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MEESCHAERT
Asset Management

Rare metal supply chains

Challenges for a sustainable energy transition

May 2019

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Created in 2017, Shareholders for Change is a European network for shareholder engagement, composed of institutional investors representing over €24 billion in assets under management.
Its members are highly involved in shareholder engagement at the local level, participating jointly in general meetings, co-signing letters to businesses and meeting with companies to discuss their respective commitments. The network describes itself primarily as a “facilitator platform” and is intended to intervene only when and where necessary.
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INTRODUCTION

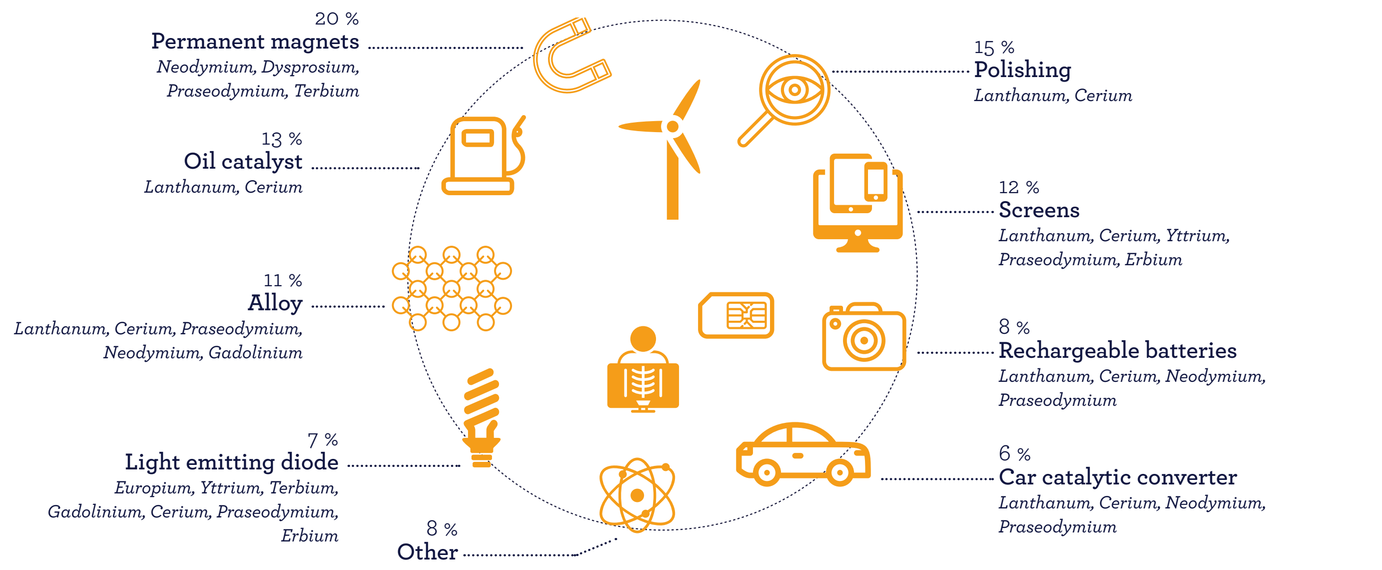
> "Little attention has been paid to the implications of growing demand for materials required in the construction of renewable technologies and zero emission infrastructure. Minerals and metals will play a key role in the transition to a significantly lower carbon future, with potentially significant changes for the minerals and metals market. Metals are crucial to the way in which energy is generated and used. The future move to a low carbon economy […] has huge potential to shift both the scale and composition of the demand for minerals and metals".
>
> Source : World Bank[1]

Rare metals (see annex p.38) are now indispensable components in many everyday items from mobile phones and computers to lighting, smart energy-saving systems, renewable energy equipment and electric vehicles.

However, their production is not without consequence: depending on the extraction conditions, rare metal mining can have significant adverse effects on people and the environment.

These effects, which occur throughout the chain of production of high-value technological products, must be taken into consideration as digital innovation picks up pace and we move towards a low-carbon economy.
It is therefore crucial to understand the key role played by rare metals in the evolution of the energy system, in order to tackle climate change, decarbonise the economy and extend the use of fossil fuels by improving their efficiency. The conclusions of the World Bank's report should be considered in the light of other studies[2], which are more concerned with the potential impact of recycling on supply, and emphasise that additional demand varies according to the metal. However, it is widely agreed that compliance with the 2°C target laid down in the COP21 Paris Agreement will impact the energy mix and the mapping of demand for raw materials. This paradigm shift must therefore take account of supply needs for the construction, maintenance and dismantling of new technologies in this field.

THE RARE EARTH, A GROUP OF STRATEGIC METALS



Source : BRGM (Bureau des Recherches Géologiques et Minières), « Les terres rares, un groupe de métaux stratégiques », January 2017.

[1] World Bank, EGPS, « The growing role of minerals and metals for a low carbon future », June 2017.
[2] http://www.carbone4.com/marche-metaux-va-doubler-boom-technologies-vertes-info-intox/

Responsible investors should assess the companies in the sectors concerned, using an appropriate methodology. In this context, the concept of extended responsibility makes perfect sense: henceforth, companies are not only responsible for what goes on in their factories and the direct consequences of their production activities. They must also be vigilant to the indirect impacts of their operations, particularly in the supply chains upstream from production. Extending the spectrum of responsibility to the entire value chain shifts the balance and redefines the role of companies in their ecosystem.

How can the concept of "extended responsibility" be adapted to rare metal supply chains? The aim is to prevent any transfer of responsibility from the company, which would externalise the social and environmental issues arising from its activities to its suppliers. To do this, companies must ensure their supply chains are transparent, investigate potential means of replacing or reducing the raw materials they use, and consider recycling products.

Companies that fail to address these emerging issues leave themselves open to considerable risk, be it operational, environmental, human, reputational or regulatory.

The risks are even greater for companies that use rare metals. The very specific characteristics of these materials, which explain their strategic use in the energy system for example, determine the potential for divergent trends in supply and demand.

We will therefore examine these issues as they relate to the solar energy, wind power and electric vehicle sectors, which are key components of the energy transition: What policies should companies adopt in this respect? How transparent are they on these issues? Have they already identified best practices? What is the scope for improvement? By conducting a detailed analysis of companies operating in these sectors, in the light of the specific problems they face, we will be able to define the awareness and engagement actions needed.

THE MINERAL SUPPLY CHAIN

The process of supplying minerals to the consumer market involves multiple actors and generally includes the extraction, transportation, handling, trade, processing, smelting, manufacture and sale of the final product. The term "supply chain" refers to all the activities, organisations, actors, technologies, information, resources and services involved in the ore's journey from the downstream extraction site to the final consumer product.

Source : OECD Due Diligence Guidance for Responsible Mineral Supply Chains, 2016.

THE RESPONSABILITY OF COMPANIES FOR THEIR SUPPLY CHAIN: CHALLENGES RELATED TO CRITICAL RAW MATERIALS

The strategic challenge of securing critical raw material supplies

The rare earths trade dispute between China and Japan came to a head in 2010-2011 (for rare earths list, see annex p.38), following China's territorial claims over the Senkaku Islands. The introduction of quotas by Beijing had a direct impact on their price: the transaction value of terbium, for example, increased nine-fold in the span of just a few months[3]. In March 2012, the United States, the European Union and Japan filed a complaint to the WTO following the imposition of export restrictions on rare-earth elements by the country that owns more than a third of accessible reserves and produces over 95% of the world's supply[4]. The dispute was settled two years later in favour of the complainants and prices fell again in 2012, but this event is symptomatic of the potential use of this quasi-monopolistic market as a diplomatic lever and an economic weapon.

China's tougher environmental stance has also had operational repercussions for western companies[5]: more than 30,000 businesses have been penalised by Beijing's efforts to prevent environmental violations. Inspections carried out between 2015 and 2017 led to the closure of several factories, which had a direct impact on large companies in many sectors (textile, automotive, heavy metals, gas and coal, consumer goods). These factories belonged to tier 1, 2 and 3 suppliers, some of which were very high up in the supply chain. The result was delays and major disruptions in the supply chain, and even production suspensions. The companies' reputation with their end customers was also damaged.

The automotive sector was the hardest hit. Thus, the closure of a factory belonging to a key supplier of Schaeffler Group - which itself manufactures bearings and mechanical components - affected the production of nearly 200 car models owned by over 49 automotive manufacturers. The economic cost was estimated at nearly $47 billion.

Likewise, in 2018, the Norwegian group Norsk Hydro[6] - one of the world's leading producers of aluminium and energy - was seriously affected by a production embargo at its alumina refinery in Alunorte (Brazil). In February 2018, extreme rainfall caused heavy flooding in this northern part of the country. As the refinery was located in the flooded area, the Brazilian authorities and local communities feared harmful spillages into the surrounding environment. Production was stopped to allow numerous inspections to take place, slashing the refinery's output by 50%. Although the reports concluded that the rivers close to the site had not been contaminated, the authorities imposed new measures regarding the bauxite residue disposal area in particular. Restrictions on the company's operations were tightened, as the mine is located in the Amazon rainforest.

Shutting down the supply of critical raw materials, whether for diplomatic, economic, environmental or societal reasons, can have a snowball effect on many industrial companies that rely on a sustainable supply of these raw materials. This is particularly true for rare metals, which are vital to the production of renewable energies (such as solar and wind power) and electric vehicles.

This potential instability is all the greater because the rare metals market is limited and is under the almost monopolistic influence of China.

Therefore, before even beginning to consider ethical issues, it is vital that companies have a thorough knowledge of even the most upstream parts of their supply chain: those that rely heavily on strategic raw materials - some of which are rare and highly concentrated in one particular area - must ensure that their supply chain is fully transparent.

Looking beyond the direct economic impact of a potential disruption in supply, it is important to assess the environmental and social conditions in which mining is carried out at the very top of the supply chain. The impact of companies that consume large quantities of metals cannot be assessed without first addressing the major controversies surrounding this extremely sensitive sector.

[3] https://www.lemonde.fr/economie/article/2014/03/26/terres-rares-l-omc-denonce-les-quotas-chinois_4390186_3234.html
[4] https://www.huffingtonpost.fr/2012/03/13/terre-rare-chine-_n_1342015.html
[5] Ecovadis, « The Environmental Crackdown in China : Supply Chains Impacts Continue »
[6] Hydro, "Fourth quarter 2018 – Investor Presentation", February 2019.

The environmental and social challenge of addressing the impacts of activities upstream in the value chain

The recent disaster in Brazil is emblematic of the risks involved in mining operations. A tailings dam owned by Brazilian mining company Vale collapsed in January 2019, killing 228 people (49 more are still missing). The torrent of mining waste also contaminated a river used by an indigenous community, which is now deprived of drinking water. The toxic mud is also likely to affect the Sao Francisco, one of the longest rivers in South America. The NGO Greenpeace has described the incident as yet another environmental crime; it follows the collapse of another tailings dam in 2015, which was under the joint ownership of Vale and Anglo-Australian company BHP Billiton[7]. Again, the human and environmental consequences were disastrous.
The Brazilian authorities have decided to impose a $66.5 million (€58 million) fine on mining giant Vale[8] (i.e. 0.2% of its turnover).

While this recent disaster involved an iron ore mining operation, the working conditions in rare metal mines - and their environmental impacts - are equally controversial: toxic waste release, groundwater pollution, poor worker protection, erosion and damage to soil fertility, deforestation, loss of biodiversity, contamination of water, soil, air and ecosystems by metals and chemicals, carcinogenic emissions, etc.

COMPANY ANALYSIS

- What critical raw material supply risks have been identified by the company?
- Has the company already experienced disruptions in the supply of critical raw materials?
- How are these supply risks managed? Who is in charge of monitoring them?

> "The Chinese showed no regard for environmental standards. Their sole aim was to meet global demand for rare-earth elements at the lowest possible cost. This 'race to the bottom' has caused colossal environmental disasters in mineral extraction and refining regions. One of the most serious forms of damage [found] in China are the "toxic lakes" around Baotou. There are several "cancer villages" where people are dying a slow death due to the high concentration of heavy metals in the soil".
>
> Source : Guillaume Pitron, « La guerre des métaux rares : La face cachée de la transition énergétique et numérique », Published in 2018 by *Les liens qui libèrent*.

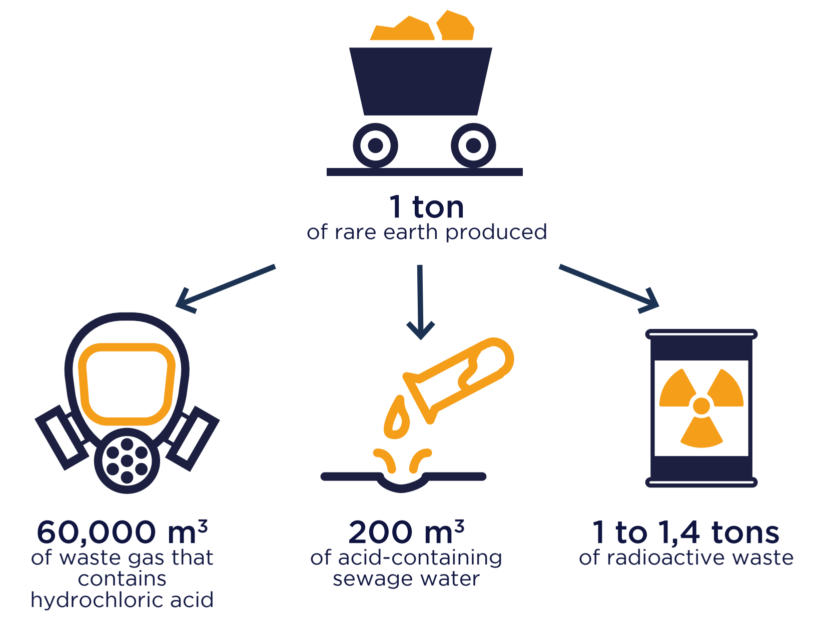
[7] https://www.lepoint.fr/economie/catastrophe-au-bresil-le-groupe-vale-sous-pression-29-01-2019-2289804_28.php
[8] https://www.europe1.fr/international/catastrophe-au-bresil-amende-de-665-millions-de-dollars-pour-vale-3845963

In most of the countries concerned, rare earth extraction and purification techniques are in fact highly polluting. They involve hydrometallurgical processes and acid baths that discharge heavy metals, sulphuric acid and radioactive elements.
In China, radioactivity measured in the villages of Inner Mongolia near the rare earth mine in Baotou, which is considered the "capital of rare earths", is 32 times the norm. Many cases of cancer are reported locally[9]: radioactive toxic waste and groundwater pollution have led to the development of "cancer villages" in the surrounding areas. This pollution has been condemned by many Chinese and international NGOs and environmental associations.
For example, China Water Risk, a Chinese NGO, is pointing fingers at rare earth mining operations close to the Yellow River, arguing that they are a health and environmental time bomb. Any contaminated water leak could threaten the safety of water that several million Chinese people consider drinkable [10].

Tailings disposal sites also have a disastrous effect on biodiversity, destroying the surrounding soil and vegetation. However, some rare earth extraction and production methods comply more closely with environmental and health standards.

In their 2016 report[11], Amnesty International and African Resources Watch condemned the conditions in which artisanal miners extract cobalt in the Democratic Republic of Congo (DRC). There are an estimated 110,000 to 150,000 artisanal miners in the DRC, including a large number of children; they reportedly account for around 15% of the country's current cobalt production (80,800 tonnes produced in 2017).

RARE EARTH PRODUCTION COMES WITH TOXIC WASTE



Source : China Water Risk Report, « Rare Earth : Shades of Grey », June 2016

[9] https://www.renouvelle.be/fr/debats/lenergie-durable-se-developpera-sans-terres-rares
[10] China Water Risk Report, « Rare Earth : Shades of Grey », June 2016.
[11] Amnesty International, Afrewatch, "This is what We Die Fir: Human Rights abuses in the Democratic Republic of the Congo power the global trade in cobalt", January 2016.

In November 2017, a new study by the NGO revealed that the 26 companies investigated have failed to implement due diligence measures to establish the origin of the cobalt they use and clarify the conditions in which it is extracted and sold[12].

Finally, in early 2019, the UN Committee for the Elimination of Racial Discrimination asked the French government to consult Amerindians about a mining project in French Guinea: "the Montagne d'Or[13]". France is suspected of not having adequately consulted indigenous communities in advance, and must therefore inform the United Nations of the measures put in place to "ensure the right to consultation and free, prior and informed consent to all indigenous peoples affected by the project"[14]. In the meantime, the UN believes that France should consider suspending the project. In May, the French President concluded that the project was incompatible with environment protection requirements. He commissioned the Ecological Defence Council to carry out a full study of the project, and it is due to decide on the project's feasibility in June 2019.

Companies are therefore responsible for assessing the social and environmental impacts resulting from the production of the materials they consume; hence the importance of conducting ESG (Environmental, Social and Governance) audits and assessments of suppliers. This extension of responsibility to the upstream end of the supply chain is all the more necessary because the regulatory landscape has changed significantly in this area.

> "Using basic hand tools, miners dig out rocks from tunnels deep underground, and accidents are common. Despite the potentially fatal health effects of prolonged exposure to cobalt, adult and child miners work without even the most basic protective equipment."
>
> Source : Amnesty International

COMPANY ANALYSIS

- Are ESG criteria taken into account when selecting suppliers and drawing up contracts?
- How does the company manage its high-risk suppliers?

[12] Amnesty International, "Time to Recharge: Corporate Action and Inaction to tackle abuses in the cobalt supply chain", novembre 2017.
[13] https://www.lesechos.fr/finance-marches/marches-financiers/mine-de-montagne-dor-lonu-epingle-la-france-373060
[14] https://tbinternet.ohchr.org/Treaties/CERD/Shared%20Documents/FRA/INT_CERD_ALE_FRA_8820_E.pdf

The regulatory challenge of applying new national standards

New regulations have increased the responsibility of companies upstream of their direct operations, along their whole supply chain. Whether through the Dodd-Frank Act in the United States, the Modern Slavery Act in the United Kingdom or the recent Duty of Vigilance Act in France, companies are now required to have a greater understanding of the impact of their suppliers on human rights.

The Dodd-Frank Act, which came into force in the United States in 2012, includes conflict minerals in its chapter on consumer protection and the management of risks associated with the funding of terrorism and wars. It applies to all American or foreign companies listed on the U.S. Stock Exchange. In addition to complying with import restrictions on minerals originating in conflict zones such as the Democratic Republic of Congo, companies must ensure full traceability along their entire supply chain. There are four conflict metals: gold, tin, tungsten and tantalum. Listed companies are required to file a traceability report with the SEC (Securities and Exchange Commission) to ensure their transparency regarding the use of these metals in their technologies.

Promulgated in the UK in 2015, the Modern Slavery Act applies to any company or supplier of goods or services that conducts all or part of its operations in the UK and has a turnover of £36 million or more.

Under section 54 on transparency in supply chains, companies must publish an annual statement on their website presenting the measures they have taken internally to prevent slavery and human trafficking: description of the supply chain, due diligence policy, staff training, risk management, performance indicators, etc.

The goal is to:

- identify and analyse the risks of human trafficking and slavery in the supply chain;
- create and maintain internal accountability standards and procedures;
- perform supplier audits;
- require direct suppliers to certify that the materials in the product comply with relevant local laws;
- provide employees and managers who are directly responsible for supply chain management with training about human trafficking and slavery.

THE OECD FRAMEWORK OF DUE DILIGENCE GUIDANCE IN 5 STEPS

The law on the duty of vigilance is based in particular on the guiding principles and the guidelines of the OECD. The five steps as presented in the OECD's guide on due diligence for responsible supply chains of minerals coming from conflict-affected or high risk areas are the following:

France's The French Law on the duty of vigilance, which was adopted in March 2017, introduced an obligation for contracting companies[15] to better control environmental and social risks within their subcontracting chain. This followed several scandals, such as the collapse of the Rana Plaza building in Bangladesh and incidences of forced labour on World Cup construction sites in Qatar.
Companies that fall within the ambit of the law must draw up a reasonable vigilance plan to "identify and prevent severe impacts on human rights and fundamental freedoms, the health and safety of persons, and the environment"[16], not only within their own operations but also those of their subsidiaries, subcontractors and suppliers.
The plan must include the following elements:
- risk mapping to identify, analyse elements and prioritise risks;
- procedures for regularly assessing the situation of subsidiaries, subcontractors and suppliers, with which the company has an established commercial relationship;
- tailored actions to mitigate risks or prevent severe breaches;
- an alert mechanism on the existence or materialisation of risks, established in collaboration with trade union representatives in the said company;
- a system for monitoring the measures implemented and assessing their effectiveness.
Thus, the concept of extending a company's responsibility to its supply chain is gradually taking hold at both the operational and reputational levels, and is being incorporated into strategic policies and internal regulatory compliance systems.

COMPANY ANALYSIS

- How does the company meet the regulatory requirements for extended responsibility?

[15] Law no. 2017-399 of 27 March 2017: affects companies established in France who employ at least 5,000 employees in France or 10,000 employees in the world
[16] Ministry of the Economy and Finance

THE CHARACTERISTICS OF RARE METALS: APPLICATION TO THE ENERGY SECTOR

Characteristics of rare metals

Rare metals have specific economic characteristics[17], which are different to those of precious metals (such as gold or silver) or base metals (such as copper, aluminium or zinc). Imported from a small number of countries, they are mined in small quantities and are difficult to replace in their specific applications. Due to their low concentration in alloys, they are impossible or difficult to recycle.

Furthermore, they are not traded on futures markets[18] and are therefore not protected from possible price fluctuations. Hence, there is a higher risk of supply disruption with rare metals.

This risk is all the greater because of the considerable inertia in opening new mines, which require 10 to 15 years of development before becoming fully operational.

CLASSIFICATION OF METALS

	Weight (in value and/or quantity)	Geological characteristics	Economic characteristics	Recyclability
Base metals Examples: Copper, Aluminium, Zinc	-72 % of the total value - 98 % of the tonnage	High concentration (extraction in large quantities)	- Relatively low prices - Procyclical - Stable growth	High recycling
Precious metals Examples: Gold, Silver	23 % of the total value	Moderate concentration	- High use and exchange value - Speculative (safe investment) - Counter-cyclical	High recycling
Rare metals	Low and volatile productions, monopolised by a small number of countries	Very low concentration	- Markets unstable (variation exceeding 20%) and not very organised - High use value in some sectors (high tech)	Low recycling (alloys, dispersive uses)

Source : Meeschaert AM

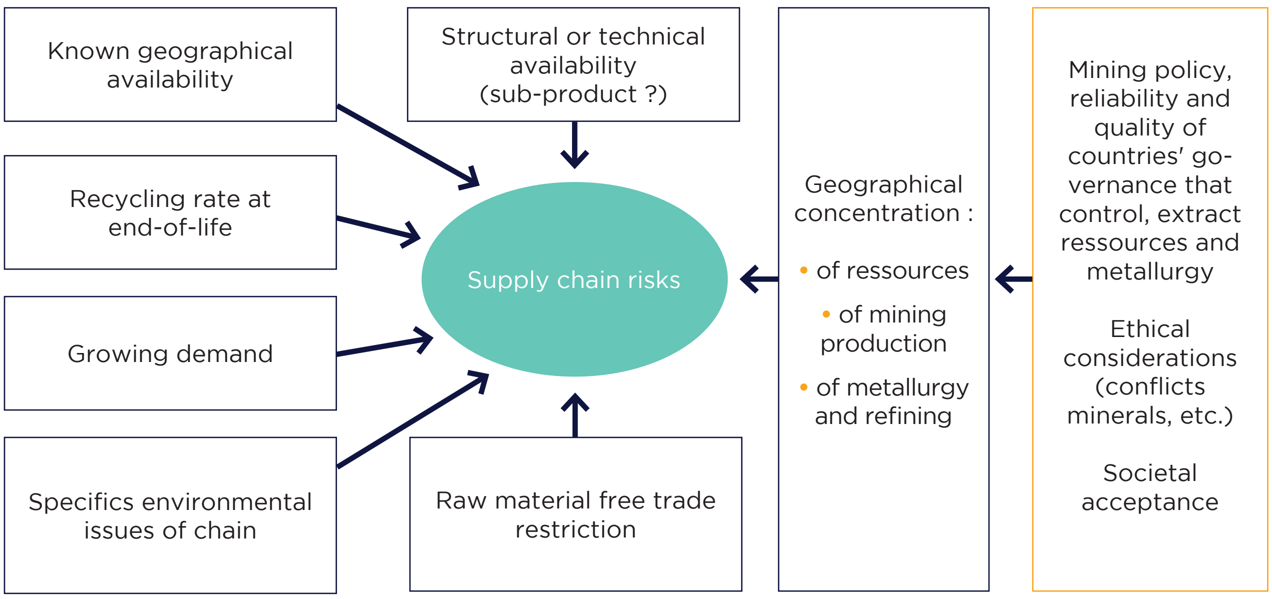
[17] Florian Fizaine, « Les métaux rares, opportunité ou menace ? », Editions Technip, 2015
[18] Molybdenum is the only rare metal listed on the London Metal Exchange (LME)

• Production in small quantities as a "by-product" or "co-product"

Due to the way they are extracted, rare metals are regarded as by-products or co-products. In fact, because of their low geological concentration and their current recovery rate, they cannot be mined separately. Hence, they are extracted alongside other metals.
There are two possible scenarios:
- Joint extraction is necessary to ensure the profitability of the operation. In this case, the rare metal is considered a co-product and is an integral part of the mining operation's business model.
Examples of co-products include rare-earth elements, cobalt (combined with copper or nickel) and lithium (combined with potassium chloride).
- The rare metal is extracted at the same time as another metal, which is already profitably mined on its own. In this case, it is a by-product, i.e. the "residue from the manufacture of the primary product"[19].
It provides additional added value to the project, but is not essential to its economic viability. Examples of by-products include indium (extracted with zinc), tellurium (extracted with copper) and gallium (extracted with aluminium).
The production of by-products is driven exclusively by the demand for the base metal. If demand for the by-product and the primary product evolves differently, the quantity of by-product extracted is no longer in line with needs.
This imbalance between supply and demand can result in the by-product being rationed, and therefore further supply problems.

RISKS FACTORS ALONG THE SUPPLY CHAIN

Below are the criteria that have been established to evaluate the level of criticality of each metal.



Source : BRGM (Bureau des Recherches Géologiques et Minières), Meeschaert AM

[19] Florian Fizaine, « Les métaux rares, opportunité ou menace ? », Editions Technip, 2015.

• **"Critical" raw materials**

The availability of rare metals is therefore a crucial issue, although few indicators exist to assess the risk of depletion (level of reserves, changes in production costs, etc.).

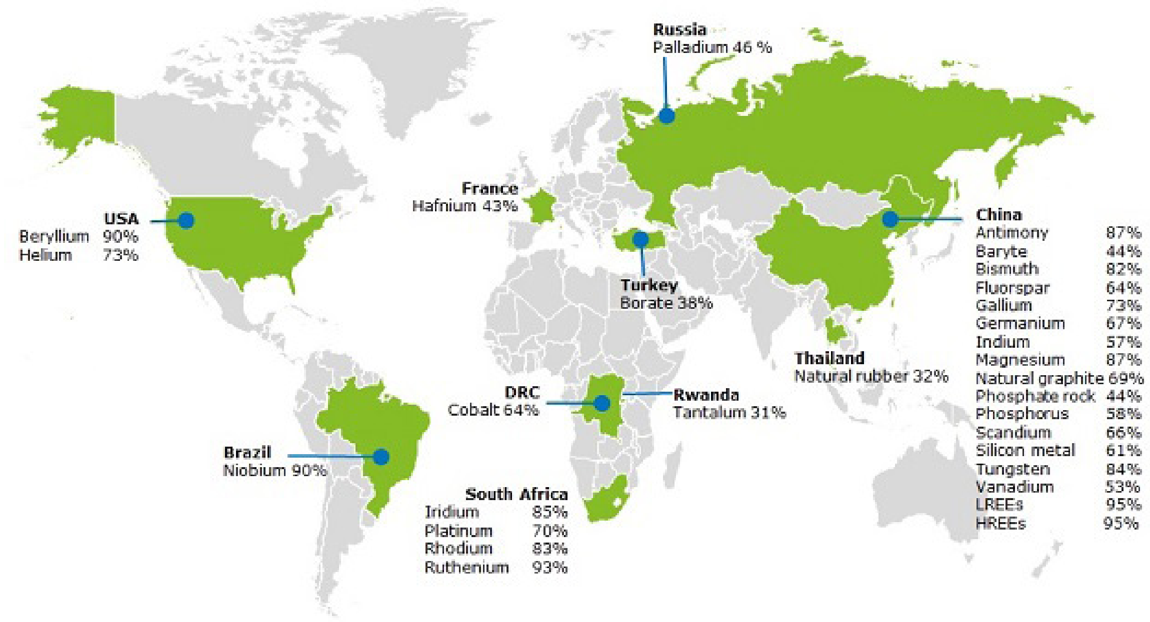
On the other hand, the high geographical concentration of this oligopolistic market, combined with the geopolitical risks inherent to the main producer countries, has prompted many countries to draw up a list of "critical metals".
The "criticality" level is based on various factors, as shown in the graph on page 13 (example of the method used in France)[20]:

The European Union has identified twenty-seven raw materials as "critical"[21], as the risk of shortage is high and they play a very important role in the current economy. They include:
- Rare-earth elements (see appendix p. 38), magnesium, tungsten, antimony, gallium and germanium (mainly produced in China)
- Platinoids (the extraction of which is concentrated in Russia and South Africa)
- Cobalt (the Democratic Republic of Congo accounts for 64% of worldwide production)

COMPANY ANALYSIS

• Does the company establish a list of the "critical" raw materials it uses?
• Is there a map showing the geographic location of its supply points?

MAIN PROVIDERS OF CRITICAL RAW MATERIALS IN THE WORLD



Source : European Commission (2017)

[20] Rémi Galin, « Panorama des métaux stratégiques en Europe et en France », Bureau de la politique des ressources minérales, June 2018
[21] https://eur-lex.europa.eu/legal-content/FR/TXT/PDF/?uri=CELEX:52017DC0490&from=EN

Energy-related opportunities and risks

> "There is one major difference between rare metals and traditional metals like iron, silver and aluminium: they are not used in their pure state in green technologies. Manufacturers involved in the energy and digital transition are increasingly keen to use alloys in their products. By mixing several metals together, they can create "composite" materials with many more properties than "simple" metals. [...] Translucent concrete, paper bricks, insulating gels, reinforced wood, etc. We are now flooded with new materials that completely change the properties of matter. These alloys are so promising that green technologies will become increasingly reliant on them in the future".
>
> Source : Florian Fizaine, « Les métaux rares, opportunité ou menace ? », published by Technip in 2015

• The role of rare metals in our energy system

Rare metals are playing a key role in the ongoing digital and energy revolution. Not only are they used to develop new technologies, but also to improve the performance of existing technologies throughout their value chain, from energy production to consumption. Like "vitamins"[22] that boost the body's strength and performance, rare metals have thermal, mechanical and anti-corrosive properties that maximise the capabilities of the other materials used.

Improvement of existing technologies in fossil fuel production

Upstream: to decarbonise and reduce the environmental footprint of fossil fuels: improvement of physical and mechanical properties during drilling (tungsten, beryllium), catalysis (cobalt), refining (germanium), desulfurization, cracking (lanthanum, cerium, dysprosium, neodymium, molybdenum) and distillation (tantalum). The use of rare metals improves the energy efficiency of gas- and coal-fired power plants at each of these stages.

Downstream: energy storage, transportation and distribution. Gas and oil transportation is optimised through the use of molybdenum, niobium and vanadium. The development of smart grids[23] requires beryllium for microwave telecommunication and germanium for optical fibre cables. The same applies to energy storage.

Development of new technologies for renewable energy production, sustainable transport or enhanced energy efficiency

Upstream: as part of the development of alternative energies.
These include solar energy (indium and gallium in some CdTe solar panels) and wind energy (neodymium in direct-drive turbine technologies).
Downstream: energy end-uses consume a lot of rare metals.
Batteries in electric or hybrid vehicles are often cited as an example, including lithium-ion batteries (which use cobalt and 4 to 12 kg of lithium per vehicle) and NiMH (Nickel Metal Hybrid) batteries, the anodes of which contain a mixture of rare earths called mischmetal. The same applies to hydrogen vehicles and catalytic converters on traditional vehicles, which use large quantities of platinoids (platinum, rhodium and palladium).
Last example: compact fluorescent lamps and LEDs are also made of rare metals. LEDs use gallium and arsenic, which are virtually impossible to replace.

The growing use of rare metals is therefore a real asset when it comes to the energy transition and reducing CO2 emissions. The entire energy production chain benefits, as energy consumption rates are reduced at every stage.
However, it is important to consider the strong interdependence between the metals and energy sectors. Indeed, 10% of the primary energy produced worldwide is used by the metals sector. Conversely, a substantial share of metal production (for example, 5 to 10% of global steel production) is absorbed by the energy sector[24]. Looking ahead, the weight of the metals sector in energy consumption is expected to increase further by 2030 (by an estimated 40%).
Furthermore, the impact of resource depletion on energy consumption levels should not be overlooked. Indeed, the poorer the quality of the minerals, the more the per-unit energy consumption of the final product increases.

[22] Florian Fizaine, « Les métaux rares, opportunité ou menace ? », Editions Technip, 2015.
[23] Smart Grids: «Optimisation of the management of the energy thanks to amplified knowledge of the available information on the supply and demand but also on the means of storage»
[24] Florian Fizaine, « Les métaux rares, opportunité ou menace ? », Editions Technip, 2015.

• A broader view of the energy impact of rare metals

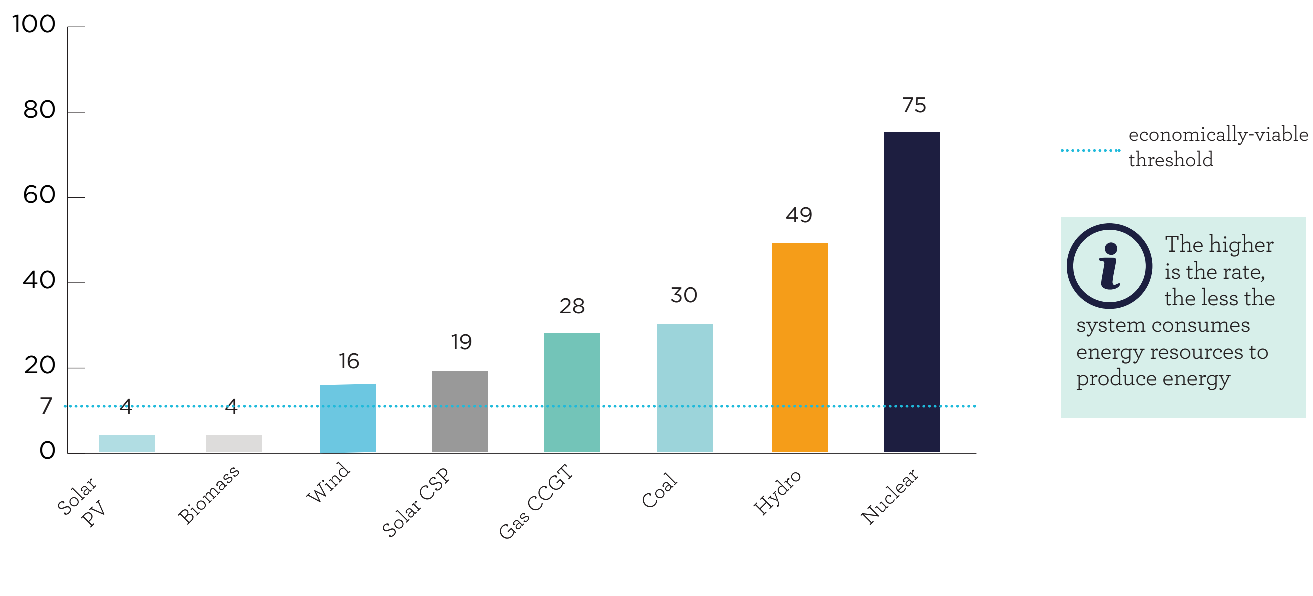
To ensure sustainable and responsible investment (SRI), the added value of these technological developments in energy terms must be analysed in a more holistic manner to clarify both the opportunities and risks they entail.

With this in mind, different approaches may offer an additional perspective on the significance of these technologies in energy terms. For example, the energy return on investment (EROI) rate is useful in that it can be used to compare a system's energy production with its energy consumption. This holistic approach is consistent with a broader view of corporate responsibility: energy consumption and CO_2 emissions at the upstream end of the manufacturing chain must also be taken into consideration.

> "Japan is developing technologies for recovering rare metals from electronic waste and re-using them in new devices. These are known as circular economy processes: the ores remain in a consumption loop where, instead of being discarded, they are re-used.
>
> However, these processes are not fully implemented. Unlike metals such as aluminium, copper, gold and silver, few rare metals are recycled. The latter are more difficult to recycle because they are never used in their pure state. They are always alloyed with other metals, such as iron. So, before they can be recycled, they have to be "de-alloyed" or separated. However, the process used to separate rare metals and re-use them is extremely complex and energy-intensive, and therefore very expensive".
>
> Source : Guillaume Pitron[25]

Other important aspects include the possibility of recycling. As part of a reverse supply chain approach, recovery, processing and recycling processes offer a new lever for value creation. In a circular economy, it is estimated that the energy impact per tonne of metal

ENERGY RETURN ON INVESTMENT (EROI)



Source : James Conca, « EROI : A tool to predict best energy mix », Forbes, 2015

[25] https://legrandcontinent.eu/fr/2018/01/13/lempire-des-metaux-rares/

could be reduced by 65 to 95%[26]. Some recycling best practices are starting to emerge, although they are still technically complicated and not very profitable.

Recycling also severs the link between the production of the primary product and that of the associated by-product. Companies therefore have two possible supply sources: mining and recycled rare metals.

COMPANY ANALYSIS

- What industrial partnerships have been built to promote metal recycling?
- What best practices exist in terms of the reverse supply chain approach?
- What is the energy return on investment (EROI) of photovoltaic and wind power systems developed by companies?

[26] Florian Fizaine, « Les métaux rares, opportunité ou menace ? », Editions Technip, 2015.

Supply and demand dynamics

The outlook for supply growth is difficult to project. It depends first of all on the rate at which rare metals are recovered as by-products. As they are not always recovered when the associated primary product is mined, mostly due to the additional fixed costs, there is room to increase the supply.

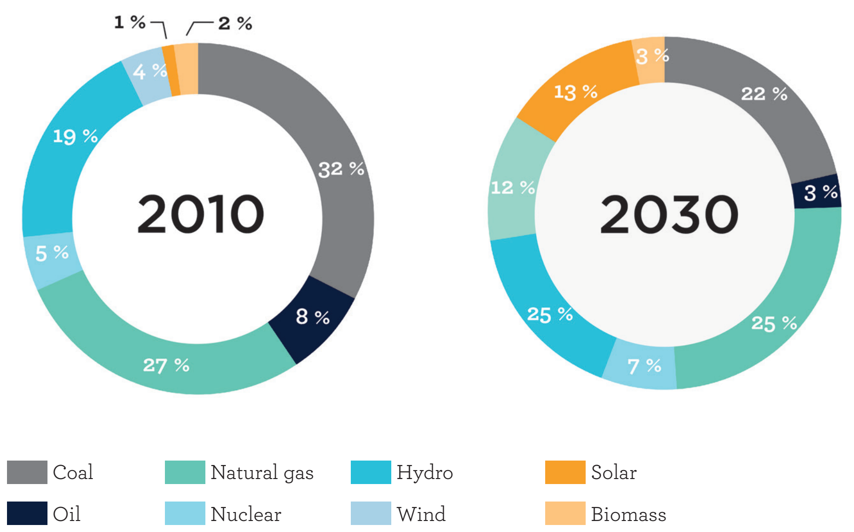
The recovery rate depends on the technological choices made by mining companies. For example, only 10% of the gallium in bauxite is recovered, due to a lack of equipment in aluminium smelters. Likewise, outside of China, only 26% of the indium in zinc is recovered.
Supply trends are also determined by political choices. In 2018 for example, the total primary production of rare-earth elements increased by 20.8%, following China's decision to increase its domestic extraction and production quotas for the first time in five years.

Meanwhile, production in Myanmar and the United States increased significantly over the same period. However, the sharp drop in illegal production in China (-50%) resulted in net imports of seven rare-earth elements into Chinese markets in 2018, including dysprosium, terbium and gadolinium. So, if imports from Myanmar are banned in 2019 and Chinese production is not increased to compensate, there could be a shortage in the supply of these three rare-earth elements and of high-performance magnets[27].

Demand dynamics are closely tied to structural changes in energy consumption. If the objectives defined in the COP 21 Paris Agreement are met, including the 2°C scenario on global warming, the International Energy Agency[28] predicts that the global energy mix will change according to the diagram below.

The decarbonisation of the energy mix is therefore heavily reliant on the development of wind and solar energy. Wind and solar investment in 2017 reflects this trend: $268 billion, up 3% from 2016[29].

EVOLUTION OF THE ELECTRIC MIX ACCORDING TO THE 2 DEGREE SCENARIO



Source : Enerdata

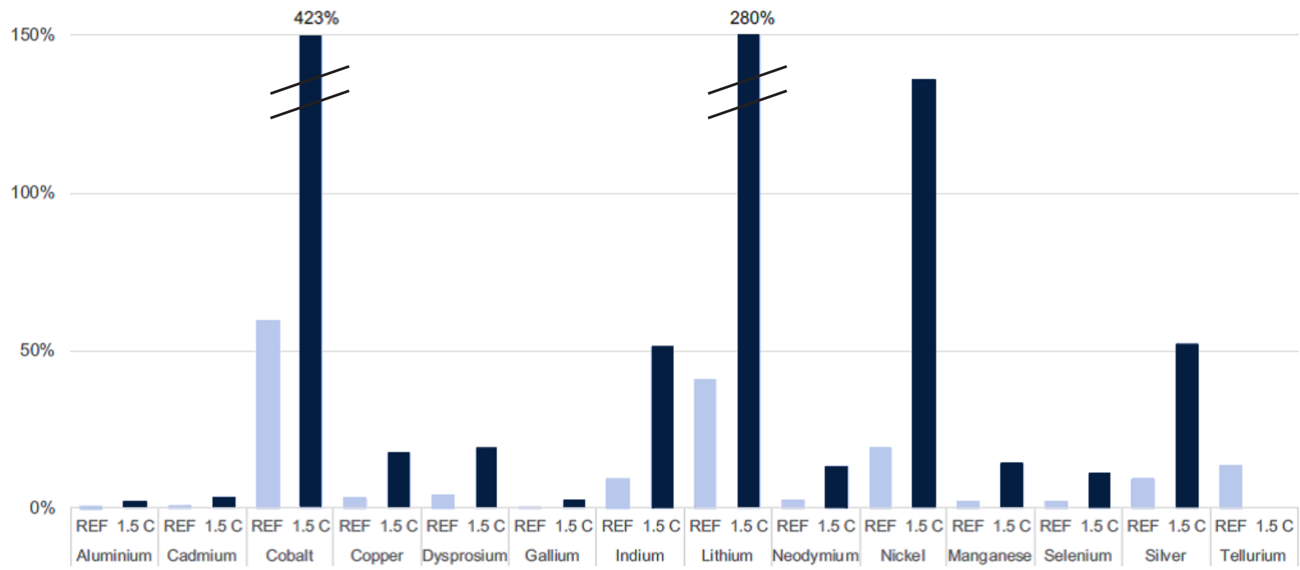
[27] Adamas Intelligence, "Rare Earth Recap 2018 : Global Production, Trade and Prices », 2019
[28] « Energy Technology Perspectives », IEA, 2017
[29] Clean Energy Investment Trends 2017, Bloomberg (2018)

This could create a new reliance on certain resources, thus raising concerns about demand for strategic metals.
It is therefore vital to gain a greater, forward-looking and dynamic understanding of the raw materials needed to develop renewable energies, particularly strategic metals.

COMPANY ANALYSIS

- What technological innovations have been developed with a view to replacing rare metals?

CUMULATIVE TOTAL DEMAND FROM RENEWABLE ENERGY AND STORAGE BY 2050 COMPARED TO RESERVES IN THE 1.5 DEGREE SCENARIO



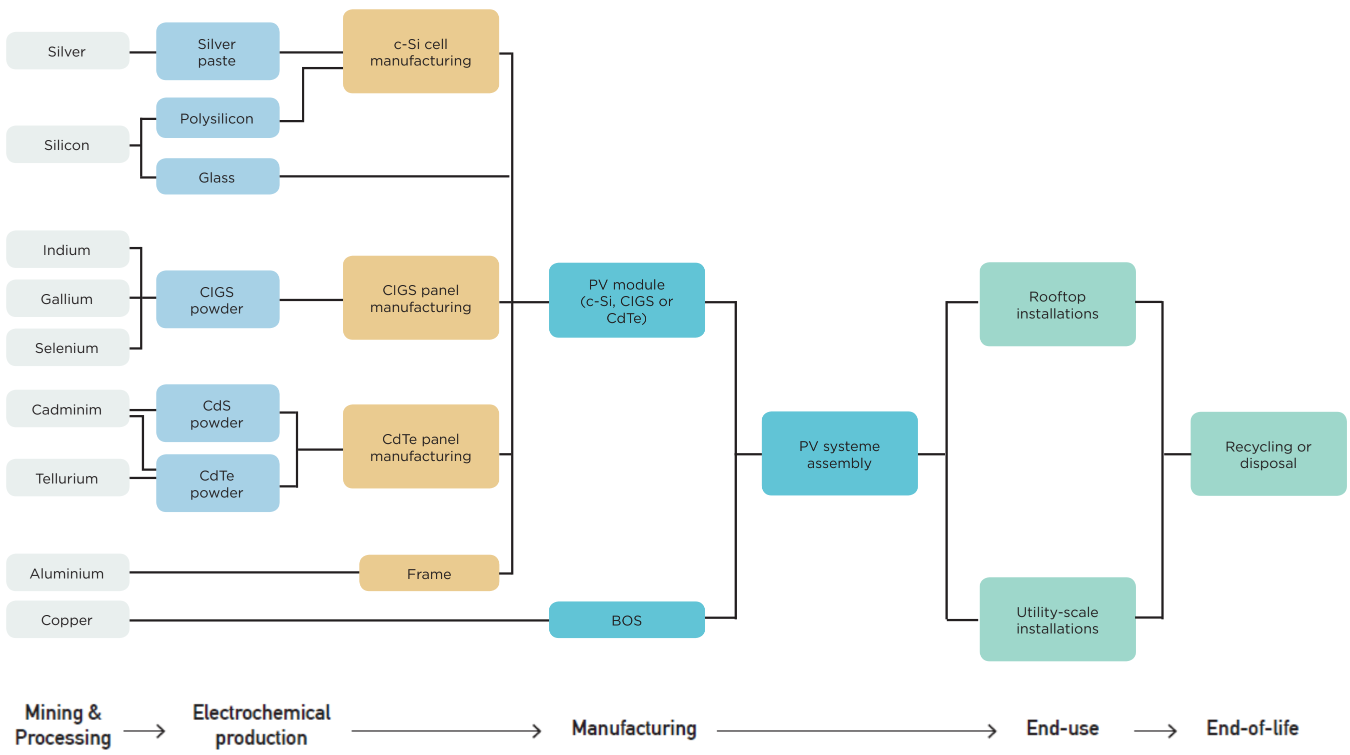
Source : Dominish E, Florin N, Teske S, "Responsible Minerals Sourcing for Renewable Energy", Earthworks, Institute for Sustainable Futures, University of Technology, Sydney, 2019.

Main sectors of study: solar panels

Rare metals are used by manufacturers involved in the energy transition. They are used in the permanent magnets found in offshore wind turbines, some solar panel technologies, the rechargeable batteries in electric vehicles and other connected objects, automotive catalysis and other petroleum catalysis processes.

> "If we take a broader look at today's renewable and carbon-free energies, we immediately realise that none of them are genuinely renewable because they are still based on exhaustible raw materials."
>
> Source : Florian Fizaine [30]

OVERVIEW OF SOLAR PANNELS SUPPLY CHAIN



Source : Dominish E, Florin N, Teske S, "Responsible Minerals Sourcing for Renewable Energy", Earthworks, Institute for Sustainable Futures, University of Technology, Sydney, 2019

[30] Florian Fizaine, « Les métaux rares, opportunité ou menace ? », Editions Technip, 2015.

- **The main existing technologies**

- Crystalline silicon
Today, more than 85% of solar panels on the market[31] are made out of silicon, a semi-conductive material resulting from silica processing. They contain crystalline silicon, aluminium, copper and/or silver and, in some cases, plastic. More specifically, there are two types of silicon panel :
- monocrystalline panels, whose cells consist of a single silicon crystal.
- polycrystalline panels, whose cells consist of many silicon crystals.
Thus, the vast majority of solar panels do not contain rare-earth elements.

- Thin-film solar panels
Thin-film solar panels account for nearly 15% of the market. They consist of a very thin-film of one or more semi-conductive materials (measuring just a few thousandths of a millimetre thick), deposited on an amorphous substrate (glass, steel or plastic). They mainly include:
- CdTe solar panels made of tellurium and cadmium. (world leader: First Solar)
- CIS solar panels that use a copper, indium and selenium alloy, to which gallium is sometimes added (CIGS).
- Finally, the amorphous silicon solar panels, in which the thin-film is made of non-crystalline silicon.

The average lifespan of a panel is approximately 20 years.

SUMMARY OF PHOTOVOLTAIC TECHNOLOGIES

Technology	Benefits	Weaknesses	Market share
Polycrystalline silicon	- Lifespan (approximately 30 years) - High energy efficiency (12 to 20 %)	- High manufacturing costs	Approximately 25 %
Polycrystalline silicon	- Lifespan (approximately 30 years) - Good energy efficiency (11 to 15 %) - Technology offering the best value for money - can be installed on all types of roof		Approximately 55 %
Amorphous silicon	- More suited to regions with a low sunshine - Flexible material that allows curved structures	- Low energy efficiency with high sunshine (5 to 9 %) - Short lifespan (approximately 10 years)	Nearly 10 %
CdTe (cadmium telluride)	- Low cost of production - Low quantities of cadmium telluride required to absorb a large amount of light Cadmium and tellurium 71 % recycled	- Scarcity of tellurium - Toxicity of cadmium: risks to health and the environment	Nearly 10 %
CIGS (copper, indium gallium and selenium)	- The materials used are not toxic - High resistance	- Contains rare metals: indium, which is used in the manufacture of flat screens	
CIS (copper, indium selenium)	- Energy efficiency the highest observed for thin-layer technologies (9 to 11 %)	- Contains rare metals: indium, which is used in the manufacture of flat screens. - Nil recycling rate of gallium, indium and selenium (despite a recycling potential increased to 81 %)	

Source : Meeschaert AM

[31] Ademe, Janvier 2019 « L'électricité solaire, mener à bien un projet photovoltaïque pour votre maison »

THE METALS USED IN THE DIFFERENT TECHNOLOGIES

	Crystalline silicon	Amorphous silicon	CIGS	CdTe
Aluminium	■			
Cadmium *				■
Copper			■	
Gallium *			■	
Indium *			■	
Iron	■			
Lead	■			
Nickel	■			
Silver	■			
Zinc		■		■
Selenium *			■	
Tellurium *				■

* Rare metals
Source : World Bank, "The Growing Role of Minerals and Metals for a Low Carbon Future », June 2017.

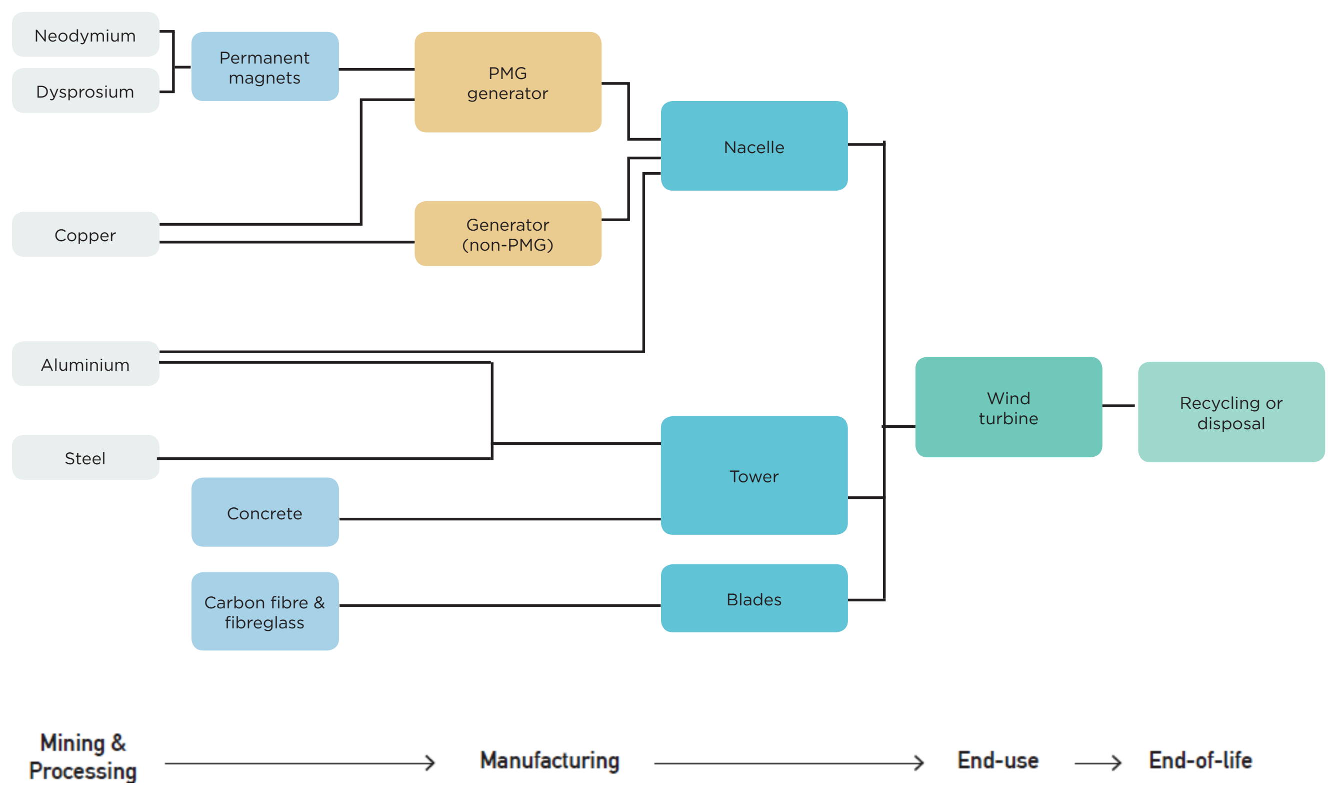
• Outlook

Although silicon-based technologies are currently largely in the majority, some studies have suggested that thin-film panels should become more widespread in the coming years, securing a 45% market share by 2025. This will depend on the relative production costs of the different technologies. Supposing a technological lock-in developed, in which a single type of thin-film solar panel dominated the market. CdTe technology would require 6 to 11 kilotons of tellurium per year (i.e. 12 to 24 times more than current total consumption), while CIGS technology would require 1.8 to 2.5 kilotons of indium per year[32]. It is also important to monitor technological developments in the use of rare metals, for example the reduction in the thickness of solar panels and the increase in energy efficiency.

[32] Florian Fizaine, « Les métaux rares, opportunité ou menace ? », Editions Technip, 2015.

Main sectors of study: wind turbines

OVERVIEW OF WIND POWER SUPPLY CHAIN



Source : Dominish E, Florin N, Teske S, "Responsible Minerals Sourcing for Renewable Energy", Earthworks, Institute for Sustainable Futures, University of Technology, Sydney, 2019

• The main existing technologies

- Geared turbines ("onshore"): wind turbines incorporating a generator, the manufacture of which requires a large quantity of copper. On the other hand, very few rare metals are used.

This technology is used in onshore wind farms, where wind speeds are lower and access is relatively easy.

- Direct drive ("offshore"): wind turbines incorporating a permanent magnet generator, the manufacture of which requires rare-earth elements such as neodymium and sometimes dysprosium. This technology is mainly used in offshore wind farms, where wind speeds are higher and access is difficult. Rare-earth elements can account for up to one third of the weight of the permanent magnets.

UP TO ONE TONNE OF RARE-EARTH ELEMENTS IN A WIND TURBINE

Up to 600 kg of magnets - consisting of one third rare earths - are needed to generate 1 MW of power. Therefore, an offshore wind turbine, which has a power output of up to 7 MW, contains one tonne of rare-earth elements.
Source : BRGM

THE METALS USED IN THE DIFFERENT TECHNOLOGIES

	Geared turbines	Direct-drive turbines
Aluminium	■	■
Chrome	■	■
Copper	■	■
iron	■	■
Lead		■
Manganese *	■	■
Neodymium *		■
Nickel	■	■
Steel	■	■
Zinc	■	■

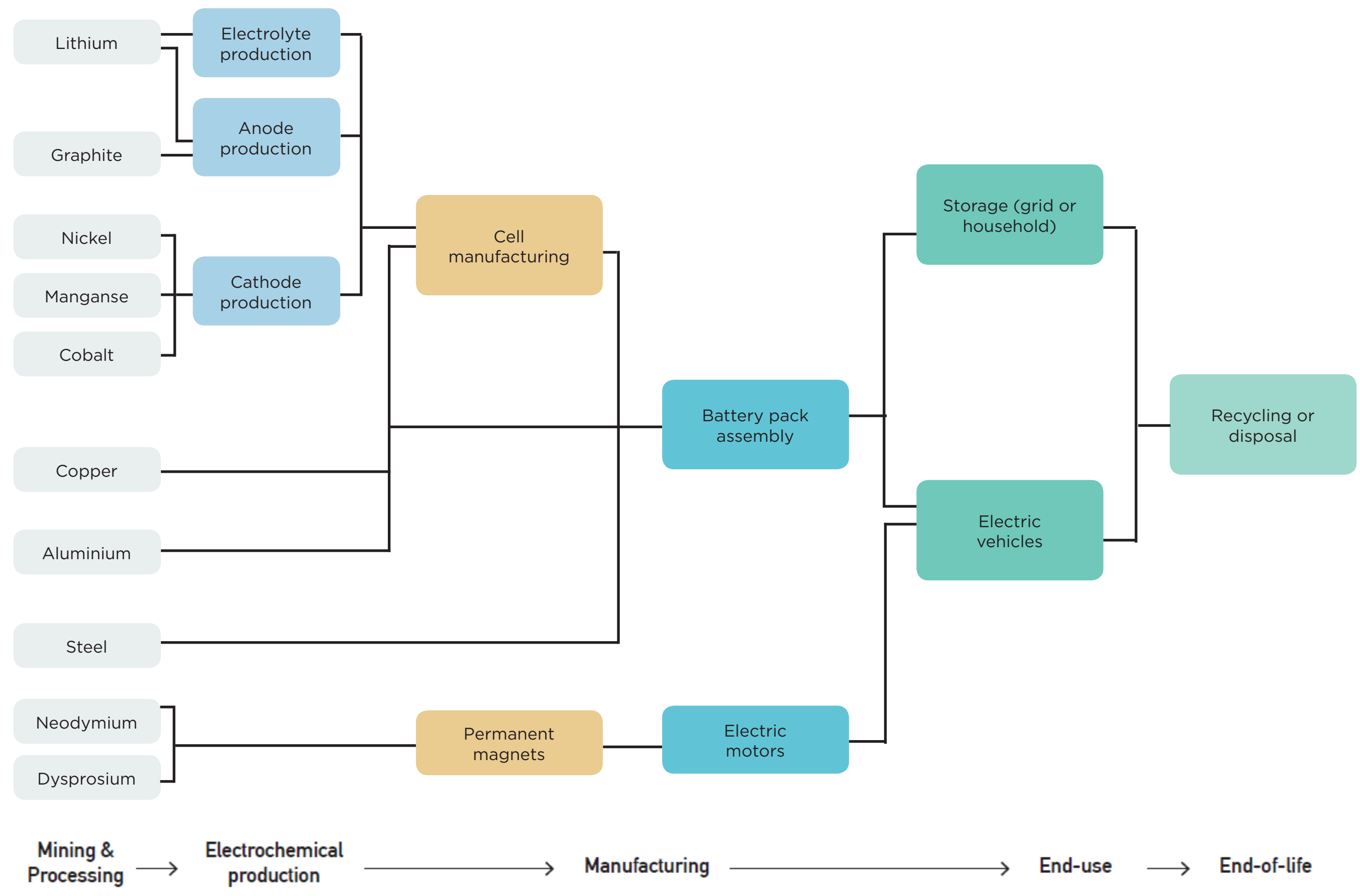
* Rare metals
Source : World Bank, "The Growing Role of Minerals and Metals for a Low Carbon Future », June 2017.

• Outlook: estimated trend in neodymium demand in the wind sector

Estimates vary according to the technological choices made and the extent to which the Paris Agreement targets are met. Assuming that direct-drive turbines continue to make up 75% of the offshore wind market and that the onshore market also moves towards this technology (which currently accounts for just 10% of the market), the cumulative demand for neodymium for the overall production of wind turbines is expected to exceed 50,000 tonnes. Bearing in mind the two-degree target, demand could even climb to 400,000 tonnes. These levels of potential consumption should be considered in the light of the current total production of neodymium, which amounts to 7,000 tonnes per year.[33]

[33] World Bank, "The Growing Role of Minerals and Metals for a Low Carbon Future », June 2017.

OVERVIEW OF LITHIUM-ION BATTERY SUPPLY CHAIN



Source : Dominish E, Florin N, Teske S, "Responsible Minerals Sourcing for Renewable Energy", Earthworks, Institute for Sustainable Futures, University of Technology, Sydney, 2019

• The main existing technologies

Electric batteries are assessed on the basis of discharge time, battery life, recharge capacity and thermal stability. They are powered by a flow of electrons from the cathode to the anode (made of graphite).

The most mature technology is lead batteries (which contain cadmium, antimony or tin). They are regarded as good value for money, but they are heavy, not very mobile and highly polluting.

NiMH (Nickel Metal Hybrid) batteries, which use metal hydride and nickel, are very stable. However, their lifespan is shortened by repeated recharging.

The lithium-ion battery technologies presented below are named after the materials that go into the cathode. The latter accounts for 90% of the battery's cost and 25% of its weight[34].

The first generation of lithium-ion batteries is based on technologies developed in the 1990s, which offer poor performance and stability/safety:

- The LCO (Lithium – Cobalt – Oxide) battery: poor performance and stability/safety;
- The LMO (Lithium – Manganese – Oxide) battery: the cobalt is replaced with manganese. The use of manganese instead of cobalt lowers the cost, but this is offset by the battery's low specific energy and the fact that it ages prematurely at high temperatures;

[34] Gratz, E., Sa, Q., Apelian, D. and Wang, Y., 2014. A closed loop process for recycling spent lithium ion batteries. Journal of Power Sources.

- The LNO (Lithium – Nickel – Oxide) battery: average performance and poor stability/safety. This technology is being developed to improve performance (eLNO);
- the LMP (Lithium - Metal - Polymer) battery is marketed by the Bollore group and used in car-sharing;
- The LTO (Lithium – Titanium – Oxide) battery: relatively low performance, but high level of stability/safety;
- The LFP (Lithium - Iron - Phosphate) battery: mainly used in China;
- The NMC (Lithium – Nickel – Manganese – Cobalt) battery: still the most common technology, used in several types of battery.

Since the mid-2010s, technological developments have consisted in improving NMC technology by varying the proportions of nickel and manganese in the cathode. Today, NMC batteries are the most commonly used in electric vehicles, along with NCA (Lithium - Nickel – Cobalt – Aluminium) batteries, which are mainly used by Tesla.

THE METALS USED IN THE DIFFERENT TECHNOLOGIES

Critical metals can be found in various electric vehicle components:
- batteries containing cobalt and lithium,
- engines containing neodymium, dysprosium and praseodymium,
- power semiconductors: the proportion of these in electric vehicles is increasing, thus pushing vehicle performance up (GaN technology, which uses gallium),
- fuel cells in fuel-cell vehicles (platinum).

	Lead batteries	Lithium-ion batteries
Aluminium		X
Cobalt *		X
Lead	X	
Lithium *		X
Manganese *		X
Nickel		X
Steel	X	X

* Rare metals
Source : World Bank, "The Growing Role of Minerals and Metals for a Low Carbon Future », June 2017.

• Outlook

In new generations of NMC batteries, the focus is on reducing the amount of cobalt and replacing it with nickel, which is a less expensive metal. More cost-effective materials are also being trialled in batteries that are still in development and not yet on the market, and the goal is to increase their capacity and safety.
Lithium-sulphur batteries are thought to be the most likely to replace lithium-ion batteries, which are the most widely used at present[35]. Lithium-sulphur technology offers several advantages: sulphur is a plentiful, more lightweight and cheaper material. It would increase the range of electric vehicles by a factor of three.

[35] Responsible minerals sourcing for renewable energy", 2019, Institute for Sustainable Futures.

MAIN COMPONENTS OF ENERGY TRANSITION TECHNOLOGIES

	Importance for renewable energies	Effectiveness of materials and substitution	Current recycling rate	Demand in 2050 vs. current production	Criticality of the supply chain for the EU
Aluminium	Wind turbines, photo-voltaic panels (PV), batteries	Substitution by steel or plastic with lower performance	70-80 %	< 5 %	Low
Cadmium	CdTe technology: low market share of PV	- Performance in growth - Substitution by other types of PV	75-80 %	< 5 %	Medium
Cobalt	Lithium-ion batteries dominating the market	- Performance in growth - Substitution by other types of batteries with lower performance (LFP)	90 %	> 500 %	High
Copper	Wind turbines, PV, batteries	Difficult substitution	Very variable	< 50 %	Low
Dysprosium	Wind turbines and batteries	Substitution by other magnets	Not recycled	> 500 %	Medium
Gallium	CIGS technology: low market share of PV	- Performance in growth - Substitution by other types of PV	Not recycled	< 50 %	High
Indium	CIGS technology: low market share of PV	-Performance in growth - Substitution by other types of PV	Very limited	< 50 %	High
Lithium	Lithium-ion batteries dominating the market	Performance in growth, but used in all batteries	10 %	> 500 %	Low
Manganese	Lithium-ion batteries dominating the market	- Performance in growth - Substitution by other types of batteries (LFP, NCA)	Very limited	< 50 %	Low
Neodymium	Wind turbines, PV, batteries	Substitution by other magnets	Not recycled	> 500 %	High
Nickel	Lithium-ion batteries dominating the market	- Performance in growth - Substitution by other types of batteries with lower performance (LFP)	90 %	> 100 %	Low
Selenium	CIGS technology: low market share of PV	- Performance in growth - Substitution by other types of PV	Not recycled	< 20 %	Medium
Tellurium	CdTe technology: low market share of PV	- Performance in growth - Substitution by other types of PV	75-80 %	> 100 %	Medium

Sources : Responsible minerals sourcing for renewable energy, 2019; European commission; Meeschaert AM

Importance for renewable energies :

- High importance (used in multiple technologies)
- Medium importance
- Lesser importance

Effectiveness of materials and subsitution :

- Substitution or reduction difficult
- Substitution is possible with reduced performance
- The most effective or substitutable technology

TO WHAT EXTENT ARE COMPANIES AWARE OF THE IMPORTANCE OF THIS ISSUE?

Wind sector

• Economic context

The European Union wants 32% of its energy mix to come from renewable energy by 2030 (compared with 22.7% currently). Depending on the scenario, renewable energy and hydropower are expected to account for 65 to 81% of Europe's energy mix by 2040, including 30 to 35% wind power. The majority of the turbines in the current installed base have a geared turbines. However, by 2020, half of offshore wind turbines will use direct-drive technology. Now, this technology uses rare-earth elements like neodymium and dysprosium. Therefore, actors in the wind turbine value chain have a responsibility to conduct reasonable checks on their suppliers to identify, prevent and reduce any negative impacts. This responsibility is all the greater because there are only a small number of companies in the market, which therefore have a strong potential to influence over the entire supply chain.

• Company analysis

	Vestas	Siemens Gamesa	Orsted	Iberdola	Nordex
Onshore/offshore positioning	Mainly onshore – Offshore development via the joint venture "MHI Vestas Offshore Wind"	Onshore and Offshore	Onshore and Offshore	Mainly onshore. Development of offshore wind farm projects, the first of which is expected to be completed in 2020 in the United Kingdom	Onshore
Level of exposure to the use of rare metals	Neodymium and dysprosium used in the towers of all models, and in the permanent magnet generators of older models	Neodymium used in NdFeB magnets	The company, which already operates offshore wind farms, is mainly exposed to the use of neodymium through its turbine suppliers, including Siemens Gamesa.	Exposure to technologies that use neodymium and dysprosium, through future offshore projects supplied mainly by Vestas and Siemens Gamesa.	The company is developing its own asynchronous turbine technology that does not involve the use of permanent magnets. The development of an offshore strategy could potentially expose it to the use of rare metals.
Supply chain responsibility policy	The Business Partners Code of Conduct includes only traditional commitments on forced labour, child labour, environmental protection, etc. It makes no specific mention of "conflict minerals".	The Supplier Code of Conduct mentions "conflict minerals". The company aims to limit their use without, however, banning them altogether.	The Supplier Code of Conduct and the RPP (Responsible Business Partners Program) identify supply chain risks and assess suppliers' social and environmental performance. The code of conduct is aligned with Wind Europe's supply chain sustainability principles. No specific mention of rare metals	The Code of Ethical Conduct has been ratified by all suppliers and includes only traditional commitments on forced labour, human rights, child labour, environmental protection, etc. It makes no specific mention of rare metals. Whistle-blowing system extended to all suppliers.	The Supplier Code of Conduct has been ratified by all suppliers. It makes no specific mention of rare metals (the technology does not require them). Whistle-blowing system applicable internally and to suppliers.
Environmental governance	Existence of a "Technology and Manufacturing" committee. One of the committee's tasks is to assess the impact of products, and their environmental and social performance. It supports the Product Portfolio Board and the Product Value Chain Board. It establishes innovation and design investment priorities.	No specialised committee. However, the Audit Committee is tasked with monitoring CSR strategy and practices and assessing their compliance. Implementation of the 2018-2020 CSR Plan, which comprises five key pillars including the development of innovative and circular wind turbines, and a responsible supply chain.	The Sustainability Committee is supervised by the Chief Financial Officer, who monitors the progress of the CSR policy. The Board of Directors approves the goals and principles of the CSR policy and oversees its application.	The Sustainable Development Committee manages the implementation of the CSR policy and is supervised by the Board of Directors. The policy comprises five key pillars, including sustainable value creation, transparency and innovation.	QHSE (Quality, Health, Safety & Environment) department, directly supervised by the CEO. The department is responsible for managing, communicating and coordinating the implementation of the company's CSR policy

	Vestas	Siemens Gamesa	Orsted	Iberdola	Nordex
Supplier mapping	Monthly dashboard of key supplier performance, including a social and environmental assessment. In 2018: 154 suppliers were assessed on site (98 approved, 14 rejected, 42 ongoing) But no mention of suppliers further upstream (tier 2, 3, etc.)	Comprehensive mapping of 17,000 tier 1 suppliers, identifying “critical suppliers” and “social and environmental high-risk suppliers” But no mention of suppliers further upstream (tier 2, 3, etc.)	Creation of a “sourcing team” tasked with supervising social issues in the supply chain with the purchasing department. Moderate supplier audit coverage with 20% of sites audited in 2017 and no mention of suppliers upstream in the supply chain (tier 2, 3, etc.)	Sustainability scoring system for tier 1 suppliers. This score accounts for 40% of the final assessment (with 60% relating to the financial situation of suppliers). 89% of purchases were scored in 2018. 75% of suppliers were audited. No mention of suppliers further upstream in the supply chain (tier 2, 3, etc.)	Sourcing department split between four locations (Spain, Germany, USA and Brazil). Suppliers are assessed regularly, with 182 audits performed in 2018 (vs. 250 in 2017). All new suppliers are audited. But no mention of suppliers further upstream in the supply chain (tier 2, 3, etc.)
Mapping of rare metal supply risks	Risks identified: While the “adapting markets to greater complexity” risk incorporates the concept of sanctions and social performance, there is no specific mention of supply chain security and sustainability.	Risks identified in the “general risk control and management policy”: - Governance, ethics and compliance (supplier relationship code) - Strategy and environment (including geopolitical risks) - Operational (including product life cycle management)	Risks identified in the RPP and the Supplier Code of Conduct. But they are not related specifically to rare metals, which are not mentioned. Raw material supply risks do not appear in the materiality matrix, which identifies the company's main risks.	Risks identified No mention of rare metal supply risks. Risks identified in the supply chain include human rights breaches, fraud, cybercrime, CSR issues and tax fraud	Risks identified No mention of the risks connected with rare metals. The technology used does not contain any. However, the development of a lithium-ion storage battery in 2018 has not been assessed in terms of the potential risks involved in using rare metals.
Applicable legislation	Modern Slavery Act	Modern Slavery Act Dodd Frank	Modern Slavery Act	Modern Slavery Act	
Solutions and innovations	Eco-design: DreamWind project to develop sustainable new components for blades. Recyclability: 83 to 89% of a turbine is recyclable End-of-life solutions: research to optimise recovery and the recycling rate	Eco-design: Project to develop lighter composite materials (elastomer materials and 3D textiles) Development of a new magnet manufacturing method with suppliers, to reduce production waste. Recyclability: participation in consortia such as the Horizon2020 project “FiberEUse”. However, the company does not seem to provide any information about the current recyclability rate of its turbines	Recyclability: Waste recovery: 99% of hazardous waste and 77% of non-hazardous waste recycled in 2018.	CSR scoring system (covering 89% of purchases in 2018). Signatories to circular economy agreements: MAPAMA and MITECO	Eco-design is a priority for the group, from design through to recycling. Wind turbine recyclability target for 2018: 85% (this has been reached, since the minimum recyclability rate is 86.7% (excluding the base) and the maximum is 98.3% (including the base)

	Vestas	Siemens Gamesa	Orsted	Iberdola	Nordex
Indicators to assess the environmental impact of wind turbines	In the total product life cycle analysis, depletion of the rare-earth elements used in magnets accounts for less than 0.1% of impacts. This analysis takes into account approximately 25,000 wind turbine components. "Energy payback time": 5 to 12 months depending on the turbine	Total life cycle analysis presented in Environmental Product Declarations (EPDs). "Energy payback time": 7.4 months Development of the SCOE model: To better understand the impact of its turbines, the company has made the transition from the LCoE (Levelised Cost of Energy) model to the SCoE (Society's Cost of Electricity) model, which integrates different energy costs at the societal level.*	No current indicators on product life cycle analysis. However, a clear objective to develop a product life cycle assessment method to support the management, mitigation and transparency of environmental risks along the value chain.	The CEF (Company Environmental Footprint) assesses the company's environmental impact from a product life cycle perspective (ISO/TS 14072: 2014)	No current indicators on product life cycle analysis. A partnership has been established with the University of Hamburg to look for ways to optimise the power of the wind energy system. One of the key topics in the 2019-2021 CSR strategy is the assessment of the environmental life cycle of products.
Questions/areas of engagement	How does the Technology and Manufacturing Committee incorporate rare metal supply issues into its assessments? Consideration of higher tier suppliers, further upstream in the supply chain How do you use the monthly dashboard of key supplier performance in their social and environmental assessment? How many suppliers are monitored? What research is needed to optimise recovery and recycling rates (as mentioned in the Sustainable Development Report)? What are the target rates? How are supply chain security and sustainability taken into account in risk mapping? How are the metals used monitored, taking into account the European Union's list of critical materials? What is the EROEI (energy returned on energy invested rate) of your turbines	How does the "Responsible Supply Chain" pillar of the 2018-2020 CSR plan focus on the issue of rare metals? Consideration of higher tier suppliers, further upstream in the supply chain How do you use the monthly dashboard of key supplier performance in their social and environmental assessment? How many suppliers are monitored? What research is needed to optimise recovery and recycling rates (as mentioned in the Sustainable Development Report)? What are the target rates? How are supply chain security and sustainability taken into account in risk mapping? How are the metals used monitored, taking into account the European Union's list of critical materials?	As your suppliers' turbine technologies use rare metals, are the associated risks monitored? How broad is the coverage of supplier audits? How is the impact management and reduction system applied to storage battery production? Are rare metals used in storage battery technology? If so, how are they incorporated into this management system? How are supply chain security and sustainability taken into account in risk mapping?	As your suppliers' turbine technologies use rare metals, are the associated risks monitored? Are rare metals integrated into circular economy processes? How broad is the coverage of supplier audits and the scoring system?	Are there any plans to develop offshore technologies and fleets? If so, which technology will be used? What data is used to measure improvements in the product life cycle? The development of lithium-ion storage batteries requires a supply of rare metals. Is there a system for monitoring lithium supply risks? Do the financial risks mentioned in the risk management policy take into account the risks associated with raw material prices and rare metal (lithium) procurement? How broad is the coverage of supplier audits?

Source : Corporate reports, Meeschaert AM

• Questions/areas of engagement

Increase the traceability of the neodymium and dysprosium supply chain to identify the risks of disruption.

Integrate supply chain sustainability criteria into the variable component of managers' compensation packages.

What is the EROI (energy return on investment) of your turbines?

Focus : the SCOE cost model
By integrating various energy costs at the societal level, the SCoE cost model complements the LCoE (levelized cost of energy) method that calculates the price of energy based on the lifetime of the system. New elements such as hidden fossil fuel subsidies, social costs and geopolitical impact are added in. This innovative method provides a truer picture of the cost/benefit ratio. However, it does not seem to take into account the environmental and social costs generated by the production of materials along the supply chain.

Focus : "Energy payback time"
The number of months an energy system must operate to generate as much energy as that used to manufacture it.

Focus : EROI
The energy return on investment rate can be used to compare the amount of energy generated by a system with the amount it consumes.

CEF model :
Iberdrola's environmental management policy includes calculating the CEF (corporate environmental footprint), which assesses the company's environmental impact from a life cycle perspective (ISO/TS 14072: 2014). The objectives of the CEF model are to:
- Quantify, standardise and unify the group's environmental performance.
- Determine the effect of Iberdrola's activities in the various environmental impact categories.
- Help track the organisation's environmental performance, and monitor operational objectives and environmental improvements.
- Identify and assess the environmental aspects most important to Iberdrola's operations.

Automotive manufacturers

• Economic context

The electrification of road transport is a key step in limiting global warming and improving air quality.
In its “2°C scenario”, the International Energy Agency predicts a very strong growth in road transport electrification by 2060; for example, the number of light electric vehicles is expected to reach 1.25 billion.

In 2017, the number of electric vehicles sold worldwide topped the one-million mark for the first time. According to Bloomberg Energy Finance, nearly two million vehicles must have been sold in 2018.
The European market grew by nearly 50% in 2018 and is the second largest market after China, which has almost 220,000 electric vehicles.
To meet growing demand from the electric vehicle market, the European Commission has stated that it would be in the strategic interests of the European Union to develop an electric vehicle battery industry. Plans are underway to create a consortium between PSA, its German subsidiary Opel and French battery manufacturer Saft (a subsidiary of Total), and convert an Opel factory in Germany to manufacture electric vehicle batteries. In total, six European consortia are expected to be established in the coming years.

• Company analysis

	PSA	Renault	Daimler	BMW
Positionning on EV and battery technologies	- Hybrid or electric version of all new models from 2019 - By 2021: launch of 8 plug-in hybrid models and 7 EVs - 50 kWh lithium-ion battery	- Nearly 55,000 EVs sold in 2018 (2.6% of sales) - 25% of market share in Europe	In 2018, <1% of vehicles sold were electric and 1.5% were hybrid 2025 outlook: 15% to 25% of turnover generated by sales of its 10 electric models	140,000 electric models in 2018 (2020 target: 500,000) 2025 outlook: 15% to 25% of turnover generated by electric vehicles, thanks to the market launch of 25 electric models
Critical metal supply risks	- Rare-earth elements = 0.3% of material purchases - Material and supply chain risks identified - Mapping of materials criticality in progress	- No information on the rare metals used - Material and supply chain risks identified - Analysis of materials criticality	Cobalt and lithium supply risks identified Commitment reinforced in 2018 with the creation of the Human Rights Respect System to ensure responsibility in raw materials purchasing	Identification of the economic, environmental and social risks associated with the supply of critical raw materials Risks identified specifically in the lithium and cobalt supply chain
Battery and/or rare metal suppliers	Industrial partnerships: - PSA-Opel/Saft to convert an Opel factory in Germany to manufacture cells - Nidec-PSA joint venture	Lithium-ion battery technology developed by Renault	Supplier : Primarily CATL (NMC technology)	Supplier : CATL (NMC technology) Industrial partnership: Umicore and BMW for battery recycling

	PSA	Renault	Daimler	BMW
Supply chain management	- Scope: tier 1 suppliers - Supplier assessment process: EcoVadis questionnaire; audit of supplier sites in accordance with IATF 16949; external audits of high-risk suppliers - Transparency of on-site audit results - Incident management procedures within the supply chain. Measures to support suppliers + Specific questionnaire for suppliers using conflict minerals	- Scope: tier 1 suppliers - Common guidelines for the Renault-Nissan Alliance - Supplier assessment process: external audit of high-risk production sites based on a three-year plan - Insufficient transparency of audit findings - Measures to support suppliers - 2017: Involvement in a controversy over child labour in a Congolese mine (Amnesty International) >Work in progress with an external agency to trace the entire cobalt supply chain	- Scope: assessment of tier 1 suppliers, with an in-depth study of the supply chain for some critical materials; however, insufficient transparency regarding the scale and results of audits - Training provided to suppliers in eight countries in 2018 - Policy of zero tolerance in the event of a breach - 2017: Involvement in a controversy over child labour in a Congolese mine (Amnesty International) - Participation in sectoral initiatives	- 95% of contracts contain a clause relating to social and environmental issues - Self-assessment questionnaire for tier 1 suppliers, audits and on-site visits - In-depth study of the supply chain for some critical materials - 193 cases of non-compliance revealed in 2018; no contracts have been terminated on these grounds - Participation in sectoral initiatives - A member of the Board is in charge of this issue, and a Human Rights report is presented to the Executive Committee and the Purchasing Committee - A supplier progress report has been published, showing that 23 suppliers engage in forced labour and 11 have implemented a corrective action plan since 2016 - 2017: Involvement in a controversy over child labour in a Congolese mine (Amnesty International)
Solutions and innovations	**Eco-design** - R&D programme to provide a second life for EV batteries before recycling them - Founding member of EcoSD (project on the eco-design of traction batteries) **Battery recycling solutions** - Contract with a partner on the European market - Opel and Vauxhall have been rebuilding high-voltage batteries since 2012	**Eco-design** Willing to limit the use of rare metals **Battery recycling solutions** - Battery rental scheme that enables Renault to control the collection and disposal of batteries. - Partnerships and commercial contracts relating to the collection, repair, second life and recycling of electric vehicle batteries. Indra subsidiary: recycling of end-of-life vehicles Gaïa subsidiary: repair/renovation of batteries	Supply security: One-billion-euro investment to expand the internal battery production network Recycling: - LCA (life cycle analysis) process including recycling to secure the supply of raw materials. - A subsidiary that targets the reuse of batteries for stationary storage (1920 battery modules restored and given a second life)	Supply security/recycling: - Aims to manufacture batteries in-house - Long-term contract with CATL - Opening of a battery cell competence centre in Munich, where experts will conduct research into cell and technology design in order to secure the associated technological expertise Recycling: - Battery storage factory in Leipzig, which uses old BMW i3s batteries to optimise energy flows in the factory. Objective: upgrade 700 batteries to give them a second life. - Partnership with Umicore for battery recycling

	PSA	Renault	Daimler	BMW
Questions/areas of engagement	- Impact of EV development on the supply of rare metals - Traceability in rare metal and battery supply chains - Battery technologies envisaged, associated rare metals	- Improved traceability in the cobalt sector - Rare metals used in batteries, suppliers of lithium and other rare metals - Battery recycling - R&D programme to reduce the use of rare metals	- Transparency regarding the battery technologies used - Traceability in the battery supply chain - Transparency of supplier audits	- What is the procedure when a supplier audit reveals non-compliance, bearing in mind that 193 cases of non-compliance were reported in 2018? - What about suppliers that engage in forced labour but have not taken any corrective action? - Do the above-mentioned cases include rare metal suppliers?

Source : Corporate reports, Meeschaert AM

• Questions/ areas of engagement

Increase the traceability of the lithium supply chain to identify risks of disruption.
Increase transparency regarding the technologies used in battery anodes and cathodes.
Integrate supply chain sustainability criteria into the variable component of managers' compensation packages.
What is the current battery recycling rate?

Chemical sector

• Economic context

Chemical manufacturers play a key role in the energy transition of other sectors. Chemicals are used to make components that promote energy efficiency and low-carbon energy development. Cathodes, for example, are vital components of electric vehicle batteries and catalytic converters, which reduce the pollution caused directly by vehicles with combustion engines. Thanks to their innovation capacity and their position in the supply chain, chemical manufacturers are able to improve technologies to shift toward recycling and substitution materials. The sector's supply chain comprises mines, smelters and metal refineries. The big names in the chain include Norsk Hydro, Vale and Glencore.

• Company analysis

	Johnson Matthey	Umicore	Solvay
Activity and position in the chain	Manufactures catalysts and cathodes (LFP/eLNO) for the automotive sector; recycles metals 1.5% of turnover generated by electric vehicles [36]	Manufactures NMC cathodes and catalysts for the automotive sector; recycles materials 36% of turnover generated by electric vehicles [36]	Produces fluorine and rare earth formulations for automotive applications Battery component sales account for 0.5% of turnover but are growing strongly
Critical metal supply risks	Rare metal supply risks identified, geographical mapping of supply	Risks identified and solution developed for securing supply internally through recycling	Rare metal supply risks identified
Supply chain management	Recent development of sustainability programmes for suppliers to identify high-risk profilesidentify high-risk profiles and monitor progress A minority of suppliers are audited. 2025 target: 100% audited and compliant with the Code by 2025 The programme applies only to the top 227 suppliers No measures identified to support suppliers	Specific procurement policy for critical raw materials Action plans established for each material, but not published Assessment of an undisclosed number of tier 1-suppliers, EcoVadis assessment of 335 indirect suppliers No information on alert procedures in case of non-compliance with the procurement charter, or on the system for monitoring supplier audits	Formalised and decentralised risk management approach, but not specific to rare metal procurement 810 critical suppliers identified Completion of supplier CSR assessments; corrective action plan required in case of failure, monitored by purchasing teams External assessment procedures (EcoVadis and TfS survey of suppliers), but no alert procedure for flagging lapses in the supply chain
Solutions and innovations	Eco-design Manufacture of catalytic coated substrate (replacement of precious metals) Recycling Recycling of metals such as platinum, palladium, rhodium, iridium, ruthenium, rhenium and osmium	Eco-design - 58% of the materials used have been recycled. The rest come from primary sources, the supply of which is ethically and sustainably monitored - Active member of the circular economy working group established by the World Economic Forum's Global Battery Alliance Recycling - Operation of a precious metal recycling plant - Closed loop approach to battery recycling (including partnership with BMW)	Eco-design Circular economy training for employees - particularly those who design molecules - to ensure the circularity of end products.

[36] Citi Research - Electric vehicles - Ready(ing) for adoption, juin 2018.

Questions/areas of engagement	Johnson Matthey	Umicore	Solvay
	Consideration of higher tier suppliers, further upstream in the supply chain?	Transparency of rare metal supplier audits?	What specific actions are taken to secure the supply of rare metals?
	Is there a procedure for supporting suppliers that do not comply with the Code?	Transparency regarding material recycling rates per metal (particularly lithium and cobalt)?	How does the supply chain alert mechanism work?
		Greater transparency of the vigilance plan, beyond cobalt and conflict metals?	Are all critical suppliers audited?
		Geographical mapping of rare metal mines?	What recycling measures are in place for rare metals?
			Geographical mapping of rare metal mines?

Source : Corporate reports, Meeschaert AM

• Questions/ areas of engagement

What action plan should be followed when tier 1 or other suppliers (such as Norsk Hydro or Vale) are involved in serious controversy?
Have companies already experienced disruptions in the supply of critical raw materials?
Integrate supply chain sustainability criteria into the variable component of managers' compensation packages.

APPENDICES

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GLOSSARY

Rare metals

Also called minor or small metals. They are produced in low tonnages but are used in key, cutting-edge areas such as digital and renewable energy technologies

Gold (Au), Beryllium (Be), Bismuth (Bi), Cadmium (Cd), Chrome (Cr), Cobalt (Co), Gallium (Ga), Germanium (Ge), Mercury (Hg), Indium (In), Lithium (Li), Magnesium (Mg), Molybdenum (Mo), Niobium (Nb), Osmium (Os), Palladium (Pd), Platinum (Pt), Rhenium (Re), Rhodium (Rh), Ruthenium (Ru), Antimony (Sb), Silicon (Si), Tantalum (Ta), Tellurium (Te), Titanium (Ti), Uranium (U), Vanadium (V), Tungsten (W)

Rare-earth elements

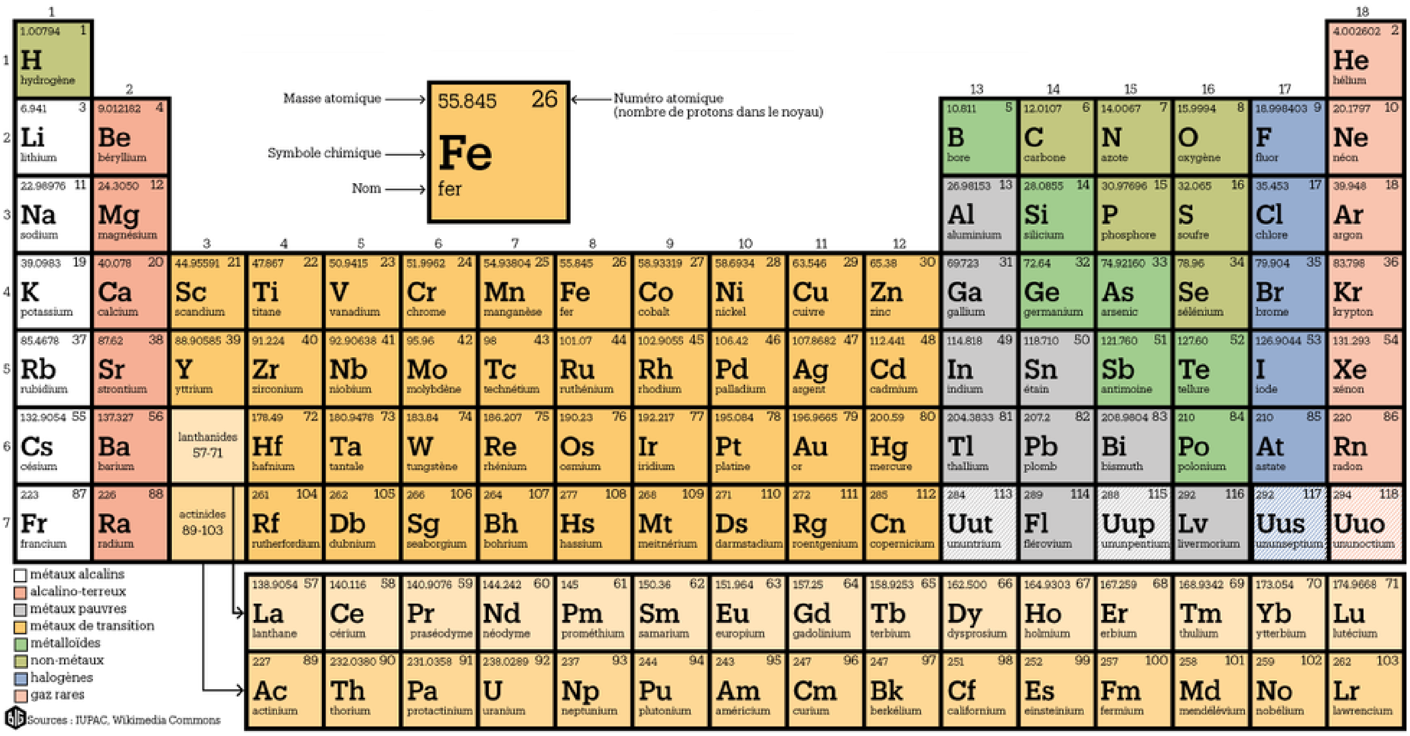
Rare-earth elements are a family of rare metals.

A set of 17 chemical elements in the periodic table: Scandium (Sc), Yttrium (Y) and Lanthanum (La), and 14 lanthanides: Cerium (Ce), Praseodymium (Pr), Neodymium (Nd), Promethium (Pm), Samarium (Sm), Europium (Eu), Gadolinium (Gd), Terbium (Tb), Dysprosium (Dy), Holmium (Ho), Erbium (Er), Thulium (Tm), Ytterbium (Yb) and Lutetium (Lu).

Précious metals

A precious metal is defined by its economic value. The three main ones are Gold (Au), Silver (Ag) and Platinum (Pt).

PERIODIC TABLE



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