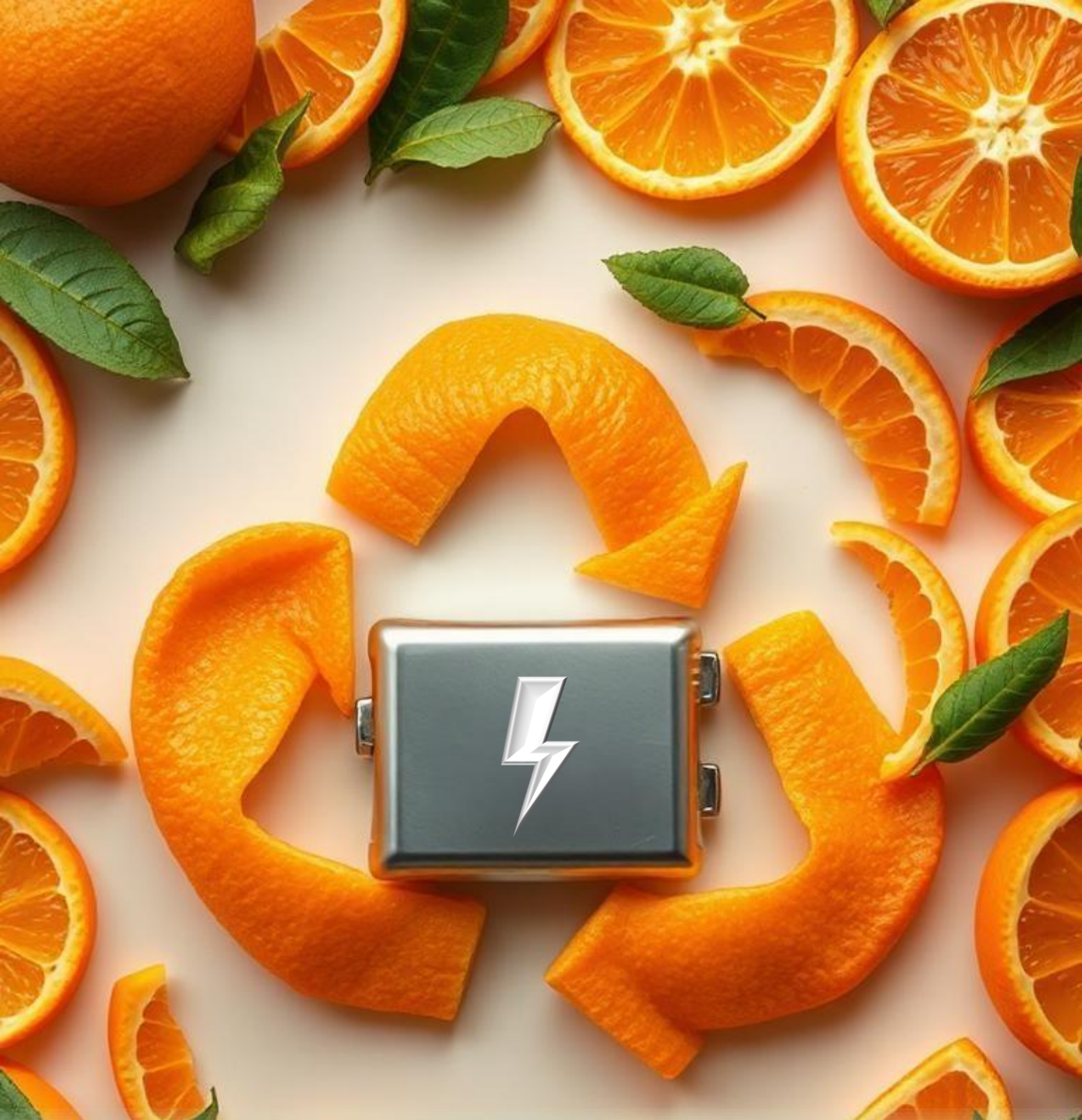

Turning Orange Peels into a Circular Battery Future

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WASHINGTON | CORE

Lithium-ion batteries have become the backbone of renewable energy storage, allowing solar and wind power to be stored and released when needed. Their use is soaring, especially as electric vehicle adoption accelerates, but this growth comes at a cost. By 2030, more than 1.2 million tons of lithium batteries will need to be recycled. According to the Nano Energy scientific journal, one single lithium battery can emit over 100 toxic gases, including carbon monoxide (CO).[1] Without sustainable solutions, the depletion of raw materials and toxic emissions from spent batteries risk undermining the very transition they are meant to enable.

Traditional recycling methods, while effective at extracting valuable metals, are far from ideal as they rely on harsh chemicals and energy-intensive processes, typically leaving behind dangerous emissions. The race is on for safer, cleaner, and more cost-effective solutions, and a small startup in Puglia, a region in southern Italy, is pioneering a surprising solution.

What happens when Lithium-ion batteries reach the end of their lives?

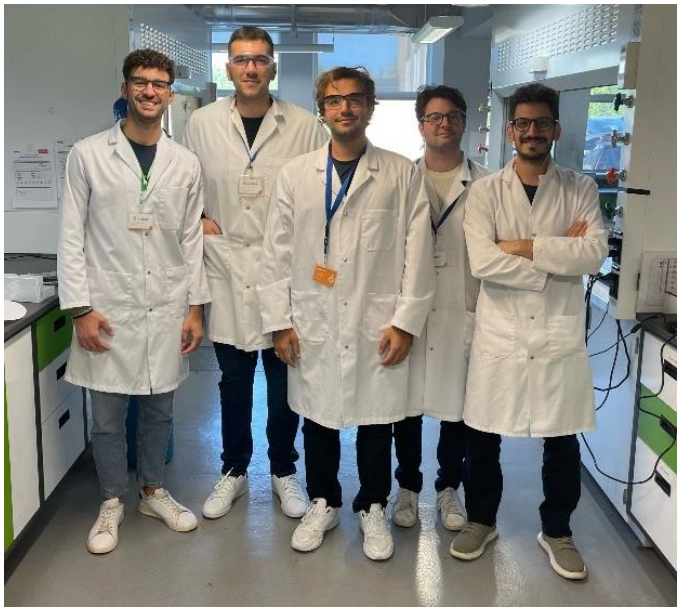
Map of Puglia, Italy

AraBat's Journey Toward Sustainable Lithium-Ion Recycling

AraBat, founded in 2022 by a group of five students, is pioneering a bio-based approach to recycling. The company has developed a patented "green hydrometallurgy" process called "AraMet" that uses biomasses and agricultural waste - notably orange peels, but also artichoke leaves, fennel, red algae, broccoli, lemons, sea algae, and many others - to recover valuable metals from batteries. By drawing on the principles of circular economy, AraBat seeks to replace hazardous chemical processes with sustainable alternatives while proving that recycling can be both cost-effective and environmentally sound.

At the center of this vision is Raffaele Nacchiero, AraBat's co-founder and CEO. In a recent interview with Washington CORE, Nacchiero shared his reflections on AraBat's unlikely beginnings, the obstacles facing the recycling industry, and the promise of biomass as a key to battery circularity.

From Idea to Startup: A Student-Led Journey



AraBat Team
Source: AraBat

AraBat was not born in a laboratory, but in a student association devoted to the values of sustainability and circular economy.[2] Nacchiero and his four co-founders were students of management, engineering, finance, marketing, chemistry, and materials engineering. They decided to turn their philosophy into action, starting with motivation and a vision before the technical solution followed.

Their intuition was simple yet bold: use fruit and vegetable waste to recycle batteries. The spark came from their home region of Puglia, where orange production is a major industry, and waste from unsellable fruit often goes unused. Nacchiero wondered if these discarded peels could be repurposed for industrial processes. The team approached the University of Foggia, where Professor Matteo Francavilla gave them access to laboratory facilities.

With modest family means, the group bootstrapped the early experiments. "The university let us use their labs, but we had to pay them after one year," Nacchiero noted. Awards, small grants, and prizes of nearly €200,000 helped cover costs. International support soon followed. For example, a Canadian partner offered pilot-scale testing facilities, enabling AraBat to move from testing grams to testing kilograms of material. This transition was critical. At the pilot level, AraBat achieved over 95% leaching efficiency in extracting metals, an early proof of the technology's potential.

Financing the Cleantech Startup

Like many deep tech ventures, AraBat faced steep hurdles in attracting investors. "We are the only Italian startup working on battery recycling innovation," Nacchiero noted, and local venture funds lacked the technical expertise to evaluate their work. In fact, Italy lacks domestic battery recyclers altogether. Most consortia simply collect batteries and ship them to facilities in Belgium, France, Germany, Poland, or elsewhere in Northern Europe.[3] Early fundraising attempts failed, bogged down by the need for detailed technical documentation and lifecycle analyses.

Gradually, the AraBat team built up momentum. They compiled lifecycle assessments, secured university certifications, and prepared precise business plans. These efforts attracted attention abroad, and today AraBat aims to finalize its first $1 million investment round with a large international fund. This funding has enabled the company to scale up production and build its first pilot facility in southern Italy, creating a local network of suppliers and customers. By 2026, AraBat aims to transition its bio-based method from pilot validation to industrial-oriented deployment.[4]

AraBat Leaching Process
Source: AraBat

How the Technology Works

Most conventional recycling relies on either pyrometallurgy, the process of burning batteries at extremely high temperatures, or hydrometallurgy, which uses harsh acids. Both approaches carry high environmental costs.

AraBat's patented AraMet process takes a different path, replacing corrosive chemicals with organic acids and agricultural waste.

This approach makes recycling safer, cleaner, and adaptable while maintaining high recovery and purity rates.

The process unfolds in three main stages:

Spoke section — Hub section

1 Mechanical Pretreatment

- Discharge and dismantle batteries
- Separate copper foils and materials
- Crush remainder into black mass powder containing metals

90-95% of materials are separated into black mass

2 Bio-based Leaching

- Treat black mass with organic acids (e.g., citric acid) and biomass (e.g., orange peels)
- Heat mixture to 90 °C to release metal ions

90-99% of metals are released into solution

3 Selective Precipitation

- Adjust acidity to separate metals
- Recover nickel, manganese, then cobalt
- Extract lithium carbonate, graphite, copper, aluminum

80-95% of metals are recovered for reuse

Metals recovered


Graphite


Nickel


Manganese


Lithium


Cobalt

Source: AraBat

For Nacchiero, the driving force behind AraMet lies in the feedstock itself:

"Why biomass? Biomass is our secret. It contains reducing sugars, flavonoids, phenolics, and all these substances cooperate with organic acids like citric to extract metal ions from the black mass."

Economics of Fruit Waste

A major advantage of AraBat's method is cost. In Italy, one ton of orange peels can be purchased from farmers or juice producers for as little as €30. This gives AraBat a competitive edge over recyclers dependent on expensive inorganic chemicals. The process is also versatile. AraBat's patents cover a range of feedstocks ensuring adaptability to different agricultural regions.

The company has even tested industrial waste, such as e-waste and gas meters. At the pilot scale, AraBat estimates unit processing costs of about €4 per kilogram of lithium battery materials treated, with room for significant reduction through economies of scale.

AraBat's approach has been described as one of the most economical and sustainable lithium battery recycling processes worldwide. Beyond lowering operational costs, this dual use of agricultural and industrial waste helps mitigate the hazards of used batteries, prevents the environmental damage associated with mining for new metals, and buffers against the price volatility of critical raw materials often shaped by shifting global political dynamics.[5]

Puglia Orange Orchard
Source: Landscape

The Three Challenges of Battery Recycling

The push to make battery recycling both viable and sustainable is accelerating worldwide, yet beneath the promise of innovation stand three persistent obstacles the industry must address to reach its potential.

01 Supply Chain

Building a reliable network for collecting spent batteries, the concentrated mix of valuable metals left after crushing, remains difficult. It requires building networks across industries. While demand for recycling is expected to surge by 2030, current volumes today are still limited. Companies must remain flexible, ready to process not only conventional lithium-ion batteries but also alternative chemistries and industrial scraps.

02 Profitability

Many recyclers, including large players in Canada, have struggled to generate consistent profits. According to Nacchiero, this stems from weak assumptions in business planning, such as underestimating the growth of lithium iron phosphate (LFP) batteries or mismanaging investment structures. Only innovative technologies with strong unit economics can sustain the industry.

03 Sustainability

While hydrometallurgy is a step forward from older pyrometallurgical methods, it still relies on hazardous reagents such as sulfuric or hydrochloric acid, often combined with hydrogen peroxide, an explosive mixture. These chemicals are costly, difficult to manage, and environmentally harmful.

Environmental Impact

Despite these challenges, AraBat's method has demonstrated tangible environmental gains in significantly reducing carbon emissions and acidification. By avoiding inorganic acids, the company prevents the release of sulfur oxide (SOx) and nitrogen oxide (NOx) emissions, which in conventional recycling can reach 5–15 grams per kilogram of battery. AraBat's process reduces CO_2 emissions to less than 2 kg per kilogram recycled.

At scale, this could yield significant gains. AraBat's planned industrial facility, capable of processing 5,000–6,000 tons annually, would deliver substantial reductions in greenhouse gases and acidification effects. Beyond batteries, Nacchiero envisions adapting the process to decarbonize other industries, such as oil and gas or photovoltaics.

Market Applications and Global Partnerships

The automotive and battery manufacturing sectors are AraBat's primary customers, given their demand for high-purity materials. Other industries, including metallurgical, glass, ceramics, and pharmaceutics, also represent potential markets for cobalt and other recovered elements, such as lithium carbonate and nickel. Demand across these sectors is intensifying as international supply chains become more fragile.[6]

In Europe, policy incentives like the Critical Raw Materials Act,[7] which mandates that a 20% share of the EU's overall raw material consumption must come from recycled sources, are creating strong demand. Other regions are beginning to follow suit. For example, China recently approved black mass standardization regulations,[8] and the U.S. has reopened federal battery recycling grants.[9]

Despite its Italian roots, AraBat has always thought globally, beginning with their pilot-scale testing in Canada. More recently, the company has opened a U.S. subsidiary to establish partnerships with American universities and research centers. Patents have been obtained in Europe, the U.S., Canada, China, Japan, India, and South Korea.

Interestingly, many of these partnerships were initiated informally, sometimes through LinkedIn messages. Their Canadian testing partner flew from Montreal to Foggia to meet the team after being contacted online. AraBat's international growth reflects both the cosmopolitan mindset of its founders and the global urgency of the recycling challenge.

A Dream of a Bio-Based World

For Nacchiero, AraBat's story is about more than just technology. It reflects a broader philosophy that sustainability and circularity can drive industrial innovation. "We dream of a bio-based world," he said, envisioning not only battery recycling but also applications. It is a vision rooted in the fields of Puglia but aimed squarely at the global stage.

The road ahead will require scaling technology, securing financing, and building regulatory support across continents. If AraBat succeeds, the company may prove that the most sustainable recycling solutions are not manufactured but grown.

AraBat's Dream in Action
Source: AraBat

Awards and Recognition

AraBat has been named "the Apulian Miracle" and "the most awarded startup in Italy," having won numerous awards and competitions, such as the ENI Award 2022, a major Italian energy innovation prize supported by the President of the Italian Republic and ENI, the country's largest energy company, along with Start Cup Puglia 2022, a regional startup competition in Italy's Apulia region, the Premio Nazionale dell'Innovazione 2022 for Cleantech & Energy, Italy's national innovation award, the Canada-Italy Innovation Award 2023, an award sponsored by the Embassy of Canada in Italy that promotes collaboration between Canadian and Italian innovators, and the Impact Award 2025, which recognizes diverse fields of innovation.

AraBat Receiving the 2022 ENI Award

Source : AraBat

Moreover, AraBat has been selected by the renowned TechCrunch news website for its 2025 Startup Battlefield list of the 200 most innovative startups in the world. StartUs Insights, a global innovation and startup scouting platform, also includes AraBat among the top 10 battery remanufacturing startups in the world.[10]

Endnote

1. https://www.renewableinstitute.org/arabat-pioneering-sustainable-lithium-ion-battery-recycling-for-a-renewable-future/
2. https://innovationorigins.com/en/recycling-batteries-with-orange-peel-arabat-knows-how-to-do-it/
3. https://www.wired.it/article/startup-riciclio-batterie-arancia-arabat/
4. https://innovationorigins.com/en/recycling-batteries-with-orange-peel-arabat-knows-how-to-do-it/
5. https://www.repubblica.it/green-and-blue/native/2022/10/18/news/lenergia_di_domani_e_salita_sul_podio-370566710/
6. https://www.wired.it/article/startup-riciclio-batterie-arancia-arabat/
7. https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials/critical-raw-materials-act_en
8. https://rhomotion.com/news/china-releases-legislation-allowing-the-import-of-black-mass-industry-update/
9. https://www.recyclingtoday.com/news/us-department-energy-battery-recycling-grants-lithium-nickel-2025/
10. https://www.renewableinstitute.org/arabat-pioneering-sustainable-lithium-ion-battery-recycling-for-a-renewable-future/
11. https://d2xcel.eu/d2xcel-news/ventures-spotlight-series-arabat

Raffaele Nacchiero is the CEO of AraBat, a circular economy startup that has developed a cost-effective and sustainable hydrometallurgical process to recycle lithium batteries using biomass and agri-food waste. The venture was co-founded by Raffaele Nacchiero, CEO, Leonardo Renna, CFO, Giovanni Miccolis, COO, Leonardo Binetti, CTO, and Vincenzo Scarano, CMO.

Beyond recycling, it engages in renewable energy production, circular process development, and green economy consultancy, with sustainability at the core of its strategy.[11]