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The future of energy transition between critical materials and geopolitics.

Lithium and the South American context

By

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Declaration

I hereby declare that, the contents and organization of this dissertation constitute my own original work and does not compromise in any way the rights of third parties, including those relating to the security of personal data.

Elena Giglio
18/06/2021

* This dissertation is presented in partial fulfillment of the requirements for **Ph.D. degree** in the Graduate School of Politecnico di Torino (ScuDo).

I would like to dedicate this thesis to

My parents, the pillar of my life. This thesis is for you, and to you I dedicate the joy of a unique achievement, with immense and boundless gratitude.

To Prof. Marina De Maio, for teaching me that life deserves to be lived to the fullest, with determination and passion. ALWAYS. That you should never give up, despite the difficulties. Marina, your incomparable strength and your overwhelming will to live will be a source of inspiration in my professional and life path. Wherever you are right now, I know you are celebrating with me. Thank you.

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Abstract

The energy market is changing: new policies, technologies and sources are prompting us to embark on a long journey towards a new world, an “energy transition” to achieve a sustainable consumption model and solutions to tackle global warming and climate change.

Battery sector is one of the pillars of the low-carbon energy transition with a huge economic impact in the decades ahead.

The issue of energy transition in the automotive sector and battery production is not only technological. The geopolitical aspects are relevant if it is considered the relations between Europe, United States, Russia and China and the geographical division of the world, high-income countries (benefiting from the technology), and low-in-come countries but depositaries of the raw materials needed for that technology.

Nickel, Cobalt, Manganese, Lithium, Aluminum, Graphite and Copper are the most important elements implied for cells units battery (Huisman et al. 2020) and lithium is undoubtedly a central element in the production of electric batteries, one of the fundamental materials in the process of ecological transition, particularly in the transport sector. The careful analysis of the geopolitical dynamics around this material are crucial also for the support of ecological and sustainable urban regeneration processes, i.e. “smart cities”.

Half of all lithium reserves on the planet are located between Chile, Argentina and Bolivia, the so-called “lithium triangle” but what should be of greatest concern, however, is not the amount of lithium present on the Earth's crust, but its global

distribution. The social impact and the lack of information and consultation with the local population, together with a difficult industrialization on site (due to poor technological preparation), are issues directly related and consequent to the "geopolitics of extractivism".

The 'Sustainable and Smart Mobility Strategy' together with the proposed "Batteries and Waste Batteries Regulation" published by the EU Commission on 10 December, 2020 stating: 'It is a fact that improving the design of batteries – making them more sustainable, readily removable and easily recyclable – is a pre-condition to transition towards a circular economy. It is also part of the solution to tackle acute problems faced by recyclers linked to the ever-increasing battery fires during the collection, transport, and treatment of the booming end-of-life products containing batteries, which pose major problems'.

The EU strategic document underlined the urgent need we have in Europe to improve our knowledge on battery and the whole life cycle, including raw materials. That assumption is confirmed by the evidence that the EU is sourcing primary battery raw materials mostly from third countries such as Democratic Republic of Congo, Russia, Chile and Brazil with a strong geopolitics implication and of course a strong technological dependency by extra EU Countries.

Contents

List of Figures

List of Tables

Chapter 1

Energy Transition Vs European Union

Rare earths are used today in a vast range of products. One of the fields of greatest expansion is in fact that of permanent magnets, hence their use in the electric motors of new-generation vehicles and in wind turbines, two fundamental segments for decarbonisation and the simultaneous ecological transition to which global industry is currently undergoing.

This first chapter aims to highlight the efforts at the global level, especially European, that are being made with reference to the energy transition, highlighting objectives and priorities.

From the commitment taken at global level with the SDGs to the concreteness of the EU measures put in place with the Green Deal through, for example, programs such as Horizon Europe, but also with targeted and specific actions in favor of the energy transition of cities (eg ad hoc Horizon Europe -Missions, European Battery Alliance).

1.1 Global Energy transition and EU priorities

The main reason to turn the world into the sustainable paradigma is to improve the quality of life. To achieve this objective, smart cities and the development of intelligent mobility represent key points. Indeed, we are witnessing a gradual energy transition, which sees the affirmation of new technologies, from renewables to electric mobility, necessary for the global decarbonization process. A transformation that will have a strong impact on the raw materials needed and, parallelly, a drastic decrease in the use of coal, oil and gas.

The energy sector has actually become the main user of the critical minerals market. Such a phenomenon is attributable to the indispensable and massive development of renewables materials: lithium, nickel, cobalt, manganese and graphite are crucial for the performance of batteries; rare earths are crucial for permanent magnets, which in turn are vital for wind turbines and electric motors; copper and aluminum are indispensable for the massive development of the electricity transmission networks that will serve. However, the future availability of minerals may not be able to maintain the energy transition up with the renewable sources availability, jeopardizing the achievement of climate objectives. In a scenario in line with the Paris Agreement, the quotas necessary to fulfil the new technologies will, in fact, significantly increase the overall demand for many minerals. This is what emerges from the recent special report "The Role of Critical Minerals in Clean Energy Transitions" (International Energy Agency (IEA) 2021), that addresses the critical issues that may emerge if not dealt with timing and intelligence. The report is the most comprehensive global study of this subject to date, underscoring the IEA's commitment to ensuring energy systems remain as resilient, secure and sustainable as possible.

It shall be noted that the IEA, created to ensure the security of oil supplies, is now also analyzing the problems of raw materials in relation to their geographical concentration and the possible volatility of prices. While oil production is marketed worldwide in liquid market, the production of many minerals, such as lithium, cobalt and some rare earth elements, is concentrated mainly in three states (Australia, Democratic Republic of Congo and China), which represent the world's largest producers of such raw materials and also control more than three-quarters of the global market.

In addition, in a context of high growth in demand, the current supply plans for many critical minerals are not sufficient to faster the distribution of solar panels, wind turbines and electric vehicles, in the view of achieving the goal of full decarbonisation. As an example, for an electric car it is needed six times more minerals than a conventional car; for an onshore wind farm nine times more than a gas-fired power plant. Electric cars and batteries have already surpassed consumer electronics in the use of lithium and will surpass the steel industry in the nickel industry in 2040. With the decline of the costs of technologies, the use of minerals as key components, taking into account the demand prospects and the supply vulnerabilities of each mineral, a potential fluctuation in prices will possibly occur. Today the revenues from the production of coal are ten times higher than those realized with the production of the minerals used in the process of transition. But this situation will be reversed by 2040.

Even though dozens of countries and many leading companies have announced plans to bring their emissions down to net zero by around the middle of this century, supplies of critical minerals essential for key clean energy technologies like electric vehicles and wind turbines need to pick up sharply over the coming decades to meet the world's climate goals, creating potential energy security hazards that governments must act now to address, according to the new report by the International Energy Agency. In order to accelerate energy transition, the IEA is committed to help governments in this direction by addressing potential vulnerabilities.

In addition, while the world was going through the second year of pandemic of Covid-19, last IEA drafted the "Global Energy Review 2021" report, assessing the direction taken by energy demand and carbon dioxide emissions in same year. As a result, in 2021 it is predicted to be registered a sharp increase in gases emissions. In absolute terms, the forecast stops just before the values of 2019, but the growth rate following the pandemic is almost unprecedented and, according to the estimates mentioned in the report, it going to reach an about 5% surplus. The only year in which the global emissions curve was steeper was 2010, due to the economic crisis of 2008, with a percentage that reached 6%. As a result, global energy demand is expected to increase by 4.6%, more than offsetting the contraction of 4% in 2020 and pushing demand by 0.5% above 2019 levels(International Energy Agency (IEA) 2021). Two factors driving this increasing in emissions are: the growth in demand for coal and the fossil component in the recovery plans of many countries. More than 80% of the expected coal demand growth is expected to come from Asia, led by China in 2021. The use of coal in the United States and the European Union is also set to increase, but it is supposed to remain almost below the pre-crisis levels.

Oil consumption, on the other hand, is also increasing, but it will not return to levels before the pandemic. The rebound post Covid-19, however, continues to reward renewables. According to the IEA data, renewable energy sources, the only growing in demand in 2020, will mark a +8% of electricity production in 2021. The biggest contribution to this growth comes from solar and wind, which could mark their biggest annual increase in history. In 2021, China will once again represent half of the global increase in electricity production from renewable sources, followed by the US, the European Union and India.

One of the possible consequences of the gradual reduction in fossil fuel consumption on an international scale, is underlined in a new study, known as "*Political Risk Outlook 2021" (*Maplecroft 2021). According to this report, the pandemic has greatly increased uncertainties about the likely development of the world crude oil market and the achievement of the so-called peak oil and many countries will not be able to adapt the transition to the new rules, also by transforming at least part of their economies (in short, from strictly oil-producing countries to countries that invest in clean technologies). As a result, such Countries are likely to be always more exposed to political turmoil, revenue collapse (previously guaranteed by fossil sources) and increased credit risks. In fact, after the collapse of oil prices in 2014 and until the outbreak of the pandemic, most of the oil-producing nations failed to diversify their economic-energy mix, remaining hooked to black gold exports. As the only alternative to the economies diversification, the study highlights also highlights some "*forced economic adjustments*", such as the devaluations of national currencies or the drainage of their foreign-exchange reserves.

The forecasts on how the oil market will change in the next few years are discordant, if compared to the estimates of the IEA and IRENA (International Renewable Energy Agency).

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According to the IEA (IEA 2021) report "Oil 2021" , in the reference scenario, based on current policies, it is expected that oil demand will grow to 104 million barrels per day in 2026, thus marking a +4% on 2019 levels, thanks mainly to the tow of Asian countries. China, in fact, is the only major economy where oil demand in 2020 was above 2019 levels, and demand in 2021 is expected to grow further to almost 9% above 2019 levels. The demand for oil in China, in the first quarter of 2020, decreased by 1.3 mb/day, at a time when the virus was stronger and mobility was greatly reduced. But, with the end of restrictions and the economic recovery recorded in the rest of the year, the demand for oil rose restarted, bringing the world demand to a higher percentage point in 2021 than in 2019. In other countries, such as the United States, only due to the pandemic restrictions in early 2021, oil demand is expected to remain around 0.8 mb per day below 2019 levels. In the European Union, where multiple blockages have been imposed in almost all Member States, annual CO2 emissions have fallen by 10% compared to 2019 and oil demand has remained below 0.4 mb/g in the same year. Overall, about 2 billion tonnes of CO2 were lost last year, the most marked drop in history in absolute terms, most of which were attributable to lower oil consumption. Already in 2022, the demand for crude oil, the IEA says, will return substantially to the values seen ahead of the pandemic (2019), that is about 99-100 million barrels per day. At the sime time, because of the uncertainty dictated by the course of the pandemic, which imposed a sharp decrease in consumption in the oil market last year, it is not granted that the decline in demand for oil will necessarily be long-lasting. As stated by Fatih Birol, director of the IEA, much will depend on the actions taken by the governments. Moreover, Birol explains that it is possible to reduce oil consumption by 5-6 million barrels per day by 2026, as long as you immediately accelerate the sales of electric cars, improve the standard of vehicle efficiency, with lower fuel consumption and hybrid technologies, and more generally by investing more in clean technologies in all economic sectors (IEA 2021).

On the contrary, the new report by IRENA, "World Energy Transitions Outlook" (IRENA 2021), offers a scenario more focused on renewables with the peak of oil prices definitively on the sideline, and only reached once, in 2019, and no longer reached in the following years. In the study, for example, it is noted that the global oil production at 1.5°C (the target compatible with the Paris agreements) will fall to 11 million barrels per day in 2050, about -85% compared to nowadays. Recent trends indicate an ever-widening gap between where we are and where we need to be to achieve such targets.

1.2 Sustainable Development Goals

The strategic ambitions to promote energy transformation, in line with the United Nations Sustainable Development Goals and the consequent acquisition of a decarbonisation process as crystalized in the Paris Agreement, aim to reduce gas emissions by transforming more than half of global energy into renewable one by 2030. An increasing need for cooperation between the countries involved is essential, especially by those involved in a high share of renewable energy in their energy systems, in order to ensure a secure, reliable and more accessible energy supply and to encourage economic advantages.

The most important achievements in international sustainable development research, which paved the way for Agenda 2030, are underlined in the following chart.

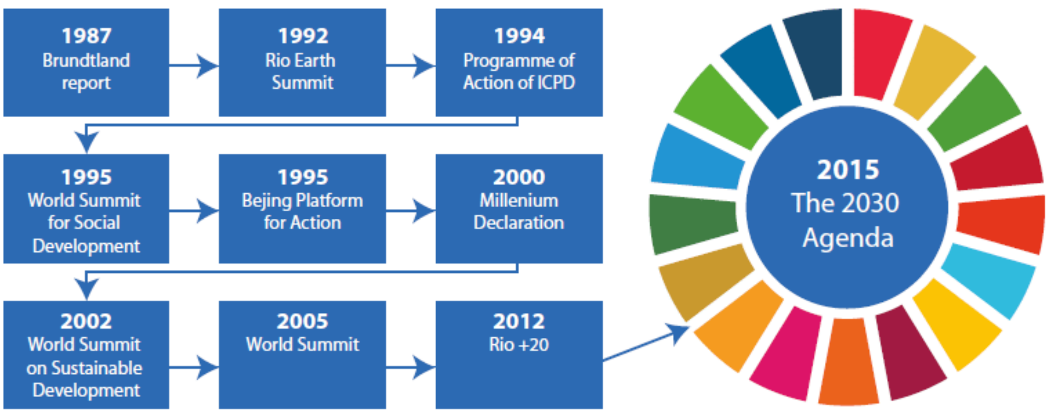


Figure 1.1: Important milestones on the road to the Agenda 2030. Source: "Monitoring report on progress towards the SDGs in an EU context — 2021 edition"

Since the 2015 the Agenda 2030, adopted by all UN Member States for Sustainable Development, and its 17 Sustainable Development Goals (SDGs), also known as Global Goals, has inspired and motivated governments and all stakeholders to pursue transformative actions, individually and collectively, for people, planet and prosperity, to reach a wider social, economic and environmental sustainability.

Figure 1.2: The 17 Sustainable Development Goals. Source: (United Nations Department of Economic and Social Affairs 2020)

The 17 SDGs are linked to one another, a positive or negative action in one area will affect results in others. For this reason, it is necessary that the collaboration between parties, the know-how, the technology and the financial resources of the whole society are balanced and concentrated to achieve these ambitious goals in each context.

Specifically to the European Union, in November 2016 the EU Commission has clearly made the SDGs an EU priority and announced a gradual approach towards the execution of the SDGs objectives, as underlined in the Communication “Next steps for a sustainable European future: European action for sustainability” (COM (2016) 739), by slowly integrating the SDGs into the European political and legal framework. The communication also announced a periodic detailed monitoring of the SDGs progress in an EU context, starting in 2017, noted into annual reports. In this respect, in May 2017, Eurostat within the European Statistical System (ESS) has set up a framework of benchmarks, in cooperation with other Commission services. Each SDG is covered by five or six key indicators, selected on the basis of the availability and quality of the data, relevant to the EU. Out of 231 global indicators, 65 of the current EU SDG indicators are aligned with UN indicators. Overall, thanks to these indicators, the interconnections between SDGs can be identified in order to design increasingly efficient policy actions. This has enabled the EU to identify its long-term benefits in a reflection work after 2020. Lately in January 2019, the Commission has presented the Reflection Paper "Towards a Sustainable Europe by 2030", an EU Performance Assessment Paper on the 2018 Monitoring Report in relation to the SDGs (Commission, n.d.). The document sets out the complex and interconnected challenges that the European Union is facing for climate and technological change.

Urban areas, despite being cradle of innovation and sustainable development, are crucial in environmental change on multiple scales, specifically in relation to transport, mobility, food supply and waste production. While taking into account the different socio-economic situations between the EU Member States, there are many important intrinsic interconnections between the SDGs. To provide an example on the interconnected nature of SDGs, models of production and consumption (SDG 12) have an important impact on resources and energy efficiency (SDG 7), and consequently also on biodiversity (SDG 15). Sustainable energy systems drive towards a more resilient low-carbon transition, thus affecting our climate (SDG 13) and consequent energy consumption (SDG 7). Being core of economic growth (SDG 8), cities can stimulate employment which will contribute to reducing poverty (SDG 1) and reducing inequalities (SDG 5). But the pressure of urbanization (SDG 11), having an impact on resources and the consumption of materials (SDG 7 and SDG 12) and on climate (SDG 13), will also play an essential role on biodiversity (SDG 15). The pollution caused by industries will in fact influence the quality and availability of water (SDG 6), while sustainable agriculture (SDG 2) will contribute to the protection of biodiversity; both of which are linked to the overall state of the ecosystem (SDG 15). (Eurostat 2021)

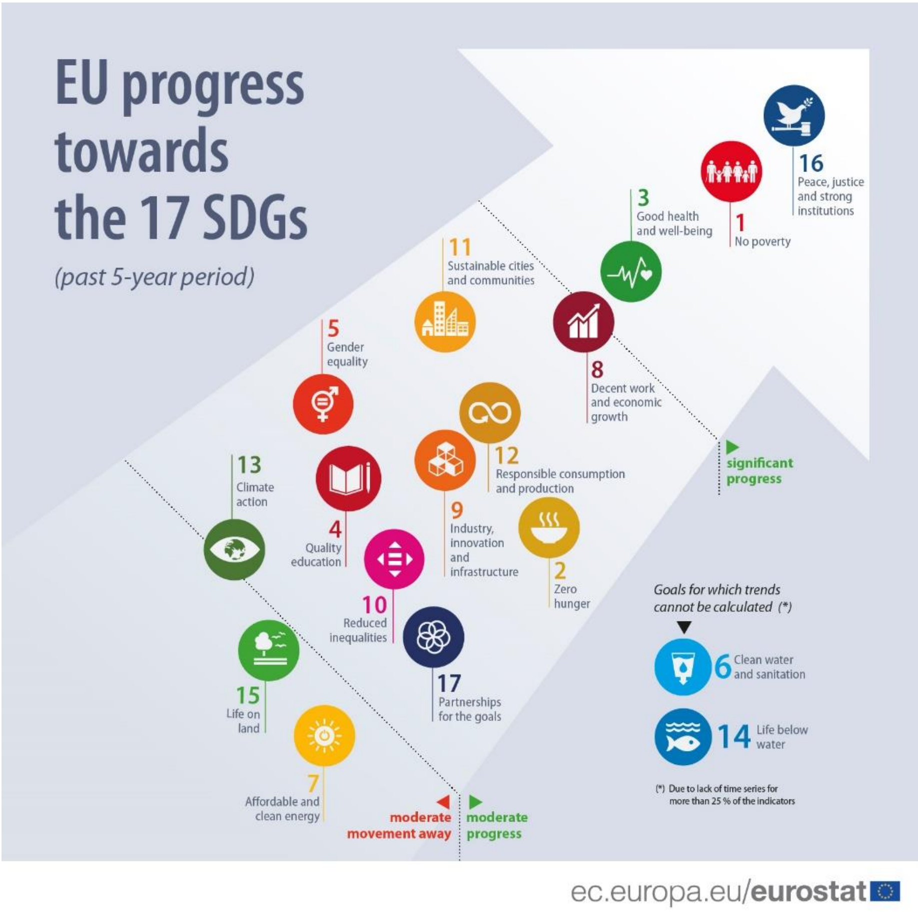


Figure 1.3: Eu progess towards the 17 SDGs. Source: Eurostat Overview of EU progress towards the SDGs over the past 5 years, 2021 (Data mainly refer to 2014–2019 or 2015–2020)

Sustainable transport is integrated into several SDGs of the Agenda 2030 for Sustainable Development; however the main focus is on Goal 11 “Making cities inclusive, safe, resilient and sustainable”, among the targets (specifically in point 11.2 of the SDG 11) set to provide provide, “access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons” by 2030 (Spencer 2021).

The European Commission implemented the SDGs in non-energy extractive industries through its policies (European Commission 2017) derived from the Raw Materials Initiative and through policies, programs and actions

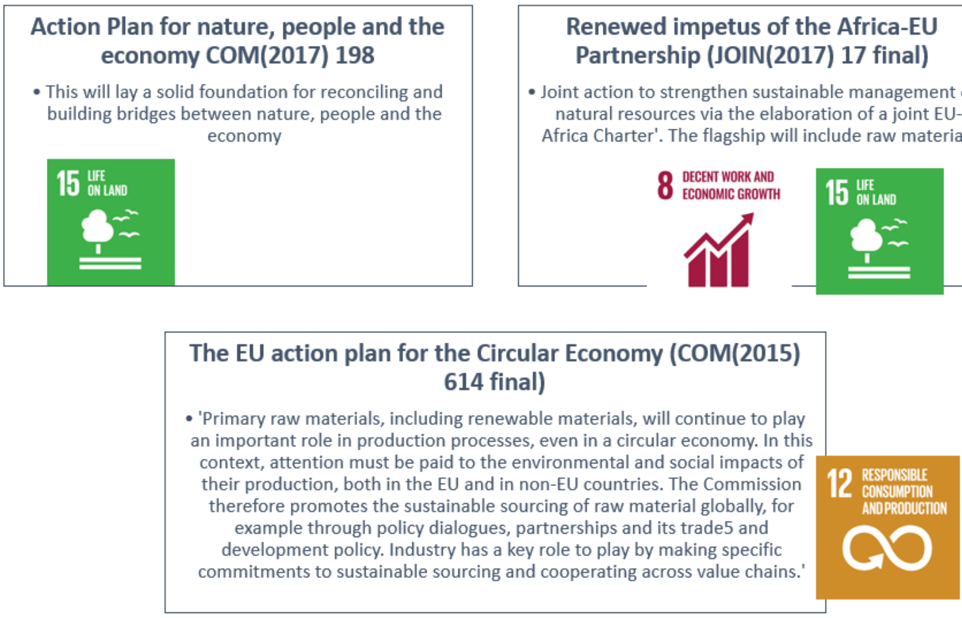


Figure 1.4: Example of SDGs in non-energy extractive industries .Source (European Commission 2017))

The role of transport in sustainable development was previously discussed in the Agenda 21, at the 1992 United Nations Earth Summit in Rio De Janeiro, Brazil. In most recent years, the global attention increasingly points to sustainable transport as an opportunity to improve the economy while respecting the environment, especially in developing countries. The UN Secretary-General Ban Ki-Moon has convened the first Global Conference on Sustainable Transport, in Turkmenistan, on November 2016, where the main stakeholders from Governments, together with the United Nations and other international organizations, involving also private sector and civil society, have dealt the topic on sustainable transport as crucial in supporting the achievement of several SDGs. The need to work on the development of multimodal, motorized and non-motorized transport systems has been emphasized, with specific focus on a low-carbon transport model and the use of interconnected transport networks, including public transport systems, to allow mobility and connectivity of people and goods. In support of smart multimodal transport systems and considering the discontinuity and delays associated with global supply chains, Conference participants agreed to adopt multidisciplinary strategies to accelerate the transition to low-carbon energy sources and technologies, encouraging the adoption of innovative technologies and increasing investment in transport infrastructure resilient to climate change. This means to encourage electric mobility, to support industries in production of "New Energy" Vehicle (NEV) technologies - which have the advantages of a high energy efficiency and a zero-emission exhaust pipe (which include electric battery, plug-in hybrid)- and to improve the use of public transport by achieving a more compact urban planning and reducing road congestion also by encouraging vehicle sharing. However, although the use of EV reduces the demand for imported liquid fuels, it will not reduce the environmental impact if electricity keep being mainly powered by fossil fuels. That's why the development of low-carbon energy production, including the supply of electricity to NEV, represents a better measure in national strategies to face energy and environmental issues. The use of lighter materials for vehicle parts, such as those used in aviation to reduce aircraft weight and improve aerodynamics, can also contribute to significant energy and carbon emission reductions. It was also emphasized that sustainable public transport can offer enormous benefits to cities, not only in terms of reducing air pollution, but also by meeting the needs of those who are particularly vulnerable (such as women, children, people with disabilities and the elderly) and contributing to the economic vitality of cities. Ultimately, the representatives of the first Global Conference of Turkmenistan, solicitated by the UN Secretary to draft always more and new initiatives on sustainable transport, reiterated their commitment to continue working on the purporse and expressed the need to collect data on the improvements on sustainable transport issues on specific platforms, made available through the United Nations.

To support the exchange of experiences, lessons learned and technical cooperation, IRENA established the Collaborative Framework ("Enhancing Dialogue on High Shares of Renewables in Energy Systems") (IRENA.org 2021), still in progress today. The Collaborative Framework meetings among IRENA Members and the acceding States also include work streams aimed to develop cross-border interconnections and to promote cross-border trade of renewable electricity. During the pilot-phase in 2021, the focus will be also on energy system planning, to be reinforced through effective use of long-term projects. Uruguay and Canada, elected as co-facilitators, will discuss with the other Members about possible solutions to deal with the variability of renewable power and grid stability issues to long-term. In addition to cross-border cooperation, members will propose cross-sectoral strategies through which the development of renewable energy could contribute to the achievement of other Sustainable Development Goals (SDGs), with a focus on water resources, food safety and health.

Countering climate changes and reducing environmental impact are also a priorities for Europe. To overcome these challenges and achieve carbon neutrality by 2050, the European Parliament, in January 2020, approved the Green Deal, an official document providing a roadmap for transforming climate issues and environmental challenges into growth opportunities in all sectors. The European Green Deal Action Plan aims to promote the efficient use of resources for the development of a clean and circular economy, reducing global pollution (COM.640.final 2019).

Figure 1.5: The European Green Deal. Source: (COM (2019) 640)

In order to ensure an equitable and inclusive transition, it will be necessary to:

- investing in environmentally friendly technologies;
- supporting industry in innovation;
- introducing cleaner, cheaper and healthier forms of private and public transports;
- decarbonising the energy sector;
- ensuring greater energy efficiency of buildings;
- working with international partners to improve global environmental standards;
- ensure monitoring and possible review of all relevant climate policy instruments;
- implement a sustainable and intelligent mobility strategy.

The European Union will mitigate the socio-economic costs of climate change by supporting Member States through the so-called Just Transition Mechanism (JTM), focusing on the regions with the highest carbon intensity, mobilizing around €100 billion for the period 2021-2027. The JTM will provide to citizens and companies more pro-actions in the transition and more opportunities for requalification to invest in renewable energy with a consequent creation of new jobs in the green economy.

In order to ensure that these new economic strategies can realistically become concrete actions, the EC has identified groups of indicators relating to the sustainable and circular management of mineral RMs in European countries, in order to assess whether the actions taken are appropriate and, eventually, to amend them accordingly. The selected set of indicators are grouped into four main areas of the circular economy, namely: production and consumption, waste management, raw and secondary materials and competitiveness and innovation (as in figure below). An update of each indicator is available on the Eurostat website.(Smol et al. 2020)

Figure 1.6 - Circular-economy-CE-Monitoring-Framework

Specifically, out of 10 indicators selected in the CE monitoring framework, four are closely related to RMs:

- EU self-sufficiency for raw materials;
- Share of secondary raw materials in the demand for raw materials;
- Trade in secondary raw materials;
- Patents related to recycling and secondary raw materials.

The "EU self-sufficiency in raw materials" indicator defines the degree of independence of the EU from the rest of the world in relation to selected raw materials, including CRMs. This list shall be updated every three years to assess changes in production and RMS increases, taking into account market and technology developments. Although the EU is quite self-sufficient for most non-metallic raw materials, CRMs still depends on imports. The implementation of CE models is therefore necessary in order to facilitate secure access and diversification of the supply chain, in particular of CRMs. Moreover, it could significantly help to reduce environmental negative impacts caused by their extraction methods and the concentration of global production in limited countries (especially China and Russia).

In a circular economy, the use of secondary raw materials is crucial to reduce the demand of raw materials and consequently reducing the environmental impact of the extraction of natural resources. The indicator "Share of Secondary RMs in the Demand for Mineral Resources" in the CE monitoring framework, also called "Input rates for end-of-life recycling (EOL-RIR)" measure the results of recycling a given raw material in a production system. Such "secondary raw materials", once generated within a national economy, can also be exchanged and shipped as primary raw materials from the traditional extractive resources industries.

Secondary raw materials, that therefore consist in derived by recycled residual materials and then replaced on the market as new raw materials, are considered valuable resources of cross-border exchange. The indicator "Trade in recyclable raw materials" measures the quantities of selected waste passed through the borders of the European Union and shipped between the Member States, based on the International Trade in Goods Statistics (ITGS) published by Eurostat. Cross-border movements of secondary RMs have increased considerably in recent years.

The development of new technologies and innovation represent a solid basis for the transition to a circular economy. The indicator "Patents Related to Recycling and Secondary Raw Materials" establishes the number of patents related to recycling and secondary raw materials, using the relevant codes in the Cooperative Patent Classification (CPC). The introduction of innovative techniques for the collection and storage of waste and for the transport and recycling of materials will help to make the EU less and less dependent on primary resources and to develop greater competitiveness in domestic industries.

The "Communication on the Raw Materials Initiative" of 2008 (COM 699) and the "Roadmap to a Resource Efficient Europe" of 2011 (COM 571), published by the European Commission to ensure sustainable access to raw materials, especially in relation to critical raw materials (CRM), and to contribute to the growth of a fair Europe in the distribution of low-cost resources, marked a turning point for European mining policy.

In the EC Reflection Paper "Towards a sustainable Europe by 2030", published in 2019, the EU recommends to the Member States to review and develop their mineral policy according to their own needs and priorities in the sector.

The first European countries which joined and introduced new mining policy, between 2010 and 2012, were Greece, Portugal, Germany, Finland and the United Kingdom. The common objective was to propose sustainable access to primary and secondary mineral resources, in line with other environmental policies that aim to climate neutrality by reducing waste (Janikowska and Kulczycka 2021). According to its national legislation, Germany establishes the goal of a climate neutrality by 2050, definitively renouncing to the use of nuclear energy and fossil fuels and focusing on reducing greenhouse gas emissions in all sectors, increasing the use of renewable energy. This objective lead to social and economic progress, with respect for human rights and the environment. In the mining sector, Finland is a leader in the sustainable use of mineral resources, mainly thanks to the introduction of policy instruments that improve financing opportunities. Tax incentives promote the exploration and efficient use of natural resources, providing both a reduction in waste and the recycling of raw materials. However, due to the hydrological situation in the Nordic countries, greenhouse gas emissions in Finland tend to fluctuate widely. The United Kingdom focuses mainly on the long-term sustainable use of minerals, ensuring adequate supply to the demand, with a greater focus on the sustainable extraction of critical raw materials from the country domestic resources and, at the same time, trying to minimize the environmental impact caused by extraction and transport. Furthermore, by implementing the principle of decoupling, namely the separation of mining production from resource productivity, the UK has an ambitious plan to reduce emissions to zero by 2050. As a result of the long-term economic crisis, which led to the fall in national GDP per capita, energy consumption and CO2 emissions were also reduced in Greece. One of the main objectives of Greece's political strategy is therefore to ensure progress and economic development through the exploitation of mineral raw materials, creating new jobs while respecting the environment and sustainable development. The National Strategy for Geological Resources launched in 2012 by the Council of Ministers of the Republic of Portugal stresses the importance of the mining industry as driving force to ensure an economic and employment return. Although it is one of the countries most affected by climate change, Portugal, through the principle of decoupling between GDP and emissions, aims at a 40% reduction in CO2 emissions by 2030.

1.3 Europe and battery value chain

The lack of raw materials in the EU pushes to increase competitiveness in the lithium value chain to create alternative systems leading to a leading position in the global market. In such view, the discovery of new mineral deposits can enable the EU market to enfranchise by the importation of lithium (mainly coming from China), essential to the energy transition and to create a self-made production of batteries for electric cars. However, much will depend on the balance between supply and demand, influenced by factors such as exploration, extraction and refining projects, substitution and recycling, together with the competition between regional access to raw materials for new industrial energy strategies. All these factors melt together determine the flexibility of supply in a future perspective.

According to a recent EU's foresight study, the growing annual demand for rare earths (especially dysprosium and neodymium) will considerably exceed global annual production by 2030. The supply of dysprosium will be particularly critical, due to its low natural percentage present in the REE. As regards the nickel market, demand is increasingly shifting towards Class 1 nickel, the high purity of which finds application in the production of battery cathodes. The lithium market, on the other hand, is still in balance in the short term, due to the recently developed world-wide extraction and refining capacities, althoguhserious deficit in the medium term may arise due to the rapidly growing demand for this mineral. As regards the cobalt distribution, the main concern remains the high concentration of supply. Although the reserves placed in the Democratic Republic of Congo will still drive the supply of cobalt market in the future, the low level of governance and the high instability of the country may presage a barrier to demands in the medium term, causing the recourse to new mining projects in starting from the 2025. With regard to the market for natural graphite, used for battery anodes, the prospective remain positive, thanks to the development of new mining projects such as in Africa. Furthermore, as the use of spherical graphite for battery anodes is booming, especially in China, the increase in the production of synthetic graphite as a potential substitute for natural graphite could meet the growth in the global demand (EC.JRC 2020). Based on these concrete data, the European Commission shows that the use of critical raw materials in the field of electronic mobility and renewable energies will increase the future cumulative demand of Europe in 2030 and 2050.

Within the aim of building the battery value chain in Europe, facilitating and promoting access to lithium resources, nickel and cobalt located in the European Union and ensure supply to Member States, the European Commission launched the European Battery Alliance (COM.293.final 2018), a project that brings together more than 500 public and private players in the sector.

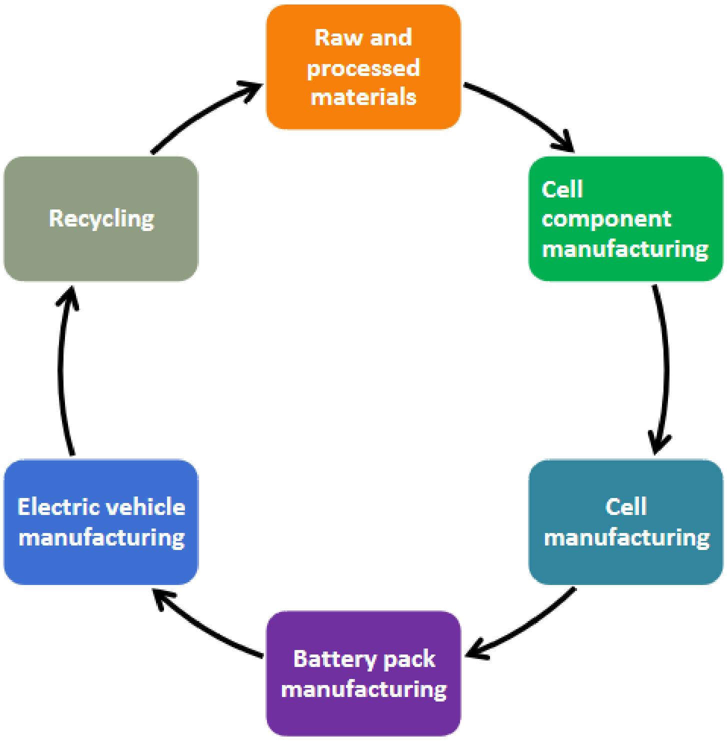


Figure 1.7: European Battery Alliance value chain cycle. Source: EU European Commission

According to the battery value chain cycle, to improve its capacity in technology and battery production, European alliance aims to:

✓ securing access to raw materials for batteries: creating a list of critical raw materials (CRMs) - subjected to a regular review and updating - with a high risk for their supply and of the great importance for the EU;
✓ supporting European battery cell manufacturing and other investments through the European Investment Bank or the IPCEI, the Important Projects of Common European interest. The first battery IPCEI was approved in 2019, the second at the beginning of 2021;
✓ strengthening industrial leadership through accelerated research and innovation programs: such as Horizon 2020, Batteries Europe, Horizon Europe,

Battery 2030+, funding programs to promote and support innovation, to build a low-carbon climate resilient future, thanks to new generation batteries;

✓ securing a highly skilled workforce along the whole value chain: launching projects which support local or regional initiatives aimed to training or reskilling workers in automotive sectors;

✓ supporting a sustainable EU battery cell manufacturing industry: proposing Battery Regulations.

In addition, the European Union is working on the "New EU regulatory framework for batteries Setting sustainability requirements" (European Parliament 2021). This specific European Parliament Research Service (EPRs) aims to empower producers about the entire life cycle of their products by introducing mandatory sustainability requirements (e.g. carbon footprint, minimum recycled content, performance and durability criteria), requirements related to the marketing and commissioning of batteries and requirements for end-of-life management and also due diligence obligations for economic operators on the sourcing of raw materials.

With the expansion of electric mobility, waste disposal and mineral recycling for electronics and batteries becomes increasingly important. The supply chain for metals and minerals must include the recycling process as an essential step in order to ensure a low-carbon economy. Extracting metals and minerals from products and infrastructures that are no longer in use could partly compensate for shortages in some raw materials. Therefore, considering the recycling of minerals (in particular cobalt and lithium) as a part of the circular economy could help overcome these and other challenges (International Institute for Sustainable Development 2019).

In March 2020, the European Commission presented the Action Plan for a New Circular Economy (Commission 2020), a production and consumption model focused on the re-use, reconditioning and recycling of materials, while also minimizing waste. The direction established in the Action Plan is an essential step that the European companies need to take in order to reduce the environmental impact while remainingn innovative and competitive on the global market. Due to the increase in the world's population and the growing need for raw materials supplies, some EU Members States continue to depend on other foreign countries. With a more sustainable production through the reuse of materials and the reduction of waste, European companies would achieve greater savings, while reducing total annual CO2 emissions. In this context, on 10 December 2020, the Commission points also to revisit the standards on vehicles, considered no longer sustainable, by proposing a new regulatory framework for batteries (COM.798.final 2020)- which are an essential source of energy in our society-focusing above all on those that have a lower carbon footprint and better respect human rights, as well as social and ecological standards, taking into account the sustainability and recovery requirements of the materials used and the security of theraw materials supply. Every year about 800,000 tons of vehicle batteries, 190,000 tons of industrial batteries and 160,000 tons of consumer batteries enter the European Union.

As not all of these batteries are collected and recycled correctly at the end of their life, it has become necessary to establish a regulation that ensures sustainability and safety throughout the life cycle of the batteries placed on the EU market. These products shall not only be as green as possible, using materials obtained in full compliance with social and ecological standards, but in addition they shall be durable for a long time period, be intended for a second life, regenerated or recycled everytime they can no longer be used for the purpose they were firstly created. The high amount of exhausted batteries and the still little advanced stage of recycling potential materialsaresource of considerable concern in the EU waste management. Actually, only about the 10% of the materials present in the batteries are recovered, according to the EESC’s opinion about the implementation of the Strategic Action Plan on Batteries defined in May 2018 by the European Commission (COM.176.final 2019). As the battery production sector has become a priority in the EU’s industrial policy, the European Economic and Social Committee states that, in the logic of a circular economy, a value chain approach shall be pertinent. It therefore considers the application of the IPCEI (Important Project of Common European Interest), adopted by the European Commission, a valuable aid instrument for the European industry concerned, through the granting of substantial public funding. The Committee stresses that these investments must go hand in hand with the combined effort of all the social partners, involved to achieve the technological skills needed to develop a more productive sustainability in the battery sector. Regarding the importance of recycling materials recovered from discarded batteries, the EECS states that urban mining can contribute to the construction of new batteries, thanks to the recovery of elements present in used products. In order to address the reduction of dependency on raw materials, the

EESC endorses and highlightthe importance of developing different types of batteries based on new advanced materials, asproposed by EBA by 2025, such as solid-state batteries which, unlike traditional lithium accumulators, have higher energy density, ensure more autonomy and allow to store electricity in a faster manner.

The Battery Regulation lays down specific requirements for each stage of the value chain and for each market segment (portable, industrial, automotive and electric vehicles). From the 1st July 2024, only rechargeable batteries will be allowed on the industrial and vehicle market, accompanied by a carbon footprint declaration. From the 1st January 2026, they must also be labelled to indicate, in addition to their lifetime and technical specifications, the requirement for separate collection and the presence of dangerous substances, including their carbon intensity performance class. From the 1st of July 2027, these labels will have to comply with the maximum thresholds for carbon footprint. From 2027, it will also be mandatory to declare the proportion of recycled cobalt, lead, lithium and nickel, considered as valuable materials. From 2030 the percentages will get higher: 12% for cobalt, 85% for lead, 4% for lithium and 4% for nickel. A third rise is expected from 2035: 20% cobalt, 10% lithium and 12% nickel. This will increase the efficiency targets of recycling processes and address to lithium technology a specific target. For all the storage devices, the existing restrictions on the use of hazardous substances, such as mercury and cadmium will remain. As reported in the Annexes which supplement the new regulatory framework and repeal the current EU Battery Directive, which dates back to 2006 (COM.789.final 2020), to the new rules will further strengthen the existing requirements for removability, requiring manufacturers to design equipment in order to easily remove storage systems. A new requirement for substitutability will also be introduced, whereby equipment shall continue to operate even by replacing batteries. In addition, with regard to safety measures for fixed storage systems, only those models considered safe after having passed certain tests, regardless their origin, will be placed on the EU market. This will be supported by a solid legal framework, providing regulatory requirements in terms of safety, performance, duration and re-use capacity for batteries to calculate their environmental footprint along the entire life-cycle. Moreover, to ensure an immediate and coordinated approach with the development of the newstandards, the EC collaborates with the European specific technical standardization bodies (CEN / CENELEC). For imported batteries, it will therefore be a duty for the distributor to ensure compliance with the requirements laid down in the regulation.

Although the EU is at the forefront of lead-acid batteries recycling process for the automobile sector, the proportion of recycled lithium is still lower. That's why the Commission proposes to increase the batteries recycling process for motor vehicles to 100%, both electric and non-electric, by introducing specific reporting requirements, especially for lithium batteries, and by facilitating the application of the established rules. In addition, binding targets on quantities are set out in order to regulate the recovery of materials, specifically for cobalt, copper, nickel, lead and lithium. Indeed, to be placed on the market, new batteries will need to contain minimum levels of recycled materials, thus contributing to circularity. Batteries for used electric vehicles, however, can be converted into fixed energy storage systems. Reconciling the lithium industry and sustainability through its extraction from the batteries already produced could therefore be a winning strategy for the challenges that the future expansion of electric mobility will present.

Moreover, at the end of 2020 the EU commission has introduced a new strategy comprising 82 initiatives, in order to turn the transports system towards a *smart, sustainable and resilient* mobility and achieve a 90% reduction in CO2 emissions by 2050, as stated in the European Green Deal. Alternative fuels, intelligent transport means and sustainable mobility constitute focal points. Taking into account the three key words of the strategy for a green transformation of European transports, as simplified in the figure below, the actions to achieve the three fixed objectives, could be grouped as follows:

- *sustainable Mobility*: to achieve a zero-emission mobility is necessary an irreversible transition, making all modes of transport more sustainable, together with the transport infrastructures (e.g. by installing 3 million public charging points by 2030), providing sustainable alternatives and encouraging demand from users);
- *smart mobility:* the digital transition should go together with the green one, through the integration of intelligent transport systems (ITS), taking the opportunity to create connected and automated multimodal mobility;
- *resilient mobility:* being the transport sector, along with that of travel and tourism, among the most affected by the containment measures imposed by the

pandemic COVID-19, the Single Transport Market must be strengthened and become accessible to all citizens and companies, to not leave anyone behind, and it must be resilient to future crises and security challenges.

1.4 Cities (r)evolution

Cities play a key role in the energy transition, starting by their ecological impact. They are responsible for about three-quarters of global final energy consumption and global energy-related CO2 emissions. With a view to an ever-growing share of the world's urban population, regional and national governments have the task of financing and making more and more viable projects to complete their transition from fossil fuels.

Transport sector is crucial for an effective energy transition process. More than a dozen European countries plan to eliminate cars with internal-combustion engines by 2035 and 2040. California has adopted a law according to which all trucks in the United States must be emission-free by 2045. Although oil consumption continues to be high, all vehicle production goes towards the electrical. The technologies used for this transformation are constantly improving and increasingly economic. The cost of batteries already reduced by 90% in ten years and the chances of converting them to store energy or recycle them once exhausted is one of the possible example.

Cities are responding to this emergency by implementing initiatives to reduce traffic, with the rise of pedestrian and greener areas, promoting active mobility on foot or by bicycle, banning the use of petrol and diesel cars, mainly by 2030 and 2040. In many cities this is already becoming a reality. As an example, in metropolises like Barcelona and Bogota the sale of electric bicycles is growing exponentially thanks to the opening of new spaces for cycle paths for commuters. Paris is one of the first to experience the so called "city from 15 minutes", organizing a path to meet all the essential needing within walking distance or by bike in a 15 minutes route.

As established in the Clean Air Action Plan (Municipality of Amsterdam 2019), Amsterdam has planned to achieve the target of zero emissions by 2030, in three stages: buses and couriers and in general travelling from the center outwards, will be emission-free by 2022; extend the commitment to all public and commercial traffic by 2025; let all the transport, including private cars and motorcycles, be emission-free by 2030.

The REN21 report (REN21 2021) notes an increase in renewable targets and a greater citizens participation in the last period. Also, the commitment is more active in creating market opportunities for renewable energy at local level. Moreover, as reported by the statistics the governments of 834 cities in 72 countries have adopted a renewable energy target in at least one sector, for a total of about 1,100 targets. Of these, over 610 cities have set targets for 100% renewable energy, both for buildings or public property and for the entire city.

In support of an increasingly awareness on climate changes, projects such as the C4ET (Citizens for Energy Transition) funded by the European Commission, aim to raise awareness and orient adult citizens towards sustainable practices and behaviors. The C4ET, started in 2015, realized in 6 countries of the European Union (Croatia, France, Belgium, Italy, Hungary and Germany), is supported by the Erasmus+ program of the European Commission and coordinated by the non-profit association ENERGIES 2050. Through a pedagogical and interactive training program, the project aims to inform those who are still unaware of the benefits and opportunities of the energy transition and to induce individual consumers, aspart of wider groups, to take sustainable actions.

From a first analysis on the state of the art, the importance of influencing the attitudes of every citizen is relevant in a 360 degrees approach and involving the home and work routine, in the living areas, whether urban or rural, and also involving the political and economic life, so that the overall approach can generate a greater impetus to the achievement of a global energy transition. In this regard, the program highlights six main starting-themes as following:

1. Climate change and energy (one of the biggest challenges we face today, linked to our consumption patterns and our energy systems, mostly dependent on fossil

fuels. We should therefore limit their use, preserving at least 2/3 of the current reserves).

2.Connecting both home and working life with regard to energy transition (companies' energy and resource management systems should raise awareness among workers by highlighting sustainable best practices, to continue to adopt them in their home lives).

3. Citizen-driven circular economy in the “built” environment (a circular economy that can reduce the environmental impact of materials and energy used for the renovation or maintenance of the houses, limiting their waste and making the best use of renewable resources).

4. Involvement of citizens in the energy transition policies (the importance of involving citizens from an early stage in policy development processes for the energy transition in order to increase their knowledge of this subject).

5. Rural people towards energy transition (the necessity to create new opportunities for the development of renewable energy in rural areas, through technological and social innovations, gradual changes involving citizens from the bottom up, also generating new jobs).

6. The way citizens may influence companies to behave in a more eco-friendly way(workers can support the transition by taking more environmentally friendly decisions, influencing in this way at the same time the behaviour of the companies globally) (Energies2050 and C4ET 2016).

The C4ET, according to the “Transtheoretical Model” (La Morte 2019) (also known as the Stages of Change Model), developed by Prochaska and DiClemente in the late 1970s, identifies five stages for changing citizens' behavior, on the basis of their knowledge on the subject of energy transition, in all areas in which they may be involved:

1. pre-contemplation phase: in which are recognized people unaware of the problem. Purpose: to instill awareness to change their opinion;

2. phase of contemplation: where there is already awareness and desire to change. Purpose: to stimulate them;

3. preparation phase: persons ready to act. Purpose: to train them;

4. action phase: persons who put into practice the desired behaviours and practices. Purpose: to facilitate the implementation;

5. maintenance phase: people accustomed to good practice. Purpose: to strengthen the implementation.

To be able to implement the change, it will therefore be necessary first of all to make European citizens aware of their carbon footprint as well as making them aware of all the appropriate information needed to reach an effective transition, by providing a clear framework (through interactive tools) on possible economic and social developments, including new job opportunities, in order to build more equitable and resilient societies. In this sense, every individual will become aware of the needing to improve their habits, starting from everyday life and to the workplace and then being ready to participate actively and have decision-making power in the political field.

Although most of the renewable energy targets are recorded in North America and Europe followed by Asia, they have slightly increased in all regions of the world. Nevertheless, still much is needed to be improved. For example, although good results have been achieved in cities with regard to renewable energy in the electricity sector in Europe and in the United States, the growth is still slow in terms of targets for heating and cooling from renewable sources in residential areas and for the decarbonization of transportation.

In the transport sector, there are at least 67 cities with e-mobility intentions in force in 2020, up from the 54 in 2019. However, there are still few cities that have taken e-mobility as an opportunity to increase the share of renewable energy. In order to improve air pollution and reduce congestion and noise, thus also protecting public health, city governments have made progress in decarbonizing municipal transport fleets and mobility infrastructure and subsidizing the use of renewable electricity to recharge electric vehicles. Low-emission zones and bans have been established for certain fuels or vehicles; walking and cycling infrastructure are improved to reduce the need to use individual motorized transports and promote movement by bus, trams and subways which use renewable energy.

Municipal governments use participatory governance to include citizens in urban planning processes. More and more people, in fact, choose to buy renewable electricity and thermal energy. Many municipal governments also cooperate at regional level or become global partners. In the United Kingdom, around 100 local governments wish to move to 100% clean energy by 2050. Between 2019 and 2020, many initiatives have involved local governments, in collaboration with city networks, in energy and climate action. The *Global Covenant of Mayors for Climate & Energy*, the *Covenant of Mayors for Sub-Saharan Africa*, the *Mayors for Climate*, *Race to Zero*, the *Sierra Club's Ready for 100*, just to mention a few of these global coalitions of cities and local governments.

To emphasize the importance of the cities in national economies for a global energy transition is a new report recently published by IRENA (International Renewable Energy Agency 2021).

Consideringthat urban centers will welcome around two-thirds of the world's population in 2050, accelerating local renewable energy production could strengthen the urban economy by reducing GHG and creating new jobs, thus helping to improve people's living conditions and well-being.

Big cities offer more opportunities to develop climate-resistant future infrastructures, not only increasing the efficiency and electrification of buildings through the integration of high shares of solar and wind energy, but also by enhancing smart grids related to electric vehicles and energy storage. However, the report also presents case studies of small and medium-sized virtuous cities for sustainable strategies and the use of renewables that they have put in place.

The attention seems therefore more and more focused on the importance of coordination between local and national governments, businesses and citizens. An interesting case is, for example, Guanacaste in Costa Rica, where local government is investing in projects to support e-mobility, increasing charging infrastructure and providing incentives to purchase electric vehicles.

Costa Rica is one of the countries with the highest percentage of renewable energy sources used in energy production and transport, for different reasons. Almost the 99% of electricity comes from renewable sources and most of the country has a reserve power supply. In addition, unlike many European cities, most private homes and other buildings have a garage, where most of the EV charging can be placed. The fact that Costa Rica is a small country where the average travel distance is 35 km per day, limits the need of road charging policy for long journeys, but above all, it allows to use electric cars with short range for daily driving needs within cities. Finally, the average country temperature is 24.7°C, an optimal temperature for the function of electric vehicles. Based on the example of Norwegian e-mobility, the government presented a special "green plate" in February 2019. This simplifies the distinction of100% of electric cars from the petrol and diesel ones and offers some added benefits, as free parking and no driving restrictions. Among the various support measures of the current government, there is the extension of the EV incentives beyond the five years provided by the current law. It is also hoped that the sale of cars with internal combustion engines will be halted by 2025, while at the same time implementing charging structures for electric cars. With regard to public transport, it is expected that 100% of buses and taxis will be emission-free by 2050, as well as trains. This will encourage people to replace private cars as their first option of mobility, thereby improving the quality of life. Two years after the presentation of the National Plan of Decarbonization, despite the health emergency generated by COVID-19 has presented great challenges to achieve the objectives set, the progress in the transport sector therefore remain firm and constant.

However, the small size of Costa Rica leads the country to still have a highly centralized governance structure, both for energy and for transport. Although central govrnament recognizes the importance of involving and making municipalities more responsible for mobility and urban planning, cities play a rather marginal role in making energy and transport decisions. They have the capacity to act only on matters related to cycle paths and shared transport systems.

The decarbonization plan, up to 2050, offers a real opportunity to review the direction of cities in formulating proposals and involving implementation of possible solutions in short, medium and long-term, though the current level of centralization may be an obstacle to its achieving. Given the country's large share of renewable energy, the integration of electronic mobility interfaces with the importance of ecotourism for the economy. It is necessary to offer new experiences and valuable proposals and zero-emission tourist experiences, opening up a new space for projects in which municipalities can engage and perhaps even propose new plans. The debate on how to involve local governments and stakeholders is still ongoing.

Taking as an example the city of Guanacaste, considered the "renewable energy capital" of Costa Rica, it has welcomed several pioneering projects in the wind, solar and geothermal sectors. In 2018 Coopeguanacaste (a local independent electrification cooperative) installed the first EV charger in the province to attract EV users to this popular tourist destination. The cooperative, which sells electricity and wants to develop new business opportunities around electric mobility, has installed many other chargers thenceforth. In a country where energy and transport decisions are centralized, Guanacaste developments suggest that a multi-stakeholder's collaboration could help open up new ways to reach renewable energy and clean transport targets, not only in Costa Rica, but everywhere. Learning from other countries and cities with successful policies becomes, in this context, essential, and will encourage the avoidance of mistakes and the acquisition of new knowledge about these emerging programs.

Despite the shared goal of a safe and affordable energy supply, each city has its own needs and capabilities to achieve the goal. There are several factors to consider, some of which are difficult to modify. For example, climate, which determines the heating or cooling needs of a city. The demographic settlement sometimes not adequately proportional to the infrastructures could be resolved only over time. Naturally, the richest cities have more freedom of action than the poorest. Some cities have more power to make decisions on how to invest their income streams or they do not have the technical know-how to manage their resources. All these factors may interact and determine the roles that cities can play in the energy transition not only as energy clients but also by becoming funders and facilitators of new initiatives and committing to become regulators and project planners.

While cities and their inhabitants become more aware of the need to seek increasingly sustainable solutions to climate change, new networks of action plans are focusing on these objectives, such as C40, a global network of 97 megacities committed to respond to the climate crisis for a healthier and more sustainable future, in order toimprove the resilience and the equity of the cities, within a decade and extending these practices all around the world. Three of the strategic financiers engaged to reach the goal of this Global Green New Deal are Bloomberg Philanthropies, Children's Investment Fund Foundation (CIFF) and Realdania. The coordinator of nearly 100 mayors involved in the network is the current mayor of Los Angeles Eric Garcetti, assisted by the President of the Board Michael R. Bloomberg (three times mayor of New York). Committed to promoting equity, inclusion and equal opportunities, the C40's Annual Report 2020 offers free advices on best climate actions in apeer-to-peer, which means that a successful policy undertaken by a city sets a new standard for other cities to follow, even if in different contexts (C40 2020). The climate crisis, exacerbated by the Covid-19 pandemic, has pushed major city leaders to a further effort for a green and fair recovery. More than 40 cities made up the Global Mayors COVID-19 Recovery Task Force to address the immediate challenges of the pandemic, but also to ensure a just transition to a long-term inclusive economy.

Nine of the principles that the Task Force shared in the Agenda 2020 of the C40, to guide in the right direction the mayors in the green transformation of our cities, in terms of a Global Green New Deal are listed in the following image.

C40 Mayors' Agenda for a Green and Just Recovery

1. **The recovery should not be a return to 'business as usual'** - because that is a world on track for 3°C or more of over-heating;
2. **The recovery, above all, must be guided by an adherence to public health and scientific expertise**, in order to assure the safety of those who live in our cities;
3. **Excellent public services, public investment and increased community resilience will form the most effective basis for the recovery;**
4. **The recovery must address issues of equity that have been laid bare by the impact of the crisis –** for example, workers who are now recognised as essential should be celebrated and compensated accordingly and policies must support people living in informal settlements;
5. **The recovery must improve the resilience of our cities and communities**. Therefore, investments should be made to protect against future threats – including the climate crisis – and to support those people impacted by climate and health risks;
6. **Climate action can help accelerate economic recovery and enhance social equity,** through the **use of new technologies and the creation of new industries and new jobs.** These will drive wider benefits for our residents, workers, students, businesses and visitors;
7. **We commit to doing everything in our power and the power of our city governments to ensure that the recovery from COVID-19 is healthy, equitable and sustainable**;
8. **We commit to using our collective voices and individual actions to ensure that national governments support both cities and the investments needed in cities**, to deliver an economic recovery that is healthy, equitable and sustainable;
9. **We commit to using our collective voices and individual actions to ensure that international and regional institutions invest directly in cities** to support a healthy, equitable and sustainable recovery.

Figure 1.8: Task Force's Principles for a Green and Just Recovery. Source: C40 Cities (2020) Mayors Agenda (C40 COVID-19 task force 2020)

An innovative approach, incorporated into several projects of local governance and urban transformation, is the concept of the "city of 15 minutes" in 2015 by Carlos Moreno[1]. Moreno offers a concept of city that goes in the opposite direction to modern urban planning, proposing a sustainable urban planning based proximity, so as to reduce travel by car to favor those by bike or on foot. In a recent interview[2] that appeared in September 2021 in Revolve, a magazine dedicated to sustainability, Moreno reiterated the ideas behind this concept, which aim at the same time to rebalance urban inequalities. The recent effects of the COVID-19 pandemic further encourage the adoption of this concept. A plan to reduce the greenhouse gas emissions of cities but maintaining a social perspective.

The key actions for cities are divided into three categories.

1. Inclusive work and economy (supporting essential workers and promoting training and updates in order that jobs may be green and directed to a just transition.

2. Resilience and equity (offering a secure and resilient post-Covid-19 mass transport system for everyone).

3. Health and well-being (developing "15-minute cities" to give back streets to people and create more green spaces) (C40 COVID-19 task force 2020).

According to Moreno'concept, to reach the well-being and reestablish a climate balance, we should rethink cities according to four guiding principles, namely:

- Ecology: for a green and sustainable city;
- Proximity: to reduce distance in the various daily activities;
- Solidarity: creating links between people;
- Participation: involve citizens in the transformation of their neighbourhood in an active way, so that everyone has access to essential services in the immediate proximity, sharing spaces.

The development of new services for each neighbourhood, as well as economically favouring local shops, would encourage the transformation of the infrastructures, in order to allocate them to multiple uses. Conceived in this way, the "city of 15 minutes" would

[1] Scientific Director of the ETI Chair, IAE Paris, Panthéon Sorbonne University
[2] https://revolve.media/the-15-minute-city-from-forced-to-chosen-mobility/

be a space to live enjoying green spaces and working without the need to move constantly, greatly reducing traffic and its effect on the climate.

At the moment, the best practice examples which adopted the concept of the "15-minutes city", according to the Agenda C40 Cities 2020, are the following.

- Milan, that in response to the recovery post-Covid-19, has reopened all its street markets safely, created 35 kilometers of new bike paths, and made pedestrian several streets in the vicinity of schools. To reduce traffic, the mayor of Milan together with the business leaders are also discussing how to encourage teleworking and smartworking.
- Paris, which promotes the use of existing services, by inviting to use places used for work in standard hours, for non-work activities, such as clubs that could serve as gyms during the day or use schools as playgrounds on weekends. By restricting the circulation of cars near schools, Mayor Hidalgo favors the use of bicycles and walks. She also encourages distance work, so that people can work safely near or at home.
- Portland, which has been working since 2012 to create complete and inclusive neighborhoods. Its Climate Action Plan provides that by 2030 the 90% of residents can benefit of the main commercial and public services, recreational facilities and the access to reliable and frequent transport. Portland, in addition, has already turned over 90 miles of traffic streets into neighborhood green streets.

To achieve a green and a right recovery and to return people to the streets, the mayors will need to be assisted by regional and national governments and the central banks, which will undertake to secure funds for economic recovery, investing in the future and helping to create more prosperous, equal and sustainable societies. This financial support should always be distributed in accordance with the scientific emission reduction targets and the transition plans in line with the objectives of the Paris Agreement. Prioritizing investments in clean energy, moving further away from those in high-carbon fossil fuels, and investing in resilient cities as engines of recovery, also allowing the creation of new green jobs, will help support a more prosperous urban, national and global economy.

Knowledge Hubs have also been established in Europe, enabling the exchange of experience and best practices between European cities, such as the URBACT

Action Planning Networks. The European territorial cooperation program, co-financed by the European Regional Development Fund, the 28 Member States, Switzerland and Norway, has been presented in 2002. The project, which is now operating for more than 15 years, has enabled cities to network and ensured that decision-makers at European, national, regional and local level interact and share know-how on sustainable urban development aspects, in order to improve urban policies. The latest update of the URBACT III program manual was approved by the Monitoring Committee in March 2021.

One of the most important challenges for European cities is the mobility planning as a key element for a sustainable urban development, farther the efficiency of transport systems, reducing traffic congestion and consequently greenhouse gas emissions. Although every city has these kinds of problems, the local background is deeply diversified. To enable cities to interact and to create joint visions and common measures for their progress, the European Union has adopted new approaches of sustainable planning of the transports in an urban area, with the aid of a Coordination Group that includes experts from all Europe, co-funding plans and platforms that involve the stakeholders closely, raising their awareness. A successful implementation of the measures is strongly linked to good communication with stakeholders and citizens concerned.

As an example, *Civitas* is a network launched by the European Commission in 2002. Its initiative is to bring cleaner and better transport to cities. *Civitas*, through its projects, offers the opportunity to learn and/ or implement innovative and sustainable transport solutions and to compare their experiences with experts in the field.

The *CityMobilNet* project, funded through the URBACT programme, brought together 11 European cities to help them create their own SUMP (Sustainable Urban Mobility Plan) (Rupprecht consult - Forschung & Beratung GmbH 2019). The European Commission firmly believes that European cities, large or small, should embrace this concept, in order to greatly improve their quality of life. The main objective of a SUMP is to improve accessibility through sustainable mobility and transport in urban areas (Polis and Rupprecht Consult 2019).

The *Eltis* platform, funded by the "Mobility and Transport" of the European Commission, facilitates this exchange of information, experiences and good practices in the field of sustainable urban mobility, between the project's partner cities. The section dedicated to Mobility Plans provides information and guidelines to support urban mobility professionals in their work, through an annual conference, each time in a different European country.

The European Commission has also suggested a set of Sustainable Urban Mobility Indicators (SUMI), useful for cities to document and identify the pros and cons of their adopted mobility system and to understand what to improve. The SUMI Benchmarking Tool Set of Indicators shall be divided between core and non-core indicators:

European Commission Sustainable Urban Mobility Indicators (SUMI)

Core indicators

- 1. Affordability of public transport for the poorest group
- 2. Accessibility of public transport for mobility-impaired group
- 3. Air pollutant emissions
- 4. Noise hindrance
- 5. Road deaths
- 6. Access to mobility services
- 7. Greenhouse gas emissions
- 8. Congestion and delays
- 9. Energy efficiency
- 10. Opportunity for Active Mobility
- 11. Multimodal integration
- 12. Satisfaction with public transport
- 13. Traffic safety active modes

Non-core indicators

- 1. Quality of public spaces
- 2. Urban functional diversity
- 3. Commuting travel time
- 4. Mobility space usage
- 5. Security

Figure 1.9: Source: Clean transport, Urban transport. Sustainable Urban Mobility Indicators (SUMI) https://ec.europa.eu/transport/themes/urban/urban_mobility/sumi_en

The differentiation between the indicators outlines are considered strategically relevant bythe European Commission. However, although from 2017 to 2020, 46 cities voluntarily collaborated on the SUMI project through the compilation of hundreds of spreadsheets for each indicator, no individual score was made public. The benchmarking tool provides only the minimum, average and maximum score for each indicator, without specifying to which city the result belong. Therefore, the data will only be a tool to better understand the overall situation regarding sustainable urban mobility in Europe, by using various strategies.

Unlike traditional planning approaches, SUMPs pay particular attention not only to the involvement of citizens and stakeholders, but also to the coordination of policies between sectors (transport, energy, environment, health and safety, economic development, etc.) and cooperation between government and private players. In order for a Sustainable Urban Mobility Plan to be efficient, it is necessary to address transport problems in urban areas (public and private, passengers and goods, motorised and non-motorised) with a long-term vision containing a strategy that includesg implementation programs and related budgetary plans aimed at achieving the objectives and at the same time encouraging the transition to a more sustainable way of transport. Also, this should be accompanied by reliable monitoring and evaluation, through accessible data and statistics, to inform citizens and stakeholders about their SUMP progress and developments.

A Sustainable Urban Mobility Plan, is specifically based on the eight following principles:

Figure 1.10: The Urban Mobility Package (2013) Sustainable Urban Mobility Plans (SUMPs) concept as follow up of different stakeholders exchange. Source: https://www.eltis.org/mobility-plans/sump-concept

The publication of a second edition of the "European Guidelines for Developing and Implementing a Sustainable Urban Mobility Plan" has been drafted from the need to enrich a first edition inside the Urban Mobility Package published by EU at the end of 2013 (COM (2013-913 final), by integrating all cities developments and the experiences, and to provide a customized support to meet the practical needs of planners and policymakers all over Europe. This compendium (Rupprecht consult - Forschung & Beratung GmbH 2019) is made up of "Guides", which offer comprehensive planning recommendations on consolidated topics, and of "Briefings", less complex documents facing emerging themes with a higher level of uncertainty. Further, it is a support for the planning e-mobility authorities to find solutions as an integral part of a SUMP process. The guide is accompanied by several Annex (Developing, Urban, and Plan, n.d.) which include a glossary of important terms, a checklist for a SUMP process, examples of good practice, guidance on SUMP specific topics and an experts consulted list.

By comparing Traditional Transport Planning and the concept of a Sustainable Urban Mobility Planning, new aspects have been taken into account. As examples, the previous focus on traffic was shifted on people and the consequent accessibility and quality of life; the short and medium-term delivery plan was incorporated in a long-term vision and strategy; the exclusively involvement of experts in planning has been extended to include citizens and stakeholders, thanks to a participatory approach; the limited impact assessment was replaced by systematic evaluation ones, to facilitate the planners in learning and improvements (Rupprecht Consult, Guidelines, Second Edition 2019). These helps the Sumps to be seen as an effective tool for successful change, inspiring new ways of thinking. To simplify the complexity of the implementation of a sustainable urban mobility plan, it has been drafted a "SUMP cycle" (see Figure below), that is a visual representation aiming to help in the process of the developing the plan. This has been adopted not only in many urban areas in Europe, but also globally.

Figure 1.11: The 12 Steps of Sustainable Urban Mobility Planning (2nd Edition) – A planner's overview. Source ELTIS

The SUMP cycle consists of four phases, each of which start and end with a milestone. The four phases made up of twelve steps, furtherly subdivided into 32 activities. The metaphor of a clock face, used to make this set of steps, shows how should be a regular planning cycle within a process of continuous improvement.

In the first version of the 2013 SUMP guidelines, e-mobility had not been dealtto yet due to its most recent development. Anyways, the fact that today it involves every kind of the transports of people and freight, both public and private, has induced the EU commission to think the e-mobility like integral part of a plan of urban mobility, also to decrease the harmful emissions of air pollution. A topic guide (Polis and Rupprecht Consult 2019), drawn up within the SUMPs-Up context, funded under the European Union’s Horizon 2020 Research and Innovation program, collecting information on how to electrify transport successfully in the framework of a Sustainable Urban Mobility Plan, in accordance with the eight main principles of SUMP and following the different stages of the SUMP cycle, in support of the planning authorities. Basically, the project states that to replace diesel and petrol vehicles with their electric equivalents it is not enough to reach the targets. The guide offers a wider view that includes planning for charging infrastructure, for the electrification of different types of fleet and vehicles, guidance on the regulatory and policy measures that can be implemented by mobility planning authorities to support and incentive the EV users. The guide also provides tools and methods in support of the planners and a selection of good practices coming from major European cities on e-mobility.

1.5 Horizon Europe: the world's largest transnational R&I programme

The next long-term EU budget will run for seven years from 2021 to 2027 and will invest substantially in climate- and environment-related objectives. To achieve the climate objectives, the European Commission has set a target of at least 25% of its total to contribute to climate action across multiple programs.

The Multiannual Financial Framework (MFF) 2021-2027 - adopted in December 2020 - provides a total budget of 1074.3 billion euros (in 2018 prices), in addition to the 750 billion euros of the Next Generation EU recovery instrument. The total package of 1824.3 billion is complemented by 15 billion in additional funding agreed by the European Parliament.

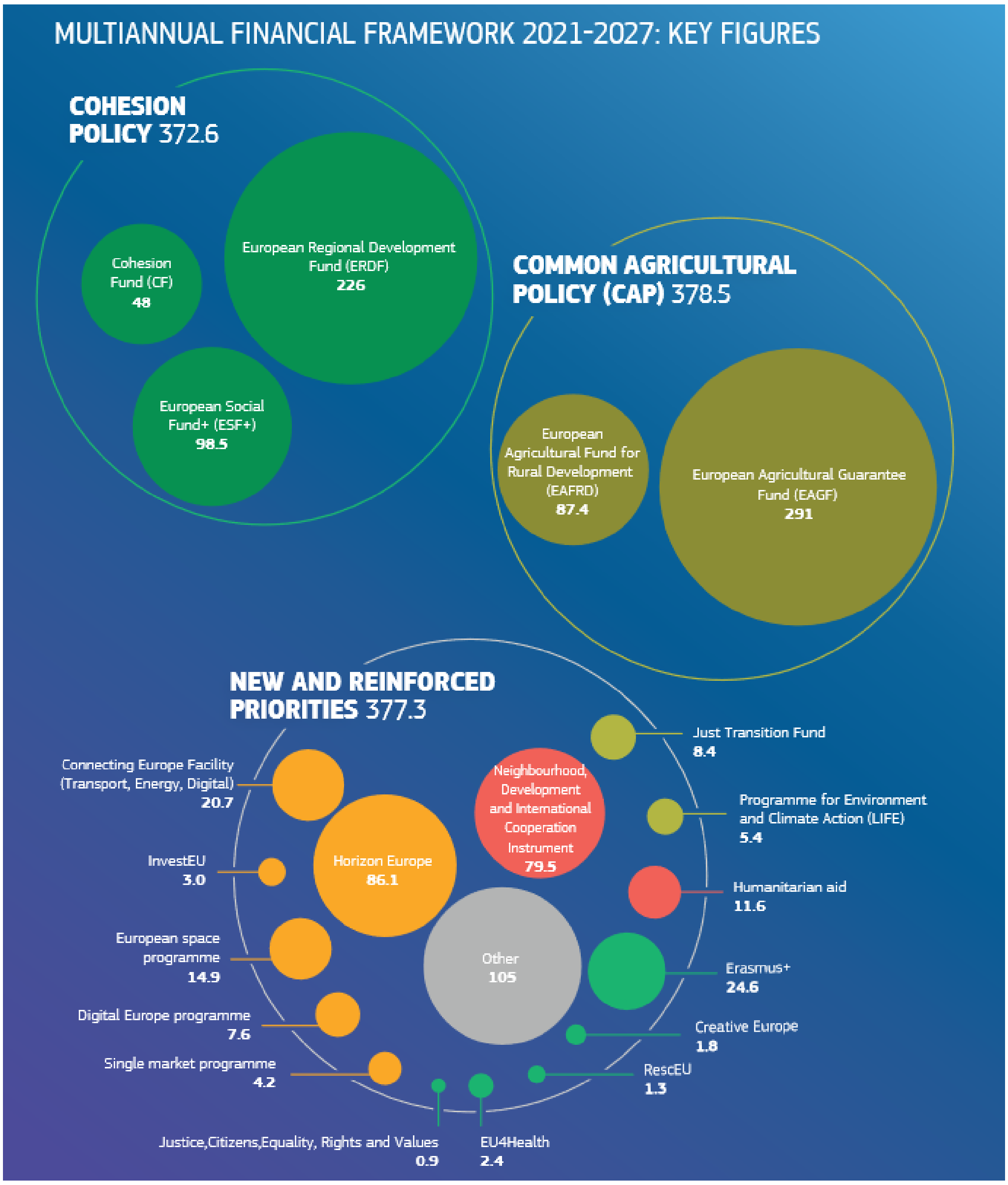


Figure 1.12: Multiannual Financial Framework 2021-2027 - Key Figure. The Eu's 2021-2027 Long-Term Budget & Next Generation Eu. Source European Commission.

The MFF covers seven spending chapters and provides the framework for funding 37 European programs for the years 2021 to 2027.

With the main objective of achieving scientific, technological, economic and social impact from EU investments in research and development, Horizon Europe, with a budget of €95.5 billion, is the world's largest transnational research and innovation program. The program will run for the period 2021-2027 and aims to consolidate some of the objectives set in the previous research and development program of the European Commission (Horizon 2020 -period 2014-2020), with new challenges and priorities that will implement policy and macro strategic guidelines, focusing on objectives and activities that cannot be effectively achieved by individual Member States.

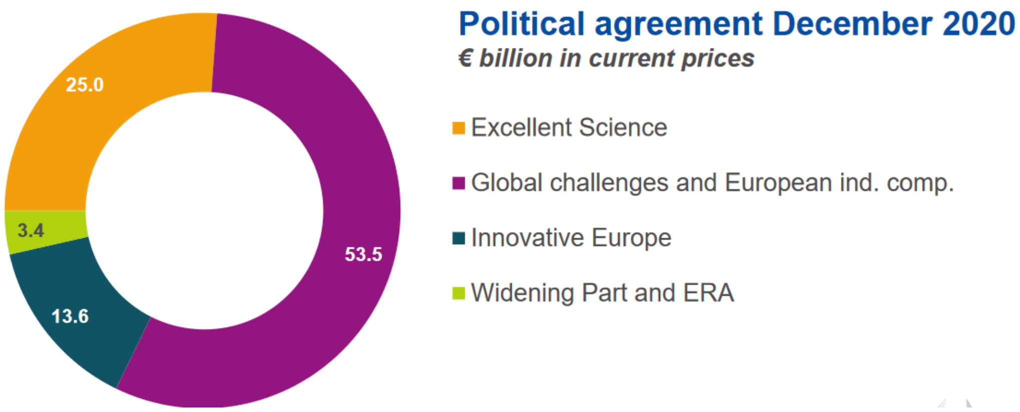


Figure 1.13: The Horizon Europe programme is structured in 3 pillars. Source European Commission.

Pillar I – "EXCELLENT SCIENCE" . The first pillar is worth a total of around 25 billion euros, or 26% of the total budget of the Framework Program. It aims to reinforce the Union's science excellence by attracting the best talent to Europe and provides appropriate support for early-stage researchers in Europe.

The pilar main initiatives are:

- European Research Council with a total of €16 billion euro to support the frontier research;

- Marie Skłodowska Curie Actions supporting new knowledge and skills through mobility and training. That actions foreseen a total of €6.6 billion euro dedicated;
- World-class research integrated infrastructures with €2.4 billion euro.

The main characteristic of the pillar is to have a bottom-up approach: it is up to the researcher or the consortium to defines the priorities and objectives of the project. The capacity to respond to European needs and requirements is obviously taken into account in the evaluation.

Pillar 2 – "Global Challenges and European Industrial Competitiveness"- which brings together the second and third pillars of Horizon 2020 ('Industrial Leadership' and 'Societal Challenges'). The second pillar is worth a total of around 53.5 billion euros and the 56% of the total budget of the Framework Programme. It aims to tackle global challenges (including climate change and the Sustainable Development Goals) and supporting industrial competitiveness (notably in SMEs) by implementing EU policies. This pillar has an impact-driven and top-down (topics are predefined) approach: have to be targeted impact on society, economy and science, but it is up to the applicants how to implement this on the proposals.

Pillar III – "Innovative Europe", a new novelty in the new Framework Program, with a budget of €10.6 billion which is just over 14% of the total budget of the Framework Programme. It aims to stimulate market-creating breakthroughs and ecosystems with a strong emphasis on innovation and where possible, by connecting regional and national innovation actors.

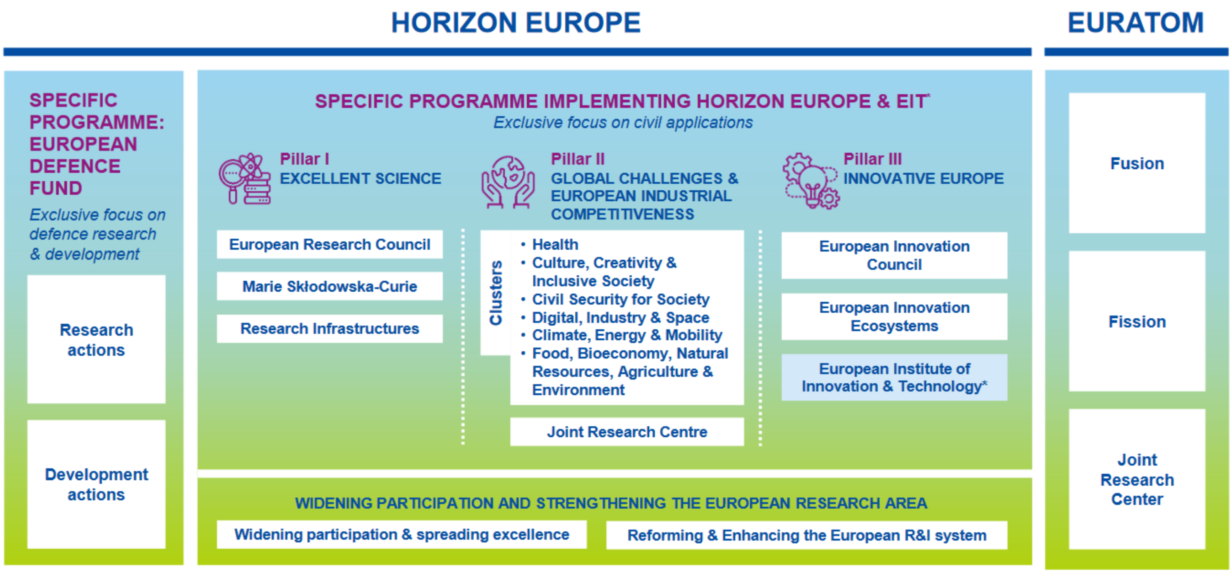


Figure 1.14: Horizon Europe (Research and Innovation European Framework Programme) and the 3-pillar structure. The Pillars for the 2021-2017 (Pillar I – Excellent Science, Pillar II – Global Challenges and European Industrial Competitiveness, Pillar III – Innovative Europe). Source: European Commission Horizon Europe infodays

Horizon Europe main goals are:

- strengthen the Union's scientific and technological foundations and promote member state competitiveness;
- implementing the Union's strategic priorities to address the global challenges set out in the Sustainable Development Goals (SDGs) of the United Nations 2030 Agenda and the Paris Climate Agreement;
- strengthening the European Research Area.

These goals will be implemented and achieved via a specific road map:

- a Legal base: which will cover the entire 7-year period (2021-2027)
- the 2021-2024 Strategic Plan: It defines the strategic guidelines for the Union's research and innovation investments over the period 2021-24:
    - EU policy priorities Defined for the EU

- Key Strategic Orientations for R&I Defined at Horizon Europe programme level
- Expected impacts defined at cluster level

- the Work programme - 2021-2022: the biennial documents adopted by the Commission for the implementation of the specific program. They include calls for proposals, topics and budget allocated to each topic.

The EU's main key-point is to support a sustainable, fair and prosperous future for people and planet based on European values by:

- Tackling climate change;
- Helping to achieve Sustainable Development Goals;
- Boosting the Union's competitiveness and growth;
- Implementing EU policies while tackling global challenges and facilitating collaboration within and outside Europe;
- Creating jobs and supporting EU's talents;
- Boosts economic growth and promote industrial competitiveness and investments.

In order to increase the effectiveness of European funding in pursuing global objectives and challenges, the program has foreseen the launch of "missions" on research and innovation. Each action has its own policy measures and legislative initiatives that will be pursued through research projects and ad hoc actions. These projects and ad hoc actions will aim to:

- to mobilize additional resources at European, national and local levels;
- to activate a virtuous process of interdisciplinary contamination, linking activities between different disciplines and types of research and innovation;
- to enhance citizens' understanding of the real value of European R&I investments.

Following, the reason why EU support R&I on climate, energy, and transport sector in a nutshell (taken from EU official web site):

WHY EU supports R&I on climate

- R&I investments play a crucial role in achieving the goals related to the two most urgent global challenges: climate change (To limit warming to 1.5°C) and digitalization. Urgent therefore is to meet the commitments of the Paris COP21 agreement and align with the EU's broader transport, climate and energy goals. Clean hydrogen can play a key role in long-term energy storage.

WHY EU supports R&I in energy

- Energy is currently responsible for more than 75% of the EU's greenhouse gas emissions. Boosting renewable energy sources significantly and improving the energy efficiency of the entire renewable energy value chain are essential elements of the transition to climate neutrality by 2050. A transition that must be just, inclusive, affordable, safe and secure. In this context, central investments in R&I are essential to drive the industry to develop new and disruptive renewable energy technologies and innovative energy storage solutions.

WHY EU supports R&I in transport

- The transport system must respond to the major environmental challenges of our time by drastically reducing its impact on the climate and the environment. The EU Commission has adopted STRIA - EU's Strategic Transport Research and Innovation Agenda - that defines the 7 priority areas of intervention of the EU and Member States in order to radically change the world of transport, which are: electrification, alternative fuels, vehicle design and manufacturing, connected and automated, transport, infrastructure, network and traffic management systems, smart mobility and services.

1.5.1 Cluster 5 "Climate, energy and mobility"

Horizon Europe will provides many opportunities in the field of climate and environment mainly (not only) under the Cluster 5 "Climate, energy and mobility".

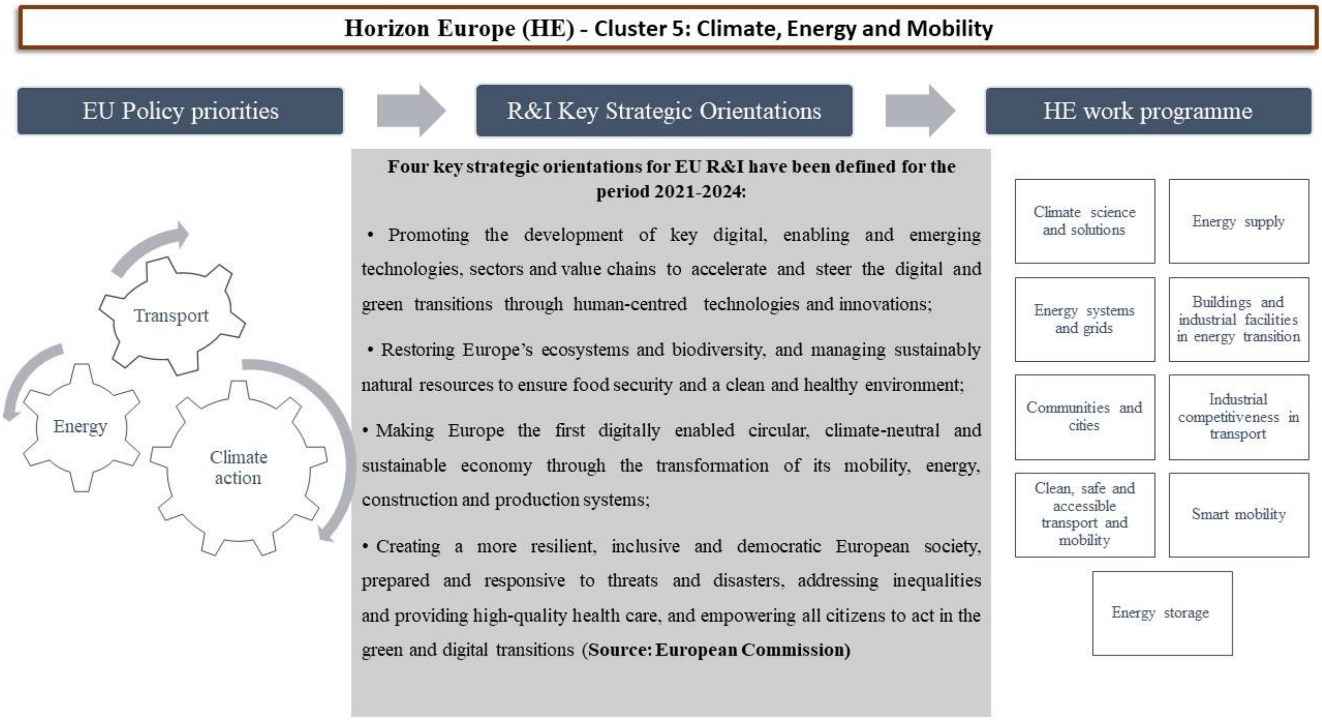


Figure 1.15: Cluster 5 “Climate, energy and mobility” impacts and areas. Source: author elaboration based on EU documents.

The actions funded under this cluster will aim to accelerate the EU’s dual green and digital transition in line to the Paris Agreements and the Sustainable Development Goals by (manly):

- understanding climate change causes, evolution, risks, impacts and opportunities;
- making the energy and transport sectors more climate and environment-friendly (more efficient competitive, smarter, safer and resilient).

The expected impacts of this cluster are contained in the Horizon Europe strategic plan with specific areas of intervention:

- climate science and solutions;
- energy supply;

- energy systems and grids;
- buildings and industrial facilities in energy transition;
- communities and cities;
- industrial competitiveness in transport;
- clean, safe and accessible transport and mobility;
- smart mobility;
- energy storage.

With a total budget of €15.35 billion, the cluster is divided into six 'destinations' (Figure 1.16), the first four of which are related to climate and energy.

CL5 Work Programme 2021-2022 - budget distribution per destination

Destination	Number of topics	Budget mln EUR	% Share
D1 Climate sciences and responses for the transformation towards climate neutrality	17	274	9%
D2 Cross-sectoral solutions for the climate transition	27	388,5	13%
D3 Sustainable, secure and competitive energy supply	67	1.226,30	40%
D4 Efficient, sustainable and inclusive energy use	18	244	8%
D5 Clean and competitive solutions for all transport modes	31	511	17%
D6 Safe, Resilient Transport and Smart Mobility services for passengers and goods	28	380	12%
Other actions	35	44,97	2%
Total	223	3077,39	100%

Table 1.1: CL5 Work Programme 2021-2022 - budget distribution per destination.
Source: European Commission – CL5 Work Programme

Politecnico di Torino - Castello del Valentino – Viale Mattioli 39, 10125 - Torino, Italia
Ph.D. in URBAN AND REGIONAL DEVELOPMENT
Ph: +39 011.090. 6439 /7460
dottorato.d.ist@polito.it - http://dottorato.polito.it/urb

Horizon Europe – Cluster 5 structure

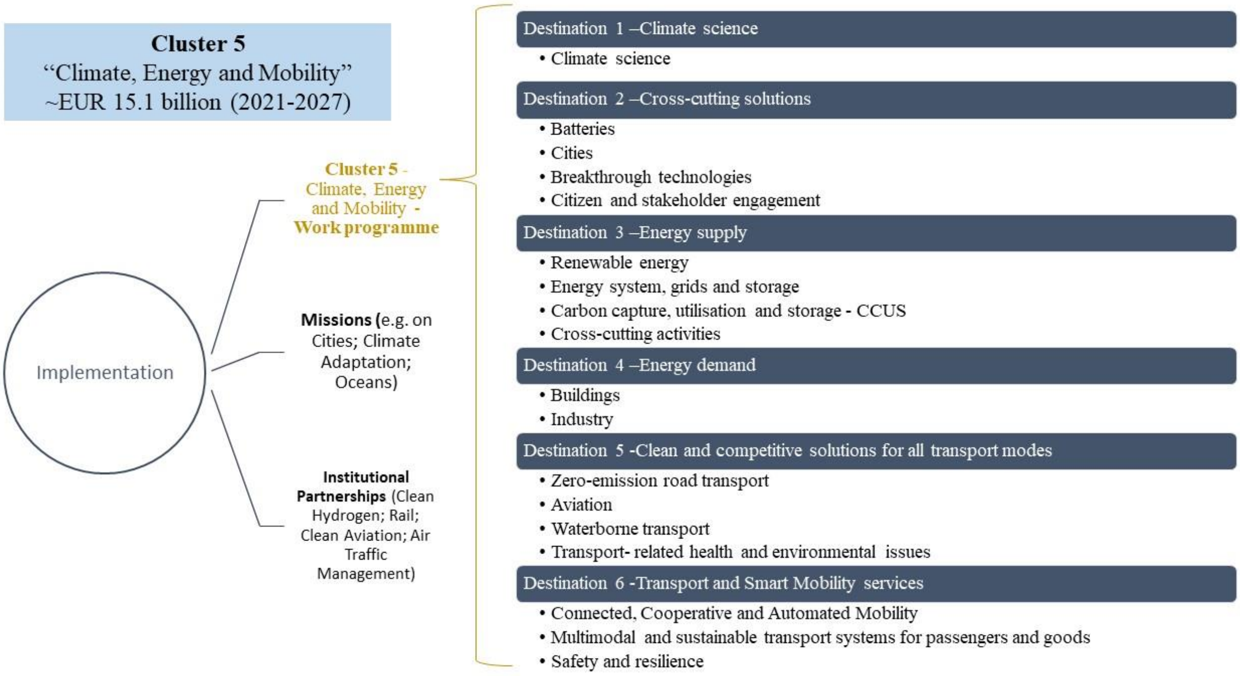


Figure 1.16: Cluster 5 implementation. Source: author reproduction based on EU documents (COM.HE 2021)

All actions funded under CL5 destinations must help to deliver the respective main impacts:

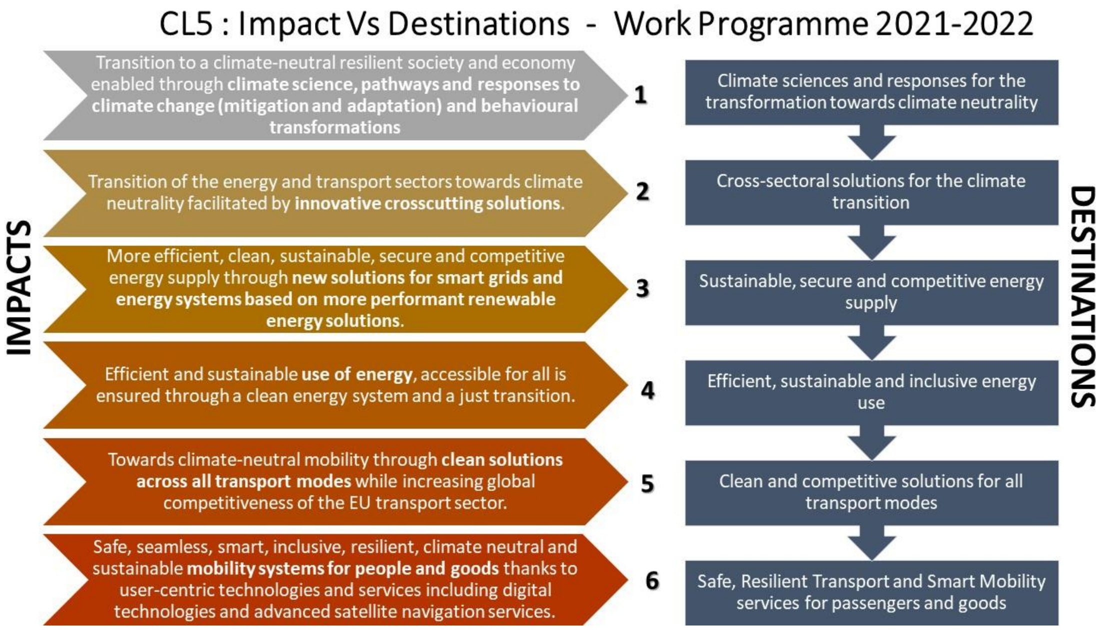


Figure 1.17: CL5: Impact Vs Destination – Work Programme Horizon Europe. Source: own reprodcation based on EU documents (COM.HE 2021)

Horizon Europe will also drive the efforts started via Horizon 2020 on climate change related actions liaisons with different EU raw materials policies to ensure a secure, sustainable and responsible supply of raw materials, especially CRMs, tackling vulnerabilities in the whole value chain.

The European Innovation Partnerships (EIPs) are partnership initiatives between European Commission and public or private sector partners to address global challenges and industrial modernization through the joint efforts of private and public partners and to help avoid duplication of investment and reduce fragmentation of the Union's research and innovation activities. The partnerships will cover different areas of the energy transition process such as:

- **EIP - Batteries: Towards a competitive European industrial battery value chain**

Aimed at supporting world sustainable and circular European battery value chain to drive the transformation towards a European ecosystem of research and innovation for batteries with a view to establishing Europe's industrial leadership in battery design and manufacturing for the next generation. The long-term goal is to develop a futuristic battery technology that looks beyond 2030 both for electric mobility, replacing combustion engines in transportation (air, road, rail and water) and for renewable energy systems.

- **EIP - EIT Climate-KIC**

Aims to bring together the R&I stakeholder community to accelerate the transition to a climate-neutral society to a carbon-neutral, climate-neutral and resilient society. It aspires to create a network of universities, businesses, and research organizations that will develop solutions to mitigate the impact of climate change and improve citizen adaptation, while fostering while bringing disruptive innovations closer to the marketplace.

- **EIP- EIT Raw materials-KIC**

A significant portion of EIT's budget is dedicated to support the “Knowledge and Innovation Communities” (KICs), which are European partnerships involving companies, research institutions, universities and businesses boosting innovation in Europe, creating growth and jobs, and creating the entrepreneurs of tomorrow. The EIT sets the educational, entrepreneurial and innovation strategies for the Knowledge and Innovation Communities by integrated activities of higher education, research and innovation. They allow:

- innovative products and services to be developed in every area imaginable, including climate change, healthy living and active ageing
- new companies to be started
- a new generation of entrepreneurs to be trained

1.5.2 Horizon Europe Mission on "Climate-Neutral and Smart Cities"

The Missions of Horizon Europe are a policy tool designed from a series of proposals submitted to the EU Commission in September 2020 and then better identified in the strategic plan of Horizon Europe.

The missions are one of the novelties of the new Horizon Europe program and their main impact is to create synergy between research and innovation actions with new forms of governance and collaboration, involving the citizenship.

Each mission will have dedicated actions, policy measures and legislative initiatives aimed at increasing the effectiveness of EU funding (also mobilizing additional national resources) by pursuing major objectives related to the major challenges of our time and not achievable through individual actions.

The 5 EU missions identified are (European Commission, "Missions in Horizon Europe" web site):

1) Adaptation to Climate Change: support at least 150 European regions and communities to become climate resilient by 2030;
2) Cancer: working with Europe's Beating Cancer Plan to improve the lives of more than 3 million people by 2030 through prevention, cure and solutions to live longer and better;
3) Restore our Ocean and Waters by 2030;
4) 100 Climate-Neutral and Smart Cities by 2030;
5) A Soil Deal for Europe: 100 living labs and lighthouses to lead the transition towards healthy soils by 2030.

Assuming that the main difficulty to an effective climate transition is not the lack of technologies but the ability to implement them, the Climate-Neutral and Smart Cities mission adopts a strong cross-sectoral approach and is demand-driven, creating synergies between the various initiatives that currently exist and basing everything on the real needs of cities highlighting how it has ambitious but realistic and administratively feasible goals.

With the strong contribution to the European Green Deal, the Multiannual Financial Framework (MFF) and the EU Recovery and Resilienceto assured, the

Climate-Neutral and Smart Cities mission will be characterized by a more strategic, holistic and long-term approach, together with a new city governance. This therefore precludes a strong commitment from the political leadership in order to bring all stakeholders, i.e. business, academia, and civil society, together and to cooperate.

In a broad sense, the main common goal is for as many cities as possible to become climate neutral as soon as possible.

In particular, the mission features two main objectives and 6 specific objectives. The main goals of the Climate-Neutral and Smart Cities mission are:

1) To have 100 climate-neutral and smart cities by 2030;

2) To make these 100 cities hubs of innovative experimentation for other cities, driving their changes in becoming climate-neutral and smart cities by 2050.

At the heart of the mission there will be "Climate City Contracts" managed by an ad hoc platform (established by the NetZeroCities project), (1) co-created with local stakeholders and citizens, (2) drafted, signed and implemented by each participating city that (3) will define the various projects to achieve climate neutrality by 2030 (including an investment plan). This, although not legally binding, represents a clear and highly visible political commitment to citizens.

Citizens will be change agents and main actors in order to achieve common benefits such as better air quality, job creation, healthier lifestyles, sustainable mobility.

Chapter 2

Rare Earth, Critical Minerals and its Geopolitical dimension

By introducing the concept of rare earths and critical materials, this section then intends to deepen the geopolitical dimension of the theme.

In spite of the name, these minerals are actually present in large quantities in the earth's crust but localized in a few geographical areas with deposits that are often not easily exploitable and with a strong socio-environmental impact.

A specific focus will obviously be dedicated to China and its role in the global chessboard. Today China, while holding 35% of reserves, can boast 60% of the output of rare earth oxides. The biggest risk is that China can almost entirely absorb the global supply capacity with a consequent risk of using the threat of blocking exports of these materials as a weapon for diplomatic and strategic issues. While for the West this could mean delays and possible negative impacts on the ongoing sustainable energy transition process, for America the impact would also be evident from a military point of view, with Biden recently highlighting the vulnerability of its supply chains and its implications for national security.

The objective of Western countries, Europe in primis, is therefore to make themselves as independent from China as possible, investing as much as possible and on a large scale in refining and processing industries outside China, investing and working on the entire value chain.

These policies and the actions put in place, will then be seen in their viability, giving overview of their distribution on the Earth's crust and the global dynamics of the issue and the geo-strategic games taking place (Chapter 2) followed by the deepening of the socio-environmental impact generated by the process of lithium extraction in South America (Chapter 3).

2.1 Rare Earth Elements

The REEs (Rare Earth Elements), or rare earths, are elements with unique physical and chemical properties found in the Earth's crust, which are mainly found in carbonatites, which are magmatic rocks or igneous alkaline rocks. They are 17 in total and include scandium, yttrium and 15 lanthanide elements and, according to their atomic weight, are traditionally divided into two groups: LREE (light elements) and HREE (heavy elements). Their use roams in many sectors and, depending on their different physical properties, they have become indispensable for a considerable number of industries dealing with the most modern and sophisticated technologies, such as smartphones, computers, wind turbine generators, hybrid and electric vehicle batteries, occupying in this way a vital role in renewable energy. Although it is used a small part of them in the composition of the products in which they are assimilated, their presence is essential for an optimal performance of those devices in which they are employed.

Although the name may be misleading, rare earths are not particularly rare. The Geological Society of London specifies, in an informative note on rare earths that, on average, in the terrestrial crust, in terms of percentage, the cerium is present in the most abundant percentage, with 43 parts per million (ppm), lanthanum and neodymium are present in 20 ppm, while the rarest rare earth element is tulium, with 0.28 ppm. Their abundance can therefore be compared to important elements such as lithium (present in 17 ppm), copper (27 ppm), tin (1.7 ppm) and uranium (1.3 ppm) (The Geological Society of London 2011).

The terminology used to define these elements "rare earths" is in part due to their reactivity, which makes it difficult to isolate them in pure form, and the similarity of their chemical properties, which makes it laborious to separate them from each other. It is also difficult to find these metals in concentrations high enough for an economic extraction. The world's two major REEs sources are found combined in mineral deposits such as bastnaesite, a carbonate-fluoride containing cerium, lanthanum, neodymium, and praseodymium, and monazite, a phosphate mineral containing samarium, in addition to cerium, lanthanum, and neodymium.

Most rare earth mines are all open cast except for some where rare earth is produced as a by-product. The mining techniques used are standard, namely drilling, blasting and transport. REEs are extracted through a series of steps, such as roasting with acid or alkali, leaching, chemical precipitation and evaporation. The process to separate each of the REEs can be complex and may vary from the production of each individual metal. This results in an expensive and time-consuming process. Many minerals containing REEs, in fact, cannot yet be extracted and separated economically. That's why some rare earths are leached locally, passing solvents through the rock, or to make them cheaper and suitable for industrial use, are marketed as oxides. The extraction and treatment of REEs, like most mining and processing activities, therefore causes environmental problems, because of the chemicals used, the large amount of energy that comes from coal plants and the consequent carbon emissions, and the percentage of radioactive elements, such as thorium and uranium, present mainly in deposits of heavy rare earth, which contribute to polluting water, soil and air.

Although rare earths are relatively abundant in the earth's crust, the minable concentrations are well below lower than other minerals. According to the latest data from the US Geological Survey, for 2020 the share of mining production was 140,000 tons, divided between 120,850 tons of light rare earths and 19,150 tons of ionic absorption clays. The countries that hold the largest reserves of rare earths in the world are: China, with 44,000 tons; Vietnam, with 22,000 tons; Brazil, with 21,000 tons; Russia, with 12,000 tons; India, with 6.9 million tons; Australia, with 4.1 million tonnes; the United States and Greenland, with 1.5 million tonnes. China, in addition to holding the largest reserves in the world, is also the largest producer (in 2020 it produced 140,000 tons). Some countries, despite having huge reserves, have low production. This is the case of countries such as Vietnam and Brazil, which in 2020 produced only 1000 tonnes for the clean energy sector, a very small number compared to the potential of their reserves. Russia and India also seem to be making modest use of their reserves, with a production in 2020 of 2,700 and 3,000 tonnes respectively. Countries such as Australia and the United States, instead, show a higher production of rare earths in comparison to the availability of their reserves. In 2020 Australia produced 17,000 tons, while the United States

38,000 tons. Although little information is available from some countries about their mineral deposits, their production is increasing. This is the case of Myanmar which produced 30,000 tonnes of Rees in 2020, of Madagascar with 8,000 tonnes in the same year and of Thailand which produced 2,000 tonnes. There are also important reserves in Canada, South Africa, Tanzania, and other countries (U.S. Geological Survey 2021).

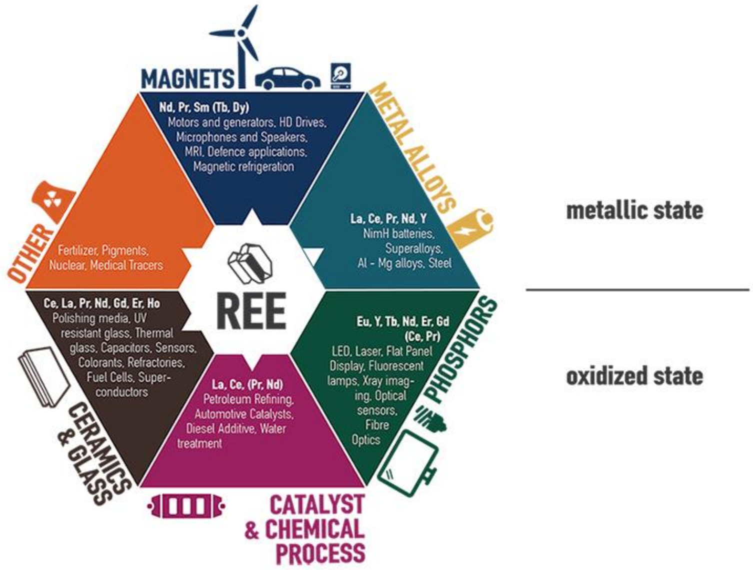


Figure 2.1: Uses of the Rare Earth Elements. Source: EURARE (Development of a sustainable exploitation scheme for Europe's Rare Earth ore deposits). FP7-NMP project

Rare earth elements play an important role also for the European Union in the production of electric batteries, solar panels and wind turbines. The EURARE project, funded by the EU, through a detailed geological and laboratory work, identified the different rare earth deposits across Europe. Although countries such as Sweden, Finland, Greece and Spain have enough rare earth deposits to reduce dependency in supply chains, China still accounts for 98% of REEs supply in the EU.

In September 2020 the European Commission announced the creation of the "European Raw Materials Alliance", established with the aim of creating a chain of value of raw materials, complete from the beginning of the process to recycling, to reduce dependence on third countries and increase the EU's resilience to the use and reuse of materials present in the rare earths (COM.474.final 2020b). A fourth list of CRMs was published in the Raw Materials Communication. The first list was published in 2011 (COM (2011) 25), the second, after three years, in 2014 (COM (2011) 297) and the third, based on a refined methodology, in 2017 (COM (2011) 490). The 2020 assessment follows the same methodology as in 2017 and, using as main parameters the economic importance and the risk of supply, the points in the value chain in which the criticality is manifested were more carefully analysed, that is, extraction and processing. Out of 83 raw materials analysed, the EU 2020 list contains 30 CRMs:

2020 Critical Raw Materials (30)			
Antimony	Fluorspar	Magnesium	Silicon Metal
Baryte	Gallium	Natural Graphite	Tantalum
Bauxite	Germanium	Natural Rubber	Titanium
Beryllium	Hafnium	Niobium	Tungsten
Bismuth	HREEs	PGMs	Vanadium
Borates	Indium	Phosphate rock	Strontium
Cobalt	Lithium	Phosphorus	
Coking Coal	LREEs	Scandium	

Figure 2.2: 2020 List of critical raw materials for the EU (CRMs) - on the evaluation of 83 candidate raw materials. Source (COM.474.final 2020b)

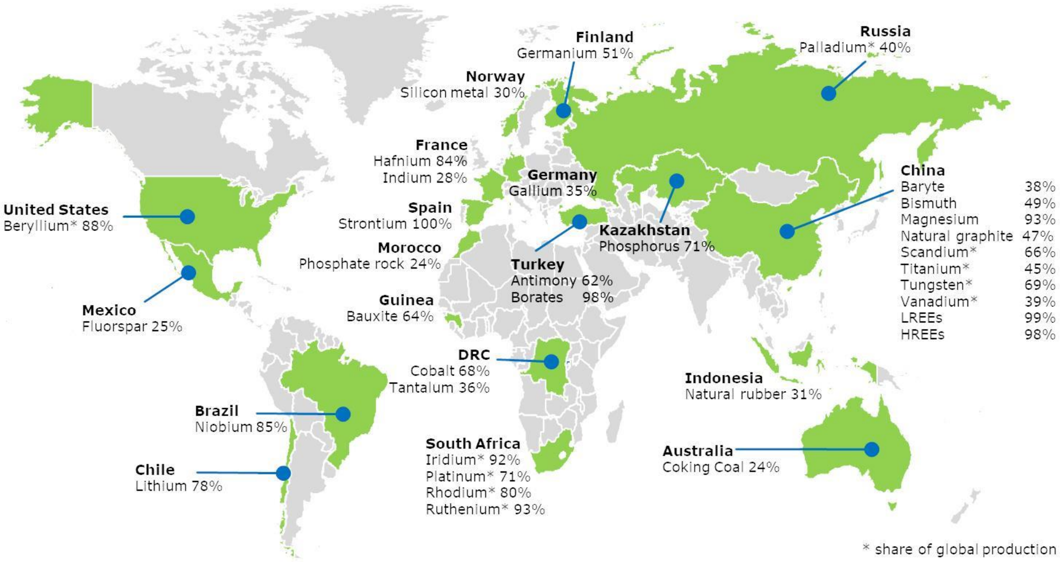


Figure 2.3: Main EU suppliers of critical raw materials. Source: European Commission report on the 2020 criticality assessment (European Commission 2020c).

Taking into account population growth, decarbonisation of transport, energy systems and the growing demand from developing countries, in a global context, estimated demand for raw materials, in a scenario of European Union climate neutrality for 2050, there are risks of supply on different levels of supply chains. For example, considering the current demand for electric vehicle batteries and energy storage, it is expected that the EU would need up to 18 times more lithium and 5 times more cobalt in 2030. This amount would result in a 60 times higher demand for lithium and a 15 times higher demand for cobalt in 2050. Demand for the use of rare earths in permanent magnets for electric vehicles and digital technologies, on the other hand, could increase tenfold by 2050. This translates, for the EU, into a percentage of import dependency of between 75% and 100% (European Commission 2020c).

Following the COVID-19 crisis, there has been a higher risk of supply disruption. This has led the Commission, in its proposal for the Recovery Plan, to regard critical raw materials as one of the areas where Europe needs to be more resilient, in order to be prepared in the future to deal with such issues and to adopt a more open autonomous strategy. While countries such as China, the United States and Japan are already diversifying their sources of supply through partnerships with resource-rich countries to develop their raw materials value chains, the EU Action Plan should reduce dependence on CRMs through the circular use of resources, strengthening sustainable national supply and processing, thus diversifying supplies from third countries, so that it can develop resilient value chains for its industrial ecosystems. In order to address value chain deficiencies in the extraction, processing, recycling and separation of metals such as lithium and rare earths, the European strategy requires adequate inventories to avoid unexpected interruptions in production and large-scale public and private investments. The European Bank has recently adopted a new lending policy for investments in the energy sector to encourage projects relating to the supply of critical materials for sustainable technologies.

Although the EU has increased the use of secondary raw materials, in the field of the circular economy, in the case of raw materials such as rare earths, this production does not yet make an essential contribution, causing great environmental and climate stress.

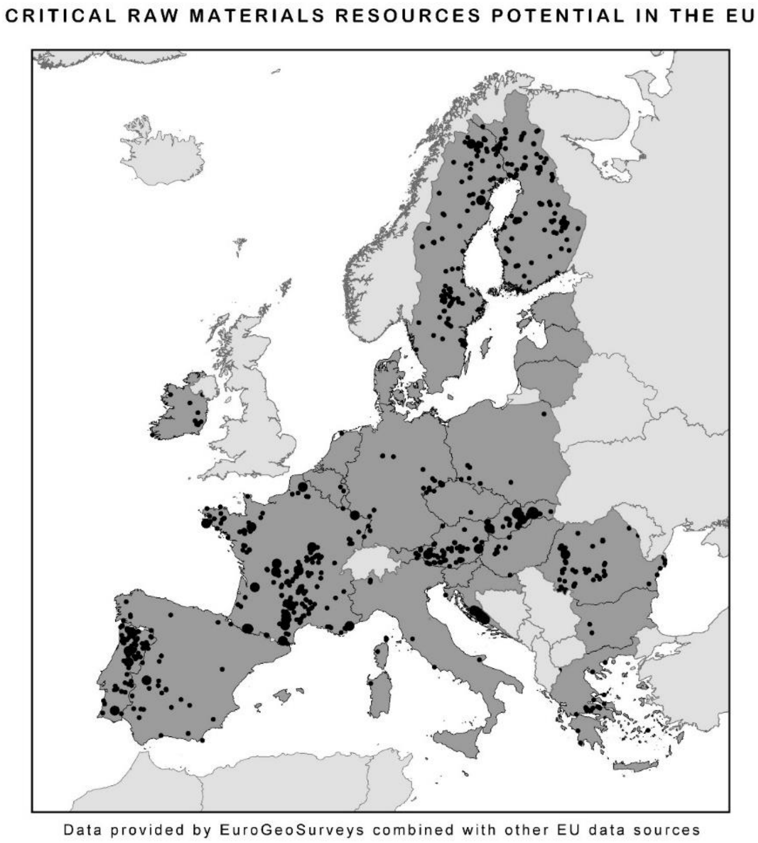


Figure 2.4: Critical raw materials resourcses potential in the EU. CRM deposits EU-27 (2020). Source: European Commission (European Commission 2020c)

Although it is rich in industrial aggregates and minerals, Europe is proving ineffective in developing projects that guarantee critical raw material supplies, due to a lack of investment in exploration and mining.

This geographical distribution shows that companies in the Member States that are part of the European Battery Alliance could benefit from interesting opportunities for the exploitation of raw materials for batteries, such as lithium, nickel, cobalt, graphite and manganese. To make better use of the resources available in Europe, the Commission will work with Member States to identify mining and commodities processing projects in the EU that can be operational by 2025.

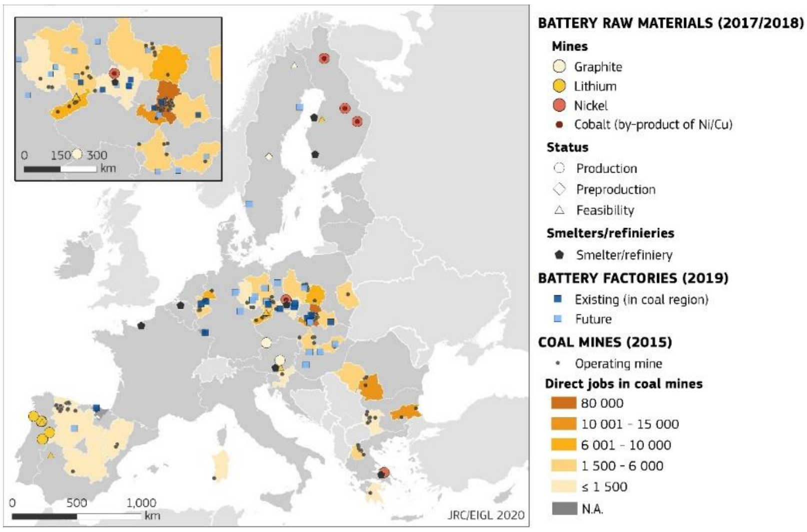


Figure 2.5: Battery raw material mines, battery factories and coal mines.
Source: Joint Reasearch Centre

Many of these raw material resources for EU batteries are located in regions heavily dependent on carbon-intensive industries. Greater attention will therefore be given to regions where coal is still mined and to other regions in transition, where skills and processing capacities will be increased, in addition to those extraction, to reduce dependence on other countries. To improve the exploratory activity, the Copernicus satellite observation programme will also be used.

By supporting research and innovation in mining technologies, sustainable criteria to finance the mining industry will be defined by the end of 2021, and it will be mapped the potential for secondary raw materials, that is extracted from waste, rich in CRMs, identifying viable recycling projects by 2022. As regards the dependence of raw materials on other territories, partnership projects will be launched with resource-rich countries, such as Canada, Australia, African and Latin American countries and other countries territorially close to Europe, such as Norway, Ukraine and the Western Balkans. The EU will help its strategic partner countries to develop their resources in a sustainable way, by spreading responsible mining practices and avoiding high supply concentrations in countries with lower governance standards, to not aggravate environmental problems and to not feed social problems such as child labour (COM.474.final 2020a).

Due to their difficult degradation, rare earth elements used in products such as magnets, batteries and catalysts could be reused as recyclable material. But currently only 1% of finished products are recycled. The main obstacle is the separation and purification of individual Ree, due to their chemical similarities, from which derives a high-energy and waste-intensive process. There is therefore a need to develop new technologies to reduce the cost of separating and recycling REE on an industrial scale. In this context, important is the contribution made by researchers from the Schelter Group, of the University of Pennsylvania Department of Chemistry, who, by synthesizing new organic compounds, have developed a simple, fast and low-cost technology for effective separations of Rees mixtures. This would contribute to reducing mining activity and exploiting recycled material to be added to the supply chain. Other studies, started in 2018 and still ongoing, carried out by the CMI (Critical Materials Institute) of the Department of Energy of the United States, show potential progress in recycling REEs, with economic and feasible methods. It involves using Gluconobacter bacteria, which, by consuming sugar, produce acids to dissolve and separate rare earth elements from the shattered electronics. A method that would be not only economic, but also environmentally friendly.

Due to environmental, cost, supply and recycling problems, many research studies have recently been undertaken to find alternative or substitute materials and reduce the amount of use of REEs. The United States Department of Energy, along with many companies, are working to find these substitutes in their products. Toyota, among others, is developing new hybrid vehicles that do not require REEs or that limit their use. For example, the reduction of cerium in the design of new automatic catalysts would allow both a rapid release and large storage capacities for oxygen, and would not decrease the high performance, for conversion to less harmful materials, of NO_x, CO and total hydrocarbons. Another alternative includes cerium-cobalt compounds ($CeCO_3$) and cobalt with iron germanium compounds (Fe_3Ge) for use in electric vehicle batteries. It is also working on magnets in which the amounts of neodymium can be replaced in favour of iron and nickel alloys. If markets move to these alternatives, REEs' demand may decline (Balaram 2019).

Electric car manufacturers are exploring new batteries in recent years, trying to reduce or replace cobalt, in favor of nickel or manganese.

In the different energy sectors, thanks to the introduction of new alternatives, a potential variability in the demand of various minerals is evaluated according to the different trends of technological evolution. In improving the performance of a lithium-ion battery, not only energy density, durability and safety will be taken into account, but particular attention will be paid to reducing environmental, social and political costs arising from the acquisition of the used materials.

A cathode with a higher percentage of manganese will reduce costs but may decrease stability and consequently compromise its duration. The predominant choice of the material used for the anode is graphite, although the manufacturers are looking for substitutes that have an efficient charge collection capacity. The substitutes that are under consideration are lithium titanate, silicon, pure lithium metal, depending on the increase of potential in performance or the reduction of costs in supplying them. The production of cobalt is subject to ethical questions about mining practices in the Democratic Republic of Congo, which provides much of this mineral. The sustainability of cobalt is therefore also questionable because of the extremely variable price. For this reason, more and more companies appear to be converging towards nickel-rich cathodes, eliminating the need for cobalt. Nickel, more geographically distributed, is produced in larger quantities. But if this is done quickly, it could cause problems in the nickel supply chain. On the other hand, a delayed shift to nickel-rich chemicals in cathodes will result in increasing demand for cobalt and manganese and lower demand for nickel than in the base cases, also involving an increase in their prices. As for the technological evolution applied to the anode, are favoring all-solid state batteries (ASSB), which have a higher potential to achieve a higher energy density because they contain a solid electrolyte instead of liquid. But since the anodes used by the ASSB are pure lithium metal instead of graphite, this implies a higher consumption of lithium, thus increasing its demand, and a consequent lowering of demand for graphite. The same fluctuation in demand will occur if companies adopt a more silicon-rich anode, increasing demand for silicon and slightly decreasing demand for graphite (International Energy Agency (IEA) 2021).

2.2 Geopolitics of Critical Minerals

The energy transition and decarburization process induced - primarily but not exclusively - by the global fight against climate change, reveals the inadequacy of international institutions.

The issue of energy transition in the automotive sector and battery production is not only technological. The geopolitical aspects are relevant if it is considered the relations between Europe, United States, Russia and China and the geographical division of the world, high-income countries (benefiting from the technology), and low-in-come countries but depositaries of the raw materials needed for that technology.

A redefinition of the balance of power between producers and consumers and the emergence of new areas of geopolitical and strategic interest are the consequences of this new energy paradigm on global scale and this highly concentrated, and often disruptive, production raises concerns about security of supply.

The concentration of lithium in a few geographical areas of the planet, associated with local political capacity, level of development of the mining process and production capacity, are the central elements that move the geostrategic dynamics of this material, attracting the interests of most of the relevant actors on the international scene.

Mineral exploration involves high costs and in most developing countries, including South America, exploration is in the hands of foreign companies, with adequate capital to also assume risk (implicit in this sector).

Many are the powers and players that are entering South America in the hunt for lithium. These include above all the Chinese, Americans and Germans. China more than any other is investing in relations with South America, especially in Argentina where the government has completely liberalized the sector.

To this must be added the dynamism and farsightedness of China which, although is already rich in deposits of raw materials necessary for LIBs production, is adopting policies aimed at acquire mineral resources of other producer countries.

However, to ensure fair distribution of resources between extracting countries and leading countries in the production of these resources, it is crucial for the territory to develop new technologies and processes to bring these goods into production independently at the local level.

On the evolution of energy geopolitics in the context of the low-carbon transition is focused the study conducted by IFPEN (IFP Energies nouvelles) and IRIS (the French Institute for International and Strategic Relations). The researchers of the project GENERATE (Geopolitics of Renewable Energies and prospective analysis of the energy transition), funded by the French National Research Agency (ANR), analyzed, through the model TIAM-IPFEN (Times Integrated Assessment Model) which factors could have an impact on energy geopolitics in the coming decades. Through bottom-up linear programming, over a long-term period, the global multiregional model has reconstructed the value chains (from resource extraction to final energy use) of cobalt, copper, lithium, nickel and rare earths, and was able to assess their respective requests on the basis of different scenarios, determining the possible consequences at the energy, environmental and legislative levels. Using the Tiam-IPFEN Model, it was possible, for Emmanuel Hache and his team, to determine a high level of criticality of cobalt and copper, based on two climate scenarios of 2° C and 4° C. Specifically, the depletion of resources of these two materials (over 90% known to date) is expected by 2050 at the latest. In this context, countries such as Chile, China, Australia and Russia, which produce or are specialised in refining these materials, could make a difference in global strategy. While for the 75% of the lithium resources known to date, in a scenario of 2°C, it estimates a lower criticality level, by 2050.

By applying two mobility scenarios to the two climate scenarios, the IFPEN team was also able to assess the global evolution of the vehicle fleet until 2050.

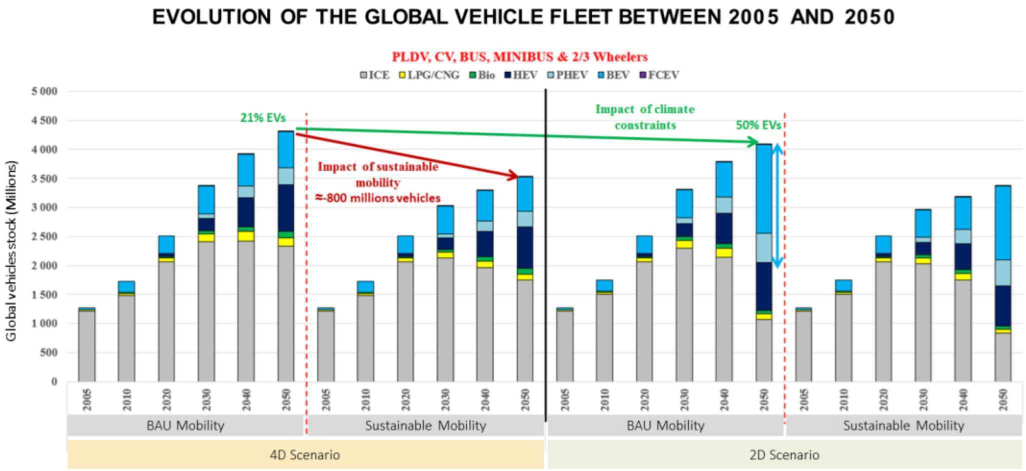


Figure 2.6: Evolution of the global vehicle stock between 2005-2050. Source IFPEN.

In the case of a scenario of 2° C, that is in line with the Paris Agreement, applying a mobility scenario BAU (Business as Usual) is expected a greater dependence on cars and an electrification of 50% of the fleet. By applying a sustainable mobility scenario that favours the use of public and non-motorised transport, in a climate scenario of 4°C, where the use of internal combustion vehicles remains dominant, the global fleet could be significantly reduced. We are talking of about 800 million fewer vehicles. A more rigid scenario and a situation of hypermobility, shows how the dynamics of energy transition can increase the security risk of the metal in the 2°C. But even in the long-term scenarios there is always an economic, geopolitical and environmental vulnerability, although the least concern about the geological criticality of the reserves and resources of raw materials(Dr. Emmanuel HACHE, Dr. Gondia-Sokhna SECK, Marine SIMOEN 2019).

The security of supplies of raw material in the long term for importing countries could be compromised by the lack of transparency on prices and by the strategies adopted by the producing countries, whereby Argentina, Australia, Bolivia and Chile.

2.3 China in the global chessboard

Before 1965 the demand for rare earth elements was relatively low and the main producers were Brazil, India and South Africa. In the mid-1960s, thanks to Mountain Pass Mine reserves in southeastern California, the United States became the world's leading producer of rare earths. At least until the '90s. China, which had already begun to extract and process large quantities of rare earth oxides in the early 1980s, increasingly strengthened its position on the world market. In the 1990s and early 2000s, its prices were so low that Mountain Pass Mine, together with other producers around the world, were unable to compete. A record that Beijing still holds today, after having gradually monopolized the global production of these elements.

Leading the South American geopolitical chessboard is also China, where many governments cannot (want to) break the alliance with China which, for years now, has been the region's main trading partner and largest investor.

Figure 2.7: China investment in South America. Source: K. P. Gallagher & M. Myers. China–Latin America Finance Database (Inter-American Dialogue, 2019).

Since 2015, relations with the Asian giant have been intensifying to the point where several Latin countries have signed bilateral agreements under the Belt and Road Initiative (BRI), also known as the "new silk road," inaugurated by Chinese President Xi Jinping in September 2013 and extended to the Latin American and

Caribbean region during the 2018 China-CELAC Ministerial Forum. The BRI is a pharaonic Trans-American Corridor project, the backbone of the Central Interoceanic hub, a series of river port terminals and other infrastructure in the Tapajós corridor," the Amazon hub", as well as numerous mining projects in Venezuela and Chile. The first of these projects was proposed in 2015 as part of the visit of Chinese Prime Minister Li Kequing, and was ratified by the signing of a memorandum between Brazil, Peru and China, which gave the project to China Railway Eryuan Engineering Group Co. However, in recent years doubts have arisen generated by the high engineering costs of the work, which has been subject to competition from two alternative projects (Peregalli 2020).

To foster a mechanism of international cooperation between key countries along the Belt and Road Initiative, China has over the years signed cooperation papers with several countries to promote development strategies that are of common prosperity. To quote a more recent example, reported from Belt and Raod Portal, in January 2021, China and the Democratic Republic of Congo signed a Memorandum of Understanding (MoU) in Kinshasa. This MoU represents a strong positive signal for Foreign Minister Wang Yi to send globally, which will serve to provide broader perspectives for the bilateral relations of the two countries.

But let's see how China manages to establish a relationship with the different countries that have joined the BRI to date, starting from its financing system.

The Chinese "Policy Bank", created to finance Beijing's political initiatives, consists of two major banking institutions, the Chinese Export-Import Bank (ExIm Bank) and the China Development Bank (CDB), both under the direct control of the State Council of the People's Republic of China. The amount of funds that the two banks provide for foreign development is comparable to that of the World Bank, which is the largest multilateral funder in the world.

According to data emerged from the 2020 "Monitoring of Foreign Development Funding for China" of the Boston University's Global Development Policy Center, it appears that, between 2008 and 2019, the two banks provided about half a trillion dollars to finance development to foreign governments. However, the impact of the change in trade dynamics in recent years and the spread of Covid-19 has drastically reduced loans from CDB and ExIm Bank from $75 billion in 2016 to just $4 billion in 2019.

There was a drop of about 54% in 2020, compared to 2019, according to a report concerning Chinese foreign investment to BRI countries, conducted by the Green Belt and Road Initiative Center, of the Beijing Central University of Finance and Economics, based on China Global Investment Tracker data. While the share of investments in renewable energy has seen an increase of 57% compared to 38% in 2019. This suggests that in 2021, Chinese BRI investments will focus mainly on green projects, smaller, financially more sustainable and faster to be carried out, and will significantly reduce the risk of losses in larger and less profitable projects, like coal. The analysis of the report also highlights how in non-BRI countries, which are countries that have not signed MoU with China, investments have even decreased by 70% compared to 2019 (Nedopil 2021).

Based on Statista data, Green BRI Center shows that, in 2020, China invested such as 26 billion dollars in Asia (in West and East regions), 13 billion dollars in Africa and about 4 billion dollars both in South America and Europe.

Figure 2.8: China's BRI Map. Source: Green BRI Center IIGF 2021

Because of the blockages caused by the Covid-19 pandemic, low- and middle-income BRI countries have seen their sovereign debt become unsustainable. China's initial total loan of 49 billion of dollars, dating back to 2014, to 52 of the 130 BRI countries, is more than doubled to 102 billion of dollars in 2019, also exceeding the sum of other official bilateral loans.

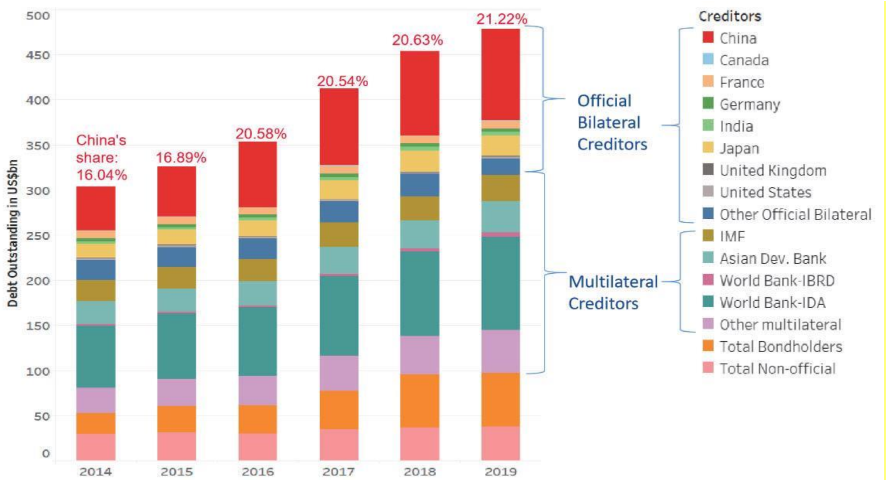


Figure 2.9: Official External Debt Outstanding in 52 Selected BRI Countries by Creditors, 2014-2019. Source: World Bank International Debt Statistics and Green BRI Center authors' depiction.

The above chart shows in red the substantial share of China in relation to other creditors. At the end of 2019, China's loans exceeded those of other creditors in several countries, but the ones that increased its debt compared to 2014 are in particular: Djibouti, whose debt ratio to China increased by 34,64% compared to 2014; while the initial debt of 2014 of the Republic of Congo varied from 13.62% to 38.92% and Angola from 5.87% to 18.95%. These are the data reported in the "Brief on Debt in the Belt and Road Initiative" by the Green BRI Center in 2020.

In 2019, the five countries that have incurred the largest debt to China are: Pakistan, Angola, Kenya, Ethiopia and the People's Republic of China. The economic decline reinforced by the pandemic, led several BRI countries to demand the cancellation of their debt. These countries are still negotiating with the main Chinese creditor institutions to try to postpone the repayment of their debts. The Brief also makes it clear that some countries were struggling to pay their debts even before the pandemic. A couple of years ago, the DRC, for example, had agreed to a debt restructuring with China, with an extension of another 15 years (Yue and Nedopil 2020).

Some Latin American countries, especially those with a high-risk rating, have also tried to renegotiate their existing debts. Among them emerge Venezuela and Ecuador. Until 2020, in the previous seven years, China has announced loans to Venezuela for 24 billion dollars. While the two main Chinese banking institutions have supported Ecuador with large funding, in the last two decades, during the boom in oil prices. Due to the fall in prices, however, the South American country has not been able to repay its debts in recent years. In the renegotiation, Ecuador managed to obtain, between August and September 2020, two agreements to delay the payments of 474 million dollars with Exim Bank (the Chinese Export-Import Bank) and of 417 million dollars with the China Development Bank.

The difficult two years that has just passed, which has seen Latin America hit hard by the pandemic and a consequent economic crisis, has brought for the first time the two Chinese political banks, the CDB and the Exim Bank, not to engage in new financing towards South American governments. However, there has been no shortage of health aid from China, donating 215 million dollars to Latin American countries, of which over USD 100 million destinated only to Venezuela. These data emerge from the recent "China-Latin America Economic Bulletin", published by the Global Development Policy Center of Boston University. The report indicates that, based on diplomatic interests (with BRI-affiliated countries) and on commercial ones (with AIIB-affiliated countries), the relationship between China and Latin America takes its direction.

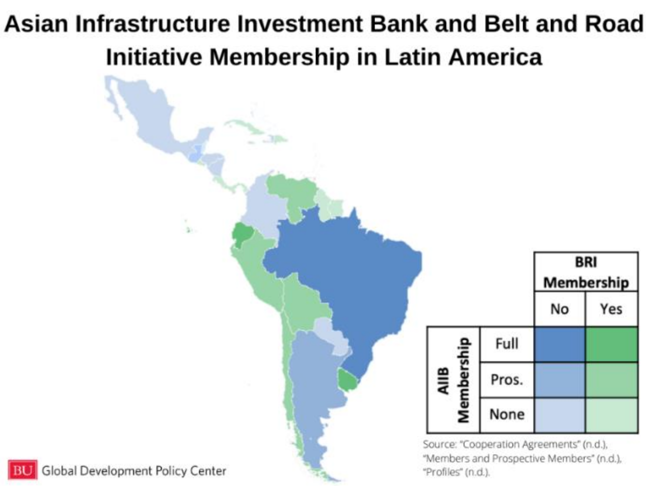


Figure 2.10: Asian infrastructure Investment Bank and Belt and Road Iniative memberships in Latin America. Source: Global Development Policy Center – BU

In the chart, based on the colors, we can distinguish how some countries have joined both the Asian Infrastructure Investment Bank (the multilateral economic and sustainable development bank that invests in infrastructure and productive sectors mainly in Asia, but which welcomes members at a global level) and both members belonging to the BRI, and therefore have concluded MoU with China. The countries that are members of both the AIIB and the BRI are Ecuador and Uruguay (in dark green). Bolivia, Chile, Peru and Venezuela (in medium green) are signatories to the BRI, but due the lack of payments of their bank shares, they may only be potential members of the AIIB. Brazil (in dark blue) is the only full member country of the AIIB, without joining the BRI, unlike Argentina (in medium blue) which is a member country of the BRI, but only a potential member of the AIIB.

Although it appears that China's investment in Latin America is currently relatively braked, researchers at Boston University conclude that by next year there may be a resumption of relations between the two governments in the post-Covid, for the negotiations initiated by China in some fields, although the uncertainty in that of metals remains, due to commercial volatility.

By analyzing the Belt and Road Initiative more closely, so emerges that, although it focuses on the principle of good governance and connectivity between countries, some contradictions may raise concerns about the sustainability of the Chinese initiative and its economic success.

As China is not a member of the Organisation for Economic Cooperation and Development (OECD), it does not have to comply with the OECD's international aid requirements and recommendations. This allows China to provide loans in exchange for the right to extract mineral resources from foreign countries, favouring a sort of predatory economy model, taking advantage of foreign resources, relegating the same suppliers to remain exclusively exporting countries. Another concern is aroused by the high rate of corruption that exists within the country, complained by Chinese investors themselves. A factor that could jeopardise the success of a BRI-related project may be the fact that many of the funds allocated to Chinese regions remain within the Chinese system. Are an example the five Central Asian States, where a loan from a Chinese bank to one of them is reinvested in the Chinese company that got the contract, which will use Chinese equipment and manpower, not creating new jobs and the project will therefore not have a higher economic impact. In addition, the huge loans from the Chinese government will constitute such a debt able to create, for countries such as those of Central Asia or which cannot afford to invest in infrastructure projects, a total dependence for decades (Lain 2018).

This sort of economic imperialism will, over time, allow China to exercise greater control over the poorest and smallest countries. The gap in terms of development and demography between China and the Central Asian states, denotes that China has all the geopolitical resources to project its power, with a harder impact within its government. While internationally, it can exercise a kind of soft power, through the BRI and the spread of this peaceful model of growth and development, intended as a vision, but also strategy, especially in less developed countries and isolated regions such as Africa (Dave 2018).

Through its support to the BRI, China can increase its position in global value chains by expanding its export markets, but we have seen how the pandemic has created a setback along the supply lines of all the countries that have joined it.

Faced with serious economic challenges, China itself may be forced to take a step back on foreign investment to safeguard its domestic economy. The failure of countless Chinese companies that did not survive the pandemic, led state-owned banks to support them with large loans. However, an internal credit squeeze could limit new loans for ambitious BRI projects. Which is why, as we have already seen, many projects that are still evolving or considered too risky have been abandoned (or temporarily suspended) by Chinese investments and if domestic economic pressure continues, there is no doubt that the chinese government will be more interested in spending its resources domestically, than in distributing them elsewhere.
On the other hand, the effects of the pandemic are increasingly reducing the possibilities for new investors, committed to facing their own economic difficulties at home, to be an alternative to China's loans. The absence of alternatives would therefore offer to China the opportunity to create new relations with emerging and developing countries. Furthermore, historically, China has used "the Silk Roads" as a channel for health care in areas such as Asia and Africa. Paradoxically, the Coronavirus once again presented China with the opportunity to be a valuable health aid, along the Belt and Road Initiative. Its role as a benefactor in this area, during the pandemic, will increase the probability that more and more countries will have confidence in cooperation with the BRI. Of course, Bejing will have to focus more attention first on the domestic economy, so as to strengthen it and to continue to be the main investor in these projects (Mouritz 2020).

To align and homogenize the efficiency and quality of Chinese manufacturers, Premier Li Keqiang in May 2015, issued the Made in China 2025, a programme with which China aims to increase the domestic content of basic components and materials to 70% by 2025. Given the large amount of Chinese production of LIB, several private Chinese companies in recent years have grown a lot, thanks to the acquisition of significant national and global market shares and the use of lithium products refined internally employed directly in the production of batteries. The bilateral trade relationship between China and Australia, led the latter to become in 2017 the main exporter of raw lithium minerals and China the main importer. China, as a large lithium compound refiner, exports most of its products to the United States and, in lesser quantity, to Japan and South Korea. However, concerned about China's growing economic influence, the Australian Government has recently increased loans to strategic nations on the Pacific Islands to counter Chinese loans, and encourage companies to build and operate lithium hydroxide treatment plants. In addition, the free trade agreement between the USA and Australia remains in force, eliminating duties on exports of lithium hydroxide (LaRocca 2020).

Of the five large multinationals that have so far integrated the entire lithium value chain, the two Chinese companies, Tianqi Lithium and Jianqxi Ganfeng Lithium, have entered the global market more recently than the other three competitors, the Chilean SQM (Sociedad Química y Minera de Chile) and the American companies Livent and Albemarle Corp, because they invested more abroad in mining, before specializing in the lower passages of the value chain. The important role given to companies like SQM, Livent and Albemarle Corp depends on the fact that they control just over 50% of the world's productive capacities. The two Chinese companies, in less than ten years, have grown considerably also thanks to joint ventures with other companies, in the extraction of ore outside China. For example, the Tianqi in partnership with the Australian Talison, manages together the huge deposit of Greenbushes in Australia. Compounds intended for the manufacture of lithium-ion batteries focuses on China. The production of spodumene concentrates (6% $Li2\ O$) in Australia is delivered entirely to Chinese customers, for conversion into lithium chemical compounds. While that of lithium carbonate concentrates is imported from Argentina and Chile. This concentration would explain the decrease in prices observed in 2018. In the same year, in fact, the overproduction of technical lithium from Australia, remained waiting to be processed in the Chinese conversion plants that proved obsolete and not ready to process the new sources of lithium.

This has led to an imbalance between supply and demand and a consequent drop in prices, also due to a slower take-off than expected in the global production of electric vehicles. Purity degree in lithium compounds intended for the manufacture of LIBs is very important. It is not by chance that the lithium compound preferred by producers of battery cathodes was lithium carbonate, which ensured a purity of 99.5%. But because of the risks of cobalt supply and the increased costs of this material, the evolution of cathode chemistry is now more oriented towards a growing demand for lithium hydroxide (LiOH), with a minimum purity of 56.5%. However, the challenge of mining producers to meet this growing demand becomes a paradox. They will need substantial investment to make up for the lack of predisposition of the present deposits, which according to their geological characteristics, are not able to produce the required quality of compounds. Efforts to eliminate impurities would be equivalent both in the field of extraction from lithiniferous rocks and in the field of brine. Because of the variability of prices, the financing difficulties and the consequent technical difficulties that derive from them, the so-called junior and intermediate companies that could develop projects on lithium production, find difficulties also to position themselves in the market. In a short-term at least. In Europe, for example, six projects have the characteristics for a future feasibility in this respect, expecting to integrate a quality refining useful for batteries. However, the initial market capitalisation employed by these companies is considered by investors inadequate in relation to their ambition. The prospect to see realistic results by 2025 seems to be moving away, and these delays in European projects only benefit the Chinese majors. In fact, it seems that, for their lithium supplies, BMW and Volkswagen, have signed contracts with the company Ganfeng Lithium, until 2025; the Swedish company Northvolt, instead, has turned to Tianqi Lithium for its supply of lithium hydroxides (Lefebvre & Tavignot, 2020).

As previously mentioned, according to USGS data, China holds most of the rare earth deposits. It has one third of the world's reserves, followed by Vietman, Brazil, Russia, India, Australia, the United States and Greenland. The almost monopoly of the Asian giant in terms of REE, is due not only to the presence of metals on its territory, but also to the growing development of know-how of processing of the same. Beijing dominates the processing and refining of minerals, with quotas ranging from 35% in the case of nickel to 50-70% for lithium and cobalt and up to

90% of rare earth. To date, this predominance continues to be a matter of strategic relevance for the industrial policies of all countries.

The bilateral trade relationship between China and Australia, led the latter to become in 2017 the main exporter of raw lithium minerals and China the main importer. China, as a large lithium compound refiner, exports most of its products to the United States and, in lesser quantity, to Japan and South Korea. But given the large amount of Chinese production of LIB, several private Chinese companies in recent years have grown a lot, thanks to the acquisition of significant national and global market shares and the use of lithium products refined internally emploied directly in the production of batteries. These are the political objectives set by the Chinese authorities within the Made in China 2025 programme. However, concerned about China's growing economic influence, the Australian Government has recently increased loans to strategic nations on the Pacific Islands to counter Chinese loans, and encourage companies to build and operate lithium hydroxide treatment plants. In addition, the free trade agreement between the USA and Australia remains in force, eliminating duties on exports of lithium hydroxide (LaRocca 2020).

Different but similar in some aspects is the situation in Africa. The Democratic Republic of Congo produces more than 70% of cobalt, China more than 60% of rare earth. Beijing also dominates the processing and refining of minerals, with quotas ranging from 35% in the case of nickel to 50-70% for lithium and cobalt, up to 90% of rare earth.

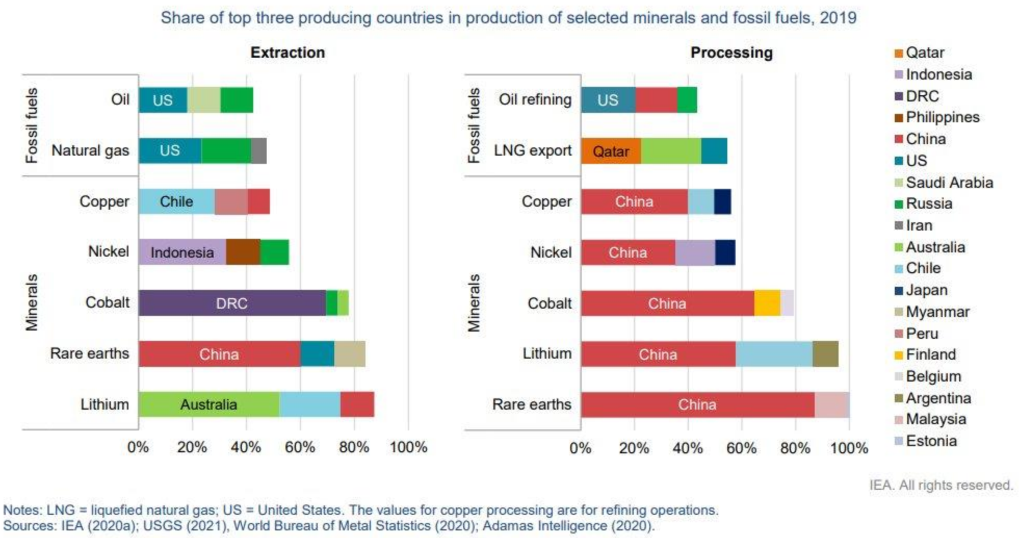


Figure 2.11: Share of three producing countries in production of selected minerals and fossil fuel, 2019. Source: IEA "The Role of Critical Minerals in Clean Energy Transition"

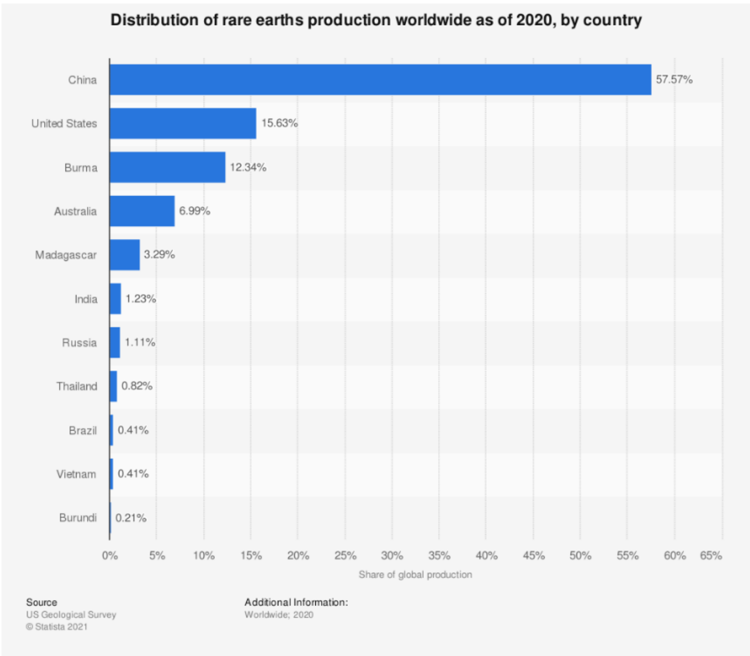


Figure 2.12: Distribution of rare earth production worldwide as of 2020 by country. Source: Graph by Statista.com, using data from the US Geological Survey.

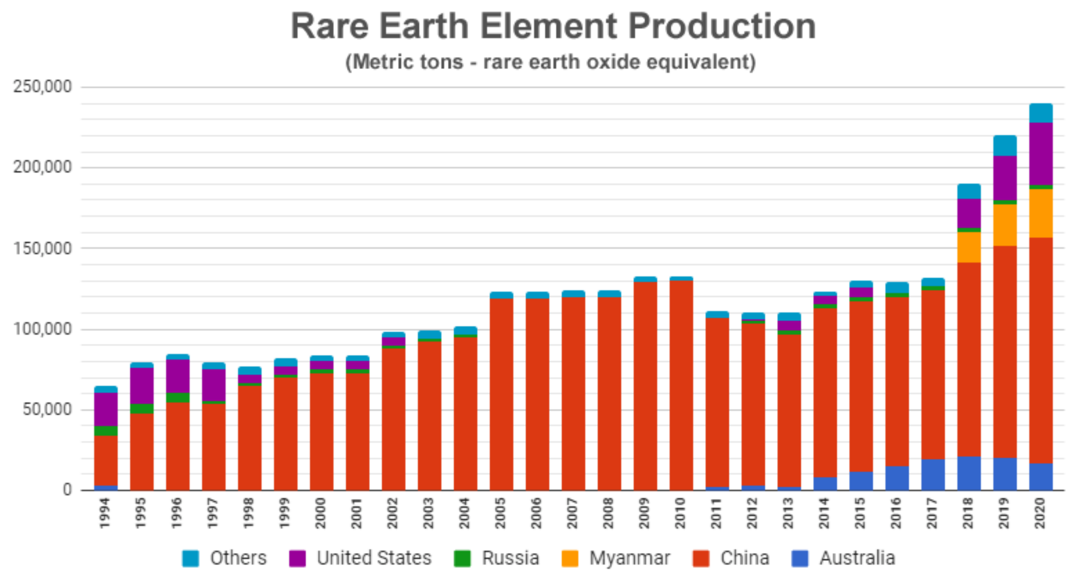


Figure 2.13: Rare Earth Element Production. Source: Graph by Geology.com, using data from the US Geological Survey

From the graphs we see that China is in practice a leader in controlling the majority of the world supply of REEs, with 57.6% and about 80% in the processing of rare earths in 2020.

According to a recent study, Colin Barnes of the C-EENRG of the University of Cambridge, states that Fujian, Hainan, Jiangxi, Guandong and Guanxi in southeast China offer the largest REEs deposits of China. Jiangxi Province alone produces 38% of the total HREE and 50.3% of the production of high-quality Rees in China.

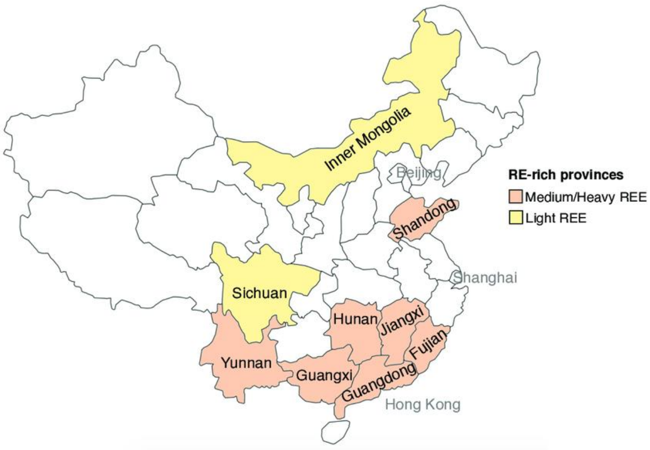


Figure 2.14: Chinese Provinces rich in REEs. Source: CJSP 2020

The attempt by the central government police to stop illegal exports has made China dependent on imports of some rare earths minerals, from countries such as the United States, Myanmar, Vietnam and Greenland, and has pushed Chinese companies to invest more and more in REE resources from other countries, so as not to exhaust the national ones (Barnes 2020).

The supremacy of China emerges even by analyzing the rare earth supply chain, dividing the main stages into three parts:

1) extraction and production of concentrates;

2) separation and conversion into metals;

3) manufacturing of commercial products.

During the extraction, following the crushing of the ore, it is produced a concentrate which must be further processed to remove the waste materials and, since at this stage the oxides have not yet been separated, there will also be elements of limited commercial value. There are still many extractive plants in the world today that are unable to complete production and have to send to China the mineral at this stage to be completed.

The second stage is used to separate the oxides, in order to obtain 99.9% pure oxides. Even this stage is now completely controlled by China, which, thanks to substantial government subsidies, supports research in the convertion process in metallic powders, metals and alloys.

The Chinese objective of achieving a self-sufficiency that aims at the technological supremacy reiterated in the Made in China 2025 program, also provides for the exploitation of their reserves of rare earths present on national territory. This has led domestic demand for these metals to grow significantly in recent years, resulting in a decrease in Chinese exports of rare earths. However, the domestic use of metals in the homeland, has prompted China to invest in strategic foreign plants, such as those in Africa, especially regarding the extraction of cobalt.

Finally, these powders will be used in the manufacture of products through the sintering process which, compared to traditional metallurgy, makes it possible to obtain alloys more resistant to segregation during melting.

Another strong point of China, compared to the rest of the world, is the issue of more and more patents for the production and use of REEs: from the application of formulations able to maintain the same magnetic power of a product, while lowering the content of rare earth elements; to the creation of magnesium alloys with elements such as lanthanum, praseodymium, cerium and yttrium, which improve their ductility and resistance to high temperatures, making them up to a third lighter than those in aluminum. These alloys, resistant to electromagnetic radiation and easier to recycle, are used in cars, smartphones, computers and aerospace applications (Brussato, 2021).

The REEs mining and processing industry is therefore an important part of the development of an increasingly green economy and a transition to low-carbon economies, despite being at the centre of great geopolitical issues that cause disruptions in the supply chains. Current demand for the Rees sector, according to end-uses, is expected to increase.

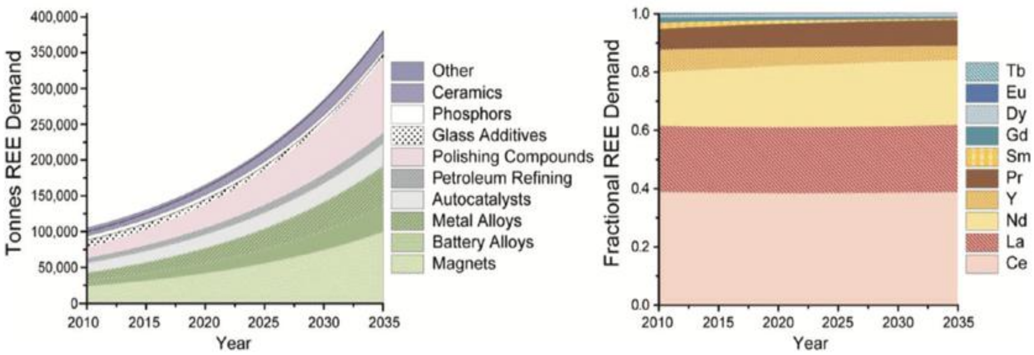


Figure 2.15: Projected demand for REEs by end-use sector. Source: American Chemical Society

The greatest demand will be for neodymium (Nd), terbium (Tb) and dysprosium (Dy) elements needed to produce magnets in wind turbines. While the increased demand for cerium (Ce), lanthanum (La), praseodymium (Pr), yttrium (Y), along with neodymium (Nd), will be determinant to produce Nimh batteries and metal alloys.

Back to cobalt, there can be no talk about cobalt without approaching the subject from an ethical point of view. The extraction of this mineral has a high human tribute. Cobalt in nature is found both underground and in many rocks. However, it is not extracted pure, but as a secondary material from the extraction and refining of other metals, such as nickel and copper. The most common forms are cobaltite, carrollite, linnaeite, and heterogenite. The highest concentration of cobalt is found in the DRC, in particular in Katanga, where the mineral is mined in open-cast mines - without any safety equipment inside and outside them - by miners, mostly artisans called “creuseurs”, whose health is threatened by high levels of toxic fumes from metals. Systematic violations of human rights occur mainly because of the exploitation of child labour. The rise in prices resulting from the continuing and increasing demand for cobalt could also have disruptive effects on local communities. Only recently some NGOs have brought to light significant accusations against some leading technology companies, accused of not applying strict enough controls on their supply chains. A striking example was the lawsuit brought by International Rights Advocates, on behalf of Congolese families, against five great technological giants, Apple, Google, Tesla, Microsoft, Dell, and two mining companies, Glencore and Zhenjiang Huayou Cobalt, accused of the cobalt used in their products coming from activities at risk of child labour and exploitation and of having done nothing to prevent it. Often, cobalt dug under such conditions of exploitation ends up in the global supply chain through intermediaries, or traders. These traders, who are increasingly coming from China, buy material from anyone who is willing to sell it, then resell it to the mining companies. These, in their turn, supply the refineries and factories with cobalt components. Amnesty International has reported that are often the miners themselves who are forced to sell directly to the operator of the mining site where they work, under a monopoly regime and with lack of control by the State, creating a largely opaque supply chain that does not allow the traceability of minerals from source to export, forced to sell directly to the trading company, without any rules guaranteeing them a fair price.

Several actions are being developed recently to limit the exploitation of child labour and improve the conditions of Congolese workers. The Minister of Mines of the Democratic Republic of the Congo, Willy Kitobo Samsoni, recently joined the Cobalt Action Partnership (CAP), a program among whose objectives is to create a responsible supply chain of cobalt, by involving the main actors of the DRC government. This was announced by the Responsible Minerals Initiative, in a statement in December 2020. The CAP is an initiative created in collaboration with the Global Battery Alliance, formalized in May 2020, which brings together public and private organizations of the sector, committed to identify actions that legitimise the artisanal and mining cobalt produced on a small scale in the Democratic Republic of Congo, so that it can be put on the global market. This will allow, at the same time, to monitor ASM operations to eradicate child labour and human rights violations. CAP support will bring new useful inputs to GBA in the implementation of the Battery Passport, a digital representation that provides all information about the characteristics of an EV's battery, including environmental requirements, social and governance, so as to ensure a resource-sustainable battery value chain. In an effort to achieve the goal that batteries can contribute to sustainable development and climate change, by 2030, the Global Battery Alliance, in its report (Forum 2019), provides recommendations for achieving this potential, through ten guiding principles:

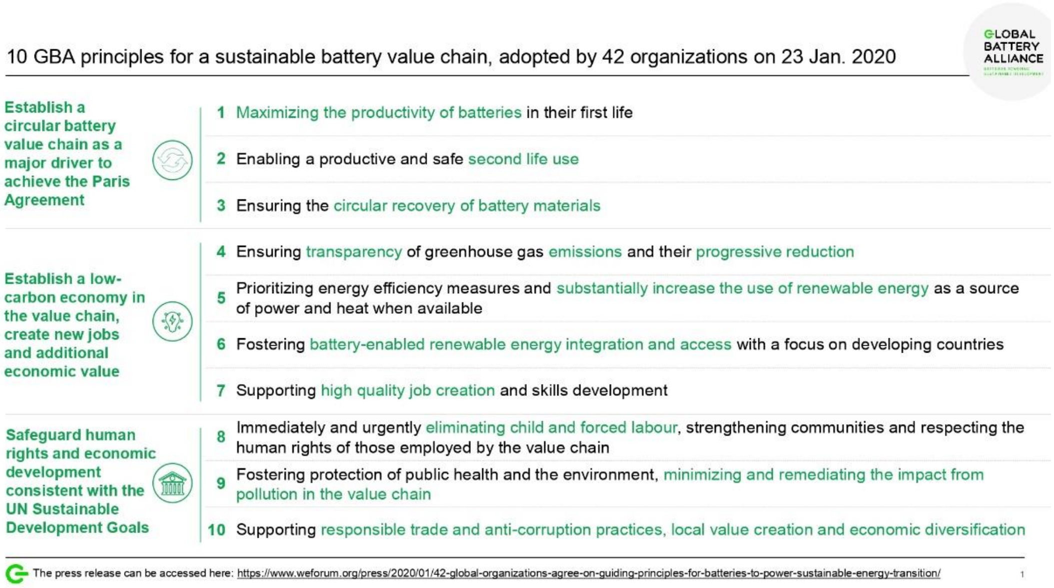


Figure 2.16: 10 GBA principles for a sustainable battery value chain.
Source: Global Battery Alliance

The 10 GBA principles for a sustainable battery value chain have been adopted by 42 organisations, on the basis of three main points, which are in line with the UN SDGs, namely achieving the objectives of the Paris Agreement, create new jobs and protect human rights. To ensure a sustainable and responsible cobalt supply chain in the DRC, stakeholders will need to assess national projects through a common monitoring framework, as well as establish a common standard to be followed for the ASMs. Through the Fund for the Prevention of Child Labour in the Mining Communities, administered exclusively by UNICEF, initiatives will be financed to address the causes of it. Another initiative in support of the national strategy to combat child labour and provide alternatives in the cobalt supply chain was the investment of 115 million of dollars by the African Development Bank. Initiatives aimed at a low-carbon economy aim at exploiting second-life batteries, assessing innovative solutions and through cross-border agreements to reduce recycling costs.

According to the US Geological Survey (USGS), the world's total cobalt reserves amount to 7 million tonnes. And although most of the reserves are located in the Democratic Republic of Congo (with 3.6 million tons), Australia has a high degree of reliability in terms of supplies with reserves of about 1.2 million tons. Although the DRC holds the first place in the production of cobalt, concerns over the country's political instability have prompted some electric car manufacturers to think of Australia as one of the countries providing supplies in the future. The other resources of cobalt are then divided into Cuba (500,000 tonnes), the Philippines (260,000 tonnes), Russia (250,000 tonnes), Canada (220,000 tonnes), Madagascar (100,000 tonnes), China (80,000 tonnes), Papua New Guinea (51,000 tonnes) and other countries (about 640,000 tonnes). The bottom of the Atlantic, Indian and Pacific oceans could provide an additional 120 million tonnes of cobalt, but their extraction is not yet feasible due to technological, economic and legal barriers(U.S. Geological Survey 2021).

As cobalt is mostly extracted from copper and nickel, its availability is constrained by the market trends of these two metals. This generates a potential uncertainty and instability on prices. Another element of concern that threatens the value chain of this mineral is the refining process, which takes place almost entirely in China, which makes it predominant in cathode production compared to all other countries.

In the "Cobalt: demand-supply balances in the transition to electric mobility" (Alves Dias P., Blagoeva D., Pavel C. 2018) the Joint Research Centre of the European Commission (JCR), suggests some specific actions for an improvement of the market, to avoid an impasse in the growth of electric mobility. This problem is already being felt by the European market, which aims to become increasingly less dependent on Chinese hegemony throughout the cobalt value chain. The JRC argues that this risk is expected to last in the short term but sees the possibility of reducing this gap between 2020 and 2030, thanks to new exploration projects in progress that could add new suppliers, diversifying the market. Researchers' optimism is represented by the consideration that the substitution of cobalt with other metals to be technically possible, albeit in the long term.

Among the specific actions that aim to achieve these objectives, the JRC study proposes:

- promoting cobalt extraction by attracting private investment in mineral exploration by improving regulatory conditions;
- to consolidate trade agreements with countries such as Australia and Canada, whose importance as cobalt producers is set to grow in the future;

- to ensure that waste batteries, including those of plug-in hybrid electric vehicles, are collected efficiently to increase cobalt recycling;
- exploring ways to bring low-cobalt chemical solutions and cobalt-free alternatives to the market.

Developing new efficient and less expensive methods for recycling lithium batteries is one of the main challenges for the renewable industry and many researchers are working to find alternatives to traditional recycling methods involving complex chemical processes to melt and separate metals, and then recover them, with a considerable waste of energy.

Interesting about it the theory developed recently by a group of Finnish researchers from Aalto University. The study proposes an innovative practice that would allow to reconstruct the lithium-cobalt oxide electrodes of spent batteries, keeping intact the existing structure. With lower energy consumption, through an electrolytic process commonly used in some industrial sectors, it is planned to reintegrate spent lithium into the electrodes, so that the compound LiCoO2 can be directly reused, with similar performance as new electrodes. However, this innovative solution has at present only been tested in the laboratory (Lahtinen et al. 2021).

Beyond the ethical discourse on the practices and methods of critical minerals supply in certain developing countries, such as the Democratic Republic of Congo, it should also be considered how much the recent disruptions caused by the Covid-19 pandemic, have influenced the chain of production. The severe imposition by the South African Government in the second quarter of 2020 to suspend the transport of cobalt from the DRC to other countries, has caused many concerns and delays in the manufacturing of products essential for the development of clean energy.

No less important was the announcement by China, in early 2021, to adopt a set of guidelines, under the control of the State Council, in order to safeguard its resources against potential disruptions caused by the imbalance between supply and demand of rare earth elements and to regulate its industrial chain. In reporting the approval of this new regulation, the China Daily, also managed by the State, has mentioned that the guidelines will cover responsible procedures for the extraction, fusion and separation of rare earths elements, in order to reiterate the ban on the purchase and sale of illegal rare earth products. Rare earth import and export companies will also have to respect the laws regarding foreign trade and the export control[3]. This will only fuel the volatility of the prices of these precious critical minerals.

The ongoing competition represented by China (whose dominant position is determined by the fact that besides being one of the main suppliers, it is also a key consumer of minerals and raw materials) and the growing concern about the fragility of critical mineral supply chains in some economies, has led many countries to review their strategies and introduce new action plans to address technological challenges.

The recent analysis of March 2021, conducted by Jane Nakano, for the CSIS (Center for Strategic & International Studies), shows an overview of geopolitical strategies adopted by three economies, which are seats of innovation and production in terms of climate change technologies (Nakano 2021).

[3] Liu Zhihua and Liu Yukun, "China to step up protection of rare earth resources," *China Daily*, January 16, 2021, https://global.chinadaily.com.cn/a/202101/16/WS60023d3aa31024ad0baa3039.html

	United States	European Union	Japan
Term Used in Strategic Documents	Critical minerals	Critical and raw materials	Rare metals
Key Interests/ Considerations	Defense requirements; economic security; industrial competitiveness. No specific focus on clean energy sector.	Industrial competitiveness in clean energy sector. Political commitment to climate neutrality.	Industrial competitiveness.
Research and Innovation Focus	Domestic resource survey capacity; separation and processing; substitute development; recycling technologies.	Separation and processing; substitute development; recycling technologies.	Substitute development; recycling technologies.
International Cooperation Focus	Cooperation is alliance-oriented. The tone is confrontational against China.	Cooperation within and near the European Union is important.	Trade and investment with resource-rich countries. Funding to resource-rich developing countries for capacity building.
Domestic Land Access Issue Focus	Permitting.	Permitting.	Not applicable.
Workforce Issue Focus	Extractive industry workers and processing expertise.	Extractive industry workers and processing expertise.	Expertise in substitution and recycling technology researchers.
Critical Minerals List	35 entries on the list. No regularly scheduled criticality assessments. Updates per the White House. The most recent list was published in 2019.	30 entries on the list. Regularly scheduled criticality assessments, every three years. The most recent list was published in 2020.	34 entries on the list. No regularly scheduled criticality assessments. METI updated the list sometime since 2014.
Stockpile	For DOD use, managed by the DLA (The current NDS contains 37 materials between processed metals and other downstream products, including rare-earth and lithium-ion precursors.)	None at the EU or EU member nation level (The European Commission deliberated on the efficacy of national stockpiling of critical minerals in 2012 but found no support for it.)	Stockpiling since 1983, for industry use; national (70%) and private industry stocks (30%) both managed by JOGMEC.

Figure 2.17: Comparing the Strategies/Responses. Source: “The Geopolitics of Critical Minerals Supply Chains” – CSIS 2021 (own table based on data provided by the author).

The table reproduced from the report of Energy Security and Climate Change Program of the CSIS, compares the strategies of the United States, European Union and Japan, based on their profiles of endowment of resources and industrial structures.

Traditionally, the United States is considered a country rich in mineral resources and very strong in the production of minerals of the main rare earth, useful for the manufacture of high-performance magnets required in clean energy technologies. However, in recent decades, interest in contributing to climate change by more and more countries, has prompted the United States to shift much of its production abroad. Giving priority to this aspect, the United States, since 2000, has increased its almost total dependence on rare earth oxides separated from imports from abroad, in particular from China. In the coming decades, poor there have been the attempts to reduce this dependence. The failure of Molycorp, from 2012 to 2015, to reopen the only historic American rare earths project extraction in Mountain Pass, is an example of this. And even if there have been initiatives over the years aimed to reactivate national supply chains, starting several rare earth elements separation and processing projects in California, Texas, Alaska and Colorado, the supply of critical minerals remains a national security issue. In response to this concern, in 2010, the American DOE (Department of Energy) published the "Critical Materials Strategy", its first strategic document to define the importance of the role of critical minerals in the clean energy economy. Initially there was no specific note in the document on the worrying dependence on a single supplier. The various updates of the Critical Materials Strategy of the United States, in the following years, have highlighted instead the prominent role of China in the national and global supply chains, up to the current Biden administration, where can be probably glimpsed a more comprehensive strategic plan, based on a single alignment of policy priorities for climate change mitigation.

According to Nakano, while the heated tones of the United States towards China's dependence take a hostile attitude, the strategic response of the European Union seems to have a more friendly tone in respect of the Chinese giant. As shown in the previous chapter on Europe, in its "Critical Raw Materials Resilience" the European Commission, despite expressing its concern about the current dependence on imports of minerals and raw materials, does not nominate China as main competitor for supplies, nor does it assign it the title of primary cause of concern for global supplying. This will serve to preserve and maintain the balance for economic ties between the EU and China, but at the same time it could protect Europe from the geo-economics influence of the United States. Another strong point of the European Union highlighted in the report, is to be able to take advantage of more funding (such as the recent funds made available by the European Investment Bank) supporting projects for the supplying of raw materials necessary to low-carbon technologies, so as to promote its interests in global competition in the mining supply chains and to attract more private investment, both at national level and in resource-rich third countries.

In the current geopolitical context described in the Nakano report, also Japan, despite being a manufacturing economy, depends on imports of critical minerals. While they have no reserves of their own, Japanese companies account for 15% of the global annual production of high-performance permanent magnets and, thanks to the acquisition of intellectual property rights for the first inventions in the process, companies like Hitachi are in possess of license, granted by China and Germany, to produce and sell batteries. Japan, like the European Union, invests in foreign mining projects, in storage and the research and development of substitutes and recycling technologies, to address the internal capacity shortage of critical minerals. In this respect, cooperation with the United States is important. Thanks to Japan's ability to reuse materials and develop substitutes, its dependence on rare earths supplies from China decreased from 86% in 2009 to 58% in 2018. However, Japan continues to depend on imports for supplies of essential minerals.

Although concerned by different reasons, the United States, Europe and Japan have in common the lack of security in critical mineral supply chains and this inevitably compromises or continues to hamper multilateral partnerships. While Europe and Japan are similar in their approach to fostering innovation through research, to reduce, reuse and recycle the materials they lack and the US is mostly concerned with ensuring uninterrupted access to mining components for defense applications and reducing dependence on a single supplier, the three economies have in common the necessity of an effort and a greater political engagement in support of the field of the technological innovation.

Lithium: the South America perspective

It was highlighted (chapter 1 and chapter 2) that there is, globally, a necessary and urgent need for rare earths in order to follow up on the process of decarbonization and ecological transition. However, what is the socio-environmental impact of this investment? In this section we attempt to investigate the lithium mining process as much as possible with an overview in South America, where more than half of the planet's lithium reserves are located.

The process of extraction/processing of this material harms communities and damages fragile local ecosystems and is, in fact, often opposed by local organizations that attempt a dialectic of negotiation/resistance with the central government (often unsuccessful).

The intensive development of mining activities leaves the local population in a position of extreme vulnerability and the exploitation of water resources caused by the mining process is, for example, one of the major open issues. Water resources are contaminated, diverted and consumed by the lithium mining process, causing conflicts and exacerbating the long process of dispossession of local communities.

3.1 Lithium – Batteries and Green Transport in a nutshell

As the world strives to reduce greenhouse gas emissions, the use of renewable energy is becoming increasingly fundamental, from wind turbines to solar panels, from electric vehicles to battery storage. These low-carbon technologies currently rely on some key metals. In recent years there has been a rapid and significant growth in the production of hybrid electric vehicles and e-vehicles. Demand is set to grow further in the coming decades, according to sustainable climate targets. Depending on the type of engine adopted, electric vehicles can make use of different types of batteries. Lithium-ion technology is the most common technology for EV batteries. The production of these batteries has greatly increased, in some countries rather than in others, depending on the availability of raw materials within their territory to produce them. While easily available, low-cost and often replaceable materials are used to make the coatings or accessories of an electric battery, the materials used for the interior of the cells must have particular characteristics, so it is difficult to find a substitute that ensures the same performance and, consequently, will have a much higher economic value. Not all LIBs on the market today are equal. The most important elements implied for battery cells units can be reassumed in seven essential components: Lithium, Nickel, Cobalt, Manganese, Aluminum, Graphite and Copper (Mayyas, Steward, and Mann 2019). The components of a lithium-ion battery are: a negative electrode or anode (generally made of graphite with a copper collector), a positive electrode or cathode (consisting of an aluminium collector and a transition metal oxide which may vary depending on the chemical composition), a separator and an electrolyte, as depicted in the following figure.

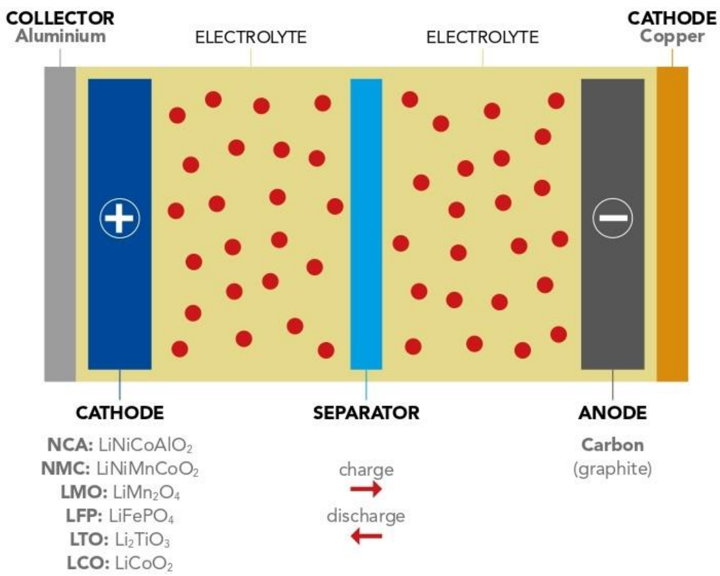


Figure 3.1: A Li-ion battery model. Source: SOMO "The battery paradox"

According to a recent report by SOMO (the danish Center for Research on Multinational Corporations engaged in research and offering strategies for social and sustainable change), the most common types of lithium-ion batteries used today for Evs, depending on their cathodic composition, are:

- Lithium nickel cobalt aluminum (NCA), used by Tesla.
- Lithium nickel manganese cobalt (NMC), which has a higher energy density, used by BMW, Hyundai, Volkswagen, Nissan, and Mercedes-Benz.
- Lithium manganese oxide (LMO), used by the first generation of Nissan and by BMW.
- Lithium iron phosphate (LFP), commonly used in public transportation for their stability.
- Lithium titanate (LTO), employed in public transportation for its fast-charging properties.

There is also another type of battery, lithium-cobalt oxide (LCO), which is not considered to be very safe for cars, and is mainly used in consumer electronics (González and De Haan 2020).

Specific range of raw materials provides relevant characteristics of the Li-ion battery such as specific energy and power, durability and safety. To mention an example, the success of the lithium and nickel-manganese-cobalt oxide battery (Linimncoo2) – NMC 111 is due to the cathode in nickel, manganese and cobalt, which allows to obtain maximum energy and power. While the anode of the battery is in graphite. The combination of nickel and manganese allows to have at the same time a high energy, characteristic of nickel and a crystalline structure, specific to manganese, thus obtaining both electrical and structural advantages. NMC batteries may contain one part of nickel, one of manganese and one of cobalt. But manufacturers are trying to reduce costs by decreasing the amount of cobalt (considered at the moment one of the most important materials, at the center of world attention for geopolitical and market reasons), in favor of nickel, although a percentage of cobalt could lower the cell voltage (Cutaia et al. 2018). Therefore, the need for each mineral varies according to the materials used for each component of a battery, depending on the performance you want to achieve. Compared to the other varieties of lithium-ion batteries, the NMC battery has a longer cycle life, characteristic that make it the favored choice for BEVs and PHEVs production.

The electric mobility market highlights the enormous potential for the development of lithium-ion battery technology. But this will not only lead to an improvement in energy efficiency, in terms of durability and safety, favoring the circulation of more electric vehicles. The need to minimise the resulting environmental, social and political costs is becoming more and more evident in the acquisition of the materials that make up these batteries. Many minerals have limited reserves and are found in a small number of countries globally. The limited geological position, its presence in the territory of the country, the substitution and the recycling are some factors that determine the criticality of a mineral. The assessment of the "criticality" of a raw material would depend basically on two factors, economic importance and supply risks. Criticality is a concept that changes over time according to market conditions, technological evolution and internal political factors, changing the geopolitical framework in supplier countries. Identifying these minerals would help many countries to develop strategies to reduce their dependence on the supply of these raw materials, encouraging recycling and new investments in mining activities, to reduce the risk of supply.

During the year 2020, Lithium, Cobalt and Graphite were includedby the European Commission in the list of "Critical Raw Material",that is, within the list of chemical elements that are essential for the functioning and integrity of a wide range of industrial ecosystems andwhich, at the same time, have verylimited reserves and are found in asmall number of areas in the world.

Of the materials currently used in the production of lithium-ion batteries, also metal silicon, titanium and niobium are included in the list of CRM 2020, since considered of great importance for battery efficiency in terms of durability, safety and energy density.

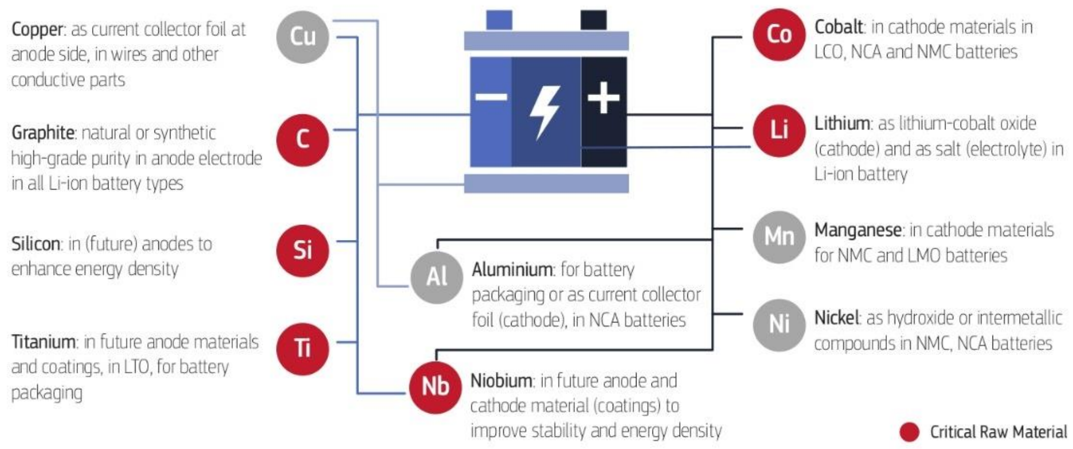


Figure 3.2: Raw materials used in the battery. Source: "European Commission, Critical materials for strategic technologies and sectors in the EU - a foresight study, 2020"

Lithium is a primary constituent in rechargeable LIBs for mobile devices and electric vehicles and is used in the cathode and some electrolyte materials. Lithium has the lowest reduction potential of any element, giving it the highest possible cell potential. It also is the third lightest element and has one of the smallest ionic radii of any single charged ion. These properties ensure that lithium will continue to play a critical role in batteries.

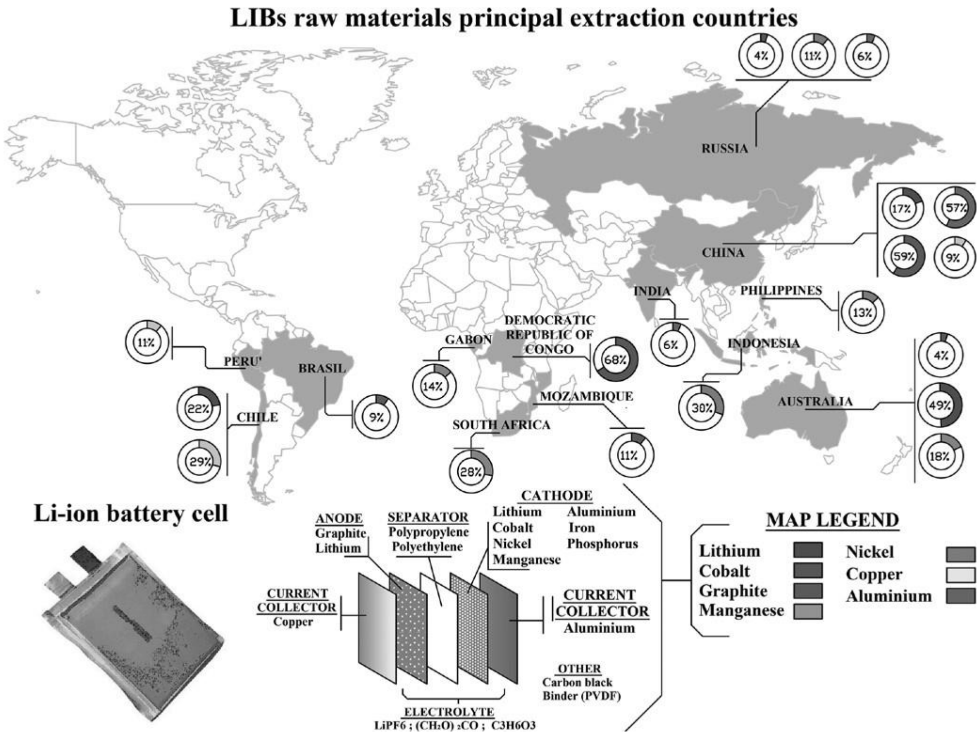


Figure 3.3: Li-ion battery cell representation and composition; LIBs cell principal raw materials and their main extracting countries worldwide during 2020 according to U.S.. Source: Geological Survey (2021)

Figure above shows the distribution of most important LIBs raw materials by disassembling the battery cell components (GainesKirti, Jeffrey Spangenberger,

2018) and deploying them on the geographical representation according to extraction information provided by U.S. Geological Survey (U.S. Geological Survey 2021).

It's important to underline the conceptual and methodological frame of resource potential exploitation. The economic and technical conditions of a given period in a given country permit or not the mining activity of a mineral resource that become a reserve, which is an exploitable resource. Most of resources ore grades are currently calculated with sophisticated mathematical models, on the basis of established knowledge of the geology of a territory. However, a raw material reserve may also step back to a resource, according to the industrial and economical trend, for example if the mineral demand decreases driven by the reduction in sales of a product.

The value chain of LIBs sector engages a high number of industries, starting from the mining industry to obtain the raw materials.

The Lithium value chain goes through 6 steps, from geological exploration to mineral extraction, from refining process to manufacturing and use of products, up to the collection and recycling of lithium.

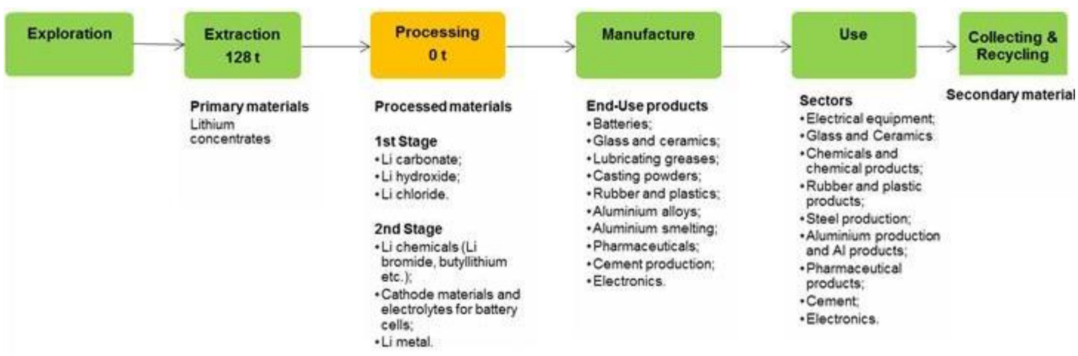
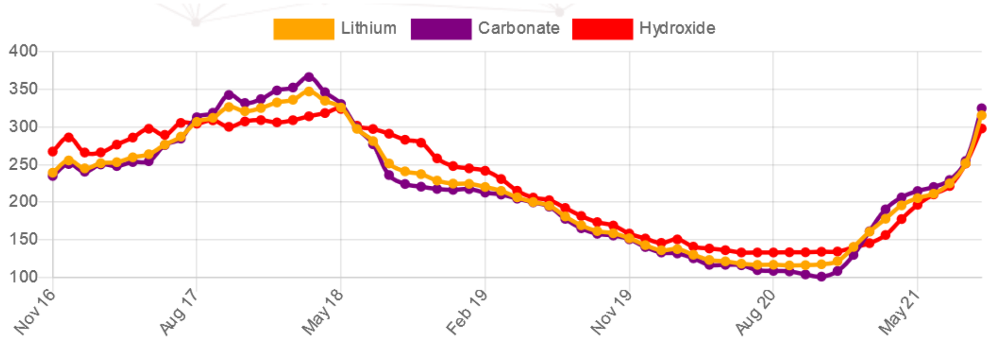


Figure 3.4: Lithium value chain. Source: "European Commission, Study on the EU's list of Critical Raw Materials (2020), Factsheets on Critical Raw Materials".

Lithium in nature can be extracted in two ways: through salt deposits and from the rock. The first method is cheaper, but takes longer; the second is more expensive, but takes less time. As regards rock extraction, among minerals conteining lithium there is spodumene. Spodumene is a mineral of the granitic pegmatites, abundant in magmatic rocks, a crystal of very large and elongated shape. Spodumene deposits are excavated by underground or open-cast mines. By crushing the rock, piece by piece, the lithium minerals are separated into a concentrate which, in about a month, through leaching and roasting processes, produce lithium-based substances. From the salt deposits, on the other hand, is extracted a solution of salt water, the brine. The water that is extracted from wells in the aquifers of the salt deposit, is placed in evaporation tanks, where impurities are eliminated. In these tanks are added substances that lead lithium sulfate to crystallize. The liquid is then mixed with lime, from which magnesium is extracted in the form of gray paste. The calcium sulphate is then filtered and are added compounds to form lithium carbonate, which is being dried. Of the two, the second method of extraction is much more laborious, but it is the least expensive. Lithium is employed pure for the production of ceramics and glass. Lithium carbonate and lithium hydroxide are both used in the production of lithium-ion battery cathodes (Cutaia et al. 2018).

According to U.S. Geological Survey (U.S. Geological Survey 2021), lithium reserves have progressively risen up during years due to the increasing interest in technological field and consequently in market shares values. Furthermore, the importance resource primary supply for a given application is based on the recycling capacity, reusage and life-time, in few words the material life cycle. Thanks to continuous exploration and strategic alliances with technology companies to ensure a reliable and varied supply of lithium for battery suppliers and vehicle manufacturers, based on new information from government and industrial sources, approximately 86 million tonnes of lithium resources have been identified, broken down as follows.



	1M	Y-O-Y	YTD	TODAY	LAST
LITHIUM INDEX	25.3%	172.5%	159.8%	315.6	251.8
CARBONATE INDEX	27.6%	201.6%	199.8%	325.0	254.8
HYDROXIDE INDEX	18.5%	123.5%	122.0%	298.0	251.4

Figure 3.5: Lithium price trends. Source Benchmark Minerals' Lithium Price Assessment https://www.benchmarkminerals.com/lithium-prices/

From 2013 to 2019 the total amount of electric vehicle BEV (Battery Electric Vehicles) and PHEV (Plug-in Hybrid Electric Vehicle) increased from 400.000 units up to7.200.000 units according to statistics of International Energy Agency. Today, more than half of the lithium in circulation is used for the production of rechargeable batteries and, the increase in the production of electric cars, will further increase the demand for this mineral in the next 10 years. The Sustainable Development Scenario (SDS) aims to reach almost 250 million EV and in 20 years have 600 million electric cars in circulation around the world, to be ableto contain the average warmingof the planet below two degrees established by Paris climate agreement (International Energy Agency (IEA) 2020).

The developers of the batteries are always working to make them lighter, to increase the duration and decrease the charging times, and part of these processes is related to the type of lithium used. Some companies are also working on the metals coefficient in an effort to improve the range of the available batteries, which includes other important metals, such as nickel and cobalt. Depending on the cathode and the anode chemicals used in the production of a battery, the need for each material changes considerably(International Energy Agency (IEA) 2021). Table 1 shows the rise of demand of some basic raw materialused in EV LIBs according to International Energy Agency (IEA) statistics.

	Lithium	Cobalt	Manganese	Nickel
2019 material demand for EV Li-ion batteries	17 kt/y	19 kt/y	22 kt/y	65 kt/y
2019 material demand for EV Li-ion batteries respect to total annual extraction	20 %	13 %	0,1 %	2 %
2030 material demand for EV Li-ion batteries (STEPS)	190 kt/y	180 kt/y	177 kt/y	925 kt/y
2030 material demand for EV Li-ion batteries respect to extraction of 2019 (STEPS)	221 %	125 %	1 %	35 %
2030 material demand for EV Li-ion batteries (SDS)	370 kt/y	375 kt/y	370 kt/y	1920 kt/y
2030 material demand for EV Li-ion batteries respect to extraction of 2019 (SDS)	430 %	260 %	2 %	74 %

Tab. 3.1 – Annual demand projection for active cathode raw material to make batteries for electric vehicles according to IEA (Notes: kt = kilotonnes; y = year; STEPS = Stated Policies Scenario; SDS Sustainable Development Scenario). Source (International Energy Agency (IEA) 2020).

New policies and research areworking hard on the potential improvement of materials recycling and reuse share, otherwise, withthe increasing demand, it would mean to push strongly on primary supply for batteries basics elements procurement. For example, some authors stated that lithium annually recycled is less than 1% (Bobba et al. 2020),translating this information into primary supply, that would mean to extract annually around 365 kilotonnes of lithium by 2030. The upward trend to fulfil the objectiveof 2040 of more than twice of EV respect 2030 is easily translated into almost 900 kt/year extracted just for electro-mobility.

The IEA estimates a future surge in demand for lithium, nickel, cobalt, manganese and graphite (crucial metals to ensure performance, longevity and energy density of a battery) in two different scenarios, SDS and STEPS.

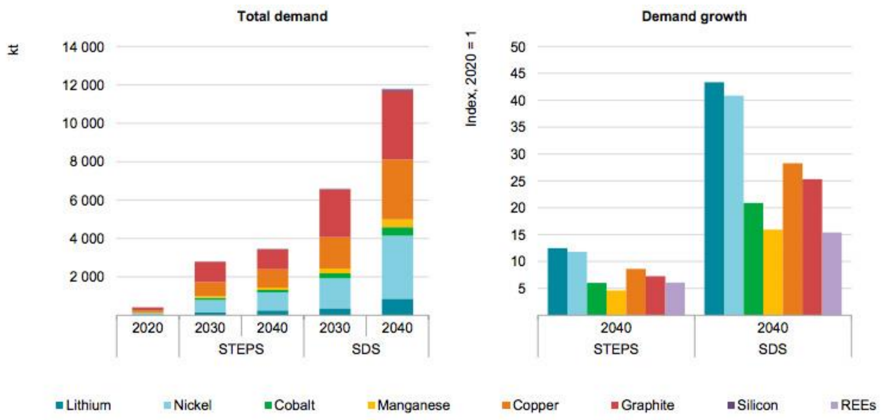
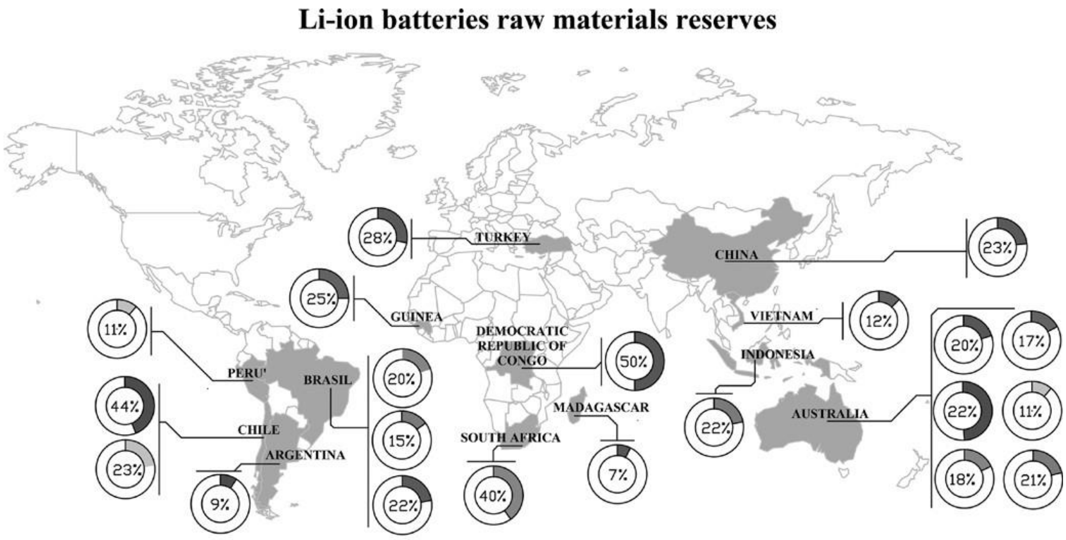


Figure 3.6: Mineral demand from new electric-vehicle sales. Source: IEA "The Role of Critical Minerals in Clean Energy Transition".

As reported in the figure, in the Sustainable Development Scenario (SDS), in the battery sector, the demand for minerals such as lithium and nickel grow by about 30 times by 2040. The Stated Policies Scenario (STEPS) should provide an indication of the possible and reachable targets in energy sector through today's policy measures and plans. It is expected also a significant increase in demand for minerals such as rare earths needed for permanent magnets in wind turbines and EV engines. With the expansion of electricity networks there will be greater demand for copper and aluminum. There is considerable uncertainty about future demand for minerals, which varies according to market prices or the evolution of a specific technology. The causes are therefore attributable to the development of the various climate policies and the consequent direction in which the new technologies move. With regard to the ambition of global climate policies, policy makers need to be clear about their ambitions, in order to reduce investment risks, ensuring a flow of capital appropriate to new projects, turning objectives into actions towards a scenario consistent with the Paris Agreement(International Energy Agency (IEA) 2021).

Many challenges come to surface just watching the aforementioned scenarios imposed by supranational institution and agencies such as: availability of raw materials to fulfil the objectives, the environmental burden for resource supply and the shifting interest on countries that own huge storage of LIBs basic elements as South America.

Based on data collected (U.S.Geological Survey, 2021), global reserves of raw materials were estimated during 2021, including the basic materials for the construction of lithium batteries. The figure later shows the countries that possess most of the resources. It is noted that there is anunbalance toward few countries of the globe in Oceania, Africa and South America continents, in few words toward the southern hemisphere.



	Lithium	Cobalt	Manganese	Graphite	Nickel	Bauxite	Copper
$R_{m\,2020}$ (kilotonnes)	21.000	7.100	1.300.000	320.000	94.000	30.000.000	870.000
E_{2020} (kilotonnes)	82	140	18.500	1.100	2.500	371.000	25.000
$ERR(\%)_{2020}$	0,4	2,0	1,4	0,3	2,7	1,2	2,9

MAP LEGEND
Lithium
Cobalt
Graphite
Manganese
Nickel
Copper
Bauxite

Figure 3.7: Li-ion battery cell principal raw material reserve percentually calculated during 2020 according to U.S. Geological Survey (2021). Below: total reserves estimated during 2020, global extraction in 2020 and ERR (%) index of the same year. Source: U.S. Geological Survey (2021).

3.2 Lithium Triangle: South America

Nickel, Cobalt, Manganese, Lithium, Aluminum, Graphite and Copper are the most important elements implied for cells units battery (Huisman et al. 2020).

Lithium is undoubtedly a central element in the production of electric batteries, one of the fundamental materials in the process of ecological transition, particularly in the transport sector. As a matter of fact, scooters, bicycles and electric cars will all have lithium batteries, so the careful analysis of the geopolitical dynamics around this material are crucial also for the support of ecological and sustainable urban regeneration processes, i.e. “smart cities”.

The same material, however, is also important to run smartphones, tablets and advanced weapons systems, indispensable technologies for the modern world.

In recent decades, East Asia has become the main pole of technological innovation in industrial processes based on the use of lithium. China, one of the largest consumers of hydrocarbons in the world, is the country that is investing more in sustainable projects also to limit external energy dependence. Precisely for this reason, the Asian dragon's investments in Latin America have strengthened. It currently controls Sociedad Química y Minera de Chile (SQM), the main private lithium mining company (which holds 47% of the country's known reserves to date) and is heavily investing economically in Argentina, Bolivia and Brazil.

Unfortunately, to date there are still few studies of the real socio-environmental impacts related to the process of lithium extraction and there are several local organizations that push policy makers to curb and / or moderate agreements / projects for the benefit of the geopolitical game mainly of China and the United States.

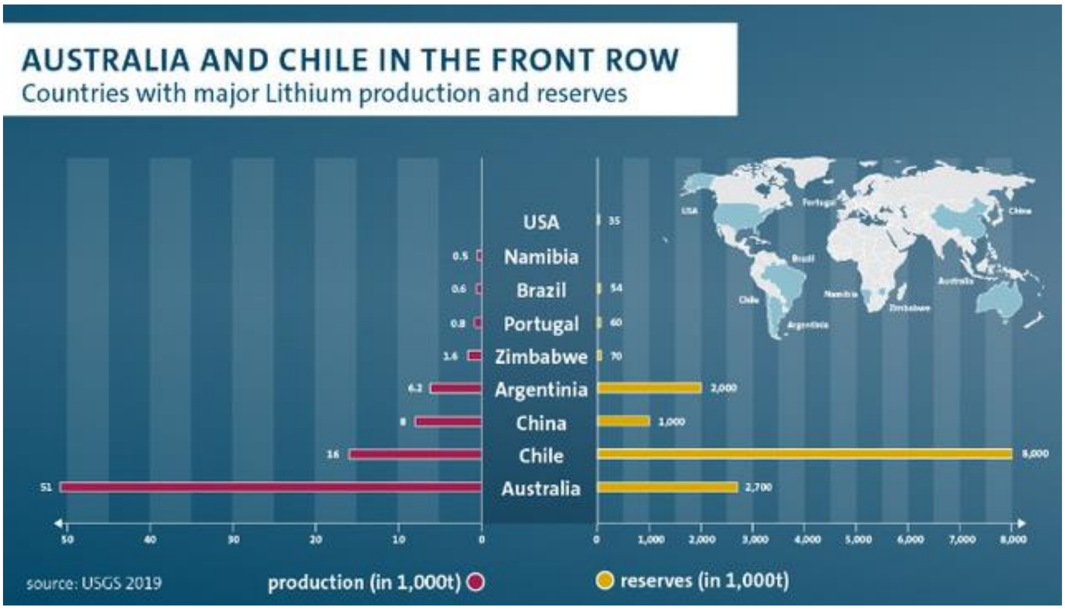


Figure 3.8: Countries with major Lithium production and reserves. Source: Volkswagen Group Italia S.p.A. based on USGS 2019 data https://modo.volkswagengroup.it/it/q-life/lestrazione-del-litio-fatti-e-cifre-da-conoscere

Latin America is famous for the well-known "lithium triangle" that encompasses the lithium brine deposits present under the salt flats, or "salares", of Northwest Argentina, Northern Chile, Southwest Bolivia. Approximately 58% of the world's lithium resources are found in these three countries, according to the 2021 USGS Mineral Commodity Summary.

Giving the terminology of the mining industry and the different project we have seen so far in South America, we should first of all make a difference between the following terms (Emily and Hersh 2019):

- Deposit: The mineral in question is present;
- Resource: The mineral is present and quantifiable;
- Reserve: The mineral is present and quantifiable. Furthermore, the costs to extract and commercialize the mineral are estimated to an accepted margin of error.

According to this terminology and Latin America state of art of these deposits, only Argentina and Chile are in possession of reserves. As of now, Bolivia's lithium is only a resource – measured but currently not known to be feasibly extractible.

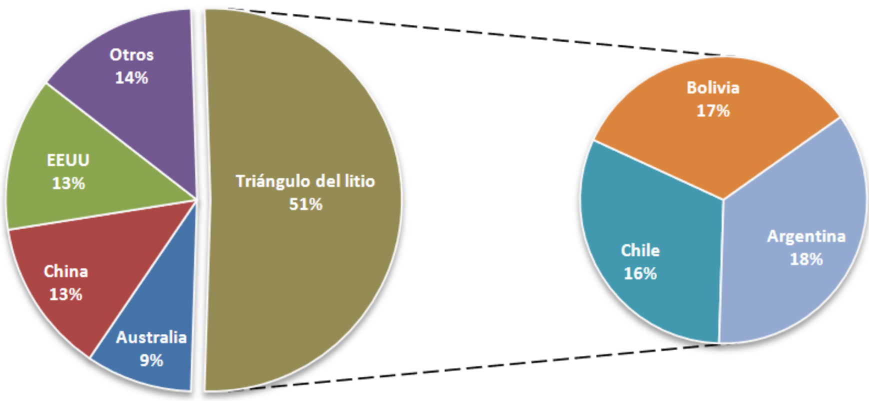


Figure 3.9: Composition "Lithium Triangle" in world resources 2017.
Source USGS 2018.

Half of all lithium reserves on the planet are located between Chile, Argentina and Bolivia, the so-called "lithium triangle". From the salty desert in Bolivia, Salar de Uyuni, to the Chilean Atacama Desert, and continuing eastward into Argentina. What should be of greatest concern, however, is not the amount of lithium present on the Earth's crust, but its global distribution.

The assessment of the "criticality" of a raw material would depend basically on two factors

- economic importance;
- supply risks.

Criticality is a concept that changes over time according to market conditions, technological evolution and internal political factors, changing the geopolitical framework in supplier countries. The economic and technical conditions of a given period in a given country permit or not the mining activity of a mineral resource that become a reserve, which is an exploitable resource (U.S. Bureau of Mines and U.S. Geological Survey 1980).

The lithium market, under pressure from an ever-increasing push for a sustainable energy transition, is growing exponentially, but in Latin America logistical costs are very high due in part to inadequate reliable infrastructure, political and economic instability, lack of technical expertise and large capital investments.

Figure 3.10: The lithium triangle. Source: https://www.economist.com/the-americas/2017/06/15/a-battle-for-supremacy-in-the-lithium-triangle

Lithium resources are mainly placed in Bolivia, 21 million tons; Argentina, 19.3 million tons; Chile, 9.6 million tons; United States 7.9; Australia, 6.4 million tons; China, 5.1 million tons, according to USGS data (U.S. Geological Survey 2021). Here are located most of the continental brines in the world, where lithium rich solution is pumped up from groundwater to the plant where lithium increase percentage step by step through evaporation ponds till is ready to be refined into lithium carbonate (Liu, Agusdinata, and Myint 2019).

3.2.1 Chile

Chile has the largest and most certified lithium reserve in South America and is the world's second-largest commercial producer after Australia.

The logistical advantage, the political stability of the recent years and the low rate of corruption (different from other countries of the same content) combined with liberalist policies, let Chile dominate the market.

The main companies that control the Chilean industry are:

- Albemarle: a company based in the United States that also controls large lithium reserves in Australia;
- Sociedad Química y Minera de Chile (SQM), the largest lithium mining company in Chile.

Chile today is trying to break away from the role of producer and, also in an attempt to respond to the growing share of the market, is pushing the production on site (example is the agreement with Albermarle under which the company agrees to sell at a favorable price part of the lithium extracted to Chilean companies engaged in on-site production).

The oldest lithium reserve is located in the Atacama Desert, 3,000 km2 at 2,300 m above sea level, one of the driest and most complicated places in the world (Cubillos et al. 2018), therefore not ideal for extraction and storage given its high flammability. This reserve has the great logistical advantage of being located near the city of Antofagasta, which is one of the most important industrial ports in the country.

Atacama Desert presents extremely arid climate and unique topography produce the saline groundwater containing 0.15% lithium that serves as the major water source for lithium extraction. The Atacama Desert's exceptional topography and environmental features produce a combination of physical conditions conductive to the formation of brine and its low-cost exploitation.

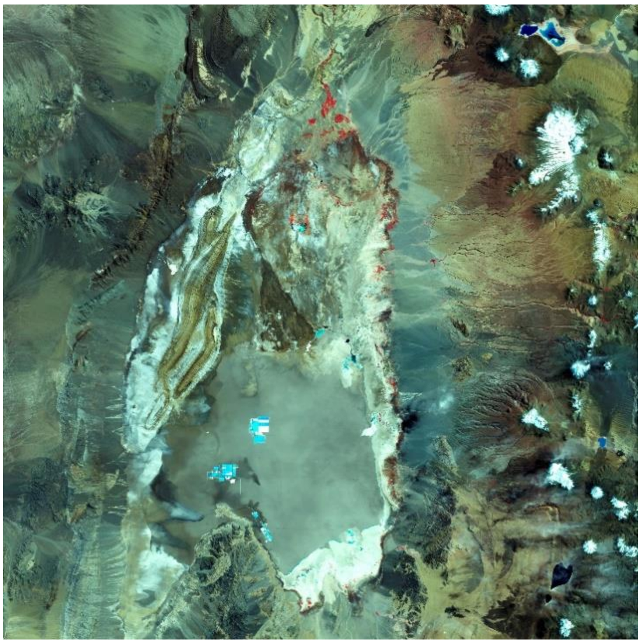


Figure 3.11: Salar de Atacama photo taken by Landsat 7 satellite in March 2002. Red indicates vegetation (more abundant around the springs that dot the northern edge of the salt marsh). Source: NASA https://earthobservatory.nasa.gov/images/76518/salar-de-atacama-chile

Generally, the saline groundwater containing lithium is pumped through a cascade of ponds where impurities are precipitated by solar evaporation, wind, and chemical additives. After that, the concentrated brine is transported back to the recovery plant in Antofagasta for future purification and processing. The extraction is chemical intensive, extremely slow, and delivers large volumes of waste. This technology is heavily dependent on the geological structure of the deposits, brine chemical composition and both climate and weather conditions (Flexer, Baspineiro, and Galli 2018).

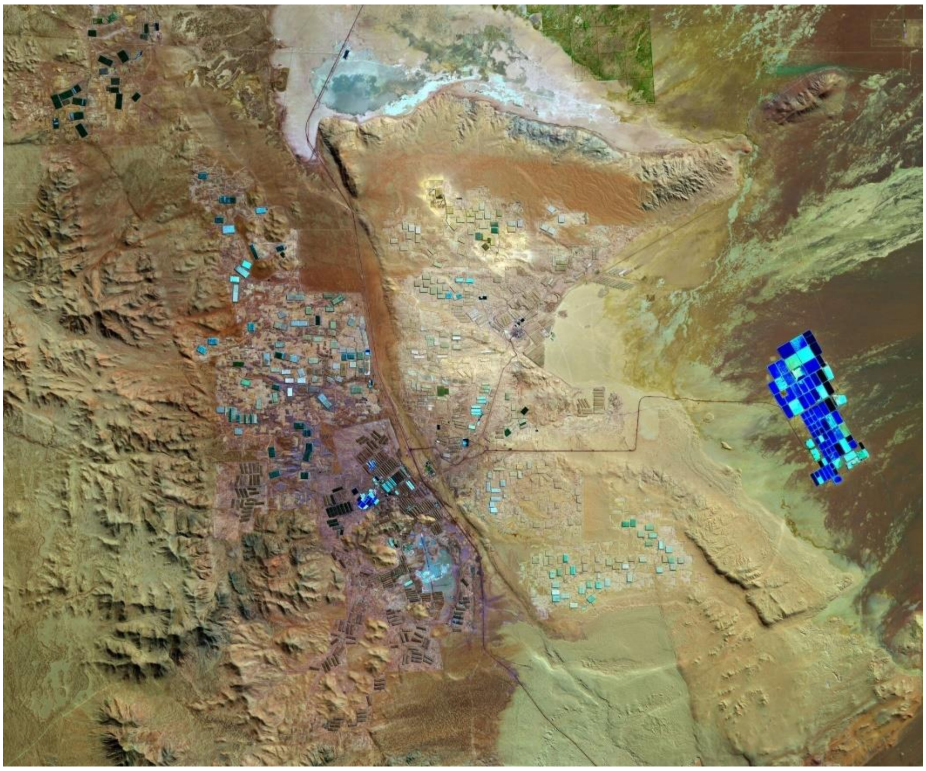


Figure 3.12: Atacama minerals. Chile's Atacama Desert. In this image, captured on 26 June 2019, a specific area in the Tarapacá Region, in northern Chile, is featured – where some of the largest caliche deposits can be found. It is here where nitrates, lithium, potassium and iodine are mined. Source: ESA, Copernicus Sentinel-2 mission https://www.esa.int/ESA_Multimedia/Images/2020/05/Atacama_minerals

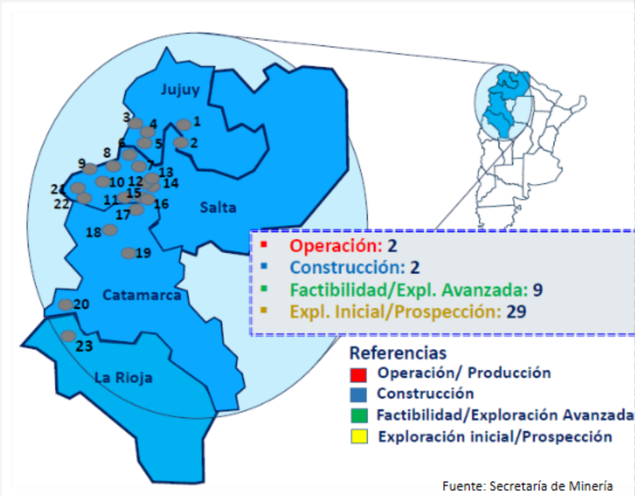
3.2.2 Argentina

Argentina holds the world's second-largest identified lithium resources (behind only Bolivia), and the third-largest quantity of commercially viable lithium reserves behind only Chile and Australia.

Jujuy, Salta and Catamarca are the provinces with the largest deposits of lithium and the operating salt flats are Salar de Olaroz and Salar del Hombre Muerto.

The take-off of the extractive sector has been limited mainly by several changes of government in the last 20 years that have alternated phases of total liberalization of the market with processes of nationalization of the major companies in crucial and strategic sectors (eg oil company YPF). The statist policies of the left-wing government (eg Kirchner and Fernandez) which have increased taxes on exports and imposed heavy controls on access to foreign currency, also due to strong internal economic crises, has discouraged foreign investment and / or large companies often forced to disentangle between provincial and national regulations have thus opposed important liberalization processes, in some cases reducing the country's global market power. According to the data provided by Fornillo (Fornillo and Zicari 2019), these are the large multinational companies that to date have set foot in Argentina:

- Japanese company Toyota partnered with the Australian mining company Orocobre Limited to exploit the Salar de Olaroz (province of Jujuy);
- Magna and Mitsubishi (also from Japan) did the same in the Salar de Cauchari (Salta province) with the Canadian mining company Lithium Americas
- the Korean automaker Kores did so with Lithium One (Canadian-Chinese mining company) to exploit the Sal de Vida deposit in Catamarca, Argentina.



		Cantidad de proy. s/estado			
1	Laguna Guayatayoc				1
2	Salinas Grandes				6
3	Salar de Jama				1
4	Salar de Olaroz	1			
5	Salar de Cauchari		1	1	1
6	Salar del Rincón		1		3
7	Salar de Pocitos				3
8	Salar de Icahuasi				1
9	Salar de Pular				1
10	Salar de Arizaro				5
11	Salar Tolillar				1
12	Salar de Pozuelos				1
13	Salar de Pastos Grandes				2
14	Salar Centenario			1	
15	Salar de Ratones			1	
16	Salar de Diabillos			1	
17	Salar del Hombre Muerto	1		2	
18	Salar de Antofalla			1	
19	Salar Carachi-Pampa				1
20	Laguna Tres Quebradas			1	
21	Salar Llullaillaco			1	
22	Salar Río Grande				3
23	Laguna Mulas Muertas				2

Figure 3.13: Lithium mining projects, by stage of development. Source: Secretaría de Minería- Subsecretaríade Programación Microeconómica (https://www.argentina.gob.ar/sites/default/files/sspmicro_cadenas_de_valor_litio.pdf)

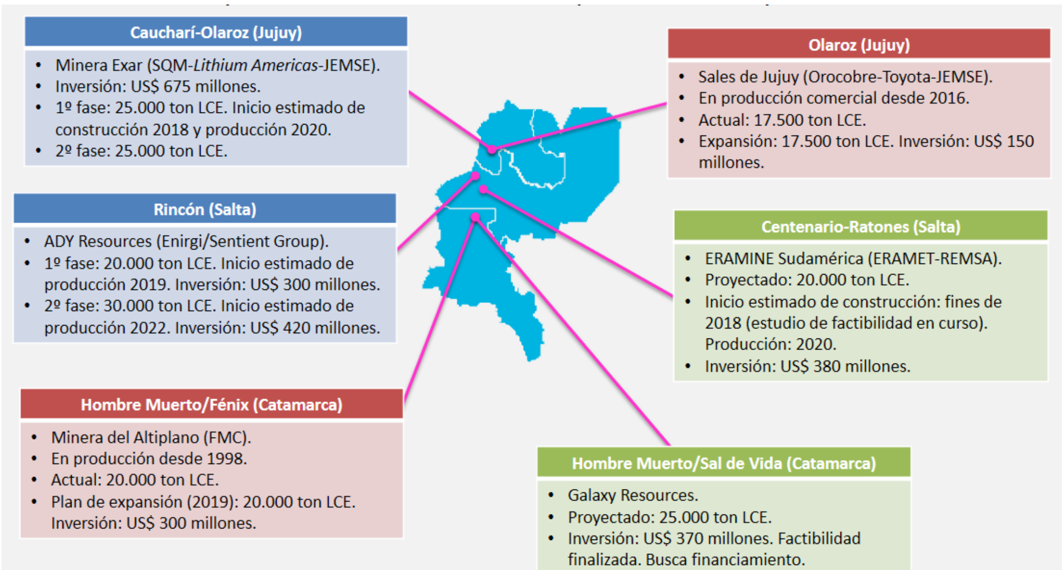


Figure 3.14: Most advanced lithium mining projects: in operation, construction and feasibility. Source: Secretaría de Minería- Subsecretaríade Programación Microeconómica (https://www.argentina.gob.ar/sites/default/files/sspmicro_cadenas_de_valor_litio.pdf)

Another example is Argentina the recent agreement signed by BMW (ANSA news) jointly with the US company Livent for the extraction of lithium in the Andean lake system in the Argentine province of Catamarca worth over 300 million dollars. Reaching a new agreement in this area was considered a priority by BMW because in its plans, the construction of electric cars will represent 50% of its global sales by 2030.

3.2.3 Bolivia

Bolivia possesses the world's largest identified lithium resources. Endless deposits of lithium in the area of the Salar de Uyuni, not far from Potosi, and in the Salar de Coipasa.

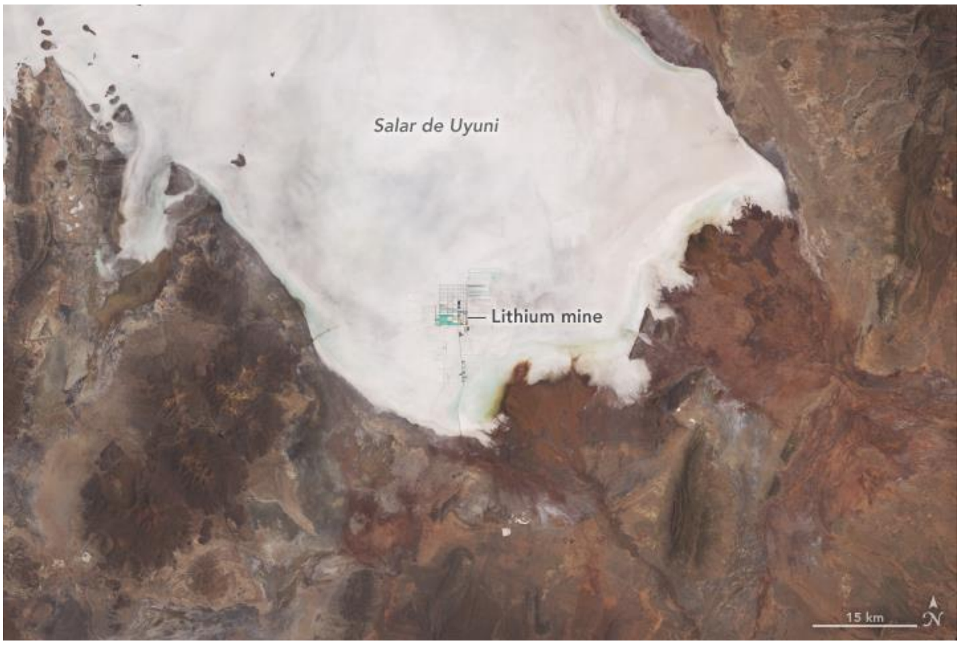


Figure 3.15: Landsat 8 detecting evidence of buildings and evaporation ponds in the southern end of the salt flat in 2011. Source: https://earthobservatory.nasa.gov/images/144976/lithium-harvesting-at-salar-de-uyuni

Despite the fact that its deposits are estimated to be among the largest in the world, lithium contributes only a small part to the GDP of the country and the local Government is struggling to turn the resources into commercially viable reserves. The poor development is due to political factors (not least the Attempted Golpe of former President Evo Morales in 2019), the high rate of internal corruption, the technological inadequacy of the extraction process (predominantly left in the hands of local companies due to nationalization) , local environmental and geopolitical issues, namely the heavy rains to which the Salar de Uyuni is subject (which complicates its extraction), and the difficult relations with Chile that prevent Bolivia from using the nearby port of Antofagasta for exports.

The Bolivian case in the international scenario should be analyzed in itself. In fact, in order to better analyze the local context, it is necessary to be able to decontextualize the facts from a “Left' and 'Right' political ideology.

The resign of Evo Morales in Nov.2019 for many was a concomitant of a geopolitical conflict for the access to the immense reserves of lithium that are in the salar of Uyuni.

Morales, highly critical of neoliberal governments responsible for climate change (mostly at the expense of the world's poorest people), has pushed an economic model that is ambiguous to many: based on indigenous values but pushing the need to continue abstracting natural resources to provide for the well-being of Bolivians. Nationalization of resources and push for infrastructure, small industries, social assistance programs for indigenous peoples are also the main points of MAS (Movimento al Socialismo), which implicitly aims at the intensive exploitation of the subsoil for economic and social purposes and for local welfare (Andean-Amazonian capitalism). The basic idea is to use surpluses from the export of raw materials on the world market to stimulate industrialization to emancipate indigenous peoples and decolonize the state. According to the (few) public data, this did not happen. The main result was the renegotiation of the shares of multinationals operating in the country and the modification of the royalty percentages that companies are obliged to pay to the State (Supreme Decree 28701 of May 2006), replacing North American capital with that of China and other European and Latin American companies.

According to the last data available (De Ambroggi 2020) after three years of Morales' government, 67% of oil reserves were in the hands of the Spanish company Repsol, while the state-owned companies Chaco and Andina owned only 28% of shares; as for natural gas reserves, 61% were controlled by the Brazilian company Petrobras, 22% by Repsol and only 13% by the nationalized companies Chaco and Andina. In addition, the country's largest debt to China was incurred (7.5 billion dollars, equal to 17% of Bolivia's GDP), aimed at an ambitious program of mega-projects in the region - including infrastructure, hydroelectric dams and mines - which, however, were totally conditional on being carried out by Chinese companies. Likewise, surpluses of raw materials were not reused in the welfare system in favor of the rural population, but mainly to improve the extractive process from a structural point of view or, in any case, focusing on the massive export of raw materials on the world market.

An example of political short-sightedness is the currently halted Rositas's project in Bolivia awarded by the National Energy Company (ENDE: Empresa Nacional de Energía) to the Chinese company Rositas Accidental in September 2016.

The project foresees the construction of a dam on the Rositas River that when completed will have an installed capacity of 600 MW and would generate 3,064 GWh per year. This project, which according to Morales should have declared Bolivia the "energy heart of the continent", has in fact further highlighted the influence of foreign capital and of the world's great powers, namely China. The construction of the dam was in fact given in concession by the National Energy Company (ENDE: Empresa Nacional de Energía) to the Chinese company Rositas Accidental with clauses that are still unclear and dossiers that are not totally public.

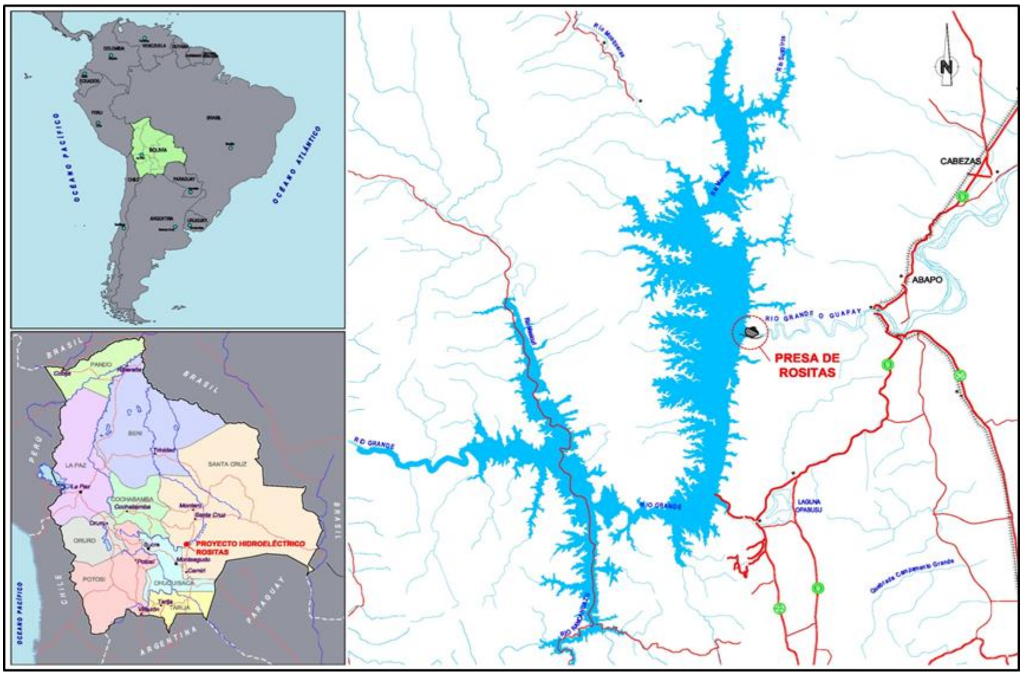


Figure 3.16: Proyecto: Hidroeléctrico Rositas. Proyecto Múltiple Rio Grande Rositas. Source: http://www.ende.bo/proyectos/resena/proyecto--hidroelectrico-rositas

According to data published by the Solon Foundation, Rositas would be one of the most expensive mega-hydroelectric plants in Bolivia, with an investment cost of

US$2.5 million per megawatt. The mega-dam would generate electricity at a cost of US$74.33 per megawatt-hour ($US/MWh) when the average purchase price is US$41/MWh.

The project, which has never seen "prior consultation" within the indigenous territory (as required by law), is arousing huge tensions globally precisely because it would have a huge environmental impact:

- would damage three protected areas:
  - the *Serranía del Iñao National Park*;
  - the Río Grande-Valles Cruceños Natural Area;
  - the Parabanó Municipal Reserve.
- It would damage the cultural heritage of the "Ruta del Che".
- It would endanger 570 species of fauna and 2,415 species of flora.
- It would flood the territory of 10 communities and damage 23 others.

The dam's reservoirs will modify the ecosystem of a large part of Chaco's territory, altering the climate of the entire region and indirectly affecting a larger number of communities, risking to compromise their agricultural and livestock activities and therefore the material conditions of their subsistence.

3.3 Lithium and its environmental impact

The ecological transition, environmentally sustainable, green and therefore environmentally friendly and able to combat global warming is a priority objective on the political agenda of all countries. Lithium plays a crucial role in this process, but at the same time, its extraction has a significant socio-environmental impact (Khobragade 2020): in this area, environmental problems are linked to resource availability.

The real consequences of mining activities have been for years hidden to the world population. The economic expansion generated by the extractive process in its early stages was accompanied by a lack of visibility and recognition of the territorial and socio-environmental conflicts by the local governments, exacerbating the situation in these territories (Svampa and Teran 2019). This coexistence of local communities with mining activities was definitely broken with the publication of the first medical and toxicological studies (OCMAL 2020) on the impact of the mining process on human health and on local ecosystems.

Despite the presence of clear regulations governing mining activities especially to protect the rights of indigenous communities in their territories (eg Convention 169 of the International Labor Organization - ILO, which recognizes the rights of indigenous peoples), many local communities denounce the absence of free, prior and informed consultation with the Government, a mechanism provided for by the aforementioned Convention 169 (eg new contract signed by the Chilean state-owned Corporación de Fomento with the company SQM to expand lithium extraction in the Atacama salt flats)(OCMAL 2020).

The same impacts of climate change could, in turn, disrupt the supply chains of raw materials (Manhart et al. 2019). Flooding, caused by heavy rain or rising sea levels, may negatively affect the availability of fresh water or may introduce salt water into water containment systems in a mining site. This may also lead to an uncontrolled release of metal-contaminated effluents, creating a real toxic waste storage, or render the working areas in the mines impracticable, even if only temporarily. Climate change can potentially have few positive impacts: eg. A positive case could be regard the lithium extraction sites in Chile, which, benefiting from increased temperatures, this would save evaporation time by applying smaller evaporation ponds. But solar evaporation could be slowed down by the already very low moisture levels (Manhart et al. 2019) (Vogt, Lepold, and Rüttinger 2019).

The supply of lithium can hide extraction methods often not sustainable, which risk compromising the green revolution of which it is the protagonist. It is not only the emissions of CO2 from the extraction of underground deposits, but also the excessive use of the soil that derives from it, with the enormous expanses of evaporation ponds that disfigure entire landscapes, in addition to significant water consumption for lithium extraction in brine.

As already mentioned, the lithium deposits in these territories have variable characteristics. This “Triangle” is characterized not only by very different landscape (from desert to 4 thousand meters of altitude almost completely arid and often crossed by huge saline expanses) but also by a very different mining strategies. That affect the processing and the consequent removal of impurities with a significant impact both on the amount of energy used and in the type and quantity of reagents used to extract these impurities. This increases the cost and environmental impact.

Main Socio-Economic Impacts

- Impacts on livelihoods of local communities (eg soils, water, biodiversity, and forest resources)
- Community access to services
- Impacts to cultural resources (eg sacred landscapes, historical infrastructures, and natural landmarks)
- Pollution and contamination (eg respiratory desease)
- Local related conflicts
- Human displacement and resettlement
- Corruption, Poverty & Employment
- Human rights (childrens & Women rights)
- Urbanization Implosions and explosions

Main Environmental Impacts

- Water and air pollution
- Surface and groundwater pollution
- Loss of biodiversity & Habitat
- Change in land use
- Land degradation/subsidence and landslides
- Deforestation

As already mentioned, the lithium deposits in these territories have variable characteristics. This "Triangle" is characterized not only by very different landscape (from desert to 4 thousand meters of altitude almost completely arid and often crossed by huge saline expanses) but also by a very different mining

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strategies. That affect the processing and the consequent removal of impurities with a significant impact both on the amount of energy used and in the type and quantity of reagents used to extract these impurities. This increases the cost and environmental impact.

Lithium brine deposits are dynamic liquids that move underground and whose characteristics change over the life of a project as pumping and refill occurs. The permeability of the host material affects brine's ability to flow from the underground deposit to the surface. Hydrometeorological weather parameters including precipitation, temperature, wind, and altitude affect evaporation rates. New and complementary technologies to the currently employed evaporation ponds are under development, but in all cases imply increased energy consumption and increased chemical reagent use. When assessing sustainability of lithium extraction, existing and emerging technologies must take these environmental impacts into consideration. Lithium producers must be skilled operators capable of managing complex chemical parameters. Referring to the "lithium triangle" as a homogenous deposit creates a false understanding and unrealistic expectations (Emily and Hersh 2019).

Furthermore, mining is the result of a long series of expropriations and environmental degradation in Latin America. Extractivism (we refer to extractivism (Svampa and Teran 2019) as economic activity based on the use of large 'natural resources', most of which are destined for export on the global market) involves the exploitation of large volumes of natural resources (usually unprocessed) and the "mono-product" specialization of the territories involved. This entails necessary transformations linked to the construction of ad hoc infrastructures (eg, connection of extraction sites to ports or exchange nodes), increased demand for energy and obviously significant repercussions on the management and use of another crucial resource, water.

These transformations can be seen as necessary to generate social welfare, but at the same time disrupt local indigenous communities to the prerogative of large multinationals or transnational corporations also bringing the presence of the "State" in territories usually excluded where often the Government manages the distribution of wealth preventing access and control of resources to local communities. All this is defined by "*the devil's cauldron*", that is, a series of socioterritorial contradictions that put pressure on society and with uncertain political outcomes (Romero-Toledo 2019).

Biodiversity of the region is spread on the territory according to some zones and protected areas such as Los Flamencos National Reserve, permanent lagoons which support diverse biodiversity serving as an important nesting center for flamingos and some areas mostly covered by barren soil and salt crests providing habitats to diverse species.

Recently this area of around 7000 km^2 were monitored by satellite sensing in order to observe the effects induced by the mining area increasing activity (20 km^2 to 80 km^2) on surrounding environment. 20 years of monitoring with LandSAT satellite images and spectroradiometer have brought to surface several changes on all the area monitored such as:

- Soil moisture decreasing
- Land surface temperature increasing
- Vegetation depletion

Negative outcomes of extracting activity identified by the aforementioned index are recognized as aquifer running out that lead to hydraulic unbalance and ecosystem wormed up and impoverished (Liu, Agusdinata, and Myint 2019).

All of this is generating an increasing interest in green lithium, which is the lithium that is found in geothermal brine. The extraction of geothermal lithium, unlike the traditional one, takes place with an environmental impact of almost zero and involves a lower use of water and soil, because the brine is pumped directly to the surface from the geothermal wells. The same brine, once the lithium is extracted, is reinjected into the well, while the heat transported by it is used to produce renewable energy. An advantage, therefore, not only in environmental terms, but also in economic ones. Some lithium geothermal reserves are found in the United States, but also in Europe (especially in Germany, France, United Kingdom) (European Council for Geothermal Energy (Egec) for greenreport.it). Although it is a production chain still at the beginning, with costs and feasibility still being defined, some scientists at the Berkeley Lab believe that geothermal brine could give a strong boost to the Green Economy of California. This is the case of the

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Salton Sea, a shallow Califonian lake, but rich in critical metals, deep beneath the surface. Salton Sea Geothermal Field (SSGF) could produce more than 600,000 tons of lithium carbonate to potentially meet 40% of global demand. The Berkeley National Laboratory is helping two companies by evaluating and analyzing their lithium mining technologies. Both projects were subsidized by the CEC, California Energy Commission. Several companies are working on extraction technologies, with a pre-treatment process, separating and removing impure metals from the brine, before extracting lithium, thus reducing energy production costs by up to 35% and developing, cost-effectively, more geothermal brine to convert lithium into lithium carbonate for batteries. The CEC also funded the Berkeley Lab for a project able to map geothermal deposits, through seismic and electromagnetic data, and to better position production wells, identifying areas full of steam from those full of fluid (California Energy Commission 2020).

Calculating with precision the climate impact of the Lithium-ion battery value chain is complex. It's not enough to consider only what happens along all the passages (from the place where the raw materials are extracted, to the refining process) up to the production process, which will have a different climate impact depending on the energy source used. The type of battery produced should also be taken into account, by assessing the elements that make up the cathode and the anode, but also the cells, assembled in modules and packs that, depending on the materials in which they are made, will affect the CO2 footprint and the climate impact of the battery itself (Hans, Melin, and Storage 2019).

According to a study by Transport & Environment, the increase in emissions from the battery production process is likely to reduce the climate benefits of using electric vehicles. The study bases on the several studies conducted in the United States, between 2018 and 2019, by the Systems Assessment Center of the Argonne National Laboratory on the LCA (Life Cycle Analysis) of a lithium battery. Data was incorporated and used as an inventory for the Life Cycle Database of the GREET (Greenhouse gases, Regulated Emissions, and Energy use in Technologies). GREET is a useful tool for examining energy and environmental effects starting from various fuels to vehicle technologies in the main transport sectors (roads, air, maritime and rail), to finish to energy systems. In practice the full life cycle. The GREET 2020 was released by Argonne who updated the model collecting the various studies and dividing them in various areas (ANL 2020). The

Argonne synthesis report contains the LCA of a NMC111 battery, which cathode consists of one-third of nickel, one-third of cobalt and one-third of manganese. To do this, the study was based on actual data from two Chinese plants, for the cell production, and three mines in the Democratic Republic of Congo, for the cobalt value chain. The metrics used for measuring the CO2 footprint from lithium-ion batteries are primarily two: CED (Cumulative Energy Demand) and the amount of GHG or CO2 emissions (CO2e). The first is useful to know how much energy has been used to produce a battery, independently from the source. The second one is useful if combined with the CED. For example, a company that buy green energy from the grid, it will shift fossil fuel consumption to someone else on the grid. To be useful and comparable, the two variables need to be combined with functional units, which are, in case of the battery, the capacity, the weight and the amount of CO2 emission from the battery per driven kilometer. It is therefore clear that the energy source used during all stages of the value chain, which varies depending on where the materials are produced, also has a climate impact. As an alternative to direct supply (using fuels such as natural gas) or indirect (through electricity), in addition to making agreements with their suppliers for the purchase of green energy, companies can also choose to generate by their own the energy they use for heat, building microgrids with solar or wind energy. Plotting the energy mix for electricity is just as important. The GREET update states that a NCM111 battery, produced in the United States, hypothetically and entirely with electricity from the national grid mix, can reach a total greenhouse gas emissions of 73Kg Co2e/kWh. This impact would probably have been less if the same battery had been produced in Europe, where the energy mix is mainly hydroelectric and nuclear energy. The same battery, produced in China, would have had a greater impact because of the prevailing share of coal in the energy mix.

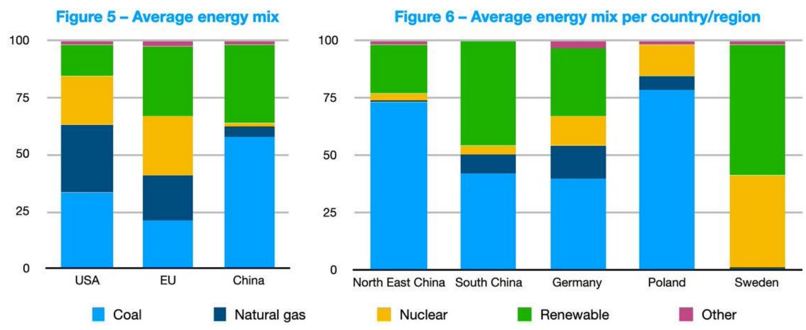


Figure 3.17: Average energy mix applied on a lower aggregate level as the regional or country. Source Circular Energy Storage

However, further differences can be noted by analysing the energy mix applied at a lower level, or at a regional level (as shown in the figure above). If a battery is produced in regions in the South of China, it will notice a lower carbon intensity than that of Poland, although it is equal to that of Germany. This is because in the South of China there are many companies producing batteries, while in the other two European countries the production capacity is increasing in recent years. Sweden, on the other hand, where the production capacity of the battery is under construction, the carbon intensity will be much lower than in all other markets.

In this context, transport emissions must also be taken into account. The variables to be analysed would be the distance travelled from the production sites to the final destination of the battery, the means of transport and, consequently, the type of energy it uses.

3.3.1 Lithium Mining and water use

In South America, lithium deposits are often located in desert areas, so the extraction process would create a severe water shortage. Although the water in the plant tends to be recovered, the large amount needed and the difficult environmental context of the South American salt flats makes the problem almost unsolvable (Lithium National Commission 2010).

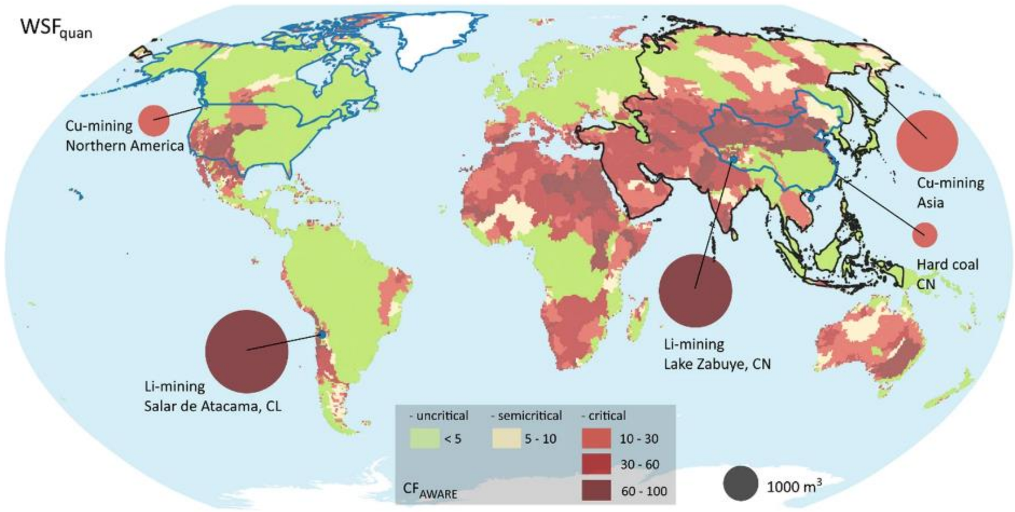


Figure 3.17: Spatially-explicit quantitative water scarcity footprint of processes with highest impact (Schomberg, Bringezu, and Flörke 2021). Sources: https://www.nature.com/articles/s43247-020-00080-9/figures/2

Lithium extraction in Latin America has a high impact on water resources generating water injustices due to the transformation of local hydro-social processes (Jerez, Garcés, and Torres 2021).

Mining practices, and the in some cases the privatization of water resources / water supply services, lead to water shortages which can compromise lagoon structure and jeopardize the ecological value of these hypersaline lakes rising the social conflicts associated with water.

Lithium mining breaks the water cycle. The process affects the water table and the subterranean flow of water between the Cordillera and the sea. Drilling for lithium can reach depths of up to 300 meters where freshwater basins are often found, risking the mixing of fresh and salt water with devastating impacts on the ecosystem.

One estimate is that it requires 1 liter of brine water to produce 0.05–1 mg of lithium. This translates into as much as half a million gallons to produce 1 ton of lithium. Dynamical modeling, such as the one that has been used to assess water carrying capacity in East Africa, could be a constructive approach (Mancini and Sala 2018a).

This process is carried out using brines (liquid streams) located in the salt flats of Argentina, Bolivia, Chile and Brazil. As a result, intensive water consumption can reach up to 640 liters per second in mining concessions that can last at least 15 years. (Fornillo and Zicari 2019). In Salar de Atacama, approximately sixty-five percent of the region's water is diverted for mining practices (Balcázar 2021) and the rural populations have been agitating for years against the exploitation of land by the extractive industries because the deposits are in desert areas and the extraction process creates a strong water imbalance often to the detriment of local populations of the “lithium triangle”.

If we look at the specific example of the “Norte Grande” in Chile, the result of neoliberal policies that have allowed the expropriation of water has generated a massive transformation of the Norte Grande with enormous pressure on water resources located in the territories where the Aymara, Quechua and Atacameño indigenous communities live. The water used by the mining sector corresponds to 44% of surface water and 42% of groundwater, with seawater coming in third with 8%. In addition, highland water is withdrawn by mining companies from aquifers, impacting the entire territory (Romero-Toledo 2019).

Again, Toledo in his study notes different types of impacts generated on the community due to water exploitation:

- Water extraction that affects communities in the highlands.
- Water scarcity affecting communities downstream of the extraction area.
- Water scarcity allegedly accelerating the migration process of some indigenous communities, predominantly the Aymara in rural areas.
- And finally, suspended dust and its impact on water, land and living beings, due to the transport of minerals and residues in communities near the deposit.

The displacement of populations occurred in a forced way due to the degradation of the surrounding environment, as happens with the intensive development of mining activities, leaves the population in a very high position of vulnerability. In these contexts, a response is expected from the State and political decision-makers, as guardian of the territory, with adequate solutions and concrete responses to local problems often related to primary activities.

In Argentina, lithium extraction projects are mainly located in the Puna, in high altitude salt flats. To extract the mineral, drilling fields are set up where, through a pumping system, large quantities of brackish water containing lithium are extracted from the salt flats. This water is deposited in evaporation and concentration pools. There, the water is evaporated by solar radiation and wind, and the brine is concentrated through a precipitation process. The concentrated brine then enters a plant process to produce lithium carbonate, at which point the ore is marketed.

The salt flats are wetlands that, due to their composition, represent important freshwater reserves, both for the biodiversity of the region and for the indigenous communities that live there. The salt flats are endorheic basins composed of an aquiferous area of brackish water with lithium and another area with low salinity (“fresh”) water. Although these areas are kept separate by their density, there is a mixing area between them (Marazuela et. al., 2018). The natural sources of water recharge of the salt flats are rainfall and temporary rivers, while discharge is by evaporation.

Salt accumulation occurs on the surface of the basin, due to the proximity of the aquifer water level to the surface. Therefore, alteration and damage to the saline interface could have repercussions on the brackish and freshwater areas, causing them to mix. Likewise, a water imbalance caused by a large discharge of brackish water could mobilize freshwater towards the saline area, causing its salinization (Houston et al. 2011).

The process adopeted in Argentina for lithium mining requires the extraction of large quantities of water, which causes a rupture in the water balance of the basin, generating a level of water discharge that exceeds the existing load level. This represents a risk of increased water stress in the area and salinization of freshwater reserves.

The impact on these reserves, in an arid region with a fragile ecosystem such as the Puna, would represent a decrease in the water available for vegetation and animal life, as well as a lower level of water available for human use. This alteration of water reserves would also have repercussions on the traditional primary economic activities of the local communities (livestock, agriculture and salt extraction).

The impact not only translates into loss of water, but also in the disappearance of vulnerable species that only exist in these places, the loss of the cultural heritage of indigenous peoples, the losses of millions of years of evolution of adaptation processes of species, including the extremophilic organisms (Garcés and Alvarez 2020).

Although brine is considered a type of water, the issue is very delicate. Indeed, if the mineral brine were officially referred to as water, it would be subject to stricter regulations, as is already the case in Chile, where the mineral brine is owned by the State, which grants licences to mining companies, whose have every interest in keeping it that way. This would be of benefit to indigenous peoples, who generally hold water rights, to limit mining expansion and brine extraction. This is what Admir Razmjou, a researcher at the University of Technology in Sydney, says in his study conducted with other researchers (Ejeian M., Razmjou A. 2021) .

Using a molecular dynamics software, Razmjou and his colleagues performed brine simulations of Salar de Atacama and pure water. The similarities that emerge from the research results by analyzing both liquids, concern the molecular structure, namely the atomic irregularity, their surface charge density and the numbers of hydrogen bonds. Therefore result, 99.1% of the energy needed to form the brine comes from water molecules and ion-water bonds and not from dissolved minerals. Reclassifying brine as water, rather than as mineral, could therefore be a way for local communities to protect their rights, but at the same time could indicate to the mining companies an alternative and more responsible way of acting.

Recent studies by E&T, the English Institution of Engineering and Technology, in collaboration with satellite analysis companies SpaceKnow, have found further evidence of the heavy environmental effect on the fragile water ecosystem of the saltpans of Atacama, caused by the extraction of brine. The analysis has evidenced as the increase of the level of some reservoirs of water in the ponds of companies like SQM, is inversely proportional to the drainage of the water of the lagoons of the area of Soncor, inside of the National Reserve Los Flamencos, nesting place for Andean flamingos.

The increase in drought conditions in the national reserve areas, with the consequent increase of the temperatures in the lagoons and the decrease of the vegetal cover, also alter the balance of the microbial life, with possible consequences at trophic levels. All this suggests a real paradox: on the one hand we try to decarbonise to mitigate climate change and the loss of biodiversity, on the other the extraction of lithium, useful for the revolution of electric mobility, is one of the main stress factors for environmental degradation (Balcázar 2021). This is becoming a source of concern for countries such as San Pedro de Atacama and its overexploited basins, such as Sistema Hidrológico de Soncor, Salar de Tara, Laguna Tebinquinche, and for small towns, often considered of international importance under the Ramsar Convention, within walking distance of gigantic lithium brine mines, as Peine, declared a National Monument in 1982.

The socio-environmental impacts of lithium mining are leading to constant protests from local communities living in the immediate vicinity of the brines. Although the lack of environmental information on the water balances of the basins that the provincial authorities manage to have from extractive companies, there are many protests and complaints advanced and documented by indigenous peoples, environmentalists and NGOs, to ask for a change. But even where the authorities are aware of the irreversible impacts of extractions, continue to support them through the expansion of projects involving an increase in the extraction of water from almost exhausted basins and the discharge of additional mining waste, like the Fénix extraction project by the FMC Lithium in the Salar del Hombre Muerto in Argentina. In October 2019, the authorities granted the construction of the Río Los Patos aqueduct as an extension of the Fénix project, and even in this case the actions of resistance by the local population were not enough (Evelyn Vallejos 2020).

CORFO, the Chilean decentralised public service in support of innovative entrepreneurship that has an interest in contributing to the economic development of the country, has recently found itself at the center of a dispute between an indigenous association and the SQM. The latter, together with the other giant of the world production of lithium, the American Albemarle Corp., has obtained the consent, by the Chilean government, to greatly increase the extraction of the metal in the Atacama desert, at the beginning of 2018. However, the environmental regulator of Chile CORFO expressed its concerns about the exploitation of the basins by SQM and its way of monitoring the wells, making it difficult to detect the actual impacts of pumping. All this arbitrarily and without consulting local communities. However, the environmental regulator of Chile CORFO expressed its concerns about the exploitation of the basins by SQM and its way of monitoring the wells, making it difficult to detect the actual impacts of pumping. All this arbitrarily and without consulting the local communities. In response to these indictments, SQM submitted to the authorities, in about two years, four regulatory plans to remedy the serious violations of its environmental obligations (Reuters.com). But, even in 2019, the Primer Tribunal Ambiental de Antofagasta, prompted by the requests of the Council of Peoples of Atacama (CPA), once again rejected the plan of environmental compliance presented by SQM, not affecting, however, the operation of the same. In 2020 a new PdC presented by SQM was approved. In the meantime that the proceedings against SQM are still ongoing, the mining company is making cooperation agreements with three of the 18 communities involved in the process, to invite them to leave, like the Camar community in return for $2 million (Americaeconomia.com).

Anyway, within the “Lithium Triangle” ecological and socially responsible extraction projects are being developed, such as that of the Salar de Olaroz and Salar de Caucharí announced by Minera Exar, in its “Corporate Sustainability Report” of 2019(Minera Exar S.A 2019). A production capacity of 40,000 tonnes of lithium carbonate per year is expected to last for 40 years. Most of the Caucharí-Olaroz pumping pits could already be operational in early 2021, but the COVID-19 pandemic has slowed down work. Although the World Resources Institute classifies the Caucharí-Olaroz site as an area with a lower water stress risk than the northern and western areas of the region, Minera Exar recognizes the importance of the access to water as fundamental for local communities. It will therefore undertake to operate in water from groundwater that does not produce drinking water and to comply with water use regulations. In addition, to establish relationships of trust with local communities, it will communicate in transparency the information useful to monitor the environmental impact and it will support social and environmental initiatives.

3.4 Satellite Earth Observation and New Space Economy

Satellite Earth Observation is a mature and fast-growing market. Not only the market, with its clear institutional and commercial interests, but also the institutional world is increasingly looking at the services and applications that derive from Earth Observation data and the potential that this information presents to citizens.

These data identify and provide information for research and decision-making, including the achievement of sustainable societies, in a wide variety of areas: from weather forecasts, monitoring of natural disasters and the health of ecosystems and communities, climate change monitoring and biodiversity and wildlife measures, changes in land use and deforestation (Earth Observations For Sustainable Development Goals - EO4SDG 2020).

Remote sensing data can provide support for mitigating and managing the impact of natural disasters, including fires, floods, earthquakes and tsunamis, and the sustainable management of natural resources such as energy, water and agriculture (Anderson et al. 2017).

As highlighted in the previous paragraphs, the ability to monitor the environmental impact of the mining industry on the territory is crucial. Constant monitoring of mining sites is important for institutions and local communities, for international associations, but also for investors and industries, and the reasons are many and interconnected:

- planning and forecasting production volume levels
- detecting any changes taking place in mines
- Tracking/preventing cases of illegal extraction
- Monitoring of water resources both in terms of resource management (eg evaporation, infiltration) and compliance with legislation).

Satellite monitoring is even more important if we consider that the extraction process often takes place in inaccessible and/or hostile territories, thus significantly reducing the costs of on-site monitoring.

High (ca10-60 m) and very high resolution (ca 0.3-10m) satellite remote sensing are the most relevant and important for the mining sector. The most relevant high resolution optical satellite sensors are Landsat 7 and 8, Copernicus Sentinel-2 (Davids and Rouyet 2018).

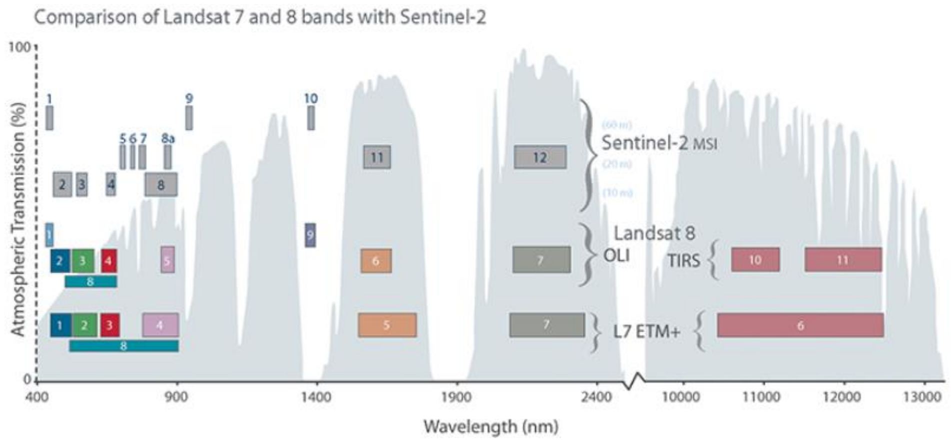


Figure 3.18: Comparison of the spectral bands of Landsat 7/8 and Sentinel- 2. Atmospheric transmittance spectrum as background.Source: http://landsat.gsfc.nasa.gov/?p=10643

There are many uses for multispectral and hyperspectral satellite remote sensing in the mining sector (Davids and Rouyet 2018):

- it is used to provide information on the geology of the area, mineralogy and surface geology, etc;
- it can provide indications of mineral contamination;
- can quantify soil properties;
- facilitates the monitoring of the biodiversity ecosystem around the mine: important for the correct management of the territory in all phases of the life of the mine, with an understanding of the possible appropriate location of the mine itself and an evaluation of the environmental impact;
- can analyse the consequences induced by the mining process on the vegetation and assess any contamination.

SAR is the branch of remote sensing in which the response of a target to an emitted signal whose characteristics are known and controllable is observed. In the specific case of earth observation and SAR, the target corresponds to the surface of the earth itself and the objects on it, while the emitted signal is a high-frequency waveform (C-band for Sentinel-1) emitted by an antenna, whose aperture is increased synthetically through the motion of the satellite platform.

Like more traditional optical images, which are acquired passively, SAR images allow qualitative and quantitative information about the environment to be extracted, but in all atmospheric conditions and at any time of day. They are not dependent on solar illumination and work in a portion of the electromagnetic spectrum that is immune (for most applications) to atmospheric absorption.

A summary of the main features of the SAR data follows:

Band	Frequency	Wavelength	Typical Application
X	8–12 GHz	3.8–2.4 cm	High resolution SAR (urban monitoring; ice and snow, little penetration into vegetation cover; fast coherence decay in vegetated areas) • TerraSAR-X • COSMO-SkyMed
C	4–8 GHz	7.5–3.8 cm	SAR Workhorse (global mapping; change detection; monitoring of areas with low to moderate penetration; higher coherence); ice, ocean maritime navigation • ERS-1/2 SAR, • RADARSAT-1/2 • ENVISAT ASAR
L	1–2 GHz	30–15 cm	Medium resolution SAR (geophysical monitoring; biomass and vegetation mapping; high penetration, InSAR) • JERS-1 SAR, • ALOS PALSAR
S	2–4 GHz	15–7.5 cm	Little but increasing use for SAR-based Earth observation; agriculture monitoring (NISAR will carry an S-band channel; expends C-band applications to higher vegetation density) • Almaz-1
P	0.3–1 GHz	100–30 cm	Biomass and vegetation mapping and assessment. Experimental SAR • AIRSAR
K	18–27 GHz	1.7–1.1 cm	Rarely used • Dominio militare

Tab 3.2: Summary of the main features of the SAR data. Source: NASA https://earthdata.nasa.gov/learn/backgrounders/what-is-sar

For this and other important implications of SAR in the monitoring of critical infrastructures, the development of these sensors is of considerable importance, especially considering that only a small number of countries are currently developing this technology: Italy, world leader thanks to the CosmoSkymed constellation, Argentina with the SAOCOM satellite, and Canada with the RADARSAT system are the main holders of this technology. A special note should be made of The SIASGE project (Italian-Argentinian satellite system for Disaster Management and economic development) results from the partnership between the two countries, which have decided to develop an operationally integrated system to manage and prevent major natural and environmental emergencies. It consists of the COSMO-SkyMed satellites, which acquire images in the X-band, and the SAOCOM satellites, which can take images with an L-band SAR.

The space sector is in de facto going through a very important technological revolution, which sees a strong technological contamination between sectors by linking the development of micro-satellites and mega-constellations of hundreds of satellites, small carriers and broadband, and the Internet of Things to commercial space flights.

An important contribution to monitoring the impact of the mining process could come from the 'new space economy'. In other words, the process which aims to develop initiatives for the development of enabling technologies, even radically innovative ones, fostering opportunities from sectors other than space.

These new technologies actually have the great added value of being cheaper than normal space services and, at the same time, thanks to this cross-sector contamination and the growing presence of the Internet of Things (IoT), they are user friendly for the end user, overcoming the technological GAP that typically exists in current Earth Observation services.

A perfect example would be the NOCTUA project, the pilot of a commercial service for the collection, processing, analysis and distribution of data for monitoring infrastructures and the Lombardy landscape through a SAR (Synthetic Aperture Radar) satellite.

NOCTUA plans to install the SAR satellite on a platform for mini/microsatellites, with the main objective of enabling a state-of-the-art Earth observation service for monitoring infrastructures and artefacts (such as roads, bridges, dams, buildings, urban and rural areas, etc.) and natural resources (such as mountains, rivers, lakes, glaciers, snowfields). The project aims to demonstrate the ability to implement a dedicated low-cost, high-resolution space segment that is commercially viable and user-friendly and that can also be used within a constellation, thus making the Earth observation service competitive and scalable. According to current data(Meta and Speziali 2021) the sensor will guarantee top-level performance, with resolution sub-meter/<1m.

Conclusion

In line with the climate emergency of these days, the main consideration is that even in the mining sector, business as usual is no longer acceptable. The social, economic, environmental sustainability of this sector is related and interconnected to the global climate issue and cannot be ignored.

Economic, environmental and social needs are considered the three pillars underpinning the principle of sustainable development, the mining industry can contribute to future economic growth and social progress by safeguarding the environment. In order to achieve collaborative progress on SDGs, European mining companies should contribute to economic sustainability through governance that maintains a high return on their capital, so as to make the sector financially strong and innovative, maintaining high ordinary dividends and constantly monitoring results. In this way, the European mineral raw materials industry can also contribute to social sustainability, ensuring gender equality and making workplaces safer, reducing accidents. All this will ultimately contribute to improving the sustainability of the environment, reducing energy use and limiting carbon emissions and discharges into water (Euromines 2019).

A major priority of all those involved in the extractive process must be indeed a social and environmental sustainability (Janikowska and Kulczycka 2021)(Global Commission on the Geopolitics of Energy Transformation 2019) by developing projects that benefit the local community to achieve the specific Sustainable Development Goals dedicated to the mining sector (Figure: 4.1) set by the international community (UNDP. WRF. CCSI 2016).

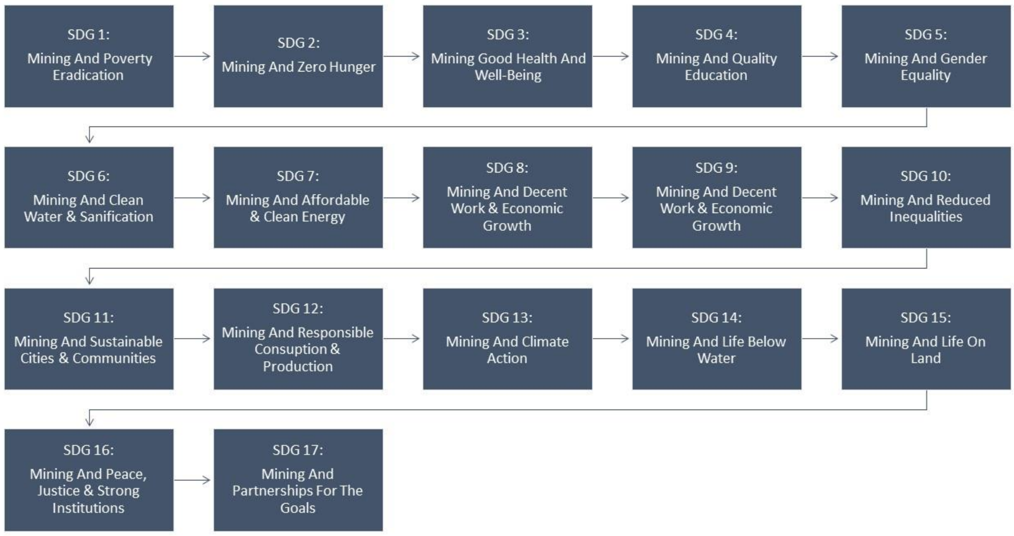


Figure 4.1: Sustainable Development Goals dedicated to the mining sector. Source: ATLAS (UNDP. WRF. CCSI 2016)

The due diligence mechanisms extensively described by Lohia in her analysis of "Mining and sustainable development: Current issues" (Lodhia 2018), could respond to this imperative: the mining industry is not the problem but rather part of the solution to sustainability. This would allow building a constructive dialogue with the mining industry facilitating sustainability solutions with a different approach by assuring the awareness and consciousness of mining companies of the social and environmental aspects of their operations, in the form of social and environmental impact assessments, now essential and necessary.

The real commitment and contribution of the mining industry to the local development process can be seen by analyzing 3 elements (Yakovleva, Kotilainen, and Toivakka 2017):

- Fiscal contributions issued in the area;
- Incorporation in core business activities, voluntary initiatives to support the process of sustainable development;
- Concrete contribution in terms of goods and services and educational assistance.

An example is the case of Sicomines (Jansson 2011), a consortium of Chinese state-owned companies, in 2008 signed an agreement with Congo for copper and cobalt mining rights until 2033, worth an estimated $84 billion. In return, it committed to invest $6 billion in the country's infrastructure and about $3 billion in the mining sector. The main objective is to combat the exploitation of children in Congo's mines. Obviously, a clear assessment of the impact of this agreement and how much it has been used over the years is almost impossible.

The extractive industry inexorably and permanently alters the environment, and mining projects (necessary and inevitable for the global ecological transition process) must work to minimize the impacts (Figure 4.2). There is no perfect solution to the environmental consequences, but it is necessary to use environmentally sustainable technologies and processes and to focus on eco-sustainable business models regarding energy consumption, CO2 emissions, water use, chemical reagent use and waste streams.

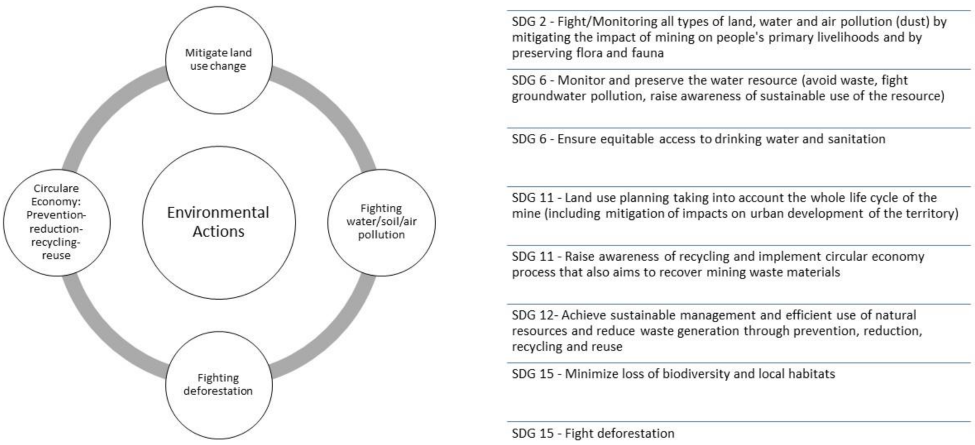


Figure 4.2: Environmental impacts on mining activities. Source: own reproduction based on (UNDP. WRF. CCSI 2016)

The mining process brings with it what may appear to be positive impacts, namely the ability to generate income and employment (Mancini and Sala 2018b) but the most impactful social aspects of the mining sector appear to be environmental impacts and impacts on land use that negatively reflect on human health and human rights of local populations.

The common effort of local institutions, international organizations and the industrial world must be to contrast and monitoring any kind of pollution deriving from the extraction process that has an impact on 3 fundamental resources: soil, water and air:

- Soil/subsurface resource: the objective here must be to prevent pollution of the soil and subsoil (for example, due to the use of toxic products required by the mining industry) by constantly monitoring its use and by considering the entire life cycle of the mine;
- Water resource: communities must have equal access to the water resource as an essential and primary asset for human subsistence, thus also reducing loss of biodiversity and local habitats, this resource must be unpolluted.
- Air pollution derived for example from the lifting of dust related to the process of processing and extraction of minerals, generating negative impact on the health of local communities, but also on the agricultural sector.

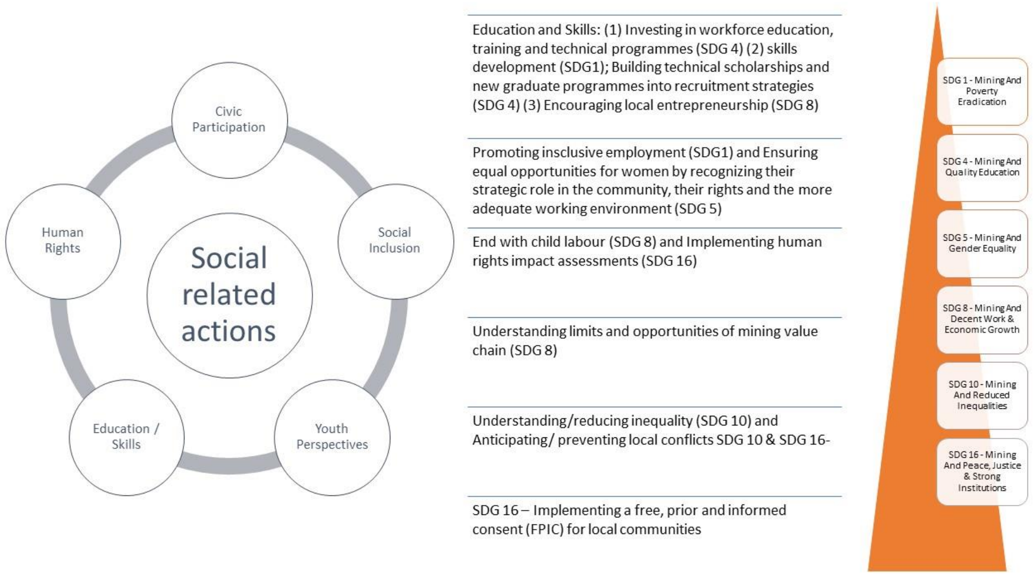


Figure 4.3: Summary of the main actions to be carried out related to social aspects. Source: own reproduction based on (UNDP. WRF. CCSI 2016)

In the challenge to achieve a sustainable development, mining potentially affects different SDGs across the value chain and by analysing mining activity along the value chain, a mining company's actions will indeed affect environmental sustainability, social inclusion and economic development.

Local communities must co-participate in the development activities of mining projects and must become the primary stakeholders.

The mining industry has the opportunity to contribute by establishing a dialogue with governments, civil society and other industrial sectors, so that companies can work together to minimize waste, reusing and recycling materials.

Political expropriation can be thought of as an intentional strategy of disarticulation of social organizations and resistance movements-employed by state actors, corporations, or other social groups-but at the same time allows us to link such interventions with the disarticulation of community ties."

This ambiguous role of the Government can be summarized with the concept of "political expropriation"(Andreucci, Radhuber, and Chávez León 2021) which associates this term with the consequences of all those interventions implemented to facilitate the extractive process by counteracting the processes of community resistance, disarticulating them politically and thus losing decision-making and management power. Andreucci points out how "the increase in the enclosures of human resources, is accompanied by the inherent expropriation of the capacity for political action and self-determination of the affected populations".

The international community must therefore work and support local communities to ensure that this potential risk of intentionally disrupting community through the destabilization of social organizations and resistance movements is overcome.

The process of transformation of these territories is, in fact, often considered purely a "bargaining chip". This generates, as in the case of Chile (Romero-Toledo 2019), a sort of local resistance that causes ongoing conflicts and often ambiguous adaptation processes. The growth of the mining industry in northern Chile has led to the territorial expropriation of indigenous communities, which in turn has generated a process of indigenous self-identification that has generated ethno-territorial conflicts in response to these socio-environmental transformations.

Government, local institutions and international communities must work together to implement a development of the mining sector that meets the basic needs of local communities and respects their rights such as:

- Respecting the basic rights of education, health and decent work;
- Strengthening the inclusion of marginalized groups and reducing inequality;
- Encouraging the development of policies that focus on youth, women and children, focusing on education and skills that keep pace with the technological innovation required by the sector;
- Ensure easy access to information: Institutions and Industries must inform and educate local communities about their rights, and provide them with the legal and professional means to exercise them to ensure that communities have access to objective, complete, and understandable information.
- Ensure a local development process based on civic participation and inclusiveness: the local communities must actively participate in the consultation process between communities - mining companies -institutions to reduce the power asymmetries in place.

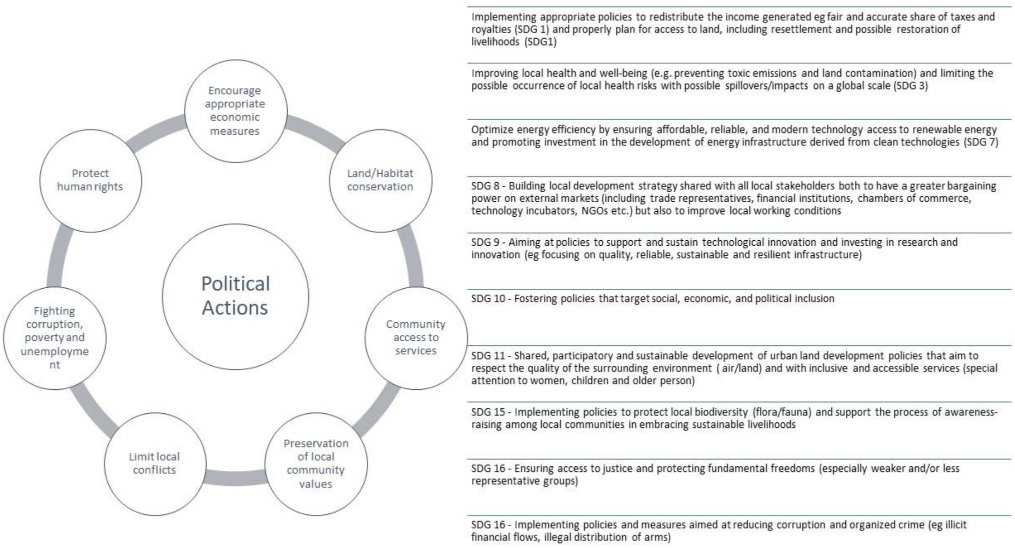


Figure 4.4: Summary of key policy actions that need to be pursued. Source: own reproduction based (UNDP. WRF. CCSI 2016)

Regional and geo-economics cooperation with a redefinition of the balance of power between producers and consumers is another key element.

In these territories the continuous process of privatization of resources for the benefit of large players and the construction of ad hoc regulations to deregulate resources has exacerbated the long process of expropriation of local communities, mainly indigenous. The objective must therefore be to break the logic in which the foreign company extracts resources and profits from the territory without local added value. There is indeed a need for fair distribution in terms of royalties and taxes by examining the relationship between taxation of mining revenues and the real (socio-economic-environmental) impact on the territory to ensure a fair and balanced distribution of mineral wealth.

On this point, a strong contribution could be provided by the Extractive Industries Transparency Initiative (EITI), which aims to achieve transparent governance with full publication and verification of company payments and government revenues from oil, gas and mining activities. The initiative also provides economic support (the Multi-Donor Trust Fund administered by the World Bank) and technical assistance to countries that decide to implement the standards defined by the EITI.

Participation in the initiative is on a voluntary basis and currently 51 countries are implementing the EITI (of which 31 are compliant).

Nevertheless mineral exploration is risky, inevitable, expensive and with negative ecological footprint especially on local communities (Svampa and Teran 2019). The lithium industry is growing rapidly and needs to adapt quickly to battery-related technological innovation understanding the value chain and the lithium industry (Peyré and Dorn 2020).

Technological innovations (Calzada Olvera 2021) (Fornillo 2018) related to mining and new discoveries of lithium deposits represent (potentially) for South America redemption on the global scene (in terms of local economic and technological development). Weak infrastructure (logistics and energy infrastructure) brings increased project costs. Adequate infrastructure is needed to develop competitive local industries throughout the extractive chain taking advantages by the great opportunity driven by the energy transition.

Total dependence on mineral production is another risk common to almost all emerging low-income countries, and the risk associated with it is high. At the local level, economic policies that diversify national and regional economies should be encouraged, targeting sectors such as agriculture, construction, etc., making societies more resilient.

An interesting perspective in this regard comes from research (Yakovleva, Kotilainen, and Toivakka 2017) that confirms the strategic role of mining companies in helping to diversify local economies. In fact, companies, thanks to the in-house expertise of highly qualified employees (managers, accountants, engineers and geologists, but also human resources and external relations), could share knowledge and actively and concretely support local actors in many sectors.

Anatoher example are international public-private partnerships between producing Countries, extracting Countries and processing Countries could be stimulated, with multiple benefits:

- helping countries on a global scale to reduce carbon emissions;
- supporting technological innovation, for example by making the supply chain more independent, complete and sustainable, with positive social and environmental impacts.

Another important factor influencing the dynamics of rare earths geopolitics: the commodities market is priced in dollars, therefore its cost depends on currency fluctuations. In this context, obviously, it is easier to activate mechanisms of financial speculation in favor of companies and/or countries already economically strong.

Raw material costs are also affected by taxes and the possible entry into force of regulations related to the value chain. An example of this was the introduction of the new regulation approved by the International Maritime Organization requiring lower sulfur quotas in ship fuel oil.

This has generated the scrapping/replacement of many container ships dumping costs on prices. According to the Dry Baltic Index this has generated the 605% cost escalation.

According to the IEA(International Energy Agency (IEA) 2021), revenues from coal production are ten times higher than those realized from the production of the minerals used in the transition process but, this situation will be reversed in 2040.

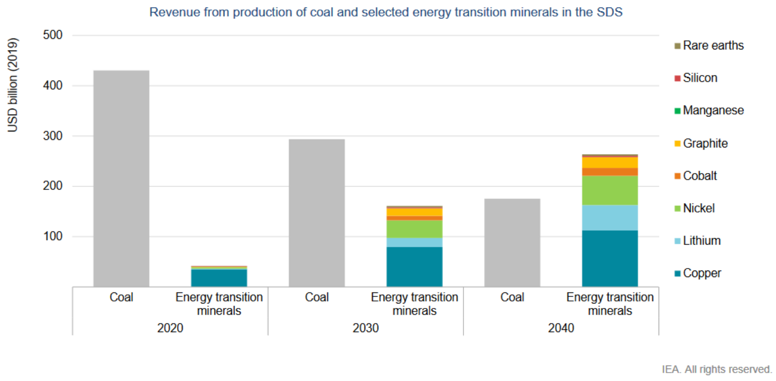


Figure 4.5: Revenue from the production of coal and selected energy transition minerals in the SDS. Source: IEA (Energy Agency 2021)

China to date is the one that is having a more aggressive strategy in this regard: major extractors of many raw materials (copper, lithium, rare earths) in house; importers of as many raw materials (nickel from Philippines and Indonesia and cobalt from Congo); major in-house processors of these materials. According to Benchmark Mineral Intelligence (Vivas Kumar 2020), 80% of the raw materials needed to build lithium-ion batteries come from Chinese companies.

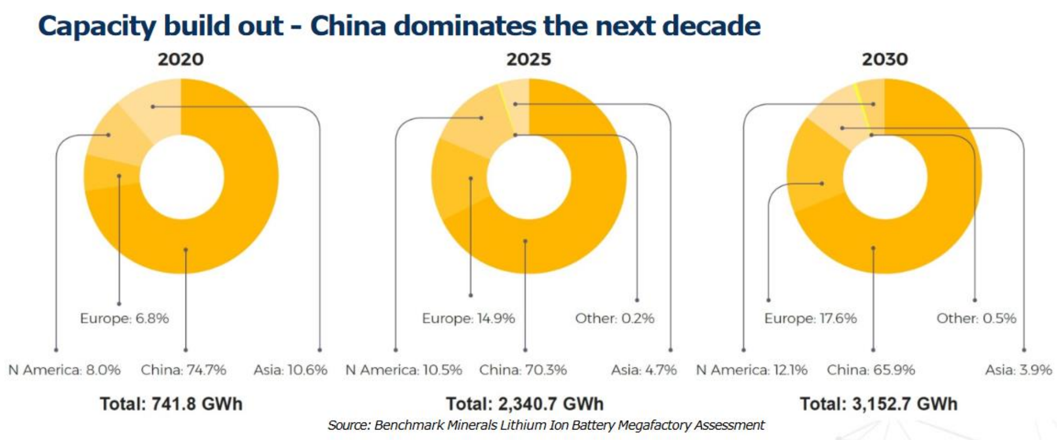


Figure 4.6: Capacity build out - China dominates the next decade. Source: ALBATTS Workshop: Battery Cells Manufacturing – Job Roles & Skills (2021) Benchmark Minerals Lithium Ion Battery Megafactory Assessment

In Europe, the supply of rare earths is 98% reliant on China. According to the Commission's estimations, for the batteries of electric vehicles and energy storage in 2030 the EU will need a supply of lithium up to 18 times higher than today, and 5 times of cobalt and, these percentages, are expected to increase dramatically in the coming years if we take into account the estimated growth and projected needs. It is estimated that for the market of rare earths, used for example for electric vehicles, digital technologies, wind generators, the demand will in fact increase tenfold.

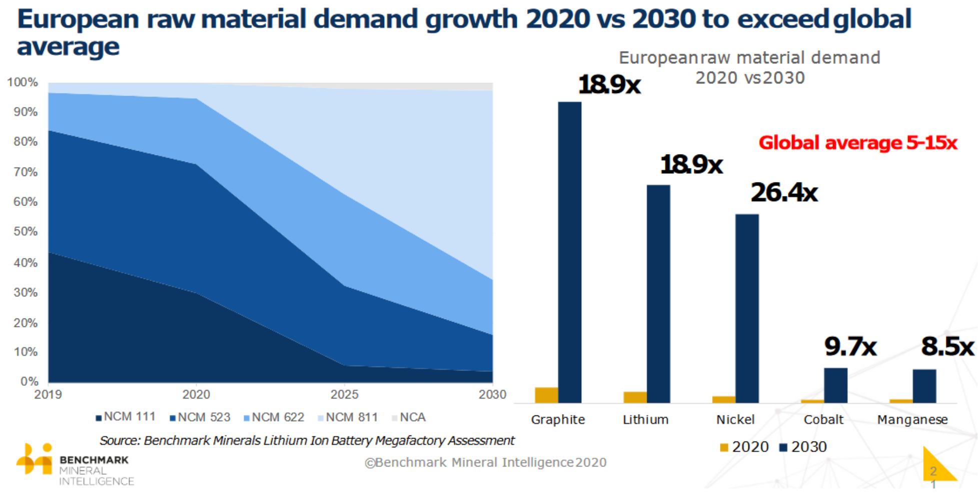


Figure 4.7: European raw material demand growth 2020 vs 2030 to exceed global average. Source: ALBATTS Workshop: Battery Cells Manufacturing – Job Roles & Skills (2021). Benchmark Minerals Lithium Ion Battery Megafactory Assessment (https://www.project-albatts.eu/Media/NewsEvents/5/NewsEvents_5_SLIDES_20210122_141131.pdf)

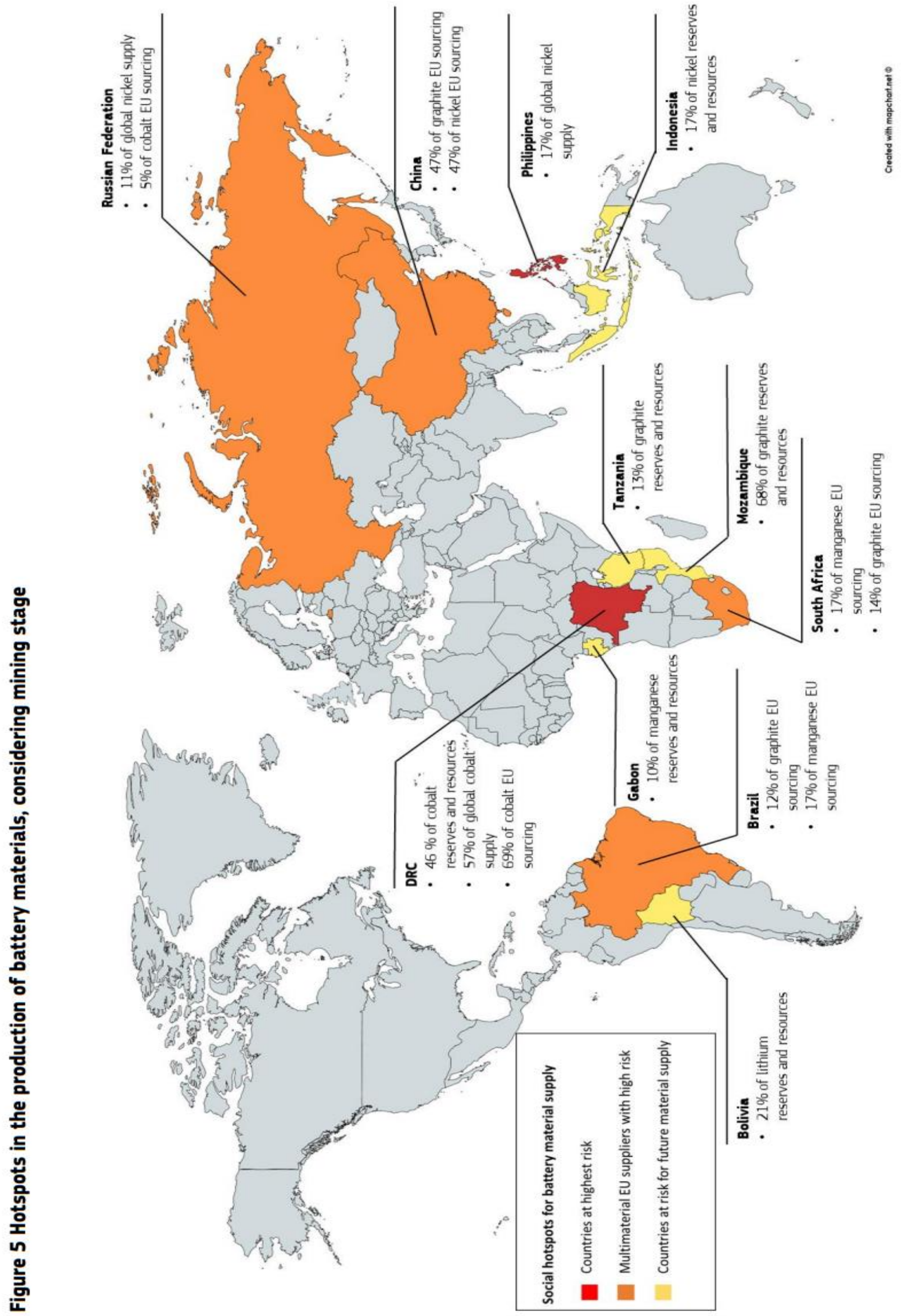
As already said, there is no structured and super-solid literature that can suggest one theory rather than another, but by reviewing what can be the possible strategies adopted in similar sectors, and considering what has already been defined by European Commission via the EU Smart Mobilty Strategy (COM.789.final 2020) and the the way to achieve sustainable development of the sector and get out of this geopolitical crisis is necessary:

- to become as self-sufficient as possible by promoting metal mining in Europe using advanced technologies that limit environmental impacts
- maximize the supply chain of collecting, storing and recycling: the activity of recycling of precious metals by investing in R&I and highly innovative technologies in order to have a recycling process that limits as much as possible the environmental impact on the territory of this process (eg for the use of highly toxic chemical reagents) and that recuperates the highest possible amount of material, avoiding further waste. According to the data of the European Commission (Matos, C.T.; Ciacci, L; Godoy León, M.F.; Lundhaug, M.; Dewulf, J.; Müller, D.B.; Georgitzikis, K.; Wittmer, D.;

Mathieux 2020), the EU pays to import 40,000 tons every year, half end up in products that remain within the EU, where recycling at the end of life, however, is minimal, when instead a percentage that can be close to 50% is recoverable.

- With the assumption that there is no doubt that the extractive industry brings clear economic and social benefits (generation of employment, income, development of infrastructure, etc.), it is equally urgent and necessary to recognize and assess the impacts of the process through constant monitoring actions (currently insufficient) (Widana 2018)(Mancini and Sala 2018a) especially in developing countries.

ANNEX 1



Hotspots in the production of battery materials, considering mining stage
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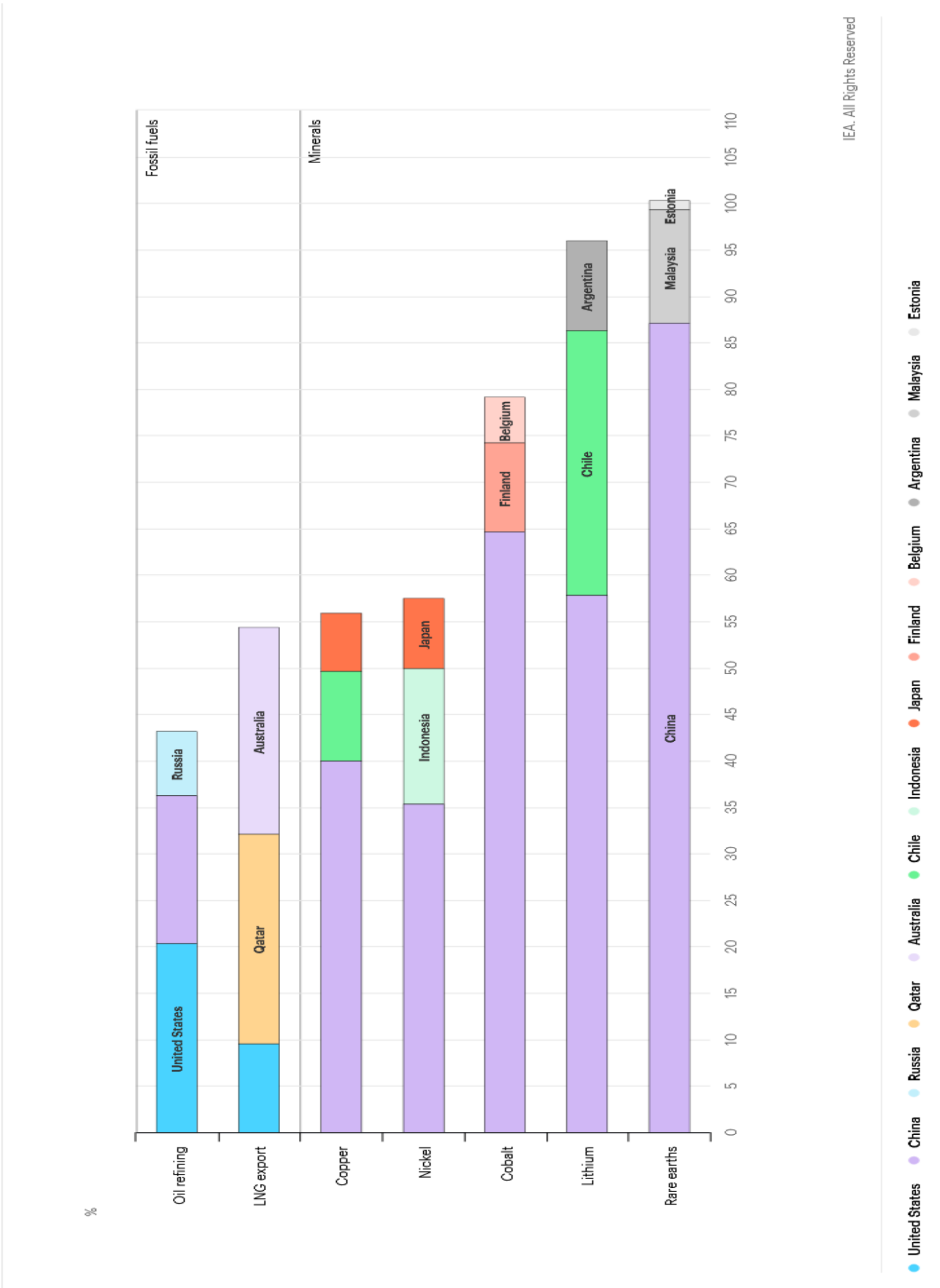
ANNEX 2



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