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Discussion Paper

The Unfolding Potential of GCC-China Collaboration on Critical Minerals

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Key Points

As a clean energy system begins to be implemented worldwide, the demand for critical minerals is expected to increase dramatically in the coming decades. Thus, demonstrating how mineral collaboration benefits the economy is key to building long-term supply resilience and keeping the global energy transition on track. In this work, we utilize a gap analysis of supply and demand and find that both China and the GCC are facing challenges in ensuring the mineral supply that is necessary to support future development. Because of growing efforts to develop investor-focused legislation and regulatory frameworks and expand international collaboration, the influence of the GCC over critical minerals has grown. Although China will continue to be a significant player in global mineral supply chains, its strategy has shifted toward a more balanced approach to domestic capacity development and overseas market participation. However, both the GCC and China can benefit from technology development and knowledge sharing for mineral resource exploration and production. Moreover, the coordination of financial and technical resources and the stimulation of supportive trade and investment regimes for mineral exploration, extraction, processing, and downstream production in the African, Western, and Central Asian regions can create long-term strategic value for both sides.

1. Introduction

Critical minerals are essential inputs for clean energy technologies, including renewable power, nuclear power, electricity networks, electric vehicles (EVs), battery storage, and hydrogen. As examples, six times the mineral inputs of a conventional car are needed for a typical EV, and nine times more mineral resources are needed for an onshore wind plant than for a gas-fired plant of the same capacity (IEA 2021). Additionally, the growing electrification in the transportation, building, and industrial sectors is shaping the infrastructure on which the world economy has relied. Thus, the energy transition from fossil fuel to clean energy actually involves an economic system transition from fuel intensive to material intensive (IEA 2021; IRENA 2023).

Since production is concentrated in a small number of countries, the supply chains that rely on specific minerals are vulnerable, not only to market power and logistical risks, but also to geopolitically-induced disruptions. Resource-rich countries are increasingly using state control policies to increase the benefits of extracting and processing industries while simultaneously building downstream sectors. Numerous governments of nations with mineral consumers have prioritized supply chain diversification and friendshoring options in their critical mineral strategies, as well as measures to incentivize investment in local production, technology innovation, and material recycling. Additionally, the differing strategies of major suppliers and major consumers have increased market dynamics. Furthermore, heightened geopolitical tensions between the U.S. and China and the rise of derisking strategies in Western economies have added uncertainties to the already precarious market supply landscape.

As the energy transition accelerates in the GCC region and China, the development of reliable, diversified, sustainable, and responsible supply chains for critical minerals and clean energy manufacturing becomes crucial for both sides. Although China has rich mineral resources and well-established manufacturing bases for clean energy technologies, it still values overseas resource exploration and global market participation. The GCC states just began generating new economic growth from mineral resource exploration to downstream product manufacturing. Thus, enhancing GCC-China collaboration along mineral supply chains can help both sides achieve their economic transition goals.

2. Minerals and Metals: State of Development in the GCC Countries and China

2.1 Mineral Resource Reserves

Historically, the GCC region has focused more on extracting oil and gas resources than on obtaining metals and minerals. Only around 3% of the world's global mineral reserves are found in the GCC, and less than 1% of the total global mineral exploration and extraction budget is invested in the region (USGS 2024). Thus, the GCC region has considerable untapped potential for the exploration, extraction, and processing of nonfuel mineral resources.

The Western Arabian Shield of Saudi Arabia contains substantial amounts of precious and base metals, such as gold, silver, aluminum, iron, copper, zinc, manganese, and chromium. Valuable minerals, such as tantalum and niobium, can also be found in the Arabian Shield. To date, over 48 minerals have been identified in the Kingdom, and at least 15 of these minerals have been deemed commercially viable (Alqarout 2023). After a reassessment in 2024, Saudi Arabia raised its estimate of the value of the country's potential mineral reserves to $2.5 trillion, almost double the previous estimate in 2016 (CNBC 2024). Since much of Saudi Arabia's land still needs to be explored, this figure is likely to rise.

Oman is a nation that is well-endowed with natural mineral resources, concentrated mainly within 700 km of the 150-km mountain range, which offers an exposed ophiolite geological outcrop containing minerals such as copper, gold, silver, chromite, lead, nickel, manganese, and zinc. Moreover, deposits of dolomite, limestone, gypsum, silica, cobalt, marble, and iron can be found in other regions of the sultanate. According to the latest geology data, Oman has approximately 30 million tons of chromite ore. The main copper reserves in the nation, which have been estimated at approximately 54.5 million tons, are located in the Sohar area of the Al Batinah region (Oxford Business Group 2020).

Although Quaternary sediments can be found across large areas of the UAE, the bedrock geology is well exposed in the Hajar Mountains and the Musandam Peninsula of the eastern UAE and along the southern side of the Arabian Gulf west of Abu Dhabi (Saibi et al. 2021). Thus, the UAE has various mineral ores, including limestone, gypsum, and silica. These minerals are crucial for the construction and manufacturing industries. Moreover, the country has deposits of valuable metallic minerals, including copper and gold, as well as substantial bauxite reserves, which are essential for aluminum production. Furthermore, recent exploration efforts have revealed potential reserves of rare earth elements.

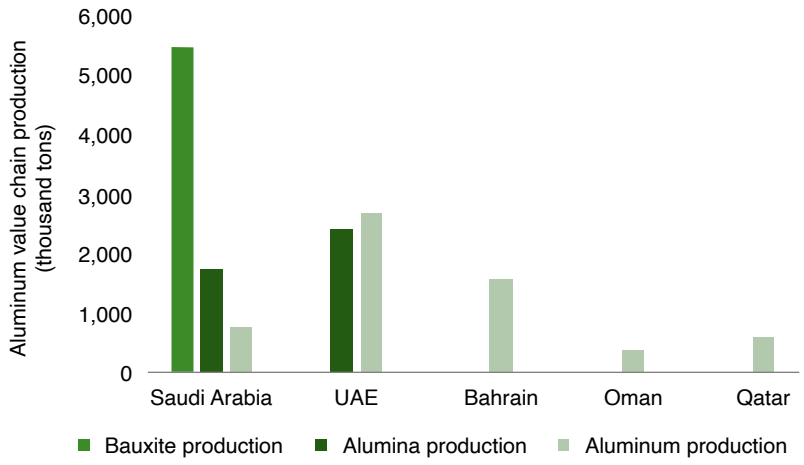
Limited information regarding the mineral and metal reserves in other GCC states is available. However, given the size of their landmass, it is reasonable to assume that Qatar, Bahrain and Kuwait have small potential reserves.

In contrast with the GCC, which is in the early stage of mining exploration, China has been a mature major supplier of minerals and metals for the last decade. By 2022, 59 metallic minerals and 95 nonmetallic minerals had been discovered in the country (China Ministry of Natural Resources 2023). China has the world's largest reserves of antimony, bauxite, molybdenum, rare earths, strontium, tin, titanium, and tungsten, as shown in Annex 1. Moreover, the iron ore reserves in China are extensive, especially in Hainan, Gansu, Guizhou, southern Sichuan, and Guangdong. However, the copper resources are moderate, accounting for only 4% of global reserves, and high-quality ore is present in only a few deposits. In recent years, substantial growth has been reported for lead, zinc, nickel, cobalt, lithium, beryllium, gallium, germanium, fluorite, and crystalline graphite.

2.2 Mineral Production and Trade Flow

Because of low energy costs and industrial incentives, the aluminum industry has gained a strategic position in the GCC region. Five of the six GCC countries have smelter production of aluminum, but Saudi Arabia is the only country that has full value chain capacity from bauxite mining to alumina refining and aluminum production (Figure 1). In 2022, the total aluminum production from the GCC countries reached 6.13 million tons per annum, which accounted for 4.35% of the total world production. The UAE is the world's fifth largest producer of aluminum. Moreover, it was the first country in the GCC and in the world to produce aluminum with solar power.

Figure 1. Aluminum production in the GCC.



Source: British Geological Survey (2024).

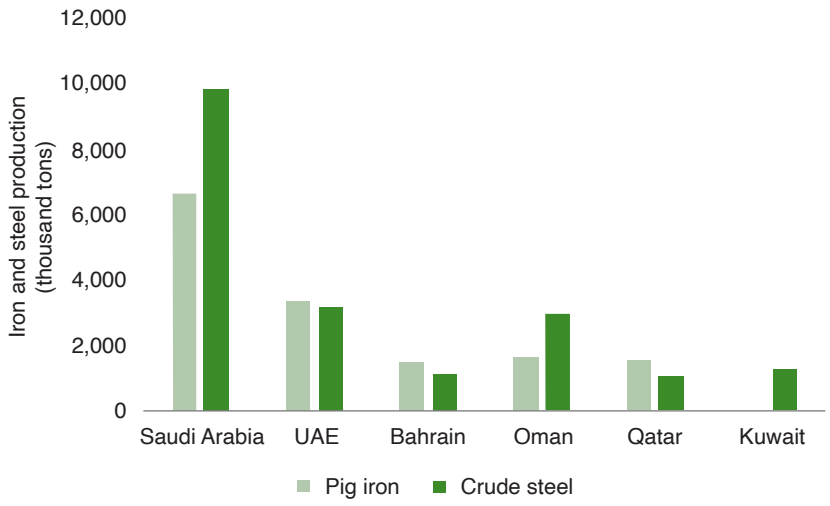
Infrastructure development and new industrial growth in the GCC region has increased dramatically in recent years, and this has driven the demand for iron and steel. Saudi Arabia is the largest market and producer of iron and steel in the GCC region and accounts for approximately 40% of the market share and 50% of the total production in the region (Figure 2). Between 2018 and 2022, crude steel production in Saudi Arabia increased from 8 million tons to 9.8 million tons per annum, in Oman from 2 million tons to 3 million tons per annum, and in Bahrain from 0.72 million tons to 1.17 million tons per annum. At the same time, the UAE and Kuwait maintained steady production rates of 3.2 million tons and 1.3 million tons per annum, respectively. Qatar had a different trajectory, declining from 2.5 million tons to 1 million tons per annum from 2018 to 2022.

Notably, the copper value chain production in the GCC is distributed unevenly among the states. Saudi Arabia is the major producer of copper ores and concentrates, while the rest rely on imports of copper ore for the domestic manufacturing of downstream copper products, such as copper bars, rods, tubes, and pipes. This has presented opportunities for copper value chain integration at the GCC regional level, through which resource exploration and downstream value creation can be optimized and the growing demand arising from the green energy transition can be secured.

The discovery of copper deposits in the Arabian Shield presents substantial potential for Saudi Arabia. These deposits have a confirmed value of $7 billion of copper resources, and the estimated value could reach $222 billion (Ministry of Industry and Mineral Resources 2022). This resource potential of 26 million tons of copper reserves has positioned Saudi Arabia as the largest producer of copper concentrate in the GCC region. Its production capacity is supported by mines at Jabal Sayid, Al Masana, and Al Amar, totaling 340 thousand tons per annum (KTPA). Thus, the mine production output of Saudi Arabia has increased steadily in recent years, increasing from 36 KTPA (copper [Cu] content) in 2017 to 75 KTPA (Cu content) in 2022 (BGS 2024).

However, the lack of smelting and refining operations in this country has led to fragmented value creation. Saudi Arabia primarily exports its copper ore and concentrates to countries such as China, India, and Japan. However, since it lacks midstream facilities for transforming scrap into more valuable products, Saudi Arabia exports its copper scrap, mainly to Korea, India, and Japan. On the other hand, rising investments in tourism-specific projects and booming infrastructure expansion are driving demand for copper downstream products, so Saudi Arabia needs to import refined and semifabrication copper products for downstream product production. Realizing the importance

Figure 2. Iron and steel production in the GCC.



Source: British Geological Survey (2024).

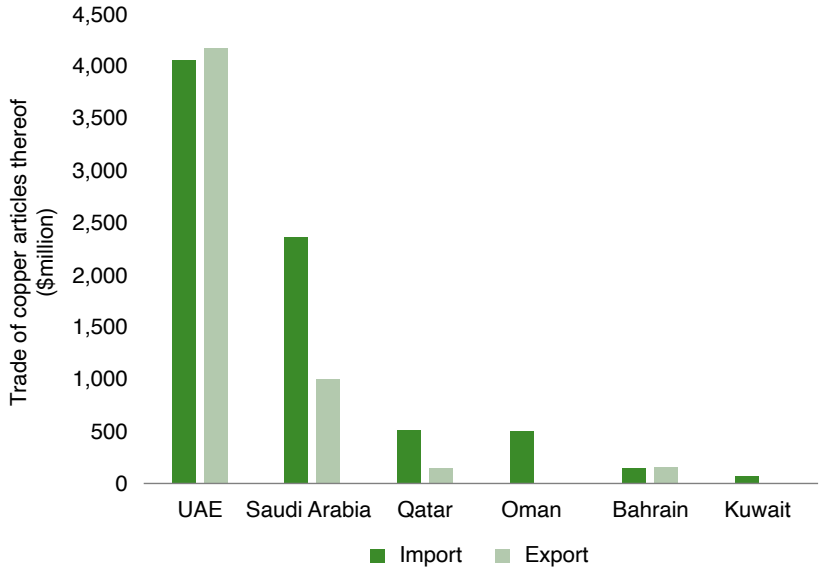
of leveraging locally produced raw materials for local value-added downstream industries, Saudi Arabia has begun to build regulatory and policy frameworks to incentivize investment in the midstream and downstream sectors. The project plans that have been announced include a 300 KTPA copper cathode smelting plant, a 115 KTPA copper rod plant, a 50 KTPA secondary copper smelting plant, a 10 KTPA copper tube manufacturing plant, and a 10 KTPA of copper section products (Invest Saudi 2023).

Oman has a sizeable copper ore presence, with more than 40 million tons of available copper ore reserves with 1%-3% Cu (Oman Mining Expo 2017). However, the production output of this country has been declining over the past decade. Notably, in 2015, the copper concentrate output of Oman decreased by 60% from its peak level of 111 KTPA in 2011 (USGS 2024). The data from the USGS revealed a pause in copper concentrate production after 2015. Thus, its refining output in 2018 dropped more than 75% from its peak level of 26 KTPA in 2015. However, with the endorsement of the mineral wealth law in 2019, new momentum energized the development of the mineral industry. Specifically, four concessions are planned to mine copper at Yanqul, Khaboura, and Samad. In 2023, a joint venture with the Australia-based mining firm Alara Resources started commissioning a copper concentration processing project in North Al Sharqiyah Governorate. This project is expected to transform the development of the copper industry in Oman.

In the GCC, the UAE has the strongest capacity for copper product manufacturing. Specifically, it has a continuous cast copper rod plant established in the Furairah Free Zone, with a capacity of 100 KTPA (USGS 2024). This made the UAE the world's largest exporter of copper wires (HS code 740811) in 2022, accounting for 15% of total global exports (World Bank 2023). The UAE is also the largest exporter of copper and articles thereof in the GCC region. In 2023, the UAE signed a MOU with Thailand to construct a production unit with an installed copper processing capacity of 30 KTPA (Zawya 2023). This demonstrates that the UAE is continuing to strategically focus on manufacturing high-quality copper products, including ETP and oxygen-free copper bus bars, profiles, strips, sheets/tapes, alloys, and magnet wires.

Over the last decade, the copper consumption in Qatar has steadily increased. As shown in Figure 3, its imports of copper and articles thereof totaled $521 million in 2022, which was an 80% increase compared with 2013, but its exports of copper and articles thereof rose 14-fold during the same period, reaching $158 million in 2022 (World Bank 2023). Bahrain specializes in producing copper tubes and pipes and is the 15th largest exporter in the global market. Its import and export of copper and articles thereof are well balanced. Kuwait's copper consumption has decreased since 2017. Compared with 2021, its imports and exports of copper and articles thereof totaled $75 million and $9.26 million, respectively, in 2022, a decrease of 67% and 83%, respectively (World Bank 2023).

Figure 3. Trade of copper and articles thereof in the GCC.



Source: World Bank (2023).

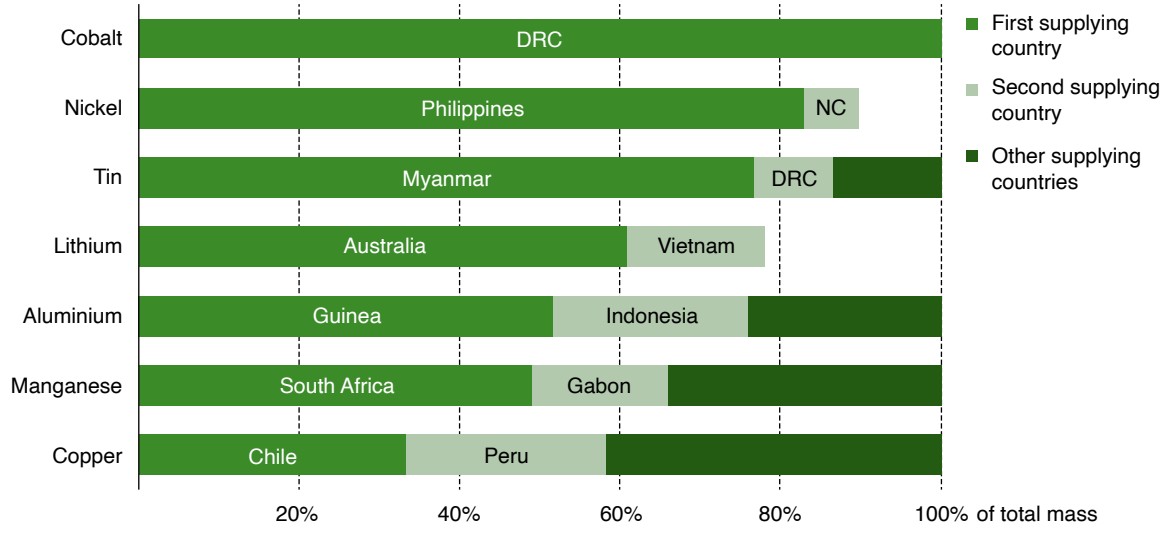
Unlike GCC states, China has been a major player in the global critical mineral market for decades. Notably, China is one of the few countries in the world that has vast quantities of resources that are also highly complete. China extracts nearly 70% of graphite globally and 68% of rare earths (IEA 2023a). Moreover, it is the largest producer of zinc, lead, and gold in the world. However, many mineral resources have been depleted because of continued exploration and extraction for decades. Between 1998 and 2021, the reserve-production ratios of copper, tin, nickel, and rare earth in China decreased by 64.69%, 61.43%, 74.77%, and 69.55%, respectively (Jin, Yu, and Wang 2022). Some minerals have large reserves in China but mainly consist of low-grade resources, so challenges arise because of both complex mineral compositions and scattered distributions. For example, China has a lithium reserve of 4.5 million tons, which accounts for an estimated 14% of the total global lithium reserve. The largest granitic pegmatite-type lithium deposit is located in Aba Prefecture and Ganzi Prefecture of Sichuan Province (Liu et al. 2017). However, poor transportation, along with other geological constraints, hinders the development of lithium resources in this area. Furthermore, the lepidolite content in lithium-rich Jiangxi and Qinghai Provinces is quite low, so extraction costs are very high. Regarding iron ore, only approximately 30% of the resources in China reach average-grade quality, and the industry faces the issues of complex processing routes, poor adaptability to variations in low-grade ore, and challenges in addressing the large number of tailings generated in the process (Zhu et al. 2022).

China's dominance of critical minerals in the global market mainly involves the processing stage. Specifically, China controls nearly 100% of the refining process of graphite, 90% of the world's rare earths, 74% of cobalt, 65% of lithium, 42% of copper and 43% of nickel (IEA 2023a). Despite increased global efforts to diversify supply chains and advance mineral exploration, China will continue to be an important player in refined minerals. By 2030, China is expected to produce a major share of refined metals for the global market: 46% of copper, 57% of lithium, 74% of cobalt, 93% of graphite, and 77% of rare earths (IEA 2024a).

However, the focus on global mineral processing and rising mineral demand from industrial product manufacturing have led to an increase in China's reliance on mineral imports from overseas markets. Notably, China relies almost entirely on the DRC for cobalt imports; more than 80% of nickel is imported from the Philippines, more than 60% of lithium is imported from Australia, and nearly 50% of manganese is imported from South Africa (Figure 4). China produces half of the world's steel but heavily relies on imported ore, importing more than 80% of the ore it processed between 2015 and 2020. Of this ore, approximately three-fifths of it is from Australia, and one-fifth is from Brazil. Additionally, with the applications of aluminum in electrical appliances, heat dissipation materials, and aviation, China has become the world's largest consumer and producer of aluminum. Its aluminum import dependence has been approximately 50% in the past decade and reached as high as 60% in 2023 (World Bank 2023). Major locations for bauxite imports include Guinea, Australia, and Indonesia. Additionally, China has been the world's largest importer of copper core since 2009, and more than 50% of its imports have been obtained from Chile and Peru.

In summary, securing the mineral supply is just as important for China as it is for the GCC countries. Improving resource productivity and material recycling, increasing investment in domestic exploration activities, and diversifying the global supply of critical minerals are realistic strategies that China can employ.

Figure 4. China's import reliance on selected unrefined raw materials.



Source: IEA (2023a).

2.3 Assessing Demand for Minerals and Metals in the Renewable Energy Transition

Over the past decade, renewable energy has increased dramatically in the GCC, with total installed power capacity growing to 10 GW in 2023 from close to zero a decade earlier (IRENA 2024). The largest contributor to this growth is the UAE, which aims to increase its share of clean energy (renewable and nuclear) in the energy mix to 50% by 2050. Qatar's renewable capacity increased 34-fold in 2022 compared with the previous year because of a strong push from the World Cup. Oman aims for 30% of its electricity to be generated from renewable sources by 2030.

In this paper, we use Saudi Arabia as a case study to illustrate the future growth of mineral demand in the GCC to support the manufacturing needs of renewable energy technologies. Compared with other GCC states, Saudi Arabia has the most developed policy frameworks, which encourage both renewable installation and local manufacturing. In 2019, a target of installing 58.7 GW of renewable energy by 2030 was announced. Of these, 40 GW is for solar PV, and 16 GW is for wind. In 2021, Saudi Arabia committed to producing 50% of its power from renewables by 2030 as part of a new National Determined Contribution for climate change. More recently, the Minister of Energy announced plans to add 20 GW of renewables annually to reach 130 GW by 2030 (Saudi Gazette 2023). Accordingly, Saudi Arabia has developed policy roadmaps and identified key segments for local manufacturing in the short, medium, and long term to maximize the benefit from the deployment of renewable energy technologies. We assume that its new 130 GW target will follow the same ratio of wind and solar PV development as the target announced in 2019, resulting in 35 GW installation for wind turbines, 89 GW installations for solar PV, and the rest for other renewable technologies by 2030. By the end of 2023, Saudi Arabia had installed 2.5 GW of solar PV and 400 MW of wind turbines (IRENA 2024).

Over the last two decades, China has achieved stunning growth in renewable energy development. By the end

of 2023, the total installation of renewables in China had reached more than 1.5 TW, of which 609 GW were solar and 441 GW were wind. In 2023, China commissioned as much solar PV as the entire world did in 2022, while the amount of wind additions also increased by 66% year-over-year. Based on these developments, China will likely achieve its 2030 national target for wind and solar energy (1,200 GW) six years ahead of schedule. To assess mineral demand, we adopt the forecast from the World Energy Outlook (IEA 2023b) as a reference for China's outlook on wind and solar development. Under the Announced Pledges Scenario (APS), the total installed capacity will be 946 GW for wind turbines and 2,558 GW for solar PV in China by 2030.

China's efforts in transport electrification have also increased the pace of the global energy transition. The scaled-up production of EVs in China has significantly lowered costs, which has accelerated consumer uptake globally. In China, the number of new EV registrations reached 8.1 million in 2023, which marked an increase of 35% compared to that in 2022 (IEA 2024b). The Chinese government has announced targets to achieve a 50% new energy vehicle sales share in key air pollution control regions and a 40% sales share nationwide by 2030. This would drive the stock of EVs[1] to 113 million by 2030 under the APS scenario (IEA 2024b). By the end of 2023, the total stock of EVs was nearly 22 million.

Each renewable energy technology has different types of subtechnologies, and different types and amounts of minerals and metals may be needed for the production of each subtechnology. To simplify the estimation, we adopted the assumptions and hypotheses of Valero et al. (2018) regarding the type of subtechnology, its market share and mineral intensity. Two types of wind turbines are considered in relation to wind power. Wind turbines with gearboxes have a market share of 75%, while those with a direct drive account for 25% of the total market. In the case of solar PV, 85% of the market is dominated by crystalline technologies, and the remainder is filled by thin-film technologies, with each subtechnology (CIGS, CdTe and a-Si) having a 5% market share. The mineral intensity for light-duty EVs was obtained directly from Liang et al. (2022). The mineral intensities used for the calculations are provided in Annex 2, and the assessment results are presented in Annex 3.

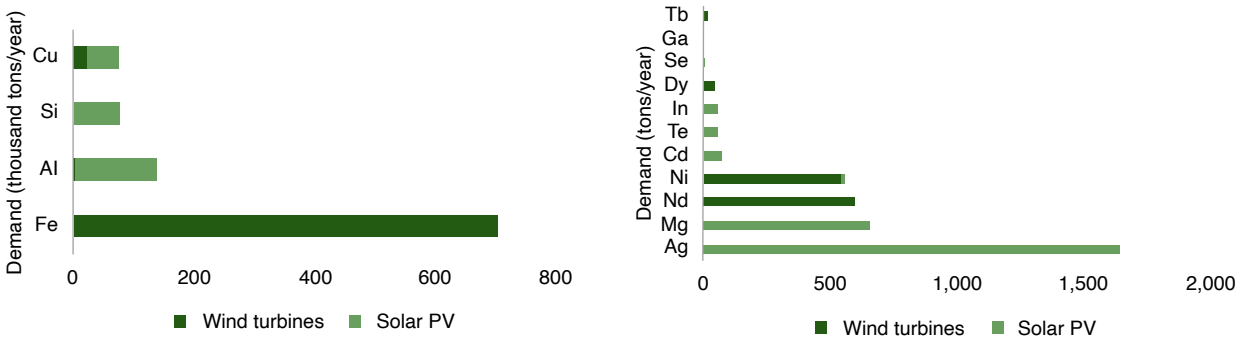
In this paper, we aimed to provide an understanding of the magnitude of mineral and metal demand for manufacturing major clean energy products and identify the major gap between local supply and estimated demand. However, because of the constraints of research resources, the expansion of electricity infrastructure that is needed to support a low-carbon transition and the competing demand from other sectors, such as construction and digital technologies, were not included in the research scope.

The assessment in this paper revealed that iron and steel, aluminum, silicon, copper, and silver are in high demand in both China and Saudi Arabia. The copper demand for solar PV manufacturing is more than two times greater than that for wind turbine manufacturing, whereas the majority of the iron and steel demand is for wind turbine manufacturing.

Saudi Arabia wants to become the manufacturing hub for clean energy products in the region. The preliminary assessment revealed challenges in securing the mineral demand for wind turbine and solar product manufacturing if this nation relies on the current local capacity. As aforementioned, the production capacity of iron and steel in Saudi Arabia reached more than 9.8 million tons per annum in 2021. This can satisfy the demand for wind turbine and solar PV manufacturing, 700 KTPA, from 2024-2030 (Figure 6). However, the outlook for other minerals and metals is not as promising as those for iron and steel are. Saudi Arabia has substantial reserves of copper, approximately 26 million tons, according to the latest estimation in 2023. Moreover, its copper mine production doubled from 36 KTPA to 76 KTPA from 2017 to 2021. If renewables are installed in the Kingdom from 2024 to 2030 as expected, 75,000 tons of copper will be needed annually for wind turbine and solar PV products (Figure 5). The market is more or less balanced if only the needs for wind turbines and solar PV products are served by the current copper production. However, given the wide usage of copper in many other sectors, such as industrial equipment, machinery, electric systems, railways, ships, and building constructions, the stress on the copper supply could be significant since the Kingdom is also expanding its investments in industrialization and urbanization. Furthermore, other minerals that are needed for wind and solar PV, such as nickel, magnesium, cadmium, gallium, indium, and rare earths, are rarely produced in Saudi Arabia.

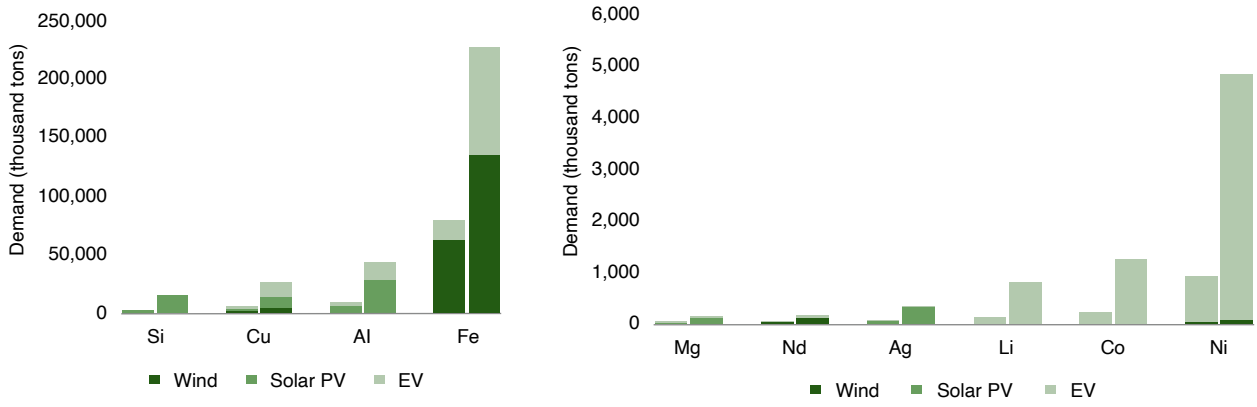
[1] *In this study, electric vehicles include battery electric and plug-in hybrid electric light-duty passenger vehicles but not 2/3-wheelers.*

Figure 5. Annual mineral demands for wind turbines and solar PV systems in Saudi Arabia from 2023 to 2030.



Source: Authors' calculation (details are provided in Annex 3).

Figure 6. Accumulative mineral demands for wind turbines, solar PVs and EVs in China.



Source: Authors' calculations (details provided in Annex 3).
Note: The left-hand bar shows demand by 2023; the right-hand bar shows demand by 2030.

To meet its ambition for wind, solar, and EV in 2030, China would need to increase its demand for minerals by nearly four times for copper, 4.5 times for aluminum, and approximately three times for iron and steel from the level of 2023. In addition to basic metals, China's demand for nickel, cobalt, and lithium would also increase by more than four times from the current level, as shown in Figure 6. While the demand has been increasing, the domestic supply of these minerals has not improved significantly and has even decreased.

This paper considers only the clean energy products that would be used for the Chinese domestic market. However, if we include clean energy products that are made in China but exported to overseas markets, the mineral demand could be much greater. Given its high dependence on overseas mineral sources, as aforementioned, any risk or interruption in supply will negatively impact China's progress in the energy transition and its influence on the global market for clean energy products.

3. Great Game Changes in the GCC

3.1 New Mining Strategy and Market Reforms

With the development of the mining industry, economic diversification has gained new momentum, as GCC states have increased their efforts in reforming domestic policy and regulation frameworks and directing new investment into this sector.

In Saudi Arabia, the mining sector is prioritized as the third most important industry after energy and petrochemicals (NIDLP 2021). The Kingdom has increased the 2024 estimates for its untapped mineral resources, including phosphate, gold, and rare earths, to $2.5 trillion, from a 2016 forecast of $1.3 trillion. Investments in the exploration and processing of mineral resources must be increased to ensure the domestic needs of the nation for energy transition and industrial diversification.

Saudi Arabia has undertaken numerous structural reforms in the mining sector. For example, it updated and approved a new Mining Investment Law in 2020 to encourage foreign investment and international collaboration. Moreover, to reduce the risk of investment in green field projects and junior miners, Saudi Arabia launched a $182 million mineral exploration incentive program in 2024. The financial incentive package can provide co-funding of up to 75% capital expenditure (CAPEX) through the Saudi Industrial Development Fund, exempt miners from royalty fees for the first five years of a license and offer royalty fee discounts of up to 30% for each stage of local downstream processing (KAPSARC 2022).

The National Geological Database was developed as a central repository of the Kingdom's geological, geochemical, geophysical, topographic, and geographic information. Additionally, the new geological survey program was rolled out in 2020 and has a budget of over $530 million.

All of these efforts have effectively incentivized mining activities in Saudi Arabia. Notably, the number of building material quarry licenses rose from 158 in 2021 to 538 in 2023, and exploration licenses increased from 58 to 258 during the same period (Arab News 2024).

In Oman, mining has been highlighted as one of the five priority industry sectors under Vision 2040. The output of mining production is set to increase from 26 million tons in 2018 to 147 million tons in 2023 (Invest Oman 2023). Estimates show that the mining sector may contribute $779 million to the GDP by 2030 (S&P Global 2020).

Like Saudi Arabia, Oman has also updated its policy and regulation frameworks to drive new economic growth from the mining sector. For example, it adopted a new mineral wealth law in 2019. This law strengthened the responsibility of the Public Authority for Mining and established specific regulations for the process of contracting, bidding, awarding, and bid evaluation. In addition to streamlining investment procedures, the government has further opened up its market to 10% foreign investment without requirements on minimum capital or local partners. Moreover, royalty payments have become more flexible. Although royalty was previously set at 10%, it dropped to a minimum of 5%, depending on market conditions.

To support and leverage private investment in the mining sector, Oman established Minerals Development Oman (MDO), a partnership among the State General Reserve Fund (50%), Oman Investment Fund (25%), and Oman National Investments Development Company (25%). As of 2019, MDO had invested in six major projects, including joint ventures with Mawarid Mining and a state-owned Oman Mining Company (Oxford Business Group 2020).

Oman began to create a national geological database in 2023. The Ministry of Energy and Minerals signed a MOU with the German University of Technology in Oman to develop the country's geological database. This collaboration also includes conducting geological surveys and training programs to develop competencies in Oman's minerals and metals sector.

In the UAE, the development of the mining sector is playing an increasingly important role in securing the long-term economic growth of the country, which aims to increase the contribution of this sector to nonoil GDP to 5% by 2030. In its first mineral wealth strategy launched in 2023, the UAE included detailed targets, such as increasing the number of companies in mining and manufacturing industries, increasing the sector's added value, increasing relevant exports, substituting mining extraction industry imports valued at $558 million with local products, and declaring six geological reserves (Arabian Business 2023).

The UAE does not have a unified law regulating mining activities. Article 23 of the UAE Federal Constitution granted each Emirate ownership of, as well as the ability to manage and mine, its mineral resources. Related articles that are covered by the Federal Environment Law, Federal Cabinet Resolution, and Federal Ministerial Resolution provide guidelines on issues such as the environment, health, and safety concerning mining and quarrying activities.

However, the wide-ranging reform of its legal system in 2021 has affected more than 40 laws, bringing new developmental aspirations to the UAE. In particular, with the new Commercial Companies Law taking effect in 2022, foreign investors and entrepreneurs are allowed to have up to 100% ownership in almost all sectors, except activities deemed to be strategic (UNCTAD 2022). This represents a positive step forward for the growth of the mining sector.

The UAE government has also created initiatives to support the development of the mining sector. For example, the country completed the second phase of geological and mineral surveys between 2006 and 2012. The outcomes and outputs from these surveys have become essential for establishing an integrated mineral resource database.

Compared with these three large players, the other GCC states have had relatively slow progress in terms of policy and project development. Qatar enacted a new foreign investment law in 2019 to ease restrictions on foreign investment in most sectors. The Natural Resource Law has established a licensing system that governs all upstream activities, including natural gas, petroleum, and mineral resources. Neither Bahrain nor Kuwait has created legislation of policy incentives to encourage mining investment. In Kuwait, mining activities are regulated through laws established for business, such as the Commercial Companies Law in Bahrain and the Environment Law.

Overall, the GCC governments have recognized the importance of the mining sector for their economic diversification plans. These countries have increasingly made efforts to develop transparent and investor-focused legislation and regulatory frameworks. Moreover, initiatives to accelerate development across the mining value chain have been announced, and the development of a national geological database has been prioritized in national strategic initiatives. Further opening to foreign investors has increased market attractiveness in the GCC countries. However, the rise of mining activities could add pressure to transportation infrastructure and impact the local environment and social sustainability. These issues still need to be prioritized in plans and regulatory frameworks.

3.2 A Regional Approach to Integrated Value Chains

Over the last 40 years, the GCC countries have been developing cooperative frameworks to enhance security and economic cooperation. While the GCC has not developed institutional structures to unify foreign policy, coordinate customs and monetary regulations, or establish a common market, it has remained the most advanced model of economic and political regional integration in the Arab world (Al-Saidi 2021).

Given its unique geological position for international trade and logistics, low-cost advantage for manufacturing, and ambitious plans for a clean energy transition, the GCC has envisioned becoming a mining, processing, and manufacturing hub for low-carbon technologies.

This presents an opportunity for the GCC member states to align their resources, plans, and policies and thus embrace the future of integrated mining value chains.

With a recent development under the GCC framework, a mineral resources committee was established to enhance cooperation and streamline operations among the GCC countries within the mineral resources sector. This committee has begun to play a role in coordinating mining strategies and sharing best practices among member states. Additionally, the committee has explored the creation of a regional map highlighting the potential for mineral investment (OneArabia 2024).

In parallel with the GCC framework, a superregion partnership encompassing Africa, Western Asia, and Central Asia has been undergoing development since 2022, when Saudi Arabia started to organize and promote the Future Minerals Forum (FMF) in Riyadh. Several initiatives for the superregion partnership have been identified and discussed in the annual gathering of FMF and include the following: developing regional strategies for critical minerals to meet their rising demand for manufacturing low-carbon technologies; developing a regional sustainability framework to better deploy ESG standards; developing regional centers of excellence for knowledge sharing, data transparency, and technology transfer; and establishing regional integrated value chains for green metals that could build upon local mining and processing advantages.

In addition to a coordinated framework for superregion partnerships, growing investment and project cooperation between the GCC states and Africa-Asia countries have been identified.

In 2024, Saudi Arabia signed MOUs with Egypt, Russia, Morocco, and the Democratic Republic of Congo (DRC) to explore and process mineral resources in the Asia-Africa superregion. The Kingdom also reached an agreement with Japan for investment in Africa and other resource-rich areas with a focus on securing nickel, lithium, and other minerals for the production of EV batteries. Moreover, the Saudi Public Investment Fund (PIF) has been looking to invest in Pakistan's Reko Diq gold and copper mine through a 25% equity stake.

The UAE has been a major investor on the African continent for many years, with a focus on infrastructure and logistics. However, in recent years, the country has quickly shifted to focusing on mining investments. In December 2023, Zambia's government announced that Abu Dhabi-based International Resources Holding (IRH) had bought a 51% stake in Mopani Copper Mines for $1.1 billion. Shortly afterward, the IRH announced its interest in the Lubambe Mine and other mining projects in Zambia. It also signed a $1.9 billion mining partnership in the DRC.

All of these moves have reflected a common roadmap for the region, which aims to increase its advantage in the clean energy transition by facilitating investment in resource-rich countries and establishing a regional hub for mineral supply chains.

3.3 Rising Influence in the Global Market

Given its success in influencing the global oil and gas market, the GCC has the desire and potential to play a vital role in the global mineral market. Thus, countries such as Saudi Arabia, the UAE, and Oman have begun to actively engage with international investors and mining majors.

The first interest of the GCC countries involves seeking the international funding, technologies, and experiences that are most needed at the early stage of mining development. With capacity established at home from upstream exploration and extraction to downstream product manufacturing, GCC countries can expand in the global market.

In Saudi Arabia, collaboration with international players has focused on achieving breakthroughs in geological surveys, exploration, and processing capacity. In the joint venture setup between the Saudi state-owned miner Ma'aden and the U.S.-based exploration group Ivanhoe Electric, gaining access to Ivanhoe Electric's breakthrough Typhoon™ geophysical survey technology was key for Ma'aden (Maaden 2023). This technology can detect metallic minerals buried below 1,500 m, which can accelerate exploration activities in Saudi Arabia, where bedrock is buried beneath 1,000 m of sand and gravel soil. Furthermore, the MOU that Saudi Arabia signed with the Chinese Jiangxi Copper Company aims to strengthen the Kingdom's ability to evaluate and explore investment opportunities across the whole copper value chain (SPA 2024).

In Oman, international collaboration is expected to strengthen its capacity in the copper value chain. As part of a joint venture with an Australia-based mining firm, Alara Resources, the construction of a copper concentration processing project in North Al Sharqiyah Governorate began in 2023 (Zawya 2023b). With a designed capacity of 1 million tons per annum, this project is expected to be a game changer in the new era of copper mines in Oman. Additionally, the Ministry of Energy and Minerals announced that it had signed its first mining agreement with UK-based Knights Bay to extract nickel and its derivatives.

In the UAE, the overall strategy consists of retaining its advantage in metal product manufacturing. For example, in 2023, Dubai Holding, the investment arm of the Dubai Government in the commodities, mining, power, energy, and industrial sectors, signed a MOU with Thailand-based Oriental Copper Company to manufacture high-quality copper products in the UAE (Zawya 2023a). In 2021, the UAE announced a deal between Khalif Industrial Zone Abu Dhabi and the Australian firm Lepidico to establish the first lithium production facility in the Middle East (Arabian Business 2021).

The second interest for the GCC countries involves acquiring the overseas mineral resources that are necessary for their energy economy transition. Diversifying the supply chain for critical minerals has been the strategy for major economies such as the U.S. and the EU, and the same logic applies to the GCC countries.

As a major leader in the GCC, Saudi Arabia has proactively extended its efforts to overseas mineral resources beyond the Africa-Asia superregion. For example, Saudi Arabia signed a partnership with the U.K. to secure mutual access to vital resources for economic and national security and reached an agreement with Australia to collaborate across the entire mineral supply chain from new exploration to downstream processing.

To support international asset acquisition activities, Saudi Arabia launched a mining fund, Manara Minerals, which is a joint venture with 51% owned by Ma'aden and 49% owned by the Public Investment Fund. This fund is prepared to deploy more than $15 billion of capital for investments over the coming years as suitable opportunities emerge in the international market (Arab News 2023a). Manara's first major foray abroad involved a deal with Brazil's biggest miner, Vale SA, for a 10% interest in mines from Canada to Indonesia that produce copper, nickel, and other industrial metals.

Similarly, the UAE is engaged in discussions with Australia to reach a trade deal with the potential to unlock billions of dollars of investment in Australia's critical minerals mining and processing sector. A trade agreement could offer priority under the foreign investment review board's rules and facilitate easier dispute resolution.

Additionally, the Gulf states have shown strong interest in establishing trading exchange platforms for mineral and metal commodities. For example, Saudi Arabia is exploring the potential launch of a new commodity trading platform for battery materials, including graphite and rare earths (Arab News 2023b). The UAE announced the launch of the Critical Minerals Trade Finance Fund and a new TradeFlow Metals digital platform under joint efforts with the Singapore-based fintech-powered fund management firm TradeFlow Capital Management (Open Mineral 2023). However, owing to the limited quantities for mineral trading in the region and the existence of the London Metal Exchange and Chicago Mercantile exchange for lithium and cobalt trading, many uncertainties regarding the future development of these plans remain.

Overall, the Gulf states have become active players in the global mineral market. Their efforts to reduce reliance on mineral imports, diversify supply chain options, and establish commodity trading platforms have set the stage for changes in the global investment landscape and trade flows.

4. Global Mineral Geopolitics and China's Strategies

4.1 Minerals in the Context of Geopolitical Risks

The production of minerals is heavily concentrated geographically both at the mining stage and at the processing stage. Large investments, environmental permits, and community consultations are needed to scale up production but can delay a supply response to price changes. Moreover, setting up processing capacity comes with challenges such as regulation restrictions, infrastructure investment, and access to minerals and technology. As a result, approximately 45% of global mineral production is dedicated to trade, and approximately half of the countries worldwide rely on three or fewer exporting countries for their imports of minerals (IMF 2023). These findings suggest that minerals and metals are vulnerable to supply disruptions.

On the supply side, resource nationalism has been growing, and numerous governments have increased state control over mineral resources to enhance the benefits of extracting and processing industries. The risk index of resource nationalism increased significantly in 34 countries, including most resource-rich countries in Africa, Latin America, and Asia (Verisk Maplecroft 2021). The policies that are being implemented include strengthening tax regimes, increasing royalty rates, renegotiating existing contracts, and restrictions on foreign investments and exports. Mineral producers are increasingly taking steps to build downstream sectors to maximize the benefits of their mineral resources. Countries endowed with critical mineral resources, such as the cobalt-rich DRC and nickel-rich Indonesia, as well as lithium triangles, including Chile, Argentina, and Bolivia, are now geopolitical hotspots. They find themselves at the forefront of a global contest for resource control and access, as these minerals are not evenly distributed globally.

An example of this is Indonesia, which is the world's largest producer of nickel, has the eighth-largest producer of copper, and has significant reserves of bauxite, cobalt, and tin. To promote domestic processing, this country has placed progressively stringent restrictions on the export of mineral ores, including a ban on all nickel ore exports that was announced in January 2020. To complement these defensive policies, Indonesia is also developing special economic zones and providing tax holidays for investors in onshore processing facilities to encourage the development of downstream industries such as battery manufacturing (Gupta 2023). This strategy has effectively led to significant investments in nickel mining and smelter operations in Indonesia. Unsurprisingly, the growth of nickel production from Indonesia has increased the level of supply concentration and subsequently shaped the global rivalry over nickel.

On the demand side, ensuring the supply security of minerals and building advantages in clean energy industries has become a prominent feature for major consumers. The diversification of supply chain options has been prioritized in their critical mineral strategies, along with measures to incentivize investment in local production, technology innovation, and material recycling. For example, the EU's Critical Raw Materials Act includes targets of 10% domestic mineral extraction and 40% local processing by 2030, while the U.S.'s Inflation Reduction Act provides tax credits for critical mineral production and mandates the domestic sourcing or friendshoring of

the critical minerals used in EV batteries as a condition for subsidies.

However, the differing prospects and strategies between major suppliers and major consumers have introduced a complex dynamic in international relations.

Given their importance in the mineral market, resource-rich countries have gained leverage to influence the global geopolitical landscape. They are tactically expanding their engagements to diminish their dependence on a singular global power. By diversifying their partnerships, resource-rich countries can secure advantageous terms for resource extraction, equitable pricing, technology transfer, investments in local infrastructure, and the expansion of the mining industry and downstream sectors (Abrar 2024). For example, African countries have successfully developed collaborations with major players, including China, the U.S., the EU, Australia, and Japan, on cobalt, lithium, nickel, rare earth, and other basic metals from extraction to refining and industrial manufacturing. This can facilitate increased regional cooperation and economic integration, while heightened competition among external powers for influence over strategic minerals could also introduce a layer of geopolitical complexity.

The desire to ensure access to vital mineral resources has motivated the formation of new alliances and partnerships among major consumers. For example, the Energy Resource Governance Initiative was developed by Australia, Botswana, Canada, Peru, and the U.S. to promote sound mining governance. The Minerals Security Partnership includes aligned interests from Australia, Canada, Estonia, Finland, France, Germany, India, Italy, Japan, Norway, Sweden, the Republic of Korea, the EU, the UK, and the U.S., with the aim of derisking the supply chain from geographic concentration and diversifying access to responsibly sourced critical minerals. Additionally, the G7 members are pursuing the idea of creating a buyer's club for critical minerals (IRENA 2023).

As geopolitical tensions increase, especially since the beginning of Russia's war in Ukraine and with the escalating economic rivalry between the U.S. and China, the world economy is at risk of a potential split into different blocs. The flows of trade, capital, technology, and workers are being increasingly restricted to safeguard national interests. In the scenario of the World Economy Outlook (IMF 2023), if there were no trade between two hypothetical blocs – China-Russia+ and U.S.-Europe+ – the minerals and metals market would become more volatile and uncertain. In the China-Russia+ bloc, the price of mined minerals, including cobalt, lithium, copper, and nickel, would increase substantially. At the same time, the U.S.-Europe+ bloc could experience similar increases in the prices of refined minerals. Moreover, commodity producers would have powerful incentives to switch allegiances given potentially significant differences in commodity prices among blocs. This would induce more supply shocks, volatility, and uncertainty in commodity markets, challenging fiscal, monetary, and financial stability (IMF 2023).

4.2 China's Strategies for Mineral Resources

The policy and regulation frameworks in many countries have begun to overcome the barriers to project permitting and construction, and global investment in the mineral supply has increased. However, the geographical concentration is set to remain high in most cases for mining and refining operations. Between now and 2030, approximately 70%–75% of projected supply growth for refined lithium, nickel, cobalt, and rare earth elements will come from the current top three producers. For battery-grade spherical and synthetic graphite, almost 95% of the growth comes from China (IEA 2024a). The gap between supply and demand varies across minerals, and the risks associated with mineral security also differ. However, if the anticipated supply from the largest global supplier and the projected demand from that country were both removed from the market, the available supply outside the largest producing country would fall significantly below the materials needed to achieve global energy transition in most cases in 2030 (IEA 2024a). This highlights the need for concerted efforts to expedite project development in diverse regions and the important role of major suppliers, including China, in balancing the global market for energy transition.

China is and will continue to be a key player in global critical mineral production, processing, and supply chains. Supportive policy frameworks, entrenched production networks, proximity to suppliers, and large pools of skilled labor have set fundamentals for the cost competitiveness of Chinese mineral industries, but open access and international trade integration are also essential for its

growth. Based on its participation in the global trade system, China has gradually developed its technologies and expertise in mining, processing, and refining. As the hub of global manufacturing, China has also benefited from the import of mineral resources and the export of downstream industrial products.

China began to formalize the institutional administration of mineral resources in 1982, which coincided with the establishment of the Ministry of Geology and Mineral Resources. A major milestone in this period was the release of China's first mineral resources law in 1986, which established an exploration and mining permits system and defined the major role of state-owned enterprises (SOEs) in mining activities. To enforce market reforms for better resource allocation, address environmental issues related to resource exploitation, and reduce the gap between supply and demand, China established a new Ministry of Land and Resources in 1998. During this period, a series of new policies and guidelines were formulated. For example, the Measures for the Implementation of Mineral Resources Planning were published in 2012 to enhance the coordination of resource exploration between national and local administrations. The Opinions on promoting comprehensive conservation and efficient utilization of mineral resources were published in 2016 to improve the mining recovery rate, the mineral processing recovery rate, and the comprehensive utilization rate through technological innovation and the continued assessment of key indicators.

In 2018, the governing body for mineral resources was reformed as the Ministry of Natural Resources. With specific functions pulled from the Ministry of Land and Resources, the National Development and Reform Commission, the Ministry of Housing and Urban-Rural Development, the Ministry of Water Conservancy, the Ministry of Forest, the Ministry of Agriculture, the State Oceanic Administration, and the National Administration of Surveying, Mapping, and Geoinformation, this new ministry had, for the first time, the most consolidated power for every type of natural resource. Thus, China entered a new stage of development in terms of mineral resource management. This country has continued reforming its mining rights transfer system, significantly decentralized mining rights approval authority, and established a national royalty system for mineral resources.

Over the years, China has used the five-year plan system to guide national economic and social development. Increasing exploration efforts, achieving breakthroughs in geological prospecting, and establishing a strategic mineral resource reserve system have been priorities of the national plan. Depending on the major concerns and pressing issues, the strategic direction and policy priorities may be adjusted in each five-year-plan period.

One such case could be the development strategy for the rare earths industry. China began to dominate the supply of rare earth concentrates and separations in the early 1990s, when its total production of upstream and midstream products accounted for more than half of global rare earth production. To address illegal mining and smuggling issues and concerns about overexploitation and environmental pollution, China released its first development plan for the rare earth industry (2009-2015). Under this plan, environmental obligations for mining and refining activities were specified, and mining operations were consolidated to a handful of SOEs. These changes were accompanied by a shift in policy priorities to use domestic rare earth resources to foster more value-added downstream manufacturing more sustainably (Kalantzakos 2018). Increasingly strict rare earth policies have reflected the desire of China to seek a balance between economic growth and sustainable development (Shen, Moomy, and Eggert 2020). Moreover, the change in strategic priorities from "dominating" to "securing" rare earth supply chains is affirmed in China's current policies for the 14th five-year period (2021-2025).

Over the past decades, China's strategic focus on mineral resources has shifted toward more balanced development, expanding higher value-added downstream sectors while ensuring supply security and environmental protection. This approach differs greatly from the strategies that were used in the early stage and focused on boosting mine production and encouraging material exports.

In its first mineral strategy, which is known as the National Plan for Mineral Resources (2008-2015), the Chinese government focused on increasing domestic reserves and outputs of coal, oil, natural gas, and coalbed methane. The major tasks related to important minerals involved increasing the levels of domestic supply in total demand, such as 50% for iron, 30% for copper, 65% for bauxite, 25% for potassium salt, and 55% for lead and zinc. The application of new theories, new technologies, and new methods of mineral resource exploration

were encouraged to achieve breakthroughs in mineral prospecting. Moreover, geological environment protection and land reclamation were highlighted, with recovery and treatment targets set for new mines and historical mines by 2015 and 2020. The strategy mentioned international cooperation but focused mainly on increasing foreign investment utilization and introducing advanced foreign mining technology and management experience.

With its second mineral strategy, the National Plan for Mineral Resources (2016-2020), which addressed potential shortages and supply chain risks due to fast-growing domestic demand and intensified global competition, China increased its state control over critical minerals. For the first time, the Chinese government released a catalog of 24 strategic minerals (Annex 3), which were selected for their perceived importance to China's economy, defense, and the advancement of its high-tech industries. The minerals that are essential for major green technologies, such as lithium, copper, nickel, cobalt, graphite, zinc, chromium, and rare earths, are all included in the list (NDRC 2016). This plan involves China's robust industry policy with even stronger commitments to promoting the development of strategic and emerging industries, with overarching objectives for the exploration, development, and downstream application of mineral resources for the period of 2016-2020 and longer-term goals up to 2025.

The domestic supply is fundamental to China's mineral security. Thus, this country has implemented a plan that aims to increase the reserves and outputs of strategic minerals through enhanced financial support for geological prospecting and prioritized exploration activities in 297 key mining areas. Preferential policies are provided to projects with the potential to improve the efficient use and preservation of minerals, upgrade industrial structures, advance technology innovation, and promote green transition. Further efforts will be dedicated to building a risk warning and reporting system and stimulating the mining rights trading market.

International cooperation is also an integral element of China's mineral security strategy. Certainly, the government expects to retain the participation of foreign capital and expertise in domestic mineral resource exploration. However, its move toward protecting and optimizing domestic critical minerals has limited foreign participation in some strategically sensitive sectors. For example, as stipulated in the latest negative list for foreign investment, which was released in 2021, foreign entities are prohibited from investment in exploration, mining, and beneficiation of rare earth, radioactive minerals, and tungsten. In contrast, engaging in overseas resource exploration and market participation has played a more important role in China's mineral strategy. The country wants to build a joint investment model under the Belt and Road Initiative that promotes full supply chain cooperation from exploration to extraction, refining, processing, and manufacturing. Such collaboration targets not only mining activities but also essential infrastructures, including electricity, waterways, and ports. Additionally, China aims to build international forums, promote policy dialog, and strengthen technological cooperation in the field of geosciences.

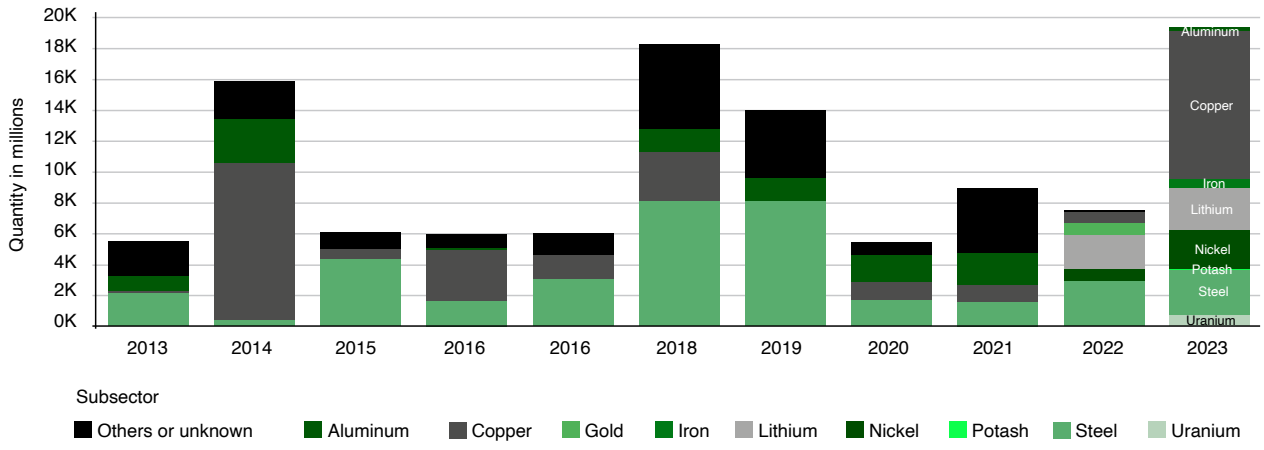
Given the complexity of geopolitical rivals and rising concerns of developed economies regarding China's influence on critical minerals, it has become more difficult for Chinese companies to invest and become involved in mining activities in developed markets. Three Chinese companies, Sinomine (Hong Kong) Rare Metals Resources Co., Ltd., Chengze Lithium International, Ltd., and Zangge Mining Investment (Chengdu) Co., Ltd., were ordered to sell their holdings in three Canadian mining companies in November 2022, after the Canadian government tightened rules on foreign investment in the critical mineral sector (The Guardian 2022). Five international companies linked to China, including the Yuxiao Fund, were ordered to offload shares in Australian rare earth mines in June 2024, as per the advice from the Foreign Investment Review Board of Australia (Australian Broadcasting Corporation 2024). Beginning in January 2024, the "foreign entity of concern" blocks eligibility for any company to obtain access to U.S. IRA subsidies and tax breaks for the production or processing of critical minerals and the production of critical mineral-related components for EVs if the company has more than a cumulative 25% of shares or voting rights or board seats held by Chinese, North Korean, Russian or Iranian investors (Financial Review 2023). With the implementation of this guidance, Chinese investment flow to the U.S. and its foreign trade agreement partners or critical minerals agreement partners would be deeply impacted.

Thus, more Chinese firms are looking for opportunities in emerging markets for critical mineral development. In 2023, Chinese overseas investments in mining and metals under the Belt and Road Initiative (BRI) framework reached $19.4 billion, the highest level in a decade, with a remarkable 160% increase from 2022 (Nedopil 2024).

Engagement has been strong in African countries, Bolivia and Chile in Latin America, and Indonesia. Chinese battery players such as CATL, Sunwoda Electronic, and EVE Energy have formed JVs with nickel miners and refinery businesses in Indonesia (S&P Global 2023). In Argentina, Ganfeng Lithium has invested in five lithium projects in the provinces of Salta and Jujuy (Ganfeng 2023), whereas Zijin Mining is developing the Tres Quebradas lithium project (Zijin Mining 2022). In Africa, Chinese companies have been more actively investing in the mining sector. Some $7.8 billion of Chinese investment went to projects, including copper mine projects in Botswana; cobalt and lithium mines in Namibia, Zambia and Zimbabwe; and copper and cobalt projects in the DRC (Reuters 2024). However, while Chinese investments in Africa are significant, Chinese mining companies represent only 8% of Africa's total output in the sector (Egyin 2024).

This investment has become more visible in the vertical integration of Chinese carmakers or battery-makers into the upstream mining sector in recent years. Acquiring minority interests in mining assets or forming mining and refinery joint ventures can ensure direct access to raw materials and secure upstream supplies for the production of batteries and EVs. This strategy shows value in improving cost management and margin protection, especially when the critical mineral market experiences a tight supply accompanied by strong price volatility.

Figure 7. Chinese BRI engagement in metals and mining 2013-2023 H1.



Source: Nedopil (2024).

5. Prospects of a GCC–China Collaboration

China's advantages in new energy product manufacturing and mineral supply chains are exposed to the risks associated with increasing geopolitical tensions and rising trade barriers in the U.S. and EU markets. Thus, China needs to adapt to changes in the global environment for trade and investment, being more diversified in its overseas investment and sufficiently integrated with local demand and local production capacity. Moreover, to achieve a robust and extensive economic transition, the GCC countries need to increase their efforts to develop investor-focused legislation and regulatory frameworks. This may include ensuring fiscal sustainability for public spending, strengthening the role of private sector competition, developing backward and forward linkages across sectors, and implementing labor market reforms. Additionally, these countries need to build regional and global influence for export diversification on the basis of domestic industrial infrastructures.

In the future, both China and the GCC states can benefit from jointly advancing theoretical and technological innovation in mineral resource exploration, assessing the criticality of mineral resources given market dynamics and technology changes, and promoting material recycling and substitution. More strategically, China and the GCC can enhance their collaboration on superregional partnership initiatives, coordinating financial and technical resources and stimulating supportive trade and investment regimes for mineral exploration, extraction, processing, and downstream production. The potential that has been unlocked in the African, Western Asian, and Central Asian regions could be critical for both China and the GCC countries to realize their ambitions toward economic transition, national security, and climate actions.

5.1 Enhancing Regional Cooperation Platforms

The BRI framework has been the major venue for GCC-China collaboration. All six member states of the GCC have endorsed the agreements for BRI cooperation in industrial capacity and infrastructures. The China-GCC Summit held in Riyadh in December 2022 was the first summit between China and the GCC as a bloc. Both

sides adopted a five-year joint action plan to develop partnerships in 15 key areas, from comprehensive political and security dialogs to deeper economic partnerships. Additionally, the China–Arab States Cooperation Forum has played an increasingly important role in GCC-China collaboration. During the China-Arab forum in May 2024, the adoption of the Beijing Declaration and the Action Implementation Plan for 2024-2026 marked important steps toward promoting China-Arab community development and bilateral cooperation on counterterrorism, human rights, climate change, artificial intelligence, and new technology development.

These initiatives have laid an important foundation for cooperation in the development of mineral resources. On the basis of the superregional partnership proposed by Saudi Arabia in the Future Minerals Forum in 2022, China and the GCC states can focus their collaboration on coordinating financial and technical resources and stimulating supportive trade and investment regimes for mineral exploration, extraction, processing, and downstream production in the African, Western Asian, and Central Asian regions. A regional cooperation framework can facilitate data sharing, as well as policy dialog and cooperation. Such an initiative could include actions for (i) collecting and sharing data on critical mineral production and markets; (ii) providing a better understanding of supply and demand dynamics and explore opportunities along the supply chain; (iii) facilitating the mapping of key critical mineral and downstream producers and customers; (iv) promoting knowledge transfer and capacity building; and (v) influencing and establishing global regulatory standards and supporting the deployment of best practices in safety, stakeholder engagement, and environmental management.

5.2 Promoting Technology Development and Knowledge Sharing

After decades of development in mineral exploration, discovering mineral deposits in surface or near-surface regions of the crust has become more difficult. Going deeper from known deposits or shifting toward undercover has become a new direction in mineral resource exploration. However, the continued research and development of deep exploration theories and new technologies are needed to accomplish this task. At the same time, the average number of ore grades in mines has been decreasing, which drives the development of new technologies for processing.

Through a joint research program focusing on the abovementioned areas, China and the GCC states can both benefit from a better understanding of the formation, distribution, and evolution of mineral deposits. For example, the development of exploration geochemical methods could improve the analysis of element concentrations and states at the microscale, even at the nanometer or molecular scale. The use of new technologies such as big data and artificial intelligence could lead to a new round of scientific and technological revolution in mineral resource science. Moreover, the advancement of theoretical and technological innovation in mineral resource exploration can inform decision-makers with the latest assessment of the criticality of mineral resources.

Strengthening knowledge exchanges between China and the GCC states could also improve intermediate processing and manufacturing capabilities, promote material recycling and substitutions, and advance technology development related to the processing of low-grade ores, residual mineral deposits, byproduct elements, and tailings.

5.3 Integrating Mineral Supply Chains

Chinese companies have grown beyond their traditional role as suppliers of renewable energy components to become investors and project developers in the GCC region. The GCC-China collaboration along the supply chains for clean energy product manufacturing has been particularly visible in recent years.

In Saudi Arabia, the Public Investment Fund (PIF) has announced a series of joint venture agreements with Chinese companies to build local manufacturing and assembling capacity to meet the clean energy market needs in Saudi Arabia and the MENA region. This includes an agreement with Envision Energy to manufacture wind turbines and components, an agreement with Jino

Solar to localize the production of photovoltaic cells and modules, an agreement with TCL Zhonghuan Renewable Energy to localize the production of ingots and wafers for solar power, and an agreement with Longi to manufacture solar PV products and provide related services (PIF 2024; MEED 2023). The first Saudi automotive brand to produce EVs (Ceer), a joint venture between PIF and the Chinese Hon Hai Precision Industry Company, already started constructing its manufacturing complex in King Abdullah Economic City.

In the UAE, the Chinese solar panel maker Trina Solar announced plans to set up production facilities in the Khalifa Economic Zones for up to 50,000 tons of high-purity silicon, 30 GW of silicon wafers, and 5 GW of photovoltaic modules per year across the solar industry chain. In Oman, Chinese Hanan Drinda New Energy Technology announced its investment intention agreement with the Omani Investment Authority to establish a large-scale solar cell manufacturing base with the aim of producing 10 GW of high-efficiency TOPC on solar cells annually.

The development of downstream product manufacturing, such as copper mining, iron refining, and steel plate manufacturing, has encouraged the investment of Chinese companies in the upstream and midstream sections. However, much can still be done to build technological and cost competitiveness for locally-made clean energy products in the GCC region.

Continued improvements in policies and regulations to encourage business investment, increase labor productivity, and catalyze the establishment of local suppliers continue to be important for the GCC states so that they can strengthen their mineral supply chains. Increasing collaboration with the GCC institutes on the technology front, integrating an overseas expansion strategy with a local setup of industrial clusters in the GCC region, and prioritizing investment in strategic sections along the mineral supply chains are crucial for Chinese companies to continue to play an active role in the global clean energy market. This is especially relevant given the constraints of increasing trade barriers and the ever-changing international environment.

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Annex

Annex 1. China's nonfuel mineral reserves.

	Minerals	Unit	China's reserves	Global reserves	China's share in global reserves (%)
1	Antimony	Million tons	0.64	2	32.00%
2	Bauxite	Million tons	711	30,000	2.37%
3	Chromite	Million tons	3.09	560	0.55%
4	Cobalt	Million tons	0.14	11	1.27%
5	Copper	Million tons	41	1,000	4.10%
6	Gold	Thousand tons	2.964	59	5.02%
7	Iron ore	Billion tons	16.12	190	8.48%
8	Lead	Million tons	20.41	95	21.48%
9	Lithium	Million tons	4.05	28	14.46%
10	Manganese ore	Million tons	281.69	1,900	14.83%
11	Molybdenum	Million tons	5.85	15	39.00%
12	Nickel	Million tons	4.22	130	3.25%
13	Platinum	Tons	87.69	71,000	0.12%
14	Rare earths	Million tons	44	110	40.00%
15	Silver	Thousand tons	71.783	610	11.77%
16	Strontium	Million tons	24.64	NA	NA
17	Tin	Thousand tons	1,130	4,300	26.28%
18	Titanium	Million tons	223.83	750	29.84%
19	Tungsten	Million tons	2.95	4.4	67.05%
20	Vanadium	Million tons	7.87	19	41.42%
21	Zinc	Million tons	44.23	220	20.10%

Sources: China Ministry of Natural Resources (2023); USGS (2024).

Annex 2. Mineral intensity used for mineral demand assessment (units: kg/MW for wind and solar, g/vehicle for EV).

	Wind	Solar	EV
Ag		133	23
Al	700	10953	136,900
Au			0.32
Cd		6	0.00
Ce			0.15
Co			11,234
Cr			9,910
Cu	4850	4178	110,196
Dy	10		161
Er			0.18
Eu			0.23
Fe	142385		828,731
Ga		0.1	1
Gd			0.17
Ge			0.09
In		5	0.28
La			7
Li			7,234
Mg		54	200
Mn			19,577
MO			1,835
Nb			426
Nd	122		552
Ni	111	1.1	42,184
Pb			2,156

(*Continued*)

Annex 2. Continued.

	Wind	Solar	EV
Pd			0.12
Pr			77
Se		1	0
Si		6327	0
Sm			3
Ta			8
Tb	3.3		26
Te		5	34
V			790
Y			0.41
Yb			0.16
Zn			100

Sources: Valero et al. (2018); Liang et al. (2022).

Annex 3. Minerals demand for new installations of renewables in Saudi Arabia and China from 2024-2030 (EVs included for China: unit: tons).

	Saudi Arabia – solar PV	Saudi Arabia – wind turbines	China – solar PV	China – wind turbines	China – EVs
Cu	361,397	167,810	8,142,922	2,449,250	10,138,032
Fe	0	4,926,521	0	71,904,425	76,243,252
Al	947,435	24,220	21,347,397	353,500	12,594,800
Ni	95	3,841	2,144	56,055	3,880,928
Nd	0	4,221	0	61,610	50,784
Dy	0	336	0	4,899	14,812
Tb	0	114	0	1,667	2,392
Ag	11,505	0	259,217	0	2,116
Cd	528	0	11,889	0	0
Ga	9	0	195	0	92
In	389	0	8,771	0	26
Mg	4,628	0	104,272	0	18,400
Se	43	0	975	0	0
Si	547,286	0	12,331,323	0	0
Te	407	0	9,160	0	3,128
Li			0	0	665,528
Co			0	0	1,033,528

Source: Authors' calculations.

Annex 4. China's national categorization of critical minerals.

14 metallic minerals		4 nonmetallic minerals	
Aluminum	Lithium	Fluorite	Phosphorous
Antimony	Molybdenum	Graphite	Potassium
Cobalt	Nickel	**6 energy resources**	
Copper	Rare earths	Coal	Petroleum
Chromium	Tungsten	Coalbed methane	Shale gas
Gold	Tin	Natural gas	Uranium
Iron	Zirconium		

Source: NDRC (2016).

Notes

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About the Project

China's evolving Belt and Road Initiative (BRI) was first conceived by President Xi Jinping in 2013 and officially launched in March 2015 by the Chinese government under the title Vision and Actions on Jointly Building the Silk Road Economic Belt and 21st-Century Maritime Silk Road. The initiative has become a focal point in the analysis of the impact of Chinese policies on the international community, particularly in the countries of the GCC.

The project seeks to answer the following key questions:

- What are the economic and geopolitical impacts of China's investment in clean energy supply chains in the GCC region?
- How would the development of critical minerals and metals in the GCC region help improve global supply security for energy transition and support regional economic diversification goals?

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