Adapting to a changing climate: implications for the mining and metals industry
In October 2010, ICMM’s Council of CEOs approved the establishment of a new program of activities aimed at the climate change issue. The program would have at its core the idea of championing a “principle-based” approach to guide developing climate change policies, regulations and laws. In addition, it would establish ICMM as a “thought leader” in certain key topics. The following year, the council approved a set of seven principles for climate change policy designed to guide the development of effective and efficient national and sub-national climate change approaches that contribute to sustainable development while remaining competitive in a low carbon economy.

Adapting to a changing climate: implications for the mining and metals industry is one of a series of three reports that describe our work in those areas over the last two years. The other publications examine options for revenue recycling out of carbon pricing policies and the impacts of carbon prices on the competitiveness of commodities in four regions.

There is a growing awareness that a changing climate and its impacts represent a physical risk to mining operations and installations. Investment funds and reporting regimes such as the Carbon Disclosure Project are seeking information on how companies are planning for impacts – such as rising sea levels or water scarcity – associated with a changing climate.

This report addresses three key issues. Firstly, it explains why it is important for the mining and metals sector to understand the impacts from a changing climate and to develop strategies to adapt. It then looks at relevant climate impacts and how mining and metals companies can evaluate risks and opportunities associated with those impacts. And finally, it examines the available options for adapting to climate change impacts.

ICMM and its members are committed to playing a constructive and substantive role in the ongoing climate change policy dialogue. This report is a demonstration of that commitment.

Ultimately, our aim is to ensure that we strengthen our contribution to sustainable development by playing our part in addressing the climate change challenge, while at the same time securing the continued competitiveness of the mining and metals industry.
Much of the existing assessment in the public domain of the impacts of a changing climate and strategies for adaptation has focused at community or national levels. This report’s objective is to elaborate on these risks for the physical operations of the mining and metals industry. It also initially explores how mining and metals companies might begin to design and develop coping strategies to address those risks. While there are critical opportunities for the mining and metals industry to develop and design adaptation strategies in ways that work to complement other priorities, such as community relations, the focus of this work is on impacts and adaptation for the mining and metals industry more narrowly. This report advances the public understanding of climate change impacts on the mining and metals sector and options for adaptation by addressing three central questions:

1. Why is it important for the mining and metals sector to understand the impacts from a changing climate and to develop strategies to adapt?

A changing climate presents physical risks to mining and metals operations because these industries are often located in challenging geographies, rely on fixed assets with long lifetimes, involve global supply chains, manage climate-sensitive water and energy resources, and balance the interests of various stakeholders.

Increasingly, external stakeholders are asking companies to identify, disclose and plan for the risks and opportunities presented by a changing climate. By taking steps to adapt, mining and metals companies can also achieve complementary sustainable development goals related to local community engagement, social development, biodiversity enhancement, protection of sensitive ecosystems and natural resource stewardship.

2. What are the relevant climate impacts and how can mining and metals companies evaluate risks and opportunities?

The mining and metals sector is already very experienced at identifying and managing risks. Increased temperatures, changes in precipitation, sea level rise and extreme events may become additional stressors with the potential to exacerbate existing risks managed by mining and metals companies. As shown in Figure 2.2 (see page 13), this report uses a risk-based approach to develop a framework for evaluating potential climate-related impacts throughout the mining and metals cycle.

3. What are the options available to the mining and metals sector for adapting to climate change impacts?

This report also develops a framework (see Figure 4.1 on page 40) for helping mining and metals companies respond robustly to the challenges and opportunities of a changing climate – a process commonly referred to as adaptation. Many companies already have the approaches, tools, data, resources and people necessary for identifying and adapting to risks and opportunities. In fact, not dissimilar to farmers, one could say that the mining and metals industry has always had capacity in responding to the challenges of external environments, and developed and designed robust engineering strategies to address those threats. This is not so much about “reinventing” the wheel as it is about integrating these additional climate impact stressor scenarios within existing risk management and planning procedures.
Enhancing resilience in the mining and metals sector
1.1  A changing climate in context

The mining and metals sector plays a critical role in driving global economic growth (World Economic Forum 2011). The development of mineral resources is a pillar of many national economies, both in terms of contribution to gross domestic product and tax revenues, and also as an industry that directly employs millions of workers. The closely connected upstream supply sector of the mining and metals industry, which provides construction services, manufacturing, wholesale and retail trade, as well as technical, scientific and professional services, provides further employment and delivers significant additional economic benefit. The extraction and processing of minerals and metals has brought huge benefits to society. These vital commodities are used to construct communication and transportation networks, consumer electronics, vehicles, buildings, and many other items that serve as a foundation for society’s material quality of life (ICMM 2012).

The mining and metals sector faces a number of sustainable development challenges, including the impacts of a changing climate. This report focuses on managing the risks associated with a changing climate for the mining and metals sector. ICMM and its members, however, recognize the role that the industry has in helping to mitigate climate change by reducing greenhouse gas (GHG) emissions. ICMM’s Council of CEOs has outlined four commitments to which all members subscribe in order to address GHG emissions. These are to:

- introduce emissions reduction strategies
- ensure the efficient use of natural resources
- support R&D of appropriate low GHG technologies
- measure and report on progress.

The industry recognizes the need for collective action to address this global challenge.

Under a changing climate, companies will face risks both from the policies and regulations aimed at controlling GHG emissions – which could affect companies’ competitiveness – as well as from the actual physical impacts of changes in climate. This report focuses on the latter risk.

While the exact nature of climate change impacts will be location-specific and dependent on regional characteristics and ecosystems, it is possible to come to some broad conclusions regarding climate-related risks and opportunities in the mining and metals industry. Higher temperatures, changing patterns of precipitation and higher sea levels, or conversely, lower freshwater lake or temperatures, changing patterns of precipitation and opportunities in the mining and metals industry. Higher conclusions regarding climate-related risks and ecosystems, it is possible to come to some broad location-specific and dependent on regional characteristics.

While the exact nature of climate change impacts will be

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and increased competition for climate-sensitive resources such as water and energy. These and other impacts may affect asset values and require additional maintenance or upgrades; they may reduce efficiency, increase the risks of regulatory non-compliance and necessitate changes in operating practices; they may also reduce or increase demand for specific products or services. On the other hand, a changing global climate may enable access to new reserves in previously inaccessible areas, and efforts to plan and prepare for changes in climate can create opportunities to engage communities and advance sustainable development objectives.

Our climate is already changing, as evidenced by observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and the rising global average sea level (IPCC 2007a). As the climate continues to change, we will experience further changes in average temperature, precipitation, sea level and extreme events. Climate change is also expected to increase variability, resulting in climatic fluctuations beyond those that we are used to dealing with.

Mining and metals companies already operate in environments that experience extremes in weather; as the climate changes, these companies will need to cope with both gradual increases in temperature, changes in precipitation, increases in sea level, changes in fresh water levels as well as increased frequency or intensity of extreme events, such as droughts, floods, heatwaves and storms. Since mining and metals companies already manage extremes in shorter-term weather patterns, responses to long-term changes in the climate of a given region can build on conventional approaches to risk management and planning.

Some expected changes in climate are more certain than others. It is expected that global and regional temperatures will continue to increase at a rate of at least 0.2 degrees Celsius per decade for the next two decades (IPCC 2007a). It is also very likely that heatwaves and extreme precipitation events will become more frequent. Changes in precipitation patterns are more uncertain, however: while it is very likely that the amount of annual precipitation will increase in high latitudes, and likely that it will decrease in most sub-tropical regions, global climate models disagree on the magnitude – and often the direction – of change in many regions (IPCC 2007a). Global sea levels are expected to rise, but the extent of rise is highly uncertain. Finally, beyond the uncertainties in our ability to model, or project, changes in climate, the magnitude and rate of future change will also depend on the amount of additional GHGs emitted into the atmosphere.

1 This refers to a changing physical climate, including changes in temperature, precipitation, sea level and the frequency or intensity of extreme events such as storms, floods and drought.
For the purposes of this report, we have focused on climate change projections that result in a 5°C increase in global mean temperature by the end of the century. This is consistent with higher GHG emission scenarios 3 (ie A1FI or A2 scenarios) developed by the Intergovernmental Panel on Climate Change (IPCC) in its Special report on emissions scenarios (SRES) (IPCC 2000). The emissions trajectories associated with these scenarios are also consistent with current observed trends in global GHG emissions (ie they represent a “business as usual” future). Detailed risk assessments at the local scale, however, should employ a range of climate change scenarios to capture the range of potential future trajectories of global GHG emissions, as well as future impacts (IPCC 2007b).

Some particular characteristics of the mining and metals sector may increase the industry’s exposure to climate risks, for example:

- The sector relies on large fixed assets with long design lifetimes, and makes long-term planning decisions that affect both the mine site and the surrounding environment. Unless the potential impacts of a changing climate are considered at the outset, design and planning decisions may not be resilient and may actually increase climate risks to operations and the local environment in the future.

- The sector is dependent on long global supply chains, such that a climate-related disruption can have significant impacts across operations in multiple locations.

- Mining and metals companies operate in some very challenging geographies and climates, particularly as more readily accessible ores are mined, often in unique and fragile environments with ecosystems that are highly sensitive to a changing climate, or in “frontier” locations where isolation and lack of capacity and local infrastructure make it much more challenging to recover from any climate-related disruption.

- Companies work with local communities that may themselves be vulnerable to climate change risks from human health impacts, water availability and impacts on climate-sensitive industries such as agriculture. Climate change risks may impact workforce availability, economic growth and social development in local communities, and this can in turn jeopardize mining and metals companies’ operations and reputations in areas that are sensitive to a changing climate.

- The mining and metals sector is heavily reliant on water and energy for processing, both of which can be highly climate sensitive.

In addition to these direct climate risk exposures, many of the other sustainable development pressures faced by the mining and metals sector are also climate sensitive. For example, gaining and maintaining a social licence to operate, which is critical to preventing disputes that delay projects or cause existing operations to be halted, may be more challenging when a changing climate has a negative effect on local communities.

At the same time, the implications to land and water use of the mining and metals industry – both of which are important to management of risks from a changing climate – are distinct from other climate-sensitive industries. Importantly, for any mining operation the actual footprint of alienated land and volume of water withdrawals are both small in comparison to such activities as agriculture and urban development. At the same time, the mining industry recognizes that implications of any human activity can ripple out across an ecosystem, and effective risk management as well as realization of stewardship opportunities to positively contribute to ecosystem health demands an ecosystem perspective that is inevitably unique to every location. Box 1.1 and Box 1.2 highlight some of these issues by providing a summary of relevant information on the mining and metals sector’s contribution to land and water use.

Finally, the mining and metals industry is very experienced at identifying and managing risks arising from both sustainable development requirements and general operations. In order to deal with volatile geopolitical situations, unpredictable price environments, tough regulatory requirements and the highest health and safety standards, global mining and metals companies are placing increasing higher priority on the need for effective risk management, and are publicly reporting on adoption of good practice in annual sustainable development publications – this has become part of mining and metals companies’ corporate culture. In order to best utilize this existing expertise, it makes the most sense to incorporate climate risks within existing corporate strategic plans, risk management processes and engineering practices.

“As the climate continues to change, we will experience further changes in average temperature, precipitation, sea level and extreme events.”
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SECTION 1
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Box 1.1: Land use in context

Mining and metals sector’s use of land and water is often misunderstood, and thought to be much larger than actually is the case, particularly when compared to other sectors. In fact, although the mining sector owns, manages and uses substantial quantities of land and water, the relative share of water withdrawals and land use by mining activities is a relatively small portion of total use by other large users of these resources, such as agriculture and irrigation, urban land uses and other industrial users.

As an illustration, the figure and chart show information from the Australian Collaborative Land Use Mapping Program that provides national land use information for the 2001–2002 time period (ACLUMP 2006). Over this time, mining accounted for 1,370km$^2$, or 0.02% of national land use. In comparison, urban intensive uses and irrigated pastures and cropping accounted for 14,000km$^2$ and 26,000km$^2$, respectively, or 0.18% and 0.34% of total land available. Further research in other countries would prove useful as similar land use data is not available for the United States (EPA 2008, pp 4–19), and was not located for other countries with large mining sectors, such as South Africa and Canada.

![Map of land use in Australia](source: ACLUMP (2006).)

![Land use in Australia](source: ACLUMP (2006).)
Box 1.2: Water use in context

With respect to water use, several countries have estimated total water withdrawals (i.e., water inputs) at a level of detail that distinguishes mining from other large users, as shown in the chart.

- In Canada, mining accounted for 1.3% of the 42 billion m$^3$ of water inputs to residential, commercial, institutional and industrial sectors in 2005. Between 1981 and 2005, water intake by the mining sector dropped by 50%, while the value of production increased by 48% (NRT 2012, pp 46-47, 60).

- In Chile, the mining sector is responsible for 4% of consumptive water use, compared to 78% in the farm and forestry sectors, 12% in the industrial sector and 6% for drinking water (DGA 2008b).

- In South Africa, mining and large industry accounted for 8%, or 1.6 billion m$^3$, of total water use in 1996. In comparison, domestic and urban use was 11% of total water use, and the irrigation and agroforestation sector used 61% (DWAF 2004, citing DWAF 2003).

- In the United States, the mining sector withdrew water at a rate of 4,020 million gallons (15.2 cubic metres) per day in 2005, yet this only represented 1% of total water withdrawals; thermoelectric power production accounted for 49%, followed by irrigation and public supply at 31% and 11%, respectively (USGS 2009, p 5). Forty-three per cent of water withdrawn was from saline groundwater and surface water sources (USGS 2012b).

1.2 Emerging drivers for adaptation

Although the main drivers for adaptation in mining and metals companies are understanding and managing the implications of a changing climate for their businesses, companies are also responding to the changing expectations of external financial stakeholders in relation to climate risks and other corporate social responsibility and sustainable development considerations.

Several investor initiatives, such as the Carbon Disclosure Project (CDP),\(^4\) the Investor Network on Climate Risk,\(^5\) and the Institutional Investors Group on Climate Change,\(^6\) have begun to put pressure on companies to disclose climate-related risks. Each of these initiatives brings investors together to use their collective influence to engage policymakers, companies and other investors to accelerate public disclosure and management of risks associated with a changing climate. The CDP voluntary information request, which is sent to public companies, asks specifically about the business risks and opportunities arising from climate change impacts. Company responses to information requests have risen steadily over the years, as have the number of investor signatories and assets. The significant expansion of reporting schemes for the private sector, such as CDP, may herald the introduction of mandatory reporting on climate risk management. Section 2 of this report presents a structure within which the mining and metals sector can assess the risks that it faces as a result of a changing climate, and it is hoped that this will provide a useful framework for responding to climate risk management reporting requirements like those described here.

Shareholders and investors are beginning to consider the implications of climate risks for the long-term financial performance of investee companies (IFC 2010). Norway’s sovereign wealth fund, which manages US$582.7 billion in assets, offers an example of a large institutional investor assessing the risks of investing in climate-sensitive assets. The Norwegian Ministry of Finance has released an extensive study showing the specific impact of climate change on the Government Pension Fund Global portfolio of investments, showing that climate change could reduce the fund’s value by up to 10 per cent over the next 20 years (Mercer 2012).

There are indications that project financiers are also beginning to alter lending criteria to take account of climate risks. The group of private sector banks that developed the Equator Principles (a set of standards for determining, assessing and managing social and environmental risk in project financing) has established a Climate Change Working Group. This group engages with the International Finance Corporation (IFC) on the implementation of its climate change strategy into the Performance Standards, on which the Equator Principles are based, in order to share good practice in climate risk management practices. Recent revisions to IFC’s Performance Standards underscore the importance of managing environmental and social performance throughout the life cycle of a project, and specifically point to risks associated with a changing climate (IFC 2012). Development banks are also beginning to explore investment risks associated with a changing climate. The European Bank for Reconstruction and Development, for example, is integrating climate risk management into investment appraisals.

1.3 Road map to this report

This report consists of four additional sections. Section 2 discusses the implications of a changing climate for the mining and metals industry. It establishes a framework for evaluating climate change risks to the mining and metals business and provides an overview of physical risks for inputs to mining and metals operations, supply chains, markets and operations along the mining and metals cycle.

Section 3 applies this framework to three focus areas to explore the implications of a changing climate in further detail. The three focus areas are: arid or water-stressed areas, operations in tropical regions, and coastal areas or locations that may become wetter under future climate changes. Each focus area discusses the key financial and reputational business implications of potential impacts from a changing climate.

Section 4 develops a framework for developing and designing adaptation strategies to a changing climate. Within each step of the framework, the section provides examples of existing functions in mining and metals companies that can be harnessed to respond to climate change impacts. Conclusions from the report are summarized in Section 5.
Implications of a changing climate for the mining and metals sector
A changing climate presents a wide range of risks and opportunities for the mining and metals sector. Higher temperatures and sea levels, shifting patterns of precipitation and water levels, and increased frequency and intensity of extreme weather events will create site-specific risks, as well as risks to the broader network within which the mining and metals sector functions, as summarized in Figure 2.1. Primary impacts present direct physical risks to core operations, including the health and safety of employees, physical assets, processes, and operations and maintenance activities.

Climate change can also pose physical risks to the mining and metals value chain, including risks to production inputs, the workforce and market demand for goods. Finally, the broader economy or infrastructure (e.g., third-party energy or water services, supply chains, government services and market access) will experience climate change impacts [Freed and Sussman 2008]. Communities and ecosystems near mining and metals operations will also be affected by a changing climate. The surrounding community and environment may experience secondary climate change impacts if their ability to cope with a changing climate is constrained by mining and metals' operations – for example, through competition for water in arid or water-stressed areas – or by companies’ efforts to adapt to a changing climate.

Taken cumulatively, these impacts may have significant implications for the continued operation and profitability of assets. This section provides a high-level overview of the ways that a changing climate may affect the mining and metals sector.

**Figure 2.1: Categories of climate change impacts on businesses**

Source: Freed and Sussman 2008.
2.1 A framework for assessment

Figure 2.2 provides a framework for determining how a changing climate can impact mining and metals operations. The objective of this framework is not only to provide a structure to discuss the potential impacts of climate change on the mining and metals sector, but also to enable companies to assess the risks to their own operations in a consistent manner. There are three components to the framework:

- "Impact areas" denotes the points in the mining and metals cycle where impacts can occur. Core operations (shown in blue boxes) are: exploration and discovery of a mineral deposit, construction and development of the necessary infrastructure for mining a deposit, operation of the asset over its life, and reclamation of the site at closure and post-closure. The impact areas that refer to "inputs", "supply chains" and "markets" are related to the value chain and broader network surrounding a mining and metals company’s core operations. These relate to climate change impacts on inputs to mining and metals operations – such as energy and water supplies, supply chains that transport materials to and from the mine site and end-use markets for metals produced from mining operations.

- "Impact evaluation" involves assessing the possible impacts of a changing climate in terms of who is affected, the timeframe over which impacts are expected to occur, whether the impacts could directly affect mining and metals activities (i.e., primary impacts) or are expected to trigger other secondary impacts, and the likelihood that the impact will occur.

- "Business implications" refer to the consequences of climate change impacts; they involve either financial consequences from higher operating costs or unplanned capital expenditures, or reputational costs from litigation, regulatory non-compliance and negative public perception. Climate change impacts may also result in opportunities that lower the cost of doing business in certain areas, or that enable companies to engage communities and achieve sustainable development objectives.

Figure 2.2: Framework for evaluating climate change risks to the mining and metals sector

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<thead>
<tr>
<th>Impact areas</th>
<th>Impact evaluation</th>
<th>Business implications</th>
</tr>
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<tbody>
<tr>
<td>Inputs</td>
<td>Description</td>
<td>Financial</td>
</tr>
<tr>
<td>Supply chains</td>
<td>Timeframe</td>
<td>Higher operating expenditure or unplanned capital expenditure</td>
</tr>
<tr>
<td>Markets</td>
<td>Stakeholders</td>
<td>Reputational</td>
</tr>
<tr>
<td>Exploration</td>
<td>Primary/secondary</td>
<td>Increased risk of litigation, regulatory non-compliance, inability to operate</td>
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<tr>
<td>Construction</td>
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<tr>
<td>Operation</td>
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<td>Closure</td>
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<td>Post-closure</td>
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"Climate change impacts may also result in opportunities that lower the cost of doing business in certain areas."
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The framework is not an entirely new or novel structure; it was informed by existing methods of assessing and reporting risks and opportunities in the mining and metals sector. The framework was developed using the following approach:

1. We conducted a review of mining and metals company responses to CDP requests for information. The risks and opportunities identified in these reports were compiled by location, climate change variable (e.g., temperature, precipitation, sea level), stressor (e.g., sea level rise, flooding, drought) and potential impact. This provided an initial global and cross-sectoral perspective of the potential risks posed by a changing climate to mining and metals companies.

2. We incorporated secondary literature on climate-related impacts in the mining and metals sector. This step helped to validate the risks identified in CDP reports, established where impacts occurred along mine and metal cycle stages, and provided real-world examples of the business implications of potential climate change impacts.

3. We consulted mining and metals companies and reviewed existing approaches to risk assessment and how adjustments are being made to deal with climate change impacts (ADB 2005, Freed and Sussman 2008, Tiempo 2012, UKCIP 2008). This research provided insight into existing procedures, functional groups, risk management structures and planning approaches that are already used in the mining and metals industry. We applied this in developing both the climate change impacts framework in Figure 2.2 as well as the adaptation framework in Section 4.

4. We then used this information to develop the framework according to the following principles:

   a. The “impact areas” correspond to standard stages in the mining and metals cycle and distinguish between steps that mining and metals companies directly control (the blue boxes in Figure 2.2) and activities that involve other actors (e.g., material inputs, supply chains and markets).

   b. The “impact evaluation” elements are consistent with categories in CDP investor information requests. Consequently, implementing the framework will provide mining and metals companies with information that can be directly applied to existing climate risk reporting activities.

   c. The output of the framework is an evaluation of “business implications” in terms of financial or reputational risks. Using a risk-based approach helps prioritization of potential climate change impacts and provides results that are likely to be compatible with existing risk management and planning activities used by mining and metals companies.

To demonstrate how the framework can be applied using information on projected changes in climate and current and historical events, we applied the climate change impacts framework in Figure 2.2 to evaluate three focus areas in Section 3 of this report. These three focus areas help to illustrate how mining and metals companies can use the framework to evaluate potential risks and opportunities.

Each of the eight impact areas is explored broadly in Section 2.2. Companies can use this framework to explore more specific impacts on their operations, as these necessarily depend on location and site-specific conditions and activities. Potential impacts on-site and off-site are also summarized in a checklist in Appendix C.

“Research provided insight into existing procedures, functional groups, risk management structures and planning approaches that are already used in the mining and metals industry.”
2.2 The impacts of a changing climate

This section explores the broad impacts of a changing climate across each of the impact areas identified in Figure 2.2. Although efforts have been made to limit repetition of climate impacts across each area, there are certain impacts that affect more than one area of the mining and metals cycle and related services or activities. Rather than exclude duplicate impacts, we have discussed their implications at each relevant stage. Our objective is to discuss climate impacts from a business perspective, identifying where these impacts are most relevant along the mining and metals cycle.

Inputs

Water
Mining and metals operations are reliant on highly climate-sensitive inputs and processes. Water is critical for mining and metals operations (e.g., for cooling, crushing, grinding, milling ore, slurry transport and tailings storage), and any climate-related impacts on the quality and availability of water resources will have implications for efficiency and cost. In areas where water resources are currently under stress, any further reduction will likely constitute risks to production. In coastal areas, as sea levels rise in parallel with increased drawdown of wells, the potential for saltwater intrusion in freshwater supplies poses a risk to water quality. Water is an essential input in thermal and hydroelectricity generation, creating important linkages and dependencies between energy and water inputs (see the “Energy” section).

Energy
Mining and metals operations, faced with the challenge of breaking, moving and processing vast amounts of ore, are also large consumers of energy. As indicated above, there are important linkages between energy and water inputs. For example, a changing climate has the potential to affect hydroelectric power production through water availability if the estimated basis for design river flow ranges is no longer valid because of shifts in seasonal precipitation patterns or earlier and more rapid glacier melt. Conventional power facilities are also vulnerable to climate change if temperature changes reduce the water resources needed for cooling water or turbine inefficiencies.

Transmission pathways for energy (whether electricity or oil and gas) are also vulnerable to disruption by extreme climatic events, like severe flooding or storms. Demand for energy for cooling and other processes (including water treatment) is clearly linked to climatic conditions, with episodes of higher temperature increasing demand and placing greater strain on local energy transmission and distribution facilities. During these episodes, while demand for energy increases, higher temperatures simultaneously reduce the capacity of thermal generators and transmission lines. Although many sites are equipped with back-up power generators, these have limited capacity, and any climate-related damage to transmission lines and substations can potentially interrupt operations.

There are often few substitutes for existing sources of energy and water, making assessment and management of climate-related impacts vital. The cumulative effect of these and other climate risks is disruption and downtime at mining and metals operations. For some processes, work can be disrupted when a specific operational temperature is exceeded. Heavy precipitation may also present risks to operations that result in interruption to production, for example, when underground pumping systems have insufficient capacity to cope with particularly intense rainfall events.

“A changing climate has the potential to affect hydroelectric power production through water availability if the estimated basis for design river flow ranges is no longer valid because of shifts in seasonal precipitation patterns or earlier and more rapid glacier melt.”
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People
The health and safety of employees and the wider communities on which businesses depend can be affected both directly and indirectly by a changing climate, as shown in Figure 2.3. Higher temperatures directly increase the risks of heat stress for outdoor and underground workers. Heat exposure can also exacerbate chronic diseases, including cardiovascular and respiratory disease, through indirect microbial and vector-borne pathways. Over a longer time period, higher temperatures may affect regional food production and related ecosystems through impacts such as drought or competition from invasive species, which in turn can affect staff health. Clean water scarcity in times of drought may concentrate contaminants that negatively affect the chemistry of surface waters in some areas (CDC 2012). Health risks are also influenced, or modulated, by demographics and social aspects of vulnerability, as well as by systems put in place to prepare for extreme heat or weather events, prevent the spread of microbial disease and limit vector-borne disease pathways.

A changing climate can also affect the incidence, geographic extent and potential for the transmission of vector-borne diseases. As temperature rises, the malaria parasite reproduces more quickly, and mosquitoes feed more frequently. Higher temperatures and changing patterns of precipitation could introduce new (or result in the re-emergence of) water-related illnesses and other diseases. Finally, extreme weather events (e.g., storms and floods) that temporarily impact the ability to do business will have negative consequences for mining and metals employees. Local workers whose homes, communities or transport links are affected will be unable to work, and companies can experience difficulty in recruiting and retraining staff following a major natural hazard, such as a hurricane or flood.

8 Vector-borne diseases are infections transferred to humans by arthropods such as mosquitoes, ticks, triatomine bugs, sandflies and blackflies (Confalonieri et al. 2007, p. 403).
Supply chains

In addition to the direct physical risks to mining and metals infrastructure, a changing climate can impact the associated transport that is critical to mining and metals operations. Several ICMM members highlighted risks to port facilities during extreme weather events and from gradual sea level rise.

The reliability of transport routes and infrastructure is highly vulnerable to climate change impacts that have consequences for supply chains and logistics. Climate-related disruption to supply chains can occur through flooding and intense storms, changes to snow and ice, and ground instability leading to landslides or avalanches. In some subarctic operations, the timely delivery of inputs and products is vulnerable to the thawing of critical winter ice roads. Operations that are dependent on rail transport are vulnerable to speed restrictions, the potential for rail buckling and even derailment during extremes of high temperature. Damage to road and rail bridges is also a potential impact during intense precipitation events, storm surges and hurricanes.

Marine transport is highly vulnerable to the impacts of a changing climate. Rising sea levels may affect port operations and support facilities. Tropical cyclones and storm surges have the potential to disrupt coastal shipping routes and port operations, and to damage stockpiles of ore at port. Storm conditions that increase the flow of sediment into the port may require more frequent dredging. As sea levels rise, coastal ports may see an increase in salt levels in freshwater wells. Some operations in the Arctic and subarctic depend on a short shipping season to bring all resources and materials to site and take all products to market; in the event of climate-related disruption to transport, these operations will be severely affected.

These risks are particularly acute when mining and metals operations are critically dependent on a single transportation link that is owned and operated by an external body over which the mining or metals company does not have direct control. The potential disruption and delay in deliveries can cause operational losses as well as impacts on the entire value chain. Secondary impacts like these highlight the complexity of managing operations across widespread geographic regions, each of which is expected to experience different climate change impacts.

Markets

A changing climate may affect customer demand for goods and products. For example, a carbon-constrained economy may result in a different demand profile for metals and minerals. Demand may increase for materials used in the production of renewable energy, water recycling and harvesting, and diverse energy sources (eg uranium) (Acclimatise 2010). A detailed treatment of market interactions and the effects of a changing climate are beyond the scope of this report, but mining and metals companies that assess the opportunities as well as the risks of climate change may be well placed to take advantage of these changes.

Exploration

If ground stability risks can be managed, a changing climate may open access to new reserves in previously inaccessible areas. For example, the Arctic, due to rapidly declining ice levels, does appear to be opening up itself up to a veritable “resource rush”. The sensitivity of the local environment towards such incursions is acute, requiring careful design features that can effectively manage such risks.

Construction

Established approaches to environmental impact assessment are typically based on the assumption that the climate is static and tend to use historical observations of climatic and environmental conditions as a baseline. Engineering standards and building codes also tend to reflect an assumption that climate will remain static. As climate change impacts increasingly affect mine sites and mining and metals operations, the assumption of a static climate may become less valid and the long-term environmental sustainability and built resilience of projects may be reduced. This may require changes in engineering standards and guidelines, and – in turn – in facility or mine site design, including changes in design assumptions, operating thresholds, functional performance specifications, material selection and factors of safety. For example, basing mine site water balances on current or historic conditions may not necessarily guarantee that diversion ditches, water storage ponds, treatment facilities and other water management structures are sufficient to handle future seasonal water flows.

“The reliability of transport routes and infrastructure is highly vulnerable to climate change impacts that have consequences for supply chains and logistics.”
SECTION 2
Implications of a changing climate for the mining and metals sector

Operations

Mine site conditions can be affected as precipitation patterns change and as sea levels rise, through increased risk of flooding, subsidence, landslides, soil erosion, changing groundwater levels, as well as permafrost instability in some locations. Although it is not possible to link a particular event to climate change, widespread flooding in Queensland, Australia, in 2010 demonstrated how extreme changes in precipitation can impact the mining and metals sector. The floods severely limited access to mines, resulting in a rapid decline of export stocks at port and financial losses in excess of US$1 billion for the state coal industry.

Mining and metals operations are dependent on substantial fixed assets and infrastructure, which are vulnerable to damage as a result of flooding, subsidence, erosion and storms. The performance and value of existing infrastructure can be affected by a changing climate in several ways:

- Increased temperatures can reduce the efficiency of major equipment and cooling or water treatment processes.
- Equipment operating thresholds may be exceeded during episodes of extreme high temperature or wind speed.
- Intense precipitation events and storms can jeopardize the integrity of surface impoundments, and could necessitate development of additional water storage facilities to contain process solutions and capture rainfall for operational use.
- Changes in permafrost can threaten the land stability required to maintain secure tailings ponds, dams, mine access roads, haul roads, building and plant foundations, and other geotechnical structures.
- In the event of climatic disruption due to storms and floods, emergency response procedures can be compromised by poor ground conditions and lack of site access.

If the structural integrity of assets is compromised, this may require additional and unplanned capital expenditure to implement engineering safeguards. In the case of structural damage, downtime can temporarily affect operation at a site. Unless new assets are designed with a future climate in mind (i.e. using projected climate data as a design basis to ensure resilience against increased climatic variability), they may not perform as intended over their lifetime.9

In dry areas and seasons, hotter temperatures may increase the risk of wildfires that can affect access to operations and damage communications and power infrastructure. Higher temperatures and a longer ice-free season in Arctic waterways may also lengthen the operating season in some areas.

In addition to minimizing any negative impacts on the community, good sustainable development practice in the mining and metals industry necessitates broader environmental sustainability targets. Mining and metals operations generate significant amounts of waste water and rock debris, which is contained and managed through dams, waste rock piles, impoundments and tailings ponds. The changes in seasonal rainfall and temperature that are projected to occur in a changing climate will affect ground temperature, hydrology and soil moisture, and these changes may have an impact on the ability of waste containment structures to prevent contamination of land, surface water and groundwater that can harm species, habitats and ecosystems. Increased precipitation and higher temperatures may accelerate the weathering of potentially acid-generating waste rock, causing earlier onset and increased volume of acid mine drainage (MEND 2011). Arctic operations, which rely on frozen ground but are at risk of permafrost degradation as the climate changes, may see pollutant effects as mine tailings structures weaken. If the infrastructure is not sufficiently robust to limit mine waste spillage into the environment, operations may increasingly be in breach of environmental regulations (Shepherd 2012).

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9 This does not necessarily mean that assets will fail when exposed to future changes in climate: assets are often designed to accommodate a factor of safety, or buffer, to ensure they can withstand extreme events. If changes in climate remain within this margin, the asset may continue to operate normally. If changes exceed this buffer, however, the asset may fail or not perform as expected under future climate conditions. For example, tailings ponds or waste storage structures are designed to certain flood “return periods”, such as a 1-in-100-year flood event. In this case, assets designed to higher return periods will be more likely to endure future increases in flood risk better than assets designed to a lower return period. The actual performance of the asset will depend upon the standards to which it is designed, assumptions about the climate in which the asset is expected to operate and the future changes in climate to which the asset is exposed.
Closure and post-closure

Mine operators are required to calculate the costs of mine closure at the project outset and to post closure bonds that will redress any impacts a mining and metals operation causes to wildlife, soil and water quality over its lifetime. A changing climate will result in environmental impacts that are potentially quite large – particularly in the Arctic and in other highly climate-sensitive ecosystems – and this may increasingly factor into the regular reassessment of closure bonds as the risks of climate change are better understood and quantified. The potential for contamination and environmental impact are particularly important given mining and metals companies’ roles in helping to manage large landholdings, and the long lifetime of mining and metals sector assets, which are often designed to “in perpetuity” levels. For example, tailings dams and structures designed to accommodate “Probable Maximum Flood” events may be built to withstand flooding events likely to occur once in 10,000 years (Clarkin et al 2011) based on current climate and hydrological conditions. If heavier rainfall events contribute to increased frequency and severity of flooding, companies will need to ensure that their long-term closure plans incorporate additional water storage to contain excess precipitation. In other areas (particularly those already experiencing water stress), seasonal water scarcity can lead to temporary changes in mine site water balances, which can reduce the long-term effectiveness of tailings covers.

2.3 Business implications

Taken cumulatively, the wider business risks arising from the climate impacts outlined above can include:

- Risks to business continuity from both extreme events (eg floods, droughts, storms) and availability of climate-sensitive energy and water inputs, with consequences for the ability to meet customer demand and competition within the local community for goods and services.
- Health and safety risks to employees and the local communities on which businesses depend.
- Reputational risks, and risks to a company’s ability to gain and maintain social licence to operate, if mining and metals operations exacerbate the climate change impacts that a local community is facing. Reputational risks can also arise if the actions undertaken by a mining and metals company in response to climate change impacts have a negative impact on local environments or neighbouring communities.
- Risks of liability and litigation, if foreseeable impacts are not avoided and have a negative impact on others.
- Financial risks, including reduced access to project financing, higher insurance and operating costs, the need for unplanned capital expenditure and pressure from shareholders to disclose climate risks.

“A changing climate also brings opportunities. For example, there may be opportunities to increase production and market share through the opening of new areas to exploration and development, as a result of a longer ice-free shipping season in the Arctic.”

Beyond the individual climate change impacts identified above, operations and assets will also be affected by coincident impacts or sudden events triggered by a changing climate. Accounting for these impacts is very challenging, given the high levels of uncertainty surrounding when and how they might occur, and what the impacts will be. This is an area where knowledge is currently evolving, and that requires further research. Mining and metals companies, however, need to ensure that they are aware of the ways that climate risks can multiply and exacerbate existing challenges, as outlined below:

- Aggregate impacts. The compounded risk of several separate climate change impacts occurring in tandem may be greater than the risks associated with individual impacts. For example, less-developed local communities in areas prone to flooding and coastal impacts face multiple weather-related stressors that can affect human health and security, economic development and social
benefits. Changes in climate that increase the risk of inland or coastal flooding, erosion, periods of extreme heat and the incidence of disease will result in aggregate stressors that are more severe than the additional stress of any one of these changes alone.

• Cascading impacts. One impact resulting from a changing climate may in turn trigger other impacts on mining and metals companies. For example, decreased water availability, reduced precipitation or runoff (the flow of excess water over saturated land) in dry or water-stressed areas will affect both mining and metals operations, as well as the thermal or hydroelectricity generating facilities that rely on these resources. Impacts on electricity generation will further affect mining and metals operations that source electricity inputs from those facilities.

• Tipping points. A "tipping point" refers to a threshold in the climate system where a moderate, incremental change to the system triggers an abrupt transition to a new state.10 There is a high level of uncertainty surrounding how and when tipping points could be reached, but current research indicates that global mean temperature increases of 1 to 3°C could risk crossing certain thresholds. Increases above 3°C increase the risk of triggering large-scale tipping points, and the risk increases with higher levels of warming.11 Consequently, the climate change scenario of a 5°C increase in global mean temperature by 2100 considered in this report is within the range at which tipping points may be crossed. Specific tipping points are not addressed in this report, but could result in large-scale impacts on human society that affect fundamental assumptions in mining and metals sector business models. This is an active area of research; a better understanding of the likelihood of specific tipping points and the range of impacts they imply will aid in scenario analysis and risk assessment of these highly uncertain, high-consequence events.

“Changes in climate that increase the risk of inland or coastal flooding, erosion, periods of extreme heat and the incidence of disease will result in aggregate stressors that are more severe than the additional stress of any one of these changes alone.”

10 Crossing tipping point thresholds could cause rapid, unexpected changes that human systems – such as settlements, energy systems, transportation networks and industry – would have difficulty accommodating. For example, large, rapid losses from the Greenland and West Antarctic ice sheets from increased temperatures could increase sea level significantly (IPCC 2010).

Focus areas
This section builds on the diversity of risks and opportunities that were discussed in Section 2 by focusing on three topic areas and evaluating the physical impacts and business consequences of future climate changes. These three areas were selected because they are exposed to some of the most relevant climate risks that mining and metals companies currently face, demonstrate actions taken by companies to respond to and mitigate climate-related impacts and may experience climate changes that affect mining and metals operations in the short or medium term. The three topic areas are:

- arid or water-stressed areas, such as in Chile, Peru, the southwestern United States or Australia
- tropical regions such as Brazil, the west coast of Africa, Central Africa or Indonesia, where a changing climate presents potential risks to human health that may affect operators’ ability to meet social and environmental performance objectives
- coastal areas or locations that may become wetter or face increased frequency of flooding or extreme precipitation events under future climate changes.

Drawing from the framework established in Section 2, each topic includes a description of the climate risks and impact areas, an evaluation of the climate change impacts and the subsequent implications for the mining and metals business.

3.1 Focus area 1: Arid or water-stressed environments

Description of climate risks and impact areas

Mining and metals companies operate in many regions that are already water stressed, such as Australia, northern and southern Africa, Chile, Peru and the southwestern United States. Water is a necessary input for various processes in mining and metals operations and for electricity generation at thermal combustion and hydroelectric power plants. Long-term water quality issues and management of mine sites – particularly the management of acid-generating materials – can also be affected by long-term changes in water balances. In water-stressed areas, reductions in water availability resulting from higher temperatures and increased evapotranspiration,12 changes in precipitation and demand from other water users place additional stress on the water available for the following operations and services related to mining and metals activities:

- **Mining and metals operations** that require relatively large amounts of high-quality water. A direct implication of increased water stress is that mining and metals companies will not be able to access a sufficient supply of water for operations – either in terms of physical limits on water availability, or due to restrictions that regulate the volume of water that may be withdrawn by a given user in a watershed. The highest demands for water occur at the extraction, beneficiation13 and processing stages of the mine and metals cycle. At the extraction and beneficiation stage, major water uses include dust suppression, product separation and crushing, concentrate and waste transport, and further processing (Hansen Bailey 2009, pp 11–17; IFC 2007, pp 2–5; Australian Department of Resources, Energy and Tourism 2008, pp. 54–68; ICMM 2012a, p 7). Dust suppression is also a large source of water consumption in surface mining operations. Following beneficiation, water is added to the ore to form a slurry that can be transported in pipelines. Water inputs at the processing stage are process-specific and depend on the required operations, such as slag treatment, solvent extraction and electrowinning.14 A significant amount of water can be recycled after transport and in the processing stage for additional use (COCHILCO 2008, p 34; Geraldton Iron Ore Alliance 2012, p 2); typically, only what evaporates, water lost through seepage or water that remains stored in tailings is lost in the process.

12 Evapotranspiration refers to water transfer from the surface of the Earth to the atmosphere by evaporation (ie transfer of water to the air from land and water bodies) and transpiration (ie transfer of water to the air from plant leaves).

13 Beneficiation is the name given to the variety of processes used to crush and separate ore into valuable substances or waste.

14 Electrowinning is a process used to extract metals from ore by dissolving them and passing an electric current through the solution to deposit the metal.
• **Energy inputs.** The potential for a drier climate in areas currently facing water stress will also affect the operation of thermal and hydroelectric power plants, which may indirectly affect the availability and reliability of electricity provided to mining and metals operations. The electric power sector shares characteristics with mining and metals operations that make it vulnerable to climate change stressors: a reliance on climate sensitive inputs – chiefly, water for cooling or power generation at hydroelectric operations, sensitivity and exposure to extreme weather events and reliance on supply chains for the delivery of fuels at thermal combustion and nuclear power plants.

There are also important links between a changing climate and demand for electricity. Sourcing water from alternative sources may increase energy requirements for additional treatment or pumping water from further distances. A warmer climate will also increase the overall demand for power for space cooling – not only at mining and metals operations, but also from other users, potentially increasing competition for power in areas where companies import electricity from shared grids.

• **Post-closure activities** including reclamation and long-term water quality monitoring. For example, to prevent the chemical reaction that causes acid rock drainage (ARD), companies may separate acid-generating rock from oxygen by covering these materials with water. Increases in temperature, changes in precipitation and runoff, and an increased incidence of drought in the future could affect the performance of these water covers by increasing the risk of exposure of waste rock and tailings to air. Mining and metals companies may be responsible for preventing ARD post-closure over long timeframes, exceeding hundreds of years, and in some cases, “perpetually”, meaning that these structures will very likely be exposed to future climate changes (MEND 2011, Murphy and Caldwell 2012).

> “The potential for a drier climate in areas currently facing water stress will also affect the operation of thermal and hydroelectric power plants, which may indirectly affect the availability and reliability of electricity provided to mining and metals operations.”

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15 Acid rock drainage, or acid mine drainage, is the formation of highly acidic water from a chemical reaction involving oxygen, water and rocks containing sulphur-bearing metals (EPA 2012).
SECTION 3
Focus areas

Impact evaluation

Global regions that currently experience water stress are shown in Figure 3.1. In particular, the volume of annual water withdrawals as a percentage of the total available flow is extremely high (i.e. greater than 80 per cent) in the south-western United States and Mexico, Chile, northern and southern Africa, the Middle East, Central Asia and Australia. Projected changes in temperature and precipitation are likely to increase the severity of existing water stress in these areas.¹⁶

Impact evaluation

In many of these areas, annual precipitation is projected to decrease, as shown in Figure 3.2. The figure represents changes under a scenario where global temperature is likely to increase by between 1.7 and 4.4°C by the end of the century; stippled areas show where there is a high level of agreement in the direction of the change in precipitation across climate change models.

Figure 3.1: Global baseline water stress¹⁷

Baseline water stress represents the share of total annual water withdrawals as a percentage of total annual available flow. Values above 80 per cent indicate high levels of competition for water resources that may lead to business risks (WRI 2012).

¹⁶ The IPCC, in its assessment reports and special reports on climate change, adopts a specific terminology for assessing the likelihood of an outcome. For example, the terms “virtually certain”, “very likely” and “likely” are associated with probabilities of 99–100%, 90–100% and 66–100%, respectively. Due to the range of data sources consulted in this study, it is not possible to adopt a similar treatment of likelihood and uncertainty throughout this report. We have, however, maintained IPCC assessments of likelihood wherever possible based on IPCC guidance. Note that the IPCC refined its guidance on the treatment of uncertainties following the Fourth Assessment Report (IPCC 2007a), making comparisons between that report and the latest Special Report on Managing the Risks of Extreme Events (cited in this document as IPCC 2012) difficult if not impossible (IPCC 2012, p 21).

¹⁷ Baseline water stress represents the share of total annual water withdrawals as a percentage of total annual available flow. Values above 80 per cent indicate high levels of competition for water resources that may lead to business risks (WRI 2012).
In Chile, scenarios consistent with a 5°C increase in global mean temperature by end of century project that annual precipitation could decline by 10 to 40 per cent in some areas by end of century, although smaller decreases or moderate increases in rainfall in some areas cannot be ruled out (Bárcena et al 2009).

The World Resources Institute’s (WRI) Aqueduct database examines projected changes in water stress globally. Aqueduct maps baseline water stress, reuse and socio-economic drought conditions globally, and projects changes in water stress over the next century under different climate change scenarios. Aqueduct develops a water stress index based on 14 indicators in three categories: water quantity, quality and regulatory and reputational risk.

Figure 3.2: Projected changes in global precipitation by end of century

![Projected changes in global precipitation by end of century](image)

Source: Meehl et al 2007, p 769.

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18 Multi-model results are shown for an A1B scenario (ie approximately a carbon dioxide equivalent atmospheric concentration of 850 ppm by end of century) for the period 2080 to 2099 relative to 1980 to 1999. Stippling indicates regions where 80 per cent of the models agree on the direction of the change in precipitation.

19 Projections for the years 2025, 2050 and 2095 are based on IPCC scenarios B1, A1B and A2, which are approximately consistent with carbon dioxide equivalent atmospheric concentrations of 600, 850 and 1,250 ppm by end of century, respectively (IPCC 2007a, p 12).

20 Aqueduct evaluates water risk within the three categories of water quantity, quality and regulatory and reputational risk, using data on baseline water stress, inter-annual variability, seasonal variability, flood frequency, upstream storage, water reuse, water quality (eg BOD, COD and other pollutant loadings), monitoring station coverage and media coverage. Indicators for groundwater supply trends and ecosystem services are under development.
The current level of water stress in Chile, and the projected change in water stress in each region in 2095 (WRI 2012), is shown in Figure 3.3. The northern regions of Antofagasta and Atacama already face extremely high stress and are projected to face conditions that are at least twice as severe in the future.

Similar trends are expected in already water-stressed regions in Australia, southern Africa and the southwestern United States. In southern Africa, areas of Namibia, Botswana, northern South Africa and Free State province in South Africa currently experience medium to extremely high water stress. Areas of Namibia and Botswana are projected to face increased water stress by 2095, but the direction and magnitude of change is less certain along the border between Botswana and South Africa. Australia is projected to experience moderate to exceptional increases in water stress (ie 1.7 to 8 times above baseline stress), particularly in the west, where iron, nickel, zinc, bauxite and gold mining operations are located. In the United States and northern Mexico, gold and copper mines operate in areas of extremely high water stress – predominantly southern California, Nevada, Arizona and northern Sonora. These areas are projected to become severely or extremely more stressed by the end of the century (ie 2 to 2.8 times above current water stress levels); there is uncertainty in the magnitude of these changes in regions in the southern United States, and in both the magnitude and direction of changes in northern Mexico (WRI 2012).

Chile provides a useful example of how mining operations have responded to water stress. Water issues are particularly acute in northern Chile as the Atacama Desert is the driest on Earth. Chile is characterized by large differences in climate due to its long and narrow extension across latitudes, which cross several climate systems: desert, tropical, subtropical, temperate and polar. The mining sector directly contributes 8 per cent of Chilean national gross domestic product (GDP), of which copper mining represents the largest share (CEPAL 2009, pp 23, 36), and provides a much larger share of indirect economic benefits. Mining operations are primarily located in the north and central regions of Chile (CEPAL 2009, pp 15, 17).

The northern region is very dry, receiving runoff from snow melt in the Andes. Companies in this area have, over the last 10 years, operated under acute water scarcity, focusing on efficiency and a high level of reuse and recycling to meet water requirements [as outlined in Section 2.1]. It is estimated that 78 per cent of copper production is located in basins with a water deficit (ie where annual precipitation is below 100 mm) (CEPAL 2009, pp 15, 17). The availability of water for operations, however, is increasingly insufficient, and companies are developing desalination plants to meet freshwater requirements. For some processes, such as copper flotation or oxide leaching, companies are beginning to source raw seawater to meet water requirements, but certain processes require the use of desalinated water that is free of chlorine and sulphates, such as freshwater for drinking, sanitation, cooling, concentrate washing and electrowinning (Mining Magazine 2012, ICMM 2012a).

Further south, in the Atacama region and central Chile, mining and metals companies operate in areas with established agricultural sectors and larger urban populations. Water supply remains limited in these areas, and must be carefully managed. To meet their requirements, mining and metals companies purchase water rights from the agricultural sector, or use treated water from urban areas (Mining Magazine 2012). Operations maintain high rates of water reuse to maximize efficiency: mining accounts for 4 per cent of consumptive use in Chile, and in concentrating copper, freshwater consumption would be seven times higher per tonne without water reuse (DGA, 2008a).

“The availability of water for operations, however, is increasingly insufficient, and companies are developing desalination plants to meet freshwater requirements.”
Results are shown for the A2 climate change scenario (i.e. a carbon dioxide equivalent atmospheric concentration of 1,250 ppm by end of century).
At construction and operation stages, there are financial risks from increased capital and operating expenses to secure new sources of water for expansion of existing operations in water-stressed areas. The level of investment in desalination plants, pumping and transportation infrastructure can be substantial, ranging from several hundred million to billions of dollars. Sourcing water from longer distances also increases operating costs: in Chile and Peru, pumping seawater from sea level to elevation and hundreds of miles inland can account for 60 per cent of the total operating costs of a desalination project. Direct use of raw seawater requires additional investment in coatings and anti-corrosion materials (Mining Magazine 2012). There are also research and development costs associated with developing technologies for alternative water sourcing and treatment. To the extent that these investments enable profitable expansions of capacity, they become a share of the cost of doing business in water-stressed areas.

At construction and operation stages, there are also reputational risks arising from competition for scarce water resources and from conflict with other large users or local communities, which can affect a company’s social licence to operate. Companies operating in water-stressed areas must already carefully manage relationships with local stakeholders – particularly in areas where there is competition for water, such as for agricultural use or demand from urban centres. For example, water availability issues in Quillagua and Copiapó in northern Chile have caused tension between mining, agricultural and local community stakeholder groups (Barrionuevo 2009, Moskvitch 2012). Annual water rights in the Copiapó valley range from US$80,000 to US$120,000 for a litre per second of flow, high enough that many local fruit growers have sold their rights to mining operations (Bitrán et al 2011, Moskvitch 2012). Historical regulation of water resources in Copiapó, dating back to 1981, has led to over-exploitation of the basin, placing further strain on available resources (Bitrán et al 2011). Mining and metals companies have responded by engaging with government and local stakeholders in the region, but may face business risks from increased conflict with agricultural and urban stakeholders, regulatory changes in provisional water permits and requirements to source water from alternative supplies, such as desalinated seawater (Bitrán et al 2011, Moskvitch 2012).

There may also be opportunities to enhance reputation by engaging stakeholders in water resource management decisions at the construction and operation stages. Through investments in alternative water supplies, mining and metals companies have created partnerships with local water authorities and municipalities to supply potable water back to local communities. For example, in consultation with the city of eMalahleni in South Africa, Anglo American is supplying the city with treated water from its eMalahleni water reclamation plant, built to treat water from four coal mines in the area (ICMM 2012a).

There are secondary financial risks from the possibility of reduced reliability in electricity supplied by third parties. Mining and metals companies may face higher costs from having to rely on back-up generators or on-site facilities, or from production shortfalls. Both hydroelectric and thermal power production facilities are susceptible to water availability shortages. For example, in the United States, water shortages are likely to constrain electricity production from thermal power plants in Arizona, Utah, Texas, Louisiana, Georgia, Alabama, Florida, California, Oregon and Washington by 2025. Concerns over water supply have already affected permitting for new and existing power plants in the United States (CCSP 2007, USGCRP 2009). In 2011, high water temperatures on the Tennessee River shut down the Browns Ferry nuclear power plant in Alabama, and regulators in Texas warned that drought conditions in the state could contribute to power cutbacks or plant shutdowns (Fowler 2012, Koch 2012). A recent study found that lower summer river flows and higher river water temperatures could reduce power generation capacity by 4 to 16 per cent in the United States and 6 to 19 per cent in Europe, while tripling the likelihood of complete or almost total shutdowns in power generation (Vliet et al 2012).

At closure and post-closure stages, there are both financial and reputational risks from a changing climate in water-stressed areas. Companies face the potential for higher costs associated with long-term monitoring and management of closed mine sites – increased rates of evapotranspiration or reduced levels of precipitation may affect the water cover depth or the supply of water required to maintain a sufficient cover depth. Changes in climate may also affect vegetation used to stabilize covers to prevent erosion. In Canada, a recent report on the impacts of climate change on acid rock drainage found that risks of exposure could likely be managed through minor adjustments to water cover depth (MEND 2011); in water-stressed areas, companies may need to re-evaluate estimates of the water that will be required in order to ensure adequate long-term management under future climate change.
3.2 Focus area 2: Tropical climates

Description of climate risks and impact areas

Mining and metals companies operate throughout the tropics in Central America, northern South America, West and Central Africa, Southeast Asia and the Pacific. They have a significant presence in the national economies of tropical countries such as Brazil, Democratic Republic of the Congo, Indonesia, Mali and Mozambique, among others (CountryMine 2012). These countries tend to be low- to medium-income states and may face challenges related to human health, nutrition, population migration and delivery of social services. Human health risks are influenced by climate, and are particularly acute in areas that face other social development challenges.

As a result, a changing climate in these regions has the potential to impact the mining and metals sector in the following areas:

- **Human resources.** Increases in temperature, changes in precipitation and extreme weather events such as flooding can influence the spread of vector-borne diseases and health issues, leading to direct impacts on productivity, workforce availability, absenteeism and worker morale, and the ability to source materials and supplies from local vendors. In hot climates – including tropical areas – an increase in periods of extreme heat will directly affect worker productivity, ranging from needing more frequent rest periods to shifting working hours into the evening to avoid heat stress during extended periods of extreme heat (CSIRO 2010, BSR 2011).

- **Mining and metals operations** also face indirect impacts related to the lack of resilience or adaptive capacity in communities that are vulnerable to vector-borne disease impacts (IPCC 2012, p 10). For example, Table 3.1 shows that people in isolated and low-income areas are vulnerable to multiple health stressors related to vector-borne disease, nutritional deficiencies, HIV/AIDS and diarrhoeal disease. They may also live in areas likely to face other risks from extreme weather events, such as tropical cyclones and flooding.

Tropical areas of regions such as Brazil, Central Africa, Southeast Asia, and the Pacific are also characterized by rich biodiversity. Mining and metals companies operating in these environmentally sensitive areas can manage impacts on plant and animal species through good-practice land and water management and conservation strategies at various stages of the mining and metals cycle. Companies operating in sensitive, biodiversity-rich areas – including tropical regions – are also typically subject to stricter regulations or commitments with authorities, and to higher scrutiny from stakeholders such as civil society groups, local communities and conservation groups.

Although direct land use by mining operations is the most visible aspect of land management, it does not necessarily represent the largest portion of land owned and managed by mining and metals companies. For example, of the roughly 120,000km² of land held by Rio Tinto in 2010, two-thirds was made up of landholdings outside of operational activities, held by the company’s exploration branch. Compared to land disturbed for active operations, these landholdings are not in use, but are instead passively managed at lower levels of land-use change (Rio Tinto 2012a).

Impact evaluation

Human health is influenced by climate change primarily through changes in temperature and precipitation, prolonged periods of hot, dry weather (eg heatwaves and drought) and extreme weather events such as flooding (Confalonieri 2008, Confalonieri et al 2007, McMichael et al 2003). For a scenario consistent with a 5°C increase in global mean temperature at the end of the century, projections show a similar range of warming across tropical areas, including Brazil, Central Africa and Indonesia. Precipitation extremes are generally expected to increase in the tropics (Meehl et al 2007, pp 750, 784). Annual mean precipitation is projected to increase in some tropical areas, including the tropical Pacific and East Africa. Other areas may experience decreases in mean precipitation, such as Central America and regions of Brazil (see Figure 3.2), although there is a wide range of uncertainty associated with projected changes in precipitation.

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23 For more information, see ICMM (2006) Good practice guidance for mining and biodiversity.
24 Although this focus area highlights biodiversity issues in tropical areas, biodiversity considerations are not limited exclusively to these regions. Land and biodiversity management issues apply broadly across geographic regions in which mining and metals companies operate. Similar issues related to mitigating and compensating for impacts on land, sensitive ecosystems and biodiversity under a changing climate also apply to other areas. Increased public scrutiny and sensitivity to biodiversity impacts also apply to these other regions, particularly in areas where mining and metals companies operate in sensitive ecosystems that are threatened by long-term changes in climate.
25 See Appendix A for information on annual temperature and precipitation changes for Brazil, Central Africa and Indonesia.
An illustrative example of how a hotter, drier climate could influence health in northeastern Brazil is shown in Figure 3.4. Based on regional climate change modelling, temperature is expected to increase while precipitation decreases in this area (Confalonieri 2008, p 333). The diagram shows both direct, physical effects from higher temperatures and low humidity, as well as indirect effects. These effects start with water scarcity leading to poor hygiene and malnutrition, triggering migration to urban areas that consequently increases the transmission of infectious and chronic diseases.

Tropical areas in South America, West and Central Africa and Southeast Asia are some of the most vulnerable to human health impacts from a changing climate. These regions already face health risks that are influenced by weather, such as the influence of El Niño-Southern Oscillation on outbreaks of malaria, dengue, diarrhoea, cholera and other vector-borne diseases (Republic of Indonesia 2009). Low-income countries and communities face the highest risk since they may lack sufficient resources for sanitation, quality housing and early-warning systems (McMichael et al 2003). Within these areas, children, the elderly and outdoor workers are the most vulnerable to health impacts and outdoor workers are particularly susceptible to heat stress (Confalonieri et al 2007, p 406).

A summary of the human health effects that are related to climate factors can be seen in Table 3.1. Climate change has been linked to the transmission of several vector-borne diseases, such as malaria, dengue, hantavirus, bluetongue, Ross River virus and cholera. Changes in temperature and precipitation are expected to cause regional expansions and contractions in the extent of malaria in sub-Saharan Africa, but the impact of climate on malaria in the African highlands and South America is less clear (Confalonieri et al 2007, p 404; Ermert et al 2012). While climate is a factor, a number of other influences – including the establishment of disease control programs – affect the spread of these diseases and may counteract the effects of weather and future climate change. For example, malaria has receded globally since 1990 and is not always present in areas where the climate would allow it to be transmitted. (Gething et al 2010, Ermert et al 2012).

**Figure 3.4: Climate change stressors and effects on human health in northeastern Brazil**

Source: Adapted from Confalonieri 2008.

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26 Leishmaniasis is a disease spread by female sandfly bites.
Given this uncertainty and the fact that the effects of a changing climate on vector-borne diseases are likely to be gradual, mining and metals companies are focusing on current risks from diseases such as malaria and dengue on workers and local communities rather than impacts from future changes in climate. Disease control programs monitor infection rates in order to identify trends and develop appropriate responses. In Mozambique and the Democratic Republic of the Congo, for example, malaria control programs have been scaled up to respond to population growth in these areas, which is a near-term change in conditions that can increase transmission rates of malaria.

The loss of biodiversity and the extinction of species at risk are expected to be influenced by future climate change and land-use change, particularly in biologically diverse tropical areas. In tropical biodiversity hotspots, a changing climate will exacerbate existing stresses on species from deforestation, and will likely play an overall larger role in extinction rates than will land-use changes over this century (Fischlin et al 2007, citing Malcolm et al 2006). Depending on the increase in annual mean temperatures, there is a risk to biomes, which are large areas of land containing distinctive plant and animal groups that are adapted to that particular environment. In Brazil, a biome such as the Cerrado could face the extinction of between 38 to 57 per cent of plant species (Fischlin et al 2007). Temperature increases of 2.5°C above pre-industrial climate (ie mid-1800s) could cause major losses of biodiversity within the Amazon rainforest from drought and extreme dryness or desiccation (Fischlin et al 2007).

### Table 3.1: Summary of human health effects related to climate stressors

<table>
<thead>
<tr>
<th>Health effect</th>
<th>Vulnerable locations</th>
<th>Vulnerable populations</th>
<th>Climate-related interactions</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased incidence and geographic spread of infectious diseases (ie malaria, dengue, hantavirus, bluetongue, Ross River virus, and cholera)</td>
<td>Brazil (Northeast and Amazon) Central and South America Africa Southern Asia</td>
<td>Isolated communities, urban flood-prone areas with poor waste collection systems Peri-urban populations in low-income countries Populations living in large cities</td>
<td>Decreases in rainfall and increases in temperature may increase aridity Drought, water and food shortages may aggravate health issues, causing migration from rural to urban centres, increasing incidence Flooding of open sewers and streets during the rainy season Increase in mosquito populations by the occurrence of above-normal rainfall Evidence from control programs, other site-specific factors have larger effects on limiting malaria</td>
<td>Brazil 2010, p 426 Confalonieri et al 2007, p 404 IPCC 2012, p 316 Gething et al 2010</td>
</tr>
<tr>
<td>Increase in acute or chronic nutritional deficiencies</td>
<td>Developing countries in southern Africa, Amazon</td>
<td>Children HIV/AIDS populations Riverine traditional subsistence farmers</td>
<td>Drought diminishing dietary diversity and reducing overall food consumption, Rivers drying up, isolating communities</td>
<td>Confalonieri et al pp 399–400</td>
</tr>
<tr>
<td>Increased risk of diarrhoeal disease</td>
<td>Southern Asia, Latin America</td>
<td>Children Lower-income communities, populations in coastal or flood-prone areas</td>
<td>Water contamination following flood events and water deficits</td>
<td>Confalonieri et al 2007, pp 398–399, 407 Brazil 2010, p 413</td>
</tr>
<tr>
<td>Increased risk of cardio-respiratory diseases</td>
<td>Tropical regions</td>
<td>Children</td>
<td>Air pollution following forest and bush fires events Increases in the concentration of air pollutants, such as ozone, in the troposphere, influenced by higher temperatures</td>
<td>Confalonieri et al 2007, pp 402, 407</td>
</tr>
<tr>
<td>Increased risk of heat stress</td>
<td>Urban areas</td>
<td>Children and the elderly Outdoor workers</td>
<td>Increased average seasonal temperatures More frequent and prolonged heatwaves</td>
<td>Brazil 2010, p 421</td>
</tr>
</tbody>
</table>
**Business implications**

In addition to the direct financial risks of climate change stressors on human health, such as higher health costs and reduced productivity, mining and metals companies may face deeper challenges in mounting effective responses to manage and mitigate these risks.

At the operations stage, the lack of resources and multitude of stressors affecting the communities may impede efforts to improve worker and community health, maintain relationships with local community members, achieve other community-based objectives such as training and education, and develop effective disaster risk management responses. These indirect effects may lead to chronic workforce availability issues and increase tensions between communities and mining and metals operations, leading to reputational issues that may affect a company’s social licence to operate.

However, at the same time, there are also significant opportunities at the development, construction and operations stage. Climate change effects on human health and community well-being are only one potential factor in addition to a large number of other factors, such as population growth, economic development, sanitation, and health education and awareness. Mining and metals companies provide opportunities for economic development and, through engagement with communities, can work to enable social development. In addition to helping maintain a social licence to operate, these initiatives also enhance resilience to risks from future climate change. Meanwhile, increasing community awareness of climate change-related risks and the efforts being taken to adapt to them offers companies another opportunity to develop strong relationships with local communities.

For example, although the motivation for malaria control programs are driven primarily by current risks from transmission of the disease, these programs also increase community resilience to increased transmission of the disease from future changes in climate. In addition, the linkages between a changing climate and the spread of vector-borne diseases are highly uncertain; in fact, some areas may experience a contraction in vector-borne diseases from future changes in temperature and precipitation, reducing the stress on workers and their families.

The business implications discussed in this section deal directly with human health-related impacts. Business implications stemming from climate change risks to biodiversity management are more indirect and difficult to explicitly characterize. Assessing non-mining-related threats to biodiversity, however, is good practice in biodiversity management and can enhance the effectiveness of conservation initiatives (ICMM 2006, p 76). Incorporating climate change considerations into biodiversity management practices can help companies anticipate potential risks that may affect progress towards conservation objectives and the long-term sustainability of maintaining these objectives.

More broadly, addressing climate change impacts through biodiversity management provides significant reputational opportunities. The adjustments that companies need to make to respond to climate change impacts can provide them with a suite of options that can achieve complementary sustainable development goals related to local community engagement, social benefits and environmental stewardship.

“Increasing community awareness of climate change-related risks and the efforts being taken to adapt to them offers companies another opportunity to develop strong relationships with local communities.”
3.3 Focus area 3: Coastal regions and areas likely to become wetter in the future

Description of impact and impact areas

In contrast with the focus area of arid and water-stressed regions, mining and metals companies also operate in many regions that are prone to periods of too much water, such as high water flows from episodes of heavy rainfall, seasonal snowmelt or precipitation, inland flooding, coastal flooding and sea level rise. The areas and types of operations that may experience wetter conditions in the future are diverse, but are predominantly located at higher latitudes and in tropical areas that are already “wet” in terms of annual precipitation.

Water management is a key operational issue for mining and metals companies. In addition to water use for ore extraction, beneficiation and processing (see Section 3.1), mining and metals operations in wetter regions also involve non-consumptive management of water, such as diversions of rainwater and runoff away from mining operations, pumping accumulated water out of mining pits, or the diversion and storage of runoff that enters the mine site for treatment and discharge, if necessary (MCA 2012, p 11). Water can also have an important impact on transportation infrastructure, both for marine and land transport.

Consequently, changes in the amount and frequency of precipitation can have the following impacts on mining and metals company activities.

Operation

During the operation of a mine or metal processing facility, the impacts on water management include:

- Incremental increases in the absolute quantity of precipitation and runoff can affect the mine site’s water balance. Depending on the hydrological conditions for which the tailings, water and waste rock storage facilities were designed, a wetter climate may necessitate updates to water balances and changes in the capacity of water and tailings storage or water treatment facilities.

- Seasonal changes in either the timing or flow of water in discharge streams may affect operations. Earlier flows in the winter and spring, followed by lower flows in the summer, may limit the volumes of treated water that mine and metals facilities can discharge to receiving bodies of water. In response, companies may need to increase the capacity of water storage or divert runoff away from the site. Otherwise, they may risk exceeding discharge permits to receiving bodies of water.

- Companies may need to increase the capacity of pumping systems to move water out of mining pits or underground mines into storage areas during heavy rainfalls or flooding events.

- The stability of embankments, open pit highwalls, tailing storage ponds, water dams, leach pads and waste rock piles are dependent on factors such as slope geometry, strength of the foundation, material properties and the location of the “phreatic surface” or water table (Meintjes 2010, ASCE 2000). Wetter conditions may alter the phreatic surface, resulting in slope instability issues (CSIRO 2010, p 10).

- Saltwater intrusion from sea level rise can threaten freshwater supplies drawn from aquifers in coastal areas. This may affect freshwater inputs at mining operations or at other coastal operations, such as storage or port facilities.

Post-closure water management and water quality monitoring

Companies have long-term obligations to protect water quality and maintain tailings and waste storage structures. Requirements may range from a period of hundreds of years to perpetuity, meaning that structures must be designed to withstand events that are likely to occur only once every several thousand years. Structures designed to the current or historical climate may not perform as planned in a wetter future climate.

Transportation supply chains

Mining and metals companies also face indirect risks from transportation supply chain infrastructure that is located in coastal areas and regions susceptible to inland flooding. In coastal areas, the operation of port and storage facilities may be affected by gradual sea level rise, as well as higher storm surge during extreme weather events such as tropical cyclones and hurricanes. Roads and railways are also susceptible to impacts in these areas, as well as impacts from inland flooding from increased precipitation and runoff, where wash-outs can damage road and rail segments.

“Structures designed to the current or historical climate may not perform as planned in a wetter future climate.”
Impact evaluation

In general, northern regions of North America and Eurasia and the wet tropics are projected to become wetter in some seasons under a warmer future climate. The global change in annual runoff\(^27\) by mid-century relative to 1900–1970 is shown in Figure 3.5. Climate projections generally show that annual runoff will increase by 10 to 40 per cent in northern North America and Eurasia. Runoff is projected to increase in the wet tropics (ie the Amazon, East Africa, East and Southeast Asia) although with less certainty among different climate models.

In northern regions where winter precipitation falls as snow, higher temperatures will mean earlier and more rapid onset of snowmelt that will alter the seasonality of stream flows. Winter flows will increase and summer flows will decrease, with peak flows occurring at least a month earlier in regions including North America, Russia, Scandinavia and the Baltic. Regions without snowfall will generally experience increased runoff in wet seasons and lower flows or extended dry periods during low flow seasons, with little change in timing of peak and low flows (Kundzewicz et al 2007, p 184).

It is likely that a wetter climate in the high latitudes and tropics will increase the frequency of heavy rainfalls in these regions. A heavy rainfall event that occurs once every 20 years currently (ie a 1-in-20-year event) is likely to occur between once every fifteen to once every five years by mid- to end-of-century in many regions, including the higher latitudes of North America and Eurasia, North America, East Africa, and South and Southeast Asia (IPCC 2012, pp 13–14). It is difficult to project how these trends in precipitation will influence flooding in rivers and streams, particularly as many are highly managed, but increases in heavy rainfall suggest an increased likelihood for local flooding in some catchments (IPCC 2012, p 13).

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\(^{27}\) Runoff is the flow of excess water over land that takes place when the ground is saturated and can no longer absorb water from rain, meltwater or other sources.

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Figure 3.5: Change in annual runoff in 2041–2060 relative to 1900–1970 time period under an A1B emissions scenario\(^28\)

Source: Kundzewicz et al 2007, p 184.

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\(^{28}\) Note that, although the results are shown for an A1B emission scenario (ie consistent with carbon dioxide equivalent atmospheric concentration of 850 ppm by end of century), which results in a lower increase in global mean temperature by end of century than the A2 scenario (ie approximately 1,250 ppm by end of century), GHG emissions under the two scenarios are relatively similar until mid-century, which is the timeframe for the projection in Figure 3.5, so the results can be assumed to be similar to the A2 scenario.
Changes in precipitation, runoff and the timing of peak flows will affect local communities in addition to the impacts on mine site water balances, operations and transportation infrastructure, identified above. The effect that population growth between 1970 and 2030 will have on populations exposed to river flooding in different areas of the world is shown in Figure 3.6, assuming the flood hazard remains constant over this period (i.e., not accounting for changes in the frequency or intensity of flood events). Large populations are currently exposed to flood hazards, especially in Asia, and population growth in the future is projected to increase the level of exposure, particularly in Africa, Asia, Central and South America, and the Caribbean, where the estimated exposure more than doubles (IPCC 2012, p 241).

Coastal areas will also face impacts from a changing climate. Coastal erosion and flooding will very likely be affected by rising sea levels, changes in the intensity of extreme events and storm surge. Coastal impacts are influenced by mean sea level height, relative changes in shoreline elevation (i.e., from local heaving or subsidence of land), changes in the frequency or intensity of storms, changes in sedimentation along the coast, changes in wave speed and losses of natural protective barriers such as coastal reefs (IPCC 2012, pp 182–183). Apart from increases in mean sea level, observed climate changes have not been identified as a major cause of impacts in coastal areas. Low-lying areas that are already at risk from high rates of erosion, flooding and rising sea levels, however, will continue to face these impacts in the future (IPCC 2012, p 186). The IPCC projects that sea level rise will increase by 0.2 to 0.5 metres by 2100 (Meehl et al 2007, p 750)29 although more recent analyses indicate that a rise in global mean sea level rise of up to 1.2 metres by 2100 for high emissions futures (i.e., double the upper bound of IPCC projections) is more likely (Rahmstorf 2007).

Figure 3.6: Average exposure to river flooding in 1970 and 2030, assuming constant flood hazard, in thousands of people per year

Circles are proportional to the number of persons affected

*Only catchments bigger than 1,000 km² were included in this analysis. Therefore, only the largest islands in the Caribbean are covered.


29 Assuming an A2 climate change scenario (i.e., consistent with carbon dioxide equivalent atmospheric concentration of 1,250 ppm by end of century).
Globally, the frequency of tropical cyclones is likely to decrease or remain the same, but the average maximums for wind speed and heavy rainfall associated with tropical cyclones are likely to increase with higher temperatures. Increases in wind speed may not occur in all regions. There is some evidence that the occurrence of extratropical cyclones (i.e., cyclones occurring in mid-latitudes outside of the tropics) will decrease, potentially shifting further towards the poles (IPCC 2012, p 13).

Transportation assets in coastal areas – predominantly ports and associated storage facilities, but also roads and railways – are vulnerable to impacts from a changing climate. Increases in sea level will very likely contribute to adverse impacts from erosion and flooding that can affect the operation of port facilities and coastal infrastructure, such as storage facilities. For example, erosion along a 60-kilometre portion of the Beaufort Sea coastline in Alaska doubled between 2002 and 2007, with melting sea ice, increasing summer sea temperature, sea level rise and increases in storm intensity believed to be contributing factors (IPCC 2012, p 263). Saltwater intrusion from sea level rise may jeopardize the availability of freshwater for storage and port facilities.

The largest risks to coastal areas less than 10 metres above sea level (i.e., low-lying or low-elevation areas), however, are anticipated to result from the combined effect of increases in sea level rise and storm surge from tropical and extratropical cyclones (IPCC 2012, p 248). These events can lead to damage, and delays from damage, to roads and railway lines when waves rise above embankments. High winds and increased storm surge levels can also cause damage and disruption to the operation of port facilities, while increased rainfall and runoff can increase the need for dredging at port facilities and shipping channels (IPCC 2012, p 249, TRB 2008).

Figure 3.7: Population in low-lying coastal areas exposed to flooding from a storm projected to occur once every 100 years currently, and in 2050 assuming 0.15 and 0.5 metres of sea level rise

Height of columns represents the number of exposed persons

Population exposed in 2050 in millions

<table>
<thead>
<tr>
<th>Region</th>
<th>Current population exposed</th>
<th>0.15m sea level rise</th>
<th>0.50m sea level rise</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td>4.8</td>
<td>4.2</td>
<td>8.9</td>
</tr>
<tr>
<td>South America</td>
<td>4.6</td>
<td>5.6</td>
<td>7.4</td>
</tr>
<tr>
<td>Europe</td>
<td>9.6</td>
<td>16.4</td>
<td>21.1</td>
</tr>
<tr>
<td>Asia</td>
<td>47.8</td>
<td>60.2</td>
<td>82.7</td>
</tr>
<tr>
<td>Africa</td>
<td>2.8</td>
<td>5.8</td>
<td>7.4</td>
</tr>
<tr>
<td>Oceania</td>
<td>1.8</td>
<td>2.3</td>
<td>2.7</td>
</tr>
</tbody>
</table>

Source: IPCC 2012, p 249.
The impacts on coastal areas from sea level rise and storm surge will affect local communities as well as mining and metals operations. The number of people in low-lying coastal areas who are exposed to flooding from a 1-in-100-year storm (i.e. a storm of such size and strength that it is expected to only occur on average once every 100 years) is shown in Figure 3.7. The figure shows both the number of people exposed under current conditions, and the number of people who would be exposed under 0.15 and 0.5 metres of sea level rise by 2050. Large populations are already vulnerable to coastal flooding – particularly in Asia – but the combined effect of 0.5 metres of sea level rise with an extreme storm event in 2050 could double the population exposed in Africa, nearly double exposure in North American and Asia, and increase exposure by over 50 per cent in South America, Europe and Oceania. By 2070, recent studies have estimated that population exposure to flooding could triple in major coastal cities (i.e. cities with over 1 million inhabitants) (IPCC 2012, p 248, citing Nicholls et al 2008, Hanson et al 2011).

Increased exposure to flooding in local coastal communities could affect mining and metals operations through workforce availability, human health and safety issues. The relationship between a changing climate and its effects on migration and displacement is contested, and it is hard to link the movement of stressed populations to specific future climate changes (IPCC 2012, p 81). Although there is no consistent trend, there is some evidence that disasters associated with climate extremes do influence population movements. To the extent that a changing climate influences climate extremes in areas where mining and metals companies operate, this variability will result in some movement of stressed populations and could create or further stress social tensions or conflicts in host communities (BSR 2011, p 4; IPCC 2012, pp 16, 80–81).

Business implications

Climate change risks in coastal areas or regions likely to become wetter involve financial and reputation risks to mining and metals companies’ operations, post-closure water management activities and transportation supply chains.

- Companies may face increased financial risks at the operation and post-closure stages from increased capital or operating costs related to addressing hydrological changes. The uncertainty associated with longer-term changes in climate – particularly changes in precipitation, runoff and the likelihood of extreme events – and the obligation for mining and metals companies to maintain tailings and waste storage facilities over long timescales may increase post-closure costs and the financial guarantees that companies must post to ensure that mine decommissioning and long-term environmental costs are covered.

- Although it is more difficult to link the occurrence of specific weather events to changes in climate, mining and metals operations will likely continue to face both financial and reputational risks from extreme events such as flooding, storms and rising sea levels.

For example, in 2008 and 2009, the Minto mine in central Yukon experienced back-to-back deluges of spring runoff that were considered “two 100-year water events in a row” (Thompson 2011). The deluges temporarily shut down ore extraction and forced the mine to flood its extraction pit, preventing access to high-grade ore at the bottom of the pit. This led the mine to make several emergency releases of water into the Yukon River. Hydrology tests in the 1990s had raised concerns that the mine would not have access to enough water, but when the mine began operation in 2006, operators realized that the climate had become much wetter (Munson 2009, Thompson 2010a, Tobin 2011). In response, the mine installed a US$2.5 million water treatment plant capable of processing four times the original volume of water, dug new ditches to divert runoff away from the mine site and updated its water balance based on recent climate data and hydrology (Thompson 2010a, 2010b). The emergency water releases authorized by the Yukon Water Board were criticized by conservation and First Nations groups (Thompson 2010b).

- Companies may face financial risks from delays or damage to transportation supply chains. To the extent that transportation services are owned by the company, efforts can be taken to prevent or mitigate potential risks. Where companies are reliant on other transportation providers, however, they may not be able to exert the same level of control, or even fully identify potential risks. For example, during heavy flooding in Queensland, Australia in late 2010 and 2011, segments of the Central Queensland Coal Network were damaged and closed for
repairs for three to six weeks before operations resumed; a longer 12-week disruption occurred on the West Moreton Line, which services coal mines southwest of Brisbane (Queensland Floods Commission of Inquiry 2012, p 256).

- Finally, companies may face financial and reputational risks from the heightened vulnerability of local communities in flood-prone and low-lying areas to increased flooding as a result of changes in precipitation patterns, sea level rise and extreme storm events. Impacts associated with individual extreme events may be temporary, but could result in long-term damage if extreme climate events occur with greater frequency and intensity such that they have an adverse impact on local communities’ ability to maintain a livelihood (IPCC 2012, pp 16, 300–301).

“Companies may face financial and reputational risks from the heightened vulnerability of local communities in flood-prone and low-lying areas to increased flooding as a result of changes in precipitation patterns, sea level rise and extreme storm events.”

Empowered community members that have been taught to generate sustainable fresh produce projects by the Rossing Foundation. They run a hydroponic vegetable operation and an indoor mushroom farm, both of which are flourishing and provide them with an income. Courtesy of Rio Tinto
Framework for adapting to a changing climate
The nature of the mining and metals business already requires companies to address risks from variable weather, changing environments and challenging geographies. Many of the approaches, tools, information, resources and people necessary for identifying and adapting to climate risks and opportunities are likely to already exist within companies, even if these activities or resources do not currently incorporate climate change considerations. Examples of existing functions in mining and metals companies that are relevant to adapting to climate change impacts include:

- internal risk management policies, procedures and assessment
- emergency response planning
- asset management
- capital and long-term planning
- environmental health and safety programs
- biodiversity management
- community engagement
- financial and sustainability measurement and reporting
- dealing with uncertainty in business and operational decision making.

This section develops a framework of the options available to the mining and metals industry for adapting to a changing climate. Figure 4.1 identifies six categories of options. Several existing processes for framing responses to climate change informed this framework, including the Canadian National Roundtable on the Environment and the Economy’s dashboard for business success in a changing climate (NRT 2012), the UK Climate Impacts Programme’s “Identifying adaptation options” guidance (UKCIP 2008), Tiempo (2012), the Asian Development Bank (ADB 2005), Freed and Sussman’s (2008) business approach for adapting to climate change, and a review of recent mining and metals company responses to the Carbon Disclosure Project.

The framework begins with awareness, engagement and objective-setting activities that increase companies’ internal capacities to identify climate change risks and opportunities. Once companies have developed an initial understanding of the potential impacts on their business, set objectives and engaged key stakeholders, the next step typically involves conducting risk and opportunity assessments to identify, evaluate and prioritize the likelihood and consequences of climate change impacts. These assessments inform planning efforts and the implementation of actions to adapt to climate change risks or exploit opportunities. Monitoring, evaluation and reporting are necessary to assess progress towards objectives for adapting to climate change, to evaluate the benefits of measures taken to tackle climate change impacts, to ensure resources are utilized effectively and to identify opportunities for continuous improvement and learning. Finally, all of these activities are supported by partnership and collaboration with key stakeholders, including local communities, governments, civil society and academic groups.

Figure 4.1: Adaptation framework categories
Since mining and metals companies are very experienced at managing operational risks – including those related to extreme weather events, and challenging operating environments and geographies – it is highly likely that existing initiatives can be tailored to support implementation of the adaptation framework in Figure 4.1. The process is also likely to be highly iterative. This framework provides a general structure for framing adaptation responses, and for co-ordinating activities at both strategic decision-making levels and within the operational management of specific processes and assets.

Each of the six categories in the framework is defined in the following pages by a list of options that companies can undertake to help them to respond to a changing climate. Each category also provides examples of existing initiatives undertaken within the mining and metals sector. These activities are often motivated by current risks, such as extreme weather impacts, the presence of vector-borne diseases or limited water availability, but they also provide co-benefits from increased resilience to future climate change risks, or by enabling companies to harness opportunities. This emphasizes that mining and metals companies are already familiar with strategies to identify, prioritize and manage current risks and opportunities. Consequently, companies can use these existing resources and expertise to incorporate climate change considerations and adaptation strategies into business and operational activities.

**Awareness, engagement and objective setting**

Through these activities, companies can increase their internal capacity to identify climate change-related risks and exploit opportunities. Internally, companies can educate staff and disseminate information on how a changing climate affects their business and operations. In particular, high-level objective setting and awareness building can help bridge gaps between corporate and operational groups, or across different business units and geographic locations. Externally, these activities enable companies to communicate their efforts to regulators and investors, and identify resources available from multilateral organizations, trade groups, academia and civil society. Options include the following:

- **Explore how broad sustainability objectives at the corporate level relate to climate change impacts and adaptation activities and use these to inform high-level adaptation goals and objectives.**
- **Encourage senior management buy-in, and identify champions in key business units to support activities to respond to climate change impacts.**
- **Provide formal training and informal education opportunities on climate change impacts, adaptation approaches and relationship with business operations.**

- **Identify and share** internal tools, operational models, best practices and lessons learned across business groups and geographic areas.

- **Develop awareness in local communities** on climate change impacts that affect those beyond mine and metals operations, such as water availability, human health and extreme events; link outreach to existing engagement programs.

- **Externally communicate existing activities** relevant to potential future climate change impacts, even if these activities are motivated by non-climate change-related risks or opportunities.

- **Participate in workshops and conferences** to better understand climate change impacts, adaptation options and state-of-the-art tools and resources.

- **Share knowledge externally** through trade associations and industry groups.

**Investigating mining sector adaptation to climate change in the Goldfields region**

Australia’s national science agency, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), has conducted a workshop to understand the potential impacts of future climate variability on the mining and metals industry and communities. The workshop was supported by the Goldfields-Esperance Development Commission. Participating organizations included mining companies, such as AngloGold Ashanti and Gold Fields Australia, local and state government, infrastructure and utility providers, environmental groups and community representatives. The initiative is part of a broad survey of mining industry adaptation.

**Engagement in international and national climate change adaptation activities**

Mining and metals companies are represented in activities that are advancing awareness of adaptation in the sector. Relevant organisations include the Private Sector Initiative under the Nairobi Work Programme of the United Nations Framework Convention on Climate Change (UNFCCC), the Intergovernmental Panel on Climate Change (IPCC) and at the Organisation for Economic Co-operation and Development (OECD) through the Business and Industry Advisory Committee (BIAC).

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30 For more information, see the "Climate adaptation flagship" project under Partnership and collaboration.
**SECTION 4**

Framework for adapting to a changing climate

**Risk and opportunity assessment**

These activities integrate climate change considerations into existing risk management practices to identify, evaluate and prioritize the likelihood and consequences of climate change risks and opportunities (see Section 2.2). They can be used to evaluate the costs and benefits of different response options, and the timeframe over which responses should occur to inform adaptation planning and actions. Typically, these activities will involve internal stakeholders from across the business, including planners, project managers, engineers, corporate risk managers, operations and maintenance officers, and health, safety and environment personnel. External trade and industry associations can play a role in examining risks and opportunities across the mining and metals sector.

- Conduct internal workshops or tabletop exercises\(^{31}\) to scope and prioritize relevant climate change stressors, identify vulnerabilities and opportunities, and determine how these relate to existing business risks and opportunities.

- Develop an inventory of existing tools, data and resources to inform risk assessments, including existing risk management or emergency preparedness procedures; lists of assets, their operational characteristics and performance; maintenance and health and safety records; and assessments of previous extreme weather events.

- Evaluate the need for and availability of climate projections; consider the level of detail and uncertainty associated with climate data.

- Consider the timeframes over which impacts are likely to emerge; this can identify short-term priorities, help integrate adaptation planning and design into capital turnover cycles, and identify longer-term considerations where more information is needed to inform decisions.

- Conduct risk assessments of current and future climate change vulnerabilities, their likelihood and consequences; prioritize risks and consider their relevance to other non-climate risks and opportunities.

- Assess the adequacy of existing facility, site and operational design criteria, the magnitude of risk and cost of implementing changes. Prioritize areas where the cost of modifying existing design criteria is justified by prevention or mitigation of high-magnitude risks.

- Incorporate climate change considerations into existing risk management and emergency preparedness procedures; integrate climate risk and opportunities into business planning.

**A framework for assessing sensitivity to climate change risks**

Rio Tinto Alcan has developed a climate change sensitivity framework to assess the exposure of operations and infrastructure to climate change risks. This framework provides a strategic perspective on the exposure to climate change risks in any geography by illustrating the exposure of potential sites to current and future climate change impacts. It presents potential climate changes and draws on the expert knowledge of company staff in a wide range of job functions.

**Integrating climate change into existing risk assessment practices**

Risk assessment is one area where companies are beginning to integrate climate change considerations into existing management frameworks. For example, Gold Fields’ climate strategy requires that each site identify climate-related risks and opportunities, develop and implement responses, and monitor these actions using existing management systems. Hydro has incorporated climate change considerations into existing risk assessment processes within the company. Hudbay Minerals uses environmental management systems at its operating subsidiaries to identify climate change risks (BSR 2011).

“Gold Fields’ climate strategy requires that each site identify climate-related risks and opportunities, develop and implement responses, and monitor these actions using existing management systems.”

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\(^{31}\) Tabletop exercises are team problem-solving workshops that assemble relevant individuals from different business groups to brainstorm solutions to a theoretical problem.
Adaptation planning

The objective of these activities is to develop an integrated approach to adaptation planning alongside business and sustainable development considerations. Mining and metals companies are already undertaking many of the activities necessary to adapt to future climate changes, but relevant stakeholders, tools and data, and responsibilities are often spread across different business and operational units and geographic locations. Planning provides a structure for implementing adaptation activities, prioritizing focus areas, setting near- and long-term targets and developing metrics for evaluating performance and continuous improvement. Options include:

- **Establish principles and guidance on adaptation** at the corporate level that enable business or operational units to internalize climate change adaptation considerations in their own day-to-day activities. Ensure these are consistent with adaptation goals and objectives.

- **Develop qualitative and/or quantitative targets** to promote the integration of adaptation planning into corporate and operational policies, and to track performance towards targets and objectives.

- **Integrate adaptation principles and considerations into existing corporate policies, management, and engineering and design systems.** For example, including climate change considerations in environmental, health and safety policies or corporate social responsibility goals and reporting, or within environmental management systems. Must also work to integrate climate risk scenarios at the outset of any installation development or engineering activities.

- **Incorporate climate change considerations and adaptation planning in existing land and water use and management planning.**

- **Invest planning resources in areas that promote understanding of climate risks and opportunities,** and the development of adaptation approaches that are consistent with the company’s operational and corporate culture.

Setting targets: reducing water usage

In 2011, Anglo American approved a technical standard that sets detailed requirements for water targets and monitoring, site management and water action plans (WAPs). To set water use targets, Anglo American developed a water balance tool, called the “Water Efficiency Target Tool” (WETT), which measures the company’s current water consumption against its future business production plan. The tool was first implemented in seven sites before being introduced across the group, and has achieved a 21 per cent improvement in water efficiency during the first year. Although climate change was not the main driver in the development of this tool, its emphasis on objectives and future planning offers a practical way to integrate climate risk management within water planning.

Adaptation planning in corporate guidelines

Vale has incorporated climate change and adaptation considerations in its corporate guidelines and strategic business plan. A cross-functional group from climate change, energy, operations, risk management and planning departments is working to address climate change risks and opportunities throughout the company. The company is also identifying changes in facilities management, and working with legislations on policies that support adaptation efforts (BSR 2011).

“To set water use targets, Anglo American developed a water balance tool, called the “Water Efficiency Target Tool” (WETT), which measures the company’s current water consumption against its future business production plan.”
Adaptation actions

This element involves concrete actions taken to prevent and mitigate climate risks, and to protect people, operations, the environment and the mining and metals business from those risks. Adaptation actions may also be taken to harness opportunities associated with future changes in climate. Actions will be specific to a company’s operations and the risk or opportunity being addressed. They may involve higher-level, “strategic” activities, such as changes to business practices or investment and planning decisions, or more “engineering” or operational considerations such as the design, location or operation of specific assets.

Eliminate or avoid risks:

- **Reinforce assets** to withstand future climate conditions (e.g., storm surge, sea level rise, higher temperatures, heavy rainfall episodes).
- **Amend engineering design standards, design criteria and contract specifications** to account for a changing climate (e.g., increased capacity in water and waste storage ponds).
- **Relocate or raise assets** and operations outside of high-risk areas (e.g., flood plains, coastal areas).
- **Increase the frequency of maintenance and monitoring** of assets sensitive to weather effects.

Mitigate or protect against risks:

- **Build in flexibility** to reinforce, increase the capacity or improve the redundancy in assets and operations in the future; develop land-use management and mine and metals site expansion plans.
- **Increase the redundancy** of critical operations and systems (e.g., alternate supply chains, back-up sources for water and energy inputs).
- **Diversify business operations** and investments across geographic regions, commodities and markets.
- **Insure** against unavoidable risks.
- **Build relationships with local communities** to communicate adaptation actions, potential risks and early-warning systems.
- **Retain or restore natural buffers** in coastal and river environments to increase resilience against flooding, erosion, storm surge and other extreme weather events.
- **Remove or reduce non-climate pressures on natural ecosystems** and species at risk through conservation and land management planning.

Remedy impacts:

- **Incorporate climate change considerations into existing contingency and emergency management planning** (e.g., planning for drought, extreme precipitation events, tropical storms, heat stress, community health).
- **Evaluate whether retreat is necessary over the longer term** in certain areas or investments, based on expected changes in climate and other stressors.

Increasing resilience to water scarcity through efficiency

In arid or water-stressed regions, companies are taking action to improve water efficiency, do more with lower-quality water inputs and develop new water sources:

- **Between mid-2004 and mid-2009, BHP Billiton achieved a 15 per cent improvement in water efficiency at Olympic Dam in South Australia. Improvements have included use of hypersaline (i.e., having a higher salinity than ocean water) groundwater for dust suppression and vehicle wash, covering water storage to limit evaporation, and increased water reuse and recycling at storage ponds, tailing dams and in metallurgical processing.**
- **Barrick obtained 31 per cent of its externally sourced water inputs from brackish, saline or hypersaline sources in 2010. Sourcing saline groundwater helped the company’s Cowal mine in Australia reduce its freshwater intake by 26 per cent between mid-2008 and 2010, with an additional 10 per cent reduction targeted in 2011.**

Malaria control programs

Since the early 2000s, BHP Billiton has participated in the Lubombo Spatial Development Initiative, in partnership with the governments of Mozambique, Swaziland and South Africa. The initiative includes a malaria control program that, in 2005, lowered the infection rate to below 20 per cent, down from 85 per cent, in the Beluluane region of southern Mozambique [BHP Billiton 2005, pp 364–365]. The program has enabled BHP Billiton to mitigate risks to workforce availability due to absenteeism and low morale at its Mozal aluminium smelter [UNFCCC 2009]. Although the company’s involvement was not motivated by climate change adaptation considerations, these ongoing efforts to control mosquito populations and raise malaria awareness contribute to a higher level of resilience against malaria in the region.

Freeport-McMoRan Copper & Gold operates malaria control programs in Papua New Guinea, Indonesia and the Democratic Republic of the Congo (DRC). The programs involve management of disease carriers through spraying and larvae control, diagnosis and treatment of malaria. Freeport McMoRan closely monitors disease trends in both areas and modifies its programs to respond accordingly. In the DRC, employee infection rates have dropped by 66 per cent and cases in children in the local community have decreased by 47 per cent since 2007 [ICMM 2012b].

Climate Change
Adaptation to current and future climate-related risks
Many companies are taking actions to increase the resilience of their operations and facilities to current weather- and climate-related impacts (BSR 2011):

- Kumba Iron Ore has incorporated climate change risks into its risk management program. Through this framework, the company is collecting information on the likelihood and consequence of extreme weather impacts to determine their impacts on structures at mine sites.
- Capstone installed a new water treatment plant, dug ditches to divert runoff from the mine site and updated its water balance to respond to increased runoff and extreme seasonal water flows at its Minto mine in the Yukon (Thompson 2010a, 2010b).

Biodiversity conservation
The Vale Nature Reserve is a 43,000-hectare biodiversity conservation area. It forms the largest protected area of the Espírito Santo Atlantic Forest, accounting for roughly 10 per cent of the remaining original forest cover in the Brazilian state of Espírito Santo. Vale voluntarily decided to preserve the area after deeming that production of railroad ties from wood stock on the land would be uneconomical.

The Reserve has enabled Vale to demonstrate its commitment to environmental stewardship in Brazil, where all of the company’s mining operations in the northern state of Pará are located within the Carajás Conservation Unit Mosaic, a collection of protected national forests and biological reserves. Through research undertaken over the past 30 years, the Reserve has also increased Vale’s understanding of ecological restoration and the performance of species under different environmental conditions. The Reserve is recognized as a significant preservation of biological richness and evolutionary history and has attracted high-level recognition from external stakeholders, having been identified by UNESCO as an advanced area of the Atlantic Forest Biosphere.

“Vale and the Espírito Santo State Government are developing a state-of-the-art environmental monitoring and forecasting system for the benefit and well-being of the people of the state.”

Monitoring, evaluation and reporting
These tools enable companies to perform a number of due-diligence functions, including validating the results of risk and opportunity assessments, ensuring that resources are being utilized effectively on high-priority issues, identifying emerging trends that could have implications for their business, and transparently disclosing information on risk, opportunities and actions to key stakeholders, including regulators, investors and the public. Options include:

- long-term environmental and climate monitoring, and monitoring effects on regional stressors, such as water availability, ecosystem integrity, changes in flora and fauna varieties, and frequency and magnitude of extreme events
- periodic review of the design basis for equipment and infrastructure to determine whether the original climatic assumptions are still valid
- tracking implementation and effectiveness of adaptation actions and measuring performance against planning targets or goals
- incorporating climate change-related considerations into existing monitoring of system components; for example, tracking maintenance and repair records to assess the impacts from historical extreme events or more gradual effects from incremental changes in historical temperature or precipitation
- public reporting on climate change impacts, adaptation activities, and progress towards performance goals or planned targets.

Early warning of extreme events and understanding climate change effects on ecosystems
Vale and the Espírito Santo State Government are developing a state-of-the-art environmental monitoring and forecasting system for the benefit and well-being of the people of the state, and to improve economic activities in the area – including Vale’s needs for accurate weather and climate information. The system is composed of a weather radar, a mesonet network of surface stations, a satellite reception system and a supercomputing facility. These systems are integrated and operated by a team of professionals that work around the clock, seven days a week. The objective of the monitoring system is to mitigate the effects of severe weather events in the state of Espírito Santo in the context of climate change and variability.
SECTION 4
Framework for adapting to a changing climate

Partnership and collaboration

These activities forge relationships with important external actors to advance the availability of tools, resources and the latest techniques for adapting to a changing climate. Companies already proactively engage with many of these stakeholders, and can develop existing relationships to begin to adapt to climate change. Key partners include trade and industry groups, standards developers, regulators, vendors and consultants, state and municipal governments, local communities, civil society groups and academics. Options include:

- Develop and test improved decision-support tools through trade and industry associations, civil society groups, academia or mining and metals sector consultants and equipment vendors.
- Engage with industry or international standards-development organizations to assess the need for updates or guidance on integrating climate change considerations into codes, standards and technical guidance.
- Consult on international, national, state/provincial and municipal regulations or policies that recognize climate risks and adaptation; support the development of adaptation programs and resources within the public sector.
- Work with local communities to develop and implement community-based risk and opportunity assessments, adaptation actions, and monitoring and evaluation programs.
- Engage with investors to develop robust and transparent reporting on climate change risks and opportunities within the mining and metals business.

Climate adaptation flagship

In Australia, the mining sector is working with CSIRO to identify regional risks and opportunities of climate change and explore adaptation strategies. Through workshops and a survey of the industry and local government stakeholders, the initiative is developing a better understanding of climate change impacts in Australia, the role of climate variability, and priority areas and case studies for detailed analysis (CSIRO 2011).

Community-level water management in Peru

Cerro Verde, a copper and molybdenum mining complex near Arequipa, Peru, is currently a zero-discharge facility that recycles 85 to 90 per cent of its process water. To meet the additional water requirements of a planned expansion, Freeport-McMoRan Copper and Gold’s majority-owned company, Sociedad Minera Cerro Verde (SMCV), is working with the regional water utility, Sedapar, and local, regional and national governments. SMCV plans to build a waste-water treatment plant for Arequipa. In addition, SMCV has invested directly in the construction of a water treatment plant that will provide potable water to the residents of Arequipa [Freeport-McMoRan 2011, SMCV 2012, ICMM 2012a].

Assessing climate change implications to develop business and climate risk models

Anglo American is working with Imperial College, London, and the UK Met Office to develop a detailed climate change impact assessment of its Minas-Rio project. Anglo American will use regional climate change modelling to develop business risk templates to incorporate adaptation actions into new and current operations. The results of this work will also feed into the company’s internal climate risk model.

“In Australia, the mining sector is working with CSIRO to identify regional risks and opportunities of climate change and explore adaptation strategies.”

The regreening initiative at the Thabazimbi Mine, South Africa. Courtesy of Anglo American
Conclusions
This work seeks to advance the understanding of climate change impacts on the mining and metals sector by focusing on impacts to the sector and its operations. The report provides frameworks for evaluating climate change risks and adaptation activities, which are shown in Figure 5.1 and Figure 5.2.

**Figure 5.1: Frameworks for evaluating climate change risks and categorizing adaptation actions**

<table>
<thead>
<tr>
<th>Impact areas</th>
<th>Impact evaluation</th>
<th>Business implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inputs</td>
<td>Description</td>
<td>Financial</td>
</tr>
<tr>
<td>Supply chains</td>
<td>Timeframe</td>
<td>Higher operating expenditure or unplanned capital expenditure</td>
</tr>
<tr>
<td>Markets</td>
<td>Stakeholders</td>
<td>Reputational</td>
</tr>
<tr>
<td>Exploration</td>
<td>Primary/secondary</td>
<td>Increased risk of litigation, regulatory non-compliance, inability to operate</td>
</tr>
<tr>
<td>Construction</td>
<td>Likelihood</td>
<td></td>
</tr>
<tr>
<td>Operation</td>
<td></td>
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<tr>
<td>Closure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-closure</td>
<td></td>
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</tr>
</tbody>
</table>

**Figure 5.2: Adaptation framework categories**

- Awareness, engagement and objective setting
- Risk and opportunity assessment
- Adaptation planning
- Monitoring, evaluation and reporting
- Adaptation actions
- Partnership and collaboration
There are several important messages from this work that are relevant to stakeholders both within and outside the industry. These messages encompass the nature of the mining and metals business, emerging external drivers around climate change impacts and adaptation, the risks and opportunities presented by a changing climate, and the actions that companies are taking in this area.

A changing climate presents a range of physical risks for the mining and metals sector
Higher temperatures, rising sea levels, shifting patterns of precipitation and increases in the frequency and intensity of weather events will have impacts across the mining and metals cycle globally. Several particularly vulnerable aspects of mining and metals companies’ operations include:

- access to critical climate-sensitive inputs, such as energy and water
- supply chain reliability, including the delivery of inputs such as fuels, electricity and materials to the facility or site, and the delivery of ore or processed metals to market – risks at these stages may be particularly acute when owned and operated by an external party over which a mining or metals company does not have direct control
- operational exposure to extreme weather events, such as heavy rainfall, flooding, storm surge, tropical cyclones and storms, and heatwaves
- operational resilience to changes in the water balance over the operating life of mines or facilities
- long-term management of mine sites and wastes post-closure
- cost implications that affect the return on investment and the profitable operating life of mines or facilities
- company reputation and relationships with local communities, civil society groups and governments in the areas where companies operate.

The mining and metals industry exhibits particular characteristics that increase the industry’s exposure to physical climate risks
The sector operates in extremely challenging geographies and climates – often in isolated “frontier” locations or unique and fragile environments with ecosystems that are highly sensitive to a changing climate. Company operations rely on large fixed assets with long design lifetimes, and on global supply chains that are sensitive to changes in climate. Mines and metals processing require climate-sensitive inputs, such as water and energy, and may compete with other large users for these resources in certain areas. Finally, mining and metals companies balance the interests, well-being and requirements of a number of important stakeholders such as employees, governments, local communities outside the mine or facility site, civil society groups and shareholders.

The mining and metals sector is very experienced at identifying and managing risks
Companies already face geopolitical risks, unpredictable price environments, tough regulatory requirements, impacts from extreme weather events, water scarcity and a need to maintain the highest health and safety standards. In this environment, effective risk management processes at both operational and corporate levels have simply become part of the culture. A changing climate is one additional stressor that may exacerbate current risks being managed by the mining and metals sector, or create new opportunities.

The expectations of external stakeholders are changing in relation to climate risks
Shareholders and investors are beginning to consider the implications of climate risk to long-term financial performance of investee companies. Investors are coming together to exert collective influence on policymakers, companies and other investors to accelerate management of risks associated with a changing climate. There are indications that project financiers are beginning to alter lending criteria to take account of climate risks. These emerging drivers are increasing the importance of actions being taken by mining and metals companies to identify, disclose and adapt to the risks and opportunities of a changing climate.

Adaptation activities provide a suite of opportunities to strengthen reputations with key external stakeholders in local communities, state/provincial and national governments, and the investment community; they are also a way to achieve sustainable development objectives
Taking steps to adapt to climate change can help to achieve complementary sustainable development goals related to local community engagement and social development, biodiversity enhancement and protection of sensitive ecosystems, and natural resource stewardship. Adaptation actions can also strengthen a company’s bottom line by helping to anticipate risks to climate-sensitive operations and inputs, such as water and energy, and responding to investor concerns about more disclosure and transparency regarding climate change risks to the mining and metals business.
A changing climate also holds financial and business opportunities for the mining and metals sector

In contrast with the potential risks, changes in future climate may also present unique opportunities to companies within the mining and metals sector, such as the following:

- Climate changes may reduce current weather-related risks, such as the contraction of vector-borne diseases in some areas.
- Higher temperatures and a longer ice-free season may increase access to new reserves, and enable a longer operating season in northern areas.
- Geographically diversified companies and those prepared for potential climate change impacts in the future may have the ability to leverage changes or impacts on competitors to increase market share.

Mining and metals companies are already taking action to adapt to a changing climate but will need to increase their focus on the risks over time.

The nature of the mining and metals business already requires companies to engage in activities that support adaptation to future climate change. Many of the approaches, tools, data, resources and people necessary for identifying and adapting to risks and opportunities exist within companies. Often, however, these resources are not currently explicitly focused on, or motivated by, adaptation consideration to the extent that they will need to be once the impacts of climate change become more severe.

A key next step is to identify ways to further incorporate, or enhance the treatment of, climate change considerations within existing risk management and planning procedures.

Companies are already familiar with strategies to identify, prioritize and manage risks and opportunities. Existing functions in mining and metals companies that are relevant to climate change include risk management policies and procedures, emergency response planning, asset management, capital and long-term planning, environmental health and safety programs, biodiversity management, community engagement, financial and sustainability measurement and reporting, and dealing with uncertainty in decision making. Mainstreaming climate change considerations within these functions will require identifying the right sources of information, tools and resources to leverage within the company. It will also involve determining key areas of vulnerability or opportunity, the types of information required on changes in climate and the level of detail necessary to start framing responses.
References and appendices
Acclimatise (2010).

Land use in Australia – ut a glance. Australian Collaborative Land Use Mapping Program (ACLUMP).

ADB (2005).

ASCE (2000).
*Guidelines for instrumentation and measurements for monitoring dam performance.* American Society of Civil Engineers (ASCE) Task Committee on Guidelines for Instrumentation and Measurements for Monitoring Dam Performance.


La economía del cambio climático en Chile [The economics of climate change in Chile].


BHP Billiton (2005).
*A Sustainable Perspective: BHP Billiton Sustainability Report 2005.*


BSR (2011).
*Adapting to climate change: a guide for the mining industry.*

CCSP (2007).
*Effects of climate change on energy production and use in the United States.* A report by the US Climate Change Science Program and the Subcommittee on Global Change Research. Climate Change Science Program (CCSP).

CDC (2012).
Climate and Health Program: health effects. Centers for Disease Control and Prevention (CDC).

COCHILCO [2008].

Confalonieri, U [2008].
*Mudança climática global e saúde humana no Brasil* (Global climate change and human health in Brazil). *Parcerias Estratégicas*, 27, 323–349.


CountryMine [2012].

CSIRO [2011].

DGA [2008a].
*Derechos, extracciones y tasas unitarias de consumo de agua del sector minero regiones centro-norte de Chile.* Chilean Water Authority [DGA], Government of Chile.

DGA [2008b].
*Uso consuntivo del agua* [Consumptive water use]. Figure of consumptive water use by sector in Chile. Chilean Water Authority [DGA], Government of Chile.

DWAF [2004].

EC [2009].

EPA [1995].

EPA [2008].

EPA [2012].

EPA [2012b].

The impact of regional climate change on malaria risk due to greenhouse forcing and land-use changes in tropical Africa. *Environmental Health Perspectives*, 120(1), 77–84. doi:10.1289/ehp.1103681

EPA [2012].
EPA [2012].


Adapting to a changing climate: implications for the mining and metals industry

IFC (2010).

IFC (2012).
Performance Standards on Environmental and Social Sustainability. International Finance Corporation (IFC).

IPCC (2000).

IPCC (2007a).

IPCC (2007b).

IPCC (2010).

IPCC (2012).


Lenton, T (2012).


References


MCA [2012].

Climate change and human health: risks and responses. World Health Organization [WHO], Geneva, Switzerland.


Meintjes, H A C [2010].

MEND [2011].

Mercer. [2012].

Mining Magazine [2012].

MMSD [2002].

Moskvitch, K [2012].

Muson, J [2009].

Murphy, F, and Caldwell, J [2012].

NIOSH [2003].

NRC [1999].
Adapting to a changing climate: implications for the mining and metals industry


Thompson, J (2011).
Capstone concocts next plan. *Yukon News.*

Tiempo (2012).
_Tiempo Climate Newswatch_ and Tiempo Climate Portal.

Mining company wants second open pit and underground operations at Yukon mine. *Whitehorse Star.*

TRB (2008).
_Potential impacts of climate change on U.S. transportation._ Transportation Research Board of the National Academies (TRB).

UKCIP (2008).
Identifying adaptation options (AdOpt). UK Climate Impacts Programme (UKCIP).

UNFCCC (2009).
. United Nations Framework Convention on Climate Change (UNFCCC).

USGCRP (2009).
_Global climate change impacts in the United States._ United States Global Change Research Program (USGCRP).

USGS (2009).

USGS (2012a).


USGS (2012c).

Vulnerability of US and European electricity supply to climate change. *Nature Climate Change.* doi:10.1038/nclimate1546

World Bank (2002).
_Treasure or trouble?: Mining in developing countries._
World Bank Group Mining Department. World Bank and International Finance Corporation.


_Responsive Mineral Development Initiative: a framework for advancing responsible mineral development._

WRI (2012).
Aqueduct: measuring and mapping water risk. World Resources Institute (WRI).
Table A.1 summarizes climate projections for several arid or water-stressed regions where mining companies operate.

Table A.1: Regional climate projections in arid or water-stressed areas

<table>
<thead>
<tr>
<th>Region or country</th>
<th>Climate variable or effect</th>
<th>Timeframe</th>
<th>Projected change relative to 1960–1990</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chile</td>
<td>Annual mean temperature</td>
<td>2010–2039</td>
<td>0 to 1.5°C</td>
<td>Increases are highest in the northern parts of the country and Andean highlands.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2070–2099</td>
<td>2.5 to 5°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Annual mean precipitation</td>
<td>2010–2039</td>
<td>0 to -10%</td>
<td>Northern areas (Tarapacá, Antofagasta, Atacama) have received 13mm of annual precipitation historically (1960–1990). Steepest declines in the central region of Chile, between Antofagasta and Los Lagos. Precipitation increases in northern Atacama, at southern tip across the Strait of Magellan, and Tierra del Fuego.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2070–2099</td>
<td>+10 to -30%</td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>Annual mean temperature</td>
<td>2020–2039</td>
<td>1.2°C [0.7 to 1.6°C]</td>
<td>Largest increases in temperature occur in northern Australia. The mean result for an ensemble of 15 models is shown. High/low ranges are 10th and 90th percentiles, A2 scenario.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2080–2100</td>
<td>3.8°C [2.9 to 4.6°C]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Annual mean precipitation</td>
<td>2020–2039</td>
<td>1mm [11 to -11mm]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2080–2100</td>
<td>0mm [13 to -16mm]</td>
<td></td>
</tr>
<tr>
<td>South Africa</td>
<td>Annual mean temperature</td>
<td>2020–2039</td>
<td>1.2°C [0.7 to 1.7°C]</td>
<td>The mean result for an ensemble of 15 models is shown. High/low ranges are 10th and 90th percentiles, A2 scenario.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2080–2100</td>
<td>4.1°C [3.1 to 4.9°C]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Annual mean precipitation</td>
<td>2020–2039</td>
<td>0mm [8 to -11mm]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2080–2100</td>
<td>-2mm [8 to -16mm]</td>
<td></td>
</tr>
</tbody>
</table>

Table A.2 provides a summary of regional climate projections in tropical areas, including Brazil, Central Africa and Indonesia.

Table A.2: Regional climate projections in tropical areas

<table>
<thead>
<tr>
<th>Region or country</th>
<th>Climate variable or effect</th>
<th>Timeframe</th>
<th>Projected change relative to 1960–1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>Annual mean temperature</td>
<td>2020–2039</td>
<td>1.3°C [0.8 to 1.7°C]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2080–2100</td>
<td>4.2°C [3.1 to 5.4°C]</td>
</tr>
<tr>
<td></td>
<td>Annual mean precipitation</td>
<td>2020–2039</td>
<td>2mm [16 to -16mm]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2080–2100</td>
<td>5mm [28 to -30mm]</td>
</tr>
<tr>
<td>Central Africa</td>
<td>Annual mean temperature</td>
<td>2020–2039</td>
<td>1.3°C [0.8 to 1.5°C]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2080–2100</td>
<td>4.3°C [3.0 to 5.0°C]</td>
</tr>
<tr>
<td></td>
<td>Annual mean precipitation</td>
<td>2020–2039</td>
<td>3mm [14 to -10mm]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2080–2100</td>
<td>6mm [27 to -20mm]</td>
</tr>
<tr>
<td>Indonesia</td>
<td>Annual mean temperature</td>
<td>2020–2039</td>
<td>0.9°C [0.7 to 1.1°C]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2080–2100</td>
<td>3.1°C [2.5 to 3.5°C]</td>
</tr>
<tr>
<td></td>
<td>Annual mean precipitation</td>
<td>2020–2039</td>
<td>4mm [29 to -29mm]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2080–2100</td>
<td>16mm [59 to -34mm]</td>
</tr>
</tbody>
</table>

32 Adapted from World Bank (2012) unless otherwise noted; results are based on an ensemble of 15 climate change models. High/low ranges are 10th and 90th percentiles, A2 scenario (ie consistent with carbon dioxide equivalent atmospheric concentration of 1,250 ppm by end of century).

33 Compiled from information from two sources: World Bank (2012) and Bárcena et al (2009), using the HadCM3 general circulation model running the A2 scenario (ie consistent with carbon dioxide equivalent atmospheric concentration of 1,250 ppm by end of century).

34 Adapted from World Bank (2012); results are based on an ensemble of 15 climate change models. High/low ranges are 10th and 90th percentiles, A2 scenario (ie consistent with carbon dioxide equivalent atmospheric concentration of 1,250 ppm by end of century).
Definitions are adapted from the US Environmental Protection Agency (EPA) Glossary of climate change terms (http://epa.gov/climatechange/glossary.html).

**Adaptation**
Adjustment or preparation of natural or human systems to a new or changing environment that moderates harm or exploits beneficial opportunities.

**Climate**
Usually defined as the “average weather” or, more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands of years. These quantities are usually defined by temperature, precipitation and wind. The classical period is 30 years, as defined by the World Meteorological Organization (WMO).

**Climate change**
Any significant change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation or wind patterns, among others, that occur over several decades or longer.

**Climate variability**
Variations in the mean state of climate beyond individual weather events. These variations result from internal processes within the climate system as well as external influences, such as volcanic activity and variations in the output of the sun.

**General circulation model (GCM)**
A global, three-dimensional computer model of the climate system that is generally used to project long-term changes in climate. GCMs are highly complex and represent the effects of such factors as reflective and absorptive properties of atmospheric water vapour, greenhouse gas concentrations, clouds, annual and daily solar heating, ocean temperatures and ice boundaries. The most recent GCMs include global representations of the atmosphere, oceans and land surface.

**Intergovernmental Panel on Climate Change (IPCC)**
A scientific intergovernmental body established jointly by the United Nations Environment Programme and the WMO in 1988. The purpose of the IPCC is to assess information in the scientific and technical literature related to all significant components of the issue of climate change. With its capacity for reporting on climate change, its consequences, and the viability of adaptation and mitigation measures, the IPCC is also looked to as the official advisory body to the world’s governments on the state of the science on climate change.

**Resilience**
The capability to anticipate, prepare for, respond to and recover from significant multi-hazard threats with minimum damage to social well-being, the economy and the environment.

**Scenarios**
Plausible and often simplified descriptions of how the future may develop based on a coherent and internally consistent set of assumptions about driving forces and key relationships.

**Special Report on Emission Scenarios (SRES)**
A report published by the IPCC in 2000 that describes a series of greenhouse gas scenarios that are widely used to develop projections of possible future climate change. These scenarios, referred to as “SRES scenarios”, defined four storylines (denoted A1, A2, B1 and B2) that describe how greenhouse gas and aerosol emissions will evolve over the twenty-first century based on underlying demographic, social, economic, technological and environmental drivers.

**United Nations Framework Convention on Climate Change (UNFCCC)**
An international environmental treaty that sets an overall framework for intergovernmental efforts to tackle the challenge posed by climate change. It recognizes that the climate system is a shared resource whose stability can be affected by industrial and other emissions of carbon dioxide and other greenhouse gases.
### Changing climate variables and stressors

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Precipitation</th>
<th>Sea level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher average temperatures</td>
<td>More precipitation falling in some seasons and regions, less precipitations falling in others</td>
<td>Sea level rise</td>
</tr>
<tr>
<td>Increased frequency and/or severity of heatwaves</td>
<td>Increase in the proportion of precipitation falling as heavy rainfall events</td>
<td>Increase in storm surge height and frequency</td>
</tr>
<tr>
<td>Decreased number of cold days</td>
<td>More intense tropical cyclones, with larger peak wind speeds and more heavy precipitation</td>
<td></td>
</tr>
<tr>
<td>Increased melting of glaciers, ice and sea ice</td>
<td></td>
<td></td>
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<tr>
<td>Contraction in snow cover, and increases in thaw depth over permafrost areas</td>
<td></td>
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</tr>
</tbody>
</table>

### Indirect or secondary stressors

- Changes in evaporation and soil moisture levels
- Changes in availability and quality of water resources
- Changes in timing of peak runoff and stream flows
- Increased risk of flooding in some areas
- Increased risk of drought in some areas
- Increased risk of wildfire
- Longer growing season length
- Land and coastal erosion
- Changes in species distribution and habitat
- Saltwater intrusion

### Potential climate change impacts on-site

**Throughout the mining cycle**

- Risks to structural integrity of surface impoundments and site conditions from flooding, subsidence, landslide and soil erosion, as well as thawing permafrost in some locations.
- Risk of health, economic impacts on local communities and environments.
- On-site health and safety risks from increased risk of floods and wildfire.
- Exploration: increased access to new reserves.
- Operations: reduced efficiency, increased downtime and higher operational costs from higher temperatures, increased intensity of extreme weather events, and reduced water quality and availability, particularly in areas where water resources are already under stress.
- Reduced performance or inadequate capacity for water treatment, water, and waste impoundments due to changes in hydrological conditions.
- Construction, closure and post-closure: environmental impact assessment may need to take future climate into account; long-term closure and reclamation plans should reflect the expected climate over the site lifetime.
- Potential for creation of new pollution pathways, exacerbating material management risks.
- Operations, closure and post-closure: increased weathering of potentially acid-generating rock due to increases in temperature and precipitation.

### Potential climate change impacts off-site

**Inputs to mining and metals operations**

- Water: reduced availability of critical climate-sensitive inputs such as water and energy, particularly in water-stressed regions.
- Energy: lower reliability in generation and transmission of power due to disruption by extreme climatic events, insufficient water for cooling or hydroelectric generation, increased demand during extreme heat events or from higher seasonal temperatures.
- People: absenteeism, illness and reduced labour availability due to increased risk of heat stress, chronic diseases, health and social impacts from drought and other ecosystem changes.

### Supply chains

- Damage to transport infrastructure (e.g., road, rail, marine, air) from extreme events (e.g., flooding, tropical cyclones, droughts, landslides) and sea level rise (e.g., erosion, inundation).
- Reduced reliability from disruptions or delays to transport routes (via rail, road, sea and waterway) from seasonal changes and extreme events.
- Increased risk of damage to stockpiled ore/metals due to supply chain disruptions.
- Changes in the periods over which remote locations are accessible by land or marine transportation modes.

### Markets

- Changes in demand for metals and minerals to meet need for technologies to mitigate or adapt to climate change.
- Opportunities to capitalize on changes, or risks from loss of competitive advantages or the emergence of competitive disadvantages.
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**ICMM Steering Group**

Bernt Malme (Hydro)
Edwin Mongan (BHP Billiton)
Elize Swart (Lonmin)
Sofia Shellard (Vale)

**ICMM Land Use and Adaptation Working Group**

Chris Adachi (Teck)
Andrés Alonso (Codelco)
Ben Chalmers (Mining Association of Canada)
Rubao Come (BHP Billiton)
Carlos Gajardo [SONAMI]
John Groom (Anglo American)
Troy Jones (Teck)
Ron Knapp (International Aluminium Institute)
Erika Korosi (BHP Billiton)
Vivian Mac Knight (Vale)
Stan Pillay (Anglo American)
Stuart Price (BHP Billiton)
Nerine Botes Schoeman [African Rainbow Minerals]
Ana Carolina Srbek (Vale)
Salvador Traquino (BHP Billiton)
Adam Whitmore (Rio Tinto)

**ICMM team**

John Drexhage and Simone Cooper led the process to develop this publication on behalf of the ICMM Secretariat, with support from Gemma James and Meera Thankey.

**Consulting team**

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