Bio-based Industries Consortium

VIA SOLUTIS

Winning the First-of-a-Kind Challenge

Practical insights from UPM, Avantium & Fibenol about feedstock, offtake, financing & regulation

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Foreword

Crossing the innovation valley of death: Europe's first movers in biomanufacturing.

Biorefineries are already strategic assets for Europe. They help to defossilize industry, build skills and industrial ecosystems, shorten supply chains, and bring growth, jobs and resilience, often to rural regions.

First-of-a-Kind (FOAK) plants bring additional strategic value. FOAK plants are instrumental because they are the bridge between a technology that works in the lab and an industry that works at scale. Without a first plant, a new technology never reaches the market, however promising it is. FOAK cross the innovation valley of death.

FOAK developers are, above all, pioneers i.e. a company who is among the first at something that is new to their industry. They take on risk to open up new pathways. Today, a new generation of bio-based pioneers is setting out to go beyond what has been achieved so far.

The report aims to contribute to the ongoing debate on the future EU budget (2028-2034) as well as on delivering the vision of the EU Bioeconomy Strategy that "by 2040, sustainable bio-based materials and products such as construction materials, biochemicals, textiles, fertilizers and plant protection products and plastics are widely deployed in the EU."

Given how long it takes to plan, build and ramp up a FOAK plant, 2040 is effectively tomorrow. The decisions we take today will shape how Europe produces for decades to come.

Hence, a clear political agenda and a strong EU budget window for the bioeconomy (both under Horizon Europe and the EU Competitiveness Fund) will drive the vision outlined in the EU bioeconomy strategy by helping to deploy more FOAKs in Europe.

This report offers first-hand insights from three FOAK projects that have moved from investment decision to physical plant. Their experience yields valuable deployment lessons, while stable commercial operation and long-term profitability remain milestones to be assessed. The report provides the reader with a pragmatic and solution-oriented approach on how to tackle the hurdles of finance, feedstock and offtake when building a First-of-a-Kind plant.

On behalf of BIC, I would like to thank UPM, Avantium and Fibenol, and the teams who contributed to this study, for their time and openness. Behind each plant lies sustained industrial effort and hard-earned experience.

Their willingness to share that experience gives this report its practical value.

The insights from this report are meant to help companies, investors and policy-makers make the next generation of FOAK projects in the bio-based industries a success.

Key findings of this report:

Pioneering the way for the next-of-a-kind: A First-of-a-Kind (FOAK) plant should not only be judged on whether it found the best route at the first attempt. It should be judged on how much it helps those who follow to refine and improve that route.

Patient capital is essential. Key challenges only appear once the plant is made to run, so after construction. This increases the need for patient capital through commissioning, ramp-up and customer qualification. Patient capital can include private and public sources such as the from up-coming European Competitiveness Fund as well as the European Investment Bank.

Start simple, then scale. Being able to use many feedstocks is an attractive goal, but in a First-of-a-Kind it makes the industrial process more complex. Starting with one controlled feedstock route and widening it later leads to faster learning. Looking ahead, being able to use all sources of sustainable biomass and a less fragmented certification systems will be key.

Sustainability must pay. Performance and customer acceptance must come from the bio-based product itself. However, where customers are unwilling to pay a green premium, public policy can create or improve market conditions, for example through binding mandates, targets and public procurement.

The focus of this study is on FOAK in the bio-based industries and challenges related to financing, feedstock and offtake, thereby complementing existing reports such as BIC's *Financing the bio-based revolution: crossing the valleys of death* as well as *Scaling up Europe's bio-based industries from the* European Investment Bank.

Marco Rupp
Deputy Executive Director, BIC





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Executive Summary

Across Europe, a number of bio-based First-of-a-Kind (FOAK) plants have moved from concept and final investment decision into physical realization. These plants are not abstract technology promises. They are the industrial evidence of how novel bio-based chemicals and materials routes move from laboratory and pilot stages into commercial-scale assets.

This report examines the behind the scenes success measures. It draws practical evidence from FOAK projects by UPM, Avantium and Fibenol. Together, they show what helped European bio-based FOAK projects move forward, and what future developers, investors, public finance actors and policymakers can learn before committing capital, customers and support. They expose three different ways to make FOAK a reality: corporate-backed industrial deployment, listed technology-platform scale-up, and project-led lignocellulosic commercialization.

Successful FOAK deployment depends on several interdependent conditions that must advance together throughout realization and early operation. Much of the decisive work takes place beyond the visible milestones, as the project moves from physical completion towards sustained industrial and commercial performance.

Whilst this report describes the FOAK reality in the bio-based industries, in general all industries face similar risks when going for FOAK.

Infobox

Definitions used in this study

First-of-a-Kind (FOAK)

- First-of-a-Kind means a new or substantially upgraded technology facility
- which provides innovation with regard to the manufacturing process of the net-zero technology
- that is not yet substantively present or committed to be built within the Union

Next-of-a-Kind (NOAK)

- a repeated commercial deployment after the First-of-a-Kind project,
- incorporating lessons learned from earlier units and
- expected to reduce cost, construction and delivery risk.

The central finding is clear: FOAK progress depends less on removing uncertainty than on making it manageable early enough. A first plant is not fully validated when construction is funded, finished or opened. The decisive tests often arrive later after construction.

The first measure is financial resilience beyond construction. FOAK finance covered both construction CAPEX and post-construction phase in which the plant is staffed, operated, debugged, modified, commercialized and supported through commissioning and ramp-up. The practical implication is direct: developers and capital providers should fund the validation phase before Final Investment Decision (FID), not rediscover it after opening.

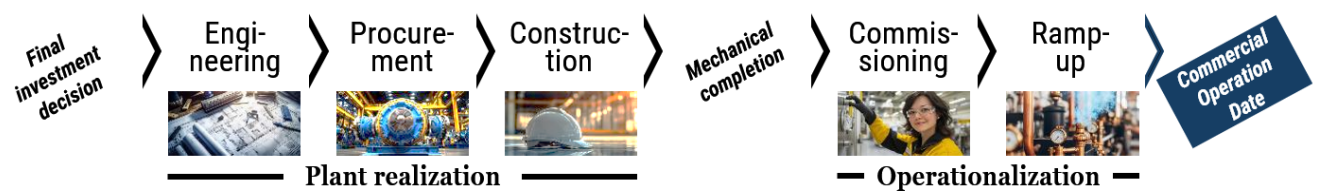
The second measure is controlled feedstock learning. A first plant should not always be asked to demonstrate maximum flexibility. In process-sensitive FOAKs, too much feedstock variability can weaken diagnosis and slow learning. The stronger first-plant objective is disciplined repeatability: one controlled feedstock route, tight quality control, supplier qualification, logistics discipline and fast feedback between plant performance and feedstock specification. Flexibility still matters. Sequence matters more.

The third measure is demand that can survive ramp-up. FOAKs have a lot of customer curiosity. but which needs to be converted into interest into qualified, structured and ramp-compatible demand. Letters of intent may show market attention, but successful FOAKs have binding or conditioned offtake agreements, giving stronger evidence for FID and financing discussions. Offtake does not remove FOAK risk. It makes part of the risk explicit enough to allocate, monitor and finance.

The fourth measure is regulation that makes sustainable value usable. Policy cannot make a weak business case strong. It can determine whether the value created by a strong first plant can be recognized in customer, finance and investment decisions.

Infobox

FOAK Project Delivery Pathway to Commercial Operation (simplified)



Bio-based carbon recognition, credible claims, workable certification, demand signals and route-aware support decide whether customers can act on FOAK value. Like in the case of other renewables in the past, policy can create markets. Product performance and customer application evidence still win the order.

This report asks a useful question:

What did projects have to manage in order to be successful?

The answer is practical. They financed beyond construction, narrowed early feedstock variables, built customer evidence step by step, and worked through policy and market uncertainty without treating FOAKs as standard repeat projects.

The conclusion is not that FOAKs are easy, safe or fully de-risked. They are not. The conclusion is that future FOAKs can become more investable when the right capabilities are designed early: operating stability, feedstock control, customer qualification, demand quality, regulatory recognition and a stronger next investment case.

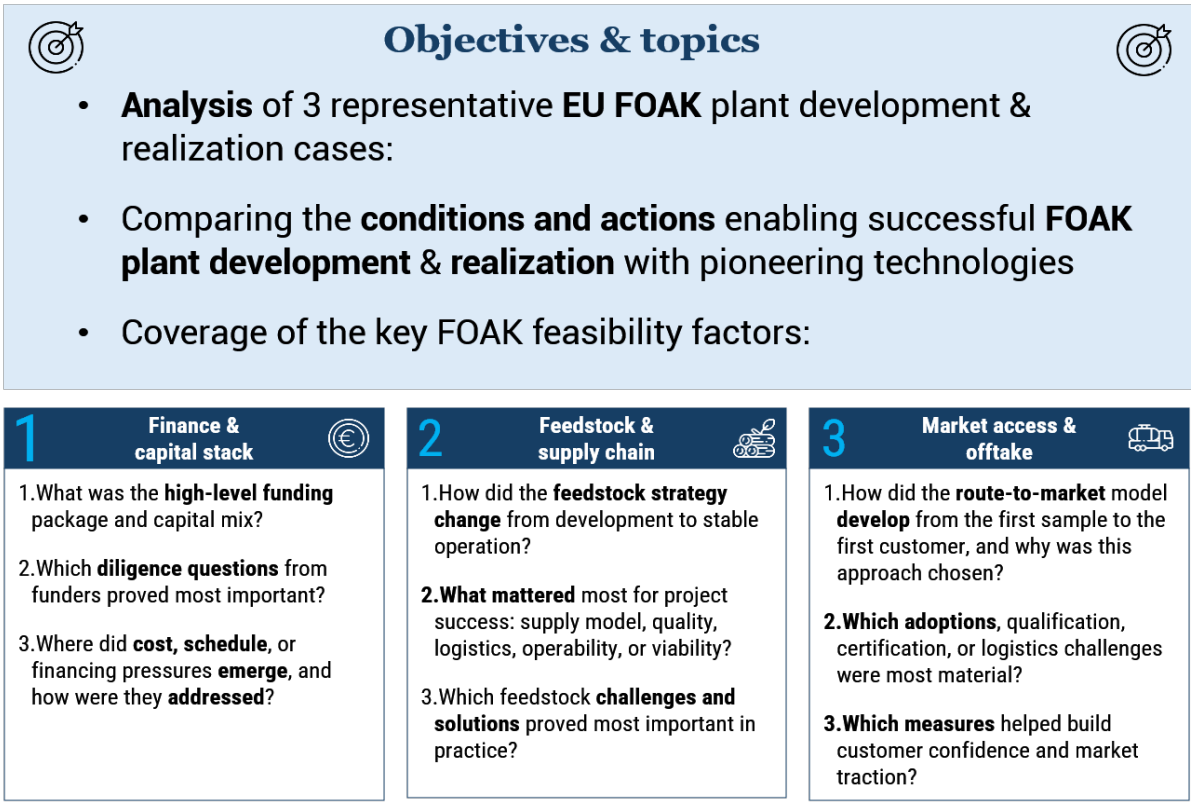
For a developer, this is a design brief. For an investor, it is a diligence lens. For a policymaker, it shows where public action can improve private-capital confidence without replacing project discipline. The next advantage will belong to those who turn rare first-plant experience into transferable industrial capability.

Methodology

This report uses a structured, evidence-led case-study methodology. Its purpose is to make practical FOAK experience visible in a form that is comparable, publishable and useful for future deployment decisions. The study does not attempt to provide a statistical survey of all European FOAK projects. It examines selected industrial cases in depth to understand how plants moved through development, realization and operational learning.

Exhibit 1: Objectives of the study

Converting First-Plant Experience into Practical Guidance for Future FOAKs



The work followed a four-step process:

1. **Public sources,** Bio-based Industries Consortium (BIC) materials and company primary information were reviewed to establish a factual base-line and avoid relying on interviews for information already available in the public domain.

2. **A common interview framework** was prepared around the main FOAK feasibility dimensions: feedstock and supply chain, market access and offtake, finance and capital stack, and regulation as a cross-cutting fac-tor.

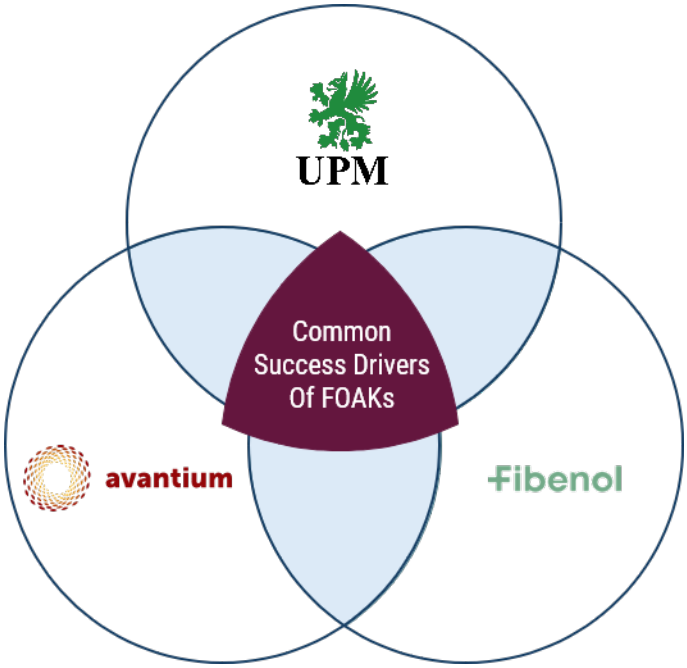
3. **Focused expert interviews** with UPM, Avantium and Fibenol were con-ducted to capture practical execution experience behind public mile-stones. 299 statements were documented and cross-referenced.

4. **Interview-derived statements were shared** with the relevant companies for review before use, allowing them to correct, rephrase, approve or re-move content intended for publication.

The analysis then compared the validated evidence across the common themes. Each case was first assessed on its own terms, then compared with the others to identify recurring mechanisms, relevant differences and transferable lessons. The method therefore avoids treating all FOAK projects as identical. It distinguishes between project-specific facts and broader patterns that can inform developers, investors, public finance actors, customers and policymakers.

Exhibit 2:

Three EU Bio-Based Flagship FOAK Projects Reveal Common Success Drivers



The findings should be read as qualitative industrial evidence. Their strength lies in the combination of public-source grounding, structured expert input, company validation and cross-case comparison. Their limitation is that the study does not replace technical due diligence, financial audit or market assessment. Its contribution is practical: it turns rare first-plant experience into a clearer reference for how future bio-based FOAK projects can be structured, financed, qualified and supported.

Disclaimer: This report draws on practical insights from three first-of-a-kind (FOAK) projects. These cases illustrate the opportunities and challenges examined within the report's scope and do not constitute a comprehensive overview of all FOAK activity in Europe.



Projects at a Glance

Three Different Starting Positions for European Bio-Based FOAK Deployment.

This section gives the reader a controlled overview of the three FOAK projects before the functional analysis begins. It explains what the projects are, how they differ, and why each belongs in the study.

The interviewees UPM Leuna, Avantium Delfzijl and Fibenol Imavere differ in sponsor model, technology route, feedstock basis, product logic and development pathway. That variation is useful: it allows the report to compare FOAK deployment across three different industrial archetypes rather than deriving lessons from one project model only.

Exhibit 3: Comparative Project Snapshot

Each Flagship Project Combines Its Own Capital, Feedstock and Product Logic

	UPM	avantium	Fibenol
Company type	Corporate-backed, large industrial incumbent extending a forest-based materials position into renewable chemistry.	Technology-platform company scaling a new FDCA / PEF route from pilot and partnerships into first commercial production.	Project-led company using wood-industry capability to industrialize lignocellulosic fractionation in a multi-product biorefinery.
Project site (embedded in)	UPM Leuna Biorefinery, Chemical Park Leuna, Saxony-Anhalt, Germany. 	FDCA Flagship Plant, Chemie Park Delfzijl, Groningen province, the Netherlands. 	Co-location to own pellet plant (Graanul), in Imavere, Järva County, Estonia 
Why a FOAK?	World's 1st commercial hardwood-to-biochemicals refinery	World-first commercial plant for plant-based FDCA production	First-of-its-kind hardwood biofractionation flagship in Estonia, proving the Sunburst technology

	UPM	avantium	Fibenol
Products & capacity	220,000 tons per year of, BioMEG, BioMPG, Industrial Sugars, Renewable functional fillers (RFF / lignin) for packaging, textiles, cosmetics, detergents, rubber and plastic applications.	5,000 tons per year FDCA flagship plant under PEFerence for packaging, textiles, films and bottle applications.	~30,000 dry tons of biomass per year LIGNOVA™ lignin, C6 sugars, C5 sugars, Specialty cellulose (MCC) throughput for downstream biomaterial applications.
Feedstock	Beechwood, Saxony-Anhalt and neighboring states Triple certification, June 2025, ISCC PLUS, PEFC, FSC™	High fructose syrup (commodity product from Tereos)	Birch hardwood chips (regionally sourced from existing supply chain of Graanul, certified)
Investment / funding	Latest investment estimate: €1,370m; original €550m. € 373M FY2024 write-down from overruns & delays Disclosed funding: €200m NIB loan, €898m green-bond allocation. €20m Saxony-Anhalt grants	Latest capex read-through: ~€196m, Initial Budget: €116M CAPEX with Total investment cost (TIC) Latest TIC: €255M revised from €192M €105m senior debt and €85m 2025 equity raise, Including €15m Dutch State placement. €25M BBI JU "PEFerence" grant. Regional: €7.5M Groningen grant. €30M third-party equity from BPIG / Worley	~€70 million (inc. R&D activities) Latest investment Initial budget was €43.2M CBE JU grant: €21m for SWEETWOODS. Private equity-backed, with early risk capital from Graanul Invest
Status as reported on	**29 April 2026:** Industrial sugars and lignin production ongoing. Targets: RFF production next; glycols during 2026; full production and positive EBIT during 2027.	**30 April 2026:** Utilities and sugar dehydration unit operational; remaining commissioning continuing. Targets: full plant start-up by mid-2026; commercial product sales in the second half of 2026.	**26.08.2026:** Mechanical commissioning was finalized end of 2023. FOAK plant fully functional and in operation by end of 2025

UPM Leuna Biorefinery

UPM Leuna shows how a corporate-backed FOAK can turn certified regional hardwood into a staged, multi-product industrial platform.



UPM Leuna is one of the clearest European examples of an incumbent industrial group using its existing resource base to enter a new field of renewable chemistry. UPM is not approaching the bio-based transition as a forest-industry company with established biomass sourcing, industrial operations, customer relationships and balance-sheet capacity. The Leuna investment extends that position into wood-based chemical intermediates and functional materials for markets still largely served by fossil-based inputs, including packaging, polyethylene terephthalate (PET) bottles, cosmetics, pharmaceuticals, textiles, detergents, rubbers and resins.

The Leuna project asks whether UPM's balance-sheet strength, forest-industry capabilities and materials-market base can be converted into a new biochemical platform at European chemical-site scale and provide the basis for a replicable industrial model. Its FOAK value sits in the combination of certified regional hardwood, first-time industrial wood conversion, multiple product families and customer qualification. The case therefore frames a corporate-backed, feedstock-integrated FOAK in which technology readiness, sourcing, certification, ramp-up and market validation are developed together to establish the industrial basis for future replication.

Leuna's FOAK character is not only a capacity claim. UPM described the Leuna site in 2025 as the world's first industrial-scale facility of its kind for converting wood into advanced biochemicals at scale. In December 2025, UPM reported that the site had reached stable operation in separating lignin and sugars after industrial-scale hydrothermal breakdown of wood, a prerequisite for conversion into glycols and Renewable Functional Fillers (RFF). That sequence makes the case useful for FOAK delivery because the project has to convert biomass logistics, intermediate stability and application-market proof into one ramp-up path.

Strategically, Leuna extends UPM's forest-based industrial position into renewable carbon chemistry. UPM's Q1 2026 report links the project to new markets and says product value is driven by sustainability performance, brand differentiation for consumer goods and technical performance. The same report sets a 14% Return on Capital Employed (ROCE) target for UPM Biochemicals, which positions Leuna as a business platform rather than a lab extension. The implication is that technology commercialization and FOAK project delivery are related but distinct: UPM is commercializing a biochemical platform while still moving the first plant through staged commissioning, qualification and scale-up.

Avantium Delfzijl Plant

Avantium Delfzijl shows how market pull can support the first industrial proof point for a sugar-to- 2,5-furandicarboxylic acid (FDCA) polymer platform.



Avantium Delfzijl qualifies as a FOAK case because the proof point is not laboratory polymer chemistry alone. The case tests commercial-scale operation of a sugar-to-2,5-furandicarboxylic acid (FDCA) route, downstream polymerisation into polyethylene furanoate (PEF) and customer qualification for a new material platform. The European Commission's Community Research and Development Information Service (CORDIS) describes PEFerence as a globally First-of-a-Kind industrial-scale 5,000 tons per year FDCA flagship plant, while Avantium's own development sequence moved from YXY® work in 2006, a pilot plant in 2011 and plant opening on 22 October 2024. The project's early development was supported by EU grant funding through PEFerence under the Circular Bio-based Europe Joint Undertaking (CBE JU). The FOAK object is therefore the integrated technology-to-market pathway, not just a single unit operation.

For Avantium, Delfzijl is a proof asset for technology commercialization and a bridge to licensing. The company's 2025 materials cite 21 contracted offtakes, 13 capacity reservations for future plants and 1 technology license, which makes the plant a credibility anchor for customers and prospective industrial partners. That role is strategically different from a conventional owned-production expansion. The plant must supply first industrial product, generate operating evidence and reduce uncertainty for future third-party plants, while product markets continue to validate recyclability and application fit.

The distinctive learning is that market creation can be strong before industrial proof is complete. Avantium had recycling evidence, feedstock arrangements and offtake traction, but its 2026 updates still show a structured commissioning path: utilities and steam distribution header (SDH) were operational, weld remediation had been completed, the oxidation has been commissioned, and commissioning of the purification unit is being finalized. The next milestones are first 2,5-furandicarboxylic acid (FDCA) production, qualification campaigns and the transition to commercial operations, with initial sales expected at the end of 2026. For future platform-material FOAKs, the useful signal is discipline: offtake, recycling recognition and licensing interest are necessary, but financeable replication still depends on reliable on-spec production and a ramp-up runway.

Fibenol Imavere Biorefinery

Fibenol Imavere shows how wood-industry capability can become a lignocellulosic, multi-product FOAK when feedstock control and product validation advance together.



Fibenol Imavere is a feedstock-integrated FOAK because the plant tests whether hardwood residues can become a reliable industrial input for chemicals and materials, not only a low-value energy stream. Fibenol, a spin-off of Graanul Invest Group, used its wood-industry base to develop the SWEETWOODS biorefinery in Imavere, Estonia, a CBE JU-funded plant inaugurated in May 2024. For European FOAK delivery, the value lies in the combined proof burden: local biomass logistics, Sunburst pretreatment, enzymatic separation and several product markets had to advance inside one First-of-a-Kind hardwood biorefining platform.

Imavere qualifies as more than a plant-opening story because the first proof point was simultaneous industrial integration. SWEETWOODS aimed to demonstrate high-purity lignin and C5/C6 carbohydrates from hardwood at an 80 bone-dry tons (bdt) per day biorefinery while using all biomass fractions and at least 95% of initial carbon content. The project therefore tested technology scale-up, feedstock transformation, product-market pathways and value-chain creation in the same FOAK boundary, rather than proving a single molecule in isolation.

For Fibenol, Imavere created an industrial proof base for a broader biomaterials platform. CORDIS final reporting states that the project scaled a wood fractionation platform, converted wood residues into biobased raw materials using 100% renewable energy and high process-water recycling, and developed LIGNOVA™ lignin and wood-sugar products with sustainability assessment via Environmental Product Declaration (EPD). The follow-on logic is visible in the planned Valmiera project, publicly framed by Latvian investment authorities at EUR 600 million to EUR 700 million, with public media reporting a 26-hectare Valmiera site.

The distinctive lesson is that a lignocellulosic FOAK carries multi-product complexity by design. LIGNOVA™, wood sugars and specialty cellulose can address different markets, but each route has its own performance, qualification, certification and customer-adoption burden. Future FOAK actors should treat Imavere as evidence that feedstock proximity and wood-processing capability can reduce one class of risk, while creating a different need for patient product validation across several downstream applications.





Findings and Recommendations

The findings focus on the three project-side factors through which the cases advanced: finance, feedstock and offtake. The evidence is woven into the narrative rather than separated into proof blocks, because the aim is to explain what worked and why it mattered in one continuous executive storyline.

Finance and capital stack

FOAK finance becomes stronger when capital supports the full proof curve.

FOAK projects can combine sponsor or shareholder equity, loans and public grants, drawing on both public and private funding. The mix depends on sponsor strength, funding eligibility and the project's technical and commercial maturity. During construction and early ramp-up, equity and eligible grants can help fund stages in which costs, timing and revenues remain uncertain, while loans may require strong sponsor support. As reliable production and cash generation are demonstrated, the scope for additional debt or refinancing may increase.

FOAK finance is not only a question of whether a first plant can be built. The more demanding question is whether the project can remain funded while the plant turns from a constructed asset into an operating, qualified and commercially useful asset. That distinction matters because several of the most decisive FOAK proof points arrive after the public construction milestone: commissioning, system integration, corrective works, ramp-up, working capital build-up, product qualification and early customer delivery. The evidence from UPM Leuna makes this sequence visible. The reported pressure points did not sit only in construction.

“Pressures emerged mainly during:
• commissioning and system integration
• corrective works
• extended ramp-up
• working capital build-up”

Statements describe these pressures as “These reflect first-time industrial integration effects typical for FOAK projects."

This is the first finance lesson:

FOAK risk does not simply decline after the plant is physically complete. It changes form.

That shift explains why construction CAPEX is an incomplete financing lens. One interview states the point directly: “The project must be transparent with investors before Final Investment Decision (FID). Financing a FOAK is not only about construction Capital Expenditure (CAPEX), but also about funding the long post-construction phase in which the plant is staffed, operated, debugged, modified, commercialized, and supported through commissioning and ramp-up." The wording converts a generic funding issue into a sequence of specific cash needs.

A FOAK can be funded for construction and still be underfunded for industrial proof.

The time dimension is equally material. One statement cautions that “Many teams still plan only three to six months for hot commissioning, which is unrealistic. From cold commissioning to real operational stability, a FOAK should plan for at least two years of commissioning, troubleshooting, and remaking." The financing base case should therefore not depend on a short, smooth transition from mechanical completion to revenue. If early sales arrive, they help. They should not be the survival condition. As the same company puts it, “Meaningful sales should not be assumed during the first two years after commissioning. During this period, the project should be treated

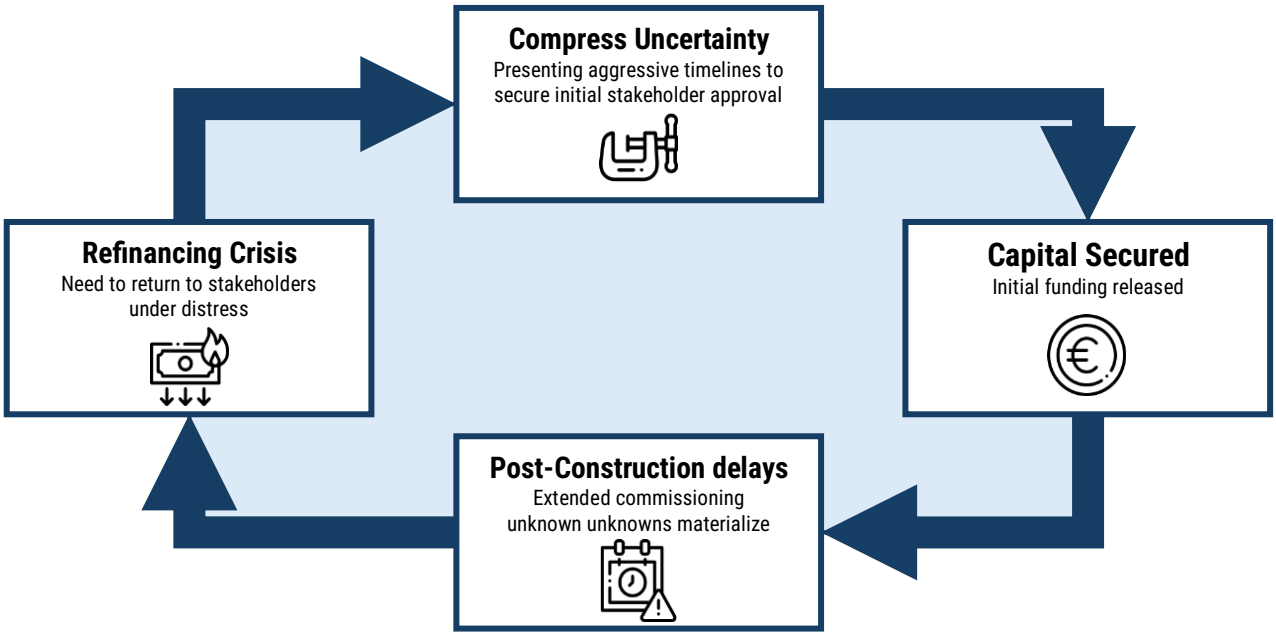
as pure cost, with personnel, operating, troubleshooting and remaking costs, but potentially no real commercial revenue."

Optimistic planning becomes a financing issue when uncertainty is compressed into milestones that stakeholders can finance, govern and communicate. The pressure is understandable, and the evidence is careful on intent: "FOAK companies sometimes set timelines that are unrealistic, not necessarily because they want to mislead, but because they are forced to. To access financing, they must show that the project will be completed within a certain time and reach the market within an acceptable period."

This creates a difficult financing circle: to get money, the company accepts aggressive timelines; later, it may have to return to the same stakeholders because the original assumptions were too tight." The conclusion is not that developers should present pessimistic plans.

Capital structure must make room for realistic uncertainty before the project reaches the pressure phase.

Exhibit 4:
Realistic Timelines and Contingencies Reduce Later Financing Adjustments



Resilience can come from different sponsor models. UPM described Leuna as “a large-scale FOAK investment, enabled by UPM's balance sheet and long-term commitment to build an industrial-scale biorefinery in Europe." Avantium illustrates a different financial position: “Avantium does not have the financial buffer of an incumbent with large existing product lines." The practical distinction is the sponsor's capacity to absorb cost overruns and fund a longer commissioning and ramp-up period before the plant generates dependable cash flow. At the same time, investment decisions are increasingly shaped not only by technology risk, but also by policy and market uncertainty. Technology readiness alone may therefore be insufficient to unlock investment without sufficient confidence in the wider market and policy environment.

The practical lesson is that FOAK companies need some form of financial backbone:

- internal cash generation,
- a committed strategic sponsor,
- patient shareholders[1],
- public support
- or another source of resilience.

“Without that, delays and unknown unknowns become existential." The practical finance point is therefore not that every FOAK needs the same sponsor model. It is that every FOAK needs a credible source of resilience once construction has ended and industrial proof still lies ahead.

[1] For FOAK projects: shareholders prepared to fund and tolerate commissioning, ramp-up, and early operating volatility without demanding a quick exit or immediate profitability.

Infobox

Unknown unknowns are latent, non-foreseeable technical system dynamics of a constructed plant

1 What are "unknown unknowns"?

Latent, potential system-level risks

- They only surface once the full-scale plant is built and runs as one live, integrated system.
- The risks are driven by the total configuration of process units, utilities, grid and logistics.



2 When do they appear?

Distributed across the execution cycle of the project

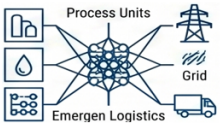
- Mainly concentrated during commissioning, starting at first live system test.
- As well as at ramp-up phases.



3 Why do they exist in FOAK projects?

FOAK configurations are genuinely novel

- Unknown unknowns are driven by interface complexity, concentrating at boundaries of process units and utilities.
- Non-linear scaling physics in volume and heat

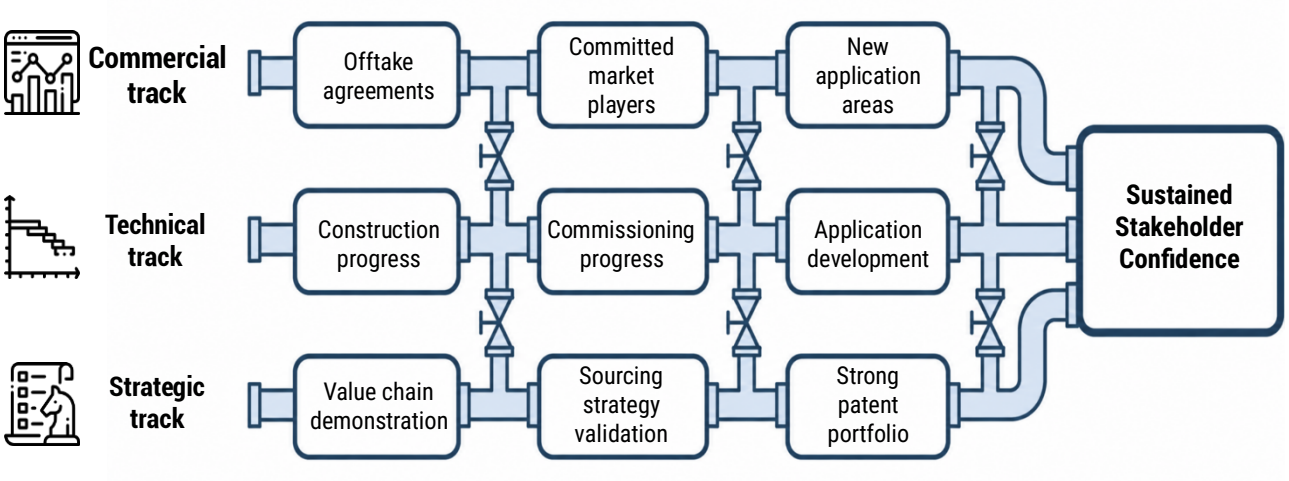


Customer and market evidence can strengthen resilience, but it does not replace it. In Avantium's case, "The binding offtake agreements were central to financing discussions. Avantium could show banks and other financing parties that there was committed demand for polyethylene furanoate (PEF). The company had a portfolio of binding agreements with agreed pricing and five-year rolling customer commitments." Yet the same evidence base adds: "However, strong offtake did not make the financing easy. The project was still seen as risky. Interest rates were high. The use of first-generation feedstock was viewed negatively under the earlier eligibility framework. The offtake agreements helped significantly, but they did not make FOAK debt cheap or straightforward." First-generation sugars come from crops that can also be used for food or feed, such as corn or wheat. According to the Avantium interview, the European Investment Bank's earlier Paris Alignment eligibility criteria excluded projects using these feedstocks from certain funding or loan structures, limiting the financing options available to the company.

Demand evidence improves financeability, but it does not remove plant, qualification, feedstock or policy risk.

The strongest finance cases therefore combine several forms of proof. One comment from Leuna describes “Risk perception was reduced through consistent evidence across the value chain, including demonstration experience, a credible sourcing strategy, early customer engagement, and strong certification." Another describes how additional stakeholder confidence required more than capital: “The solution was not only to ask for more money. Avantium had to keep shareholders, banks and public stakeholders convinced that the project was still progressing. This required evidence across several fronts: more offtake agreements, more committed market players, construction progress, commissioning progress, application development, a strong patent protection portfolio on polyethylene furanoate (PEF) and applications, and new application areas that expanded the perceived market potential." Stakeholder confidence is easier to maintain when technical, commercial and strategic proof accumulate together.

Exhibit 5:
Combined Commercial, Technical and Strategic Progress Sustains Stakeholder Confidence



The quantitative downside warning should be handled as an uncertainty marker, not as a universal benchmark. One specific interview statement says: “If the initial plan says the plant will cost X, the project should be prepared for up to 3X by the end. If the initial timeline says four years, it should be prepared for roughly twice as long. This is not a precise formula, but a warning about the magnitude of uncertainty." The sentence itself contains the boundary: the point is not the exact multiplier.

FOAKs must carry a wider uncertainty for financing duration as well as financing volumes than a conventional repeat project.

Strategic capital matters because it can stay with the project while the first plant learns. An interviewee states:“FOAK projects need patient, strategic capital. Construction CAPEX is only part of the story, because years of post-construction funding maybe needed before meaningful revenue begins. Investors must understand before FID that costs, timelines and early sales can differ materially from plan. A pure Venture Capital VC model is unlikely to be sufficient; strategic industrial backing is more suitable." The point is not to reject venture capital or public finance, but to match capital type to proof phase.

FOAK projects are financeable when financing matches industrial reality. “Leuna demonstrates that FOAK projects are financeable, but scaling requires frameworks that enable capital to flow repeatedly into similar projects." The first plant is more than a cost center or Earnings Before Interest, Taxes, Depreciation and Amortization (EBITDA) asset. It is a learning asset whose value increases when its evidence transfers to the next investment case. “The real success is proving consistent production quality, customer acceptance and willingness to pay, and financeability of the next larger projects."

A FOAK plant may become commercially viable after several years of commissioning, ramp-up and improvement, while informing more competitive NOAK designs. NOAK development can begin during FOAK ramp-up, provided investment decisions distinguish demonstrated performance from expected improvements. FOAK-specific support should be reviewed against

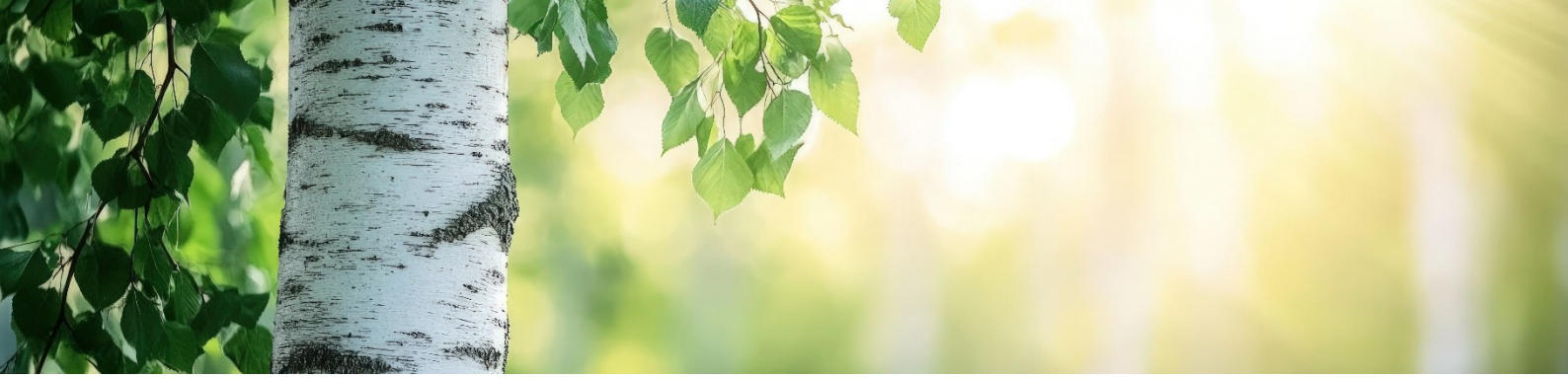
progress towards both first-plant viability and credible replication, and adjusted as the underlying risks decline.

Exhibit 6: Transferable financing measures

Full proof-curve funding, transparent uncertainty and resilient capital strengthen FOAK financeability

	Measures	Why it matters
1	**Fund the proof curve, not only construction.**	The cash need continues through commissioning, corrective works, working capital, commercialization and ramp-up.
2	**Make uncertainty visible before FID.**	If uncertainty is compressed to secure financing, it can return later as refinancing pressure.
3	**Keep resilience capital available through commissioning.**	Balance sheet, patient shareholders, strategic sponsors or public support keep unknowns from becoming existential.
4	**Use demand evidence to strengthen financeability, not to replace contingency.**	Offtake improves the financing story, but does not remove startup, qualification, feedstock or policy risk.
5	**Convert FOAK learning into next-plant lender proof.**	The first plant becomes strategically valuable when it improves the next investment decision.

FOAK finance becomes powerful when it is honest about what the first plant is actually buying: not only steel, equipment and construction services, but time to modify, stabilize, learn, qualify, commercialize and finally convert the first asset into the next financing case. That is why the finance lesson is positive rather than defensive. Once capital is aligned with the proof curve, the next question is operational: what should the first plant be asked to prove, and how can the feedstock system be structured so that the learning is reliable enough to scale?



Feedstock and supply chain

The first plant creates the most value when it proves one disciplined feedstock route under controlled conditions.

Feedstock is often described as a supply question. In FOAK deployment, it becomes something larger: an operating system. The key distinction is between feedstock availability and feedstock system performance. Having sufficient material is only one part of the challenge; supplier integration, quality control, logistics and certification are equally important to making that material work reliably in plant operation. The first plant needs a feedstock route stable enough to support commissioning, troubleshooting, customer confidence and later scale-up. This is why none of the interviewed companies point to maximum early flexibility.

Simplify the supply chain where possible.

The Leuna experience shows how a feedstock concept becomes operational only when it moves beyond volume security. UPM had planned the supply chain before operation through certified volumes and supplier relationships, but the supply chain itself only became fully visible when first deliveries, commissioning and ramp-up forced the system to operate in real conditions. “During development, the concept focused on securing certified volumes and building supplier relationships. However, as the project moved into commissioning and first deliveries, it evolved into an integrated operating system, including:

- structured supplier qualification
- tighter incoming quality control
- coordinated logistics into the site"

Those are not support functions around the plant. They are part of whether the plant can ramp up to full-capacity production.

This is the sharper lesson: in a FOAK, the supply chain is commissioned with the plant. They have to evolve through operational learning during commissioning and ramp-up. At Leuna, “the most significant challenges emerged during first deliveries and early ramp-up, when design assumptions met industrial reality." The challenges were concrete: “variability in incoming wood," “synchronization of supply with ramp-up," “scaling of quality control systems" and “logistics adaptation." The response was equally operational: “long-term supplier integration," “enhanced quality control and fast feedback loops," “logistics adjustments" and “continuous operational learning."

In that phase, feedstock quality was no longer an abstract specification. “Feedstock quality was particularly critical during commissioning. For example, variations in moisture and chip size can directly affect process stability, requiring rapid adjustments in handling and control procedures." A project may therefore have feedstock on paper and still face instability if quality, handling, logistics and plant feedback have not yet been tested as one operating system.

FOAK feedstock systems cannot be fully de-risked upfront, they must be built and optimized during operation.

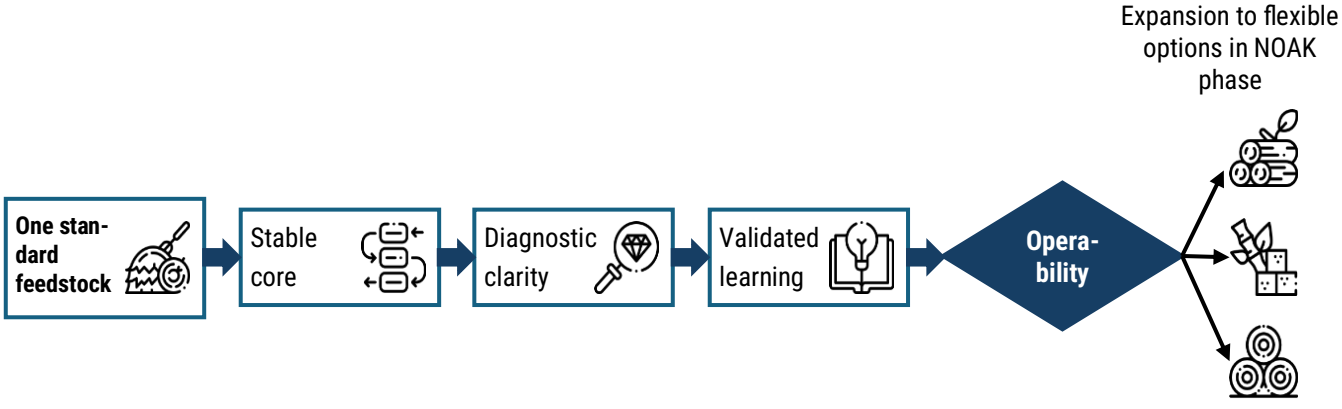
The same diagnosis problem becomes even sharper in lignocellulosic pretreatment. A FOAK plant already carries enough uncertainty in the core process. If the feedstock also varies across species, composition, moisture, particle size, storage and handling, the project may not know what it is learning from. One manager states this straight forward: “The FOAK team already has enough uncertainty in the core process. If the feedstock varies too much, it becomes difficult to diagnose whether problems come from the core technology, upstream preparation, storage conditions, moisture changes, or feedstock composition." Controlled feedstock is not a conservative choice. It is a stabilization, and ramp-up strategy.

This is also why the first plant should not be asked to prove every future sourcing option in order to be flexible. “The team initially considered mixing feedstocks, but this created too many variables. For a First-of-a-Kind project with a new pretreatment process, the better approach is to choose one feedstock, optimize around it, reduce variability, and scale on that basis." The evidence then turns this into a broader FOAK rule: “The feedstock should therefore be homogenized and standardized as much as possible. Early plants should not be designed to demonstrate maximum flexibility, but to generate reliable learning under controlled conditions."

Reduce variables first, expand optionality later.

Feedstock discipline also protects technology developers from a common scale-up trap. Many technologies are marketed as flexible across multiple feedstocks, but the first industrial plant may not be the right place to prove that range. “Many technology developers say in their pitches that they can use whatever biomass is available. This is one of the biggest mistakes. The process needs to be developed, optimized and fine-tuned around one feedstock. Once the First-of-a-Kind plant is running and the second-of-a-kind financial investment decision is done, the company can start looking at other routes." This does not reject future flexibility. It sequences it.

Exhibit 7:
Using One Feedstock First Simplifies to Optimize the Core Process, Enabling Later Flexibility



A second feedstock lesson concerns capability boundaries. Adjacent industrial experience can help, but it can also mislead when the core process is new. One example from wood preparation was described: “Initially, Fibenol's engineers trusted their pellet experience. Once the plant was commissioned, after delays and complications linked to COVID and the Russian invasion, one of the first major changes was the wood chips downsizing unit. What worked well for pellet production did not work equally well for pretreatment. Once the wood downsizing equipment was changed, it worked perfectly. If the licensor had been listened to earlier, there would have been fewer issues."

The broader lesson follows immediately: “The lesson is that adjacent industry experience can be useful, but it can also mislead. Pellet production and lignocellulosic pretreatment are not the same. Upstream feedstock preparation must be designed around the core process and core technology." In FOAKs, familiar material handling can still become unfamiliar process preparation.

The third feedstock lesson is scale. At FOAK scale, co-location and existing infrastructure can make supply manageable. “Fibenol's first plant was relatively small in industrial terms, with an output capacity of around 30,000 tons per year. Because it was co-located with an existing industrial site at Imavere, feedstock logistics were manageable." But the next plant changes the question. “The situation changes completely at the next scale. For a planned second-of-a-kind project in Latvia, at around 300,000 tons per year, feedstock availability becomes a critical FID issue, making pre-agreements covering at least about 70% of supply very important."

FOAK feedstock operability and NOAK feedstock bankability are not the same test.

The Avantium evidence adds a different but equally important boundary condition. Feedstock may be technically manageable and still commercially sensitive. “The practical lesson is that feedstock is manageable at 5 tons per year scale, but regional availability, quantity and supplier capability become more important as the technology is scaled or licensed." The issue can also be perception, eligibility and customer legitimacy. “For Avantium, the burden is that the 1G versus 2G discussion repeatedly puts the company

in defense mode with customers and stakeholders. This is a legitimacy and perception issue, not mainly a feedstock logistics issue. The argument was that the current 1G route is efficient, controlled and scalable, but the public and industry narrative still makes it difficult to defend." For future FOAKs, this turns feedstock into a technical and market-facing choice at the same time.

This is where feedstock connects to regulation without becoming a regulation chapter. Certification, traceability and sustainability frameworks influence whether a feedstock route can be accepted by customers and financiers. “Certification systems such as FSC™, Programme for the Endorsement of Forest Certification (PEFC) and International Sustainability and Carbon Certification (ISCC) PLUS are essential structural elements, not only for compliance, but to enable traceability and downstream market acceptance."

The challenge is therefore not sustainability certification itself, but fragmented implementation across frameworks, limited mutual recognition between schemes and the associated administrative burden. Projects may therefore need to prepare separate documentation and undergo overlapping assessments for the same feedstock route, increasing compliance costs. Unclear or conflicting implementation requirements can also delay certification and customer acceptance.

This becomes more material as projects scale: “Scaling further requires:

• harmonized sustainability framework requirements
• reliable infrastructure performance
• clear linkage between certification and market recognition"

The regulation chapter returns to this system question. The feedstock lesson here is narrower and more operational: a robust feedstock operating model must integrate certification, traceability and logistics in a way that can function despite fragmentation in the surrounding framework.

Exhibit 8: Transferable feedstock measures

A simplified feedstock system concentrates FOAK plant ramp-up on core-process learning and synchronizes supply-chain commissioning with plant commissioning.

	Measures	Why it matters
1	**Focus on one feedstock.**	One controlled feedstock route enables more efficient process diagnosis and creates usable learning during FOAK ramp-up.
2	**Design upstream preparation around the core process.**	Adjacent industry experience can help, but the upstream feedstock preparation must fit the specific core process being scaled.
3	**Treat first feedstock deliveries as supply-chain commissioning.**	Supplier qualification, incoming quality control, logistics and feedback loops can be planned before operations. But they can only be built and optimized synchronously to commissioning and ramp-up.
4	**Use partnerships to reduce the feedstock burden.**	Leverage existing infrastructure and external operational knowledge for the FOAK team to focus scarce attention on the core technology.
5	**Rebuild feedstock diligence for the next scale.**	FOAK-scale operability does not automatically prove NOAK supply bankability.
6	**Prepare the feedstock legitimacy case early.**	Feedstock choice must be defended technically, commercially and socially where customer or finance perceptions matter.

Feedstock discipline is not a retreat from ambition. It is how a first plant makes ambition useful. The strongest feedstock measures in the evidence are practical: narrow the initial feedstock task, control quality, treat first deliveries as supply-chain commissioning, integrate suppliers and logistics, learn under stable conditions, and rebuild the feedstock case before the next scale. Once that operating system can deliver controlled industrial material, the next question becomes commercial: how does customer interest turn into qualified, structured and finance-relevant demand?

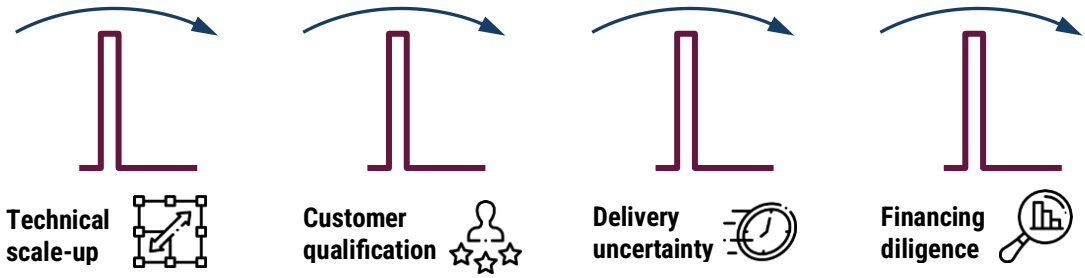


Market access and offtake

Customer interest becomes commercially valuable when it turns into qualified, structured and ramp-compatible demand.

FOAK projects rarely suffer from a complete absence of interest. The harder challenge is different.

Exhibit 9:
Offtake becomes credible only when demand survives four tests



This is why the offtake question is not simply whether customers like the product. It is whether they can qualify it for their business, contract it, receive it, use it and continue buying it as the plant moves through a variable ramp-up.

The evidence from Leuna makes the customer-side risk explicit: "The main barriers are not technical, they are risk-related on the customer side." Customer demand for renewable solutions exists, but converting that willingness into qualified and repeat demand depends on the speed of qualification, confidence in supply and credible regulatory recognition of sustainability attributes. In the same conversation, those requirements are described concretely: "Customers require confidence in:

• product consistency
• supply reliability
• sustainability credibility"

Even when the technology works and customers are willing to adopt, switching, qualification and supply-risk questions still have to be reduced before interest can translate into recurring demand.

This customer-risk lens also explains why offtake work must begin early but cannot be completed entirely before industrial operation. Leuna's customer engagement "Customer engagement evolved from:
• early positioning
• to sampling and testing
• to qualification and first deliveries"

This sequence shows demand building through proof steps, not through one commercial event. The same evidence adds that "Qualification processes are often sequential and time-intensive, while FOAK ramp-up is gradual, creating a mismatch." FOAKs therefore face a timing challenge:

Developers need customer confidence before the plant is fully proven, while customers need plant proof before they can fully commit.

That confidence depends not only on technical performance, but also on confidence in the producer's long-term industrial supply capability and credibility.

Avantium's route-to-market shows one way to manage that timing problem. "The commercial team initially considered using letters of intent to show customer commitment. The idea was to collect letters of intent from customers to demonstrate demand for the 5 KTA plant. However, the team questioned whether letters of intent were firm enough to support the investment case. The key question became whether the project needed more "skin in the game." The response was not simply more customer conversations. It was a different form of commitment: "Avantium therefore moved from letters of intent to binding offtake agreements. These are real purchasing

agreements. They include conditions precedent, so certain conditions must be fulfilled before the agreements fully apply. If Avantium meets those conditions, customers are bound to take the material."

This is the central offtake mechanism in the evidence base. Conditions precedent allow commitment and uncertainty to coexist. The customer can commit before every FOAK proof point is complete, but the final obligation is linked to defined conditions. "The conditions precedent created a risk-allocation mechanism. Avantium has to demonstrate that it can start up the plant, produce material and deliver it. Customers need confidence that polyethylene furanoate (PEF) works in their specific applications before they are fully exposed. Avantium therefore uses pilot plant material to carry out application development with customers before the flagship plant is fully producing." The lesson is to structure offtake so that it reflects the actual FOAK development sequence.

Where this is commercially feasible, binding and conditioned offtake provides stronger financing evidence than soft interest. "The offtake agreements are binding and rolling. They are not one-year agreements, but five-year agreements designed to derisk the investment. The practical lesson is that soft customer interest is not enough for FOAK financing. Letters of intent may help show early interest, but binding offtake agreements with clear conditions precedent provide stronger evidence for FID and financing discussions." The value of this structure is not only commercial. It strengthens the financing story because it shows customer exposure once the project reaches defined milestones.

At the same time, offtake does not remove FOAK risk. It narrows one part of the uncertainty while leaving plant, feedstock, qualification and policy risks in place. "The binding offtake agreements were central to financing discussions. Avantium could show banks and other financing parties that there was committed demand for polyethylene furanoate (PEF). The company had a portfolio of binding agreements with agreed pricing and five-year rolling customer commitments." One sentence further added: "However, strong offtake did not make the financing easy. The project was still seen as risky. Interest rates were high. The offtake agreements helped significantly, but they did not make FOAK debt cheap or straightforward."

The project should identify who bears construction, commissioning, qualification, volume and price risks at each stage. Conditional offtake does not

necessarily fund the period before qualification; any early customer support should specify its scope, duration, financial exposure and value received in return, alongside who funds the remaining requirements.

Customer structure also matters. Large early offtakers can help absorb volume, but concentration can create ramp-up exposure if one product, application or customer pathway is delayed. One interviewee describes the advantage of a broader portfolio: “This diversified offtake portfolio has several advantages. It creates awareness around polyethylene furanoate (PEF), brings recognizable names into the market development process and gives Avantium flexibility during ramp-up. A small number of very large offtakers can create concentration risk. If one product or application has a problem once the flagship plant starts up, a large part of the offtake commitment may be affected. With several smaller offtakers across different applications, Avantium can ramp up more flexibly, starting with one customer, then another." The trade-off is higher management effort, but the benefit is clear.

Diversified demand can make ramp-up less dependent on a single application path.

The route-to-market itself may also need to evolve. “These early agreements were mainly with converters and bottlers. The advantage was that converters could take larger volumes and essential for turning material into applications. At the same time, Avantium learned that final market adoption also requires strong engagement with the brand owners and retailers that shape consumer-facing demand, marketing and product positioning." The later model connected downstream demand and conversion capability: “This became one of Avantium's strongest commercial lessons.

For a new material, adoption requires engagement across the value chain. Brand owners and retailers are important because they influence consumer-facing positioning and can help create market pull. Converters remain important because they make the applications. Avantium's later approach was therefore to build direct demand with brands and retailers and then connect that demand with the relevant converters."

For new bio-based materials, offtake is not only a contract. It is value-chain orchestration.

The Fibenol evidence adds a further correction to market optimism. Samples matter, but they are not commercialization. “But this was only preliminary engagement, not real commercialization. Until the FOAK plant is operating and producing consistent industrial batches, customer work is mostly about relationship-building, learning, and early testing." Customers may engage early, run trials and become familiar with the product, but the commercial threshold changes when the plant produces at industrial scale. “Customers may be interested, but cannot fully commit until the company can produce and deliver reliable industrial volumes at scale." Offtake becomes meaningful when it is connected to industrial delivery capability.

The industrial proof point is specific. “Real commercialization begins after the difficult commissioning phase, when the company can deliver consistent truckloads, IBCs, or industrial batches from different production runs. Customers need to see:
• consistent product quality and stable specifications
• repeatable production from different batches
• reliable and on-time delivery
• industrial-scale volumes
• material delivered under the right time, quality, and supply conditions"

Before stable production, customer work builds readiness. After stable production, customer work becomes commercialization.

This is particularly important for differentiated products and multi-product biorefineries. The Leuna evidence notes that “The approach varies by product:
• Drop-in products integrate more quickly into existing value chains
• Differentiated products require deeper customer collaboration and longer qualification cycles" Fibenol's evidence shows why this becomes harder when multiple product streams must be commercialized simultaneously: “Fibenol has three product streams: lignin, C6 sugars, and C5 sugars. Each stream needs:
• an application
• a customer base
• a specification

• a value chain" The follow-on point is operationally important: “This makes commercialization significantly harder than in a single-product commodity plant. The company cannot optimize one output without considering trade-offs between product quality, process conditions, yield, functionality, and market value."

Application qualification is part of ramp-up, not a postscript. Avantium's evidence shows that pilot material and industrial material must still be connected through proof: “Customers ask whether Avantium can replicate pilot plant specifications at larger scale. This is also reflected in the offtake agreements. Avantium must prove that the quality from the flagship plant equals the quality from the pilot plant." Longer customer-line operation can reveal issues that short tests do not: “The risk does not only apply to the plant. It also applies to applications. Avantium has done extensive application testing with material from the pilot plant. For example, bottles have been made on industrial lines for 30 minutes. However, industrial customers may want to run lines for at least 48 hours. Some problems may only appear during longer runs." That is why “The practical lesson is that application qualification should be treated as part of FOAK ramp-up, not as something fully completed before FID or before startup. FOAK funding and planning should include room for customer-line learning, not only plant commissioning."

The same issue appears in Fibenol's product-market-fit evidence. “A company may engage with customers for years based on early samples, only to discover later that the final industrial product has different characteristics. The early work still builds relationships and customer familiarity, but companies must not overpromise before they know what the industrial plant will actually produce." This is not a negative finding. It is a sequencing lesson. Early customer work is valuable, but it must be framed as preparation until industrial quality, repeatability and delivery reliability are proven.

Exhibit 10: Transferable offtake measures

Structured commitments, application qualification and diversified demand strengthen offtake bankability.

	Measures	Why it matters
1	**Classify customer evidence by maturity.**	Interest, samples, trials, qualification, conditioned commitments, deliveries and repeat orders carry different financing value.
2	**Convert soft interest into structured commitment where feasible.**	Binding or conditioned offtake, including conditions precedent tied to defined milestones, can strengthen FID evidence while allocating remaining FOAK uncertainty between producer and customer.
3	**Build demand across the stakeholder value chain.**	New materials often need converters, brands, retailers and application partners to work together before market pull becomes real.
4	**Diversify committed demand where possible.**	A broader portfolio can reduce exposure to one customer, one application or one product path during ramp-up.
5	**Turn willingness to adopt into rewarded market behavior.**	Customer demand can exist before deployment reaches scale. Clear market recognition and incentives for renewable solutions help convert that willingness into purchasing decisions and repeat demand.

Offtake evidence carries a positive but disciplined message. Demand does not need and cannot wait until every FOAK uncertainty has disappeared. It can be built earlier through customer engagement, application testing, conditioned commitments and value-chain orchestration. But it becomes commercially valuable only when it is tied to qualification, delivery capability and realistic ramp-up. Finance carries the proof curve, feedstock stabilizes the learning, and offtake turns industrial output into customer evidence. The remaining question is what the wider system must do so that these project-level measures become easier to repeat. That is the role of regulation and policy.



Regulation and Policy

Sustainability strengthens demand only when recognition, economics and customer decisions align.

Finance, feedstock and offtake are project-side disciplines. Regulation is different. Projects can navigate regulation, prepare sustainability evidence, manage certification and engage with public frameworks, but they cannot create the rules that determine recognition, eligibility, demand certainty or customer claims. Regulation affects both production and products: the former concerns permits to build and operate the plant, including environmental and safety requirements. The latter concerns the applicable registration, safety and application-specific requirements for placing the resulting material on the market and using it.

For a new bio-based industry, regulation is therefore not a fourth project success factor. It is the market framework around the projects. It determines whether the sustainable value created by FOAKs can be recognized by customers, accepted by financiers and repeated by the next wave of investors.

A central cross-industry opportunity is the clear recognition of bio-based carbon.

This directly influences customer adoption, the substantiation of product claims and the investment case for scaling. Customers may be ready to adopt bio-based solutions, but final decisions can slow when the value of bio-based carbon is not clearly recognized in regulatory and market frameworks. This broader market experience is expressed clearly by UPM: “However, scaling is still constrained, customers are ready to adopt, but uncertainty around how bio-based carbon is recognized in regulation slows final decisions." The issue is therefore not a lack of customer interest. It is whether renewable carbon can be translated credibly into product claims, carbon accounting and procurement decisions, and thereby into investment confidence for further deployment.

That is why recognition, claims and predictable frameworks sit together. The same exchange defines the system requirement in practical terms: "To unlock full scale, the system must provide:
• clear EU recognition of bio-based carbon
• alignment between carbon accounting and product claims
• predictable regulatory frameworks" This is not abstract policy language. It describes the bridge between sustainable product value and the customer's ability to act on that value.

Bio-based content, demonstrated life-cycle environmental benefits and product claims have to be distinguished; bio-based origin alone does not establish a lower life-cycle carbon footprint.

The second regulatory issue is reward. The evidence is clear that industry does not scale renewable solutions simply because they are renewable. "The broader insight is systemic: Industry does not scale what is not rewarded. Renewable solutions will scale fastest when they become the default choice rather than the alternative." Sustainability value must become actionable in customer economics, public procurement, mandates, targets, green claims or other demand signals. Otherwise, the market can continue treating a lower-carbon product mainly as a higher-cost substitute.

Fibenol clarifies the same point from the business-plan side. "When Fibenol made plans around 2018, the team expected stronger support for sustainable materials, mandated markets, and CO_2-related pricing or sustainability premiums. These premiums are not present as expected, and the market is currently based only on price competition." This clarifies the commercial condition for scale-up.

"If policy and market structures do not turn sustainability into payable demand, developers and investors should not build their base case on assumed green premiums."

The customer-side mechanism is equally direct. "If customers need to change their process, invest in new equipment, adjust logistics, or accept extra operating complexity, they will not automatically pay more for the

biobased alternative. The supplier may need to sell near the incumbent price, minus the additional costs and risks the customer must carry. Without regulation, mandates, customer willingness to pay, a clear enforceable mechanism, or a committed buyer, the business plan should not rely on assumed green premiums." This sentence is critical because it links policy, customer economics and offtake. It shows why a sustainable product may still struggle if the customer must carry switching cost without a corresponding commercial reward.

Public policy can create demand space, but application proof still wins the order. The Avantium evidence states the balance well: "The broader policy lesson is that biobased content targets or mandates would create demand certainty in a similar way to fuel mandates. It was described as a wish for the whole biobased economy. However, demand certainty alone is not enough. Even if policy creates the market space, Avantium still has to prove that customers will choose polyethylene furanoate (PEF) in each specific application. Policy creates demand space; application proof wins the order." Regulation can improve the conditions for market formation, but it cannot remove the need for product performance, qualification and customer acceptance.

Exhibit 11: What enabling regulation does in a FOAK context

Policy turns bio-based value into market pull and economic FOAK deployment.

Policy function	Practical effect in FOAK deployment
Recognition	Allows customers and investors to value bio-based carbon and renewable content.
Certification simplification	Reduces administrative drag and speeds customer decisions.
Green-claims clarity	Makes sustainability communication more explainable.
Demand signals	Converts sustainability value into market pull.
Eligibility clarity	Helps public and private finance assess projects consistently.
Route-aware support	Recognizes that higher-risk sustainable feedstock routes may need dedicated market-formation tools.

Certification and traceability are another example of regulation as operating architecture. The Leuna evidence states that “Policy frameworks have been critical enablers, but also introduce friction. Key bottlenecks today include:

• limited mutual recognition across certification systems
• high administrative burden for traceability
• infrastructure constraints"

The practical consequence is not only paperwork. Greater mutual recognition between certification schemes and more digitalized traceability systems could reduce duplication, simplify implementation and accelerate deployment while maintaining the same sustainability requirements.

Fragmented certification and heavy traceability requirements can delay customer acceptance, weaken claims confidence and increase the burden that each FOAK has to carry individually.

The corresponding measures are concrete. “To accelerate similar projects, the most impactful improvements would be:
• harmonization of requirements of certification systems
• simplified and digitalized traceability systems
• targeted investment in regional logistics infrastructure" These are not requests for regulatory relaxation. They are requests for regulatory productivity. A system can remain rigorous and still become easier to navigate.

A further regulatory challenge concerns feedstock categories. The evidence shows that feedstock classification can affect customer perception, finance eligibility and public acceptance even when the physical feedstock route is technically manageable. “The formal eligibility change does not automatically remove the perception problem. The point was that first generation may now be allowed, but communication around it can still carry a “yes, but" character. Customers and financiers may continue to treat first-generation feedstock as less attractive even after formal eligibility improves. The practical lesson is that FOAK companies must manage both formal eligibility and stakeholder perception. A rule change can reopen funding options, but it

does not immediately change how brands, retailers, banks or society view 1G inputs." Formal eligibility and market legitimacy are connected, but they are not the same.

The evidence points to a more useful framing. "The first generation versus second generation terminology creates a commercial and policy burden. The more relevant question should be whether the feedstock is sustainably sourced and efficiently used." This does not dismiss feedstock sustainability. It sharpens it by focusing on sourcing quality, resource efficiency, conversion efficiency, regional availability and total sustainability performance.

The same logic appears from the lignocellulosic side. "The bioeconomy cannot be built mainly on waste and residues. Large-scale biorefineries also need sustainably managed forest-derived woody biomass. Lignocellulosic biorefineries need stronger dedicated market support; without mandates, premiums or policy mechanisms, they struggle to compete against established routes and first-generation sugar-based options." A realistic bioeconomy cannot rely only on the most politically attractive feedstock narratives. It needs sustainable resource pathways that are technically, commercially and regionally workable.

For higher-risk routes, market formation matters directly to financeability. "The industry needs a dedicated market mechanism, mandate, or support structure to help lignocellulosic sugar and lignin-based biorefineries attract finance. Without that, they compete against cheaper, established routes while carrying higher technology, market, and ramp-up risk." Public policy does not need to underwrite every risk.

Where sustainable routes carry higher technology, market and ramp-up risk, policy can help create demand conditions that private finance can recognize.

The policy conclusion is sharper than a call for support. The bio-based industries do not scale only because projects prove that a technology can work. They scale when regulation helps turn that proof into recognized market value, credible customer claims, financeable demand and executable deployment conditions. Without that link, each FOAK has to carry too much of

the market-formation burden itself: explaining why its carbon value counts, why its feedstock route is legitimate, why customers can defend the claim, why financiers can trust the demand signal and why a higher-risk sustainable route should not compete only on incumbent price.

At the same time, regulation can slow the same transition it is meant to accelerate when recognition, certification, public-finance eligibility, permitting, green claims and administrative processes remain fragmented or difficult to apply. The task is therefore not simply more regulation. It is regulation that makes sustainable value easier to recognize, easier to claim, easier to finance and easier to deploy. UPM captured the positive version of that requirement: "Industrial deployment will accelerate only if the system rewards renewable solutions through aligned policy, strong market demand and scalable financing. The priority now is repetition: turning First-of-a-Kind projects into an industrial backbone for Europe."

Exhibit 12: Transferable policy measures

Clear carbon rules and payable demand convert bio-based value into commercial market pull.

	Measures	Why it matters
1	**Clarify bio-based carbon recognition.**	Customers and investors need a recognized basis for turning renewable carbon into product, claims and procurement value.
2	**Align carbon accounting, product claims and customer economics.**	Sustainable value must be usable in customer decisions, not only visible in technical documentation.
3	**Simplify certification and traceability without lowering rigor.**	Harmonized certification and digital traceability can reduce non-value-creating administrative friction.
4	**Replace assumed premiums with payable demand mechanisms.**	Business cases should not rely on green premiums unless customers, mandates, targets or committed buyers make them enforceable.
5	**Move feedstock debate toward sustainable sourcing and efficient use.**	Binary feedstock labels can obscure sustainability performance, resource availability and conversion efficiency.
6	**Create route-aware demand support for higher-risk bio-based pathways.**	Lignocellulosic and other harder routes may need dedicated market mechanisms to attract finance while still carrying technology and ramp-up risk.


FOAK

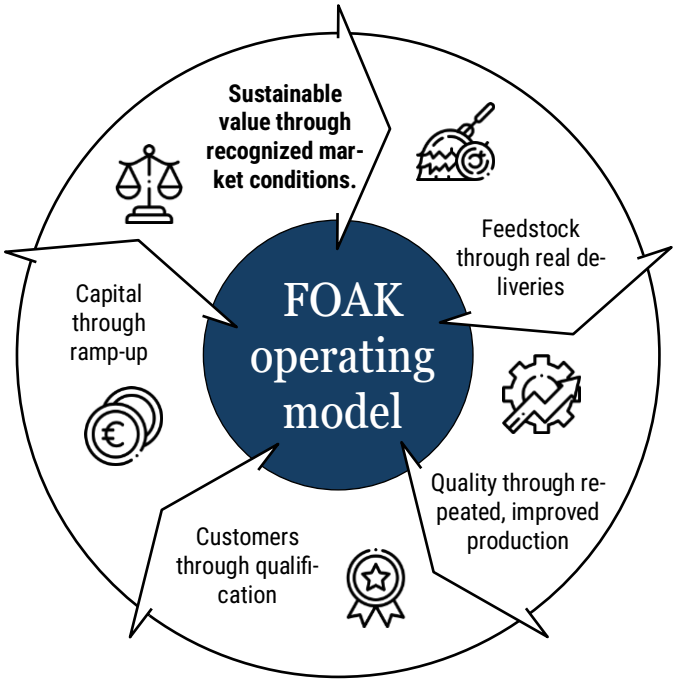
Conclusions

A FOAK creates strategic value when it turns first-plant uncertainty into evidence that the next project can use

The study changes how a bio-based FOAK should be read. A first plant is not only a construction milestone, a technology demonstration or an early production asset. It is the first industrial test of whether a new value chain can hold together under real operating conditions. The decisive question is therefore not only whether the plant can be built. It is whether the wider operating model can stabilize.

Exhibit 13: First-of-a-Kind operating model overview

The weakest link determines the FOAK success.



That is why the three cases are useful precisely because they are different. UPM, Avantium and Fibenol show three different starting positions: a corporate-backed industrial-scale biorefinery, a listed technology-platform scale-

up and a private project-led lignocellulosic biorefinery. Whilst the study does not support one universal FOAK formula, there are lessons-learnt and practical conclusion for future FOAK to consider: different FOAK models face recurring proof challenges at the interfaces between the plant and the systems around it.

Those interfaces are where FOAK uncertainty moves. It appears between the

- constructed asset and commissioning.
- planned feedstock supply and actual incoming material.
- pilot samples and industrial product quality.
- customer interest and customer use.
- sustainability value and what customers, financiers and regulators can recognize.

It also appears between the first plant and the next investment decision. The first plant becomes strategically valuable when those uncertainties are not only survived, but converted into usable evidence.

This is the first discipline the evidence points to: the FOAK must be financed for proof, not only for construction. Physical completion does not end the capital requirement. It opens the phase in which the plant has to be staffed, operated, debugged, modified, commercialized and supported through commissioning and ramp-up. The strongest formulation is direct: “Financing a FOAK is not only about construction capital expenditure (CAPEX), but also about funding the long post-construction phase in which the plant is staffed, operated, debugged, modified, commercialized, and supported through commissioning and ramp-up." The conclusion is not that every FOAK needs the same capital stack.

Every FOAK needs financing logic that matches the length and uncertainty of its industrial proof.

The second discipline is operational: the plant cannot be separated from the feedstock system that feeds it. A sourcing plan can be prepared before operation, but real supply-chain performance becomes visible only when the plant starts receiving, testing, adjusting and reacting to material under

operating conditions. This matters because feedstock quality, logistics, supplier qualification, certification and plant feedback affect process stability. In process-sensitive routes, too much feedstock variability also weakens diagnosis. The first plant creates more useful learning when it controls the initial feedstock window, stabilizes quality and expands optionality later. The point is not to reject future flexibility. It is to sequence flexibility after reliable learning.

The third discipline is commercial: customer interest must become usable demand. Early conversations, samples and trials matter, but they do not carry the same weight as qualified specifications, structured commitments, industrial deliveries and repeat use. Offtake becomes finance-relevant when it is connected to the actual FOAK development path: conditions precedent, application qualification, delivery capability and realistic ramp-up. The interviewed companies therefore do support a simple message:

Customer business matures with the plant.

The fourth factor is external to the project. Unlike finance, feedstock and offtake, regulation is determined by policymakers than project teams. Developers can comply with regulatory requirements, document sustainability and manage certification, but they cannot determine whether bio-based carbon is recognized, which customer claims are permitted, whether projects qualify for public finance or whether policy creates dependable demand. This matters because environmental performance creates commercial value only when customers and investors can recognize and use it in procurement, claims and investment decisions.

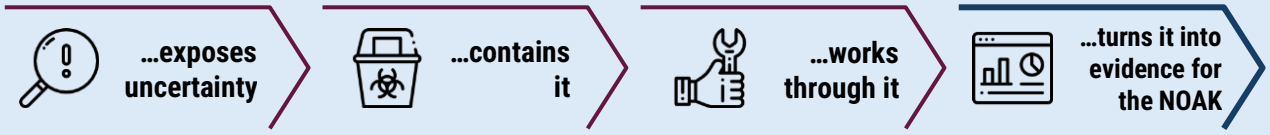
Renewable carbon, sustainable sourcing and lower-carbon production can be technically real and still commercially fragile if customers cannot claim them, financiers cannot treat demand as credible, or feedstock routes remain contested.

The evidence therefore supports the policy conclusion that regulation can make valid industrial proof easier to recognize, easier to claim, easier to finance and easier to deploy. At the same time, regulation can slow deployment when certification systems, traceability requirements, eligibility rules, green claims or administrative processes remain fragmented or difficult to apply. The policy task is not simply more regulation. It is regulation that turns sustainable value into usable market value without adding avoidable friction.

The common thread across these disciplines is not risk removal. It is uncertainty conversion. A FOAK does not eliminate uncertainty before it operates. UPM, Avantium and Fibenol have demonstrated it.

Callout

A successful FOAK...



The evidence can include operating limits, feedstock tolerances, quality data, commissioning lessons, customer qualification results, working-capital needs, realistic timelines and more credible investment assumptions. This is why the first plant should not be judged only by early optimized economics. It should also be judged by the quality of the uncertainty it removes for the next project.

That transfer is the decisive point. A second plant is not automatically bankable because a first plant exists. Feedstock volumes may change. Customer commitments may need new qualification evidence. Financing assumptions may need to be reset. Public-finance eligibility, certification and claims may still require new diligence. The first plant helps the next plant only if its experience is captured as structured evidence: what worked, what had to be

changed, what took longer, what cost more, what customers accepted, what suppliers could deliver and what the next project should not assume again.

This is the practical meaning of repetition. Repetition is not copying the first plant. It is using the first plant to reduce avoidable uncertainty in the next one. A FOAK becomes more than a one-off when its evidence improves the next financing case, the next feedstock strategy, the next customer qualification path, the next ramp-up plan and the next policy discussion. Without that transfer, the first plant may still be important, but its learning remains trapped inside one project.

Callout

The implications for...



…project developers: The first plant should not be overloaded with every future ambition at once. It should be designed and financed to create trustworthy proof: stable operation, controlled feedstock learning, realistic ramp-up, customer qualification and evidence that can travel.



…investors: The investment question is not only whether the plant can be built, but whether the project can survive long enough to become technically stable, commercially qualified and useful for the next financing decision.



…for policy makers: Emerging bio-based industries need rules that help sustainable proof become recognized demand, rather than leaving every FOAK to rebuild the same legitimacy case alone. As successful FOAKs move beyond technology validation, the priority is increasingly to enable rapid replication through aligned market, policy and financing frameworks.

The strategic value of a FOAK lies in converting first-plant uncertainty into transferable industrial proof. Europe does not simply need more first plants. It needs first plants that make the next investment better by establishing

credible evidence on performance, economics, execution and market acceptance. No second plant should have to pay twice for the same lesson.

The move from FOAK to Next-of-a-Kind (NOAK) turns that evidence into industrial advantage. Repetition makes performance more predictable, improves reliability and efficiency, shortens ramp-up and creates the basis for lower capital and operating costs. Financing also changes: decisions can increasingly draw on demonstrated industrial performance rather than assumptions about how a new technology might behave.

From there, repetition becomes industrialization. Individual projects begin to form an ecosystem of experienced engineering teams, specialized suppliers, established supply chains, qualified markets and investable projects. Europe already has a base to build on: CBE JU reports 23 flagship biorefineries and 198 demonstration plants built or under construction, mobilizing €2.5 billion of investment.

The First-of-a-Kind is where that journey becomes real. The Next-of-a-Kind is where it becomes competitive. Repetition is where it becomes an industry.

About the Author



Melich Seefeldt is a senior commercial executive with more than 25 years of international experience scaling low-carbon technologies and developing First-of-a-Kind industrial projects. Across Europe, the Americas and Asia, he has led technology commercialization, market development and strategic alliances in advanced biofuels, e-fuels and next-generation biochemicals.

His executive roles have covered technology licensing, project development, key equipment manufacturing and engineering, procurement and construction. His work has included greenfield and brownfield projects (co-location and refinery-retrofit models), as well as the contractual structures needed to prepare biorefineries for final investment decisions.

He has led cross-functional technical, commercial, financial and legal teams on projects with total investment costs of up to €500 million.

His work has required coordination across industry, private and public finance, and government. He has been a member of the Core Team of the Programming Group of the Biobased Industry Consortium, also contributed to other European industry coalitions and policy work on renewable fuels and bio-based value chains. An invited speaker and panel moderator at international conferences, he is the author of books and articles on scaling climate tech, developing First-of-a-Kind projects and renewable strategies.

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from UPM, Avantium & Fibenol

about feedstock, offtake, financing & regulation.

by Melich Seefeldt

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