Umwelt Bundesamt

German Environment Agency

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Addressing climate change impacts in mining and raw material supply chains

Recommendation paper

Climate change impacts are challenging the mining sector

The mining sector is vulnerable to the impacts of climate change. Climate change has the potential to affect many aspects of the sector, leading to disruptions in supply as well as exacerbating its environment and social impacts (see Table 1 for details and Rüttinger et al. 2020a-f). The sector needs to implement effective and enduring adaptation initiatives to maintain the global metal supply and mitigate environmental, community and societal impacts along the metals value chain.

While there are technical solutions for climate change adaptation for the mining sector, a range of factors limit their uptake. Climate change adaptation is therefore not merely a technical issue, but also a governance challenge linked to political and economic considerations.

This paper is the result of the research project “Impacts of climate change on the environmental criticality of Germany’s raw material demand” (see textbox below). It presents a set of policy recommendations on how to best adapt the mining sector, incentivise climate change adaptation measures in the mining sector and foster effective mechanisms for sharing knowledge and expertise on this topic globally.

Project background

In one of the first research projects on climate change and mining, adelphi, the Institute for Energy and Environmental Research Heidelberg (ifeu) and the Sustainable Minerals Institute (SMI) of the University of Queensland investigated how climate change could affect the environmental risks associated with mining. In addition, the project addresses how raw material supply chains might be disturbed by climate change impacts.

The project "Impacts of climate change on the environmental criticality of Germany’s raw material demand” (short: KlimRess) was commissioned by the German Environment Agency. In addition to this recommendation paper, the project team published five country case studies that assess the vulnerability of mining and raw material production in different climatic contexts and a final report. The case studies were published as individual reports and cover nine minerals and metals in five countries. The final report summarises the qualitative insights of the case studies and presents the results of a quantitative climate change vulnerability assessment of raw material-producing countries.

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Table 1: Potential adverse climate change impacts on mining and the environment

The compilation of potential adverse impacts is based on findings from the project's five case studies on several mines and processing sites in Australia (bauxite, iron ore and coking coal), Canada (tungsten and nickel), Chile (copper and lithium), Indonesia (tin) and South Africa (PGMs and nickel). The list presents only a set of most different cases to serve as examples and is not exhaustive; additional or different climate change impacts might occur.

Climate stimuli and direct climate impact	Potential impacts
Sudden onset, extreme events	
Occurrence of heat waves	**Environmental impacts** - Reduced resilience of rehabilitated mined land (e.g. suppression of growth and/or loss of vegetation due to heat stress) - Biodiversity stress **Disruption of mining operations** - Extreme heat damage to road and rail infrastructure - Workforce capacity reduced due to heat stress
Occurrence of droughts[1]	**Environment impacts** - Reduced resilience of rehabilitated mined land (e.g. plant development which reacts sensitively to water stress) - Biodiversity stress - Increased sensitivity to pollution loading in surface watersheds **Disruption of mining operations** - Reduced production at mine site due to water shortages
Occurrence of wildfires	**Environmental impacts** - Smoke from fire combined with dust and air emissions from mining/processing can lead to increased levels of air pollution - Reduced resilience of rehabilitated land (loss of vegetation due to fire, degraded soil) - Biodiversity stress **Disruption of mining operations** - Damage to transportation infrastructure - Workforce capacity reduced due to evacuation of workforce
Occurrence of flooding events *Flooding can be caused by heavy rain, in particular during cyclones, typhoons and hurricanes.*	**Environmental impacts** - Land degradation and erosion - Water contamination - Unscheduled release of contaminated effluents - Reduced resilience of rehabilitated mined land (e.g. damaged plants, wash outs) - Biodiversity stress **Disruption of mining operations** - Lost production due to flooding - Damage to transportation infrastructure - Workforce capacity reduced due to evacuation of workforce
Occurrence of erosion/landslide[2]	**Environmental impacts** - Reduced resilience of rehabilitated mined land (not only revegetation but also landscape) - Biodiversity stress **Disruption of mining operations** - Lost production - Damage to transportation infrastructure - Workforce capacity reduced due to evacuation of workforce

[1] Droughts are an extreme weather event but are linked to slow-onset change (UNFCCC, 2012).

[2] Erosion and landslide were merged in one category as they have similar impacts. However, erosions are usually classified as slow onset, gradual events.

Climate stimuli and direct climate impact	Potential impacts
Occurrence of heavy wind	**Environmental impacts** - Dispersion and behaviour of air emissions and dust emissions affected **Disruption of mining operations** - Transport and other infrastructure damaged - Workforce capacity reduced due to evacuated or harmed workers
Slow onset, gradual changes	
Increase of mean temperature	**Environmental impacts** - Increased risk of mined land rehabilitation failure (e.g. plant development potentially reacts sensitively to elevated temperatures) - Biodiversity stressed **Disruption of mining operations** - Workforce capacity reduced (e.g. increased transmission of malaria and dengue)
Increase of mean precipitation	**Environmental impacts** - No expected direct impacts on rehabilitation success and biodiversity **Disruption of mining operations** - Workforce capacity reduced (e.g. increased transmission of malaria and dengue)
Decrease of mean precipitation	**Environmental impacts** - Risks and failures in mined land rehabilitation - Biodiversity stressed **Disruption of mining operations** - No potential supply disruptions due to this climate stimuli/direct climate impact
Sea warming	**Environmental impacts** - Biodiversity stressed (increased sea surface temperatures can be harmful for marine ecosystems which are impacted by offshore mining) **Disruption of mining operations** - No potential supply disruptions due to this climate stimuli/direct climate impact
Permafrost degradation	**Environmental impacts** - Reduced integrity of tailing storage facilities **Disruption of mining operations** - Transport infrastructure impacted
Sea level rise	*In the long term, sea level rise potentially exacerbates the risk of coastal flooding and may have impact on ship loading facilities or mine infrastructure at sea level.*

Spotlight: Acid Mine Drainage (AMD) and climate change

Climate change could increase the potential for AMD generation. However, AMD generation is a complex process which depends on various factors. Therefore, the actual impacts of climate change on AMD generation are very difficult to project. In general, the AMD generation process (especially the abiotic one) requires oxygen and water to oxidize the sulfides. Changes in water supply and in the frequency of dry and wet phases at the site (especially on heaps) are factors that might increase AMD generation. More or heavier precipitation might also lead to a higher potential for AMD runoff. In addition, AMD generation dynamics are generally temperature dependent. However, small changes are not expected to accelerate the generation process. Only in rare and exceptional cases, e.g. when the average temperature at Arctic or high mountain locations rises above freezing for a longer period, might AMD generation increase.

Recommendations for the mining sector and national authorities in producing countries

Climate change adaptation needs for mining companies

Recommendation 1: Climate change adaptation should be central to the policies, procedures and strategies of mining companies and associated national environmental regulatory bodies.

Adaptation for planned and ongoing operations: The case studies show that although some mining companies and countries have started to adapt to climate change, there is room for more comprehensive climate change adaptation strategies and measures. By conducting thorough climate change vulnerability assessments of their operations in the context of regional climate change projections, mining companies can identify and implement adaption initiatives. They can build on existing knowledge and expertise to assess climate change impacts on the various aspects of mining operations (e.g. water, energy, transport, tailings safety) (Fraser Basin Council, 2014). Environmental Impact Assessments, which are normally conducted before mining operations start, could be a first point of entry.

Implementing early warning systems and adaptation measures is also a way to increase the environmental and social responsibility of mining and processing operations by helping to make them more resilient. One example is the drying and compacting of bauxite residue ('red mud') at alumina refineries. This treatment is a good practice of environmental management and is at the same time a climate change adaptation measure: it reduces the risk of an uncontrolled release in case of a dam wall break in general (e.g. due to a technical failure), but also when triggered by a climate change related event (e.g. increased intensity of heavy rain or increased frequency of cyclones). Such adaptation options are beneficial for both climate change adaption and day-to-day environmental management.

National authorities for environmental management and regulation in producing countries also need to mainstream climate change into activities related to the mining sector. While large international mining companies often have the means to acquire additional expertise or consult with international experts, national authorities often do not have the financial capacities to do so. Therefore, local know-how and personal capacities on climate change should be developed. Bilateral or multilateral cooperation could support such endeavours.

The new international standard ISO 14090 and the upcoming ISO 14091 provide practical guidance for climate change adaptation applicable to any type of organization (Naden, 2019; ISO, 2020).

Recommendation 2: As climate change impacts can affect relationships with local communities and the rehabilitation of mined land, both aspects need to be incorporated into the design and implementation of adaptation measures.

Adaptation and local communities: Mining operations interact with other pressures to put additional stress on biodiversity and local communities (e.g. noise and pollution by mining operations in an area experiencing drought and characterized by high poverty rates). Climate change can act as a 'risk multiplier', which means that it exacerbates various risks already prevalent in the mining region. Relationships with local communities will become increasingly important in addressing the negative impacts and harnessing potential positive impacts of climate change. An example from the Canada case study underlines this point: sea ice change could open up new shipping routes or prolong the shipping season at a nickel mine in Canada. However, the local indigenous community would have to agree to modify the current agreement between the mine and the community in order to allow new shipping routes or a prolonged shipping season.

Adaptation and rehabilitation: Rehabilitation of mined land is often challenging. Climatic changes, such as changing temperature and precipitation regimes and extreme weather events, can make this task even more difficult. In addition, rehabilitation has a very long timeframe and extends into the distant future, when climate change impacts are projected to be far more pronounced than in the nearer future (Stratos, 2011).

Rehabilitation measures need to be site-specific, as the climatic, soil, vegetation and other conditions differ substantially across mine sites. However, knowledge exchange between sites and companies on different methods and approaches for integrating climate change into rehabilitation efforts is essential. One example of a successful exchange format is the annual rehabilitation event with the Mongolian mining industry, administration, academia and consultants, supported by the German Federal Institute for Geosciences and Natural Resources (BGR), which helps to develop, adapt, and disseminate locally appropriate rehabilitation approaches and solutions. Similar events could be held in other countries to address not only particular local conditions, but also the impacts of climate change on rehabilitation.

Spotlight: Mining as a contributor to climate change

In addition to improving climate change adaptation, the large-scale mining sector needs to reduce its greenhouse gas (GHG) emissions to help reach the global goal of limiting the world's temperature increase to 2°C or even 1.5°C, as set in the Paris Agreement. The sector, including mining and mineral processing, smelting and refining, is highly energy intensive. This energy usually comes from fossil fuel sources, making the industry a significant contributor to global GHG emissions. In some cases, mining and mineral processing is less energy intensive than downstream smelting and refining and therefore produces lower GHG emissions than the latter. For example, the global CO_2 emissions for the mining of bauxite and iron ore were 1.4 Mt and 38.8 Mt in 2016, while aluminium- and steel-making accounted for 1 Gt and 3.1 Gt CO2 emissions in the same year (Tost et al., 2018). Nevertheless, there is a large potential to increase the use of renewable energy in mining: over recent decades, the contribution of renewable energy to mining has been below 10%, when also including the average electricity generation mix from the grid (Maennling and Toledano, 2018). There are now examples of mining companies implementing measures to reduce the use of fossil fuels and CO_2 emissions at their mine sites by transitioning to renewable energy sources.

Large tailings dams and abandoned mine sites are particular challenges in the context of climate change

Recommendation 3: Given the potential catastrophic consequences from tailings dam failures, adaptation initiatives involving large tailings storage facilities require special and detailed attention.

The failures of large tailings dams can result in extensive environmental damage and destroy livelihoods, harm infrastructure and cause fatalities. Tailings dams can be impacted by extreme weather events as well as by the slow onset of gradual changes (see Figure 1 for an overview of potential impacts on a tailings dam). These gradual changes are often less evident than the impacts of sudden, extreme events, but they are nevertheless important (e.g. permafrost degradation, which can lead to the destabilisation of tailings facilities). In this context, a particular challenge is to identify the impacts of combined or sequential extreme events, as these are more difficult to anticipate. One example of combined and sequential extreme events is repeated heavy rain and snowfall combined with sudden and rapid snowmelt. Further research would help gain a broader understanding of slow-onset and combined climate change impacts.

Mining operations have always faced extreme weather, but climate change is expected to increase the frequency and intensity of extreme events. However, tailings dams are often designed based on assumptions about past or current climatic conditions (ICMM, 2013). Therefore, the integrity of tailings dams need to be regularly monitored and assessed given their exposure to climatic changes. If required, mining operators should implement climate change adaptation measures for their tailings dams.

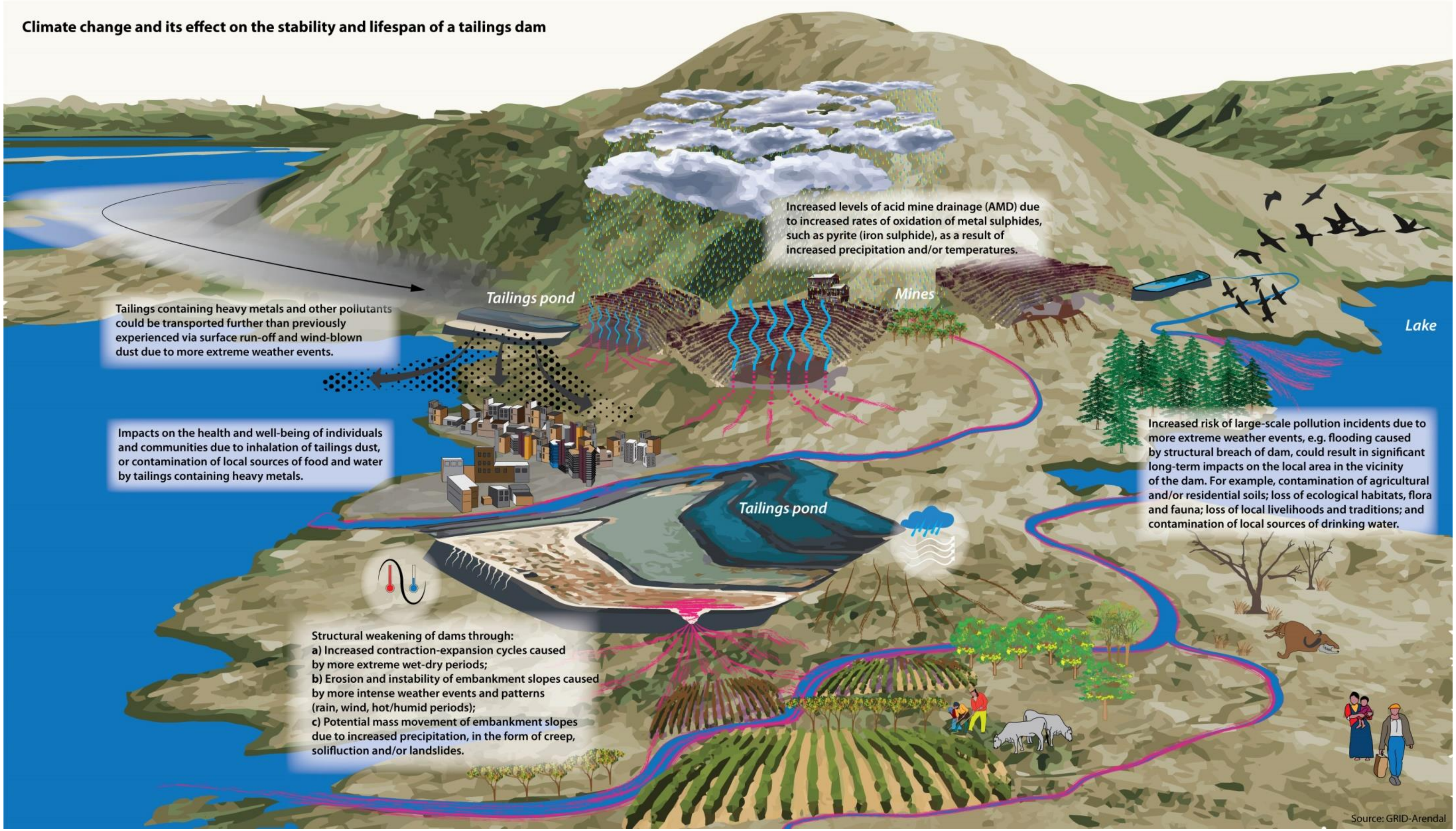
However, there is currently a lack of concrete regional or international guidelines for doing so. Two examples of guidelines lacking in this area are the recently published EU's "Best Available Techniques (BAT) Reference Document for the Management of Waste from Extractive Industries" (Garbarino et al., 2018) and the "Safety guidelines and good practices for tailings management facilities" by the United Nations Economic Commission for Europe (UN-ECE) (UN-ECE, 2014). Although the BAT document briefly mentions that the impacts of climate change should be considered in environmental baseline studies, when identifying a site for the deposition of extractive waste and when designing of dams or ponds to ensure high safety, no detailed recommendations are provided. Similarly, the UN-ECE guidelines refer to climate change as a challenge in the foreword, but do not specify any details in the main document. There is a need to develop more comprehensive climate change sensitive guidance.

In response to the Brumadinho tailings dam failure in Brazil in January 2019, the International Council on Mining and Metals (ICMM) started working with UN Environment and the Principles for Responsible Investment on a review aimed at establishing a global standard for tailings storage facility safety (Mining Technology, 2019). These efforts offer a near-term entry point to include climate change considerations in an international industry standard. However, in order to turn improved standards and guidance into action, the implementation of climate-proof safety measures also needs to be encouraged by non-governmental organisations, industry associations and regulatory bodies. The International Commission on Large Dams (ICOLD) would be a suitable international forum to mainstream climate change adaptation into safety measures for large tailings dams.

Spotlight: Hazard assessment tools need to account for climate change impacts

The Tailings Hazard Index (THI) is a tool that helps to assess the potential hazard of tailings storage facilities. It was developed on behalf of the German Environment Agency and piloted in Ukraine. It considers parameters on the volume of tailings, the toxicity of substances in tailings, the management status of the facility, the natural conditions (geological, seismological, hydrological conditions) specific to the site and dam safety (Vijgen and Nikolaieva, 2016). This useful tool could be enhanced by also including climate change projections.

Figure 1: Potential impact of climate change on a tailings dam



Source: Roche, Thygesen and Baker (2017), graphic created by Kristina Thygesen, http://www.grida.no/resources/11425. Used with permission.

Recommendation 4: As climate change can have substantial impacts on abandoned mine sites, suitable adaptation initiatives need to be developed in a similar manner to operating mines.

Countries with a long history of mining often have to deal with abandoned mines. These sites are in many cases the legacy of times when there were no comprehensive environmental regulations or rehabilitation provisions, let alone climate change adaptation policies. Operational mining sites are under continual monitoring and can put measures in place to adapt in advance or react to climatic changes. In contrast, abandoned mines are generally the responsibility of the state, which in some cases does not have the resources for detailed monitoring. Unless the abandoned sites are adequately managed, they may create negative environmental impacts such as acid and metalliferous drainage issues. As these impacts can conceivably be exacerbated by changing climatic conditions, there is a sense of urgency regarding the need to rehabilitate abandoned mine sites.

Addressing climate change impacts in the artisanal and small-scale mining sector

Recommendation 5: The impacts of climate change on the artisanal and small-scale mining sector need to be better understood in order to enable the identification and development of suitable adaptive measures to support this sector.

Artisanal and small-scale mining (ASM) is an important livelihood for about 40.5 million people globally, but it usually comes at a high environmental and social cost (IGF, 2018). As ASM operations tend to be informal or even illegal, they are mostly uncontrolled and often have no environmental monitoring or mitigation measures in place. Workers often operate under precarious and dangerous conditions. In addition, access to financial resources or capacity building is often inadequate due to the lack of formalisation in the sector. These circumstances make the sector especially vulnerable to climatic changes. However, ASM practices are very diverse, and they face varying local and different challenges (see for example IGF, 2018) that require tailored answers. Climate change impacts in the ASM sector and the responses to these impacts are not well understood. Therefore, research should focus on better understanding these impacts to enable the identification of adaptive measures that can be implemented by small-scale miners. The informality and general lack of financial resources and capacities in the ASM sector create additional challenges for the implementation of climate change adaptation. Therefore, general formalisation efforts and the strengthening of the local capacities need to be supported.

A potential entry point could be the CRAFT code that was developed by the Alliance for Responsible Mining (ARM) and RESOLVE in 2018 (ARM and RESOLVE, 2018). The code is a market entry standard for ASM gold producers, enabling them to join legal supply chains. While the code does provide guidelines to address complex aspects of legality and formality, its environmental criteria need to be enhanced. Climate change considerations are not included in the current version of the code.

Recommendation for investors and lending institutions

Recommendation 6: The potential consequences of climate change impacts at mining and processing sites should be part of the risk assessment process for investment decision-making.

Industrial large-scale mining projects usually depend on international investments for exploration and the development of operations. To help lower their investment risks, investors and lending institutions can use their leverage to encourage responsible business practices by requiring compliance with certain environmental and social standards as well as sound adaptation to climate change impacts. While the insurance sector is well aware of the risks that come with climate change, banks and other financial institution do not yet comprehensively assess risks related to climate change in their credit and lending portfolios. In general, the risks associated with the transition to a low-carbon economy have received greater attention than the sudden or slow-onset physical impacts linked to climate change (Connell et al., 2018). The immediate physical impacts on mines, processing and transport that might trigger cascading negative impacts – such as changes in the public perception towards mining, anti-mining campaigns, changes in the political evaluation of risk, and impacts on the general investment environment – are often also overlooked. These cascading impacts might result in larger overall costs and increased financial risks.

In cooperation with sixteen banks, the UN Environment Finance Initiative and Acclimatise have piloted methodologies to assess physical impacts of climate change on credit and lending portfolios in the agriculture, energy and real estate sectors (Connell et al., 2018). Using these methodologies as well as the new ISO standards 14090/14091 as a basis, specific assessment methodologies could be developed for the mining sector (Naden, 2019; ISO, 2020). Furthermore, climate change issues should be incorporated into key guiding documents on responsible mining, such as the Environmental, Health, and Safety Guidelines for mining of the International Financial Cooperation (IFC, 2007) and the Equator Principles – a financial industry risk management framework for environmental and social risk in projects – (Equator Principles, 2013). Beyond integrating climate change into risk assessments, banks and other investors and lenders can support the mining sector by investing in climate change adaptation initiatives.

Recommendation for the European Commission

Recommendation 7: The European Union should mainstream climate change considerations into its cooperation with raw material producing countries.

The European Commission adopted its Raw Material Initiative (RMI) in 2008[3] with the aim of improving European access to raw materials. The RMI covers all raw materials except agricultural materials and materials used for fuel (European Commission, 2019b). One of its priorities is to ensure a "fair and sustainable raw material supply from global markets" (European Commission, 2014). Various EU policy areas are involved in raw materials-related cooperation (e.g. industry, trade, development cooperation, diplomacy and finance). Accordingly, various EU institutions are in charge of cooperation on raw materials, such as the Directorate General for Internal Market, Industry, Entrepreneurship and SMEs (DG GROW), the European External Action Service (EEAS), the Directorate General for Trade (DG TRADE), the Directorate General for International Cooperation and Development (DG DEVCO), the European Investment Bank (EIB), and the European Parliament (EP) (for details on mandate, role and functions in relation to raw materials cooperation, see Carstens et al., 2018). When engaging in raw material cooperation, these institutions should mainstream climate change considerations into their activities with partner countries.

In the past, the EU has largely focused on securing its external supply through its trade policy, notably through free trade agreements (FTAs) (Farooki et al., 2017). In line with the RMI, the EU has also implemented a trade strategy for raw materials, which also aims at including raw materials in negotiating free trade agreements (FTA) with non-EU countries (European Commission, 2019d). For the EU, this is an especially powerful entry point to mainstream climate change considerations, as most trade provisions[4] fall under the exclusive competence of the EU and do not require ratification by member states. There are three specific ways in which the FTA negotiation process could better take into account climate change impacts on mining and raw material supply chains.

First, adding an expert to the negotiating team. The European Commission conducts the main preparatory work and decides on the group of negotiators (European Commission, 2018b). In order to encourage the Commission to take a holistic perspective on trade barriers (including climate change impacts on environmental risks related to mining and raw material supply chain risks), an expert familiar with such impacts and risks could be added to the team and accompany the Sustainability Impact Assessment[5]. Second, including a reference to climate change impacts in the relevant provisions of FTAs. The European Commission has introduced dedicated provisions on energy and raw materials (ERM) as part of FTA negotiations (European Commission, 2017). None of the FTAs that are currently in force entails dedicated provisions on ERM, whereas proposals for ERM chapters exist for six FTAs under negotiation (Australia, Chile, Indonesia, Mexico, New Zealand and Tunisia) (Groneweg, 2019). Third, considering climate change impacts on mining and raw material supply chains in the chapter on trade and

[3] The RMI was further developed in 2011.
[4] Only agreement provisions on investment require the approval by the EU and all its member states (Council of the European Union, 2018).
[5] The SIA "is a DG Trade-specific tool for supporting major trade negotiations. SIAs provide the Commission with an in-depth analysis of the potential economic, social, human rights, and environmental impacts of ongoing trade negotiations. These assessments are an opportunity for stakeholders in both the EU and in the partner countries to share their views with negotiators" (European Commission, 2019c).

sustainable development (TSD) (European Commission, 2019a). For example, in the case of the modernisation of the EU-Mexico Global Agreement, while the TSD chapter under negotiation refers to the promotion of climate change mitigation and adaptation, it does not explicitly to the mining sector (European Commission, 2018a).

Following a transparency initiative, EU policies allow for comments by stakeholders throughout the policy process. As of October 2019, the following FTAs under negotiation are open for comments: Chile, China, Mexico, and Turkey (European Commission, 2019e).

Recommendations for the German government

To meet its demand for extractive resources, Germany needs to import metals, industrial minerals and energy resources (BGR, 2018). The country's economy is heavily dependent on these imports and therefore the government needs to support a secure supply. At the same time, from a footprint perspective, Germany has a responsibility to limit the environmental impacts of mining when sourcing from abroad, in particular from countries that face challenges with regard to governance of the mining sector. The following paragraphs provide recommendations to the German government for how it can support climate change adaptation in the mining sector by integrating related issues into existing policies and processes.

Recognizing transnational climate risks in climate change adaptation policies

Recommendation 8: Climate change impacts in resource supplying countries should be addressed in German climate change adaptation policies.

Climate change not only affects countries within their own national territories, but also through climate change impacts occurring in other places of the world. Risks are shared and transmitted via global trade flows, supply chains, finance, the movement of people and transboundary ecosystems (Benzie et al., 2018). These risks are often referred to as transnational climate risks. Most national adaptation plans primarily address climate impacts that occur within a state's own territories and often fail to cover transnational climate risks. Nevertheless, societal awareness of such risks is increasing, and more research[6] is being directed towards better understanding these risks.

One important set of transnational climate risks is linked to global supply chains, in particular to imports from countries vulnerable to climate change. Producing countries and supply chains are increasingly affected by climate extremes that reduce the production of materials or interrupt exports. For example, severe floods in Australia in 2010-2011 and in 2017 substantially affected the production of coal mining operations and the transportation systems that delivered the washed coal to port facilities for global export markets. In Chile, when the authorities imposed water restrictions because of drought conditions in 2014-2015, it led to a reduction in copper production.

One illustrative example of how Germany "imports" climate vulnerability is the supply of raw materials for aluminium production: Germany imports more than 95 percent of its bauxite and alumina from Guinea, a country that is highly vulnerable to climate change.[7]

The current **German Strategy for Adaptation to Climate Change**, the German Adaptation Action plan and the first Progress Report focus predominantly on climate impacts occurring within Germany, rather than on impacts occurring abroad and affecting Germany indirectly (Federal Government of Germany, 2008; BMU, 2011; BMU, 2015). Based on existing and forthcoming research results, transboundary climate risks should be thoroughly addressed in the next Progress Report on Germany's Adaptation Strategy, scheduled for 2020.

The **International Climate Initiative** (Internationale Klimaschutzinitiative, IKI) could be an adequate funding instrument for the implementation of climate change adaptation in the mining

[6] Examples are the German research projects Impact-CHAIN (Peter et al., 2018) and CLIC (Climate Impact Chains in a Globalized World: a Challenge for Germany) or the newly launched European research project CASCADES - Helping European Societies Address Cascading Climate Risks from outside Europe.

[7] Trade statistics for 2016 derived from UN Comtrade Database; climate change vulnerability based on ND-GAIN data.

sector. Currently, only a few mining-related projects are funded by IKI. Most of them focus on the rehabilitation of former mine sites.

Climate-proofing the German resource strategies

Recommendation 9: German resource strategies and initiatives should address climate change impacts on mining, mineral processing and raw material supply chains.

Germany has several national strategies that address a secure and sustainable supply of non-energy mineral resources.

The **Raw Material Strategy** by the German Federal Ministry for Economic Affairs and Energy (BMWi) proposes measures to diversify the supply of raw materials (BMWi, 2010). However, the Strategy does not yet take into account supply chain disturbances due to climate change impacts. Due to its dependency on imports, Germany has pushed for raw materials to be on the agenda of a number of international bodies such as the G7 and G20 (see below). In previous years, the discussions were mainly focussed on the general availability of raw materials, potential efficiency gains and price developments.

Germany could include the impacts of climate change on mining operations and consequently on security of supply in the revised version of its national Raw Material Strategy and promote the topic on the international agenda. One implementation instrument in the Raw Materials Strategy that could be useful is the bilateral raw material partnerships.[8] Climate change related considerations, exchange and support could be integrated into these partnerships.

New bilateral resource partnerships could be established

The following criteria could be helpful for establishing new resource partnerships with a focus on climate change adaptation. The partner country should be an important producer of minerals and metals and vulnerable to climate change. In addition, the existence of links to Germany through trade relationships, partnerships in other fields and international cooperation would facilitate the initiation of a partnership.

ProgRess, the German Resource Efficiency Programme by German Federal Ministry of the Environment, Nature Conservation and Nuclear Safety (BMU), seeks to increase German resource efficiency over the entire life cycle of products (BMU, 2012). One component of ProgRess focuses on strengthening environmental, social and transparency standards in raw material production internationally as well as securing a sustainable raw material supply for Germany (chapter 7.1.2). Another component aims at considering ecological limits and social inequalities in the assessments of raw material availability (chapter 7.1.3). These are potential points of entry to include transnational climate impacts in the next version of ProgRess that is due in 2020.

Germany's dependence on imports of extractive resources already played a role in the 2010 **Extractive Resources Strategy Paper** by the German Federal Ministry for Development and Economic Cooperation (BMZ) (BMZ, 2010). The link between the extractive industries and climate change was missing at that time. This changed following the UNFCCC's[9] 23rd Conference of the Parties (COP23) in 2017, when the Sector Programme Extractives for the Development of the BMZ and the World Bank's Energy and Extractives Practice established the "Climate-Smart Mining" program (BMZ, 2018). This new initiative is mainly directed towards mitigation aspects,

[8] The German government has signed partnership agreements with Mongolia, Kazakhstan and Peru. Other bilateral partnerships are based on declarations of intent (Chile and Australia) or on correspondence between governments (Canada) (BMWi, 2019).

[9] United Nations Framework Convention on Climate Change

i.e. the question of how to minimise emissions from the mining sector. Adaptation is on the agenda of the program, but has not been a focus so far. The initiative could be a good starting point to enhance adaptation action.

Furthermore, the BMZ should mainstream climate change adaptation into mineral resource governance projects as part of its international cooperation projects. For example, the BMZ could support measures to enhance the preparedness of mining countries, such as the establishment of climate-proof requirements for Environmental Impact Assessment and Environmental Management Plans and the identification of areas that are particularly vulnerable to climate change, where there could be potential repercussions for the granting of mining titles and licenses.

G7 and G20 as potential entry points on the international level

Recommendation 10: The German Federal Ministry of the Environment, Nature Conservation and Nuclear Safety (BMU) should place climate change adaptation for mining, mineral processing and raw material supply chains on the agenda of the G7 and G20.

On the international level, there are limited suitable international fora for mining related climate change adaptation. In general, transnational climate risks have not received much attention within key international bodies. For example, the **UNFCCC,** which is crucial in coordinating global responses to climate change, has not yet announced actions on transnational climate risks. The UNFCCC would be the best place to address transnational climate risks, but the process is already tasked with a large number of highly controversial issues and adoption might be slow (for detailed discussion on what the UNFCCC can do, see Benzie et al. 2018).

Although the **G7** and **G20** do not have climate change adaptation high on their own agendas, they could be pioneering fora to put transboundary climate change risks linked to the extraction of non-energy mineral resources on the international agenda. Both the G7 and G20 are informal groups with no permanent secretariats and are largely driven by the agenda of the hosting country. Nevertheless, they provide a good entry point for setting the global agenda. The G20 could be a particularly interesting forum because it brings major producers and importers to the table. Over 75 percent of global production of bauxite, iron ore, PGMs[10], tungsten and coking coal and over 50 percent of the world lithium, tin and nickel production takes place in G20 countries.[11] In contrast, the G7 countries[12], except for Canada and the United States, have no notable mineral resource production and are dependent on imports.

In the past years, the BMU has been very active in promoting the topic of resource efficiency on the agenda of the G7 and G20. Under its auspices, the G7 Alliance on Resource Efficiency and the G20 Resource Efficiency Dialogue were launched in 2015 and 2017, respectively. The BMU could build on these existing initiatives and broaden their focus to sustainable materials management policies in general. In this way, climate change adaptation in the mining sector could be addressed. Although each G7 and G20 presidency sets its own priorities, the German government can try to raise awareness for the mining and climate change nexus and champion the integration of the issue into the agendas of summits in the years to come.

[10] Platinum Group Metals

[11] Based on data from Reichl et al. (2016), USGS (2017), USGS (2018) and World Energy Council (2016).

[12] The G7 countries are: Canada, France, Germany, Italy, Japan, the United Kingdom and the United States.

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On behalf of the German Environment Agency

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