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Strategic Resource Partnerships

A step towards resilient supply chains and geopolitical sovereignty for the EU

André Wolf

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European industry's transition to the use of climate-neutral technologies is generating a variety of new resource needs. As a result of multiple crises, current supply routes are prone to disruption and threatened by increasing scarcity. Using the instrument of Strategic Resource Partnerships, the EU is aiming to cooperate with selected third countries to establish alternative supply chains that meet European needs for greater security and higher environmental standards. At the same time, they offer a starting point for developing the EU's open strategic sovereignty as an alternative to protectionist, subsidy-based industrial policy. This cepInput offers a systematic analysis of this instrument.

Key points:

- The partnership strategy should not be limited to accessing critical mineral resources but should also focus on other European resource bottlenecks, such as **renewable energies, innovation potential and human capital,** for the success of future technologies.
- Deepening relations with established resource-rich partners such as Australia, Chile and New Zealand is a sensible first step, but a risk-avoidance strategy should also **seek to uncover blind spots on the resource map**.
- To address the **risk of long-term instability in partnerships**, the EU needs to provide sustainable growth prospects, especially to the developing countries among its partners.
- The partner portfolio should be **managed by the EU holistically according to risk-return aspects**, especially regarding the right degree of redundancy of supply routes. This requires permanent monitoring based on an extended indicator system.

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1 Background

Europe's established industrial value chains have recently come under pressure from various quarters. Short-term shocks that have highlighted the vulnerability of existing supply channels are coupled with long-term structural trends that create new risks to the provision of resources. Europe's industry is faced with the challenge of broadening its supply of essential mineral raw materials, energy sources and intermediate products. (Re-)nationalization of resource extraction would involve high social costs for an economically highly developed continent that is essentially based on knowledge-intensive industries. Securing stable supply channels through closer cooperation with third countries is a more promising strategy.

The EU has recently developed a new instrument for cooperation with third countries in the form of Strategic Resource Partnerships. The focus is on establishing joint supply chains to meet the resource requirements of future technologies. This is not just about reducing trade barriers and promoting investment in the raw materials sector. The spectrum of the agreements also includes infrastructure development, research cooperation, knowledge exchange and regulatory cooperation. The aim is to address various forms of supply risk simultaneously and strengthen the economic ties between the partners. In its Green Deal Industrial Plan, the European Commission recently announced the establishment of a Critical Raw Materials Club as an overarching framework for the individual bilateral partnerships.[1] Questions arise as to how promising such agreements are against the backdrop of systemic competition with countries like China, and how the portfolio of partners will have to be shaped to strengthen Europe's resilience. Most notably, there is a need to clarify how Europe can use its value system as a competitive advantage in shaping the clubs, to ensure reciprocity of relations and to create sustainable growth prospects for the partner countries.

This cep**Input** offers the first comprehensive analysis of the instrument of Strategic Resource Partnerships and its design issues. It first explains the features and economic mechanisms of the new concept before going on to empirically examine the instrument's potential based on selected future technologies as well as analysing Europe's external dependence. The cepInput will then evaluate the currently known resource potentials in third countries and identify the various barriers to cooperation. The analysis is not limited to critical mineral raw materials but also addresses the availability of renewable energies, innovation potential and human capital and in doing so highlights the special role of the Global Gateway Initiative in leveraging these potentials. Finally, it analyses the challenges imposed by the competition with China's Belt and Road Initiative and develops strategic guidelines for the EU in planning its future partnership portfolio.

1 European Commission (2023). A Green Deal Industrial Plan for the Net-Zero Age. Communication from the European Commission to the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the Regions. (2023) 62 final.

2 EU Resource Partnerships

2.1 The concept and its origin

The EU's classic instrument for advancing economic integration with individual third countries is bilateral trade agreements. The scope of these agreements has expanded over the decades. Whereas the original aim was to reduce or eliminate customs duties, i.e., to lower the costs of cross-border trade in goods, more recent trade agreements have also included detailed regulations on the elimination of non-tariff barriers to trade (regulatory harmonization), the facilitation of capital movements (cross-border investment) and the cross-border provision of services. The anchoring of common goals and minimum standards beyond trade policy, particularly regarding environmental protection and human rights, is now also a common component of EU trade agreements.[2]

The concept of partnership is mentioned in this context in the form of Economic Partnership Agreements (EPAs). According to its origins, this is a special form of trade agreement that pursues both trade and development policy objectives. The concept goes back to the Cotonou Partnership Agreement concluded in its original form in 2000 between the EU and a large number of states from the African, Caribbean and Pacific (ACP) region.[3] It enables the EU and individual ACP countries to negotiate development-oriented trade agreements known as Economic Partnership Agreements. These involve a reciprocal but asymmetric reduction of trade barriers over time, as well as increased development cooperation to facilitate market opening. According to the EU, such agreements are currently in force or provisionally applied with 30 ACP countries.[4]

The concept of "strategic partnership", on the other hand, originates from a completely different sphere. EU communication used it for the first time in 1998 in relation to Russia. In connection with the financial crisis in Russia at the time, the EU emphasized its willingness to help, referring to the country as a "strategic partner".[5] In 2003, the EU informed the public about the development of a "comprehensive strategic partnership" with the People's Republic of China.[6] Subsequently, further strategic partnerships were announced with India, Brazil, South Africa, Mexico and South Korea.[7] In addition, the EU has repeatedly stressed the strategic importance of its long-established partnerships with the United States, Canada and Japan. The nature of such strategic partnerships differs fundamentally from cooperation instruments in the area of trade policy. As a rule, they are not rooted in legally binding agreements but in non-binding declarations of intent. Their focus is not primarily on economic integration but is mostly on the area of foreign and security policy.

In its 2020 Action Plan on Critical Raw Materials, the European Commission introduced a new form of cooperation. As a step towards greater security of supply for mineral raw materials that are essential for the future, such as lithium, cobalt, and rare earth metals, it wants to promote strategic partnerships

2 Bartels, L. (2013). Human rights and sustainable development obligations in EU free trade agreements. Legal Issues of Economic Integration, 40(4).

3 https://www.consilium.europa.eu/en/policies/cotonou-agreement/#cotonou

4 https://policy.trade.ec.europa.eu/eu-trade-relationships-country-and-region/negotiations-and-agreements_en

5 Marcus, D., & Sangsari, M. (2015). Strategic partnership as an instrument of EU foreign policy. In Workshop Report of Carleton University.

6 Cihelkova, E., Nguyen, H. P., Fabuš, M., & Čimová, K. (2020). The EU concept of the'strategic partnership': identifying the'unifying'criteria for the differentiation of strategic partners. Entrepreneurship and Sustainability Issues, 7(3), 1723-1739.

7 Marcus, D., & Sangsari, M. (2015). Strategic partnership as an instrument of EU foreign policy. In Workshop Report of Carleton University.

between the EU and resource-rich countries. All available instruments of EU foreign policy are to be used for this purpose. The horizon is explicitly global, and both high-income economies with established mining sectors and resource-rich developing countries are mentioned as potential partners. In addition to the elimination of bilateral barriers to trade in raw materials, cooperation is also to include financial and practical support for the development of local production capacities and infrastructure, both in the field of raw materials extraction and processing. In this context, the Commission attaches particular importance to the concept of responsible sourcing, i.e. compliance with environmental and human rights standards. This is to be ensured through intensive cooperation in the area of local governance.[8]

In June 2021, the EU announced a first resource partnership with Canada.[9] In a joint statement by Internal Market Commissioner Thierry Breton and Canadian Resources Minister Seamus O'Regan Jr., a month later, forms of future cooperation were outlined.[10] In addition to the joint development of specific mining projects, the financial support system is to be coordinated bilaterally and incentive instruments for innovations in the area of supply chain decarbonization are to be created. In the same month, a second partnership was established with the Ukraine. In a memorandum of understanding, the objectives, principles and initial work steps of the cooperation were defined. One focus is on supply chains for battery production. The aforementioned forms of future cooperation include not only incentives for private investment but also permanent regulatory cooperation, joint research activities and knowledge exchange.[11] In November 2022, on this basis, another cooperation agreement was concluded between the European Bank for Reconstruction and Development and the Office of Geology of Ukraine to support the modernization of geospatial data management in Ukraine.[12] This can be seen as a clear signal of the determination to press ahead unabated with the raw materials partnership despite the ongoing war situation.

A whole series of additional resource-related partnership agreements were also concluded in 2022, namely with Egypt, Azerbaijan, Kazakhstan, Morocco, and Namibia. Not all of these are related to critical mineral commodities. The agreements with Egypt, Azerbaijan and Morocco relate to the development of supply relationships for energy sources, in the case of Egypt specifically renewable hydrogen.[13] By contrast, agreements with Kazakhstan[14] and Namibia[15] explicitly concern mineral resources. In all cases, the agreements are merely memoranda of understanding outlining the main features of future cooperation.

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8 European Commission (2020a). Critical raw materials resilience: charting a path towards greater security and sustainability. Communication from the European Commission to the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the Regions. (2020) 474 final.

9 European Commission (2021). EU and Canada set up a strategic partnership on raw materials. Press Release, 21 June 2021.

10 European Commission / Canada (2021). Joint Statement by European Commissioner for Internal Market and Canada's Minister of Natural Resources. Brussels, 19 July 2021.

11 European Union / Republic of Ukraine (2021). Memorandum of understanding between the European Union and Ukraine on a Strategic Partnership on Raw Materials. Kyiv, 13 July 2021.

12 https://neighbourhood-enlargement.ec.europa.eu/news/eu-ukraine-strategic-partnership-raw-materials-european-bank-reconstruction-and-development-will-2022-11-17_en

13 European Union / Arab republic of Egypt (2022). Memorandum of understanding on a strategic partnership on renewable hydrogen between the European Union and the Arab republic of Egypt. Sharm El-Sheikh, 16 November 2022.

14 European Union / Republic of Kazakhstan (2022). Memorandum of understanding between the Republic of Kazakhstan and the European Union on a strategic partnership on sustainable raw materials, batteries and renewable hydrogen value chains. Sharm El-Sheikh, 7 November 2022.

15 European Union / Republic of Namibia (2022). Memorandum of understanding on a partnership on sustainable raw materials value chains and renewable hydrogen between the European Union represented by the European Commission and the Republic of Namibia. Sharm El-Sheikh, 8 November 2022.

Table 1 compares the documents in terms of the content of the partnership agreements listed. The difference in each partner's level of economic development results in slightly different priorities. In the case of Canada, a special feature is that the resource partnership is not the prelude to a deepening of general economic relations but is, in fact, designed as the next step in a long-term integration process which has already achieved major success with the comprehensive trade agreement CETA.[16] Apart from this, a clear pattern emerges. All agreements emphasize the will to cooperate on research. The focus is never solely on efficiency aspects but also on innovation to improve the ecological footprint of the supply chains concerned. The exchange of existing knowledge is also mentioned in all cases as a cooperation element. Moreover, the willingness to cooperate on regulatory issues with regard to mining standards receives particular emphasis. In the end, all agreements show that the establishment of stable utilization chains for critical raw materials requires more than just long-term supply contracts. This may become crucial for the future stability of the partnerships, as discussed in more detail in the following section.

The emerging type of resource partnership thus combines aspects of the forms of cooperation discussed above. In common with EPAs, it seeks to link trade with long-term development cooperation in capacity building. In common with the strategic partnerships of the 2000s, it is motivated by the security and stability aspect due to the increasing geostrategic importance of access to raw materials. An unique characteristic of the new resource partnerships, however, is their focus on the supply chain perspective: It is not just about resource procurement but also about building globally competitive value chains to the exclusion of China as a geostrategic rival.

The legally non-binding nature of the agreements to date still guarantees a considerable degree of freedom for the practical shaping of partnerships in the future. For the EU, however, this also means that it still has a long way to go in building stable partnership relations. It must think carefully about which cooperation instruments are suitable in individual cases to create ties to resource-rich partners and which roadmap of integration steps is feasible. This first requires a sober economic analysis of the benefits and costs of such partnerships from the perspective of all partners.

[16] European Union / Canada (2016). Comprehensive economic and trade agreement between Canada and the European Union. Brussels, 28 October 2016.

Table 1: Overview of previous partnership declarations

Partner **Title**	**Canada** Strategic Partnership on Raw Materials	**Ukraine** Strategic Partnership on Raw Materials	**Kazakhstan** Strategic Partnership on Sustainable Raw Materials, Batteries and Renewable Hydrogen Value Chains	**Namibia** Partnership on Sustainable Raw Materials Value Chains and Renewable Hydrogen
Date of declaration	Jul 21	Jul 21	Nov 22	Nov 22
Type of declaration	Joint Statement	MoU	MoU	MoU
Focus	Critical raw materials	Critical raw materials for battery production	Critical raw materials for battery production; renewable hydrogen	Critical raw materials; renewable hydrogen
Trade agreement in force	Yes	No	No	Yes
		Mentioned forms of cooperation		
Cooperation in mining regulation		X	X	X
Joint resource exploration activities	X	X	X	
Exchange of knowledge / technologies	X	X	X	X
R&D-cooperation	X	X	X	X
Development of investment platforms (Matchmaking)		X	X	
Reduction of trade barriers			X	X
Coordination investment support	X			

Sources: European Commission / Canada (2021); European Union / Republic of Ukraine (2021); European Union / Republic of Kazakhstan (2022); European Union / Republic of Namibia (2022); own representation.

2.2 Partnership economics

Strategic partnerships can only bring stability in resource access if, from the point of view of all parties involved, the benefits of maintaining them permanently exceed the costs of the partnership commitment. In determining the optimal design of such arrangements, therefore, the first essential step is to establish the shape of this benefit in concrete terms. From the perspective of economic club theory, this corresponds to the nature of the club good which means the good that is jointly and exclusively available to the partners vis-à-vis the outside world.[17] It represents the basic motivation for the formation of partnerships as a club of economies. In the resource partnerships that are currently forming, the club good is not simply a single (tangible or intangible) product, but consists in the **establishment and preservation of entire cross-border value chains**. Strengthening and stabilizing the competitiveness of these value chains is the primary motivation of all forms of cooperation agreed upon in the course of the partnerships. This perspective makes them new compared to established forms of economic clubs.

The benefit of this jointly provided club commodity can be differentiated into a direct and an indirect effect. Directly, it consists of a contribution to hedging against existing supply chain risks on the world markets. From the perspective of resource-processing industries, this means a **reduction in price and supply risks in the procurement of critical, imported resources**. From the perspective of the upstream partner, it consists of a reduction in price and sales risks. The result of this risk reduction is greater security regarding the utilization of existing production capacities in the partner countries. If the

[17] Sandler, T., & Tschirhart, J. T. (1980). The economic theory of clubs: An evaluative survey. Journal of economic literature, 18(4), 1481-1521.

partners take up complementary positions in the supply chains, i.e. engage in intra-club vertical specialization, this benefit is non-rivalrous within the club, as is usual for club goods. This is an essential prerequisite for establishing a firm relationship in the first place.

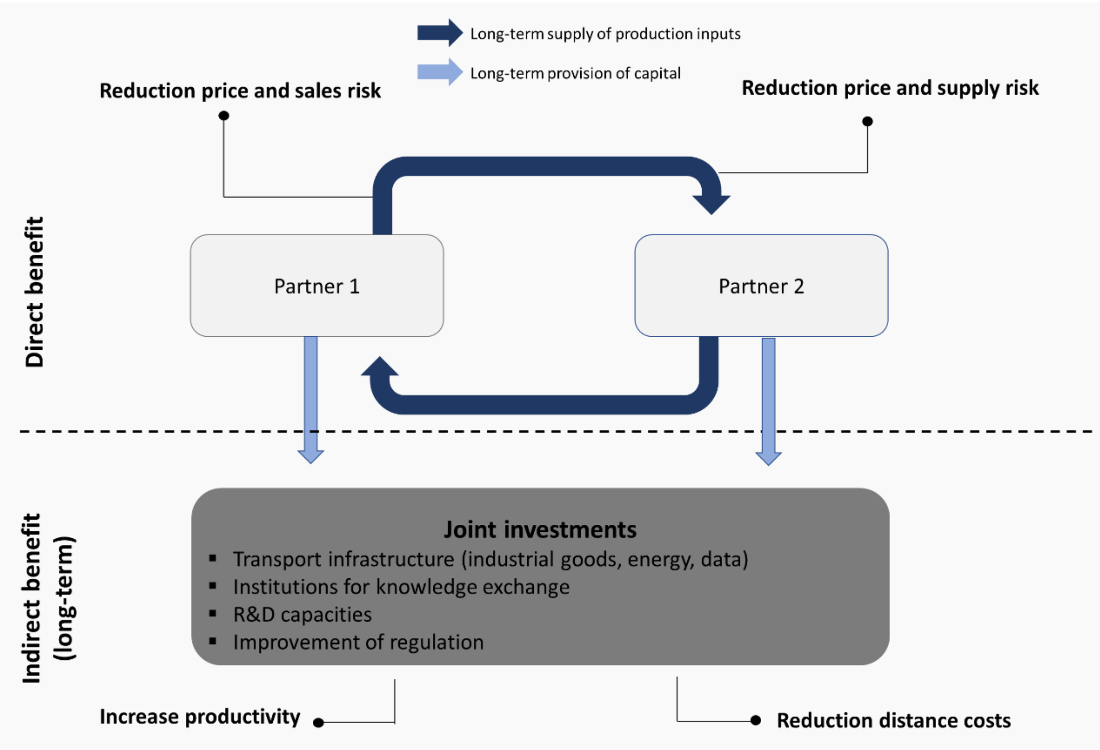
However, the resource partnerships envisaged by the EU are not limited to long-term supply relationships. In addition to direct benefits, there is also the prospect of a form of long-term indirect benefit. It results from the **pooling of partnership capital resources to strengthen the efficiency and competitiveness of joint supply chains**. By pooling capital for the expansion of complementary production capacities, the partners strive to realize macroeconomic productivity gains from vertical specialization. In the case of emerging technologies, there is also the prospect of cost reduction through scaling. By jointly investing in the development of transport infrastructure (transport of goods, energy, information), partners contribute to the reduction of costs caused by the geographical distance between processes. By sharing existing knowledge, they increase the speed of adoption of new technologies. By building joint R&D capabilities, they strengthen the innovation capacity of the sectors involved. By engaging in regulatory cooperation, they can lower administrative inefficiencies and reduce non-tariff trade costs.

The envisaged long-term benefit of pooling is thus the **creation of new non-rivalrous goods, and the associated macroeconomic growth effects**. By contrast with the direct benefit of risk hedging, however, non-rivalry often extends beyond club boundaries. Once a transport infrastructure has been created, it can of course be used to trade with partners beyond the supply contracts that have been concluded. Strengthening R&D capacities can generate innovations beyond the club's internal value chains. It is precisely this lack of excludability that makes the alternative provision of capital via global markets difficult. It also implies that those partners who have contributed relatively less to the common pool will tend to benefit more from the joint investment.

In these two aspects - and the expected asymmetry of the EU vis-à-vis its partners - lies the danger of long-term instability of resource partnerships. For many of the partners, whether already established or under discussion for the future, the balance between direct and long-term indirect benefits is likely to differ from that of the EU. As a net importer of raw materials essential for future technologies (see section 3), the EU's focus is clearly on securing critical raw materials for the supply channels of its own industry. The raw material-supplying partner countries see little immediate benefit from this since their long-term sales risks are low in view of very positive forecasts for the development of global demand.[18] The expected return on club-internal investment in new non-rival goods, on the other hand, is usually relatively low from an EU perspective, since a large part of the club capital invested will come from within the EU. Partner countries, on the other hand, can look forward to infrastructure development largely financed by imported capital, which will benefit their economic productivity in the long term.

[18] Watari, T., Nansai, K., & Nakajima, K. (2020). Review of critical metal dynamics to 2050 for 48 elements. Resources, Conservation and Recycling, 155, 104669.

Figure 1: Expected benefits from resource partnerships



Source: own representation.

However, as these long-term returns are realized, there is a risk of a **growing asymmetry in the overall benefits between the partners**. Since these returns are not tied to club membership and are also irreversible, they are no longer relevant for the decision to remain in the club. The direct benefit remains as the basis for decision-making, and this is often likely to be one-sided in favour of the EU. Consequently, the EU faces an increasing risk of club exits on the side of its partners.

To counter this risk as far as possible ex ante, i.e., in the design of the clubs, club theory opens up the possibility of a number of incentive instruments. One obvious instrument would be to extend the contractual commitment between club members over time, i.e., to establish particularly long-term supply contracts, club funds and other concrete cooperation obligations. However, this would be tantamount to increasing the cost of joining the club for all participants; that cost consisting specifically in the loss of flexibility associated with the commitment. Informational asymmetries increase the danger of an adverse selection of partners. Typically, the EU will only have limited information about the quantity and quality of the resource potential of potential partners. In view of the dynamics of exploration activities and the lack of global standards in data collection, this is especially true for geological resources.[19] The information situation of the local authorities is likely to be better in many cases. Under these conditions, a long-term commitment to the EU would be attractive above all for those partners whose future supply of resources is lower than expected by the EU.

An alternative approach would be to try to enforce the exclusion principle for club-generated non-rival goods. In principle, this could be approached by technical or purely legal means. Technically, an attempt could be made to gear the production process of non-rival goods to a high degree of

[19] Lewicka, E., Guzik, K., & Galos, K. (2021). On the possibilities of critical raw materials production from the EU's primary sources. Resources, 10(5), 50.

specialization, which would largely limit the usability of the goods to the area of internal club relations. In this way, joint research efforts could be deliberately limited to efficiency and quality improvements in supply-chain-specific production steps. However, the future raw materials in focus, and the intermediates produced with them, are largely usable for a variety of applications, so that efficiency gains would be difficult to internalize completely. Alternatively, an attempt could be made to enforce the exclusion principle by purely legal means, i.e., through exclusive rights of use to the club goods produced. In areas of cooperation such as infrastructure development, however, this would hardly be enforceable in practice, notwithstanding the potentially highly problematic impression for external policies.

Instead of trying to eliminate existing externalities, a promising approach would be to provide additional goods that can only be used within the club from the outset. This could include planning a **roadmap with various stages of general trade integration between the partners**, even beyond the commodity-related supply chains. The trade potential associated with the partnership would thus expand over time. To give developing countries in particular room to upgrade their domestic value creation toward downstream production, the integration stages could be tied to the achievement of certain industrial growth targets. This would mean that they would not have to open their domestic markets to European competition until the domestic downstream industry has reached a certain level of competitiveness.

Long-term cooperation in the development of process standards can also represent such a purely internal club asset. In this way, partners can exert influence on the technical design of standards in order to keep their own adaptation costs low and to gain a first-mover advantage over global market competitors. At the same time, they benefit from European economic power in the global implementation of jointly developed standards. On the part of the EU, this presupposes a certain pragmatism and a willingness to engage in intensive dialog with the partner countries when implementing its own policy goals.

Thus, securing access to critical raw materials through strategic resource partnerships at least requires a **permanent commitment from Europe, and also a form of renunciation**. Here, as in other cases, risk reduction cannot be obtained for free. Without new hedging mechanisms, the upcoming transformation processes will shift the risk profile of global value chains to the disadvantage of European industry. Counteracting this requires a willingness to share the tangible (capital) and intangible (knowledge, global influence) pillars of European prosperity with the likely beneficiaries of change.

This also means that Europe must weigh up the long-term benefits and the costs of individual partnerships very carefully. On the one hand, this means assessing the potential of secured resources. In view of the diversity of future technologies, the analysis must not be limited to access to individual raw materials but must consider the range of possible technology paths. In addition to the critical mineral raw materials highlighted by the EU, this also includes access to forms of renewable energy and to skilled workers, as well as the innovation potential resulting from partnerships. At the same time, the potential assessments must be contrasted with an honest analysis of existing barriers to cooperation, both at the technological and the regulatory level. In the following sections, we take a look at the status quo of potentials and barriers in a country comparison and outline a preliminary analytical framework.

3 Resource requirements for future technologies

3.1 Selection of technologies

The climate-neutral, digitalized European economy of the future will bring with it a wealth of new resource requirements. The individual requirements are always process-specific. In principle, there are at least three ways to categorize processes: according to the industries affected, according to the products generated, and according to the process technologies used. In this paper, we use the latter categorisation as it enables us to follow the concept of future technologies pursued by various studies and to derive from this a catalogue of critical resources for the future. Since there is no generally accepted idea of which technologies have particular relevance for the future, the basis for our technology selection is a comparison of the lists given in various recent studies. Specifically, the following studies were consulted:

- Bertelsmann (2020)[20]
- European Commission (2020b)[21]
- Schmoch et al. (2020)[22]
- Marscheider-Weidemann et al. (2021)[23]
- Bosch (2022)[24]
- McKinsey (2022)[25]

What these studies have in common is that they do not focus on individual sectors but look at the entire spectrum of tomorrow's technologies. Our approach is to consider the intersection of the technologies examined. In doing so, we must first deal with the fact that the terms used for technology have a narrower meaning in some studies than others and sometimes overlap (e.g., battery storage vs. solid-state batteries). Since the goal of our analysis is to identify specific resource needs, we have harmonized the technology terms in such cases by using the narrower meaning. Subsequently, we preselected those technologies that were identified as future technologies by at least two of the studies examined. This preselection was adjusted based on three further criteria that are essential for the purpose of our investigation. First, we excluded those technologies which, due to their purely digital nature, do not involve any immediate additional demand for tangible resources. Second, we removed those technology terms which, due to their complexity or multi-layered nature, actually consist of a bundle of individual technologies (e.g., robotics, Internet of Things). Third, technologies that do not require the use of raw materials classified as critical by the EU were filtered out.[26]

[20] Bertelsmann (2020). Weltklassepatente in Zukunftstechnologien – Die Innovationskraft Ostasiens, Nordamerikas und Europas. Bertelsmann Stiftung.

[21] European Commission (2020b). Critical Raw Materials for Strategic Technologies and Sectors in the EU – A Foresight Study.

[22] Schmoch, U., Beckert, B., Reiß, T., Neuhäusler, P., & Rothengatter, O. (2020). Identifizierung und Bewertung von Zukunftstechnologien für Deutschland. Karlsruhe: Fraunhofer ISI.

[23] Marscheider-Weidemann, F., Langkau, S., Baur, S.-J., Billaud, M., Deubzer, O., Eberling, E., Erdmann, L., Haendel, M., Krail, M.; Loibl, A., Maisel, F., Marwede, M., Neef, C., Neuwirth, M., Rostek, L., Rückschloss, J., Shirinzadeh, S., Stijepic, D., Tercero Espinoza, L., Tippner, M. (2021). Rohstoffe für Zukunftstechnologien 2021. DERA Rohstoffinformationen 50: 366 S., Berlin.

[24] Bosch (2022). Bosch Tech Compass 2022 – Wir Fragen. Die Welt Antwortet. Robert Bosch GmbH.

[25] McKinsey (2022). McKinsey Technology Trends Outlook 2022. McKinsey & Company.

[26] According to technology information from Marscheider-Weidemann et al. (2021) and the list of critical raw materials of the EU (European Commission, 2020a).

Table 2: Overview of selected future technologies

Technology		Relevant sectors	
Short name	**Description**	**Application technology**	**Application product(s)**
5G, 6G	Provision of mobile network technologies for the fifth and sixth generation	ICT-Services	Private households, all production sectors
Additive layer manufacturing	Application of additive layer manufacturing technologies	Various industrial sectors, private households	Various industrial sectors, private households
CCS	Capture, transport and storage of CO_2 from industrial processes (Carbon Capture and Storage)	Various industrial sectors, energy provision	Chemical industry, steel industry, cement production
Thin-film PV cells	Manufacturing of solar cells using thin-layered semiconductor materials	Manufacturing of electronic elements	Energy provision, private households
Electric motors	Manufacturing of electric motors for vehicles	Automotive manufacturing	Private households, all production sectors
Solid-state batteries	Production of a new generation of batteries in which both electrodes and the electrolyte are made of solid material	Electric equipment	Energy provision, logistics, private households
Fibre optic cables	Production of cables with fibres made of quartz glass for high-bandwidth data transmission	Electric equipment	Private households, all production sectors
Sensors for autonomous vehicles	Production of laser scanners for three-dimensional recording of the environment in computer-controlled vehicles	Instruments for measurement and control	Private households, all production sectors
Water-electrolysis	Production of hydrogen by electrolysis of water	Energy provision	Energy provision, chemical industry, steel industry, logistics
Wind power generators	Manufacture of permanent magnet generators for use in wind power plants	Electric equipment	Energy provision

Source: own representation.

The final selection of ten technologies is presented in Table 2. It comprises a broad spectrum of sectors, and both industrial and service-related processes. The central European long-term goals of decarbonization and digitization are clearly pronounced in the selection. A detailed description of the single technologies and their potential contributions to the policy goals must be omitted here for reasons of space, readers are referred to e.g., the study by Marscheider-Weidemann et al. (2021).

3.2 Resource needs

Application of the selected technologies creates a multitude of diverse resource needs. Only some of them can be considered critical in terms of supply security or systemic importance. We limit our analysis to those resources that play a role in the public debate on supply security. This first concerns **critical raw materials**. In the definition of criticality, we adhere to the European Commission and its current list of critical raw materials.[27] The study by Marscheider-Weidemann et al. (2021) analyses the demand for mineral resources associated with future technologies. Table 3 displays the critical minerals required for the technologies in our analysis. Marscheider-Weidemann et al. (2021) and other studies also present quantitative demand projections under different scenarios. For our analysis, these projections are not very useful as they are dependent on a range of assumptions for technological progress and economic growth, and do not consider the degree of technical substitutability of raw materials as an important criterion for criticality. In the following, we limit our attention to the question of whether or not a certain mineral will be essential for a technology.

[27] See European Commission (2020a).

Table 3: Critical minerals required for future technologies

Technology / Minerals	Gallium	Germanium	Indium	Cobalt	Lithium	PGM*	REE**	Tantal	Titan	Vanadium
5G, 6G	X		X		X			X		
Additive layer manufacturing				X					X	
CCS				X						X
Thin-film solar cells	X		X							
Electric motors							X			
Solid-state batteries				X	X		X		X	
Fibre optic cables		X								
Sensors for autonomous vehicles							X			
Water-electrolysis				X		X	X		X	
Wind power generators							X			

Source: Marscheider-Weidemann et al. (2021); own representation. *PGM: Platin group metals. **REE: Rare earth metals.

Beyond the field of mineral resources, the provision of sustainable forms of energy is an important requirement for all technologies. Most immediately, this holds true for the electric energy used in the electrolysis of water. But given Europe's ambitions to achieve climate neutrality, other technologies will also be relying, directly or indirectly, on access to renewable energies, whether in the form of electricity or process heat. Thus, the availability of such energy sources will also be an integral part of resource security. In Europe and globally, the most important sources of energy are **wind and solar power**, mainly because of their unlimited nature. However, the achievable generation potential differs according to the natural conditions on site. Scarcity here results from the limited availability of suitable land. The technical potentials of countries and regions for energy production from wind and sun are therefore also the subject of our analysis.

Beyond raw materials and energy, the technologies also give rise to a considerable demand for intangible resources. Only some of the selected technologies are already ready for the market. And even in the case of technologies that have been on the market for some time, there is hope for future efficiency improvements through technological upgrades.[28] Generally speaking, therefore, **innovation potential** is also an important resource with a view to the long-term market success of the technologies. The technology-specific innovation potential of a country or region does not result solely from the existence of a research infrastructure but depends on a large number of institutional factors.[29] One intangible resource to be distinguished from this is the availability of **human capital**, i.e. the economically relevant knowledge available in the working population. This is a decisive prerequisite for the application and dissemination of new technologies in the economy.

28 See Schmoch et al. (2020).

29 Furman, J. L., Porter, M. E., & Stern, S. (2002). The determinants of national innovative capacity. Research policy, 31(6), 899-933.

3.3 External dependences of the EU

As a supplier on the global raw materials markets, Europe currently plays either no role at all or only a very minor role for the vast majority of the mineral raw materials we are concerned with. The exception is indium, a material used in the field of future technologies, especially for the production of screen displays, light and laser diodes, and thin-film solar modules. Here, France is an important producer country. Against this background, the Critical Raw Materials Alliance considers the EU to be largely self-sufficient in indium.[30] However, this refers to refined production: indium is obtained as a by-product from zinc smelting. The zinc ores used in this process do not come from European deposits but from US mines.[31] Among the other minerals, cobalt, lithium, platinum group metals and tantalum are currently mined within the EU, each in very small quantities by global standards.

Information on raw material deposits in the EU area is patchy and differs, in some cases, according to the source. However, the given information is sufficient to conclude that the current low level of self-sufficiency is not due to a lack of geological resources. In its Mineral Inventory, the Joint Research Center (JRC) of the European Commission has documented the existence of large or very large deposits for almost all future raw materials.[32] Concentrations can be seen in a few regions, especially the south of France, the Alpine region and Finland. At the same time, according to the European Minerals Yearbook, reserves, i.e., economically usable resources, are only indicated for only some of the raw materials.[33] Information on the extent of these resources is scattered and incomplete.

In general, it is likely, in the near future, that the renewed interest in mineral mining in Europe will lead to a significant increase in commercially exploitable resources even outside traditional mining regions, whether through new exploration or through the exploitation of existing resources by means of improved mining technologies. The recent major discoveries in Germany,[34] Sweden[35] and Norway[36] are already an indication of this. However, these are not yet statistically proven reserves. And in addition to physical potential, Europe's prospects of participating in the value chains of raw materials processing also depend on other factors. China's dominance in the raw materials of the future, for example, is largely based on labour cost advantages in processing, and low environmental standards.[37] The European economies cannot and will not compete in this respect. In markets with a high concentration of supply, it is also likely that the currently dominant suppliers will react to competition with price wars, which will make market entry even more difficult for high-wage regions.

[30] Critical Raw Materials Alliance (2022). Critical Raw Materials – Indium. https://www.crmalliance.eu/indium
[31] https://www.nyrstar.com/operations/mining
[32] European Commission (2022a). EU Science Hub – Raw Materials Information System (RMIS). https://rmis.jrc.ec.europa.eu/?page=geological-data-157d8a
[33] Minerals4EU (2022). European Minerals Yearbook.
[34] EURACTIV (2021). Lithium from German geothermal plants could supply a million electric vehicles a year from 2025. 1 December, 2021.
[35] CNBC (2023). Sweden finds Europe's largest deposit of rare earth metals, which could become 'more important than oil and gas'.
[36] CNN (2023). Norway discovers huge trove of metals, minerals and rare earths on its seabed.
[37] Shen, Y., Moomy, R., & Eggert, R. G. (2020). China's public policies toward rare earths, 1975–2018. Mineral Economics, 33(1), 127-151.

Table 4: Known deposits of mineral resources for future technologies in the EU

	Deposits			Production 2020	
Mineral(s)	Existence	Large deposits	Declared reserves	Quantity (in t)	Global share (%)
Gallium	Yes	No	No	None	-
Germanium	Yes	1 very large, 1 large	No	None	-
Indium	Yes	1 very large	Yes	58	6%
Cobalt	Yes	2 large	Yes	1,420	1%
Lithium	Yes	2 very large	Yes	348	< 1%
Platin-group metals	Yes	2 large	Yes	1.3	< 1%
Scandium	Unkown	No	No	None	-
Rare earth metals	Yes	1 very large	No	None	-
Tantal	Yes	1 large	No	> 0	< 1%
Titan minerals	Yes	4 large	Yes	None	-
Vanadium	Yes	2 large	No	None	-

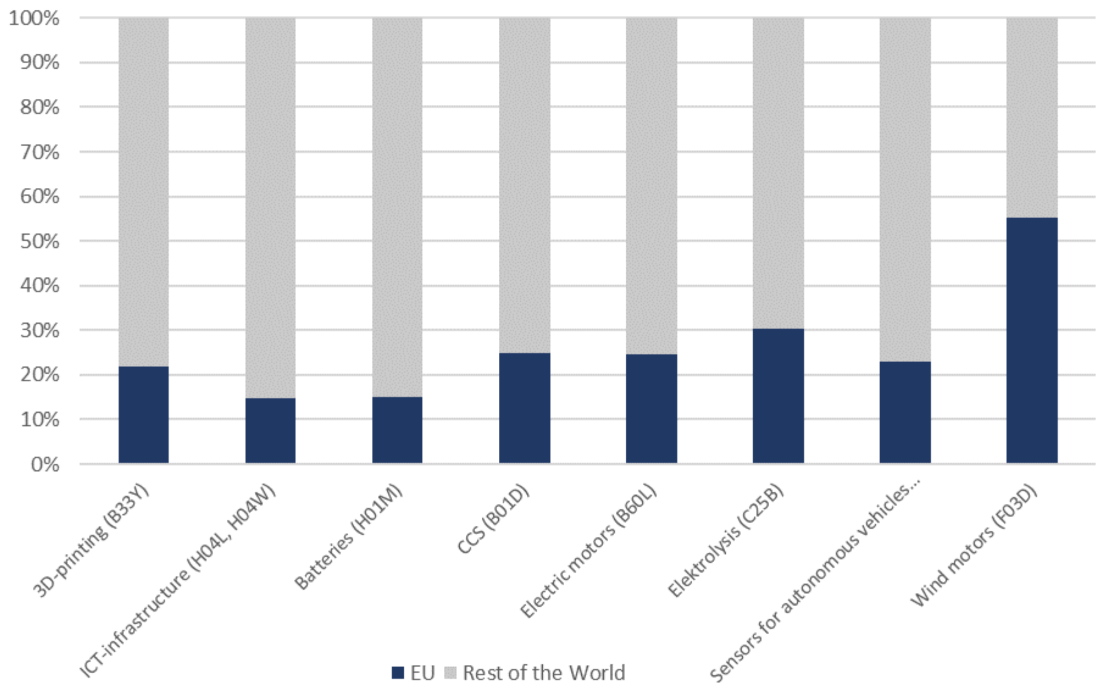
Sources: USGS (2022); Minerals4EU (2022); own representation.

Regarding **innovation potential**, Europe is in a somewhat better position when it comes to future technologies. Based on data from the PATSTAT database, Figure 2 shows the share of globally registered patents attributable to inventors resident in the EU-27 for a selection of relevant technology classes (defined according to the International Patent Classification (IPC)) over the past ten years. [38] In the case of wind turbines, Europe's innovation activity was particularly pronounced, with more than half of the patents granted worldwide being attributed to inventors from the EU. In the other classes, however, Europe's quantitative contribution was significantly lower. In the fields of digital communications and battery technology, it was only about 15% each. In the field of battery technology, inventors from Japan and South Korea each filed almost twice as many successful patent applications as the EU-27 combined. In the area of ICT infrastructure, the number of patents filed by US inventors was more than double that of the EU. The average number of patent approvals per patent family, a common indicator of the international dissemination of inventions, clearly shows that this is not compensated for by an increase in quality. [39] Results for the EU-27 in this respect are at about the same level as those for Japan and the USA.

[38] EPO (2023). PATSTAT. Worldwide Patent Statistical Database. European Patent Office.

[39] See Schmoch et al. (2020).

Figure 2: Share of EU inventors in global patent grants 2013-2022



Sources: EPO (2023); own calculations; in parentheses: IPC-Codes.

The relative availability of **human capital** in the form of suitably qualified workers varies greatly between individual occupational fields and member states. However, the latest analyses by the European Labour Agency (ELA) point to widespread shortages, particularly in some of the occupational fields that are highly relevant for future technologies.[40] For example, a particularly strong tendency toward labour shortages was noted for the group of STEM occupations in general. Specifically, 14 EU member states identified the occupations of civil engineer and software developer as shortage occupations. In the case of software developers, as many as seven member states even reported a high degree of shortage. Various groups of mechanics and electricians are also among the most frequently cited shortage occupations. Comparing qualification levels, the highest proportion of shortage occupations was in the highest qualification level, i.e. professionals. Taken together, this argues for the inclusion of human capital in a European resource strategy. This also matches the focus of the European Commission, which has defined the promotion of skill formation and training as one of the four pillars of its Green Deal Industrial Plan.[41]

4 Short-term potentials: country analysis

4.1 Methods and data

The resource partnerships envisaged by the European Commission are not only cooperations with individual (private or public) actors in third countries, but with a country and its specific potentials as a whole. For the evaluation of the perspective benefits of such partnerships, it is therefore helpful to look at indicators for international country comparison. We structure these using the three categories

[40] ELA (2022). Analysis of shortage and surplus occupations 2021. European Labour Authority. 19 January 2022.
[41] See European Commission (2023).

discussed in Section 3.1 (raw materials/renewable energy sources, innovation potential, human capital).

In addition to resource potentials, the extent of the obstacles to cooperation must also be examined. One way of conceptualizing the various forms of obstacles to cooperation is to imagine different dimensions of distance between the respective countries and the EU. Their most visible manifestation is geographical distance. Despite technological change, the negative effect of geographical distance on trade flows between countries has been repeatedly confirmed empirically over the decades.[42] In the context of resource partnerships, higher geographical distance primarily means higher transportation costs in bilateral trade in material resources or greater investment requirements for creating cost-competitive supply chains.

A less intuitive concept that has been increasingly used recently is institutional distance. There are very different ideas as to what exactly is meant by this.[43] It is therefore helpful to differentiate between individual dimensions. One dimension is distance in the **quality of political governance**. In this dimension, the greater the distance between third countries and the EU, the more they differ from the EU in the foundations of their political-legal system, such as the rule of law, political participation, and accountability.[44] This aspect touches on differences in state constitutions as well as in practical administrative action. For resource partnerships, a high distance is problematic in view of the EU's desire to uphold elementary values in its relations with partner countries. In addition, non-transparent administrative actions can cause high transaction costs for European companies.[45]

This must be distinguished from **regulatory distance**. This dimension is not about the quality of political institutions but about the focus of their regulatory activity. The more the partners differ in terms of which areas of their domestic economy (sectors, products) are regulated by the state and in terms of the regulatory instruments applied, the higher the overall level of regulatory distance. This form of distance also leads to higher costs in cross-border exchange, for example when companies have to meet different minimum legal requirements with regard to product quality or have to go through different product approval procedures. The failure of the TTIP negotiations has impressively demonstrated the relevance of such discrepancies for economic integration. The negative impact of regulatory distance on the volume of bilateral trade has also been empirically documented.[46]

Finally, another potentially relevant dimension is **cultural distance**. This, too, can be defined in various ways. In a direct sense, it could be seen as differences in language, customs, and traditions. However, there are also approaches to understanding and measuring cultural distance primarily as a difference in people's mentality and inner attitudes.[47] The potential channels for the impact of cultural distance on the exchange of resources are similarly complex. Empirical evidence shows that there is a significant

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42 Chaney, T. (2018). The gravity equation in international trade: An explanation. Journal of Political Economy, 126(1), 150-177.

43 Xu, D., & Shenkar, O. (2002). Institutional distance and the multinational enterprise. Academy of Management review, 27(4), 608-618.

44 De Groot, H. L., Linders, G. J., Rietveld, P., & Subramanian, U. (2004). The institutional determinants of bilateral trade patterns. Kyklos, 57(1), 103-123.

45 Doh, J. P., Rodriguez, P., Uhlenbruck, K., Collins, J., & Eden, L. (2003). Coping with corruption in foreign markets. Academy of Management Perspectives, 17(3), 114-127.

46 Dhingra, S., Freeman, R., & Huang, H. (2023). The Impact of Non-tariff Barriers on Trade and Welfare. Economica, 90(357), 140-177.

47 Hofstede, G. H. (2001). Culture's consequences: Comparing values, behaviors, institutions and organizations across nations. sage.

negative correlation between cultural distance and bilateral trade volume.[48] Other dimensions of distance, however, are not necessarily an obstacle to resource partnerships. Differences in economic structure, for example, so-called economic distance, can even be beneficial for joint supply chains in view of the vertical specialization of the partners sought in resource partnerships.[49]

Figure 3 illustrates our methodological concept of potential for and barriers to cooperation in the context of resource partnerships. For the assessment of partner-specific resource potentials, we draw on various international databases. A country's potential for **critical mineral resources** is taken from the latest Mineral Commodity Summaries 2023 of the U.S. Geological Survey (USGS).[50] We deliberately use the estimates of a country's reserves shown there, i.e. the existing resources that can be economically exploited according to the current state of knowledge, instead of relying on individual reports on recent resource discoveries.[51] The ten future technologies we have selected for analysis (see Section 3.1) differ in their specific resource requirements. For each technology, we first calculate the shares of individual countries in the estimated global reserves of the critical raw materials required in each case (see Table 3 in Section 3.2) and calculate the mean value from this. We then calculate the mean across all ten technologies. This provides a single (dimensionless) index measure of the potential role a country can play in the future in meeting the raw material needs associated with future technologies.[52]

To map the resource potentials in the area of **renewable energy sources**, we draw on existing potential estimates for wind power and solar energy. For wind power potentials, we use the Global Wind Atlas of the Technical University of Denmark, a web tool launched with the support of the World Bank.[53] Specifically, we use a country's estimated mean wind power density (W/m2) as an indicator. To map solar potentials, we draw on a study based on data from the Global Solar Atlas maintained by Solargis, namely the estimated daily average PV electricity potential (kWh) of a standardized solar module.[54] Again, we form an overarching index, by calculating the ratio of a country's values to the global maximum (=100) and then averaging the values for wind and solar.

[48] Liu, A., Lu, C., & Wang, Z. (2020). The roles of cultural and institutional distance in international trade: Evidence from China's trade with the Belt and Road countries. China Economic Review, 61, 101234.

[49] Boisso, D., & Ferrantino, M. (1997). Economic distance, cultural distance, and openness in international trade: Empirical puzzles. Journal of Economic integration, 456-484.

[50] USGS (2023). Mineral Commodity Summaries 2023. U.S. Geological Survey.

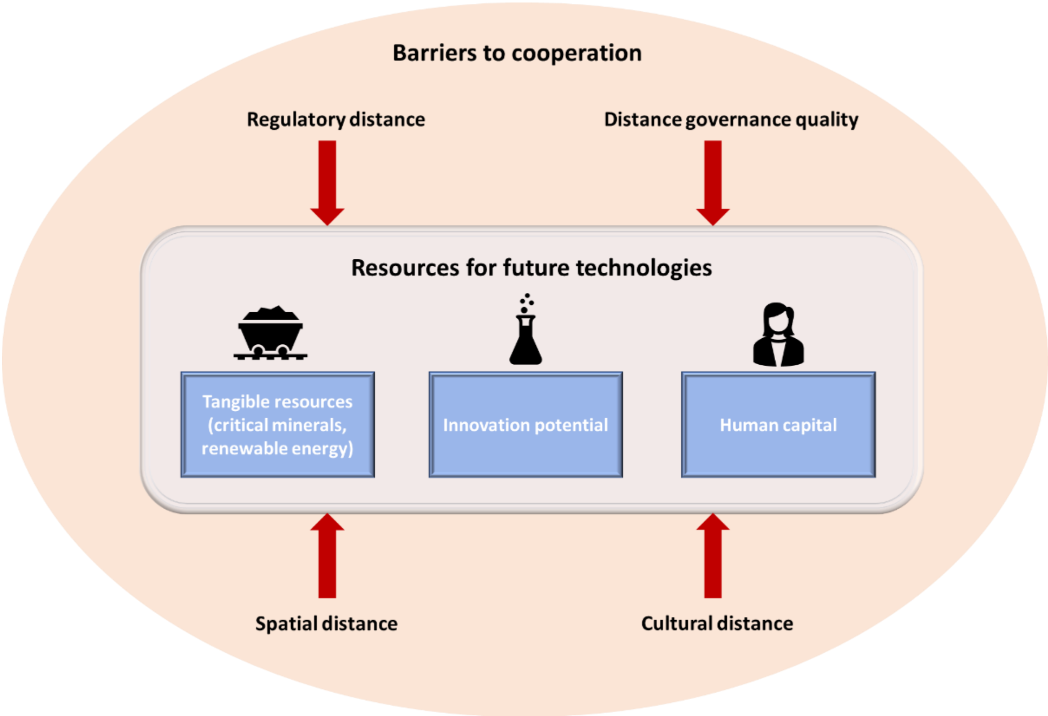
[51] Estimates of country-specific reserves are not available for all minerals. In those cases (Gallium, Germanium, Indium) USGS (2023) estimates of current production capacities were consulted instead.

[52] The maximum value in theory is 100. This corresponds to the extreme case of all global reserves being hosted by only one country.

[53] DTU (2023). Global Wind Atlas 3.0. Technical University of Denmark.

[54] ESMAP (2020). Global Photovoltaic Power Potential by Country. Washington, DC: World Bank.

Figure 3: Overview of resource potentials and cooperation barriers



Sources: own representation.

To map **innovation potential** in connection with future technologies, we use PATSTAT, the global patent database of the European Patent Office (EPO).[55] For this purpose, we identify patent applications differentiated by the residence of the registered inventors. The patent figures are available for individual technology classes defined according to the International Patent Classification (IPC). Based on a classification search, we assign each of the ten future technologies to the most appropriate IPC category (see footnote 86 in the Annex).[56] Specifically, we consider the number of different patent families as well as the average size of patent families per technology within the last ten years as common measures of the quantity and quality of a country's innovation activity in the recent period. [57][58] Here, too, we construct overarching index values by calculating a country's share of the global total and then averaging the results across all ten technologies.

We also map the potential in **human capital** using two indicators measuring quantity and quality. The first indicator is the share of persons with tertiary education in the younger part of the working-age population (20–39-year-olds) as estimated by the Wittgenstein Centre for Demography and Global Human Capital.[59] As a complementary quality indicator, we use the number of mean years of education corrected for learning success provided by the World Bank's Human Capital Index.[60] It links the average

55 See EPO (2023).

56 The maximum resolution of IPC classes available in PATSTAT is the four-digit level. This level does not clearly delineate all of the ten technologies. In these cases we adhered to the relevant major category.

57 Patent families are groups of patents that contain the same or a very similar technical content. By analysing patent families instead of single patents, one seeks to ensure that inventions patented in many countries are not counted multiple times.

58 See Schmoch et al. (2020).

59 Wittgenstein Centre (2023). Human Capital Data Explorer. Wittgenstein Centre for Demography and Global Human Capital.

60 World Bank (2020). Human Capital Project. The World Bank.

number of years of education multiplicatively with the average scores in recent tests from various programs, to obtain an international comparison of student learning success.

In mapping barriers to cooperation, we focus on gaps in **governance quality** and **regulation**.[61] We approximate the former based on current results from the World Bank's Worldwide Governance Indicators.[62] For this purpose, we calculate the EU country average for all six indicators (effectiveness of governance, control of corruption, voice and accountability, political stability, regulatory quality, rule of law). We then calculate the difference between the index values of the individual non-EU countries for each dimension and the EU average and calculate the mean value for all six dimensions. Finally, to normalize the maximum possible distance on the existing scale [-5;+5] to one, we divide this value by ten. To map the regulatory distance, we resort to the methodology developed by Cadot et al. (2015).[63] It is based on data from the Trade Analysis Information System (TRAINS) of the United Nations Conference on Trade and Development (UNCTAD), a very comprehensive database (about 20 million observations) for mapping almost all forms of measures taken by countries in the area of product regulation, differentiated by type of regulation and product category affected.[64] The Cadot indicator is a 0-1 measure of whether or not two countries apply the same type of regulation (e.g. guarantees of origin) to the same product group (four-manufacturer level of the HS classification), and averages this across all types of regulation and product categories. It is thus a measure of country differences based on the focus of government regulation, not its intensity. We calculate the Cadot et al. (2015) measure as the regulatory distance of third countries from the EU based on the most recent researcher file available at TRAINS.[65]

4.2 Results - resource potentials

Globally, the distribution of the identified **mineral resource** and **renewable energy** potentials is quite concentrated. Table 5 shows the top 3 countries according to our index measures, both on a global level and within individual world regions. According to USGS information, China, as the currently dominant player in the supply chains of critical raw materials, thus also possesses by far the largest raw material reserves overall for the ten future technologies we have considered. This applies not only to the rare earth metals essential for permanent magnets in electric motors and wind power generators, but also to gallium and indium (raw materials for thin-film solar cells) and vanadium (for CCS). Globally, Australia and the Democratic Republic of the Congo follow in second place. In Australia's case, this is mainly due to large reserves of lithium (for solid-state batteries and 5G-/6G technology) and titanium minerals (for solid-state batteries, water electrolysis and additive manufacturing). In the case of the D.R. Congo, this is not only due to the known large cobalt reserves (for solid-state batteries, additive manufacturing, CCS, and water electrolysis) but also to the large amounts of tantalum (for 5G/6G). A comparison of world regions shows that the main potential for mineral raw materials is in the Americas, southern Africa, and East Asia. Almost no potential is identified for the rest of Asia or northern Africa (see Figure 4). In the field of renewable energies, Chile has by far the greatest global

61 Impacts of geographical distance on cooperation costs are highly product- and partner-specific. Cultural distance is in our opinion a concept that is still too vague for an analysis of the implications for resource partnerships.

62 World Bank (2022). Worldwide Governance Indicators. The World Bank.

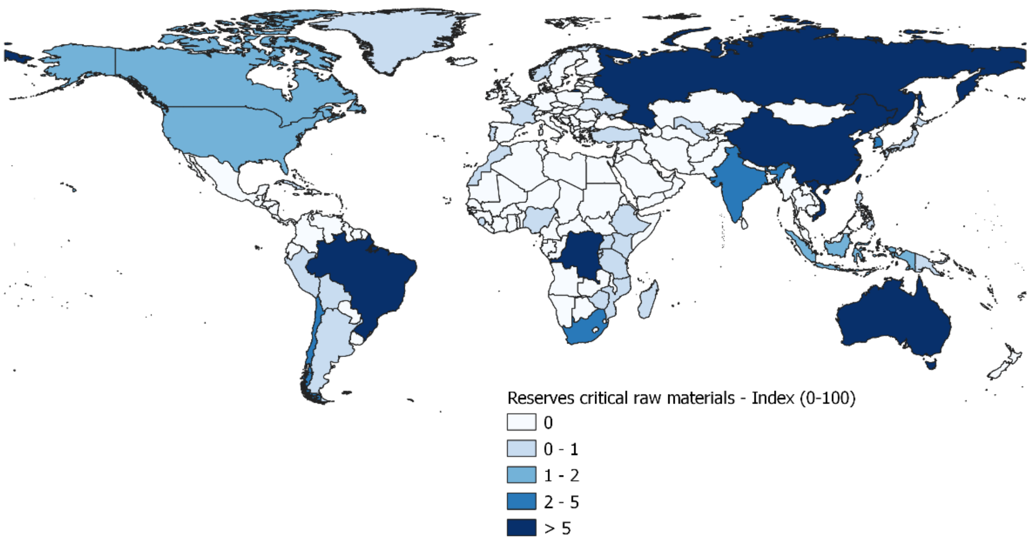
63 Cadot, O., A. Aspilla, J. Gourdon, C. Knebel, and R. Peters. (2015). 'Deep Regional Integration and Non-Tariff Measures: A Methodology for Data Analysis', UNCTAD Policy Issues in International Trade and Commodities Research Study 37 Series 69, United Nations Conference on Trade and Development, Geneva, Switzerland.

64 UNCTAD (2023). Trade Analysis Information System (TRAINS). United Nations Conference on Trade and Development.

65 The European Union is already included as a single regulation area in TRAINS, requiring no further adjustments to the dataset.

potential. The geographic and climatic conditions there create ideal conditions for the use of both solar and wind energy. This also applies to a lesser extent to New Zealand and Argentina (the latter country primarily for solar energy).

Figure 4: Potentials for mineral resource reserves – global distribution



Source: USGS (2023); own representation.

Table 5: Top 3 potentials for mineral resources and renewable energies

Reserves critical minerals (Index)						Potentials renewable energies (Index)					
Global			**Northern Africa / Middle East**			**Global**			**Northern Africa / Middle East**		
Rank	***Country***	***Score***	*Rank*	*Country*	*Score*	***Rank***	***Country***	***Score***	*Rank*	*Country*	*Score*
1	**China**	**39,29**	1	Morocco	0,02	**1**	**Chile**	**99,87**	1	Egypt	58,64
2	**Australia**	**9,32**	2	..	..	**2**	**New Zealand**	**70,02**	2	Morocco	58,34
3	**Dem. Rep. Congo**	**8,57**	3	..	..	**3**	**Argentina**	**68,32**	3	Oman	57,18
North America / Oceania			**Sub-Saharan Africa**			**North America / Oceania**			**Sub-Saharan Africa**		
Rank	*Country*	*Score*	*Rank*	*Country*	*Score*	*Rank*	*Country*	*Score*	*Rank*	*Country*	*Score*
1	Australia	9,32	1	Dem. Rep. Congo	8,57	1	New Zealand	70,02	1	Lesotho	61,67
2	Canada	1,83	2	South Africa	3,15	2	USA	55,27	2	Chad	59,23
3	USA	1,44	3	Madagascar	0,48	3	Mexico	52,20	3	Djibouti	58,35
Central and South America			**West-, Central- and South Asia**			**Central and South America**			**West-, Central- and South Asia**		
Rank	*Country*	*Score*	*Rank*	*Country*	*Score*	*Rank*	*Country*	*Score*	*Rank*	*Country*	*Score*
1	Brazil	6,87	1	India	3,09	1	Chile	99,87	1	Afghanistan	60,81
2	Chile	2,04	2	Uzbekistan	0,01	2	Argentina	68,32	2	Iran	56,77
3	Argentina	0,59	3	..	..	3	Bolivia	52,83	3	Tajikistan	53,82
Non-EU Europe			**East- and Southeast Asia**			**Non-EU Europe**			**East- and Southeast Asia**		
Rank	*Country*	*Score*	*Rank*	*Country*	*Score*	*Rank*	*Country*	*Score*	*Rank*	*Country*	*Score*
1	Russia	8,07	1	China	39,29	1	Albania	48,45	1	Mongolia	55,09
2	Norway	0,48	2	Vietnam	6,07	2	Switzerland	47,99	2	Bahrain	50,15
3	Ukraine	0,25	3	South Korea	2,24	3	Montenegro	47,28	3	North Korea	46,54

Sources: USGS (2023); DTU (2023); ESMAP (2020); own calculations.

As expected, the distribution of **innovation activity** in connection with future technologies shows a completely different picture. In terms of their scope (number of patent families), which can be read from the patent statistics, the USA is the global leader among third countries, followed by South Korea and Japan. If the EU countries were included here, those three countries would also be well ahead of Germany as the EU member with the strongest innovation in future technologies (see Section 3.3). The USA has a high number of patent families in all the technology categories considered, especially in mobile communications (IPC code: H04W), additive manufacturing (B33Y), electrolysis (C25B) and data cables (H04B). South Korea's strengths are mainly battery technology (H01M) and computer systems (G06N). Japan is at the forefront of global innovation activity in electric motors (B60L) and solar cells (H01L). China is well ahead of other populous countries such as India and Brazil. The main areas of innovation here are solar cells (H01L) and data cables (H04B). By contrast, the other non-EU countries fall significantly behind in terms of innovation volume. The quality of innovation activity (measured by the average number of patent applications per family) is distributed somewhat differently. Small countries can also occupy top positions here. Globally, New Zealand and the European non-EU members Norway and Switzerland lead the field in this indicator among the non-EU countries. Inventors from New Zealand have a very high distribution radius of their patent families in a global comparison, especially for battery technology (H01M) and computer systems (G06N). In Norway, this applies to solar cells (H01L) and data cables (H04B), and in Switzerland to battery technology (H01M) and computer systems (G06N). The geographic pattern is less concentrated in the quality dimension overall. Countries such as Israel, South Africa and Chile also score well in this respect.

Table 6: Top 3 potentials for innovation

Number of patent families (Index)						ø size patent families (Index)					
Global			**Northern Africa / Middle East**			**Global**			**Northern Africa / Middle East**		
Rank	***Country***	***Score***	*Rank*	*Country*	*Score*	***Rank***	***Country***	***Score***	*Rank*	*Country*	*Score*
1	**USA**	**85,57**	1	Israel	1,68	**1**	**New Zealand**	**57,41**	1	Israel	55,08
2	**South Korea**	**78,89**	2	Saudi-Arabia	0,76	**2**	**Norway**	**56,70**	2	Saudi-Arabia	48,76
3	**Japan**	**52,39**	3	Utd. Arab. Em.	0,14	**3**	**Switzerland**	**56,32**	3	Turkey	47,99
North America / Oceania			**Sub-Saharan Africa**			**North America / Oceania**			**Sub-Saharan Africa**		
Rank	*Country*	*Score*	*Rank*	*Country*	*Score*	*Rank*	*Country*	*Score*	*Rank*	*Country*	*Score*
1	USA	85,57	1	South Africa	0,15	1	New Zealand	57,41	1	South Africa	44,56
2	Canada	4,94	2	Ghana	0,01	2	USA	50,36	2	Kenia	12,72
3	Australia	1,40	3	Namibia	0,00	3	Canada	49,97	3	Eswatini	5,62
Central and South America			**West-, Central- and South Asia**			**Central and South America**			**West-, Central- and South Asia**		
Rank	*Country*	*Score*	*Rank*	*Country*	*Score*	*Rank*	*Country*	*Score*	*Rank*	*Country*	*Score*
1	Brazil	0,91	1	India	1,18	1	Chile	38,33	1	India	37,91
2	Chile	0,13	2	Iran	0,09	2	Peru	18,86	2	Iran	30,22
3	Argentina	0,06	3	Georgia	0,05	3	Panama	18,32	3	Kazakhstan	20,68
Non-EU Europe			**East- and Southeast Asia**			**Non-EU Europe**			**East- and Southeast Asia**		
Rank	*Country*	*Score*	*Rank*	*Country*	*Score*	*Rank*	*Country*	*Score*	*Rank*	*Country*	*Score*
1	Russia	8,50	1	South Korea	78,89	1	Norway	56,70	1	Japan	48,73
2	United Kingdom	6,35	2	Japan	52,39	2	Switzerland	56,32	2	Singapore	48,20
3	Switzerland	3,54	3	China	12,08	3	United Kingdom	52,66	3	China	44,45

Source: EPO (2023); own calculations.

Similar patterns emerge for the resource **human capital**. Here, too, countries from North America and East Asia are at the top of the third-country rankings, and at the same time would also outperform almost all EU members. In terms of the proportion of persons with tertiary education among the younger working population, Singapore is clearly ahead, followed by South Korea and Canada. There is a significant gap between North and South America, but also within Europe. In terms of the number of learning-adjusted years of schooling, Singapore is ahead of Japan and Canada. In the top countries, there is a strong congruence between the two indicators. The situation is different at the lower end of the scale. In addition to university degrees having a lower informative value in such countries, this is probably also related to problems with the international comparability of learning tests and a related inaccuracy of the World Bank measure.[66] Nevertheless, the estimated disparity between world regions should be robust to any inaccuracies in the measurement.

Table 7: Top 3 potentials for human capital

Shares 20-39 years old with tertiary education (%)						Learning-adjusted years of schooling (LAYS score)					
Global			Northern Africa / Middle East			Global			Northern Africa / Middle East		
Rank	***Country***	***%***	*Rank*	*Country*	*%*	***Rank***	***Country***	***Score***	*Rank*	*Country*	*Score*
1	**Singapore**	**75,10**	1	Saudi-Arabia	38,50	**1**	**Singapore**	**12,81**	1	Israel	10,59
2	**South Korea**	**65,60**	2	Israel	35,10	**2**	**Japan**	**11,74**	2	Utd. Arab. Em.	9,65
3	**Canada**	**65,10**	3	Egypt	31,60	**3**	**Canada**	**11,72**	3	Turkey	9,23
North America / Oceania			Sub-Saharan Africa			North America / Oceania			Sub-Saharan Africa		
Rank	*Country*	*%*	*Rank*	*Country*	*%*	*Rank*	*Country*	*Score*	*Rank*	*Country*	*Score*
1	Canada	65,10	1	Botswana	23,30	1	Canada	11,72	1	Kenia	8,47
2	New Zealand	50,00	2	Zambia	13,80	2	New Zealand	11,39	2	Zimbabwe	7,01
3	Australia	48,40	3	Cameroon	11,80	3	Australia	11,22	3	Lesotho	6,31
Central and South America			West-, Central- and South Asia			Central and South America			West-, Central- and South Asia		
Rank	*Country*	*%*	*Rank*	*Country*	*%*	*Rank*	*Country*	*Score*	*Rank*	*Country*	*Score*
1	Peru	29,50	1	Georgia	48,10	1	Chile	9,41	1	Uzbekistan	9,13
2	Venezuela	27,80	2	Armenia	31,60	2	Ecuador	8,70	2	Kazakhstan	9,13
3	Panama	27,70	3	Sri Lanka	30,80	3	Peru	8,63	3	Kirgizstan	8,65
Non-EU Europe			East- and Southeast Asia			Non-EU Europe			East- and Southeast Asia		
Rank	*Country*	*%*	*Rank*	*Country*	*%*	*Rank*	*Country*	*Score*	*Rank*	*Country*	*Score*
1	Norway	47,50	1	Singapore	75,10	1	United Kingdom	11,54	1	Singapore	12,81
2	United Kingdom	45,70	2	South Korea	65,60	2	Norway	11,23	2	Japan	11,74
3	Switzerland	41,70	3	Japan	59,90	3	Switzerland	10,93	3	South Korea	11,68

Sources: World Bank (2020); Wittgenstein Centre (2023); own calculations.

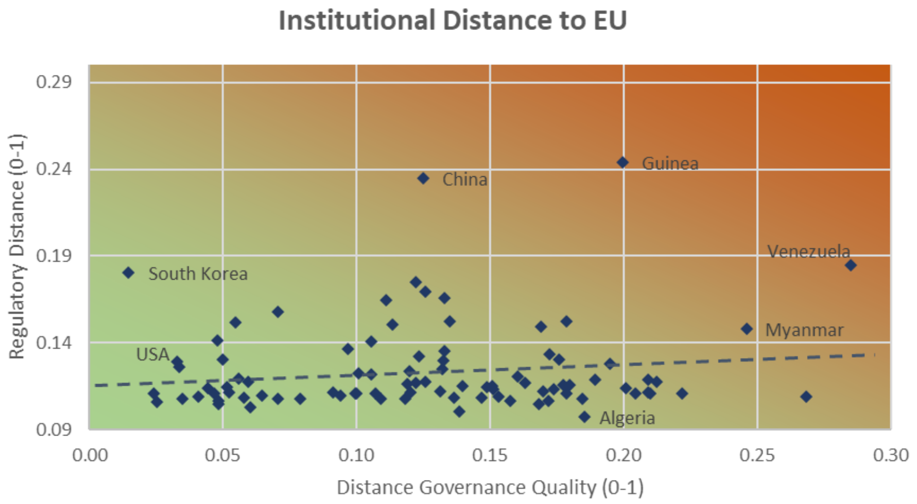
4.3 Results - cooperation barriers

Figure 5 first provides an overview of the distribution of the two forms of institutional distance we examined. It positions third countries according to their distance from the EU in the areas of governance and regulation. Overall, both distance measurements could be estimated for 94 third countries worldwide based on the available data. Some developing countries are missing, mostly due to a lack of information on regulatory instruments. The weak correlation of the two measures suggests that they are indeed different dimensions of institutional distance. A look at individual outliers among the countries makes the relevance of the distinction even clearer. For example, South Korea is the

66 CGD (2019). Does education need a QALY and is LAYS it? Center for Global Development, Blog Post.

country with the lowest distance to the EU in the dimension of governance quality among all third countries covered, but is among the countries with the largest differences in the regulatory dimension. To a lesser extent, the same asymmetry also applies to the USA. China shows a considerable distance to the EU in both dimensions, but a much greater one in regulation than in the area of governance. Conversely, a comparatively low regulatory distance is by no means an indication of proximity to the EU in terms of political constitution, as the example of Algeria makes clear.

Figure 5: Two dimensions of institutional distance



Sources: World Bank (2022); UNCTAD (2023); own calculations.

In any case, both dimensions must be kept in mind when assessing the challenges of resource partnerships. From the EU's perspective, the quality of governance in partner countries is important in terms of political stability, which is essential for long-term cooperation. It also touches on efficiency aspects and can thus influence the transaction costs for European companies (and other institutions) active in the partnerships. In terms of political participation, it also affects the EU's core value propositions, as recently restated for partnerships with third countries (see Section 5.1). A high regulatory distance in quality standards can lead to additional costs for the supply chain management of European companies. Large differences in statutory environmental and safety regulations increase the costs of exercising due diligence obligations in supply chain monitoring.

Figures A1-A3 in the Annex contrast the distance measurements with the potential indicators discussed in Section 4.2. In general, they differ significantly in their correlation with the countries' resource potentials (see correlation table A3 in the Annex). The distance in governance quality in some cases shows no signs of a correlation (for mineral resources, renewable energy), and in some cases signs of a negative correlation (for innovation activity, human capital). The latter is in line with the expectation of a positive interaction between innovativeness, education, and institutional quality.[67] Regulatory distance, on the other hand, shows a weak positive correlation with human capital and innovation activity, and a strong positive correlation with mineral resource potentials. Indeed, a relatively strong regulatory gap with the EU can be observed not only for China, the dominant raw material supplier, but also for other countries with significant reserves, such as Vietnam and Brazil.

[67] Tebaldi, E., & Elmslie, B. (2013). Does institutional quality impact innovation? Evidence from cross-country patent grant data. Applied Economics, 45(7), 887-900.

The situation is different for renewable energy potentials, also due to the regulatory proximity of some particularly sun- and/or wind-rich countries such as Chile and New Zealand.

4.4 Overview across categories

Overall, this results in a relatively differentiated picture of suitable partners in the various resource categories. Figure 6 summarizes a selection of particularly high-potential partnerships. For mineral resources in particular, the countries differ significantly in terms of the obstacles to cooperation that can be expected. Nevertheless, there are countries in each category that are already relatively close to the EU in institutional terms. Moreover, the vast majority of these countries are already linked to the EU through bilateral trade agreements or are engaged in intensive trade negotiations. Free trade agreements have been in force with Chile[68] and South Korea[69] for some time, and have been concluded with South Africa[70], Japan[71], Singapore[72] and Vietnam[73] in recent years. The more recent agreements provide not only for tariff-based trade facilitation but also for various forms of regulatory cooperation. These include the reduction of technical trade barriers through mutual recognition of approval procedures and the convergence of product requirements towards recognized international standards. Particular attention is also paid to the mutual obligation to maintain existing environmental and occupational safety standards and to comply with the greenhouse gas reduction commitments made in the Paris Agreement. The agreements are thus already designed to reduce the existing regulatory distance between the partners, at least in some segments of the supply chain. In the recent negotiations of new agreements with Australia and New Zealand, as well as in the modernization of the existing agreement with Chile, the aspect of access to raw materials was or is also explicitly a subject of discussion.[74] The EU thus already possesses established instruments to intensify cooperation with resource-rich partners.

[68] European Union / Republic of Chile (2003). Agreement establishing an association between the European Community and the Republic of Chile. 1 February 2003.

[69] European Union / Republic of Korea (2011). Free Trade Agreement between the European Union and the Republic of Korea. Official Journal of the European Union, 14 May 2011.

[70] European Union / SADC EPA (2016). Economic partnership agreement between the European Union and its Member States, of the one part, and the SADC EPA States, of the other part. Official Journal of the European Union, 16 September 2016.

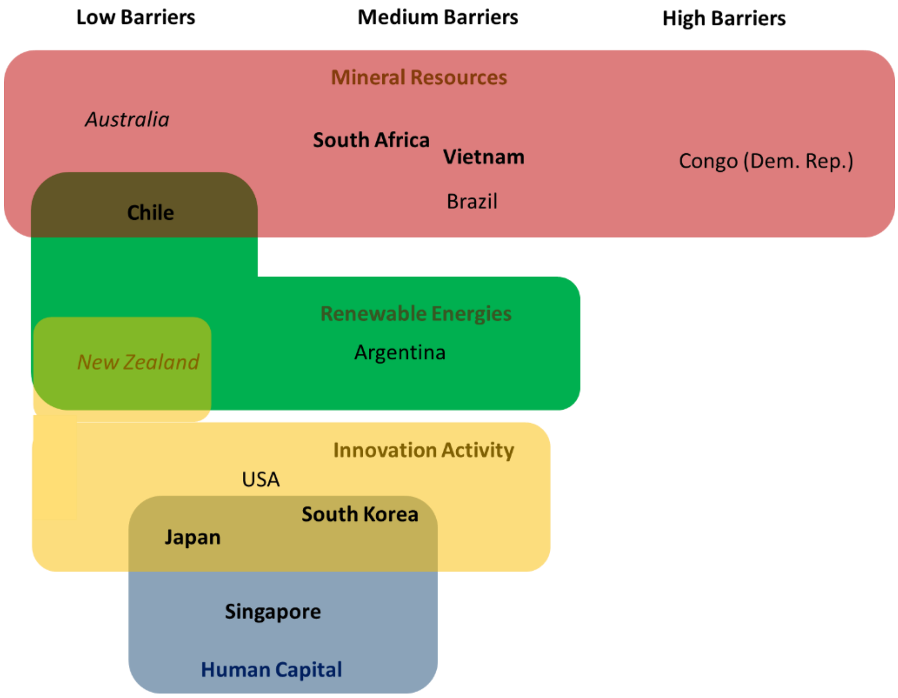
[71] European Union / Japan (2019). Agreement between the European Union and Japan for an economic partnership. Official Journal of the European Union, 1 February 2019.

[72] European Union / Republic of Singapore (2019). Free trade agreement between the European Union and the Republic of Singapore. Official Journal of the European Union, 14 November 2019.

[73] European Union / Republic of Vietnam (2020). Free trade agreement between the European Union and the Socialist Republic of Vietnam. Official Journal of the European Union, 12 June 2020.

[74] EURACTIV (2022). EU, Chile conclude negotiations on new trade agreement. 9 December, 2022.

Figure 6: Countries with high partner potential by resource category



Source: own representation; **bold:** trade agreements with EU in force; *italic:* trade agreements soon to come into force.

However, the exploitation of known resource potentials should only be one of the pillars of an EU partner portfolio. The expected shortage of resources for future technologies has recently led to strong exploration activities worldwide, even beyond established mining regions. As activity increases, so does the likelihood of finding significant, commercially viable deposits that could become geographic game changers in the commodity markets. Since no-one can reliably estimate the extent of such unknown potentials from today's perspective, the EU should position itself as broadly as possible in geographic terms when developing them through resource partnerships. Again, this does not apply to the exploration of mineral resources alone. Access to the undiscovered resources in people's minds must also be opened up, as globally as possible, for example through the development of joint research infrastructures and programs for the exchange of knowledge and experts. All of this requires long-term direct engagement alongside supply contracts, for which the prerequisite is a coherent investment strategy.

5 Long-term potentials: strategic recommendations

5.1 The Global Gateway Initiative as driving force

In many cases, the establishment of stable supply chains within the framework of resource partnerships generates a high demand for infrastructure investment. This not only applies to expansion of the transport infrastructure in partner countries, essential for transporting the traded goods, but also to energy supply and digital communications. Against this backdrop, progress on the Global Gateway Initiative, announced by the European Commission in December 2021, is of key importance for the future success of EU resource partnerships. This is an EU investment strategy to fund infrastructure development in third countries, basically on a global scale. Between 2021 and 2027, a total of up to 300 billion euros is to be made available for this purpose. Thematically, the investments are to cover the following areas: Digital, climate/energy, transport, health, education and research. The focus should be on high-quality projects that are also in line with the interests and values of the EU. Compliance with democratic standards, sustainability principles and transparency requirements are among the fundamental principles. The initiative is based on mixed financing from EU funds, funds from the member states and public credit institutions, and will also mobilize private capital.[75] At the first Global Gateway Board Meeting in December 2022, 84 lighthouse projects were presented, including the laying of a submarine power cable from Georgia through the Black Sea to Romania.[76]

Basically, the EU has two goals with the Global Gateway Initiative. On the one hand, it wants to strengthen connectivity with third countries by way of investment projects that will reduce the cost of crossing various geographical spaces . This will lead to greater economic integration. On the other hand, it would like to extend the scope of its political values and long-term goals to third countries, especially regarding human rights and environmental protection standards. In the long run, achieving both goals will help to increase Europe's global influence in the political as well as in the economic field. For this reason, the initiative is also seen as Europe's response to China's Belt and Road Initiative.[77] At the same time, it could represent the starting point for a paradigm shift in European development policy, according to which, structural aid will be coordinated primarily on the basis of strengthening the EU's geostrategic influence.[78] Limiting China's influence as its biggest geopolitical rival is a desired side effect. Attractiveness is to be created not only by the volume of funds provided by Europe, but also by tying them to the goal of sustainable local development, which is seen as an essential difference to China's approach within the framework of the Belt and Road Initiative.[79] The prerequisite for this, however, is that the local partners also perceive this as a contribution to development, and not primarily as undesirable interference in local institutions.

For the envisaged strategic resource partnerships, the Global Gateway Initiative thus harbours both opportunities and risks. One opportunity is undoubtedly the upgrading of infrastructure as a contribution to lowering the barriers to cooperation discussed in Section 4.3. In addition to reducing the cost of geographical distance, the Global Gateway projects could also reduce regulatory distance between the partners in the medium term by increasing the need for legislative cooperation. This is because, to the extent that the infrastructure created strengthens the economic ties of third countries to the EU, it also increases the relevance of remaining trade barriers as a constraint on growth. Moreover, it offers additional incentives for cooperation in the technological upgrading of the infrastructure components that have been created. This is also in line with the concept of resource partnerships as a platform for growth cooperation beyond individual supply chains (see Chapter 2). At the same time, however, there is also a risk in the commitment to European values. In some cases, partner countries could perceive this as an institutional overload or even a narrowing of their own scope for growth policy. Our analysis of institutional distances in Section 4 indicates that this could be

[75] European Commission (2021). The Global Gateway. Joint Communication to the European Parliament, the Council, the European Economic and Social Committee, the Committee of the Regions and the European Investment Bank. JOIN(2021) 30 final.

[76] European Commission (2022b). Global Gateway: Team Europe’s first meeting of the Global Gateway Board. News Archive, 11 December 2022.

[77] Huang, Y. (2016). Understanding China's Belt & Road initiative: motivation, framework and assessment. China Economic Review, 40, 314-321.

[78] Furness, M., & Keijzer, N. (2022). Europe's Global Gateway: A new geostrategic framework for development policy? (No. 1/2022). Briefing Paper.

[79] Masina, P. (2022). Challenging the belt and road initiative: The American and European alternatives. Robert Schuman Centre for Advanced Studies Research Paper No. PP_2022_09.

the case, especially in some of the countries particularly well endowed with future raw materials. In the worst-case scenario, instead of institutional convergence, there is a risk of divergence if the countries turn away from the EU towards China and its political-regulatory system.

Beyond ambitious investment plans, there is therefore a need for a consistent long-term political strategy that explores the priorities and scope for action of the EU's foreign trade and development policies. The basis of such a strategy should be a sober economic analysis of which types of clubs with third countries are necessary to secure European value chains, and how the cost-benefit ratio of individual clubs for the EU should be evaluated in such a portfolio. The clubs for critical raw materials announced by the European Commission in the Green Deal Industrial Plan provide an occasion for the development of such a strategic approach.[80] However, partnerships with resource-rich countries are only one of the building blocks for long-term resilient supply chains and should be complemented in particular by collaborations with partners specializing in the downstream segment (see Chapter 4). The following section provides some basic conceptual ideas for such a strategy.

5.2 Strategic guidelines

An essential element of a long-term strategy for partnerships to strengthen economic resilience will be to specify the form of the clubs to be created. Economic theory identifies three basic elements: the number of members, the costs to individual members of entering the club, and the volume of goods provided within the club.[81] These three variables cannot be chosen independently but are linked to each other. For example, for some potential partners, a strongly value-linked EU investment policy will give rise to a high level of access costs in the form of institutional adjustments, which therefore limits the achievable number of club members. Smaller clubs, providing an equivalent level of club assets , will, in turn, mean higher deployment costs for the individual members.

On the EU side, the choice of design parameters should always be made in the context of the overall portfolio of resource partnerships. This involves, on the one hand, the right **balance between complementarity and substitutability**. Our analysis in chapter 4 has shown that securing competitive supply chains for the EU will require a bundle of complementary partners, each covering different needs in the application of future technologies. However, relying solely on complementary partners does not mitigate the risk of long-term instability (see Section 2.2). Additional substitutive partners are required for this purpose, and the greater the systemic importance of the traded goods, the more this is case. For example, it would be negligent to base the future supply of rare earth metals, as a central raw material for the climate-neutral economy, solely on a strategic partnership with a single large supplier country. To avoid this, a certain **degree of redundancy** is needed in the portfolio of partnerships.

At the same time, however, substitutability imposes limits on investment opportunities. The more the third countries involved are competing with each other due to similar economic specialization, the lower their individual benefit from participating in the provision of jointly usable goods, and therefore the lower their willingness to contribute. The EU would have to compensate for this with an even greater financial contribution. And even if the use of goods can be largely limited to individual partners,

[80] See European Commission (2023).
[81] Cornes, R., & Sandler, T. (1996). The theory of externalities, public goods, and club goods. Cambridge University Press.

Europe's budget constraints represent a limit to the number of investments that can be carried out in parallel for each resource.

Another limiting factor from the EU perspective is the global competitive situation between the clubs. Here, China's extensive investment commitment in resource-rich countries comes to mind.[82] The countries concerned are faced with the choice of which clubs to join. A key competitive factor is the level of club-specific access costs. These consist, on the one hand, of the costs of adaptation required to meet the accession requirements. For poorer countries with relatively underdeveloped institutions, the costs of political-regulatory adjustment will often be in the foreground, i.e., the expenses for monitoring specified quality and environmental standards, for creating administrative transparency and for controlling corruption. In addition to these immediate costs, however, joining the club can also entail additional long-term costs. For resource-rich countries, the main issue is the **risk of economic lock-in**: The establishment of joint supply chains threatens to permanently limit them to the role of raw material supplier in international trade, with no prospect of participation in the usually more innovation-intensive manufacturing stages in the downstream segment. This is due to the demand for raw materials in the partner countries, which keeps domestic productive resources tied up in the raw materials sector. The expansion of infrastructure that primarily serves to reduce the costs of raw material extraction can further intensify the lock-in. Strategic partnerships thus threaten to trigger a new form of "resource curse," which has been the subject of empirical research for some time.[83]

The respective composition of access costs may vary depending on the partner. Observations of China's involvement in resource-rich countries to date suggest that the political and regulatory hurdles to cooperation are set rather low.[84] The risk of lock-in, on the other hand, can be considered quite high for China's partners, at least in the case of low-income countries with large primary sectors.[85] This is an opportunity for Europe in the competition between clubs. With the Global Gateway Initiative, the EU has made it clear that it does not want to engage in a race-to-the-bottom with China: Fundamental European values and objectives are presented as non-negotiable.

This means that keeping the second component of access costs low for potential partners is even more crucial for Europe's success. One way forward, already discussed in Section 2.2, is the **binding inclusion of steps to value chain upgrading in the roadmaps of future cooperation.** Partner countries are given the perspective of expanding their role within joint value chains to downstream processing steps over time, thus advancing their industrial development while benefiting even more from club-internal knowledge and innovation. To make this possible, joint infrastructure and research projects should be designed with downstream uses in mind. In addition, intra-club trade integration should be as conditional as possible. While the EU should open its markets to partner countries as a signal of commitment at the shortest possible notice, a step-by-step approach could be agreed upon for the opening of partner countries' markets, which should be oriented toward the development of industrial capacities.

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82 Kaplinsky, R., & Morris, M. (2009). Chinese FDI in Sub-Saharan Africa: engaging with large dragons. The European Journal of Development Research, 21, 551-569.

83 Ploeg, F. V. D. (2011). Natural resources: curse or blessing?. Journal of Economic Literature, 49(2), 366-420.

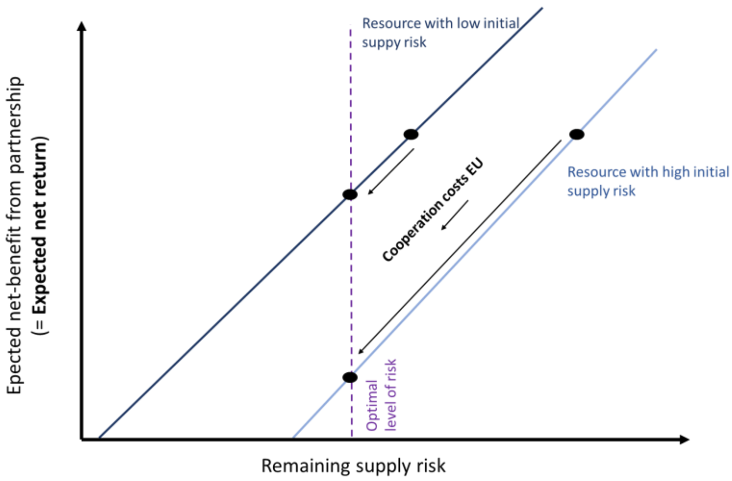
84 Mohsin, A. K. M., Lei, H., Tushar, H., Hossain, S. F. A., Hossain, M. E., & Sume, A. H. (2021). Cultural and institutional distance of China's outward foreign direct investment toward the "Belt and Road" countries. The Chinese Economy, 54(3), 176-194.

85 Sun, Y., Zhang, K., & Zhang, S. (2021). The impact of Chinese Outward Foreign Direct Investment on the comparative advantage of the Belt and Road countries. Journal of the Asia Pacific Economy, 1-35.

At the same time, a certain degree of flexibility should be retained for the concrete design of partnership agreements. The optimal approach differs not only according to the initial conditions in the partner country, but also according to the overall economic significance and the existing supply risk along the supply chains concerned. From the perspective of portfolio theory, the target can be formulated as the realization of an appropriate risk-return ratio. Specifically, the expected net benefit to the EU from the intra-club provision of non-rival goods (i.e., infrastructure, knowledge exchange, innovation) should be commensurate with the remaining supply chain risk. **A key variable here is the degree of redundancy** in the choice of partners. A higher level of redundancy can help to limit the supply chain risk for the EU resulting from the instability of individual relationships. However, to increase redundancy in the partner portfolio, the loss of attractiveness of club cooperation (competitive relationship of the partners) would have to be compensated by lower access costs for the partners, for example by way of stronger concessions from the EU regarding value chain upgrading. In both cases, higher cooperation costs for the EU (and thus lower expected net benefits of cooperation) are the consequence.

The relationship between redundancy and risk is supply chain specific. If a raw material or intermediate product is to be assessed as particularly critical for the EU due to its high systemic importance, a higher degree of redundancy in the sourcing of the resource is required to achieve the same level of risk. Indeed, from a portfolio perspective, the complementarity of the different future technologies (see Section 3.1) argues for distributing risks in such a way that no technology exceeds a certain level of supply chain risk. The optimal level of redundancy in the selection of strategic partners for the supply of a critical resource is thus derived from its importance to the overall system of a carbon-neutral and digital economy of the future. Figure 7 illustrates this principle schematically.

Figure 7: Risk-return rationale behind resource partnerships



Source: own representation

To make these considerations useful for the practical design and management of EU resource partnerships, first and foremost a broader information base is needed. The methodology developed by the European Commission for the criticality assessment of mineral raw materials represents a good starting point. On the one hand, it must be expanded to include the criticality of non-mineral resources. On the other hand, it should also assess the benefits of potential strategic partnerships as a contribution to risk reduction in the medium term. This concerns not only the categorization of exploitable resource stocks, but also the indicator-based assessment of existing barriers to cooperation. Our analysis provides initial suggestions for this, based on publicly available information. For commodity-specific studies, more detailed indicators are needed, especially for the identification of regulatory barriers.

6 Conclusion

The transition of Europe's industries to a climate-neutral and digitalized mode of production brings new risks for the stability of their supply chains. Growing demand for key resources essential for future technologies will lead to new global scarcity in the coming years. Europe is not well equipped for this in terms of its domestic capacities. This is true not only for the availability of critical mineral raw materials such as lithium and cobalt, but also to some extent for innovation activity and skilled labour requirements related to future technologies. In the case of mineral raw materials, this is compounded by the fact that supply channels have so far been concentrated in countries with high specific risks and, from a European perspective, inadequate environmental and occupational safety standards.

Europe must free itself from this growing dependence. There is no simple remedy for this. However, the EU has developed a promising new instrument in the form of strategic resource partnerships. Its principle is to strive for long-term supply chain cooperation with countries that have particularly large resource potentials related to future technologies. This includes not only the establishment of stable supply relationships, but also joint investment in the development and expansion of supply chain-related infrastructure and regulatory cooperation, particularly concerning environmental standards. In addition to reducing supply risks, the objective is also to increase the competitiveness of joint supply chains vis-à-vis global competitors by reducing transport costs and increasing productivity through joint research and the exchange of existing knowledge.

Our empirical analysis of the resource potentials of third countries for selected future technologies shows that, beyond the agreements already concluded, a number of additional partners are attractive for Europe. In the area of mineral resources and renewable energies, this applies to countries such as Australia, Chile, and New Zealand, but also to countries such as Japan and South Korea with regard to the future demand for innovation potential and human capital. Many of these countries already have strong economic ties with the EU through trade agreements and are also comparatively close to the EU in terms of their domestic regulatory systems.

Deepening economic relations with such established partners with a focus on future technologies is an obvious first step. However, in view of the diversity of future resource needs and the considerable level of technological uncertainty, this should not remain the only arrow in the EU's quiver. In the global race for the resources of the future, it is also important to uncover the still hidden potential of today and make it usable. This also requires the establishment of resource partnerships with countries at the lower end of the global income scale since this is the primary area where undiscovered potential may lie dormant. To achieve this, however, Europe must first provide attractive growth prospects to such countries. The Global Gateway Initiative could play a decisive role here. It can be used to channel capital specifically into promoting infrastructure in partner countries. Ideally, these funds would not only be an investment in Europe's supply security. Linking the funds to a commitment to values means they could also contribute to the spread of higher environmental and occupational safety standards along the supply chains concerned.

However, it is also a fact that no-one is waiting for Europe. The outlined model of supply chains guided by European interests and values is in fierce global competition with other cooperation initiatives, above all China's Belt and Road strategy. From the perspective of developing countries, this new competitive relationship opens up room for manoeuvre, which they use for their own diversification strategy. Former colonial countries, in particular, will attach great importance to avoiding strong ties to individual partners. In this context, a crucial design problem of resource partnerships lies in their increasing instability with growing duration. Once joint investments in capacity and infrastructure have been realized, the incentives for resource suppliers to maintain the partnership diminish. Increased knowledge exchange and research cooperation alone are not a sufficient antidote to this problem since their returns are irreversible.

To build long-term stable resource partnerships with developing and emerging countries, the EU must give them the space to upgrade their position as production locations within the common supply chains, in the long term. They need a clear perspective for moving away from their role as pure suppliers of raw materials for future technologies, to undertaking more value-added and knowledge-intensive process steps at the downstream level. Gradual, conditional trade integration and intensive cooperation in the (further) development of standards are an appropriate means of achieving this. In its cooperation policy, Europe must succeed in the balancing act of initiating regulatory convergence without exposing itself to the accusation of paternalism. If it succeeds, Europe will have an asset that should not be underestimated in its political and economic competition with China.

From a strategic perspective, this is a lengthy, multi-step process. With the declarations of intent collected so far, the EU is just about to take the first step. The urgency requires a clear focus for the way ahead. Instead of maximizing the number of non-binding agreements, the next negotiating steps with selected partners should be taken as quickly as possible. Looking at partnerships as a portfolio can be helpful. Overall, the choice of partners and cooperation instruments should be about establishing an appropriate risk-return ratio in the portfolio of partnerships for various critical resources. For resources of systemic importance and those with high supply risk, a special focus should be placed on reducing their risk contribution. This will usually entail a higher need for redundancy among resource suppliers and/or stronger concessions by the EU to the cooperating partners, in any case higher cooperation costs for the EU.

Additional monitoring instruments and a better information base are necessary for the implementation of such a strategy. The indicator system developed by the EU for assessing the criticality of mineral raw materials provides a good basis for this. However, it should be extended to include risk assessments for other future-relevant resources such as renewable energies, human capital, and innovation potential. It should also look at potentials and barriers for cooperation with specific partners. The distance measurements presented in this article provide an initial suggestion but need to be complemented by more specific data collection, in particular to identify differences in resource-related regulation.

7 Annex

7.1 Data sources

Table A1: External sources

Category	*Indicator*	*Explanation*	*Time*	*Unit*	Source	*URL*
		Resource potentials				
Material resources	**Reserves mineral resources**	Estimated geological reserves of critical minerals (see Section 3.2)	2023	tonnes	USGS (2023)	Link
	Potential solar power	Average electricity generation potential of a technically comparable PV plant	2020	kWh/kWp/day	ESMAP (2020)	Link
	Potential wind power	Average wind power density	2023	W/m2	DTU (2023)	Link
Innovation activity	**No. of patent families**	Number of patent families for ten future technologies[86] (see Section 3.1) by country of residence of the inventor	Period 2013-2022	No.	EPO (2023)	Link
	ø size patent families	Average size of patent families for ten future technologies (see Section 3.1) by country of residence of the inventor	Period 2013-2022	No.	EPO (2023)	Link
Human capital	**Share tertiary education**	Share of 20-39 years old with tertiary education	2020	Share (%)	Wittgenstein Centre (2023)	Link
	Learning-adjusted years of schooling	Index based on the product of expected years of schooling and average test scores	2020	Dimensionless	World Bank (2020)	Link
		Cooperation barriers				
Institutional distance	**Governance Quality**	Six Worldwide Governance Indicators	2021	Dimensionless (-5 to +5)	World Bank (2023)	Link
	Regulatory distance	Database on non-tariff measures by regulatory type and product category	2023	Dimensionless (Yes/No)	UNCTAD TRAINS (2023)	Link

Source: own representation.

[86] The future technologies were approximated by IPC-classes in PATSTAT as follows: 5G, 6G: H04L, H04W; Additive layer manufacturing: B33Y; CCS: B01D; Electric motors: B60L; Batteries: H01M; Solar cells: H01L; Optic fibre cables: H04B; Sensors for autonomous vehicles: G01S; Elektrolysis: C25B; Wind motors: F03D.

7.2 Detailed results for country potentials

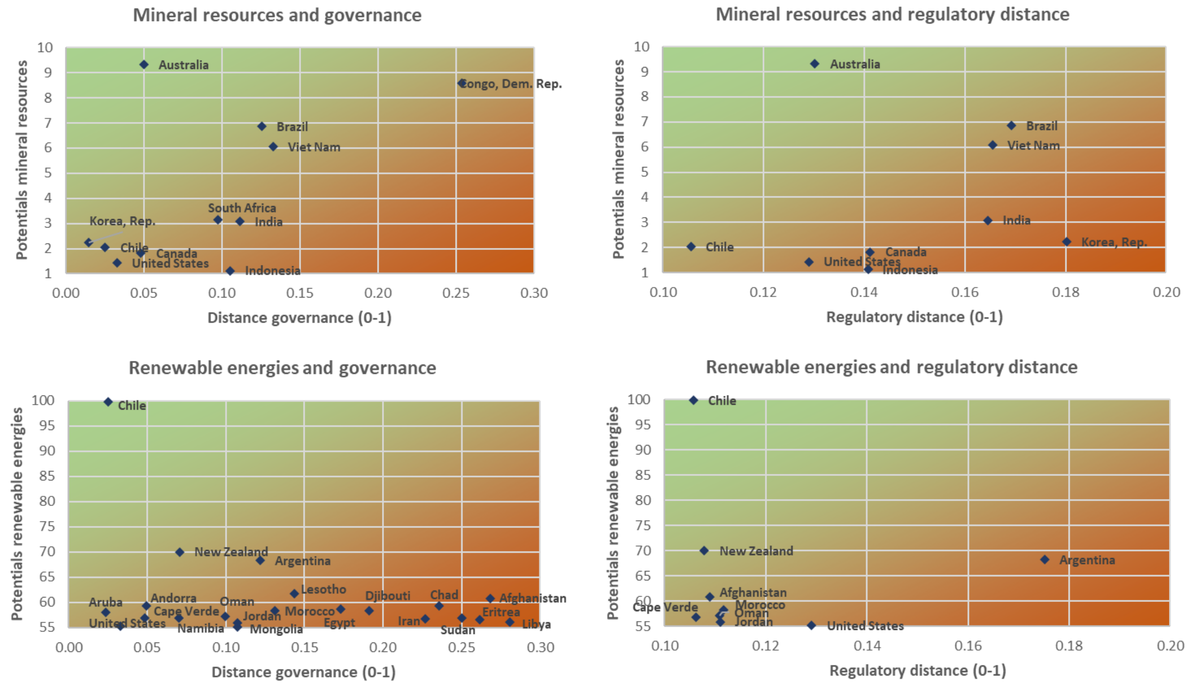
Table A2: Top 20 country potentials by resource category (only non-EU countries)

Critical minerals			Renewable energies			No. of patent families			Adj. years of schooling		
Rank	*Country*	*Index*	*Rank*	*Country*	*Index*	*Rank*	*Country*	*Index*	*Rank*	*Country*	*Index*
1	China	39,29	*1*	Chile	99,87	*1*	USA	85,57	*1*	Singapore	12,81
2	Australia	9,32	*2*	New Zealand	70,02	*2*	South Korea	78,89	*2*	Japan	11,74
3	Dem. Rep. Congo	8,57	*3*	Argentina	68,32	*3*	Japan	52,39	*3*	Canada	11,72
4	Russia	8,07	*4*	Lesotho	61,67	*4*	China	12,08	*4*	South Korea	11,68
5	Brazil	6,87	*5*	Afghanistan	60,81	*5*	United Kingdom	6,35	*5*	United Kingdom	11,54
6	Vietnam	6,07	*6*	Chad	59,23	*6*	Canada	4,94	*6*	New Zealand	11,39
7	South Africa	3,15	*7*	Egypt	58,64	*7*	Switzerland	3,54	*7*	Norway	11,23
8	India	3,09	*8*	Djibouti	58,35	*8*	Israel	1,68	*8*	Australia	11,22
9	South Korea	2,24	*9*	Morocco	58,34	*9*	Singapore	1,42	*9*	Switzerland	10,93
10	Chile	2,04	*10*	Oman	57,18	*10*	Australia	1,40	*10*	Belarus	10,78
11	Canada	1,83	*11*	Yemen	56,96	*11*	India	1,18	*11*	Iceland	10,72
12	USA	1,44	*12*	Sudan	56,92	*12*	Brazil	0,91	*12*	Vietnam	10,68
13	Indonesia	1,12	*13*	Namibia	56,86	*13*	Norway	0,89	*13*	Israel	10,59
14	Cuba	0,94	*14*	Iran	56,77	*14*	Saudi-Arabia	0,76	*14*	USA	10,56
15	Japan	0,78	*15*	Eritrea	56,47	*15*	Ukraine	0,46	*15*	Ukraine	9,87
16	Argentina	0,59	*16*	Libya	56,04	*16*	Mexico	0,28	*16*	Serbia	9,75
17	Philippines	0,49	*17*	Jordan	55,94	*17*	Malaysia	0,27	*17*	Utd. Arab. Em.	9,65
18	Madagascar	0,48	*18*	Somalia	55,93	*18*	New Zealand	0,18	*18*	Chile	9,41
19	Norway	0,48	*19*	USA	55,27	*19*	Turkey	0,17	*19*	Bahrain	9,29
20	Rwanda	0,44	*20*	Mongolia	55,09	*20*	South Africa	0,15	*20*	China	9,27

Source: own calculations.

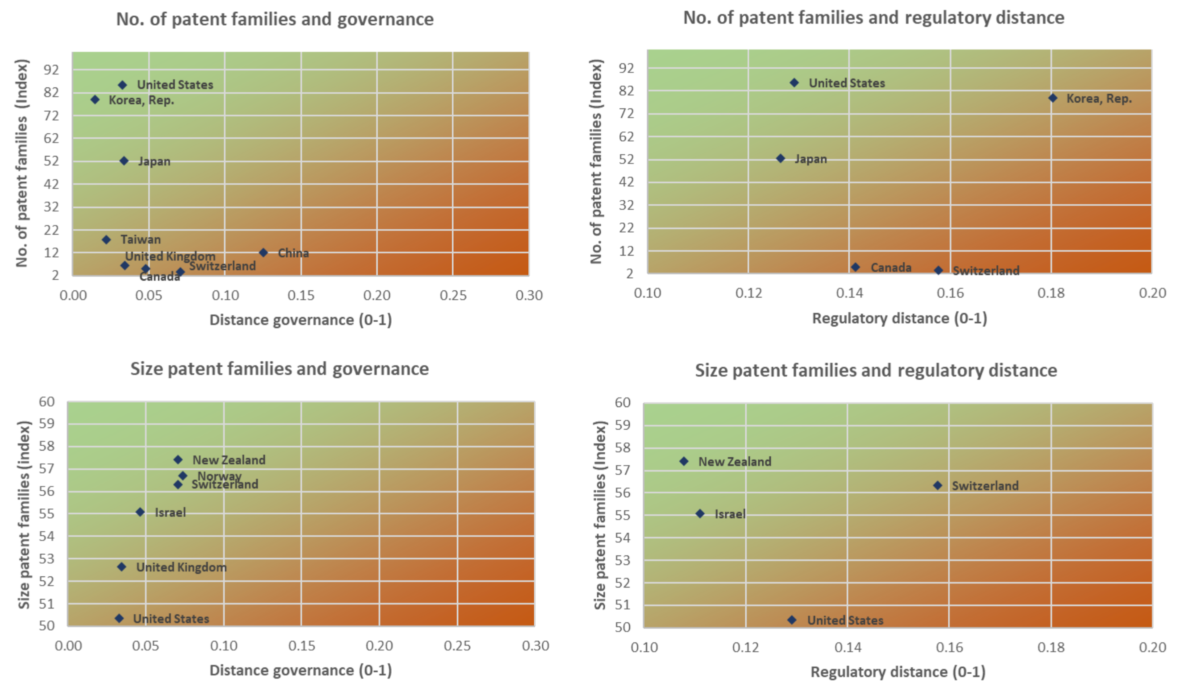
7.3 Detailed results for potentials and barriers

Figure A1: Potentials for tangible resources and cooperation barriers



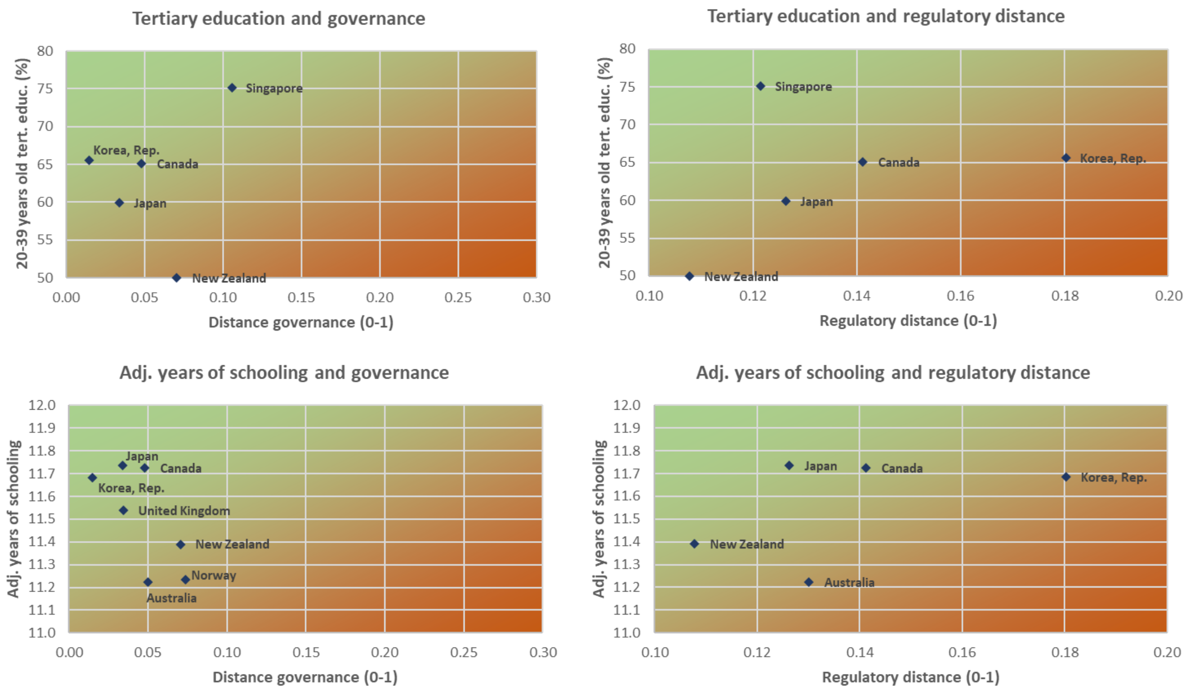
Sources: USGS (2023); Global Solar Atlas (2023); Global Wind Atlas (2023); World Bank (2022); UNCTAD (2023); own calculations.

Figure A2: Innovation potentials and cooperation barriers



Sources: EPO (2023); World Bank (2022); UNCTAD (2023); own calculations.

Figure A3: Human capital potentials and cooperation barriers



Sources: Wittgenstein Centre (2023); World Bank (2020, 2022); UNCTAD (2023); own calculations.

Table A3: Correlation coefficients between resource potentials and cooperation barriers

	Potentials / Barriers	Distance governance quality	Regulatory distance
Tangible resources	Critical minerals	+0.01	+0.52
	Renewable energies	+0.12	-0.13
Innovation activity	No. of patent families	-0.21	+0.21
	ø size patent families	-0.48	+0.20
Human capital	Share tertiary education	-0.59	+0.17
	Adj. years of schooling	-0.71	+0.18

Source: own calculations.

Centrum für Europäische Politik
FREIBURG | BERLIN

Author:

Dr. André Wolf
Head of Division Technology, Infrastructure and Industrial Development
wolf@cep.eu

Centrum für Europäische Politik FREIBURG | BERLIN
Kaiser-Joseph-Straße 266 | D-79098 Freiburg
Schiffbauerdamm 40 Raum 4315 | D-10117 Berlin
Tel. + 49 761 38693-0

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