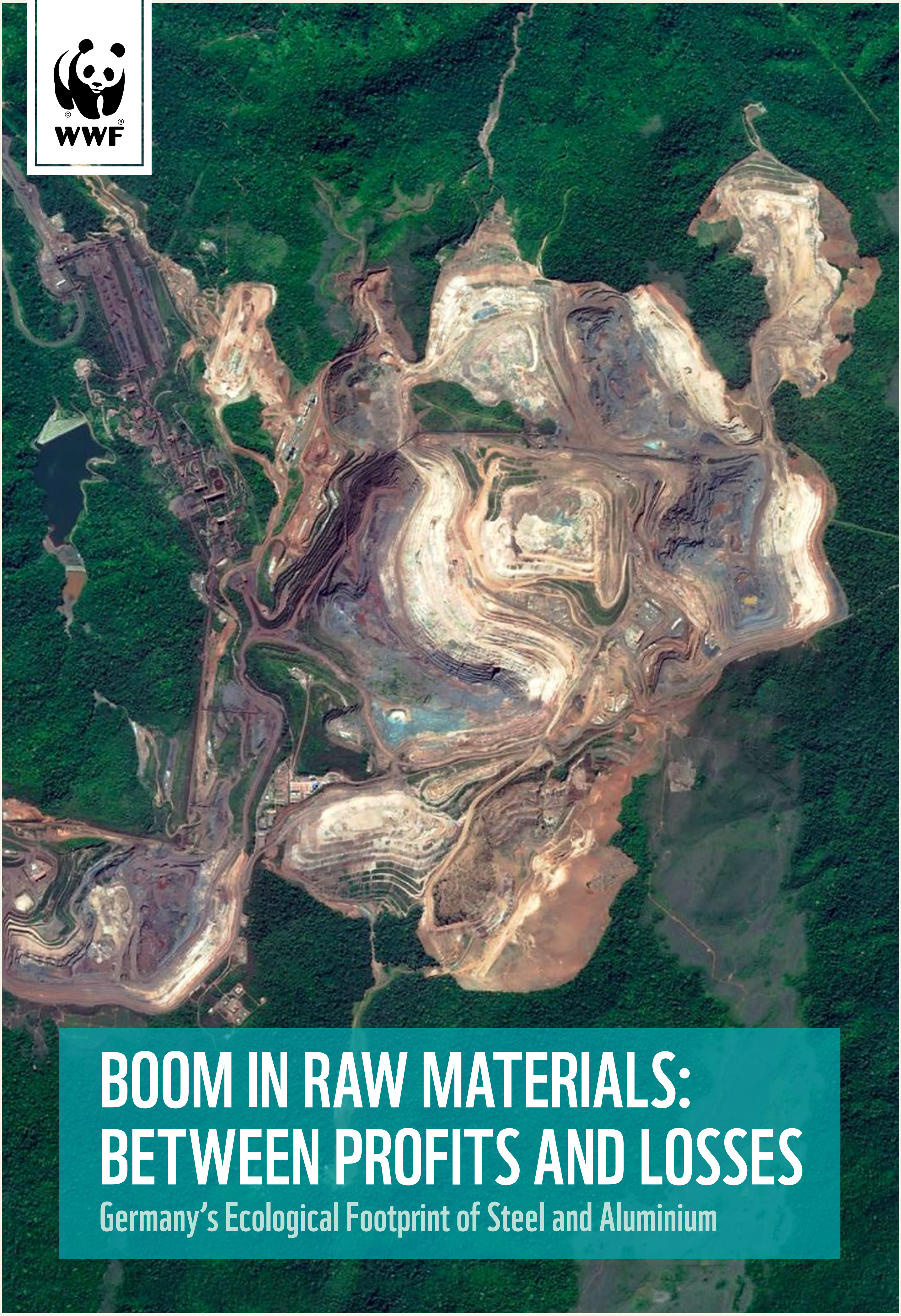


BOOM IN RAW MATERIALS: BETWEEN PROFITS AND LOSSES

Germany's Ecological Footprint of Steel and Aluminium

ISBN 978-3-946211-20-4

Publisher	WWF Germany
Date	October 2018
Lead authors	Tobias Kind (WWF Germany)
	Katalina Engel (Engel Consulting)
Co-authors	Dr. Malika Virah-Sawmy (Terrleben)
	Mélissa De Hertogh (WWF Germany)
Coordination	Tobias Kind (WWF Germany)
Contact	Tobias Kind (WWF Germany), tobias.kind@wwf.de
Layout	Wolfram Egert (Atelier für Graphic Design)
Production	Sven Ortmeier (WWF Germany)
Credits	Getty Images/iStockphoto | Reuters | Arco Images
	Google Earth. 2018 | Sonja Ritter/WWF

Many thanks to the following contributors: Jörg-Andreas Krüger (WWF Germany), Jan Kosmol (Umweltbundesamt), Philipp Wagnitz (WWF Germany), Libby Neumann (eco-accents), Susanne Schmitt (WWF UK), Justus Kammüller (WWF Germany), Thomas Köberich (WWF Germany), Sonja Ritter (WWF Germany), Matthias Kopp (WWF Germany), Diana Süsser (WWF Germany), Felipe Costa (WWF Germany), Laura Garcia-Velez (WWF UK), Andrea Dreifke-Pieper (WWF Germany), Johannes Schmiester (WWF Germany), Sonja Ritter (WWF Germany). Finally, we would like to acknowledge the input of various reviewers of this report and its assessment, those involved in this publication as well as its funder the Umweltbundesamt.

Foreword from the Chief Conservation Officer of WWF Germany

Houses, bridges, factories, cars, electronic devices and a zillion other products contain metals extracted from the Earth's surface. Metals are essential for the development of human civilisation and the life we live today. But the footprint left by the extraction, production, processing, use and disposal of these commodities is largely considered unsustainable.

As one of the leading import country of iron and steel products and the second-largest importer of aluminium, Germany relies heavily on these natural resources. Key economic sectors such as the automotive, construction, machinery and plant engineering sectors are primary users of steel and aluminium. Globally, extraction and production of these resources has been skyrocketing in past decades. As an incremental part of almost every industry's value chain, this trend will continue as consumption increases and many countries experience rapid growth.

Often ignored, the mining industry has tremendous negative environmental and social impacts, threatening the Earth's ecosystem and planetary boundaries. Mineral extraction and metal production severely degrade fragile ecosystems through soil contamination, excessive water use or greenhouse gas (GHG) emissions.

Equally important and certainly linked to this issue are the rights of indigenous communities. They are at risk in certain regions where mining expansion or processing of ores destroy ancestral territories, affecting and violating community interests. Negative social impacts and human rights violations are accompanied by bad mining practices and must be addressed. Even though this study focuses on the environmental impacts and solutions, human rights and environmental rights go hand in hand.

This report highlights specific supply chain challenges and proposes several starting points for more sustainable steel and aluminium life cycles. The German government is in an excellent position to exert influence on and broaden the scope of existing policies such as ProgRess or the EU Regulation on Critical Raw Materials. As consumer awareness grows, the demand for more sustainable products increases as well. Using technologies such as blockchain and tapping into the potential of IT systems, companies can begin to gain a more in-depth understanding of their supply chains and tackle challenges on the ground. There is significant potential for positive improvement!

WWF calls upon governments, companies, investors and civil society to reform, challenge and improve the existing mining, production and life cycle processes associated with aluminium and steel.

Jörg-Andreas Krüger
Chief Conservation Officer,
WWF Germany

Table of contents

List of abbreviations

3TG	Tin, tungsten, tantalum and gold (i.e. conflict minerals)
AMD	Acid mine drainage
ASI	Aluminium Stewardship Initiative
ASM	Artisanal and small-scale mining
AWS	Alliance for Water Stewardship
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (Federal Ministry of Economic Cooperation and Development)
BOS	Basic oxygen steelmaking
CDP	Carbon Disclosure Project
CE	Circular economy
CO_2	Carbon dioxide
CO_2-eq	CO_2-equivalents
CRM	Critical Raw Materials
EAF	Electric arc furnace
EU	European Union
FPIC	Free, Prior and Informed Consent
GHG	Greenhouse gas
HCVA	High Conservation Value Areas
ICMM	International Council on Mining and Metals
ILO	International Labour Organisation
IRMA	Initiative for Responsible Mining Assurance
ISA	International Seabed Authority
KBA	Key Biodiversity Areas
MDG	Millennium Development Goals
NDC	Nationally Determined Contributions
NNL	No net loss
PA	Protected area
RMI	EU Raw Materials Initiative
SD	Sustainable development
SDG	Sustainable Development Goals
t	Metric tonne
UAE	United Arab Emirates
UBA	Umweltbundesamt (German Environmental Protection Agency)
UNESCO	United Nations Educational, Scientific and Cultural Organization
WHS	World Heritage Site

Shipments are crossing rivers to reach production facilities.

1. Executive summary

Steel and aluminium are vital resources to our civilisation. Without them, our current way of life would be inconceivable. Virtually every industrial value chain uses steel and aluminium to generate trade, employment and economic income in countries around the world.

Over 60% of Germany's imports are related to the metal production and processing industries; a staggering 99.7% of metal ores are imported.

In 2016, Germany was the largest importer of iron and steel products and the second-largest importer of aluminium globally. At the same time, Germany is the world's largest exporter of automobiles and the second-largest exporter of steel and aluminium goods. Over 60% of Germany's imports are related to the metal production and processing industries; a staggering 99.7% of metal ores are imported. This is a worthwhile investment as the value created between the raw material and the finished product is enormous. Besides the economic importance of these industries, the numbers are also an indication of Germany's role in the environmental impact in countries such as Guinea, Jamaica or Brazil. With power comes responsibility.

At mining sites, primary natural habitat is destroyed and acid drainage from sludge retention ponds and mine dumps poisons soils and groundwater. At the processing stage, the steps of separating the mineral from the ore and further refinement are highly energy intensive and therefore emit high levels of carbon dioxide (CO_2) and contribute to climate change.

In the energy production sector, the global shift to sustainable electricity to meet the goals of the Paris Agreement will require the construction of vast numbers of wind turbines, solar power stations and other facilities. For an equivalent installed capacity, solar and wind facilities require up to 15 times more concrete, 90 times more aluminium and 50 times more iron, copper and glass than conventional energy systems. This implies a 5% to 18% annual increase in the global production of these metals over the next 40 years - despite rising recycling rates. Even with recycling rates rising as more existing aluminium and steel go back into production, mineral extraction is bound to increase and expand by exploring new sources.

Mining in Australia is a significant primary industry and contributor to the Australian economy. The country has the biggest iron ore reserves in the world, mainly located in Western Australia.

Environmental impacts along the aluminium and steel supply chains

The environmental and social impacts extend far beyond the direct vicinity of mining operations. When a mine opens at a given location, the level of human activity automatically increases there. The infrastructure needed for mining such as roads, railroads, dams and power lines has to be built in previously pristine landscapes and wilderness areas. Job opportunities lead to the migration of mine workers, causing additional pressure on ecosystems and wildlife through logging, pasture use, agricultural development or water abstraction and poaching.

So far, these indirect effects are often not accounted for when a new mining operation opens in pristine landscapes such as the Amazon of Brazil and Guinea. More effort is being made to address the direct impacts.

Direct impacts of bauxite and iron ore mining

1. Globally, the mining industry is responsible for around 2–4.5% of average national **water use**. The groundwater table is lowered when groundwater is withdrawn, contributing to aquifer depletion. Land clearance and surface mining change surface permeability which also lowers rates of groundwater replenishment. In September 2017, Norsk Hydro, a Norwegian aluminium and renewable energy company and one of the largest aluminium companies in the world, warned customers of a shortfall in supplies of bauxite from the Brazilian Mineração Rio do Norte bauxite mine after the mine experienced problems with its tailing systems due to a water shortage caused by dry weather.
2. **Water pollution** is a major concern as the discharge of mine water to the environment, seepage of waste into the ground and surface water, containment breaches or uncontrolled stormwater contaminate drinking water for downstream communities or destroy forest and wildlife habitat. On 5 November 2015, a dam holding approximately 50 million cubic m of waste from iron mines, jointly owned by Vale and BHP Billliton, burst near the city of Mariana in Brazil's Minas Gerais state. The toxic sludge wiped out whole villages downstream, leaving 19 dead and suffocating 600 km of the Doce, one of Brazil's largest rivers outside the Amazon basin.
3. One of the major causes of **deforestation** is land clearance for open-pit and large-scale mining. Impacts of Vale's mining activities in its Carajás mine in Brazil include the almost total destruction of the rainforest along the 80 m-wide, 890 km-long railway line transporting the ore to the Atlantic Ocean.
4. Deforestation and habitat loss cause biodiversity loss in often pristine and untouched region with notably high biodiversity value.
5. **Downsizing, downgrading and degazettement of protected areas** (PAs) are a major challenge linked to mining operations. For example, the Mount Nimba Biosphere Reserve, a World Heritage Site in the Republic of Guinea, was downsized by 1,550 ha to allow for iron-ore prospecting. This is also likely to extend to marine PAs as metal ore prospecting activities are intensifying in the deep-sea bed.
6. **Soil contamination** by heavy metals and other pollutants can persist long after mine remediation caused by leaking tailing ponds and the erosion of waste piles.

7. **Acid mine drainage**, a natural oxidisation process which creates acidic conditions in ore deposits, causes metals and other geologic materials to dissolve and leach into surface and groundwater.

8. **Air emissions** from mining activities include diffuse particles, sulphur and nitrogen oxides, carbon oxides or methane that originate from land clearing, excavation, transport and blasting activities.

9. Mining operations generate considerable **noise**, which reduces habitat quality and increases stress levels for wildlife and humans.

GHG emissions

Energy is used directly and indirectly at every stage of the metal production process, causing CO_2 and other GHG emissions along the entire supply chain. The global primary aluminium industry was estimated to be responsible for 1% of global GHG emissions in 2008, while the steel industry accounts for about 7% of global CO_2 emissions.

Indirect environmental impacts of iron ore and bauxite mining

1. A recent study found that indirect mining-related **deforestation** is 12 times greater than deforestation that occurs on land leased for mining alone.

2. **Conflicts over water** are particularly common as iron ore and bauxite operations are often carried out in arid or semi-arid regions.

3. Throughout the 20th century, more and more mining operations have been moved to developing countries. Besides some positive effects and economic prosperity, **conflicts** between communities, indigenous peoples and mining operators have increased. The right to "Free, Prior and Informed Consent" (FPIC) is not granted with any regularity in many parts of the world. Mining-related land dispossession and evictions often lead to violent conflict. In India, the government has given permission for the British-owned Vedanta mining company to begin extracting bauxite from the Niyamgiri mountain in Orissa state. The decision, which has led to massive protests, is endangering the livelihood of the Dongria Kondh tribe, who regard the mountain as sacred and live off its jungle cover.

Environmental impact of aluminium and steel processing

1. The storage and management of **red mud** is a serious challenge for the industry. The high salinity of the mud causes soil salinisation, and its high content of contaminants such as arsenic, mercury and chrome adversely affects human health and agriculture. In February 2018, after flooding during a thunderstorm, red-coloured water leaked from a tailing dam of Alunorte, Brazil's largest alumina refinery belonging to Norsk Hydro. Contradicting the findings of a Brazilian government-backed investigation, Norsk Hydro denied that its alumina refinery had contaminated local waters with red mud.

2. In 2013, 3% of global electricity and 1% of global **GHG emissions** was linked to aluminium industry. Up to 80% of the total emissions can be attributed to the highly energy-intensive Hall-Heroult electrolytic process.

3. To meet the high energy requirement of aluminium smelting, hydropower plants are constructed in pristine river reaches. The impacts of hydropower and dams include hydrological fragmentation, alteration of base water flows, disruption of species migration needed for inland fisheries, flooding of vast land areas and habitat fragmentation through road development and the installation of transmission lines.

4. The steel industry is the world's biggest industrial **emitter of CO_2**. The main share of the steel industry's CO_2 emissions can be attributed to the use of coke and coal for pig iron production. The use of charcoal in pig iron production not only causes higher CO_2 emissions, but is also a driving force behind massive **deforestation** in the Brazilian Amazon.

Changes are needed

There is a pressing need to adopt global strategies to manage the environmental impacts associated with mining activities.

With the ever-increasing future demand for steel and aluminium, there is a pressing need to adopt global strategies to manage the environmental impacts associated with mining activities. Responsible mining can be achieved through a combination of policies, market initiatives and technological improvements, e.g.:

1. **Ensure the right to "Free, Prior and Informed Consent" (FPIC)** to guarantee that the rights, health and safety of indigenous people, local communities and workers are not violated.

2. **Define and respect no-go areas and respect the mitigation hierarchy** including biodiversity offsets to support biodiversity protection.

3. **Ensure integrated planning for mine closures** to minimise the negative environmental and health and safety impacts from the very outset.

4. **Manage pollution, energy consumption and waste** through best management practices and technologies that comply with international standards.

5. **Address indirect impacts of mining** through strategic land-use planning, e.g. by establishing private-public sector partnerships and adopting a Water Stewardship framework.

6. **Certify best practices** through initiatives such as the Initiative for Responsible Mining Assurance (IRMA).

7. **Establish a high degree of transparency** to prevent corruption and contribute to initiatives such as Science Based Targets (SBT) for GHG emissions, Global Reporting Initiative (GRI), CDP Water Disclosure or the Sustainable Development Goals (SDG).

Sustainability is based on the prudent use of materials. Sustainable consumption plays an essential role in minimising resource overuse and environmental and social impacts. Furthermore, sustainable development is only possible from a systemic perspective if resource use and the environmental impact from economic activity are decoupled. In this context, the **circular economy** (CE) is emerging as a key strategy. The CE aims to keep resources in use for as long as possible and seeks new ways of linking resources, product design, production and consumption.

Aluminium and steel are materials that are easy to integrate into a circular economy as they are infinitely recyclable without quality losses, and there are many positive effects: the production of secondary raw aluminium requires only 5% of the energy and produces only 5% of the emissions compared to the primary aluminium production process.

Reuse and remanufacture (as well as a reduction of use) form an integral part of the circular economy model and take precedence over recycling.

Call to action

WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature. WWF believes that long-term prosperity can only be achieved if sustainability is at the heart of everything we do. To this end, we have to scrutinise unsustainable practices and transform them into solutions that benefit people, nature and economies in equal measure. Establishing a functioning circular economy for the metal and mining industries could serve as an example for the kind of transformation needed – requiring a collaborative and coordinated effort from different actors and stakeholders at various levels. To become a sustainable actor in the metals and mining industry …

The German government needs to:

1. Prioritise policies and legislation that promote the reduction of absolute resource use and inform the German population about resource reduction, reuse and recycling options.
2. Identify potential renewable resource alternatives to aluminium and steel and subsidise research and development to turn these alternatives into commercially viable solutions
3. Revise the German Raw Materials Strategy in a democratic and inclusive process to include the environmental and social criticality of raw materials.
4. Implement the German Sustainability Strategy in all federal agencies and departments.
5. Integrate concrete and binding resource efficiency rates for aluminium, steel and other mineral resources to meet the goal of the German resource efficiency programme (ProgRess) to double resource efficiency by 2020 from 1994 levels. Integrate a goal for reducing the absolute consumption of mineral resources into the same programme.
6. Define a clear list of social and environmental criteria for importing mineral resources to the EU. Develop a legally binding regulation that requires companies and government bodies of the EU to comply with the guideline.
7. Support bauxite and iron ore in the EU Regulation on Conflict Minerals which will enter into force in 2021. This regulation already includes four critical raw materials – tin, tantalum, tungsten and gold. Not recognising and including these two critical "conflict minerals" deeply undermines the aim and impact of the regulation.
8. Include environmental and social criticality in the EU Critical Raw Materials (CRMs) list as well as in the Raw Materials Strategy.

9. Take into account the key Sustainable Development Goals, i.e. 6, 7, 9, 11, 12, 13, 15 , when developing or updating policies that deal with mineral resources at German federal level.

10. Undertake and implement thorough Environmental Impact Assessments (EIAs) of extractive projects including the exploration licensing phase considering the indirect impacts of linear infrastructures.

Investors need to:

1. Define integrated environmental and social criteria or safeguards covering all steps in the mining value chain to be mandatory decision-making criteria in the investment or direct financing process.

2. Create tools that enable systematic analysis to determine which business practices contribute to staying within planetary boundaries and which don't.

3. Develop standards and policies for environmental risk analysis and impacts in internal decision-making processes.

Companies need to:

1. Identify their risks, impacts and responsibilities related to the mining and metals value chain.

2. Develop and implement company-specific strategies together with scientists, NGOs, government agencies and other stakeholders to improve Best Available Practices (BAP) and Best Available Techniques (BAT).

3. Demand supply chain due diligence from their suppliers to ensure mining standards are upheld.

4. Incorporate relevant Sustainable Development Goals (SDGs) such as SDGs 6, 7, 9, 11, 12, 13, 15[1] to guide business planning and management.

5. Seek to develop alternative sustainable sources such as urban mining.

6. Follow the principles of eco-design taking into account the environmental impact of products during their entire life cycle to facilitate their reuse, remanufacturing, recovery and ultimately, recycling.

7. Use renewable energy for their businesses.

8. Implement credible certification schemes, e.g. IRMA.

Consumers need to:

1. Reduce overall consumption of mineral resource-intensive products by choosing eco-friendly alternatives.

2. Inform themselves about the origin of products (incl. raw material production) and demand access to this information from companies if not easily available.

3. Demand sustainable solutions for all products and make changes to the products and services they buy.

4. Demand transparency from companies through various channels (including point-of-sale).

2. Introduction

Now that the global population has exceeded the 7 billion-mark, general awareness that human activities are greatly affecting the global environment is growing. By 2050, the world's population is expected to reach 9 billion, and the continuing global demand for a higher standard of living will put an unprecedented strain on natural resources limited by our planet's boundaries.

Planetary boundaries represent a set of nine thresholds within which humanity could continue to develop and thrive. The nine planetary boundaries are: stratospheric ozone depletion, loss of biosphere integrity (biodiversity loss and extinctions), chemical pollution and the release of novel entities, climate change, ocean acidification, freshwater consumption and the global hydrological cycle, land system change, nitrogen and phosphorus flows to the biosphere and oceans and atmospheric aerosol loading[2].

Over the last 70 years, the impact of human activity on the natural processes of the Earth's biophysical systems has reached the point where we have started to cross certain planetary boundaries.

Anthropogenic climate change, mass biodiversity extinction or over-abstraction of local water resources increases the risk of irreversible change to the global environment, with potentially grave consequences for humanity. A global transformation in the direction of sustainable development, aligned within the planetary boundaries, is imperative in order to counteract this process[3].

Steel and aluminium are two important metals in our civilisation, integral to products such as cars, airplanes, buildings, turbines for electricity generation and household and electronic appliances, without which our everyday lives as we know them would not be possible[4]. The mining and metals industry is central to the development of any economy and society. As a provider of essential raw materials, it is connected to almost every industry value chain and generates trade, employment and economic income.

Steel and aluminium are common metals used in car manufacturing.

A growing global population, rapidly growing economies in China and developing nations and the advancement of electronic or low-carbon energy and mobility technologies are spurring the demand for metals[5].

Climate change is one of the biggest challenges humankind is facing today. The shift towards a global low-carbon economy requires a large-scale transition involving the implementation of renewable energy technologies. The renewable energy technologies available today are much more resource intensive than energy systems for fossil fuels. Lithium, tantalum and rare earth metals are prominent examples of mineral resources experiencing increased demand as a result of technological advances and renewable energy[6]. However, the need to build massive numbers of large structures, e.g. for wind or solar power generation, will also require considerable amounts of steel and aluminium[7]. The success of the German "Energiewende", or energy transition, will therefore also be highly reliant on these minerals. As a result, they are central to the success of meeting the demand of global development in a more sustainable world.

More and more metal exploration and production are intensifying pressure on the environment and high-value biodiversity areas along the entire supply chain. At mining sites, primary natural habitat is destroyed and drainage from sludge retention ponds and mine dumps poisons soils and groundwater. The steps of separating the mineral from the ore and subsequent purification and processing are highly energy intensive and therefore emit high levels of carbon dioxide (CO_2) and contribute to climate change. The share of raw material imported by the German metal production and processing industries is over 60%[8], making Germany one of the drivers of this increasing pressure.

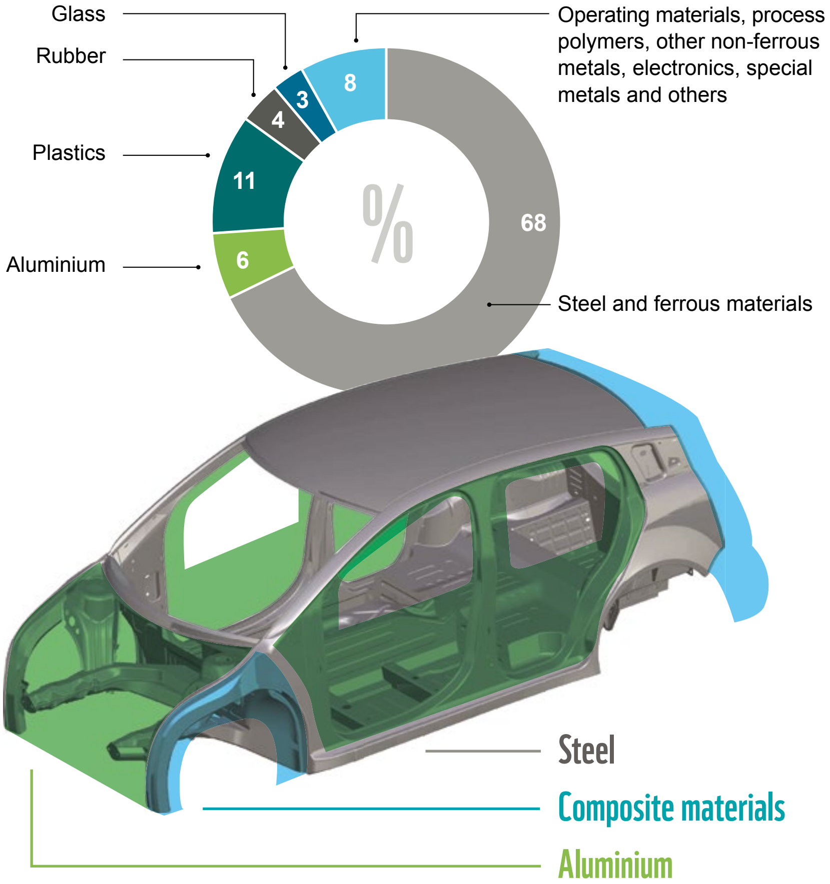
Germany is the world's third-largest user of primary aluminium and around 40% of its aluminium production is channelled into export goods.

Germany is the world's fourth-largest economy and the automotive and mechanical engineering industries are its backbone[9]. Vehicles and automotive parts are Germany's most important export commodity (EUR 407 billion in turnover in 2016[10] or 18.9% of the total export value in 2015), followed by machines (EUR 219 billion in turnover in 2016 or 14.1% of the total export value in 2015)[11]. For both industry sectors, aluminium and steel are essential raw materials that are imported either as ore, primary metal or intermediates or as secondary (recycled) metal[12]. Germany is the world's third-largest user of primary aluminium and around 40% of its aluminium production is channelled into export goods[13, 14].

The environmental impacts of metal production along the supply chain and over the life cycle, such as its contribution to climate change, water depletion, soil degradation or biodiversity loss, have been studied and described in many different scientific publications[15]. A number of organisations and publications draw attention to human rights violations in mines and the negative impacts of mining on local livelihoods[16]. Industry associations, civil society organisations, academia and mining companies are all aware of the challenge and necessity of mining and sourcing metals in a more responsible way, responding to pressure from stakeholders, policymakers and civil society[17]. Mineral industry associations stipulating voluntary best practice guidelines and stewardship standards are currently being developed[18].

From a policy standpoint, the metal resource strategies of the German federal government focus on securing a long-term supply for the German economy, which is crucial for an economy so dependent on metal imports. The issue of the environmental and social impacts of metal extraction and production, however, are not prioritised or adequately addressed; they are acknowledged to exist but are left for

Fig. 1:
Material composition of an average car.
Sources: Hagemann & Partner (2017), Booz & Company (2010).



development cooperation programmes to deal with[19]. The government does not assume responsibility for ensuring that German companies operating or investing in or sourcing from other countries abide by their laws or make sure that best practices regarding environmental management and human rights are in place[20].

For the minerals tin, tungsten, tantalum and gold (3TG), the European Parliament adopted a regulation in 2017 which stipulated that all companies that import these minerals from conflict-prone regions into the European Union will be required by law to present due diligence certification of their supply chains from 2021 onwards[21]. This regulation is less ambitious than the draft presented by the European Parliament in 2015 and includes various loopholes that allow companies to bypass their obligations. For example, it does not apply to imports below a minimum amount of mineral and is limited to four minerals while there are a number of other minerals that are also mined in precarious social and environmental conditions[22].

A large amount of information is available on the environmental effects along the supply chains of some critical consumer goods and commodities, such as conflict minerals[23] in cell phones, plastic, fossil fuels, textiles and many others. Consumer awareness of these issues is quite high. However, although actors in the mining and metal production industries are well aware of them, the general public's awareness of environmental issues related to very common metals such as aluminium, steel, copper or silver, is relatively low. Even though there has been much research, little has been produced to explain the full environmental impact of the German industry's aluminium and steel supply chains to the broader public. Environmental constraints and the importance of aluminium and steel are simultaneously on the rise. It is therefore necessary more than ever before to raise awareness among companies, consumers, politicians and investors to highlight environmental impacts and risks along the supply chain to support the transition to a more sustainable global economy.

This study analyses the imports of raw materials for the aluminium- and steel-intensive sectors in Germany and highlights their environmental impact at mining sites and during the production processes. It then identifies possible pathways for companies and policymakers to assume responsibility for the environmental and social impacts of operations and to take action to avoid or mitigate these impacts. The last section calls upon investors, companies, consumers and the German government to contribute to reducing the negative environmental and social impacts of the industries that use German aluminium and steel.

While we present a comprehensive overview, we cannot claim to address the entire range of issues and possibilities. For instance, the environmental impacts of product production are as diverse as the products manufactured using steel and aluminium. It is not feasible to generally describe the impacts of the production phase within the scope of this report. In addition to what is outlined here, there are a myriad of possible future pathways for companies that go beyond the scope of this report; ranging from individual company initiatives on the ground that can make a difference to new and potentially disruptive developments (e.g. blockchain technology) that could be harnessed to improve transparency along the supply chain.

Mining and human rights

Around 75% of the world's poor population lives in countries rich in extractive resources[24]. While the extractive industries are widely promoted as central to alleviating poverty and generating economic growth in developing countries, the term "resource curse" was actually coined to describe the paradox that countries with abundant natural resources tend to have lower economic growth, less democracy and more conflict than countries with fewer natural resources[25].

A vast number of human rights abuses and violations have been documented and reported from mining operations in developing countries all over the world. Just recently the Max Planck Foundation for International Peace and the Rule of Law analysed human right violations in the mining sector on a global scale in a report commissioned by the German Federal Institute for Geosciences and Natural Resources (BGR)[26]. A number of human rights organisations have deep insight into and expertise in this field and are working on improving working conditions for mine workers and affected local populations in developing countries. These organisations include, but are not limited to, Amnesty International[27], Oxfam[28], Global Witness[29], Misereor[30] or Powershift e.V.[31].

In most cases, environmental and social issues are closely linked. When mining operations jeopardise an entire watershed's water supply either through pollution or over-abstraction, this is not only an environmental problem but also threatens the water supply of local residents' homes, their livestock and agriculture. The United Nations Human Rights Council recently published a report describing the importance of ecosystem services and biodiversity for the full enjoyment of human rights: "Often the links between environmental defence and the enjoyment of human rights are clear, as when a community objects to a mine that would pollute its drinking water. But even people who protect components of ecosystems whose benefits to humans may be less obvious, such as endangered species (…), are still defending the biodiversity on which we all depend. They are also environmental human rights defenders, and they deserve our protection"[32].

3. Aluminium and steel production

3.1 Bauxite mining and aluminium production

The commercial use of aluminium dates back only about 150 years. However, it plays an important role in our everyday lives and is one of the most widely used metals in the transport, construction, packaging and digital industries. The three main properties that make aluminium so widely applicable are its low density, its mechanical properties (durability, flexibility, impermeability, thermal and electric conductivity) and its corrosion resistance[33].

Aluminium is the most common metal on the planet but, due to its chemical properties, does not occur naturally in its pure form. The most common raw material for primary aluminium is bauxite. About 90% of global bauxite supplies are found in a belt around the equator, with 73% in just five countries: Guinea, Brazil, Jamaica, Australia and India. Bauxite deposits are typically found in horizontal layers beneath the surface. It is usually extracted using a method called strip mining which is the process of removing a strip of overburden above the deposit and continuing along the length of the deposit dumping the waste behind the deposit.

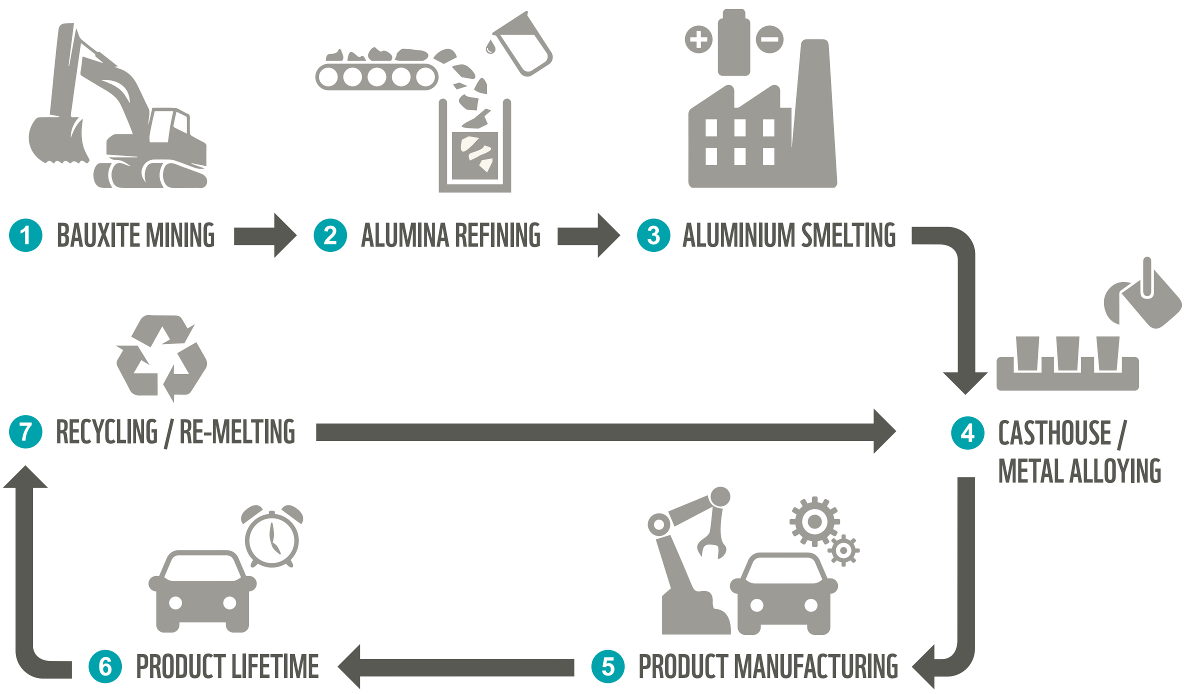


Fig. 2: Simplified diagram of the aluminium life cycle

After extraction of the ore, aluminium inside the bauxite is extracted into alumina (aluminium oxide, Al_2O_3) using what is known as the Bayer process. First the bauxite is ground and mixed with concentrated caustic soda and the mixture is heated. The aluminium hydrate contained in bauxite dissolves in caustic soda at high temperatures while the other elements do not dissolve or recrystallise at higher temperatures and thus can easily be filtered out when the mixture cools. This admixture, called red mud, is a waste product of the process. The crystallised aluminium hydrate is subsequently isolated, washed with water and dried to yield alumina[34].

In Germany, most aluminium (48%) is used in transport (vehicles), followed by construction (15%) and packaging (10%).

The refined alumina is processed into aluminium through electrolytic reduction in an aluminium smelter. Electric currents break the chemical bond between the aluminium and oxygen atoms, resulting in liquid aluminium. This process, called the Hall-Heroult process, requires huge amounts of electricity: In 2013, 3% of global electricity and 7.4% of industrial electricity were consumed by the aluminium industry[35]. This is why aluminium smelters are always built in the vicinity of power plants.

Depending on how the aluminium will be used in the future, it is then cast into billets, ingots, slabs or billets. which are then further processed. In Germany, most aluminium (48%) is used in transport (vehicles), followed by construction (15%) and packaging (10%)[36].

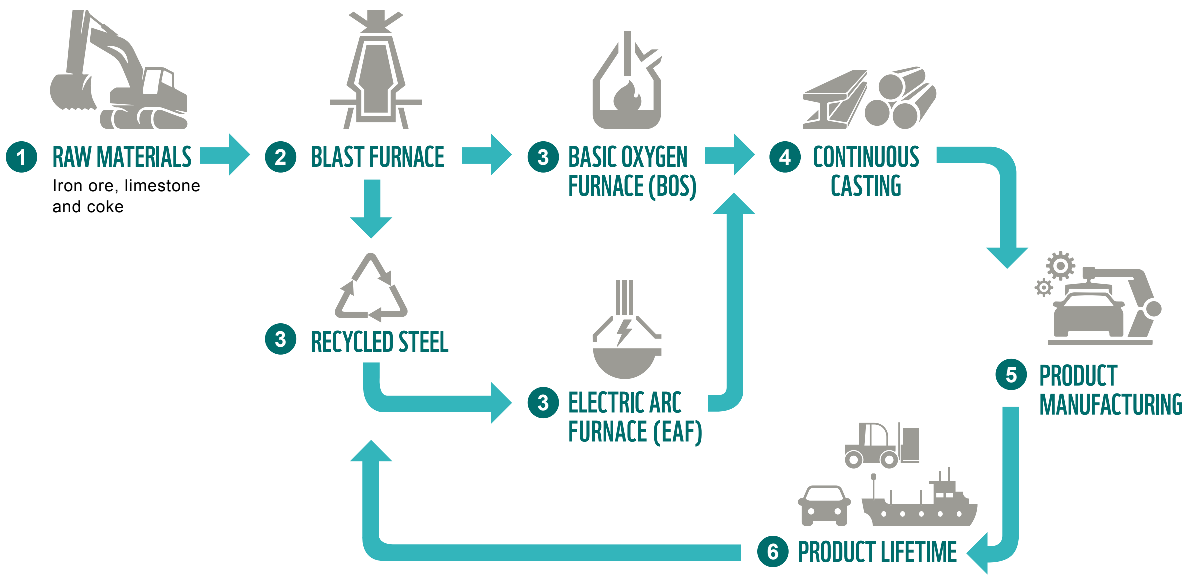
Aluminium can be recycled over and over without losing any of its characteristics or quality. Recycling aluminium to produce secondary aluminium only uses 5% of the energy needed to produce primary aluminium.

3.2 Iron ore mining and steel production

Steel is an alloy of iron and other elements, primarily carbon. Pure iron is relatively soft, but impurities such as carbon (0.002% to 2.1% content) can make it up to 1,000 times harder, yielding steel. Because of its high strength and low cost, it is today the most commonly used metal and has thousands of applications, including in buildings, infrastructure, tools, ships, automobiles, machines, appliances and weapons. Humans have been making steel since antiquity. Industrial steel production began in the second half of the 19thcentury and became a driving force of the Industrial Revolution. Modern steel production is based on the principles of the Bessemer process which involves the use of oxygen to remove carbon from molten iron.

Iron is the most common element on Earth. Mining iron ore is a low-margin and capital-intensive business and thereby only profitable on a large scale. Conse-

Fig. 3:
Simplified diagram of the steel life cycle



quently, the iron ore mining industry is limited to a few global players. Most iron ore is extracted in open-cast mines in Australia and Brazil. The average iron content for high-grade ores is 60% to 65%[37].

Two distinct processes make up the bulk of commercial steel production: basic oxygen steelmaking (BOS) and electric arc furnace (EAF). BOS is the most common, accounting for about three quarters of all the steel produced globally and around 70% of German steel production[38]. In this process, the ore is first smelted with coke, a derivative of coal, in a blast furnace. Carbon is removed from the resulting pig iron by mixing the molten iron with scrap iron and blowing it with oxygen to turn it into steel. Oxygen steelmaking is fuelled predominantly by the chemical reactions inside the vessel. This steelmaking method, on average, uses 1,400 kg of iron ore, 800 kg of coal, 300 kg of limestone and 120 kg of recycled steel to produce 1,000 kg of crude steel[39].

In EAF steelmaking, recycled steel scrap is the main input along with electrical energy to melt it down. The EAF operates on the basis of an electrical charge between two electrodes providing the heat for the process.

Before molten steel can be rolled or formed into finished products, it is made into semi-finished casting products which are available in standard shapes called billets, blooms or slabs, by a process called continuous casting. The casting products are then further processed through various manufacturing processes such as forging, extrusion and forming.

Finally, when steel products reach their end of life they are recovered and recycled. Like aluminium, steel is 100% recyclable and loses none of its properties in the process. Recycled steel scrap is used in both of the BOF and EAF steel production processes, making it the most recycled material in the world. It is estimated that around 80% of all globally produced steel is recycled[40].

A worker supervises the flow of hot liquid metal as it flows from the blast furnace during the iron smelting process at a plant in Russia.

Rolled aluminium can be presented in several forms including sheets, plates and foils, and is used in many industries adding to the flexibility and its position as a critical material for modern applications.

4. Aluminium and steel in the German economy

In 2016, Germany was the largest importer of iron and steel products and the second-largest importer of aluminium worldwide[41]. At the same time, Germany is the third-largest export economy, the biggest exporter of automobiles and among the top three exporters of machines, tools, aluminium, iron and aluminium products, locomotives and railway tracks, weapons and even air and spacecrafts[42]. In 2016, it was ranked the second-largest exporter of iron and steel products and of aluminium and aluminium goods second only to China[43].

	Imported value (in EUR millions)			Exported value (in EUR millions)			
Countries	**Bauxite**	**Unwrought aluminium**	**Aluminium and aluminium products (including semis)**	**Aluminium semis**	**Machinery, mechanical appliances, nuclear reactors, boilers**	**Electrical machinery and equip-ment**	**Vehicles other than railway or tramway**
World	3,553	41,816	16,313	66,586	1,699,888	2,085,908	1,218,689
Germany	98	4,415	15,124	8,825	201,643	124,451	220,831
USA	198	7,376	16,927	6,591	172,250	151,006	112,552
China	2,256			12,971	310,618	499,823	
Ireland	212						
Japan		3,891	6,255				128,124
Hong Kong						234,485	

Tab. 1: Overview of figures for Germany and the top 3 import and export countries of bauxite and selected aluminium products as well as commodities with high aluminium content, in 2016[47]. *Source: International Trade Statistics Trade Map, various datasets. Accessed 08.11.2017 and 04.12.2017.*

	Imported value (in EUR millions)				Exported value (in EUR millions)				
Countries	**Iron ore**	**Raw iron and steel**	**Iron and steel semis**	**Iron and steel products**	**Iron and steel semis**	**Iron and steel products**	**Machinery, mechan. appliances, nuclear reactors, boilers**	**Electrical machin-ery and equip-ment**	**Vehicles other than railway or tram**
World	76,384	47,216	231,835	238,985	225,327	234,139	1,699,888	2,085,908	1,218,689
Germany	2,206	2,630	18,190	19,101	16,651	25,653	201,643	124,451	220,831
USA		3,993	16,302	30,355		15,808	172,250	151,006	112,552
China	52,436	5,274				46,888	310,618	499,823	
Japan	6,640				19,580				128,124
Korea	3,662				16,162				
Turkey		4,245							
Italy			10,431						
France				8,823					
Hong Kong								234,485	

Tab. 2: *Overview of figures for Germany and the top 3 import and export countries of iron ore and selected iron and steel products as well as commodities with high iron and steel content in 2016[48]. Source: International Trade Statistics Trade Map, various datasets. Accessed 08.11.2017 and 04.12.2017.*

The share of imports of the German metal production and processing industries is high at over 60%, compared to an import share of 34.8% for all goods in 2015[44]. For metal ores, the share of imports is a staggering 99.7%[45]. As there has been no domestic mining of non-ferrous metals in Germany since 1992, and even though there is a high recycling rate of base metals in the German metal industry, a significant share of raw and intermediate materials had to be bought on the international commodities market in 2015[46]. The value created between the raw material and the finished product is enormous. Tables 1 and 2 show the dependence of the export-oriented German economy on imports of steel, aluminium and their ores.

4.1 Aluminium

4.1.1 …. in Germany

In 2016, Germany imported around 2.2 million t of bauxite and around 845,000 t of aluminium oxide (alumina) as input materials for the production of alumina and primary aluminium respectively, as well as over 2.7 million t of alloyed and unalloyed raw aluminium[49]. 52% of Germany's total aluminium production came from recycled (or secondary) aluminium in 2016[50].

Uses of aluminium in the Germany industry

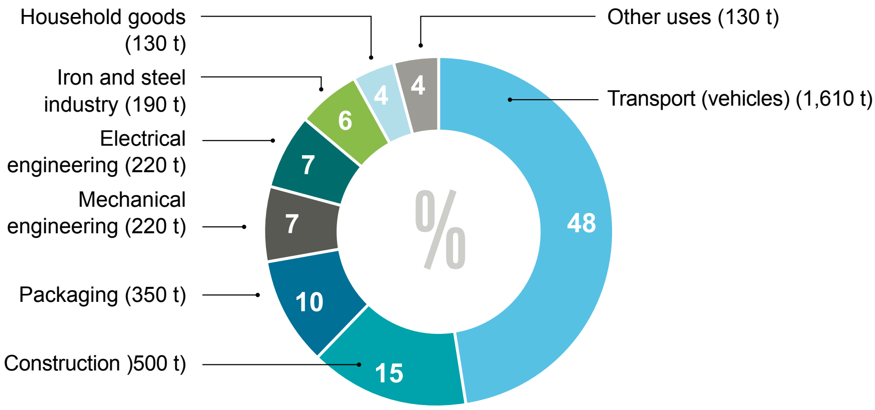


Fig. 4: Uses of aluminium in the German industry. *Source: adapted from WVM 2017a, p.7*

The primary origin of alumina imported to Germany is Jamaica, with 39%, followed by the Netherlands (19%), Ireland (17%), Spain (8%) and France (5%). Primary aluminium (alloyed and unalloyed) imports mainly came from the Netherlands (21%), the Russian Federation (15%), Norway (12%) and the United Kingdom (9%)[51].

In 2016, 546,806 t of aluminium were produced in four primary smelters in Germany, while 595,265 t of secondary aluminium were produced in the same year[53]. Three of the four aluminium smelters operating in Germany belong to the country's largest aluminium producer Trimet Aluminium SE. Trimet produces primary and secondary aluminium, cast aluminium products as well as automobile parts and components for the electrical and mechanical engineering industries.

The fourth and largest aluminium smelter in Germany, the Rheinwerk in Neuss, is operated by Norsk Hydro ASA, one of the biggest global players in the aluminium industry. Norsk Hydro also operates recycling plants and furnaces.

Origin of bauxite imported to Germany

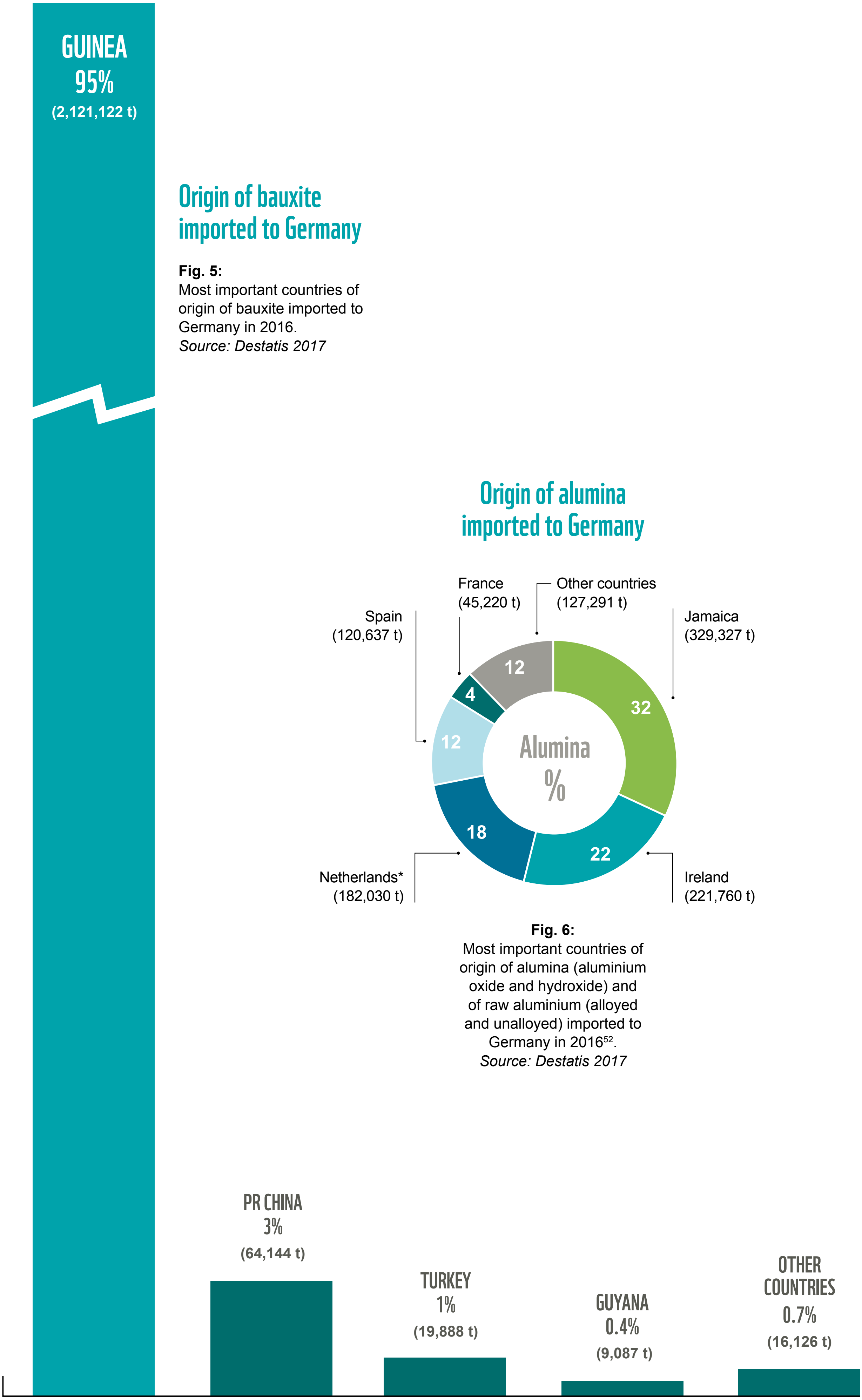


Fig. 5:
Most important countries of origin of bauxite imported to Germany in 2016.
Source: Destatis 2017

Origin of alumina imported to Germany

Fig. 6:
Most important countries of origin of alumina (aluminium oxide and hydroxide) and of raw aluminium (alloyed and unalloyed) imported to Germany in 2016[52].
Source: Destatis 2017

4.1.2 … and in the global context

While it is not the primary producer, Guinea has the world's largest reserves of bauxite, followed by Australia, Brazil, Vietnam, Jamaica and Indonesia. The top bauxite producing countries in 2016 were Australia, China, Brazil, India and Guinea[54].

Tab. 3: Important bauxite producing countries and their bauxite reserves in 2016. *Source: USGS 2017*

	Figures in million t	
Region	**Mine production 2016**	**Reserves**
Guinea	19.7	7,400
Australia	82	6,200
Brazil	34.5	2,600
Vietnam	1.5	2,100
Jamaica	8.5	2,000
Indonesia	1	1,000
China	65	980
Guyana	1.6	850
India	25	590

The exploration of Guinea's bauxite and iron ore reserves has been limited by the country's sustained political instability and lack of infrastructure. Additionally, the country's electricity sector is severely underdeveloped and does not meet the energy-intensive mining sector's requirements[55]. Just recently, bauxite mining activities had been repeatedly disrupted by riots due to protests against electricity cuts and a lack of jobs and services[56].

The global aluminium industry is dominated by a few large companies, and in keeping with China's growing role in the global aluminium sector, Chinese businesses are increasingly emerging as key players in this market. One third of the

Tab. 4: Top 10 bauxite mining and alumina and raw aluminium producing companies by volume (2016). Companies operating in more than one value chain segment are shown in different colours. *Sources: SNL 2017[59], Young et al. 2016, Rusal 2016.*

Bauxite		Alumina		Raw aluminium	
Company	**Production (million t)**	**Company**	**Production (million t)**	**Company**	**Production (million t)**
Rio Tinto (UK)	44.2	Chalco (China)	16.4	Hongquiao (China)	5.9
Alcoa (USA)	28.5	Xinfa (China)	12.6	RUSAL (Russia)	3.7
South32 (Australia)	17.2	RUSAL (Russia)	12.2	Rio Tinto (UK)	3.6
Alumina Ltd. (AWC) (Australia)	16.9	Hongquiao (China)	9.6	Xinfa (China)	3.2
Chalco (China)	13.5	Rio Tinto (UK	8.0	Chalco (China)	3.0
RUSAL (Russia)	12.0	Alcoa (USA)	7.7	EGA (UAE)	2.5
Norsk Hydro (Norway)	12.0	Norsk Hydro (Norway)	5.6	Alcoa (USA)	2.4
Government of Guinea	7.9	South 32 (Australia)	5.3	SPIC (China)	2.3
National Aluminium Co. (India)	7.3	Alumina Ltd. (AWC) (Australia)	5.1	East Hope (China)	2.1
Vale (Brazil)	6.6	Jingjiang Group (China)	4.8	Norsk Hydro (Norway)	2.1

upstream and midstream segments of the aluminium value chain are vertically integrated, meaning that the companies operating in these segments control more than one production process[57]. This is reflected in the ownership of the largest mine operators, alumina refineries and aluminium smelters, as many of the companies are big players in more than one value chain segment, as table 4 illustrates. Artisanal and small-scale mining (ASM) plays a negligible role in the aluminium sector[58]. Most of the world's largest bauxite mines are co-owned by multiple companies and private/public joint ventures.

4.2 Steel

4.2.1 … in Germany

Germany's demand for iron ore in 2016 was met solely by imports, amounting to around 41.3 million t[60]. In 2015, iron ore accounted for 89% of Germany's ore imports[61]. Coke imports amounted to 12.3 million t. 11. 7 million t of coke were used for German steel production in 2015[62]. Additionally, around 568,000 t of pig iron were imported as an input material for raw steel production. Crude iron and steel imports for further processing amounted to around 760,000 t and steel alloy imports to around 925,000 t. Imports of semi-manufactures were high, with 17.3 million t of iron and unalloyed steel semis, 4.2 million t alloyed steel semis and 2.1 million t of crude and semi-manufactured stainless steel[63]. 43% of Germany's total crude steel production came from recycled material in 2015[64].

Demand for steel by industry sector

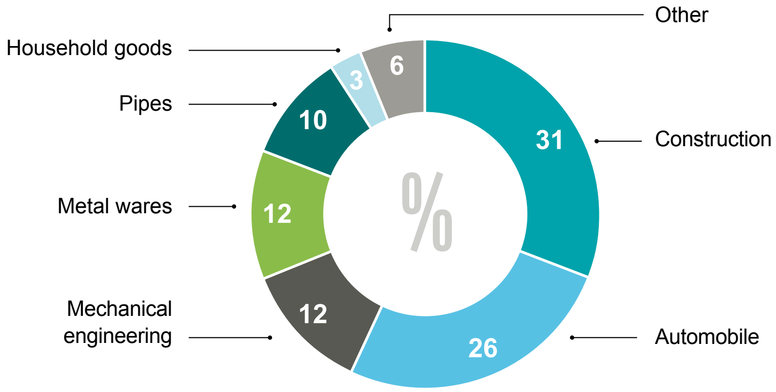


Fig. 7: Demand for steel in the German industry, by sector. *Source: adapted from WV Stahl 2017, p. 7.*

In 2016, Brazil provided Germany with 51% of its demand for iron ore, followed by Canada (17%), Sweden (13%), South Africa (7%) and Ukraine (4%)[65].

Coke imports came mainly from Australia (49%), the USA (24%), Canada (12%) and Russia (10%). Of the more than 55 million t of coal (also used for coke production) imported to Germany, 32% came from Russia and 20% from Colombia[66]. Colombia has South America's largest coal reserves.

While Brazil as the largest source of iron ore still plays a significant role as a source of pig iron (18%) and especially as a provider of unrolled semi-manufactured

Tab. 5:
Origin of iron ore imported to Germany and total production and reserves of source countries in 2016.
Source: Destatis 2017, USGS 2017.

	Figures in million t		
Region	**Iron ore imported to Germany**	**Total country production**	**Total country reserves**
Brazil	21.1	391	23,000
Canada	6.9	48	6,000
Sweden	5.5	25	3,500
South Africa	3.0	60	1,200
Ukraine	1.6	58	18,000
Other countries	3.2	1,648	118,300

steel (52%), the main source of semi-manufactured and stainless steel, especially rolled products, are countries in the European Union. In 2016, 17.3 million t of semi-manufactured steel and 2.1 million t of stainless steel were imported to Germany for further processing.

In 2015, Germany produced 30 million t of crude steel by BOS and 12.6 million t by EAF[67]. In 2015 Germany was the seventh-largest steel producer in the world after China, Japan, India, USA, Russia and Korea, while assuming first place in the EU before Italy and France and making up 25% of the EU's crude steel production[68].

Biggest crude steel producers in Germany in 2015

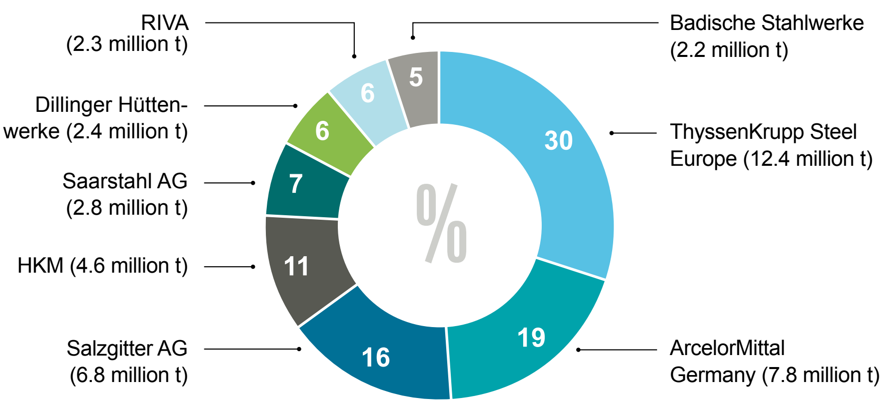


Fig. 8:
Biggest crude steel producers in Germany in 2015.
Source: adapted from WV Stahl 2017.

In 2015, 7.5 million t of high grade steel were produced in Germany[69]. High grade steels are alloyed or unalloyed steels of particular purity. Common alloy components are chromium, nickel, molybdenum, vanadium or manganese. These alloy metals provide them with specific properties, most notably corrosion, heat resistance and hardness.

Tab. 6:
Most common alloy metals used in high-grade steel production and the properties they add to the alloy. *Source: OECD 2012, BaP 2017.*

Alloy metal	Properties of steel
Tin	Protective coating for steel (food and drink cans)
Nickel	Corrosion (e.g. acid, saltwater) resistance in stainless steel
Zinc	Enhanced corrosion resistance
Molybdenum	Resistance to heat and corrosion Adds weldability to construction steel
Vanadium	Increased processability Adds extreme hardness to high-strength steel
Manganese	Increased strength
Tungsten	Adds extreme hardness to high-speed steel

4.2.2 … and in the global context

Global iron ore mine production in 2016 was 2,230 million t, while 1,150 million t of pig iron and 1,600 million tons of raw steel were produced[70].

Tab. 7:
Important iron ore, pig iron and raw steel producing countries and their iron ore reserves in 2016. *Source: USGS 2017, BGS Commodities & Statistics online tool (data for 2015)*

	Figures in million t			
2016	**Mine production**	**Reserves**	**Pig iron production**	**Raw steel production**
World	2,230	170,000	1,150	1,600
Australia	825	52,000	3.6*	4.9*
Brazil	391	23,000	25	30
China	353	21,000	685	800
India	160	8,100	62	83
Russia	100	25,000	52	70
South Africa	60	1,200	7*	7.6*
Ukraine	58	6,500	24	25
USA	41	3,000	23	80
South Korea	0.4*	No information	45	67
Germany	0.5*	No information	28	44
Japan	– *	No information	81	105

*) 2015

In 2016, the top 10 iron ore producing companies worldwide together produced 54% of the world's iron ore, while 28% of the world's steel was produced by the top 10 steel-making companies.

Although some companies in the steel industry are vertically integrated, like Arcelor Mittal or Tata Steel, vertical integration is far less pervasive in the steel sector than in the aluminium industry. Because iron ore mining is a low-margin business, iron ore mines are operated by a few large companies, while the steel production sector is more diversified.

In 2016, the top 10 iron ore producing companies worldwide together produced 54% of the world's iron ore, while 28% of the world's steel was produced by the top 10 steel-making companies (see table 8).

Tab. 8:
Global top 15 iron ore and steel producers and their production volumes in 2016.
Sources: USGS 2017, SNL 2017[71], World Steel Association 2017.

	Company	Iron ore production 2016 (million t)	Cumulative % of global production
	Global production	2,230.00	
1	Vale (Brazil)	346.2	15.5
2	Rio Tinto (UK)	262.8	27.3
3	BHP Billiton (Australia)	215.3	37
4	Fortescue Metals (Australia)	156.7	44
5	ArcelorMittal (Luxemburg)	49.6	46.2
6	Mitsui & Co. (Japan)	40.9	48
7	Metalloinvest (Russia)	37.3	49.7
8	Hancock Prospecting (Australia)	32	51.2
9	Kumba Iron Ore (South Africa)	31.2	52.6
10	Metinvest (Netherlands)	30.1	53.9
11	Luossavaara-Kiirunavaara (Sweden)	26.4	55.1
12	Cleveland-Cliffs (USA)	26.4	56.3
13	Companhia Siderúrgica Nacional (Brazil)	25.7	57.4
14	National Mineral Development Corporation (India)	25.3	58.6
15	Steel Authority of India (India)	22	59.6

	Company	Steel production 2016 (million t)	Cumulative % of global production
	Global production	1,600.00	
1	ArcelorMittal (Luxemburg)	95.5	6
2	China Baowu (China)	63.8	10
3	HBIS (China)	46.2	12.8
4	NSSMC (Japan)	46.2	15.7
5	POSCO (South Korea)	41.6	18.3
6	Shagang (China)	33.3	20.4
7	Ansteel (China)	33.2	22.5
8	JFE Steel (Japan)	30.3	24.4
9	Shougang (China)	26.8	26
10	Tata Steel (India)	24.5	27.5
11	Shandong Steel (China)	23	29
12	Nucor (USA)	22	30.3
13	Hyundai Steel (South Korea)	20.1	31.6
14	Maanshan Steel (China)	18.6	32.8
15	Thyssenkrupp (Germany)	17.2	33.8

5. Future outlook

5.1 Trends in the global steel and aluminium sectors

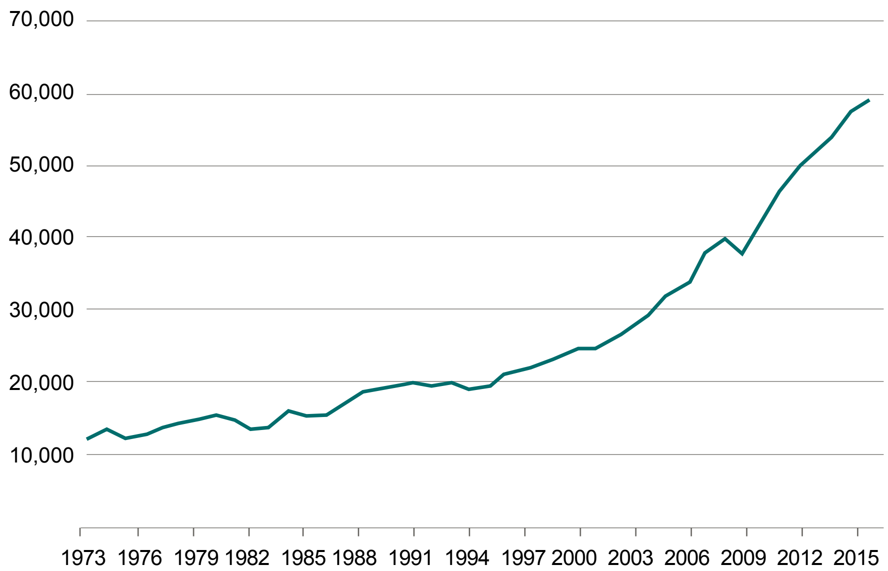
Steel production, just like the aluminium industry, has been skyrocketing since 2000, largely due to economic growth in developing countries, particularly in China. This trend is not likely to last and will probably not be repeated at the same pace in other developing countries[72].

The most common materials used for cladding on modern city builds are stainless steel and aluminium.

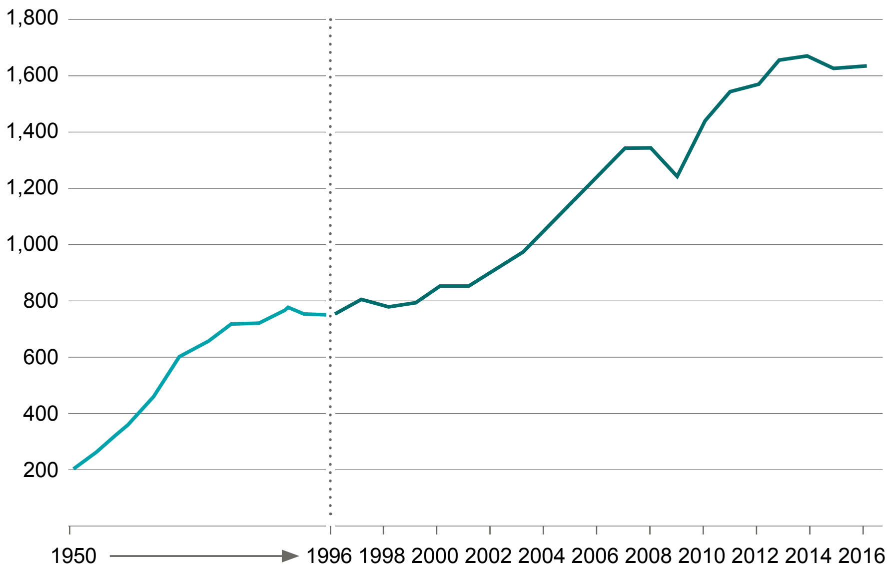
Recent years since 2015 have seen an oversupply on the raw steel market due to global overcapacity of steel mills. China has been heavily criticised for subsidising production in unprofitable steel mills. Steps have been taken to remedy the situation by closing smaller and unprofitable steel smelters in China[73]. However, due to a decline in domestic demand in China, some estimate that the oversupply will continue for at least a few years[74].

Fig. 9: Annual global steel production and primary aluminium production since 1950 and 1973. *Source: World Steel Association 2017, World Aluminium 2017.*

Global primary aluminium production



World steel production



Aluminium recycling rates are high at around 48% of secondary aluminium input into production in Germany[75] and 30% globally[76], the availability of recyclable material generally being the limiting factor. Global steel scrap input for crude steel production was 34%[77] in 2016. The World Steel Association estimates that 80% of recoverable and recyclable steel is being recycled every year, and global scrap availability is expected to increase in the medium and long term[78].

5.2 The role of steel and aluminium in mitigating the effects of global climate change

At the United Nations Climate Change Conference held in Paris in 2015, all 196 parties agreed to adopt an agreement for coordinated international efforts to tackle climate change, one of the biggest challenges of the 21st century. The Paris Agreement includes the long-term target to keep global temperature rise well below two degrees Celsius above pre-industrial levels or limit the temperature increase even further to 1.5 degrees Celsius[79]. To meet these goals, global GHG emissions will have to be reduced to at least 10% below 2010 levels by 2030 and 55% by 2050[80]. For Germany, this means reducing GHG emissions by 80% to 95% to achieve the goal of virtual climate neutrality by 2050[81].

In this context, the ambitious goal of Germany's "Energiewende", or energy transition, is the creation of an energy system based on 80% renewable energy by 2050[82]. This transition will have long-term impacts on the steel and aluminium industries in terms of demand, products and production processes.

In addition to energy-efficiency measures, a low-carbon society is based on the elimination of coal, the reduction of other non-renewable energy sources, the expansion of renewable energy sources in the electricity and transport sectors and eco-friendly production. The development of low-carbon technologies for wind and solar power and in the area of energy storage will have implications for the commodities market. Not only rare earths, but also aluminium, copper, silver, iron, lead and other materials will all potentially be affected by a massive shift to low-carbon technologies[83].

While the steel and aluminium sectors will play a crucial role in mitigating the effects of climate change, they are still major emitters of GHGs.

The trend towards a low-carbon society will affect steel-intensive sectors to varying degrees. In the energy production sector, the global shift to sustainable electricity will require the construction of vast numbers of wind turbines, solar power stations and other facilities. For an equivalent installed capacity, solar and wind facilities require up to 15 times more concrete, 90 times more aluminium, and 50 times more iron, copper and glass than conventional energy systems[84]. This implies a 5% to 18% annual increase in the global production of these metals for the next 40 years, while at the same time global demand for ferrous, base and minor metals is already increasing by about 5% per year[85].

It is thus evident that restructuring global energy systems and the shift to clean energy through advancing wind, solar, hydrogen and electricity technology systems required to meet the Paris climate target will be significantly more material intensive in their composition than traditional fossil fuel-based energy supply systems[86].

In the construction and automobile sector, demand for steel may decrease due to a trend towards lighter vehicles and buildings either through the use of lighter-weight materials or reducing the steel content of the design[87]. Improving energy efficiency in the transport sector is achieved through weight reductions and the use of lighter materials such as aluminium[88].

While the steel and aluminium sectors will play a crucial role in mitigating the effects of climate change, they are still major emitters of GHGs. If these industries are to benefit from a shift to alternative energy systems, scrutinising and overhauling their production processes should be an integral part of their mission.

5.3 Sourcing trends

If we look today at which resources are likely to be needed in the climate-friendly global economy of the future, it is clear that the production of primary aluminium and steel will increase. Even as recycling rates rise and more and more existing aluminium and steel is channelled back into production, the availability of scrap metal will continue to be limited. Mineral extraction is likely to increase and expand in existing mines and new mines will be opened and new sources explored.

Steel and aluminium are critical metals in the renewable energies production sector. Wind and solar energies for example require up to 90 times more aluminium than conventional energy systems.

Deep-sea mining
Unlike aluminium, iron ore is a candidate for deep-sea mining. Seabed mining puts fragile deep-sea ecosystems at risk that represent globally important biodiversity reservoirs and provide critical ecosystem services (e.g. carbon sequestration, nutrient cycle, habitats and nurseries for fisheries)[89]. In deep sea conditions, conventional mining mitigation processes are unlikely to be successful due to extremely slow recovery rates[90].

Even as recycling rates rise and more and more existing aluminium and steel is channelled back into production, the availability of scrap metal will continue to be limited.

By November 2017, the International Seabed Authority (ISA), which is responsible for managing mining in international waters, had entered into 15-year contracts with 27 contractors for mineral exploration in the international seabed area.[91]. Since 2006, Germany has held an exploration licence for manganese in the Pacific, and since 2015 for sulphides in the Indian Ocean[92]. In August 2017, New Zealand's Environmental Protection Authority approved the mining of iron sands from the seabed of South Taranaki Bight. The export of iron ore from the site to Asia is expected to start in 2020[93].

Urban mining

Urban mining is a concept promoted, among others, by the German Environmental Protection Agency, the Umweltbundesamt (UBA), as a strategy for underpinning the circular economy (see section 7.1.). Urban mining refers to the secondary extraction of recoverable resources from man-made objects, whether from construction, automobiles, electronic devices or deposits in landfills[94].

A prominent example is electronic waste, which contains large amounts of precious metals such as gold and silver, that is mostly thrown away. A study in 2012 found that the annual production of electronic goods worldwide required 320 t of gold and over 7,500 t of silver, with a combined value of US$ 21 billion, with only 15% of the total amount recovered[95].

Urban mining is also appealing because national resources (i.e. goods, buildings, etc.) can be exploited, thereby reducing dependence on imports for countries like Germany[96].

6. Environmental impacts along the supply chain

Section 3 gave an overview over the life cycles of aluminium and steel. A product's life cycle includes both the upstream and downstream segments of the supply chain. This means that the life cycle factors in the (upstream) production processes until the product leaves the factory also includes a product's (downstream) use and disposal phases along with it reuse and recycling phases. In addition to the upstream environmental impacts, the life cycle perspective makes it possible to identify downstream environmental (or social) impacts that are not caused by production or transport processes but may be influenced by product design, materials used, etc. It thus facilitates the process of identifying additional ways to reduce the environmental impacts of a company's business activities. The life cycle perspective is relevant for planning a circular economy (see section 7).

The main environmental impacts of mining or smelting are similar for many metals, including steel and aluminium.

In contrast, a conventional supply chain looks at the sequence of processes involved in a product's production and distribution but ignores its use and end-of-life phases. The following section focuses on the environmental impacts of the traditional upstream supply chains for aluminium and steel.

There are quantitative and qualitative differences in the environmental impacts of the aluminium and steel supply chains depending on the different materials and processes involved. However, the main environmental impacts of mining or smelting are similar for many metals, including steel and aluminium. The following sections describe and give an overview of some of the typical environmental impacts of the aluminium and steel supply chains, highlighting relevant differences where applicable.

GHG emissions

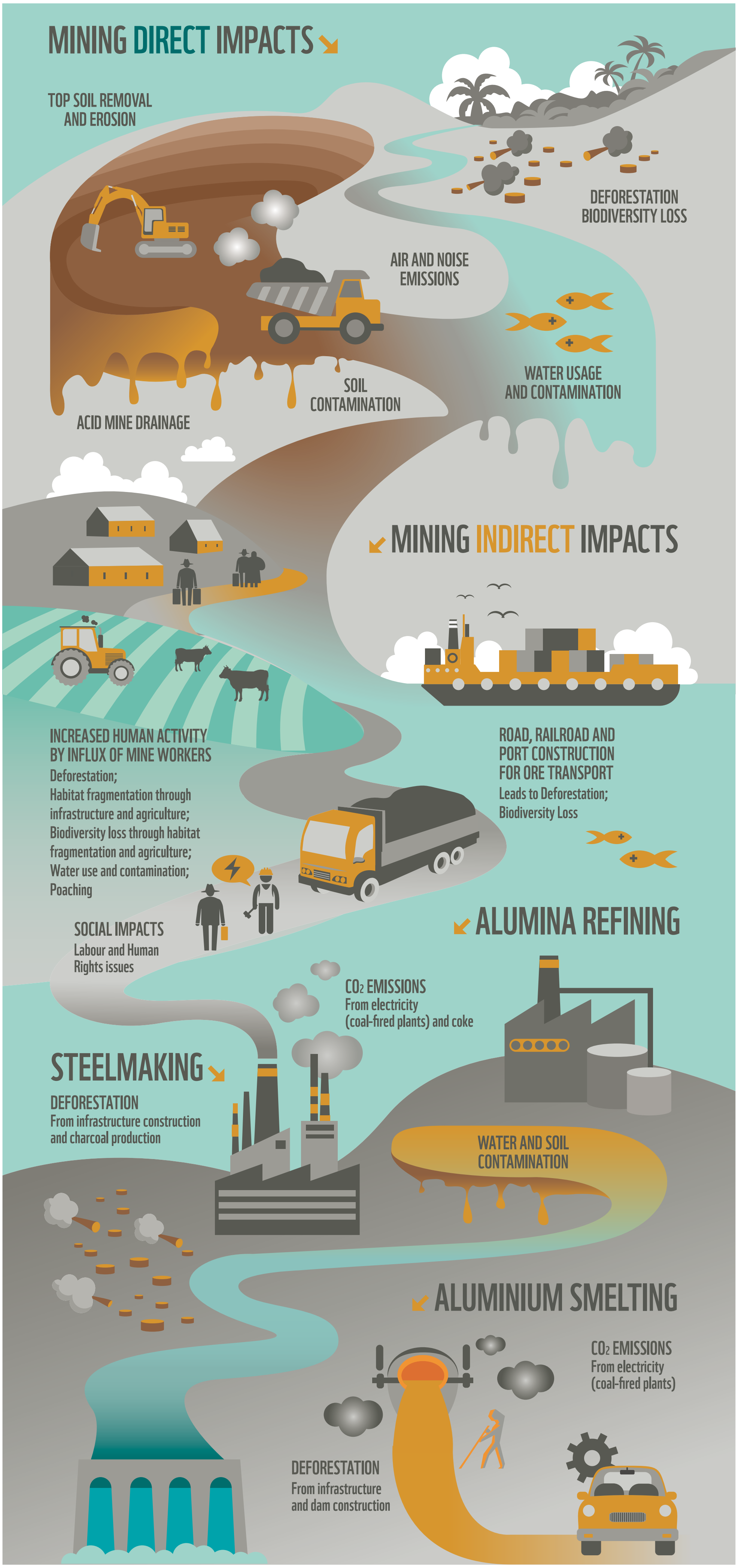
Energy is used directly and indirectly at every stage of the metal production process. Depending on the energy source, this generates CO_2 and other GHG emissions along the entire supply chain. The global primary aluminium industry was estimated to be responsible for 1% of global GHG emissions in 2008[97], while the steel industry, which is much larger by production volume, accounts for about 7% of global anthropogenic CO_2 emissions[98].

At the mining stage, fossil fuels power mine vehicles and energy is needed to operate conveyor belts to transport ore inside the mine. Transport of the ore from the mine to the refinery or smelter is usually also powered by fossil fuels. Refining and smelting processes consume large amounts of energy and electricity and thereby produce GHG emissions (see below). Finally, transport to the final processing stages and the production processes themselves use energy and thereby indirectly cause GHG emissions.

6.1 Direct impacts of mining

Large-scale mining projects have one of the biggest environmental impacts in the entire industrial world, often only surpassed by gigantic hydropower projects[99]. Humans have been mining for metals for millennia, and some mines opened in Roman times are still contaminating their environment today with acid mine drainage (AMD) (see below, ibid.).

Fig. 10:
Examples of the main environmental impacts along the steel and aluminium supply chains.



6.1.1 Water

Water is crucial to the mining industry and essential for mineral processing, metal recovery, cleaning, pumping and transportation, cooling and dust control. The mining industry is estimated to be responsible for around 2–4.5% of average national water use[100]. As high-grade iron ores are depleted, the industry increasingly extracts lower-grade ores which require larger amounts of water per tonne of ore extracted[101]. Mining activities affect both water quantity and quality to varying degrees, often depending on local conditions.

The mining industry is estimated to be responsible for around 2-4.5% of average national water use.

A mining project's impact on local and regional water supplies depends mainly on the climate and on competition with other water users. Water supplies for all users may be altered by groundwater extraction for mining activities because the groundwater table is lowered, ultimately contributing to aquifer depletion. Changes in surface permeability due to land clearance and surface mining may also lower the replenishment rates of groundwater as they can cause runoff and decrease seepage into the groundwater. Other mining activities that may alter runoff patterns and increase surface flows include dam construction, storm water management and river diversion[102].

In September 2017, Norsk Hydro warned customers of a shortfall in supplies of bauxite from the Brazilian Mineração Rio do Norte bauxite mine after the mine experienced problems with its tailing systems due to a water shortage in the wake of dry weather[103].

Mining operations can negatively affect water quality by discharging mine water into the environment, seepage of mine waste into ground and surface water, containment breaches or the release of uncontrolled stormwater, thereby contaminating water resources or even destroying aquatic habitats. Water pollution from mines can come in the form of suspended or dissolved solids or water acidification caused by acid mine drainage (AMD). Apart from the immediate effects such as dead fish, water pollution can have more far-reaching consequences including the contamination of the drinking water of downstream communities or even forest and wildlife habitat destruction in the long term.

Suspended solids in water usually originate from erosion of disturbed soil and alter or may even destroy aquatic habitats and are toxic for fish. Dissolved solids include heavy metals that are highly toxic to aquatic fauna and make their way up the food chain through bioaccumulation. They usually originate from AMD, mined ore and waste rock piles, tailing piles or contaminated water from the mine.

On 5 November 2015, a dam holding approximately 50 million cubic m of waste from iron mines, jointly owned by Vale and BHP Billliton, burst near the city of Mariana in Brazil's Minas Gerais state. The toxic sludge wiped out whole villages downstream, leaving 19 dead and suffocating 600 km of the Doce, one of Brazil's largest rivers outside the Amazon basin. In the Doce and two small rivers near the dam, the sludge destroyed plankton, algae, freshwater shrimp and other life forms - the base of the food chain. Speaking at the climate summit in Paris, Brazil's President Dilma Rousseff called the dam collapse "the worst environmental disaster in the history of Brazil."[104]

In February 2018, after flooding during a thunderstorm, red-coloured water leaked from a tailing dam of Alunorte, Brazil's largest alumina refinery belonging to Norsk Hydro. Contradicting the findings of a Brazilian government-backed investigation, Norsk Hydro denied that its alumina refinery had contaminated local waters with red mud. Authorities ordered the plant to cut its output in half until the issue was resolved; the process was ongoing in May 2018[105].

6.1.2 Biodiversity loss

Biodiversity loss as a direct and indirect consequence of mining activities is primarily linked to land clearance and the resulting deforestation and habitat loss in often pristine and untouched regions. the creation of protected areas (PAs) helps to reduce biodiversity loss and makes a major contribution to global conservation efforts. However, despite the fact that the total surface area of designated protected areas has steadily increased since 1970, the rate of biodiversity loss continues to increase dramatically.

A study from 2013 found that globally 0.14% of observed bauxite mines and 1.48% of iron ore mines overlapped with terrestrial PAs entered in the World Database on Protected Areas[106], the most comprehensive global database of protected areas which are categorised using IUCN designations. Globally, 0.63% of bauxite and 7.62% of iron ore mines were located within 10 km of a PA[107]. Looking at the regions relevant for supplying the German economy with raw materials, in Africa 1.53% of the bauxite mines overlap with PAs and 3.05% of them are within 10 km of one. 2.01% of South America's iron ore mines are inside a PA, and 9.23% are located within a 10-km radius of a PA[108]. When all metals are considered, 44% of Africa's major metal mines were inside a PA or within 10 km of one; in Asia and South America, the percentage was around 25%[109].

Another study in 2015 found that 38% of Natural World Heritage Sites (WHS) contained mining concessions, 22% oil and gas concessions and 5% mining operations. In total, 70 natural World Heritage sites, or 31%, have been identified with one or more forms of extractive activity within their boundaries[110].

Iron ore mine pit in the Pilbara region, one of the most active mining area in Western Australia.

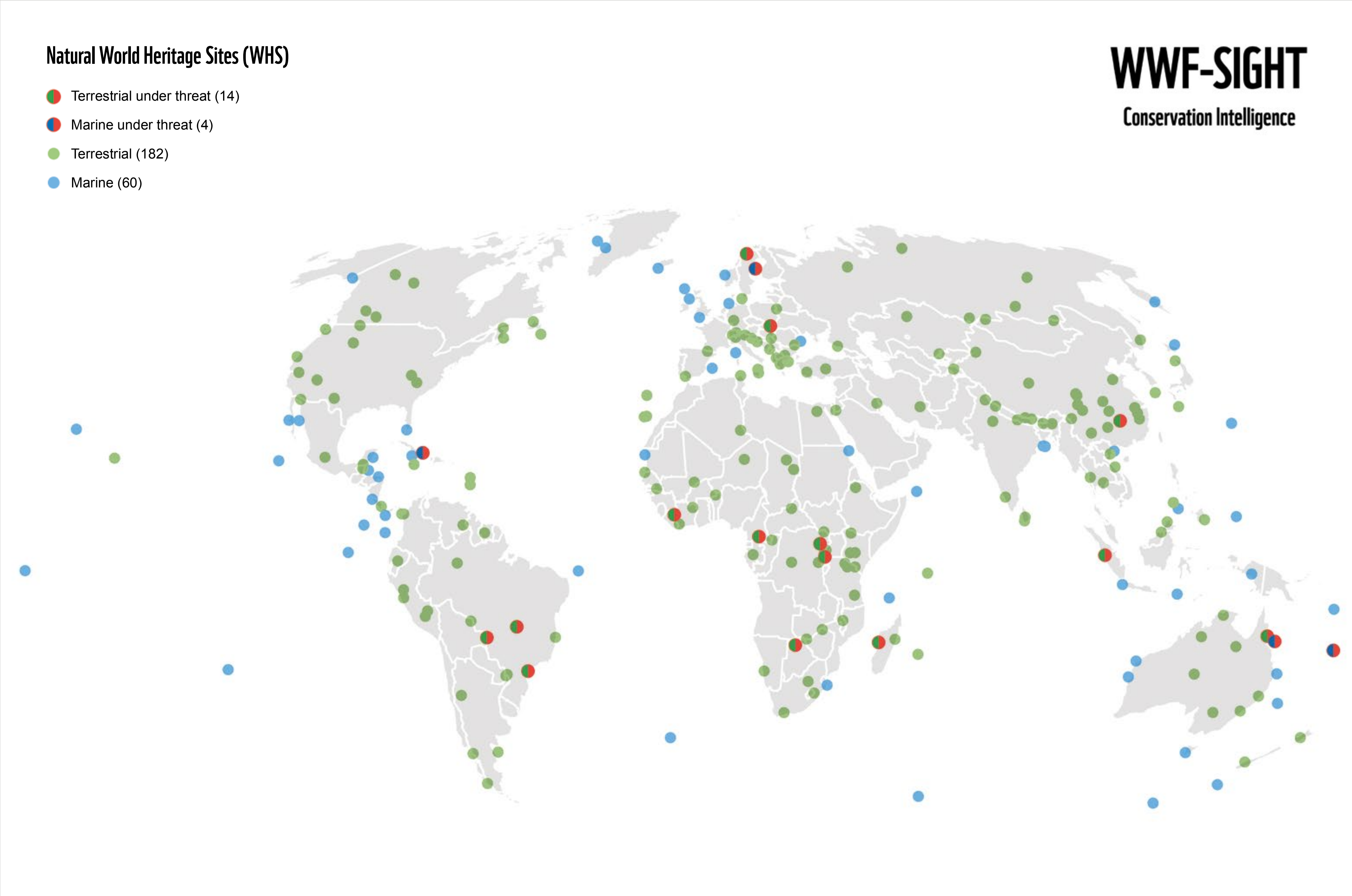


Fig. 11: Iron ore and bauxite projects and concessions that overlap with WHS[112]. Source: WWF-Sight Conservation Intelligence 2018

Data from 2018 in Figure 11 shows that of the 242 WHS, 18 are currently under threat or impacted by bauxite or iron ore extractive projects and concessions in the world[111].

PAs often tend to be located at higher elevations, with steeper slopes, lower primary productivity and/or lower economic value[113], or in other words, in parts of the landscape that are a priori unlikely to face land conversion pressures even in the absence of protection[114]. Like PAs, ore deposits for some key metals also tend to be located in less accessible areas and at high altitudes. Increasing demand for metals and rising prices are pushing mining activities into previously unmined regions, many of them with remarkably levels of high biodiversity. Mining activities have proven to be a real threat to a number of PAs and are a driver for downsizing, downgrading and degazettement of PAs[115]. For example, the Mount Nimba Biosphere Reserve, a World Heritage Site In the Republic of Guinea, the Mount Nimba Biosphere Reserve, a World Heritage Site located on the borders of Guinea, Liberia and Côte d'Ivoire, was downsized by 1,550 ha to allow for iron-ore prospecting[116].

In 2012, the government of Guinea issued mining licences for 115,260 square km of its total national territory of 245,860 square km[117]. According to Guinea's National Directorate of Water and Forests, PAs cover at least 115,000 square km of the national territory[118]. According to this calculation, 131,000 square km of Guinea's national territory are not protected, an area not very much larger than the area designated for mining. Overlaps between PAs and mining concessions are thus very likely.

In Brazil, the Carajás iron ore mine is the largest in the world. In 2017, the operator, Vale, opened the S11D iron ore mine just 50km south of the Carajás mine, planning to double the company's iron ore production. Both mines are located within the Carajás National Forest. The company's activities, which include mining for copper, manganese and gold, take up 3% of the nearly 4,000 square km of the national forest's area[119]. Research in 2014 found that in the Amazon alone, 34,117 square km of strictly protected areas and 281,443 square km of indigenous lands were in areas of registered mining interest - an area larger than the United Kingdom[120].

As metal ore prospecting activities are intensifying in the deep-sea bed, the conflict between mining activities and biodiversity conservation is also likely to extend into marine PAs in the future.

The 11 deforestation fronts

Half of the world's tropical forests have been destroyed over the last century. If business as usual continues, up to 170 million ha of additional deforestation will occur by 2030 according to the WWF Living Forests model, and large areas of remaining forest will continue to be degraded. Most of this deforestation will happen in 11 deforestation fronts, places that will account for over 80%of the forest loss projected globally by 2030. Deforestation rates in the Amazon have declined over the last decade but continue at an alarming rate. Today, this area still accounts for the biggest deforestation front in the world. Brazil is responsible for half of the deforestation in the Amazon, but deforestation in the Andean Amazon countries – namely Bolivia and Peru – is on the rise.

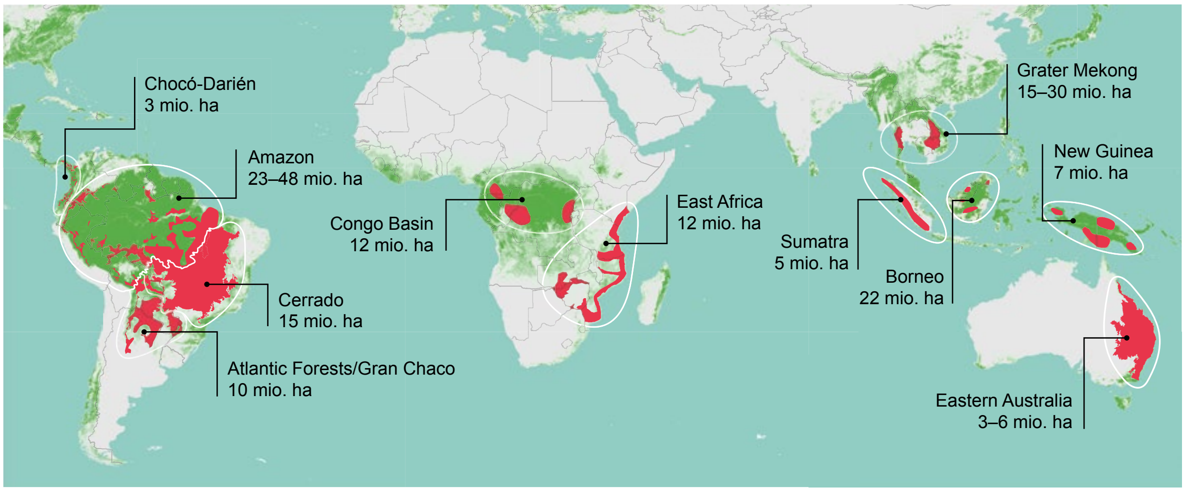


Fig. 12:
The 11 deforestation fronts with projected losses, 2010-2030, 2015 WWF Living Forest Report

Protected areas

Protected areas (PA) are areas that receive protection because of their recognised natural, ecological or cultural value. PAs are essential for biodiversity conservation and to maintain functioning natural ecosystems, to serve as a refuge for species and to maintain ecological processes that cannot survive in the most intensely managed landscapes[121].

The International Union for Conservation of Nature (IUCN) classifies six categories of protected areas according to their management objectives:

1. **Ia Strict Nature Reserve:** strictly protected areas set aside to protect biodiversity and also possibly geological/geomorphological features, where human visitation, use and impacts are strictly controlled and limited to ensure protection of the conservation values.
2. **Ib Wilderness Area:** large unmodified or slightly modified areas, retaining their natural character and influence without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition.
3. **II National Park:** large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible, spiritual, scientific, educational, recreational and visitor opportunities.
4. **III Natural Monument or Feature:** set aside to protect a specific natural monument, which can be a landform, sea mount, submarine cavern, geological feature such as a cave or even a living feature such as an ancient grove. They are generally quite small protected areas and often have high visitor value.
5. **IV Habitat/Species Management Area:** aim to protect particular species or habitats and management reflects this priority. Many Category IV protected areas will need regular, active interventions to address the requirements of particular species or to maintain habitats.
6. **V Protected Landscape/ Seascape:** an area where the interaction of people and nature over time has produced an area of distinct character with significant, ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values.
7. **VI Protected area with sustainable use of natural resources:** conserve ecosystems and habitats together with associated cultural values and traditional natural resource management systems. They are generally large, with most of the area in a natural condition, where a proportion is under sustainable natural resource management and where low-level non-industrial use of natural resources compatible with nature conservation is seen as one of the main aims of the area.

Additionally, there are a number of other criteria and definitions for classifying areas valuable for conservation. Depending on the conservation focus, these are, among others:

8. **High Conservation Value Areas (HCVA):** natural habitats of outstanding significance or critical importance due to their high biological, ecological, social or cultural values that need appropriate management to maintain or enhance those identified values. The concept was originally developed for use in forest management certification, but the scope was later widened from "HCV Forest" to "HCV Area" (HCVA). It is now a keystone principle of sustainability standards for palm oil, soy, sugar, biofuels and carbon, as well as being widely used for landscape mapping, conservation and natural resource planning and advocacy.
9. **Key Biodiversity Areas (KBA):** sites contributing significantly to the global persistence of biodiversity. KBAs represent the most important sites for biodiversity conservation worldwide and are identified nationally using globally standardised criteria and thresholds. They present an important approach to national gap analyses and prioritisation to increase effectiveness and establishment of protected areas. KBAs are an "umbrella" designation including, among others, Important Bird and Biodiversity Areas (IBAs), Important Plant Areas, (IPAs), Important Sites for Freshwater Biodiversity, or Alliance for Zero Extinction (AZE) sites.
10. **Ramsar Sites:** a wetland site designated of international importance under the Ramsar Convention (Convention on Wetlands)
11. **World Heritage Sites (WHS):** landmarks or areas selected by the United Nations Educational, Scientific and Cultural Organization (UNESCO) as having cultural, historical, scientific or other form of significance, and legally protected by international treaties. The sites are judged important to the collective interests of humanity and are intended for practical conservation for posterity.
12. **Indigenous and community conserved area (ICCA):** defined by the IUCN as "natural and/or modified ecosystems containing significant biodiversity values and ecological services, voluntarily conserved by (sedentary and mobile) indigenous and local communities, through customary laws or other effective means". There are also a number of national laws that recognise the right of indigenous peoples to manage and/or own their own lands, such as Indigenous Protected Areas in Australia, or Indigenous Territories (terras indígenas) in Brazil.

6.1.3 Soil

Soil contamination is an ongoing problem that affects active mines and can persist long after mine remediation. Mining involves the excavation of massive amounts of underground materials and bringing them to the surface. These materials, which can contain heavy metals and other pollutants, can potentially contaminate surface soil. Mining waste products such as tailings, waste rock, slag and mud are usually stored in open-air piles or tailing ponds. Large areas of land can become contaminated when tailing ponds collapse or leak or waste piles erode or are mismanaged. Soil contamination can also occur as a consequence of erosion, waste disposal or mine water, which affects vegetation, wildlife and livelihoods.

Bauxite and iron ore are usually mined from the surface in open-cast mines which requires the large-scale removal of vegetation and topsoil and leaves wide areas of the landscape deforested. This complete loss of habitat and ecosystem disruption can devastate large areas of natural landscape, resulting in a direct loss of biodiversity and habitat fragmentation. The stripping ratio refers to the ratio of the volume of overburden (waste material such as topsoil and non-ore-bearing rock) required to be handled in order to extract one tonne of ore. The volume of overburden varies depending on factors such as ore depth and quality. For high-quality iron ore mines, the stripping ratio may be as high as 6 or 7, while for low-grade ores, a ratio of 1.5 is often considered the economic limit[122].

In India, the typical stripping ratio for bauxite is 1.2 while for Australian bauxite it is on average 0.1[123].

The coke used for iron reduction is produced from coal. The coal mining method depends on the depth and quality of the coal seam and can be operated on the surface or underground. Underground mining currently accounts for a larger share of world coal production than open-cast mining[124]. The stripping ratio of open-cast mining is higher than for underground coal mining.

The Bento Rodrigues dam disaster occurred on 5 November 2015, when an iron ore tailings dam in Mariana, Minas Gerais in Brazil, suffered a catastrophic failure. It has been described as the worst environmental disaster in Brazil's history as around 60 million cubic meters of iron waste flowed into the Doce River, causing toxic brown mudflows to pollute the river and beaches around.

The loss of topsoil or its dilution due to mixing with overburden can lead to the loss of beneficial microbial communities, thus hindering rehabilitation efforts[125]. Rehabilitation to pre-mining conditions is not possible; studies have shown that plant species diversity is significantly lower in reclaimed areas, beneficial microbial and fungal biomass in reclaimed soils has decreased and the availability of important plant nutrients is lowered[126].

Mining activities often exacerbate soil erosion. Wind erosion can result in air quality problems through dust creation, while rainwater runoff or drainage from stockpiles, waste dumps or exposed tailings can cause high sediment loads in surface waters, negatively affecting aquatic species.

6.1.4 Acid mine drainage

AMD is one of the major environmental issues related to mining. AMD is an accelerated natural process whereby sulphide minerals commonly found in ore deposits oxidise when they are exposed to air and water. This process creates acidic conditions in which metals and other geologic materials dissolve. This acidic water contaminated with metal then seeps into waterways and the groundwater, potentially rendering them toxic[127].

According to Buxton, there has been little advancement on environmental issues surrounding legacy sites where legal responsibility is unclear[128]. For example, a May 2017 New South Wales Audit Office report confirmed that Australian taxpayers continue to carry the long-term risk for contamination events at former mine sites[129] despite regulations for mine rehabilitation. Similarly, in South Africa, although legislation stipulates that all mining operations in the country be required to make provisions for environmental rehabilitation during the life of the mine and at closure, very few companies actually abide by such regulations and can do so with impunity[130].

6.1.5 Emissions

Air emissions
Air emissions from mining activities can be gaseous or particulate and their effect can be felt not only in the immediately surrounding areas, but at regional or even global level. Gaseous emissions from mining activities include sulphur and nitrogen oxides, carbon oxides or methane and usually originate from mining equipment and processes, such as diesel motors or blasting. Some gaseous pollutants, such as methane, can originate from the mineral deposits themselves[131]. Particulate emissions resulting from land clearance, excavation, ore crushing or transport pose the majority of air quality problems at the mining site[132].

In 2014, after the Indonesian government issued a bauxite export ban, Malaysia became the primary source of bauxite for China within 18 months. Mining companies offered farmers large sums in return for mining rights to their land. Red dust from adjacent mining operations eventually killed the orchards of farmers who continued farming their land[133].

In the eastern Amazon, local residents suffer from iron ore dust emitted by the smelters around the Carajás mine[134].

During coal extraction, large quantities of coal dust are emitted and can contribute to air pollution when filter systems are not in place or not sufficient. In 2011, researchers studying coal mine workers in northern Colombia found that coal dust could have carcinogenic effects on humans[135].

Noise emissions
A number of processes in mining operations generate considerable noise, e. g. overburden removal, drilling and blasting, excavating, crushing, loading and unloading, vehicular traffic and the use of generators. Noise pollution receives little attention, however. It is disruptive to wildlife species because it reduces habitat quality, increases stress levels and masks other sounds. It is particularly harmful to species that rely on sound for communication, such as bird species, or hunting, such as bats. Noise pollution often exacerbates the problems associated with habitat destruction and fragmentation[136].

6.2 Indirect environmental impacts of mining

The direct impacts of mining activities indirectly cause changes in land-use patterns locally, which in turn have further environmental, economic and social implications. Indirect impacts include the migration of mine workers to areas with newly opened mines, which brings about additional land-use changes due to logging, pasture use, agricultural development and water abstraction. This leads to additional habitat fragmentation and loss of wildlife species. Hunting by families of mine workers puts additional strain on wildlife populations. The impacts of a mine extend far beyond its direct vicinity. Associated infrastructure such as roads, railways, dams and power lines that have to be built in previously pristine landscapes facilitate access and migration to former wilderness areas.

6.2.1 Deforestation

Five Amazon countries – Brazil, Peru, Colombia, Bolivia, and Suriname – account for considerable quantities of the world's production of bauxite (14%) and iron ore (14%). Production of iron ore and bauxite is especially significant in the Brazilian Amazon biome, particularly the state of Pará[137]. 60% of mining leases, concessions and exploration permits in Brazil are located in the Amazon forest. A recent study found that indirect mining-related deforestation is 12 times greater than deforestation that occurs on land leased for mining alone and has caused 9% of all deforestation in Brazil's Amazon forest since 2005[138].

In 2014, a study showed that 95% of deforestation was within 5.5 km of a road or 1 km of a navigable river; and 35.2% of the Brazilian Amazon was highly accessible by river or road. The study estimated that in the Brazilian Amazon alone, the road and highway network is over 264,068 km, with 72% dirt roads and 8.6% highways[139]. Deforestation along the rapidly expanding network of highways and local roads has created a unique fishbone pattern. While the fishbone effect of official roads can be seen in Google Earth images, there may be other unofficial roads in areas that are not picked up by remote sensing images used by governments, which may cause further degradation and fragmentation[140].

The estimated area affected by bauxite mining and aluminium production (including infrastructure) in Brazil is 16,000 square km, almost as large as the entire area of the Hawaiian Islands. The bauxite reserves lie entirely within the Amazon rainforest[141].

The indirect impacts of Vale's mining activities in its Carajás mine include the almost total destruction of the rainforest along the 80 m-wide, 890 km-long rail-

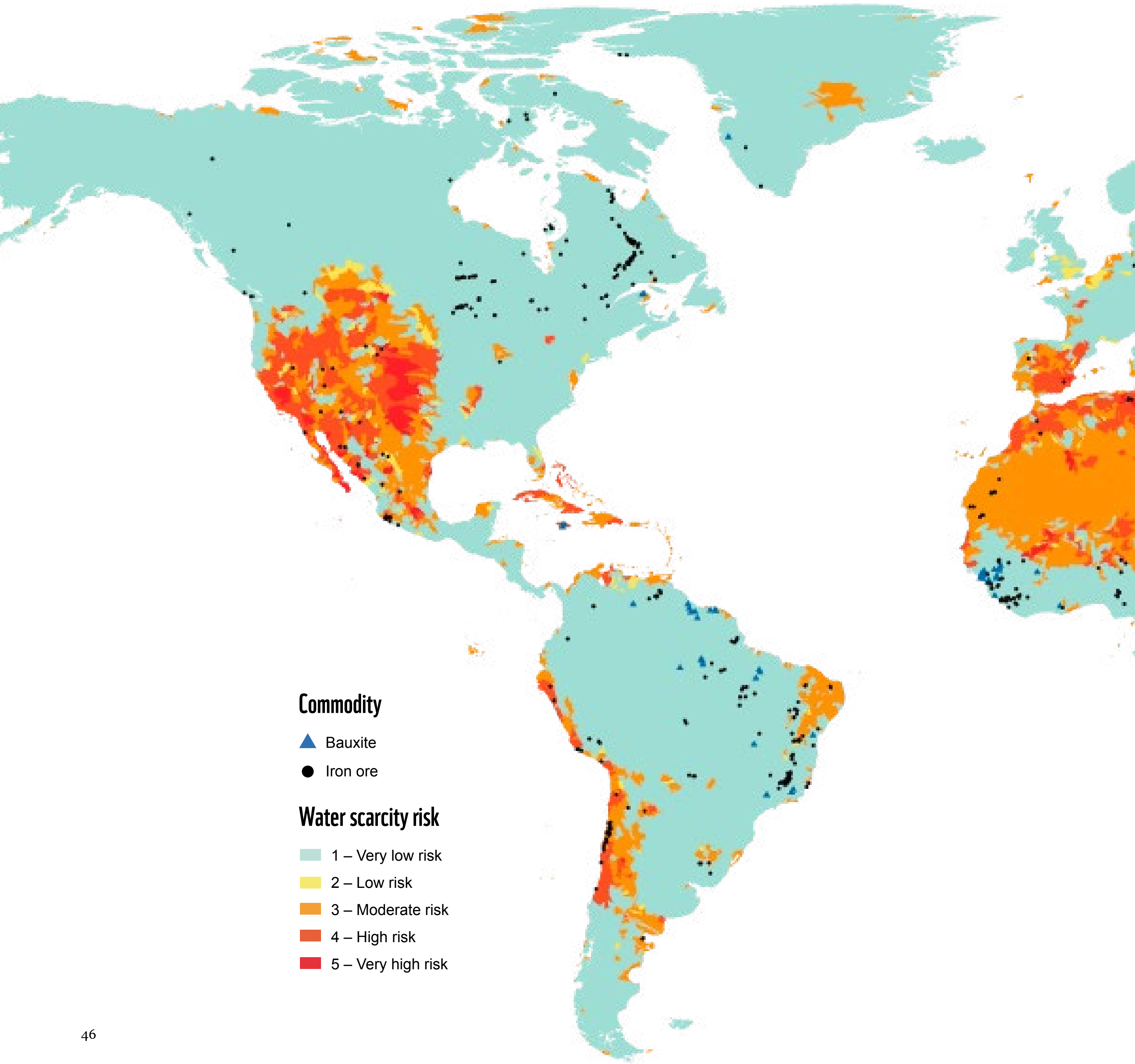
Fragmentation in the Brazilian Miritituba Amazonian forest

Consequences of mining activity	Activity affecting the environment	Effect of activity	Effect on impact category	Potential global effects
Mined ore needs to be transported to a port or distribution site	Road and railroad construction	Deforestation	Water quantity	Changing water regimes jeopardise global climate stability
			Biodiversity	e.g. loss of species supplying crucial ecosystem services such as plant pollination
			Soil erosion	
		Habitat fragmentation	Biodiversity	e.g. loss of species supplying crucial ecosystem services such as plant pollination
Humans settle in previously remote areas, either as mine workers and their families or to take advantage of new areas made accessible by infrastructure development	Logging	Deforestation	Water quantity	Changing water regimes jeopardise global climate stability
			Biodiversity	e.g. loss of species supplying crucial ecosystem services such as plant pollination
			Soil erosion	
		CO_2 emissions	Air emissions	GHG emissions cause global warming
	Farming	Habitat fragmentation	Biodiversity	e.g. loss of species supplying crucial ecosystem services such as plant pollination
		Water abstraction	Water quantity	Changing water regimes jeopardise global climate stability
	Hunting	Pressure on wildlife populations	Biodiversity	e.g. loss of species supplying crucial ecosystem services such as plant pollination
	Charcoal production indirectly related to iron ore mines in Brazil	Deforestation	Water quantity	Changing water regimes jeopardise global climate stability
			Biodiversity	e.g. loss of species supplying crucial ecosystem services such as plant pollination
			Soil erosion	
		CO_2 emissions from firing process	Air emissions	GHG emissions cause global warming
Hydropower dam construction	Road and railroad construction	Deforestation	Water quantity	Changing water regimes jeopardise global climate stability
			Biodiversity	e.g. loss of species supplying crucial ecosystem services such as plant pollination.
			Soil erosion	
		CO_2 emissions from rotting plant material	Air emissions	GHG emissions cause global warming
	Fossil fuel fired power plant construction	Effects of (e.g. coal) mining	All direct and indirect effects of mining activities	All global effects of mining activities
		CO_2 emissions from fossil fuel combustion	Air emissions	GHG emissions cause global warming

Tab. 9: Examples of indirect environmental impacts of mining and metal processing activities (not exhaustive).

way line transporting the ore to the Atlantic Ocean. Trees are felled to produce charcoal for firing pig iron smelters, around 60% of which originate from illegal logging and have to be sourced from increasingly remote locations as timber is depleted along the easily accessible forest tracts. Eucalyptus monocultures have been planted over large areas[142]. Already in 2002, the area of influence of the transportation corridor from the Carajás mine to the Atlantic Ocean was estimated to be 300,000 square km[143]. Another effect of the massive deforestation of the eastern Amazon is the disturbance of the regional water cycle and climate[144]. Another 101 km of railway tracks are being constructed together with the new S11D mine, putting more rainforest and indigenous tribes at risk[145].

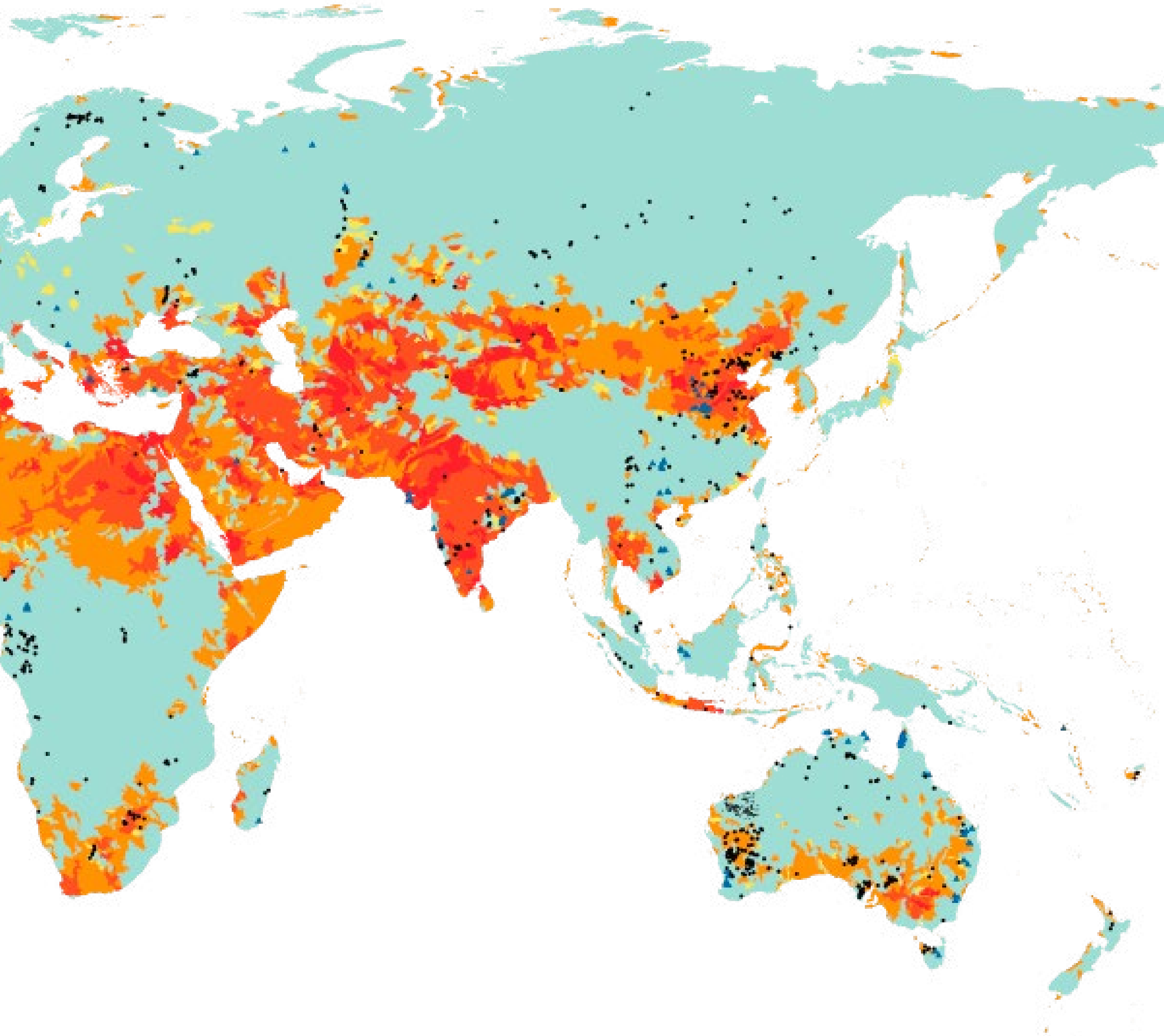
Fig. 13:
WWF water scarcity risk map (2018)



Additionally, the energy intensity of the extractive sectors is largely responsible for the high number of planned hydropower dams across the Amazon biome[146].

6.2.2 Water issues

As water is one of the most critical sustainability issues facing the mining industry globally and access to it is acknowledged as a prerequisite to upholding universal human rights, conflicts over water are a salient issue for the industry[147]. Conflicts over water use and pollution are particularly common where mining projects are carried out in arid or semi-arid regions of the world[148].



In August 2017, indigenous leaders in Colombia protested against the El Cerrejón open-pit coal mine in the La Guajira department, expressing their concerns over the mine's expansion plans. This would imply a significant increase in the site's water consumption, jumping from the current 142 l to 307 l per second, making it necessary to divert the course of the nearby Bruno creek to compensate for water shortages. The indigenous leaders feared the depletion of their water sources and the disappearance of the dry tropical forest the creek runs through. In August 2017, Colombia's Constitutional Court ordered the multinationals to temporarily stop actions aimed at changing the course of the Bruno creek[149].

6.2.3 Social impacts

In the past, many mining projects had little regard for environmental impacts to the point where some abandoned sites cannot be used for other purposes and are still undergoing remediation to this day. In the last quarter of the 20th century, the environmental impacts of mining were finally recognised. This initiated the drafting of appropriate legislation, and remediation activities got under way, mainly in North America and Western Europe[150]. Laws in these regions were increasingly enforced, driving up the operating costs of mines which led many mining companies in developed countries to move their operations to other regions such as remote locations in Canada and Australia or to developing countries in South America, Asia and Africa, where mining laws are not as strict or enforcement is weak[151]. The negative impacts of mining were thus generally transferred to developing countries where they often degrade the living conditions of the local population, giving rise to conflicts between communities and mining operators in many places, while ore processing, the real value-adding step, takes place in industrialised countries[152]. The term "resource curse" was coined to describe how natural assets can distort the economy of developing countries to such a degree that the benefit actually becomes a curse[153].

Indigenous peoples are among the groups most affected by mining activities. The environmental impact of many mining activities threatens to affect or even destroy their ancestral territories, thereby depriving them of the right to use these lands to preserve and cultivate their identities and cultures. The right to "Free, Prior and Informed Consent", an obligation to consult and cooperate with indigenous peoples prior to the implementation of any measures affecting them, is not granted with any regularity in many parts of the world. The environmental impacts of activities of large-scale mining projects frequently affect the interests of indigenous and non-indigenous communities. Prior to mining operations all of the settlements in the area need to be removed and destroyed, often causing extensive resettlements and displacement. Since communities are not very likely to just abandon their lands, mining-related land seizures and evictions often result in human rights conflicts, which in turn lead to violence. Unwarranted resettlement is a pervasive problem, leaving affected communities without adequate housing and access to food, water and work[154].

Many countries have laws that the underground mineral deposits belong to the national state, and the landowners have no claim to the valuable deposits under their land, creating a jurisdictional dilemma for indigenous communities. International agreements, such as the Indigenous and Tribal Peoples Convention 169 of the International Labour Organisation (ILO) which came into force in 1991 to protect indigenous and tribal lands, have pushed for changes in the national laws that regulate mining activities, but often this has not been enough to protect indigenous peoples' rights[155]. In Brazil, for example, the Proposed Constitutional Amendment (PEC) 215/2000 is currently being moved through Congress and seriously threatens indigenous land rights and biodiversity. This amendment, which favours the bancada ruralista, an informal bloc made up of representatives who defend agribusiness, would allow commercial activities such as mining, power generation and transport without considering the key role that these protected areas play in protecting forests, water, biodiversity and the climate.

Other issues that concern not only indigenous peoples include, but are not limited to, a rise in AIDS/HIV transmission linked to migrant labour, the socially disruptive effects of increased alcohol and substance abuse, exacerbated gender inequality and related issues[156].

Conflict minerals in aluminium and steel alloys

Steel and aluminium are not usually associated with conflict minerals - the electronics industry tends to be in the limelight when it comes to minerals sourced from regions where their sales finance armed conflict. "Conflict minerals," as defined by US legislation, include the metals tantalum, tin, tungsten and gold, the mining of which in the affected countries is likely to finance armed conflict. Downstream companies often refer to these metals as 3TG. Section 1502 of the Dodd-Frank Wall Street Reform and Consumer Act of 2010[157] requires all companies using these minerals to disclose whether they sourced them from the Democratic Republic of the Congo (DRC) or a neighbouring country, and if so, to submit a report describing the measures taken to exercise due diligence on the conflict minerals' source and chain of custody[158]. The EU regulation on conflict minerals passed in May 2017 is the counterpart of the Dodd-Frank Act for the EU. The implementing policy body in Germany is the Federal Institute for Geosciences and Natural Resources (BGR).

A number of minerals including tin, tungsten, copper and nickel are added to steel and aluminium to make alloys with special properties including corrosion resistance or strength. The Dodd-Frank Act 1502 is limited in scope and region to 3TG and the DRC and surrounding countries. However, violent conflicts are associated with more than just these four minerals and are geographically not limited to central Africa. Globally, the Heidelberg Institute of Conflict Research (HIIK) identified 402 conflicts in 2016, 98 of which were related to resources. Furthermore, 67% of the conflicts over resources were violent, these types of conflict having a higher tendency for violence than conflicts related to other issues[159].

As ore extraction and processing for many of these minerals are not vertically integrated and sometimes informal in nature, companies often have limited ways to fully retrace their upstream supply chains. In 2013, Bloomberg Magazine verified that the German companies BMW, Porsche, Volkswagen and Siemens sourced tungsten from Colombia through an Austrian supplier. This tungsten came from a mine controlled by the guerrilla group FARC[160].

In 2017, the European Union adopted a regulation which entered into force in 2021 and imposes requirements on EU importers of 3TG originating from conflict-affected and high-risk areas. This European counterpart of the US Dodd-Frank Act 1502, while being limited in scope to the same minerals, goes a step further by not being geographically limited to the central African region[161]. While welcomed as an important step in the right direction, it has been criticised by a number of civil society organisations for not being comprehensive enough and for offering several loopholes. For example, it only applies to imports above a minimum amount, e.g. 100 kg for gold.

A number of relevant minerals such as cobalt or lithium, which are also mined in the DRC, are not included. The EU regulation which is legally binding is largely based on the OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas[162]. While being a normative, not legally binding guideline directed at companies sourcing potential conflict minerals, the OECD guidelines apply to all mineral resources and to the entire supply chain up to the final product. The EU directive only covers a small part of the supply chain[163].

Tab. 10: Examples of non-3TG conflict minerals *(Schele & ten Kate 2015, Smith 2013):*

Country	Mineral (relevant for German steel and aluminium industry)	Conflict
Brazil (various regions)	Possibly aluminium/bauxite, copper, nickel, iron ore and steel, chromium, manganese, titanium, zinc …	• Indigenous groups and landless workers movement versus government
Colombia (nationwide)	Nickel, iron ore, copper, tungsten …	• Neo-paramilitary groups • Drug cartels versus government • Illegal mining
Mexico (various regions)	Iron ore, copper, possibly many more (aluminium, manganese, molybdenum, …)	• Inter-cartel violence, paramilitary groups • Drug cartels versus vigilante groups versus government
Indonesia (West Papua)	Copper	• Independence movement versus Government
Philippines (Mindanao, Palawan, Sulu)	Copper, nickel, iron ore, chro-mite, zinc, manganese …	• Armed groups versus government • Rural mobilisation

6.3 Environmental issues in aluminium and steel processing

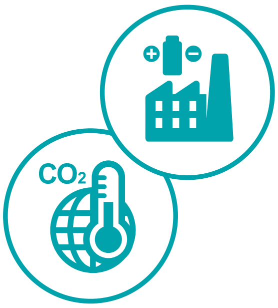
6.3.1 Aluminium

Alumina refinement

The Bayer process, used in about 90% of alumina refineries, releases alumina from bauxite in a caustic soda solution. The most important output from the Bayer process after alumina is the bauxite residue or red mud with a ratio of around 1-1.5 t of red mud for every tonne of alumina produced. The chemistry of red mud depends on the nature of the original bauxite ore and consists of up to 50% water.[166]

Red mud poses an environmental problem because it is highly alkaline and saline, and in some cases contains radioactive elements as well as elevated levels of arsenic and chromium[164]. The highly caustic nature of red mud poses the most immediate health risk to humans upon direct contact and inhaling alkaline dust particles from dried red mud can cause respiratory tract infections and eye irri-tation[165]. The long-term environmental effects lie in the high salinity of the mud, which causes soil salinisation, and its high contaminant content which adversely affects agriculture[167].

The storage and management of this waste is a serious challenge for the industry. In the past, red mud has been disposed of at sea. The only alumina plant in Greece still disposed of its red mud via pipeline in the ocean in 2006 and, a number of shore-based alumina plants around the world still continued this practice in 2012[168]. The most common disposal method, however, is to keep the red mud in lined lake-sized, artificial holding ponds where the mud is washed and filtered repeatedly to form thick slurry[169]. In October 2010, approximately one million m^3 of red mud were spilled into the surrounding countryside in Ajka in Hungary when a retaining wall broke, killing ten people and injuring 150, and contaminating an area of almost 40 square km. Life in most of the nearby rivers was wiped out[170].



Aluminium smelting
The most significant waste products from the production of aluminium from alumina are air emissions including perfluorocarbon gases and CO_2 from anode comsumption and electricity production[171]. In a comparison of the life cycle analyses of 8 metal production processes, aluminium has the second highest energy consumption after titanium, at 211MJ/kg of primary aluminium, about the energy of 6 l of gasoline, and generates emissions of 22.4 kg of CO_2-equivalents (CO_2-eq)/ kg of raw aluminium[172]. In 2013, 3% of global electricity was consumed by the aluminium industry, responsible for 1% of global GHG emissions[173]. Up to 80% of the total emissions of the primary aluminium value chain can be attributed to the highly energy-intensive Hall-Heroult electrolytic process depending on the electricity source[174].

Aluminium smelters are always located near a power plant to guarantee their electricity supply. In many cases, these are coal-fired power plants causing air pollution and GHG emissions. Coal-fired power plants currently fuel 41% of global electricity and, in some countries, an even higher percentage[175]. Globally, 61% of all aluminium smelters were coal-powered in 2016. In Europe, the percentage of coal-powered aluminium smelting was 9%, while hydropower assumed a prominent role in the energy mix at 72%. China's aluminium smelters were 90% coal powered[176].

However, even renewable energy sources can have considerable environmental impacts. Aluminium smelting is one of the drivers of dam building worldwide[177]. In Brazil, hydropower plants such as the giant Belo Monte dam complex on the Xingú River are being constructed for the power supply of alumina smelters, among others[178]. The Tucuruí Dam, built on the Tocantins River in 1984, was built primarily for aluminium[179]. A case study conducted by the Amazon Environmental Research Institute (IPAM) on the Tapajos river basin suggests that much of the Brazilian 10-year energy plan is designed to deliver energy for the extractive sector[180]. And while dams being built by the Brazilian government produce electricity that is bought by aluminium smelters, building and ownership of dams by aluminium companies themselves is also on the rise[181].

Dams have major impacts, including hydrological fragmentation and critical changes in continental water flows, flooding of vast land areas, construction of new roads, installation of transmission lines and significant environmental damage with unpredictable ecological effects[182]. Dams also have an impact on the climate, releasing potent GHGs, including CO_2, from the decomposition of trees and large amounts of methane from reservoir surfaces, turbines and spillways. The social impacts of dams are also substantial, such as a loss of fish and other river resources of indigenous people. Downstream communities are also at risk of the loss of livelihoods depending on fishing and agriculture in floodplains and people can be displaced[183].

Some of the world's largest bauxite suppliers are developing countries exporting the unprocessed ore to industrialised countries where it is then processed into aluminium, a much more valuable commodity. As a result and to promote domestic value creation, the Indonesian government imposed an export ban on unprocessed bauxite in 2014 and only issued 5-year export licences to companies that were verifiably building alumina refineries and smelters[184]. In countries like Guinea, the main source of bauxite for Germany, an unreliable power supply is one of the main limiting factors for aluminium processing. In a speech at a mining conference in May 2017, the president of the Republic of Guinea decreed that miners who produce over a certain amount of bauxite ore "will be obliged to build an alumina plant."[185] It is to be expected that, with increasing efforts to process bauxite in the country, the power supply will need to be guaranteed by building new power plants. Electricity production for aluminium processing in Guinea releases more than four times the amount of GHG per unit as in Norway due to a high percentage of fossil fuels in the electricity mix[186]. Since Guinea is the country with the largest bauxite deposits, the potential environmental effects of expanding aluminium production industry could be dramatic.

6.3.2 Steel

The steel industry is the world's biggest industrial emitter of CO_2, responsible for 25% of industrial CO_2 emissions. Most of the steel industry's CO_2 emissions can be attributed to the use of coke and coal for the pig iron production process[187]. In the steel production process, coal has multiple functions. It is used as a fuel and reduction agent for iron ore in primary steel production, as a fuel for the blast furnace and indirectly for electricity production for EAF steel production or in rolling mills. The reduction of iron in the blast furnace uses 330 kg of coal and coke per tonne of steel and releases over 400 kg of CO_2/t[188]. In an integrated facility, about 50% of the energy input comes from coal, 35% from electricity, 5% from natural gas and 5% from other gases[189].

The use of charcoal in pig iron production not only generates higher CO_2 emissions, it is a driving force behind massive deforestation in the Brazilian Amazon[190]. The use of charcoal sourced from native forests as a reduction agent instead of coke has been increasing in Brazil, resulting in up to nine times more CO_2 emissions per unit of steel than coke[191].

Worsley Alumina bauxite mine located near the town of Boddington in Western Australia

6.4 Company risks related to environmental impacts along the steel and aluminium supply chains

The environmental impacts of a company's operations also represent a risk for the company as they may directly or indirectly affect its operations. Company risks can be categorised as physical, regulatory or reputational. Physical risks involve negative effects on a company's operations due to external physical impacts. A company is exposed to regulatory risk by changing laws or by not complying with existing regulations that are being more strongly enforced. A company's reputation helps it to obtain a licence to operate on the ground and ensures good business relations with its suppliers and clients. Reputational risks arise when a company's actions generate unfavourable attention which may turn into a regulatory risk when regulations are changed or licences revoked, or when customers or suppliers discontinue or limit business operations.

Tab. 11: Examples of potential physical, regulatory and reputational risks for mining and ore processing industries arising from their operations' impact on the environment.

Risk category	Mining	Ore processing
Physical	A limited local supply of water forces company to curb its operations, e.g. Norsk Hydro in Brazil in 2017.	Unreliable electricity supply from hydropower in dry years can jeopardise smelting operations in regions affected by climate change (e.g. SANDRP 2016).
Regulatory	National regulatory changes, e.g. • Mining bans in response to local protests (e.g. for the El Cerrejón in Colombia) • changes in national or international environmental or waste treatment regulations	National regulatory changes, e.g. • German energy transition regulating electricity sources • Changes in waste storage and treatment regulations Internatl. regulatory changes, e.g. • due diligence requirements such as Dodd-Frank-Act 1502, EU Conflict Mineral Regulation …
Reputational	• Local issues related to water quantity and quality may lead to conflict with local population, potentially tarnishing the mining company's reputation. • Tailing dam spills contaminate large areas and draw media attention.	Companies sourcing metals from conflict regions violate their due diligence, which generates negative media attention.

The concept of circular economy goes beyond recycling after the product-use phase.

7. The path forward

7.1 The concept of the circular economy

There is a growing urgency to adopt global strategies for sustainably managing our societies and economies. Businesses, particularly large corporations, have been making continuous improvements to corporate responsibility and sustainability information in their reporting; however, the concern is that reporting gives companies a licence to conduct "business as usual"[192]. In this respect, the Sustainable Development Goals (SDGs) laid out by the UN serve as guidelines for companies and governments to embrace as part of their strategic vision and help achieve their sustainability objectives.

Yet, there has also been a clear lack of understanding of the fact that business itself is fundamentally dependent on ecological systems, known as "ecosystem services", as they underpin the functioning of many direct and indirect processes that businesses build upon. It is also clear that the interdependencies between companies in globally connected supply chains are a serious source of risk and resilience to external shocks will be much more important in the future.

> The concept of sustainable development (SD) originates from the 1987 Brundtland Report, the first document to call international attention to the consequences our consumption and production patterns have on our environment and ultimately on the future of humanity as a whole. The report sparked a continuing debate on the failure of business to address the critical concerns relating to sustainability: overuse of natural resources, inadequate responses to global warming and a lack of focus on social justice.

In the meantime, while solutions towards sustainability and alternative economic concepts have been debated and developed by politicians and academics around the globe, the consensus is that, although change is overdue, governments seem unable to assert adequate policies against current capitalist structures, invoking the perceived threat to economic growth[193].

Decoupling resource use and environmental impact from economic activity is the underlying systemic prerequisite for enabling sustainable development. Revenue generation is tied to the extraction and use of resources which are associated with different kinds of impacts on the physical world. Decoupling implies that the same amount of value can be delivered with fewer resources and, consequently, with a smaller environmental impact. Of course, the appeal of decoupling for businesses and policymakers alike lies in the possibility of coexistence of sustainability and economic growth[194].

The CE thus aims to keep resources in use for as long as possible and seeks new ways of linking resources, product design, production and consumption.

The 2030 Agenda for Sustainable Development and the SDGs, which represent the world's plan of action for social inclusion, environmental sustainability and economic development, however, serves as a basic tool to help businesses achieve their sustainability goals. In this context, the circular economy (CE) is emerging as a possible sustainability strategy that companies of all sizes can adopt[195]. The Ellen MacArthur Foundation, one of the leading champions of the CE, defines the concept as "one that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles"[196]. The CE thus aims to keep resources in use for as long as possible and seeks new ways of linking resources, product design, production and consumption[197], in contrast to a linear economy which converts natural resources into waste via production and ultimately leads to environmental degradation through resource depletion and pollution[198].

Because the vision of the circular economy builds on existing business models[199], it may meet with less resistance from the corporate world than concepts that require a complete paradigm shift. The circular economy has gained in popularity among both businesses and governments over the last few years, it was featured in the last two Five-Year Plans drawn up by the Chinese government and is being operationalised in China[200]. In 2015, the European Commission adopted a Circular Economy Package, which includes revised legislative proposals on waste to stimulate Europe's transition to a circular economy, although this package has been criticised by WWF as not meeting the challenge of reducing the EU's massive footprint[201]. In Germany, the Resource Efficiency Programme (ProgRess) was initiated in 2012 and includes CE approaches[202].

CE goes beyond recycling after the product-use phase; relying on system-wide innovation and underpinned by a transition to renewable energy sources, CE aims to redefine products and services to design waste out, keep products and materials in use and regenerate natural systems[203].

7.2 Aluminium and steel in the circular economy

For the implementation of a circular economy in practice, Metabolic have developed seven pillars which also provide a benchmark to determine whether projects meet the demands of a truly circular economy. These pillars apply to both small (business) and large scales (national or global economies)[204]:

1. Materials are incorporated into the economy in such a way that they can be cycled at continuous high value.
2. All energy is based on renewable sources.
3. Biodiversity is structurally supported and enhanced through all human activities.
4. Human society and culture are preserved.
5. The health and wellbeing of humans and other species are structurally supported.
6. Human activities generate value in measures beyond just financial.
7. The economic system is inherently adaptable and resilient.

For aluminium and steel, including mining, pillars 1 to 4 stand out as particularly relevant at this point. Aluminium and steel are materials that are easy to integrate into a circular economy. Mainly, they are infinitely recyclable without quality losses, with more than 90% of the aluminium in building and automotive parts recycled at the end of use, and an estimated 80% of recoverable and recyclable steel is recycled every year[205]. Steel is ideal for recycling because of its magnetic properties which make it easy to recover from all efficient waste streams. Nonetheless, only one third of steel demand came from global scrap in 2015, although scrap availability is expected to grow in China and emerging economies.

The production of secondary raw aluminium requires only 5% of the energy and

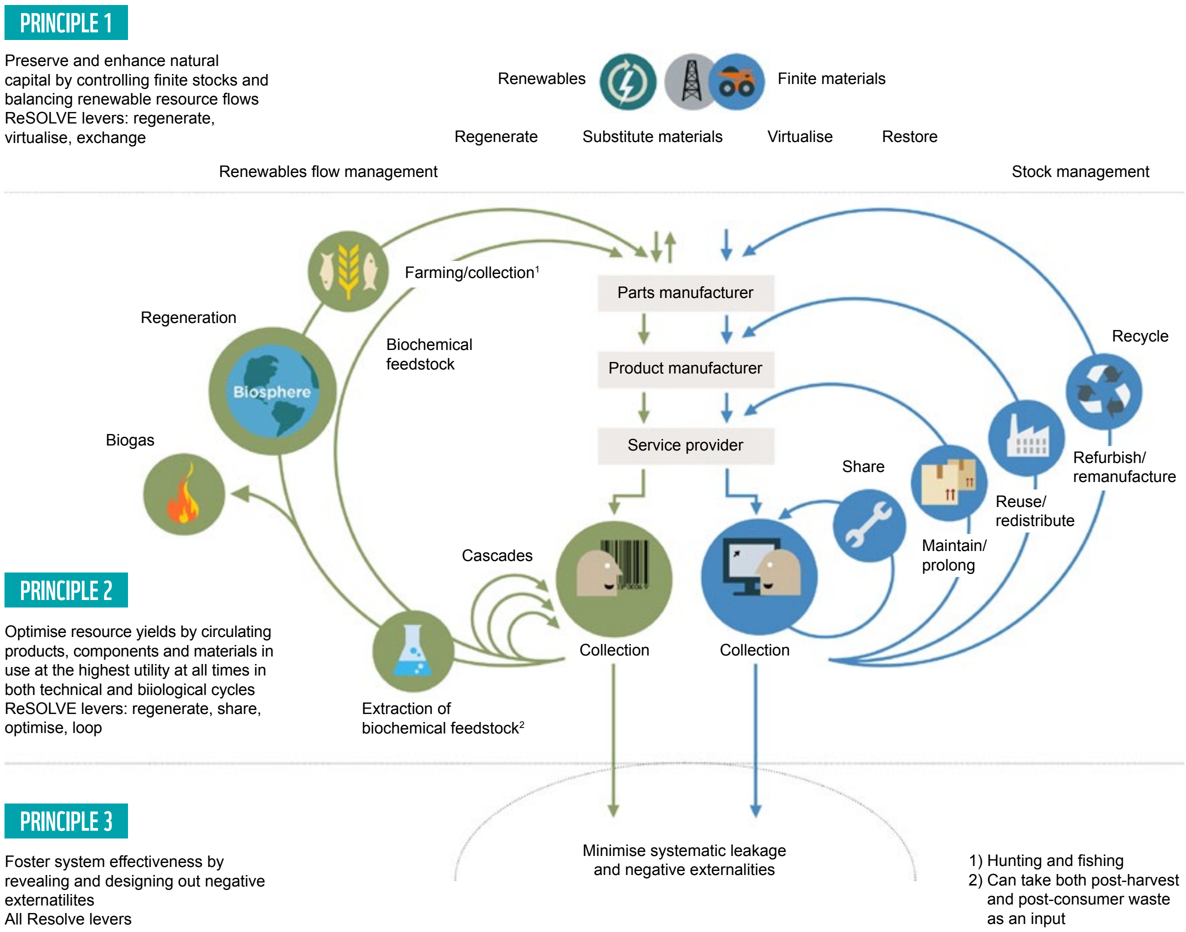


Fig. 14: Outline of a ciruclar economy. *Source: EMF 2015*

produces only 5% of the emissions compared to the primary aluminium production process. A shift to renewable energies could reduce these emissions to zero.

Given a continued and growing role of aluminium and steel as raw materials for more sustainable products such as renewable energy solutions, there is an increasing demand for improving product design and the manufacturing processes that aim at improving the environmental and social performance of products.

Manufacturers of steel and aluminium products should make sure that the design and manufacture of their products facilitates their reuse, remanufacture, recovery and eventually recycling. In order to align with a circular economy, there are five hierarchical requirements for product design.

1. Products should be designed to reduce the volume of materials needed.
2. Products should be designed to be durable so they can be used and reused.
3. Products should be designed in such a way that they can easily be repaired.
4. Products or parts of products can be disassembled so they can easily be remanufactured.
5. Recycling is the last resort where scrap is returned to the production process.

Reuse and remanufacture (as well as a reduction in overall consumption) form an integral part of the circular economy concept and are prioritised over recycling. In this respect, companies using steel and aluminium products are still lagging behind with strategies that prioritise reuse and remanufacture. For example, it is bad enough that beverage companies that supply their products in aluminium cans don't use recycled aluminium cans, they are far from supporting approaches that could allow the reuse of aluminium cans[206].

Examples of aluminium and steel in a circular economy

Reduce:
In 2013, Unilever launched "compressed" cans for brands including Sure, Dove and Vaseline – the aluminium containers contain half the gas and a quarter less metal. They have saved more than 1,500 t of aluminium to date, enough to make a million bicycles. A few years later, British firm Boots and Natura Cosméticos in Brazil followed suit, thereby also reducing the carbon footprint by 25% per can. Meanwhile, the Ardagh Group has produced "the world's lightest three-piece steel aerosol container" for a range of consumer products for Henkel. It has reduced the thickness of Drei Wetter Taft hairspray cans, resulting in a saving of over 15% of the material and water used in the production phase[207]. In addition to reducing resource use, these initiatives directly benefit the company's bottom line.

Reuse:
Faced with budget cuts and aging infrastructure, the Muskingum County Engineers Office in Ohio (USA), decided to use salvaged steel beams from old bridges to replace the superstructure of the local Green Valley Road Bridge. The county estimates that they saved USD 51,000 by reusing beams in the new superstructure.[208]

Remanufacture:
Around 80% of a typical wind turbine is made up of steel components. Various parts can be remanufactured, including gearboxes, generators, bearings and rotors. Demand for wind turbines is growing so rapidly that it can take up to two years for manufacturers to fulfil orders. By contrast, existing wind turbines can be remanufactured and delivered in as little as four months at a fraction of the cost of a new wind turbine. Remanufacturing can almost double the return on the original investment by extending turbine life by up to 20 years. The remanufacturing process can also be tailored to change the turbine's output, and it is also possible to change generator windings, gear size, and even the software driving the turbine to accommodate local conditions or increase energy production[209].

Recycle
South American steelmaker Gerdau began its Base of the Pyramid (BOP) project in 2007 in partnership with public sector and non-profit organisations. During the project, over 1,200 informal scrap collectors in Brazil, Chile, Peru and Uruguay received training to develop their technical and management skills. In the cities where BOP was implemented, approximately 1,630 t of waste are now correctly recycled or disposed of each year. Between 2011 and 2013, scrap collection grew by 228% a year while the average income of the scrap collectors rose by 155%[210].

Because global aluminium and steel cannot originate from recycled sources only, mining is likely to continue to play an important role in their supply. Manufacturers should therefore look upstream to make sure that the companies they source from integrate structural pillars 2-4 of the circular economy into their business strategies and operations. In practice, this means that the metals and minerals they purchase should not cause environmental or social damage, and a shift to renewable energy sources should take place. Emerging certification schemes with best practices or other measures of verification may be helpful in these efforts.

The next section provides examples of measures that bauxite, coal and iron ore mining companies can take to avoid or mitigate environmental and social damage and thereby clear the way for establishing and involvement in a circular economy.

7.3 Corporate measures for responsible mining

WWF advocates strong corporate strategies in the metal and mining industry as they can go beyond regulatory targets in developing, emerging and developed countries.

Mining is, by definition, not sustainable if our definition of sustainability implies the use of resources at rates that do not exceed the Earth's capacity to replace them. We therefore argue that it is misleading to use the term sustainability in the context of the extractive sector. The mining and metals industries are increasingly aware of this discrepancy and have instead adopted the terms "responsible" mining or "stewardship" to reflect the non-renewable nature of the resource. Most industry associations and certification schemes use these terms, e.g. the Initiative for Responsible Mining Assurance (IRMA), Responsible Steel, or the Aluminium Stewardship Initiative (ASI). Still, others like the International Council on Mining and Metals (ICMM), a mining and metals industry association, describes itself as "international organisation dedicated to a safe, fair and sustainable mining industry"[211].

The design and importance of government policies, regulations and agreements to support environmental and social stewardship in the mining and metal industry play an important role in the transition to responsible mining. However, they must reflect the capacity of national and regional governments to implement them. In the short term, where there is insufficient capacity, strong corporate strategies and ethics are a crucial basis for achieving this goal.

Business interest in the SDGs has grown since they were adopted in 2015, and 40% of the world's largest companies reference them in their reporting today[212]. As all of the SDGs are relevant to the metals and mining industry (see Fig. 15), reporting on them enhances companies' understanding of their impacts and helps finds ways to minimise or eliminate them. A range of tools is available to companies to help align their operations with the requirements of a circular economy (see the seven pillars above) and other SDGs.

WWF advocates strong corporate strategies in the metal and mining industry as they can go beyond regulatory targets in developing, emerging and developed countries.

One Planet Approach[213]

If current population and consumption trends continue, we will soon need the equivalent of two planets to provide the natural resources and services humanity consumes in a year. Exceeding the Earth's biocapacity to such an extent is possible only in the short term. The negative consequences of the depletion of our natural capital will grow over time, increasing material risks for companies, including water scarcity, higher prices for commodities and food and energy security.
Maintaining the habitability and resilience of our planet for future generations requires addressing the most relevant issues and setting targets at sufficiently ambitious levels. WWF aims to support companies throughout the economy to work on solutions that enable a thriving economy within the planetary boundaries. The means, for example, engaging with companies to develop methodologies and strategies for setting targets and measuring progress so that economic development and environmental degradation can be decoupled.

While mining may have some positive regional or national benefits, it often has tremendous negative social and environmental impacts at the local level. This report has described the main social and environmental impacts of mining. Responsible mining is primarily concerned with managing these social and environmental impacts equitably and effectively. This includes respecting the rights and well-being of indigenous people and local communities, undertaking effective land-use planning and resource use and ensuring the transparency of operations with respect to disclosure on financials, impacts and activities in the area of corporate social responsibility.

7.3.1 Human rights and transparency

Respecting the rights and health and safety of indigenous people, local communities and workers

Just as there is significant overlap between mining concessions and protected areas, there is also often considerable overlap between the remaining indigenous land and mining concessions. Corporate social responsibilities to protect the right of indigenous peoples and support principles of participation are now considered one of the most critical elements of mining and development, and "Free, Prior and Informed Consent" (FPIC) has emerged as an influential process in these efforts.

Although presently there is no singular or universally accepted definition of FPIC, guidelines suggest that consent and the associated consultation processes should be self-directed at local level by the people affected by the project[214]. The ICMM's Position Statement on Indigenous Peoples and Mining[215] is a good reflection of how the industry views FPIC concepts and processes[216]. ICMM's position statement on indigenous people and mining[217] requires members to: 1.) engage with potentially impacted indigenous peoples; 2.) understand and respect the rights of indigenous peoples; 3.) undertake baseline and impact assessment studies to understand impacts and rights issues; 4.) ensure meaningful participation in decision-making processes ; 5.) agree what would constitute "consent" in specific circumstances;

In India, the government has given permission to mining companies to begin extracting bauxite from the Niyamgiri mountain in Orissa state. The decision, which has led to massive protests, is endangering the livelihood of the Dongria Kondh tribe, who regard the mountain as sacred and live off its jungle cover.

and 6.) seek to achieve it through dialogue and collaboration with government authorities responsible[218]. The ICMM's position statement further requires its members to respect national laws related to FPIC processes. However, it is known that the industry often takes a "commit yet contain" position with FPIC[219]. In other words, there is a risk that some companies publicly commit to FPIC but exploit the process to their advantage[220]. Furthermore, mining companies, including ICMM members that operate in countries that have not incorporated FPIC into national laws do not need to uphold its principles as a corporate strategy[221]. It has been argued that companies that don't respect FPIC could be in violation of international human rights standards[222].

Just as there is significant overlap between mining concessions and protected areas, there is also often considerable overlap between the remaining indigenous land and mining concessions.

In summary, the FPIC process is a critical yet complex participatory process and needs to be carefully structured and practiced due to the risk of unintended consequences to social groups, the risk of coercion and the risk that companies take advantage of the process to their own advantage[223]. Certification in the future, e.g. through the Initiative for Responsible Mining Assurance (IRMA) - an organisation dedicated to establishing new standards for environmental and social issues related to mining - might support or incentivise more rigorous FPIC processes.

Improved transparency to prevent corruption associated with mining and its effects on socioeconomic development

A recent report by Transparency International based on research in 18 resource-rich countries from Australia to Zimbabwe identified systemic corruption risks in mining licencing and permit approval processes[224]. Corruption contributes to the resource curse, affecting how economic rents from mineral resources are redistributed for socioeconomic development.

The **Extractive Industries Transparency Initiative (EITI)** is a country-led initiative aimed at incorporating a set of principles and procedures designed to strengthen accountable and transparent governance in resource-rich countries through the verification and full publication of company payments and government revenues from oil, gas and mining. However, it also works by collaborating with companies that disclose all payments to governments. Moreover, company advocacy has even resulted in several countries initiating EITI implementation[225].

7.3.2 Biodiversity, water and soil resources

Biodiversity conservation
Mining often occurs in or close to protected areas affecting their cultural and biodiversity value. No-go areas and mitigation hierarchy including biodiversity offsets have emerged as policies to support biodiversity protection.

No-go areas generally means "respecting legally designated protected areas and ensuring that any new operations or changes to existing operations are not incompatible with the value for which they were designated". For example, the ICMM's position statement requires members to "not explore or mine in World Heritage properties"[226]. WWF has called for no-go areas for mining to be broader and to also include other sensitive areas such as important watersheds, going beyond the national legally protected status[227]. The future IRMA standard has a broader definition for no-go areas that includes World Heritage Sites as well as official candidates for World Heritage Site inscription, IUCN category I-III

The Carajás mine is one of the biggest iron ore mine in the world and located in the Brazilian Amzazon rainforest. Mining activities in this region result in deforestation of certain areas.

protected areas, IUCN category I-V marine protected areas, core areas of UNESCO biosphere reserves and areas where indigenous peoples live or are assumed to live in (voluntary) isolation[228]. However, like the ICMM requirements, the IRMA standard is voluntary. It will fall to national legislative authorities to agree and implement no-go areas that are off-limits for the extractive sector.

No-go areas have been difficult to implement or have been inadequately adhered to by the extractive sector. For example, although the ICMM no-go area statement guides its members to respect legally protected areas and maintain their value, this statement is not binding for ICMM members, while the rest of the industry (most companies) are under no obligation to follow the principles of no-go areas. For example, only 1.7% of companies registered in the MSCI Energy Index[229] have made no-go commitments, and most of them are ICMM members[230]. One consequence is that mining still affects even globally important areas such as Natural World Heritage sites, which cover less than 1% of the Earth's surface, or slightly more than 10% of the combined area covered by protected areas globally[231]. This suggests that stronger corporate policies for no-go areas, from downstream to upstream, are urgently needed.

Another important approach for biodiversity protection in the extractive sector is the mitigation hierarchy[232]. It is a policy that helps to ensure that potential adverse impacts on biodiversity from new operations or changes to existing operations are adequately addressed[233]. In the mitigation hierarchy, biodiversity needs to be considered early on in the planning and design stages of development projects so that there is no net loss (NNL) of biodiversity in the end or even a net gain[234]. The mitigation hierarchy is widely recognised as a best practice in environmental management of development projects.

The mitigation hierarchy to limit the impacts on biodiversity consists of four hierarchical options which are prioritised in the following order[235]:

1. Avoid – anticipation and prevention of adverse impacts on biodiversity before actions or decisions are taken. In this respect, agreed no-go areas should fall under 'avoid'.
2. Minimise – reduction in the duration, intensity, significance and/or extent of impacts that cannot be realistically avoided.
3. Restore – measures taken to repair degradation or damage to specific biodiversity features and ecosystems.
4. Offset – conservation outcomes applied to areas not impacted by a project to compensate for significant and adverse impacts of a mining project that cannot be avoided or restored.

The mitigation hierarchy is now increasingly part of regulatory compliance, government-mediated payments and voluntary provisioning, also commonly known together as compensatory mitigation, to offset impacts of infrastructure projects[236]. These approaches have channelled at least USD 4.8 billion toward environmental rehabilitation and protection in 2016, representing roughly double the transaction value in five years[237]. The majority of funding came from the private sector with the energy, transportation, and mining/minerals sectors dominating demand.

However, voluntary offsets represented an insignificant component of the estimated USD 4.8 billion in offsets and compensation markets in 2016. A key lesson learned from the application of offset projects in the last ten years is that developers of offset projects (such as mining companies) are unlikely to undertake biodiversity offsetting without some sort of regulatory driver or market demand[238]. This suggests that the mitigation hierarchy is likely to be mainstreamed in the future only if the regulatory driver and market demand are further developed.

Tab. 12: Very few voluntary offset projects: number implemented and in development and total land area in 2016 by region. *Source: Bennett et al. 2017, p. 48.*

Region	Implemented	In development	Land area (ha)
Africa & Middle East	2	–	n/a
Asia	1	–	n/a
Europe	9	3	2,591
Latin America & Caribbean	2	1	22
North America	2	3	236,069
Total	**16**	**7**	**272,999**

Managing mine closures

Planning for integrated mine closures in order to address significant adverse environmental and health and safety impacts is an ongoing challenge in the mining sector. Clark et al. describe the evolution of mining closures as characterised by "a general lack of concern in most nations for comprehensive mine closure prior to the 1960s; followed by an increasing concern for environmental issues related to mine closure (acid mine drainage, reclamation and rehabilitation) in the 1970s and 1980s to the consideration of the broader spectrum of sustainable economic, environmental and social development issues related to comprehensive mine closure in the 1990s and that continues into the new millennium"[239].

Currently, mine closure plans are demanded by most regulatory agencies around the world (Sassoon 2009) and are often a component of the environmental impact assessment process as practiced in over 100 countries[240]. Nonetheless, environmental impact assessment standards and legislative requirements such as the process of closure, the release of company responsibility of a site and the rights of landowners and communities around the mine are all addressed differently in various countries[241]. Reviewing critical gaps in mine closure provisions in the mining laws and associated implementing rules of various countries, Clark et al. note that: 1) mine closure legislation and regulations are often based on the environmental aspects of a site, they rarely include socioeconomic aspects; 2) most countries do not have comprehensive legislation for mine closures, this includes surety (financial) regulations such that companies can default from their obligations; 3) regulators often have limited capacity with respect to mine closures, especially in developing countries[242]. In addition, only two countries, New Zealand and Canada, mandate a cumulative impact assessment as part of the environmental impact assessment and thus the quality or impact of a mine closure plan will vastly vary depending on legislative requirements and capacity.

Although legislation plays an important role in supporting effective mine closures, corporate measures are also needed to supplement either weak legislative requirements or inadequate capacity to deal with mine closure requirements.

In summary, although legislation plays an important role in supporting effective mine closures, corporate measures are also needed to supplement either weak legislative requirements or inadequate capacity to deal with mine closure requirements. Some progress has been made. The World Bank has developed policies for financial surety for mining closures to prevent companies from defaulting when closing a mine[243], and ICMM has created a toolkit to help the sector re-think mine closure policies[244]. The ICMM mine closure toolkit is an iterative approach to mine closures and incorporates the use of risk and opportunity as guidelines for planned closures[245]. This can allow companies to go beyond regulatory measures for mine rehabilitation and risk minimisation, to also turn risks into social opportunities, maximising the possibilities for surrounding communities to capitalise on opportunities for lasting benefits. For example, Anglo American has turned some of its mining sites in Australia into wind farms and jatropha production for green energy production[246]. However, without verification of the process of mining closures and the quality of the closures, there is a risk that companies may cut corners, especially in countries without agreed standards, capacity and scrutiny. Certification by IRMA in the future, including its standard on mine closures[247], may provide incentives for a more reliable mine closure process.

Managing pollution, energy consumption and waste management through better assessment and reporting.

Science-based targets are a quantified target commitment adopted by companies to reduce GHG emissions that corresponds to the level of decarbonisation required to keep global temperature increase below 2 degrees Celsius compared to pre-industrial temperatures[248]. Companies formulate clearly defined pathways, specifying how much, how and how quickly they will reduce their GHGs emissions. The CDP, formerly the Carbon Disclosure Project, which runs the global disclosure system that enables companies, cities, states and regions to measure and manage their environmental impacts, supports companies in reaching these targets. CDP has built a comprehensive collection of environmental data reported by the individual companies in the world. This allows companies to measure their own performance, enabling them to raise their ambitions to address climate change.

Among the 44 companies that have committed to science-based targets in all sectors, five are mining companies and of these five, four are involved in the iron ore value chain. They are China Steel, Mahindra Sanyo Special Steel, Manni Group SpA and Outokumpu Oyj, which have all committed to the scheme of science-based targets, although all these companies have yet to declare their targets and strategies[249].

The GRI helps businesses and governments worldwide understand and communicate their impact on critical sustainability issues such as climate change, human rights, governance and social well-being.

While regulations play an important role in the management of waste and pollution levels as well as in energy consumption, especially in regions with a carbon tax or emission trading schemes, schemes for companies to assess and report on their sustainability activities in this area can also support this aim. **The Global Reporting Initiative (GRI)** is a network-based organisation that produces a comprehensive framework for sustainability reporting comprised of principles and performance indicators that organisations can use to measure and report their economic, environmental and social performance. It helps businesses and governments worldwide understand and communicate their impact on critical sustainability issues such as climate change, human rights, governance and social well-being.

Alcoa, which is among the world's top bauxite mining companies, reports in compliance with the GRI standard in two regions: aluminium extraction in Latin America and Oceania (Brazil) and its mining operations in Oceania (Australia). Rio Tinto uses the GRI reporting standard for several of its Europe, North America, Asia and Oceania operations. Norsk Hydro, the Aluminium Corporation of China (Chalco) and Compagnie des Bauxites de Guinea (CBG) do not report at all and none of Alcoa's and Rio Tinto's operations in developing countries use the GRI reporting standard.

Among the significant iron ore mining companies, GRI is standard for Vale's operations in Latin America and the Caribbean (Brazil) and Asia (Indonesia). Rio Tinto applies GRI standards to reporting for its Europe, North America, Asia and Oceania operations, BHB Billiton Group to its African (South Africa), Latin American and Caribbean (Chile) operations, Fortescue Metals Group Limited to its Oceania (Australia) operations, ArcelorMittal to its Latin American and Caribbean (Brazil, Argentina, Mexico) and Asia (India) operations and activities in Europe, Mitsui & Co to its Asia operations (Thailand, but non-GRI reporting) and activities in Japan, Mellanoinvest to its Europe activities and Kumba Iron Ore to its 2 African operations (South Africa)[250]. Remarkably, none of these companies, in particular those that have a number of operations in Africa such as Rio Tinto, report on their activities there.

7.3.3 Addressing the indirect impacts of mining

The immediate and relatively local impact of mining is often dwarfed by the potentially far more wide-ranging and long-term impacts of mining infrastructure and socioeconomic change. Cumulative impacts are the effects on the environment which are caused by the combined results of past, current and future activities. This includes direct and indirect human activities[251]. Estimating cumulative impacts is therefore an important factor in decision-making with respect to mining and addressing the larger impacts. However, only two countries, New Zealand and Canada, mandate a cumulative impact assessment. WWF recommends more and better assessment of cumulative impacts. For example, indirect impacts and assessments can be found in the Industry Guide on Cumulative Impact Assessment by the Minerals Council of Australia (2015), the Good

Practice Guide on Cumulative Impacts by the University of Queensland[252] and various other scientific publications.

Indirect environmental impacts can be partially or fully mitigated through strategic land-use planning, also known as landscape approaches. Land-use planning is an approach involving a number of stakeholders including governments, businesses and local populations. One initiative for mining companies is, for example, the establishment of **private-public sector partnerships** for this purpose prior to or at the onset of mining activities. There are currently attempts at forming private-public sector partnerships to support sustainable development in growth corridors - growth corridors are hubs where natural resource-based industries, like agriculture and mining, are being strategically developed in a bid to stimulate economic growth. For example, the World Bank is supporting Mozambique and Liberia in the development of growth corridors to ensure that mining investments can be integrated into the development of locally tailored activities such as agriculture, forestry and small-scale mining to help facilitate indirect benefits and employment from mineral developments[253].

Cumulative impacts are the effects on the environment which are caused by the combined results of past, current and future activities. This includes direct and indirect human activities.

However, for these kinds of partnerships and approaches to work in development corridors, a thorough understanding of the impacts, direct and indirect, on resources is needed. For example, mining of bauxite and iron ore requires access to water that is often the basis for the livelihoods of local communities. It has to be ensured that a Water Stewardship Framework is adopted and implemented. Interestingly, however, no mining and mineral companies have worked towards certification for water stewardship, and none has therefore been certified e.g. by the **Alliance for Water Stewardship**[254]. ICMM has also developed a Water Stewardship Framework that can support companies address water issues. It revolves around four key elements: 1.) be transparent and accountable; 2.) engage proactively and inclusively; 3.) adopt a catchment-based approach; and 4.) effective water resource management[255]. However, without certification or other form of verification, it is difficult to know how the guidance issued by ICMM is implemented on the ground, especially in water sensitive areas.

7.3.4 Best practices, standards and certification

Compared to the agriculture sector where round tables and certification of best practices form the cornerstone of sustainability, efforts to change practices in the extractive sector have been less high profile. Certification of best practices seeks to inform consumers about the sustainability status of the goods and services they potentially consume to direct their purchasing power towards environmentally and socially responsible products[256]. It is only recently that certification of best practices as well as industry associations for sustainability have emerged in this sector. This can help encourage the development of more sustainable products downstream.

However, as in the agriculture sector, the partial success of these schemes is likely to depend not only on the standard or best practice guidelines, but also on the scheme governance including, in particular, the quality of the measures and the implementation and verification processes. Additionally, traceability – knowledge about the origin of minerals, accurate documentation tracking their movement through the supply chain and identification of the actors who handle them – is not well developed in the metal and mineral sector. Finally, though certification may appear to be the panacea for verifying environmental and social equity, even in the agricultural sector where organic certification is the most widely applied, a mere 1.1% of the global production area is certified[257]. Certification schemes for the metal and mining industries are just emerging and have a long way to go.

Some key initiatives supporting responsible mining through certification of best practices or industry associations for sustainability include:

Certification schemes for the metal and mining industries are just emerging and have a long way to go.

The **Initiative for Responsible Mining Assurance (IRMA)** is a coalition of non-governmental organisations, businesses purchasing minerals and metals for resale in other products, affected communities, mining companies and trade unions formed in 2002. It will act as a standards organisation and certification body to certify mining projects (it will not certify products like the Aluminium Stewardship Initiative). IRMA is currently developing standards for environmental and social issues related to mining, including labour rights, human rights, indigenous peoples and cultural heritage, conflict response, pollution control and site closure. IRMA will begin offering auditor-verified scoring of achievement against the IRMA Standard for Responsible Mining in 2018-2019. Therefore, certification of companies will only start from 2018 onwards. As with all certification governance, the success of the scheme is likely to depend not only on the standard, but also on the governance of the scheme including especially the quality of certification and the implementation and verification process.

The **Aluminium Stewardship Initiative (ASI)** is an emerging standard and initiative for labelling aluminium products and aims to define globally applicable standards for sustainability performance and material chain-of-custody for the aluminium value chain. Sustainability (GHG emissions, biodiversity conservation and management, waste management) and human rights principles in particular are embedded in this stewardship programme. Members that are industrial users include several car companies including BMW Group, Audi and Jaguar Land Rover. Members that are producers include some major companies including Alcoa, Norsk Hydro and Rio Tinto[258]. The ASI Certification programme was formally launched in December 2017.

Similarly, **ResponsibleSteel** is the steel industry's first global multi-stakeholder standard and certification scheme. ResponsibleSteel is developing an independent certification standard (to be finalised sometime in 2018/2019) to support businesses and consumers in ensuring that the steel they use has been sourced and produced responsibly at every stage. This organisation collaborates with IRMA and seeks to ensure sustainability goals regarding the availability of clean water, the reduction of GHGs, the creation of jobs that benefit individuals and communities and ensuring that responsible patterns of production and consumption are met.

The International Council on Mining and Metals (ICMM) was founded in 2001 and is an international organisation of 25 mining and metals companies and over 30 regional and commodities associations dedicated to strengthening environmental and social performance in the mining industry[259]. ICMM members commit to implementing its 10 principles[260] and seven position statements[261] which provides guidance on best practices for sustainable development in the mining and metals industry. Nonetheless, an assessment of corporate strategies pursued by its members indicates that while these members have made a lot of headway on the development of best practices for sustainable development, even the best of the best companies in the mining and metal Industry have lagged behind on implementation, monitoring, reporting and ensuring consequences for non-compliance[262].

7.4 The financial sector

The financial system is a, if not the, key enabler of economic activity. Its initial purpose is to transfer individuals' money, savings etc. to economic and other activities. The way these transfers are organised is through lending, direct project finance, insurance cover provision, investment or by allowing equity stakes to be capitalised, to name a few. It also allows individuals to lend and save money, without which retirement provisions or home and land acquisition would not be accessible for the most part, at least not to the extent and with the ease we see today. It serves a positive and essential purpose if pursued through these activities.

Investors as well as banking institutions need to develop policies and principles for lending activities and engage in dialogue with the mining sector.

The financial system is relevant for the mining sector in terms of the volumes and recipients of capital flows to the real economy as well as in the conditions attached to capital access. Economic activity and its impacts on ecosystems, habitats, biodiversity loss, climate change and many more resources we all depend on, are essentially enabled or supported by access to financing.

The financial system consists of the investment and financing of sub-systems. It is therefore useful to look at the actual institutions and financial actors involved. In the investment sub-system, these are investors (retail and institutional), insurance companies or asset owners who have direct oversight of the rules and requirements according to which investments are made. Where environmental impacts represent risks, these aspects should already theoretically be factored in. The investment system is critically impacted or influenced by intermediaries such as ratings agencies, investment consultants and advisors and the actual market place or regulated financial markets, i.e. stock exchanges and trading markets.

A key element of the financial system is lending, i.e. when a financial institution or bank makes funding available as a loan to sectors of the economy. These institutions are not just private. For the metal and mining sector, public banks such as multilateral and development finance institutions are potentially much more relevant. KfW, AFD, EBRD, EIB and AIIB are examples of public entities of this kind that are the main vehicles through which governments pursue their own interests of securing access to raw materials, for instance.[263]

Investors as well as banking institutions need to develop policies and principles for lending activities and engage in dialogue with the mining sector. The first element of this kind of investment policy should be a clearly defined set of guidelines such as, no-go areas, adherence to industry guidelines on Free, Prior and Informed Consent, corruption prevention, reporting, etc., as described in section 7.3. Based on these guidelines, no financing or capital should be granted to companies that violate these criteria, for instance when applying for concessions to exploit minerals. Concrete criteria therefore need to be established to help in the decision-making process for investments or financing.

An even more relevant and appropriate approach would be to assess the role of companies, across sectors and in the mining sector, in relation to the planetary boundaries. Financial institutions need to systematically analyse the degree to which business models contribute to staying within these boundaries. The findings of these analyses should be a core element in deciding whether to grant loans and make investments. No-go areas would be integrated into an approach of this kind, but the company strategy and forward-looking decisions about capital expenditures and their implications for planetary boundaries would be addressed systematically, not as an add-on to a reputational risk assessment.

7.5 Policy

The following section presents an overview of policy pathways and mechanisms designed to minimise the environmental impacts of mining and to facilitate the transition of the metals and mining industries to the circular economy. Policy plays an extremely important role in different ways; various publications demonstrate direct links between good and bad governance and environmental impact[264]. Policy can have significant influence on environmental impacts at the international, national and regional level and is relevant for exporting as well as for importing countries. Due to the existence of different levels of policy, this section is divided into international, European Union and German policy.

7.5.1 International policy

In September 2000, leaders of 189 countries gathered at the United Nations headquarters and signed the Millennium Declaration in which they committed to achieving a set of eight measurable goals that range from cutting extreme poverty and hunger in half to promoting gender equality and reducing child mortality by 2015. The Millennium Declaration included what are known as the Millennium Development Goals (MDGs)[265]. In September 2015, the Millennium Declaration and MDGs were replaced by Agenda 2030 and the Sustainable Development Goals (SDGs) at the United Nations General Assembly. The 2030 Agenda for Sustainable Development and the SDGs represent the world's plan of action for social inclusion, environmental sustainability and economic development. Compared to the MDGs, the SGDs comprise 17 goals instead of 8 and 169 specific targets.

For all 17 goals, mining plays a role to a greater or lesser extent. The link between mining and the SDGs was analysed by the Columbia Centre on Sustainable Investment (CCSI), UN Sustainable Development Solutions Network (SDSN), United Nations Development Programme (UNDP) and the World Economic Forum. The major overlaps and issue areas of mining and the SDGs are summarised in Fig 15.

The biggest challenges include transposing the targets and goals into national legislation. This includes defining national goals and targets for each country and commodity based on the original 17 SDGs and implementing comprehensive national action plans.

International policymakers need to take a closer look at supply chains and the environmental/social impacts of metals and ores which are closely related to the SDGs.

The core of the signed Paris agreement in 2015 is what are referred to as the Nationally Determined Contributions (NDCs). NDCs embody efforts by each country to reduce national emissions and adapt the impacts of climate change. Steel and aluminium play, as described in the previous sections, a significant role and need to be taken into account not only in the NDCs where mining takes place, but in the entire supply chain.

That being said, to contribute to the SDGs each country needs to set targets for mining companies with clear timelines and guidance. Furthermore, policymakers need to work more closely with different stakeholders from civil society, science and the private sector on fulfilling the SDGs. International policymakers need to take a closer look at supply chains and the environmental/social impacts of metals and ores which are closely related to the SDGs. To understand the effect that each commodity and company has on the environment and social issues, transparency must be mandatory so that specific guidance and roadmaps for improvement can be monitored and evaluated.

Fig. 15: Major issue areas for mining and the SDGs. *Source: The Columbia Center on Sustainable Investment (CCSI), UN Sustainable Development Solutions Network (SDSN), United Nations Development Programme (UNDP) and the World Economic Forum, 2016.*

Along the supply chain, resource efficiency plays a significant role in lowering the environmental impact which was addressed last year by the G20 but needs to be further explored. The lack of data and the different approaches in each country need to be merged and coordinated by an international authority. The report by the International Resource Panel[266] points out that the “right policies could cut the use of natural resources by up to 28% and GHG emissions by around 74%, while increasing economic activity by 1% in 2050”. Resource efficiency can only be one factor in minimising the environmental impact and has to be addressed as such in the discussion. Furthermore, the question of sufficiency and degrowth is a key to minimising environmental impact and has to be addressed as such more prominently in international policy.

Alternative economic concepts to growth-focused capitalism are, for example, zero growth, degrowth or sufficiency strategies. These concepts align with the sixth pillar of the circular economy- Human activities generate value in measures beyond just financial. Essentially, they call for a paradigm shift and a reordering of societal and environmental values. For now, they remain mostly theoretical discussions. With growing awareness and the development of the circular economy, sufficiency concepts may find their way into the mainstream economic paradigm in the future.

7.5.2 European Union policy

There are various directives, initiatives and processes in the European Union concerning mining and metals. Some of these are directly linked to bauxite/aluminium and iron ore/steel, others are indirectly linked, such as the conflict mineral regulation, which is linked to steel through tin. This section addresses the EU Raw Materials Initiative (RMI), Conflict Minerals Regulation and the EU Critical Raw Materials List as well as the Circular Economy Package.

The RMI was launched in November 2008 under the "Communication on the Raw Materials Initiative - Meeting our critical needs for growth and jobs in Europe" with three pillars (COM(2008)699):

1. Fair and sustainable supply of raw materials from global markets
2. Sustainable supply of raw materials within the EU
3. Resource efficiency and supply of "secondary raw materials" through recycling

The EU focuses on minimising supply risks and creating a level playing field for access in third countries. As a result, the EU initiated policy dialogue on raw materials with countries like Argentina, Brazil, Canada, Chile, China, Colombia, Greenland, Japan, Mexico, Peru, Russia, the United States and Uruguay. Besides bilateral contracts, promoting mining in the EU is another big focus. The strategy covers all raw materials used by European industry except materials from agricultural production and materials used as fuel. Resources that are important for technologies used in climate change mitigation, telecommunications and high-tech play a particularly significant role. Ensuring access to these raw materials is crucial to the competitiveness and growth of the EU economy and to the objectives of the Europe 2020 strategy.

However, the initiative displays an enormous lack of coherence, predominantly in relation to development policy goals and sustainability. Even though it mentions sustainability and development, it promotes means which most certainly undermine development opportunities of resource-rich developing countries at their core[267].

Another important European policy is the Regulation on Conflict Minerals, the European counterpart of the US Dodd-Frank conflict minerals legislation. The new regulation will take effect on 1 January 2021 and includes four critical raw materials (also called 3TG) - tin, tantalum, tungsten and gold. Conflict minerals are described by the EU as follows: "In politically unstable areas, the minerals trade can be used to finance armed groups, fuel forced labour and other human rights abuses, and support corruption and money laundering".[268]

The new regulation aims to:

1. Ensure that EU importers of 3TG (tin, tungsten, tantalum and gold) meet international standards for responsible sourcing set by the Organisation for Economic Co-operation and Development (OECD).
2. Ensure that global and EU smelters and refiners of 3TG source responsibly.
3. Help break the link between conflict and illegal exploitation of minerals.
4. Support local development and help put an end to the exploitation and abuse of local communities, including mine workers.

A number of other raw materials such as bauxite, iron ore or cobalt would also fall under the scope of this regulation based on the definition of "conflict minerals" but were not included in the list, which deeply undermines the ambition and impact of the regulation. Nevertheless, it has to be kept in mind that it is the first of its kind in the sector and can been seen as a starting point for expansion to other raw materials.

The third policy addressed in this section is the Critical Raw Material list. Critical Raw Materials (CRMs) are raw materials which are economically and strategically important for the European economy but have a high risk associated with their supply[269]. The first analysis of CRM for the EU was published in 2010 by the Ad-Hoc Working Group on defining critical raw materials. Besides academics, the Working Group included business associations and national authorities. The most recent report was published in 2017. 27 of 78 non-energetic and non-food raw materials were classified as "critical" by the EU[270].

The list does not include environmental and social criticality; it is only based on economic supply risks and importance for the EU. Besides the fact that criticality cannot be explained if the social and environmental realm is ignored, an approach of this kind poses a high risk for European companies and authorities. As shown in various previous sections, aluminium and steel play an important role for the European economy and have a big impact on the environment and many social issues, but neither one is included in the list.

As one of the world's largest economies, German industry has a great deal of power to improve mining operations in relevant countries.

Furthermore, the EU developed an action plan for the circular economy which outlines a set of different measures and actions. It includes general measures such as product design, production processes, consumption, waste, innovation, investment and other cross-cutting issues. Besides plastics, food, biomass and fertilisers, the measures also go into detail on critical raw materials and construction where steel and aluminium play a role. In terms of the CE for critical raw materials, it discusses cross-cutting policies such as the Waste Framework Directive. The EU heading up efforts to share best practices for the recovery of critical raw materials from mining waste and landfills. Nevertheless, the action plan is weak in areas such as the waste directive, and the level of ambition for a European circular economy is not high enough. For example, the BAP on mining waste is not outlined in detail and what it means for EU in terms of reduction of metal imports and mining in the EU itself.

7.5.3 German policy

The centrepiece of the German sustainability policy is found in the National Sustainable Development Strategy. Germany adopted its first sustainable development strategy back in 2002. Since then, it has been updated at regular intervals, with the latest version published in 2016. The new updated National Sustainable Development Strategy is aligned with the UN's SDGs with a focus on global responsibility.

In terms of raw materials such as bauxite/aluminium and iron ore/steel the strategy focuses on resource efficiency whereas ultimately, only an overall reduction in resource consumption can reduce the actual strain on the environment and help prioritise individual raw materials. As explained in previous sections, the concept of decoupling needs to serve as the foundation and become the focus of policy.

The new updated 2016 National Sustainable Development Strategy is aligned with the UN's 17 SDGs and focuses more on global responsibility. The Cabinet of Germany adopted the new strategy on 11 January 2017.

Apart from the National Sustainable Development Strategy, the raw materials strategy of the German government is the core policy directly linked to raw materials such as iron ore and bauxite. The strategy published in 2010 with its full title "Securing a sustainable supply of raw materials[271] in Germany with non-energetic mineral raw materials" is similar to the RMI at its core.

The strategy's action plan includes bilateral raw material partnerships, exploration funding programmes, unbound financial loans (UFK), so-called Hermes guarantees and innovation subsidy programmes in the areas of raw materials research, raw materials and material efficiency as well as recycling. In addition, interdisciplinary approaches between different ministries and international raw material diplomacy plans have been put in place.[272]

There are a number of different activities and processes being carried out by the German government and its institutions which cannot be explained in depth in this section, but some are mentioned in the footnote.[273]

On behalf of the German government, resource efficiency was put on the agenda for the first time at the G20 summit in Hamburg in 2017 and the "G20 Resource Efficiency Dialogue" initiated[274]. Resource efficiency plays a major role in the German raw materials strategy.

The goal of ProgRess, the German resource efficiency programme, is to double resource efficiency by 2020 (baseline year 1994). The German Federal Ministry of the Environment, Nature Conservation and Nuclear Safety summarised the goal of ProgRess as follows: "[...]the Federal Government aims to decouple economic growth as far as possible from the use of resources and to reduce the associated environmental impact, to strengthen the future and competitiveness of the German economy and thus to promote stable employment and social cohesion".

Beside the security of supply and diversification of raw materials, ProgRess and therefore resource efficiency is an important pillar for the German strategy on raw materials. ProgRess is a step in the right direction but fails to include concrete targets for higher rates of resource efficiency and does not reflect a commitment to the absolute reduction of resource consumption.

In order to promote sustainable supply chains, policies need to push initiatives, tools, etc. that promote transparency in supply chains and address shortcomings in import and export goods to and from Germany. EITI, a global initiative for greater financial transparency and accountability in the raw materials sector, is a start but unfortunately does not apply to the entire supply chain because it focuses on transparency in the extractive sector of the implementing country.

As the title of the German raw materials strategy implies, its goal is to secure a sustainable supply of raw materials with an economic focus on supply rather than sustainability. In 2017, the BDI (Federation of German Industries) published a position paper on the supply of raw materials for the German economy. The upcoming challenges for German industry were identified particularly in the fields of renewables, electric vehicles and industry 4.0. As described in the European policy section, supply and economic risks are the focus of the German raw materials strategy as well as in the BDI position paper and are not sufficiently linked to the environmental and social impacts of the imports of non-food and non-energy-related raw materials.

Calls for innovative raw material projects such as in the area of deep-sea mining are not only illogical due to the lack of a legal framework, but also counteract the demand for sustainability and environmental protection[275].

Furthermore, the circular economy cannot be limited in scope to a single country or sector, it must have a global focus and be accompanied by an implementation plan. German industry exports goods such as cars, machines and aluminium semis to countries that do not have well- functioning circular economies. This highlights the importance of promoting knowledge transfer and linking it with development policies. According to the BDI, "German industry wants to make a contribution to improving the situation for people and the environment. However, their possibilities are very limited. One reason for this is that there are no relevant German mining companies that "extract raw materials in emerging and developing countries"". But this statement is far too short-sighted and does not take into account the powerful position of German industry in relation to mining companies. As one of the world's largest economies, German industry has a great deal of power to improve mining operations in relevant countries, as it can exert pressure on mining groups and states engaging in poor practices and promote sustainable and more responsible and transparent supply chains through supplier selection.

Like German industry, German legislation can make use of various mechanisms to exert considerable influence on environmental and social impacts. Integrated in the German strategy are raw material partnerships which so far have been formed with Mongolia, Kazakhstan and Peru. In addition, there is a comparable agreement with Australia and Chile, not as an intergovernmental agreement but on a ministry level. These agreements need to include obligatory due diligence for companies and policymaking entities at all levels on environmental and social aspects and need to be established for every agreement between Germany and other countries in the context of mining.

8. Call to action

WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature. WWF believes that long-term prosperity can only be achieved if sustainability is at the heart of everything we do. To this end, we have to scrutinise unsustainable practices and transform them into solutions that benefit people, nature and economies in equal measure. Establishing a functioning circular economy for the metal and mining industries could serve as an example for the kind of transformation needed –requiring a collaborative and coordinated effort from different actors and stakeholders at various levels.

8.1 Investors

To become a sustainable actor in metals and mining, investors need to:

1. Define integrated environmental and social criteria or mandatory decision-making criteria for all steps along the mining value chain to guide the investment or direct financing process.
2. Create tools for systematic analysis to determine which business practices contribute to staying within planetary boundaries and which don't
3. Develop standards and policies for environmental risk analysis and impacts in their internal decision-making processes.

8.2 Companies

The Federation of German Industries (BDI) states that German industry wants to contribute to improving the situation of people and the environment. However, according to their own statement, their possibilities are limited as there are no key German mining companies operating in developing countries and emerging economies (BDI 2017). In our opinion, this statement is unconvincing. As portrayed in this study, Germany is one of the main importers of aluminium and steel and one of the world's leading exporters of semi-manufactured goods. This tremendous economic power has the power to bring sustainable change and should therefore be positively leveraged. In this respect, WWF calls upon companies to:

1. Identify their risks, impacts and responsibilities related to the mining and metals value chain.
2. Develop and implement company-specific strategies together with scientists, NGOs, government agencies and other stakeholders to improve Best Available Practices (BAP) and Best Available Techniques (BAT).
3. Require supply chain due diligence from their suppliers to ensure mining standards are upheld.
4. Incorporate relevant Sustainable Development Goals (SDGs) such as SDGs 6, 7, 9, 11, 12, 13, 15 to guide business planning and management.
5. Seek to develop alternative sustainable sources such as urban mining.
6. Follow the principles of eco-design taking into account the environmental impact of products during their entire life cycle to facilitate their reuse, remanufacturing, recovery and ultimately, recycling.
7. Use renewable energy for their businesses.
8. Implement credible certification schemes, e.g. IRMA.

8.3 Consumers

In a circular economy, what is known as the waste pyramid or waste hierarchy can act as a guideline for consumers to systematically reduce resource use and waste generation. WWF therefore calls upon consumers to

1. Reduce overall consumption of mineral resource-intensive products by choosing eco-friendly alternatives.
2. Inform themselves about the origin of products (including raw material production) and demand access to this information from companies if not easily available.
3. Demand sustainable solutions for all products and make changes to the products and services they buy.
4. Demand transparency from companies through various channels (including point-of-sale).

8.4 Government

The government's main priority should be on reducing resource consumption and transitioning to a truly equitable and circular economy. The EU Circular Economy Package[276] focuses heavily on waste management and recycling. Recycling, however, should only be take precedence after exhausting possibilities for waste avoidance and reduction. Resource policies in Germany should focus on reducing resource use to a globally equitable and environmentally sound level. As due diligence reporting and standards in the industry are mostly voluntary, environmental laws are often not enforced on the ground, and human rights violations often go unpunished, the German government should assume responsibility as a strong regulatory driver for German companies involved in mining either directly or through their supply chain. In this regard, the German government needs to:

1. Prioritise policies and legislation that promote the reduction of absolute resource use and inform the German population about resource reduction, reuse and recycling options.
2. Identify potential renewable resource alternatives to aluminium and steel and subsidise research and development to turn these alternatives into commercially viable solutions
3. Revise the German Raw Materials Strategy in a democratic and inclusive process to include the environmental and social criticality of raw materials.
4. Implement the German Sustainability Strategy in all federal agencies and departments.
5. Integrate concrete and binding resource efficiency rates for aluminium, steel and other mineral resources to meet the goal of the German resource efficiency programme (ProgRess) to double resource efficiency by 2020 from 1994 levels. Integrate a goal for reducing the absolute consumption of mineral resources into the same programme.
6. Define a clear list of social and environmental criteria for importing mineral resources to the EU. Develop a legally binding regulation that requires companies and government bodies of the EU to comply with the guideline.

7. Support bauxite and iron ore in the EU Regulation on Conflict Minerals which will enter into force in 2021. This regulation already includes four critical raw materials - tin, tantalum, tungsten and gold. Not recognising and including these two critical “conflict minerals” deeply undermines the aim and impact of the regulation.
8. Include environmental and social criticality in the EU Critical Raw Materials (CRMs) list as well as in the Raw Materials Strategy.
9. Take into account the key Sustainable Development Goals, i.e. 6, 7, 9, 11, 12, 13, 15, when developing or updating policies that deal with mineral resources at German federal level.
10. Undertake and implement thorough Environmental Impact Assessments (EIAs) of extractive projects including the exploration licensing phase considering the indirect impacts of linear infrastructures.

References

AI (2017). Guinea to Mandate Domestic Refining of Bauxite.
Aluminium Insider. https://aluminiuminsider.com/guinea-mandate-domestic-refining-bauxite/ (accessed 24.10.2017).

Ali, S.H., Giurco, D., Arndt, N., Nickless, E., Brown, G., Demetriades, A., Durrheim, R., Enriquez, M.A., Kinnaird, J., Littleboy, A., Meinert, L.D., Oberhänsli, R., Salem, J., Schodde, R., Schneider, G., Vidal, O., Yakovleva, N. (2017). Mineral supply for sustainable development requires resource governance. Nature 543, 367-372.

ASI (2017). About Aluminium. Aluminium Stewardship Initiative.
https://aluminium-stewardship.org/about-asi/aluminium-and-sustainability/ (accessed 17.10.2017).

Auty, R. M. (1993). Sustaining Development in Mineral Economies: The Resource Curse Thesis. Routledge.

Aviva, Investec, WWF (2015). Safeguarding outstanding natural value. The role of institutional investors in protecting natural World Heritage sites from extractive activity. Aviva Investors, Investec Asset Management and World Wide Fund for Nature.

Banerjee, S. B. (2012). A Climate for Change? Critical Reflections on the Durban United Nations Climate Change Conference. Organization Studies, 33(12), 1761-1786.

Barber, C.P., Cochrane, M.A., Souza, C.M. Jr., Laurance, W.F. (2014). Roads, deforestation, and the mitigating effect of protected áreas in the Amazon. Biological Conservation 177, 203–209.

Barbier, E.B., Moreno-Mateos, D., Rogers, A.D., Pendleton, L., Danovaro, R., Henry, L., Morato, T., Ardron, J., Van Dover, C.L. (2014). Protect the deep sea. Nature, Vol. 505, 475-477.

BaP (2017). Werkstoffe – Materialien. BaP stainless steel solutions GmbH.
http://www.bap-edelstahl.de/Werkstoffe_Materialien.html. (accessed 06.12.2017).

BBOP (2012). Standard on Biodiversity Offsets. Business and Biodiversity Offsets Programme.
http://www.forest-trends.org/documents/files/doc_3078.pdf (accessed 15.12.2017).

BDI (2017). Rohstoffversorgung 4.0 - Handlungsempfehlungen für eine nachhaltige Rohstoffpolitik im Zeichen der Digitalisierung. Bundesverband der Deutschen Industrie e.V..
https://issuu.com/bdi-berlin/docs/201710_position_bdi_rohstoffversorg (accessed 16.05.2018)

Bennett, G., Gallant, M., ten Kate, K. (2017). State of Biodiversity Mitigation 2017. Markets and Compensation for Global Infrastructure Development. Forest Trends' Ecosystem Marketplace.

BIR (2017). World Steel Recycling in Figures 2012 – 2016. Bureau of International Recycling.

Biswas, B. (2012). Red Mud Disposal: The Ecological Concern of Alumina Refining. Al Circle Blog.
http://blog.alcircle.com/2012/10/11/red-mud-disposal-the-ecological-concern-of-alumina-refining/ (accessed 17.01.2018)

BMUB (2016). Klimaschutzplan 2050 - Klimaschutzpolitische Grundsätze und Ziele der Bundesregierung. Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit.
https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Klimaschutz/klimaschutzplan_2050_bf.pdf (accessed 15.05.2018)

BMUB (2017). (2017). G20-Gipfel beschließt Ressourceneffizienz-Dialog. Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit. https://www.bmu.de/themen/wirtschaft-produkte-ressourcen-tourismus/ressourceneffizienz/ressourcen-effizienz-in-der-g20/ (accessed 04.02.2018).

BMWi (2010). Rohstoffstrategie der Bundesregierung. Bundesministerium für Wirtschaft und Technologie.

BMZ (2010). Entwicklungsfaktor extraktive Rohstoffe. BMZ SPEZIAL 166 , Ein Positionspapier des BMZ. Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung.

Booz & Company (2010). Driving a Green Revolution in the Global Auto Industry - Implications of New Automotive Trends for Steel Makers. Worldsteel-44 conference in Tokyo on October 5, 2010, Booz & Company.
https://www.slideshare.net/wrusso1011/driving-a-green-rev (accessed 16.01.2018).

BPB (2017). Deutschland: Entwicklung des Außenhandels - Import, Export und Exportüberschuss in absoluten Zahlen, 1993 bis 2016. Bundeszentrale für Politische Bildung.
http://www.bpb.de/nachschlagen/zahlen-und-fakten/globalisierung/52842/aussenhandel (accessed 25.04.2018).

Butterworth, T. (2012). Welcome To The Age Of Urban Mining. Forbes.
https://www.forbes.com/sites/trevorbutterworth/2012/07/17/welcome-to-the-age-of-urban-mining/#6af1a76633d5 (accessed 19.01.2018).

Buxton, A. (2012). MMSD+ 10: Reflecting on a decade of mining and sustainable development. International Institute for Environment and Development.

Carvalho (2017). Mining industry and sustainable development: time for change. Food and Energy Security, Vol. 6(2), 61–77

Ciacci, L., Eckelman, M., Passarini, F., Chen, W., Vassura, I., Morselli, L. (2014). Historical evolution of greenhouse gas emissions from aluminium production at a country level. Journal of Cleaner Production 84, 540-549.

Çiftçi, B. (2017). The challenges ahead for the steelmaking materials markets. World Steel Association.
https://www.worldsteel.org/media-centre/blog/2017/steelmaking-materials-markets.html (accessed 17.05.2018).

Clark, A. L. Koh N. & Clark, J. (2000). Legal Framework for Mine Closure. In Mine Closure and Sustainable Development Workshop, organized by the World Bank and Metal Mining Agency of Japan', Washington D.C.

Critical Raw Materials Alliance (2018). What are Critical Raw Materials? http://criticalrawmaterials.org/critical-raw-materials/ (accessed 07.01.2018).

Dagenborg, J., Solsvik, T. (2018). Hydro denies Brazil alumina plant contaminated local environment. https://www.reuters.com/article/us-norsk-hydro-brazil/hydro-denies-brazil-alumina-plant-contaminated-local-environment-idUSKBN1HG1MH (accessed 15.05.2018).

Destatis (2017). data for 2016, various datasets. Statistisches Bundesamt. https://www-genesis.destatis.de.

Deutscher Bundestag (2017). Antwort der Bundesregierung auf die Kleine Anfrage der Abgeordneten Niema Movassat, Anette Groth, Heike Hänsel, weiterer Abgeordneter und der Fraktion DIE LINKE. – Drucksache 18/10832 – Die Rolle der Kompetenzzentren Bergbau und Rohstoffe an den Auslandshandelskammern in der Deutschen Rohstoffstrategie.

Dias, A.S., Lawrence, K., Suárez, C.F., Charity, S., Granizo, T., Maretti, C. (eds.) (2017). State of the Amazon: Deforestation trends. WWF Living Amazon Initiative and Latin America and Carribbean.

Direction Nationale des Eaux et Forêts (2015). Liste des aires protéges de Guinée. http://www.eaux-forets.gouv.gn/index.php/mot-du-directeur/9-uncategorised/112-liste-des-aires-proteges-de-guinee (accessed 21.11.2017).

Dongyong, C. (2017). Future Megatrends and the Steel Industry. Asian Steel Watch Vol.03, 6-11.

DSMA (2017). Objectives. Deep Sea Mining Alliance. http://www.deepsea-mining-alliance.com/en-objectives.php (accessed 07.12.2017).

Dudley, N. (Editor) (2008). Guidelines for Applying Protected Area Management Categories. IUCN.

Duran, A., Rauch, J., Gaston, K.J. (2013). Global spatial coincidence between protected areas and metal mining activities. Biological Conservation 160, 272–278.

Edwards, D.P., Sloan, S., Weng, L., Dirks, P., Sayer, J., Laurance, W.F. (2014). Mining and the African environment. Conservation Letters, 7(3), 302-311.

EMF (2015). Towards a Circular Economy: Business Rationale for an Accelerated Transition. Ellen Mac Arthur Foundation. https://www.ellenmacarthurfoundation.org/assets/downloads/TCE_Ellen-MacArthur-Foundation_9-Dec-2015.pdf (accessed 21.12.2017).

EPA (2017). TENORM: Bauxite and Alumina Production Wastes.

United States Environmental Protection Agency. https://www.epa.gov/radiation/tenorm-bauxite-and-alumina-production-wastes (accessed 24.10.2017).

EPA (2017a). Decision on the TTRL marine consent application. New Zealand Environmental Protection Authority. http://www.epa.govt.nz/news/epa-media-releases/Pages/TTRL-2017-decision.aspx (accessed 13.11.2017).

Escobar, H. (2015). Mud tsunami wreaks ecological havoc in Brazil. Science 350, 1138.

European Parliament (2017). Supply chain due diligence by importers of minerals and metals originating in conflict-affected and high-risk areas. European Parliament legislative resolution of 16 March 2017, (COM(2014)0111 – C7-0092/2014 – 2014/0059(COD)).

Fearnside, P.M. (2016). Environmental and Social Impacts of Hydroelectric Dams in Brazilian Amazonia: Implications for the Aluminum Industry. World Development, 77, 48–65.

Feldt, H. & Kerkow, U. (2013). Menschenrechtliche Probleme im peruanischen Rohstoffsektor und die deutsche Mitverantwortung. Bischöfliches Hilfswerk MISEREOR e.V..

Ferretti, I., Zanoni, S., Zavanella, L., Diana, A. (2007). Greening the aluminium supply chain. International Journal of Production Economics, Vol. 108, 236–245.

Franks, D.M., Brereton, D., Moran, C.J., Sarker, T., Cohen, T. (2010). Cumulative Impacts - a Good Practice Guide for the Australian Coal Mining Industry. Centre for Social Responsibility in Mining & Centre for Water in the Minerals Industry, Sustainable Minerals Institute, The University of Queensland. Australian Coal Association Research Program.

Galarraga Gallastegui, I. (2002). The use of eco-labels: A review of the literature. Environmental Policy and Governance, 12(6), 316-331.

Gelencsér, A., Kováts, N., Turóczi, B., Rostási, Á., Hoffer, A., Imre, K., Nyirő-Kósa, I., Csákberényi-Malasics, D., Tóth, Á., Czitrovszky, A., Nagy, A., Nagy, S., Ács, A., Kovács, A., Ferincz, Á., Hartyáni, Z., Pósfai, M. (2011). The Red Mud Accident in Ajka (Hungary): Characterization and Potential Health Effects of Fugitive Dust. Environmental Science & Technology 45 (4), 1608-1615.

Gibson, G., Klinck, J. (2005). Canada's Resilient North: The Impact of Mining on Aboriginal Communities. Pimatisiwin: A Journal of Aboriginal and Indigenous Community Health 3(1), 116-139).

Google Maps. (2018). Google Maps. [online] Available at: https://www.google.de/maps/place/4%C2%B013'13.3%22S+55%C2%B002'08.1%22W/@-4.1078702,-55.3385181,114206m/data=!3m1!1e3!4m5!3m4!1s0x0:0x0!8m2!3d-4.220373!4d-55.035584 (accessed 21.06. 2018).

Guj, P., Martin, S., Maybee, B., Cawood, F.T., Bocoum, B., Gosai, N., Huibregtse, S. (2017). Transfer pricing in mining with a focus on Africa : a reference guide for practitioners. World Bank Group.

Gunther, M. (2014). Why are major beverage companies refusing to use a 90% recycled can? The Guardian. https://www.theguardian.com/sustainable-business/2014/oct/30/recycled-aluminum-novelis-ford-cocacola-pepsi-miller-bud-weiser-beer (accessed 26.01.2018).

Hagemann & Partner (2017). Chemie am Auto. Folie 1: Eisen und Aluminium, zwei unverzichtbare Metalle im Autobau. Hagemann & Partner Bildungsmedien. http://www.chemie-am-auto.de/begleitmaterial/pdfs/Folie_Eisen_Aluminium_1.jpg (accessed 18.01.2018).

Haalboom B. 2012. The intersection of corporate social responsibility guidelines and Indigenous rights: examining neoliberal governance of a proposed mining project in Suriname. Geoforum. 43(5):969–979.

Hanna, P., & Vanclay, F. (2013). Human rights, Indigenous peoples and the concept of Free, Prior and Informed Consent. Impact Assessment and Project Appraisal, 31(2), 146-157.

Head, J. (2016). Bauxite in Malaysia: The environmental cost of mining. BBC. http://www.bbc.com/news/world-asia-35340528 (accessed 24.10.2017).

Heinrich Böll Stiftung (2011). Analysis of the EU Raw Materials Initiative. https://www.boell.de/en/ecology/resource-governance-analysis-of-the-eu-raw-materials-initiative-11124.html (accessed 14.02.2018).

HIIK (2017). Conflict Barometer 2016. Heidelberg Institute for International Conflict Research.

Hoekstra, J., Boucher,T., Ricketts,T., Roberts,C. (2005). Confronting a biome crisis: global disparities of habitat loss and protection. Ecology Letters 8, 23–29.

Huy, D., Andruleit, H., Babies, H.-G., Elsner, H., Homberg-Heumann, D., Meßner, J., Röhling, S. Schauer, M., Schmidt, S., Schmitz, M., Szurlies, M., Wehenpohl, B., Wilken, H., Bahr, A., Hofrichter, W., Tallig, A. (2016). Deutschland – Rohstoffsituation 2015. Bundesanstalt für Geowissenschaften und Rohstoffe.

ICMM (2008). Planning for Integrated Mine Closure: Toolkit. International Council on Mining and Metals.

ICMM (2012). Trends in the mining and metals industry. The International Council on Mining and Metals.

ICMM (2012b). The role of minerals and metals in a low carbon economy. The International Council on Mining and Metals.

ICMM (2013).Community Development Toolkit. Available from https://www.icmm.com/news-and-events/news/ articles/icmm-presents-updated-community-development-toolkit (accessed 04.01.14).

IIED (2002). Breaking New Ground: Mining, Minerals and Sustainable Development. Chapter 9: Local Communities and Mines. Breaking New Grounds. International Institute for Environment and Development.

International Resource Panel (2017). Resource Efficiency: Potential and Economic Implications.

IRMA (2016). IRMA Standard for Responsible Mining IRMA-STD-001 Draft v2.0. Initiative for Responsible Mining Assurance.

ISA (2017). Deep Seabed Minerals Contractors. International Seabed Authority. https://www.isa.org.jm/deep-seabed-minerals-contractors (accessed 20.11.2017).

IUCN/PACO (2012). Mining sector development in West Africa and its impact on conservation. IUCN/PACO, Gland, Switzerland and Ouagadougou, Burkina Faso.

Jain, R., Z. C. Cui, Domen, J. K. (2016). Environmental impact of mining and mineral processing. Elsevier, Butter-worth-Heinemann Publ., 322 pp.

Jégourel, Y., Chalmin, P. (2015). Aluminium and GHG Emissions: Are all Top Producers playing the same game? Cyclope for AluWatch.

Jennings, S.R., Neuman, D.R., Blicker, P.S. (2008). Acid Mine Drainage and Effects on Fish Health and Ecology: A Review. Reclamation Research Group.

Joppa, L.N., Pfaff, A. (2009). High and far: biases in the location of protected areas. Plos One 4, 8273.

Jungmichel, N., Schampel, C., Weiss, D. (2017). Umweltatlas Lieferketten – Umweltwirkungen und Hot-Spots in der Lieferkette. adelphi/Systain.

Kemp, D., Bond C.J., Franks D.M., Cote, C. (2010). Mining, water and human rights: making the connection. Journal of Cleaner Production 18, 1553-1562.

KPMG (2014). Guinea Country mining guide. KPMG Global Mining Institute, KPMG International.

KPMG (2018). How to report on the SDGs. KPMG International Cooperative. https://assets.kpmg.com/content/dam/kpmg/xx/pdf/2018/02/how-to-report-on-sdgs.pdf (accessed 16.05.2018).

León-Mejía, G., Espitia-Pérez, L., Hoyos-Giraldo, L.S., Da Silva, J., Hartmann, A., Pêgas Henriques, J.A., Quintana, M. (2011). Assessment of DNA damage in coal open-cast mining workers using the cytokinesis-blocked micronucleus test and the comet assay. Science of the Total Environment, 409, 686–691.

Leotaud, V.R. (2017). Seabed mining approved in New Zealand despite environmentalists' concerns. Mining.com. http://www.mining.com/seabed-mining-approved-new-zealand-despite-environmentalists-concerns/ (accessed 13.11.2017).

Leotaud, V.R. (2017a). Colombian First Nations protest against coal mine. Mining.com. http://www.mining.com/colombian-first-nations-protest-coal-mine/ (accessed 13.12.2017).

Lernoud, J., Potts, J., Sampson, G., Garibay, S., Lynch, M., Voora, V., Willer, H., Wozniak, J. (2017). The State of Sustainable Markets – Statistics and Emerging Trends 2017. ITC, Geneva. http://www.intracen.org/uploadedFiles/intracenorg/Content/Publications/State-of-Sustainable-Market-2017_web.pdf (accessed 16.05.2018).

Li, J.C. (2008). Environmental Impact Assessments in Developing Countries: An Opportunity for Greater Environmental Security? Foundation for Environmental Security and Sustainability.

Lichtenstein, J., Oppelt, R. (2017). Five inconvenient truths for the global steel industry. https://www.accenture.com/us-en/blogs/blogs-five-global-steel-industry (accessed 13.11.2017).

Lutter, S., Giljum, S., Lieber, M., Manstein, C. (2016). Die Nutzung natürlicher Ressourcen – Bericht für Deutschland 2016. Umweltbundesamt.

Mayes, W.M., Burke, I.T., Gomes, H.I., Anton, Á.D., Molnár, M., Feigl, V., Ujaczki, É. (2016). Advances in Understanding Environmental Risks of Red Mud After the Ajka Spill, Hungary. Journal of Sustainable Metallurgy, 2 (4), 332–343.

McKinsey (2014). Learnings from upstream integration of steelmakers. OECD workshop, Cape Town, December 11, 2014. McKinsey & Company. http://www.oecd.org/sti/ind/Session%202%20%20-%20McKinsey%20-%20OECD-SA%20Dec%20 2014.pdf (accessed 10.10.2017).

MMSD (2002). Mining for the Future. Mine Closure Working Paper. http://pubs.iied.org/pdfs/G00884.pdf (accessed 24.01.2018).

Minerals Council of Australia (2015). Cumulative Environmental Impact Assessment Industry Guide.

miningfacts.org (2012). What is Artisanal and Small-Scale Mining? http://www.miningfacts.org/communities/what-is-artisanal-and-small-scale-mining/ (accessed 16.11.2017).

Moser, C. (2013). Die Folgen des Bergbaus in Brasilien. In: Vom Erz zum Auto. Rohstoffe für die Reichen – schlechte Lebensbedingungen für die Armen. Misereor, 13.

Muñoz, S.O., Gladek, E. (2017). One Planet Approaches- Methodology Mapping and Pathways Forward. Metabolic, WWF Netherlands, WWF Switzerland, IUCN Netherlands.

Murray, A., Skene, K., Haynes, K. (2017). The Circular Economy: An interdisciplinary exploration of the concept and its application in a global context. Journal of Business Ethics 140, 369-380.

New South Wales Audit Office (2017). Mining rehabilitation security deposits. https://www.audit.nsw.gov.au/publications/latest-reports/mining-rehabilitation-security-deposits (accessed 24.01.2018).

Natural Resource Governance Institute (2017). 2017 Resource Governance Index.

Norgate, T.E., Jahanshahi, S., Rankin, W. (2006). Assessing the environmental Impact of metal production processes. Journal of Cleaner Production, Vol. 15, 838-848.

OECD (2010). Materials Case Study 2: Aluminium. Working Document. OECD Global Forum on Environment focusing on Sustainable Materials Management, 25-27 October 2010, Mechelen, Belgium. OECD Environment Directorate.

OECD (2012). Steelmaking Raw Materials: Market and Policy Developments. Organisation for Economic Co-operation and Development; Directorate for Science, Technology and Industry, Steel Committee.

OECD (2016). OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas. Third Edition, OECD Publishing, Paris.

OECD (2017). Due Diligence Guidance for Meaningful Stakeholder Engagement in the Extractive Sector. OECD Publishing, Paris. https://read.oecd-ilibrary.org/governance/oecd-due-diligence-guidance-for-meaningful-stakeholder-engagement-in-the-extractive-sector_9789264252462-en#page1 (accessed 16.05.2018).

Öko-Institut (2017). Elektromobilität – Faktencheck. https://www.oeko.de/fileadmin/oekodoc/FAQ_Elektromobilitaet_Oeko-Institut_2017.pdf (accessed 18.10.2017).

Olmez, G.M., Dilek, F.B., Karanfil, T., Yetis, U. (2016). The environmental impacts of iron and steel industry: a life cycle assessment study. Journal of Cleaner Production, Vol. 130, 195-201.

Owen, J. R., & Kemp, D. (2014). Free prior and informed consent', social complexity and the mining industry: Establishing a knowledge base. Resources Policy, 41, 91-100.

Parry, L. (2014). New laws could hand miners 10% of Brazil's national parks and indigenous lands. The Conversation. http://theconversation.com/new-laws-could-hand-miners-10-of-brazils-national-parks-and-indigenous-lands-33912 (accessed 22.11.2017).

Phillips, D. (2015). Another huge and open iron mine is carved out of Brazil's rain forest. Washington Post. https://www.washingtonpost.com/world/the_americas/another-huge-and-open-iron-mine-is-carved-out-of-brazils-rain-forest/2015/04/13/cc1ce49a-cd75-11e4-8730-4f473416e759_story.html?utm_term=.49147566cf29 (accessed 22.11.2017).

Pilgrim, H., Groneweg, M., Reckordt, M. (2017). Ressourcenfluch 4.0 - Die sozialen und ökologischen Auswirkungen von Industrie 4.0 auf den Rohstoffsektor. PowerShift e. V.

Pooler, M., Feng, E. (2017). Steel industry grapples with curse of oversupply. Financial Times. https://www.ft.com/content/992ad270-b4d3-11e7-aa26-bb002965bce8 (accessed 13.11.2017).

Pontikes, Y. (2006). Disposal. Red Mud Project. http://redmud.org/red-mud/disposal/ (accessed 17.01.2018).

Prosser, I., Wolf, L., Littleboy, A. (2011). Water. CSIRO Science and Solutions for Australia Series, Chapter 10. Commonwealth Scientific and Industrial Research Organisation (CSIRO). http://www.publish.csiro.au/ebook/chapter/9780643103283_Chapter_10. (accessed 15.05.2018).

Pulitzer Centre, 2016. Mine Closures: What's happening in the backyard? https://pulitzercenter.org/reporting/mine-closure-whats-happening-south-africas-backyard (accessed 24.01.2018).

Reckordt, M. (2017). EU: Konfliktmineralien-Verordnung tritt in Kraft. Press release, Powershift e.V. https://power-shift.de/pressemitteilung-eu-konfliktmineralien-verordnung-tritt-in-kraft-breites-buendnis-der-zivilge-sellschaft-fordert-nachbesserungen/ (accessed 17.01.2018).

Reuters (2017). Guinea bauxite mining back to normal after week of riots. September 25, 2017. https://www.reuters.com/article/us-guinea-mining/guinea-bauxite-mining-back-to-normal-after-week-of-riots-idUSKCN1C025D (accessed 16.11.2017).

Reuters (2017a). UPDATE 1-Aluminium producer Norsk Hydro warns of Brazil bauxite shortfall. September 25, 2017. https://www.reuters.com/article/norsk-hydro-brazil/update-1-aluminium-producer-norsk-hydro-warns-of-brazil-bauxite-short-fall-idUSL8N1M60OF (accessed 20.11.2017).

Reuters (2018). Norway's Hydro says Brazil plant made unauthorized spills. https://www.reuters.com/article/us-norsk-hydro-brazil/norways-hydro-says-brazil-plant-made-unauthorized-spills-idUSKCN1GN0SN (accessed 15.05.2018).

Rünker, R. (2017). Intelligente Industrie durch zirkuläre Wertschöpfung. Friedrich-Ebert-Stiftung.

RUSAL (2016). Creating value. Annual Report 2016. UC RUSAL.

Russau, C. (2016). Erzabbau in Brasilien: Der hohe Preis eines billigen Rohstoffs. In: Diebstahl unter der blanken Oberfläche: Wie die Stahlindustrie sich aus der Verantwortung stiehlt. Christliche Initiative Romero e.V. (CIR).

Rüttinger, L., Treimer, R., Tiess, G., Griestop, L. (2016). Umwelt- und Sozialauswirkungen der Bauxitgewinnung und Aluminiumherstellung in Pará, Brasilien. adelphi.

SANDRP (2016). Drought hits hydropower: Shows how unreliable is hydro in changing climate. South Asia Network on Dams, Rivers and People. https://sandrp.wordpress.com/2016/06/10/drought-hits-hydropower-shows-how-unreliable-is-hydro-in-changing-climate/ (accessed 17.01.2018).

Sarna, S.K. (2015). Understanding Iron Ores and mining of Iron Ore. http://ispatguru.com/understanding-iron-ores-and-mining-of-iron-ore/ (accessed 20.11.2017).

Sassoon, M. (2009). Financial Surety: Implementation of Financial Surety for Mine Closure. World Bank Oil, Gas, and Mining Policy Division.

Scheele, F., ten Kate, G. (2015). There is more than 3TG. Stichting Onderzoek Multinationale Ondernemingen.

SEC (2012). Final Rule: Conflict Minerals. [Release No. 34-67716; File No. S7-40-10]. United States Securities and Exchange Commission. https://www.sec.gov/rules/final/2012/34-67716.pdf (accessed 13.12.2017).

SERI, GLOBAL 2000, Friends of the Earth Europe (2013). Kein Land in Sicht. Wie viel Land benötigt Europa weltweit zur Deckung seines Konsums? Sustainable Europe Research Institute, GLOBAL 2000, Friends of the Earth Europa.

Serrenho, A.C., Mourão, Z.S., Norman, J., Cullena, J.M., Allwood, J.M. (2016). The influence of UK emissions reduction targets on the emissions of the global steel industry. Resources, Conservation and Recycling, 107, 174–184.

Smith, M. (2013). Terrorist Tungsten in Colombia Taints Global Phone-to-Car Sales. Bloomberg. https://www.bloomberg.com/news/articles/2013-08-08/terrorist-tungsten-in-colombia-taints-global-phone-to-car-sales (accessed 13.12.2017).

Sonter, L.J., Barrett, D.J., Moran, C.J., Soares-Filho, B.S. (2015). Carbon emissions due to deforestation for the production of charcoal used in Brazil's steel industry. Nature Climate Change 5, 359–363.

Sonter, L.J., Herrera, D., Barrett, D.J., Galford, G.L., Moran, C.J., Soares-Filho, B.S. (2017). Mining drives extensive deforestation in the Brazilian Amazon. Nature Communications 8, 1013.

Spohr, M. (2016). Human Rights Risks in Mining. German Federal Institute for Geosciences and Natural Resources (BGR) and Max-Planck-Foundation for International Peace and the Rule of Law.

Stanford, K. (2016). Red mud – addressing the problem. https://aluminiuminsider.com/red-mud-addressing-the-problem/ (accessed 03.09.2018).

Statistisches Bundesamt (2017). Statistisches Jahrbuch 2016.

Stephens, C., Ahern, M. (2002). Worker and Community Health Impacts Related to Mining Operations Internationally. Mining, Minerals and Sustainable Development, International Institute for Environment and Development (IIED).

The Columbia Center on Sustainable Investment (CCSI), UN Sustainable Development Solutions Network (SDSN), United Nations Development Programme (UNDP), and the World Economic Forum (2016). Mapping Mining to the Sustainable Development Goals: An Atlas.

The Guardian (2016). Outrage as plant bosses acquitted over fatal toxic spill in Hungary. https://www.theguardian.com/world/2016/jan/28/outrage-plant-bosses-acquitted-fatal-toxic-spill-hungary (accessed 24.10.2017)

Transparency International (2017). Combating corruption in mining approvals: assessing the risks in 18 resource-rich countries. https://www.transparency.org/_view/publication/8093 (accessed 24.01.2018).

Tripathi, N., Singh, R.S., Hills, C.D. (2016). Reclamation of Mine-impacted Land for Ecosystem Recovery. John Wiley & Sons, 208 pp.

UN (2015). Adoption of the Paris Agreement. Conference of the Parties, Twenty-first session Paris, 30 November to 11 December 2015. https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf (accessed 15.05.2018).

UNHRC (2017). Report of the Special Rapporteur on the issue of human rights obligations relating to the enjoyment of a safe, clean, healthy and sustainable environment. United Nations Human Rights Council.

USGS (2017). Mineral Commodity Summaries 2017. U.S. Geological Survey.

Vale (2016). S11D Railroad extension nearing completion. http://www.vale.com/en/aboutvale/news/pages/s11d-railroad-extension-nearing-completion.aspx (accessed 17.01.2018).

Van Dover, C.L., Ardron, J.A., Escobar, E., Gianni, M., Gjerde, K.M., Jaeckel, A., Jones, D.O.B., Levin, A., Niner, H.J., Pendleton, L., Smith, C.R., Thiele, T., Turner, P.J., Watling, L., Weaver, P.P.E. (2017). Biodiversity loss from deep-sea mining. Nature Geoscience 10(7), 464–465.

VDMA (2017). Maschinenbau in Zahl und Bild 2017. VDMA Verlag GmbH.

Vidal, O., Goffé, B., Arndt, N. (2013). Metals for a low-carbon society. Nature Geoscience, Vol. 6, 894- 896.

Virah-Sawmy, M., Ebeling, J., Taplin, R. (2014). Mining and biodiversity offsets: A transparent and science-based approach to measure “no-net-loss”. Journal of Environmental Management, Vol. 143, 61-70.

Wedding, L.M., Reiter, S.M., Smith, C.R., Gjerde4, K.M., Kittinger, J.N., Friedlander, A.M., Gaines, S.D., Clark, M.D.,Thurnherr, A.M., Hardy, S.M., Crowder, L.B. (2015). Managing mining of the deep seabed. Science, Vol. 349 (6244), 144-145.

WEF (2015). Mining & Metals in a Sustainable World 2050. World Economic Forum

World Aluminium (2017). Primary Aluminium Production. The International Aluminium Institute. http://www.world-aluminium.org/statistics/#data, accessed 17.10.2017.

World Aluminium (2017a). Primary Aluminium Smelting Power Consumption. International Aluminium Institute. http://www.world-aluminium.org/statistics/primary-aluminium-smelting-power-consumption/#data (accessed 11.12.2017).

World Bank (2017). Commodity Markets Outlook. International Bank for Reconstruction and Development / World Bank.

World Bank (2017a). The Growing Role of Minerals and Metals for a Low Carbon Future. International Bank for Reconstruction and Development / World Bank.

World Coal Association (2017). Coal mining. https://www.worldcoal.org/coal/coal-mining (accessed 23.11.2017).

World Coal Association (2017a). Coal & electricity. https://www.worldcoal.org/coal/uses-coal/coal-electricity (accessed 11.12.2017).

World Steel Association (2016). Fact Sheet - Steel and raw materials. https://www.worldsteel.org/en/dam/jcr:140482e9-5875-4c2d-abc4-19767ed48437/fact_raw+materials_2016.pdf (accessed 08.11.2017).

World Steel Association (2016a). Energy use in the steel industry. Fact Sheet.

World Steel Association (2017). World Steel in Figures.

WVM (2017). 16.17 Der Geschäftsbericht der Nichteisen-Metallindustrie. WirtschaftsVereinigung Metalle.

WVM (2017a). Metallstatistik 2016. WirtschaftsVereinigung Metalle.

WV Stahl (2017). Fakten zur Stahlindustrie in Deutschland 2016. Wirtschaftsvereinigung Stahl.

Young, P., Mulholland, A., Beristain, J., Ding, S., Sporre, G., Buzhenitsa, G., Kleyweg, R. (2016). Global deep dive: China well supplied. Deutsche Bank Markets Research, Deutsche Bank AG/Sydney.

Footnotes

1) Goal 6: Clean Water and Sanitation,
Goal 7: Affordable and Clean Energy,
Goal 9: Industry, Innovation and Infrastructure,
Goal 11: Sustainable Cities and Communities,
Goal 12: Responsible Consumption and Production,
Goal 13: Climate Action, Goal 15: Life on Land.
2) http://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html
3) http://www.stockholmresilience.org/research/planetary-boundaries.html
4) Carvalho 2017
5) e.g. Ali et al. 2017, Huy et al. 2016, ICMM 2012 and 2012b, Pilgrim et al. 2017, WEF 2015
6) Pilgrim et al. 2017
7) Vidal et al. 2013, World Bank 2017
8) Jungmichel et al. 2017
9) Lutter et al. 2016
10) https://www.destatis.de/DE/ZahlenFakten/ImFokus/IndustrieVerarbeitendesGewerbe/AutomobilindustrieWirtschaftDeutschlandKartell.html (accessed 19.01.2018)
11) Statistisches Bundesamt 2017, VDMA 2017
12) for clarification of terms and production processes, please see chapter 3
13) Huy et al. 2016
14) http://www.aluinfo.de/statistik.html (accessed 18.01.2018)
15) e.g. Olmez et al. 2016, Norgate et al. 2006, Virah-Sawmy et al. 2014
16) e.g. Spohr 2016, Feldt & Kerkow 2013
17) e.g. WEF 2015, Ali et al. 2017, ICMM 2012
18) e.g. ICMM; IRMA; ASI or ResponsibleSteel, see chapter 6
19) BMWi 2010, BMZ 2010
20) ibid., Deutscher Bundestag 2017
21) Regulation (EU) 2017/821
22) Scheele & ten Kate 2015, Reckordt 2017
23) The term "conflict minerals" refers to minerals, such as such as tin, tantalum, tungsten and gold, that are mined by armed groups in politically unstable areas, often using forced labour, to fund their activities (e.g. to buy weapons)
24) BMZ 2010
25) Auty 1993
26) Spohr 2016
27) www.amnesty.org
28) www.oxfam.org
29) www.globalwitness.org
30) www.misereor.de
31) https://power-shift.de
32) UNHRC 2017
33) Ferretti et al. 2007, ASI 2017
34) http://www.aluminiumleader.com/production/how_aluminium_is_produced/
35) Rüttinger et al. 2016
36) WVM 2017
37) World Steel Association 2016
38) WV Stahl 2017
39) World Steel Association 2016
40) Çiftçi 2017
41) International Trade Centre Trade Map, Product Code 72- Iron and Steel, Data for 2016. http://www.trademap.org/Country_SelProduct_TS.aspx?nvpm=1|||||72|||2|1|1|1|2|1|2|1|1. Accessed 08.11.2017
42) International Trade Centre Trade Map, various datasets for 2016. Accessed 08.11.2017
43) International Trade Centre Trade Map, Product Code 73- Articles of Iron and Steel, Data for 2016. http://www.trademap.org/Country_SelProduct_TS.aspx?nvpm=1|||||73|||2|1|1|2|2|1|2|1|1. Accessed 08.11.2017
44) Jungmichel et al. 2017, BPB 2017
45) Lutter et al. 2016
46) Huy et al. 2016
47) Data on traded volumes of alumina not available
48) Data on traded volumes of alumina not available
49) Statistisches Bundesamt (Destatis), 2017, data for 2016, various datasets
50) WVM 2017
51) Statistisches Bundesamt (Destatis), 2017, data for 2016, various datasets
52) The Netherlands have no alumina refineries. Any alumina imported from the Netherlands is a re-export, meaning that it is imported to the Netherlands from somewhere else and then re-exported without processing. Aluminium imported from the Netherlands also likely contains re-exports, as the volume imported from the Netherlands exceeds the country's annual production in 2016. The latter also applies to aluminium imported from the UK and from Austria (Austria had no aluminium production in 2016).
53) WVM 2017
54) USGS 2017
55) KPMG 2014
56) Reuters 2017
57) McKinsey 2014
58) This is in contrast to valuable metals such as gold or silver where ASM plays a relevant role with more than 100 million people, mainly in developing countries, estimated to be directly dependent on ASM for their livelihoods (miningfacts.org 2012)
59) SNL Metals & Mining, a group within S&P Global Market Intelligence
60) Statistisches Bundesamt (Destatis), 2017, data for 2016, various datasets
61) Huy et al. 2016
62) WV Stahl 2017
63) Statistisches Bundesamt (Destatis), 2017, data for 2016, various datasets
64) WV Stahl 2017

65) Statistisches Bundesamt (Destatis), 2017, data for 2016, various datasets
66) Statistisches Bundesamt (Destatis), 2017, data for 2016, WA2701 Steinkohle, Steinkohlenbriketts
67) WV Stahl 2017
68) Ibid.
69) Ibid.
70) USGS 2017
71) SNL Metals & Mining, a group within S&P Global Market Intelligence
72) Lichtenstein & Oppelt 2017
73) Pooler & Feng 2017
74) Lichtenstein & Oppelt 2017
75) WVM 2017
76) http://recycling.world-aluminium.org/review/recycling-indicators/
77) BIR 2017
78) Çiftçi 2017
79) UN 2015
80) Dongyong 2017
81) BMUB 2016
82) http://www.bmwi.de/Redaktion/DE/Dossier/energiewende.html
83) World Bank 2017a
84) Vidal et al. 2013
85) Ibid.
86) Vidal et al. 2013, World Bank 2017
87) Dongyong 2017
88) Öko-Institut 2017
89) Wedding et al. 2015, Barbier et al. 2014
90) Van Dover et al. 2017
91) ISA 2017
92) DSMA 2017
93) EPA 2017a, Leotaud 2017
94) https://www.umweltbundesamt.de/themen/abfall-ressourcen/abfallwirtschaft/urban-mining#textpart-5
95) Butterworth 2012
96) https://www.umweltbundesamt.de/themen/abfall-ressourcen/abfallwirtschaft/urban-mining#textpart-5
97) Jégourel & Chalmin 2015
98) Sonter et al. 2015, Çiftçi 2017
99) Spohr et al. 2016, Carvalho 2017
100) Jain et al. 2016
101) Prosser et al. 2011
102) Jain et al. 2016, IRMA 2016
103) Reuters 2017a
104) Escobar 2015
105) Dagenborg & Solsvik 2018, Reuters 2018
106) https://protectedplanet.net/c/world-database-on-protected-areas
107) Duran et al. 2013
108) Ibid.
109) Ibid.
110) Aviva et al. 2015
111) located within a 20km radius from a WHS
112) Both granted and applied concessions with more than 1% of its area overlapping a WHS are included. The WWF´s Assessment* considers: Active mining projects overlapping WHS
113) Hoekstra et al. 2005, Joppa & Pfaff 2009
114) Joppa & Pfaff 2009
115) Duran et al. 2013
116) Edwards et al. 2013, https://whc.unesco.org/en/list/155
117) IUCN/PACO 2012
118) Direction Nationale des Eaux et Forêts 2015. This number is the result of a conservative calculation as it excludes some Ramsar sites that (partly) overlap with one or more other designated protected areas
119) Phillips 2015
120) Parry 2014
121) Dudley 2008
122) Sarna 2015
123) Tripathi et al. 2016
124) World Coal Association 2017
125) Jain et al. 2016
126) Ibid.
127) Jennings et al. 2008
128) Buxton 2012
129) New South Wales Audit Office, 2017
130) Pulitzer Centre, 2016
131) Jain et al. 2016
132) Ibid.
133) Head 2016
134) Russau 2016
135) León-Mejía et al. 2011
136) Jain et al. 2016
137) Dias et al. 2017
138) Sonter et al. 2017
139) Barber et al. 2014
140) Dias et al. 2017
141) SERI et al. 2013
142) SERI et al. 2013
143) IEED 2002
144) Moser 2013
145) Vale 2016
146) Dias et al. 2017, Parry 2014, see also section 6.3.1
147) Kemp et al. 2010
148) Spohr et al. 2016
149) Leotaud 2017a
150) Carvalho 2017
151) Guj et al. 2017
152) Jain et al. 2016, SERI et al. 2013
153) Auty 1993
154) Spohr et al. 2016
155) Buxton 2012
156) e.g. Gibson & Klinck 2005, Stephens & Ahern 2002
157) Dodd-Frank Act 1502

158) SEC 2012
159) HIIK 2017
160) Smith 2013
161) Regulation (EU) 2017/821
162) OECD 2016
163) Reckordt 2017
164) OECD 2010, EPA 2017
165) Gelencsér et al. 2011
166) https://www.aluminiumleader.com/production/how_aluminium_is_produced/, Standford 2016.
167) Mayes et al. 2016
168) Pontikes 2006, Biswas 2012
169) Ibid.
170) The Guardian 2016, Mayes et al. 2016
171) OECD 2010
172) Norgate et al. 2006
173) Jégourel & Chalmin 2015, Rüttinger et al. 2016
174) Ciacci et al. 2014
175) World Coal Association 2017a
176) World Aluminium 2017a
177) Fearnside 2016
178) Pilgrim et al. 2017
179) Fearnside 2016
180) Dias et al. 2017
181) Fearnside 2016
182) Fearnside 2016, Dias et al. 2017
183) Ibid.
184) USGS 2017
185) AI 2017
186) Paraskevas et al. 2016
187) Serrenho et al. 2016
188) Backmann et al. 2016
189) World Steel Association 2016a
190) Sonter et al. 2017
191) Sonter et al. 2015
192) Ibid.
193) e.g. Banerjee 2012
194) Muñoz & Gladek 2017
195) Murray et al. 2017
196) EMF 2015
197) Rünker 2017
198) Murray et al. 2017
199) Muñoz & Gladek 2017
200) Murray et al. 2017
201) http://wwf.panda.org/wwf_news/?257498/EU-circular-economy-package-a-failed-promise
202) https://www.ellenmacarthurfoundation.org/case-studies/german-resource-efficiency-programme-progress-ii
203) EMF 2015
204) https://www.metabolic.nl/the-seven-pillars-of-the-circular-economy/
205) Çiftçi 2017
206) Gunther 2014
207) https://www.theguardian.com/innovative-sustainability/2017/dec/08/shrink-reuse-create-story-five-sustainable-packaging-wins
208) https://www.worldsteel.org/steel-by-topic/circular-economy/case-studies/reuse-case-studies.html
209) https://www.worldsteel.org/steel-by-topic/circular-economy/case-studies/remanufacture-case-studies.html
210) https://www.worldsteel.org/steel-by-topic/circular-economy/case-studies/recycle-case-studies.html
211) https://www.icmm.com/en-gb/about-us
212) KPMG 2018
213) http://www.oneplanetthinking.org
214) Owen & Kemp 2014
215) ICMM 2013
216) Owen & Kemp 2014
217) ICMM 2013
218) Owen & Kemp 2014; ICMM 2013
219) Owen & Kemp 2014
220) Hanna & Vanclay 2013
221) Buxton 2012; Hanna & Vanclay 2013; ICMM 2013
222) Haalboom 2012; Hanna & Vanclay 2013
223) Owen & Kemp 2014; Hanna & Vanclay 2013
224) Transparency International 2017
225) http://eiti.org
226) https://www.icmm.com/en-gb/members/member-commitments/position-statements/mining-and-protected-areas-position-statement
227) http://www.wwf.org.za/?3780/WWF-calls-on-banks-and-mining-companies-to-avoid-no-go-zones
228) http://www.responsiblemining.net/irma-standard/irma-standard-draft-v2.0/chapter-3.7-protected-areas#1
229) this includes large and medium securities (a tradable financial asset) across 23 Developed Markets and Emerging Markets countries
230) Aviva et al. 2015
231) Aviva et al. 2015, https://www.iucn.org/content/world-heritage-and-iucn-green-list-protected-areas
232) BBOP 2012
233) Ibid.
234) Ibid.
235) The number of points varies between BBOP publications from 4 to 6, but the 4 options are the most widely used
236) Bennett et al. 2017
237) Ibid.
238) Ibid
239) Clark et al. 2000
240) http://www.fess-global.org/workingpapers/eia.pdf
241) MMSD 2002
242) Ibid.
243) Sassoon 2009
244) ICMM 2008
245) Ibid.
246) Buxton 2012
247) http://www.responsiblemining.net/irma-standard/irma-standard-draft-v2.0/chapter-4.2-reclamation-and-closure

248) http://sciencebasedtargets.org/what-is-a-science-based-target/
249) http://sciencebasedtargets.org/companies-taking-action/
250) http://database.globalreporting.org/search/
251) Li 2008
252) Franks et al. 2010
253) Buxton 2012
254) http://a4ws.org/water-stewards/registered-sites/
255) https://www.icmm.com/water-stewardship-framework
256) Galarraga Gallastegui 2002
257) Lernoud et al. 2017
258) https://aluminium-stewardship.org/about-asi/current-members/
259) https://www.icmm.com/en-gb/about-us
260) http://www.icmm.com/en-gb/members/member-commitments/icmm-10-principles
261) http://www.icmm.com/en-gb/members/member-commitments/position-statements
262) Buxton 2012
263) KfW (Kreditanstalt für Wiederaufbau), AFD (Agence française de développement), EBRD (European Bank for Reconstruction and Development), EIB (European Investment Bank), AIIB (Asian Infrastructure Investment Bank)
264) e.g. Natural Resource Governance Institute 2017
265) http://www.sdgfund.org/mdgs-sdgs
266) International Resource Panel 2017
267) Heinrich Böll Stiftung 2011
268) http://ec.europa.eu/trade/policy/in-focus/conflict-minerals-regulation/regulation-explained/index_en.htm
269) CRM Alliance 2018
270) Antimony, Baryte, Beryllium, Bismuth, Borate, Cobalt, Coking coal, Fluorspar, Gallium, Germanium, Hafnium, Helium, HREEs, Indium, LREEs, Magnesium, Natural graphite, Natural rubber, Niobium, PGMs, Phosphate rock, Phosphorus, Scandium, Silicon metal, Tantalum, Tungsten, Vanadium
271) BMWi 2010
272) Hermes guarantees, raw material competence centres, EU Accounting & Transparency, EU Directives / (EU balance and transparency guidelines and German implementation), research projects of UBA / BMU, German implementation law for the regulation of EU conflict minerals, National Action Plan on the UN Guiding
273) Principles (NAPs), BMZ Sector Policy Raw Materials / BMZ Human Rights Concept, Deep Sea Mining / National Maritime Technologies Master Plan (NMMT), future legislation on due diligence obligations, multi-stakeholder-partnerships for different raw materials
274) BMUB 2017
275) BDI 2017
276) http://ec.europa.eu/environment/circular-economy/index_en.htm

100%
RECYCLED

Support WWF

IBAN: DE06 5502 0500 0222 2222 22

Bank für Sozialwirtschaft Mainz

BIC: BFSWDE33MNZ

Why we are here

To stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature.

wwf.de | info@wwf.de

WWF Deutschland

Reinhardtstraße 18
10117 Berlin | Germany

Tel: +49(0)30 311 777 700
Fax: +49(0)30 311 777 888