THE BATTERY CHRONICLES

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AETC'S direct recycling processor for automotive lithium-ion batteries: Solid plan for upcycling anodes and cathode active materials

In the summer of 2025, I joined American Energy Technologies Co. (AETC) as a chemical engineering intern. On my first day, I was introduced to the Direct Recycling of spent lithium-ion batteries under the STREAMS project. I had the opportunity to learn about the many parts of the process conducted at our company, as well as the broader context of the initiative. Then, I participated in the operation of the recycling line and collected yield data at every step of the way. My work was specifically centered around recycling of 18650-sized NMC811 (lithium nickel manganese cobalt oxide) cells. Within a few months of my internship's completion, I was fortunate to have travelled to Imperial College London, where we have collaborators who work on life cycle analyses and techno-economical assessment of the process of Direct Recycling created at AETC. I shared my data with them, and I am excited to say that a joint study between AETC and ICL is now underway.

For the remainder of this article, I would like to share some of the less-discussed but nevertheless critical achievements of STREAMS, which I have delved into upon my return to AETC in June 2026. Direct Recycling of batteries focuses heavily on the recovery and "healing" of graphite anode, but the separator and cathode each prove valuable to recover as well. The separator would be an easy component to overlook, at least in the case of a singular cell.

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It constitutes less than five percent of the cell's mass. On a larger scale, however, these spent separators become miles of wet electrolyte-penetrated plastic strips. They are not clean, so immediate re-use is not an option. Separators can be dried, but the contaminants -- electrolyte fluid and some electrode mass -- remain in place. How then, can this plastic be saved from the landfill? And is there any economic value in doing so?

The affirmative answer lies in the separator's carbon content. Through an engineered heat treatment cycle, the hydrocarbon sheet can be converted into pure carbon. Whereas the original polyolefin sells for only 1400 euros per metric ton, this carbon product has a market value of 8500 euros per metric ton in the recycled form. This represents a dramatic increase in value, which makes the processing worthwhile. The recovered carbon powder can go back into NMC batteries as a conductive additive in the cathode. As evidenced by the increase in value, we go beyond recycling; this is now upcycling. Though the yield of battery-ready carbon is only 4.5 % of the mass of the original separator, this is an economically viable operation at scale because metric tons of separator material can be graphitized together. The upcycling also contributes to the problem of sustainably sourcing graphite material, supplemented via the recycling.

The value of the spent cathode is more intuitive, as it contains a mix of metals: lithium, nickel, manganese, and cobalt. Unrolled cathodes are processed to separate active material from the aluminum foil current collectors. AETC partners of STREAMS project in Ukraine (ISPE and UNE) then convert the recovered end-of-life cathode active material into solid manganese dioxide and a nickel-cobalt alloy. Lithium is recovered in two ways. First, it comes out of the cathode and anode wash as a mixture of LiF and Li_2CO_3 salts. Then, lithium metal can be obtained from the cathode active material via electroplating, a process operating at ISPE. Overall recovery is high, reaching up to 60% of cathode ingredients which were recovered through AETC's Direct Recycling process. Finally, the manganese salt, lithium components, and nickel-cobalt alloy undergo further reactions to create fully healed NMC ready for use in a new round of cell. The latter operation is performed by UOULU, a prominent consortium member of STREAMS.

In short, Direct Recycling for batteries does far more than enable re-use of anode material. It also produces valuable new carbon additives and enables an efficient turnover of the cathode. By implementing our recycling line, we reduce both mining requirements and landfill contribution. As this technology matures, AETC and its partners will gain further understanding of improvements in efficiency, yield, and product characteristics. Such developments will enable a higher percentage of recycled materials to be used in newly manufactured batteries.

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