The World of COBALT
The Technology Enabling Material
Cobalt is an amazing element, a technology enabling metal essential for the energy transition, global economic growth and sustainable development.

Due to its unique properties - high temperature resilience, hardness and process efficiency allowing for great energy and environmental benefits, among others - cobalt is a critical material for the EU and considered a strategically important metal globally.

Moreover, it is found at the centre of vitamin B12, making it also fundamental for healthy plants, animals and the well-being of humans.

No other element is so crucial as cobalt to such a great variety of fields and industry sectors. Cobalt is currently irreplaceable in many of today's technologies and plays a major role in supporting an overall circular economy strategy.

Building on this, in January 2019 the Cobalt Institute (CI) launched the Cobalt Industry Responsible Assessment Framework (CIRAF), a reporting and management tool which makes ethical and sustainable risk assessment and mitigation in cobalt production easier and more standardized across the cobalt industry.

The Cobalt Institute promotes the sustainable and responsible use of cobalt in all forms.
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Cobalt is largely obtained as a by-product from nickel and copper production, with a smaller amount from primary cobalt mining. A range of technologies are used for production, including both underground and surface mining, and the processing of different nickel and copper ores by both pyrometallurgical and hydro-metallurgical techniques.

The members of the Cobalt Institute (CI) are the main producers, large scale mining companies (LSM), and although CI membership do not represent the entire cobalt industry, it does represent over 70% of mined production globally.
The Cobalt Institute (CI) is committed to promoting the sustainable and responsible use of cobalt in all forms and has worked with its members to develop the **Cobalt Industry Responsible Assessment Framework (CIRAF)** which was launched on 9th January 2019.

**CIRAF Main Features:**
- It strengthens the ability of cobalt producers and buyers to assess, mitigate, and report on responsible production and sourcing risks in their operations and supply chain.
- It also enables a more coherent and consistent approach to cobalt due diligence and reporting by the cobalt industry.
- It is a management tool which allows participants to prove that they are aligned with global good practice on responsible production and sourcing with annual public reporting being a mandatory requirement.

The framework is now being applied by Cobalt Institute members in an initial implementation year. For further information, please refer to the CIRAF external primer.
Primary Cobalt, Intermediate Chemicals, and Secondary Materials

I

The primary cobalt materials from global sources include refined cobalt metal, cobalt concentrate, and cobalt complex intermediates.

II

Secondary materials recovered at end of life include cobalt-containing metal alloys and complex intermediates. These can be reprocessed into cobalt chemicals for reuse in many key applications.

The refined cobalt metal can be used directly for a variety of applications or converted into other cobalt compounds (e.g. cobalt salts and oxides) that are used in numerous applications.

Cobalt compounds are used as chemical precursors for production of cobalt dihydroxide used in the positive electrodes for nickel-based batteries (both Ni-Cd and Ni-MH), for which the market is expected to remain stable. The use of cobalt compounds in the future (next 10-15 years) is crucial for rechargeable batteries that are already powering hybrid and electric vehicles (EVs), where cobalt dihydroxide or tricobalt tetraoxide are transformed into lithiated cobalt oxides (LiCoO₂ or NMC or NCA) used in positive cathodes for lithium-ion batteries.

The battery sector
Cobalt is an important metal used in a wide range of applications that can be divided into two overall categories:

**Chemical Applications**
- chemical precursors
  - rechargeable battery components 44%
  - catalysts 8%
  - pigments 5%
  - other specialty chemicals 6%

**Metallurgical Applications**
- corrosion resistance
  - super alloys 17%
  - hard metal 9%
  - hard-facings 3%
  - high strength steel 5%
  - magnets 3%

**The battery sector**

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Cobalt is a naturally-occurring element in the earth’s crust at around 20-30 parts per million (mg/kg) and cobalt substances are naturally and ubiquitously present in the air, soil, sediments and water. Exposure to each cobalt substance is described and documented in the Exposure Scenarios developed for EU REACH, which has produced extensive dossiers on the registered cobalt compounds. Based on both hazard and exposure, risk is assessed and controlled, by implementing a hierarchy of controls, ranging from engineering measures, to protective gear, which are collectively referred to as risk management measures (RMMs).

Cobalt metal is self-classified as Carcinogenic (by inhalation), and five cobalt salts (Co carbonate, Co sulphate, Co dichloride, Co dinitrate and Co diacetate), are classified as CMR and identified as SVHC (substance of very high concern). Other cobalt compounds such as Co oxide and Co dihydroxide have recently been self-classified as Carcinogenic (by inhalation). Industry has detailed knowledge of the characteristics of cobalt compounds and the risk management measures (RMMs) to protect workers and the environment, and two major epidemiology studies have been conducted in the cobalt industry. Many cobalt compounds, including those used as battery precursors chemicals, have been registered for REACH and have been (self-) classified under CLH.

There are many overlapping regulatory pressures on cobalt compounds in Europe, including: proposed restriction under REACH (five Co salts), possible restriction under RoHS (several Co compounds), CLH proposal (Co metal as CMR), and possibly further CLH proposals (and/or SVHC proposals) on other Co compounds, as well as status as a Critical Raw Material (CRM) in Europe.
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Cobalt is a critical raw material fundamental to industry and essential for enabling technological development and a low carbon future. To better describe the cobalt sustainability profile, the CI has generated an industry-supported ‘cradle-to-gate’ life cycle inventory (LCI) and life cycle impact assessment (LCA) study for refined cobalt, which is the first of its kind for the cobalt sector. This new cobalt LCI/LCA dataset has been produced to support downstream users of cobalt in their efforts to produce more sustainable cobalt-containing products. The EU Circular Economy Plan (2018) emphasises reuse and recovery of resources as a key strategy to mitigating possible supply interruptions and ensuring efficient and cyclical use of resources.

This is exemplified through the recycling of the EoL (End-of-Life) battery materials playing a pivotal role in ensuring sufficient supply of cobalt salts for the production of the lithiated cobalt oxides for the batteries that power hybrid and electric vehicles (EVs). The EU Commission is promoting different industrial initiatives, for the development of the value chain for the EU battery sector, through the policy framework of the European Battery Alliance (2017). Cobalt compounds are key raw materials in the production of catalysts, which are used worldwide to produce clean transportation fuels. Compliance with the European Directive on fuel quality has only been achievable with the use of cobalt-containing catalysts. These applications are important for achieving the EC’s climate change/clean air initiatives.
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Cobalt represents a high value resource, and it is economically viable to recover cobalt and cobalt compounds within End-of-Life (EoL) materials, with good (high) recycling rates (which vary by sector). Much of this recycling takes place downstream through the recovery and reconditioning of hard metal tools, the recycling of alloy scrap into new alloy, or within the chemical sector as complex intermediates requiring additional refinement. The cobalt recovered from EoL batteries is processed into cobalt chemical precursors for production of new battery materials. The largest opportunities for cobalt to be recycled are within the alloy, battery, and catalysts sectors.