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The Mineral Reality of the Energy Transition: Why Oman Needs a Strategic Shift

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Rooted in local expertise and identity, the Majan Council is a proud Omani enterprise based in Muscat, dedicated to leveraging local knowledge and collective decision-support to drive development, advancement, and innovation across the GCC.

We empower policymakers, business leaders, and societies with actionable insights and foresight on emerging issues, providing them with the strategies they need to navigate the future.

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Address: Al-Khoud, Seeb, Sultanate of Oman, 617 P.O Box: 160

Website: http://majancouncil.org

Contact Email: info@majancouncil.org

Authors

Lead Author: Abdulrahman Baboraik

Contributing Authors: Salah Al-Khirbash, Intisar Al Busaidi

Research Contributors: Sultan Al Julandani, Amer Al Rasbi

Research Support: Mahmoud Al Shadadi, Shahad AlHoqani, Atheer Al Maamari, Istabraq Al Maskari

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ABOUT INITIATIVE

The Majan Council launched this initiative to address a critical and often overlooked dimension of the energy transition: the shift from fuel dependency to material and mineral dependency. While global and national strategies have focused on accelerating renewable energy deployment and reducing emissions, far less attention has been given to the structural risks associated with highly concentrated and geopolitically sensitive supply chains for the minerals that underpin clean energy technologies.

For Oman,, this issue is not peripheral, it sits at the intersection of every major national priority: energy security, economic diversification under Vision 2040, green hydrogen export ambition, and the long-term competitiveness of the country's industrial base. The country has set ambitious renewable energy and green hydrogen targets under Vision 2040, positioning itself as a future leader in clean energy production and export. However, a transition model that relies primarily on the deployment of imported technologies introduces new dependencies that may expose Oman to supply disruptions, price volatility, and external geopolitical pressures.

At the same time, this transition presents a significant economic opportunity. While the deployment of clean energy projects generates short-term activity, the long-term socioeconomic value lies in localizing manufacturing, developing value chains, and building industrial capabilities. This requires a strategic shift from a deployment-focused approach toward establishing a green industrial base that can capture higher value, create stable employment, and support economic diversification.

Realizing this opportunity depends fundamentally on the availability and strategic management of minerals and materials. In this context, the mining sector becomes a key enabler of green industrialization. However, Oman's current mining model remains largely focused on the extraction and export of raw materials, with limited expansion into processing and value-added activities. This structure constrains the country's ability to capture the full economic benefits of the transition.

In parallel, the scale of planned renewable energy and hydrogen deployment introduces an additional strategic dimension: the need to plan for the lifecycle of clean energy systems. Over time, large volumes of solar panels, wind components, batteries, and electrolysers will reach end-of-life, creating both environmental challenges and economic opportunities. Developing circular economy systems, recycling infrastructure, and secondary material value chains will be essential to enhance resource efficiency, reduce import dependence, and create new industrial activities.

This initiative was therefore developed to provide a strategic, evidence-based assessment of how critical minerals shape the feasibility, resilience, and competitiveness of Oman's energy transition. It aims to kick-start a national conversation on aligning energy ambitions with mineral strategy, industrial development, and circular economy planning.

By linking energy deployment with value-chain development, mineral supply security, and recycling systems, the initiative underscores a central message:

Without an integrated strategy that aligns energy transition planning, mineral development, industrial policy, and circular economy principles, Oman risks limiting its ability to capture the full economic value of the energy transition while increasing exposure to supply-chain disruptions, higher project costs, and long-term competitiveness challenges.

Ultimately, this initiative advocates for an energy transition that goes beyond clean energy deployment—one that is industrially integrated, economically transformative, and strategically resilient, positioning Oman to become a competitive participant in the global green economy.

The Energy Transition and Its Material Foundations

The global energy transition is no longer a matter of choice—it is a strategic and economic necessity. This transformation is driven by three core shifts: the expansion of renewable energy sources, the gradual reduction of fossil fuel dependence, and the improvement of energy efficiency across all sectors. Together, these changes are reshaping how energy is produced, distributed, and consumed worldwide.

At the centre of this transformation is the rapid scale-up of solar and wind power. According to the International Renewable Energy Agency (IRENA), these technologies could supply nearly two-thirds of global electricity by 2050 under a 1.5°C pathway. At the same time, electrification is accelerating across transport, industry, and buildings, with global electricity demand expected to nearly triple. The transport sector alone is undergoing a fundamental shift, with electric vehicles projected to reach close to two billion units globally by mid-century.

However, this transformation introduces a fundamentally different challenge from previous energy transitions. While the world is reducing its dependence on fossil fuels, it is simultaneously increasing its dependence on minerals. Clean energy technologies — including solar panels, wind turbines, batteries, and electrolysers— require substantially larger quantities of metals and critical minerals than conventional energy systems—between three and thirteen times more per unit of electricity generated, according to the International Energy Agency (IEA). This shift is creating unprecedented demand for mineral resources, exposing countries to new supply-chain vulnerabilities and elevating mineral security as a strategic pillar of the global energy transition. At the same time, it presents a significant opportunity for resource-rich countries to move beyond raw material extraction by developing domestic processing, manufacturing, and integrated green industrial value chains.

As a result, the energy transition is increasingly becoming a materials transition. The shift away from fossil fuels is being replaced by a growing dependence on critical minerals, many of which are geographically concentrated and exposed to geopolitical risks. At the same time, the construction of new energy systems and infrastructure is driving additional demand for bulk materials such as steel, cement, and copper.

These dynamics highlight a fundamental reality: the energy transition is not only about deploying clean technologies—it is about securing the materials, supply chains, and industrial systems required to build a low-carbon future.

The Hidden Material Reality of the Energy Transition

The global shift toward renewable energy is widely presented as a clean solution to climate change. However, this transformation carries a substantial and often overlooked material burden. Solar panels, wind turbines, batteries, and electrolysers require large quantities of industrial materials and minerals. However, the material composition differs significantly across technologies. Solar PV systems primarily require silicon, silver, copper, aluminium, glass, and polymers, while battery technologies depend more heavily on critical minerals such as lithium, nickel, cobalt, and graphite. While these critical materials are used in smaller volumes, their demand is increasing far more rapidly than current mining and supply systems can easily accommodate.

Wind energy provides a clear illustration of this material intensity. A typical wind turbine is composed primarily of steel (66–79%), along with fiberglass and resins (11–16%), iron or cast iron (5–17%), and smaller amounts of copper (Mone et al., 2017). It also requires a concrete foundation of approximately 2,000–4,000 tonnes (Hartman, 2023). Total material inputs can reach around 400 tonnes for onshore turbines and up to 3,000 tonnes for offshore installations (Mathern et al.,2021). Moreover, due to lower capacity factors compared to conventional power plants, a larger installed capacity—and therefore greater material input—is required to deliver equivalent electricity output (Office of Nuclear Energy, 2020).

To further illustrate these differences, Figure 1 compares mineral requirements across conventional and clean power generation technologies.

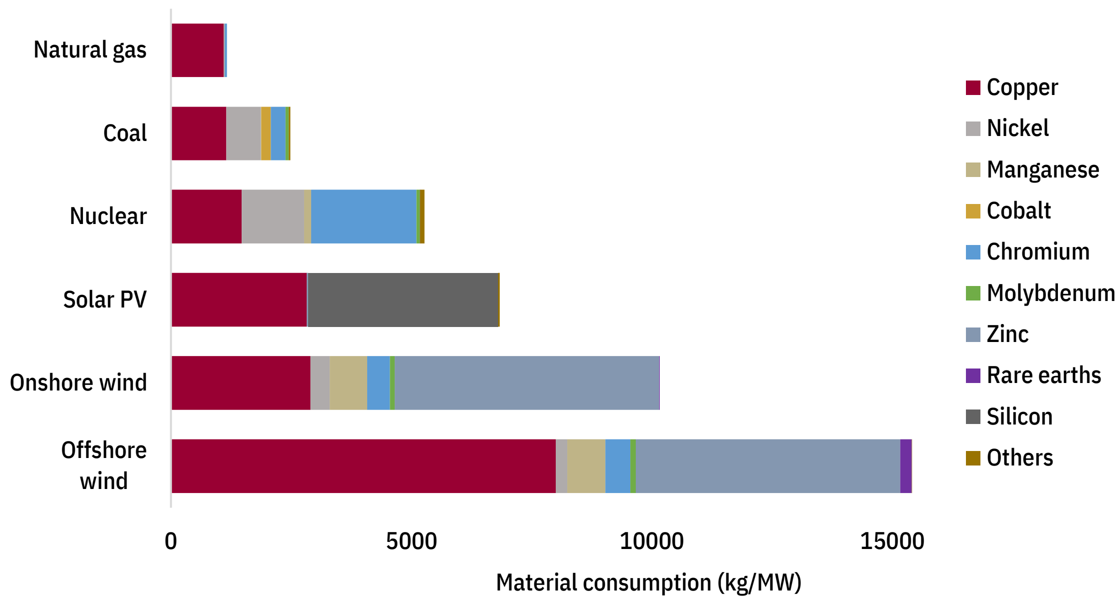

Figure 1: Material requirements for power generation technologies (kg per MW). (Data Source: IEA,2022).

The figure highlights a critical shift: clean energy technologies are significantly more material-intensive per unit of output than fossil fuel and nuclear systems. Electric vehicles, for example, require several times more critical minerals than conventional cars, while solar and wind technologies—particularly offshore wind—demand substantially higher material inputs per unit of capacity.

This trend is accelerating rapidly. Global battery demand has grown rapidly in recent years, reaching approximately 750

GWh in 2023 and exceeding 1 TWh in 2024, according to the IEA Global EV Outlook 2024, implying a massive expansion of mineral supply chains and the development of dozens of new lithium, nickel, and cobalt mining projects.

These dynamics underline a fundamental reality:

"The energy transition reduces dependence on fossil fuels but simultaneously increases dependence on critical minerals and material supply chains."

This shift has profound implications for energy security, industrial development, and long-term economic resilience (IEA,2022).

Geopolitics and Global Supply Chain Risks of Critical Minerals

Rare earth elements (REEs)—a group of seventeen metallic elements—are essential to modern clean energy technologies. As global demand for renewable energy accelerates, driven by economic growth, electrification, and climate commitments, demand for these materials is rising rapidly. However, supply expansion has not kept pace, raising growing concerns about supply security and market concentration.

Clean energy technologies depend on complex and globally interconnected supply chains that span multiple stages, including extraction, processing and refining, component manufacturing, and recycling. While this structure enables global scale, it also introduces significant vulnerabilities. Each stage is dependent on a limited number of actors, often located in different regions, making supply chains highly sensitive to disruption.

Despite this complexity, mineral supply chains are highly geographically concentrated, particularly at the extraction and processing stages. A small number of mostly developing countries dominate mining activities, while processing and refining are even more concentrated in a few states.

Among these, China leads the rare earth elements market, accounting for most of the global production and gaining substantial political and economic influence over countries that rely on imports (HCSS, 2013).

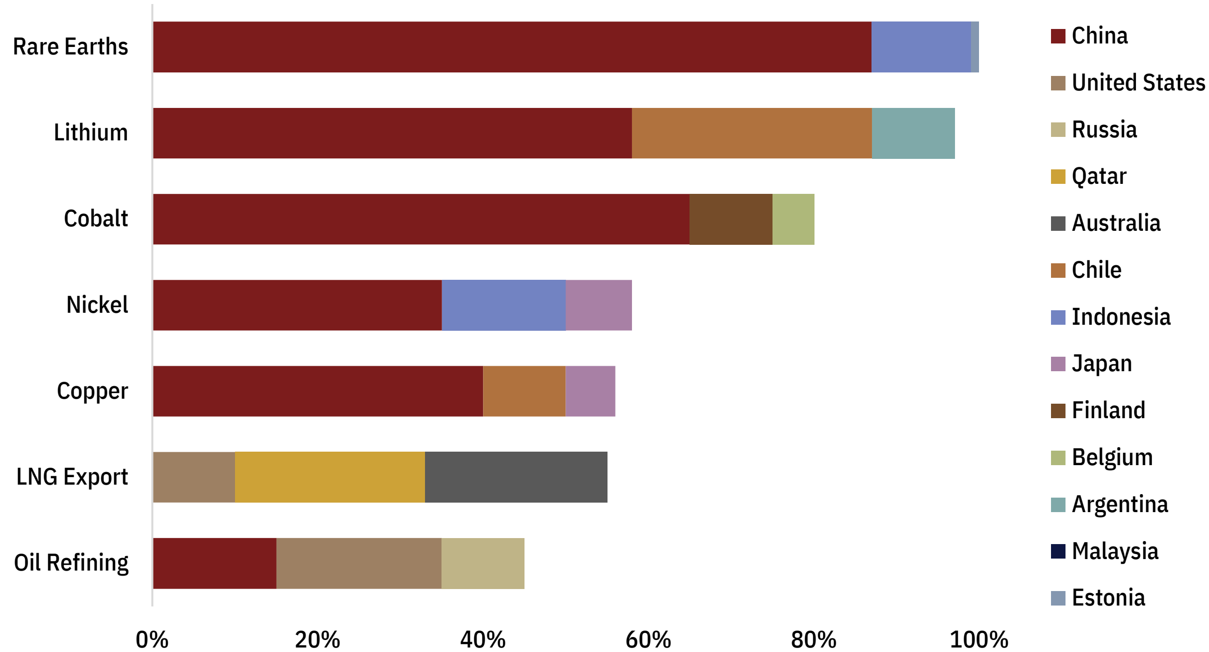

Figure 2: Share of top producing countries in total processing of selected minerals and fossil fuels, 2019 (Data Source: IEA,2021).

Figure 2 illustrates the extent of this concentration, highlighting China's dominant position in rare earth element (REE) processing and refining. According to IEA and USGS estimates, China accounts for approximately 85–90% of global REE refining capacity and around 70% of global REE mining output. In specific segments—such as heavy rare earth separation and certain magnet-grade NdPr products—China's share can reach up to 97%, creating significant strategic dependencies for importing countries. China has emerged as one of the most influential actors in the global minerals market, where any disruption in its production, processing capacity, or export policies can have immediate and far-reaching impacts on global supply chains. This concentration provides significant economic and geopolitical leverage to producing nations, particularly during periods of supply disruption, trade tensions, or policy shifts (Maps of World, n.d.).

At the same time, this relationship is not one-directional. China's industrial strength in mineral processing and manufacturing is closely linked to its energy security, much of which depends on stable energy flows from the GCC region. A significant share of China's oil and gas imports passes through critical maritime routes, particularly the Strait of Hormuz, making regional stability a key factor in sustaining global industrial and mineral supply chains. Recent tensions and incidents in the Strait have highlighted the vulnerability of these routes, reinforcing the interconnected nature of energy flows, industrial production, and critical mineral supply chains.

"Global mineral supply chains are not only shaped by resource concentration, but also by the security of energy flows that sustain industrial production."

This pattern extends beyond rare earth elements. China, Japan, and the Republic of Korea dominate battery material processing, while China, India, and several European countries play leading roles in wind turbine manufacturing. Downstream production is similarly concentrated in a small number of global industrial hubs, reinforcing the systemic nature of these dependencies.

Importantly, concerns about mineral scarcity are often misunderstood. The primary constraint is not the physical availability of resources, but rather the economic and strategic concentration of supply chains, where a limited number of countries control extraction, processing, and refining capacities.

China's dominance in rare earth elements is the result of sustained strategic investment, cost advantages in labour, and comparatively looser environmental standards—factors that led countries such as the United States to scale down domestic production and increase reliance on imports. Beyond REEs, China also leads global production of minerals used in clean-energy technologies show similar patterns of geographic concentration, as summarized in Figure 3

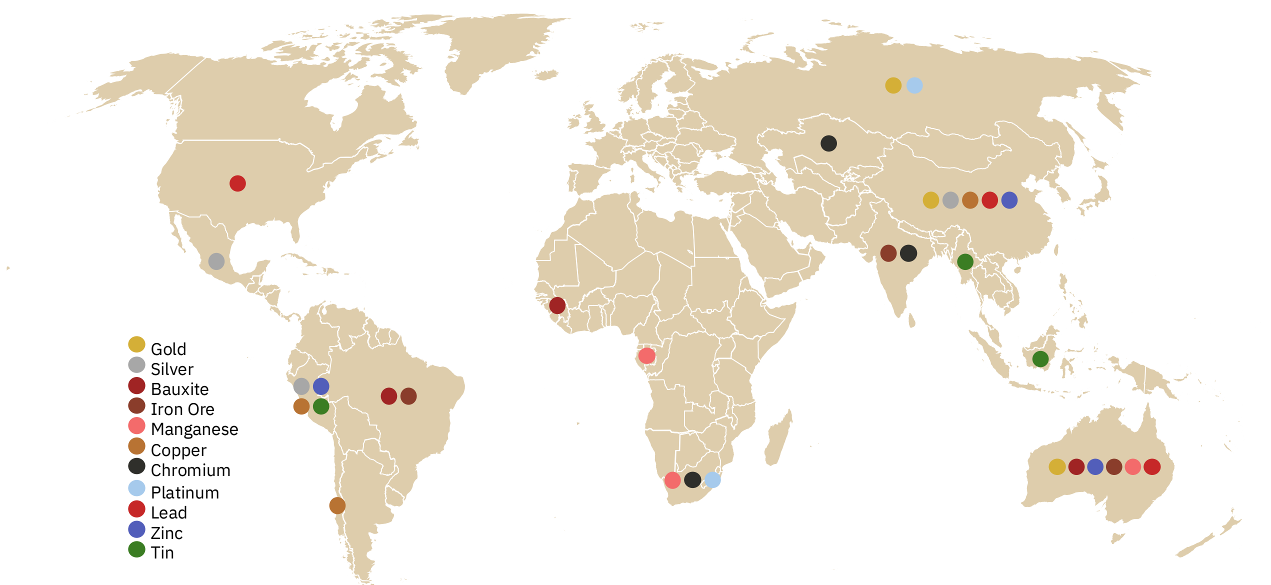

Figure 3: Geographic Concentration of Key Critical Minerals Used in Clean-Energy Technologies (Source: Majan Council Analysis).

This concentration raises a critical strategic question for countries pursuing energy transition pathways: how to reduce dependency on externally controlled supply chains. In this context, circular economy approaches—particularly recycling and material recovery—are emerging as a key pathway to enhance supply resilience. By recovering valuable materials from end-of-life solar panels, wind turbines, batteries, and other clean energy systems, countries can develop secondary sources of critical minerals, partially decoupling their energy transition from global supply chain constraints.

While recycling cannot fully replace primary extraction, it can play a significant role in diversifying supply, reducing import dependence, and strengthening long-term resource security, especially as the volume of deployed clean technologies continues to grow. In this context, recycling is not only an environmental solution—it is a strategic tool for supply chain resilience.

For countries pursuing ambitious energy transition pathways, these dynamics have significant implications. As deployment of renewable energy, storage, and hydrogen technologies accelerates, dependence on imported minerals increases exposure to supply disruptions, price volatility, and geopolitical risks. Limited access to key materials—or sudden price increases—can delay projects, increase system costs, and affect long-term competitiveness.

These challenges are particularly relevant for Oman. While the country benefits from abundant solar and wind resources, its large-scale renewable energy and hydrogen ambitions depend on reliable access to globally traded minerals and materials. Disruptions in supply chains or sustained market volatility could directly affect project economics, investment timelines, and the overall feasibility of planned developments.

In this context, mineral supply security becomes a central pillar of energy security. For Oman, managing these risks will require a more strategic approach that goes beyond clean energy deployment to encompass supply-chain resilience, industrial development, and long-term resource planning. Within the GCC, Oman's direct access to the Arabian Sea and Indian Ocean outside the Strait of Hormuz, together with its competitive investment environment and network of international trade agreements—including its Free Trade Agreement with the United States—provides a distinctive advantage for attracting investment in critical mineral processing and value-added manufacturing. As major economies in North America, Europe, and Asia seek to diversify critical mineral supply chains and reduce dependence on highly concentrated markets, these strategic assets position Oman as an attractive destination for export-oriented green industrial value chains.

Oman's Clean Energy Ambitions: Opportunity and Exposure

Oman has positioned itself as an emerging leader in the global energy transition, with ambitious targets under Vision 2040 aimed at achieving long-term decarbonisation and economic diversification. The national strategy recognizes that expanding renewable energy must be complemented by responsible resource management, including securing critical minerals, promoting material efficiency, and integrating circular economy principles into future energy systems.

Under this vision, Oman has set clear renewable energy targets, with renewables expected to contribute around 30% of electricity generation by 2030 and approximately 60% by 2040. Achieving these targets requires large-scale deployment of solar and wind capacity, supported by a growing pipeline of utility-scale projects. Key developments include the Ibri II Solar Power Plant (500 MW), the Amin Solar Project (100 MW), and the Manah I & II Solar Projects (1,000 MW combined), alongside a series of wind projects such as Dhofar II, Ras Madrakah, and Jalan Bani Bu Ali. These projects form the foundation of Oman's expanding clean energy infrastructure (Ansari & Baboraik, 2025).

In parallel, Oman is advancing one of the region's most ambitious green hydrogen strategies. The country has committed to achieving net-zero emissions by 2050 and aims to produce approximately 1 million tonnes of renewable hydrogen by 2030, increasing to 3.75 million tonnes by 2040 and up to 8.5 million tonnes by 2050 (Hydrom, 2024). If realized, hydrogen could become a major export commodity, potentially reaching energy-equivalent levels comparable to—and eventually exceeding—current LNG exports.

These ambitions position Oman at the forefront of emerging clean energy markets. However, they also introduce a strategic paradox. While the country is investing heavily in deploying renewable energy and hydrogen infrastructure, the technologies required—solar panels, wind turbines, batteries, and electrolysers—depend on complex global supply chains for critical minerals and materials.

Developing Oman's renewable energy and green hydrogen systems at scale will require significant volumes of industrial materials, including steel, aluminium, copper, and concrete, alongside critical minerals such as nickel, silicon, iridium, platinum, and other specialised materials used in electrolysers, batteries, and energy storage systems. As a result, Oman's energy transition is not only a question of abundant solar and wind resources, but also of securing reliable and affordable access to the materials that underpin these technologies.

Exposure to mineral supply risks varies significantly by technology. Bulk industrial materials are generally supplied through more mature and diversified global markets. By contrast, several critical minerals—particularly those used in advanced electrolyser technologies and energy storage systems—are produced and processed through highly concentrated supply chains. This creates a strategic challenge for large-scale deployment and reinforces the need for supply-chain diversification, mineral security, and long-term resource planning.

This creates a dual dynamic. On one hand, Oman's renewable resources provide a strong foundation for leadership in clean energy and hydrogen production. On the other, reliance on imported technologies and materials introduces exposure to supply-chain risks, price volatility, and geopolitical uncertainties—factors that could affect project timelines, costs, and long-term competitiveness.

At the same time, these ambitions create a significant opportunity. The scale of planned deployment opens the door for localizing parts of the value chain, including manufacturing, processing, and supporting industries. Moving beyond a deployment-focused model toward an integrated industrial approach can enable Oman to capture greater economic value, generate long-term employment, and strengthen its position within global clean energy value chains.

In this context, Oman's energy transition is not only an environmental and energy strategy—it is also an industrial and economic transformation pathway. The challenge lies in aligning energy ambitions with mineral strategy, industrial development, and supply-chain resilience to ensure that the transition is both competitive and sustainable over the long term.

From Deployment to Value Creation: The Missing Industrial Layer

Oman's energy transition is currently driven by the large-scale deployment of renewable energy and green hydrogen projects. While this approach is essential, it captures only a limited share of the broader economic value. A deployment-focused model relies heavily on imported technologies and external supply chains, resulting in short-term, project-based economic benefits.

In contrast, most of the value in clean energy systems lies within industrial value chains, including manufacturing, materials processing, and component supply. These activities generate higher-value, long-term employment, strengthen industrial capabilities, and support economic diversification.

For Oman, the scale of planned renewable and hydrogen projects presents a clear opportunity to move beyond deployment and localize parts of the value chain. This creates a strategic opportunity to localize parts of the clean energy value chain, whether through:

- Manufacturing selected components
- Developing materials processing industries
- Supporting supply-chain services and logistics
- Integrating industrial clusters around energy hubs such as Sohar, Duqm, and Salalah

However, capturing this opportunity will require moving beyond a deployment-focused approach toward a more integrated energy–industry strategy. This shift depends on a critical enabler: establishing policy mechanisms that encourage local value creation and strengthen domestic participation across clean energy value chains. Instruments such as local content requirements, investment incentives, procurement frameworks, and industrial partnership programmes can play an important role in supporting the development of mineral processing, manufacturing, and associated industries.

Without a strong foundation in mineral supply, processing, and industrial capabilities, efforts to localize manufacturing will remain limited. In this context, the energy transition should be viewed not only as an energy strategy, but also as an industrial development pathway. Aligning energy ambitions with mineral strategy and industrial policy will be essential to ensure that Oman captures the full economic value of its transition. The GCC already provides valuable examples of how policy can accelerate industrial development. Saudi Arabia's In-Kingdom Total Value Add (iktva) programme demonstrates how procurement-based policies and supplier development initiatives can strengthen domestic industrial capabilities and increase local value creation. While Oman's policy framework should reflect its own economic structure and strategic priorities, similar approaches could help stimulate investment, strengthen supply chains, and support the development of competitive green industrial value chains.

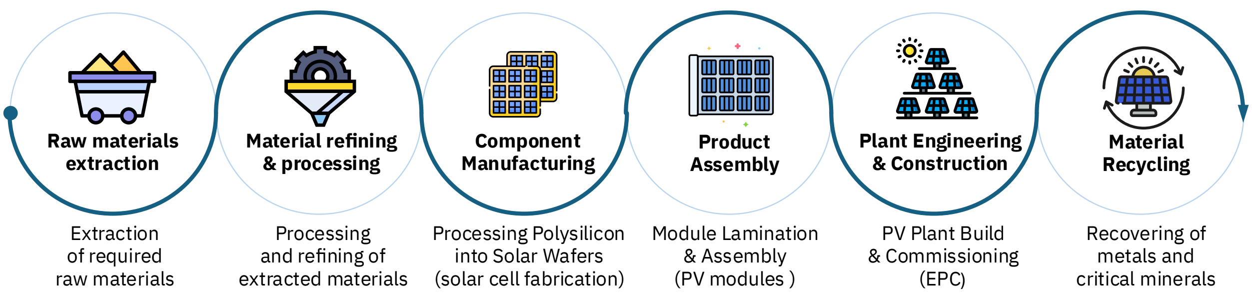

Figure 4: Solar PV Value Chain and Potential Localization Pathways (Source: Majan Council).

Material Demand and Industrial Opportunity in Oman by 2040

Oman's transition toward large-scale renewable energy and green hydrogen deployment between 2030 and 2040 will require millions of solar PV modules, thousands of wind turbines and electrolysers, and extensive supporting infrastructure. This scale of deployment will significantly increase demand for a wide range of industrial materials and critical minerals.

Clean energy technologies differ in their material intensity, but all rely on a combination of bulk materials—such as steel, aluminium, glass, and copper—and high-value critical minerals, including those used in electrolysers and energy storage systems. Solar PV systems drive demand for glass, silicon, and polymers, wind energy requires large volumes of steel and copper, while hydrogen technologies depend on smaller quantities of highly strategic and supply-constrained minerals.

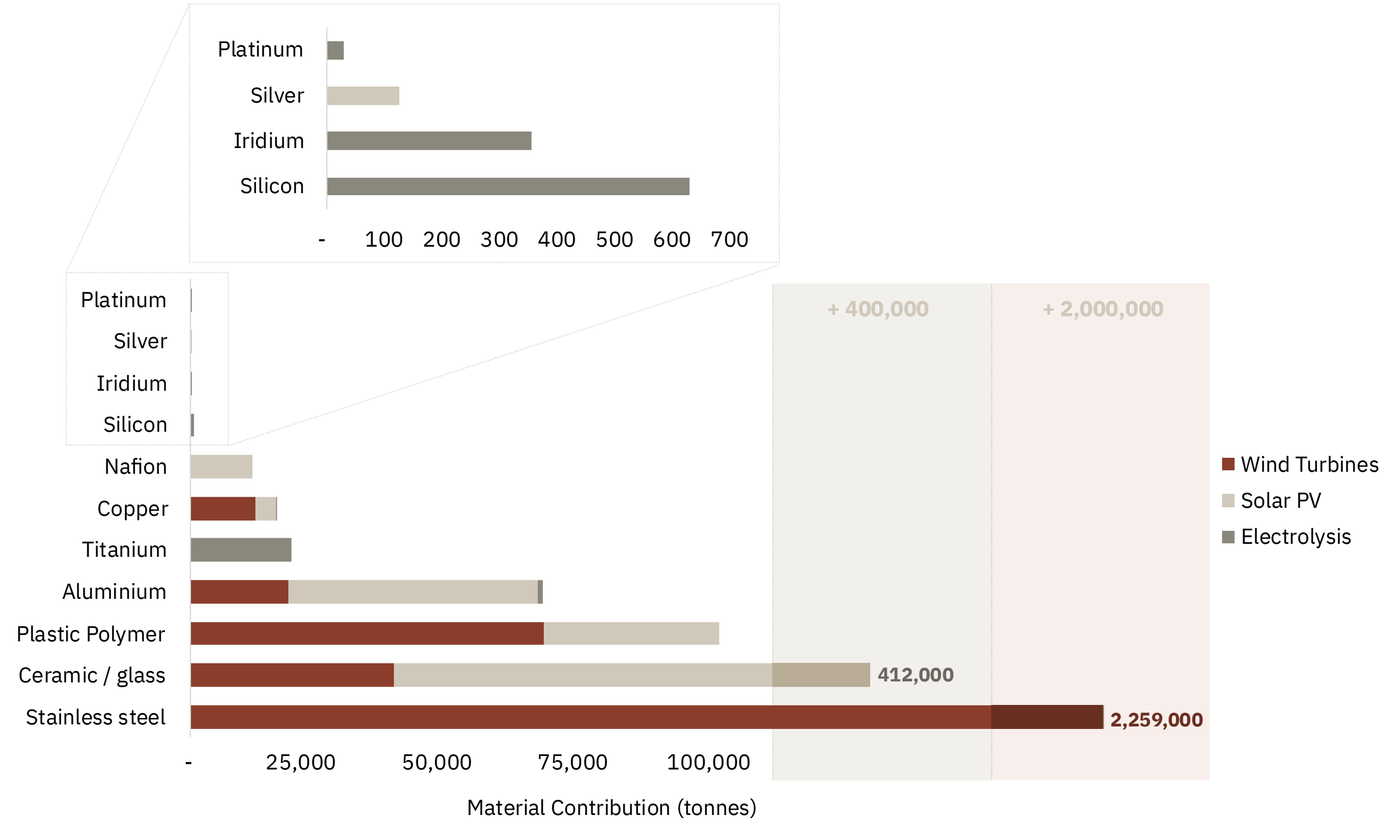

Figure 5: Material Contribution by Technology in Oman's Renewable Energy and Green Hydrogen Systems, 2040 (Source: Majan Council Analysis)

By 2040, material demand is expected to increase significantly, particularly for hydrogen-related infrastructure. The scale-up of electrolyser capacity will drive strong demand for materials such as steel, aluminium, and titanium, while reliance on critical minerals—including platinum-group metals and other scarce inputs—will intensify. This creates two distinct types of supply risk: volume-driven risks associated with bulk materials, and strategic risks linked to highly concentrated critical minerals.

At the same time, this growing demand presents a major economic opportunity. Rising requirements for materials and components create pathways for local manufacturing, mineral processing, and downstream industrial development in Oman. Expanding domestic capabilities in these areas can enhance value addition, reduce import dependence, and support the development of integrated clean energy value chain

The expansion of material demand is also closely linked to investment potential and job creation. Increased demand for metals, materials, and system components can stimulate industrial activity across multiple sectors, supporting economic diversification and creating long-term employment opportunities.

An important policy consideration is that different materials offer distinct combinations of capital intensity and socioeconomic impact. Some segments—such as steel and other heavy industrial materials—tend to require substantial capital investment and support large-scale industrial development, while other segments, including selected manufactured inputs and intermediate materials, may generate comparatively higher employment opportunities relative to investment size.

This highlights the need for strategic prioritization in industrial planning. Not all material value chains deliver the same economic returns, and policy decisions should therefore balance multiple objectives—including investment scale, employment generation, industrial complexity, and long-term strategic value—when determining which segments to prioritize for domestic development.

This distinction is critical for strategic planning. Evaluating and prioritizing sectors based on both capital intensity and socioeconomic impact enables more balanced industrial development, ensuring that investments not only deliver economic returns but also maximize job creation and local value addition.

In this context, mineral demand is not only a supply-chain challenge—it is a strategic economic opportunity. Aligning material demand with industrial development, local manufacturing, and circular economy systems will be essential to maximize the value of Oman's energy transition.

Circular Economy and Future Resource Systems

As highlighted in the previous section, the rapid growth in material demand driven by renewable energy and green hydrogen deployment creates significant opportunities for industrial development, investment, and job creation. At the same time, it introduces a new long-term consideration: how to manage these material flows across the full lifecycle of clean energy systems.

In this context, as Oman scales the deployment of renewable energy and green hydrogen technologies, a new dimension of opportunity is emerging—the development of circular economy systems and secondary resource flows. Over time, large volumes of solar panels, wind turbine components, batteries, and electrolysers will reach the end of their operational life, creating both an environmental challenge and a significant economic opportunity.

Among these technologies, wind turbine blades present one of the most significant end-of-life management challenges due to the complexity of recycling fibre-reinforced composite materials. This highlights the importance of integrating circular economy principles into project planning from the outset, including end-of-life management requirements, decommissioning obligations, recycling infrastructure, and material recovery systems. Establishing these frameworks early will help minimize future environmental liabilities while creating new industrial opportunities in recycling and secondary material markets.

Rather than treating these components as waste, Oman can position itself to recover, recycle, and reintroduce valuable materials—including copper, aluminium, and critical minerals—back into the economy. This enables the development of secondary supply chains, complementing primary mining and reducing long-term dependence on imported materials.

From an economic perspective, circular systems create new industrial activities, support local value addition, and generate employment across recycling, processing, and material recovery industries. From an environmental perspective, they reduce waste, lower resource extraction pressure, and improve overall system sustainability.

While recycling cannot fully replace primary mineral supply, it plays a critical role in diversifying supply sources, enhancing resource efficiency, and strengthening long-term resilience. Early investment in recycling infrastructure, regulatory frameworks, and market mechanisms will therefore be essential.

In this context, circular economy approaches are not only an environmental consideration—they represent a strategic pillar of resource security and industrial development within Oman’s energy transition.

Oman's Mining Sector: Potential and Structural Constraints

Oman's mining sector has deep historical roots, with copper extraction dating back to ancient "Majan," positioning the country as one of the earliest mineral producers in the region. Today, the sector is recognized as a strategic pillar under Vision 2040, with ambitions to significantly increase its contribution to GDP and support economic diversification.

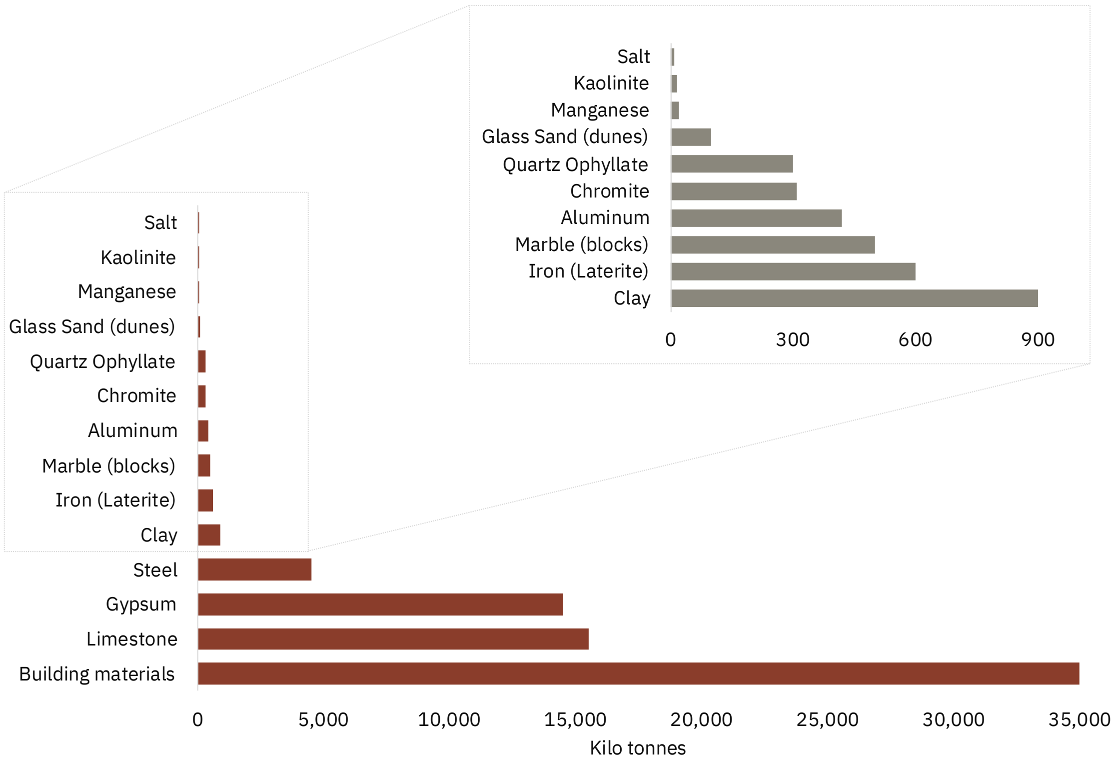

Figure 6: Oman's Mineral Production Capacity in 2024. (Data Source: National Centre for Statistics and Information [NCSI], 2024).

Oman's mineral base is diverse and geographically widespread, including copper, chromite, gypsum, limestone, silica sand, and other industrial minerals.

In recent years, the sector has experienced rapid growth. Mineral production increased from 26 million tonnes in 2018 to 78.85 million tonnes in 2023, reflecting rising investment, improved operational capacity, and expanding exploration activities. Production reached approximately 67.7 million tonnes in 2024, indicating continued large-scale sector activity despite year-on-year fluctuations.

In 2021, mining activities contributed approximately USD 629 million to Oman's GDP, while the total sales value of mineral products reached approximately OMR 121.9 million (around USD 317 million) in 2023, highlighting the sector's growing macroeconomic importance. In addition, mineral exports reached approximately 36 million tonnes in 2024, reflecting the sector's expanding production and export activity. According to the Ministry of

Energy and Minerals Annual Report (2024), the total sales value of minerals reached approximately OMR 121.9 million in 2023 and declined to around OMR 114.3 million in 2024, reflecting a year-on-year decrease of approximately 6%. Despite contributing only around 0.6% to national GDP in 2023, the mining sector is expected to expand significantly under Oman Vision 2040, with sectoral contribution targets estimated at approximately 1–2% of GDP through increased exploration, mineral processing, and value-added industrial activities. By the end of 2024, ten companies were operating across 21 mineral concession areas, see Figure 7.

Oman's mining sector today is anchored in a well-established base of industrial and construction materials, supported by an expanding footprint of concession-driven development. The geographic spread of mining activities and licensed areas reflects a scalable resource platform, underpinned by growing private sector participation and increasing operational capacity.

Oman's mining landscape is characterized by a large and expanding concession base, covering approximately 131,500 km² across the country. In total, around 57 mining blocks have been identified, distributed across key governorates including Al Batinah, Al Dhahirah, Al Sharqia, Al Wusta, and Dhofar.

However, the sector remains at an early stage of development. Only about 20 blocks are currently assigned to operators, while approximately 65% of blocks remain unallocated or under early-stage exploration. The sector is led by a mix of public and private entities, with Minerals Development Oman (MDO) playing a dominant role alongside several private operators. This momentum provides a strong foundation for expanding mining activities and enabling downstream industries.

Despite recent growth, the sector remains structurally underrepresented in national GDP, underscoring the importance of accelerating downstream processing and value-added activities.

Beyond current production, Oman holds emerging potential in a range of critical minerals that are essential for clean energy technologies (Figure 8), including solar, wind, and hydrogen systems. This positions the country not only as a resource producer, but as a potential contributor to global clean energy supply chains.

Taken together, the current production landscape and future mineral potential point to a clear strategic reality:

Oman is not constrained by resource availability, but by the absence of a fully integrated value-chain strategy.

The country combines two important advantages:

- A strong base in industrial minerals
- Emerging potential in critical minerals linked to energy transition technologies

However, these advantages remain structurally underutilized. The prevailing model continues to emphasize extraction and export, with limited progression into processing, manufacturing, and downstream industrial activities.

From a strategic perspective, this represents a missed opportunity. Without a deliberate shift toward value-chain integration, Oman risks remaining a supplier of raw materials in a global market where value is increasingly captured in processing, technology, and manufacturing.

The strategic priority is clear: transition from a resource-based model to a value-driven mining and industrial system aligned with clean energy supply chains.

Under Vision 2040, the mining sector is positioned as a strategic pillar for economic diversification, with a clear objective of reducing dependence on oil and gas revenues. The Ministry of Energy and Minerals is advancing this agenda through enhanced geological mapping, expanded exploration, and more efficient resource utilization, alongside a stronger emphasis on value addition and local processing.

This direction is supported by efforts to develop downstream industries—such as glass and metals manufacturing—and to strengthen governance frameworks through initiatives like the Smart Oversight Initiative, aimed at improving transparency, efficiency, and sector returns.

In parallel, Minerals Development Oman (MDO) plays a central role in operationalizing this strategy by driving investment in exploration and project development, attracting both local and international partners, and expanding Oman's footprint in mineral and metals trading. The establishment of dedicated trading platforms for key minerals, including chromite and gypsum, reflects a broader ambition to capture greater value from global demand for energy-transition materials.

Together, these efforts signal a clear policy direction toward strengthening the sector's role in industrial development and long-term economic resilience.

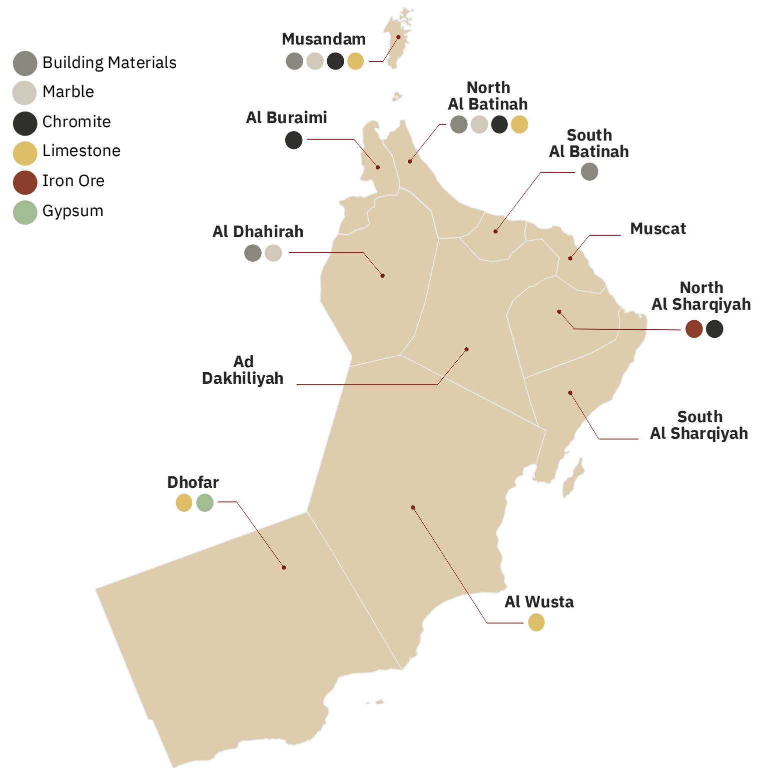

Figure 7: Mineral occurrences and associated mining license areas across Oman's governorates (Source: Majan Council Analysis).

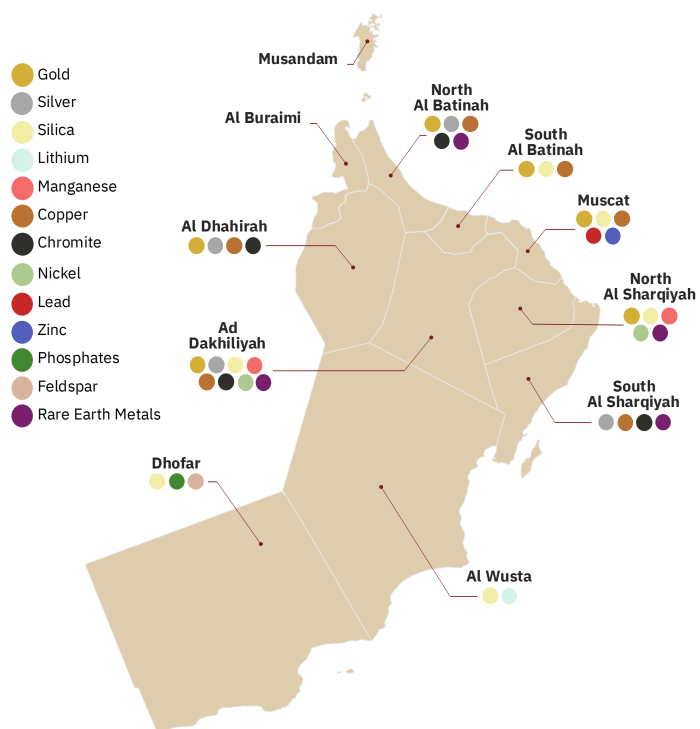

Figure 8: Oman Minerals Concessions map (Source: Majan Council Analysis).

Socioeconomic Impact and Employment Potential of the Mining Sector

Beyond its role in resource extraction, Oman's mining sector holds significant potential as a driver of employment, local value creation, and economic diversification. In 2024, the mining sector employed approximately 3,942 workers, of whom around 890 were Omani nationals, resulting in an Omanization rate of approximately 23% of the total workforce. This reflects the sector's current focus on extraction and exploration activities. Moving toward mineral processing and downstream value-added industries could substantially increase employment, improve Omanisation rates, and create greater economic value for the national economy (Trading Economics, n.d.)

According to Shehu et al. (2026), global manganese reserves are estimated at approximately 1.9 billion metric tonnes, while Oman is estimated to hold more than 1 million metric tonnes. Although modest compared with major producers such as South Africa, Australia, and China, these reserves represent a strategic resource that could support selected downstream industrial and clean-energy value chain opportunities.

However, the structure of employment remains closely linked to the sector's current focus on extraction and primary activities. As a result, much of the employment generated is concentrated in operational roles, with more limited opportunities in higher-value segments such as processing, manufacturing, and advanced materials.

This highlights an important opportunity. Expanding the sector beyond extraction toward value-added processing and industrial integration can significantly enhance its socioeconomic impact. Downstream activities—such as metals processing, materials manufacturing, and recycling—have the potential to generate higher-skilled, longer-term, and more stable employment opportunities, while also supporting knowledge transfer and industrial capability development (Annual Report, 2023).

In addition, increasing Omanisation rates within the sector remains a key policy priority. Strengthening local workforce participation, particularly in technical and specialized roles, will be essential to ensure that the benefits of sector growth are more widely distributed across the national economy.

Insights from recent labour market intelligence analysis (LMIA) highlight an important area for development within the mining sector. While Oman has made progress in building local workforce participation, achieving higher Omanisation rates remains linked to the availability of specialized skills aligned with evolving industry needs.

Current academic and training programs in minerals provide a strong foundation in general geology; however, there is an opportunity to further strengthen applied, mining-specific and processing-related expertise. Enhancing alignment between education outcomes and industry requirements will support the development of a more technically specialized workforce.

In this context, continued investment in targeted training, industry-oriented programs, and skills development initiatives will be essential to expand local capabilities and gradually reduce reliance on external expertise in advanced and technical roles.

From a broader perspective, the mining sector can play a central role in supporting Oman's transition toward a green industrial economy. By linking mineral development with clean energy value chains, manufacturing, and circular economy systems, the sector can contribute not only to GDP growth, but also to job creation, skills development, and long-term economic resilience.

In this context, maximizing the socioeconomic impact of the mining sector requires a shift from a volume-driven model toward a value-driven model, where resource extraction is closely integrated with industrial development and employment generation.

Strategic Vulnerabilities in Critical Mineral Projects: Lessons from Oman

The experience of the Strategic and Precious Metals Processing Company (SPMP) provides a clear illustration of the structural risks associated with critical mineral supply chains. Established in 2014 as a joint venture between Tristar Resources (UK) (~40%), the Oman Investment Fund (predecessor of the Oman Investment Authority) (~40%), and DNR Industries Limited (~20%). The Sohar-based facility was designed as Oman's first antimony processing plant, with a capacity of 20,000 tonnes per year. The project incorporated advanced processing technologies and met international environmental standards, positioning it as a technically robust and strategically significant industrial investment.

However, the project's viability was fundamentally constrained by external supply dependencies. Antimony—a critical mineral used in batteries, electronics, and industrial applications—is highly concentrated globally. China accounted for approximately 48% of global antimony mine production in 2023, according to the U.S. Geological Survey (USGS, 2024), with additional supply concentrated in a small number of countries (SPMP, 2019). Although this is lower than the historical peak levels of approximately 75–80% observed prior to 2018, China continues to maintain significant influence over global antimony supply chains due to its dominant position in processing and refining activities.

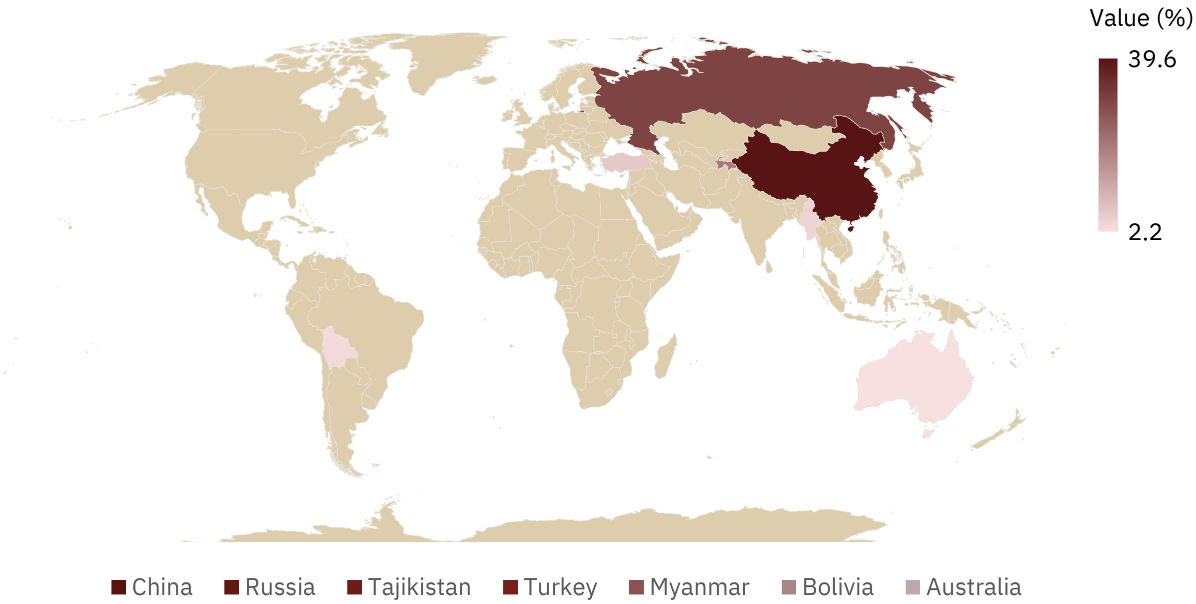

Figure 9:Antimony Global Supply Concentration (Source: Majan Council Analysis)

This concentration created significant exposure to supply disruptions. Regulatory changes in China, including stricter environmental controls, led to mine and smelter closures, reducing global supply and increasing price volatility. As a result, SPMP—reliant almost entirely on imported antimony concentrates—faced increasing operational uncertainty.

The absence of diversified supply sources, long-term supply agreements, or domestic feedstock alternatives amplified these risks. Despite its technical strength, the project remained vulnerable to external shocks beyond its control.

The SPMP case highlights a critical strategic lesson: Industrial projects in critical minerals cannot succeed without secure and resilient supply chains.

For Oman, this has direct implications for future clean energy and industrial ambitions. As the country seeks to develop local manufacturing, processing, and hydrogen-related industries, reliance on externally concentrated supply chains introduces significant structural risk.

This underscores a clear policy imperative: industrial development must be aligned from the outset with upstream resource access, supply diversification, and long-term supply security

Without this alignment, even well-designed and well-executed projects risk becoming economically unviable.

The Strategic Gap: Misalignment Across Systems

Despite strong progress across individual sectors, Oman's energy transition currently faces a fundamental structural gap: the lack of alignment between energy ambitions, mineral development, industrial policy, and circular economy systems.

Each of these areas is advancing, but largely in parallel rather than as part of an integrated national strategy. Renewable energy and hydrogen projects are scaling rapidly, while the mining sector continues to expand and industrial initiatives are emerging. However, the connections between these systems remain limited.

This misalignment creates several challenges:

- Energy deployment is increasing dependence on imported materials and technologies
- Mining activities remain focused on extraction, with limited integration into industrial value chains
- Industrial development is not fully linked to domestic resource availability
- Circular economy systems are not yet embedded within long-term resource planning

As a result, Oman risks capturing only a partial share of the economic value associated with the energy transition, while remaining exposed to external supply-chain risks.

The challenge is not the absence of ambition or resources—but the absence of integration.

Addressing this gap requires a shift toward a more coordinated approach that aligns:

- Energy planning with material demand
- Mining strategy with industrial development
- Manufacturing with resource availability
- Circular economy systems with long-term supply security

Without this alignment, Oman's clean energy transition risks remaining deployment-driven rather than economically transformative.

Unlocking Oman's Mining Potential: Opportunities, Challenges, and Policy Pathways

Oman's clean energy and green hydrogen ambitions create a clear opportunity to advance green industrialization and capture greater value from emerging clean energy value chains. This opportunity is supported by the country's strategic location outside the Strait of Hormuz, its established industrial and logistics infrastructure, and a competitive investment framework.

However, realizing this potential depends on strengthening key enabling sectors—most notably the mining sector. Despite its strong resource base, the sector remains constrained by structural challenges that limit its integration into industrial value chains, requiring a coordinated and forward-looking policy response.

Strategic Opportunities

Oman holds a strong position in selected industrial minerals, particularly gypsum, demonstrating its ability to operate at scale in global markets. This provides a solid foundation for expanding into higher-value, downstream industrial activities.

The global energy transition further strengthens this opportunity. Rising demand for materials used in renewable energy, energy storage, and green hydrogen systems creates a pathway for Oman to reposition its mining sector from a resource-based model to a value-driven industrial system.

Oman's strategic advantages reinforce this potential. Its geographic location established industrial hubs (Sohar, Duqm, and Salalah), and access to competitively priced renewable energy create favorable conditions for developing mineral processing, energy-intensive manufacturing, and hydrogen-linked industrial activities.

Importantly, Oman is uniquely positioned as one of the few countries in the region with direct access to open seas outside the Strait of Hormuz, enabling secure and uninterrupted trade flows. Combined with strong connectivity to GCC, Asian, and African markets, this enhances Oman's role as a reliable and resilient node in global supply chains.

This positioning is further strengthened by Oman's investor-friendly policy and institutional framework, which provides a competitive environment for industrial development. Key features include:

- Flexible foreign ownership structures
- Long-term tax incentives and customs exemptions
- Access to free zones and special economic zones
- Competitive operating costs and industrial land availability
- Streamlined licensing through one-stop-shop platforms

Together, these factors create a strong foundation for attracting greenfield investments and expanding existing industrial operations, particularly in sectors linked to clean energy and materials processing.

In particular, copper represents a key strategic opportunity. With estimated resources of 2.78 million tonnes and rising global demand driven by electrification and clean energy technologies, copper can serve as a critical link between resource development and industrial value chains.

Oman has already taken initial steps toward this transition. Developments such as Ibri Industrial City, copper processing facilities in Sohar, and the planned concentrate plant in Yanqul reflect a shift toward local value addition and industrial integration.

The opportunity for Oman is not only to produce minerals, but to develop integrated value chains supported by strong infrastructure, strategic location, and a competitive investment framework.

Key Structural Challenges

The most critical challenge is Oman's high dependence on globally concentrated and externally controlled mineral supply chains. Many materials essential for renewable energy systems and hydrogen technologies are sourced from a limited number of countries, exposing Oman to supply disruptions, price volatility, and geopolitical risks (StoneNews, 2024).

A second challenge is the limited domestic processing and refining capacity. Despite a diverse mineral base and strong export performance in industrial minerals, most value addition takes place outside the country, for example steel processing generates 2-5x more jobs per mineral unit than extraction, amplified by recycling. This constrains Oman's ability to capture higher economic value and limits its integration into clean energy value chains.

A third constraint is the shortage of specialized skills across mineral and industrial value chains, particularly in processing, advanced materials, and related technologies. Without targeted vocational workforce development, the sector risks continued reliance on external expertise, affecting both costs and timelines.

While important, these challenges are secondary to the core structural issues of supply concentration, limited value addition, and capability gaps.

Together, these constraints highlight a central policy challenge: transforming mineral potential into integrated industrial capability.

Policy Pathways: Strengthening the Mining Sector to Enable Green Industrialization in Oman

To fully capture the economic value of the energy transition, Oman must move beyond a deployment-driven model toward an integrated strategy that aligns energy planning, mineral development, industrial policy, and circular economy systems within a coherent and phased framework.

A. Short-Term Priorities: Securing Foundations

In the short term (by the end of 2028), Oman has a timely strategic opportunity to strengthen its position within the evolving global critical minerals landscape. Policy initiatives such as the US Inflation Reduction Act, the EU Critical Raw Materials Act, and broader international efforts to diversify critical mineral supply chains are reshaping global investment patterns and creating new opportunities for mineral processing and value-added manufacturing. To capitalize on these developments, Oman should prioritize strengthening mineral supply security while establishing the governance, investment, and procurement frameworks needed to attract long-term industrial investment and reduce exposure to external risks.

This requires systematically integrating critical mineral considerations into energy transition planning, including renewable energy and green hydrogen deployment, with a focus on strengthening local content and enabling green industrialization across value chains. This should include structured assessments of material demand and supply-chain vulnerabilities—particularly for minerals that are highly concentrated or subject to price volatility.

This is especially important given the high concentration of global mineral processing in a limited number of countries, particularly China, where policy or production changes can rapidly affect global markets. At the same time, recent geopolitical tensions affecting key trade routes—such as disruptions around the Strait of Hormuz—highlight the vulnerability of interconnected energy and industrial supply chains.

In response, Oman should prioritize diversified sourcing strategies, including long-term supply agreements with reliable partners. Strategic stockpiling of selected high-risk materials may also be considered to mitigate potential disruptions. In parallel, strengthening data systems, resource mapping, and coordination across energy, mining, and industrial stakeholders will be essential to align future demand with secure and resilient supply.

Medium-Term Priorities: Building Industrial Capacity

Over the medium term (2029-2033), mining sector in Oman should focus on developing domestic processing and industrial capabilities linked to the energy transition. This includes expanding mineral refining capacity and supporting local manufacturing of materials and components used in renewable energy and hydrogen systems.

Given increasing global competition—particularly from countries such as China that dominate processing and manufacturing—Oman should prioritize strategic partnerships and joint ventures to access technology, markets, and expertise. Developing industrial clusters in key hubs such as Sohar, Duqm, and Salalah will be critical to scale operations and improve efficiency.

At the same time, targeted investment in workforce development is essential to build local technical capabilities and reduce reliance on external expertise.

Long-Term Priorities: Building Resilient Systems

In the long term, Oman should focus on establishing an integrated and resilient resource system that supports both energy security and sustainable industrial development. This requires embedding circular economy principles across renewable energy and green hydrogen value chains by promoting recycling, material recovery, and the development of secondary raw material markets. These measures will reduce long-term import dependence, improve resource efficiency, and strengthen the resilience of domestic supply chains.

At the same time, Oman should continue strengthening regional and international partnerships to diversify critical mineral supply chains and enhance resilience to geopolitical and market disruptions. Integrating mineral availability into long-term renewable energy, green hydrogen, and industrial planning will ensure that future deployment pathways remain aligned with resource availability, industrial capabilities, and evolving market conditions.

Over time, these efforts can position Oman as a regional hub for mineral processing, circular economy industries, energy-intensive manufacturing, and high-value clean energy value chains, supporting long-term economic diversification, industrial competitiveness, and resilience beyond hydrocarbons.

Conclusion

The global energy transition is not only transforming how energy is produced and consumed—it is reshaping the underlying systems of materials, supply chains, and industrial value creation. As reliance shifts from fossil fuels to clean energy technologies, dependence on critical minerals becomes a defining feature of the new energy landscape.

For Oman, this shift presents a clear strategic choice. A transition driven primarily by technology deployment risks increasing external dependence on concentrated global supply chains. In contrast, a transition anchored in value-chain development and industrial integration offers a pathway to strengthen economic resilience, enhance supply security, and capture long-term value.

Oman possesses a distinctive combination of strategic advantages that position it to play a larger role in emerging clean energy value chains. These include its Free Trade Agreement with the United States, direct access to the Arabian Sea and Indian Ocean outside the Strait of Hormuz, extensive mineral concession area 131,500 km^2 with only 35% currently assigned to operators, ambitious renewable energy and green hydrogen development plans, and well-established industrial infrastructure hubs in Sohar, Duqm, and Salalah. Together, these assets provide a strong foundation for expanding mineral processing, advanced manufacturing, and value-added industrial activities.

However, realizing this potential will require moving beyond sector-based approaches toward an integrated strategy that aligns energy planning, mineral development, industrial policy, investment promotion, and circular economy principles. Such an approach will be essential to maximize domestic value creation, strengthen supply-chain resilience, and support long-term economic diversification.

Achieving the ambitions of Oman Vision 2040 will require a coordinated strategy that integrates energy transition planning with mineral development, industrial policy, workforce development, and circular economy principles. Strengthening governance, expanding domestic processing and manufacturing, promoting local content, and building resilient supply chains will be essential to transform mineral demand into long-term industrial value.

The analysis presented in this perspective demonstrates that such an integrated approach has the potential to generate approximately 14,000 jobs between 2030 and 2040, and significantly increase the economic value retained within Oman through mineral processing, manufacturing, and resource recovery.

Ultimately, Oman has the opportunity to position itself not only as a producer of renewable energy and green hydrogen, but as a regional hub for green materials, advanced manufacturing, and circular industrial systems. The success of the energy transition will therefore be measured not only by the amount of clean energy deployed, but by the value created through resilient domestic supply chains, competitive industries, and integrated green industrial development.

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