

esib SPOTLIGHT

ISSUE NO. IV 2026

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Europe`s Biotech Moment: Will it Deliver?



Dear esib community,

On 27 November 2025, the European Commission presented its new Bioeconomy Strategy for a sector that supports 17.1 million jobs.[1] Less than three weeks later, it proposed the first European Biotech Act, focused on health.[2] A second act for industrial biotechnology and biomanufacturing is expected to follow.[3] Industrial biotechnology is moving up Europe's political agenda. The challenge now is to turn scientific progress into industrial production.

For acib, this is familiar ground. Since 2010, we have worked between the laboratory research and industrial production, together with more than 180 partners from science and industry. We know that a promising process is only part of the story. Getting it from the pilot stage into a first commercial plant is one of the sector's toughest hurdles. The technology must work at a much larger scale, the economics must add up, and the investment must be secured. The European Investment Bank has identified structural financing gaps at precisely these stages.[4]

In preparing the second act, the Commission asked for evidence on three barriers: fragmented regulation, the difficulty of financing first-of-a-kind plants, and the price gap with fossil-based products.[5] The Bio-based Industries Consortium names matching priorities: fewer regulatory bottlenecks, markets for bio-based products, and support with financing and offtake.[6] The barriers are connected: a process that works technically can still fail if the next step costs too much.

That makes scale-up infrastructure essential. Pilot and demonstration plants are where a process proves itself to investors, but they rarely pay off for a single process. Many companies therefore rely on shared facilities or contract partners. At esib 2026, the session "Scale me up, Europe!" presented facilities of this kind, including the open-access Bio Base Europe Pilot Plant in Ghent, with a 75-cubic-metre demonstration line;[7] Slovenia's Acies Bio, which is bringing a 30-cubic-metre fermenter into operation; and Italy's Biosphere, which develops fermentation processes up to pre-industrial scale.[8] Open-access demonstration lines on the scale of Ghent's are rare in Europe. That matters, because where a process is scaled up can decide where its first plant is built, and which region gains the jobs that follow.

The interviews in this issue show what is at stake. Michael Köpke, Chief Innovation Officer of LanzaTech, describes how the company had four commercial plants running in China before its first one opened in Europe, where regulation and financing took longer. Sarah Hickingbottom from FutureBridge recounts how a first-of-a-kind plant in France came close to construction but was never built. In both cases, the obstacles lay beyond the technology itself.

Policy can help with all three barriers. What it cannot do is make scale-up predictable. Enzymes can now be designed almost entirely on a computer; how a process will behave in a production tank still cannot be reliably foreseen. Our lead article explores this gap, and the interviews show what it means for the people working to close it. Closing it takes science and industry working together. That is what esib is for, and we hope the conversations started in Graz will continue well beyond it.

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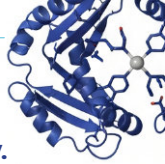
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Design is solved. Scale is not.

From enzyme design to industrial production: where prediction meets reality.

A cell in an industrial bioreactor can experience very different conditions within a matter of seconds. Near a feed point, it may be flooded with sugar; moments later, it may find itself short of nutrients or oxygen. Even cells of the same strain can behave differently depending on where they are in the tank.[1] Meanwhile, enzymes can now be designed from scratch on a computer, and a few dozen candidates are enough to find active ones.[2] But precision at the molecular level does not carry over to the production scale. It is in this gap that promising processes stall on the way to a plant. This article follows that gap up through five scales, and asks what it would take to close it.

INTERVIEW: KATHARINA SCHWAIGER

ZOOM 1
THE ACTIVE SITE •
A FEW NANOMETRES

A pocket just a few nanometres wide, where a handful of amino acids position molecules so that a chemical reaction can take place. For decades, finding that arrangement meant searching rather than designing: build a library of variants, test it, keep the best, repeat. Structural knowledge narrowed the libraries; it rarely removed them. Now, computational models can generate promising designs before the first experiment begins.

Within six months, three papers in *Nature* demonstrated just how far this approach has come. Researchers at the Weizmann Institute of Science designed an enzyme entirely on a computer, without the usual rounds of laboratory evolution. It achieved a catalytic efficiency of 12,700 M^{-1} s^{-1} on a benchmark reaction that no natural enzyme performs, differs from every known natural protein in more than 140 positions and stays stable above 85 °C.[3] At the University of Washington, David Baker's group used the generative model RFdiffusion2 to build zinc hydrolases around active-site geometries taken from quantum chemistry. Two rounds of 96 designs were enough; the best reached 53,000 M^{-1} s^{-1}.[4] At TU Graz, Gustav Oberdorfer's group designed enzymes for two mechanistically distinct reactions and screened as few as 35 sequences in one case, fewer than 100 in all. Almost all of the designs stayed folded above 90 °C.[2]

Why does this work? Because a chemical reaction imposes precise constraints on the protein that catalyses it. Specific chemical groups must be positioned at the right distances and angles to stabilise the transition state: the fleeting arrangement of atoms between reactants and products. The tolerances are unforgiving. Deviations of less than an ångström, a tenth of a nanometre, can slow a reaction by orders of magnitude.[5] Quantum-chemical calculations can help define that geometry, generative models can build a protein around it, and the laboratory shows whether the design actually catalyses the reaction.

For comparison: natural enzymes cluster around a catalytic efficiency of 100,000 M^{-1} s^{-1} and turn over roughly ten molecules a second.[6] On the benchmark reaction the Weizmann team chose, design has closed that gap. One variant from the same work reaches 30 turnovers a second, three times that median, and it got there by changing a residue that every earlier design for this reaction had treated as indispensable.[3]

Benchmarks, however, are not products, and the sharpest version of that caveat comes from the Weizmann group itself. Dina Listov and Sarel Fleishman, first and senior authors of that design, reviewed the field in 2026 and noted that purely computational methods have reached natural-like rates for that one reaction only, which proceeds in a single step. Where designs attempt multistep chemistry, the rates fall drastically, one to three orders of magnitude below natural enzymes, and much of their apparent efficiency comes from binding the substrate more tightly rather than converting it faster. De novo design, they conclude, is "still far from addressing real-world challenges in enzyme engineering".[5]

Complexity is what sets the limit, and a living cell is nothing but complexity.

ZOOM 2
THE CELL •
A FEW MICROMETRES

Enzymes are used both ways in industry: purified and immobilised in a reactor, or working inside a living cell. Let's assume a process of the second kind, where the enzyme sits inside a bacterium or a yeast. And unlike an isolated enzyme, a cell is not a system we can fully map or control. Even in *E. coli*, one of the most extensively studied bacteria, 35% of genes lack experimental evidence

establishing their function.[7] Models that predict cellular metabolism inherit these knowledge gaps. A review in *Genome Biology* names the weak points: genes marked only as hypothetical, and holes in the network plugged with reactions no genome supports.[8]

Even in *E. coli*, one of the most extensively studied bacteria, 35% of genes lack experimental evidence establishing their function.

WHAT IS STILL UNKNOWN ABOUT THE BEST-STUDIED BACTERIUM

An active site can be calculated. A cell cannot: its behaviour has to be learned from data, and much of that data has never been measured. Thousands of enzymes interact in a network that regulates itself, so a new pathway is not simply followed. The existing metabolism keeps running alongside it. Sugar is the everyday example. When it is abundant, *E. coli* can excrete acetate and baker's yeast can produce ethanol even when oxygen is available, diverting carbon away from the desired product. Michael Köpke has seen a related effect in industrial biotechnology: when his team transferred an efficient pathway for isopropanol into LanzaTech's gas-fermenting bacteria, the cells began generating by-products the team had not expected (p.11). And all of this happens in a stirred laboratory vessel, where every cell sees much the same conditions.[9] In a production tank, they no longer do.

ZOOM 3
THE TANK • TEN METRES

Inside a large bioreactor, cells experience constantly changing conditions.[1] They must continually adjust their metabolism to these fluctuations, diverting energy and resources away from product formation. The consequences can include lower yields, more by-products and changes in product quality compared with laboratory-scale experiments. One experiment measured the cost: yeast cells were repeatedly sent through a sugar-rich zone for a minute at a time, as they would be near a feed point. Biomass yield fell by 6–7%, the same drop measured in a 215-cubic-metre bubble column.[1] The vessel need not be stirred for this to happen. Most microbial production runs in stirred tanks; commercial gas fermentation is built on bubble columns and loop reactors, where the rising gas does the mixing.[10] The gradients change shape. They do not disappear.

Prediction becomes difficult for a second reason: the tank couples two complex systems, fluid dynamics and cellular biology. A model must capture how the liquid moves and how cells respond to that movement, at the same time. Testing those predictions at full scale is rarely possible. Experiments in a 100-cubic-metre reactor are expensive, and the data needed to validate a model are not always available.

Researchers attack the problem from three sides. In the laboratory, scale-down reactors connect small vessels so that cells pass repeatedly between a sugar-rich and a starved zone, recreating part of what a large tank does to them.[1] In the tank itself, sensor particles now drift through industrial reactors and record what they meet on the way.[11] Each one is four centimetres across, where a cell measures a few micrometres, and they resolve nothing smaller than the impeller, so what a single cell experiences is still inferred rather than measured.[11] And on the computer, models are beginning to follow the spread within a population instead of an average cell: cells that take different routes through the tank end up in different states, and that spread shows up in the yield.[12] At esib, a session chaired by Gerald Striedner (BOKU Vienna) took up the computational half of that effort: fluid dynamics, population balance models and data-driven models.

Measurements like these are getting sharper, and prediction feeds directly on them: a model is only as good as the data behind it. The measurements that would matter most come from real production plants, and most of them stay with the companies that made them, rarely reaching the literature (Köpke, p.11).

ZOOM 4
THE PLANT • TEN YEARS

Change perspective once more, from the engineer to the investor. Three numbers decide whether a bioprocess pays, and a submission from the think tank Centre for Future Generations names them along with the problem: "Titre, rate and yield often collapse from lab to factory."[13]

Titre, rate and yield often collapse from lab to factory.

CENTRE FOR FUTURE GENERATIONS, IN ITS SUBMISSION TO THE EUROPEAN COMMISSION

At this scale, the decisive variables are no longer scientific. A plant depends on what a tonne of feedstock will cost in three years, on how long a permit takes, on whether the customer still wants the product when production starts, and on whether the site has the steam, the water and the trained operators the process needs. All of it can move while the plant is being built. A design can be wrong many times in a year; a plant can afford to be wrong once.

Two interviews in this issue show what that means in practice. LanzaTech, founded in 2005, started its first commercial plant in 2018, at a steel mill of the Shougang Group in China.[14] Sarah Hickingbottom of FutureBridge, who worked on the EU flagship project ReSolute, saw a first-of-a-kind plant for the bio-based solvent Cyrene come close to construction and never get built (see the interview, p.23). In both cases the core technology worked.

ZOOM 5
THE CONTINENT • FOUR MILLION SQUARE KILOMETRES

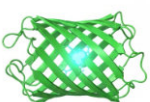
One last zoom, to the scale of Europe. Every cell in every tank needs carbon. The EU's Bioeconomy Strategy of November 2025 builds new markets largely on biomass.[15] In the same year, researchers at BOKU University in Vienna put the EU's biomass consumption at three times its fair share of the planetary boundary for biosphere integrity, driven above all by livestock products, feed crops and biofuels.[16] The two pull in opposite directions. Waste gases, residues, CO_2 and plastic waste are therefore no longer niche feedstocks. On a continent short of land, they are arithmetic. At esib, a session chaired by Katalin Barta-Weissert (University of Graz) put biomass, CO_2 and plastic waste side by side as carbon sources for chemistry. Each of them varies more in composition than refined sugar and brings new impurities and fluctuations into the tank. Prediction, already hard with sugar, gets harder still.

CLOSING THE GAP

What is missing has a name. The Centre for Future Generations calls it a predictive scale-up digital twin: a model that forecasts how a process will behave as it moves from one scale to the next.[13] Companies build such models for their own processes. What does not exist is a shared one, trained on more than a single plant.

Three things would build it. Tanks: shared pilot plants between roughly 100 and 25,000 litres, the range where equipment costs more than any one company can justify; the United States has put more than $200 million into exactly that gap.[13] Data: a common way of recording bioprocess results, so that measurements from different sites can be compared instead of ending as "digital islands" when a grant runs out.[13] Money: funding that can change direction. Grants are built for projects that know their route, and a first-of-a-kind process rarely does (Hickingbottom, p.23).

Every scale adds a layer the one below could ignore, and science is learning to measure them one by one. The last layer is not scientific: markets, rules and money, which move while the plant is being built. A cell adapts when its surroundings change. A plant cannot, but the project behind it can, if its contracts, permits and funding allow it.



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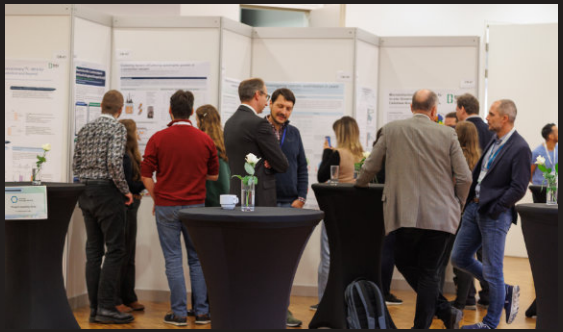
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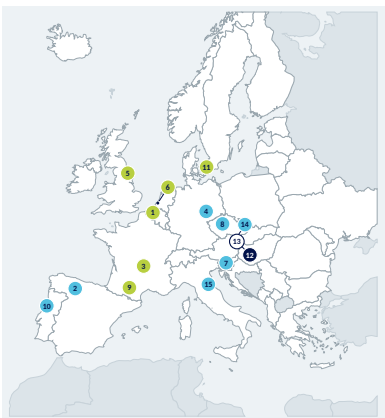

FROM SCIENCE TO SCALE.

Where Europe can scale up

15 plants publish the size of their largest fermenter. Put them on a ladder and the shape of Europe's scale-up problem appears.

At the top of the ladder, ADL Biopharma in León runs more than 1,800 cubic metres of contract capacity. At the bottom, research plants stop at a few hundred litres. Between 100 litres and 25 cubic metres, the range where equipment costs more than any single company can justify and where a process either proves itself or stalls, the continent is thin.

The colour of each dot says who may use the plant, and that changes the picture again. Much of Europe's large fermentation capacity belongs to contract manufacturers: bookable, but on commercial terms and in competition with paying production. Some belongs to a consortium or to the operator alone. The largest openly bookable vessel on this map is the 75-cubic-metre line at Bio Base Europe in Ghent.



LARGEST FERMENTER AT EACH SITE

2	ADL Biopharma León, ES	1,800 m³
1	Bio Base Europe Pilot Plant Ghent, BE	75 m³
7	Acies Bio Kamnik, SI	30 m³
3	Biotech Open Platform Clermont-Ferrand, FR	15 m³
4	Fraunhofer CBP Leuna, DE	10 m³
5	CPI Industrial Biotechnology Wilton, UK	10 m³
6	Bioprocess Pilot Facility Delft, NL	8 m³
13	Sysbiotech Vienna, AT	7.5 m³
14	BOKU Biotechnikum Tulln, AT	6 m³
8	Institute of Microbiology CAS Prague, CZ	1.5 m³
15	Biosphere Forlì, IT	1.5 m³
9	Toulouse White Biotechnology Toulouse, FR	300 L
10	Biotrend Cantanhede, PT	200 L
11	Danish Technological Institute Taastrup, DK	200 L
12	BOKU BioIndustrial Pilot Plant Vienna, AT	150 L

1,000 m³ · 100 m³ · 10 m³ · 1 m³ · 100 L

THE GAP: 100 L TO 25 m³

COLOUR = ACCESS — Open access, bookable · Contract manufacturing or research · Consortium or in-house only · Access not published

Numbers link map and ladder. Where two sites share a city the dot is offset. Grey landmasses are context: the survey covers Europe without Türkiye and Russia.

Sources: biopilots4u.eu (COPILOT, Circular Bio-based Europe Joint Undertaking) and operator data, each figure checked in November 2026. Nominal vessel volumes, not working volumes.


WC, Lift, Ausgan






CAPRICORN
ZEISS
bartelt
Primary Cells &
iPSCs




acib
RIEGER



Give that carbon a second life

Steel mills produce large amounts of carbon monoxide, a gas that is usually flared or burned to generate energy. At LanzaTech, bacteria recycle the carbon and turn it into ethanol, which can be used as a fuel or as a building block for products such as polyester. To develop its technology, LanzaTech went straight to the source: the team collected waste gas from a steel plant and brought it back to the lab, contaminants and all. Michael Köpke has worked on LanzaTech's biotechnology since the early days, when genetic tools for these bacteria were not yet available. In this interview, he reflects on how far the science has come and on a challenge that remains difficult to predict: how can a process that works in the lab be scaled reliably to industrial production?

ABOUT MICHAEL KÖPKE

- Chief Innovation Officer, LanzaTech
- Joined LanzaTech in 2009; built up the company's biology platform and directs its innovation strategy and technology partnerships.
- PhD in biotechnology, Ulm University; more than two decades in synthetic biology and biomanufacturing.
- Holds more than 500 patents and has led over 50 peer-reviewed studies, among them the 2022 Nature Biotechnology cover article on carbon-negative acetone and isopropanol by gas fermentation.
- Presidential Green Chemistry Challenge Award, ACS National Award for Team Innovation, The Bioeconomy 500.
- Adjunct professor at Northwestern University; board member of the Engineering Biology Research Consortium (EBRC) and the International Metabolic Engineering Society (IMES).

LANZATECH AT A GLANCE

FOUNDED:
2005 in New Zealand; headquartered in Skokie, Illinois. Listed on Nasdaq (LNZA) since February 2023.

TECHNOLOGY:
Gas fermentation: anaerobic acetogens such as *Clostridium autoethanogenum* convert carbon monoxide, carbon dioxide and hydrogen into ethanol and other chemicals.

FEEDSTOCKS:
Industrial off-gases, for example from steel mills; syngas from gasified biomass or solid waste; CO_2 plus hydrogen.

PLANTS:
First commercial plant in China in 2018. Today: 6 commercial plants globally. In Europe: Steelanol at ArcelorMittal Ghent, Belgium, 80 million litres of ethanol per year, first commercial ethanol in November 2023.

PRODUCTS: Ethanol for fuel, as a building block for sustainable aviation fuel and for polyester and other consumer products.



INTERVIEW: KATHARINA SCHWAIGER

You joined LanzaTech in 2009. How long did you expect commercialisation to take?

Going in, it was always clear that this was a very ambitious project. We were working with non-model organisms, so the biology was not very well defined, and we didn't have any genetic tools when we started. On the engineering side, a key challenge was that the gases we work with, carbon monoxide and hydrogen, are not very soluble. We therefore had to develop bioreactor systems with high gas mass transfer at low energy input. This required innovation in biology, but also in engineering and scale-up. One thing LanzaTech did well, in my view, was to have as many scientists as engineers from the beginning. It was a very cross-functional approach.

It took the company about 15 years to go from the bench to commercial scale. LanzaTech was founded in 2005, although the first couple of years were run on a very small budget. We had our first commercial plant in 2018. In retrospect, that was probably what we expected from the beginning. For a first-of-its-kind technology like gas fermentation, which had never been scaled up and demonstrated at that scale, this is not unusual. In fact, I would call it a good timeline, but with the knowledge gained and lessons learned we could do it faster today.

And the first plant was in China.

That's right. Plant designs in China and Europe started at the same time, but by the time our first European plant, Steelanol with ArcelorMittal, came online in 2023, we already had four plants operating in China. Regulation and financing took longer in Europe, and construction is also simply faster in China. China was really important for us. We were able to scale the technology quickly, although this also presented some risks that we had to manage.

To get to that point, we went through several pilot and demonstration units. In China, for example, we worked through several demonstration plants, which are already at 10,000 litres plus; the commercial bioreactors are in the order of several hundred thousand litres to a million litres. In Europe, we skipped that step. We really had to demonstrate the technology at every step to make customers commit to a full commercial unit. We had over 100,000 operating hours at various pilot and demonstration scales. Without those steps, we would not have been able to scale to full commercial scale. Hopefully, we can help other gas fermentation technologies scale up faster, so that not everyone has to repeat all the steps.

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>
> MICHAEL KÖPKE ON THE ROAD TO LANZATECH'S FIRST COMMERCIAL PLANT

Apart from regulation and financing, what did the steel plant in Ghent need for Steelanol to work?

First of all, ArcelorMittal is a great partner. They are really invested in innovation. A key driver for them was to generate value from their off-gases, but there was also pressure to reduce emissions. That is really where LanzaTech's technology comes in. Financing plays a key role for first-of-its-kind technologies, and we were fortunate to receive support from the European Union as well. Securing that support obviously takes time too.

Today, the gas at the steel plant is used to generate power, which is not the most efficient use of it. Power can be generated from renewable sources without wasting valuable carbon. So, we can offer more value and give that carbon a second life. The challenge is that gas concentrations fluctuate and the gas may contain contaminants. That makes it difficult for traditional catalysts to work. But this is where biology can help, because it can handle these gases.

How can the organisms tolerate these fluctuations and contaminants?

The organism needs a carbon source, which can be carbon monoxide or carbon dioxide, as well as an energy source. If you have only carbon dioxide, it doesn't work. Carbon monoxide can provide both carbon and energy, and the organism can also get its energy from hydrogen. So it can work with 100 per cent carbon monoxide at one end, carbon dioxide and hydrogen at the other, and essentially any ratio in between. That gives the biology flexibility. If you have a carbon-rich stream with some energy content, the biology can deal with it.

It is also relatively robust in the face of typical contaminants that are problematic for catalytic processes. Sulphur, for example, doesn't bother the microbe; in fact, it needs a source of sulphur. It also needs some nitrogen and metals, which are present and not inhibitory in these gas streams. These anaerobic microbes, the acetogens, can work with different inputs and channel them into a central intermediate, acetyl-CoA. From there, they can grow. We set the conditions so that, as they grow, they also produce ethanol or other products.

BEYOND THE KEYNOTE

Asked what would not fit into his esib talk, Köpke said:

"Focus of my talk will be LanzaTech's commercialization journey. I will touch on some of our innovation pieces but may not be able to cover it in full detail. Particularly our work with new organisms, such as aerobic gas-fermenting organisms for nutritional protein. That's an area where we're now working towards the next stages of commercialisation."

What other feedstocks could the technology work with?

In a sense, our technology is feedstock-agnostic. We started with industrial off-gases because they are rich in carbon and usually still contain some

energy. We can also work with CO_2 but require hydrogen as energy. With cheaper green hydrogen now available, that is becoming much more realistic. We can also use syngas, which can be produced from almost any biomass source, agricultural waste or solid waste stream. These materials can be gasified to produce a mixture of CO_2, hydrogen and CO. Gasification adds some cost at the front end, but it allows us to use solid waste streams.

In the AtmosFUEL project, LanzaTech worked with CO_2 captured directly from the air. Is that a proof of concept or the company's future direction?

Direct air capture is an area where we partner with companies that specialise in it. We don't have our own technology for concentrating carbon from the air, but once we have a concentrated stream of CO_2, we can use it. Looking further ahead, we could couple the technology with direct air capture. That is still expensive today, but it would give us access to an almost unlimited feedstock.

Europe's new bioeconomy strategy is built around biomass. What is the perspective of a gas fermentation company?

My first question would be whether Europe has enough biomass. It is an important pillar, but we also need to use waste streams and consider all available sources, from industrial waste gases and recycled carbon fuels to solid waste and CO_2-to-X. We need a level playing field for all technologies that are commercially ready today. We cannot afford to wait decades for a perfect solution; we should use what is available and support these technologies.

In the end, what really matters is: can you reduce carbon emissions, and can you get from a linear economy to a circular bioeconomy? Right now, in certain aspects, I don't see a level playing field. Recycled carbon fuels are disadvantaged. If you start from recycled carbon, for example the gas from a steel plant, you have to take into account its prior use, such as power production, and you get a carbon penalty, and renewable power purchase agreements are currently not allowed. If you start from fresh fossil carbon and make a product, you don't have that penalty. So that's not really a level playing field.

THE RULE BEHIND THE "CARBON PENALTY"

Under EU Delegated Regulation (EU) 2023/1185, the emissions calculation for recycled carbon fuels must account for what happens when an industrial waste gas is diverted from its existing use. If blast-furnace gas is used to make fuel instead of generating electricity, the calculation includes emissions associated with the electricity no longer produced. This can increase the fuel's calculated carbon footprint, making it harder for recycled carbon fuels to demonstrate the required emissions savings.

LanzaTech has been listed on Nasdaq since 2023. As a bioengineer, what has changed about your technical decisions?

I certainly can't give investment advice. But there has been more focus on how we can reduce the overall cost of the technology and of our own operations. We were one of the first carbon management companies on Nasdaq. Markets have changed over the past two years, and we have learned a lot. We also restructured to make the company more focused.

Overall, we've shown that the technology works. It is now licensed at six commercial plants, and we've produced more than 150 million gallons of ethanol. The ethanol has been used as fuel, either directly or upgraded to sustainable aviation fuel, but it has also been converted into polyesters and other products. There are now more than 100 products on consumer shelves. The next step is to roll out the technology more widely. It is important that the public knows this technology exists, that it is ready and that it is on everyone's radar. That was one of the key motivations for going public.

Did anything get shelved that you would still have liked to pursue?

In a company, there are always things you find interesting that don't necessarily drive the market or the products. It is important to focus on your key questions. For us, the first question was scale-up. Then it was: can we engineer the microbes? Now we are asking: can we reduce the cost of the technology further? You try to answer these questions quickly, even if the answer is that something doesn't work, so you know how to reduce the risk. For some of the more scientific questions, we found ways to partner with academic groups. We wouldn't be here today without a lot of partnerships with academic groups and with other companies that helped us characterise our system. When we started, acetogens were not well characterised. The basic biochemistry was understood, but the molecular mechanisms were not. As a start-up, we couldn't necessarily carry out, or even afford, detailed omics studies. That is where our partnerships helped build the background knowledge.

> We wouldn't be here today without a lot of partnerships with academic groups and with other companies that helped us characterise our system.
>
> MICHAEL KÖPKE ON THE IMPORTANCE OF COLLABORATION

A doctoral student in Graz has a strain that works in a two-litre vessel. What is the single most useful thing they can do in the next year?

Understand the economics and, if possible, work with someone who can help with techno-economic analysis. What performance do you need to achieve? Which factors matter most for the process? That means thinking about how the process would work at scale and as an integrated

whole, including downstream processing. Test real-world feedstocks as early as possible or simulate real-world conditions.

At LanzaTech, we started our first pilot unit in 2008, just three years after the company was founded. The process was certainly not fully optimised at that point, and production was still at a low level, but we had a real-world facility. As we optimised the process in the lab, we could demonstrate the first results at scale and learn from them. Pure gases were also expensive. The company started in New Zealand, where shipping made everything more expensive. So we began bottling gas at the steel plant and bringing it back to our labs. All our development work was carried out using real feedstocks, with real contaminants.

AI is a big topic at this conference and in this magazine. How much have you used AI in strain design, and how much in scale-up?

We're using AI across the board, from strain engineering to the process side. Early on, we focused on how to get and structure data, which really helped once the AI tools matured. With partners, we built genome-scale metabolic models that were predictive and helped guide development. We used AI tools for enzyme engineering, and we found that works very well. We also tried tools around the broader design–build–test–learn cycle: there have been some successes, and some things still need more development. And on the process side, we're looking at how AI can help steer our process and support plant operators in their decisions.

The critical point is that you need high-quality data to make use of AI. For strain engineering, we use high-throughput methods, robotics and our biofoundry. On the process side, our continuous operation generates billions of data points a year across lab, pilot and commercial units.

DESIGNED ON PAPER, SURPRISED IN THE CELL

Köpke on LanzaTech's work to make isopropanol, a solvent and chemical building block, with its gas-fermenting bacteria:

"Through high-throughput enzyme mining and engineering, we developed a highly efficient pathway. But when we introduced it into the cells, we didn't achieve the selectivity or performance we expected. Instead, we observed other products we had never seen before. This showed us that when optimised enzymes or pathways are introduced into a new organism, its native metabolism also comes into play. We had to spend considerable time optimising the system further to achieve a highly efficient process."

What would you want AI to predict five years from now that we cannot predict today?

We've made a lot of progress in enzyme optimisation. But whole-organism design is, to me, still the next frontier. On the biology side, how can we go from sequence to function, especially for whole organisms? Even for model organisms such as *E. coli* or yeast, we don't yet know the function of every gene. Non-model organisms such as the acetogens we work with are even less well characterised. Cells are complex networks. As I said, data is really important, and we are seeing more and more biofoundries that can produce the necessary data. In Europe, we're working with the BRIGHT centre at DTU on building a biofoundry for gas-fermenting organisms.

And then there is scale-up. That is critical, because a lot of the cost lies there. Can we make the move from millilitre-scale experiments to larger scales more predictable? For us, another question is how to move from batch to continuous processes. The challenge is that there is much less data in the literature. That data is kept much more closely by the companies that did those scale-up studies. And there is still a gap in scale-up infrastructure.

> The challenge is that there is much less data in the literature. That data is kept much more closely by the companies that did those scale-up studies.
>
> MICHAEL KÖPKE ON WHY SCALE-UP IS STILL HARD TO PREDICT

GLOSSARY

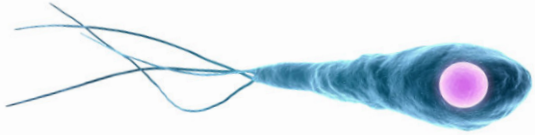
ACETOGENS
Anaerobic bacteria that fix carbon monoxide or CO_2 (with hydrogen) via the Wood–Ljungdahl pathway into acetyl-CoA, the hub of their metabolism.

SYNGAS
A mix of carbon monoxide, hydrogen and CO_2, made by gasifying biomass or solid waste at high temperature.

BIOFOUNDRY
An automated lab in which robots design, build and test thousands of strain variants in parallel, and the data feed the next round (the design–build–test–learn cycle).

TECHNO-ECONOMIC ANALYSIS
A model of what a process would cost at commercial scale, used early to show which performance figures, such as titre, rate and yield, really matter.

GENOME-SCALE METABOLIC MODEL
A computer model of all known metabolic reactions of an organism, used to predict how genetic changes affect growth and products.













The Plant Before the Plant

Before a biopharmaceutical plant reaches its customer, ZETA builds it twice: first as data in Lieboch, then in stainless steel in Werndorf. On the opening morning of eslb 2026, a busload of participants got to see both.

AUTHOR: KATHARINA SCHWAIGER

THE MOST IMPORTANT PART OF THE PLANT WAS MISSING.

Across ZETA's fabrication hall in Werndorf, south of Graz, stood steel frames, known as skids, carrying the equipment for an 80,000-litre bioreactor system: air distribution, sterile filters, even a section of clean-room wall, ready for the customer to seal on site. The vessel itself was not there. In Europe, ZETA does not build its vessels; suppliers make them, and Werndorf turns them into working systems with pipes, filters, valves and controls. Most of those systems hold up to 15,000 litres. A vessel of 80,000 litres is too big for the hall, and too big for the Alpine tunnels unless the roads are closed. It travels straight from its maker to the customer's site, where the skids from Werndorf will join it. Until then, they had been assembled and tested for a tank they had never seen.

At the entrance, the instructions had been clear: "Don't make any pictures. Otherwise, we get problems with our customers."

LIEBOCH, 09:15 TECHNOLOGY, PEOPLE AND THE DIGITAL PLANT

The morning had begun half an hour away, at ZETA's headquarters in Lieboch. Founded in 1989, the company designs, builds and qualifies plants for aseptic biopharmaceutical production, and models each of them digitally along the way. Martin Mayer, Director of its Digital Solutions business line, had called his talk "Technology Evolves. Do We?" To answer the question, he went back 40,000 years. Early on, he put up a picture of the Iceman, the man preserved in an Alpine glacier for more than 5,000 years, and introduced him, deadpan, as a relative. For most of the time Homo sapiens has looked as we do today, Mayer argued, the safest strategy was to trust the people you knew and repeat what had worked the day before. Those who trusted strangers or tried unfamiliar food mostly did not survive. Our caution towards the new is not a flaw. It kept us alive.

Industry, Mayer argued, still runs on that instinct, and no software will switch it off. "The theory is that technology will do the job, and I don't think so." ZETA's own servers make the point. They hold 3D models and connected plant data from some 350 projects, and most of it goes unused once a plant is handed over. What customers ask for is the classic documentation: drawings, manuals and qualification records, as PDFs or on paper. The connected model behind them, which could help run, maintain and modify the plant, stays in Lieboch. When ZETA began offering its digital tools to other companies four years ago, nobody queued at the door. The technology was ready. The customers were not.

Hence the title of one of his slides: "The order still matters". A digital plant rests on four things: people, process, data and technology. Data and technology deliver the core, Mayer said, but that is not where the work starts.

Where the resistance sits, he showed with deliberately ordinary examples. To a process engineer, the building exists to keep the plant dry; ask the architect and the priorities reverse. Or take batch release. Before a batch of medicine can leave the plant, quality assurance has to approve it. In most plants today, that means reading the entire production record, line by line, after the batch is finished, even though almost every value is fine. Mayer's alternative: let the software flag the few values that fall outside their limits, and have people check only those. The software for this already exists in most plants. In a plant that cost 1.5 billion euros, with 40 to 45 people in quality assurance, this alone would save 15 to 20 per cent of the work, the equivalent of eight to ten people. Nothing would have to be bought. Only a habit would have to change.

And the cost of not changing is rising. New biopharmaceutical plants are being built in parts of the United States where experienced personnel are scarce, and training new operators after start-up can take six to eight months. By Mayer's estimate, a plant of that size produces roughly 1.5 billion euros' worth of product a year, so every month saved during start-up can be worth tens of millions. ZETA is therefore working with a Viennese company on augmented-reality training, so that operators can learn a plant before it runs.

ZETA holds itself to the same standard. For Lieboch to remain the company's European headquarters, its engineering has to become 50 per cent more efficient within three years, with the same people. "It's not the tools that are the challenge," Mayer said, "but currently it's the people." Himself included. He hadn't been running lately, he admitted, although he owns the shoes and lives near a gym. "So it must be me, right?" The room laughed.



ZETA's main prefabrication site in Werndorf.

WERNDORF, 11:00

"It's not the tools that are the challenge, but currently it's the people." said Martin Mayer

Here, Mayer's argument about digitalisation had a very different setting. The data had become steel, pipes, welds and equipment, and every detail mattered, because once a system leaves the hall, changing it becomes far more complicated. The hall is set up to imitate the customer's site. Since the 80,000-litre vessel itself would never arrive, platforms stood in for it, so that the equipment could be connected exactly as it would sit on top of the real tank.

That is where the customers come in. For many of them, the testing in Werndorf matters more than anything that happens later, because whatever is checked here does not have to be checked again on site. They test the mechanics, measuring slopes in every direction. They run water and air through the system, exactly as the functional specification describes. The control cabinet is wired up, and the software is tested in-house as well. For a system like this, the process takes two to three months. Even the markings on the frames serve a purpose: they allow customers to repeat the levelling with a laser after installation and sign off on the equipment without having to requalify it. Nothing is disconnected before shipping unless absolutely necessary. Every connection that is taken apart may have to be qualified again. Installation on site, by comparison, is often given just two months.

The precision continued at the welding stations. The machines download their parameters from the cloud and will not start until the welder has entered his card number. Around 99 per cent of the sterile welds are made by orbital welding, a process that produces consistent, repeatable joints around the full circumference of a pipe. A few metres away from the welding station, Kamil checks every weld against the ASME BPE standard for bioprocessing equipment, using a borescope worth 60,000 euros. "You can buy it after," he joked. He looks for discolouration that could lead to corrosion and for incomplete penetration, which would make the pipe harder to clean. Every weld is then documented and signed off twice: on paper and digitally.

"We deliver more tons of paper than equipment sometimes."

The remark brought the discussion in Lieboch back to mind. Of the two records, the digital one is the more traceable: every entry is tied to a personal login, so it is always clear who signed off what, and when. Yet it is the digital system that customers would like to see certified by an outside auditor. ZETA has declined. Such certification is difficult to obtain, and nobody asks the same of paper. A handwritten initial on a form is simply accepted. ZETA hopes to take paper out of the workshop within a year or two. The harder part is the people: the workforce ranges in age from 15 to 65, and not everyone grew up with a tablet. "But we will get there," the guide said.



"Technology Evolves. Do We?" Martin Mayer's talk in ZETA's Digital Experience Center began 40,000 years ago and ended with a three-year target.



"The order still matters": for Martin Mayer, data and technology deliver the core of a digital plant, but the work starts with people and process.

THE DETAILS THAT DETERMINE THE SCALE

Not everything in the hall follows established practice. In a converted X-ray room, ZETA has installed a 2,000-watt laser welder. It works around four times faster than conventional welding and introduces so little heat that the frames barely distort. ZETA says it is currently the only company in Austria qualified to run the process itself. In Asia, including at ZETA's own site in India, the method is already in use. In Europe, structural calculations written around conventional welds still demand bigger seams, and the safety rules are strict, for good reason. A glance into a conventional welding arc leaves your eyes burning, as if full of sand. "One thing is it hurts," the guide said. "The other thing is you are blind."

Other limits are set not by regulators but by the size of a doorway. A skid can leave Werndorf at up to 4.5 by 4.5 metres in cross-section and 18 to 20 metres in length; anything bigger has to be divided. For a customer in the United States, ZETA split a 30-metre bioreactor system into eight pieces. That only works if the customer knows from the very first drawing how large the openings in the new building will be. "We don't want to cut when we deliver," the guide said. From Werndorf, the equipment leaves by truck, ship, plane or rail; the railway line runs right next to the site. One system for China travelled the whole way by train and arrived with a few problems of its own.

The final stop was the packing area. A complete plant can leave Werndorf in 200 to 400 crates. The fitter who dismantles a skid here is also the one expected to reassemble it at the customer's site. That takes an intimate knowledge of every connection, component and detail of the original assembly. Sometimes, after weeks of ten-hour days, seven days a week, a system is complete and approved, only for the customer to ask ZETA to hold the delivery because construction at the site is not yet finished. The skids may then wait another six months before they can be shipped.

Someone asked what one of the systems would eventually produce. "We don't know. Most of the time, we don't know."

For ZETA, not knowing what a plant will eventually produce is perfectly normal. The company builds the infrastructure, but what flows through it is up to the customer. At a quarter to twelve, the bus left for Messe Graz, where the next three days would be devoted to strains, enzymes, molecules and the future of biotechnology. And this morning had offered a glimpse of everything that has to happen before any of them can become a product.

ZETA IN BRIEF

Founded: 1989; headquarters in Lieboch, Styria
What it does: Designs, builds, automates, digitalises and qualifies plants for aseptic biopharmaceutical production, including clean-room, HVAC and building design
Footprint: 27 subsidiaries worldwide; main prefabrication site in Werndorf; own vessel fabrication in India
Next: ZETA Symposium 2027, "ai + digitalization", 8–10 March 2027, Schloss Seggau, Austria (zeta-symposium.com)



Briefing at the reception in Werndorf: visitor vests on the rail, the group split in two, and one firm rule for the hall – no photographs.



Reception in Lieboch, beneath a wall-sized photograph of process piping – closer to ZETA's steel than any camera got in Werndorf that morning.







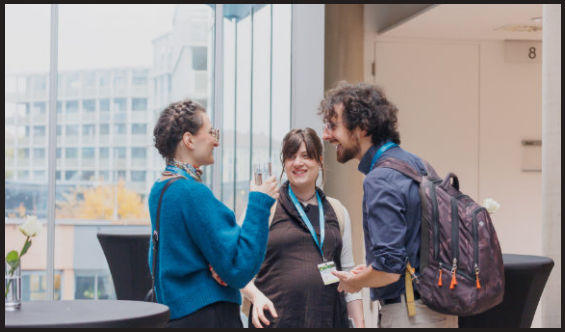



esib / 2016













It’s not the core technology that will kill it!

Many bio-based processes work: in the lab, at pilot scale, sometimes in a demonstration plant. Far fewer make it to a commercial plant, and fewer still are built a second time. Sarah Hickingbottom looks at exactly this gap. She advises companies on which bio-based technologies are worth backing. She also knows it from the inside: at the start-up Circa, she worked on a first-of-its-kind plant in France that came within reach of construction but was never built. In this interview, she explains why the technology itself is rarely what fails, and what founders, investors and funders can overlook until it is too late.



ABOUT SARAH HICKINGBOTTOM

- Global head of chemicals, materials & natural resources, futurebridge
- Advises senior leaders on strategy, innovation, sustainability and long-term growth; expertise in bio-based chemicals, feedstocks, circularity and the commercial realities of scaling new technologies.
- Previously at Circa Group, where she worked on the flagship CBE JU project ReSolute, and CEO of the UK innovation cluster BioVale.
- Studied at Imperial College London; PhD in Chemistry from UCLA in the group of Sir Fraser Stoddart (Nobel Prize in Chemistry 2016).
- Frequent speaker on the future of the bioeconomy.

FUTUREBRIDGE AT A GLANCE

WHAT IT DOES:
Techno-commercial consulting and advisory: tracks and advises on the future of industries from a 1-to-25-year perspective, helping clients track technologies, identify new markets and business models, and find partners.

INDUSTRIES:
Six, among them chemicals and materials, energy, food and nutrition, and mobility.

SIZE:
Founded in 2000; more than 500 people working across three continents, with clients in over 70 countries.

INTERVIEW: KATHARINA SCHWAIGER

When a company shows you a new bio-based process, what is the first thing you want to know?
What the feedstock is. I assume the core chemistry or biology, the step that turns the feedstock into the molecule, works. My job is to check the physical economy around it. At first, it's only about orders of magnitude: not just what the feedstock is, but how much of it is genuinely accessible, rather than theoretically available. That has to match the volume you want to sell, and that volume has to match the market. A complicated perfume molecule sold by the kilo is a very different case from a commodity at a hundred thousand tonnes.
When I was CEO of BioVale, I often broke young entrepreneurs' hearts with this check. Six or seven times out of ten, it killed the business plan. One team wanted to make tens of thousands of tonnes of chemicals from coffee grounds. There might be millions of tonnes of coffee grounds in the world. But once you factor in yield and where a plant would be, the amount that is financially feasible and available is nowhere near enough.

Suppose the numbers add up. What comes next?
Even before capital, the next question should be: why would anyone buy this product? And if it's a drop-in, a bio-based version of a molecule that already exists, why would a customer switch? An existing market is not the same thing as a market that's wanting your product. So before being seduced by technology, you want to look at the physical and the commercial ecosystem around the process.

> An existing market is not the same thing as a market that's wanting your product.
>
> SARAH HICKINGBOTTOM ON THE FIRST QUESTIONS TO ASK ABOUT A BIO-BASED PROCESS

Many plants have been announced in Europe over the past ten years. How many of them are actually running?
I don't have a defensible percentage, partly because it depends on what you call "running". Take Avantium's 5,000-tonne FDCA plant. It was officially opened in 2024, commissioning ran through 2025 and 2026, and the first commercial sales are expected towards the end of 2026. So when do you declare it running? I would distinguish between a plant being announced, financed, built and commissioned, the first product, and commercial sales. The real test is sustained operation at meaningful yields and utilisation.

Then what is the better measure of success?
The second plant. A first-of-a-kind plant is one particular set of circumstances that came together once. Only the second or third plant tells you whether you have a repeatable industrial business or a one-off.

LanzaTech built four plants in China before its first one in Europe. Is that kind of path typical?
It depends on markets, and on the economics of production and funding. LanzaTech has a fascinating replication story, and it achieved that by licensing its technology rather than building and financing every plant itself: six commercial plants around the world, all of them making ethanol today, which can be used as a fuel or turned into products such as polyethylene. The process is offered as a platform, so in theory it can make other molecules, and they are now looking at other gases too. Neste is another good example. At the time, they had a novel process for a different type of biodiesel. They started in Finland, then built a huge plant in Singapore and another in Rotterdam. And it goes back to the feedstock question I started with. Neste wanted to use used cooking oil, a waste feedstock rather than a commodity like virgin vegetable oil, and no supply chain for it existed. At the beginning, I worked with them on building one from scratch. The question of feedstocks can expand into a project of its own.
But replication doesn't always work, even for the biggest companies. Around twelve years ago, large joint ventures between multinationals went into bio-based succinic acid, including BASF, DSM and Purac, which is now Corbion. I was involved in some of that as well. Eventually, they all closed. Every company and every molecule has its own reasons for succeeding or failing.

How LanzaTech got from its first plant to six: see the interview with Michael Köpke on page 11.

You say every case is different. But do you still see a pattern in what kills a project?
There's never just one thing. If you can only name one, most people would say capital. But in a lot of cases, that's not the disease. It's the consequence, or the death certificate.
It's easier to say what doesn't kill a project. Once you're seriously building a commercial plant, it's not the core technology that will kill it, meaning the step that turns the feedstock into the molecule. The problems happen at the interfaces around it: feedstock handling, pretreatment, separation, purification, utilities, sometimes skills, logistics, commissioning, ramp-up. And location. Everybody talks about economies of scale. We talk far less about the economics of location.

> If you can only name one thing, most people would say capital. In a lot of cases, that's not the disease. It's the consequence, or the death certificate.
>
> SARAH HICKINGBOTTOM ON WHY BIO-BASED PROJECTS FAIL

Why does location matter so much?
Because for a first plant, the economics of location don't win out. What wins is where you can beg, borrow and steal support. At Circa, we had a fantastic feedstock partner. But you also look at which governments will give you capital, which regions want you there, and what obligations come with grants and investors. Your decisions focus on what is possible, not on what is ideal. You might end up too far from your feedstock, and you live with it, because you need that first plant. Then the feedstock costs more than it should, and that follows you into the economics of the second plant. Investors accept that it costs more to build small than large. We need the same understanding for location and plant ecosystems.



Whilst you can't let perfection kill the first plant, you can't let its imperfections carry over into the second.

SARAH HICKINGBOTTOM ON WHAT A FIRST PLANT SHOULD NOT PASS ON

What else can go wrong on the way to scale?
A lot: the cost of building the plant in the first place, customers delaying decisions, partners who commit but won't go public, energy and feedstock shocks, permits, and regulation such as REACH. It also depends on who owns the plant. A large company can put a project on hold for a year. A start-up cannot survive that pause.

BEYOND THE KEYNOTE

Asked what would not fit into her esib talk, Hickingbottom chose a problem she sees coming downstream:

"Over the last 20 years, the field asked: can we make the molecule? Can we secure the feedstock? Can we scale it up? Can we finance it? Now the question is whether customers can absorb the complexity we are creating. Take adipic acid, a commodity sold in millions of tonnes. Today there is bio-based adipic acid, fossil adipic acid made with renewable energy, adipic acid from recycled plastic, mass-balanced and segregated versions. The customers are the same. How do they price these when it's all the same molecule? What if one supply dries up? What do they report? If we ignore this, it could become a barrier to adoption."

You experienced many of these risks at Circa. When you joined in 2021, ReSolute was already underway. What did you see as the biggest risk?
I knew the project well. Circa had been one of our start-ups at BioVale, and I was there the day the grant was announced. When I left BioVale, Circa asked me to join. The company was fully capitalised, and I fully believed the plant would be built. But projects like ReSolute can de-risk the demonstration of a first-of-its-kind technology. They can't necessarily de-risk the business around it. When Russia invaded Ukraine, gas prices shot up like a hockey stick, and our plant had been designed to run on natural gas. The plan had been to turn our co-product, biochar, into high-value activated carbon, a key revenue stream. Suddenly, the most valuable use of the biochar was to consume it ourselves, so we had to redesign the plant to run on a biomass boiler. Things like this happen all the time when you build something new. But the grant budget had been fixed in 2019, when the proposal was written, and within a grant structure that kind of change is very difficult. That is one of the challenges of grants: a forecast can be completely invalid six months later, not because you did anything wrong, but because the world has changed.

RESOLUTE AT A GLANCE

GOAL
The first commercial-scale plant for Cyrene, a bio-based solvent made from wood residues such as sawdust, intended to replace toxic solvents such as NMP. Planned capacity: about 1,000 tonnes a year.

SITE
The Carling Saint-Avold industrial platform in north-eastern France.

FUNDING
Horizon 2020, Bio-based Industries Joint Undertaking (today the Circular Bio-based Europe Joint Undertaking, CBE JU). Total cost €23.9 million, EU contribution €11.6 million.

OUTCOME
Project start October 2020, closed early in 2025. The plant was not built, and Circa Group is now bankrupt.

How close did the plant come to being built?
Very close. We had the permits, REACH registration was coming through, we had the engineering, the staff and the contractors, and the equipment was in a warehouse on site. Other things went wrong too, so the crises weren't the only reason. But this decade has brought one shock after another: the pandemic, steel prices, the Suez Canal, inflation, interest rates, the war in Ukraine. Each one added cost, while the grant stayed exactly the same, with no allowance for inflation. If the conditions of 2019 had stayed the same, I think the plant probably would have been built.
I don't want to sound ungrateful. The French government, the region, the BBI JU and the CBE JU, universities and investors all put a great deal into it. The support was astronomical. A bigger company could have ridden out some of the bumps; a start-up can't. Public money has to be protected, and administrative certainty and innovation agility create tension. The public-private partnerships do brilliant work, and we need them. We just need them in a slightly more agile manner.

THE TRAIN AND THE CAR

How Hickingbottom describes the tension between grants and emerging technologies:

"I think of it as the difference between a train and a car. A train is absolutely superb if the route is correct. But a brand-new technology sometimes needs to reverse, take stock, go in a different direction, or even change the destination when circumstances change. A train cannot do that, and grants are designed to be trains rather than cars."

What did you take from Circa into your work at FutureBridge?
Above all, the customer side. At Circa, I worked on commercialisation: with customers, their R&D trials and their procurement teams. That taught me how risky switching is for a customer. One risk that isn't talked about enough is what happens downstream. If a company switches to a new bio-based ingredient, it isn't only about whether the product works. It's also the paperwork around it. And many companies don't want to talk about it. I was surprised how many were unwilling to go public, even with a memorandum of under-

standing. For a start-up, that hurts, because investors want to see that customers are using the product. Some multinationals have even told me they already have bio-based content in their consumer products but don't mention it, because they are worried about greenwashing. I was on the advisory board of the BBI JU project BioSwitch, which was about persuading brands to switch. I think we should persuade them to switch, and then persuade them to talk about it.

At FutureBridge, we use this when we work with lighthouse customers, the first customers for a new product. We look at why they would buy, how their procurement works, what would make them switch and what would stop them. In the past, consultants called that customer needs analysis. Today we know it's much more about behaviour and risk. Having sat in so many different shoes, I can understand why a multinational behaves the way it does. I would recommend it to any consultant: spend three years in a start-up.

Many of the risks you describe depend on each other: feedstock, location, customers, regulation. Could AI help to make better forecasts here? And what would you like it to predict in five years that we cannot predict today?

I would like AI to tell me where the industrial ecosystem is fragile. You could give it the technology, the feedstock, yields, plant scale, location, utilities, purification, customer qualification times and policies, and ask: which assumption is most likely to break the investment case? What happens if energy costs double? Using AI to design processes is the obvious answer. The more interesting use is not to predict which technology will win, but where we shouldn't put our money: dynamic industrial twins that test thousands of combinations of risks instead of treating each one on its own.

I would like AI to tell me where the industrial ecosystem is fragile.

SARAH HICKINGBOTTOM ON WHAT AI SHOULD PREDICT IN FIVE YEARS

You started out in the most fundamental chemistry imaginable, with Nobel laureate Sir Fraser Stoddart. When did the molecule stop being the most interesting part?

During my PhD, our group moved to UCLA, where research and industry worked together much more closely at the time. We were funded by DARPA, one of the funders behind GPS, and we worked with Hewlett-Packard. We were making molecules called rotaxanes. Imagine a dumbbell, like the weights in a gym, with a ring around the bar. The ring can sit in one of two positions, and you can push it from one to the other with a stimulus from outside. So the molecule works like a tiny switch: one position is a zero, the other a one. That is the binary code computers use. We were working on arranging these molecular switches into arrays… We were even talking about atomic computers.

I had chosen Fraser's group for the beautiful blue-sky chemistry. But being there as it turned into innovation, something that might one day reach a market and change the world, was exhilarating. So when I decided to leave academia, I wanted to chase the molecule: where does it go once it leaves the lab? I started out as a generalist and ended up in oleochemicals, chemicals made from plant oils and fats, because I was fascinated by the bio-based world. And the moment that world turned to new technologies, I was smitten. I've never looked back.



GLOSSARY

FIRST-OF-A-KIND PLANT
The first commercial-scale plant for a new process; the second and third show whether the business can be repeated.

COMMISSIONING AND RAMP-UP
Starting up a newly built plant and bringing it step by step to full capacity.

DROP-IN VS NOVEL MOLECULE
A drop-in is a bio-based or recycled version of a chemical the market already buys. A novel molecule, such as the solvent Cyrene or FDCA, a building block for the bio-based polyester PEF made by Avantium, has to build its own market.

ADIPIC ACID
A commodity chemical made in millions of tonnes a year, mainly used to make nylon.

MASS BALANCE VS SEGREGATED
In mass balance, renewable and fossil feedstocks are mixed and the renewable share is allocated on paper; in a segregated chain, the renewable product is kept physically separate.

REACH
The EU chemicals regulation, run by the European Chemicals Agency (ECHA). A new molecule must be registered before it can be sold in volume.

OLEOCHEMICALS
Chemicals made from plant oils and animal fats, for example for detergents, cosmetics and lubricants.


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Chromatin Removal by Fibrous Chromatography
Large-Scale EV Production with Improved Imm




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ANALYSIS

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PUBLISHER: acib GmbH, Austrian Centre of Industrial Biotechnology, Krenngasse 37, 8010 Graz, Austria
ABOUT THIS ISSUE: esib Spotlight accompanies the European Summit of Industrial Biotechnology.
This issue documents esib 2026, held at Messe Graz from 10 to 12 November 2026
PUBLISHED: November 2026
CONTACT: office@acib.at · acib.at · esib.at

CREDITS

EDITOR & TEXT: Katharina Schwaiger, PhD, science journalist, acib. Editor of esib Spotlight. Lead article, the ZETA site visit report, and the research, concept and text for the European pilot plant map.
INTERVIEWS: The conversations with Michael Köpke (LanzaTech) and Sarah Hickingbottom (FutureBridge) were conducted and edited by Katharina Schwaiger. Both interviews were authorised by the interviewees.
EDITORIAL: Bernd Nidetzky, Chief Scientific Officer, and Mathias Drexler, Chief Executive Officer, acib; Text: Katharina Schwaiger with the help of AI (Anthropic's Claude)
PHOTOGRAPHY: by Astrid Preisz and Martin Benedikt

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