LUCRA: Scaling bio-based succinic acid from side streams and waste for drop-in polymers

LUCRA is a CBE JU project, coordinated by the Bio Base Europe Pilot Plant in Belgium. The project is demonstrating a pre-industrial route to bio-based succinic acid from the organic fraction of municipal waste and sawdust. As project coordinator **Tanja Meyer** explains, by coupling fermentation with inline electrodialysis and validating performance in polyurethane applications with a large chemical company, the project aims to deliver a drop-in molecule with lower life-cycle emissions and credible costs that can compete on the market with its fossil-based equivalents

As a platform chemical, succinic acid is at the root of many very familiar modern materials, feeding into the polyesters and polyurethanes that end up in packaging, textiles, automotive components and even personal-care products. While the chemistry is familiar, however, the question now is whether Europe can make the same molecule from different carbon derived bio-based feedstocks, at a scale and cost that industry can use. This is the challenge facing the LUCRA project, a Circular Bio-based Europe Joint Undertaking (CBE JU) funded initiative it claims "is on a mission to revolutionise bio-based chemicals".

The project is coordinated by the Bio Base Europe Pilot Plant (BBEPP) and led by their European Project Coordinator Tanja Meyer. She describes

Eight pressurised stainless steel fermenters of 30L each, used in LUCRA for technology transfer from lab scale to pre-industrial scale

succinic acid as "a bio-based building block that already exists in a fossil-based form. It's what we call a drop-in molecule and that drop-in aspect matters because it keeps our focus on performance and price, not on reformulating downstream processes."

LUCRA is designed to test that proposition at pre-industrial scale, using realistic feedstocks rather than laboratory sugars and to ensure the outcome is commercially viable in terms of scale and price. This all begins with two feedstock inputs. One is the organic fraction of municipal solid waste (OFMSW), gathered from food markets and household collections. The other is sawdust supplied by Finnish partner Boreal Bioproducts (Montinutra Ltd) as a by-product from existing lignin and cellulose valorisation processes. Both streams are rich in lignocellulose and sugars, but both also come with practical complications. "OFMSW is the more difficult one?," explains Meyer. "It's completely mixed with other types of household waste, so achieving a pure enough stream is a challenge."

To address this problem, the project's waste-management partner FCC Medio Ambiente is improving sorting processes and equipment, while LUCRA's communications efforts are focusing on raising citizen awareness about how to separate their recycling because better separation at source shows up later as steadier, cheaper sugars. "This may sound like a simple issue, but contamination directly affects the fermentation outcomes and, therefore, eventual product cost," says Meyer.

Seasonality has been another concern for OFMSW in the project. It originates from Spanish food markets, where the variations between winter and summer waste led to concerns about whether summer's fruit-heavy mix would deliver more fermentable sugars than winter. "We analysed composition by season," Meyer explains. "We didn't see a significant difference: sugar levels were sufficient year-round. This was important for LUCRA's long-term scalability with evidence that it supports a year-round business case – a process that only works in one season is not sustainable commercially."

The sawdust stream tells a different story. It is a residue from Boreal Bioproducts that already valorises lignin and cellulose and wants to explore options for what remains. Because the side stream still contains cellulose, LUCRA's task is to fractionate and pre-treat so that cellulose is exposed for hydrolysis to glucose. Here the project has made the deliberate choice not to chase enzyme innovation. "We basically work with commercial enzymes," Meyer says. "The better the pre-treatment was to expose cellulose, the better the enzymes could break it down."

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What is novel here is the integration – tuning pre-treatment processes so that enzymes work efficiently on real hydrolysates, then ensuring the resulting sugar streams can be pumped, concentrated and fed consistently to pilot-scale fermenters. Once sugars are available, the core bioconversion begins.

At this half-way stage of project, the screening of succinic-producing strains at lab scale by partners AUA, Ugent and Ineuvo, has been validated and the task now is to transfer to the larger vessels available at BBEPP. "This scaling up sounds simple enough until you account for what biomass looks like after fractionation," explains Meyer. "If you fractionalise biomass, the cellulose obtained is still solid, so if you then want to pump it into a vessel , it needs to be made into a slurry and that's not easy, so a key task has been to create a pumpable, homogeneous slurry at the volumes needed for our 1,500-litre fermentation tanks being used for LUCRA."

Product recovery is where LUCRA's approach diverges most clearly from convention. The standard route is to ferment to completion and only then process the entire broth through a series of dewatering, separation and purification steps. LUCRA instead couples an electrodialysis unit, invented by start-up partner Hydrohm, directly to the fermenter to extract succinic acid while the microorganism is producing it. "The electrodialysis unit is coupled on to the fermenter and then extracts the succinic acid while it's running," Meyer says.

This approach has clear advantages. Keeping product levels even can help stability inside the fermenter, and it can also compress the sequences of the downstream purification process (DPS). "With DPS, there can be up to 10 steps before you come to succinic acid," Meyer continues. "We have shortened that to two or three steps and fewer steps mean less equipment, lower energy use and potentially lower operating costs. These are all essential if a bio-based route is going to compete with fossil incumbents."

Coupling an inline recovery unit to a live fermentation brings its own control challenges,

BBEPP engineers controlling the state of foaming in the 150L Frings fermenter, used in LUCRA for scale-up fermentation runs

however, as Meyer explains. "You can't extract more than is produced so a steering needed to be programmed." LUCRA approached this by developing models to guide the control strategy – how hard to pull, how to respond to transient changes – and it is now refining that logic on the pilot line. It is the core of what "pre-industrial" means in practice: building operating envelopes and procedures that give predictable performance outside the lab.

Following directly from this engineering logic, LUCRA aims to show that waste-derived sugars can feed a stable, pilot-scale fermentation, that inline electrodialysis can be integrated and run reliably and that the resulting bio-succinic acid can be used in polymer applications. Keeping an application partner close helps ensure that success is measured by what customers need rather than what a flowsheet can theoretically deliver.

That application partner is German chemicals company Covestro. They will evaluate LUCRA's bio-succinic acid in its own polyurethane formulations, to check if it is actually feasible for its products in terms of quality and credible cost. In addition to CNR's lab tests for formulation into Polybutylene succinate (PBS) "Ultimately, it has to be competitive," says Meyer. "We are therefore running both life-cycle and techno-economic assessments in parallel with the pilot work so that we can match process choices to greenhouse-gas and cost impacts based on real data and the pilot-scale runs will produce those data for Covestro to use."

Some of LUCRA's hardest work now sits at the lab-to-pilot handover. OFMSW will never match a synthetic medium, so the team is pursuing two paths: stabilising feedstock quality where possible and selecting strains that tolerate variability. With seasonal composition already shown to be broadly stable, the real test is running on actual hydrolysates from OFMSW and sawdust. As those replace artificial media, the pilot team is tracking growth behaviour, inhibition and contamination thresholds to define reliable operating envelopes, a decisive step towards scale.

Regulation and definitions frame all these choices. Whether a stream is certified as "waste" or "residue" changes what downstream actors can legally do with it. "Our partner Montinutra, which operates Boreal Bioproducts, prefers their side stream to be declared a residue, not waste, because the certification affects downstream options," Meyer says. "REACH thresholds do not apply at LUCRA's current scale, but they would at a flagship scale; planning for that now reduces the risk of surprises later."

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Although this planning is seen to be crucial for commercial scaling, LUCRA does not have a dedicated policy task in the project. Instead, it threads policy awareness into stakeholder engagement and process design. That engagement is unusually direct. The project runs co-creation workshops that bring feedstock providers and technology owners together to talk about volumes, qualities and constraints, set-up by Steinbeis Europa Zentrum. "It sounds basic, but the lack of such conversations is one reason bio-based value chains struggle to move beyond pilots," claims Meyer. "It does not happen so often that a large German chemical company sits in the same discussion as a waste management company," she observes. "In fossil value chains, downstream users could often ignore upstream realities, but in bio-based systems, issues like quality and traceability make it important for those conversations to take place up-front. LUCRA is making them routine, and the learning runs both ways."

Against that background, the project's achievements so far are beginning to bear fruit. The seasonality risk has been addressed with data that support year-round operation. Fractionation and pre-treatments have been mapped for both feedstocks, including solvent-aided options to produce cleaner intermediate streams. Strains have been screened at lab scale. The electrodialysis skid is being integrated with pilot fermentation and the control logic is being tuned using modelling and real-time behaviour. Despite inevitable delays, the path forward is clear, with the move from lab to pilot scale generating an

application-grade product that can be fed into polymer trials with Covestro.

Meyer is confident that if these trials succeed as forecast, a flagship-scale demonstration is what should happen after the project ends. This will, of course, depend on funding, but the underlying requirement is clear: larger units in the 15- to 75-cubic-metre class, consistent quality, robust control and a downstream that customers trust. "In the next two years, we could consider going to a flagship project," predicts Meyer, careful to stress that any decision will rely on the data and partner appetite. "We need to show that the process behaves like an industry process, with the repeatability and economic outcomes such a process requires."

For BBEPP, LUCRA is almost a signature project. The organisation exists to bridge lab demonstrations to market-ready operations by providing open-access scale-up capacity and integration expertise. "We go from 10 litre to 1,500 litre, which is already TRL 6," Meyer says.

"We then ensure everything fits together," she continues. "So, how pre-treatment shapes hydrolysis, how hydrolysate composition governs fermentation, how inline electrodialysis rewrites downstream and how to connect, clean and control the whole system so it behaves like a plant rather than a laboratory."

There is also the "one-stop-shop" dimension that LUCRA is making tangible. "We hope to show that by working along the value chain we can produce a monomer as a crystal," says Meyer. "Then our application partner Covestro will put it through chemical processes and into a polymer, into a plastic. This will be the proof needed that the route can deliver a material customers can test, specify and buy."

As LUCRA demonstrates, competitiveness in bio-based routes is decided at interfaces, from source separation and feedstock preparation through pre-treatment, fermentation control, inline electrodialysis and downstream purification. Clear policy on waste versus residue status, bio-based content and claims, procurement based on lower footprints and practical awareness efforts all reduce friction, while industry partnerships keep end-use performance central. LUCRA is addressing several of these links as it successfully develops a familiar molecule from different carbon with a shorter downstream. Real success, however, will come down to economics and reliability. As Meyer puts it: "Ultimately, it has to be competitive."

Fully automatised 150L Frings fermenter, 6 out of the 10 150L fermenters available and used in LUCRA for scale-up fermentation runs

PROJECT INFORMATION

Project Title
LUCRA – SustainabLe sUCcinic acid production using an integRAted electrochemical bioreactor and renewable feedstock

Project Objective
LUCRA aims to convert EU municipal and wood waste into bio-based succinic acid using scalable, innovative biorefinery technology, optimizing hydrolysis and electrochemical extraction. It targets industrial feasibility, fossil resource reduction, and 50% lower GHG emissions, producing competitive bio-SA for polyurethane applications.

Project Duration and Timing
M48, 4 years, July 2023 - June 2027

Project Funding
See: https://www.bbeu.org/projects/lucra/

Project Partners
Bio Base Europe Pilot Plant, BE – Coordinator
Ghent University, BE
Hydrohm, BE
Montinutra, FI
Covestro, DE
Agricultural University of Athens , GR
Consiglio Nazionale Delle Ricerche, IT
FCC Medio Ambiente, ES
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