

Discussion Paper

Opportunities From Saudi Mineral Resources – A Domestic Supply Perspective

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About KAPSARC

KAPSARC is an advisory think tank within global energy economics and sustainability providing advisory services to entities and authorities in the Saudi energy sector to advance Saudi Arabia's energy sector and inform global policies through evidence-based advice and applied research.

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Abstract

Saudi Arabia's mineral sector, long recognized as the third pillar of its economy alongside oil and petrochemicals, is becoming increasingly vital due to the global demand for minerals essential for the clean energy transition. Understanding the domestic and international implications of growing demand for these resources is crucial as the Kingdom seeks to secure developmental and competitive advantages through its mineral wealth. Saudi Arabia's accelerated exploration programs, supported by extensive geological surveys covering 600,000 km² of the Arabian Shield, aim to unlock commercially viable deposits and attract significant foreign direct investment.

This paper uses the Payne Institute for Public Policy's Mineral Systems Model to analyze the opportunities and challenges for Saudi Arabia's mineral resources development and utilization plans. Improving raw material availability could strengthen the Kingdom's ambitions to develop further copper, aluminum, and zinc value chains to help address its industrial needs and localization goals. The Kingdom's investment-constrained mining and processing capacities must be expanded through increased funding to target higher market shares globally.

Moreover, based on the model results, employment directly associated with mineral extraction in Saudi Arabia is expected to create between 37,000 and 59,000 additional jobs. Saudi Arabia's positioning as a reliable mineral resource partner and its efforts to foster globally diversified value and supply chains will contribute significantly to a resilient, inclusive energy transition, supporting its economic objectives and a sustainable global future.

Highlights

- Saudi Arabia seeks to exploit the opportunities generated by the mining sector to help diversify its economy. The Kingdom's vast and underexplored mineral resources worth approximately \$2.5 trillion could help it transition from a net importer of metals to a significant exporter of value-added products, aligning with its Vision 2030 economic diversification goals.
- The Kingdom's extensive geological exploration initiatives, such as mapping 600,000 km² of the Arabian Shield, aim to unlock the potential of at least 15 commercially viable minerals – including gold, silver, lead, copper, and zinc – and attract international investors.
- Minerals such as aluminum, copper, and zinc are critical for the clean energy transition. As part of its localization program, Saudi Arabia aims to strengthen its value chains and reduce import dependency by establishing midstream facilities, including smelters and refineries.
- Employment opportunities in the mining sector are expected to grow significantly, with projections indicating an additional 37,000 to 59,000 jobs, along with broader economic benefits through downstream industrial development.

Keywords: Mining, Minerals, Critical Minerals, Mining Strategy, Mining Policy, Industrial Strategy, Saudi Arabian Mining, Middle East.

I. Introduction

The Saudi mining and minerals industry, along with oil and petrochemicals, has long been considered the third pillar of the Kingdom's economy. It has been a developmental focus of Saudi policymakers since the 1980s (MIM 2024a). In 2019, the mining and minerals sector contributed approximately US\$17 billion to the Kingdom's Gross Domestic Product (GDP), with plans to increase it to \$75 billion by 2035 (MIM 2022a; Invest Saudi 2024). While the economic contribution of the mining sector remains modest compared to the much more established and highly successful hydrocarbons sector, there are ample opportunities for future growth, especially given the rising global demand for critical minerals.

Over the past few decades, the Kingdom has implemented a policy-led framework, including periodic updates to mining regulations, to promote greater private sector engagement (Majumder 2024; Arab News 2024). Saudi Arabia has also increased exploration spending to better understand its relatively under-explored mineral resources and has sought to develop local downstream industries to capitalize on increased raw material availability (El Yaakoubi 2024; MIM 2022a). These initiatives, combined with the global restructuring of mineral supply chains, position Saudi Arabia to attract significant foreign direct investment (FDI) and foster mineral-based domestic industries (Economist 2024; Hassan 2023; Alqarout 2023).

Saudi Arabia's established reputation as a reliable energy exporter, coupled with its position as the largest economy

in the Middle East, grants it access to major global markets. The Kingdom's stable governance, efficient banking systems, and consistent trade policies create a favorable environment for investors. With critical minerals gaining strategic importance globally, Saudi Arabia has emerged as a key contender, leveraging its mineral wealth and industrial strategy to address domestic economic goals while contributing to global supply chains (IMF 2023; Australian Trade and Investment Commission 2023). As the Kingdom seeks to align its mineral wealth with energy transition goals, it is crucial to evaluate how this demand can drive industrialization and economic diversification. This paper addresses this gap by analyzing the Kingdom's mineral strategy, focusing on critical minerals, such as copper, aluminum, and zinc, and their role in supporting both domestic and global energy transition efforts.

1.1. Aligning Mining Policy, Industrial Strategy, and Infrastructural Investments

While existing literature extensively examines Saudi Arabia's economic diversification, the mining sector has received comparatively limited attention. Few studies explore the sector's potential for economic growth or its role in developing local industrial capacity, highlighting a critical research gap that this paper aims to address.

The development and growth of Saudi Arabia's mining sector, aligned with Vision 2030's strategic objectives and the advancement of energy transition technologies, represents a significant area of underexplored research.¹ The mining sector is crucial for advancing the Kingdom's economic diversification efforts and aligning them with its industrial strategy. Ahmed (1999) identified that the prevalence of an established oil sector posed challenges for exploring and exploiting remote mineral deposits. Al Rawashdeh and Campbell (2022) explored the Kingdom's mineral policy within the ambit of the Gulf Cooperation Council (GCC) countries, highlighting the challenges of mineral investments and the need to have supporting mining policies that enable the development of the Kingdom's mineral resources. They pointed out the challenges associated with increasing exploration spending, illustrating the massive role that Ma'aden (Saudi Arabian Mining Company) plays as the largest mining company in the Kingdom, contrasting that with the exploration spending by other private sector entities.

Case studies of Saudi Arabia's phosphate and bauxite industries demonstrate the potential for developing mineral-based value chains (Aldagheiri 2011; 2017). For example, aluminum production and phosphate fertilizers, such as diammonium phosphate (DAP), have emerged as export-driven industries, contributing to the Kingdom's industrial capacity. However, these successes, led by the establishment of Ma'aden in 1997, underscore the long gestation periods required for mining projects, from resource discovery to full-scale industrial operations.

The Kingdom's mining sector benefits from clustering effects, where industries such as bauxite refineries utilize

byproducts like brine from desalination (Woertz 2014). Leveraging competitive advantages in low-cost domestic fuel and abundant mineral resources, Saudi Arabia can build export-focused industries targeting Asian markets for products such as fertilizers, aluminum, and urea (Hilpert and Mildner 2013). These initiatives align mineral policy with industrial strategy, fostering job creation and economic growth. Infrastructural investments support Saudi Arabia's mining sector, including rail links, industrial cities, and transport networks. The Kingdom enhances its competitiveness in global markets by developing industrial clusters near resource areas and export hubs. These developments enable efficient logistics, supporting downstream industries, and increase the sector's export potential (Islamic Development Bank 2009).

1.2. Employment Generation Opportunities from the Mineral Sector

A fundamental expectation from the economic diversification initiatives and the industrial strategy development was the increase in employment generation opportunities, given Saudi Arabia's population demographics and the need to provide gainful employment to a burgeoning, youthful, and educated population (Nataraj et al. 2021). While the Kingdom has invested in regulatory frameworks, infrastructure, and financial support to facilitate industrialization, aligning these efforts with workforce development remains critical. Building skills and capabilities within the labor force will enable Saudi citizens to fully benefit from the opportunities created by the growing mining sector.

The mining sector has been able to generate employment; however, as an extractive and capital-intensive industry, its employment generation is not as high or in demand as in other sectors of the economy, such as technology, tourism, healthcare, and others (Red Sea Development Company 2023). Mulligan (2023b) highlights that, despite the unavailability of granular Saudi labor force survey microdata, which complicates precise analysis, mining and quarrying (including mineral extraction but primarily focused on energy operations) accounted for only 1.4% of total employment across the Kingdom in 2023. This underscores the competitive labor market facing the mineral sector, raising challenges

for policymakers seeking to augment the sector's employment generation potential.

Hasanov et al. (2021) argue that while the capital-intensive nature of mining, which requires highly specialized labor skilled in high-end technologies, limits employment opportunities, the government's role in increasing demand for mineral products through import substitution and export-oriented industries would help improve employment generation through both mining and downstream manufacturing sectors. Mulligan (2023a) explores the employment potential of renewable energy value chains for solar photovoltaic and onshore wind turbine projects to highlight that domestic manufacturing industrial policies under local content development strategies must be framed in a way that enables higher value addition while providing meaningful employment opportunities. Such framing could allow the benefits of aligning mineral policy and industrial strategy to be reflected in increased employment generation.

The development of value chains, coupled with the upgradation of the national labor force's skills, will enable the Kingdom to better leverage the opportunities for employment generation, supporting the progress of the industrial strategy, economic diversification, and overcoming future challenges posed by automation (Mulligan 2023c; Yamada 2016; Al Naimi 2022).

1.3. Scope and Approach

Given the expectations from the mining sector and assuming prudent project execution, this paper assesses how the Kingdom's aspirations in minerals exploration and extraction align with the development of global mineral demand in light of the changes in the Kingdom's mining policies. By leveraging its mineral wealth, the Kingdom aims to position itself as a key resource partner in the global energy transition, mitigating supply uncertainties and price volatility in critical mineral value chains. Our paper aligns the timeline and market size projections with the Payne Institute for Public Policy's Mineral Systems Model (MSM) to assess the impact on local economic opportunity. The Payne model provides a framework for evaluating future mineral demand across all mineral and metal resources needed to meet energy demand. MSM's simplicity and transparency make it ideal for predicting mineral market growth under various energy transition scenarios.

Section 2 overviews the factors driving Saudi Arabia's mining policies and its push toward establishing mining-related economic value chains within the Kingdom. Section 3 outlines the methodology underpinning the MSM analysis and presents the key findings. Finally, the paper concludes with critical policy implications and recommendations for advancing the Kingdom's mining sector ambitions.

2. Saudi Mining Policy and Strategy

In developing its mining strategy, the Saudi mining industry has identified six key strengths that can provide a competitive edge: (1) vast under-explored territories that can attract international investors, (2) robust market demand for mining products both internationally and domestically, (3) globally aligned and investor-friendly mining regulations, (4) industry-leading tax benefits and incentives, (5) an extensive and advanced infrastructure network, and (6) a skilled and continuously expanding workforce. The kingdom's mining strategy is designed to address both supply and demand aspects.

2.1. Minerals Supply

Aiming to maximize the value of local resources, Saudi Arabia implemented comprehensive reforms in the mining sector to spur private sector investment and provide a transparent regulatory environment. The new Saudi mining investment law came into effect at the start of 2021, supported by a set of regulations designed to foster governance, accountability, and a fair licensing process for investors in the mining sector (Leon, Muller, and Purves 2021). The Ministry of Industry and Mineral Resources (MIM) oversees the mining sector reform and can delegate responsibilities to the Saudi Geological Survey (SGS) or other entities under its jurisdiction, such as the mining company Ma'aden (MIM 2022b).

MIM has launched the Regional Geological Survey Programme (RGP) to support data collection and improve the quality of geological knowledge. The SGS will survey and map around 600,000 km² of the mineral-rich Arabian Shield.² The Arabian Shield is a significant source of precious and base minerals. To date, occurrences of over 48 minerals have been identified in the Kingdom, with at least 15 deemed commercially viable minerals (Al Workman 2016).

Several contracts were signed with private companies to provide airborne geophysical surveys of the area. The goal is to create detailed digital geological maps that accurately reflect the types and locations of mineral resources and provide data that help infer their potential quantities. These maps will be a foundational resource for future mining investments and operations.

To fast-track supply-side development, Saudi Arabia has launched an accelerated exploration program to identify and evaluate prospective mineral deposits in the country. These endeavors are enriched through strategic partnerships, harnessing global expertise to expedite the mining and processing of critical minerals. Saudi Arabia remains receptive to forging collaborations across nations, the private sector, and academic institutions, fostering a knowledge-sharing and transfer culture.

2.2. Minerals Demand

The metals and minerals sector holds strategic significance for the Kingdom's sustained growth and forward-thinking development, driving growth

in other industries. Two main demand aspects drive the Saudi mining strategy. First, the demand for minerals across the value chain is increasing due to economic and industrial growth, with ambitious giga-projects further driving the demand. With its ambitious vision, Saudi Arabia is propelling multiple giga-scale projects requiring intensive mineral use. The country's strategic blueprint for mining is designed to ensure a resilient supply chain, catering to emergent demand-driven domestic and global applications. The best example is NEOM, envisioned as a beacon of the future: a smart city powered entirely by renewable energy and home to the world's first large-scale green hydrogen plant.

Furthermore, local content requirements mean the country must grow its mining sector to satisfy the increasing demand. The second major demand driver is EV batteries, which the Kingdom aims to manufacture locally as part of its industrial policy. The Kingdom's ambitious roadmap forecasts the annual manufacturing of 500,000 EVs by 2030 (CEER 2023).

2.3. Alignment with Industrial Strategy

Saudi Arabia has strongly encouraged its mining sector to meet the rising demand for battery minerals and renewable energy technologies, ensuring a smooth energy transition and fostering the development of a commercial market for critical minerals. This focus is central to its Vision 2030 strategy to diversify its economy beyond fossil fuels. The Kingdom views the mineral industry as a strategic pillar in its diversification efforts, and it estimates its mineral resources to be worth more than \$1.3 trillion³ (see Table 1). The Saudi government has expressed interest in attracting foreign and domestic investment into its mining sector to capitalize on this potential. This could include the exploration, production, and processing of minerals essential for various industrial applications, including those related to the clean energy transition. Appendix B provides details of the downstream mineral investment projects envisaged.

Table 1. Alphabetical listing of potential mineral resources in Saudi Arabia.

Mineral	10% confidence	50% confidence	90% confidence
Bauxite	\$14 billion	\$11 billion	\$9 billion
Copper	\$222 billion	\$23 billion	\$7 billion
Feldspar	\$18 billion	\$11 billion	\$3 billion
Gold	\$229 billion	\$101 billion	\$46 billion
Iron ore	\$70 billion	\$36 billion	\$18 billion
Limestone	Abundant		
Niobium	\$41 billion	\$38 billion	Currently being studied
Phosphate	\$321 billion	\$233 billion	\$102 billion
Silica	Abundant		
Silver	\$37 billion	\$6 billion	Currently being studied
Uranium	\$70 billion	\$22 billion	Currently being studied
Zinc	\$138 billion	\$39 billion	\$3 billion

Note: The percentages in the table indicate the Saudi Geological Survey's confidence level in the proven reserve size for each mineral. For example, the Saudi Geological Survey is 90% confident that Saudi Arabia has phosphate reserves worth at least \$102 billion (MIM 2022).

The Kingdom has invested in developing a solid value chain for aluminum, ranging from raw material (bauxite) extraction to the conversion and processing of alumina and the smelting and fabrication of diverse aluminum products. Additionally, aluminum fits well within the circular economy concept as it can be recycled several times without losing its physical properties (WEF 2020).

Saudi Arabia possesses some capabilities in the copper value chain, with a rich portfolio of upstream mines and downstream capacities, particularly in wire and cable production. However, there is a noticeable gap in refining or smelting operations, leading to a reliance on imported copper cathodes. Addressing this gap, there is an emergent need to nurture midstream capabilities, optimizing the potential of domestic copper scrap and regional copper concentrate resources. Enhancing this value proposition, empowering local establishments to innovate, and offering services such as copper tubing remain critical. Both the local and broader regional copper markets offer prospects spanning a diverse array of product categories. Despite its expansive footprint from upstream to downstream operations in the copper domain, Saudi Arabia has operated without indigenous refining or smelting facilities. This results in the export of copper ore and concentrate being restricted in economic powerhouses like China, India, and Japan.

A notable absence of intermediary infrastructure to repurpose scrap into high-value items pushes copper scrap exports primarily to Korea, India, and Japan. In tandem, the Kingdom's consumption needs for copper cathodes, especially for downstream products such as wire and cable, lead to significant imports, with a major share of over 80% sourced from the Democratic Republic of Congo (MIM 2022a). It is pertinent to note that copper's inherent recyclability makes it a sustainable choice, with opportunities for recovery from applications such as motors, transformers, and cables. To address this gap in its copper value chain, the Kingdom is working with Glencore⁴ and Rifa Copper Company⁵ to set up a smelting and refinery project with 400,000 tons per annum of copper cathode capacity (Glencore Technology 2024).

2.4. Recent Mining Auctions in Saudi

In recent years, Saudi Arabia has introduced a series of mining auctions designed to unlock its mineral resources' full potential and attract local and international investors. These auctions offer access to highly prospective sites rich in key minerals. Recent rounds have focused on a broad range of commodities. Tables 2 and 3 present a snapshot of the most notable auctions and the promising deposits they have revealed.

Table 2. Major mining projects and auctions in Saudi Arabia (MIM 2022b; 2024b).

Project	Commodity	Area (km ²)	Region	Note
Muhaddad	Copper, zinc, lead, silver, gold	215	Bishah Belt	Volcanic-hosted massive sulfide (VHMS) and shear-hosted mineralization
Khnaiguiyah	Zinc, copper, iron, manganese	380	Riyadh	Extensive zinc and copper project with semi-massive to massive mineralization
Jabal Sayid	Copper, zinc, gold	2,892	Jeddah Terrane	Known for its significant volcanic massive sulfide (VMS) deposits with active copper mining operations
Umm Ad Damar	Gold, copper, zinc, silver	450	North East of Jeddah	Volcanic-hosted massive sulfide (VHMS) and shear-hosted mineralization with rich base and precious metals

Table 2. (continued)

Project	Commodity	Area (km ²)	Region	Note
Al Hajar	Gold, copper, zinc	60	Asir Terrane	Historic gold producer with significant volcanic massive sulfide (VMS) mineralization
Wadi Al Shuwas	Gold, copper, zinc	150	Asir Terrane	Potentially rich in gold and base metals, hosted within the VMS belt of Asir Terrane
Jabal Qaran	Gold, copper, zinc	57.7	South West Saudi Arabia	Volcanic-hosted massive sulfides (VMS) with gold and base metal deposits
An Nimas	Gold, copper, zinc, silver, nickel	222	South West Saudi Arabia	Known for shear zone-type gold deposits and VMS mineralization

Table 3. Sites under competitive tender round 6 (MIM 2024b).

Project	Commodity	Area (km ²)	Region	Note
Jabal Sabha	Gold, lead, zinc, rare earth elements	171.5	Ar Riyadh	Contains silver, lead, and zinc mineralization, with potential rare earth elements (REE)
Shaib Marqan	Silver, gold copper	91.81	Ar Riyadh	Highly prospective for orogenic gold
Hazm Shubat	Gold	93	Makkah	Prospective for gold with significant quartz breccia mineralization
Huwaymidan	Gold	34	Asir	Known for its quartz veins and gold assays
Umm Qusur	Gold, lead, zinc, silver	20	Ar Riyadh	Early-stage gold exploration with promising quartz veins and mineral occurrences
Wadi Ad Dawsh (Al Farah)	Gold, copper, zinc, silver	157.76	Asir	Gold and silver mineralization with quartz vein systems
Wadi Al Junah	Gold, copper, zinc, silver	425.37	Asir	Rich in copper, silver, zinc, and gold, it is located near Bishah city

Saudi Arabia's mining strategy is marked by a comprehensive and dynamic approach that leverages its vast mineral resources, investor-friendly regulations, and growing infrastructure to position itself as a key partner in the global mining industry. With a strong focus on strategic sectors such as renewable energy, EV batteries, and industrial diversification, Saudi Arabia aims to secure its place as a global leader in the mining sector while contributing to its Vision 2030 goals of economic diversification and sustainability.

The ongoing efforts to unlock the full potential of its mineral-rich regions, backed by targeted exploration auctions and the development of downstream value chains, will boost the Kingdom's industrial capabilities and attract significant international investments. Through these combined efforts, Saudi Arabia aims to be a key hub for the exploration, processing, and refining of mineral resources, driving economic growth and supporting the global transition to cleaner energy and sustainable technologies.

3. Mineral Systems

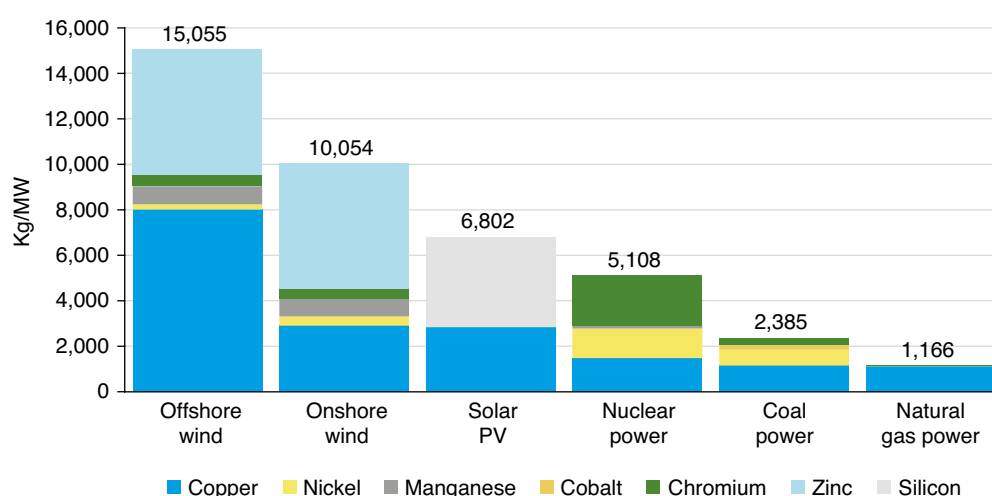
Model Findings and Discussion

A clean energy-driven system contrasts starkly with one reliant on traditional fossil fuel sources. Clean energy technologies such as solar photovoltaic (PV) installations, wind farms, and electric vehicles (EVs) demand a higher mineral input for their construction than their fossil fuel-based counterparts, as shown in Figures 1 and 2.

At the same time, an onshore wind facility requires nine times more minerals than a gas-fired plant, particularly minerals like copper and zinc. Since 2010, there has been a 50% increase in the average mineral requirements for generating a new unit of power capacity, attributed primarily to the growing proportion of investments in renewable energy systems. These mineral requirements continue to accelerate under the pressure of the energy transition (IEA 2021a). Hence,

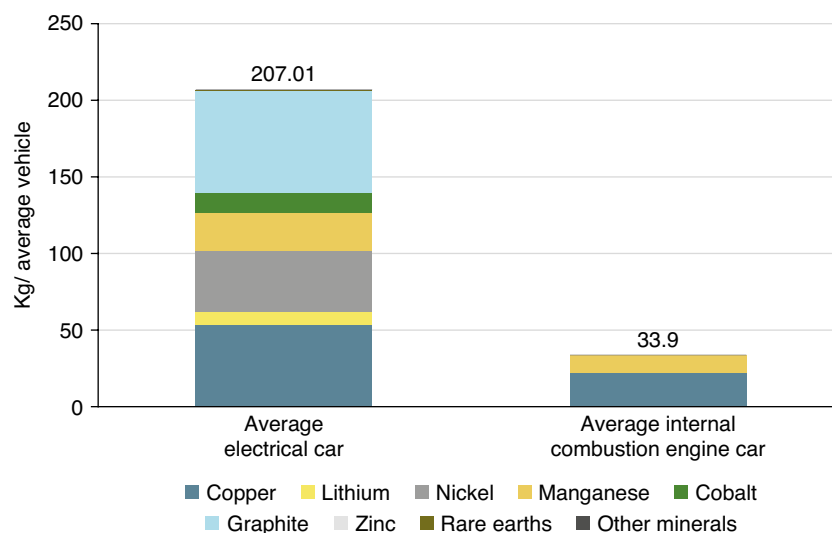
creating a domestic mineral supply market is crucial in enabling clean energy transitions and supporting the country's economic growth. Furthermore, as demand for clean energy technologies increases, so does the proportional demand for critical mineral supplies, further driving the country's economic development. This dynamic not only supports clean energy generation but also contributes to national economic growth (IEA 2021b).

Figure 1. Critical minerals are used more in clean energy technologies than in other power generation sources.



Source: IEA 2021a and authors' analysis.

Figure 2. Electric cars use more critical minerals than conventional ones.



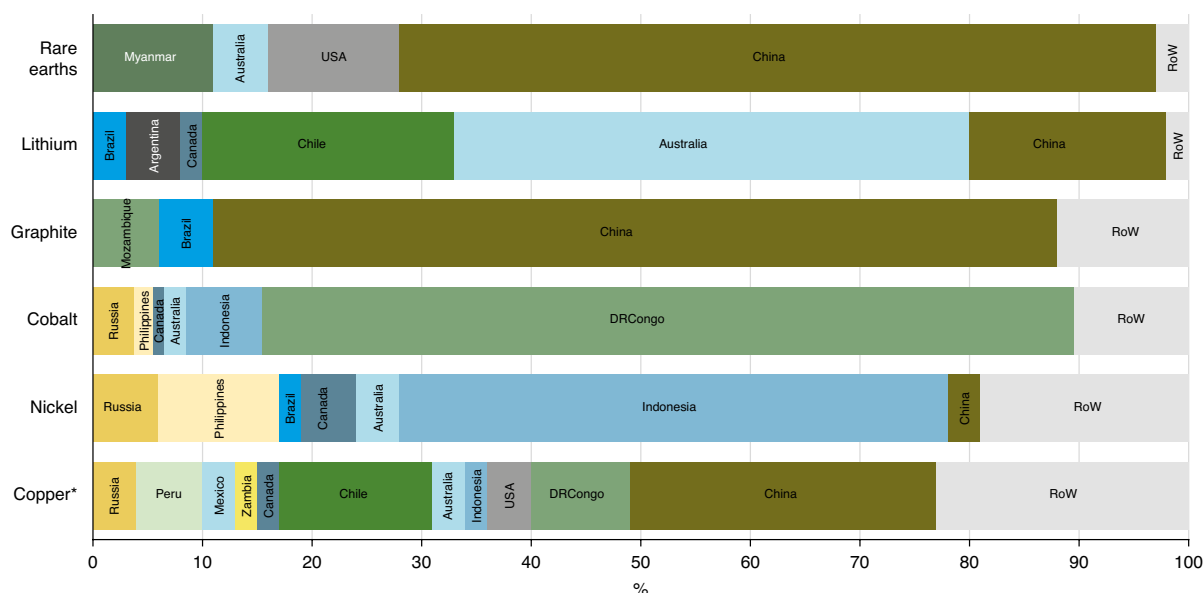
Source: IEA 2021a and authors' analysis.

Figure 2 illustrates that an average electric car requires almost six times the mineral resources of an average internal combustion engine car.

The future deployment of clean energy technologies to mitigate climate change will require a significantly more extensive supply of critical minerals than the current production levels support, which might lead to greater price volatility. Additionally, a few countries mine, process, and refine the most critical minerals. These minerals are entangled within intricate global supply networks and characterized by complex interdependencies, which highlight that the production

and processing of these minerals often fall under significant monopolistic control, resulting in substantial supply vulnerabilities. The production landscape for numerous minerals essential for the energy transition, as shown in Figure 3, demonstrates a high concentration level. The top three producing nations globally control more than 75% of the total output. Furthermore, in 2022, several significant critical minerals were predominantly produced by a single country: the Democratic Republic of the Congo (DRC) produced about 70% of the world's cobalt, while China accounted for approximately 60% of graphite and rare earth elements (Eni S.p.A. 2023).

Figure 3. Share of producing countries of selected critical minerals.

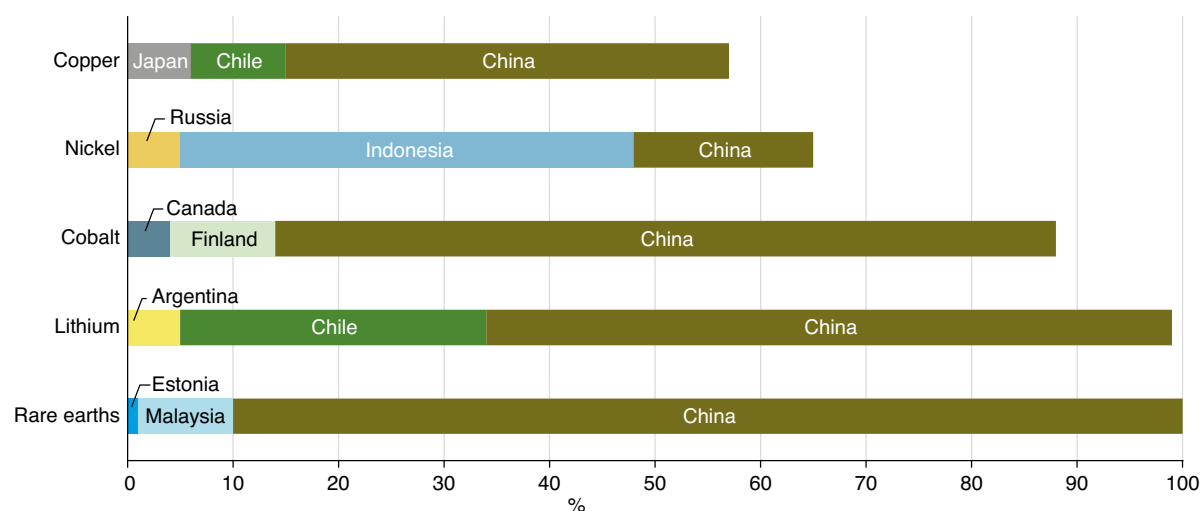


Source: IEA 2021a, Eni S.p.A., and authors' analysis.

Such geographic concentration of mineral supply is further intensified in processing operations, as shown in Figure 4, where China dominates various mineral processing value chains. China processes about 35% of nickel, 60% of lithium, 65% of cobalt, and almost 90% of rare earth elements within the processing sector. This concentration increases the potential risks from physical disruptions, trade limitations, or other developments in

significant production countries. This market monopoly might create economic and energy security issues for the importing countries (Chadha 2020). Therefore, developing and creating a domestic critical mineral supply and value chain is of interest to all major economies. Saudi Arabia has the potential to build a new industry that will support employment generation and ensure a share in the returns from its critical mineral resources.

Figure 4. Share of the top three mineral processing countries for selected critical minerals.



Source: IEA 2021a and authors' analysis.

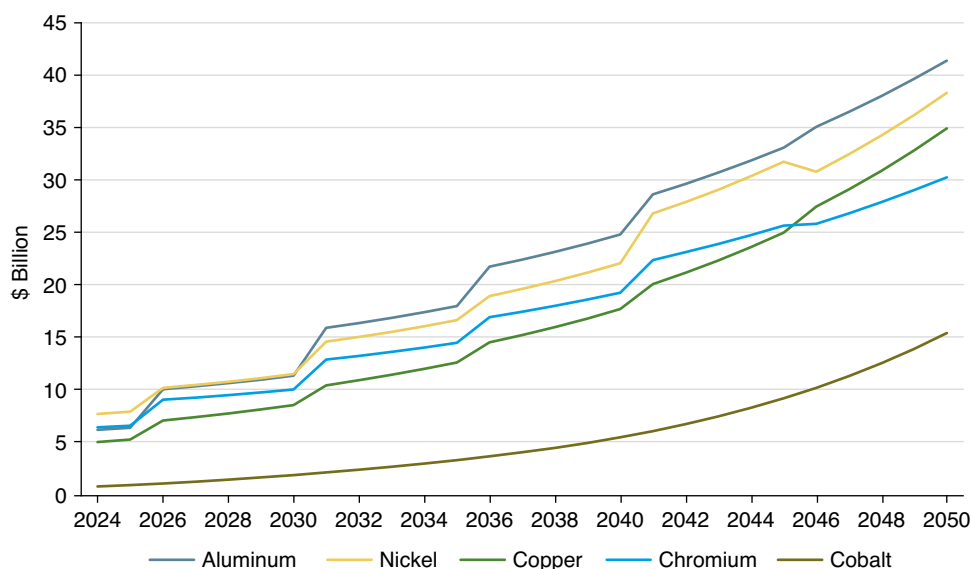
As the previous sections have highlighted, Saudi Arabia has placed itself well to take advantage of the demand for critical minerals. To define the percentage share of critical minerals that Saudi Arabia can contribute to global demand over time, this paper applies the IEA Energy Technology Perspectives World Beyond Two Degrees (B2DS) gross capacity scenario as the central framework input into the Payne Institute for Public Policy's Mineral Systems Model (MSM) (IEA 2017). The B2DS scenario utilizes the IEA Energy Capacity Scenario (net zero) and Bloomberg's Electric Vehicle Market Outlook (Bloomberg) to convey endogenous expectations/assumptions to the model (Bloomberg 2018; IEA 2023b). The net-zero scenario utilizes time-series data for given energy technology capacities to estimate the future market size for each mineral.⁶ Each technology is assumed to be decommissioned constantly with a lifetime distribution.

Multiple modeling scenarios are run to measure electricity capacities, including the IEA Energy Technology Perspectives 2017, World Beyond Two Degrees (B2DS) gross electricity capacity scenario, and 2018 Bloomberg New Energy Finance Electric Vehicle Outlook (IEA 2017; Bloomberg 2018). B2DS projects rates of capacity

expansion for 17 different electricity generation technologies, ranging from fossil fuels to renewable energies (Appendix A), to estimate the demand for each relevant mineral. It measures incremental changes in the mineral market's size and growth to project total demand in 2050. Projected results are formulated by analyzing the effects of inflow and outflow, considering recycling rates from the end-of-life of assets. The research indicates three different levels of market expansion based on the price values within mineral groups. The Bloomberg scenario informs EV-specific market dynamics. MSM decomposes these technologies into mineral requirements and projects market size throughout the scenario. We indicate a 26-year mine life to each mining scenario to synchronize with the assumptions laid out in the MSM. In this way, we can match the projected demand levels to 2050.

Figure 5 below illustrates the anticipated worldwide market demand size via the MSM through 2050. Market growth occurs at several levels, with three distinct groups composing growth on different orders of magnitude. The group that achieves market sizes of \$10 billion to \$40 billion includes aluminum, chromium, copper, nickel, and, to a certain extent, cobalt.

Figure 5. Global market demand of critical minerals: Projected from 2024 to 2050 (Group 1).

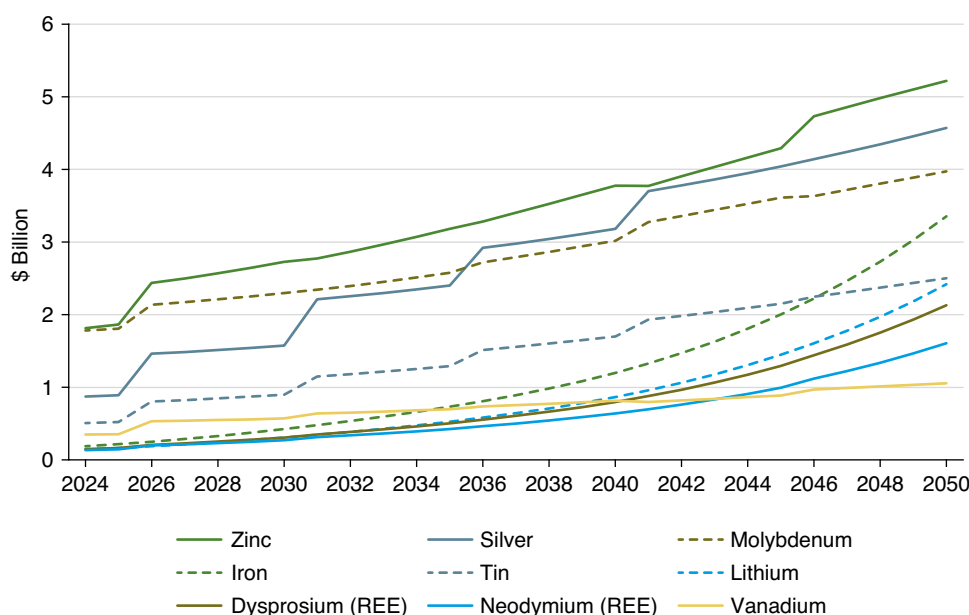


Source: Based on data from Colorado School of Mines (2022).

The second group includes minerals that achieve market sizes between \$1 billion and \$6 billion, including iron, dysprosium, lithium, molybdenum, neodymium, silver, tin, vanadium, and zinc. The third group comprises minerals

with markets of less than \$1 billion by 2050, including boron, cadmium, gallium, hafnium, lead, manganese, selenium, tantalum, tellurium, titanium, tungsten, yttrium, and zirconium. These are shown in Figure 6.

Figure 6. Global market demand of critical minerals: Projected from 2024 to 2050 (Group 2 and 3).



Source: Based on data from Colorado School of Mines (2022).

This paper focuses on three minerals that are key to the clean energy transition: bauxite, copper, and zinc. This choice is due to the abundant proven reserve levels the Kingdom is endowed with based on the Ministry of Industry and Mineral Resources (MIM) geological data (Table 1) and recent mining projects (Tables 2 and 3), which indicates the expected production level by mineral measures reserves.

It is worth noting that aluminum (bauxite) and copper are among the highest in expected global demand for critical minerals throughout the MSM model timeline (see Table 4). This prompts us to explore in depth the extraction potential of these resources, specifically in Saudi Arabia. Table 4 below lists the minerals considered in this paper and their associated reserve levels.

Table 4. Critical mineral inputs measuring share of global demand.

Mineral	MSM world demand in 2040	Ministry of Industry and Mineral Resources: Reserve levels (project ready)	Ministry of Industry and Mineral Resources: Proven level of reserves	Ministry of Industry and Mineral Resources: Probable level of reserves
Aluminum	11,269	4,300 (Bauxite)	74,600 (Bauxite)	159,000 (Bauxite)
Copper	2,929	70	328	472
Zinc	1,415	83	157	1,289

Note: Minerals resource scenarios are based on Saudi Geological Survey estimates in 2023. All metrics are displayed in kilotons. Global demand estimates are derived by inputting the IEA (2017) B2DS gross capacity estimates for 2040.⁷

Listed below are some central features each metal will contribute to this process globally:

- Aluminum: According to projections from the International Energy Agency, demand for aluminum will continue to surge upwards as the transition progresses due to the number of technologies requiring more significant use of this metal (e.g., lightweight vehicles, solar energy generation, etc.) (IEA 2023a).
- Copper: This metal is an effective conductor, making it a productive input to generate power from solar, hydro, thermal, and wind energy systems (Copper Alliance 2023). Copper and aluminum are also crucial for transmission line builds. According to the IEA, the world must invest over 80 million kilometers in transmission and distribution lines (replaced or added), more than the current total length of all grids worldwide.
- Zinc: Zinc has multiple applications, including its increasing use in zinc-ion batteries, which are considered superior to lithium-ion due to their water-based chemistry. This chemistry helps avoid the fire risks associated with lithium-ion batteries in electric vehicle (EV) battery packs (Venditti 2022).

3.1. Model Methodology – Mineral Demand

World demand in 2040 is reported in the second column of Table 2 utilizing the MSM model projections. The last three columns display mining scenarios based on reserve-level estimates from the Ministry of Industry and Mineral Resources. Estimates in columns three through five allow us to explore investment input and output spurred by the Kingdom's investment towards the energy transition. These include:

- The current level of extraction intended by mining company projects through 2040.
- The maximum level of extraction based on current Ministry of Industry and Mineral Resources estimates for 2023 and the level of proven reserves.
- The probable level of mineral reserves across Saudi Arabia, derived from current Ministry of Industry and Mineral Resources estimates for 2023. Recycling considerations from the Kingdom, such as end-of-life, manufacturing scrap, and others, are not included.

For this paper, we first estimate the share of world demand by running each scenario separately. Equation 1 displays our central economic multiplier effect estimate.

$$\frac{\text{reserves in kilotons}}{\text{mine life}} = \% \text{ of annual world demand} \quad \text{Equation 1}$$

Equation 1 explores the percentage of global demand the Kingdom contributes to the energy transition through critical minerals. Our primary estimate, scenario (i), measures proven reserve levels. These are equal to the current expected production output by minerals and are based on projects ready to break ground. We then test how these levels change by running our equation twice to explore the maximum proven scenario (ii) and the probable reserve scenario (iii). Scenario (iii) estimates each reserve's impact, assuming the reserve's total quantity would be extracted from the ground.

3.2. Model Methodology – Employment and Job Opportunity Targets

The second portion of the paper estimates job generation spurred by Saudi Arabia's energy transition in the form of jobs created as an economic catalyst in this region. This impact is measured utilizing Equation 2.

$$\frac{\text{investment generation}}{\text{cost per job}} = \text{number of job} \quad \text{Equation 2}$$

We exploit 2023 estimates reported by Saudi Arabia's Ministry of Industry and Mineral Resources for both models. This includes the expected revenue contribution of \$3.7 billion and projected workforce growth. Three employment outcomes are exploited to measure low-range, medium-range, and high-range assessments. These levels are listed below and are based on Saudi Arabia's government goals for job growth:

- Low range = 250,000 jobs.
- Medium range = 325,000 jobs.
- High range = 400,000 jobs.

We run these three assessments through the model shown in Equation 2. This allows us to project the low,

medium, and high employment growth scenarios from Saudi Arabia's mining sector.

3.3. Model Results

3.3.1. Saudi Contribution Toward Global Mineral Demand

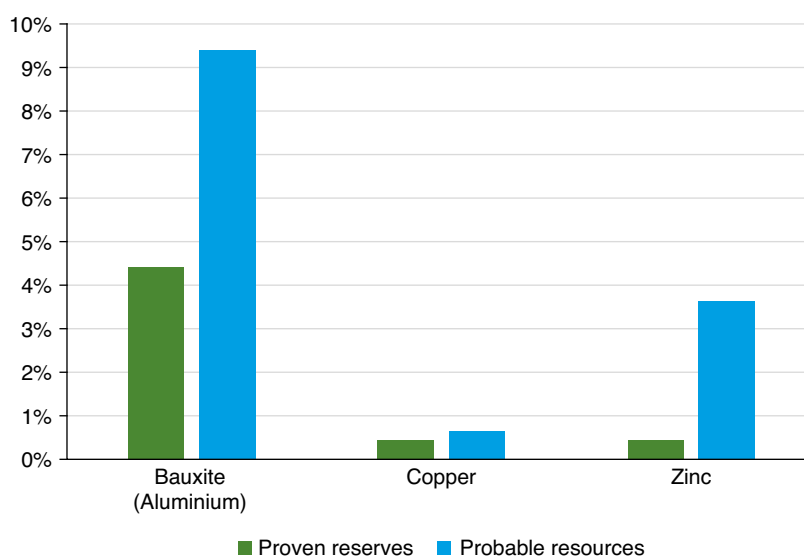
Initial approximations from the Mineral Systems Model (MSM), exploring scenario (i) in Table 2, illustrate the percentage of global demand for critical minerals – bauxite, zinc, and copper – that Saudi Arabia could meet based on confirmed mining projects in 2023. The results show that the Kingdom's current capacity will contribute no more than 0.25% of global cumulative demand through 2040. These estimates serve as a baseline for understanding the Kingdom's strategic role in global supply chains and highlight the significant potential for expansion through increased exploration and resource development. The analysis assumes equal project development across regions and the export of all extracted minerals, emphasizing theoretical plausibility under these standardized conditions.

Given their integral roles in renewable energy technologies, aluminum (bauxite), zinc, and copper are pivotal for achieving net-zero emissions. Aluminum is essential for solar panel frames and EV batteries, copper for wind turbine wiring and grid infrastructure, and zinc

for protective coatings in construction and renewable installations. According to MSM projections, demand for these minerals is expected to grow substantially through mid-century, driven by the accelerating deployment of clean energy technologies (Venditti 2022). These resources will be vital in determining the pace and feasibility of the global energy transition.

Figure 7 displays results from scenarios (ii) and (iii) in Table 2. Previous literature indicates that proven natural resource reserves are typically lower than probable (Misund, Osmundsen, and McMillan 2017; Uberman 2014; Domingo and Lopez-Dee 2007). The percentage points projected in Figure 7 show similar expected outcomes aligning under the natural resources umbrella of research as our estimates show probable reserve stock to be significantly higher than proven, allowing us to suggest these reserve estimates are reasonable. The figures illustrate that the Kingdom's objectives for developing copper, aluminum, and zinc-based value chains could benefit from increased raw material availability. The MSM's results focus on the supply-demand balance for specific milestone years, such as 2050, rather than cumulative contributions over time. This approach highlights the Kingdom's annual capacity to meet global demand during these key periods. Additionally, the availability of such resources will support the development of copper and zinc smelters, helping downstream industries.

Figure 7. Proven reserves vs probable resources and potential for the Kingdom (theoretical plausibility under several assumptions, including equal global project development and the exportation of all minerals).



Note: Global demand estimates are derived by inputting the IEA (2017) B2DS gross capacity estimates for 2050. The reserve level projections were derived from the 2023 Ministry of Industry and Mineral Resources estimates.

3.3.2. Employment and Job Opportunities

Innovation-driven industrial strategy and market expansion through product development in mineral-rich regions promise new job creation across the clean energy landscape (Brew 2022; Khorsheed 2015). While prioritizing supply chain efficiencies and industry dynamics, ensuring compliance with and adherence to high environmental and labor standards is also essential. Our analysis explores potential labor market impacts driven by the growth in Saudi Arabia's critical minerals sector.

Given an investment, the cost per job created is needed to determine the total number of jobs created. For this number, we look at the academic literature on the impacts of local economic policy on job creation. Several papers have used different tax incentives in the United States and the United Kingdom to estimate the effect of these tax incentives on investment and job growth. They then use these two numbers to get the cost per job created. Schwarz and Volgy (1988) used a British tax break for specific neighborhoods to find a cost per job of \$67,000 in 1985 dollars, equivalent to \$167,000 in 2023. Busso and Kline (2008) look at a program in the United States similar to Schwarz and Volgy (1988), revealing investments of \$100,000 per job. Freedman (2012) uses the New Market Tax Credits in the U.S. to show that each job in that program cost roughly \$50,000 in 2005 dollars, equivalent to \$78,000 in 2023. Glaeser and Gottlieb (2008) review this literature to find investments needed per job in the \$20,000 to \$100,000 range. We use the higher end of this range – \$100,000 investment per job created – in our analysis to be conservative and reflect the highly capital-intensive nature of mining.

To estimate the potential job creation in Saudi Arabia's mineral extraction sector, driven by the Kingdom's projected investment in alignment with Vision 2030, we utilized Equation 2 to calculate the number of jobs generated by the expected investment of \$3.7 billion, assuming a cost per job of \$100,000. The number of jobs was calculated by applying Equation 2 to three employment growth scenarios: low, medium, and high. The results for the low-growth scenario indicate the creation of 37,000 jobs. Adjusting this result by the ratio of medium to low job targets (1.3), the total number of jobs created in the medium-growth scenario is 48,100. Similarly, adjusting the low-growth result

by the ratio of high to low job targets (1.6), the total number of jobs created in the high-growth scenario is 59,200. These projections suggest that Saudi Arabia's investment in the mining sector can generate significant employment opportunities, ranging from 37,000 to 59,200 jobs, depending on the scenario. These jobs reflect broader economic development spillovers driven by accelerated growth in the Saudi mining sector.

Across all zones and along the infrastructure network of the Kingdom, we can assume positive spillover effects in terms of direct and indirect employment and job opportunities. Jobs associated with mineral extraction in Saudi Arabia are expected to increase over the upcoming years and rank third in the fastest growth by 2030 (MIM 2022a). The Kingdom has set goals to increase job creation within the mining sector, generating between 250,000 and nearly 400,000 new jobs during this timeframe (MIM 2022a).

The jobs created through these endeavors include specialized jobs, trade, and other industrial job profiles (potential job profiles are detailed in Appendix C). It is important to note that this analysis does not include the positive spillover impacts of indirect jobs impacted by the economic development exploration and production efforts in Saudi Arabia. As a result, we are likely to adopt a conservative approach when estimating the financial impact of the critical mineral expansion in this region.

Additionally, the availability of granularity of mining-related employment data is still to be improved. This impedes rational analysis, so we must rely on the limited publicly available information to support our findings. ALMarzouki (2023) indicates that the number of employees in the mining sector in the Kingdom is approximately 183,000. Ramady (2010) reports that every 1 billion Saudi riyal (SAR) of new exports generates 25,000 new jobs, suggesting that export diversification in mineral value-added products would positively impact employment. Ramady also highlights that while every 1 million SAR invested in a large company results in one additional job, the same investment in a small and medium-sized enterprise leads to 28 additional jobs. As the Kingdom expands its mining sector through increased exploration spending and downstream investments, employment in the mining sector is expected to continue to rise, driven by the growth of the downstream value-added sectors generating exportable products.

4. Conclusion

Our study uses the Payne Institute for Public Policy's Mineral Systems Model to show that Saudi Arabia's mineral supply potential can help support global supply chains. To realize this potential, Saudi Arabia must continue its aggressive exploration programs and create additional incentives for international partnerships and foreign direct investment (FDI) in its mining sector.

The results from the Payne Institute for Public Policy's Mineral Systems Model (MSM) suggest that Saudi Arabia's mineral reserves could meet up to 0.25% of global demand for critical minerals like bauxite, copper, and zinc by 2040, based on its current production capacity. As the model indicates, the Kingdom's current mineral processing capacity for aluminum, copper, and zinc requires substantive investments to increase its contribution to the global market share. The country's extensive mineral reserves position it to play a crucial role in the global clean energy transition. The expansion of this sector, including the development of midstream capabilities like smelters and refineries, is vital for supporting local manufacturing industries and meeting international demand for minerals used in renewable energy technologies.

Based on the model results, jobs directly associated with mineral extraction in Saudi Arabia are expected to range from 37,000 to 59,000 additional jobs. Saudi Arabia should prioritize skills development and upgradation, along with local workforce training and certification, to meet the demands of the growing mining sector. Investing in educational programs and technical training specific to mining technologies will help create meaningful employment opportunities and build a sustainable talent pipeline. With continued investment in infrastructure and human capital, Saudi Arabia is poised to solidify its position as a global leader in the mining industry, contributing significantly to the global energy transition.

Endnotes

¹ Vision 2030 is the Kingdom's reform program, launched in 2016. The program's overall aim is to transform the economy and society through economic diversification, investments in new economic sectors, and social reforms. Additional details regarding the program can be found at https://www.vision2030.gov.sa/media/rc0b5oy1/saudi_vision203.pdf.

² The Arabian Shield is a part of a larger geological ensemble, the Arabian-Nubian shield, which covers several countries, mainly Egypt, Eritrea, Ethiopia, Saudi Arabia, Somalia, Sudan, and Yemen.

³ The valuation of mineral resources has been updated to \$2.5 trillion; however, details regarding the breakup of the valuation in terms of specific minerals or resource levels are not as yet available in the public domain.

⁴ Glencore is one of the world's largest global diversified natural resource companies, with extensive copper operations, among other minerals.

⁵ Rifd Copper is a Saudi-based company focused on copper exploration and extraction within the Kingdom.

⁶ The model assumes all energy scenarios are in annual units.

⁷ It is worth noting that reserve levels do not necessarily mean that they can be exploited fully. Other factors, such as cost of production and quantity of production are also important inputs that aid in qualifying these levels.

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Appendix

Appendix A: List of Energy Technologies

Energy technologies	
Oil	SolarPVCSi
Coal	SolarPVCIGS
Coal – CCS	SolarPVCte
Natural gas	SolarPVamorphus
Natural gas – CCS	SolarCSPtrough
Nuclear	SolarCSPtower
Biomass and waste	Ocean
Biomass – CCS	Stationary li-ion batteries
Hydro	Workbook – lithium-ion batteries
Geothermal	EV (magnet/motor) BEV/PHEV/HEV
Wind – on shore	EV (battery) – BEV/PHEV/HEV
Wind – off shore	EV – fuel cell
	EV li-ion batteries

Appendix B: Saudi Arabia – Select Proposed Minerals and Metals Investments

Selected mineral investment opportunities	Predominant raw mineral/ material	Plant capacity	Expected investments range (US\$ million)
Green hydrogen-based steel complex	Iron	4 mtpa*	4,700~5000
Steelmaking facility for specialty products	Iron	7.5 mtpa	4,000
Automotive flat steel plant	Iron	500 ktpa [#]	2,500
Integrated steel plate production plant	Iron	1.2 mtpa	2,300
Engineered metals complex	Iron	380 ktpa	1,630
Pelletization plant	Iron	7 mtpa	950
Hot rolled coil plant	Iron	3 mtpa	900
Heavy profiles, marine profiles and rails	Iron	1.6 mtpa	800
Steel round billet production plant	Iron	600 ktpa	680
Thin gauge steel sheets	Iron	375 ktpa	660
Ferrochrome manufacturing plant	Iron	200 ktpa	250
Stainless steel grade seamless pipes plant	Iron	40 ktpa	227
Alloyed seamless pipes manufacturing plant	Iron	50 ktpa	220
Ferrosilicon smelter	Iron	80 ktpa	180
Stainless steel casted/forged parts	Iron	50 ktpa	100
Ductile iron pipe (DIP) production plant	Iron	200 ktpa	59
Low relaxation pre-stressed steel assembly line	Iron	10 ktpa	10~20
Nickel plant EV metals materials	Nickel	10 ktpa	950
Nickel pig plant	Nickel	15 ktpa	450
Titanium plant	Titanium	6 ktpa	500

(Continued)

Selected mineral investment opportunities	Predominant raw mineral/ material	Plant capacity	Expected investments range (US\$ million)
Titanium fabrication facility	Titanium	3 ktpa	80~100
Titanium midstream melt and forge	Titanium	8.5 ktpa	400
Titanium powder plant	Titanium	2 ktpa	150
Titanium forged plant for aerospace equipment	Titanium	2 ktpa	145
Titanium (semi-finished products)	Titanium	8.5 ktpa	870
Titanium forged plant for landing gear	Titanium	2 ktpa	190
Titanium open die forging	Titanium	1.5 ktpa	45~50
Titanium ingots and slabs	Titanium	3.5 ktpa	170~200
Titanium tubes	Titanium	3 ktpa	30~40
Magnesium metal plant	Magnesium	34 ktpa	108
Magnesium die casting	Magnesium	30 ktpa	30~50
Manganese (EV metals materials)	Manganese	40 ktpa	180
Manganese metal manufacturing plant	Manganese	30 ktpa	120
Tinplate production plant		400 ktpa	400
Gold refinery	Gold	30 tpa^	800
Rare earth elements		10 ktpa	400
Tantalum and niobium complex	Tantalum and Niobium	883 ktpa	300
Vanadium refinery	Vanadium	10 ktpa	50~60
Aluminum engine block casting plant	Bauxite	50 ktpa	492
Aluminum rolling foil	Bauxite	35 ktpa	167
Aluminum alloy wheels casting plant	Bauxite	40 ktpa	152
Aluminum fluoride plant	Bauxite	65 ktpa	105

(Continued)

Selected mineral investment opportunities	Predominant raw mineral/ material	Plant capacity	Expected investments range (US\$ million)
Aluminum plate plant	Bauxite	50 ktpa	80
Aluminum scrap recycling plant	Bauxite	120 mtpa	70
Automotive brake casting		75 ktpa	450
Aluminum circles and slug	Bauxite	20 ktpa	60
Aluminum primary foundry alloys plant	Bauxite	100 ktpa	47
Aluminum conductor manufacturing facility	Bauxite	250 ktpa	40~50
Aluminum extrusion plant	Bauxite	10 ktpa	25
Aluminum composite panel plant	Bauxite	25 ktpa	25
Aluminum rod plant	Bauxite	30 ktpa	20
Aluminum LIB foils production facility	Bauxite	115 ktpa	30
Aluminum master alloys facility	Bauxite	7.5 ktpa	15~20
Aluminum casting plant	Bauxite	25 ktpa	15
Aluminum foil	Bauxite	4-6 ktpa	6-7
Aluminum powder	Bauxite	6-8 ktpa	6-8
Aluminum forging	Bauxite	5-7 ktpa	20-25
Aluminum cables and welding wires	Bauxite	6-8 ktpa	8-12
Aluminum slugs/circle	Bauxite	15-20 ktpa	20-25
Aluminum caps and closures	Bauxite	100-150 million units/annum	3-4
Aluminum conductors	Bauxite	40-60 ktpa	20-25
Aluminum tubes/pipes	Bauxite	40-60 ktpa	50-75
Aluminum alloy drill pipes	Bauxite	5-10 ktpa	15-20
Aluminum blinds and shades	Bauxite	20-30 ktpa	6-8
Aluminum notch bars	Bauxite	3-6 ktpa	4-5
Brown sintered alumina	Bauxite	25-35 ktpa	8-10

(Continued)

Selected mineral investment opportunities	Predominant raw mineral/ material	Plant capacity	Expected investments range (US\$ million)
Calcined bauxite	Bauxite	50-75 ktpa	5-8
Aluminum foundry (automotive)	Bauxite	15 ktpa	52
Aluminum alloy wheels forging	Bauxite	1.2 million units/ annum	18.5~20.6
Aluminum (automotive) extrusions unit	Bauxite	20 ktpa	35~40
Aluminum overhead line conductor manufacturing unit	Bauxite	50 ktpa	40~50
Aluminum integrated re-melt and extrusion plant	Bauxite	65 ktpa	100
Lithium-ion battery grade aluminum foils	Bauxite	10 ktpa	30~40
Metallurgical powder		30 ktpa	50
Graphite electrode production	Graphite	70 ktpa	200
Graphite EV metal materials	Graphite	10 ktpa	200
CPC and cathode block plant	Petroleum Coke	255 ktpa	110~135
Battery manufacturing (lead acid/dry/ lithium-ion/thermal)			85-110
Automotive fuel cell stacks		50,000 fuel cells/annum	200
Automotive e-motors		500,000 units/ annum	200
Automotive wheels		2 million wheels/year	159
Electromagnets		500,000 units/year	0.7
Automotive semiconductor		420,000 wafers/year	2000
Automotive anode active material		25 ktpa	300
Solar PV module assembly			40
Automotive permanent motors		135, 000	22.5

(Continued)

Selected mineral investment opportunities	Predominant raw mineral/ material	Plant capacity	Expected investments range (US\$ million)
Copper foil manufacturing plant	Copper	10 ktpa	95
Copper rod plant	Copper	115 ktpa	30
Brass foundry plant	Copper and zinc	10 ktpa	35
Copper section products	Copper	10 ktpa	35
Copper tube manufacturing plant	Copper	10 ktpa	35
Copper secondary smelter	Copper	50 ktpa	65
Copper cathode manufacturing plant	Copper	300 ktpa	1,000
Brass and copper plant	Copper and zinc	45 ktpa	120
Refractory materials		70 ktpa	80
Polysilicon plant	Silicon	10 ktpa	1100
Silicon smelter	Silica	45 ktpa	140
Frac sand and resin coated sand	Silica	250 ktpa	40
Reactive silica plant	Silica	7500 ktpa	15~20
Container glass plant		60 ktpa	60
Processing glass plant		42 ktpa	50
Specialty glass plant		180 ktpa	220
Metal injection molding plant			30~50
Carbon (graphite) electrodes – steel		60 ktpa	235
High carbon wire rods		144 ktpa	6~10
Wires, cables, harnesses, and fiber optics			100~200
Aircraft propellers components			40~80

*mtpa – million tons per annum

#ktpa – kilo tons per annum

^tpa – tons per annum

Source: Invest Saudi (2024); Ma'aden (n.d.); and Goldman Sachs Research (2023).

Appendix C: Potential Job Profiles Resulting from Mining and Mineral Investments

Mining and mineral processing-related job profiles	
Behavioral sciences	Metallurgists
Blast hole drillers	Mineral processing engineers
Electricians	Mining engineers
Environmental specialists	Occupational safety and health specialists
Geology and geological engineers	Safety engineers
Health and safety trainers	Salespeople
Heavy equipment operators	Shot firers and blasters
Human factors professionals	Surveyors
Industrial health engineers	Trade assistants
Industrial hygienists	Tradespeople
Machinists	Welders

About the Authors



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Ahmed is a Research Fellow in the Utilities and Renewables program at KAPSARC. He is an Electrical Engineer and holds an M.Sc. degree in Renewable Energy Systems from Loughborough University. Prior to joining KAPSARC, he worked as an R&D Engineer at the Saudi Electricity Company for over five years, heading the research on renewables and energy storage. Ahmed's current research focuses on emerging technologies, critical minerals, and power system modeling to help shape the future of the energy mix and the technologies that can contribute to achieving KSA's green targets.



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Jitendra is a Principal Fellow in the Utilities and Renewables program. His ongoing research portfolio at KAPSARC covers various global and regional economic, energy, and geopolitical issues, policy developments, and the impact of such policies on international energy markets. Before joining KAPSARC, Jitendra was Director and Chief Consultant at HDR Salva, India. He has worked extensively as a commodity consultant within India's energy and infrastructure sectors, advising on the development of commodity market entry strategies. He has authored and contributed to numerous consulting studies on coal and coal policy in India, Indonesia, and China. Jitendra holds a bachelor's degree in Mechanical Engineering from the University of Pune, India, and a Post-Graduate Diploma in Business Management from Welingkar's Institute of Management, Mumbai.



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Dongmei is a Principal Fellow at KAPSARC with a focus on energy trade, energy investment, and regional energy cooperation. She has more than 20 years of experience in China's energy and climate change policy development. Before joining KAPSARC, she worked at the Institute for Industrial Productivity (IIP) as a Senior Advisor and Head of the China office, developing and disseminating best practices to improve industrial energy productivity. Before working at IIP, she worked at WWF China as the Director of the Climate Change and Energy Program, leading the design and implementation of the Low Carbon City Initiative in partnership with local Chinese governments and international networks. Prior to that, she worked at China's Ministry of Science and Technology, the Ministry of Water Conservation, and the Xinjiang Wind Energy Company.



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Caitlin is an experienced Economist with more than eight years of experience as a public servant for the state of Colorado. Her previous roles as an Economist within state government span multiple agencies, including the State Demography Office (SDO) at the Department of Local Affairs (DOLA); the Colorado Workforce Development Council (CWDC) at the Department of Labor and Employment (CDLE); the Office of State Planning and Budgeting (OSPB) in Governor Polis's Office; and the Department of Natural Resources (DNR). She is currently the Director of Research at the Common Sense Institute Colorado, a reputable think tank. Caitlin is motivated by data analysis and empirical modeling as tools for informed decision-making. She has extensive experience in public policy and econometrics.



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About the Project

The importance of critical minerals in the deployment of energy transition technologies has been increasingly recognized in recent years. Given Saudi Arabia's plans to integrate renewable energy and low-carbon transportation options into its future energy system, understanding the interactions between these technologies and critical minerals is vital. Furthermore, with ambitions to scale up mining, the question arises as to how resources can be best utilized to meet the Kingdom's goals. This project aims to develop literature relevant to both the country and the global context in these areas.



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