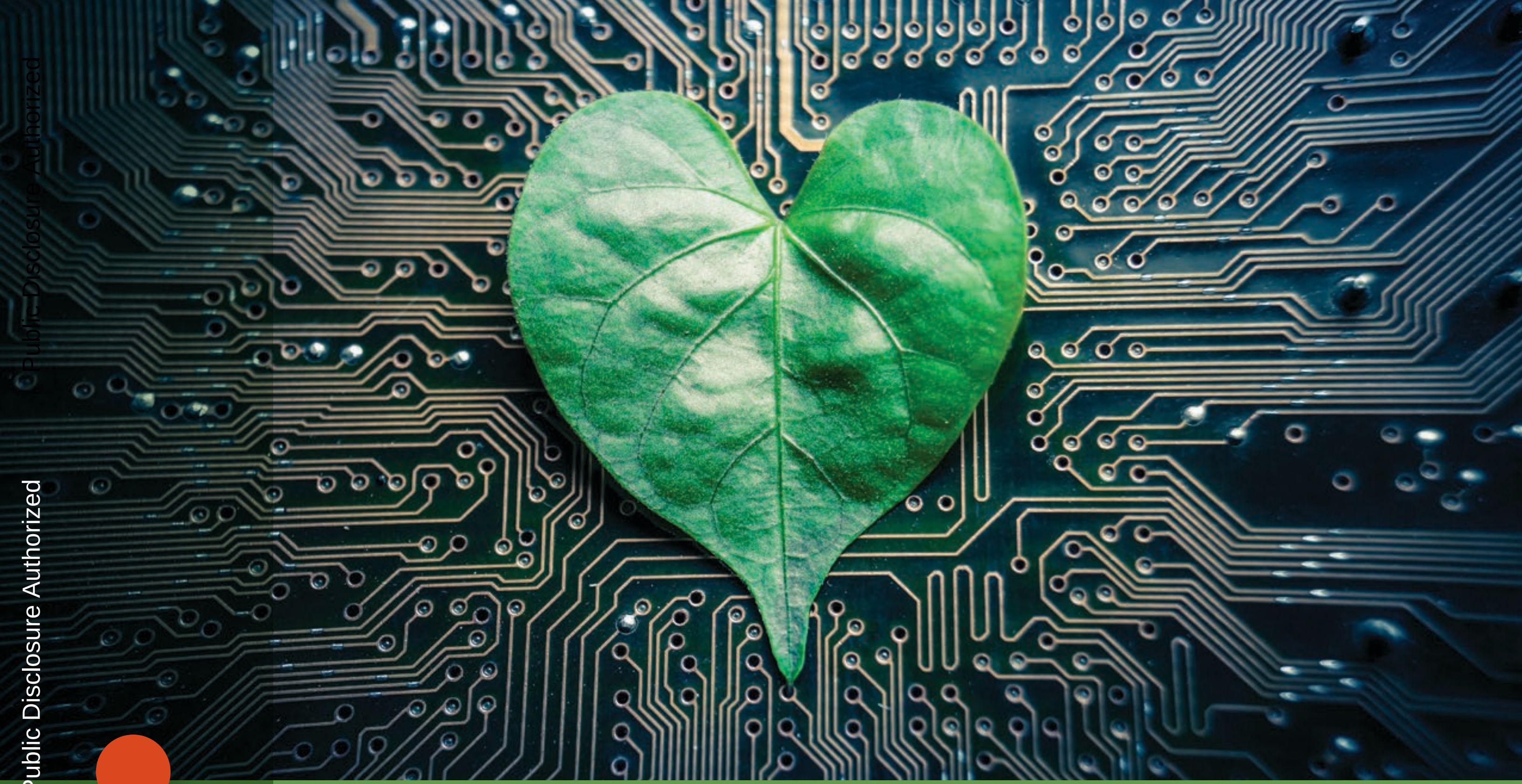

INTERNATIONAL DEVELOPMENT IN FOCUS

Building Resilience

A Green Growth Framework for Mobilizing Mining Investment

Sri Sekar, Kyle Lundin, Christopher Tucker,
Joe Figueiredo, Silvana Tordo, and Javier Aguilar

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This report investigates the potential for leveraging the mining industry to drive the uptake of climate-sensitive technologies and practices in emerging and developing markets. The report is complemented by detailed analysis contained in a series of background reports: (a) Mining Industry Value Chain Analysis and Methodology; (b) Mining Companies' Climate-Sensitive Initiatives; (c) Climate Sensitive Mining: Case Studies; and (d) Policy Approaches to Climate Change in Mineral-Rich Countries.

The report was undertaken by a team comprising Sri Sekar (Mining & Energy Lead), Kyle Lundin (Mining & Energy Research Analyst), Christopher Tucker (Mining Specialist), and Joe Figueiredo (Extractives Policy Associate), all with Deloitte Consulting LLP, with the contribution and under the guidance and direction of Silvana Tordo (Lead Energy Economist, World Bank) and Javier Aguilar (Senior Mining Specialist, World Bank) who colead the ELLED Program.

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Extractives-led Local Economic Diversification

Report Context

WHAT DOES THIS REPORT AIM TO DO?

The report aims to facilitate the uptake by the mining industry of climate-sensitive production and procurement practices that have the potential to support in-country value creation and green growth in the country of operation. To that end, the report proposes a framework through which green growth imperatives are integrated in policies and practices designed to maximize local economic value creation in mineral-rich emerging and developing economies. The report shows that such efforts have the potential to support sustainable development while generating returns for private sector investors.

WHO IS THE REPORT ADDRESSED TO?

This report addresses mining companies operating in mineral-rich emerging and developing economies seeking to climate-proof their production and procurement processes and policy makers in those economies seeking to devise policies to mitigate the impact of mining operations on the climate. It aims to help them identify what can be done to integrate climate resilience into investment and economic policies to support in-country value creation and the development of diversified sources of green growth. It may also be useful for donor organizations, institutional investors, private foundations, and fund managers—as potential mitigation and adaptation project funders—to help them understand how finance mechanisms may be tailored to support climate-sensitive mining investment and policies. This report focuses on the water-mining and energy-mining nexus, but most of the insights and findings are relevant outside that context.

WHAT DO WE MEAN BY GREEN GROWTH?

This report adopts the Organisation for Economic Co-operation and Development's (OECD) definition of green growth: "fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies." The focus of green growth strategies is to ensure that natural assets can deliver their full economic potential on a sustainable basis. To achieve this objective, green growth strategies must catalyze the investment and innovation that underpin sustained growth and generate new economic opportunities. This report focuses on the mining industry because of its criticality to global economic activity and development. As a proxy indicator of the global importance of mining, the United States Geological Survey (USGS) estimates that a single automobile requires more than a ton of iron and steel, 240 pounds of aluminum, 50 pounds of carbon, 42 pounds of copper, 41 pounds of silicon, 22 pounds of zinc, and more than 30 other mineral commodities, including titanium, platinum, and gold. The importance of minerals in everyday life is hardly recognized by the vast majority of people. According to the U.S. Bureau of Mines, over the course of a lifetime, an individual will use more than 1,050 pounds of lead, 1,050 pounds of zinc, 1,750 pounds of copper, 4,550 pounds of aluminum, 91,000 pounds of iron and steel, 360,500 pounds of coal, and one million pounds of industrial minerals such as limestone, clay, and gravel. Simply put, the world runs on minerals produced by the mining industry. Furthermore, according to a study from Oxford Policy Management, over 75 percent of all mineral-dependent countries are low or middle income, often with low levels of economic and institutional development and therefore more limited capacity to guide the sustainable development of their mineral sectors.

Policies that incentivize investment behavior in areas of climate interest in which the public sector and mining companies overlap—such as emissions, water availability, and sea level rise—can yield investments into, and local procurement supporting, new value chains built on clean energy, water infrastructure, automation, and sea walls and other retaining infrastructure within a host nation, modernizing an economy while positioning it for sustained growth. This collaborative vision, of policy-incentivized and operationally necessary procurement and investment behavior into industrial sectors whose high growth is driven by climate realities, is ultimately what this report refers to as green growth.

This report is intended to cover policies designed to drive investment behavior into productive sectors of economies. As such, policies intended to drive consumer behavior or policies related to the management of fiscal revenue generated by the mining industry are outside the scope of this report

HOW IS THIS REPORT STRUCTURED?

The report is structured as follows:

- **Chapter 1: Prevailing Policy Approaches to Climate:** In an effort to describe the climate policy context and environment in which mining firms are operating, this chapter provides an overview of the primary climate policy levers used by various jurisdictions and gives a sense of how they might be used in the context of a green industrial policy framework.
- **Chapter 2: The Mining Industry Heat Map:** This chapter identifies the primary areas of existing and potential climate-sensitive impacts to the mining value chain across four different mineral subsectors to account for variations in production operations. Areas that are more exposed to or are more likely to influence climate change are identified in a heat map. The analysis offers

insights on areas where policy focus and industry activity have the greatest potential to lead the transition to a green economy.

- **Chapter 3: Mining Firms' Climate Practices:** This chapter discusses mining companies' motivations for climate action, provides an accounting of operational activities with high potential to drive local value creation in a green economy, and points to some potential gaps that hinder the mining sector's contribution to green growth.
- **Chapter 4: A Green Growth Framework for Mining Firms and Government:** This chapter proposes a framework for policy makers and mining firms to develop their approach to climate adaptation and mitigation and local value creation in a manner that maximizes opportunities for green growth.

This report is informed by, and summarizes the findings of, four background reports that contain a more in-depth analysis of the topics presented in chapters 1 to 3 (Mining Industry Value Chain Analysis and Methodology; Mining Companies' Climate-Sensitive Initiatives; Climate-Sensitive Mining: Case Studies; and Policy Approaches to Climate Change in Mineral-Rich Countries).

Abbreviations

AI	artificial intelligence
BC	British Columbia
CAD	Canadian dollar
CDP	Carbon Disclosure Project
CEO	chief executive officer
CO2	carbon dioxide
CSIRO	Commonwealth Science and Industrial Research Organization
EIA	U.S. Energy Information Administration
ELLED	Extractives-Led Local Economic Diversification (Program)
EPA	U.S. Environmental Protection Agency
EU	European Union
FDI	foreign direct investment
FIT	feed-in tariff
GDP	gross domestic product
GEPA	Ghana Environmental Protection Agency
GHG	greenhouse gas
GPS	Global Positioning System
HFO	heavy fuel oil
ICMM	International Council on Mining and Metals
IEA	International Energy Agency
IFC	International Finance Corporation
IMF	International Monetary Fund
INDC	intended nationally determined contributions
IRENA	International Renewable Energy Agency
KPI	key performance indicator
LTIP	long-term incentive plan
MNRE	Ministry of New and Renewable Energy (India)
NDC	nationally determined contributions
NGO	nongovernmental organization
PPA	power purchase agreement
PV	photovoltaic
R&D	research and development
RPS	renewable portfolio standards

SEDAPAR	Servicio de Aqua Potable y Alcantarillado de Arequipa
TBTU	trillion British thermal units
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCC	United Nations Framework Convention on Climate Change
USA	United States of America
US$	United States dollar
USGS	United States Geological Survey
WTO	World Trade Organization

Executive Summary

GREEN ECONOMY AND GREEN GROWTH DEVELOPMENT

The World Commission on Environment and Development defines sustainable development as *development that meets the needs of the present, without compromising the ability of future generations to meet their own needs*. This concept implies a development pathway that strives to balance needs with social, environmental, and economic imperatives. The transition to a green economy can be considered as the operationalization of the concept of sustainable development, wherein macroeconomic policies are designed to support the development of sectors that are central to green growth (that is, to the greening of products, processes, services, technologies, and supply chains). The top-down policy-level approach is therefore complementary to and complemented by the bottom-up firm-level approach. Both are necessary to achieve an economywide transition.

A successful transition requires a focus on industries and institutions that have a meaningful economic impact, both directly, through their economic linkages with other industries, and through transfers of skills and technologies. In other words, a successful transition is rooted in the notion that direct investment into and policy support for industrial sectors whose foundational technology enables them to thrive in a progressively carbon-conscious world is a pathway to prosperity for nations and to continued profitability for resource-intensive firms and industries. Foundational technologies of particular interest in this report include variable-generation renewable energy sources such as solar photovoltaic (PV) and wind energy, water resource management systems, and automated transport systems.

THE MINING INDUSTRY'S ROLE IN GREEN GROWTH

A sustainable path to development has profound consequences for all economic activities and related policies. The mining industry, which provides input to almost every product and service in the world, is of great relevance to achieving sustainable development in mineral-rich countries and the economy at large.

In addition, environmental sustainability is a critical concern for mining companies, whose opportunities for growth are increasingly affected by climate change. Mining exploration, extraction, and processing activities consume copious amounts of energy and water, which are critical (although insufficient) for a green development pathway. According to industry experts, energy costs can total up to 30 percent of a mine's operating expenditure. Mining requires water at almost every stage of the process, and 70 percent of mining operations from six of the largest global mining companies are in water-stressed regions, mostly in the Southern Hemisphere.

The growing demand for resources and the scant supply in the regions in which miners operate result in risks to resource availability and volatility in pricing, which can disrupt production and harm a mine's profitability and a country's fiscal revenue. In some cases, competition for scarce resources has resulted in local stakeholders' unrest, production disruption, prohibitive compliance fees, or even expropriation—all existential risks to the operation, given the long-term nature of the investment and high up-front costs. Moreover, government in mineral-dependent countries often rely on mining investment to increase in-country value creation and support the development of local skills and the supply sector through local content policies.

Given the centrality of minerals to our way of living, this report investigates the extent to which the mining industry has been or can be an engine of change for green growth. The report highlights current and emerging best practice in three sectoral pillars of green growth:

- *Energy efficiency and renewable energy*. For example, the mining company Boliden now sources 42 percent of its energy from renewable sources.
- *Water conservation and infrastructure*. Anglo American's waterless mining effort is an example of the development of commercially viable technologies aimed at eliminating the use of freshwater in its mining processes, especially in the separation and transportation of ore and waste (tailings).
- *Automation and transportation*. Rio Tinto's Mine of the Future in Western Australia is an example of technological innovation deployed to scale up its autonomous and digitally managed haul equipment to drastically reduce greenhouse gas (GHG) emissions.

It is important to note that the areas of climate-sensitive investment listed above are areas in which industry has been more active.

THE POLICY AND PRIVATE SECTOR INVESTMENT MISMATCH

Despite what ought to be a tight nexus of public and private interest in targeted green sector investment, this report finds a vast misalignment between mining companies' investment in climate-sensitive production processes and policy makers' efforts to develop a cohesive green-economy framework for industry to navigate. As a result, neither industry nor government have yet to effectively leverage their climate imperatives and mandates to seize green growth opportunities.

Mining companies are pursuing a range of strategies to mitigate and adapt to climate change. Such practices are often intended to protect the value of their assets or to create additional value through innovation of processes and technology. Although mining operations can be important drivers for the local economy and community in which they operate, company efforts to increase local value creation (and bolster their social license to operate) are typically climate-agnostic activities or activities reflecting corporate social responsibility that are too bespoke and limited in scale to offer any real catalytic effect.

On the policy side, an impressive array of guidelines, standards, measurements, metrics, and best practices have been aimed at encouraging national and industry compliance with climate mandates. For example, emissions reporting and reduction targets, measurement of climate-sensitive resources, and taxing of carbon emissions are among an impressive array of productive policies, requirements, and guidelines aimed at creating greater local economic benefits from mineral operations through the development of economic linkages. However, these two areas of policy and government intervention are often not connected.

This report shows that what appears to be missing is a collaborative and intentional effort by industry and government to generate opportunities for green growth. Such opportunities might be more efficiently targeted if

- Industry focused more on high-value-adding climate-sensitive investments that drive operational sustainability and profitability,
- Policymakers focused more on building clusters of policies that incentivize such investment, and
- Both parties allowed their thought processes around such activities and policies to inform each other's behavior.

To start addressing this misalignment, this report proposes a framework to help mining companies and governments identify opportunities and seek new approaches to green growth. Such a framework shows that industry's climate-specific efforts that tend to be driven by compliance and audit imperatives focusing on transparency often have low near-term economic value but help earn the company "good neighbor" status. On the opposite end of the spectrum, firms attempt to add local value through local procurement, employment, and regional planning efforts to comply with local content regulation or to secure their long-term social license to operate with local stakeholders. Such plans are often not sufficiently scalable to create catalytic, broad-based economic growth, let alone green growth. They are driven by government policies that are designed to benefit discrete local communities and are completely disconnected from the green economy agenda. Catalytic green growth opportunities happen where mining firms make large capital-intensive investments in long-term green infrastructure or technologies that can be scaled up, employ hundreds, and build a local skill set and supply chain in a growth sector.

Such scalable economic impacts are inevitably tied to the existing and potential market size within the host nation of both the mining industry and the sectors in which mining firms invest. Ultimately, market potential must play a threshold role in both a firm's decision to invest and in the nation's decision to encourage such investments. Ideally, host nations, having identified technologies and sectors whose value chains are particularly well suited to grow within their borders and to drive the transition to a green economy, would have a well-thought-out set of policies to catalyze such investments. In turn, miners would respond by increasing their investments, growing their green portfolios, and establishing a comprehensive management system that embeds green growth consideration in decision-making and operations. This report finds that such a collaborative approach is the missing element that stands between a green growth opportunity and the realization of that opportunity.

A GREEN GROWTH PIVOT FOR MINING ECONOMIES AND THE MINING INDUSTRY

The gap between green growth potential and realization persists for multiple reasons. Among those reasons are country-specific barriers, which include, for instance, low market size or low potential for mining or green technology, relatively high costs of green technology, lack of human capital or capacity, regulations favoring incumbent processes, and specific technical barriers. However, it is often not the presence of these barriers that constrains the realization of a country's green growth potential. Rather, it is the lack of articulation and of transparent execution of a cohesive green economic development policy that would incentivize mining companies to broaden their focus from the localization of traditional-sector value chains to investments in highly scalable green infrastructure, technologies, and production processes.

From the public sector's perspective, the objective should be to provide transparent and predictable guidance to industry regarding what investments will yield the highest green growth return. To do this, policy makers in mineral-rich nations should approach their green industrial policy by focusing first on the middle band mentioned above, targeting those sectors that have the highest impact and show the most long-term growth potential in their markets, such as renewable energy, water infrastructure, or intelligent automation. Having identified those markets, policy makers could then work to develop *clusters* of policies to promote such sectors. Such a cluster in the autonomous electric vehicle segment, for instance, might involve setting rigorous vehicle and equipment emissions standards for those types frequently purchased by miners, repealing any subsidies that might promote the use of diesel fuel, providing tax credits for the purchase of zero emissions vehicles, and taking other measures to support local demand. The government could then establish policies to support the localization of strategic segments of the autonomous vehicles supply chain. This approach would also provide a practical measure to implement nationally determined contributions (NDCs) established by mineral-rich economies as part of the 2016 Paris Agreement on combating climate change and adapting to its effects, by making a formal link between growth policies and climate change policies.

From the private sector perspective, the biggest shift in approach involves the change in mind-set as it pertains to climate-sensitive investment. Currently the bulk of *intentional* climate efforts resides at the central office level, with dedicated sustainability teams, without investment authority, focusing on reporting and target setting. Similarly, the bulk of in-country value creation, social license to operate, and community development efforts occur at the site level, but they have a narrow project scope and are not usually sufficiently replicable to create catalytic economic impact. Furthermore, the greatest climate impact is driven by efforts to optimize business operations and reduce costs—through investment in new technologies, processes, and infrastructure—with climate viewed only as a nice ancillary benefit. The opportunity for industries is to place a direct climate

TABLE ES.1 Public policy and corporate strategy agendas for promoting green growth

THE PUBLIC POLICY AGENDA	THE CORPORATE STRATEGY AGENDA
• Facilitate investment in high-value-adding target sectors, whether through incentives, pricing based on the true cost of competing technologies, or setting of targets. • Form policy "clusters"—mutually reinforcing measures that offer transparent and predictable guidance to investors. • Continue to set or align with minimum climate standards to project policy stability and encourage investment.	• Organizationally align central office or headquarters (HQ) sustainability and government affairs units with site-level operations. • Shift resources away from HQ sustainability and site social investment teams toward site-level resource planning and investment teams. • Continue to focus on "good neighbor zone" activities metrics and expand tracking to include economic outcomes of green investments. • Where appropriate, aim for scale, and negotiate with governments for such scale.

lens on their site-level business investment decisions. Such a move also comes with trade-offs. It means acknowledging that resources may need to be shifted from both headquarters and dedicated social investment staff to site supply chain and operations managers with a green growth mind-set.

Table ES.1 summarizes some of the near-term actions proposed in this report for both the public and the private sectors.

Ultimately, institutional measures are required for both mining firms and their public sector counterparts to promote the relevant behavioral changes that are necessary to achieve maximal shared value from green growth investments. Such measures would be designed to create the space for greater collaboration across the industry and between private and public sector actors, as well as for greater coordination among operational and corporate teams. A detailed discussion of such mechanisms and their successful implementation could be the object of subsequent research.

POSSIBLE TOPICS FOR FOLLOW-UP RESEARCH

This report has identified several disconnects that warrant more in-depth analyses:

- For mining firms, the climate agenda is mainly driven by headquarters and is part of the brand name and positioning of a company. At site level, climate-sensitive production processes are driven by efficiency considerations. Neither at headquarters nor at site level is the climate strategy linked to the local value creation strategy. Because of this, even if mining firms are rolling out technological or process innovations, no information or data (besides anecdotal) are made available on the local impact of these activities beyond cost efficiency or GHG reduction.
- For policy makers, the climate change agenda is mostly driven by the Ministry of Environment, with limited involvement from other sector ministries. The local value creation agenda is often driven by the Ministry of Mines, with little coordination with the Ministry of Economy and the Ministry of Industry. As a result, NDCs in mineral-rich countries typically have no concrete actions for the mining industry; and although the countries analyzed in the research have green growth aspirations, there is no link or coordination with the local value creation policies or requirements that these countries set for the mining sector.

Making and documenting the connection between climate and value creation helps policy makers in mineral-rich countries to leverage their most relevant industrial sector to deliver economic and social value, and possibly to fast-track green growth through technology spillovers and the creation of skills that will be more in demand in the future economy. To accomplish those aims, additional research is necessary. In particular, there is scope to further our understanding of the value addition and employment generation potential of climate-sensitive production and procurement by mining firms. Such research would entail gathering and analyzing quantitative data (currently not measured or not in the public domain) on mining investment in the climate priority areas identified in this report. Furthermore, although this report proposes a framework for mining sectors contributing to green growth—a framework that is designed to focus on high-value-adding climate-sensitive investments that drive operational sustainability and profitability—there is a need to further document how to achieve this objective within the existing decision-making and organizational structures of most players in the mining industry and in the public sector.

1 Prevailing Policy Approaches to Climate

After a brief description of the link between sustainable investment and climate policy, this chapter provides a brief overview of the policy tools that are available to governments to influence their countries' development trajectories toward a green economy. Examples of the application of these tools to the mining sector are also presented.

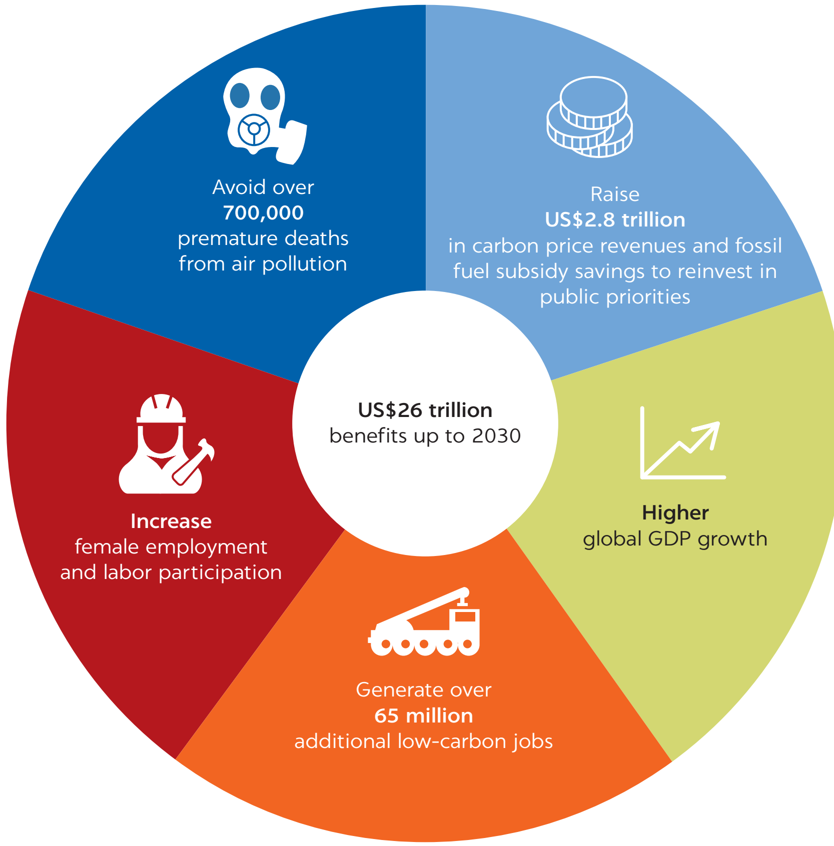
SUSTAINABLE DEVELOPMENT AND CLIMATE POLICIES

The concept of sustainable development refers to a development model that balances socioeconomic imperatives with environmental sustainability. The idea is that of meeting present needs without compromising the ability to meet future needs. Though the implementation of this concept implies trade-offs that are greatly affected by country-specific circumstances as well as by global imperatives, climate policies are one important dimension of sustainability. Countries employing the right set of policies to support sectors that are fundamental to green growth (that is, to the greening of products, processes, services, technologies, and supply chains) are well placed to achieve a successful transition to a sustainable development model. In addition to the influences of international compacts and frameworks—for example, the 2016 Paris Agreement and the 2030 Agenda for Sustainable Development adopted by world leaders at the 2015 United Nations Sustainable Development Summit—the growth of green sectors is substantially being driven by economic shifts and innovations that have made commercially viable and feasible technologies such as renewable energy, water desalination and treatment, and automated and electrified transportation, whose wide-scale adoption portends important climate benefits.

It is these sectors that drive in large part the shift to a low-carbon economy that, according to the Global Commission on the Economy and Climate, could unlock benefits worth US$26 trillion from now until 2030, create 65 million new low-carbon jobs, and avoid over 700,000 premature deaths from air pollution (figure 1.1). The green economy presents the opportunity for government to incentivize innovation and process reengineering that embraces the climate dimension of sustainability.

FIGURE 1.1

Economic benefits from climate-sensitive investment



Source: Global Commission on the Economy and Climate 2018. Used with permission; further permission required for reuse.

Yet green growth and climate policy are too often viewed by resource-rich developing countries with skepticism, limiting their economic growth potential. On the other hand, even resource-rich economically developed countries with relatively mature climate policies have yet to optimally combine disparate legislative and regulatory efforts into a mutually reinforcing green growth policy. By and large, green growth policies appear to be done in a piecemeal manner, intended to address the following disparate outcomes. Particularly, climate policies appear to fall in the following broad categories:

- **Standard setting and alignment.** Targets, measures, and data-gathering initiatives aimed at setting minimum climate-sensitive goals, complying with international compacts or guidance, or aligning a jurisdiction with leading practices
- **Sector-targeted support.** Industrial production and manufacturing subsidies, government-led research, and research grants aimed at improving the commercial viability of green technologies
- **Local employment and trade protection.** Local economic development and supply chain localization efforts adopted, irrespective of climate outcomes, to enhance the shared value of a mining project with the surrounding community and to support the development of local industries—beyond their direct fiscal contribution (royalty and tax receipts) to the central government.

GREEN GROWTH ENABLING POLICIES

Within the broad categories of policies identified above, some initial attempts have been made to leverage core industries and processes for green growth. The Paris Agreement requires signatory countries to establish nationally determined contributions (NDCs) to reduce national emissions and adapt to the impacts of climate change. Some mineral-rich economies have already started charting specific targets for the mining sector, which can play a significant role in both climate mitigation and adaptation, directly and through its economic linkages with other sectors. For example, Guinea's intended nationally determined contribution (INDC) states that "as the mining sector is destined to become one of the pillars of the Guinean economy, there is an opportunity to make it a model for the integration of climate issues (mitigation/adaptation) throughout the value chain."[1] Afghanistan's and Papua New Guinea's INDCs also envisage energy efficiency objectives for the mining sector.

In addition to high-level INDCs, a wide range of policy tools are used to create an enabling environment for green growth, including climate-based taxes and tariffs, targeted subsidies, investments in publicly available climate-sensitive data infrastructure, climate standard setting, and, to a limited extent, local content regulation. Since social and political objectives, constraints, and concerns are often country specific, it is difficult to identify a combination of tools that apply to all countries in all circumstances. Therefore, the remainder of this section provides an overview of each policy tool and its general purpose.[2] Where appropriate, examples of the application to the mining sector are also highlighted.

TAXES AND TARIFFS

Carbon taxation

In almost any scenario that envisions meeting the ambitious global GHG emissions targets laid out in the Paris Agreement, one of the most accepted and frequently considered policy options is to put a price on carbon. Notably, Chile's INDC prescribes the establishment of a carbon tax to help meet its GHG reduction targets. Carbon taxation or pricing can be used to incentivize renewable energy development. However, the extent to which such development could also catalyze local value creation is unclear. For example, building value chains for advanced technologies such as solar and wind could prove challenging in an emerging market context. While debate continues, mineral-rich jurisdictions have moved toward establishing carbon trading or carbon taxation frameworks, including Australia, Canada, and South Africa. South Africa, for instance, is implementing its second draft carbon tax, which became effective on January 1, 2019, and would cover all GHG emissions relating to the production of energy and nonenergy industrial processes at the rate of 120 rand (about US$8) per metric ton (Roelf 2018).

As a traditionally heavy emitter of GHGs, mining is significantly affected by carbon taxation. Although the industry has generally responded favorably to carbon pricing, a beneficial outcome is not guaranteed: certain rules must be observed for carbon pricing to have its intended effect of achieving the optimal balance between emission reduction and economic growth.[3]

Revenue recycling

The revenue generated by carbon pricing can be used in various ways by mineral-rich countries, including through recycling the revenue in a manner that further supports the development of climate-sensitive value chains and local value creation. For example, carbon tax revenues can be used to spur the development of clean technologies, to support wider governance issues (such as climate change programming inside governments), to protect or help ease the transition to low-carbon regimes for specific populations, and to help protect trade-exposed economic sectors. The Canadian provinces of Alberta and British Columbia provide examples of such policies. However, market principles should ideally drive the development of substitute goods such as renewable energy.

Border carbon adjustments

A carbon tax applied to domestic industries has the potential to create a competitive advantage for imports from jurisdictions without carbon taxation. This concern was expressed in the Canadian province of British Columbia, a pioneer of domestic carbon taxation, with some industry representatives complaining that it made them less competitive with imports from the United States and Mexico. For this reason, some economists have recommended that a carbon tariff or carbon import tax, also known as a border carbon adjustment, be applied. Though there are considerable logistical challenges in assessing each import's carbon footprint, current estimates suggest that carbon tariffs significantly improve the effectiveness of carbon taxation and emissions reduction policies (Larch and Wanner 2017). Particularly within the mining industry, given the relatively high level of environmental disclosure, estimating per-tonne or per-ounce GHG emissions is not particularly difficult, making carbon tariffs applied to imports of metals and mineral concentrates a viable option.

Export taxes

Export taxes (e.g., a tax on the exportation of a mineral concentrate) can be used to encourage value-adding refining and manufacturing where feasible within a host country. Export restrictions—such as the export quotas that China applied to its rare earth minerals in 2010—are common in mineral-rich countries (e.g., in Argentina, Tanzania, and Zimbabwe) and in the resource sector more broadly, where they are twice as likely to be imposed compared with other sectors. According to Ruta and Venables (2012, page 12), "more than one-third of all notified export restrictions are in resource sectors." However, China ran afoul of World Trade Organization (WTO) requirements, which place limits on the use of certain forms of export restrictions, and dropped its rare earth export quotas in 2015. Export taxes are generally permitted under WTO regulations and as such present a better option for encouraging in-country value-adding activities, such as further refining or even manufacturing where possible. However, countries' experiences with export taxes have had mixed results.

TARGETED SUBSIDIES

Industrial policies commonly include the provision of general subsidies to sectors that governments specifically target to stimulate economic growth. These subsidies include general financial subsidies (e.g., tax credits and low-interest loans), renewable energy subsidies, and research and development (R&D) subsidies to encourage innovation in a specific industry. While many countries' INDCs contain commitments to transition to renewable energy sources, few specify how that transition is to be achieved. Most countries provide some level of financial support to domestic sector development, but often countries that support green growth through NDCs also subsidize fossil fuels, thus sending perverse signals to the market. For example, mining companies that operate in countries where fossil fuels are heavily subsidized will likely find it challenging to propose to their shareholders to invest in renewable energy.[4] Ghana however has included phasing out some fossil fuel subsidies in their INDC.

Renewable energy subsidies

One specific type of green growth focused subsidy is a feed-in tariff (FIT) for renewable energy, which typically entails the provision of a guaranteed price for renewable energy supplied to the grid through a long-term contract. The contract price for the energy provided is typically higher than the market price for energy supplied from nonrenewable sources, helping to encourage investment and innovation. Many countries around the world, such as Germany and Japan, use FITs, or are planning to use them, for solar PV or onshore wind generation. FITs support the mining industry's transition toward low-carbon extraction and processing in two ways. First, they increase the likelihood that the available grid energy will have a lower emissions profile and hence lower the operation's scope 2 emissions (indirect emissions from the generation of purchased energy). Second, they create an economic incentive for mining companies themselves, or in partnership through direct power purchase agreements, to develop renewable energy supplies that they can sell back to the grid under conditions of surplus production. Ghana, for instance, in addition to committing in its INDC to a national energy policy, a national renewable energy act, and a national renewable energy fund, has included a commitment to set up a FIT for renewable energy technologies.

Support for research and development

Government funding can support the development of new, innovative climate-sensitive technologies at the early stages—when they may not yet be economically feasible for the private sector—such as supporting carbon capture and storage research in the China, Europe, and the United States.[5] According to the International Renewable Energy Agency (IRENA), thanks in part to government support at the early stage of variable-generation renewable energy technology, the cost of electricity from solar and wind power technologies could fall by at least 26 percent and as much as 59 percent between 2015 and 2025 (IRENA 2016). Between 2010 and 2017 alone, the levelized cost of energy for installed solar PV plants fell by 68 percent and that for onshore wind by 22 percent (IRENA 2018).

Given the newly cost-competitive environment, governments have started to reduce their level of fiscal intervention. In recognition of this type of progress, climate change mitigation efforts described in INDCs often include programs to build capacity, encourage research and development, and facilitate technology transfer. Because understanding and working to mitigate climate change impacts is necessarily local, those efforts align well with much of the long-term planning required for mine development and closure. For instance, many mining companies, especially those participating in the International Council on Mining and

Metals, have requirements to return their mine sites to acceptable end use states—that is, to reclaim, revegetate, and preserve biodiversity and water quality. However, effectively planning to revegetate an area decades into the future requires an understanding of what the future climate will be like and what plant species will thrive there. Much of this research is aligned with commitments to explore more sustainable (i.e., less energy- and water-intensive) forms of agriculture, such as are contained in the INDCs of Mongolia, Peru, and Zambia, where the mining sector is an important economic contributor.

SHARED DATA INFRASTRUCTURE

While large mining companies are virtually swimming in data regarding their operations and the environmental and geological environments they operate in, smaller junior mining or exploration companies that conduct much of the initial work in identifying and assessing the potential for mineral development are not. Similarly, collectively drawing reliable and defensible conclusions from such information requires a level of data sharing and comparability that currently does not exist, apart from a few notable practices described below.

Climate forecasting

Mining projects in jurisdictions around the world are exposed to increasing levels and frequency of climate hazards, including extreme weather events, sea level rise, flooding, and water scarcity. In the absence of sufficient climate data tracking, monitoring, and analysis, mining companies are unable to implement effective early-warning systems or to create probabilistic estimations of where and how often these events may occur in the future. Historically, governments, as part of their environmental programs and mandates, have had the responsibility of funding, establishing, and maintaining climate and environmental data monitoring networks. Governments have also held responsibility for funding the development of climate models to create future projections of climate under multiple scenarios.

As mining companies seek to understand their exposure to climate change, they are incorporating climate risks and scenario planning into their existing risk management procedures and mine design. For companies to do this effectively, reliable climate models and projections developed by government agencies are increasingly important. Moreover, since most users have a limited understanding of the science behind climate models and projections, they rely on government agencies to identify limitations and to communicate the overall applicability of these models.

Recognizing this responsibility and the challenges in developing climate models and climate projections, government agencies and climate research consortiums across the globe collaborate to develop suites of models instead of offering simply one set of models for their regions. The Coupled Model Intercomparison Project, initiated by the World Climate Research Programme in 1995, provides climate projections from up to 30 unique climate research centers across the globe by standardizing climate change projections, interpretations, and formulations and by providing multiple potential future climate scenarios to limit the systemic bias of individual climate models and projections. Both Australia and Canada have made regional and national efforts to collect, maintain, and share climate and forecasting data. Another mineral-rich country, Chile, includes in its INDC a commitment to create forecast models that Chile can share and distribute nationally and internationally, both through individual efforts and jointly with other countries determined to take action.[6] The broad uptake of these initiatives demonstrates the importance of comparability and consistency in climate modeling and risk assessment.

Water management and hydrological databases

The impacts of climate change on water availability and water quality will affect many economic sectors, including energy production, infrastructure, mining, human health, and agriculture, and ecosystems. Overconsumption presents threats to the availability of existing water resources; however, excessively conservative limits could result in unnecessarily and even detrimental restrictions on growth and development. Therefore, a transparent and effective water management plan is critical for sustainable development. The first step is the availability of detailed and reliable hydrological data. Best practices followed by water-stressed and mineral-rich jurisdictions, such as in Western Australia and South Africa, include establishing water accounting frameworks targeted at industries that are heavy consumers of water. These frameworks set standards for obtaining a water license and water resource data gathering and forecasting.[7]

CLIMATE-FOCUSED STANDARDS

Standards provide an important tool to slow the progression of climate change hazards and a framework for implementation of a climate action plan. Standards reduce the risk of comparing apples and pears and provide some reassurance to investors concerned by the economic and financial risks climate change presents. Some of the most notable standards that are relevant to the mining industries are listed below.

Renewable portfolio standards

Renewable portfolio standards are regulatory mandates that support increased production of renewables. Standards set a minimum amount for annual production of renewable energy. In the United States, Michigan's 2016 Clean, Renewable and Efficient Energy Act requires that electric providers increase their supply of renewables from 10 percent in 2015 to 15 percent in 2021, with an interim requirement of 12.5 percent in 2019 and 2020. Other state-level renewable portfolio standards accounted for 60 percent of new U.S. renewable development in 2012.

Energy efficiency standards

Energy efficiency standards are regulatory targets of efficiency. Energy efficiency policies combine mandatory standards and financial incentives for the adoption of demand-side efficiency measures. South Africa, for instance, provides an income tax deduction of US$0.067 for each kilowatt hour saved by the taxpayer during the year.[8] Such efforts provide a strong financial incentive for mining firms to reduce the energy intensity of their operations, and also serve as a bedrock industrial policy to boost the growth of energy services companies that develop, design, build, and fund projects that save energy, reduce energy costs, and decrease operations and maintenance costs at their customers' facilities through implementation of, for example, retrofits.

Mine closure standards

Most mining companies are required to include decommissioning and reclamation plans as part of the permitting and licensing process. However, changing climate conditions may require additional measures at the end of a mine's life to ensure that waste products are safely disposed of or stored and that there is little chance of subsidence. Climate conditions could also be different at the end of a project, so an updated strategy may be required; in particular, planning for the postclosure landscape requires an understanding of climate nuance and how the new climate will affect which vegetation is best suited to the postclosure structure and hydrological regime. Furthermore, with proper planning, former mine sites could provide an opportunity for climate-friendly uses, such as pumped storage and wind farms. Currently, such uses are a gap in public policy thinking, although some examples are worth noting, especially in the Northwest Territories in Canada, in the United States, and in Queensland, Australia.[9]

LOCAL CONTENT REQUIREMENTS

Mineral-rich countries often impose local content requirements on the mining sector in an effort to generate additional benefits to their economy—beyond the direct contribution of its value-added—through its links to other sectors. These policies often take the form of legal or regulatory requirements that commit mining companies to a minimum threshold of locally purchased or produced goods and services. Local content requirements are de facto import quotas on specific goods and services to create local demand within certain strategic sectors.

To attract foreign investment, local content requirements are often associated with incentives. Governments, especially those in economically developed countries, are no stranger to adopting a complex, interwoven fabric of tax credits, direct subsidies, preferential contracting, and even trade protection measures to foster the growth of indigenous industries. Such an approach to economic development relies on incentivizing private sector investment behavior and is known collectively as industrial or productive policy. For example, Chile, through the combination of subsidies and local content requirements that were later phased out under WTO obligations, was able to develop a more diversified export base of small and medium-size companies.

The use of local content policies to drive higher and higher skilled local employment combined with an increase in low-carbon, resource-efficient, and socially inclusive growth is still an emerging practice. A recent study by the United Nations Conference on Trade and Development (UNCTAD 2014) found that in South Africa the ambitious push to transform the country's energy future through renewable energy has encountered obstacles with respect to the efficiency and capacity of regulatory agencies. Brazil's plan to develop a global renewables industry has been stalled by its cost of doing business, reflecting weaknesses in infrastructure and regulatory oversight.

In China, the lack of transparency at the public level and weaknesses in the basic infrastructure required to achieve green economy objectives have somewhat countered the attractiveness of its growing domestic market (UNCTAD 2014).

The UNCTAD study suggests that many green energy programs, particularly their local content components, failed to account for the slower pace of regulatory and productivity change in the wider economy, the often large price differential between domestic and imported inputs, and the level of taxpayer subsidy required to honor long-term purchase agreements and ensure competitive rates for final consumers.

On the other hand, Finland offers a prominent example of successful government intervention to drive the update of green technologies and climate-conscious practices in the mining sector. Through a combination of education, training, and financing of R&D for the mineral sector, the Finnish government has played an active role in establishing Finland as a provider of innovative technologies for the green economy. Finland promotes advances in efficient use of resources and implementation of intelligent systems, together with recycling initiatives that promote sustainable mining practices, as key future areas of growth within the sector (OECD 2017).

NOTES

1. Guinea's first INDCs submission, page 12 (https://www4.unfccc.int/sites/NDCStaging/Pages/All.aspx).
2. In-depth analysis of the various policy tools referred to in this section is outside the scope of this report.
3. A full discussion of carbon pricing is outside the scope of this paper. For a good overview of the topic, see McKitrik (2016).
4. According to a commentary published by the International Energy Agency, "The battle to reduce oil-based subsidies is far from over. Governments could well come under pressure to reinstate subsidies for gasoline and diesel when oil prices start to rise." (https://www.iea.org/newsroom/news/2017/december/commentary-fossil-fuel-consumption-subsidies-are-down-but-not-out.html).
5. A May 15, 2018, press release describes Norway's plans for a demonstration project for CO2 capture, transport and storage. See https://www.regjeringen.no/en/aktuelt/the-norwegian-government-continues-with-the-planning-of-a-demonstration-project-for-co2-capture-transport-and-storage/id2601399/.
6. See Chile's INDC, section 4.2.1 (https://www4.unfccc.int/sites/NDCStaging/Pages/All.aspx).
7. See the water information tool developed by the Department of Water and Environmental Regulation of Western Australia (https://www.wa.gov.au/service/civic-infrastructure/water-supply/check-surface-and-groundwater-data) and World Resources Institute (2015).
8. For PwC tax summaries on South Africa's Income Tax Act, see http://taxsummaries.pwc.com/ID/South-Africa-Corporate-Tax-credits-and-incentives.
9. For information on these projects, see https://iclg.com/practice-areas/mining-laws-and-regulations/canada and https://www.ausimmbulletin.com/feature/mine-closure-rehabilitation-and-climate-change/.

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2 The Mining Industry Heat Map

Environmental sustainability is an important aspect of the transition to a green economy and a critical concern for mining companies whose opportunities for growth are increasingly affected by climate change.

This chapter reviews mining companies' climate priority areas, focusing on the value chains of four mineral subsectors, and provides an overview of companies' activities in these areas. This analysis offers insights into companies' strategies and the potential of those strategies to contribute to green growth.

IDENTIFYING MINING COMPANIES' CLIMATE PRIORITY AREAS

Mining involves a wide range of heterogeneous activities, processes, and technologies with varying degrees of impact on and exposure to climate change. To identify mining companies' climate priority areas, this section starts from the categorization of mining subsectors. Two criteria are used: subsectors that are sufficiently unique in operation and requirements to warrant individual treatment, and subsectors that have developing country relevance. Those criteria result in the identification of the following four subsectors and their related reference or benchmark mineral:

- Precious metals (gold)
- Ferrous metals (iron ore)
- Base metals (copper)
- Construction minerals (aggregate/cement)

Both precious and base metals are commodities that can be economically extracted even when the ore grade is relatively low, because of their relatively high unit value compared with other commodities. As such, their operations require high levels of power, energy, and water, as more rock needs to be pulverized, processed, and separated to yield valuable ore.

Ferrous metals, by contrast, present a more common, ubiquitous type of operation in which commercially viable ore grades are roughly 19–20 percent, they have low value due to a market abundance, yet they continue to have a strong presence in emerging markets (roughly 35 percent of 2017 world production, not including China). The result of those dynamics is that iron ore mining tends to entail sprawling operations that maximize production volume, and high operational costs and related emissions that result from moving materials throughout the mine site.

The fourth subsector, construction minerals such as sand, gravel, and limestone—many of which are used to make the finished product, cement—are a globally large but extremely local industry because they have a low unit value and a market that is driven by growing local economies. These features of the subsector lead to minimal reliance on international shipping, and its ubiquity leads to a comparatively non-resource-intensive extraction process, with the emissions intensity of the industry instead being driven mostly by the downstream processing of stone into cement.

Each industry subsector, in turn, has corresponding specific value chains that must be individually assessed to capture the unique activities in the subsector's end-to-end life cycle and the exposure or contribution of these activities to climate change. This section describes the stages of the mining life cycle, followed by a description of the activities entailed in each stage, with the corresponding assessment methodology. For all stages, the assessment methodology considered both climate and economic factors using quantitative factors (such as energy intensity, water consumption, and metal or mineral production in the developing and emerging economies) and qualitative factors. The energy proxy variable used in this report—energy intensity of each process in trillion BTU/year—is targeted at minimizing the difference between direct emissions (e.g., those driven by emissions from extraction and hauling equipment) and indirect emissions (e.g., those driven by electricity consumption). A full description of the methodology and its application is provided in the background report "Building Resilience: Mining Industry Value Chain Analysis and Methodology."

a. **Mine Design, Planning, and Development:** This stage encompasses the initial portion of the mining life cycle—from concept through the exploration of resources, the design and planning of the facility, and the plans for its ultimate closure.

   Methodology: The background report begins by analyzing the value and ore grade at which the extraction of any of the identified minerals or metals would become commercially viable. The analysis leads to implications as to the likelihood that miners would engage in riskier and larger-scale activity, such as exploring harsher locations that are newly accessible as a result of global warming (e.g., arctic areas). Similarly, the incentive provided by highly valuable metals or minerals and low ore grade influences whether small-scale/artisanal mining would occur and the likelihood and magnitude of tailings operations, underground mining, and risks posed at mine closure—all activities that present substantial risks to climate stability or that are affected by risk from climate change. For each of these knock-on, or cumulative, effects or considerations, a qualitative assessment was used to apply a likelihood of occurrence score between 2 (most likely) and 0 (not at all likely). Finally, the energy intensity of each subsector's drilling and exploration activities, measured by trillion BTU (TBTU) consumed per year, was also researched while controlling for each subsector's economic relevance to developing countries by applying a multiplier. This last multiplier was rooted in the proportion of

2017 global production of the reference commodity attributed to emerging markets. This multiplier was not, however, applied to the construction mineral subsector, which was considered as uniquely local, for example, sandstone's price-to-value ratio prevents companies from being able to cost-effectively ship the commodity long distances.

b. **Mine Operations—Extraction:** This stage encompasses all activities necessary to extract the subject metal or mineral from its ore body, including all of the equipment and power required to blast, dig, ventilate, and dewater during mining operations. The equipment and materials used for these operations include diamond and rotary drills, explosives, hydraulic shovels, fans, and pumps.

Methodology: While there are multiple factors to consider when assessing the climate risks that threaten (and are posed by) extraction operations, in a quest for a data-rich analysis, energy intensity (as measured by TBTU/year) of operations was chosen as the primary measure for climate risk or impact in mining operations. The report tapered the climate analysis to the specific mineral or metal by accounting for the subsector's economic relevance to the developing world through the application of a multiplier. This approach accounted for the fact that, for instance, the developing world undertakes a lower percentage of the world's gold production than of the world's copper production.

c. **Mine Operations—Materials Handling and Equipment:** This stage consists of operations that encompass all in-pit activities related to the mobilization of mine inputs and outputs. The equipment used for these activities includes service trucks, front-end loaders, bulldozers, and pickup trucks.

Methodology: Since so much of the activity at this stage is powered by diesel fuel (and some electrical equipment, including conveyors, pumps, and hoists), energy intensity in TBTU/year was selected as the primary quantitative measure of climate impact and risk. Once again, the report applied the overall emerging markets relevance factor to measure the scale of the climate mitigation or adaptation (to reduced fuel supply) opportunity.

d. **Processing:** This stage encompasses all activities required to transform run-of-mine material into the final mined product. Processing include crushing the initial material into coarse particles, grinding them into fine particles, and using physical or chemical methods to separate the valuable material from the nonvaluable substances. This stage also includes the roasting, smelting, and refining required to transform the raw material into the final substance (e.g., cement, aluminum, or steel).

Methodology: As with other operations, TBTU/year was retained because it is the metric most reported and aligned with climate impacts, followed closely by the economic scale of the particular subsector in emerging markets. The analysis used a factor of the two to determine the segment's overall relevance for climate purposes.

e. **Water Risk and Consumption:** The analysis also included the consideration of a subsector's specific exposure to water-related risks (e.g., availability, competing uses, and permeable aquifers) and the use of water in operations. Water use and risk were considered a climatic factor that runs throughout the mine's operations, from exploration through processing, operations, and closure. The report includes this analysis as its own operational stage that affects the entire assessment.

Methodology: Because of the relative dearth of water-related data per value chain segment, a qualitative assessment was used to determine the water risks and volume of water use per subsector metal or mineral. Specifically, it assigned a commodity a 3 (highest score) for water risk if it is frequently mined in arid or semiarid environments or in an environment with extreme rainfall and permeable aquifers, whereas a commodity was assigned a water risk of 0 (lowest score) if it is typically mined in areas with a moderate level of rainfall, and the mine site can easily control its flow.

None of the stages or factors above were considered in isolation when arriving at the priority areas for analysis. Rather, this report takes a holistic approach, with an understanding of how, for instance, mine planning and design choices affect other parts of the value chain, how water plays a role throughout an operation, and how economic indicators illustrate the significance of each specific value chain segment. Figure 2.1 represents this assessment.

FIGURE 2.1

Value chain and subsectors heat map

The heat map visualization technique also provides critical insights to policy makers about the areas of focus for green policy. For example, gold and copper mines often present risks to local aquifers. As such, policy makers in gold- and copper-rich areas might have an interest in developing and making available water-related data, mandating siting standards, or providing incentives to mining companies that are willing to install water treatment infrastructure as a part of the mine development process. Similarly, countries and regions in which cement processing plants are located have an incentive to set energy efficiency standards or to offer incentives (e.g., using feed-in tariffs or opening the way for direct power purchase agreements) for plants that rely on renewable energy.

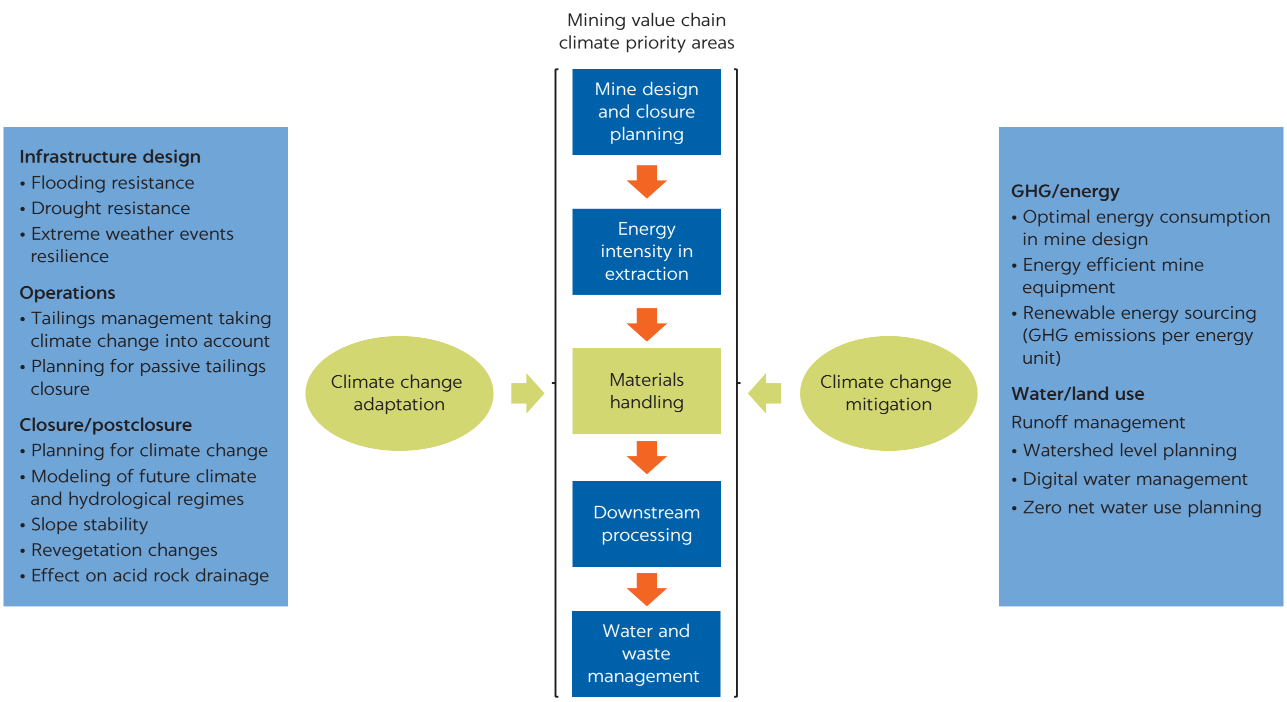
The heat map also provides a visual representation of the value chain segments for each benchmark mineral that represent climate-related pressure points for the industry. For instance, gold mine siting and development and downstream processing in the construction subsector are climate-sensitive areas. These insights yielded five cross-cutting priority areas for the industry:

- Adaptive long-term mine planning
- Energy-intensive extraction processes
- Mine site material hauling and mobility
- Emissions impacts of downstream processing
- Water conservation and preservation

Figure 2.2 summarizes the industry priority areas listed above and their relation to climate adaptation and mitigation. This reference framework is used in subsequent parts of this report to illustrate the alignment of specific private sector initiatives with the climate-related pressure points.

FIGURE 2.2

Reference framework for mining companies' priorities



INDUSTRY ACTION WITHIN THE PRIORITY AREAS

This section reviews industry activity (investment, technological innovations, and operational solutions) in each of the priority areas, and provides an assessment of such activity on the basis of two parameters: ease of implementation and strength of impact. The analysis results in the identification of a range of activities from high effort and low impact ("challenging" interventions) to low effort and high impact ("most effective" interventions).

The most effective climate-sensitive interventions in which the mining industry is involved tend to be associated with the following three discrete themes that can either be classified as climate driven or having a large potential impact on the climate: energy efficiency and renewable energy, water conservation and infrastructure, and automation and transportation. A brief overview of selected climate-sensitive initiatives undertaken by the mining industry, and their alignment to these three themes, is provided in table 2.1. These initiatives are discussed in detail in the following chapters.

TABLE 2.1 Representative industry climate investments and their alignment to priority areas

GREEN VALUE CHAIN	INITIATIVE
Energy efficiency and renewable energy	Direct power purchase agreements with grid-connected solar PV, onshore wind, and energy storage solution developers.
	Mineral processing energy efficiency through, e.g., high-efficiency grate coolers and modernized combustion systems.
	Conversion of old mine sites to pumped hydro storage facilities by creating above- and below-ground storage reservoirs. During the day, water is pumped from the below-grade reservoir in the refurbished mine to the above-ground reservoir. When electricity is needed on the grid, water is released into mine shafts and turns turbines that generate electricity.
Water conservation and infrastructure	Dry stacking tailings—an initiative used in colder climates to guard against the potential of mine tailings mixing with freshwater.
	Recycling water through installation of water treatment or desalination plants.
Automation and transportation	Alternative options to vehicular movement of material throughout the mine site, such as so-called low-loss conveyor belts, or a "rail-veyor" system incorporating an electrically powered series of two-wheeled railcars.
	Electrification of mining equipment and haul trucks.
	Management of haul truck idling through, for instance, the introduction of autonomous vehicles.

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3 Mining Firms' Climate Practices

This chapter provides an overview of the most notable climate-sensitive initiatives of the mining industry, selected on the basis of their potential to contribute to sustainable local value creation and the transition to a green economy. The chapter begins with the observation that the climate-sensitive activities of the mining industry are rarely motivated by climate-sensitive outcomes in and of themselves. Rather, these climate efforts generally fall into three categories: (a) compliance and reporting activities motivated by the desire to align with minimum industry standards, (b) resource planning activities that are primarily motivated by maximizing the operating income of a mine; and (c) local value creation activities motivated by compliance with local content regulations and the bolstering of the firm's social license to operate in a specific country.

Examples presented in this chapter mainly fall in the resource planning category, in part because these efforts entail the building of scalable infrastructure projects that offer the opportunity for large-scale employment in a green economy, along with significant transfers of technology and skills. It is in this category that the profit incentives of the mining industry and the green economy aspirations of their host countries most closely align.

POTENTIAL DRIVERS FOR MINING INVESTMENTS IN GREEN GROWTH

Like all other companies, mining companies tend to be primarily driven by the desire to maximize shareholders' value, and they are generally agnostic as to whether their investment creates shared value in a specific country of operation. However, in the mining sector, companies have a natural incentive to make investments that have the potential to contribute to green growth in their country of operation. The following factors, for instance, point to industry investments that, while driven by a firm's effort to reduce operating expenditure, increase output, and improve net operating income of mine sites, also have the potential to create “green” value:

- **Mining is energy dependent**. When considered as a portfolio that incorporates diesel, heavy fuel oil, grid electricity, gas, liquefied natural gas, and other sources, energy can represent up to 30 percent of a mining company’s total operating costs (Deloitte 2017).
- **Mining is water dependent**. Water is an increasingly critical issue for many mining operations – as ore grades decline, more water is required to extract the same amount of ore. According to the UN, water scarcity affects 40 percent of the global population and 58 percent of the mining cases lodged with the World Bank Compliance Officer relate to water issues (World Bank and UN 2018; Reuters 2018).
- **Mining requires a social license to operate**. An investment in a mine can often take decades to recoup while earning a return that is commensurate with the risk associated with the endeavor. In fact, the useful productive life of a mining operation can easily exceed 30 years on an asset with a fixed geographical position incapable of being moved should the business environment turn unfavorable. This long-term, fixed investment compels mining companies to develop lasting stakeholder engagement strategies to ensure the long-term viability of the mine—which might otherwise be expropriated, be prematurely shut down due to compliance concerns, or otherwise experience interruption to productive use due to stakeholder dissatisfaction.

These three factors provide potential avenues for the mining industry to contribute to a national green growth strategy, especially when mining represents a substantial portion of a country’s economy. Indeed, the mining sector has the potential to drive economic outcomes in mineral-rich countries, irrespective of the climate nexus. The World Gold Council (WGC), for instance, evaluated 47 countries that account for 90 percent of global gold production. In its assessment, WGC found that the gold industry added US$83.1 billion in value to those economies in 2013 and contributed to moving 11 countries out of low income status, adding 12 countries to upper-middle or high income status (Britton et al. 2015). Guided by appropriate policies, the mining sector could be an agent of change in countries that pursue a green growth path to development.

MINING FIRMS’ PERSPECTIVE ON CLIMATE-BASED INVESTMENT

Mining companies are increasingly investing in green sectors, albeit driven by an underlying profit motive. How and to what extent those investments translate into scalable and sustainable value for host nations largely depend on the policies that such nations use to channel investments to the areas of highest economic impact. The following two primary areas of climate-sensitive investment by mining companies—energy and emissions reductions and water management—have been identified based on information collected through interviews and questionnaires.[1]

The first area of investment by mining companies is energy and emissions reductions. With respect to investments whose effect is to reduce emissions, the primary motivator for mining companies appears to be economics. Companies investing in a power plant or shifting away from a diesel-based fleet do so because of cost reduction, or to hedge against a future rise in the price of high-emitting fuels on which they are reliant. The corresponding shift to lower-carbon technologies or fuels is therefore not *primarily* motivated by emissions reduction objectives. Interestingly, most of the companies interviewed in connection with this report noted that the extent to which such an investment would earn the investing firm a social license is minimal, since neither the local communities in which they operate, nor the company itself, view carbon emissions from mining as a local and near-term issue.

Water management is the second primary area of investment in climate-sensitive production. In contrast to energy-based climate investments, mining companies tend to view their water-based climate investments as driven equally by their propensity to generate local value and their ability to secure a stable supply of water for their operations. The key distinction between water management and emissions reduction is that, because mining companies tend to operate in water-stressed areas, the local community can more tangibly perceive the near-term limited nature of and competing demands on water as a resource, which leads to water availability often becoming a major production constraint. Mining companies will often view the return of saved water to the community or the construction of a desalination plant as core to their operations and to their social license–building strategy. This, however, does not necessarily translate into a concerted and deliberate strategy to create local value while ensuring water-efficient operations.

It is within the realm of policy makers to use appropriate climate policy levers to influence a tighter overlap between mining companies' climate-sensitive investments and their propensity to contribute to sustainable development. This, however, requires an understanding of the following three overarching factors:

- *Site-level mining operations generally have one primary mandate: to maximize the value of their mining asset.* This means, among other things, taking steps to optimize net operating income through measures directed at reducing costs or increasing output.
- *Site-level mining operations do have a secondary mandate of solidifying their social license to operate with the local community.* Most mining firms have dedicated sustainability teams engaged in community development activities at the site level. Many of these activities are well designed and create value for the communities surrounding a mine site.
- *Activities that directly address climate change are almost entirely confined to headquarters-level sustainability teams*. These teams report to global standard-setting bodies such as the UN Commission on Population and Development on the ancillary climate benefits of energy- and water-related investments at the mine sites, using metrics such as GHG reduction and water conservation data. These teams very rarely have operational, site-level investment authority; they are an overhead cost center to the mining company; and the scope of their responsibilities is often confined to external metric reporting and internal auditing functions.

This disconnect between headquarters and mine-site dynamics results in a gap between a firm's climate agenda (at the central level) and its local value generation agenda (at the mine-site level) and hampers a firm's ability to create a cohesive climate strategy aimed at maximizing their contribution to sustainable development. As a result, the climate initiatives in which firms typically engage result in a hodgepodge of investments and operations that generally fall into three overarching areas along the spectrum of initiatives:

- *Compliance measures.* Auditable reports and internal standard setting aimed at satisfying minimum criteria established by NGOs and international guidance–establishing bodies such as the International Council on Mining and Metals.
- *Resource planning efforts that can credibly be characterized as climate sensitive.* Investments made to shift away from price-volatile fuel and electricity sources, and to lock up long-term sources of water supply, all with an eye toward increasing mine productivity while reducing costs.
- *Social license efforts.* Local value creation efforts by site-level local content teams, often aimed at bolstering the firm's social license to operate and often small scale without a climate dimension.

A more cohesive and systemic approach is necessary to ensure that mining companies' climate-sensitive investments are also harnessed (through change management and policy intervention) to generate sustainable local development.

EXAMPLE OF MINING FIRMS' CLIMATE-SENSITIVE INITIATIVES

In comparison with the approaches of the industry at large described in the foregoing section, this section considers the very high end of the spectrum of climate-sensitive initiatives in which mining firms are engaged. These initiatives, while still falling into the three categories of compliance, resource planning, and social license, indicate the ability of a mining firm to contribute to green growth in the country of operation.

To identify good practice initiatives, this section starts by identifying climate-sensitive mining firms by means of a multifactor assessment that evaluates the maturity of a firm's climate strategy, measured in terms of the firm's (a) vision, governance, goals, and objectives; (b) processes and standards; (c) programs and initiatives; and (d) disclosures and communications. Through this assessment, the following firms were identified and categorized as "climate strategists":

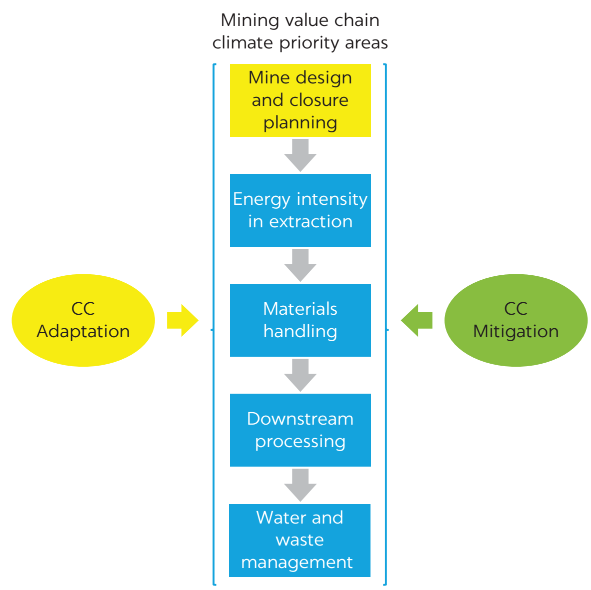
- Newmont Mining Corporation
- Vale, S.A.
- Barrick Gold Corporation
- Anglo American PLC
- Rio Tinto Group

Several of the initiatives that these firms have promoted provide useful illustrations of the potential to be scaled up to support green growth in the country of operation. The five firms' initiatives are summarized below and are linked to the five priority areas (and the corresponding area of climate policy) identified in chapter 2. For ease of reference, graphical illustrations of the priority areas and climate policy areas associated with each initiative are also provided. They are presented without reference to the policy environment in which companies deployed them.

Newmont Mining Corporation

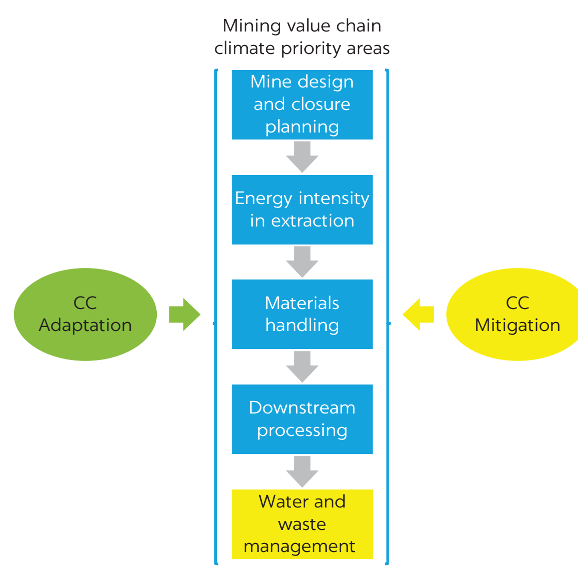
Newmont is currently employing several discrete programs and initiatives aimed at achieving its climate vision. Collectively, these activities have helped the company achieve a 62 percent savings in water withdrawal and 44 percent decrease in energy consumption over the past five years. Some of its more forward-thinking and effective activities are noted below.

Rolling out carbon pricing



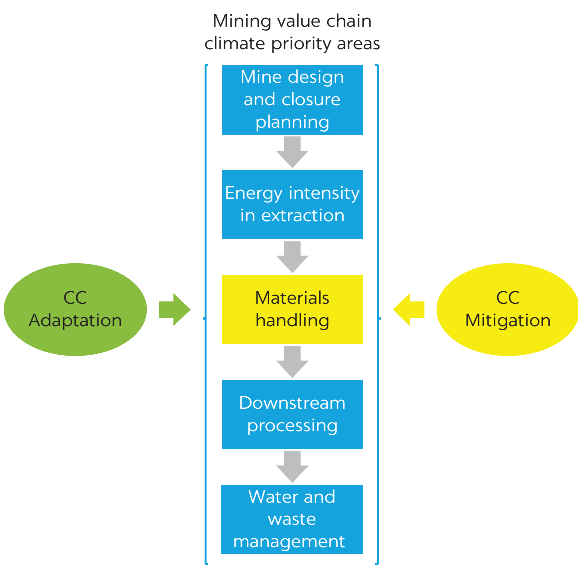
As of this report's publication, 45 national jurisdictions and over 25 cities, states, and regions are putting a price on carbon (Ramstein et al. 2018). In recognition of this trend, and of the corresponding cost implications for Newmont, the company has adopted an internal carbon price mechanism—also termed a "shadow cost of carbon"—at projects in Australia; Ghana; Nevada, U.S; and Peru, using low and high prices of \$25/ton CO_2 and \$50/ton CO_2, respectively, for scenario planning purposes. Using a pretax cost-benefit analysis, the company estimates that a \$50 million investment in Nevada to switch a coal power plant to natural gas could lead to a potential \$117.3 million cost savings at a \$25 carbon price, and a \$284.6 million savings at a \$50 carbon price (Newmont Mining 2018). Although the establishment of a carbon price may seem, at first blush, attenuated from the prospect of generating real local economic value, it is worth considering the measure as a foundational element of contributing to the growth of green value chains within a host nation. By its very nature, internal carbon pricing captures a hidden cost of an investment in a carbon-intensive energy source. Newmont's internal directive forces its hand to invest in greener energy infrastructure, and that brings with it the opportunity to develop a local supply chain to support such investments.

Treating water discharge



In Ghana, Newmont is working with the Ghana Environmental Protection Agency (GEPA). The company constructed a reverse osmosis water treatment plant that will ensure that water discharged from its Afaho operation is treated in a manner that meets all GEPA's standards. Of contextual importance is that 22 percent of the Ghanaian population lack access to safe water and 70 percent of *all* diseases are caused by unsafe water.[2] This activity's capacity to drive scalable local economic value is found on two fronts. First, it avoids the cost of environmental remediation after mine closure, which can be a tremendously costly endeavor. The U.S. Environmental Protection Agency, for instance, spent \$1.1 billion between 2010 and 2014 on environmental cleanup of water resources contaminated by metal and mineral mining operations (Brown 2017). Second, water treatment and sanitation is an extremely economically beneficial activity. According to the United Nations

Educational, Scientific, and Cultural Organization (UNESCO 2016), every $1 million invested in the U.S. water supply and treatment infrastructure generates between 10 and 20 additional jobs, and the U.S. Commerce Department estimates that each job created in the local water and wastewater industry creates 3.68 indirect jobs in the national economy (International Labour Organization 2016).

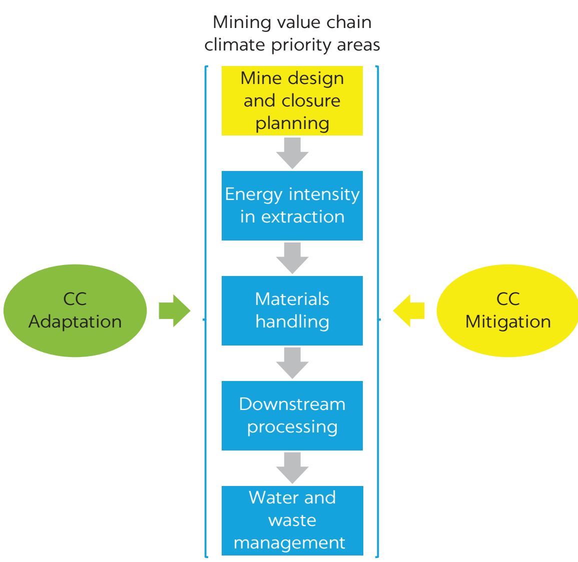


Optimization of Haul Truck routes

Newmont is using logistics planning to improve the routes its haul trucks take to and from the extraction site. It has resulted not only in greater operating efficiencies for the mine, but also in fuel savings and lower emissions on a per-ton basis. Shorter, more efficient, haul routes not only reduced Newmont's carbon footprint, it also entailed a corresponding reduction in fuel consumption for material movement on a per-ton basis. In terms of the economic impact, it stands to reason that optimized routes lead to fewer truck-driver hours over time. It also leads to the creation of job opportunities for logistics engineers that can optimize routes. Moreover, it leads to a local procurement standard by which Newmont will look more favorably on trucking firms that prioritize route optimization. As a result, Newmont and companies like it that are operating in emerging and developing economies can leverage their procurement process to drive skills transfer (e.g., logistics optimization) to local firms.

Vale S.A.

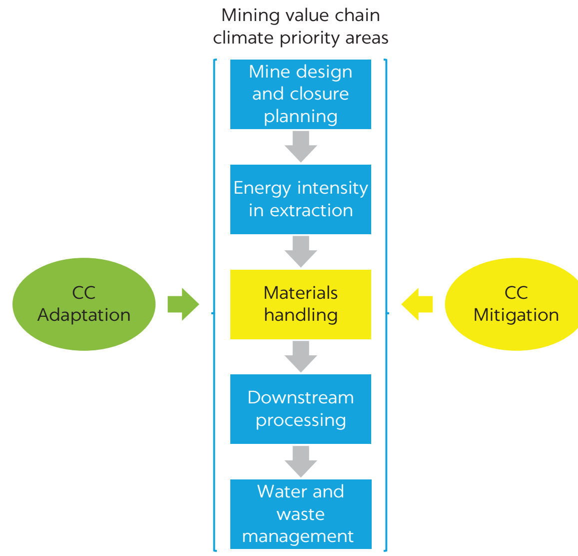
Vale employs various climate-sensitive initiatives aimed at mitigating, or adapting to, the effects of climate change, two of which are highlighted below.



Development of Captive Energy Resource (Hydro)

Vale has made a concerted effort to use renewable energy where possible. A primary example of this effort is the Karebbe Hydroelectric Plant, located at Vale's nickel operation in Indonesia. Operating since 2011, the plant can generate 90 MW of power that is used in mining operations and distributed to local communities. The plant has eliminated the need to consume 13 million barrels of high-sulfur fuel oil and about 3 billion liters of diesel fuel each year. From an economic value standpoint, developing a power project locally can have a massive economic impact (Vale 2018). In one example, the Overseas Development Institute conducted a job creation impact study on the construction of a 13 MW run-of-river hydro plant in Uganda. They found that the plant was responsible for the creation of up to 1,278 direct and indirect construction jobs (translating to 7,318 person-years of work) and up to 10,256 knock-on jobs (approximately 256,000 person-years) that resulted from the improved power supply to the grid (Scott et al. 2013).

Diesel switching

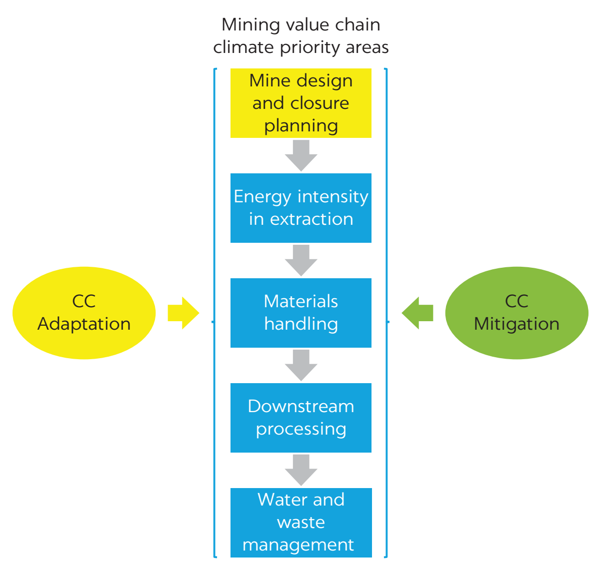


Vale has made clear commitments to modifying its transportation mechanisms to more efficient, and less carbon intensive, fuel sources. For example, the company has retrofitted its rail operations that transport ore from mine sites in Brazil to accommodate alternative fuel sources. According to the Energy Information Administration (EIA), diesel is the most carbon-intensive fuel source next to thermal coal, so any effort by multinational mining majors to switch fuels to a comparatively cleaner, less emitting source is a positive climate outcome. An exclusive reliance on any one type of fuel can leave a firm exposed to volatile input costs. Diesel prices in 2019, for instance, are set to increase by an average of 10 percent compared to 2018 prices (EIA 2019). There are several social benefits of a major sector of an economy diversifying fuel consumption from petroleum sources to other resources. For instance, a boost in the consumption of alternative fuel and a corresponding reduction in petroleum consumption frees up more of the commodity for the country to export. Brazil, for example, as of 2016 was the world's 10th-largest oil producer. Amid its recent economic malaise, and eyeing what might be historic oil production in 2018, the more Brazil can boost the productivity of other sectors of its economy (e.g., agricultural) and the more petroleum it can export, the better the country's overall economic outlook is.

Barrick Gold Corporation

Barrick's portfolio of programs and initiatives helped guide the company to reductions in overall scope 1 and scope 2 GHG emissions and water withdrawals in 2017, while obtaining 77 percent of its water supply for operations from recycled sources. One such water-preserving climate-sensitive initiative it is described below (CDP 2018).

Planning for backfilling during mine closure



In 1994 Barrick took control of Nevada's Bullfrog mine, which had been in operation since 1904. The mine had been built to such a depth that groundwater would accumulate at the bottom of the pit, forming a pit lake. Pit lakes are problematic because the standing water deteriorates in quality over time and is at risk of permeating into the local reservoir. In other instances of such an issue, especially at mine closure, mining companies have typically built a water treatment plant and operated it in perpetuity—at an exorbitant cost to the company. Barrick, by contrast, planned ahead, and in 1999 began to backfill the mine to prevent a lake from forming to begin with, by using rock stockpiled at the mine site. The lengths to which Barrick went to avoid the formation of a pit lake mitigated its long-term impact on the local Nevada aquifer.

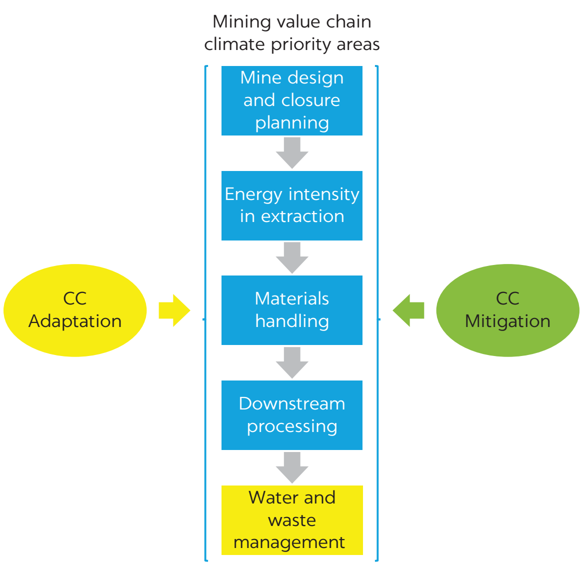
In recent years, Nevada, one of the primary beneficiaries of the Colorado River basin, has been confronted with a historic drought. Lake Mead, which supplies 90 percent of Las Vegas' water, has dropped to its lowest levels since 1937.[3] Water in this region is scarce, and Barrick's proactive steps to ensure the integrity of the local aquifer means that more of the scarce water can be put to productive use by the local community. That said, it is hard to argue that the remediation steps taken by Barrick at the old mine site somehow delivers *more* local value to the community in Nevada than the installation of water treatment infrastructure—the ordinary course of action—would have. But such are the trade-offs with which a mining firm must grapple when approaching climate-related issues—some efforts may more efficiently produce a positive climate outcome while providing fewer opportunities to benefit the local economy.

Anglo American PLC

Anglo American aims to reduce GHG emissions by 22 percent by 2020 and energy consumption by 8 percent. By 2030, the company target is to reduce GHG emissions by 30 percent (CDP 2018). In terms of water conservation, the company aims to increase its use of recycled water to 75 percent of consumption by 2020 (Anglo American 2018a). Some of the initiatives in which it is engaged to meet these goals are described below.

Waterless mining

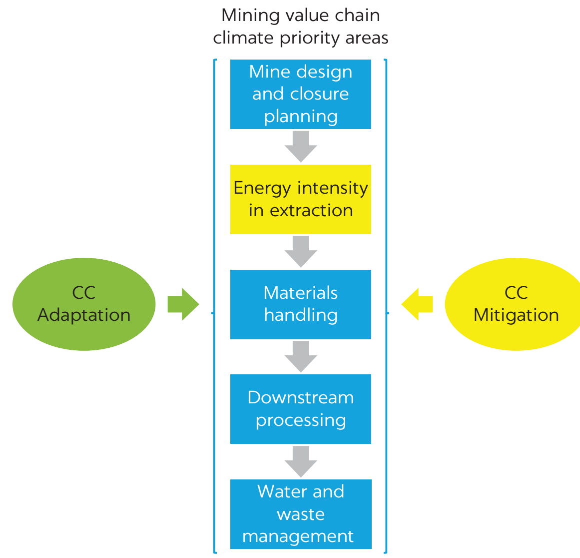
This program, though not yet fully operational, is an ambitious plan to eliminate the use of freshwater in the company's extraction processes. The company plans to further develop a closed-loop system that would recycle water with limited need to reintroduce freshwater into the system. Anglo American plans to advance this program by expanding two primary technologies: evaporation management and dry tailings disposal (Anglo American 2018b). Both innovations are particularly apt when considering that evaporation accounts for approximately 10–25 percent of water lost at a mine site. Anglo American's closed loop system has the potential to dramatically reduce the firm's operational freshwater requirements, allowing the firm to adapt to the well-known climate risk of depleted water resources. Reducing the water footprint of a mine's operation means reducing the acquisition costs for water and securing a stable supply of water, which can increase mine output.



From an economic value perspective, it is worth considering the full range of inventive new technologies that Anglo American is exploring to eliminate its use of freshwater in extraction processes. Its focus areas include state-of-the-art collection methods for evaporation data for use in automated systems, low-cost dry tailings disposal, dry separation, and nonaqueous processing. Engaging local experts and high-skill labor at the maturation phase of any one of these new technologies, could have a profound impact on local skills transfer.

Emissions reduction KPI in the CEO's executive compensation plan

Anglo American's board approved modifications to the company's long-term incentive plan (LTIP) that incorporate CO_2 emissions performance into the plan. Compensation derived from the LTIP is calculated based on a series of key performance indicators (KPI), one of which ties directly to the company's goal of reducing emissions by 22 percent by 2020. This KPI accounts for 5 percent of the LTIP calculation, and it is fully fulfilled if the 22 percent GHG reduction target is achieved by the end of 2019, whereas it is only 25 percent fulfilled if a 20 percent GHG reduction is achieved in the same time frame (CDP 2018). Anglo American's approach to executive compensation provides direct executive accountability for the achievement of its strong 22 percent emissions reduction target. That link shows that the company's commitments to mitigating climate impacts are not just ambitious; they are meaningful. Depending on the route explored by leadership to achieve companywide emissions reductions, the economic benefits delivered to the host government and citizens could span a wide range. An effort to switch to renewable energy, for instance, brings with it the opportunity to add more clean technology to a host government's grid, and for it to develop large parts of a renewable energy supply chain and the corresponding jobs such economic diversification entails. Similarly, a mining company might be incentivized to build out more of its supply chain locally to cut down its direct and spinoff emissions, creating an opportunity for knock-on economic impacts for the host government.

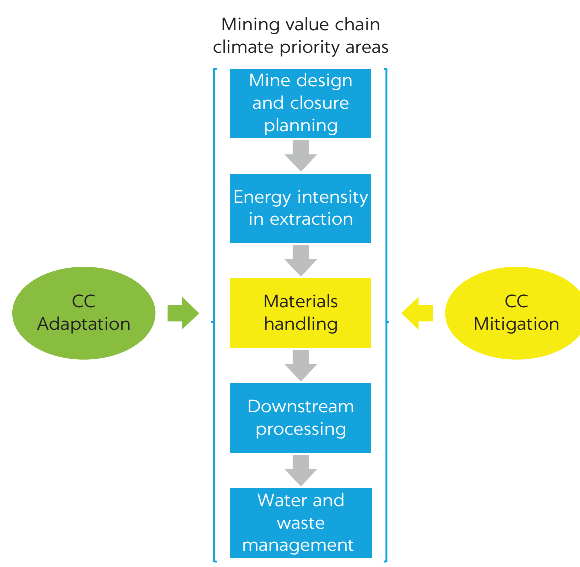


Rio Tinto group

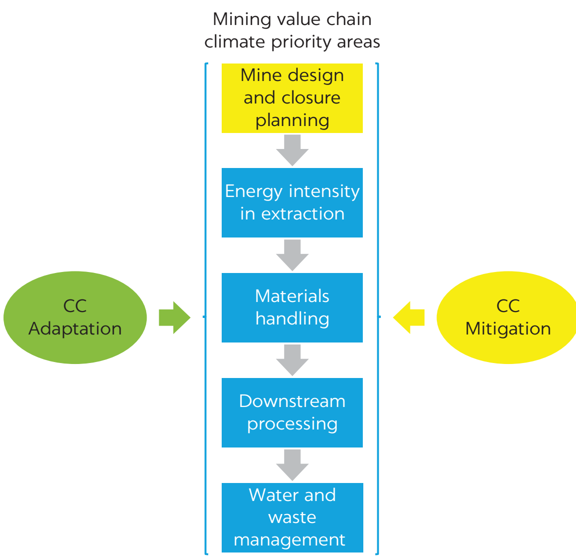
Rio Tinto has made a concerted effort to set GHG reduction targets since 1998, with the company's initial objective of achieving a 24 percent reduction in GHG emissions by 2020, from a 2008 baseline (CDP 2018). Company reports suggest that Rio Tinto has already exceeded its goal; it reported having achieved a 27 percent reduction in 2017 (Rio Tinto 2018). Some of the active measures it is taking to achieve its objectives are described below.

Mine of the future

The company is a recognized leader in autonomous and digitally managed haul equipment, having launched its first automated haul truck in 2008 at their Pilbara iron ore operation in Western Australia. This effort also marked the kick-off of the company's "Mine of the Future" initiative, an effort that turns the Pilbara site into the company's proving ground for many of its most promising climate-focused innovations. Deploying autonomous vehicles there, in combination with modifying some vehicles to electric drive, is more energy efficient, reducing GHG emissions with improved fuel efficiency of approximately 5–7 percent (Rio Tinto 2018). The vehicles can run longer and with greater consistency than a traditional truck, increasing the amount of ore the company can transport to processing, while reducing inefficient, fuel-consuming idle time. As a recent milestone, the company's automated trucks have transported more than 1 billion tonnes of material at Pilbara (Rio Tinto 2018). Rio has acknowledged that such automation efforts have traditionally entailed some level of job reduction in traditional mining roles, but the initiative offers new roles for skilled employees to program and maintain the new technology.



Although the short-term impact may reduce low-skill job opportunities, and that impact may be felt disproportionately in developing countries, automation presents the potential for technological leapfrogging.



Mine closure standard

Rio Tinto takes a strong stance when implementing rigorous climate-sensitive mine closure standards. This stance includes the stipulation that all mine sites must plan for closure from the outset of the mine and that the closure plan must include strategies to minimize financial, social, and environmental risks. The company executes this strategy by maintaining a knowledge base on the climate and social implications and conditions of each mine site. A mine closure plan must address long-term impacts on water quality and water resources in the impact zone of the mine site. The climate risks entailed in a firm's closure of a mine span a wide range of impacts: potential pollution of local water resources made scarcer by climate change, the inability to reclaim the site for agricultural uses due to water scarcity and hotter temperatures, or in some regions, heavier rainfall that might lead to tailings dam failure. From a local economic perspective, a mine site can often take up large swaths of land for very long periods of time, removing it from productive use by the local community, and a site that is improperly closed may contaminate local aquifers. Proactively operating a mine site with an eye toward the eventual reclamation and productive use of the land and local water resources is a leading approach to restoring the mine site's economically productive use as quickly after mine closure as is possible.

CLIMATE-SENSITIVE LOCAL VALUE CREATION

None of the firm-level initiatives presented in the preceding section clearly fall into the category of climate-sensitive local value creation, because most of these initiatives do not explicitly consider climate-related effects. As noted earlier in this chapter, the industry's perception is that the local governments and communities in which they operate often do not view emissions as a local concern. Similarly, while the water infrastructure-related investments that firms make do tend to provide benefits to local communities and local industries, as well as climate benefits, those investments tend to be motivated by a firm's need to develop a stable supply of water for operations or comply with regulations. Such investments are not undertaken with the direct goal of contributing to the transition to a green economy. As a result, the local value creation efforts that have a climate dimension tend to be very tailored to local communities and countries, where climate plays a tangential role, if any. A typical intervention is recounted by Anglo American, which developed a collaborative regional management approach to regional planning that takes climate change issues into account when considering agricultural options. This approach is now being jointly applied by Anglo American and the government of South Africa's Limpopo province. Although such activities certainly produce tangible benefits to local economies, they are far too tailored to and driven by the needs of local rural populations to be scaled in a way that creates catalytic green growth.

NOTES

1. Five mining companies were interviewed for this report: Barrick Gold, Goldcorp, Newmont Mining, Anglo American, and IAMGOLD. All appear in the top 50 mining companies by market capitalization. A background report on industry leaders provides greater detail as to the following insights and the questionnaires and interviews that produced them.
2. See https://water.org/our-impact/ghana/. Newmont's Yanacocha project in Peru also represents a strong example of water management.
3. See Weather.com's April 2015 coverage of the water level of Lake Mead at https://weather.com/science/environment/news/lake-mead-record-low-water-level-third-straw-construction/.

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4 A Green Growth Framework for Mining Firms and Government

As shown in the previous chapters, the current state of investments by mining firms into climate-sensitive production processes, and current policy-making efforts to develop a cohesive climate framework for mining firms to navigate, share a common trait: both firms and governments have yet to effectively leverage their climate imperatives and mandates to realize climate-based growth opportunities.

This chapter proposes a framework through which policy makers and mining companies can analyze their actions with regard to climate and local value creation, with the aim to identify high-impact opportunities for green growth. It further outlines some potential shifts of course that mining firms and policy makers might pursue to maximize the value of their climate-sensitive efforts and then illustrates the benefits that are likely to accrue from such efforts.

THE CURRENT MISALIGNMENT

From a firm's standpoint, climate is too often viewed solely as a compliance and reporting issue, and company efforts to bolster their social license to operate are typically climate-agnostic local content or community development–type activities that are too bespoke and limited in scale to offer any real catalytic economic benefit to the host economy. From a policy-making standpoint, an impressive array of guidelines, standards, measurements, metrics, and best practices have been passed at the global and national levels that aim at encouraging national and industry compliance with climate mandates, such as emissions reporting and reduction targets, measurement of climate-sensitive resources, and taxing of carbon emissions. What appears to be missing, however, is a collaborative and intentional effort between industry and government to generate opportunities for the local economy through climate objectives. Such opportunities might be more efficiently targeted if

- Firms focused more on high-value-adding climate-sensitive investments that drive operational sustainability and profitability,
- Policy makers focused more on building clusters of policies that incentivize such investment, and
- Both parties allowed their thought processes around such activities and policies to inform each other's behavior.

Mining firms should devote more strategic focus to resource planning activities, which entail securing the long-term stable supply of critical inputs to their operations through the development of or investment in green infrastructure. These activities have the capacity to address two of the mining firms' present pain points:

- The likelihood that firms' existing paradigm of local value creation and stakeholder engagement may not be yielding the desired results, as is reflected by several high profile protests, bans, and production interruptions; and
- The growing climate dimension of a firm's social license to operate. Increasingly, because of international pacts, accelerating climate impacts, and host nations' desires for diversification into and growth of sustainable sectors of their economies, firms must navigate and take advantage of a complex patchwork of policies aimed at boosting green industrial sectors (Deloitte 2018).

Firms that develop a strategy to help their host nations achieve green industrial ambitions will have a new approach to delivering local value that might differentiate them firm from their competitors.

The lesson for governments is to establish the conditions for greater levels of mining investment that lead to the development of new green value chains within their jurisdictions or countries. Governments should ask themselves what the ideal mix of policy measures is to induce private sector investment into green infrastructure. Although a government would still need to adopt policies across the spectrum of the standard setting, sector-targeted support, and local employment, categories described in chapter 1, its approach should begin with the identification of sectors and subsectors that lend themselves to driving green growth. Sector-targeted support, in turn, should inform standard setting and local employment policy strategy. Standard setting, by contrast, should not inform the sectors that are targeted.

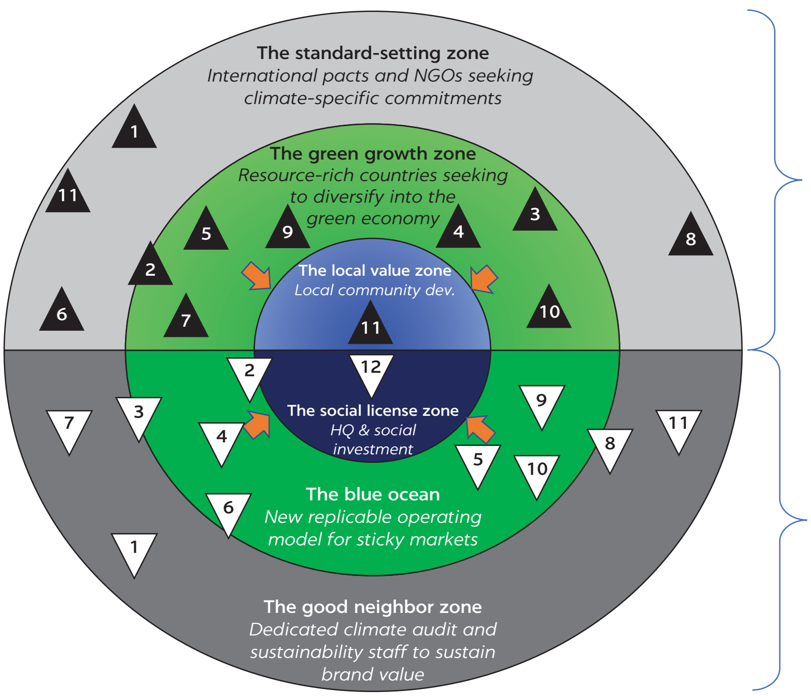
This process is how a mutually reinforcing cluster of policies can enable the creation of new green value chains. For instance, if a government sets an objective to grow a renewable energy industry within its borders, it can begin with a policy pronouncement to that effect, establish a renewable portfolio target, implement a carbon tax, use the revenues to fund a feed-in tariff for the renewable project, and mandate that renewable energy projects incorporate a realistic threshold of locally sourced labor and material. That network of legislation would provide transparent and predictable guidance to industry in terms of the incentives and policy support that correspond to any investments it might make and would form the basis of the development of an in-country supply chain to support such investments. This is what green industrial policy looks like. To achieve it, policy makers will have to begin to view climate mandates less as an obstacle that prevents progress, and more as an avenue toward economic growth and development.

THE FRAMEWORK FOR MINING-INFORMED GREEN GROWTH

This section proposes a framework through which to understand the opportunities available to mining firms and governments that are seeking a new approach to climate-sensitive investments and policy making. Figure 4.1 representation such a proposed framework. The sphere is split into two hemispheres. The lower hemisphere reflects operational activities carried out by firms in the mining industry, and the upper hemisphere reflects the policy environment—set by nations, international pacts, and standard-setting bodies—in which the firms operate. Each of the triangle icons is associated with an initiative or policy described earlier in this report and identified in tables 4.1 and 4.2. The three bands of activities are loosely tied to the three categories reflected in those tables.

FIGURE 4.1

A framework for mining-informed green growth



The Public Policy Agenda
- The highest-value-adding policies are those that target sectors and provide direct support, whether through providing subsidy , pricing the true cost of competing technologies, or setting targets.
- Form policy clusters—mutually reinforcing measures that offer transparent and predictable guidance to investors.
- Set and align with climate standards to project policy stability and encourages foreign direct investment.

The Corporate Strategy Agenda
- Organizationally align central office/HQ sustainability and government affairs units with site-level operations.
- Shift climate-related resources away from CSR teams and toward site-level resource planning and investment teams.
- Continue to focus on "good neighbor zone" activities. Expand metrics tracking to include economic outcomes of green investments.
- Aim for scale, and negotiate with governments for such scale.

Note: CSR = corporate social responsibility; NGO = nongovernmental organization.

TABLE 4.1 **Categorizing climate-sensitive mining initiatives**

	INITIATIVE		
COMPANY	COMPLIANCE	RESOURCE PLANNING	LOCAL VALUE CREATION
Newmont Mining Corp.	1 Carbon Pricing	2 Ghana Water Treatment Facility 3 Haul Truck Optimization	
Vale, S.A.		4 Indonesia Karebbe Hydroelectric Plant 5 Diesel Switching	
Barrick Gold Corp.	6 Planning for Backfilling during Mine Closure		
Anglo American PLC	8 Emission Reduction KPI in CEO Compensation Plan	7 Waterless Mining	11 Collaborative Regional Development
Rio Tinto Group	10 Mine Closure Standards	9 Mine of the Future (Automation)	

TABLE 4.2 Categorizing climate-sensitive policies

	POLICY		
POLICY LEVER	STANDARD SETTING AND ALIGNMENT	SECTOR-TARGETED SUPPORT	LOCAL EMPLOYMENT AND TRADE PROTECTION
Taxes and Tariffs	1 Carbon Pricing	2 Revenue Recycling	3 Carbon Taxes 4 Export Taxes
Sector-Targeted Subsidies		5 Renewable Energy Subsidies 6 R&D Support	
Data Infrastructure	7 Climate Forecasting 8 Water Management and Hydro Inventories		
Climate-Sensitive Standards	11 Mine Closure Standards	9 Renewable Portfolio Standards 10 Energy Efficiency Standards	
Local Content			12 Local Content Regulation

The outer band is about compliance, which is where the lion's share of a firm's climate-specific work takes place. Firms are motivated by the standard-setting zone of policy, and the reporting and auditing they conduct is aimed at projecting a good neighbor status. The activities in the innermost band are related to local content and social license, and are small scale, bespoke, and unlikely to create catalytic local economic value. Firms engage in these activities largely because they have local content obligations, or local communities want to share in the mine operation's value or want to not be socially or economically displaced by those operations.

The middle band of activities in figure 4.1 is really the thrust of this report's findings. They are the climate-related activities that have a propensity to create scalable and sustainable economic value, activities that involve significant investments in long-lasting green infrastructure that has the potential to grow into a new economic sector within the host economy. In turn, these investments are supported and incentivized by policies adopted by host economies that are tightly aligned with a green growth objective. To varying degrees, all the gold triangles in the figure are initiatives and policies that reflect this type of potential. The construction of a hydroelectric plant, for instance, creates an infrastructure with 30–40 years of useful life that provides power to the community, quite apart from the needs of the mining operation itself. By engaging local contractors—perhaps as required pursuant to a local content regulation—and by helping to develop a supply chain that supports the design, construction, assembly, operations, and maintenance of the plant, a mining firm can help create thousands of direct and knock-on employment opportunities, as well as develop skills in the local workforce that will be relevant for the future as the green economy within the host nation matures.

As the framework indicates, the middle band—investment activities that can be spurred by green growth or green industrial policies—must ultimately crowd out the smaller-scale tailored activities that currently are overrepresented in social license–building efforts. Those community development–type initiatives will ultimately be no substitute for the jobs, revenue, and development impact of large technological and infrastructure investments. This is how a "blue ocean" strategy for local value creation works: By shifting focus from traditional compliance and social license activities toward a strategic approach to developing mutually beneficial green infrastructure and inclusive automation, a mining firm can deliver such considerable value in the marketplace as to have carved out a competitive advantage. On the right-hand side, the framework captures high-level strategic shifts that both the mining industry and policy makers might make in developing-country contexts to drive value-adding benefits while achieving climate goals.

THE ADDED VALUE OF PURSUING A GREEN GROWTH PARTNERSHIP APPROACH

The mining-informed green growth framework presented in this chapter presents only a prism through which to view the disconnect that currently exists within most mining companies when it comes to large-scale, resource-driven investments that have the potential for long-term positive climate impacts. Such investments, for example, renewable energy, water infrastructure, and electric vehicle purchases are often viewed purely from a project-level return-on-investment standpoint, as opposed to as a means to create scalable, catalytic, local economic value. The latter lens would provide an even more compelling case for investment, given the potential of investment to minimize the risk of production interruptions caused by social unrest and to increase the potential of follow-on work in the host country. This is especially true if policy makers provide a policy framework to facilitate such investments.

Tables 4.3 and 4.4 outline some potential general shifts of course that mining firms and policy makers might pursue to maximize the value of their climate-sensitive efforts. The tables also illustrate the benefits that are likely to accrue from such efforts. Implementation of these measures would require institutional mechanisms designed to create the space for greater collaboration across the industry and between private and public sector actors, as well as greater coordination among operational and corporate teams. A detailed discussion of such mechanisms and their successful implementation could be the objective of subsequent research.

TABLE 4.3 Potential industry benefits from a shift in climate approach

OPERATIONAL IMPLICATIONS OF A NEW GREEN APPROACH TO GENERATING LOCAL VALUE	POTENTIAL REWARDS FROM PURSUING A GREEN MODEL FOR LOCAL VALUE CREATION
• Coordination between central office government affairs units, sustainability units, and site-level operations. • Shifting of climate-sensitive resources away from community development teams and toward site-level resource planning and investment teams. • Continued and strengthened commitment to good neighbor zone activities. Metrics tracking and reporting should be expanded to include economic outcomes from green infrastructure investments. • Aiming for scale; not just navigating policy, but helping to shape it. Scale means brokering deals with host governments that might entail multiple green infrastructure projects potentially in exchange for an expanded mining footprint and expedited permitting.	• Strengthening of the partnership with host nations, who will not only be invested in a firm's success due to the economic activity the mine is driving, but now will multiply the touchpoints with the firm given the investment in new green infrastructure. Such networking effects can increase the government's reliance on and familiarity with incumbent operators. • Reliance on the strengthened partnership with the central government and local communities, to mitigate the risk of production disruptions due to bans, protests, and punitive levies. • Increased likelihood of repeat business or market "stickiness" resulting from the competitive advantage entailed by the new approach to local value-generative implementation of climate mandates. • Better overall efficiency of operations, reduced reliance on volatile inputs, increased uptime of mine operations, and reduced operational expenditures. • Improved public image, and a corresponding increase in the value of goodwill as an asset, and improved marketability and exposure from being a leading steward of the climate and environment.

TABLE 4.4 Potential government benefits from a shift in approach to climate policy

STRATEGIC IMPLICATIONS OF A NEW GREEN GROWTH APPROACH TO CLIMATE POLICY	POTENTIAL REWARDS FROM PURSUING A GREEN GROWTH MODEL FOR POLICY MAKING
• Crafting of climate policy frameworks with the starting point being the highest-value-adding policies: those that target sectors and provide direct support, whether through providing subsidies, pricing the true cost of competing technologies, or setting targets. • Use of policy clusters—mutually reinforcing measures that offer transparent and predictable guidance to investors. • Continued setting and aligning with minimum climate standards, thereby projecting policy stability and encouraging FDI.	• Public pronouncements coupled with supporting policy frameworks that are aimed at supporting industry and provide clear and predictable guidance that will invite predictable FDI. • Incentives that motivate the purchasing and investment behavior of sectors that dominate the local economy, such as the natural resources sector, and offer a pathway to economic diversification. • The transition to a new global economy—what many describe as the fourth industrial revolution —will fundamentally be a competitive proposition. Countries that develop the conditions and supporting industries prerequisite to competitive success in the new economy will flourish, and those that do not, will not. A strategic approach to green growth helps nations achieve these prerequisites. • The increase in jobs that corresponds to a successful transition to a newly diversified economy, and the prominence associated with being a leader in the field of clean technology, resource management, and automated and electric vehicles. • Increased access to climate funds or tech-related investments from the private sector or development finance institutions.

TABLE 4.5 Case study snapshots

BENCHMARK MINERAL	TECHNOLOGY AREA	COUNTRY	COMPANY
Copper	Water Conservation and Infrastructure	Peru	Freeport McMoRan
Iron Ore	Automation and Transportation	Australia	Rio Tinto
Gold	Energy Efficiency and Renewable Energy	Burkina Faso	IAMGOLD
Cement/Aggregate	Energy Efficiency and Renewable Energy	India	Ambuja Cement

REAL-LIFE EXAMPLES OF SHARED VALUE OF MINING-DRIVEN GREEN GROWTH

According to the assessment of the current focus areas of mining firms presented in previous chapters, resource planning–type climate-sensitive investments revolve around three main themes: energy efficiency and renewable energy, water conservation and infrastructure, and automation and transportation. These areas are particularly relevant to green growth, because they lend themselves to green industrial policy and have the potential to contribute to green growth in the country of operation.

This section presents four case studies that investigate the climate priority areas of the benchmark minerals identified in chapter 2: copper with regard to water infrastructure, iron ore with regard to automation and transportation, gold with regard to renewable energy, and cement with regard to renewable energy. Each case study explores how the dynamic between policy and investment in each area could open greater avenues to green growth. The case studies do not describe an exhaustive representation of the mine sites, companies, or technologies involved, but instead are intended to highlight the most salient elements of the green growth narrative. Table 4.5 outlines the minerals, technologies, geographies, and companies covered in the case studies. Within each case study, a snapshot summarizes the key finding.

MINING FOR COPPER IN A WATER-STRESSED CONTEXT

The copper-water nexus

Case 1 Snapshot	
Copper	Water Management
Freeport-McMoRan	Peru
Strengthening water resource infrastructure supports developing local technical skill sets in water resource operation and maintenance, mitigates damage to natural resources, and installs a necessary piece of infrastructure for economic diversification and growth.	

Most copper mines are often large, low-grade, open pits. Typically, these operations process over 50,000 tonnes per day of ore, with copper head grades below 1.0 percent, and sometimes as low as 0.3 percent (Reemeyer 2016). As ore grades decline, more water is required to extract more copper. As a result, water availability—especially in water-stressed sites—becomes a major constraint on mine operations and output. This is the case in Peru, where copper miners must grapple with competing demands on a diminishing key input.

Copper's economic importance to Peru

The copper mining industry is core to Peru's economic fortunes. As the second-largest copper producer in the world, with approximately 10 percent of total global copper, the mineral accounts for nearly one-quarter of all Peruvian exports. As much as 14 percent of national GDP, and more than one-quarter of national FDI are directed at the mining industry (Ernst & Young 2018).

The success of the copper industry has fueled Peru's economic rise over the last two decades, turning it into one of the fastest growing economies in Latin America, with GDP growing more than 5 percent per year, on average, between 2000 and 2015. Any climate-sensitive policy pursued by the nation will affect the copper mining industry, which is central to its economy.

The policy context: Water resource management in Peru

Water management is one of Peru's greatest conundrums. Although Peru has abundant water resources, about 70 percent of its population lives along the Pacific coast, placing the most economically developed portion of the country in a landscape dominated by an arid, high-altitude desert that receives little to no annual rainfall. Moreover, of the limited freshwater available in the region, it is estimated that 60 percent is unusable due to a variety of factors, including pollution from industrial activities.[1] The federal government has moved ahead on this front, investing more than US$15 billion in infrastructure spending on potable water and sanitation throughout Peru to improve water access, quality, and consistency. It has set a goal of providing access to running water on a national level by 2021 (Aquino 2017). The national policy drive for improved water infrastructure includes an emphasis on partnering with private industry to bring in international expertise and build Peru's water management industry from the ground up. Improving irrigation infrastructure would enable Peruvian cities and villages to hire an estimated 30 percent more agricultural workers than comparative villages. It is further estimated that investing US$1 billion in water-related infrastructure in Latin America may yield 100,000 new and knock-on jobs in fields such as agriculture, maintenance, and technology (IFC 2013).

Mining firms’ experience

Given the policy focus on water management in the country, and the estimated job-creation benefits of investment in the water sector, it would appear that any mining investment that improves water availability—through an infrastructure whose life exceeds that of the mine it serves—brings with it an opportunity to improve the economic fortunes of the country. It is in this context that Freeport-McMoRan’s Cerro Verde copper mine is best viewed. Sitting in the foothills of Peru’s second-largest city, Arequipa, the mine is proximate to a community of more than 800,000 residents. The environment there is arid, and the city receives just three inches of rainfall annually and draws more than 90 percent of its water for consumption from a single source—the Rio Chili. The river also serves as the primary source of water for regional agriculture operations and the Cerro Verde mine, and until 2015, it was the primary discharge location for the city of Arequipa’s wastewater and municipal sewage (Fraser 2017).

In 2010, Freeport-McMoRan, as a proactive measure to address concerns over impacts to water quality in the Rio Chili that might result from the mine’s expansion, began to design a potable water treatment plant and agreed to help finance it. Commissioned in 2012, La Tomilla II provides 24-hour access to potable water for approximately 300,000 Arequipa residents. The plant was designed using modular construction that, should the city’s population continue to increase, allowed the plant to be expanded to serve approximately 750,000 households with potable water (Fraser 2017). In addition to the potable water plant, Freeport-McMoRan seized on a request stemming from its community outreach process to construct a wastewater treatment facility—La Enlozada. After construction was completed, 90 percent of wastewater discharged from Arequipa city into the Rio Chili could be treated for contaminants (Fraser 2017).

For Peru, and Arequipa specifically, this project contributed both the infrastructure and technical expertise necessary to run a more robust water sector. This conclusion is bolstered by Freeport-McMoRan’s decision to develop these facilities through public-private partnerships and in cooperation with local community leaders and local utilities. Once the plants were constructed, the project engaged local entities to help manage and run the facilities. Servicio de Aqua Potable y Alcantarillado de Arequipa (SEDAPAR), Arequipa’s regional water management and sewage utility, was heavily involved in the planning and community outreach stages of both La Tomilla II and La Enlozada. Local employees of SEDAPAR are responsible for collecting wastewater, monitoring water quality, and supervising plant operations. Freeport-McMoRan plans to eventually transfer control of both plants to full SEDAPAR control (Fraser 2017).

IRON MINING AND THE AUTONOMOUS TRANSPORTATION SECTOR

Iron ore mining as a driver of automation

Case 2 Snapshot	
Iron Ore	**Automation**
Rio Tinto	**Australia**
Increasing the degree of automation in mining activities, including material movement, has both improved efficiency of mining operations and created an avenue to diversify Australia’s economy into high-tech areas, including monitoring and operation of automated vehicles and logistics systems.	

Iron ore represents the second-largest commodity market in the world behind crude oil and is integral to the global economy. The commodity has a primary role in the production of everything from daily-use household items to large industrial projects. Iron ore is a high-volume commodity, requiring large mining operations to extract enough of the metal to make the comparatively narrow margin. Often it is not profitable to dig deep, so iron ore mines tend to be characterized by large tracts of land with a well-developed pit-to-port supply chain. Because of the sprawling expanse of the mine and the comparatively low price per tonne compared with other minerals, for an iron ore operation to be successful, companies must be capable of moving millions of tonnes annually across increasingly large distances using a variety of machinery and methods. These conditions make iron ore mines uniquely matched to the promise of automated operations, perhaps more than other commodities. In the coming decades it is estimated that, on a global scale, nearly 50 percent of all jobs currently performed manually could be subject to automation (Economist Intelligence Unit 2018). The mining industry will be among those industries at the center of this transformation, because the traditional transportation of ore, waste, and processed metals is highly labor, energy, and emission intensive.

Iron's economic importance to Australia

Australia is among the most successful mining economies in history. In 2015, Australia produced 74 million tonnes of iron ore, approximately 25 percent of global production. The state of Western Australia produces more than 98 percent of the country's iron ore (Government of Western Australia 2017). Given this dynamic between the state and the sector, smart green industrial policy enacted by the state may be able to use the sector as a staging ground for further diversifying the economy beyond mining. This logic also holds true for Australia at large, as there is likely no single mineral or metal in Australia's mining economy that so heavily influences the national economic tenor as iron ore.

The policy context: Australia catching up to the automation wave

Some analysts estimate that nearly 60 percent of fuel waste in the trucking industry is due to driver overacceleration (Morris 2015). In fact, manual transportation systems, including cars, trucks, and rail systems, are starkly inefficient compared with automated systems. For example, by equipping their fleet of more than 1,000 cars with GPS tracking systems and wireless communications, the Smithsonian Institute reduced fuel consumption by more than 50 percent (Pyper 2014). This measure resulted not only in cost savings, but also in a reduction in the amount of GHG emitted compared to manually driven vehicles. Some reports estimate that widespread adoption of automation technology in transportation could reduce global GHG emission by upwards of 50 percent in 2050 (Pyper 2014).

Use of automated transport is an economic and climate-based opportunity that Australia risks missing. A report commissioned by Google and authored by economic consultancy AlphaBeta (2018) estimated that widespread adoption of automation technology could lead to as much as a

US$2.2 trillion benefit to Australia's national income, provided that Australia acts soon. Currently, Australia ranks 10th on a list compiled by The Economist and ABB of countries most ready for the shift toward an automated economy. Although this is a globally strong position, it is one of the lowest ranked among its peer group of industrialized Western nations that would be top competitors for investment, industry, and jobs, with the United States, Japan, South Korea, Germany, and Singapore all ranking as more prepared. If Australia acts quickly to seize the opportunity, the iron ore mining industry must be prepared for the policy implications (Economist Intelligence Unit 2018).

Mining Firms' Experience

Rio Tinto's Mine of the Future operation in Western Australia is a prime example of how automation can mitigate a mining operation's impacts on climate. At the same time, such operations can develop green value chains and diversify local economic sectors. Inaugurated in 2008, the Rio Tinto's Mine of the Future automation portfolio holds four primary technological advances: (a) a modern operations center in the Western Australian city of Perth that oversees mining operations remotely, (b) an autonomous vehicle haulage system that moves ore around the mine site using a supervisory control system and remote controller from the operations center in Perth, (c) an automated drilling system that can engage multiple drill rigs simultaneously, and (d) a long-distance rail transportation system, AutoHaul®, that moves ore to ports of call for export abroad.

For Rio Tinto, and their automated haul partners Komatsu and Caterpillar, these adaptations have achieved significant efficiencies and cost savings. The fleet of approximately 80 automated haul trucks now move approximately 25 percent of ore and waste material produced across Rio Tinto's Pilbara operations (Jamasmie 2018). The adaptation has proved so successful—with the same number of trucks, or fewer, able to carry more ore—that Rio Tinto plans to roll out as many as 50 additional trucks by the end of 2019 (Rio Tinto 2017). Maximizing route efficiency and curbing the amount of truck idle time have contributed to both increased haul efficiency and reduced carbon-intensive fuel consumption—by approximately 5 percent in some operations—with overall cost reductions of approximately 15 percent compared with manned trucks (Jamasmie 2018).

Despite these successes, prospects to replicate the success of the Rio Tinto-Australia model in resource-dependent developing countries will likely face challenges owing to the significant technological gap between mining operations and the rest of an economy. Such as gap has been one of the main reasons for the difficulty of integrating the mining industry into the national economies of host nations through, for instance, local supply chains and downstream value-adding processing. It can be argued, therefore, that technological progress and automation could contribute to further isolating the mining sector from the rest of the economy as opposed to greater integration into mining-dependent developing economies' value chains. It is therefore incumbent on firms and their policy-making counterparts to make collaborative decisions about what portions of the value chain the host country can support, and how investments might be structured to maximize the capacity of local human capital.

GOLD AS AN AVENUE TO RENEWABLE ENERGY

The gold-energy nexus

Case 3 Snapshot	
Gold	**Renewable Energy**
IAMGOLD	**Burkina Faso**
To tackle a technical challenge requiring a reliable and competitive source of energy in its Essakane gold mine, IAMGOLD teamed up with Total EREN and AEMP to build the world's largest hybrid solar-thermal plant. The plant started operations in March 2018. Support from the government of Burkina Faso has been instrumental in making this project viable and bodes well for future similar projects. Developing renewable energy assets and skill sets in a nascent power sector can trigger knock-on economic and human capital development.	

Because of its high value and relative scarcity, gold can be economically extracted in very low ore grades (e.g., below 1 gram of gold per tonne of ore), depending on global prices, which results in relatively high volumes of material mined and waste generated. Similarly, the price point of the mineral makes commercially feasible those gold operations that are characterized by large-scale mining of the refractory ores (i.e., ore from which extracting gold is more challenging owing to the presence of other minerals). Each of these two factors—low ore grades and the need for separation from other minerals—drives extremely energy-intensive extraction processes.

Gold's economic importance to Burkina Faso

Burkina Faso, a small nation of 19-plus million people, is the fourth-largest African producer of gold. It is expected to produce as much as 55 tonnes in 2018, an approximately 66 percent increase from 2012 (Cocks and Aboa 2018). The International Council on Mining and Metals (ICMM) estimates that Burkina Faso's economy is the third most dependent on the mining industry in the world, ranking just behind Mauritania and the Democratic Republic of Congo (ICMM 2017).

Adaptations to processing technologies and production techniques, or advances in energy generation or usage related to mining industry activities, stand to influence the Burkinabe economy to a disproportionate degree compared with other large gold-producing countries. Mining, and particularly gold mining, perhaps more than any other single sector of the economy, may be leveraged to influence the broader economic landscape. Similarly, policy and regulatory changes that influence the adoption of new mining processes and technologies would necessarily have far-reaching impacts on economic advancement and a high likelihood of triggering new technology-related economic value chains within the country.

The policy context: The renewable energy potential of Burkina Faso

On a global scale, renewable energy has cemented itself as an alternative of choice to traditional fossil fuels, and consequently it is an area where policy can play a large role in shaping the present and future business landscape. Globally, the renewable energy industry accounts for more than 10 million jobs, with more than 3 million in solar PV technology alone, according to the International

Renewable Energy Agency (IRENA). As recently as 2012, the renewable energy industry was responsible for around 7 million jobs, adding economic advancement equivalent to an entire solar PV industry in as little as five years.

This economic potential is particularly evident in Burkina Faso. Even compared with other West African countries, Burkina Faso has a nascent power sector. The national electricity grid stops more than 300 kilometers from mine sites like IAMGOLD's Essakane, and there are no connecting transmission lines. Generation options are limited. Fossil fuels are responsible for more than 60 percent of Burkina Faso's electricity generation capacity, and 100 percent of those fossil fuels are imported from abroad (CIA 2018). In an effort to foster sector growth, energy independence, and diversification, the national government, through the Ministry of Mines and Energy, has drafted and implemented a handful of renewable-friendly policies and made a push to expand the country's renewable portfolio. It has already committed to a renewable portfolio standard of 50 percent of its energy mix by 2025 and has unveiled plans to erect eight solar parks for a combined generation capacity of 100 MW (World Bank 2017; Bellini 2018).

The economically additive nature of the renewable energy industry is particularly pronounced in Burkina Faso, where there are no naturally occurring fossil fuel resources and where the balance of jobs in industry has outpaced the number of jobs in agriculture only within the last few years. Replacing imported fuel resources, and their respective jobs abroad, with locally developed renewable energy resources stands to create an entirely new technology and employment base in the country.

Mining firms' experience

IAMGOLD's Essakane mine is the largest gold mine in Burkina Faso, producing more than 430,000 ounces of the more than 1.4 million ounces produced nationally in 2017.[2] This single site accounts for approximately one third of annual Burkinabe gold production. The mine represents a compelling snapshot of how the interests of the mining industry are aligned with the benefits of green economic growth and the opportunities for economic diversification that are associated with the renewable energy industry.

IAMGOLD understood that, because of the mine's remote location (more than 300 kilometers from a grid interconnection point) and the fledgling state of the Burkinabe power sector, Essakane would have to generate its own power. To generate the amount of electricity required to power a system that processed more than 12 million tonnes of ore annually, IAMGOLD constructed a 57 MW thermal plant. This type of generation is a proven standard for large mining or industrial operations and runs on heavy fuel oil (HFO), a notoriously inefficient, high-carbon fuel that is formed as a derivative of other fuel refining processes and that yields approximately 1 kWh for every 11 liters consumed (SEAI 2017). Supply constraints and the isolation of the Essakane mine site also meant that HFO had to be trucked in over hundreds of kilometers from neighboring countries Benin and Togo. This arrangement required more than 130 haul trucks to drive more than 1,400 kilometers to transport millions of liters of HFO annually.[3]

Relatively soon after the mine was commissioned, deeper pits struck a higher proportion of harder rock. This harder ore took longer to grind and crush than the anticipated softer rock, a process that can demand three to four times more electricity to process than a softer ore body. Responding to this obstacle, the mine's energy consumption jumped from 14 gigawatt-hours a month in 2013 to 26 GWh/month in 2015, significantly increasing the mine's HFO consumption to generate the required power. By 2015, with solar PV generation becoming relatively affordable, IAMGOLD determined that a 15 MW hybrid solar-thermal plant would be the appropriate solution, and the firm would reap the cost savings and environmental benefits of solar while ensuring that the solar-thermal integration did not compromise the power supply's reliability (IAMGOLD 2017).

For Burkina Faso, the Essakane hybrid solar-thermal plant played a role in establishing and strengthening an entirely new economic value chain in the country by being at the forefront of its in-country technical expertise in renewable energy. In addition to hiring 70–120 contractors for the project's construction phase, IAMGOLD committed to securing approximately 40 locally held operational jobs at the solar plant over the 15-year life of the asset (IAMGOLD 2017). This commitment not only creates short-term local jobs and skill sets but also builds long-term renewable energy–related local skill sets well into the future. These are key considerations for a national government that plans to renewably generate as much as 50 percent of the country's electricity capacity by 2030.[4]

The Essakane solar operation also marked the first power purchase agreement (PPA) between two private entities in the history of Burkina Faso, and one of the first in the West Africa region. This PPA demonstrates the viability of the Burkinabe market to developers looking to enter the West African market from neighboring countries such as Nigeria or firms with a more global focus. SONABEL (Société Nationale d'Electricité du Burkina Faso), the state-owned utility, is often not considered a creditworthy off-taker, and this PPA demonstrates that it is feasible for developers to find bankable off-takers like IAMGOLD in a region with a challenging risk profile. That alleviates a primary bottleneck to renewable energy development in a new market, encourages new supply chains, and influences the Burkinabe government to support policies that facilitate private party PPA transactions.

CEMENT AND BIOMASS: RENEWABLE ENERGY SOURCES FOR A CARBON-INTENSIVE PROCESS

The cement production-energy nexus

Case 4 Snapshot	
Cement/Aggregate	**Renewable Energy**
Ambuja Cement	**India**
Implementing renewable biomass technology and sourcing resources locally strengthen local supply chains, encourage alternative business development in green economic areas, and deliver generation with a reduced carbon footprint compared with using HFO as the plant's sole fuel source.	

Cement production accounts for approximately 6 percent of global GHG emissions, with most of those emissions a product of the conversion process of limestone to lime in the production of clinker (Harvey 2018). The second source of emissions is the burning of fossil fuels to generate the energy required to heat the raw ingredients to over 1,000 degrees Celsius. Initiatives such as clinker substitution and improved grinding technologies have proved they can directly reduce the thermal energy and carbon emissions associated with the production of cement for the same amount and quality of final cement produced.

The economic diffusion of cement

Economically, cement production is intensely local; aggregate is extracted around the world and often processed near the source, as aggregate is labor intensive to move and in plentiful supply. Cement processing plants exist in almost every country, and the market share of large cement companies is more fractured than that of large metal mining companies. As just one example of how diffuse the cement market is, according to the Carbon Disclosure Project, 13 of the largest publicly listed cement companies are responsible for just 15 percent of global cement production; that is in comparison to the copper industry, where 13 of the largest companies are responsible for more than 50 percent of global copper production (CDP 2018).

The policy context: Surplus biomass

Rural communities account for 80 percent of India's poor, and approximately half of the rural poor survive by laboring in an agricultural setting that produces a surplus of as much as 150 million tonnes of biomass every year. India's Ministry of New and Renewable Energy (Government of India, Ministry of New and Renewable Energy 2018) estimates that India's biomass resources, if fully utilized, could generate as much as 18,000 MW of clean power. In the meantime, biomass-powered generation plants have sprung up across India, with at least 288 biomass power and cogeneration projects. For each plant, about 100 workers are employed during the construction phase, and about 25 full-time employees are required to operate the plant. An additional 35 employees are needed in the biomass collection and logistics portion of the supply chain (Government of India, Ministry of New and Renewable Energy 2018). The logistics of bringing biomass to market, while employing dozens per biomass project, is also a primary detractor from biomass as a viable generation option. Although there is ample supply, the extremely rural nature of the country and the lack of an organized mechanism to collect and transport biomass from disparate fields or forests to a single generation site is challenging.

To capitalize on this potential for renewable energy generation and the corresponding economic boon of developing new green value chains in predominantly rural areas, the national government has actively incentivized biomass development. These initiatives include a 10-year tax holiday for newly constructed biomass plants, aggressive capital subsidies, and excise and customs duty exemptions on a state-by-state basis (Government of India, Ministry of New and Renewable Energy 2018). The viability and availability of biomass in the rural Indian market marks a scalable opportunity to build renewable infrastructure that both generates electricity and provides local jobs. Moreover, it produces economic benefits in a technology area that reduces greenhouse gases, and it has the capacity to diversify the economy beyond biomass as farmers derive additional income.

Mining firms' experience

Ambuja's Rabriyawas processing plant is located not far from the Pakistani border in Pali, a rural district in Rajasthan, India. Having identified the opportunity to leverage biomass in its fuel mixture to save on energy expenditures and reduce GHG emissions at the plant, Ambuja Cement moved to secure a supply of the fuel. As is standard in the industry, Ambuja began by purchasing biomass from third-party providers. These were private, for-profit Indian businesses, which allowed Ambuja to secure a steady supply of biomass while contributing to the regional economy through local procurement. However, the company's community development arm, ACF, determined that greater value creation may be attained by engaging local farmers to join the biomass market. Rabriyawas's rural location became an asset in this regard; the surrounding farmland provides fertile ground for biomass sourcing at a local level. ACF established a farmer producer organization to directly supply the Rabriyawas plant with biomass, securing a dedicated local supply chain to supply biomass to power part of the Rabriyawas processing facility.

To date, more than 500 farming families have taken advantage of this structure and sold biomass to the plant, including sugarcane waste, cotton stalk, and other crop residues, and successfully established elements of the biomass value chain within rural parts of Rajasthan (LafargeHolcim 2017). This program proved so popular with local communities that Ambuja exported the framework to other cement processing plants in rural areas. In 2016 alone, farmer producer organizations surrounding multiple plants sold more than 12,500 tonnes of biomass to the Rabriyawas kiln (Ambuja Cement 2018).

Demonstrating the viability of this biomass supply model mitigates one of the primary disadvantages of instituting a biomass generation system. It also demonstrates the viability of this procurement model in the rural Indian countryside, an area often devoid of local or foreign investment. A scalable farmer-supply system could provide biomass across India's remote interior, driving economic diversity by creating from scratch biomass-centered green supply chains.

A NOTE ON THE FUTURE OF THE MINING INDUSTRY AND THE GROWTH OF FRONTIER MINERALS

Frontier Mineral Snapshot	
Frontier Minerals	**Global**
Identifying minerals that are likely to hold significant market importance in the future is key to assisting mineral-rich countries in developing policy frameworks and economic development plans to maximize green-growth and economic diversification in new and growing mineral classes.	

While the benchmark minerals discussed in the foregoing case studies will remain central to the mineral mining industry, this report would be incomplete without a discussion of some of the nascent minerals at the forefront of the technological changes driving the green growth sectors this report discusses. This section presents a discussion of two such *frontier minerals*, cobalt and lithium, whose dynamic growth in demand has been driven by a market for rechargeable batteries and the growing renewable energy and electric vehicles sectors. The prodigious growth of the demand for these minerals and other frontier minerals has produced new business networks, supply chains, and geographies in which miners are operating. As such, this presents new space where a strategic green industrial policy might be applied to conscript the industry into a host nation's push for green growth.

To fully conceptualize the scale of the future market for cobalt and lithium, it is helpful to use electric vehicle ownership as a proxy, which the International Energy Agency projects could rise from 3 million in 2017 to 125 million by 2030

(DiChristopher 2018). This growth in electric vehicle ownership alone, for instance, is expected to drive a jump in the demand for cobalt by more than 40 percent in 2018 (Ferris 2018). Moreover, given the supply constraints of these minerals, growth will likely occur in new geographies and emerging markets. The Democratic Republic of Congo, for example, contains more than 60 percent of known cobalt reserves, an amount more than six times that of Australia, the second-largest reserve of cobalt. Bolivia and Chile, similarly, have two of the largest untapped reserves of lithium in the world, with Bolivia's reserves alone being nearly threefold those of Australia (USGS 2018).

The nascent nature of the extraction activity for these two minerals, and the relative immaturity of the operations, makes it a challenge to find multiple clear examples of a frontier mineral operation that implements climate-sensitive technology. A concern over future supply constraints has pushed companies to operate in new environments, some of which do not yet have well-formed policies to incentivize companies to operate in a more climate-sensitive manner. For example, the Democratic Republic of Congo only recently amended their mining royalty policy to classify cobalt as a strategic mineral, a designation that increases royalties from 2 percent to 10 percent in an effort to generate additional revenue from the in-demand metal (Shabalala 2018).

Moreover, the demand for these minerals is so new that key customers using the minerals in their products are only now beginning to actively shape the minerals' supply chains. Companies such as Apple and BMW have expressed interest in working directly with cobalt mining companies in an effort to execute long-term supply contracts for the metal (Farchy and Gurman 2018). Given the highly public nature of companies like these, and the global set of stakeholder relationships they must manage, large-end consumers increasingly have an incentive—and leverage—to be engaged in the mineral production process and potentially demand climate-sensitive production practices. In this new reality, governments pursuing green growth may even be able to reach further into the mineral consumption value chain for a point of leverage to exercise influence and to develop cohesive private sector partnerships to incentivize investments in key green industrial sectors.

These frontier minerals showcase the possibility for the mining industry, as it evolves, to increasingly direct investment toward sectors that bolster the green growth of the countries in which they operate. As new emerging markets open for mining industry investment in minerals like cobalt and lithium, those governments are presented with a white space to craft green growth policies. Moreover, as new large-end consumers with powerful incentives for clean supply chains become increasingly involved in the mining value chain, governments may find themselves with new and influential stakeholders in their green growth journey.

NOTES

1. https://www.2030wrg.org/work/peru/.
2. The IAMGOLD presentation is downloadable at https://s1.q4cdn.com/766430901/files/doc.../Essakane-Site-Tour-June-12-2018.pdf.
3. Information provided by IAMGOLD as part of consultation for the preparation of this case study.
4. Sustainable Energy for All (SE4ALL), https://www.se4all-africa.org/seforall-in-africa/country-data/burkina-faso/.

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green press INITIATIVE

A sustainable path to development has profound consequences for all economic activities and related policies. The mining industry, which provides input to almost every product and service in the world, is highly relevant to the goal of achieving sustainable development in mineral-rich countries and in the global economy. In addition, environmental sustainability is a critical concern for mining companies, whose growth is increasingly affected by climate change. Given the centrality of minerals and metals to our way of living, *Building Resilience: A Green Growth Framework for Mobilizing Mining Investment* investigates the extent to which the mining industry can contribute to green growth.

Despite what ought to be a tight nexus of public and private interest in targeted green sector investment, this report finds that there is a misalignment between mining companies' investment in climate-sensitive production processes, and policy makers' efforts to develop a cohesive green economy framework for industry to navigate. The private and public sectors regard the climate agenda and the development of local economic opportunity as separate matters. Neither industry nor government have yet to effectively leverage their climate imperatives and mandates to seize green growth opportunities. To address this misalignment, this report proposes a framework to help mining companies and governments integrate climate change and local economic opportunity activities. Going further, the report offers examples of projects and policies that support green growth: particularly climate-related activities that create scalable economic value and invest in long-lasting green infrastructure.

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