FUTURE MINERALS FORUM

In Collaboration With

center for ENERGY STUDIES
Rice University's Baker Institute for Public Policy

DEFINING THE "MINERALS HEARTLAND" OF THE FUTURE FROM AFRICA TO CENTRAL ASIA

Future Minerals Forum 2023 Knowledge Paper

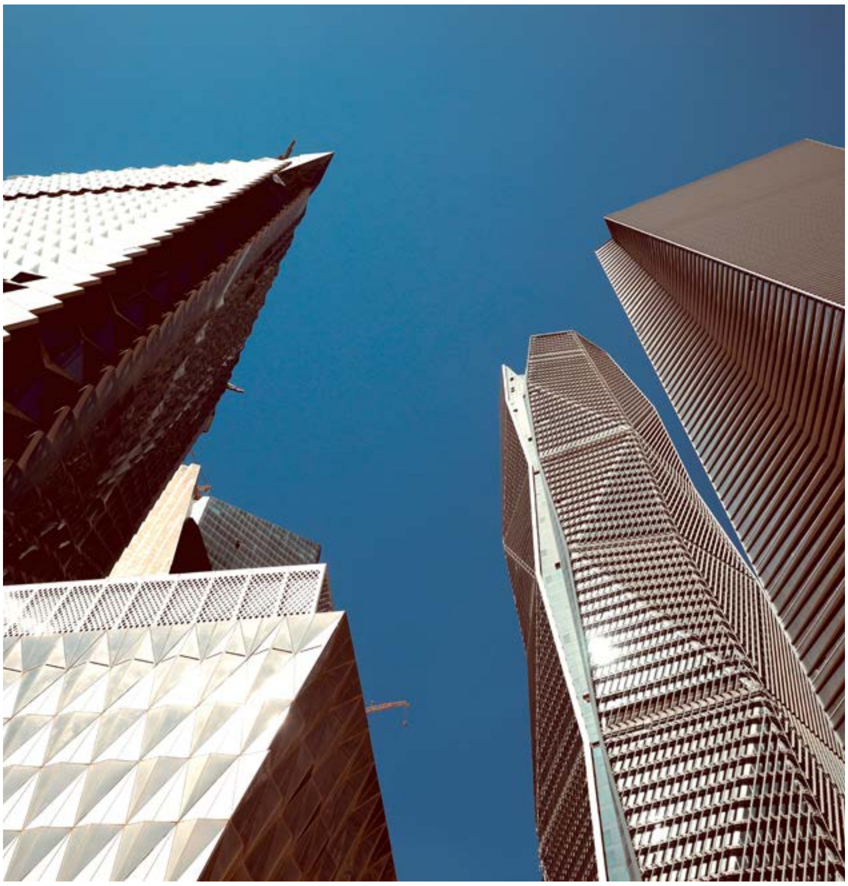
Toward A New Era of Minerals
Be Part of it

Summary

By now, the messages should be clear. For our future energy transitions, however they unfold, **we will require enormous resources in the form of energy, minerals, metals and other materials** along with all of the underpinnings. We also will require **ample human talent and vast financial commitments.**

The purpose of our knowledge paper is to examine the possibilities for an old world geography to lead future development of minerals and metals. **The Minerals Heartland, where first use of native metals by humans occurred, reaches from Africa through the Middle East and into Central Asia.** Long traditions of harvesting resources along ancient storied trade routes characterize the region. To seize their future possibilities, Heartland countries must build platforms that can support mining industries responding to rapidly changing and advancing technologies that are transforming businesses with deep implications for labor and practices. **Of great interest is whether the Kingdom of Saudi Arabia (the KSA) could serve as an investment hub for new ventures that stem from the KSA's own diversification ambitions. Can the KSA capitalize on its global heft in oil, gas and chemicals and its huge financial reserves to help spur expansion of Heartland minerals supply and value chains?**

Apart from energy transition ambitions, the global economy needs minerals, metals, and materials to sustain life, for economic growth and to achieve quality of life improvements for so many. **Our global consumption of non-fuel minerals is nearly as robust as growth in electricity.** This is no surprise since electric power is dependent upon materials inputs. Even more, **our demand for durable plastics and resins has been even stronger than for electricity, for non-fuel minerals overall, for petroleum and natural gas and for key individual commodities like copper, steel, aluminum and cement.**



FUTURE MINERALS FORUM

Our need for plastics for life and hydrocarbons for energy fuels means a responsibility for preserving and increasing hydrocarbon supplies longer than anyone imagines.

The rush to accelerate adoption of 'new energies' – wind, solar, battery-enabled electrification of transport and more – has run up against the realities of what we already use and what will be required for execution. Energy transition ambitions are driving incremental demand for minerals and materials, but wind, solar and battery investments can only proceed at a pace that critical supply chains can support. **A new concept is 'greenflation'.** The pursuit of 'green' energy targets and mandates induces stress on already fragile raw materials supply chains. Investment in raw materials lags, largely due to lengthy and complex development cycles, made more risky and uncertain by mixed signals permeating the financial community and governments. While 'green' energy and the notion of 'green materials' are broadly popular, the basic industries at the heart of supply chains are not. The lack of understanding about the sheer scope and scale of materials inputs for massive deployment of alternative energy technologies means a 'call' on resources beyond what many governments and societies can manage. **All of these factors are placing extraordinary upward pressures on commodity prices.** Worries are that greenflation will be a stubborn phenomenon.

Who is in the driver's seat and with what implications? In these times, **resource rich nations have commanding positions** but must use them wisely, or they will forfeit opportunities. Domestic and geopolitical tensions are surfacing around minerals endowments and exacerbating risk and uncertainty. International commitments to global manufacturing platforms and supply chains are wavering as countries, driven by internal imperatives, strive for increased domestic content and seek to promote national champions. Many questions swirl around China's overwhelming influence and control of capacity for minerals tonnage. China's reach stretches well beyond its national borders, and includes manufactured components that are vital to energy aspirations around the world. China's activities have helped enlarge the global pie of minerals and alt energy tech manufacturing but **the forward path will require much broader and more diverse participation.**

Within this volatile mix, opportunities exist. **As the mining industry and materials suppliers search for new targets, the ancient Minerals Heartland represents an important and alluring cradle for the future global resource base.** The region holds occurrences of, and hosts extractive operations for, most if not all of the minerals deemed critical to strategic energy and other needs. In total, the Minerals Heartland comprises 8% of global mined minerals tonnage, a small share for such a large chunk of the globe.

As well, that 8% pales against the region's dominance in petroleum and natural gas output, nearly half of world supply. Heartland countries are rich in hydrocarbons resources. **The Minerals Heartland carbon endowment is a regional strength and lends itself to opportunities in advanced materials.** Substitution for metals with advanced composites will continue, especially for lightweighting and durability (and for lower energy and emissions intensity). Composites satisfy applications such as advanced battery packaging, wind turbine blades, solar photovoltaics (PV) of all types and foundational infrastructure for modern energy systems (wires and cables that we take for granted). Industrial expansion into advanced carbon materials like carbon nanotubes, CNT, provides avenues for vastly improved performance through their superior electrical and thermal conducting properties, strength and flexibility.

With its rich geology and trading and commerce connections built over centuries, the Minerals Heartland should hold a larger share of worldwide non-fuel minerals output. Heartland countries continue to face huge development challenges. Thus, **the Future Minerals Heartland can only be a magnet for capital flows if sovereign resource owners meet key preconditions.**

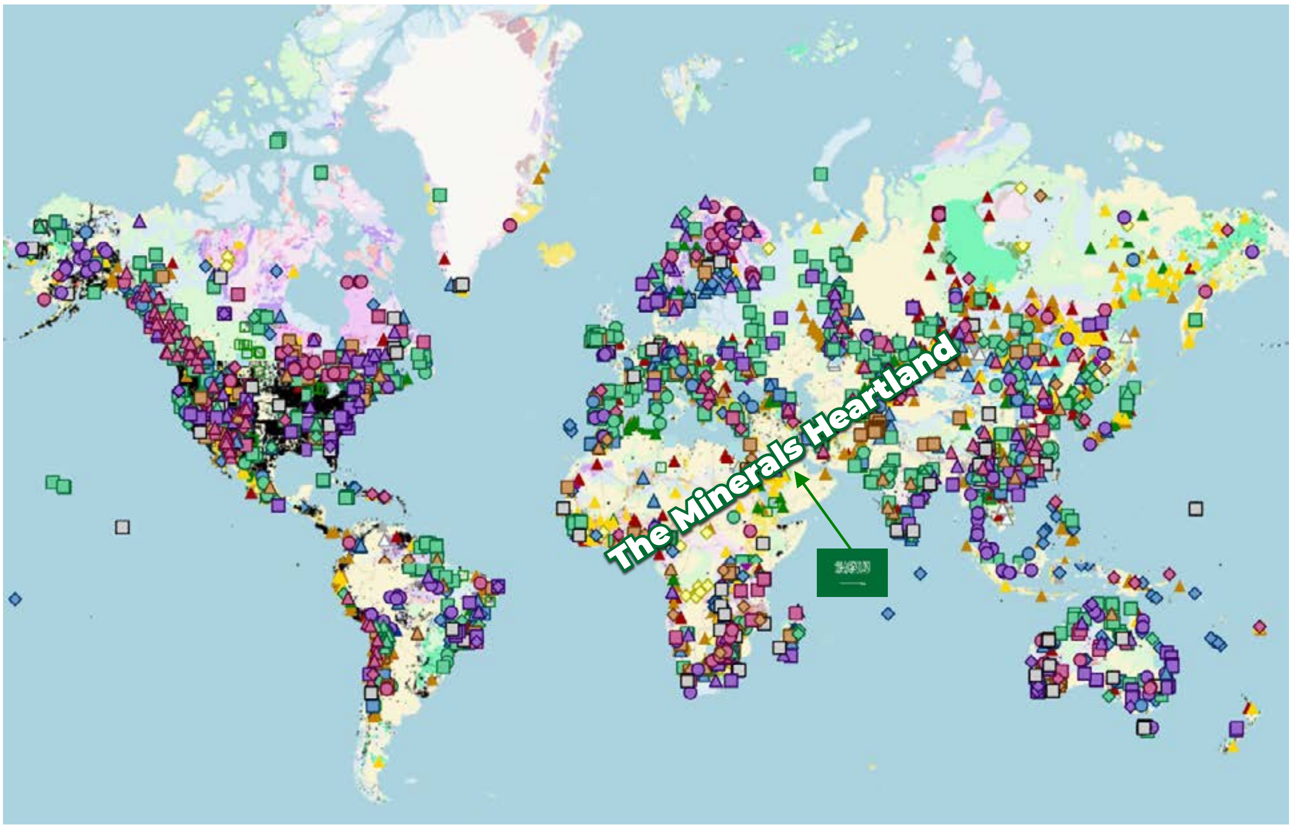
- **Infrastructure** (everything from roads, to rail, to ports and harbors, to energy and water systems) often is lacking for large-scale industries.
- In too many Minerals Heartland countries, the **"commercial frameworks"** (laws, rules, tax regimes, governance in general) that are essential for large-scale capital spending are too weak. High quality commercial frameworks are especially important if the Minerals Heartland

region is to create and capture value from its resource endowments.
- In a world of heightened scrutiny, governments also must strengthen **best practice oversight** of mining and processing businesses including how they capture, distribute and utilize economic rents.

- Large and relatively **young populations** could support robust workforces but governments and their societies must step up education, training and skills development.
- With forethought and careful management, governments and industry can combine and hone human talent and emerging advanced technologies through **centers of excellence** that create more effective clusters for integration of supply and value chains. The "digital mine" is reshaping the industry just as the "digital field" has done for oil and gas. These innovations are crucial to improving and supporting safe, environmentally sound operations.

How does the Kingdom of Saudi Arabia fit in? **The KSA is well positioned to host, invest as a partner in and lead enlargement of critical minerals and materials supply chains for the Future Minerals Heartland.** Certainly, legacy minerals and metals are of interest for manufactured products like batteries and electric vehicles that are current commercial targets. **The KSA can differentiate itself through advanced materials.** Investments already underway in CNT products globally, including by entities such as Aramco/SABIC (Saudi Basic Industries Corporation), **will foster complete redesigns of technologies such as batteries and other primary components and lead to fundamental rethinking of energy systems.** The KSA could serve as a **strategic hub** for investment in advanced materials, helping to enable new capacity and logistics.

The Very Big Picture



United States Geological Survey (USGS) interactive global map of mineral resources, major mineral deposits and critical minerals with underlay of geologic units.

https://mrdata.usgs.gov/general/map-global.html#home

Pictures are worth thousands of words.

The earth's crust is replete with minerals resources. These riches are not equally distributed in quantity, quality or accessibility and thus there is great variation in exploitation. Once we learned how to extract and use them, we humans have tended to locate ourselves where we can best capture fuel and non-fuel minerals. The story of modern economic development is one of proximity to resources and, where those were insufficient, the quest to seek them elsewhere. The most intensely developed resources are where economic development is most dense, or where humans have most easily realized far-flung deposits.

The United States is more intensely developed with exploration, claims and operations than any other country. World War II requirements played a large role. So did free enterprise, including notable 'rushes' for precious metals; access to broad swaths of public land (at least for a time); grit and determination; rapid advances in technology; and, of course, attractive resource endowments and terms (a very low royalty on public lands and, for many decades, relatively light-handed regulation).

Elsewhere lies opportunities – new frontiers and green fields. The Minerals Heartland is one of the largest regions of opportunity. The Minerals Heartland, where first use of native metals by humans occurred some 12,000 years ago, reaches from Africa through the Middle

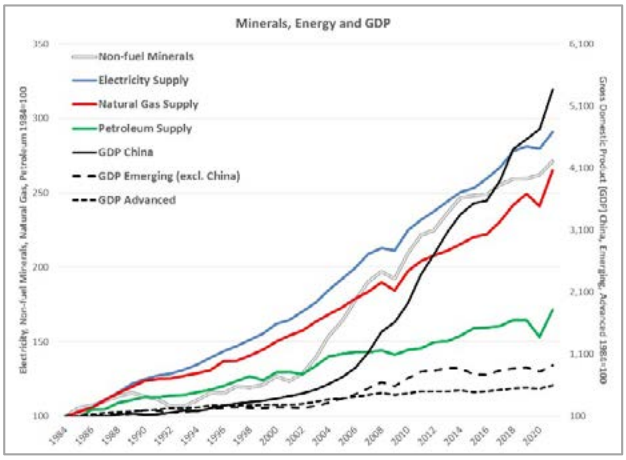
East and into Central Asia. Long traditions of harvesting resources along ancient, storied trade routes characterize the region. Some of the most alluring geology for major minerals deposits lies within Minerals Heartland geographies. The trick is how best to develop this mineral wealth, and how to do so wisely.

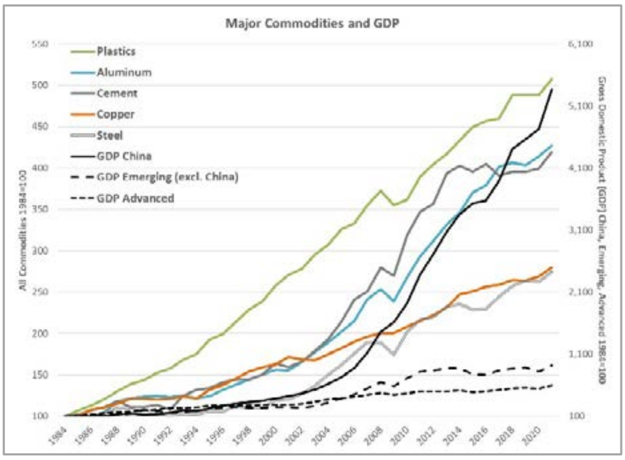
At the heart of the Minerals Heartland lies the Kingdom of Saudi Arabia. **A key question for the future of the KSA is how to play in the new great game of minerals supply chains for the energy transitions that lie ahead.** Minerals supply chains have become more complex and challenging, with their deep geopolitical inferences, enormous costs, vast requirements of technology and skill and, not least, colossal expectations for achievement. For many, that means the future of energy, and nothing less. To seize their future possibilities, Heartland countries must build platforms that can support mining industries responding to rapidly changing and advancing technologies that are transforming businesses with deep implications for labor and practices. Of great interest is whether the Kingdom of Saudi Arabia (the KSA) could serve as an investment hub for new ventures that stem from the KSA's own diversification ambitions. **Can the KSA capitalize on its global heft in oil, gas and chemicals and its huge financial reserves to help spur expansion of Heartland minerals supply and value chains?**

Economic Need, Many Considerations

The global economy needs minerals, and these needs will accelerate if the push on alternative energy technologies (hereon, alt energy tech) unfolds as many believe. Is that push 'sustainable'? Sustainability is a loaded term, subject to the eye of the beholder. We can derive as many different scenarios for how the future might unfold as there are opinions, and there are many contingencies.

The rush in recent years to accelerate adoption of 'new energies' – wind, solar, battery enabled electrification of transport, and more – has run up against a slowly, too slowly, evolving understanding of what will be required. The stampede trampled over a set of underlying fundamentals: Supply and consumption of non-fuel minerals was happening at a faster pace even than petroleum and natural gas. Demand for minerals has been nearly as robust as growth in electricity.



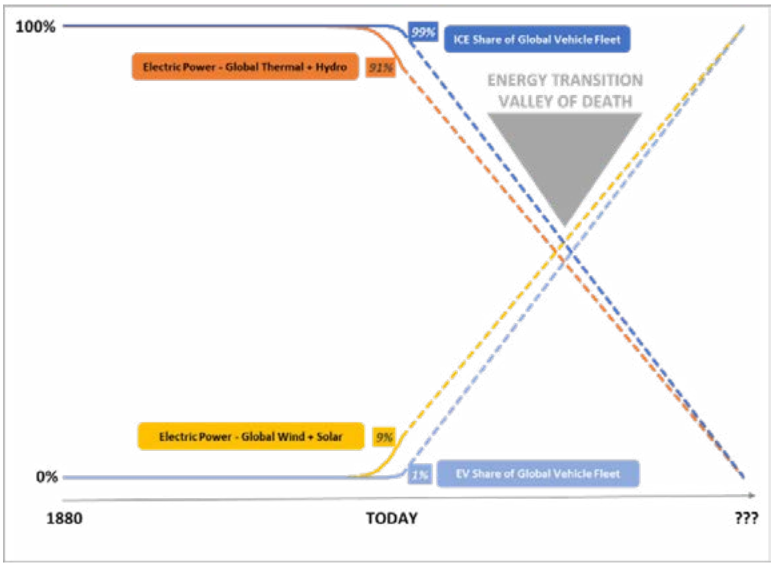


Created by author using BP Annual Statistical Review of Energy, World Mining Congress/World Mining Data, International Monetary Fund, International Energy Agency, American Chemistry Council, USGS, International Aluminum Institute, International Copper Study Group, Worldsteel. Published elsewhere, used with permission.

Even more, **our demand for plastics and resins, literally the stuff of life, has been even stronger.** Where other closely watched commodities – aluminum, cement, copper and steel – have their ups and downs with business cycles, the march in consumption of plastics has been nearly uninterrupted.

While food grade plastic waste garners the most attention, and public concern, the materials most sought after are the advanced composites, fibers, films, adhesives and countless other products that we can form into a range of items that would be difficult to live without. From bottles for baby formula to dashboards in cars and trucks, from our laptop keyboards to snazzy ear buds, from permanent press fibers to essential, life-saving medical devices and equipment, plastics command a unique position in the modern global economy. **Substitution for metals represents a first consideration for any long run view of the future:** We have long used plastics to substitute for metals, a trend that will continue and accelerate. Wherever lighter weight, durability, portability and safety are criteria, plastics have made inroads. The KSA and the immediate geographies are rich in carbon bearing minerals. Indeed, the 'Minerals Heartland' nomenclature is a derivative of an often-used precursor, 'Petroleum Heartland' to capture the region's role as a breadbasket of hydrocarbons for the globe and its long, exotic and complex Silk Road history. [1]

A second consideration stems from a basic question: What, exactly, does the future hold? Alt energy tech is entering markets – that much is a fact. Battery electric and hybrid electric vehicles are on roads and exiting production lines. Wind and solar are making incursions into electric power markets. How are these technologies likely to change as in response to calls for better performance? With what consequences for raw materials supply chains? By themselves, battery chemistries are moving targets as manufacturers seek to encourage customer adoption for larger scale energy storage and mobility. These unknowns widen uncertainties surrounding the extent and timing of market penetration of these and other technologies and, thus, their impact on legacy fuels and energy systems.



Based on a variety of sources including World Bank, IEA, BP Annual Statistical Review of Energy, U.S. Energy Information Administration. [2]

In a classic chicken or egg, alt energy developments both drive incremental supply of and demand for minerals and materials, but can only proceed at the pace at which minerals and materials supply chains can support them. A new concept is 'greenflation'. The pursuit of 'green' energy targets and mandates induces stress on already fragile raw materials supply chains. Investment in raw materials lags, largely due to lengthy and complex development cycles, made more risky and uncertain by mixed signals permeating the financial community and governments. While 'green' energy and the notion of 'green materials' are broadly popular, the basic industries at the heart of supply chains are not. The lack of understanding about the sheer scope and scale of materials inputs for massive deployment of alternative energy technologies means a 'call' on resources beyond what many governments and societies can manage.

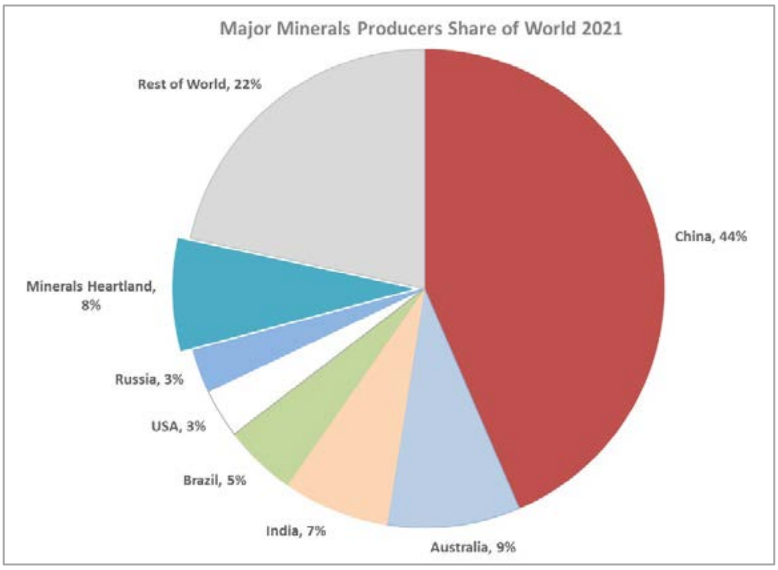
A good deal of rapidly embedding price pressure around the world can be traced to attempts by governments to accelerate the push into alt energy schemes. These priorities compete heavily with non-energy requirements, of which health stands out in the post-Covid pandemic era, and defense, an increasingly sensitive topic as security realignments unfold. Motivations for alt energy programs range from pandemic recoveries, to economic development and jobs, to purported environmental benefits (the distinct environmental footprints associated with alt energy technologies are only now being investigated [3]). No matter the source – World Bank, International

Energy Agency (IEA), private consultancies, research think tanks – very large multipliers on future demand for raw materials are being assigned as assessments for input requirements are made.[4] Yet, global capacity is constrained in a variety of ways and world events have a way of crashing into long term outlooks, making for very wide cones of uncertainty.

A third consideration emanates from who is in the driver's seat, and what that means. In these times, resource rich nations have commanding positions but must use them wisely, or they will forfeit opportunities. Domestic and geopolitical tensions are surfacing around minerals endowments and exacerbating risk and uncertainty. International commitments to global manufacturing platforms and supply chains are wavering as countries, driven by internal imperatives, strive for increased domestic content and seek to promote national champions.

Many questions swirl around China's overwhelming influence and control of capacity for minerals tonnage. China's reach stretches well beyond its national borders, and includes manufactured components that are vital to energy aspirations around the world. China's presence has been so prevalent that any risks and uncertainties to China's economic fortunes merit serious contemplation.

Since the early 2000s, China's massive 'coming out' party has been the single largest factor influencing energy and materials consumption. China's industrialization meant a nearly insatiable appetite for raw materials, an event unlike anything in human history. In large part, this has come as many industrialized nations shed their manufacturing capacity, along with underpinning supply chains, to China and other emerging markets that were better able to compete as lower cost alternatives. In particular, China has soaked up inbound, foreign direct investment in technology, equipment and factories, becoming more sophisticated in products and services as the process unfolded. As it has so many times before in the history of civilizations, industrialization in China took hold and flourished in close proximity to China's own natural resource wealth. China's position as the top producer of minerals in total tonnage reflects internal commitments to growth and recognition of raw materials necessities. China also has become a significant, if not the most significant, investor in raw materials abroad.



Based on total metric tonnes, all products, as of 2021. Created by author based on USGS as compiled by CES. [5]

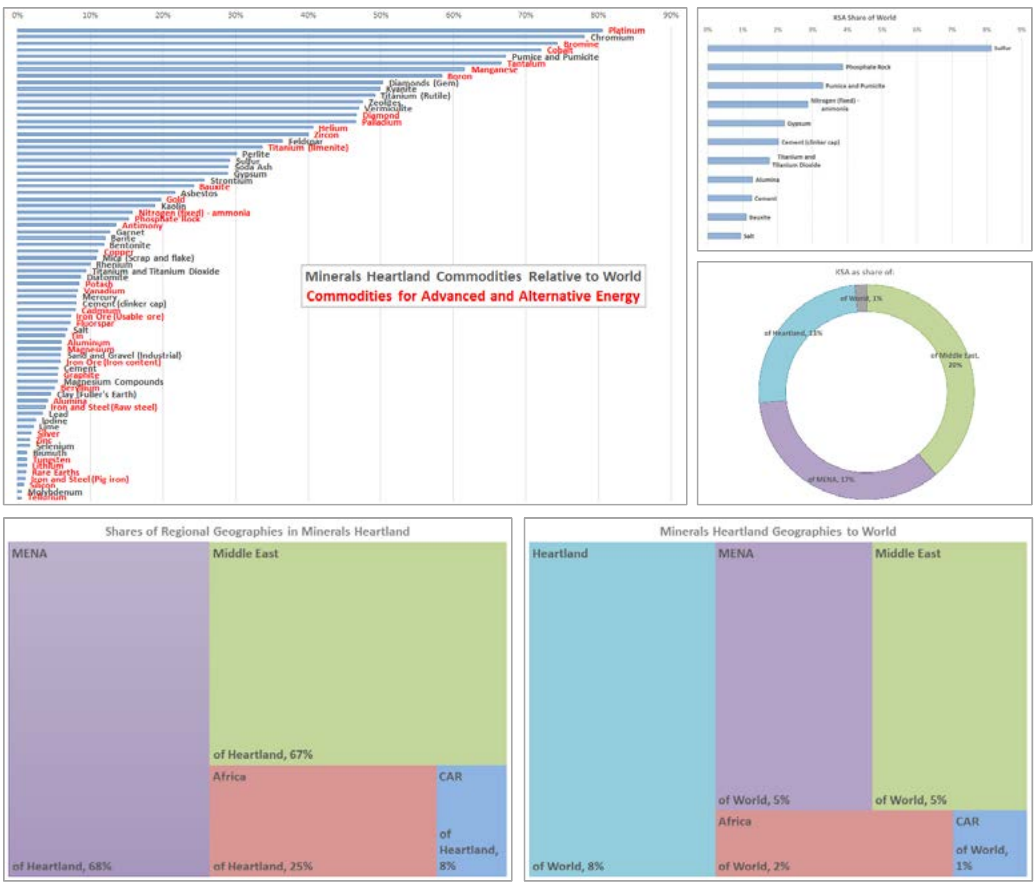
China's prevalence heightens when attention turns to advanced and alt energy tech that is widely deemed to constitute the bulk of attention into the future. Of all nations, China has made the most pronounced strategic shift toward alt energy as strategic imperative for growth and exports. Internal energy needs are benefitting as a byproduct. China's leaderships over recent administrations have focused on electric and hybrid power trains for mobility. The country commercialized solar photovoltaics (PV) from early Japanese designs and, with wind, has positioned itself with significant capacity additions. Coincident with these efforts are the push into telecommunications and electronics. All require raw materials, well beyond what domestic mines and processing facilities can contribute. Estimates are that, through both their internal industries and associated international supply chains (mining through minerals processing, refining, smelting), China controls: more than 90% each of gallium and germanium; 80% of rare earth materials (currently, all U.S. rare earth mined output is sent to China for processing); 70% of graphite/graphene; 60% of lithium; nearly 60% of vanadium; 41% of indium; 36% of cobalt. China controls 50% or more of copper refining and dominates international copper and lithium trade.[6] Along with these, China's manufacturing heft runs to roughly 60% of wind turbines, 70% of solar PV and 70-80% or more of large format batteries for vehicles, depending upon chemistry and status of capacity additions.[7] For all of the concern about Chinese presence across supply and value chains for strategic, critical and base materials, they have helped to enlarge the global pie and serve as tutorial on positioning.

China's activities have helped enlarge the global pie of minerals and alt energy tech manufacturing but the forward path will require much broader and more diverse participation.

Diving into the Minerals Heartland

Does the region have resources? The short answer is 'yes'. As the Minerals Heartland geography enlarges (from the KSA, to the remaining 17 countries of the Middle East, the remaining 53 countries of Africa, the 5 Central Asia Republics and Pakistan to complete the 'stans')[8] , current and potential future production reserves and resources also expand.

For all of its potential, given attractive geology across the greater region and existing operations and production, the Minerals Heartland punches well be below its weight in its contribution toward non-fuel minerals and materials supply. Take all together, the enormous Minerals Heartland region is a mere 8% of global total minerals tonnage. A smaller geography, Latin America (Mexico to Cape Horn) and Caribbean provides 6%. Both regions provide about as much minerals content to the global economy as India alone. When compared to China's 44%, every other geography pales. Across the Minerals Heartland region and respective countries, there is huge variation in exploitation, maturity of businesses and ability of countries to support the mineral extractives industries including, crucially, in terms of workforce and infrastructure. As well, much of Minerals Heartland simply is remote, imposing severe tests on logistics. The KSA itself produces basic commodities for applications like construction and fertilizers in keeping with its trajectory of mineral development thus far. The KSA also produces small amounts (well less than 1% of world totals) of magnesium, feldspar, talc, kaolin, gold, copper, zinc, silver and iron. Efforts such as the licensing rounds for Umm Ad Damar[9] and recent award of and exploration license for Khnaiguiyah[10] as well as recent projects like the start up at Ad Duwayhi[11] will add to the inventory of base and precious metals. Ma'aden's phosphate expansion[12] will contribute tonnage for a key KSA product.



Based on total metric tonnes, all products, as of 2021. Created by author based on USGS as compiled by CES. Note that shares reflect tonnages for countries as reported by USGS. In any given year, the USGS only reports tonnages for major country producers.

As noted previously, of interest worldwide are minerals commodities deemed critical to alternative and advanced energy applications (denoted in red in the preceding figure). The Minerals Heartland dominates among many of these, largely because of outstanding producers and in particular powerhouse African nations. The Democratic Republic of Congo's (DRC's) command of 76% of the world's cobalt is the subject of much attention. South Africa alone provides 75% of global platinum and 40% of palladium, metals in use for the only commercial hydrogen fuel cell design, and 38% of manganese, key to battery chemistries such as the lithium ion-based NMC (nickel, cobalt, manganese) and zinc alkaline. Qatar is a major supplier of helium with a 32% market share of a noble gas vital to semiconductors manufacturing. The Heartland region includes substantial producers of diamonds and gold, of interest for new semiconductors designs and advanced solar. The region is rich in phosphates, with more slated for development beyond capacity additions in the KSA. The lithium-iron-phosphate battery chemistry is gaining interest as a lower cost alternative to NMC formulas. The region overall stands at 6-7% of global total iron (ore and usable content) but ranks lower, at 4% for raw steel.

Where shortcomings in minerals contributions can be defined – for instance, nickel, iron, aluminum, copper along with essential infrastructure materials like steel – focus and diligent pursuit of solutions could cure gaps. Copper and titanium could be targets in Africa and Central Asia as well as in pockets of the Middle East. Minerals could be extracted from deep brine pools in the Red Sea[13] , long discussed as a potential target, along with other locations. Operators could capture elements like gallium, germanium, indium and tellurium[14] , with planning and ability to attract investment interest, from copper, zinc and alumina processing and refining, the latter as part of growth in aluminum output.

A Minerals Heartland SWOT

Imagine a strategic analysis of the Minerals Heartland region, a SWOT assessment if you will (strengths, weaknesses, opportunities, threats). The region's core strengths lie in vast, under- and unexplored territories that are widely thought to be minerals rich based on geology and various attempts at pursuit. Africa, Afghanistan and the broad valleys of Central Asia ('missing links' in the knowledge base on Heartland resources[15]) represent enormous frontier geographies within the greater Minerals Heartland region.
Minerals reserves can only be estimated from exploration drilling and operations. Enormous reserves of platinum group metals (PGM) reside in South Africa. Morocco has huge reserves of phosphate rock and phosphates are abundant through North Africa into the Middle East and the KSA. Natural graphite in Tanzania and Uzbekistan and rare earths in Tanzania and rare earths in Tanzania and South Africa all afford options to supply chains. Bauxite in the KSA, Kazakhstan, Ghana and elsewhere can support the aluminum value chain and coproducts. Resource potential based on occurrences throughout Africa, Middle East and Central Asia place these locations high on any overview of global minerals-enabling geology. [16]

Mining and beneficiation require energy, lots of it. Throughout the KSA, Middle East, MENA and Minerals Heartland geographies, energy is a distinct advantage. Petroleum, natural gas an coal produced in the Heartland far exceeds the region's 8% share of non-fuel minerals. The Minerals Heartland region commands large shares of global petroleum reserves with the KSA comprising, 17%; all of the Middle East, 48%; Africa, 7%; and Central Asia 2%. When it comes to natural gas reserves: Central Asia increases to 10%; the KSA and Middle East are 3% and 40%, respectively; and Africa 7%. Altogether the Minerals Heartland makes up 44% of global daily crude oil and 34% of natural gas liquids supply (43% of total world liquid energy supply), and 29% of natural gas output. Coal resources are less abundant. Overall the Minerals Heartland is about 5% of global coal reserves and 15% of mined coal tonnage (all based on 2021 data from BP Annual Statistical Review of Energy). Large suppliers of coal are proximal to the region.

Where petroleum, natural gas and other energy fuels are scarce, supply links can be forged. KSA based businesses already are building customer relationships in East Africa and beyond for petroleum products. Electric power is less robust outside of more advanced economies in the Minerals Heartland. Here lies a distinct area for improvement, with African and Central Asian electric power long a project for international donor countries and multilateral organizations and development banks. An interesting consideration for the future lies in rich endowments of uranium. Kazakhstan produces more than half of global uranium supply and contains large reserves. The KSA has invested in yellowcake preparation and the UAE and Iran operate nuclear facilities. Surging interest in small-scale modular reactors (SMR), new nuclear technologies, fusion and new materials for nuclear energy are garnering investor interest as realizations grow that nuclear is a necessary component of the global energy equation.

Opportunities are well in place for the minerals industries. The global demand drivers outlined above, in particular the notions about 'energy transitions' (there are many possibilities), are the main storyline. As noted, the cone of uncertainty in this regard is much larger than often presented in opinions and analysis. Investors and host governments will face many bumps, not least in commodity prices, as the storyline unfolds.

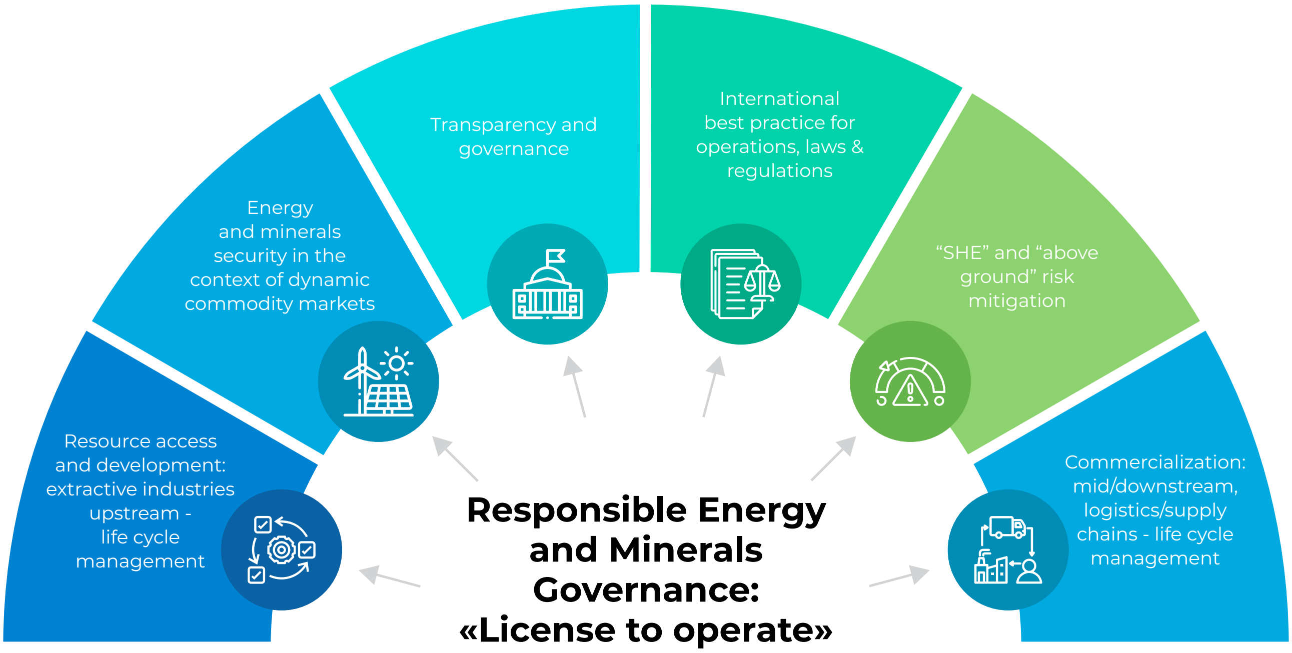
A distinct advantage in the Minerals Heartland is hydrocarbons resource abundance for both fuels and materials, including advanced materials and energy sources. The future being plastics, and carbon being the basis for life on earth, Heartland participants can consider a host of enticing options. Lithium-ion battery safety is fraught with difficulties and weight for vehicles and devices is a distinct issue, as observed. Advanced battery packaging with combinations of plastics and aluminum or other materials may ensure protection against thermal runaway events. Plexiglas is an important enabler of solar PV. Wind turbine blades are akin to oil and gas wells spinning in the skies – modern blades are sophisticated constructs of thermoplastic and fiberglass.

The value of carbon is almost endless. Highly conductive carbon nanotubes (CNT) for electric power applications, displacing copper or aluminum? CNT cables and wiring are making inroads into aerospace where light weight superior conducting materials can contribute meaningful improvements to fuel efficiency. CNT batteries are in active development. Graphene to displace natural graphite for battery electrodes and other uses? Graphene for semiconductors? Nanomaterials for water and medical filtration? 'Decarbonization' of oil and gas upstream and downstream processes as well as thermal power generation flue gases and other heavy industry smokestacks affords an array of opportunities to solve a weakness and threat attributed to fossil fuels and materials, namely greenhouse gas (GHG) emissions. Capture of carbon dioxide, CO2 coupled with recycling carbon into other uses is on active radar screens. Reduction of fugitive methane emissions makes more methane available as energy for work. Unique strategies are emerging, like pyrolysis of methane for hydrogen production with the black carbon byproduct deployed into products like tires for vehicles, soil amendments for fertility and soil remediation for treatment of hazardous materials. Used plastics can be recycled through advanced processes with conversion of materials to graphene. Those same processes can be used for 'urban mining' the nomenclature of modern harvesting of waste streams, including plastics and electronics, for metals and other key materials. [17]

Weaknesses and **threats** are many and varied. Weaknesses lie in constraints already referenced (geological attractiveness, outlooks for demand, workforce and infrastructure) along with other considerations such as energy and water resources to support development, much less populations. Threats are ever-present in rivalries and conflicts that can erupt in 'soft' disputes like trade or hard conflicts like wars.

Moreover, strengths and opportunities are contingent on how well countries run their economies, on geopolitical risk, quality of and depth of workforce and infrastructure as previously highlighted.

Mining and metallurgy – like all natural resources, extractives businesses – rely on enabling 'commercial frameworks' that often are lacking. Mining and beneficiation value chains are complex and fraught with risk (are the minerals of interest present?) and uncertainty (in what quantities, what quality and therefore what requirements for treatment and at what price??). Every commercial framework represents a 'solution' in the form of a 'license to operate' that is an often-fast moving target as political, legal, policy, regulatory, market, societal and cultural dynamics unfold.



Developed by author, used with permission.[18] 'SSHE' is safety, security, health, environment.

As these dynamics play out within host countries and locations they often are influenced heavily by external groups and interests that have no direct, or even indirect, benefits or cost, no 'skin in the game', in projects. We find ourselves in a time in which consensus on the need for raw materials is forming rapidly with imperatives for alt energy tech as a priority for many interest groups and non-governmental organizations (NGOs) who also oppose facets of or even wholesale the mining and beneficiation industries. Even within countries, even among those with the largest resource endowments, conflicts over exploitation of those endowments are growing. Some internal conflicts are taking forms that could be damaging if countries move to restrict access and/or make other moves such as restricting exports of product. Either/both can constitute a form of much-discussed 'resource nationalism'.

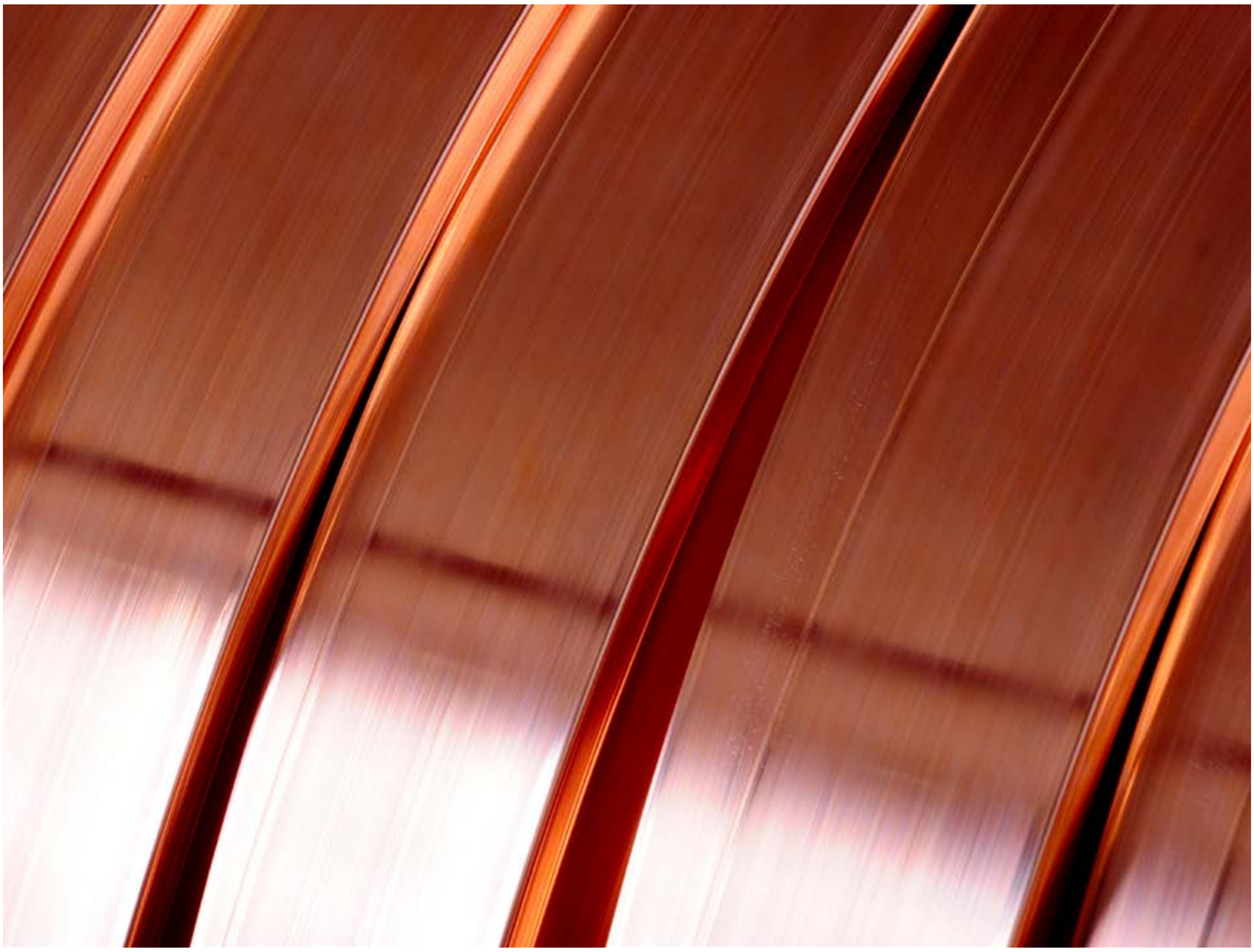
Nor are outright nationalizations no longer a risk factor. The Indonesian takeover of Grasberg drew attention to a form of government intervention that many thought to be passé. Indonesia's intention for its ban on nickel exports is to induce value added processing and battery manufacturing.[19] The ban has the effect of constraining supply and influencing price. It also plays into rumors and innuendo regarding producer associations and possibilities for cartels, an old phantom of the global metals businesses.[20] It all makes for an interesting stew.

Countries with less attractive resource endowments – and even those with major reserves and assets – can make themselves more attractive by improving any one of the pre-conditions needed for effective commercial frameworks. Countries can revisit their internal rules and playing fields for investment. They can streamline and deepen their ability to monitor and ensure 'SSHE' practices – a high priority for both workers, integrity of facilities, and safety of surrounding populations. Infrastructure – roads and rail, ports, harbors, energy and water systems – are vital for large-scale basic industries. Countries can target gaps in infrastructure, energy and water and/or other inputs, enhance workforce training and skills development. In locations within the Minerals Heartland where water supply is acute and where efforts include desalination, opportunities exist to couple water treatment and energy to serve and support minerals extraction and development. Harder work revolves around settling internal and regional disputes and tensions that could threaten economies and industries; working with local communities most immediately affected by operations, thus helping to smooth support for expansions and new projects. Altogether, these and other efforts to shore up commercial frameworks help to make the investment case.

Articulating the continuing need for raw materials will be essential for the industry and governments as they move ahead. This means clear explanations of what is entailed and how the industry along with its host governments and jurisdictions work to ensure safe, and sound, practices.

'Job One'. The Minerals Heartland can support many of the required global metals and specialty chemicals supply chains as nations move forward to meet their materials requirements. Indeed, the Heartland would add much needed diversity to global supply chains. Huge Asia-Pacific players supply iron ore, nickel, copper and other metals. Latin American countries serve as vital raw materials pipelines especially for copper and lithium. China dominates as both the largest supplier of nearly every mineral and metal of interest and as customer for all. The value chain creation and value creation propositions already alluded to plus many others are very real. Enabling, resource-owning governments must better understand the required 'lift'. For instance, the region could produce more finished aluminum than the 6% currently contributed to the world. Rather than exporting bauxite, of which the region accounts for 24% of world output, for value capture elsewhere, regional investments could be made in intermediate alumina production (current global share of 4%). Along the way, investment decisions could be focused on gallium capture, helping to achieve a highly desirable diversification for customers sourcing that element. Ghana and other countries would almost certainly look favorably on such strategies. Aluminum production thrives in locations where hydropower is abundant or prospective, and where that energy source can be pursued with government and public support.

In similar fashion, the Minerals Heartland only contributes 2% of global zinc. Kazakhstan holds large zinc reserves, other Heartland locations offer potential. Investment in zinc processing would offer the chance of improving germanium supply, again a highly desirable outcome for world economies.



Copper is the primary ingredient for electrical systems. The Minerals Heartland contributes 11% of global copper supply, the DRC is one of the larger producers and reserves holders. Copper production occurs in Kazakhstan and copper resources are believed to be substantial in Central Asia and other locations in Africa and the Middle East. Out of the copper value chain can come any number of critical materials – tellurium and indium, along with typical coproducts gold and silver – all of which are highly valued for energy and other industrial and consumers uses along with defense. One of the more prevalent data points is that electric vehicle powertrains are expected to contain 3 or more times the copper content as conventional internal combustion engine (ICE) designs. [21]

Zimbabwe is the lone producer of lithium in the Minerals Heartland, giving the region its 1% share of probably the most talked about mineral (specialty chemical). No estimates are put forth of lithium resources, but that does not mean there are no occurrences. A first lithium extraction facility is located in Abu Dhabi.[22] Lithium is a distinct price when and if investment into Afghanistan flows.[23] Lithium is dispersed in oceans and brines, including sources in the Middle East, making collection a challenge but pursuit is underway. [24]

A consideration for many materials is quality. Nickel requires different processing from laterites, common among producers like Indonesia and Philippines and the most common ore source for nickel worldwide, than it does sulfides, with Russia and Brazil as examples. Sulfides more easily support Class 1, 99.9% nickel purity that batteries and other products rely upon.[25]

Lithium carbonates, typically from brines, and hydroxides, as from Australia's spodumene, are preferred for different battery chemistries. Battery makers have gravitated to hydroxides for the NMC formulations. And so on for many other minerals bearing strategic and critical elements and their ultimate use in materials. Moral of the story, it is not just about the tonnage, it is about the composition of that tonnage. Additional processing steps mean additional costs and pressure for price premiums in order to profit from strategies in which investors chase lower ranked, if more abundant, mineral sources but must deliver the quality customers expect.

For any and all of these supply chains to establish and/or grow and mature, it takes money, and lots of it. By every measure, the hundreds of trillions in alternative energy investment will requires hundreds of billions, perhaps trillions, more for raw materials, processing and associated logistics and other inputs. One estimate is nearly U.S.$2 trillion for raw materials by 2035 alone, notwithstanding the trillions more as world pushes toward some version of our alternative energy future. [26]

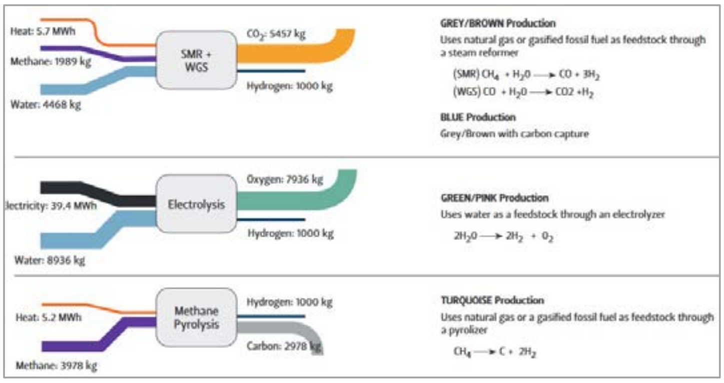
When it comes to entry investments for minerals projects and building and expanding supply chains, there is a great deal to consider. Countries that are recipients of inbound investment for minerals and materials targets often negotiate for other things. Some of these, like enhancing workforce or making side investments in infrastructure, are deal killers if the geologic target is not attractive enough or the commercial terms overall are unappealing. With outstanding opportunities come a greater willingness to invest in order to close gaps and cure shortcomings. Host governments cannot all expect the same willingness by investors to take on additional challenges. Nor can investors endlessly absorb non-core commitments.[27] The mining businesses are extremely sensitive to cycle time. In its review of critical minerals requirements for energy the IEA estimated that cycle times for mining projects can be upwards of 20 years, on average.[28] A notable copper project in the U.S., Resolution, has topped 20 years as proponents continue to try to move the huge project forward.[29] While 'green' energy and the notion of 'green materials' are broadly popular, the basic industries at the heart of supply chains are not. In capital-intensive industries with high degrees of risk and uncertainty, companies will seize any advantage to shorten cycle times from concept to final investment decision (FID) to commissioning and first paid production. Reducing cycle time increases prospects for profitability and ensures reliable minerals and materials supply, as IEA notes in its report.

FUTURE MINERALS FORUM

Considerations for the Kingdom of Saudi Arabia

The notion of the KSA as a hub for strategic and critical metals and materials is not outlandish. For the KSA in particular, ambitions for value added manufacturing and a diversified economy mean not only effective domestic extractives business and supply chains but also robust supply chains with external trade partners to fill gaps. Consequently, the KSA faces necessary, but also attractive, outbound investment opportunities. Presumably, the KSA will want to avoid the same pitfalls in order to ensure success.

Moreover, the KSA's ambitions to serve as a 'green metals' hub and source of cheap energy fueled by clean hydrogen along with fostering domestic battery and electric vehicle manufacturing[30] means metals requirements of its own. The challenges of hydrogen whether for industrial and end user customers and consumers lie in its inherent properties. The corrosive nature of hydrogen means robust metallurgies for pipelines, storage facilities and containment in vehicles. Its explosive properties mean safeguards for handling and use. Noble metals such as platinum and possibly palladium are the standards for hydrogen fuel cells. Expensive metallurgy or alternative materials for pipelines and other infrastructure and end use products means higher costs.



Rainbow colors of hydrogen. [31]

For the KSA, positioning as and building such a hub will mean proactive investment and trade outreach. In an age of active investment from oil development in the KSA, Middle East and greater Minerals Heartland regions, investors' expectations still must be met.[32] As well as the caution flags for KSA-led and backed outbound investment in key supply chains, all of the preconditions explored in this paper apply to KSA internally as well when it comes to closing gaps in commercial frameworks, workforce, and infrastructure in Saudi Arabia.

What do investors expect? Attractive returns, for sure, meaning rewards commensurate with risks. The sheer array of industries and businesses involved with inherently different, and often conflicting, cost structures, technologies, logistics and socioeconomic and sociopolitical variables makes selection of investment targets challenging, in the least. For all of the attention, 'ESG' (environment, social, governance) is proving unsatisfactory as an investment filter.[33] Increasingly, ESG is seen as an imposition from industrialized countries, their financial institutions and regulators and NGOs on the rest of the world. Yet money, sovereign wealth, is not the only answer. To achieve status as a regional hub, the KSA must grow its own market, which means opportunities for citizens, especially younger generations more sympathetic to the products and associated services that KSA-based businesses will market.

Competition for capital around the globe for energy and materials is enormous. Competition for capital for everything else – health, education, defense, and so on – is even greater. The KSA's sovereign funds and the global heft of its primary industries and businesses provides an edge relative to nearly every other nation. **Ultimately, capital will flow to and from the KSA where preconditions are most satisfactory.**

State of the Global Mining Industry

Everything addressed thus far runs smack into harsh realities that permeate the mining industries. Exploration for new resources, exploitation, beneficiation – the mining industry is trying to do it all. Companies, whether private, publicly traded or sovereign/state owned enterprises (SOEs) are working to grow production in response to all available signals while also responding to the gamut of ESG pressures. They are tackling growth and responding to increased examination of their businesses in a world in which capital has never flowed easily to mining and minerals processing. Meanwhile, the chief imperative for the industry is safety (SSHE more broadly), which more than anything drives local acceptance of mining businesses.

The major trends in mining[34] are widely known within the industry and businesses but much less widely perceived among policy makers and the public at large. Operators everywhere, even at relatively new facilities, face low and declining head and ore grades. For most products, typical grades are well below 2% per tonne of rock and usually below 1%. As mining progresses grades decline – as with oil and gas, mine plans emphasize recovery from the best locations first. That means that grades decline with maturity of assets. The industry also has targeted the most attractive, most easily accessed locations worldwide. As noted earlier, for much of the Minerals Heartland, remoteness and physical access are substantial hurdles. The better the geology, the more supportive the commercial frameworks, the more easily the industry can overcome those hurdles but they play to longer cycle times and thus pressures on profitability. Lower grades mean more intense energy and water inputs, larger emissions outputs and more waste that must be handled as companies work to extract usable metals from tonnes of extracted rock.

From drilling for exploration to mine planning to initiating excavation, the process is capital intensive and hazardous. That means training, SSHE oversight, and appropriate government oversight for both workers and communities. It also means favorable business conditions – supporting commercial frameworks. These include fiscal terms (what miners pay to governments in taxes, royalties, other distributions), commodity prices, supporting infrastructure, workforce, political/country risk and much more.

The Digital Mine

A key trend in mining is digitization. The 'digital mine' incorporates a range of innovations, from automated (driverless) haul trucks to automated control rooms to advances like drones to aid and improve locations of drill holes for blasting as excavation proceeds. The digital mine trend extends to underground operations with robotics for blasting and excavation and automated conveyer systems for removal of rock. Mine planning and project management oversight can be remote, as it is for oil and gas, and miners are taking full advantage of machine learning and emerging artificial intelligence. 'Big Data' is every bit as popular for optimizing mines and processing as it is for oil and gas fields and midstream and downstream facilities. Digitization – deployment of an array of information technology, IT tools to the mining businesses – has long emerged as a top ten, top tier priority in annual surveys of the global industries by the Big 4 accounting groups.[35] As well, all of the tracking reports coincide on:

- the major drivers – the push into alt or new energies;
- the implications – increasing competition across end uses of minerals and materials including civilian and defense needs;
- signals – volatile commodity prices;
- shifts by resource owning governments as the seek to maximize capture of economic rents and exert more control over operators in order to achieve domestic priorities; and
- ESG management in, hopefully, the most cost effective ways.

A distinct tradeoff of digitization is workforce. In general, digitization, including automation, means fewer jobs. Fewer jobs means fewer workers. Fewer workers means fewer incidents and better safety records. The end-result is not the bulk, job creation machine that many governments expect and advertise to their societies. It is, however, a job and workforce redefining and refashioning of the mining businesses that, for businesses in which lost time incidents and fatalities are unacceptable, is unquestioned.

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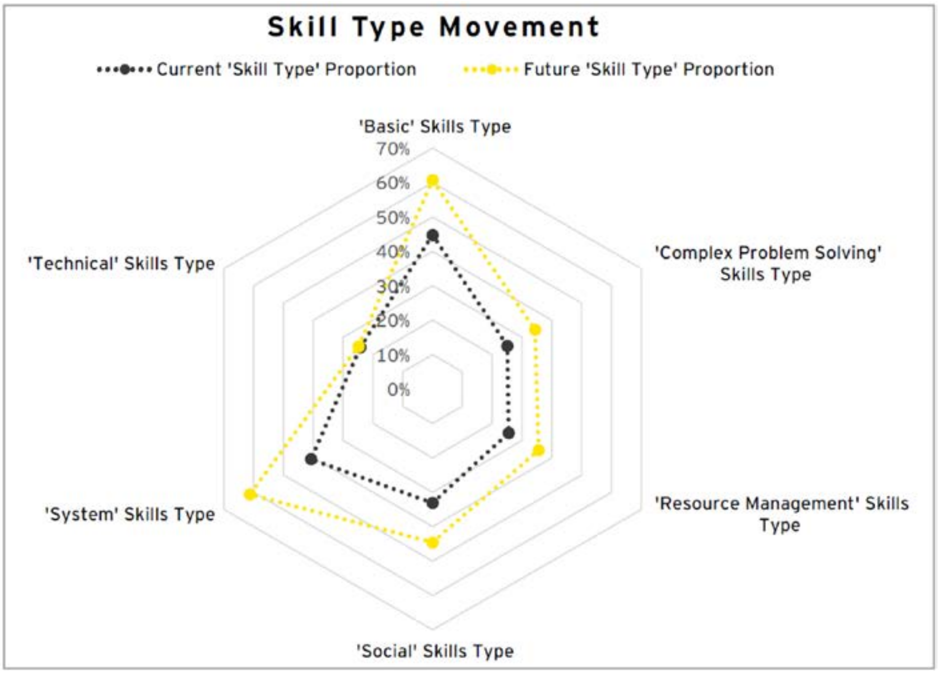
Digitization means higher level of skill and different skills required for an industry in which still, in many countries, relies on human brute force much of it provided locally. It also bears consequences for how the mining industry is organized in many countries, especially those in which small miners and artisanal and informal mining still is an active part of the mining scene, and even a protected one.



Shifts in skills requirements for the digital mine. [36]

Finally, the digital mine bears enormous implications for universities and vocational training of the future workforce. In the U.S. and Europe where enrollments in mining related programs are depleted, an outcome of a maturing, shrinking, less competitive landscape, education and training can emphasize emerging research and development, R&D, in how engineers and scientists, accountants, economists and future financiers are trained and prepped for future employment. Even in many mining countries outside of the richest OECD members (Organization for Economic Cooperation and Development), digitization is making inroads into traditional education and training as trends take hold. To be competitive for inbound investment, countries will need to present workforce attributes and educational platforms that reflect where the mining industry and businesses are heading. Along with many other pre-conditions, miners may need to up their direct workforce investments. Flexibility in government rules for hiring, movements of expatriate employees, and other considerations will be needed to smooth the pathway ahead.

Is the digital mine a consolidation trend? Will it cause the industry to coalesce around the best positioned, biggest operators most able to take advantage of the digital toolkit? Coupled with ESG, these trends would seem to undermine ability of smaller operators to survive and compete. And yet both could be enabling. The digital toolkit will eventually become cheaper and more widely available. Developers and vendors of software and control systems have every incentive to sell their wares to as many customers as they can. The broadening of the digital toolkit and declining unit costs also fit with IT patterns overall. Focused, nimble, smaller operators, especially if they are well-heeled – well capitalized, with solid balance sheets for their portfolios. Global and domestic mining industries with diverse demographics in terms of participants and backers would best ensure reliable supply and resilience to shocks. It is an outcome that everyone should want – mining businesses, governments, communities, environmental groups and investors.

Brave New World of ESG

The mining industry has always had to deal with environment, safety, security, and workforce and community relations challenges and the vagaries of host governments. Done poorly, government imposition of ESG related rules and requirements makes it more of a burden. Again, given sensitivities of cycle time and profitability, that means less attractive commercial frameworks for mining investment. Looked at another way, ESG becomes an opportunity for both mining companies and their stakeholders if governments provide constructive facilitation.

ESG management also is subject to and enabled by digitization. Experiments in using digital ledgers and blockchain to track emissions and other metrics are well underway. Importantly, they are a management tool. Like heavy industry overall, miners face a long road in satisfying increasing and yet shifting perceptions and lines in the sand on ESG, including how it all plays out in capital markets. For all of the attention to and recognition of dependence upon natural resource raw materials as building blocks for alt energy, new energies, energy transitions, that does not imply a smooth path to capital markets. Institutional investors are under equally forceful influences to direct lending toward ESG acceptable targets, whatever those are, and it is not a given that the mining industry, the purveyors of 'green' materials, will be loved.

'E' The huge pressure to reduce emissions is old news. Increasingly, awareness is dawning that there are many other 'E' values beyond and besides emissions. As noted earlier, the full environmental and social impacts of alt energy tech footprints, including their materials intensity and thus vast materials supply chain requirements, is only just now being investigated. Any number of ESG implications could derive from that attention. Critiques of alt energy footprints make the inclusion of alt energy into portfolios to satisfy ESG mandates and dictates less a sure thing. The main effect of that awareness is to throw additional uncertainty into the mix of questions regarding extent and timing of alt energy tech, thus adding uncertainty to trajectories of minerals and materials consumption.

Both mining and oil and gas companies are in the line of fire for 'decarbonization' of their own operations and associated emissions reductions (so-called Scope 1 direct emissions). Like other companies, they are expected to push metrics and reporting to emissions associated with electric power they purchase for their facilities (Scope 2 indirect). Many are voluntarily tracking and reporting on emissions embedded in their external value chains (Scope 2, indirect).

Large fossil fuels producing countries and their companies are subject to much lobbying to 'get with the program'. The KSA and the Middle East, the locus of the global petroleum breadbasket, are a special case, to include plenty of speculation regarding how these economies will diversify to adapt. The KSA and the region have plenty of options for 'decarb' strategies.[37] They and their companies as well as international companies in joint ventures are studying and implementing carbon capture and storage (CCS), purchase of carbon offsets (credits created for removing, or avoiding, GHG through approaches such as forest management), along with use of alt energy to satisfy perceptions of clean power. Some of these tactics can enhance domestic mining businesses.

Otherwise, mining and minerals beneficiations businesses are pursuing many routes. The World Bank's Climate Smart Mining initiative emerged as a best practice sharing program to ensure that minerals for 'clean' energy are themselves 'clean'.[38] One is electrification of haul trucks and heavy machinery. Electrification of haul trucks is incorporated in the digital mine with automation of service vehicles. Electric power sourcing includes the popular fallback of wind and solar. Like all heavy industry, mining facilities need reliable, 24/7 power supplies and so wind and solar use are of limited benefit without enabling thermal generation for balancing and back up or possibilities for meaningful energy storage such as batteries. State of the art for batteries for stationary storage is discharge/charge cycles of about 4 hours and so considerable planning must be done for battery support, especially in more remote areas.

For years, oil and gas producing countries in the Middle East and their national companies along with those in other Minerals Heartland locations have been shifting to natural gas for domestic use in order to maximize oil exports. Some countries are limited in this strategy by their endowments, and regional natural gas trade remains well below what could be achieved with friendlier relations. Regional relationships are vital to support natural gas resource, infrastructure, and trade. Natural gas to power represents an immediate step down in emissions associated with power purchases by miners.

Are there avenues for small scale nuclear? To the points made earlier, small scale nuclear is in the potential future energy mix for the KSA and Middle East, and gets increasing discussion elsewhere in the Minerals Heartland region. For remote mining operations, SMR could be an attractive option for meeting ongoing electric power needs.
Beyond emissions, the mining industry worldwide is working to decrease waste. Facilities for waste storage – tailing impoundments – are expensive and sources of risk. Accidents involving tailings impoundments failures are some of the more high profile incidents the mining industry must deal with. In effect, waste reduction is like swimming upstream given that waste increases as mining assets age and ore quality decreases. Mined and even processed waste can contain useful residual elements. Advances in resource recovery to capture metals from mined and processed waste has made inroads – copper and platinum production and supply both have benefitted from these innovations.

Water use and wastewater treatment already are mentioned as criteria for mining operations and potential weaknesses for Middle East and other Heartland desert countries. Opportunities exist for new technology and water supply is a priority for much R&D evolving around the world. Again, a distinct regional advantage lies in the abundance of hydrocarbons and carbon-based materials. Materials science and nanoengineering is the genesis for many advances in electrolysis, filtration, and much else.

Big Data can help on some if not most of these areas. The digital evolution is alive and well in the environmental management and mitigation arena.

‘S’ How do we define the ‘S’ in ESG? That is a question everywhere. Within engineering based industries and their companies, the tendency is to emphasize the employee base as the main interface. This contrasts with consumer product oriented businesses that are more inclined to focus on external communities and social groups. [39]

An effective mining workforce entails both skilled (“blue” collar workers for welding, heavy equipment operations and the like) and professional (“white” collar workers in the ‘STEM’ disciplines of science, technology, engineering and math). To the previous comments, digitization is shifting proportions and reducing the labor component, but upping the skill requirements to both build and deploy the digital mine toolkit.
To the extent that workforce targets include ‘gender diversity’ thus means diversity at the training level, down to the lowest educational grades. Once workers reach full employment status, retraining or closing gaps by other means, such as forced diversification through quotas or other directives, induces other workforce issues that degrade productivity and increase SSHE related risks.

Building a diverse digital workforce is easier in locations where education and literacy rates are higher. Here is where the Minerals Heartland governments and societies have their work cut out. A new report for MENA plus Pakistan indicates that half of all children in the region fail to reach a basic level of learning in primary school compared to 25% in OECD and 37%[40] worldwide. UAE has the highest attainment with 60% of children achieving a basic level of primary education. MENAP countries also lagged in digital literacy and internet access – the reverse of what digitizing industries need. The pandemic induced additional stress to MENAP educational systems, as it did everywhere. Teachers worldwide are under strain from non-teaching workloads, with administrative burdens crowding instruction to 20-40 spent of time on the job. Meanwhile, high-performing teachers can improve student performance by 53%. These latter data points suggest that in MENAP, lessons learned from observation of educational systems elsewhere could be taken to heart with the potential for notable strides in improvement.

When it comes to workforce diversity, women in MENAP have about a 27% labor force participation rate (% of total working age population) compared to more than 54% worldwide. With a nearly 77% labor force participation rate MENAP men actually do better than the worldwide rate for males of about 72%. Unemployment for MENAP women is 17% versus 7.5% for women worldwide. For MENAP men the unemployment rate is 7.4, somewhat higher than the worldwide average of 6.3%. [41]

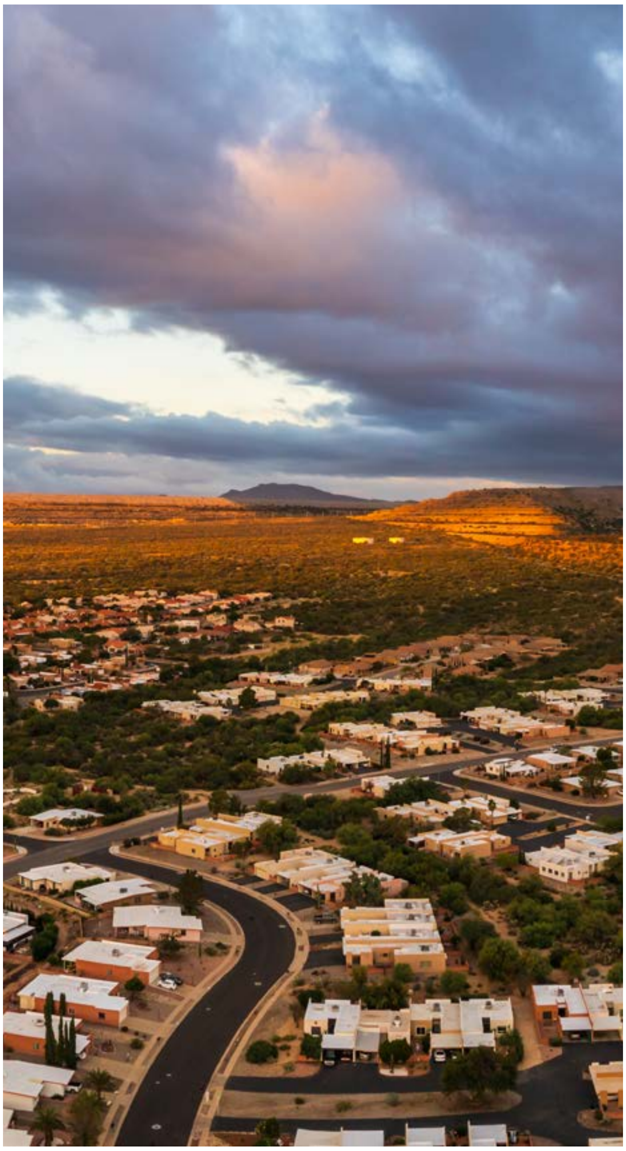
Finally, for the digital future of digital mines, MENAP region higher education also is a target for advancement. Country investments in R&D funnel into higher education research, ultimately exposing educators and students to key trends in industry. MENAP region countries fall well below other nations in R&D spending as a percent of GDP, leaving them less able to feed adept workers into innovating industries and businesses. MENAP region higher ed also faces challenges in financial sustainability and technology to support and enhance instruction. [42]

For all of these constraints, the MENAP and greater Minerals Heartland region are marked by pockets of interesting experiments. Abundant indications are in evidence that governments and societies know that educational and workforce shortcomings must be addressed in order to achieve ambitions.

Besides workforce, the ‘S’ in ESG incorporates communities. Wherever extractives industries operations are located, local populations are the immediate interface for both employment and the myriad soioeconomic impacts. Mining, along with oil and gas, tends to be ‘boom bust’. When business conditions are favorable, jobs are plenty, revenues flow to jurisdictions, and indirect spending flourishes. In too few nations and jurisdictions, local communities that bear the brunt of operations are not supported by appropriate revenue streams. This makes them less able to accommodate the inevitable downturns in inherently cyclical businesses. Mine operations eventually are decommissioned. When operations cease, jobs and income beyond any that are associated with remediation, disappear. Construction phases are more capital and labor intense than normal operations. Thus, construction phases can have more pronounced effects, with larger infusions of employment and spending than local jurisdictions will experience once construction phases are completed. They also generally incur increases in housing, security and other costs than do the lower employment levels once projects are commissioned and in operation. These costs can strain local jurisdictions until economic rents from production sales are distributed (if, in fact, that happens).

Indigenous communities are a particular challenge. Land and water rights, ancestral areas and cultural values can all impinge on access to resources for development. They can delay progress, lengthening cycle times, or prevent new projects from ever being achieved. Plenty of examples of both are in evidence worldwide.

Most mining related risks are at the community interface. These include lost time incidents (accidents, deaths) as well as failures of tailings impoundments that can exert tragic consequences on surrounding populations. The horrific collapse of a tailings dam at Vale's huge Córrego do Feijão iron mine in Brazil on January 25, 2019 with 270 deaths and destruction of much of the surrounding area shook the global mining industry. The incident still reverberates in continued legal and regulatory actions. It triggered action by the International Council on Mining and Metals (ICMM) to develop and put forth its Global Industry Standard on Tailings Management.[43] Apart from high profile accidents, ongoing problems such as heavy metals leaching out of mine waste and tailings into water supplies can exert damage that is more insidious.



Outside of the U.S., Canada, Australia many countries host informal, artisanal mining. Governments are often loathe or simply unable to block or oppose or enforce regulatory oversight on informal miners. The presence of informal mining in Africa, South Asia and portions of Latin America can be huge. Human rights, child labor and safety are all big concerns. For many communities, informal mining and even child labor are the only sources of income, stymieing government action. Some countries are moving to 'formalize' small and informal miners with licensing and inducing licensed operators to cooperate by providing value added processing. [44]

Local and domestic content is a typical lever used by governments to encourage benefits locally and nationally from mining and value added operations. Content programs are rampant through the global oil and gas industry and also found in manufacturing and other industries and sectors. Generally speaking, local and domestic content act to constrain mine operators and their vendors, more often increasing costs and reducing optimization of businesses and assets than enabling savings or stimulating business development and innovation. Content rules can be very distorting, forcing operators to substitute procurement in countries that otherwise is linked to larger supply chains for their own equipment and supplies. Content programs are often sources of corruption, undermining even the best intentions. Which leads us to the final component of ESG.

'G' Most often, the 'G' in ESG relates to governance in how companies conduct themselves. Independence of boards, internal checks and balances on management decision making and financial reporting and auditing, metrics on how companies conduct themselves are all typical indicators that find their way into ESG measurement and reporting. Governance can extend to specific issues, like diversity on boards and management. In the end, though, with rules and norms that now exist in many countries and high profile cases and penalties that erupt from time to time, a fair question is why a company would run itself in a less than responsible way and risk the sometimes vast costs and losses, not least of which is reputational integrity, when governance fails.

Of course, corporate governance can, and does, fail, and often those failures can be attributed to conduct of business in countries where rules and norms are weak. This leads back to the quality of commercial frameworks in countries hosting inbound investment. Even with the myriad of NGO transparency and anticorruption programs and efforts undertaken by multilateral institutions and development banks and agencies, government transparency relative to mining still tends to be low or absent in too many locations.

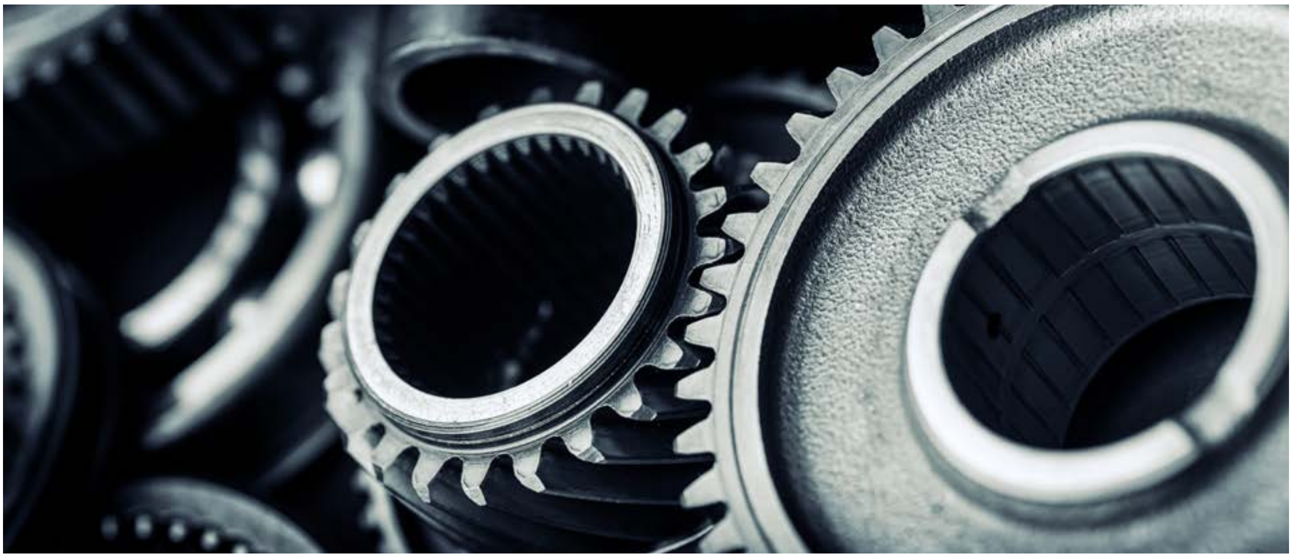
The range of difficulties can extend from corruption in revenue collections or black market activity to safety risks stemming from illegal licensing and compromised regulatory oversight. Companies that engage in mining, oil and gas, chemicals, infrastructure construction and other industries and sectors may choose to avoid certain countries rather than compromise ESG ratings. This reduces the population of responsible investors for countries that are not willing or able to improve their commercial frameworks.

For sure, many locations outside of industrialized nations can perform well on governance metrics (for that matter, many industrialized nations are less than perfect when it comes to governance). In the Middle East, a number of monarchies are considered to govern well, with effective management and functional SOEs. [45]

Ultimately, the goal is achievement of commercial frameworks that support robust, sustainable (financially and otherwise) mining operations that can contribute reliably to global supply.
Transparency in licensing has long been central in NGO-advocated and development assistance transparency and anticorruption efforts backed by many OECD member countries. Trade regimes and international relations are emerging as new areas of focus given the proclivity among governments to use trade rules as levers to

influence price and seek collusion. And in a digital world with the emerging digital mine, intellectual property, IP, protections could serve to encourage best behavior by governments in ways that encourage sharing of vital digital technologies. In the extractives industries, IP and data, including data integral to valuing resource endowments, have long been as valuable to durable wealth creation as the commodities themselves.

Forward Pathways



In such a complex world, what are the forward pathways? How can decisions get made that will attract and retain investors and sustain economic development ambitions? These are not new questions, by any means. Given that, answers can be obtained the way they have been in past, by examining success and failure through case studies.

The notions of hubs and clusters have been around for several decades. The words are merely descriptors for what humans have always tended to do by nature – congregate where activities and transactions can be linked, in ways that play to comparative advantage. Many powerful hubs and clusters have emerged around the world. Whether Italian leather fashion, London's City financial district, U.S. Gulf Coast petrochemicals or North Sea oil services, all notable examples that have been studied, lessons can be drawn to inform KSA and regional aspirations. Importantly, clusters do not shelter host locations from disruptions. Signature events like severe economic recessions and depressions that undermine finished goods consumption and financial markets also rip through clusters, bringing down the linked businesses and trade. Clusters are not immune from competition. Plenty of examples exist of clusters that disintegrated in the face of cheaper, comparable alternatives (textiles, autos and many other examples).

What constitutes a true 'centre of excellence'? That, too, has been studied and lessons learned mapped out. How does talent develop and what are the best ways to ensure it persists? How are talent development and finance combined to incentivize R&D and innovation? R&D and innovation alone have been studied exhaustively as people try to understand whether they can be fostered, whether outcomes can be directed (or at least more predictable), how the process from idea to invention to commercial realization truly happens and the key ingredients.

Few of the Minerals Heartland countries have the full suite of value creation mining and beneficiation segments, much less value added manufacturing, within their borders. For the most part, concentrated ores are shipped for further processing elsewhere, which almost always means China. This is true for much of the Petroleum Heartland overlay – too few countries host value added refining to provide clean fuels to their populations and very few host petrochemicals businesses, or chemicals businesses of any sort. Weak commercial frameworks and inherent risks that work to minimize exposed capital are the main explanation. To turn this around, Minerals Heartland countries must focus on the preconditions of bolstering commercial frameworks, closing infrastructure and education/training gaps especially for young people, and improving oversight of mining industries.

Clearly, a place to start is from the ESG imperatives and initiatives. The more easily mining investors can discern potential for success in view of the criteria they face, the more likely they are to consider putting risk capital to work in any one location.

Given the emphasis on digitization and the digital mine, along with demographics of the Minerals Heartland region and its constituent geographies, these emerging technologies and practices in mining operations lend themselves to centers of excellence concepts. But what, exactly, might that mean?

Singapore's manufacturing renaissance is a worthy analogy to explore. The apparent success by the sovereign city-state in not only restoring manufacturing but also achieving a higher-level playing field with advanced manufacturing has many analogies for the KSA and Minerals Heartland. Many of the themes are similar. They include the need to elevate Singapore's workforce with new skills for designing and building the digital manufacturing toolkit (robotics and automation). Singapore previously had to import workers for its older manufacturing businesses. The new digital manufacturing platforms require less labor but a more skilled labor force.[46] Other examples and case studies can be identified and pursued. The lessons, or failures, preconditions and caution flags, must be fully scrutinized.

Finally, for its own part in the story, the KSA can differentiate itself through advanced materials and consider clusters and centers of excellence to support new businesses and industries. Investments already underway in CNT products globally, including by entities such as Aramco/SABIC (Saudi Basic Industries Corporation), will foster complete redesigns of technologies such as batteries and other primary components and lead to fundamental rethinking of energy systems. The KSA could serve as a strategic hub for advanced materials investment, helping to enable new capacity and logistics.

For the Minerals Heartland of the future, there is a great deal to be learned.

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