources. The analysis revealed that large countries such as Canada, Japan, and Australia were positive G20 examples and other countries and multinational enterprises should consider to steer their trade flows and agreements towards this group of trading partners.

Fault lines

Where future resource-related problems may arise.

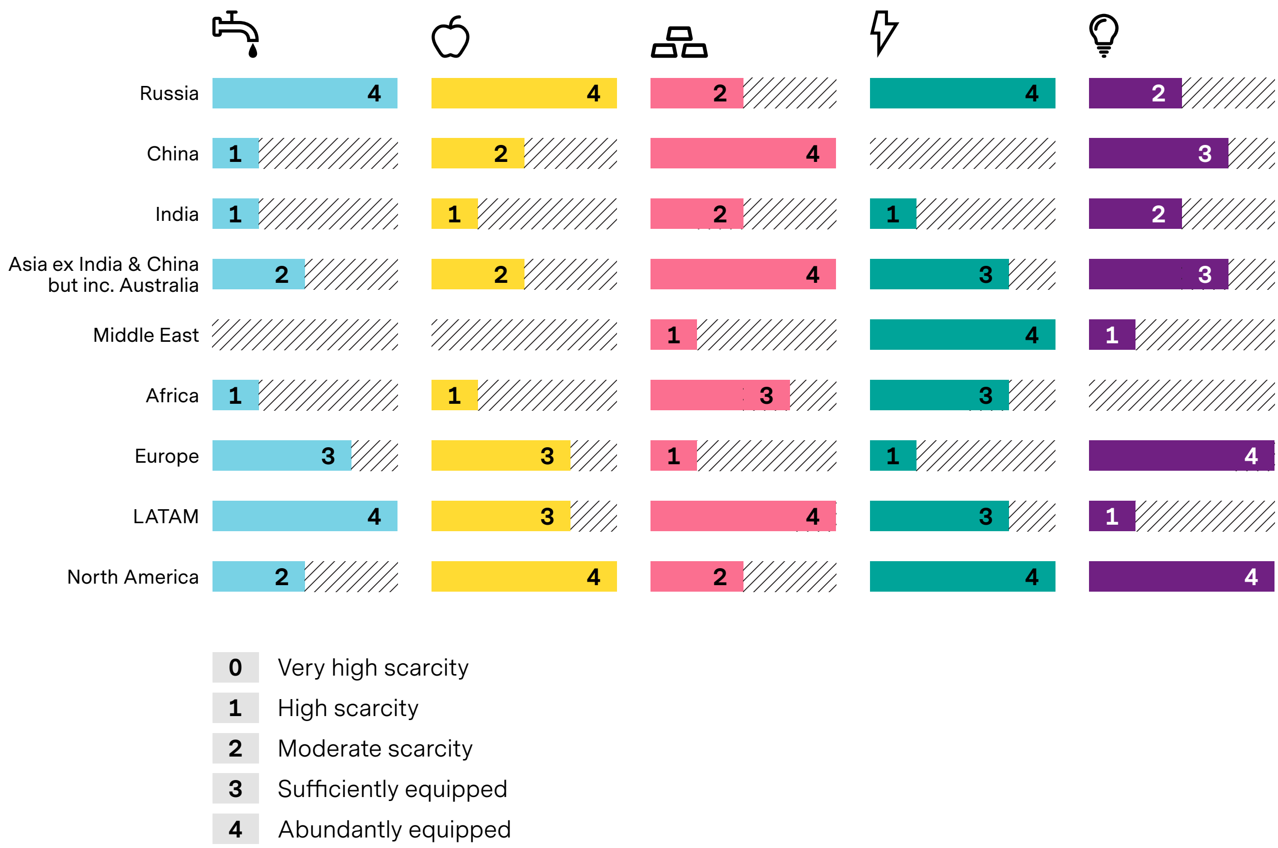


A new global order, a new cold war, or a multipolar world with bi-polar gravity?
Fault lines continually shift. We have seen this play out from the early days that followed World War II, with the US – Europe – Western NATO alliance and the Russian – East – Communist Bloc during the cold war, until the dissolution of the Soviet Union, to the period of US hegemony, followed by the rise of China that today challenges US dominance.

The US – China rivalry
When looking at Figure 27, the rivalry between the two countries mostly affected by harmful interventions becomes evident. Although there are many commentators introducing the notion of a new cold war era, between the US and China, we argue that there are two important differences: First, China is by far not as self-sufficient in raw materials as the Soviet Union was at the time of the cold war.

The Soviet Union could virtually operate without significant cross-border trading, particularly for energy (Allen 2001) while China is, for example, heavily dependent on energy imports. Also, by overlaying the maps, it becomes clear that China is not as rich in resources relative to the size of its economy and its population than its geopolitical rival, the US. China exhibits many dependencies, from water, food to energy. From an efficiency point of view, China is significantly less efficient in the use of resources as it produces about three times less wealth from each liter of water compared to the US, and the US generates almost 40% more wealth per unit of employed energy resource than its geopolitical rival (World Bank data portal 2019). However, China is catching up and also has a very strong standing in terms of resources for minerals and metals, which are key ingredients for the technology and national security sector (see figure 28).

Figure 28: All the scarcities: Water, food, minerals, energy and know-how



Second, China's military power relative to its neighbors is still less developed relative to the military strength of the Soviet Union at the time of the Cold War—to illustrate this point, China has about 410 nuclear war heads, India 164 and Pakistan 170, whereas Russia and the US still have more than 5'000 operational war heads, according to the Federation of American Scientists (Kristensen 2023). Hence, for a country that shares borders with two strong global powers—Russia and India—the regional dominance of a new Cold War style bloc in the east will be more difficult to establish for China than was the case for the Soviets before 1991.

This also highlights the inferiority of China in military power terms relative to the US. Taking into account, for example, the numbers of military bases abroad—China has about 5, Russia has 36, the UK has about 145, and the US 750 (Vine et al. 2021). Similarly, the US and Russia still lead the global firepower index that measures military strength (GFP 2023). There is a high risk, however, that China, Russia, and the US, among other players, would enter opposing sides of proxy wars, as was the case between the US and the Soviet Union during the Cold War.

The Center for Systemic Peace (CSP) tracks armed conflicts around the world and recently registered an increase in the number of armed societal wars—like the elevated numbers of wars during the Cold War and its proxy conflicts (see figure 29).

Faultlines emerge and could become entrenched China works hard to reduce its shortcomings and dependencies, particularly regarding the US. These actions do highlight China's underlying dependencies. To meet its energy needs, it cooperates with the Middle East, particularly Saudi Arabia and Iran—two countries that have been heavily involved in armed conflicts with other states for years.

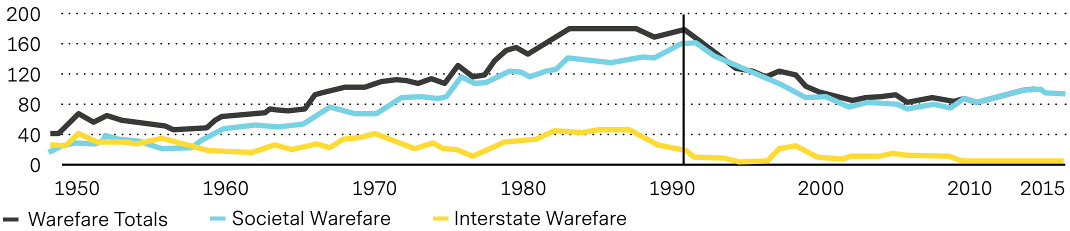
China, besides India, currently profits the most from the Russian invasion in the Ukraine, with the resulting Western sanctions and cheap oil from Russia (Heussaff et al. 2023). The conflict in the Ukraine diverted the flow of resources, mostly energy, out of Russia, from Western Europe now towards the East. A 'great resources divide' seems to emerge around Russia as the new big fault line, which makes resource flows more aligned to the current geopolitical alliances. Furthermore, China is trying to secure access to precious resources in Africa but still caters to its biggest export destinations aside from the ASEAN countries—the US and Europe.

In summary, China's dependence on other trading partners, its strong trade (export) relations with large countries like the US but also the European countries and its strong neighbors mean that China faces serious challenges in establishing a bloc with other nations while under its own lead. Unfortunately for China, some of its 19 neighboring countries, and particularly Russia, are in rather unstable political conditions. This is a problem for China as any kind of social unrest and political turmoil could spillover, as several studies confirm (Barret & Chen 2021).

Mutual trust and relations need to develop further in line with China's global aspirations in order to achieve an aligned and mutual foreign policy, forming a geopolitically solid appearance. Of course, older alliances such as NATO and younger ones like the EU can also at some point weaken, but the historic ties grown over decades makes them less vulnerable, at least in the short run.

Figure 29: Since the end of the cold war, proxy wars declined but lately, they seem to increase again

Summed War Magnitude Scores



Source: CSP (2020), Center for Systemic Peace.

Nevertheless, the latest rapprochement between Russia and China is a big opportunity for the latter as it opens access to a large set of resources. Hence, the US and its allies fear any further coalescence between the two. On the other hand, this shows how important productive alliances are, even for the strongest geopolitical players. On the flip side of the coin, smaller and geopolitically weaker countries can play important roles in the global power game, when they can secure and distribute important resources to the world and its important powers.

This is why the most likely geopolitical outlook speaks for a multi-polar world, In this scenario, alliances can change swiftly, particularly with swing states that are resource rich and economically and politically independent enough to negotiate the best conditions on a periodic basis.

Such countries with globally valued resources, can be found in Latin America, Africa and the Middle East, which will make these regions battlegrounds for the geopolitical heavy weights. The current tendencies of states on these continents—such as Colombia, Bolivia, but also South Africa or Uganda and Iran or Qatar—were to side more strongly with Russia over the last quarters, increasing the bipolar gravity between the Western Alliance lead by the US and the Eastern Alliance led by China, and supporting Russia.

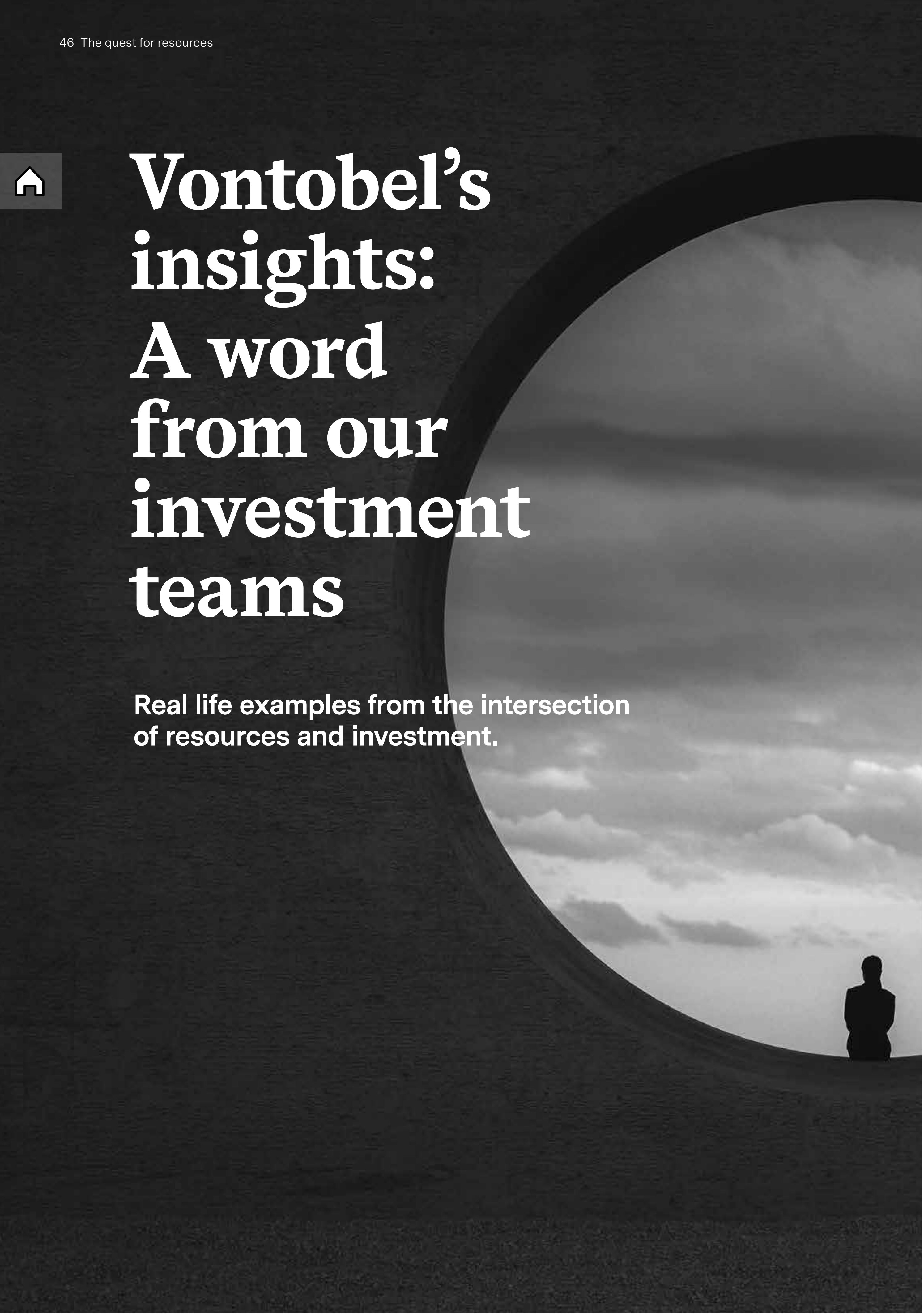
However, also here it remains to be seen how strong the ties between China and Russia are, once China further increases its trading relationship with the many central Asian countries that were former members of the Soviet Union. The Russian leadership might react sensitively to such developments. In contrast, NATO seems to have become stronger after the Russian invasion in Ukraine.

The fault lines beyond
Other fault lines exist, beyond the resources we assessed in this paper. One could mention China's ambition to develop a global payment system that is based on its own currency, so that the country can purchase commodities in Remnimbi and can reduce its dependency on the US dollar. Although this will be a long way off as the US dollar still accounts for 40% of global payments, while the remnimbi accounts for only 2%.

Another issue is the ongoing fragmentation of the worldwide web (see, e.g. Shahbaz et al. 2022). And finally, the underlying demographical shifts (think of human resources) within and across potential fault lines were out of scope for this paper, but of course also of importance for the geopolitical outlook over the next decades.

Two centers of gravity in a multi-polar world
It seems that the ongoing challenge between the US and China regarding global leadership will likely lead to two strong centers of gravity within a still multipolar world. The US also depends on allied (and non-allied) trading partners to fulfill its economy's requirements for raw materials and so does, to an even larger extend, Europe. Yet, the US and its allies seem to have a longer history of mutual trust and processes to align its various geopolitical aims, making them still the strongest and well-positioned force in today's geopolitical framework.

Vontobel's insights: A word from our investment teams



Real life examples from the intersection of resources and investment.

Listed Impact

The case of the solar panel industry and how Europe lost its dominance to China

Historically, global solar installations were dominated by European countries, particularly Germany and Spain. A local supply chain was established in Europe, covering the full value chain from the key raw material (polysilicon) to wafer, cell and solar modules.

In 2014, China surpassed European solar installations due to significant investments in leading-edge production capacities supported by low electricity prices, while manufacturing in Europe became too expensive. As a result, China currently dominates the world's energy transition supply chains. This development has had clear benefits: since 2010, the levelized costs of electricity (LCOE) generation by solar was reduced by about 80%, and solar energy has become competitive. Today, 80-95% of key solar products are manufactured in China, creating a significant dependence in renewable electricity generation comparable to that of fossil fuels/gas and Russia before the Ukraine war. China is home to the top five companies across each step of the value chain, except Germany's Wacker Chemie in polysilicon and US-based First Solar in thin-film modules.

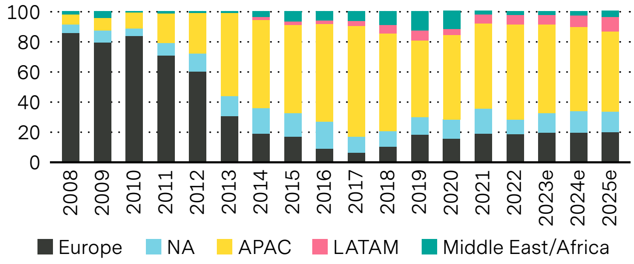
Barriers and onshoring

The US reacted to this in several ways using a carrot-and-stick approach. On the one hand, significant import tariffs and hurdles like the Uyghur Forced Labor Prevention Act were implemented, significantly slowing down module imports from China. On the other hand, the US also now offers generous tax credits, thanks to the Inflation Reduction Act (IRA) announced in August 2022, which should stimulate local production. The IRA will make the US the cheapest production cost region for solar in the world.

Based on active and planned assets, US solar module assembly capacity is set to reach almost 47 gigawatts (GW) annually by the end of 2024 (5 times more than the 9 GW today). With around 50 GW of annual installations, the US would be able to meet its demand locally.

The US is not alone in looking to onshore manufacturing. The EU and other countries, such as India, have announced plans to expand local manufacturing. For example, the European Commission launched the Solar Photovoltaic Industry Alliance in December 2022 to develop a European solar-Photovoltaic (PV) ecosystem. The EU has also defined a target of 30 GW a year of PV manufacturing across the entire supply chain by 2025. However, this reorganization will be costly. Europe will need to invest an estimated $149 billion in manufacturing plants to meet its entire clean energy demand locally by 2030, according to BloombergNEF (note: this includes batteries, solar, hydrogen, etc.)

Figure 30: China records the highest global share of solar installations (percent)



Note: Annual solar installation volume per region. Source: IEA (2022d).

It's not just the establishment of new manufacturing plants that comes at a significant cost. Replacing low-cost and efficient large-scale manufacturing capacities in China with smaller-sized facilities in high-cost countries will result higher prices for consumers.

Given the high electricity costs and production cost disadvantages in Europe, companies need strong visibility and long-term planning security to define solid business cases and de-risk potential investments, without which they will have limited interest in investing in Europe given the severe boom-and-bust cycles we have seen in the European solar industry before.

The latest International Energy Agency (IEA) report proves that large-scale deployment of renewable energy generation and energy efficiency measures does reduce the carbon intensity of our economic activity. Conversely, the higher emissions from developing countries in Asia, ex-China, show that rapid economic growth is associated with energy demand growth when installations of renewables lag. Therefore, accelerating the transition of energy supply to renewable sources globally is of great importance. Moreover, energy efficiency and behavioral change can further reduce energy usage and, with them, dispel supply security concerns.

Vontobel's Listed Impact Team think that subsidy-driven businesses ask for an active management approach, as the investment rationale may change abruptly once rules change. We invest where subsidies provide tailwinds for the further development of related businesses, but we focus on companies where economically viable solutions should be able to gain market share globally and over long-term periods, irrespective of temporary policy support.

The team manages strategies that offer attractive opportunities for investors to invest in a broad range of companies providing scalable solutions (equipment and services) that support the transition to a low carbon economy , and aim for a double dividend—attractive financial returns and positive impact.

mtx
by Vontobel

The case of battery electric vehicle (BEV) value chain: From a global market back to a divided one

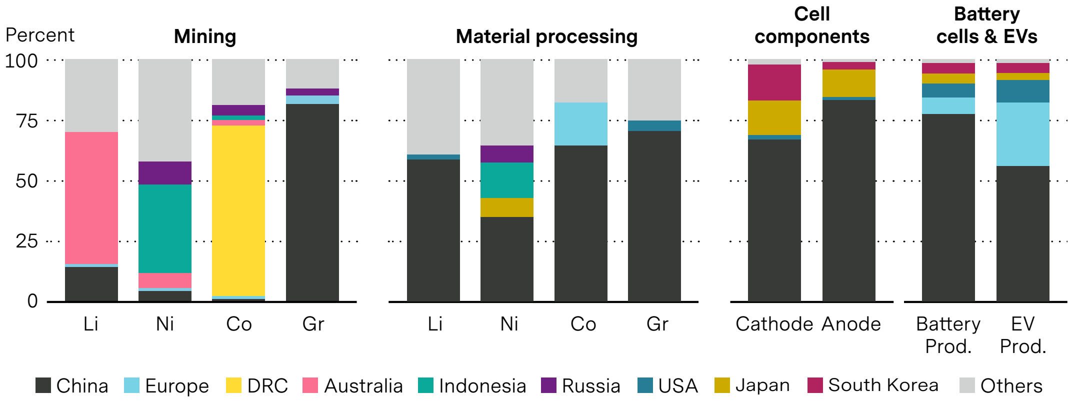
Pre-Covid, global electric vehicle (EV) penetration was 2–3% and battery costs declined by 5–7% annually. Production of any BEV that approached higher volumes was limited to Tesla and Asian battery producers. Aggregate investment was in the low tens of billions annually.

The world has changed. EV vehicles began to really compete economically against internal combustion engine (ICE) vehicles. The topic of batteries became a global one, and the amount of capital involved is 10 to 20 times higher than it was pre-COVID. Battery technology is still maturing and production costs are further reducing, but the major change is the quantity of capital and climate-oriented stimulus policies, especially outside China.

The difference between the West and China
In China, EV vehicles compete economically against internal combustion engine (ICE) vehicles. This is not the case in the EU and US; however, there are incentives through subsidies. Over the next 5–10 years, the emerging battery economy will see BEVs become vastly superior in cost and capability to ICEs. It is expected that the EV penetration rate will be around 50% by 2030 compared to 12% in 2022.

The landscape of the global battery production seems to divide into two regions: China and elsewhere. China purchases 60% of all EV cars globally and dominates the EV battery value chain 9 (see figure 31 below)—it manufactures over 60% of EV battery cells and 70–90% of all EV battery components. This dependency on China has concerned the US and, to a lesser degree, Europe, resulting in the US Inflation Reduction Act (IRA) and the EU Critical Raw Materials (CRM) Act.

Figure 31: China dominates the market for key battery materials



Source: IEA (2022b).

Low capacity, high demand
The new regulations together with battery capacity expansions in Korea and China are expected to lead to a global surplus. However, ex-China battery supply and demand will remain tight until at least 2025 due to high demand growth and low existing capacities. Thanks to large subsidies, the IRA supports US local manufacturers against Chinese imports. Europe is still expected to buy cars, battery cells, and components from China.

Korean battery cell and component manufacturers are the main beneficiaries of the US IRA and the tighter ex-China battery market. Korea has motivated its companies to expand their capacity in recent years, and the country is the second-largest EV battery producer. All other nations remain in an infancy stage in terms of scale and technology. In Korea, technology leadership, economies of scale, extensive vertical integration, and protective regional policies mean most Korean companies appear well positioned. Higher EV sales growth rates in the US should also be supportive.

In 2022, the Chinese EV market grew by over 100%, and most cars, cells, and components were close to being sold out by the end of last year. The phase-out of subsidies, and a price war in China instead resulted in lower EV sales in the first half of 2023. Together with the announcement of the US IRA and the more challenging access to US markets, share prices in Chinese EV-related companies have barely achieved a positive performance YTD compared to over +50% YTD on average by the Koreans.

Discernment is key
The current oversupply in China does not mean that this is a losing game for all Chinese companies. In recent years, investors did not distinguish between market positions, purity to the EV theme or business strategy. 2023 is likely to be the beginning of a period where the right stock picks can generate attractive alpha. Cost leadership, vertical integration, greater scalability, recognized product quality, and an outstanding customer base with binding contracts will be key elements for success. Furthermore, building the full value chain in Europe and the US will take time.

At the mtx team, we believe in the growth of EV vehicles and the attractive growth perspective of EVs and their supply chain. We are invested in a broad range of companies providing autos, batteries, components, equipment or services along the EV supply chain in our Vontobel mtx strategies. As in every new industry, innovative changes are likely to impact the way vehicles are built, the manufacturing process of batteries or in product chemistries. Hence, we constantly evaluate our investments and their suitability.

Vescore
a boutique of Vontobel

Transition, which transition do you mean?

Human ingenuity could initiate several transitions towards more efficient and / or cheaper sources of energy. The most prominent ones are the transitions from wood to coal, coal to oil, coal to natural gas, or coal to nuclear power.

A close inspection shows some odd things: did the world really transition out of old and inefficient energy sources like coal or wood, as today's consumption of both is higher than in the 60s? Or could it be that new technologies and innovations simply stimulated more economic activity but also offered the old energy sources at a cheaper price to the rest of the world, thereby accelerating overall demand for energy? Population growth multiplied by rising income will continue to drive up demand for energy, and the Energy Intelligence Agency even projects that energy consumption will accelerate by more than 50% over the coming two decades. As energy consumption in the Western world plateaus somewhere around mid-2030, consumption in developing countries jumps. When forecasting future energy trends, you should be more right about the future energy mix in developing countries.

Most countries signed the Paris Agreement in 2015 with a clear ambition to reduce greenhouse gases: decarbonization by electrification should rebalance the energy mix towards wind, solar, and biofuels. Where do we stand at the end of 2021?

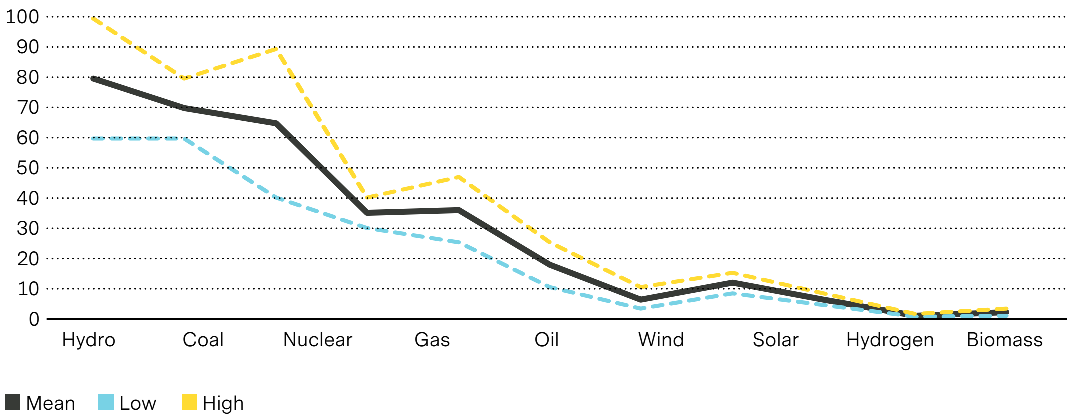
The good news is that the share of renewables (wind, solar, biofuels, other, excluding nuclear and hydro) increased from 2.8% to 5.7% of global energy consumption, while a bit gloomier interpretation is that global oil gas and coal consumption grew another 7% and would be above 10% if trend demand growth was not interrupted by Covid-crises.

How can we explain that transitions moved slowly and why did consumption of fossils kept growing? Apart from reasons already touched upon in this paper (energy mix of developing economies shifts the balance) the transition to renewables differs from all previous ones. Renewables have a very low CO2 footprint, but in terms in energy efficiency (and thus total costs) they score mediocre.

Below, the energy returned on energy invested (EROEI) demonstrates why polluting energy projects remain popular in budget constrained regions. Coal, gas oil projects produce significantly more energy during their supply chain vs the CO2-friendly alternatives. Some energy sources like biomass occasionally consume more energy than they ultimately generate (see figure 32).

Figure 32: Renewables are CO2 friendly but energy intensive

EROEI, Energy Return on Energy Invested, shows how much energy can be obtained from a particular source relative to the energy demand used to create the source (Reported in x-fold to the energy demand during production)



Source: Weisbach et al. 2013, Hall et al. 2014, Pahud & Temmerman 2022, Vontobel.

Technological breakthroughs will further shift the balances in favor of renewables but developing economies remain hesitant to be an early adaptor: costs, intermittence, diversification, and geopolitics unfortunately remain their key considerations.

The above projections on future energy mixes were sketched from a demand perspective, but what about the supply response? Western companies and investors are divesting from fossils, even though fossil demand will plateau over 20 – 30 years. Current oil and gas fields see a steady 2 – 4 % annual decline in production, meaning that large supply shortages loom, so it is no surprise that divestment from the West will be closely examined in Non-OECD countries, with geopolitical consequences. The Ukraine war already gave a clear example how vulnerable commodity importers like Europe are for supply shocks.

Renewables and expanding power grids will accelerate the demand for copper, lithium, nickel, cobalt and others, but on the metals front, the supply side is even more critical than for fossils. Production is concentrated in 4 – 5 countries, whilst smelting and processing is fully dominated by China. Also, since the peak in metal prices around 2007, no new major mining capacity has been added meaning that copper production is set to peak around 2026-2028.

The situation might further worsen considering that current copper production runs on mining projects that had more than 3 % copper ore grades when started at the previous metals bull market. Current mining projects have ore grades of less than 0.3 % making them uneconomical at current price levels. Copper prices need to increase to incentivize investments.

Investing in commodities always requires scenario planning, given that volatile factors (such as politics, technology and macro) can lead to different outcomes. Without immediate investment in metals production the transition to renewables can fail.

Vontobel's Commodity team invests in a diversified universe of commodities futures. Depending on the exposure, our strategies will be tailored towards those commodities that would strongly benefit from the above transitions (metals baskets, emissions, biofuels and gas).

Megatrends

Resource efficiency in agriculture and food production

The inefficient use of resources is apparent at various stages of the food supply chain, from growing crops to food processing and final distribution. Water and agricultural chemicals such as fertilizers and pesticides are essential but often wasteful and detrimental to the environment. Agriculture is responsible for 70% of global freshwater use, a significant concern considering the emerging water crisis.

Furthermore, agricultural chemicals are indispensable to maintaining food security. Removing their use would reduce farming output by around 50%. However, technological solutions are being developed to improve resource efficiency.

Precision agriculture is a rapidly growing field that uses different technologies to optimize crop yields while minimizing inputs, waste, and environmental impact. The range of technologies used includes GPS, remote sensing technologies such as drones and satellites for data collection, soil sensors to measure key variables, variable rate technology for targeted application of agricultural chemicals, and robotics and automation to perform tasks such as planting, harvesting, and pruning with greater precision and efficiency.

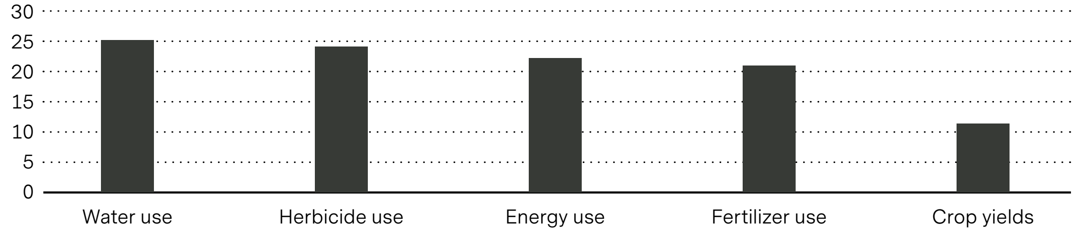
Figure 33 depicts efficiency gains from the use of precision agriculture technologies compared to traditional farming methods that should lead to a decrease in water, herbicide, energy, and fertilizer use by 20 to 25%, and an increase in crop yields by more than 10%.

The growing awareness of the need for sustainable agricultural practices, supported by initiatives such as the European Green Deal, will contribute to a faster adoption of technology in agriculture. Indeed, the EU Green Deal has set several hard targets in terms of reducing pesticide and fertilizer use by 2030. Farmers will have to meet these targets to be eligible for subsidies, which often represent a substantial part of their income. Today, precision agriculture is one of the most viable ways to meet these targets.

Our Megatrends team believes that feeding a growing population in a sustainable manner is one of the major challenges we will need to face in the decades ahead. We are invested in a broad range of companies that provide solutions for increased efficiency of food production, protection of the environment, and improvement of animal and human welfare. We constantly evaluate our investments and their relevance to the theme.

Figure 33: Precise agriculture technologies can significantly reduce the use of resources

Reduction compared to total resource consumption, in percent



Source: AEM 2021.

Connecting the dots for investors

In assessing the current and predicted situation for resources (both natural and material) and their complex relationship with geopolitics, several clusters of consideration for investors become apparent:

The emergence of a multi-polar geopolitical environment with two centers of gravity
Such a world order looks set to emerge in the decades ahead and would revolve around two centers of gravity: China and the US. It's not a replication of the more clearly formed bipolarity (in the shape of two blocs) that existed during the Cold War era. Even excluding demographic shifts or financial resources, China doesn't appear to be self-sufficient enough, particularly in the field of energy, to enable it to become sufficiently independent to achieve an unrivaled bloc leadership over the longer-term among its potential allies.

The US-led center of gravity looks relatively better positioned
On the other hand, the current US-EU-NATO bloc still appears well positioned and equipped, particularly when it comes to the all-important resource—know-how—a resource that is a facilitator and enabler for all other material resources and hence the most important of resources.

Nevertheless, the US, and more so Japan or the EU, following the decision to reverse energy dependence on Russia and move towards renewable energies, are confronted with another dependence in the form of minerals and metals. For some of these materials China has close to a monopoly, and other countries that are not NATO members also have substantial leverage.

Additionally, regarding materials and components for the tech sector of military technology, the dependency and vulnerability to trade distortions remain very high. Most prominently, the green transition towards renewable energy will demand a lot of fossil fuels, so that the EU, Japan, and South Korea, for example, will remain dependent on other oil and gas exporting countries besides Russia.

China has scarcity issues to address
Though China is continuing to catch up in terms of geopolitical power relative to western nations, it appears more vulnerable in many resource dimensions than is usually considered.

Energy is a key issue for the nation, with food, water, and know-how also scarce to some extent. In addressing these challenges, China is clearly looking to move away from western dependencies. Here, also the latest coalescence with Russia is welcome as the country holds an abundant set of natural resources and access to them is of paramount importance to China, if it wants to grow further.

But naturally, there is always a flip side of the coin, the cheap energy from Russia comes also with the threat of a big state that could swiftly drift into political instability, right at the Chinese border. Several studies confirm that social unrest and political turmoil can quickly spill over to neigboring countries, particularly when ties are strong (Barrett & Chen 2021). The USA, for example, does not face such a situation in the foreseeable future, with its two politically stable neighbors.

Trading relations with Africa and the Middle East are being strengthened too. And China hopes to pay for commodities with the renminbi and its own clearing system, moving payments away from the US dollar and western clearing systems such as SWIFT or CHIPS.

However, with almost 60% of global currency reserves held in US dollars (only about 3% for the renminbi), over 40% share of the global payments system (only about 2% for the Renminbi), the US dollar will remain key for geopolitical considerations and remain the number one currency for investors for decades to come (Eichengreen 2022).

Trade reliances and alliance shifts: What should investors expect?

Virtually all nations appear quite dependent on other non-allied countries from a resource point of view. Going forward, there are a few points investors should consider. The International Chamber of Commerce (ICC) compared several studies where, depending on the scope and pace of trade derogations, the US-centric bloc's hit to GDP ranges between 1–8%, while the Chinese-led bloc could lose up to 12% of GDP over the long term.

Acknowledging this interconnectivity can help reduce inter-state conflicts (Gartzke 2007, Jackson & Nei 2015) and this is a positive geopolitical side-effect of nations' quest for resources. If the new multi-polar geopolitical environment emerges revolving around the US and China, other large countries should retain decisive roles, including India and Russia, but also resource-rich countries in the Middle East like Saudi Arabia and Iran, and certain African and Latin American states. Investors should expect more volatile and fragile alliances of geopolitical partners beyond NATO.

Other global players will likely shift the focus of their alliances between China and the US as they attempt to leverage their negotiating power. Competition between global superpowers can lead to an increase in proxy wars (DeSoysa 2017, see also figure 29). This is particularly likely when the state is important due to its resources, and looking at current surveys of global trends in armed conflicts, presented in figure 29, seems to confirm this picture (UNEP 2009 & 2015).

Actively managed portfolios could be set to benefit

The complex, inter-related geopolitical scenario we outline could be an ideal environment for actively managed portfolios.

Investors could take advantage of the opportunities that will arise from these developments and invest in assets that benefit from the geopolitical drive outlined here—greater independence from major trading partners, the upcoming climate changes and the promotion of renewable energies.

See our insights section for commentary from four of our investment teams, explaining how they operate in this emerging multi-polar world and how they aim to deliver future-proof investment solutions for their clients.

AEM (2021), Association of Equipment Manufacturers. The Environmental Benefits of Precision Agriculture in the United States. Washington: AEM. Available at [https://newsroom.aem.org/download/977839/environmentalbenefitsofprecisionagriculture-2.pdf]

Allen, R. C. (2001). The Rise and Decline of the Soviet Economy. The Canadian Journal of Economics / Revue Canadienne d'Economique, 34(4). Available at [http://www.jstor.org/stable/3131928]. p. 859–881.

Aslam, A., Eugster, J., Ho, G., Jaumotte, F., & Piazza, R. (2018). Globalization Helps Spread Knowledge and Technology Across Borders. IMF Blog. Available at [https://www.imf.org/en/Blogs/Articles/2018/04/09/globalization-helps-spread-knowledge-and-technology-across-borders].

Backhouse, R. E., & Medema, S. G. (2009). Retrospectives: On the definition of economics. Journal of economic perspectives, 23(1), 221-233.

Barrett, P., Bondar, M., Chen, S., Chivakul, M., & Igan, D. (2021). Pricing Protest: The Response of Financial Markets to Social Unrest, IMF Working Paper, WP/21/79. Available at [https://www.imf.org/en/Publications/WP/Issues/2021/03/19/Pricing-Protest-The-Response-of-Financial-Markets-to-Social-Unrest-50146].

Barrett, P., & Chen, S. (2021). The Economics of Social Unrest. Finance & Development, International Monetary Fund. Available at [https://www.imf.org/external/pubs/ft/fandd/2021/08/economics-of-social-unrest-imf-barrett-chen.htm].

Beraja, M., Yang, D. Y., & Yuchtman, N. (2023). Data-intensive innovation and the State: evidence from AI firms in China. The Review of Economic Studies, 90(4), 1701-1723. Available at [https://www.nber.org/system/files/working_papers/w27723/w27723.pdf].

Boeing, P., & Mueller, E. (2019). Measuring China's patent quality: Development and validation of ISR indices. China Economic Review, 57. p.101331.

Boretti, A., & Rosa, L. (2019). Reassessing the projections of the World Water Development Report. npj Clean Water, 2, 15. [https://www.nature.com/articles/s41545-019-0039-9].

BP Statistical Review of World Energy 2023). Annual Statistical Review, British Petrolium (BP). Available at [https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html]

Bradsher, K. (2010). Amid Tension, China Blocks Vital Exports to Japan. New York Times. Available at [https://www.nytimes.com/2010/09/23/business/global/23rare.html].

Bradsher, K. & Swanson, A. (2018). White House Considers Restricting Chinese Researchers Over Espionage Fears. The New York Times. Available at [https://www.nytimes.com/2018/04/30/us/politics/trump-china-researchers-espionage.html].

Butts, K. H. (2015). Geopolitics of Resource Scarcity. Univ. Penn. State: Journal & International Affairs. Available at [https://elibrary.law.psu.edu/jlia/vol3/iss2/3].

Cavallo, A. J. (2004). "Hubbert's petroleum production model: an evaluation and implications for World Oil Production Forecasts". Natural Resources Research. 13 (4): 211–221. Available at [doi:10.1007/s11053-004-0129-2]

Cembureau (2019). 2019 Activity Report. The European Cement Association. Available at [https://cembureau.eu/media/clkdda45/activity-report-2019.pdf].

Cembureau (2020). 2020 Activity Report. The European Cement Association. Available at [https://cembureau.eu/media/m2ugw54y/cembureau-2020-activity-report.pdf].

CIA World Fact Book (2020-2022). Available at [https://www.cia.gov/the-world-factbook/]

Circle Economy (2022). The Circularity Gap Report 2022. Amsterdam: Circle Economy. Available at [https://drive.google.com/file/d/1NMAUtZcoSLwmHt_r5TLWwB28QJDghi6Q/view]. p. 1-64.

Coin, G. (2022). How will Onondaga County supply Micron with 20 million gallons of water every day? Syracuse.com. Available at [https://www.syracuse.com/news/2022/10/how-will-onondaga-county-supply-micron-with-20-million-gallons-of-water-every-day.html]

Coppus, R. (2022). Global distribution of land degradation. Rome: FAO. Available at [www.fao.org/land-water/solaw2021/en].

Criekemans, D. (Eds.) (2021). Geopolitics and International Relations. Leiden, The Netherlands: Brill | Nijhoff. Available at [https://doi.org/10.1163/9789004432086].

Crow, J. M. (2008). The concrete conundrum. Chemistry World – the Royal Society of Chemistry. Available at [https://www.rsc.org/images/Construction_tcm18-114530.pdf].

CSRP (2020), Center for Systemic Risk Peace. Global Trends in Armed Conflicts, 1946-2019. Available at [https://www.systemicpeace.org/conflict-trends.html#fig3]

Demertzis, M., Hilgenstock, B., McWilliams, B., Ribakova, E., & Tagliapietra, S. (2022). Policy brief: How have sanctions impacted Russia? Bruegel. Available at [https://www.bruegel.org/policy-brief/how-have-sanctions-impacted-russia].

De Soysa, I. (2017). Proxy Wars: Implications of Great-Power Rivalry for the Onset and Duration of Civil War. Oxford University Press. Available at [https://oxfordre.com/politics/display/10.1093/acrefore/9780190228637.001.0001/acrefore-9780190228637-e-526].

Dobreva, A. & Wilson, A., Parliamentary Research Service (EPRS). (2019). BRIEFING: EU policies – Delivering for citizens: Energy supply and security. European Parliamentary Research Service (EPRS). Available at [https://www.europarl.europa.eu/RegData/etudes/BRIE/2018/630275/EPRS_BRI(2018)630275_EN.pdf].

Economic Policy Uncertainty (2022). Economic Policy Uncertainty Index. Available at [https://www.policyuncertainty.com/].

EEA (2020), European Environment Agency (EEA). The European environment — state and outlook 2020: Knowledge for transition to a sustainable Europe. Available at [https://www.eea.europa.eu/soer/publications/soer-2020].

EIA (2021), Energy Information Administration of the United States (EIA). Annual Energy Outlook 2021. Washington: Energy Information Administration. Available at [https://www.eia.gov/outlooks/archive/aeo21/].

EIA (2020), Energy Information Administration of the United States. Database for US Petroleum production. Available at [https://www.eia.gov/petroleum/data.php].

Eichengreen, B. (2022). Sanctions, SWIFT, and China's Cross-Border Interbank Payments System. CSIS BRIEFS. Center for Strategic and International Studies (CSIS). Available at [https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/220520_Eichengreen_Marshall_Papers.pdf? VersionId=jXEhrB1fWZ1qMhoqlMsy_ATo.bKGdfBo].

Enerdata (2022). Bilanz des Energiehandels. Globales Energie- und Klimastatistik-Jahrbuch 2023. Available at [https://energiestatistik.enerdata.net/gesamtenergie/welt-importe-exporte-statistik.html].

Erisman, J., Sutton, M., Galloway, J., et al. (2008). How a century of ammonia synthesis changed the world. Nature Geoscience, 1. Available at [https://doi.org/10.1038/ngeo325]. p. 636–639.

European Commission (2021). 3rd Raw Materials Scoreboard: European innovation partnership on raw materials. Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs. Publications Office. Available at [https://data.europa.eu/doi/10.2873/567799].

European Commission. (2021). European Innovation Partnership on Raw Materials: Raw Materials Scoreboard. Luxembourg: European Union. Available at [https://op.europa.eu/en/publication-detail/-/publication/eb052a18-c1f3-11eb-a925-01aa75ed71a1].

European Commission. (2022). REPowerEU: A plan to rapidly reduce dependence on Russian fossil fuels and fast forward the green transition. Available at [https://ec.europa.eu/commission/presscorner/detail/en/IP_22_3131].

Eurasia-Vontobel. (2019). The Next Digital Superpower: Scenarios for the US-China Conflict and implications for the global economy. Vontobel Holding AG, Eurasia Group. Available at [https://www.vontobel.com/en-ch/impact/usa-vs-china-the-next-digital-superpower-whitepaper-17170/].

Eurostat. (2022). Energy consumption in households: Statistics Explained. Available at [https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_consumption_in_households#Energy_consumption_in_households_by_type_of_end-use].

FAO (2020), Food and Agriculture Organization of the United Nations (FAO). The state of food security and nutrition in the World. Rome: FAO. Available at: [https://www.fao.org/3/ca9692en/CA9692EN.pdf]

FAO (2022), Food and Agriculture Organization of the United Nations (FAO). Inorganic fertilizers 1990–2020. FAOSTAT Analytical Briefs, no. 47. Rome: FAO. Available at [https://www.fao.org/documents/card/en/c/cc0947en].

FAO (2021), Food and Agriculture Organization of the United Nations. Aquastat. Retrieved from [https://www.fao.org/land-water/databases-and-software/aquastat/en/].

Gartzke, E. (2007). The capitalist peace. American journal of political science, 51(1), pp.166-191.

GFP (2023), Global Firepower Index. 2023 Military Strength Ranking. Available at [https://www.globalfirepower.com/countries-listing.php].

Giljum, S. and F. Lutter (2018). Results from the UN IRP global material flows database. Slide deck, University of Vienna (WU). Available at [https://unece.org/fileadmin/DAM/stats/documents/ece/ces/ge.33/2018/mtg3/S2_2_EN_Global_trends_Lutter.pdf]

Gowlett, J. A. J. (2016). The discovery of fire by humans: a long and convoluted process. Philosophical Transactions of the Royal Society B: Biological Sciences, 371(1696), p.2015-164.

Greve, P., Kahil, T., Mochizuki, J., et al. (2018). Global assessment of water challenges under uncertainty in water scarcity projections. International Institute for Applied Systems Analysis, Laxenburg: Austria.

Griffiths, P. I. J., Smith, R. A., & Kersey, J. (2003). Resource flow analysis: measuring sustainability in construction. Proceedings of the Institution of Civil Engineer – Engineering Sustainability, Vol. 156, No. 3, pp. 147-155. Available at [https://www.icevirtuallibrary.com/doi/abs/10.1680/ensu.2003.156.3.147]

GTA (2023). Global Trade Alert Database. Global Trade Alert Initiative. Available at [https://www.globaltradealert.org/]

Hall, C. A., Lambert, J. G., & Balogh, S. B. (2014). EROI of different fuels and the implications for society. Energy policy, 64, 141-152. Available at [https://www.sciencedirect.com/science/article/pii/S0301421513003856]

Harari, Y. N. (2015). Sapiens: A Brief History of Humankind. London: Vintage Books.

Heusaff, C., Guetta, L., McWilliams, B. & Zachmann, G. (2023). Russian Crude Oil Tracker. Brussels: Bruegel. Available at [https://www.bruegel.org/dataset/russian-crude-oil-tracker]

Hubbert, M. K. (1965). National Academy of Sciences Report on Energy Resources. AAPG Bulletin. 49 (10): 1720–1727. Available at [doi:10.1306/A66337C0-16C0-11D7-8645000102C1865D]

IEA (2021a), International Energy Agency. Ammonia Technology Roadmap: Towards more sustainable nitrogen fertilizer production. Available at [https://iea.blob.core.windows.net/assets/6ee41bb9-8e81-4b64-8701-2acc064ff6e4/AmmoniaTechnologyRoadmap.pdf].

IEA (2021b), International Energy Agency. Key World Energy Statistics 2021. Available at [https://iea.blob.core.windows.net/assets/52f66a88-0b63-4ad2-94a5-29d36e864b82/KeyWorldEnergyStatistics2021.pdf].

IEA (2022a), International Energy Agency. Buildings. Paris: IEA. [Available at https://www.iea.org/reports/buildings].

IEA (2022b), International Energy Agency. Global Supply Chains of EV Batteries. Paris: IEA. [https://iea.blob.core.windows.net/assets/961cfc6c-6a8c-42bb-a3ef-57f3657b7aca/GlobalSupplyChainsofEVBatteries.pdf].

IEA (2022c), International Energy Agency. The Role of Critical Minerals in Clean Energy Transitions. Paris: IEA. [Available at https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions].

IEA (2022d), International Energy Agency. Data and statistics explorer – Renewables dataset. Paris: IEA. Available at [https://www.iea.org/data-and-statistics]

IHME. (2019). Global Burden of Disease Study. Available at [https://www.healthdata.org/research-analysis/gbd].

International Cement Review (2022). Global Cement Report, 14th edition. Available at [https://www.cemnet.com/Articles/story/171972/uncertain-times.html]

IRENA (2022), International Renewable Energy Agency. World Energy Transitions Outlook 2022. Available at [https://www.irena.org/Digital-Report/World-Energy-Transitions-Outlook-2022#page-1].

Klasing, M. J., & Milionis, P. (2014). Quantifying the evolution of world trade, 1870–1949. Journal of International Economics, 92(1), 185-197. Available at [https://doi.org/10.1016/j.jinteco.2013.10.010]

Krane, J., & Medlock, K. B. (2018). Geopolitical dimensions of US oil security. Energy Policy, 114. Available at [https://doi.org/10.1016/j.enpol.2017.12.050] p. 558-565.

Krausmann, F., Gingrich, S., Eisenmenger, N., Erb, K. H., Haberl, H., & Fischer-Kowalski, M. (2009). Growth in global materials use, GDP and population during the 20th century. Ecological economics, 68(10), 2696-2705.

Krausmann, F., Schaffartzik, A., Mayer, A., Eisenmenger, N., Gingrich, S., Haberl, H., & Fischer-Kowalski, M. (2016). Long-term trends in global material and energy use. Social Ecology: Society-Nature Relations across Time and Space, London, Berlin: Springer 199-216. Available at [https://link.springer.com/chapter/10.1007/978-3-319-33326-7_8]

Kristensen, H., M. Korda, E. johns, K. Kohn (2023). Status of World Nuclear Forces. Washington: Federation of American Scientists. Available at[https://fas.org/initiative/status-world-nuclear-forces/]

Lang, O. (2010). Row over exotic minerals that make modern life tick. BBC News. Available at [https://www.bbc.co.uk/news/world-asia-pacific-11584229].

Lovely, M. E. (2017). Technology Transfer via Intellectual Returnees in China's Solar Industry. China Economic Watch. Peterson Institute for International Economics. Available at [https://www.piie.com/blogs/china-economic-watch/technology-transfer-intellectual-returnees-chinas-solar-industry].

Lutz, C., & Giljum, S. (2009). Global resource use in a business-as-usual world up to 2030. In Sustainable Growth and Resource Productivity: Economic and Global Policy Issues, ed. Bleischwitz et al. Sheffield: Greenleaf Publishing.

Mearsheimer, J. J. (2001). The Inevitable Rivalry: America, China, and the Tragedy of Great-Power Politics. Foreign Affairs Magazine. Available at [https://www.foreignaffairs.com/articles/china/2021-10-19/inevitable-rivalry].

Needham, K. (2023). British RAF chief calls it 'unacceptable' for China to recruit western military pilots. Reuters. Available at [https://www.reuters.com/world/british-raf-chief-calls-it-unacceptable-china-recruit-western-military-pilots-2023-03-01/].

OECD (2018), Organization for Economic Co-operation and Development (OECD). Raw materials use to double by 2060 with severe environmental consequences. OECD, Paris. Available at [https://www.oecd.org/environment/raw-materials-use-to-double-by-2060-with-severe-environmental-consequences.htm].

Our World in Data, Database, University of Oxford, England. Available at [https://ourworldindata.org]

Pahud, K., & De Temmerman, G. (2022). Overview of the EROI, a tool to measure energy availability through the energy transition. In 2022 8th International Youth Conference on Energy (IYCE) (pp. 1-14); IEEE. Available at [https://hal.science/hal-03780085/document]

Papic, M. (2020). Geopolitical Alpha: An Investment Framework for Predicting the Future. United Kingdom: Wiley.

Parthemore, C., & Rogers, W. (2010). Sustaining Security: How Natural Resources Influence National Security. Center for a New American Security. Available at [http://www.jstor.com/stable/resrep06384].

PIIE (2022), Peterson Institute for International Economics (PIIE). Globalization is in retreat for the first time since the Second World War. Available at [https://www.piie.com/research/piie-charts/globalization-retreat-first-time-second-world-war].

Project Atlas (2019). A Quick Look at Global Mobility Trends. Institute of International Education. Available at [https://www.iie.org/research-initiatives/project-atlas/explore-data/infographics/2019-project-atlas-infographics/].

Redl, C., & Hlatshwayo, S. (2021) Forecasting Social Unrest: A Machine Learning Approach. IMF Working Paper, WP/2021/263, Available at SSRN [https://ssrn.com/abstract=4026493].

ResourceTrade.Earth (2023), a Chatham House database. The scale and significance of resource trade. Available at [https://resourcetrade.earth/publications/the-scale-and-significance-of-resource-trade].

Roach, S. (2023). The AI Moment of Truth for Chinese Censorship. Project Syndicate. Available at [https://www.project-syndicate.org/commentary/ai-chatgpt-style-large-language-models-dont-work-well-with-censorship-by-stephen-s-roach-2023-05?utm_source=Project%20Syndicate%20Newsletter&utm_campaign=d02545388f-sunday_newsletter_05_28_2023&utm_medium=email&utm_term=0_73bad5b7d8-d02545388f-107591130&mc_cid=d02545388f&mc_eid=d2dd4223f5&barrier=accesspaylog].

Robbin, Lionel (1932). Essay on the Nature and Significance of Economic Science. London: Macmillan Publishers.

Rubin, O. (2021). The Art of Diplomacy: Strengthening the Canada-US Relationship in Times of Uncertainty. Centre for International Governance Innovation. Available at [https://www.cigionline.org/publications/art-diplomacy-strengthening-canada-us-relationship-times-uncertainty].

Santacreu, A. M., & Zhu, H. (2018). What Does China's Rise in Patents Mean? A Look at Quality vs. Quantity. Economic Synopses, (14). Available at [https://doi.org/10.20955/es.2018.14].

Scudder, J. (2015). The sun won't die for 5 billion years, so why do humans have only 1 billion years left on Earth? The Conversation. Available at [https://theconversation.com/the-sun-wont-die-for-5-billion-years-so-why-do-humans-have-only-1-billion-years-left-on-earth-37379].

Sevastopulo, D., & Leahy, J. (2023). Beyond the balloon: the US-China spy game, The Big Read. Financial Times. Available at [https://www.ft.com/content/35d37c69-170c-4ae2-bde1-62ce0e8609b2].

Shanghai University Ranking (2022). The Academic Ranking of World Universities. Shanghai Ranking Consultancy. Available at [https://www.shang-hairanking.com/rankings/arwu/2022]

Shahbaz, A., Funk, A. & Vesteinsson, K. (2022). Freedom on the net 2022: Countering an authoritarian overhaul of the internet. Washington: Freedom House. Available at [https://freedomhouse.org/report/freedom-net/2022/countering-authoritarian-overhaul-internet]

Smil, V. (2017). Energy and civilization: A history. Cambridge, MA: MIT Press.

Smil, V. (2022). How the World Really Works: A Scientist's Guide to Our Past, Present and Future. Cambridge, MA: The MIT Press.

Song, H., & Li, Z. (2014). Patent quality and the measuring indicator system: Comparison among China provinces and key countries. Institute of Policy and Management. Beijing: Chinese Academy of Sciences. Available at [https://www.law.berkeley.edu/files/Song_Hefa_IPSC_paper_2014.pdf].

Tukker, A., Bulavskaya, T., Giljum, S., de Koning, A., Lutter, S., Simas, M., Stadler, K., & Wood R. (2014). The Global Resource Footprint of Nations - Carbon, water, land and materials embodied in trade and final consumption calculated with EXIOBASE 2.1.

UN Comtrade database (2022). United Nations commercial trade database. New York: United Nations Statistics Division. Available at [https://comtradeplus.un.org/]

UNEP (2009), United Nations Environment Programme (UNEP). From conflict to peacebuilding: The role of natural resources and the environment. Nairobi, Kenya: United Nations Environment Programme. Available at [https://www.iisd.org/system/files/publications/conflict_peacebuilding.pdf].

UNEP (2015), United Nations Environment Programme (UNEP). Addressing the Role of Natural Resources in Conflict and Peacebuilding: A Summary of Progress from UNEP's Environmental Cooperation for Peacebuilding Programme 2008-2015. Nairobi, Kenya: United Nations Environment Programme. Available at [https://www.unep.org/resources/publication/addressing-role-natural-resources-conflict-and-peacebuilding].

UNEP/Schandl et al. (2016), United Nations Environment Programme (UNEP), and Schandl, H. et al., Global Material Flows and Resource Productivity: An Assessment Study of the UNEP International Resource Panel. Paris: UNEP. Available at [https://www.resourcepanel.org/reports/global-material-flows-and-resource-productivity-database-link]

UNEP/ Bringezu et al. (2017), United Nations Environment Programme (UNEP), and Bringezu, S. et al., Assessing Global Resource Use: A Systems Approach to Resource Efficiency and Pollution Reduction. Nairobi: UNEP. Available at [https://www.resourcepanel.org/reports/assessing-global-resource-use]

UN-FAO (2022), Food and Agricultural Organization of the United Nations. The state of the world's land and water resources for food and agriculture: Systems at breaking point. Rome, Italy. Available at [https://www.fao.org/documents/card/en/c/cb9910en].

UN World Water Report (2018). The United Nations World Water Development Report. Geneva: United Nations. Available at [https://www.unwater.org/publications/world-water-development-report-2018]

United Nations (2019), UN Environment Programme and International Resource Panel (UNEP). Global Resources Outlook 2019: Natural Resources for the Future We Want - Summary for Policymakers. Available at [https://wedocs.unep.org/20.500.11822/27518].

United States Geological Service (2019). The distribution of water on, in and above Earth. Washington, DC: USGS. Available at [https://www.usgs.gov/media/images/distribution-water-and-above-earth]

USDA (2022), United States Department of Agriculture (USDA). Irrigation and Water Use. Washington: USDA Economic Research Service. Available at [https://www.ers.usda.gov/topics/farm-practices-management/irrigation-water-use/]

US Foreign Agricultural Service (2022). Impacts and Repercussions of Price Increases on the Global Fertilizer Market. International Agricultural Trade Report. Available at [https://www.fas.usda.gov/data/impacts-and-repercussions-price-increases-global-fertilizer-market].

USGS (2019-2022), United States Geological Survey (USGS). Minerals Yearbook: Metals and Minerals. National Minerals Information Center, USGS, Interior Department & Mines Bureau. Available at [https://www.usgs.gov/centers/national-minerals-information-center/minerals-yearbook-metals-and-minerals].

Vine, D., Deppen, P., & Bolger, L. (2021). Drawdown: Improving U.S. and Global Security Through Military Base Closures Abroad. Quincy Brief No. 16. Available at [https://quincyinst.org/report/drawdown-improving-u-s-and-global-security-through-military-base-closures-abroad/].

Weißbach, D., Ruprecht, G., Huke, A., Czerski, K., Gottlieb, S., & Hussein, A. (2013). Energy intensities, EROIs (energy returned on invested), and energy payback times of electricity generating power plants. Energy, 52, 210-221. Available at [https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=e4fd25bff4d6884a8faf726856d7beb4bff49e8d]

WIPO (2019), World Intellectual Property Organization. WIPO Technology Trends 2019: Artificial Intelligence. Switzerland. Available at [https://www.wipo.int/tech_trends/en/artificial_intelligence/story.html]

WIPO (2022a), World Intellectual Property Organization. Global Innovation Index – What is the future of innovation-driven growth?. Switzerland. Available at [http://www.wipo.int/global_innovation_index].

WIPO (2022b), World Intellectual Property Organization. WIPO IP Facts and Figures 2022. Switzerland. Available at [https://www.wipo.int/edocs/pubdocs/en/wipo-pub-943-2022-en-wipo-ip-facts-and-figures-2022.pdf].

World Bank Group. (2020). Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition. Climate Smart Mining. Washington, DC: World Bank. Available at [https://pubdocs.worldbank.org/en/961711588875536384/Minerals-for-Climate-Action-The-Mineral-Intensity-of-the-Clean-Energy-Transition.pdf] p. 73.

World Bank (2023). World Development Indicators (WDI), Database. Washington, DC: World Bank. Available at [https://datatopics.worldbank.org/world-development-indicators/].

World Bank Data Portal (2019-2022). Washington, DC: World Bank. Available at [https://data.worldbank.org/].

Xu, C., Kohler, T. A., Lenton, T. M., Svenning, J.-C., & Scheffer, M. (2019). Future of the human climate niche. Washington: Proceedings of the National Academy of Sciences (PNAS), 117(21). Available at [https://www.pnas.org/doi/epdf/10.1073/pnas.1910114117].

Vontobel uses only recycled paper for printing. It takes about 1.5 times less energy and 2.5 times less water to produce recycled paper than it does to produce paper from fresh fiber. Recycled paper also cuts greenhouse gas emissions by more than 20%. We offset the remaining emissions with various CO_2 projects around the world.

Further information
vontobel.com/sustainability

Vontobel Asset Management
Gotthardstrasse 43
8022 Zurich
Switzerland

vontobel.com/am