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# Critical raw materials in Li-ion batteries

*Author*: *Thomas Vranken, Researcher - Inorganic and Physical Chemistry, University of Hasselt/EnergyVille*

## Introduction

In our daily lives, we use products derived from many different metals, minerals and natural materials. The European Commission maintains a list of so-called 'critical raw materials' (CRMs). These are raw materials with high economic importance, which also carry a high supply risk. In many cases, these are sourced from outside the EU. Global competition for these materials is becoming more and more fierce. These materials play an essential role in a wide range of industrial ecosystems, as they are often vital components in the functioning of many technological innovations. Gallium and indium, for instance, are essential elements in light-emitting diode (LED) based lighting applications, whereas semiconductors and photovoltaics need silicon metal. Platinum and other precious metals are found in the electrodes of hydrogen fuel cells and electrolysers. As such, in the years to come, it will become more and more essential to reduce the use of these raw materials (where possible) and to consider the options for reusing these materials first, before recycling them. In this article, we will cover critical raw materials in the field of Li-ion battery manufacturing.

## 2020 EU critical raw materials list

The European Commission first published its list of critical raw materials in 2011. Since then, it has received a review every three years (in 2014, 2017 and just recently in 2020). The latest version was published in September 2020. To compile this most recent list of critical raw materials, data for the EU, excluding the United Kingdom, (EU-27) was used from the most recent five years. In total, 83 materials were screened (five more than in 2017). In the 2020 edition, the criticality of the materials in their value chain was more specifically pinpointed: extraction and/or processing.

Over the years, the number of materials on the EU's list of critical raw materials has increased significantly. While there were only 14 materials on this list in 2011, this number increased to 20 in 2014, 27 in 2017, and now, 30 in 2020. In the 2020 list, 26 out of 27 materials from the 2017 list remain, while four new materials were added for the first time. The one material that was removed from the most recent list is helium. While it remains a concern when it comes to supply concentration, it was removed due to its decreasing economic importance. The four new materials on the 2020 list are bauxite, lithium, titanium and strontium. Bauxite is the main ore that provides us with aluminium. The complete list of 2020 critical raw materials, according to the European Commission, can be found in Table 1.

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**Table 1: 2020 list of critical raw materials**

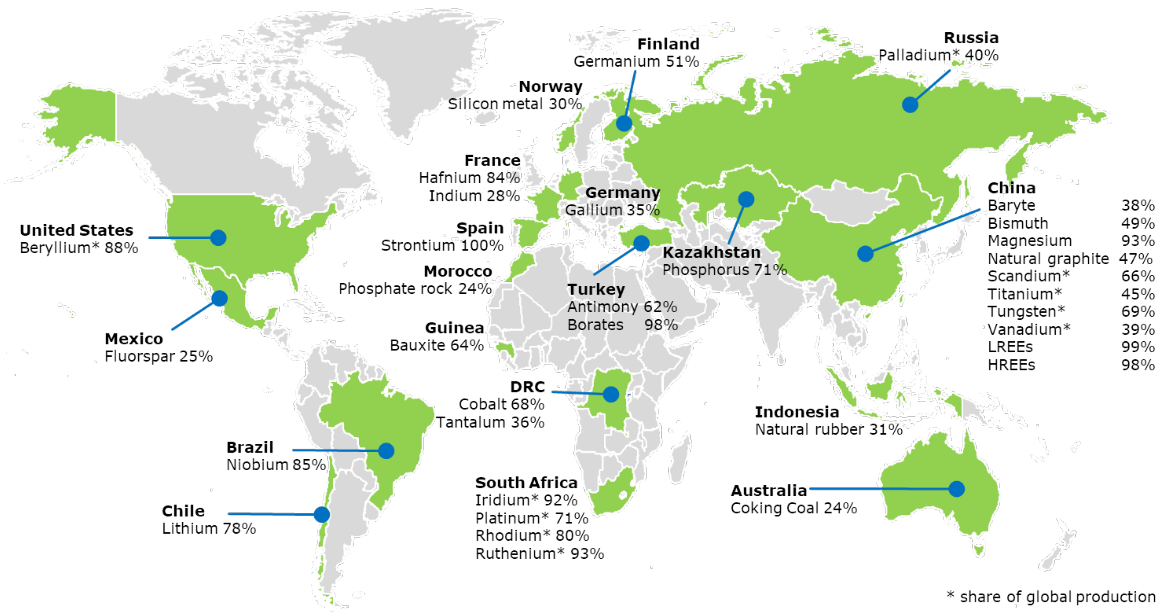
| 2020 Critical Raw Materials (new as compared to 2017 in bold) | | |
|---|---|---|
| Antimony | Hafnium | Phosphorus |
| Baryte | Heavy Rare Earth Elements | Scandium |
| Beryllium | Light Rare Earth Elements | Silicon metal |
| Bismuth | Indium | Tantalum |
| Borate | Magnesium | Tungsten |
| Cobalt | Natural Graphite | Vanadium |
| Coking Coal | Natural Rubber | **Bauxite** |
| Fluorspar | Niobium | **Lithium** |
| Gallium | Platinum Group Metals | **Titanium** |
| Germanium | Phosphate rock | **Strontium** |

Source: European Commission, 2020.

While nickel is not yet on this list, it is already being monitored closely by the European Commission as a possible future critical raw material due to increasing demand for nickel in battery applications.

As can be seen on the map in Figure 1, Europe is dependent on foreign countries for many of these CRMs. For some of these CRMs, sources are very concentrated in a few countries or, sometimes, even in just one specific country (e.g., Chile, which is responsible for 78% of the EU's lithium supply, or the Democratic Republic of Congo, which is responsible for 68% of the EU's cobalt supply).

**Figure 1: Biggest supplier countries of CRMs to the EU**




Source: European Commission, 2020.

## Critical raw materials in Li-ion batteries

Several materials on the EU's 2020 list of critical raw materials are used in commercial Li-ion batteries. The most important ones are listed in Table 2. Bauxite is our primary source for the production of aluminium. Aluminium foil is used as the cathode current collector in a Li-ion battery. Cobalt is present in most commercial Li-ion cathode chemistries. The original commercial Li-ion battery, launched by

Sony Corporation in 1991, uses lithium cobalt oxide (LCO, $LiCoO_2$) as the cathode material. This material is still present in batteries for most portable electronics. Electric vehicles (EVs) mainly use nickel manganese cobalt oxide (NMC, $LiNi_xMn_yCo_zO_2$ with x + y + z = 1) as the cathode material, which exists in several compositions, depending on the ratio of nickel, manganese and cobalt that is present. While there is certainly a trend towards reducing the content of cobalt in NMC compositions, for now, it is still an essential material in the production of most Li-ion battery cathodes. Since graphite is the primary material used as anode material in current Li-ion batteries, natural graphite is also essential in the current Li-ion battery industry.

Of course, there is no Li-ion battery without lithium. While metallic lithium is only present in non-rechargeable (primary) Li batteries, and not in rechargeable (secondary) Li-ion batteries, lithium as an element is, of course, essential in a Li-ion battery. It is initially present in two components: in the cathode material and as a salt, dissolved into a traditionally liquid electrolyte. The presence of lithium in the cathode material should have been clear already from the two cathode materials that were just mentioned: LCO ($LiCoO_2$) and NMC ($LiNi_xMn_yCo_zO_2$ with x + y + z = 1). Both contain lithium ions, as synthesised, in their lattice structure. These are deintercalated from this lattice structure upon charging of the battery, while lithium ions are intercalated in the anode material. Lithium ions are also present, originating from a dissolved salt (usually $LiPF_6$) in the organic liquid electrolyte.

### Table 2: List of critical raw materials for Li-ion batteries

| Raw materials | Critical stage | Main global producers | Main EU sourcing[1] countries | Import reliance[2] | EoL-RIR[3] | Selected Uses |
|---|---|---|---|---|---|---|
| Bauxite | Extraction | Australia (28%)<br>China (20%)<br>Brazil (13%) | Guinea (64%)<br>Greece (12%)<br>Brazil (10%)<br>France (1%) | 87% | 0% | • Aluminium production |
| Cobalt | Extraction | Congo DR (59%)<br>China (7%)<br>Canada (5%) | Congo DR (68%)<br>Finland (14%)<br>French Guiana (5%) | 86% | 22% | • Batteries<br>• Super alloys<br>• Catalysts<br>• Magnets |
| Lithium | Processing | Chile (44%)<br>China (39%)<br>Argentina (13%) | Chile (78%)<br>United States (8%)<br>Russia (4%) | 100% | 0% | • Batteries<br>• Glass and ceramics<br>• Steel and aluminium metallurgy |
| Natural Graphite | Extraction | China (69%)<br>India (12%)<br>Brazil (8%) | China (47%)<br>Brazil (12%)<br>Norway (8%)<br>Romania (2%) | 98% | 3% | • Batteries<br>• Refractories for steelmaking |

[1] Based on Domestic production and Import (Export excluded)
[2] IR = (Import – Export) / (Domestic production + Import – Export)
[3] The End-of-Life Recycling Input Rate (EoL-RIR) is the percentage of overall demand that can be satisfied through secondary raw materials. Data from: Study on the EU's list of Critical Raw Materials (2020) Final Report

Source: European Commission, 2020.

As demand for Li-ion battery technology is expected to continue to increase dramatically in the near future, a stable and sustainable supply of these critical raw materials is of utmost importance. Due to the increasing usage of batteries for EVs and energy storage systems, it is expected that, by 2030, the

EU will need up to 18 times more lithium and up to five times more cobalt, compared with the current supply for the whole EU. By 2050, this demand is expected to increase to 60 times more lithium and 15 times more cobalt.

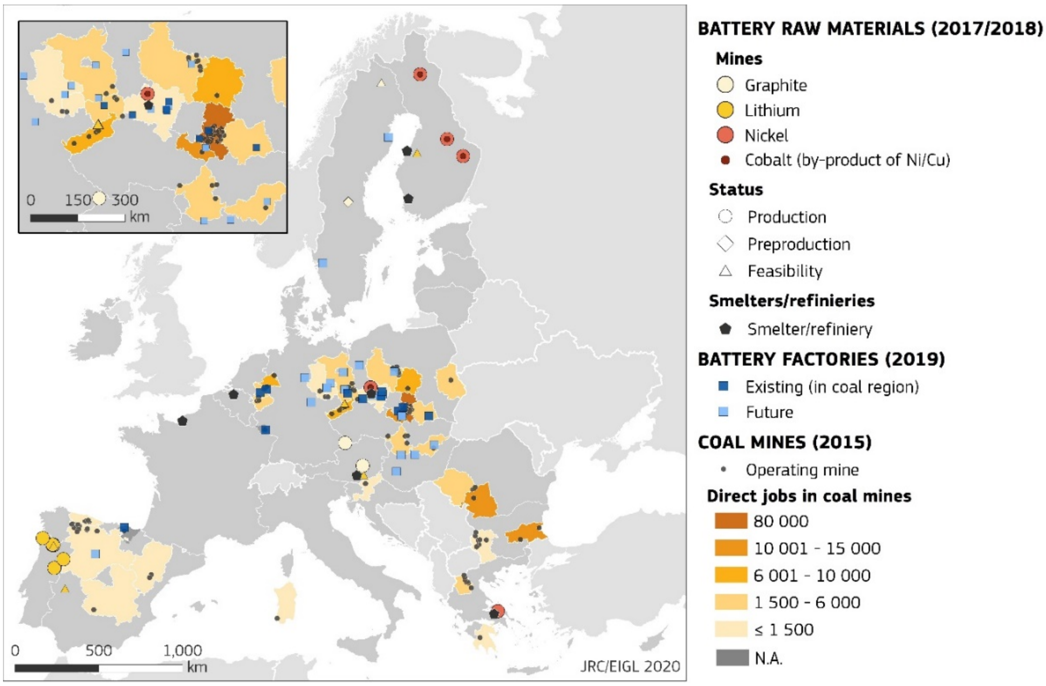
A significant incentive for the increasing use of EVs and energy storage systems is our mission of trying to limit climate change. The World Bank projects that demand for many metals relevant for batteries will grow by more than 1000% by 2050, while we try to limit the average increase in temperature to +2°C, compared to a business-as-usual scenario. Appropriate actions need to be taken at the European level to prevent future supply issues.

The critical raw materials report is taken into account when negotiating trade agreements and identifying investment needs, and it guides R&D (Horizon 2020 projects, Horizon Europe, national R&D programmes, new mining technologies, substitution, recycling). Furthermore, it is also relevant for the circular economy when it comes to promoting sustainable and responsible sourcing, and for industrial policy.

For several critical materials, such as lithium, there are gaps in the EU's capacity for extraction, processing, recycling, refining and/or separation. These gaps reflect a lack of resilience and a high dependency on supply from other parts of the world. Lithium is, for instance, also mined within Europe, but currently has to leave Europe for processing. The technologies, capabilities and skills for refining and metallurgy are a crucial link in the value chain. Strategic approaches need to be taken to build closer partnerships between critical raw material actors, to find alternative sources of supply, and to attract investments to these strategic developments, for preventing shortages, associated large price fluctuations and unexpected disruptions to manufacturing processes.

Public and private investments have been mobilised at scale through the European Battery Alliance (EBA). This should, for instance, lead to 80% of Europe's lithium demand being supplied from European sources by 2025. As Figure 2 shows, many of the EU's battery raw material resources lie in regions that are heavily dependent on coal or carbon-intensive industries, which are becoming obsolete, and where battery factories are planned. Furthermore, many mining wastes are rich in critical raw materials. Thus, altogether, this offers an interesting opportunity for creating new economic activities on existing or former (coal) mining sites, while improving the environment and protecting our climate.

**Figure 2: Battery raw material mines, battery factories and coal mines**




Source: European Commission, 2020.

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