LINK & LOOP

Technical Report

A Life Cycle Assessment of Recycling Cobalt Reactive Catalysts in Taiwan

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Linking Innovations and losing Loops

Table of Contents

Executive Summary

Due to the economic value of cobalt and its impact on the environment, government and industry are now focusing on improving recovery of cobalt metals (e.g., recycling of waste catalysts or batteries). Additionally, cobalt (and other metals) recycling of batteries has become more attractive because of the rising demand for electric vehicles. The purified terephthalic acid (PTA) oxidation catalyst is the key material in PTA production process. It is used as the catalyst during the oxidation reaction process. During the process, the waste PTA oxidation catalyst is remade, and the recycled catalyst is mixed with a proportion of virgin catalyst, replacing a proportion of virgin catalysts and reducing the usage of cobalt and manganese metals.

In this report, the life cycle assessment (LCA) approach is used to analyze the impacts of regenerative catalysts on the environment. Chemicals added during manufacturing are the main sources of environmental impacts for both virgin and recycled PTA oxidation catalysts. These impacts are mainly reflected in the category of marine aquatic eco-toxicity. However, the chemicals used in regenerative catalysts have lower environmental impacts compared with virgin catalysts. Finally, regenerative catalysts offer benefits in the category of abiotic depletion since cobalt and manganese metals do not need to be mined for regenerative catalysts.


Source: MUBI

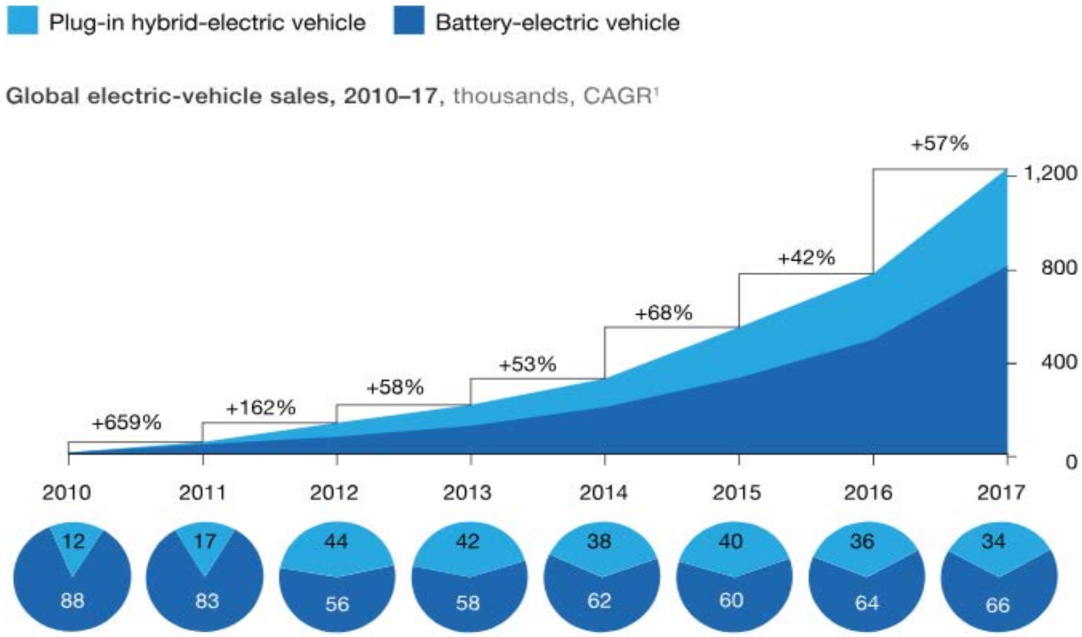
Conflict Minerals and Metal Recycling

Cobalt is an important raw material for making mobile phones, laptops and batteries for electric vehicles (EVs). In recent years, the demand for electronic products has been increasing. Worryingly, about two-thirds of the world's cobalt metals come from the Republic of Congo, where the local cobalt mining has repeatedly caused concern due to unregulated, unsafe, or artisanal mining.

A report from the World Economic Forum (WEF) published in 2018 identified cobalt mining as a serious problem. Employment opportunities for about 200,000 people in the Republic of Congo are provided, but local mining conditions are poor, and most mining areas are still excavated by hand during the early stages. The mining environment is full of dust, and workers lack adequate protection equipment and standards. These challenges are confounded with serious smuggling problems. Despite global cobalt metal prices having tripled since 2016, local working conditions are still not improving.

Cobalt mining will also have a long-term impact on the health of workers. If adequate protective measures are not taken, direct contact with cobalt metal can easily cause respiratory and skin diseases. About 10,000 Congolese children are engaged in cobalt mining making the public health impacts more severe. One solution is to establish an effective urban recycling system, recycle and reuse waste batteries, reduce resource exploitation, and encourage the recycling of cobalt and other rare and precious metals in the production process to draw production away from these unregulated and unsafe mines.

The World Bank estimates that by 2030 there will be 125 million electric vehicles in use, tripling the demand for cobalt, with each EV using 8 kilograms of cobalt. At the same time 11 million tons of batteries will be discarded. The main raw materials that makeup a cobalt-manganese catalyst are: cobalt metal, manganese metal, bromic acid, and glacial acetic acid. Contrary to the name cobalt is actually the key raw material for lithium-ion batteries which are commonly used in electric vehicles, mobile phones, and computers. Lithium remains plentiful, while cobalt is the material that requires meaningful recycling innovation. Apple, Microsoft, Tesla, and other international manufacturers have faced increasing pressure to secure lithium-ion battery supplies while balancing the human cost of unregulated cobalt mining.



Source: World Economic Forum, McKinsey

Figure 1   Global electric vehicle demand growth trend

Cobalt Recycling

A cobalt-manganese catalyst is mainly used to supply pure terephthalic acid (PTA) for production and use. It is used as a catalyst for the oxidation reaction in the PTA process and is an essential raw material in the process. It can be divided into solid state and liquid state. The solid state is mainly cobalt acetate or manganese acetate crystallization, while the liquid state is mainly cobalt acetate, manganese acetate, cobalt bromide or manganese bromide solution. The liquid state is a more convenient and easy-to-use catalyst in the process.

The resource recovery process of waste cobalt-manganese catalyst is illustrated in **Figure 2**. The process is based on acid-soluble regeneration technology. After dissolving soluble impurities from waste cobalt-manganese catalyst with acetic acid or hydrobromic acid, impurities are precipitated by adding precipitators in the sedimentation tank, and impurities are removed by adding filter aids in the filtration facilities. After adding chemical agents such as hydrobromic acid, cobalt acetate, sodium hydroxide solution and pure water, the filtrate was made into regeneration catalyst.

The regenerated catalyst can be mixed with the new material catalyst and can be re-used as the oxidation catalyst in PTA process to replace part of the compound. The new material catalyst saves the cost of cobalt and manganese catalyst raw materials.

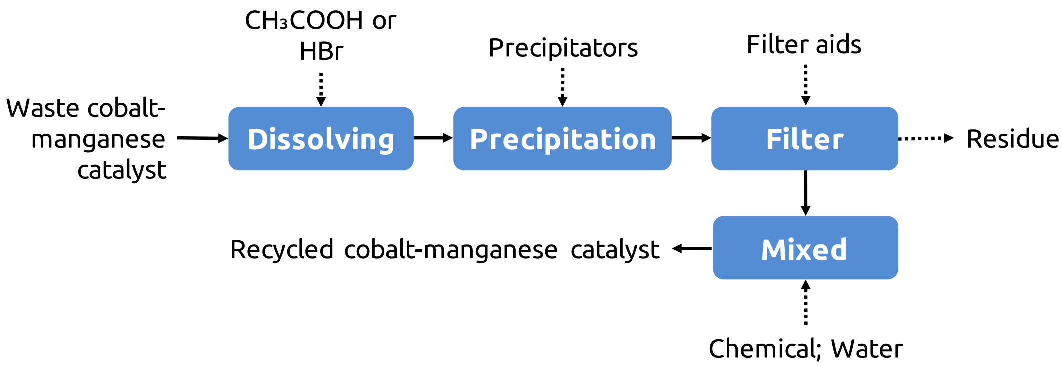


Figure 2 The resource recovery process of waste cobalt-manganese catalyst

Life Cycle Assessment

According to ISO 14040, Life Cycle Assessment (LCA) an LCA measures "the integration and evaluation of input and output and potential environmental impact in the life cycle of a product system from the acquisition of raw materials to final disposal." In summary, it evaluates the impact of the overall life process of a product on the environment.

The whole life cycle of a product consists of five stages: raw material, manufacturing, transportation, use and end of life. The impact types include human health, ecological impact and resource use. The evaluation objects focus on a specific product, process or service, and includes integrated evaluation. An LCA can be used as an environmental assessment tool for enterprise product development or sustainable policy formulation by the public sector.

The life cycle assessment of this report refers to ISO 14040. The IPCC GWP 100a model is used to evaluate the carbon reduction benefits of waste cobalt and manganese catalyst recycling, and CML2000 is used to evaluate resource impact.

- IPCC GWP 100a is widely used to evaluate the carbon reduction benefits of products. In its impact assessment method, the carbon dioxide equivalent (CO_2 eq) is used as the measurement unit to calculate the carbon dioxide equivalent impact of greenhouse gas emissions during the 100 years after the product is manufactured.

- CML2000 is an assessment method developed by Leiden University Environmental Science Center in the Netherlands. It contains 10 types of environmental impact and standardized methods.

Boundary Settings and Scenarios

This report assesses regenerated cobalt-manganese catalyst as the evaluation object, and the evaluation scope is “cradle to door”, that is, from raw materials to product manufacturing.

The set system boundary is shown in **Figure 3**. In the context hypothesis, the baseline scenario is the impact of cobalt and manganese raw materials, where cobalt acetate is used as an example for the new material catalyst, and after removing the new material, the regenerated product (regenerated cobalt and manganese catalyst) is generated after the catalyst regeneration process. The scope of inventory data includes input at different stages, including raw materials, pharmaceuticals, energy, or transportation and waste disposal procedures.

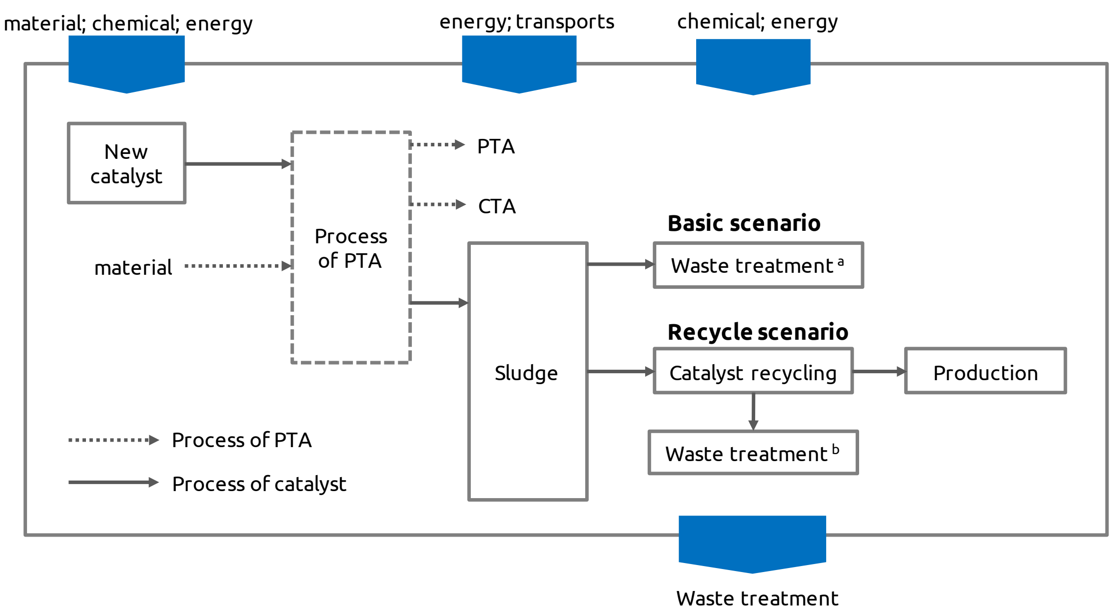
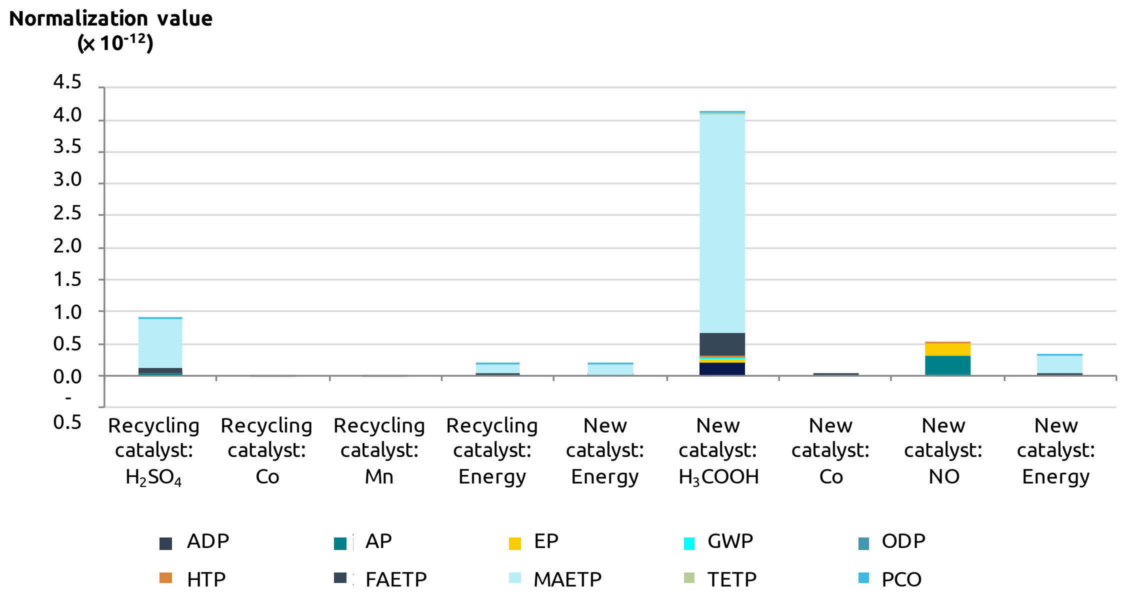


Figure 3 The system boundary and scenario setting in LCA

Results and Analysis

Chemicals are the most important impact source and mainly impact on the marine ecological toxicity. The results of the CML2000 method show that chemicals are the most important environmental impact source of new material catalyst and regeneration catalyst, and the main impact category of chemicals on the environment is marine ecological toxicity. Compared with the new catalyst, the environmental impact of the reagent used in the regenerated catalyst is still lower.

Regenerated catalysts have non-biological exhaustion benefits. The regenerated catalysts have benefits in the related categories of non-biological exhaustion because no cobalt and manganese metals need to be mined. About 16.1% of the impact can be reduced from cobalt reuse, and 4.5% of the impact can be reduced from manganese reuse.



Note: Impact categories are ADP for abiotic depletion potential; AP for acidification potential; EP for eutrophication potential; GWP for global warming potential; ODP for ozone layer depletion potential; HTP for human toxicity potential; FAETP for fresh water aquatic ecotoxicity potential; MAETP for marine aquatic ecotoxicity potential; TETP for terrestrial ecotoxicity potential; PCO for photochemical oxidation.

Figure 4 Impact source and impact category of the LCA result

Results and Analysis

The impacts of regenerated catalysts on the environment are much lower than that of new material catalysts. Across the following areas, abiotic depletion potential, acidification potential, eutrophication potential, global warming potential, ozone layer depletion potential, human toxicity potential, fresh water aquatic ecotoxicity potential, marine aquatic ecotoxicity potential, terrestrial ecotoxicity potential, photochemical oxidation the impact is lower. The total impact of regenerated catalysts on environment is only 21% of the impact of new material catalyst.

Compared with the new catalyst, regenerated catalyst has carbon reduction benefits evaluated by IPCC GWP 100a. The carbon emission of a liter of new catalyst is 2.22 kg CO_2 eq, 90.31% of which comes from acetic acid and 5.31% from nitric acid. The carbon emission of a liter of regenerated cobalt-manganese catalyst is 0.18 kg CO_2 eq, 68.00% of which comes from sulfuric acid and 32.00% from electricity. In this case, commercial extractive agents are not calculated, which shows that regenerated catalysts have carbon reduction benefits.

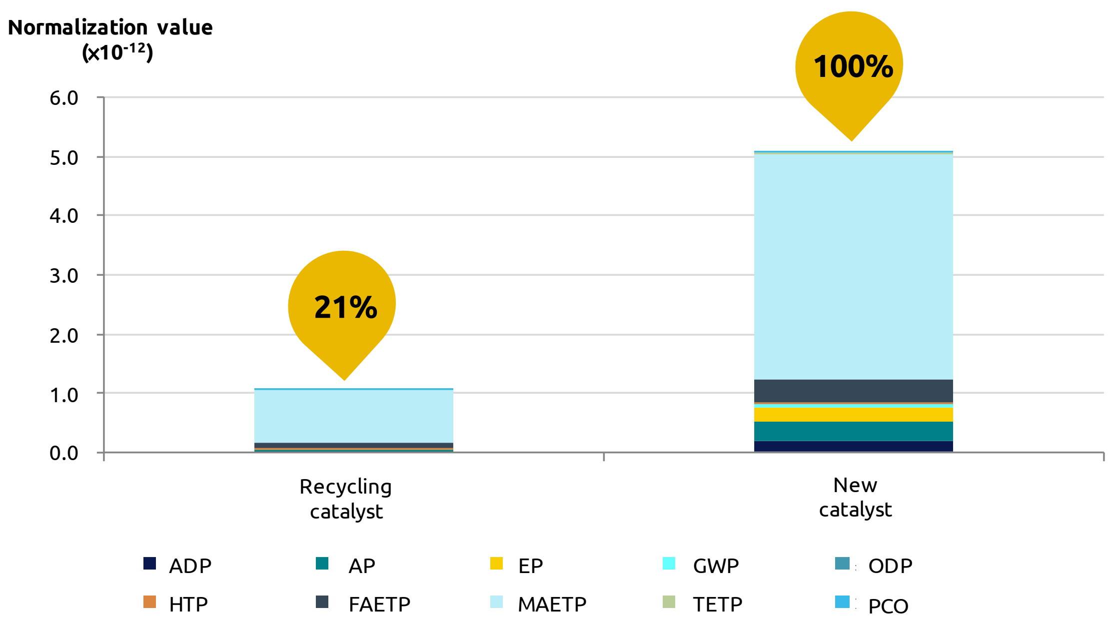


Figure 5 The total impact of LCA result

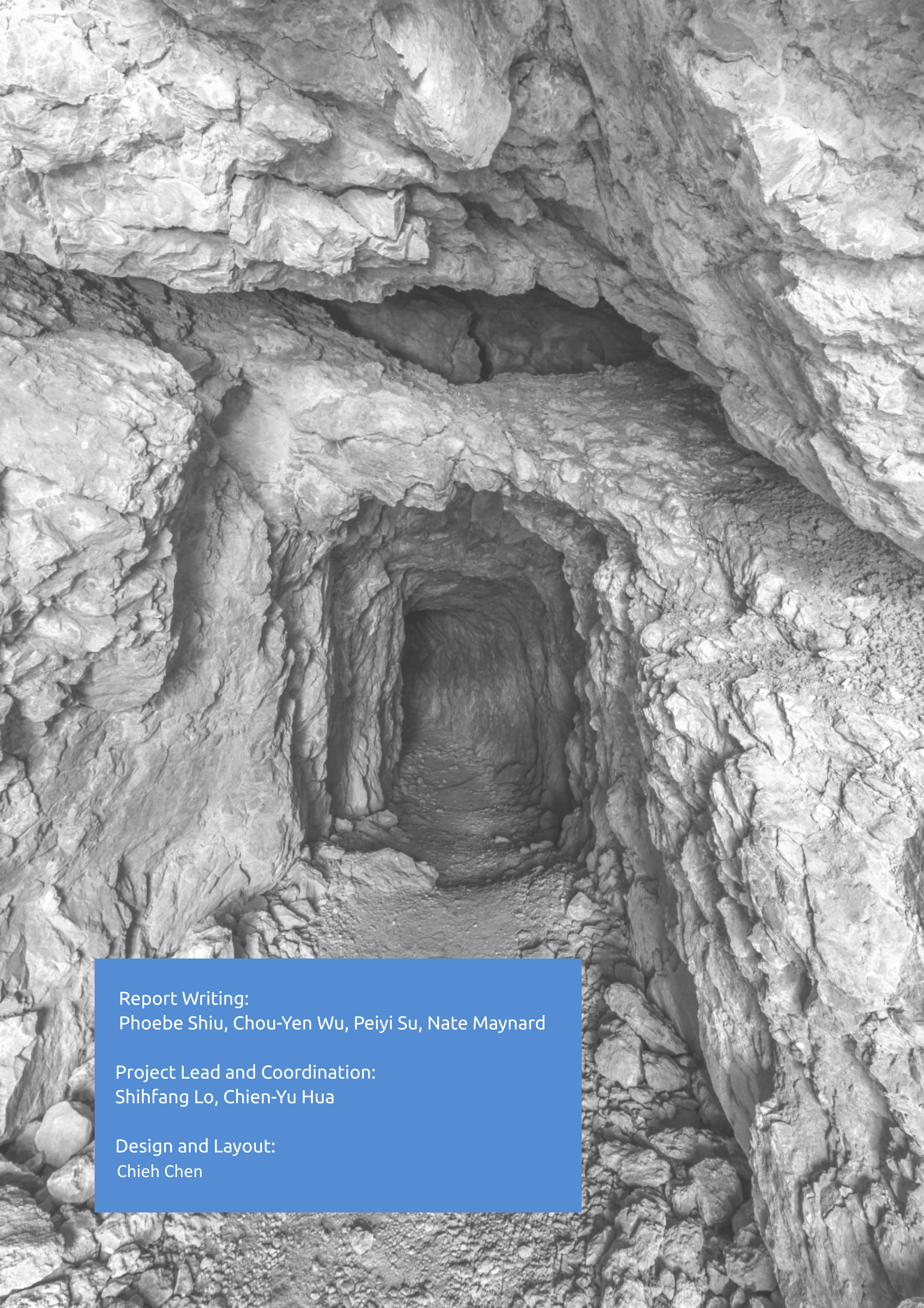
Conclusions and Suggestions

- Cobalt-manganese catalysts are a catalyst for oxidation reactions in the PTA process, and it is a key raw material for this process. Cobalt and manganese catalysts are mainly made of cobalt metal, manganese metal, bromic acid and glacial acetic acid. Among them, cobalt is the key raw material for making lithium batteries such as mobile phones, laptops and electric vehicles.

- This report takes regenerated catalyst as the evaluation target and new material catalyst as the baseline, and uses the life cycle assessment method to analyze the impact of the two on the environment. It also uses IPCC GWP 100a to evaluate the carbon reduction benefits of regenerated catalysts in the PTA process, and uses CML2000 to evaluate and compare the overall environmental impact of the two.

- The overall research results show that the impact of regenerated catalyst on the overall environment is only 21% of the new material catalyst, mainly because the regenerated catalyst does not need to mine cobalt and manganese metals and has significant benefits in the non-biological exhaustion impact category. The results of carbon reduction benefit analysis show that compared with the new material catalyst, carbon emissions are reduced by 2.05 kg CO_2 eq per liter of regenerated catalyst compared with the new material catalyst.

- In order to solve the problem of conflict minerals, unsafe mining, and reduce the impact of the overall environment of electronic products, an effective waste battery recycling system should be established to reduce mining and chemical consumption. In this new system rare and precious metals such as cobalt can be recycled and reused continuously in economic activities.



Report Writing:
Phoebe Shiu, Chou-Yen Wu, Peiyi Su, Nate Maynard

Project Lead and Coordination:
Shihfang Lo, Chien-Yu Hua

Design and Layout:
Chieh Chen

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