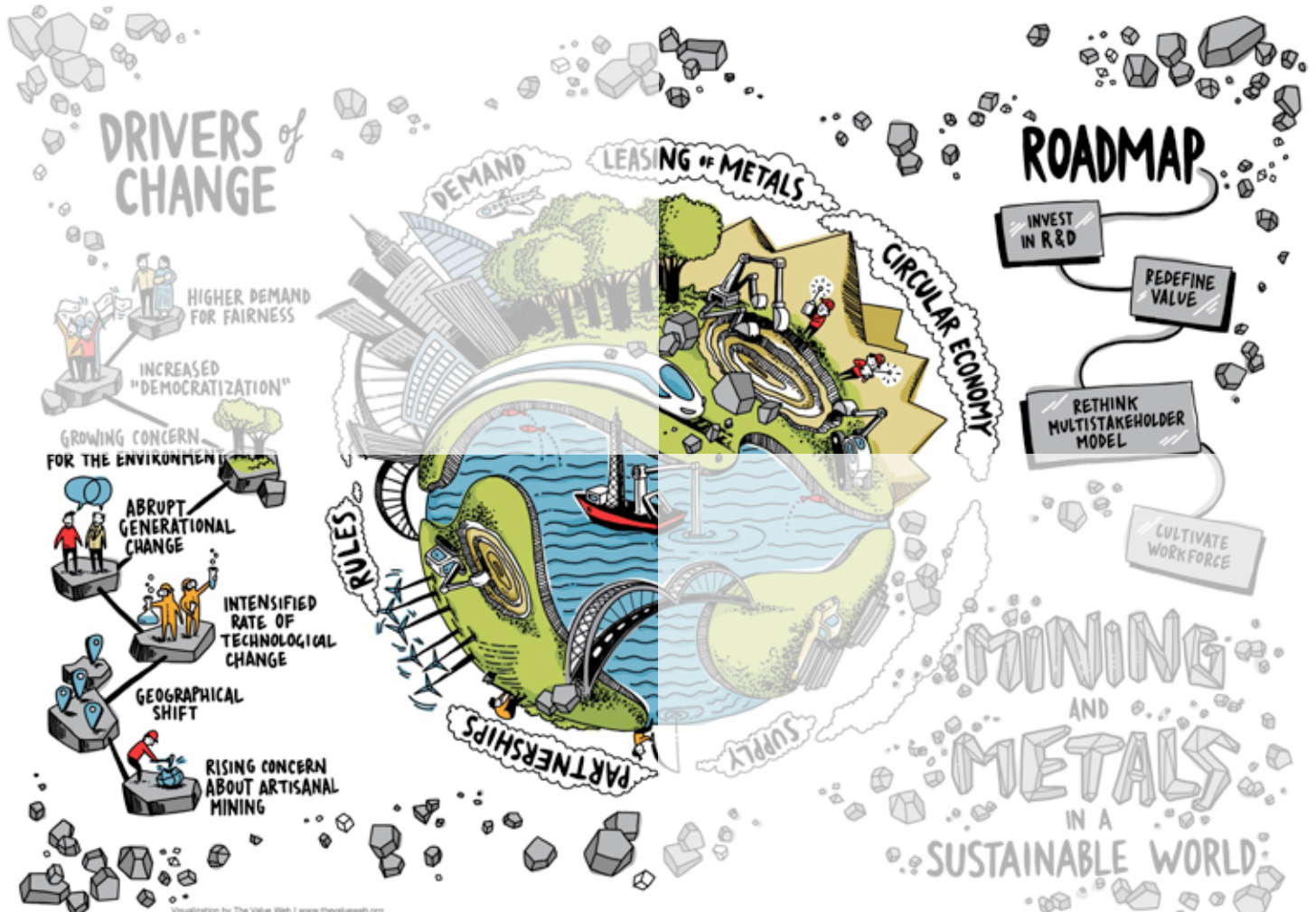


Scoping Paper: Mining and Metals in a Sustainable World

World Economic Forum Mining & Metals Industry Partnership
in collaboration with Accenture

February 2014



Foreword

For an industry accustomed to volatility, the mining and metals sector has faced many challenges and uncertainties over the past couple of years. Global markets remain weak following the global financial crisis, commodity prices have fallen, and shareholders are pushing for leaner operations and greater returns on investment.

At the same time, the stakeholder landscape for mining and metals companies is becoming increasingly diverse, with growing expectations for companies to operate in a responsible and sustainable manner. But what defines “sustainability”? How can the mining and metals sector shape the agenda on this issue rather than react to it? Taking bold actions will enable the sector to differentiate itself from other industries, find new opportunities for growth and initiate a new platform for engagement with stakeholders.

Against this backdrop, the World Economic Forum introduces this scoping paper to launch the first phase of a new initiative: Mining and Metals in a Sustainable World 2050. The paper describes the potential role and contribution of the mining and metals sector, and outlines the key drivers and trends that will shape its value chain in a sustainable world. The initiative aims to create guidance, processes and frameworks to support the industry’s transition to that world.

The development of this paper involved extensive outreach and dialogue with members of the private sector, academic community, civil society and multilateral organizations from around the world. The Forum is extremely grateful to the many stakeholders for their input and support, and looks forward to continuing the dialogue with them as this work develops.

In particular, the Forum would like to thank:

- The Sustainable World 2050 Advisory Group: Britt Banks, Stephen D’Esposito, Elaine Dorward-King, Jan Klawitter, Tara Polzer, Lisa Sachs, Marcio Senne de Moraes and Sonia Thimmiah.
- Industry Partners from the Mining & Metals Industry, and in particular the chief executive officers who served on the Forum’s Mining & Metals Steering Board in 2013: Kumar M. Birla, Nicholas A. Curtis, Gary J. Goldberg, Ivan Glasenberg, Roland Junck, Klaus Kleinfeld (Chair), Donald Lindsay and Mark Cutifani.

- Members of the Global Agenda Council on Responsible Mineral Resources Management: Anthony Andrews, Britt Banks, Edwin Basson, Beatriz Boza, David Clarke, Stephen D’Esposito, Obiageli Katryn Ezekwesili, R. Anthony Hodge (Chair), Jiao Jian, Janet Kong, Huguette Labelle, Anna Littleboy, Bruce McKenney, Henry Medina, Ligia Noronha, Antonio A.M. Pedro, Michael H. Solomon and Puntsag Tsagaan.

The Forum also extends thanks to Accenture, which served as project Knowledge Partner for this paper, and in particular to Olivia Reynolds, who worked as Project Manager in 2013.

World Economic Forum Mining & Metals team

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Executive Summary

Objective

At the World Economic Forum Annual Meeting 2013 in Davos-Klosters, Switzerland, the Governors for the Mining & Metals Industry asked the Forum to prepare a scoping paper on the role and contribution of mining and metals in a sustainable world. This paper offers one possible vision for the sector. Highlighting key issues and trends on the topic, the paper informs the Governors so they can identify the work activities for the Forum's Mining & Metals team that will best support the Industry Partners in 2014 and beyond. The paper is not intended to map the scenarios or the journey to a sustainable world.

Background

This paper uses the Vision for 2050¹ framework outlined by the World Business Council for Sustainable Development (WBCSD) as a guide on key changes to the global economy, people and populations, environment, energy mix, buildings, transportation networks and material requirements. Given this context, the paper tries to eschew the restrictions, issues and challenges of today to describe the role and contribution of mining and metals companies in a sustainable world, and to outline what companies need to do now to prepare for success.

Current Situation

In a sustainable world, the mining and metals sector will be critical to reliably and responsibly provide materials and products to global economies and communities. Societal expectations of mining and metals companies are rapidly changing and becoming more demanding. The Forum's Global Agenda Council on Responsible Mineral Resources Management has identified seven drivers for change that are affecting the sector today, based on 10 years of research from various organizations.²

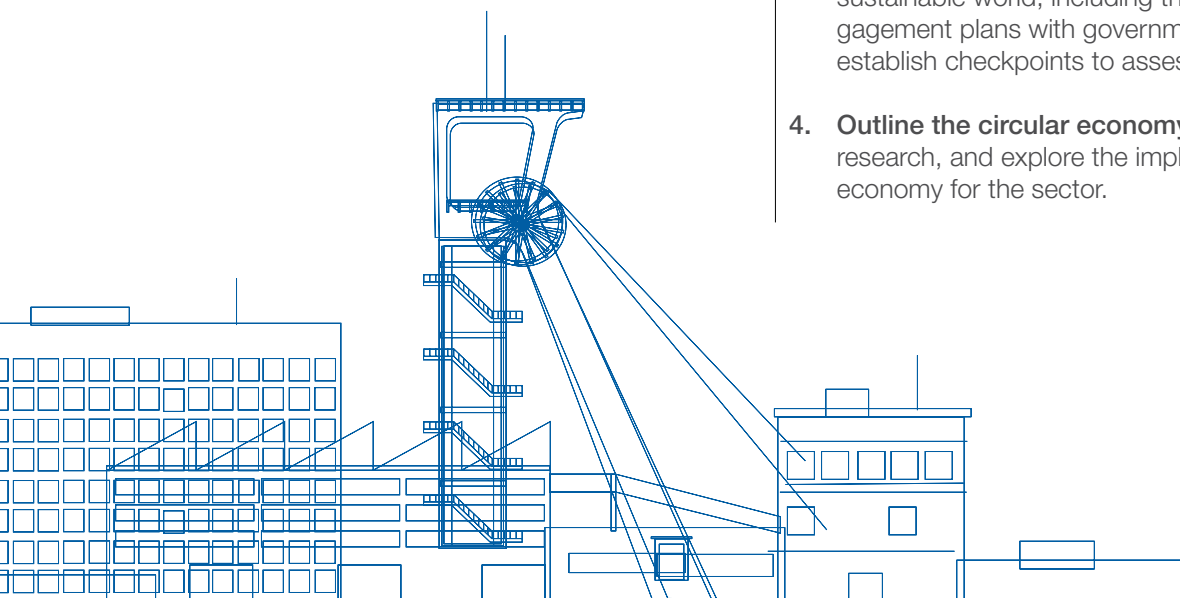
As a result of these drivers, the sector will operate in a fundamentally different way in a sustainable world. The key themes influencing mining and metals companies will be:

- Consistent global policy and regulation provide a level playing field with a clear view of what sustainability is, as well as the expectations of and requirements for companies.

- Ownership models are more varied (e.g. including leasing), with recognized roles for a wider range of stakeholders including mining and metals companies, governments, service companies, civil society and communities.
- Stakeholder relationships and partnerships are even more critical, with a commitment to delivering shared value to industry, governments and civil society.
- New customers hold mining and metals companies accountable to higher social and environmental standards for their operations, products and services.
- Advances in nanotechnology, robotics and digital technologies lead to full automation across the project life cycle, and 3D printing is routinely used for maintenance and repair.
- The accessing of new sources, such as deep sea and asteroids, is commercialized and part of the portfolio of existing mining companies.
- Operations are meeting enhanced environmental requirements for minimal emissions, waste and water use.
- Project infrastructure, tools and processes are more resilient to more extreme weather conditions.

Future Implications

The manner in which mining and metals companies respond to the drivers of change will affect their market position, reputation and value in a sustainable world. Companies in the sector should consider five actions now to proactively prepare for contributing positively to a sustainable future:



- **Re-emphasize the journey:** Businesses need to have a decisive conversation with stakeholders (companies, civil society, governments) about their visions and milestones for a sustainable world.
- **Invest in research and development (R&D):** Mining and metals enterprises must start developing the technologies to operate in a clean, affordable and safe environment in frontiers previously considered inaccessible.
- **Define shared value:** To prepare for operating in a sustainable world, companies in the sector need to look at what drives value for their customers and the communities in which they operate.
- **Rethink multistakeholder models:** Mining and metals companies can accelerate the transition to a sustainable world by embracing multistakeholder models.
- **Cultivate the workforce:** The skills and capabilities required to operate mining and metals companies in a sustainable world will be different; this needs to be considered, planned for and developed in advance.

Potential Roles for the World Economic Forum

The Forum has four key roles to support the mining and metals sector in its transition to a sustainable world:

1. **Engage industry stakeholders on the topic:** Initiate a multistakeholder dialogue to get commitment for the vision of mining and metals in a sustainable world.
2. **Continue the development of a transformation map:** Research the drivers and issues that are affecting the sector and identify the gaps between the sector as it operates today and the vision for the sector in a sustainable world.
3. **Define a roadmap:** Articulate a plan of action for mining and metals companies to guide the transition to a sustainable world, including the development of engagement plans with government and civil society, and establish checkpoints to assess progress.
4. **Outline the circular economy:** Build on existing Forum research, and explore the implications of the circular economy for the sector.

2. Introduction

The world is changing and the key drivers in a sustainable world will soon be fundamentally different from those of today. According to the *UN Global Compact-Accenture CEO Study on Sustainability 2013*, 63% of chief executives expect sustainability to transform their industry within five years.³ Mining and metals companies have a tremendous role to play in a sustainable world. The sector operates on every continent except Antarctica and provides materials that are integrated in almost every product and service around the world. Given its scope and essential role, the sector is uniquely positioned to contribute to the transition to a sustainable world.

The project life cycle for mining and metals operations can easily exceed 50 years. In addition, operations are fairly static: if the working environment becomes unsatisfactory, operations cannot be easily moved. Consequently, mining and metals companies are accustomed to investing time and money in developing long-term plans and forecasts, and effective planning helps them to protect their assets.

Planning for the future is not a precise science, and understanding the balance between what is reasonable, courageous and impossible is exceptionally difficult. History suggests, however, that society tends to overestimate what is achievable in the short term and underestimate what can be done in the long term.

At the Forum's Annual Meeting 2013, the Governors for the Mining & Metals Industry asked the Forum to prepare a scoping paper on the role and contribution of mining and metals companies in a sustainable world in order to inform the Forum's future programme of work. This paper seeks to set the strategic vision for mining and metals companies in a sustainable world and to outline their immediate priorities.

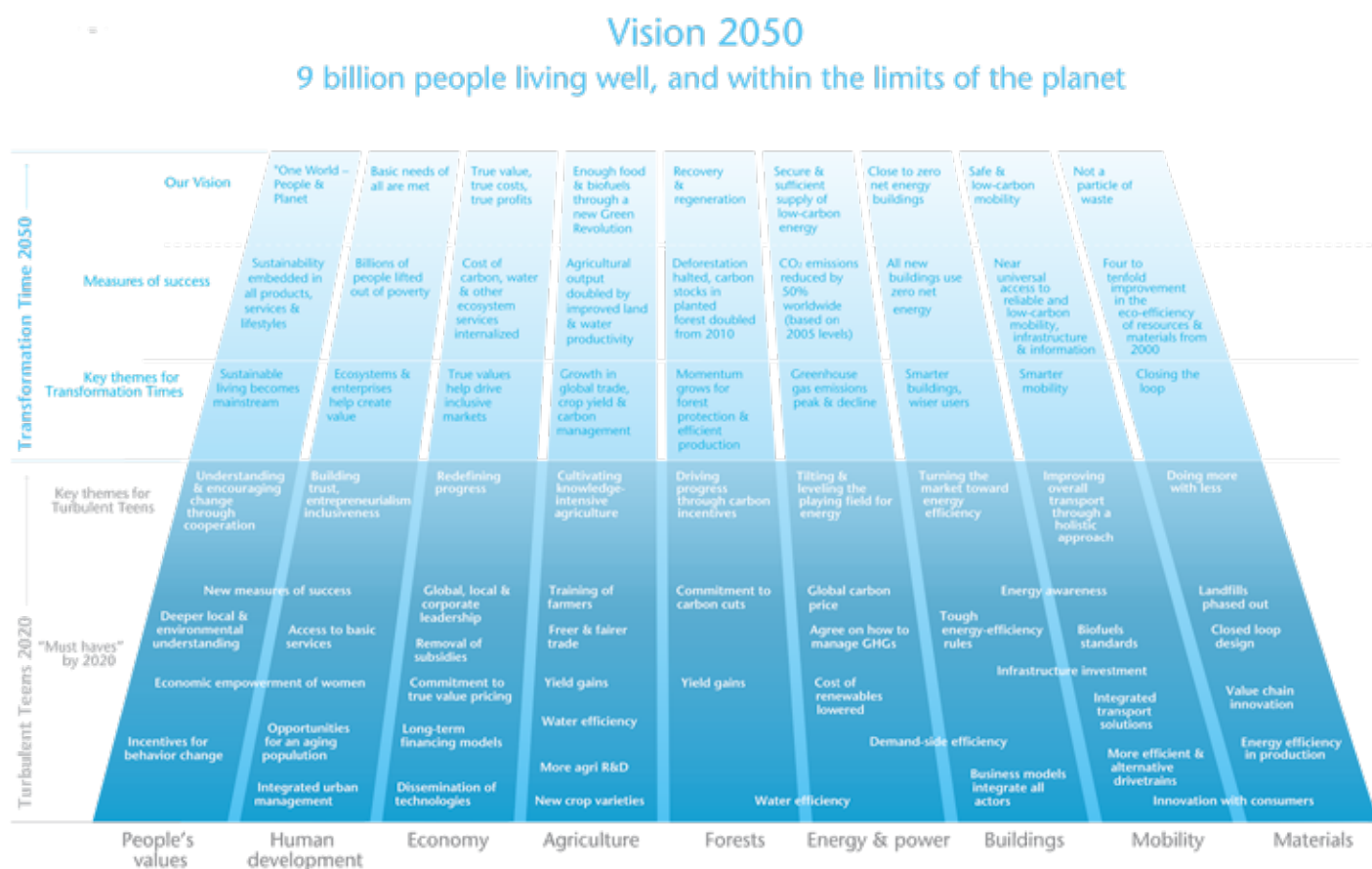
Furthermore, the paper identifies potential activities where the Forum can support the mining and metals sector to navigate the transition to a sustainable world.

3. Setting the Scene – Vision for a Sustainable World

In 2009, the World Business Council for Sustainable Development (WBCSD) produced *Vision 2050*, a framework that explores a sustainable-world scenario for 2050 across nine dimensions and plots the activities and transitions needed to reach that vision. To translate this vision into action, the WBCSD launched *Action2020* in 2013 and cited four objectives: (1) set the sustainable business agenda for the decade and share it with the global business community to inspire joint action, (2) help businesses understand the scientific, social and economic needs of the planet, (3) promote and support scalable sustainability actions for companies and



Figure 1: The Vision 2050 Framework



Source: WBCSD, 2009. *Vision 2050: The new agenda for business*

sectors to undertake, and (4) become the priority-setting framework for corporate engagement.⁴ This paper uses the vision set out in WBCSD reports as a guide for considering the role of mining and metals companies in a sustainable world. It does not assume specific timelines, but instead looks at the key trends towards and objectives of a sustainable world. Figure 1 illustrates the Vision 2050 framework.

Our Vision for a Sustainable World

Vision 2050 shows that global leaders from government, business and civil society are increasingly committed to making decisions today to make the world a more sustainable place. But what does a sustainable world look like? The only thing certain is that the economy, society, energy, environment, buildings, transportation and materials will look very different than they do currently.

In a sustainable world, pricing, markets and business models engage differently to create a new **economy**. Alternative measures of success exist beyond profit and loss, where environmental and social costs, as well as their impacts, are considered and accounted for. Value is affected by these new measures and is recognized in the marketplace by investors, among others. Economic growth, no longer tracked solely with traditional indicators like gross domestic product, is assessed on the stability of economic development.

The global economy has become more competitive, diverse and inclusive. The capabilities gap across developing and developed economies is smaller, and the market structure provides roles for all players that maximize their productivity.

Businesses in a sustainable world provide solutions more than services. Collaboration with other businesses, governments and civil-society groups is commonplace, and partnerships underpin successful business ventures. The consumer has a much stronger voice, and organizations have established channels to interact with and learn from their consumers, rapidly adapting their products based on demand.

Change has not been limited to the economy; **society** has also been transformed. Longer life expectancy, combined with lower birth rates and reduced child mortality, has resulted in a larger, albeit ageing population. Access to key basic services including healthcare, insurance, banking and education has improved and is available in some form to all. Poverty is a historical issue. Greater economic opportunities exist for the world's population, especially women, and improved access to capital and higher living standards contribute to increased global consumption.

Access to reliable, affordable **energy** remains essential. However, energy supply and demand are more diversified and are more effectively measured and managed. New technology enables power grids to respond to and balance energy supply and demand in real time. Power plants are

designed to minimize greenhouse gas (GHG) emissions, and a greater portion of the energy mix comes from renewable sources. Organizations and individuals actively measure their energy consumption and seek to limit demand to an acceptable minimum.

The shifting trend in energy is driven, in part, by a greater concern for the **environment**. A sustainable world is a warmer world. Sea levels are higher, drinkable water and arable land are limited, and the world's ecosystems are increasingly fragile. Minimizing water withdrawals and consumption are critical business drivers. The balance between peoples' values and private-sector requirements is much more attuned, and innovative models are used to ensure that land is managed effectively, water is accessible to all, and flora and fauna are preserved.

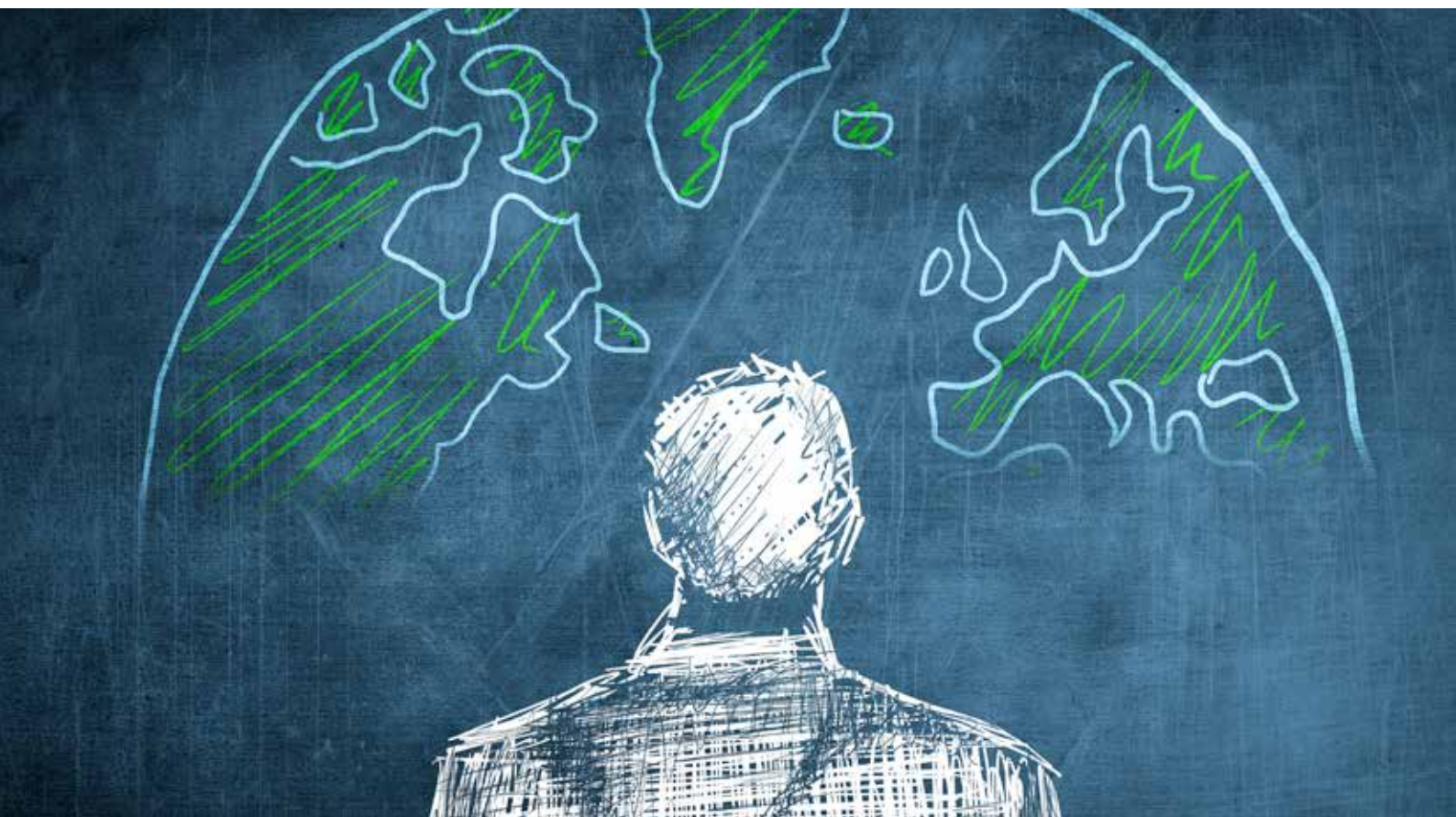
The urban fabric in a sustainable world reflects the population's social and environmental needs. **Buildings** are "smart", providing real-time information on resource consumption and efficiency, thus allowing occupants to improve resource management. Occupants pay a premium for plus-energy buildings, and existing structures are retrofitted with stronger, more flexible and lighter materials to minimize their environmental impact.

Converging trends of society, buildings and energy have contributed to sweeping changes for **transportation**. While a larger population has greater transportation needs, transport's environmental impact is lower in a sustainable world due to efficiencies from greater integration and use of accessible, low-cost urban mobility systems and technological developments. Although alternative fuels such as electricity, hydrogen and hybrids are common, the largest gains in transport efficiency come from information technology. Consumers have access to accurate, real-time data to help them make transport decisions that minimize travel time, environmental impact and cost, while maximizing

speed, safety and comfort. Vehicle manufacturers have developed improved processes and materials with significantly lower carbon intensity and virtually no particulate emissions. Closed loop designs reduce waste and increase opportunities for reuse of all materials.

Consumption is higher in a sustainable world due to a larger population, but consumption per capita is smaller as resource efficiency, circular economies and models such as sharing ensure **material** use does not exceed available resources. Robust life-cycle assessments drive the business strategies of material companies (e.g. steel, aluminium). Expectations are that established channels will exist for products which, having reached the end of their "life", can be reused both within the original sector and in different industries. Players across the value chain work together to improve material efficiency. Industry, cities and consumers have access to a greater number of waste management opportunities in a competitive waste market. The combined effect of improved product design and waste management means the virgin-raw-material demand per person is lower; energy and water supplies are balanced, and GHG emissions are within acceptable limits.

For the mining and metals sector, the most relevant trends are in energy, materials, transportation and buildings. The sector has an opportunity to strategically consider how these trends could affect both the demand for products and the means of providing sufficient supply. The project planning cycles for mining and metals companies are sufficiently long that they can plan today for how they'll operate in a sustainable world. Critically, communities, civil society, investors or governments will not tolerate unsustainable mining and metals companies, so a proactive response is imperative. With that context, the rest of this paper explores the role and contribution of mining and metals companies in a sustainable world.



4. Mining and Metals in a Sustainable World

Figure 2: Mining and Metals in a Sustainable World



Source: World Economic Forum

Figure 2 encapsulates the vision of the role and contribution of mining and metals in a sustainable world.

5. Demand Implications for Mining and Metals Companies in a Sustainable World

Strong demand for metals and mineral resources in a sustainable world makes these materials critical to supporting the energy, social and urban needs of a larger, wealthier global population of 9 billion people. Per-capita demand is lower per person than it was in the early 21st century. Consumption is no longer perceived as an indicator of wealth; instead, the concerted focus is on consuming as little as possible while enjoying higher living standards. A “circular” and sharing economy has become engrained in the global culture. This section considers the market trends and

implications of the circular economy for mining and metals companies in a sustainable world.

Market Trends

Investors in a sustainable world value and trade metals and mineral resources based on a shared understanding of and commitment to economic and social development. The mining and metals markets are more diverse. Exchanges in Latin America and Africa play a key role in the global economy. For all investors, the factors once considered externalities, such as environmental efficiency and social impact, are incorporated into the value of goods, creating a “true cost”. Life-cycle assessments are an integral component of determining value, and sustainably managed metals and mineral resources are considered premium investment opportunities.

It is impossible to predict future demand for specific materials; however, an overview can be provided of indicative trends for energy, buildings and transport in a sustainable world:



- **Energy:** The energy mix in a sustainable world is radically different than in the past. Critically, it is a more diversified blend of fuels. As a result, the materials needed to generate energy are very different. A greater portion of energy comes from renewable and alternative fuels. The demand for coal has therefore decreased but not disappeared, as clean technologies such as carbon capture and storage mean coal remains a fuel source. Renewable energy plays a key role in the energy mix in the sustainable world, with implications for metals and materials. Wind and solar technologies, for example, require significantly more steel than other energy sources. Greater use of hydrogen fuel cells and nuclear power means increased demand for metal catalysts such as zinc and platinum. Rare earth metals play a key role in clean technologies and are likely to experience significantly higher demand, though in much smaller volumes compared to core metals and commodities.
- **Buildings:** Buildings in a sustainable world require stronger, more flexible and lighter materials. This has provided good opportunities for the steel sector, for example, although it is also a threat, as more cost-effective substitutes such as composites are developed.

- **Transport:** The transportation sector continues to be demanding of the mining and metals sector in a sustainable world. However, the type of products and the associated raw material inputs required have changed. Steel for ships and cars, for example, is stronger and lighter. A complementary and competitive trend is the greater use of materials such as composites and aluminium, particularly in aviation and aerospace. Automobile demand per capita shrinks as an increasingly urban population relies on dependable, low-cost public transportation systems, or uses short-term automobile sharing schemes when necessary. Consumers have a preference for electric and fuel-efficient vehicles, creating steady demand for materials used in batteries including rare earth oxides, cobalt and lithium.

Such examples are far from exhaustive. The demand implications in a sustainable world will be different for each metal and material. While further research is required to anticipate and understand these trends, mining and metals companies will undoubtedly have significant opportunities.



Circular Economy

Global markets in a sustainable world have transitioned to a circular economy to mitigate anticipated trends such as a growing middle class (an additional 2 billion middle-class consumers by 2030), commodity price volatility, growing waste volumes and environmental regulations. The circular economy refers to a move from linear business models, in which products are manufactured from raw materials and then discarded, to circular business models where products or parts are repaired, reused, returned and recycled. The opportunity is immense – it is estimated that a subset of the European Union’s manufacturing sector will have realized net material cost savings of up to US\$ 630 billion annually through 2025, stimulating economic activity in product development, remanufacturing and refurbishment.⁵

Customers and suppliers expect mining and metals companies to align with the circular economy. Downstream players find that “closing the loop” on the supply chain through improved product design, extended asset life, reuse and recycling can deliver tangible commercial and environmental gains. Closed loop systems reduce the need for extraction and processing of new resources and, in response, mining and metals companies have adopted the following three trends:⁶

- **Reduce:** Limiting the use of virgin raw materials and more closely aligning supply with demand; improving efficiency of resource exploitation (yield rate) by mechanization, automation and optimization; enhancing the recovery rate of mineral processing and smelting; limiting pollutant emissions such as tailings, gangue and mine wastewater; developing applications for lower grade ore.

- **Reuse:** Extending the longevity of a resource, material, product or service by anticipating and planning for future applications; installing cyclic wastewater, waste and tailings systems, and improving mineral processing technology; maximizing the use of waste and by-products; collaborating with downstream players to design adaptable and easy-to-repair products; marking materials and alloys to aid identification at end-of-life and accelerate subsequent application.
- **Recycle:** Reducing waste by processing resources and metal products so that they become newly available resources; treating waste water before discharge; developing processing capabilities to accommodate higher rates of scrap.

The transition to a circular economy will reduce the environmental impact of products across their life cycles. To effectively operate within the circular economy in a sustainable world, mining and metals companies will need to address three key areas: develop a workforce with the right set of skills and capabilities; be more actively involved in scrap markets; and focus on customer and consumer relationships.

The mining and metals workforce in a circular economy requires new skills. Mining and metals companies are constantly looking for innovative means to reduce the impact of their operations, requiring new technology and business processes, and R&D skills that are in greater demand. They have in-house life-cycle assessment capabilities for collecting, managing and applying robust datasets to measure product performance against industry standards. The assessments and data help create trust and confidence in the quality of materials that design teams use in working with customers to effectively reduce, reuse and recycle materials.



Perhaps the most important skill, however, is building and managing effective relationships with suppliers, customers and consumers across the product value chain; this serves to drive product innovation and identify opportunities for improved efficiency.

The scrap markets in a sustainable world are more comprehensive, and mining and metals companies are actively involved. With material reuse a priority, scrap is more valuable. The market is more viable for some materials and products than others, with steel, aluminium, copper and zinc being good candidates. Beyond scrap purchasers, companies operating advanced scrap collection and distribution systems accelerate the effectiveness of the circular economy. The industry has agreed on a set of quality standards and a tracing mechanism to minimize the need for expensive testing to verify material composition and quality before reuse.

Finally, customers and consumers in a sustainable world have higher expectations from mining and metals companies. In a circular economy, these companies are not as removed from consumers, and their customer relationships are critical to building value across the value chain. Through strong relationships, mining and metals companies are able to adapt their production processes to more closely meet customer demands and deploy the higher environmental and social standards that consumers expect.

The circular economy is a key element of a sustainable world. Mining and metals companies thus employ new skills, build new relationships and increase activity in scrap markets to help reduce, reuse and recycle materials.

6. Supply Implications for Mining and Metals Companies in a Sustainable World

Not limited to existing material processes and sources, mining and metals companies in a sustainable world benefit from technological advances that have replaced many manual, repetitive processes with automated ones. In addition, operations exist in new frontiers such as deep sea and asteroids. Operations are managed under diverse ownership models and integrate cutting-edge equipment to maximize energy and water efficiency while reducing waste. Section 6 outlines some of the supply implications for mining and metals companies.

Existing Sources

Traditional sources of minerals and commodities continue to meet the majority of demand in a sustainable world. The extraction and manufacturing of minerals and metals are more efficient than ever, through automated mining processes and the introduction of technologies such as 3D manufacturing.

While a growing, more affluent population increases the overall demand for materials in a sustainable world, demand per capita has decreased, making it unlikely that physical scarcity will be an issue for mineral resources. Mining companies have become efficient resource suppliers. Technol-

ogy advances help operations to extract lower-grade ores than just a few decades ago (i.e. copper grades from 4% in 1900 to 1.07% in 2010).⁷

Successful mining operations in a sustainable world maximize automation technologies across the mining life cycle to improve safety, increase productivity and reduce costs. While some companies began to launch automated mining programmes in the early 2000s, they have since been adopted across the sector as both the technologies and the business case have improved after the development of open industry standards. During exploration, operations are able to put together comprehensive geometric and geophysical data profiles of a region using sensing and fusion technologies. In planning, automated robotics can be used to help design the safest, most cost-effective processes for extracting ore. Drilling is significantly improved using automated systems to reduce variation, improve quality and reduce maintenance costs. Finally, ore is transported from the site using driverless fleets or railway operations that make use of object-avoidance sensors, the Global Positioning System and wireless technology, creating a safer operating environment. Companies have access to a wealth of live data that helps them to improve decision-making and proactively manage site operations, leading to increased mineral yields, optimized energy use and reduced wear and tear.

Advances in 3D printing have had profound implications for the efficiency of mining and metals operations. Maintenance downtime is shorter because spare parts can be made on site, and time-saving approaches are multiplied for operations in remote regions. Cost savings are realized, and environmental benefits accrue. Use of 3D printing leads to lighter, smaller and more efficient designs that may last longer and work more efficiently, reducing the environmental impact of operations. Broken-down or redundant equipment

can be easily recycled for new parts. For terrestrial mines, 3D printing has helped to reduce costs by 50-80% compared with standard manufacturing methods.⁸ In the metals industry, specialist companies have applied 3D printing technology to print liquid metal that is conductive and can be printed at room temperature.⁹ Since this technology's introduction in the early 21st century, mining and metals companies have fully adopted it as initial barriers to its use have been rectified. In particular, safety and quality standards are unparalleled; the technology has a critical presence internationally and is supported with the appropriate skills; and the production cost of using 3D printing is lower than relying on external supply chains.¹⁰

Due to these shifts in technology, the following trends are anticipated to prevail in a sustainable world:¹¹

- **Employment profile:** Jobs are less physical and are located in more urban areas, with a predominantly professional and diverse workforce.
- **Knowledge and skills:** Specialized skills are required in areas such as data management, communications technology and mechatronics. Higher education is a prerequisite for a greater number of positions.
- **Diverse communities:** Historical “mining communities” are transformed into diverse economic communities supported by a range of services and industries.

To position themselves to succeed in a sustainable world, mining and metals companies need to develop new skills and invest in R&D to effectively apply new technologies in their operations.



Ownership Models

Discussions on mineral rights and ownership, particularly resource nationalism and the appropriate allocation of resource rents, dominated the mining and metals agenda in the pre-sustainable world. In the transition to a sustainable world, the debate became more constructive, and mining and metals companies adopted a commitment to shared value creation rather than cyclical profitability.

No single perfect ownership model or financing arrangement exists for mining and metals companies in a sustainable world, but seven elements should be considered:

- **Project development:** Mining and metals companies act as project developers rather than mineral-rights owners. This management shift enables mining and metals companies to focus on their strengths, for example building and operating projects, while offering governments and communities the option of owning the mineral assets and utilizing resource rents to meet the region's social and economic objectives.¹²
- **Long-term value:** Ownership models are designed to mitigate the risk of commodity price fluctuations and support corporate and economic diversification. Resource rents are managed to effectively balance current versus future investment requirements and to drive economic diversification for the region. Environmental and social stewardship is a key determinant of the overall value proposition.
- **Equitable division of profits:** Profits are distributed based on pre-agreed, reasonable levels to a wider variety of stakeholders, including governments, communities and investors. Payments may be made on commodity value at the point of extraction/production; or, commodity owners can elect to receive a portion of the commodity to use or sell at their discretion. The understanding that all stakeholders are equally exposed to operational performance and commodity price volatility is critical for this approach.
- **Inclusivity:** All players, including miners from artisanal and small-scale mining (ASM), junior players and multinational organizations, are held accountable to the same standards and policies, creating a consistent, level playing field for the sector. This drives convergence and fosters greater collaboration and partnership among the different players, with a potential scenario in which ASM miners work under the auspices of larger mining companies.
- **Shared knowledge:** Public-private bodies are created to develop geological knowledge that facilitates exploration and operation of mining and metals projects. Mining and metals companies share geological data to support wider mineral development and provide opportunities to effectively work together to rapidly deliver value.
- **Leasing minerals:** Notwithstanding the clear difficulties facing the enterprise, some companies and





governments implement models to trace the use of mineral commodities throughout the value chain and lease, rather than sell, materials to customers. This requires sophisticated tracing mechanisms; for example, companies receive a credit note against a future purchase for the reuse of mineral commodities. Under these arrangements, customers compensate companies for performance rather than for commodities ownership.

- **Service contract mining:** Commodity owners contract production responsibility out to the most effective and efficient service provider, even if it is not a traditional mining company. The transition from miner to service provider encourages competition, drives cost efficiencies and rewards organizations with the best performance standards.

Sufficient flexibility in the principles of ownership models in a sustainable world enable mining and metals companies, in collaboration with governments and civil society, to develop mutually beneficial ownership agreements. Clearly, ownership models are not opportunistic, and seek to deliver shared value for governments, companies and civil society.

Environmental Conditions Influencing Operations

The environmental conditions in a sustainable world affect mining and metals companies in two ways. First, the companies need to consider how to adapt to changing conditions such as higher temperatures and more extreme weather events. Second, they need to adjust operational processes to minimize environmental impacts associated with atmospheric emissions, water, waste and biodiversity. These principles are relevant across each of the following stages of the project life cycle:

- **Licence to operate:** Access to resources, in particular water, energy and arable land, are limited, and “true cost internalization” in the late 2020s made them more expensive. To secure and maintain their licence to operate, mining and metals companies collaborate with local governments and communities to develop and manage mutually beneficial adaptation strategies and operating standards.
- **Exploration:** Areas of high biodiversity are strictly off-limits to new operations, but opportunities for exploration exist in newly accessible Arctic regions.
- **Construction:** Energy and transport infrastructure is designed to be more durable to resist more frequent and intense weather patterns. Operations in areas where more rain is predicted have invested in more robust storm-water control systems to minimize mixing clean- and dirty-water sources. More stringent requirements exist for water reuse within operations and post-use treatment. In addition, companies with the most energy-efficient technologies hold a competitive advantage and, in some cases, secure new revenue streams by licensing the technology to peers.

- **Production:** Environmentally efficient operations are recognized by the market as more valuable. Operations are meeting tighter environmental requirements for lower emissions, energy, waste and water use. Processes are adjusted to maximize off-peak energy supply and incorporate renewable energy resources. Alternative fuel sources are widely adopted, and water management technologies ensure the watershed's balance is maintained within acceptable tolerances.
- **Distribution:** Port infrastructure has been retrofitted due to higher sea levels, and new regulations exist on efficient haulage capacity.
- **Closure/post-closure:** Rehabilitation standards are higher and more costly to meet, and management responsibility has longer terms.

Mining and metals companies, and all players across the value chain, will be held accountable to stricter environmental standards in a sustainable world. Companies therefore need to actively plan how to reduce the environmental impact of their operations to guarantee their mining licences in the future.

New Sources – Entering New Frontiers

In a sustainable world, mining and metals operations are active in new frontiers. The gold, copper, zinc and rare earth elements abundant in the ocean floor make deep-sea mining an appealing prospect, and one that has been viable since 2015. Advanced robotic technology facilitated the exploration of the ocean floor, and some tests show that undersea deposits can contain more than 10 times the concentration of minerals than deposits on land.¹³ While the business case is affected by metal prices and capital requirements, a single deep-sea mine operation initially cost US\$ 1.95 billion in capital expenditure and US\$ 9 billion to operate.¹⁴ These costs have decreased over time. At first, concerns still existed that the environmental impact of offshore mining was insufficiently understood to pursue projects at pace. However, as the number of exploration licences more than doubled, from 8 in 2010 to 17 in 2013,¹⁵ it became clear that the challenge would be addressed in parallel with the exploration rather than resolved in advance – similar to the development of offshore drilling in the oil and gas sector.

Asteroid mining is also an area for the industry to explore in a sustainable world. The abundance and quality of materials, combined with a phenomenal rate of technological development and strong capital support, mean that mining on asteroids is a reality, and has been for a few decades. Testing from meteorites in the early 21st century demonstrated that asteroid mining is especially relevant for the platinum group metals, nickel and iron. Some estimates suggested that a single platinum-rich, 500-metre asteroid contains 174 times the annual global output of platinum and 1.5 times the known world reserves of platinum group metals.¹⁶ However, it is not only about quantity. The quality of resources in asteroids is unprecedented, as the grades of iron ore, nickel and cobalt, for example, are significantly superior to those on earth.



The combination of exceptional quality and the quantity of untapped demand makes asteroid mining an attractive value proposition. The business case is further improved by the presence of non-ore commodities such as water. In terrestrial mining, while only one in 1,000 prospects identified at stage four actually becomes a mine, the proportion for asteroids is likely to be higher, as 50% of them may be water-bearing and they are 10% more accessible than the moon.¹⁷

Mining in space does not replace terrestrial mining, but complements it. The costs of shipping materials to and from earth are prohibitive, at least for now, as launch costs can range between US\$ 10,000/kilogram (kg) and US\$ 40,000/kg.¹⁸ It is more cost effective to travel from the inner solar system to somewhere else in space than to travel from earth to space. Nevertheless, some estimates suggest that low earth orbit launch costs need to drop to US\$ 200/kg for space raw-material discovery to be a viable competitor against earth launch costs.¹⁹ In 2012, NASA estimated that it would cost US\$ 2.6 billion for the government agency to capture a seven-metre asteroid and bring it into orbit so it could be mined.²⁰ The US Office of Management and Budget has estimated that commercial entities can conduct operations at one-tenth the estimated government cost. But billions of dollars more would be required to extract the actual minerals. A crucial method for controlling operational costs is 3D printing, since rather than transporting materials back to earth, mine stations can be fully equipped and operated in space. As such, space mining largely meets demand for materials in space. However, extensive knowledge sharing across asteroid and terrestrial mining helps both operate at the leading edge, especially with technologies.

Once perceived as long shots pursued by small, disruptive enterprises, asteroid and deep-sea mining are recognized by major mining and metals companies as having value; these companies in turn have developed or acquired the skills and capabilities to run their own “new frontier” departments.

7. Changing Rules of the Game in a Sustainable World

A sustainable world is not a Utopia – it is reality, with challenges and diverse and competing interests. However, it is an interactive and more informed world. Globalization has not been scaled back, and mining and metals companies, governments and civil society work closely together. To understand the dynamics of the roles and responsibilities of the mining and metals sector in such a world, and how they align with those of government and civil society, this section looks at policy and regulation, as well as partnerships.

Policy and Regulation

In a sustainable world, the mining and metals sector operates within a common set of policies and regulations at the local, national and global level.

Policies are crafted to promote shared value for industry, governments and civil society. The sector adopts global, overarching frameworks that are predictable and consistent. Regional and local policies are established that align with the global framework, but also account for local culture and sociopolitical environments. Each framework articulates a set of standards specifying what responsibility means for mining and metals companies. These standards serve as a benchmark for companies and governments to assess performance, resulting in robust policies that cover a wide range of principles including community relations, stakeholder engagement, climate change, tax avoidance, transfer pricing and resource-rent allocation.

Regulation is less formal in a sustainable world. Traditional regulatory frameworks were phased out after the 2008 global financial crisis, when industry and governments reached a consensus that those frameworks were too cumbersome to sufficiently reflect rapidly evolving, globally integrated marketplaces. Instead, certain minimum thresholds exist for safety, environmental performance, human rights protections and ethical financial behaviour. Beyond that, the market is self-regulating based on true value. The market value of every company is holistic.

Social media has lowered the cost and effort of collaboration, allowing governing institutions to respond quickly to evolving socio-economic requirements. Consumers, empowered by social media, have taken on new roles as citizen



regulators. As a result, companies are subject to much greater scrutiny. Social media and other new information and communication technologies support greater interaction and collaboration across the value chain, ensuring that policies and regulations reflect the interests of all stakeholders. Improved communication channels, and a commitment to transparency reinforced by true value, ensure that mining and metals companies operate within a sustainable world's covenants.

No government, country, corporation or state-based institution controls global resources. Multistakeholder networks – comprising government, civil society, industry, customers and financial institutions – govern global resources. Rather than simply regulating, governments improve industry behaviour by encouraging transparency and boosting civic engagement. This collaborative, trust-based governance model fosters legitimacy, inclusiveness and consensus-oriented stakeholder decisions.

Mining and metals companies need to be prepared for flexible and dynamic policy and regulation that more accurately reflects the interests of the wider stakeholder community.

Partnerships

To operate in a sustainable world, mining and metals companies depend on partnerships. All successful companies have strong relationships with governments, investors, communities, civil society, academic institutions and other stakeholders. A greater understanding across governments and civil society about the opportunities and challenges of the mining and metals sector also helps governments and companies to agree on appropriate roles and responsibilities for sustainable business models.

Partnerships are diverse, but they are all built on trust, thriving on strong leadership from all partners and rewarding collaboration. Every partnership is unique, based on each partner's objectives and context. Keeping partnerships simple and focused improves their success. Consequently, being open to multiple rather than exclusive partnership models

is important. Partnerships allow governments, companies, investors and civil society to focus on their specialities, and to rely on improved collaboration networks and knowledge-sharing facilities to fill any gaps. In a sustainable world, partnerships serve to maintain and manage shared-value opportunities rather than to focus on development.

The mining and metals sector uses a collaboration and engagement platform to identify, maintain and improve partnerships in a sustainable world. This platform has four key attributes:

- **Partner definition:** Document the stakeholder landscape to identify potential partnerships, list existing partnerships and highlight potential roles and responsibilities in partnership arrangements, and thereby build a foundation for the sector to engage in a strategic dialogue with relevant organizations
- **Shared value:** Define shared value to ensure partnerships are mutually beneficial and engaging
- **Performance catalogue:** Compile a repository of historical and existing engagement processes (e.g. Whitehorse Mining Initiative, Devonshire Initiative, Extractive Industry Transparency Initiative) and alliances (e.g. Barrick Gold, IAMGOLD, Tiffany & Co.); identify and document the key success factors of each initiative to guide future programmes and partnerships
- **Digital interaction:** Use digital technology and networking platforms to enable low-cost, flexible and highly responsive interactive and informed partnership models

Successful partnerships enable mining and metals companies to develop stable relationships with investors, suppliers, customers, governments and civil society, and to thus transcend the role of commodity provider and instead position themselves as stakeholders committed to shared value. The companies that maximize shared value will secure the strongest market position.



8. Drivers of Change

Seven drivers of change affect the mining and metals sector today and will influence sector companies in a sustainable world. The table describes the drivers and their likely associated impacts.

Table: Drivers of Change in the Mining and Metals Sector



Driver of Change	Description	Impact on Mining and Metals Companies in a Sustainable World
1. Higher demands for fairness	Greater expectations among the broader stakeholder community, including governments, communities and indigenous people, for a more equitable distribution of the benefits, costs and risks related to mining and metals activities	<ul style="list-style-type: none"> – Ownership models mitigating commodity price volatility – Multiple, multistakeholder partnerships critical to the success of mining and metals companies
2. Increased “democratization”	Regulation, decision-making, access to information and capacity becoming more representative	<ul style="list-style-type: none"> – Greater transparency by companies and governments on issues such as distribution of resource rents – Social media networks and information and communication technologies allowing greater scrutiny of and interaction with mining and metals companies – Policy and regulation providing consistent standards and levelling the playing field for all companies
3. Growing concern for the environment	Increased focus on the protection and sustainable management of water, biodiversity and the climate	<ul style="list-style-type: none"> – Operations adapted to different environmental conditions, e.g. higher temperatures and more frequent, extreme weather events – Operations adhering to stricter environmental standards for lower water consumption, GHG emissions, energy and improved waste management – Environmental performance as a more significant component in securing and maintaining a project’s licence to operate
4. Abrupt generational change	New ideas and values shaping the leadership profile in the sector, government and civil society	<ul style="list-style-type: none"> – Leaders from governments, industry and civil society expecting and relying on partnerships to generate value – Leaders with higher standards for operations to contribute to socio-economic performance

Driver of Change	Description	Impact on Mining and Metals Companies in a Sustainable World
5. Intensified rate of technological change	New, more sophisticated technologies and innovations transforming mining and metals processes and operations	<ul style="list-style-type: none"> – Use of automation and 3D printing technologies – New tools, systems and processes for deep-sea and asteroid mining – Demand for new products and services with different material requirements
6. Geographical shift	Mining operations increasingly in remote, undeveloped regions	<ul style="list-style-type: none"> – Established operations in South America, Africa and Asia – Key mining players actively pursuing deep-sea and asteroid sources
7. Rising concerns related to ASM	The social and environmental challenges associated with ASM become priority issues	<ul style="list-style-type: none"> – ASMs expected to participate in standard ownership models – ASMs working more closely with established industry players – ASMs to adhere to the same social and environmental standards as their industry peers

9. Roadmap to a Sustainable World

This scoping paper has described the role and contribution of the extractive industry in a sustainable world. However, this is clearly a world of the future. It also raises the question: What can mining and metals companies do now to move towards a sustainable world? Setting the vision is only the first step in the journey. The sector has long lead times – mining in particular is grounded on assets with life cycles of 30 or more years. If the sector is to be operating in a sustainable world at any point in the next 50 years, the planning needs to start today. Through a series of concerted changes by mining and metals companies, some of which have been under way since the Global Mining Initiative was developed by leading firms in the industry in 1998, the sector will both promote a sustainable world and be positioned to operate successfully within it.

The manner in which mining and metals companies respond to the seven drivers of change detailed in section 8 will affect how quickly and efficiently the sector will be positioned to operate in and contribute to a sustainable world. Taking the first step will require initiative and courage; moreover, the road to a sustainable world will be complicated. However, for those sector companies and stakeholders brave enough to accept the challenge, a range of opportunities lies ahead. The following are some of the activities that the sector can consider pursuing now:

- **Re-emphasize the journey:** Businesses need to have a decisive conversation with stakeholders (companies, civil

society, governments) about their visions and milestones for a sustainable world.

- **Invest in R&D:** Mining and metals enterprises must start developing the technologies to operate in a clean, affordable and safe environment in frontiers previously considered inaccessible.
- **Define shared value:** To prepare for operating in a sustainable world, companies in the sector need to look at what drives value for their customers and the communities in which they operate.
- **Rethink multistakeholder models:** Mining and metals companies can accelerate the transition to a sustainable world by embracing multistakeholder models.
- **Cultivate the workforce:** The skills and capabilities required to operate mining and metals companies in a sustainable world will be different; this needs to be considered, planned for and developed in advance.

10. Potential Roles for the World Economic Forum

The Forum has four key roles to support the mining and metals sector in its transition to a sustainable world:

- 1. Engage industry stakeholders on the topic:** Initiate a multistakeholder dialogue to get commitment for the vision of mining and metals in a sustainable world
- 2. Continue the development of a transformation map:** Research the drivers and issues that are affecting the sector, and identify the gaps between the sector as it operates today and its vision in a sustainable world
- 3. Define a roadmap:** Articulate a plan of action for mining and metals companies to guide the transition to a sustainable world, including the development of engagement plans with government and civil society, and establish checkpoints to assess progress
- 4. Outline the circular economy:** Build on existing Forum research, and explore the implications of the circular economy for the sector





Endnotes

- ¹ World Business Council for Sustainable Development (WBCSD), 2009. *Vision 2050: The new agenda for business*.
- ² The Forum is conducting a “transformation map” exercise to identify and provide context for key drivers of change, the actors and the issues related to a specific topic and their evolving development. When finished, the collective set of transformation maps across sectors, regions and issues will illustrate the connections between the topics and highlight where projects and research can be mutually beneficial. The seven drivers of change for the mining and metals sector have been identified as (1) higher demands for fairness, (2) increased “democratization”, (3) growing concern for the environment, (4) abrupt generational change, (5) intensified rate of technological change, (6) geographical shift and (7) rising concerns related to artisanal and small-scale mining (ASM).
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- ¹² Resource rents are the difference between the price at which an output from a resource can be sold and its extraction/production costs
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- ¹⁴ Sharma, R. “Deep-sea mining: economic, technical, technological and environmental considerations for sustainable development”. *Marine Technology Society Journal*, 2011, Vol. 45(5): 28-41.
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- ¹⁶ Mining.com, February 2013. “The next frontier of mining”, <http://www.mining.com/the-next-frontier-of-mining-44574/>.
- ¹⁷ Sonter, M. “Mining Economics and Risk-control in the Development of Near-earth-asteroid Resources”, *Space Future*, University of Wollongong, Australia, 2006.
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