ASCEND ELEMENTS

The Environmental Impacts of Battery Recycling at **Ascend Elements**

Summary of the prospective life cycle assessment of producing NMC 9.5.5 pCAM and Li_2CO_3 from recycled lithium-ion batteries at Ascend Elements.

Report based on a life cycle assessment of AE's product portfolio, which has been conducted in accordance with the ISO 14040 and ISO 14044 standards. The critical review was conducted by a panel of three third-party LCA experts, including two reviewers from Minviro and an independent third reviewer sourced by Minviro.

Table of Contents

About Ascend Elements

Based in Westborough, Mass., with operations in the United States and Europe, Ascend Elements is a leading producer of critical minerals and engineered lithium-ion battery materials.

Our Covington, Ga. site, which features battery shredding and lithium extraction capabilities, is set to begin commercial-scale lithium carbonate (Li_2CO_3) production by the end of 2025, making it the first new Li_2CO_3 production site in the United States this century. This will also mark the first ever commercial-scale production of Li_2CO_3 using 100% recycled content.

The precursor cathode active material (pCAM) manufacturing facility in Hopkinsville, Ky. will be the largest domestic source of pCAM in the United States. This site is expected to begin operations in late 2026 and ramp up commercial scale operations in early 2027. Using the proprietary Hydro-to-Cathode® direct precursor synthesis technology, Ascend Elements is revolutionizing battery materials production for a clean and sustainable supply chain. This facility will support battery manufacturers and electric vehicle OEMs as they work to reduce reliance on foreign battery materials.

Our Mission

Our mission is to elevate the value of recycled elements and engineer sustainable materials for the global clean-energy transition. To that end, we have developed an ultra-efficient method for manufacturing high performance pCAM and producing Li_2CO_3 by recycling spent lithium-ion batteries.

By using end-of-life lithium-ion batteries and manufacturing scrap as feedstock, we avoid the carbon emissions associated with the production of primary materials from mining. Additionally, our Hydro-to-Cathode® direct precursor synthesis process eliminates up to 15 energy and resource intensive steps in the traditional hydrometallurgical recycling process.

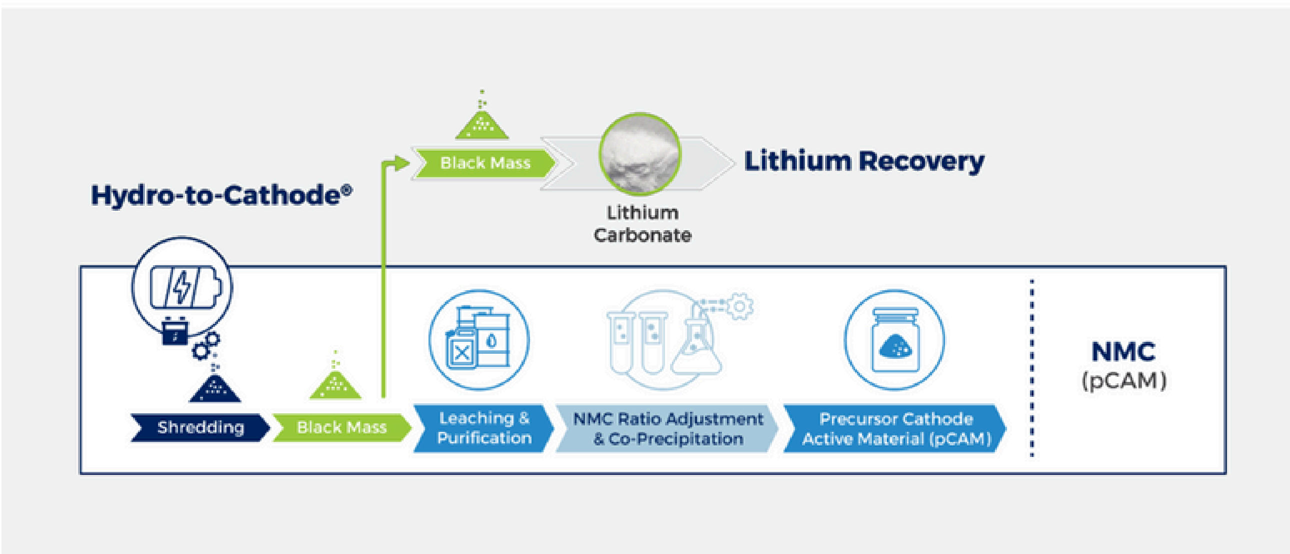
That's just one of the ways we can decarbonize new materials. We aspire to deliver zero-carbon products to electric vehicle OEMs and battery manufacturers by 2035.

Our Operations

The resource recovery process begins at our manufacturing site in Covington, Ga., where battery shredding and lithium extraction take place to produce black mass and Li_2CO_3.

The proprietary Hydro-to-Cathode® direct precursor synthesis process will occur in Hopkinsville, Ky., to produce high-quality NMC 9.5.5 pCAM.

Hydro-to-Cathode® pCAM | Lithium



Our operations close the loop on the battery materials supply chain to maximize sustainability and the value of these materials. Our commitment to quality and environmental responsibility ensure the critical battery materials are recovered and optimized for next-generation energy storage solutions.

What is Life Cycle Assessment?

Life Cycle Assessment (LCA) is a methodology used to evaluate the environmental effects of a product or activity holistically by analyzing its entire life cycle. It can also propose strategies for reducing environmental impacts and compare between different production methods.

Some key considerations of our LCA include:

Materials: Identifying and quantifying materials utilized throughout the process.

Transportation: Evaluating the method of transportation and the distances materials and final products travel to and from the production site.

Energy Consumption: Measuring the amount of energy required by the process, and determining the energy source.

Waste & emissions: Assessing the types and quantities of waste and emissions generated, and how they are repurposed or disposed.

LCA at Ascend Elements

At Ascend Elements, we integrate LCA into our R&D and decision-making processes to anticipate the potential environmental impacts and develop strategies to reduce them before they occur.

The LCA studies propose key strategies for mitigating and minimizing the climate change impact of our products, which will guide us in reducing the carbon footprint of our operations to meet net-zero goals.

Our studies assess the environmental life cycle impacts across the production chain, with a specific focus on carbon and particulate matter emissions.

This LCA marks the third critically reviewed LCA conducted by Ascend Elements. By continuously evaluating our products' environmental impacts and sharing these insights, we aim to improve transparency and sustainability leadership within the battery supply chain.

In 2024, Ascend Elements published a white paper summary of the NMC 622 LCA study. As part of our continuing commitment to sustainability and innovation, this latest LCA white paper aligns with our strategic goals and product portfolio, highlighting the **environmental impacts of NMC 9.5.5 pCAM and technical grade Li_2CO_3 (>99.0% purity).**

Decarbonization Strategies

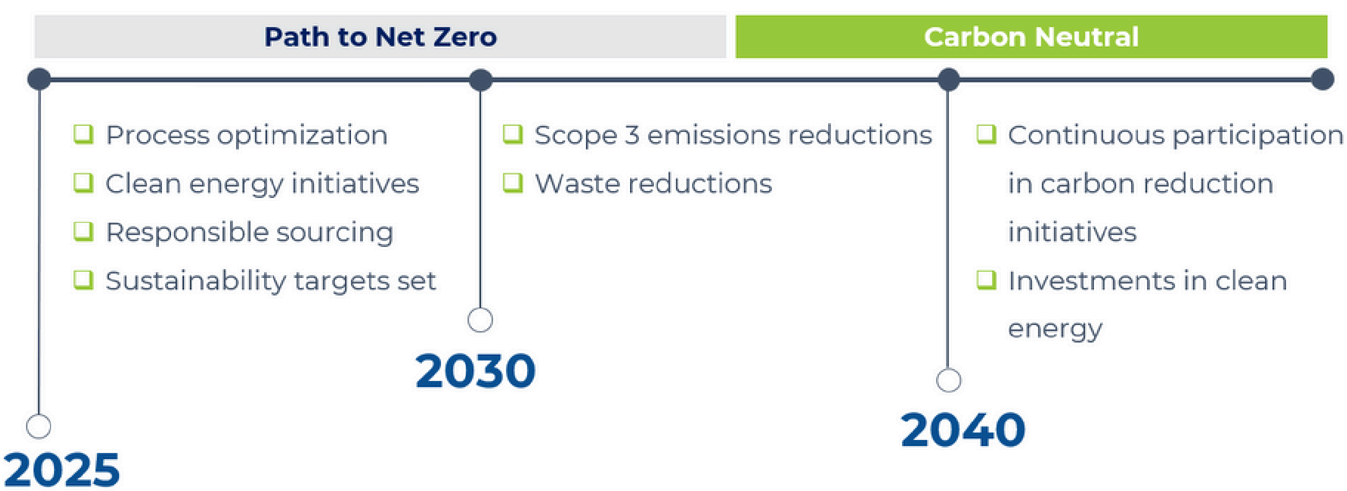
Key Findings of the LCA

Our production processes can be further decarbonized by implementing the following:

- The use of **100% renewable energy** in our recycling and manufacturing facilities.
- The application of **lower-carbon reagents** during the production processes.
- Transition from trucking to **rail** for transporting spent batteries and scrap. Additionally, transporting black mass between Covington, Ga. and Hopkinsville, Ky. by rail instead of truck. .

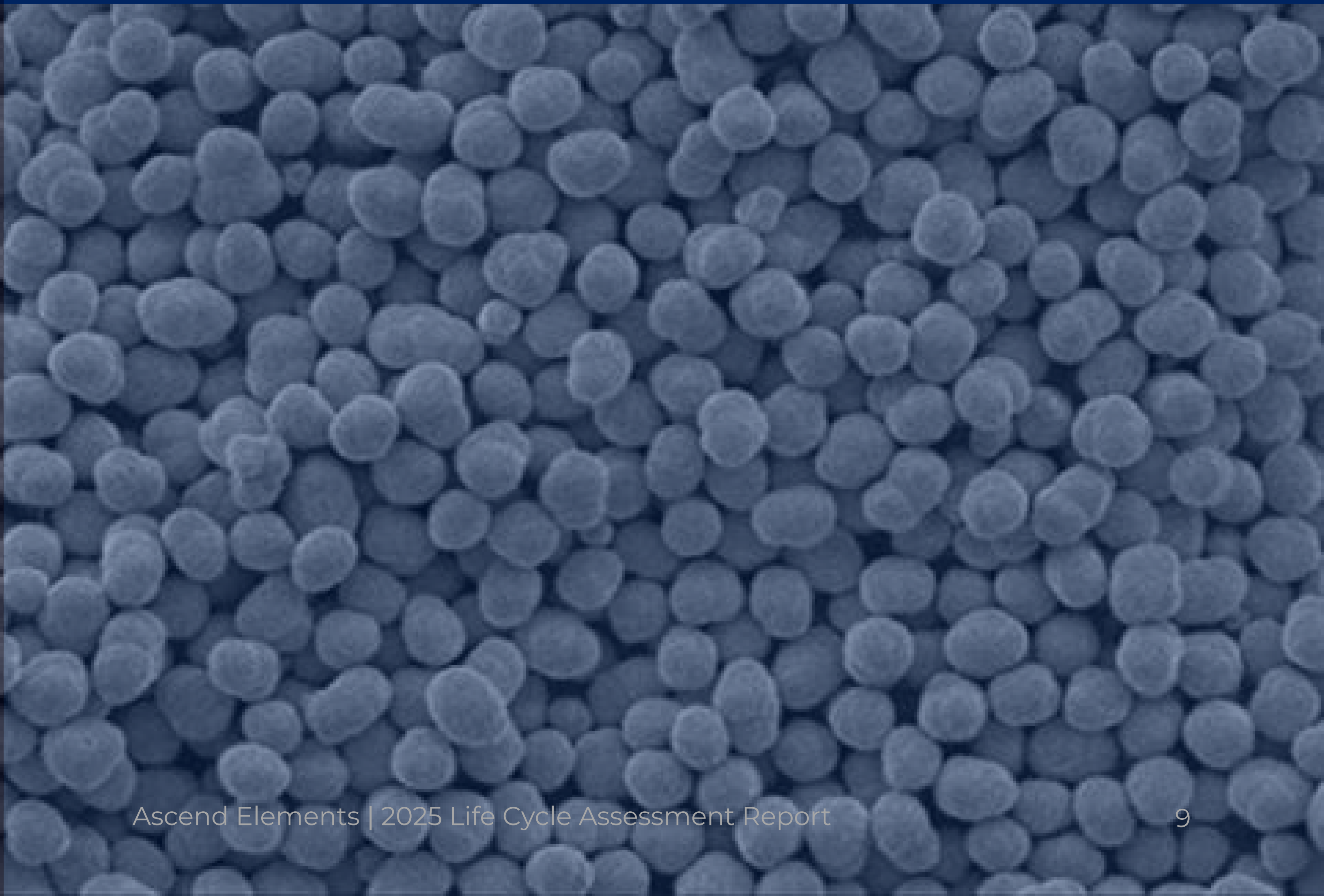
Our Decarbonization Roadmap

As an organization, Ascend Elements is working to become carbon neutral by 2035. In addition to the decarbonization strategies explored in the LCA, this will require a wide variety of actions, including clean energy investments, Scope 3 emissions reductions, and more rigorous supplier standards.



NMC 9.5.5

pCAM



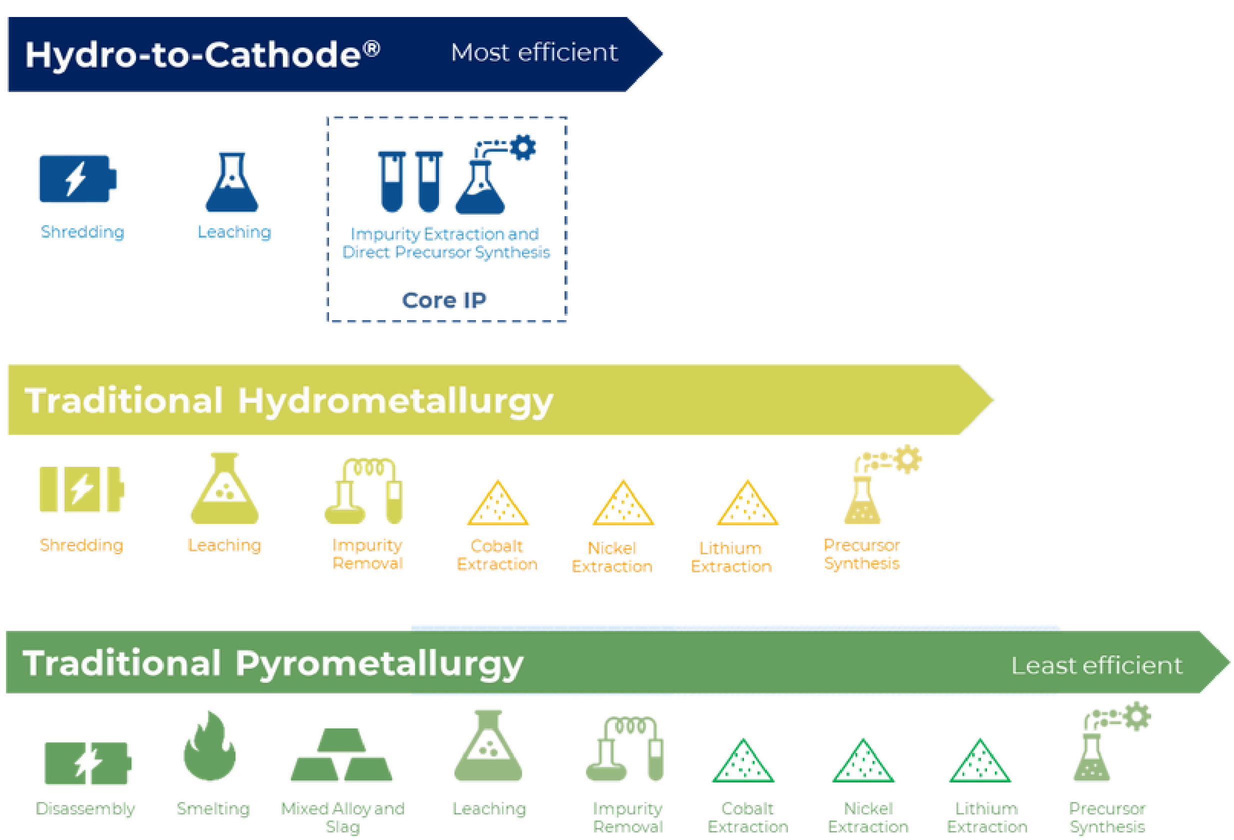
The Hydro-to-Cathode® Process

and how it compares to traditional processes

After battery shredding, lithium extraction, and black mass production, our proprietary Hydro-to-Cathode® direct precursor synthesis process leaches out impurities, keeping the valuable metals in solution and eliminating multiple steps in the recycling flow. It is more efficient, sustainable, and closes the battery supply chain loop.

Compared to Traditional Battery Recycling

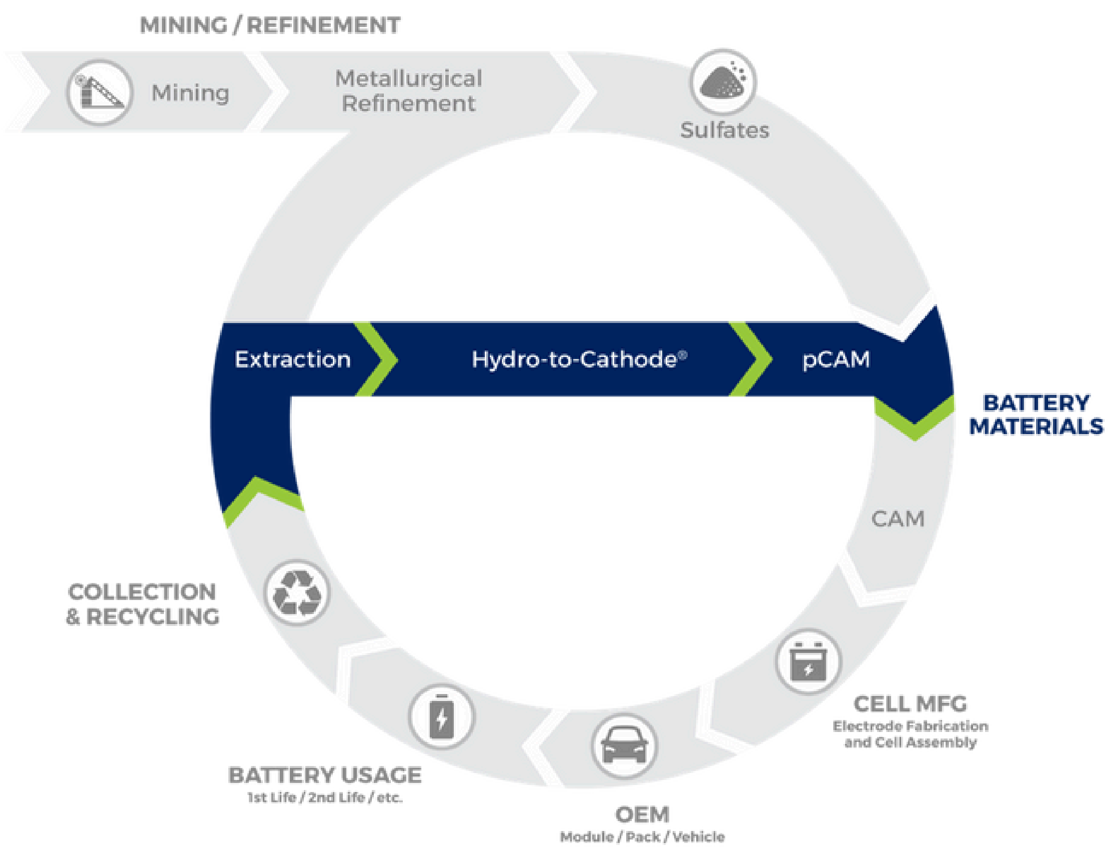
A traditional battery recycling process extracts the critical battery metals (nickel, cobalt and manganese) one by one and recombines them to form new cathode particles. The Hydro-to-Cathode® method efficiently removes impurities (aluminum, copper, plastics, and graphite) and leaves the nickel, cobalt and manganese in solution. By streamlining the process and avoiding the need to extract, precipitate, and recombine the metals, the Hydro-to-Cathode® process significantly reduces energy use and resource consumption compared to traditional recycling.



Compared to Traditional Mining

Traditional mining to produce pCAM involves the extraction of raw materials including nickel, manganese, and cobalt, using various mining techniques. This process is typically energy intensive, and can result in land degradation, the destruction of habitats, and the formation of particulate matter, which can be inhaled and pose risks to human health. In 2023, over half of the world's nickel came from Indonesia (USGS) and its production is one of the most carbon-intensive globally, making it a major emissions hotspot in the mining process supply chain.

The raw materials are then refined, mixed to the desired ratio, and then precipitated to form the precursor material. The Hydro-to-Cathode® process reduces the need for mining critical minerals by obtaining these valuable materials from spent batteries, minimizing environmental impacts, reducing energy and resource consumption, and supporting a circular economy for battery materials.

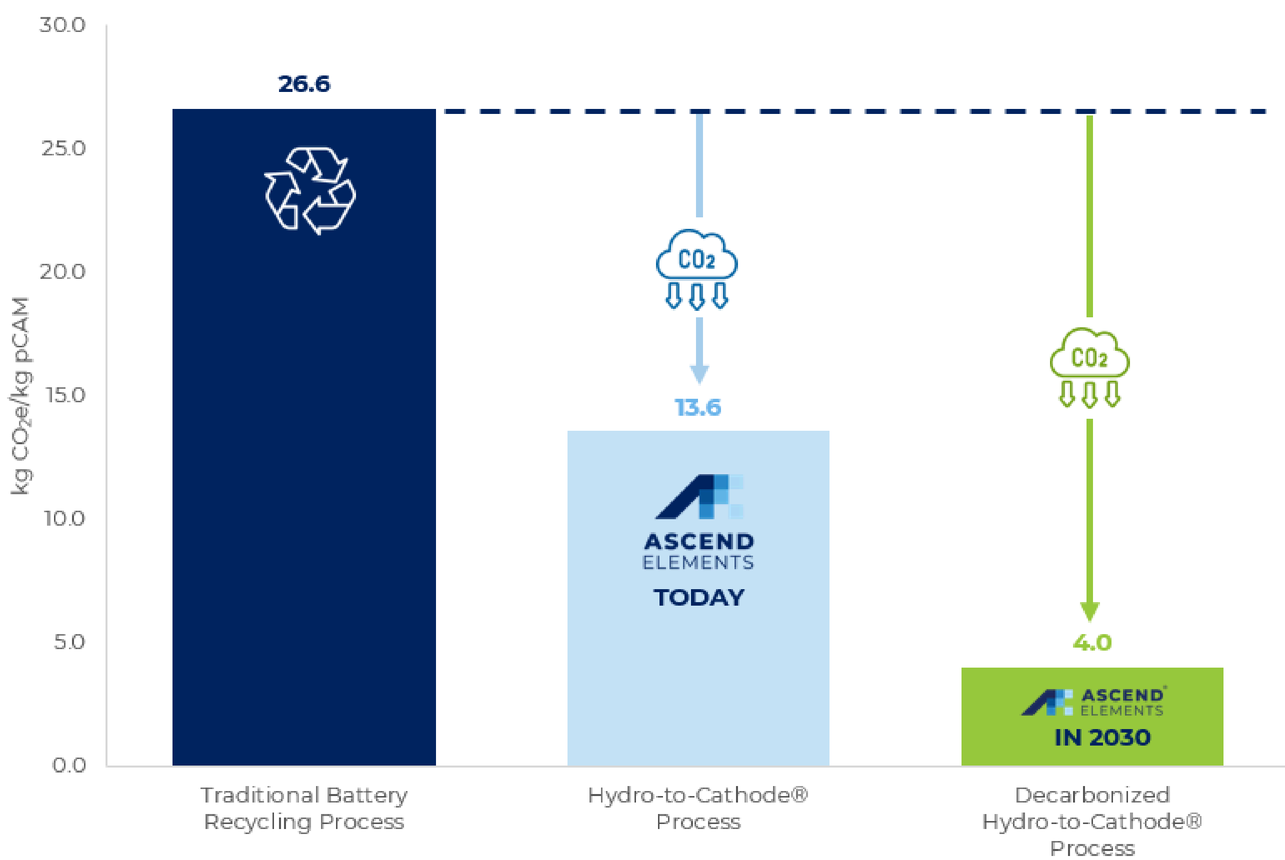


Environmental Impacts of NMC 9.5.5 pCAM Production

How much **carbon (CO_2e)** is emitted from producing 1 kg NMC 9.5.5 pCAM?

A traditional battery recycling method[a] to produce NMC 9.5.5 pCAM emits 26.6 kg CO_2e for every kg of pCAM produced. **Ascend Elements' Hydro-to-Cathode® direct precursor synthesis cuts the CO_2e impact nearly in half to 13.6 kg CO_2e per kg pCAM.**

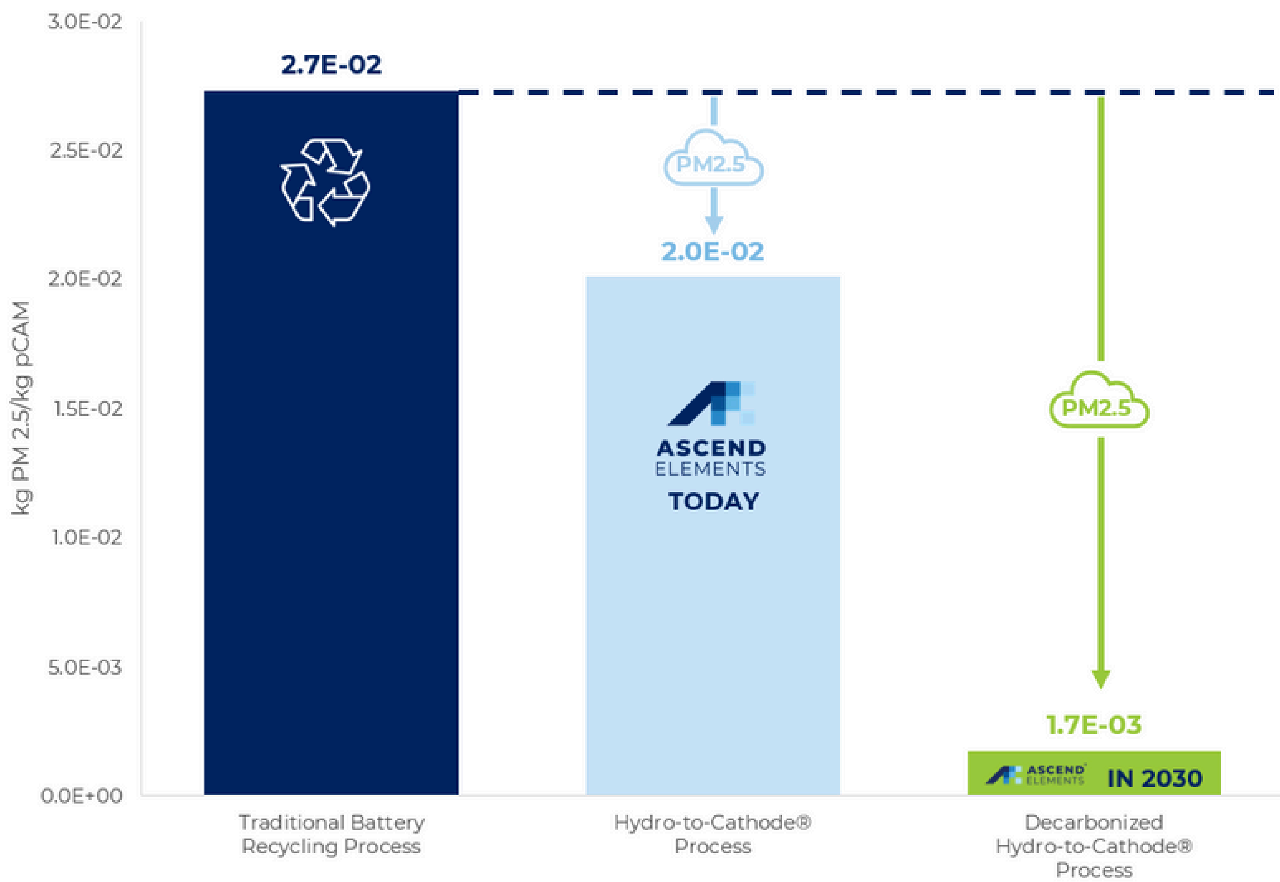
By implementing the decarbonization strategies, Ascend Elements can further **decarbonize our process to only 4.0 kg CO_2e per kg pCAM by 2030**, which is an **85% reduction** in carbon emissions compared to the traditional recycling case.



[a]Involving pyrolysis + hydrometallurgical recycling

Environmental Impacts of NMC 9.5.5 pCAM Production

How much particulate matter (PM2.5) is emitted from producing 1 kg NMC 9.5.5 pCAM?



A traditional battery recycling process[a] and Ascend Elements' Hydro-to-Cathode® direct precursor synthesis both take place indoors, making the PM2.5 formation relatively low. Most PM2.5 formation is from the embodied impacts of the electricity and materials used during the process, and transportation of the battery materials.

By implementing the decarbonization strategies, **Ascend Elements can further reduce PM2.5 formation by 94% compared to traditional battery recycling.**

[a]Involving pyrolysis + hydrometallurgical recycling

Technical Grade

Li_2CO_3

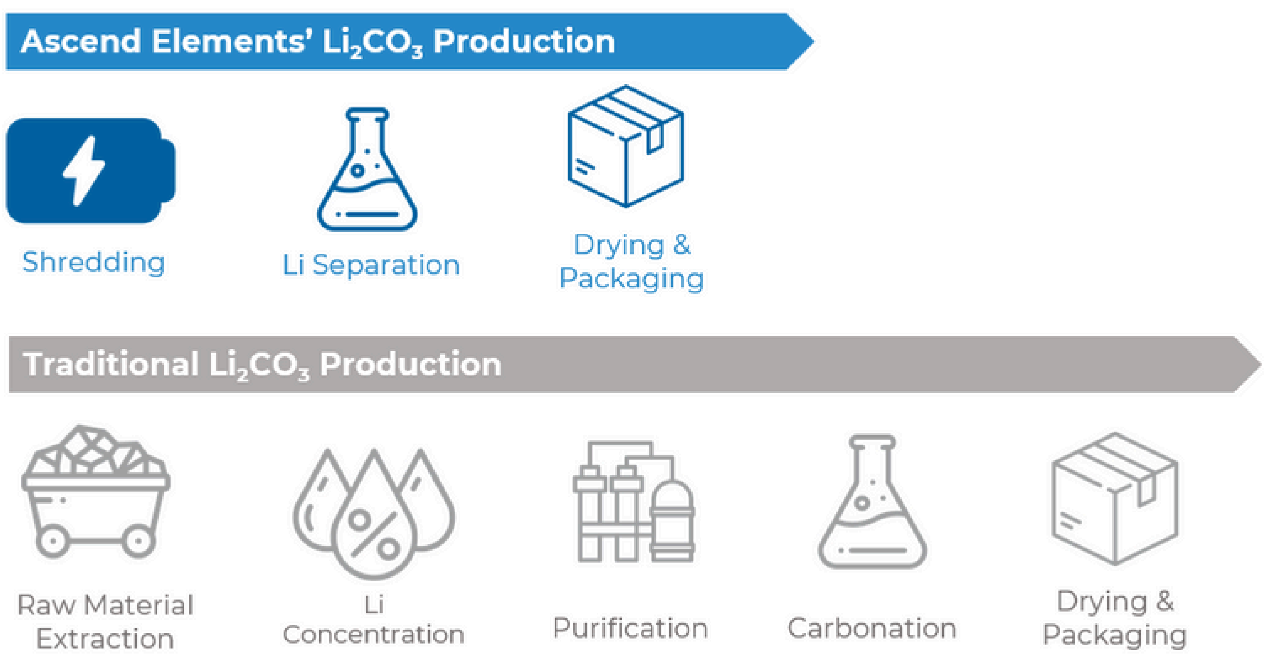
> 99.0% purity

Li_2CO_3 Production

Ascend Elements' Lithium Recovery Process

To sustainably recover all valuable materials from lithium-ion batteries, the lithium is extracted before the Hydro-to-Cathode® process. This approach allows for resource recovery while reducing the amount of non-NMC materials in the Hydro-to-Cathode® process, maximizing efficiency.

The proprietary lithium extraction process involves leaching of the black mass and subsequent processing steps to produce sustainable Li_2CO_3 using 100% recycled content.



How the Li_2CO_3 Production Process Compares

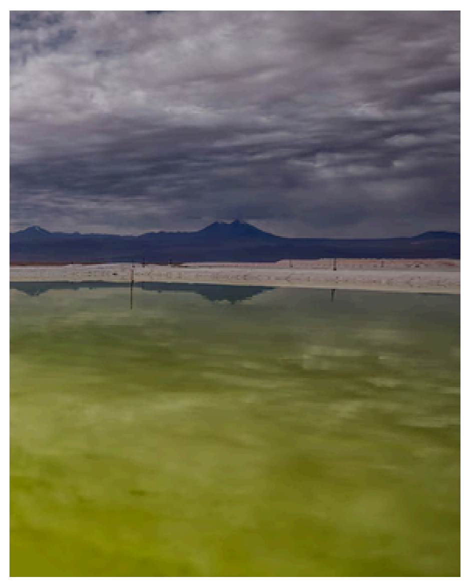
Compared to Li_2CO_3 Production from Spodumene Mining

Lithium-containing spodumene ores are mined and processed in Australia, then transported to China for the final processing stages. This a resource-intensive process than can disrupt the environment and carry a higher carbon footprint. By extracting the lithium from lithium-ion batteries, Ascend Elements can reduce the resources and energy associated with mining and refining processes to produce Li_2CO_3.

In 2023, Australian mines accounted for 45% of global lithium production, which is more than twice that of any other country including Chile (20%), China (18%), and Argentina (4%)[1]. Additionally, 96% of Australian lithium exports are exported to China for refining, making it a likely production route[2]. For these reasons, Li_2CO_3 production from Spodumene mining in Australia and refining in China was selected for the mining case in this LCA comparison.

Compared to Li_2CO_3 Production from Chilean Brine

Another method for producing Li_2CO_3 is through the extraction of lithium deposits contained in brine. In this LCA, a lower-carbon Li_2CO_3 production method was also selected for comparison using brines from Chile. In this process, the lithium is concentrated using natural evaporation methods, then purified, carbonated and dried. While this method reduces emissions compared to spodumene mining, it is still influenced by factors such as water and raw material consumption, land use for evaporation ponds, and the energy used in purification and carbonation steps (Photo: Reuters)



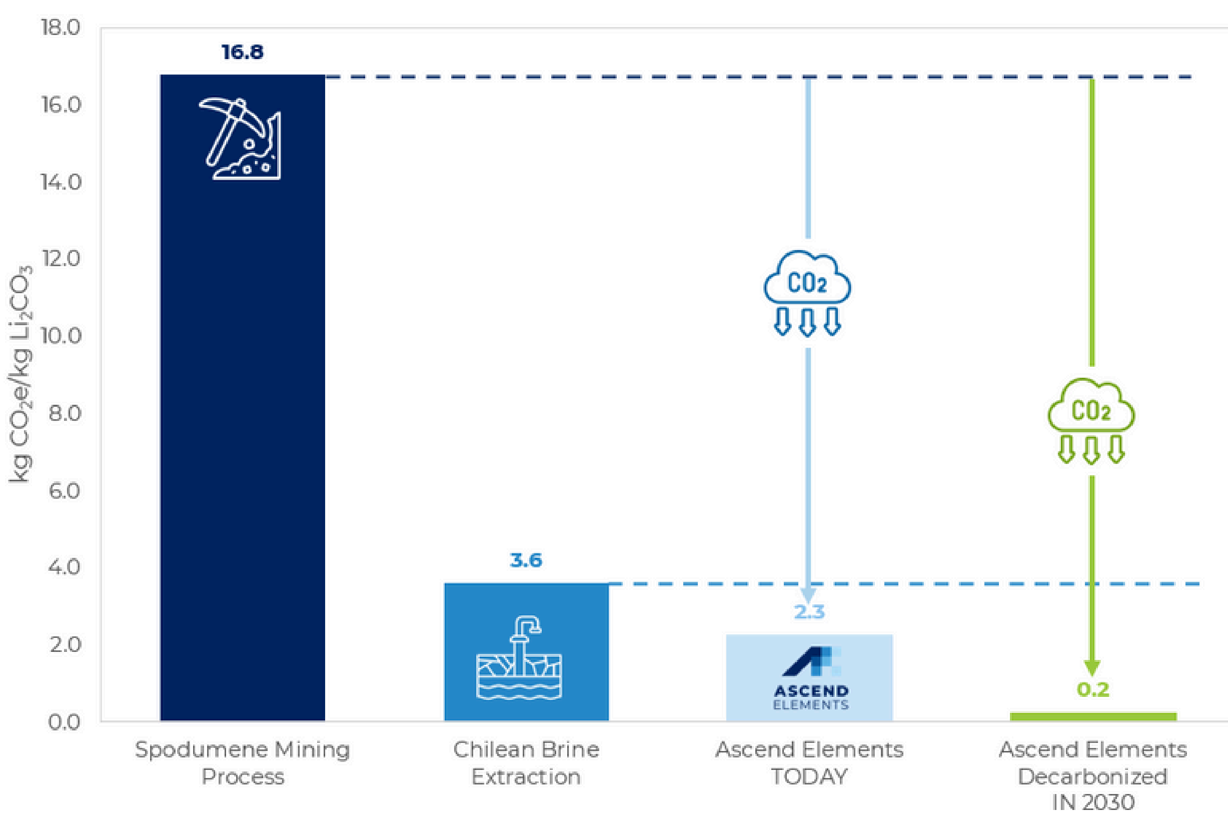
[1]United States Geological Survey
[2]Australian Government, Department of Industry, Science, & Resources

Environmental Impacts of Li_2CO_3 Production

How much CO_2e is emitted from producing 1 kg tech-grade Li_2CO_3?

Traditional spodumene mining emits 16.8 kg CO_2e for every kg of Li_2CO_3 produced, while Chilean brine extraction emits 3.6 kg CO_2e per kg Li_2CO_3. In contrast, **Ascend Elements' innovative Li_2CO_3 production process reduces emissions to just 2.3 kg CO_2e per kg of Li_2CO_3** produced, an **86% reduction compared to spodumene mining** and **37% lower than Chilean brines**.

With our decarbonization strategies, **we can reduce emissions to only 0.2 kg CO_2e per kg Li_2CO_3 by 2030**, up to a **99% reduction** compared to traditional methods.

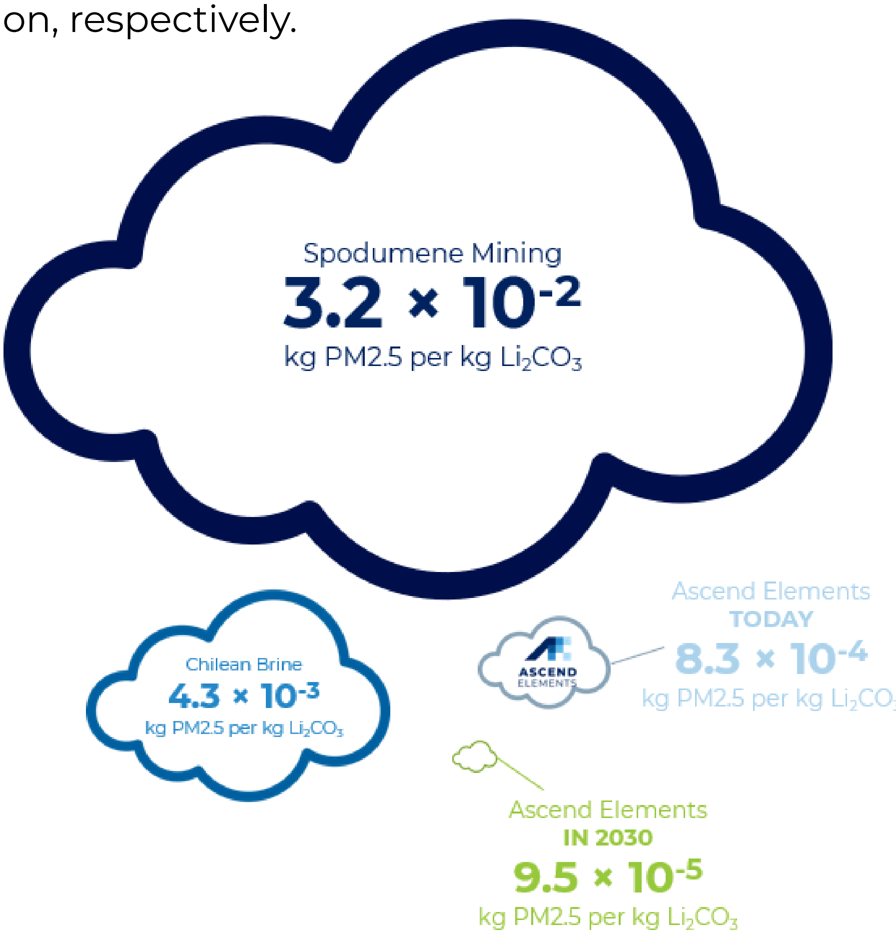


Environmental Impacts of Li_2CO_3 Production

How much **PM2.5** is emitted from producing 1 kg tech-grade Li_2CO_3?

In the base-case scenario, Ascend Elements' Li_2CO_3 is 97% and 81% less polluting of PM2.5 compared to spodumene mining and Chilean brine extraction, respectively.

AE's decarbonized processes represent drastic reductions in PM2.5 formation compared to alternative Li_2CO_3 production routes, being 99.7% and 98% less polluting than spodumene mining and Chilean brine extraction, respectively.



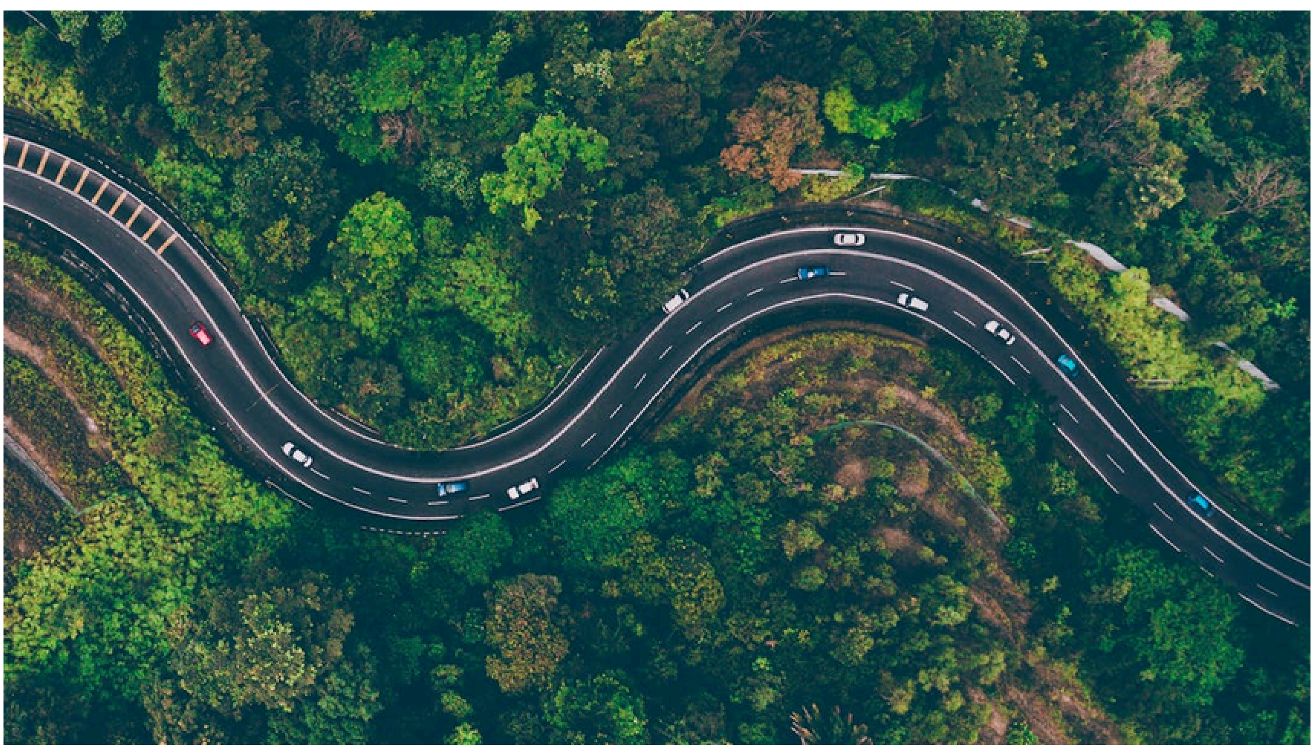
Sizes are scaled relatively to each other

Final Thoughts

This LCA provides a comprehensive analysis of the environmental impacts of Ascend Elements' products and highlights the advantages of our innovative processes compared to traditional production methods.

Through utilizing renewable energy, lower carbon reagents, and rail transport, we can continue to reduce the impacts of our operations and drive meaningful progress towards a more sustainable future.

As part of our commitment to sustainability and operational excellence, we utilize LCA as a tool to support decision making and process development. As our processes evolve, we will continue to update our LCAs to provide the most accurate assessment of the current impacts of our operations.



Author

Emma Giddings, B.S.

Editor

Thomas Frey, APR

This report is adapted by a life cycle assessment conducted in accordance with the ISO 14040:2006 and ISO 14044:2006 standards and critically reviewed by a panel of experts, including two reviewers from Minviro and a third reviewer sourced by Minviro