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Digging beyond limits: unearthing the climate reality of Mining and Metals

Author·esses :
Lou Welgryn, *Head of Product*
Victor Scache, *Analyst*

Contributors :
Constance Laroche, *Analyst*
Yi-Chen Chen, *Analyst*

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Summary

There's a circle of dependency between mineral resources and energy: the more deposits we exploit, the lower their concentration, and the more energy we need to extract these metals.

Mineral resources are as central as energy: the mining and metals sector is upstream of all other sectors (construction, transport, digital, industrial machinery, etc.). Decarbonizing this sector, which is indispensable to the rest of the economy, is therefore a prerequisite for decarbonizing other industrial sectors.

The energy transition is far from eliminating our dependence on resources, particularly metals. The "low carbon" technologies needed for the energy transition (renewable energies, electric transport vehicles and all associated infrastructures) require very large quantities of certain metals. The mining and metals sector must organize the transition away from fossil fuels, with the responsibility of managing the difficult trade-off between growing needs and physical limits.

The future of the industry: sufficiency and recycling. Many metals will experience conflicts of use (with the needs of the digital industry, for instance). They will therefore have to be prioritized. **Minimizing use and maximizing recycling** is crucial. This requires us to question the end uses of the metals we sell, and their relevance to a low-carbon economy that respects living beings.

Large metals are the forgotten transition metals. The "transition metals" (lithium, cobalt, etc.) are in the spotlight - but many other major metals (iron, aluminum, copper) are also essential to the transition for manufacturing (wind turbine masts, automobiles, etc.) and infrastructure (electricity transmission, rail networks), and decarbonizing their production is key.

A surging demand: according to the IEA, global demand for metals will increase 4-fold by 2040 in low-carbon transition scenarios. This demand is strongly driven by the needs of the energy transition, but also by the industrialization of certain countries, as well as the digital sector.

Insufficient commitment from industry players. We note a lack of commitment and transparency in the sector. Of the companies analyzed, only 45% have reduction commitments in line with the 2DS (2° scenario) and B2DS (Beyond 2° scenario) scenarios[1]. Over 30% have no targets. **Impacts that go far beyond the climate.** It is vital to consider the mine in light of its many other impacts on the environment, such as water availability and quality, air and soil pollution, and its impact on biodiversity.

[1] Relative to the year 2100 - IEA scenarios

Introduction

"In the next 35 years, we're going to have to extract the same amount of metal as has been extracted by man since antiquity".[2]

Olivier Vidal, Director of Research at the CNRS, scientific coordinator of the PEPR "sous-sol bien commun" project.

"Today, data reveal an imminent mismatch between the planet's enhanced climate ambitions and the availability of the minerals essential to achieving those ambitions."

Dr Fatih Birol, IEA Executive Director

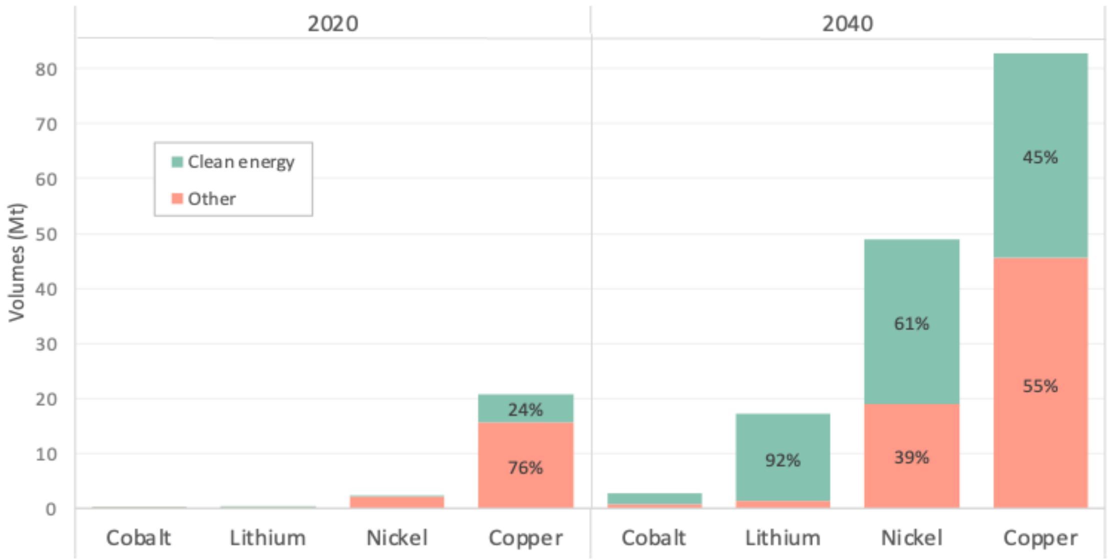
If energy is the lifeblood of the economy, metals are its backbone. Historically, all industrial revolutions began with the discovery of new mineral uses[3] . Today, they are omnipresent in our daily lives and can be found in every sector of the economy: from agriculture to energy, from construction to transport, and from paint (titanium dioxide, aluminum, copper, gold, etc. in metallic pigments for durability and resistance to wear) to toothpaste (titanium dioxide to make the paste white).

Global demand for metals continues to grow, and could **increase 4-fold** by 2040 according to the IEA, driven by three main uses:

- First and foremost, infrastructure construction in developing countries,
- The rise of the digital industry,
- The energy transition.

[2] Olivier Vidal, *Ressources minérales, progrès technologique et croissance, 2019*
[3] Ayuk et al, *Mineral Resource Governance in the 21st Century, 2019*

Projected demand for metals up to 2040 and share allocated to green energies



[4]Figure 1: Adapted from IEA data: we can see that the share of the metals presented allocated to green energies is increasing, but we can also see that other uses are increasing significantly: the IEA was already projecting a doubling in the quantity of metals required in 2040 compared with today in a 'no energy transition' scenario. The term 'Clean Energy' includes the needs of electric cars and batteries, renewable energy production and associated electrical infrastructures.

There's a **circle of dependency between mineral resources and energy**. The more deposits we mine, the lower their metal concentration, and the more energy we need to extract these metals, with energy expenditure increasing in inverse proportion to concentration. This is not conducive to an absolute decoupling of GHG emissions[5] (for example, copper mines exploited in the 1930s had a concentration of 1.8% - today, the average copper concentration is 0.8%).[6]

However, the "low-carbon" technologies needed for the energy transition (renewable energies, electric transport vehicles and all associated infrastructures) require **larger quantities of metals than their fossil fuel equivalents** (for example, a 1 MW wind turbine consumes around 10 times more steel and concrete per kWh produced than a thermal power plant). [7]

Low-carbon energies, including nuclear power, rely on large-scale metal-intensive infrastructures, which in the case of renewable energies are designed to transform diffuse energy into usable energy. To ensure that the transition of the energy system from fossil

[4] IEA, *The Role of Critical Minerals in Clean Energy Transitions*, 2022
[5] For more details on the concepts of decoupling and growth, read Carbone 4's note on the subject.
[6] Bihouix and Guillebon, *Metal scarcity: a new challenge for society*, 2010
[7] Bihouix and Guillebon, *Metal scarcity: a new challenge for society*, 2010

fuels to low-carbon energies does not lead to even greater dependency on metals, it is imperative to pair it with a **drive for sobriety and, ultimately, a reduction in the flow of materials.**

The Carbon Impact Analytics (CIA) method, developed by Carbon4 Finance, aims to **measure companies' contribution to the fight against climate change and their exposure to transition risk** via the CIA overall rating (from 1 to 15) and various sector indicators. In 2021, in line with our ambition to develop reliable and relevant climate indicators for financial players, we have developed a methodology for the Mining and Metals sector, which considers the sector's specific features (typology of players, physical flows, decarbonization challenges), and makes it possible to distinguish between companies that lead the low-carbon transformation and those that lag behind.
This report summarizes the results of a CIA analysis campaign carried out in 2022 on a sample of **over 75 listed companies** in the mining and metals industry. Thanks to our data, we were able to establish a ranking of players according to their degree of exposure to transition risks, as well as to assess the strategies put in place to align themselves - or not - with the decarbonization objectives of the global economy.

As each metal has very different risks and impacts, we'll take a look at the examples of copper (a metal needed for the energy transition, with a high level of criticality) and steel (as the foundation of the metal world: 1.8 billion tonnes were produced in 2022[8] , i.e. over 90% of the world's mass metal production).

In addition, although this study focuses on transition risk, it is vital to consider the mine's many other impacts on its environment, such as water availability and quality, air and soil pollution, and its impact on biodiversity.

Sector dynamics and challenges

What are metals used for?

In 2022, the world consumed nearly 2 billion tonnes of metal[9] .

In the same way that the oil & gas sector meets the majority of the energy needs of economic sectors, the metal industry is responsible for the manufacture of base metals that supply the entire economy, including agriculture, transport, electronics, construction and all sectors that use industrial machinery. Most companies in this sector are integrated, from ore extraction to the manufacture of semi-finished metal products. However, there are also a few players who only process the raw materials they have already extracted.

[8] World Steel association, 2022
[9] United States Geological Survey, 2022

To fully understand the dependence of the metals industry on fossil fuels, we need to describe the main stages in the transformation of mineral raw materials.

THE ABC - WHAT IS A METAL?

Metals are rarely available in their native state in the environment. They are most often found in minerals (oxides, sulfides, carbonates, etc.) which contain one or more **elements of interest** - the desired metals - but also other elements - oxygen, sulfur, carbon, etc. - from which they must be separated. The ores also contain (and very often essentially) compounds with no usable metal, which will subsequently be considered as **waste** (they are called tailings). Producing metals therefore requires a series of transformation stages, from ores to refined metals. These stages vary significantly from one metal to another, with more or less energy-intensive processes.

Metals - classification

Pure metals and alloys (metals created by mixing two or more different metallic elements to form a new material with different properties) are divided into different categories:

- **Ferrous metals:** the metal industry is largely dominated by iron ore, by far the most abundant mineral on Earth - it accounts for 94% of all ores mined worldwide every year. Steel is an alloy composed essentially of iron, combined with carbon (<1.7%) and other elements (e.g. manganese, silicon, sulfur, phosphorus).
- **Base metals:** include non-ferrous metals - the most abundant being aluminum, copper, manganese, zinc, lead, chromium, nickel and, to a lesser extent, magnesium.
- **Precious/rare metals:** Rarity is determined by abundance in the earth's crust, called concentration. This category includes gold, silver, cobalt and platinum group metals. Their concentration is often expressed in grams or kilograms per tonne. These metals are often co-products of other metals.
- **Rare earth elements:** a category made up of 16 or 17 elements - the qualifier "rare" refers to their difficulty of exploitation; it is not their geological abundance that is currently the limiting factor to their extraction. Rare earths are highly strategic, as they are used in most communications technologies. China accounts for over 60% of extraction and 90% of processing of global production.[10]

[10] IEA, *The Role of Critical Minerals in Clean Energy Transitions*, 2022

METAL PROCESSING STAGES

Metal production value chain

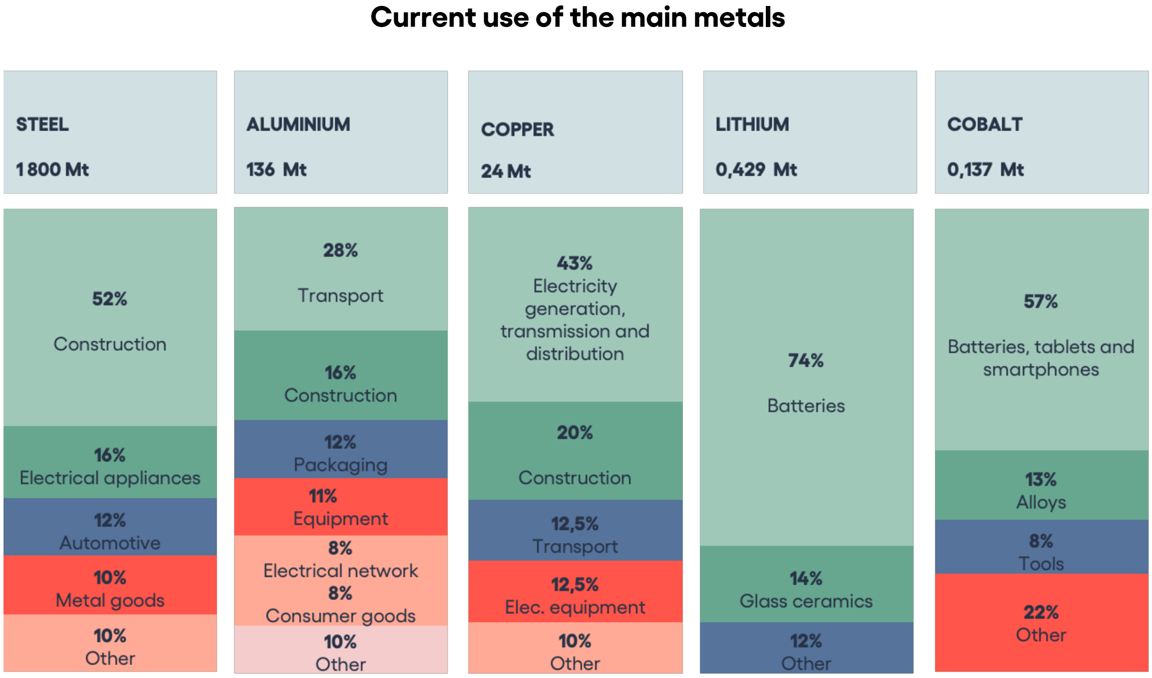
EXPLORATION	MINING	MINERALURGY	METALLURGY	REFINING	MANUFACTURING
	Mining *Ore mining in an open or underground pit* Product at the end of phase: **Crude Ores** Waste generated: **Mine waste, mine water, dust and gas**	**Concentration** *First processing of ore* Product at the end of phase: **Concentration** Waste generated: **Mine tailings, effluents, dust, chemicals**	**Chemical extraction** *Separation of a metal compound* Product at the end of phase: **Raw metal** Waste generated: **Slag, ash, mine tailings, effluents, chemicals**	**Refining** *Removal of impurities from crude metals* Product at the end of phase: **Metal**	
Ex: %Cu	0.1 à 2% - Ore	30% - Concentrated	98 à 99,5% - Blister	99,9% - Cathode	Ex: %Cu

Figure 2: Representing the metal production chain, adapted from the SystExt report May 2021 - Mining controversies "Volume 1".

Despite the differences in processes, there are four main phases in metal production:

- **Mining:** extraction of ore by various processes. Most often this involves mechanical excavation in open-pit or underground mines, but it can also involve underground brine collection (lithium), rock leaching (uranium), etc.
- **Mineralurgy (or concentration):** first ore treatment. It separates fractions rich in useful elements from waste products of no commercial value. The result is a concentrate that always contains other minerals than the one to be extracted.
- **Metallurgy or chemical extraction:** this second process applies to the concentrate and enables only the substance of interest to be recovered. There are two main techniques: **pyrometallurgical methods** (based on thermal processes) and **hydrometallurgical methods** (based on dissolving a metal). The result is a "coarse" metal that is not yet sufficiently pure to be used by industry.
- **Refining:** this final stage removes the last impurities from the metal obtained after metallurgical treatment.

THE ROLE OF METALS IN THE TRANSITION: "A METAL-INTENSIVE" ENERGY TRANSITION



[11]*Figure 3: This graph shows the current uses of several essential metals and their worldwide consumption in 2022. They are listed in order of production volume, and include volumes from both primary and secondary production.*

Generally speaking, the energy transition relies on three main levers:

- **Sobriety** (consuming less),
- **Improved energy efficiency** (consuming less energy per unit of activity),
- **Decarbonization of energy** (emitting less per unit of energy consumed).

This last lever is based on an increased demand for metals for constant energy use. This increase is due to the fact that some renewable energies require much greater quantities of metals than their fossil fuel equivalents, as illustrated by the graph below.

[11] Aluminium: IFP Energies Nouvelles, *l'aluminium dans la transition : quel avenir pour ce métal roi du monde ?*, 2018; Steel: World Steel Association, 2022; Copper: International Copper Study Group, 2022; Lithium: NégaWatt, *Lithium, vers une indispensable sobriété*, 2023; Cobalt: Cobalt Institute, 2022.

Quantity of metals used by different modes of power generation[12]

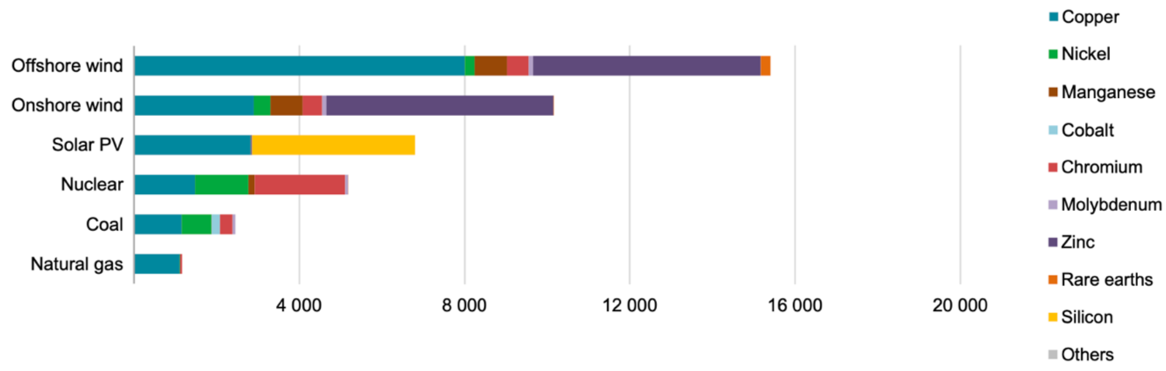


Figure 4: Weight of metal required per MW installed for various types of power generation. Please note: these various modes do not have the same service life or load factor, and the proportions are not the same per MWh of electricity produced.

Since the 1900s, demand for metals has been growing rapidly, and to this day, technological progress has constantly pushed back the limits of previously established reserves.

Trends in demand for certain metals since 1900

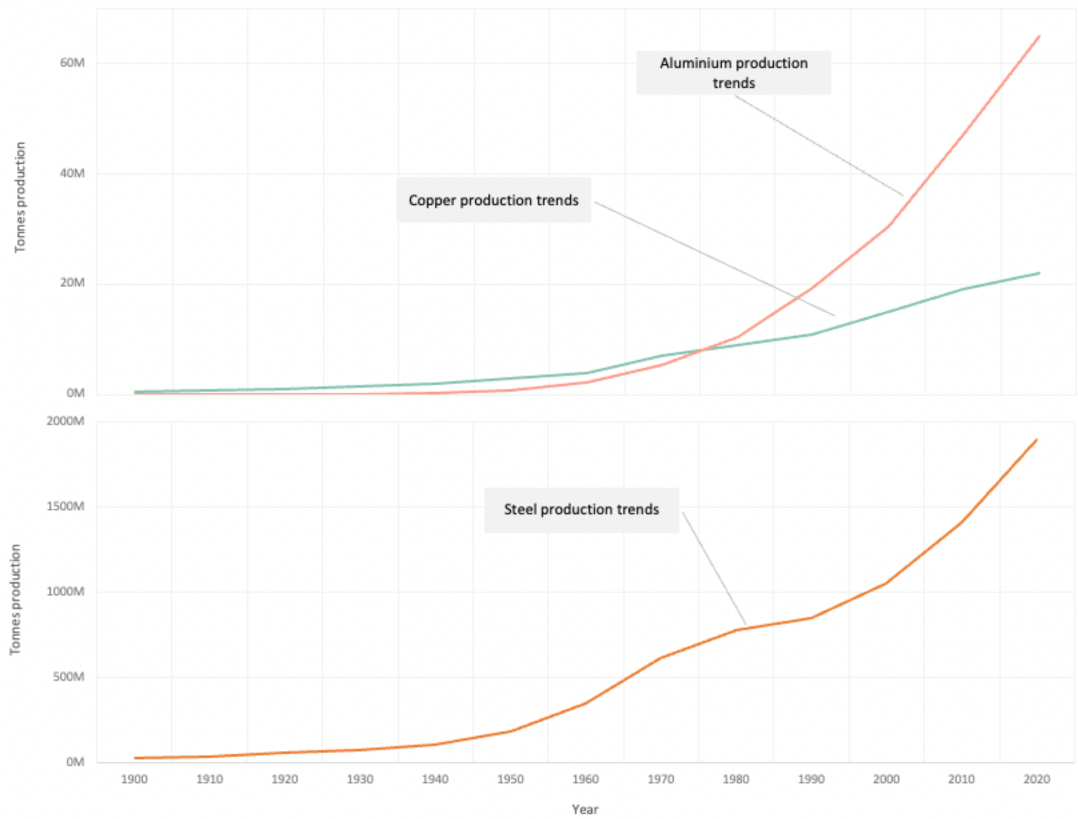


Figure 5: Trends in copper, aluminum, and steel production[13] from 1900 to 2020.

[12] IEA, *The Role of Critical Minerals in Clean Energy Transitions*, May 2021
[13] *Sources: International Copper Study Group, World Steel Association and International Aluminium Institute*

According to the IEA, by 2040, global demand for minerals could increase 4-fold for copper, 20-fold for cobalt and 40-fold for lithium to keep pace with the needs of the energy transition[14] , as illustrated by the graph in the introduction. In these projections, demand for metals specific to the[15] energy transition is driven by the needs of the electric car and its associated batteries (over 45%), and power grids (40%).

Moreover, the more ambitious the energy transition scenarios, the greater the demand for metals (for example, copper demand in the B2DS scenario[16] is 25% higher than in the RTS scenario).[17]

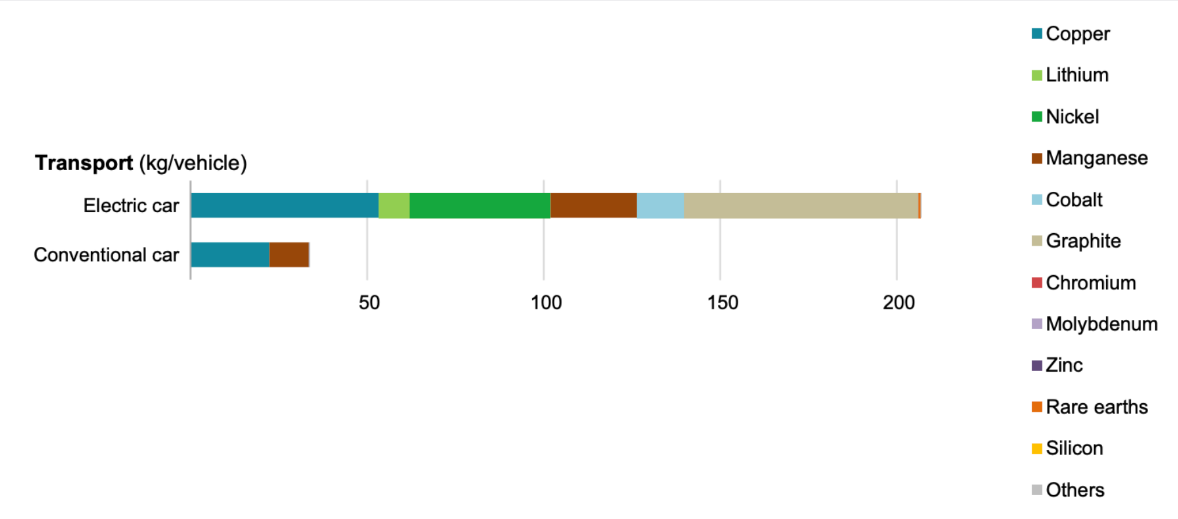
Illustration on the concrete case of the car

A combustion-powered car contains about 20 kg of copper
A lightweight hybrid car, about 40 kg of copper
An electric vehicle, between 60 and 80 kg of copper

The quantity of metal required for an electric car can therefore be multiplied by 4, without taking into account the entire network and infrastructure that needs to be built to recharge the car. **The diversity of metals** required is also greater: an electric car uses almost all the elements on Mendeleev's table[18] .

Electrification scenarios without sobriety (carpooling, soft mobility, etc.) would accentuate conflicts of use over resources, and have numerous consequences in terms of impact.

Quantity and diversity of metals used in an electric vs. a conventional car[19]



[14] IEA, *The Role of Critical Minerals in Clean Energy Transitions*, May 2021
[15] IEA, *Minerals required for clean energy transition*, 2021
[16] Beyond Two Degrees IEA scenario
[17] IEA Reference Technology Scenario, assumes that all countries meet their commitments
[18] This table lists all the known chemical elements, classified according to their number of protons, or atomic number.
[19] IEA, *The Role of Critical Minerals in Clean Energy Transitions*, May 2021

WHEN PHYSICS GETS INVOLVED

But this increase in demand is constrained by an essential physical reality. In fact, three obstacles will become increasingly apparent in the future:

- **Declining concentrations**: the metal concentration of mined ores declines over time (whatever the metal, to a first approximation). This is because the best mines were mined first, and new deposits coming on stream are generally of lower quality than those they replace, leading to a decline in global ore concentrations[20] .
- **Strong interdependence between metals:** many metals are not mined independently, but are co-products of the mining of other major metals. (e.g. cobalt is a co-product of nickel or copper; gallium, a co-product of aluminum...). The depletion of a major metal for physical or economic reasons inevitably leads to the depletion of its co-product.
- **Increasingly complex ores to extract:** The ores that are easiest to process were extracted first, giving rise to a growing proportion of so-called "complex" ores (several elements of interest mixed together) and "refractory" ores (resistant to "conventional" chemical extraction processes). This leads to more complex treatment processes, lengthening the stages and increasing the number of chemical processes required for extraction.

However, **the energy cost of production is rising due to declining** deposit **grades** and accessibility. Until now, this cost has been offset by efficiency gains of around 1% per year.[21] But there is a critical point beyond which the energy gains made possible by technological improvements can no longer compensate for the declining grades in the deposits, thus increasing the energy required for extraction. This critical point is determined by thermodynamic limits that cannot be pushed back, despite all our efforts to improve energy efficiency (for example, the amount of energy required to separate iron atoms from oxygen in the iron oxide that makes up naturally available ore).

Taking the copper industry as an example, between 2011 and 2014, energy consumption per tonne of copper produced has already risen by 17%, and this trend is set to continue. Elshkaki et al estimate that in 2050, with copper demand multiplied by 2 to 3 compared with 2016, copper alone will consume 2.4% of global energy consumption in 2050, compared with 0.3% in 2012[22] , i.e. 8 times more.

[20] United Nations Environment Programme, *UNEP,* 2013
[21] Vidal, *Mineral resources, technological progress and growth*, 2018
[22] Elshkaki, et al., 2016

The sector's main sources of greenhouse gas emissions and their trends

GREEHOUSE GAS EMISSIONS

In 2010, 8% to 10% of the world's primary energy was used to extract,[23] transport and refine metal resources in all sectors. Steel production alone accounts for 7% of global greenhouse gas emissions[24] .

Greenhouse gas (GHG) emissions from the mining and metallurgy industry are highly dependent on the conditions under which metals are extracted and processed, but also on the ore in question, its accessibility and the energy and processes used (electrification, chemistry, etc.).
For many metals, the ore processing phase accounts for the largest share of energy consumption (around 50% for copper). Next comes mining (around 36% for copper), followed by the conversion of concentrate to metal, which accounts for a small share, even in pyrometallurgy (less than 15% for copper).[25]
The following graph shows the intensity (tonnes of CO2 per tonne of metal produced) of the extraction and processing stages for a number of strategic metals, illustrating the extreme variability of intensities depending on the minerals extracted.

Intensity of certain key metals per tonne of metal produced

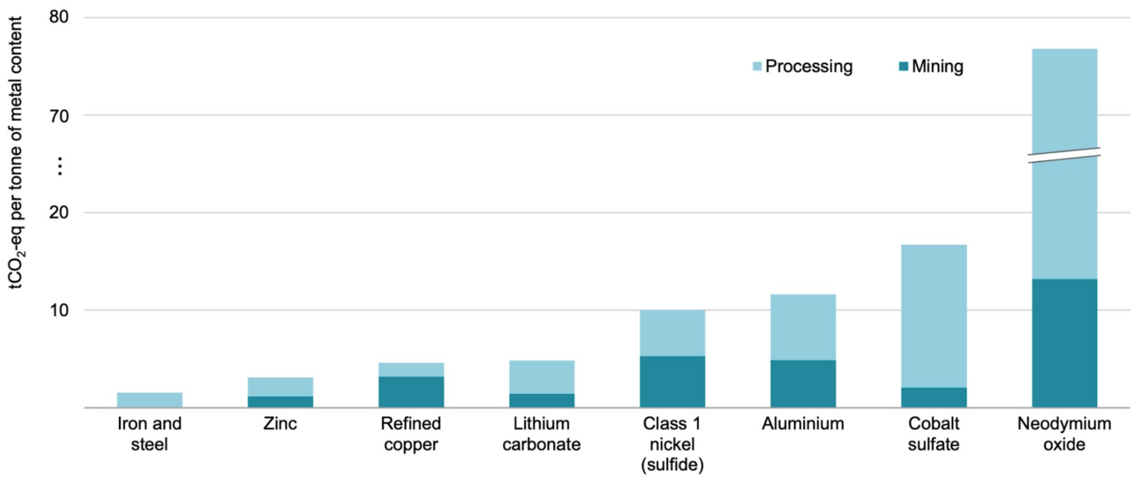
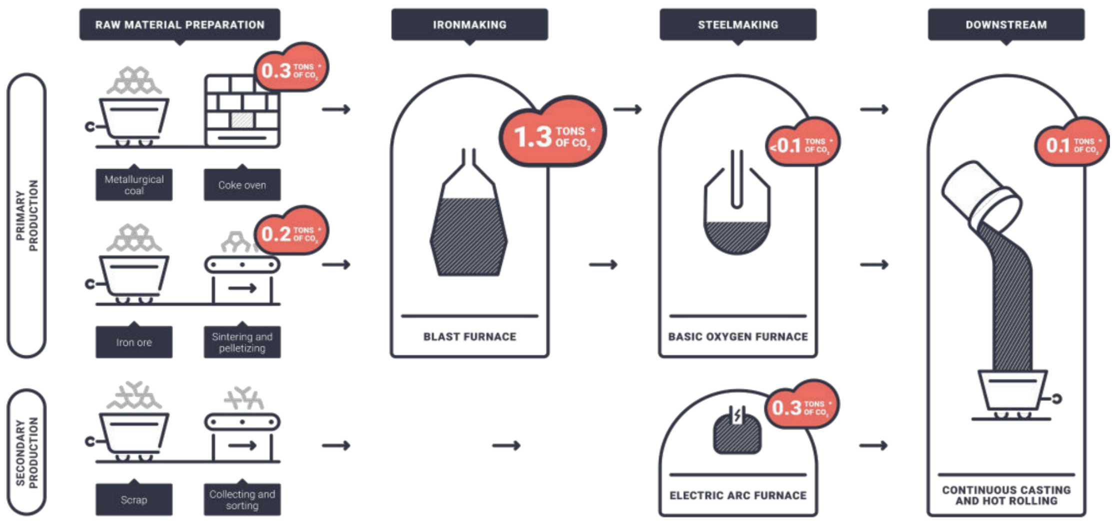


Figure 6: IEA graph showing average GHG intensities for several metals. The mining phase corresponds to mineral extraction up to concentration - processing includes the metallurgy and refining stages.[26]

[23] Philippe Bihouix and Benoît de Guillebon, *Metal scarcity - a new challenge for society*, 2010
[24] Global Efficiency Intelligence, *Steel Climate Impact: An International Benchmarking of Energy and CO2 Intensities,* April 2022.
[25] Norgate, et al., 2010
[26] IEA, *The Role of Critical Minerals in Clean Energy Transitions*, May 2021, sources: Rio Tinto, Nuss and Eckeman, Skam associates, Roskill, S&P Global, Tost et al, Argone National Laboratory

Illustration of the different stages of steel manufacturing and associated emissions



[27]Figure 7: This graph illustrates the different stages of steelmaking, and the associated emissions per tonne of steel produced, according to the different manufacturing methods. It illustrates the very strong differences in emissions between primary and secondary steel.

NUMEROUS NON-CLIMATE IMPACTS

Although the CIA note focuses exclusively on transition risk in the mining sector (excluding coal), there are many other environmental risks in this sector that cannot be ignored, as summarized in the SystExt report[28] :

- **Water consumption** - both in terms of availability and quantity. According to the EPA, water contamination from mining activity represents one of the three greatest threats to ecological security in the world[29] . Moreover, many mines are dug in areas of advanced water stress.
- **Waste**: the mining industry generates waste at every stage of the production cycle:
  - *extraction*: extracting concentrated copper at 0.5% means removing 200 kg of rock to obtain 1 kg of copper; unmined rock is called barren.
  - *manufacturing*: this stage produces water (or sludge) loaded with potentially toxic products and solid residues. These can contaminate the environment and soil, and harm biodiversity.
- **Social impacts**: for example, in 2019, the mining sector was responsible for the highest number of socio-environmental conflicts in the world[30] (including coal - in comparison, conflicts linked to fossil energy resources account for 9%).
- **Land area:** this far exceeds the area excavated by the mine, which requires the construction of a multitude of infrastructures essential to its operation (roads, ports,

[27] Reclaim finance based on data from IEA, Material Economics and Industrial Transformation 2050, *Assessing the credibility of ArcelorMittal's decarbonization strategy*, 2023

[28] SystExt, *Mining Controversy Report Part 1*, 2021

[29] Coumans, US Environmental Protection Agency (US EPA), 2022

[30] Scheidel, et al, EJAtlas39 international database, 2020.

etc.). A study published in Nature[31] uses satellite images to put the total direct footprint of the world's 6,000 mines (including coal) active between 2000 and 2017 at 57,277 km2.

Setting up the Palabora copper mine in South Africa

Figure 8: This image illustrates the amount of copper produced up to 2019 - pictorial representation by

photographer Dillon Marsh - compared with the surface area of the mine represented by SystExt - it is equivalent to the size of the city of Grenoble.

All these pressures also have an irreversible impact on the surrounding biodiversity. These risks are reflected in the BIA-GBS (Biodiversity Impact Analytics powered by the Global Biodiversity Score) database, co-developed by Carbon4 Finance and CDC Biodiversité32.

Deep Sea Mining: a threatening practice to be nipped in the bud

Deep Sea Mining is the practice of extracting metal deposits from the seabed. To date, no such operations exist, but exploration missions have been carried out and mining permits may soon be issued.

Scientists are warning of the risks of this practice, which could be disastrous for biodiversity and the integrity of ecosystems, and whose consequences are currently poorly understood. A coalition of countries and companies is calling for, at the very least, a moratorium on exploitation, to allow time to establish a scientific framework for assessing the impacts.

Human activities already exert destructive pressures on marine ecosystems, and this practice only exacerbates the situation by disrupting nutrient cycles, releasing toxic pollutants and destroying habitats critical to marine biodiversity[33] . **This practice must be banned, and financial players have a crucial role to play in ensuring that their investment does not contribute to it in any way.** What's more, such projects would appear to be very complex to implement on an industrial scale anyway.

[31] Nature, A global-scale data set of mining area, 2020
[32] For more details on this methodology, please refer to our methodology guide.
[33] United Nations Environment Programme Finance Initiative (2022) Harmful Marine Extractives: Understanding the risks & impacts of financing non-renewable extractive industries.

Economic context and scope of the study

With €3,650 billion [34] , the metals sector represents 3.5% of the world's market capitalization. Our study covers more than 75 major companies in this sector, focusing on the most highly capitalized companies in the indices of mature economies (Europe, US & Japan). Our sample represents 30% of the sector's market capitalization, including 9 of the 10 largest companies. For copper, our sample covers almost 50% of global production.

Identified transition risks

For a company, transition risks refer to all the potential risks involved in a society making the transition to a low-carbon economy. These transition risks range from policy and legal risks to reputational risks, as illustrated in the figure below.

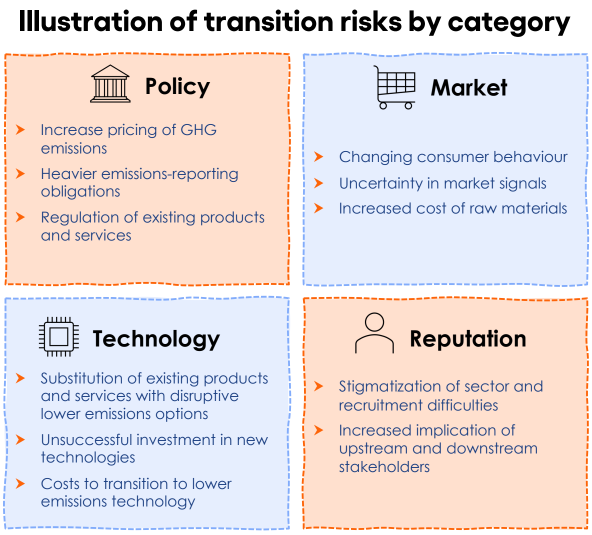


Figure 9: Representation of the various transition risks faced by industry players.

In the metals industry, the most immediate transition risks lie in the high energy dependence on fossil fuels upstream and downstream of demand, and its likely evolution in low-carbon transition scenarios.
The following chart summarizes the main risks to which players in this sector are exposed.

[34] for 2022

Description of the main transition risks identified

Description	Risks						Examples
	Direct	Indirect	Regulatory	Market	Technology	Reputational	
Social conflicts: extraction sites are often located in areas of high social tension, where workers are often exploited.	☑	☐	☑	☐	☐	☑	Mining sites are the world's number one source of conflict.
Metal market volatility: prices are highly dependent on the quantity of energy required for production, and therefore on the price and availability of energy. Moreover, prices do not necessarily reflect the scarcity of resources: there can be price peaks without scarcity, and vice versa. This can lead to higher prices for 'green' goods, particularly for non-substitutable metals.	☑	☐	☐	☑	☐	☐	Lithium prices rose by 700% between January 2021 and March 2022 (IEA)
Geological availability of metals - concentration: Metal concentration rates are falling, and some metals will be under increasing physical stress in the years ahead. Technological gains will be less and less able to 'offset' the reduced concentration of available deposits in terms of energy consumption to extract metals.	☑	☐	☐	☑	☐	☐	**Risk of scarcity of raw materials** - Copper mines operating in the 1930s had a concentration of around 1.8% (55 tonnes of ore for one tonne of metal) - today's copper mines have an average concentration of less than 0.8% (125 tonnes of ore for one tonne of metal).
Geological availability of metals - co-products: Many metals are co-products of other metals. If the main metal extracted disappears or is no longer mined for geological or financial reasons, the co-product also disappears. This complicates markets and makes supply inelastic.	☑	☐	☐	☐	☐	☐	Around 50% of cobalt (Co) production comes from copper (Cu) mines, and around 50% from nickel (Ni) mines.
Geopolitical risks: Mineral resources are highly concentrated, both geographically and capital-wise, in terms of production and refining. Modern manufacturing processes therefore require the orchestration of a wide variety of non-substitutable inputs from a very limited number of countries, in which, incidentally, China accounts for the lion's share.	☐	☑	☐	☑	☑	☐	**Risk of high geopolitical tensions** - China produces just 3% of the world's cobalt - yet refines 70% of it. It produces 60% of the world's rare earths and refines 87% of them - the dependence on China for these critical materials is therefore really high. Any quota policy (such as the one introduced by China in 2010) has a huge potential impact on all metal production chains, as well as on low-carbon technology.
EU-ETS market and carbon border adjustment	☑	☐	☑	☑	☐	☐	**End of free steel quotas by 2035** **Carbon Border Adjustment Mechanism** announced for 2026

What are the solutions for decarbonizing the sector?

DECARBONIZATION LEVERS FOR THE MINING AND METALS INDUSTRY

Climate change mitigation strategies for the sector are diverse. The decarbonization levers identified, in line with the IEA scenarios (2020) and the work of the Shift Project[35] are as follows:

- **First and foremost, we need to reduce our consumption of** metals. Négawatt[36] , for example, has calculated the impact of sobriety measures on the metal consumption of electric cars: several dimensions are being explored, in particular "dimensional sobriety" - reduction in size and weight - but also sobriety of use - through the pooling and moderation of our needs. The latter would make it possible to reduce the quantities of lithium extracted between 2020 and 2050 by 50 to 75% to meet France's anticipated consumption.

- The **development of recycling channels** for metals whose historical consumption volumes are sufficiently high, and **the reincorporation of recycled materials** into

[35] The Shift Project, Decarbonizing industry without scuttling it, 2021
[36] Association négaWatt, Lithium: towards indispensable sobriety, 2023

final production, is a major lever for decarbonizing the sector. The following graph illustrates the potential for reducing emissions by metal.

CO2 emissions from primary vs. secondary manufacturing by metal type

Metal	Energy required for recycling versus energy required for primary metal production	Quantity recycled (worldwide average)
Steel	25 - 40 %	50%
Aluminium	4 - 5 %	40 - 50 %
Copper	13 - 16 %	40 %
Tin		25 %
Nickel	> 5 / 10 %	40 - 50%
Lead	35 - 38 %	70 %
Zinc	25 - 37 %	25 - 30 %

[37]*Figure 10: This graph illustrates the decarbonization potential varies between 60 and 95% emissions for the metals shown. The quantity recycled refers to the percentage recycled from metal scrap.*

- **Electrification of** production processes where possible and more energy-efficient.

- **Breakthrough changes in processes**: on the one hand, with the sustainability of energy efficiency efforts (although the potential for reduction is low) and, on the other, by relying on cutting-edge technologies such as low-carbon hydrogen (for the steel industry, for example) or CCS (carbon capture and storage) for certain transformation processes.

Nevertheless, it is important to keep these limits in mind:

- **As far as breakthrough technologies** are concerned, the IEA's "Net Zero by 2050" scenarios [38] for heavy industry are 50% based on the development of green hydrogen, whose use in the various sectors must be prioritized according to their relevance - see the Carbone 4 publication on this subject - or on technologies such as CCS (Carbon Capture and Storage), which have not yet reached large-scale industrial maturity. There is therefore a strong case for investment in this type of process, whose investment cycles and equipment lifetimes are long. The question is whether they will ever be available on a large scale. Similarly, low-carbon hydrogen and the electrification of mining processes are not very widespread today.

- **As far as recycling is** concerned, we need to bear in mind that it is limited by the availability of metals for recycling, which is itself highly dependent on a country's level of development: the metals that can be reused are derived from past

[37] Bihouix, *What future for metals*, 2010
[38] IEA, Net Zero by 2050, *A Roadmap for the Global Energy Sector*, 2021

infrastructure and consumption. The more industrialized a country, the greater the quantity of scrap metal available. Location therefore plays a very important role in the ability to recycle, but it is also necessary to consider service life, metal substitution, the concentration of metals in the material/product to be recycled (which can sometimes be lower than the levels in the ores), the economic cost of recycling and the existence of collection chains. Metal recycling capacity therefore depends on each metal and technology considered.

Illustration of decarbonization levers for the steel sector, which accounts for over 90% of the metals produced worldwide[39] , according to IEA and Carbone 4 scenarios

	IEA Scenario (2DS)	**Carbone 4 Scenario - 2°**
Demand (2040)	Steel demand is **up 25% on 2017**. Some sectors continue to grow, such as electronic equipment, in line with a more digitized world.	Steel demand **down 15% on 2017**.
Hypotheses	Increase **energy efficiency by 3%** per year. Major contribution from **CCS** and **green hydrogen**. **Recycled steel** accounts for **35%** of final production.	Priority to the **recycling sector**: the scrap sector emits 4 times less emissions per tonne produced than the primary sector. It will account for **65%** of **steel production** by 2040. Upstream vertical diversification in **collection chains**. Reasonable contribution of energy efficiency and CCS.

A SECTOR IN NEED OF TRANSPARENCY

Players in the mining sector provide little detailed information on their activities: although metal volumes are often well reported, the end use of these metals is much less so. This lack of end-use transparency limits companies' analysis: producing copper for an electric car that replaces a petroleum-powered car has a very different impact from using it for 5G networks, for example.
What's more, players rarely report their scope 3: in the sample analyzed, over 50% of companies did not declare their scope 3 for significant positions, demonstrating a partial identification of the risks to which they are exposed.

[39] Carbone 4, *In and for a decarbonized world - case study on the steel sector*, 2019

Transparency score of companies analyzed

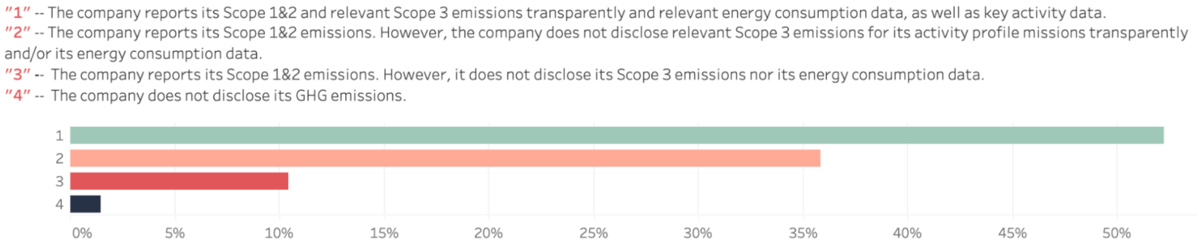


Figure 11: Around 50% of companies in the sector do not report scope 3 for significant positions.

THE ROLE OF INVESTORS IN COMPANIES' COMMITMENT TO TRANSITION

Faced with this lack of environmental information, investors have the opportunity to demand greater transparency from companies in the mining and metallurgy sector. In this document, we describe the various indicators relevant to the sector, on which transparency efforts should be focused. According to BRGM (French Geological Survey), it takes an average of seventeen years from the location of a deposit to the start of production. Investment and financing therefore play an important role in the success of the energy transition; it is yesterday's investments that finance today's production, with a particularly strong inertia of past investments. In the short term, there is a strong risk that supply will be unable to meet projected demand in decarbonization scenarios. We can therefore insist on:

- **The importance of questioning the end uses of metals sold and their viability in a low-carbon economy.** Many metals will experience conflicts of use (with digital needs, for example). It will therefore be necessary to prioritize those uses that meet the needs of the energy transition, as opposed to uses considered to be non-basic or incompatible with a low-carbon economy. Economic players will therefore have to learn to envisage much stronger competition between uses than in the past.

- **The importance of remembering that there is no such thing as a "no-impact mine"**; initial ecosystems will never be restored to their original state once a mine has been developed. SystExt[40] makes the following key recommendations for transforming mineral industry practices to develop processes that are genuinely respectful of man and nature: improve the governance, traceability and impact of mineral industries throughout the value chain, taking into account all issues (social and environmental) and following existing recommendation[41]; help companies to exclude the ten most destructive practices (cyanidation, heap leaching, etc.).

[40] SystExt, *Rapport controverse minière volet 2: Meilleures pratiques et mines responsables*, 2022
[41] United Nations Development Programme

- The importance of **developing recycling channels** when the designed metal can be recycled, and of developing production channels and processes accordingly. Favoring metals from recycling channels and investing massively in these means of production.

- The importance of **quantifying decarbonization initiatives**. How much of the Capex can be used to reduce emissions? How much CO2 will the replacement of equipment avoid? Implementing a more virtuous process? Does the company have **expansion projects that** are highly carbon-dependent (e.g. blast furnaces, etc.)?

- **The importance of verifying that real long-term** decarbonization **plans are in place**, with quantified, manageable annual targets.

Large metals, the forgotten transition partners

As the need for certain low-carbon technologies becomes clearer, the spotlight is on certain minerals, such as lithium and cobalt, which are being touted as transition metals. However, it is important to bear in mind that:

- **Low-carbon technologies (wind, solar, nuclear) cannot exist without the major metals steel (wind turbine masts)**, aluminum and copper (essential to the electricity transmission and distribution system).
- Some metals are co-products of the mining of other major metals, as mentioned in section 2.3.1, and are therefore dependent on them.
- Metals that are today considered "essential" for the energy transition could be substituted by technological breakthroughs and no longer be so indispensable.

Demand for certain minerals and metals is also strongly driven by the digital sector, with an increase in the diversity of metals called upon as the performance and functionality of digital devices increases. For more information on the sector, see Carbon4 Finance's publication "ICT: a sector disconnected from the climate reality?"

Carbon Impact Analytics (CIA) methodology

The CIA methodology calculates an **overall rating** to assess an entity's contribution to a low-carbon transition and its exposure to transition risks.

This section presents how the CIA methodology is applied to the Mining & Metals sector. For more details on the CIA methodology in general, please refer to our **CIA methodology guide**.

Calculating GHG emissions

SCOPE 1 AND 2 INDUCED EMISSIONS

For mineral extraction and metal production activities, there are two possible methods for obtaining Scopes 1 and 2 induced emissions: either by taking those published by the company under analysis, or by calculating them using the CIA methodology.

We take the emissions published by the company when the reported scope 2 emissions are calculated with location-based emission factors (based on the electricity mix of the geographical area) and the company discloses sufficient data to allow a consistency check (energy consumption).

If the company does not publish any information on its scope 1 and 2 emissions or energy consumption, we calculate them using physical production volumes (generally published) and the emission factors per tonne available in our database.

The preponderance of Scope 1&2 emissions, reflecting direct dependence on fossil fuels

The metal mining and manufacturing sector accounts for a significant proportion of global energy consumption, particularly through the **direct use of fossil fuels** (coal and coke in blast furnaces, petroleum products for mining equipment and transport), **as well as electricity.**

The **industry is responsible for an important share of GHG emissions** in its direct operations (scope 1 & 2), which transform materials that are then used by other downstream sectors.

SCOPE 3 INDUCED EMISSIONS

Scope 3 covers all greenhouse gas emissions (excluding the production of purchased electricity and heat) on which a company depends even though it is not the legal owner. It therefore includes emissions from suppliers, customers, employees on business trips, etc., corresponding to various stages in the product life cycle (production of purchased raw materials, upstream and downstream freight, product use, product end-of-life, etc.).

As the sector is made up of companies positioned along a transformation chain, they are directly dependent on each other. Thus, the product of mining companies will be the raw material of metal manufacturing companies, and the direct emissions (scope 1 and 2) of one will form part of the upstream scope 3 emissions of the next.

For the mining and metals sector, knowing where downstream Scope 3 ends is a difficult exercise. For example, for a steel producer, should we take into account emissions from the use of buildings or vehicles constructed using this steel? For a copper producer, do we need to take into account emissions from the electricity production that supplies the power flowing in the copper cables?

Mainly due to a lack of data, but also to a lack of methodologies enabling us to impute downstream emissions from end-use to companies in the mining and metallurgy sector (normally essential for assessing compatibility with decarbonization), the CIA methodology is conventionally limited, for downstream Scope 3, to emissions from the transformation of ore into metal (metallurgy, refining) for producers of iron ore and bauxite (aluminum ore).

Other downstream scope 3 emission categories - notably for the item "use of sold products"- are not calculated, as this would require access to information on the uses of the various metals produced by a given company - yet this information is scarcely available, if at all, in companies' annual reports, limiting a differentiating approach within the sector. This situation is unsatisfactory, as it is the responsibility of investors to lead ambitious commitment programs to obtain greater transparency from issuers on the end-use of metal production.

Percentage of companies in the sector with reduction targets for scope 3 and relevance

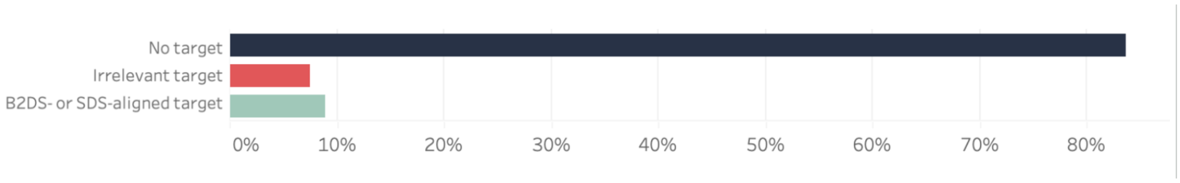


Figure 12: Over 80% of companies have no scope 3 reduction target.

Categorization of ores and metals by sub-activity in CIA

The CIA methodology distinguishes between a company's activities and the corresponding turnover. For each activity, it measures the company's performance against sector indicators.

For the mining and metal fabrication activity, we have established a **nomenclature of seven sub-activities based on** a literature review and a study of current and future uses of ores and metals:

The most abundant minerals in the earth's crust each constitute a distinct sub-activity**:**

- **Iron** (and associated ores used in steel alloys, notably chromium, niobium and tungsten);
- **Aluminum;**
- **Nickel** is also a sub-sector, even though it is not one of the most abundant ores, as we found that it is reported on separately.

For the remaining ores and metals, we have created four categories, according to their potential contribution to the low-carbon transition:

- **The metals most needed for a low-carbon transition**, used for low-carbon power production (wind, solar, nuclear), the manufacture of electric batteries for mobility (lithium), electrification (copper), among other uses;
- **Metals that contribute in part to the transition**, widely used in the economy but also in low-carbon technologies: silver (batteries, renewable energies, nuclear power, but also welding and glassware), platinum and platinoids (fuel cells, jewelry, medicine, but also catalytic converters);
- **Metals used in today's economy**, with a variety of uses that do not contribute to the transition: notably lead (construction, body sheet metal, beams, oil pipeline), potassium (chemicals, fertilizers, catalysts, PVC), various industries (LCD screens, transport equipment);
- **Metals used mainly in high-emission industries**, mainly chemicals (coatings, anticorrosives, chlorine, etc.), emissive industries (equipment manufacturing, aeronautics, oil industry), digital terminals (fiber optics, electronics), etc.

The list of metals included in each category is available in the appendix.

Overall climate performance: the CIA rating

The CIA rating assigned to each company in the mining and metals sector combines several performance indicators, which are described below.

PAST PERFORMANCE

Past performance assessment provides a historical perspective on a company's activity. For the metal extraction and manufacturing sector, it is based on changes in scope 1&2 emissions intensity per tonne of product sold.

This easy-to-use indicator expresses a company's ability to decouple volumes extracted or processed, and associated GHG emissions. It enables comparisons between players in the same sector.
The indicator takes into account "*location-based*" rather than "*market-based*" scope 2 emissions, in order to focus on reducing electricity consumption rather than buying green electricity on the market - see Carbone 4's publication on the subject.

CURRENT PERFORMANCE

For **mineral extraction companies,** the performance indicators are the same for all seven sub-sectors: current performance is calculated on the one hand on the basis of the "useful emission factor" - in tCO2/MWh, which assesses the **level of electrification of extraction operations**; and on the other hand on the basis of the rate of reincorporation of secondary source material - for conventional mining players, this rate is by definition zero, and the associated performance score will be the worst.

For **metal manufacturing activities,** the current performance of **steel**, **aluminum** and **nickel** players is assessed by the carbon intensity reported, expressed in tonnes of CO2e per tonne of metal produced.

For the less abundant **metals manufacturing activities** classified in the 4 end-use sub-activities, the current performance is a combination of the "useful emission factor" - in tCO2e/MWh of energy consumed, which assesses the carbon intensity of energy used in the processes - and the reincorporation indicator - which measures the rate of secondary source materials in the final products.

FORWARD-LOOKING PERFORMANCE

The "forward-looking" performance analysis is an assessment of the strategy and commitments made by the company to improve its contribution to the fight against climate change in the future. It is made up of four main sub-categories, the evaluation criteria for each CIA sector.

For metal mining and manufacturing players, the "Forward-looking" analysis considers:

	Ore mining	Metal manufacturing
Key points of the decarbonization strategy	Transforming mineral extraction processes to use low-carbon energy sources Replacing fossil fuel equipment with electric or alternative fuel equipment Choosing low-carbon modes of transport Reorientation of the business towards minerals useful for the transition and divestment of other activities	Reincorporation of secondary raw materials and recycling Electrification of processes and use of low-carbon energy sources Exit plans for coal-dependent processes Choosing low-carbon modes of transport Carbon capture and storage (CCS) Reorientation of business towards metals useful for the transition and divestment of other activities
Low-carbon investments	Electrical equipment or equipment running on alternative fuels that replaces existing equipment Low-carbon transport technologies: rope conveyor system, electric trucks, rail network Low-carbon electricity generation capacity (on-site or PPA)	Investments in the energy efficiency of transformation processes, and the electrification of vehicles and machinery The development of breakthrough technologies such as CCS or green hydrogen for certain incompressible emissions in metal manufacturing
Scope 1&2 and Scope 3 reduction targets	Reduction targets are compared with IEA emissions scenarios for the industry sector. These scenarios describe the evolution of the sector's emissions in absolute terms, and therefore enable us to evaluate the targets expressed in absolute terms. Where company targets were expressed in terms of intensity, we converted them to absolute terms, using the evolution of production volume over the last 5 years to estimate future trends.	
Governance	We assess the existence of internal structures dedicated to energy-climate issues (usually the CSR department), their link with the executive committee, and the introduction of training and financial incentives to help and encourage employees to tackle climate-related issues.	

Example of scenario analysis for Nippon Steel analysis

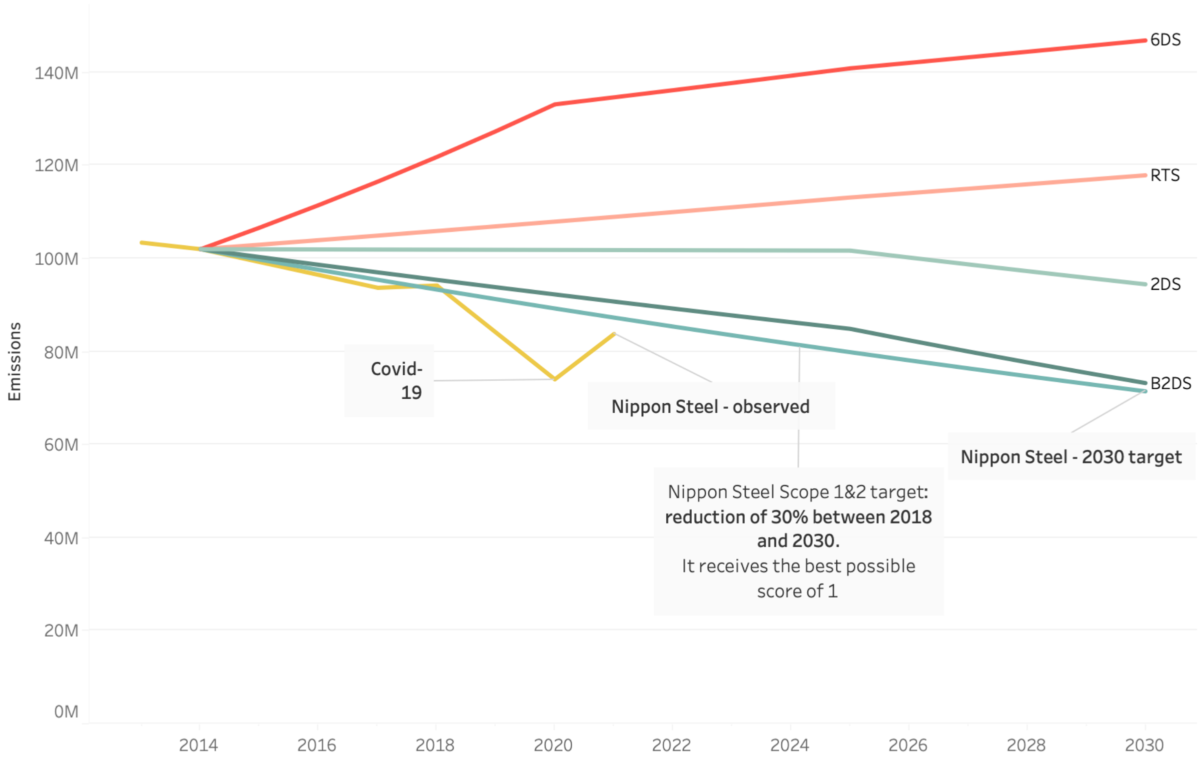


Figure 13: Illustration of IEA scenario trajectories and comparison with Nippon Steel's trajectory and targets Nb: this score only concerns the company's commitment to its scope 1 and 2, and not the evaluation of its strategy to achieve it, nor its overall score, which takes into account past, present and future performance see figures 19 and 20.

Aggregation of CIA ratings

AGGREGATION AT SUB-ACTIVITY LEVEL

Mining and Metals activities are broken down into 7 sub-activities each, presented above.

For each sub-activity, past and current performance ratings are calculated, and aggregated with the forward-looking performance rating, to obtain a CIA rating for the sub-activity concerned.

Rating of metal manufacturing activities

Metals processing activity rating			
Type Of Metals	**Past** Performance	**Current** Performance	**Forward looking** Performance
Steel, Aluminium and Nickel	Evolution over the past 5 years of scope 1&2 **carbon intensity** *tCO2e/ton of metals*	Reported scope 1&2 **carbon intensity** *tCO2e/ton of metal produced*	Strategy Low-carbon investments Target alignments for scope 1,2 & 3 Governance regarding climate
Other Metals		**Recycling** rate **Operating** conditions	
Weight	**30%**	**40%**	**30%**
Grade	**CIA Overall Rating (3 - 13)**		

Figure 14: Illustration of the main indicators used to obtain the score of the company analyzed for its "metal manufacturing" sub-sector. Online, we distinguish the 7 sub-sectors, separated into two categories: steel, aluminum and nickel and 'other metals' for the other four categories.

Rating of mineral extraction activities (excluding coal)

Ore Mining activity rating			
Type Of Ores	**Past** Performance	**Current** Performance	**Forward looking** Performance
All Ores	Evolution over the past 5 years of scope 1&2 **carbon intensity** *tCO2e/ton of metals*	**Recycling** rate *worst grade : 15/15* **Operating** conditions *tCO2e/MWh*	Strategy Low-carbon investments Target alignments for scope 1,2 & 3. Governance regarding climate
Weight	**30%**	**40%**	**30%**
Grade	**CIA Overall Rating (3 - 13)**		

Figure 15: Illustration of the main indicators used to obtain the rating of the company analyzed for its "Mining (excluding coal)" sub-sector.

The weighting of the indicators represents the importance we feel should be given to each rating criterion. The current performance rating has a higher weighting than the others for the following reasons:

- It enables players **to compare the energy intensity of their operations** (through the "useful emission factor", recalculated from reported emissions and energy consumption, or approximated from energy consumption alone and electricity intensity in the various countries of production).
- For metal players, it also measures the **ability to integrate secondary-source materials into finished products** (incorporating scrap metal into the raw materials used to produce steel, for example).

Then, the ratings obtained for each sub-activity are standardized, to enable a comparison of activities.
In concrete terms, the ratings assigned to activities are based on minimum and maximum ratings for each category of minerals and metals.
This corresponds to our desire to classify activities according to their potential to contribute positively or negatively to the transition: we consider both their usefulness in the activities of the low-carbon economy, and their contribution to greenhouse gas emissions.

These limits are therefore based on the intensity of activities and their possible role in the decarbonization of our economy.

Range of possible ratings for each sub-activity in the metal extraction and manufacturing sector.

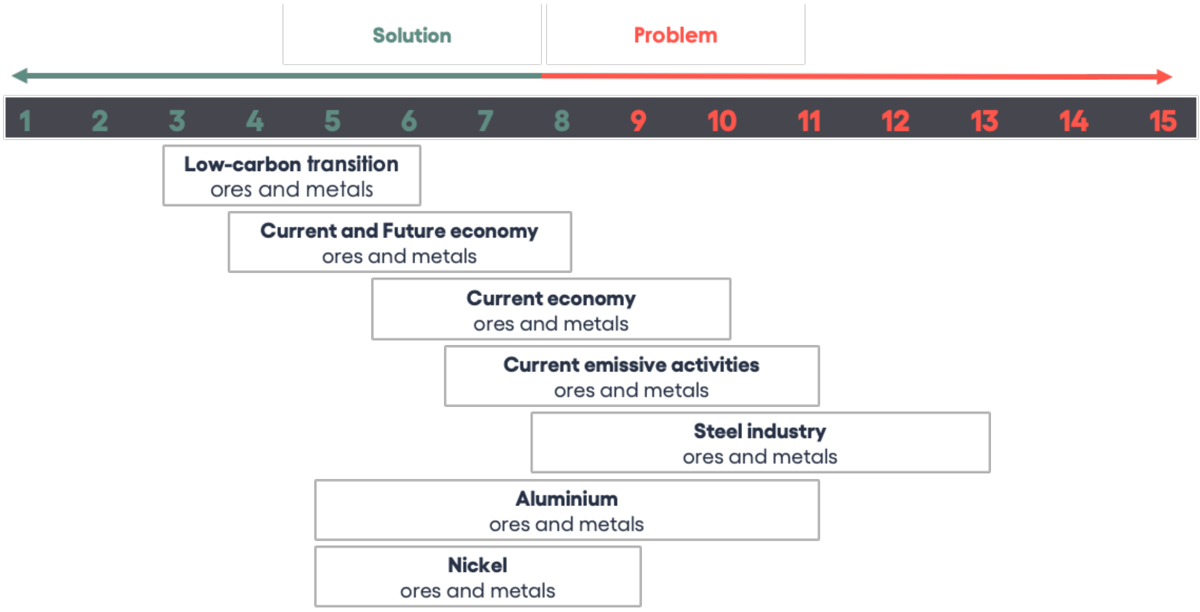


Figure 16: Illustration of Mining and Metals sector scores.

These limits may evolve with evolutions in certain sectors.

SECTOR-LEVEL AGGREGATION

For each company, the CIA sub-ratings are aggregated to obtain a single rating for the 'Mining and Metals' sector, weighted by revenues, to obtain the sector's CIA rating, as described by the MetalCorp example.

MetalCorp's revenue breakdown is as follows: 20% coal and 80% metals. To obtain the Metal activity rating, the calculation is as follows:

Metals sector rating - MetalCorp		
Metal	Copper	Steel
Sub-sector	**Low-carbon transition** metals	**Steel**
Weight	**30%**	**70%**
Sub-sector rating	**4**	**12**
Sector rating	**9.6** *(4 x 30% + 12 x 70%)*	

Figure 17: Illustration of the calculation of the sector rating for a company with revenues from the production of several different metal categories.

AGGREGATION AT COMPANY LEVEL

Finally, if the company is multi-activity, the same logic of aggregation is pursued for each activity, as shown in the diagram.

MetalCorp - a multi-sector company as mentioned above - thus obtains the following rating:

Global rating - MetalCorp		
Sectors	Metals	Coal
Weight	**80%**	**20%**
Sector rating	**9.6**	**14**
Global rating	**10.5** *(9.6 x 80% + 14 x 20%)*	

Figure 18: Illustration of the calculation of the CIA overall rating for a company with activities in several sectors, including metal production.

Results

The Results section presents the overall ranking of CIA ratings for Mining and Metals players, as well as the distribution of the main indicators that make up Past, Current and Forward-looking performance.

Comparison of companies within the sector

The following chart shows the distribution of CIA overall ratings for 40 listed companies in our sample.

Companies with the best rating (top of the graph) are considered to have a lower transition risk, thanks to the lower carbon intensity of their processes and their greater contribution to an economy in transition.

Companies with the worst ratings (at the bottom of the graph) have both a greater negative impact on the climate, and also run a significant risk of losing profitability (compared with their competitors) if transition risks materialize (carbon prices rise, regulations tighten, etc.)

Ranking by CIA overall rating, and breakdown of revenue by metal category

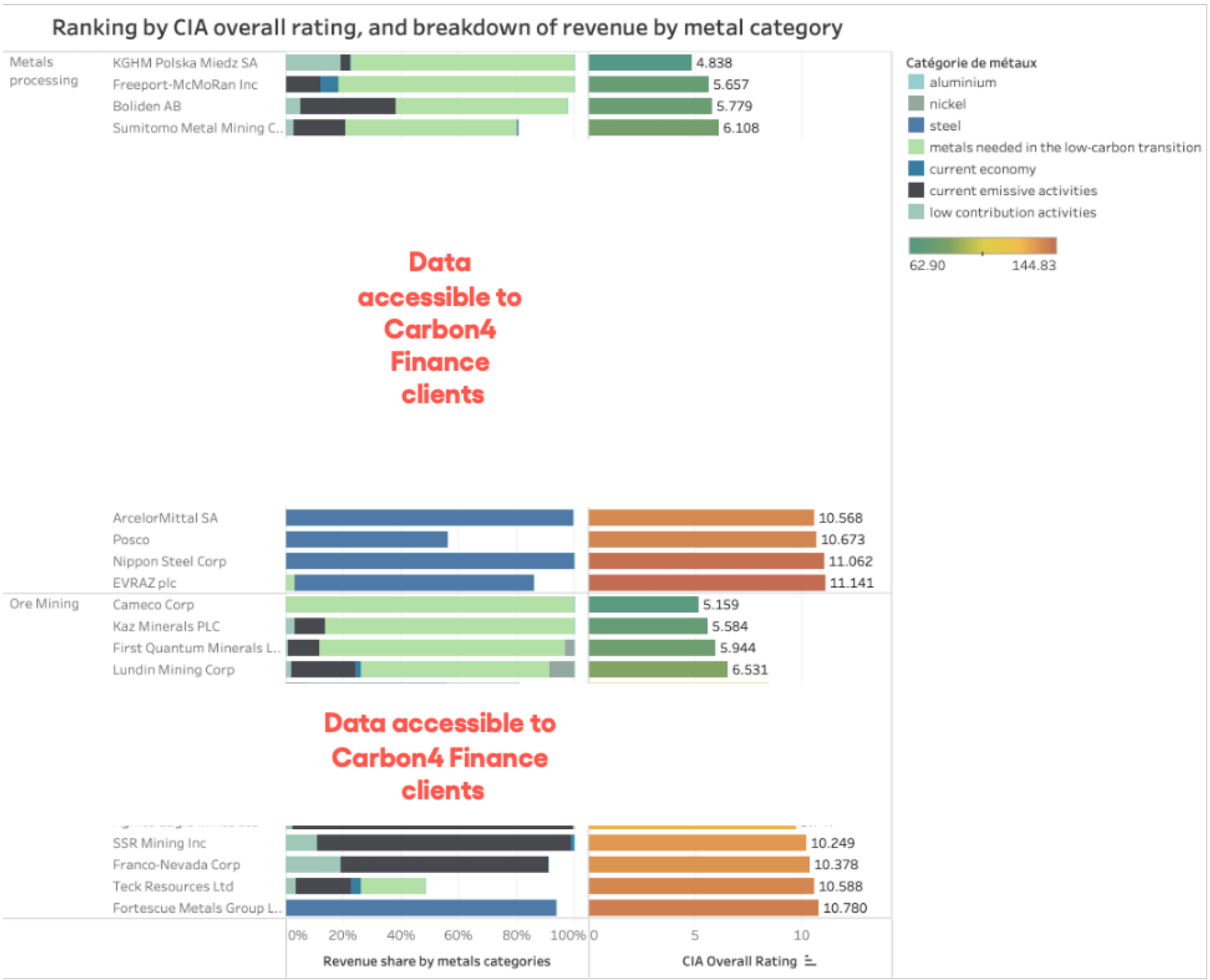


Figure 19: Ranking of the main companies analyzed in the Mining & Metals campaign, by CIA overall rating. The colors represent the distribution in sales of the seven sub-categories of metals. When the percentage of revenues by type of metal does not reach 100%, this means that the company is multi-sectoral and has activities other than metal extraction and processing.

One of the main determinants of the rating is the sub-activity to which the metal produced belongs. In fact, as explained in the methodological sections, the scores for each sub-sector are framed to reflect the potential contribution of each metal or ore to the transition.

Best past performances

A company's past performance is based on an indicator:

Variation in scope 1&2 carbon intensity per tonne of metal produced in % compared with the reference year.

Steel being one of the most mature markets, we illustrate this variation on the players in this value chain.

Trends in emissions intensity per tonne of metal produced for steel players.

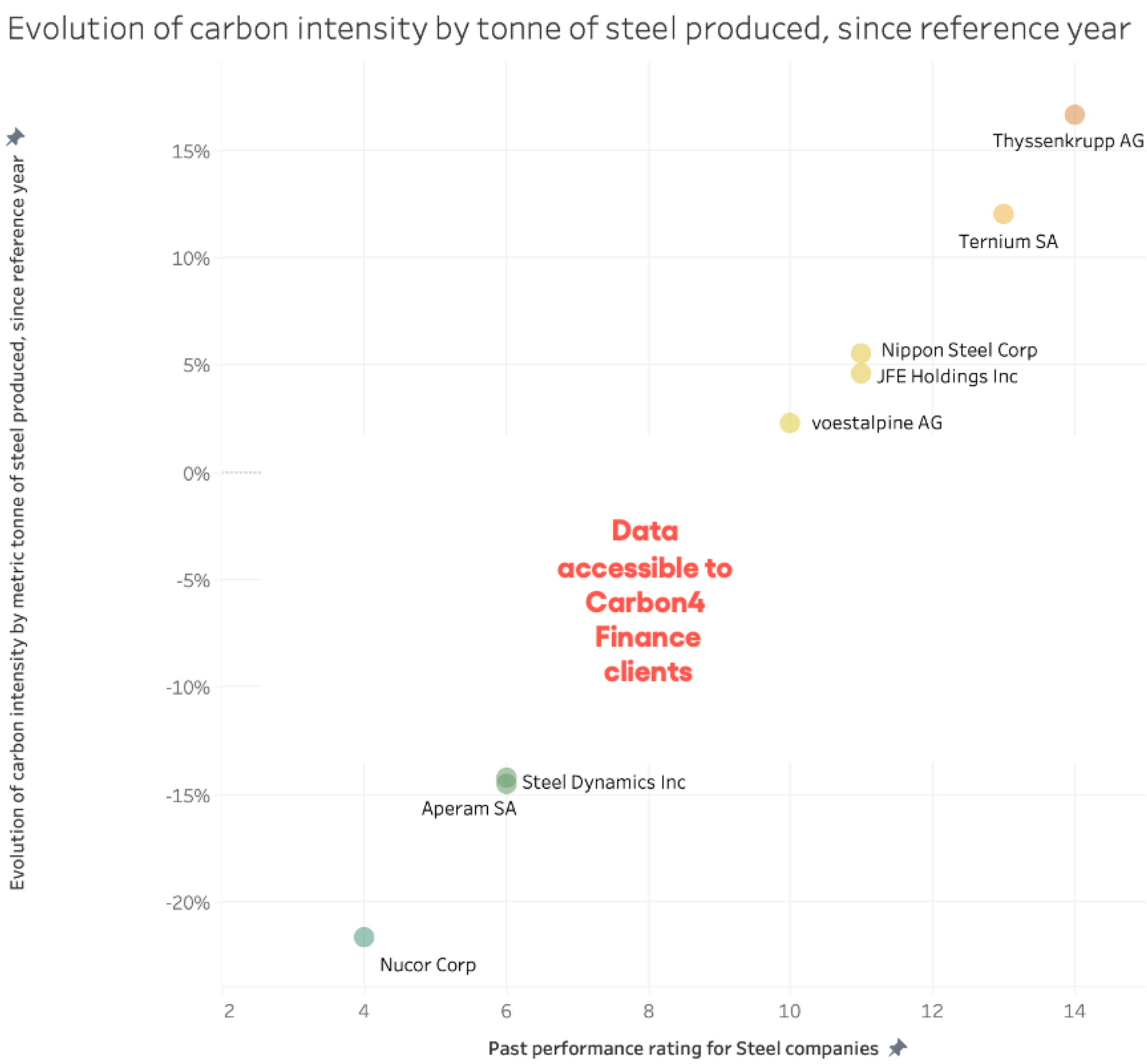


Figure 20: Intensity trends for companies in the sector over the last five years.

Some players, such as Nucor Corp, Aperam and Steel Dynamics, have succeeded in reducing the carbon intensity of their production by over 15% in 5 years. These companies have succeeded in reducing the carbon intensity of their production by developing the electrical process and secondary production. Other companies, such as Nippon Steel and Ternium, have seen their intensity increase by more than 5%.

Companies that do not defer their intensity are conventionally given the worst possible rating.

Best current performance

A company's current performance is based on 2 indicators:

Scope 1&2 carbon intensity per tonne of metal produced or useful emission factor in tCO2e/MWh.
The rate of reincorporation of secondary-source material in finished products, as a percentage of reused material in total production.

For more details on the meaning of these indicators, please refer to methodology section 4.2.2.

Share of reincorporation of scrap metal in the final production of steel manufacturing companies and comparison with intensity

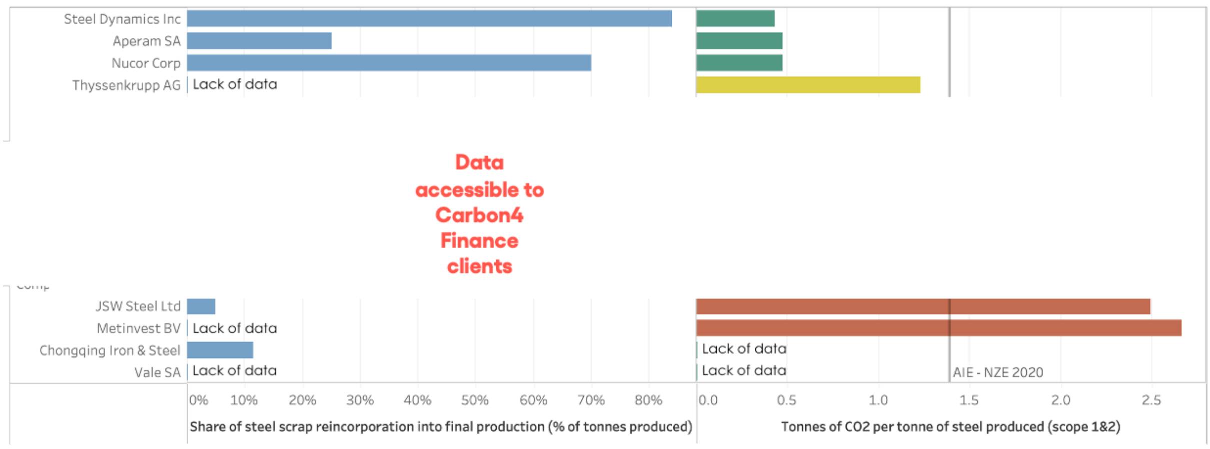


Figure 21: Carbon intensity depends on the rate of scrap reincorporation (as manufacturing processes are electrified and less intensive), but also on the carbon intensity of the energy used. Reincorporation is a necessary but not sufficient condition for decarbonization. The IEA NZE line represents the target intensity for the steel trajectory in the IEA Net Zero scenarios.

The players with the lowest intensities are those who have invested the most in electric arc furnaces, developing secondary steel production lines. The case of Aperam is special, as its low intensity is linked to the development of biochar in forests managed by the company - enabling it to replace the use of coal as a fossil fuel with biomass for its blast furnaces. It should be noted that biomass combustion can only be counted at zero if the annual quantity of biomass harvested does not exceed the forest's annual regeneration capacity, and if the forest is no longer growing. This criterion only concerns carbon, and says nothing about the other potential ecological impacts of the forest in question: thus, "neutral" wood from a monoculture will potentially have negative effects on other indicators such as biodiversity (which we also address with the BIA-GBS methodology). It is therefore important to be particularly vigilant about the origin of the wood, and to adopt a holistic, multi-criteria vision when analyzing the sustainability of the supply.

Limits on the knowledge of the end use of metals and the use of recycled metal are mentioned in the limits in chapter 5.

Analysis of forward-looking performance

Forward-looking performance examines the company's decarbonization strategy:

- Ability to identify climate change risks and opportunities
- Decarbonization strategy: ambition, quantification and target planning
- Investments that will help reduce GHG emissions
- The entity's GHG emissions reduction target for scopes 1&2 and 3?
- Governance structure overseeing climate risks within the entity

For more details on the meaning of these indicators, please refer to section 4.2.3.

Evaluation of forward-looking performance ratings on the 'decarbonization strategy' criterion

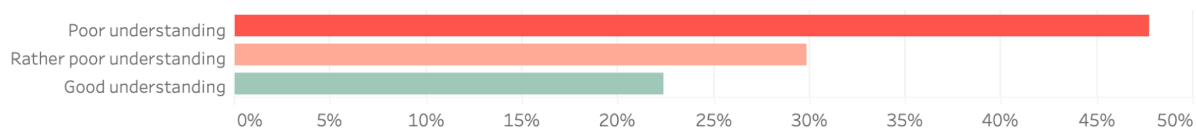


Figure 22: Nearly 50% of companies in the sector scored 4 or 5 out of 5 on the 'Strategy' criterion, corresponding to a 'Poor understanding' of the issues. No company scored 1 (very good understanding).

SBTI commitments by companies

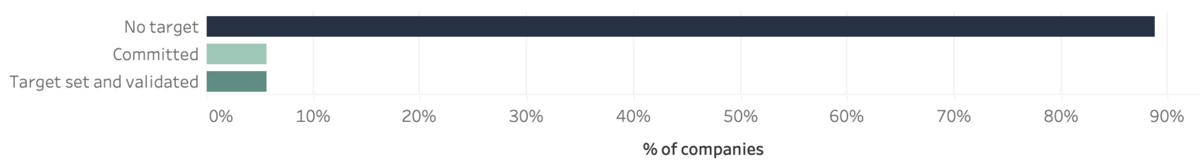


Figure 23: Share of companies in the sample that have made SBTI commitments.

As far as company commitments are concerned, only 5% of the companies analyzed have an SBTI target (Science Based Target Initiative[42]). 90% have no SBTI commitment.

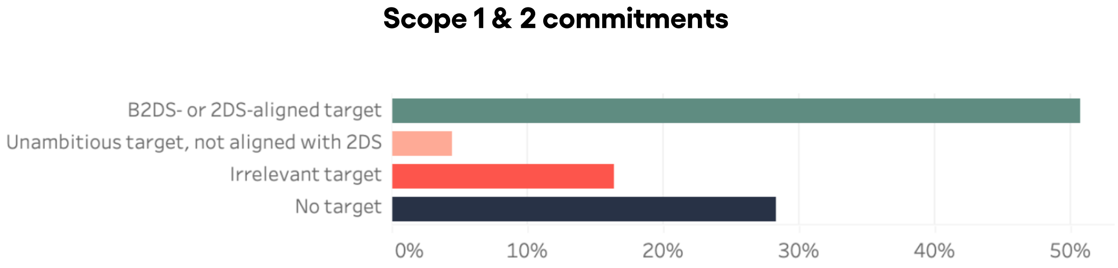


Figure 24: Percentage of companies in the sample that have made commitments on their scope 1&2

When we look at companies' commitments on their scope 1 and 2, we see that only 50% of the companies analyzed have a target that is aligned with the IEA's B2DS or 2DS scenarios. And when we look at scope 3, 84% of companies do not mention any commitment - only 9% of them have one that is aligned with 2DS (Anglo American, Newmont Corporation and Novellis Inc).

The following graph presents an analysis of three committed companies in the sector with among the best decarbonization strategies. This analysis is made from a qualitative point of view (quantity and relevance of investments in a low-carbon world) but also from a quantitative point of view (relevance of reduction targets, alignment with IEA scenarios). We note that these are companies that are transforming their models to incorporate more and more recycled materials into their production.

	Main Metal Product	Key points of the decarbonation strategy	Low carbon investments	Reduction objectives	Points of attention	Scrap reincorporation rate
AngloAmerican	Iron and copper ore	**100% renewable electrical supply** (with own capacity development) Energy efficiency, reduction of methane	Renewable energy development, more efficient ore grinding technology	Objective to **reduce Scope 1 & 2 emissions by 30% by 2030 compared to 2016.** It is one of the only actors engaged on Scope 3: **Reduction of Scope 3 of 50% emissions in 2040** compared to 2020. These objectives are aligned with a scenario within 2 ° C, "B2DS" of the IEA	**Anglo American is still involved in coal** up to 9% of its turnover. The company has announced that it wanted to get out of thermal coal, but it must go further and **set a closing date for all its activities in the coal (no sale)**	Not reported
Steel Dynamics	Steel	More than 80% of production comes from recycled scrap Renewable energy development	Electrification of investment manufacturing processes in an EAF park	**50% reduction objective of Scope 1 & 2 emissions** from its factories **by 2030.**	Energy mix still very dependent on the fossil (less than 8% renewable electricity) - the objective is to increase to 30% renewable by 2030	**84%**
eramet	Nickel and manganese	**Use of secondary material and recycling** Internal carbon price Using hydrogen and bioreducer for ore reduction Installation of renewable energy capacities and implementation of PPAs	Optimization of processes, more effective use of resources, **electrification of extraction** and use of alternative fuels	**Reduction of Scope 1 & 2 emissions by 40% between 2019 and 2035.** This objective is based on science and aligned with a scenario within 2 ° C, "B2DS" of the IEA.	Decarbonation investments are not quantified, and the company **has no objective of reducing Scope 3 emissions** linked to the downstream use of minerals and metals sold	Not reported

[42] This initiative defines best practices for Net Zero reduction and targets aligned with science.

Focus on ArcelorMittal - a two-tiered strategy

ArcelorMittal is the world's second largest steel producer, with an output of 80 million tonnes of steel in 2021. It operates 32 industrial steel production sites43 , including 19 coal-fired blast furnaces. ArcelorMittal's strategy seems to be two-speed: on the one hand, strong investment in steel decarbonization in Europe, and on the other, the opening of two new blast furnaces in India, without a clear decarbonization strategy.

ArcelorMittal	Steel	**Secondary steel sector** Increase in the use of scrap metal and development of the electrical route (EAF) **Primary steel sector** Development of direct iron reduction with low-carbon hydrogen	**Plan of $ 10 billion** to reduce its carbon footprint: Replacement of blast furnace in France (2027), Spain and Portugal by EAF Development of the **CCS** with several prototypes in France, for the production of primary steel	Objective of reducing emissions of its **Scope 1 & 2 in terms of intensity of 25%** worldwide and 35% for Europe (by 2030)	A **two-tiered decarbonization**: ArcelorMittal continues to develop new projects in **blast furnace or expansion in Brazil, India and Mexico** - no decarbonation strategy is specified on these projects	11%

Top ten market capitalizations

The ten largest market capitalizations in the sample scored between 5.7 and 11. Most of them are **exposed and vulnerable to transition risks** (by virtue of the metals they produce and their relative performance within the sector), with the exception of Freeport-McMoran Inc. which, with a score of 5.7, is on the side of companies **contributing to the transition,** notably by producing **materials needed to decarbonize the rest of the economy** (copper, needed to electrify the energy system, accounts for 90% of its production).

Top 10 largest market capitalizations

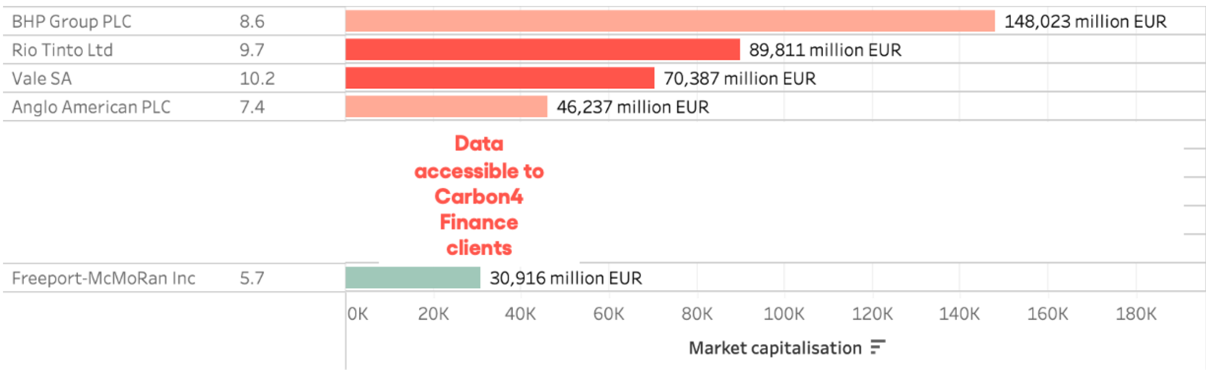


Figure 25: Rating of the top 10 largest market capitalizations in the sample analysed.

[43] Global Energy Monitor's Global Steel Plant Tracker, 2022

Appendices

Appendix 1: CIA methodology for coal players

Overview of the CIA method for analyzing coal players

The coal industry is closely linked to mineral extraction and metal manufacturing. Coal is used to reduce iron ore, and to reach the very high temperatures required in blast furnaces for steel.

Coal mining is covered by CIA, although it is not included in the scope of this sector study, we feel it is essential to outline its main issues. (15% of the companies analyzed in this review also derive part of their revenues from coal mining).

The IEA[44] stresses that alignment with a 1.5°C trajectory implies **an end to investment in fossil fuel exploration or extraction**: *"beyond the projects already committed from 2021, no new coal mines or mine extensions are required"*.

The chart below describes the indicators used to analyze this activity.

[44] IEA, *Net Zero by 2050, A roadmap for the Global Energy Sector*, 2021

Coal mining activity rating				
Type of coal	**Past** Performance	**Current** Performance	**Forward looking** Performance
Metallurgical and thermal coal	Evolution over the past 5 years of **absolute scope 3 downstream emissions** (combustion of fossil fuels) calculated from volumes sold (tonnes of coal)	Direct rating **15/15**	Coal exit strategy Low-carbon investments Target alignments for scope 1,2 & 3 Governance regarding climate
Weight	**30%**	**40%**	**30%**
Grade	**CIA Overall Rating (12 - 15)**		

Figure 24: Rating system for a company's coal mining activities.

Criteria for the forward-looking performance analysis are as follow:

- Analysis of the coal exit commitment: players must decide on a firm and definitive deadline for **closing their coal mines**.
- Assets must be closed, not sold.

No investment should go into expanding or opening coal mines (or other fossil fuels).

Appendix 2: List of metals by category

Category	Metals
Ores / metals of the low-carbon economy	Lithium, Gallium, Silicon, Copper, Tin, Graphite, Vanadium, Uranium
Ores / metals of the current and future economy	Platinum, Platinoids, Silver
Ores / metals of the current economy	Manganese, Molybdenum, Diamond gem, Potash, Lead
Ores / metals of the current economy emissive activities	Germanium, Hafnium, Thallium, Zirconium, Yttrium, Scandium, Indium, Mercury, Tantalum, Beryllium, Antimony, Cadmium, Gold, Titanium
Ores / metals of the steel industry	Iron ore, Tungsten, Chromium, Niobium, Magnésium, Tellurium, Bismuth
Ores / metals of aluminium industry	Aluminum, Alumina, bauxite
Ores / metals of the nickel industry	Nickel

Limits

As with any evaluation method, the one used for this assessment necessarily has its limitations. We summarize the limitations of this methodology below:

- Firstly, it is currently impossible to assess the end use of the metals produced, due to a lack of transparency on the part of companies. This limits our ability to assess their contribution to the transition (steel sold to make wind turbine masts does not make the same contribution as steel used to make household appliances). It also prevents us from valuing any avoided emissions in the downstream value chain.
- Downstream risk, i.e. the vulnerability or otherwise of the sector that will ultimately purchase the metals, is therefore not included in the analysis. For example, selling metal to the construction industry is riskier than selling products to manufacturers of renewable energy production devices. A systemic approach by type of customer sector could be envisaged.
- We are aware that the recycled metals used in our methodology cannot be used for all purposes, but we are keen to encourage these processes, which are necessary for the transition, where possible.
- The notion of low-carbon transition metals may evolve over time: some metals, such as lithium, are today considered essential to the energy transition. But alternative technologies may emerge that make it possible to manufacture batteries without lithium. And vice versa: in practice, copper is a metal that primarily favors the fossil fuel economy, since more than 60% of the world's electricity is generated by fossil fuels.
- The percentage of recycled material reincorporated is a criterion for all types of metal evaluated by the methodology, but its complexity varies enormously from one metal to another (particularly those used as alloys) and also depends on the degree of industrialization of the country in which the company operates: the more industrialized a country is, the more metals it has access to that can be recycled from its past infrastructures.
- There is no specific decarbonization scenario for the metals sector to serve as a reference. We have therefore compared the companies' emission reduction trajectories and targets with the emissions trajectories of the industry sector for an IEA 'beyond 2°C' scenario - which is based on production growth.

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Carbon4 Finance offers a comprehensive set of climate data solutions covering both physical risk (CRIS methodology: Climate Risk Impact Screening) and transition risk (CIA methodology: Carbon Impact Analytics). These recognized methodologies enable financial organizations to measure the carbon footprint of their portfolios, assess alignment with a 2°C-compatible scenario, and measure the level of risks arising from climate change-related events.

Carbon4 Finance applies a rigorous bottom-up, research-based approach, meaning that each asset is analyzed individually and in a discriminating manner.

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