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Unlocking Bankability: Targeted Support Mechanisms for Green Chemistry

Identifying and Assessing the Impact of Support Mechanisms on the Bankability of Green Chemistry Projects

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Summary

The fundamental transformation of Europe's chemicals industry from fossil-based to sustainable resources will require significant investments to scale First-of-a-Kind (FOAK) industrial projects. FOAK projects hold the key: they must prove operational performance and build new supply chains to turn national ambitions into tangible production capacity.

While the Netherlands is well positioned to become a leading hub for green chemistry, leveraging its highly-developed logistics infrastructure, integrated industrial clusters, and strong connectivity to Germany and Belgium, FOAK green chemistry projects face significant challenges in reaching Final Investment Decision (FID) and attracting private capital. High capital requirements and significant risks across the value chain often result in a risk allocation stalemate, limiting bankability and making projects difficult to finance under conventional project finance models, which rely on proven performance and stable cash-flow generation. As a result, access to large-scale private investment remains constrained, creating a bottleneck to project scaling and the broader industrial transformation.

Large-scale FOAK deployment will require support mechanisms to feasibly derisk projects and unlock private sector financing. FOAK success creates data and replicability, reducing the perceived risks for subsequent projects and enabling Next-of-a-Kind (NOAK) project development.

This study therefore investigated:
- Business case risks along the value chain for FOAK green chemistry projects
- High-priority support mechanisms for overcoming core bankability constraints

Financing Roundtables with Experts to Identify High-Impact Support Mechanisms

This study combined insights from existing TNO studies, a series of expert interviews and two Financing Roundtables: (i) biomass gasification to methanol and (ii) polylactic acid (PLA) production. Drawing on these complementary perspectives, the study identifies key financing bottlenecks, evaluates the effectiveness of different support mechanisms, and prioritises those with the greatest potential to materially improve project bankability.The findings from the study can also be applied more broadly to the scaling of similar value chains, such as bio-based or synthetic fuels and circular value chains.

Achieving Bankability Requires Targeted Support Mechanisms that Support Market Creation, De-Risk Ramp-Up, and Unlock EPC Participation

A key prerequisite for moving green chemistry projects forward is the **creation of a viable market** for absorbing higher-cost, sustainable products. Without sufficient and predictable demand, bankable business cases cannot be established. Insights from both the expert discussions with financiers and the business case analysis indicate that secure, long-term revenue streams based on stable offtake is a stronger determinant of bankability than once-off reductions in upfront capital costs.

While Capex subsidies and loan guarantees can improve project economics and reduce financing costs, they generally do not resolve the underlying challenge of insufficient cash flow

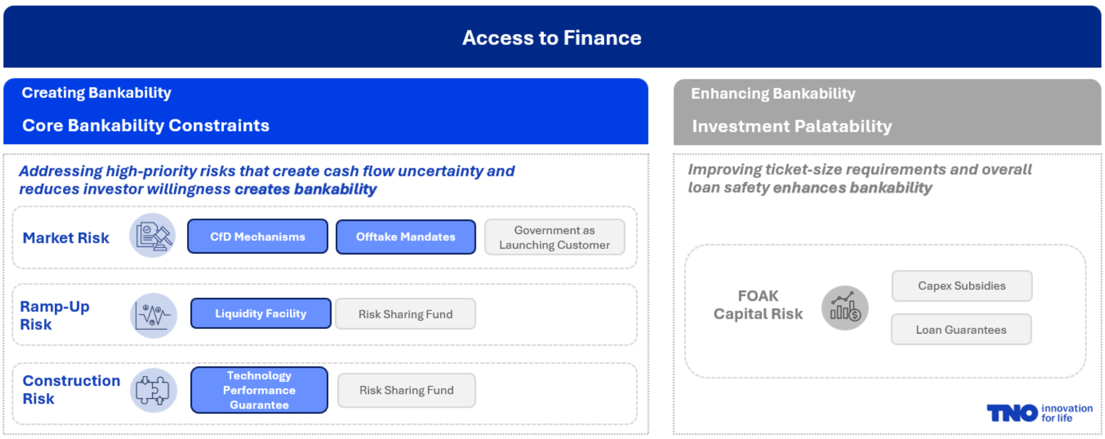
visibility and uncertain market demand. In practice, market demand based on stable, enforceable **offtake mandates**, for example, ReFuelEU Aviation sustainable fuel blending obligations or PPWR recycled plastic content requirements, will be ramping up in the coming years towards 2050. Alternative market creation or revenue stabilization mechanisms for FOAK projects are therefore key to support sufficient offtake in the short-term. Instruments such as **Contracts for Difference** (CfD) mechanisms or strategic government procurement can serve as short-term bridging solutions, enabling projects to have stable revenue streams while EU-level offtake mandates create structural, long-term demand. Although CfD mechanisms improve revenue stability for produced volumes, revenue risk associated with the facility not ramping-up to sufficient production capacity within the planned timeframe still remains.

A second structural barrier therefore relates to the **ramp-up phase**, where delays and cost overruns remain inherently unpredictable for FOAK projects. This leads to uncertainty in the ramp-up and quality of production volumes and subsequent cash flow generation. As a result, project developers are unable to completely plan for these risks, and private investors and lenders are generally unwilling to underwrite open-ended exposures with unpredictable cash flows. A dedicated **liquidity facility** therefore emerges as a key enabling instrument, providing temporary cash flow support to bridge this phase and prevent otherwise viable projects from failing due to liquidity constraints before reaching stable operations.

Thirdly, a fundamental tension in the **allocation of technology and construction risk** was highlighted. Lenders typically require turnkey performance guarantees from engineering, procurement, and construction (EPC) contractors to ensure predictable timeframes and initial operating performance. For FOAK projects where benchmarks are not yet available, EPC contractors are often unable to assume these risks in full, particularly where technology performance remains unproven at scale. This creates a structural mismatch between lender requirements and market willingness to absorb risk. Addressing this gap requires alternative risk-sharing mechanisms, such as EPC co-investment ("skin in the game"), a **technology performance guarantee fund**, or the development of third-party technology insurance solutions that can partially underwrite performance risk.

Finally, while instruments such as **Capex subsidies and partial loan guarantees** can improve project economics and make projects more palatable for investors, they **do not fundamentally change the underlying risk profile**. These instruments enhance bankability, but do not necessarily create bankability. As a result, they are **unlikely to be sufficient** on a standalone basis for unlocking large-scale private financing for FOAK projects.

Overall, **creating bankability** for FOAK projects requires a combination of support mechanisms that address three critical conditions simultaneously: **(i) creation of a viable market for sustainable products, (ii) coverage of unpredictable ramp-up risks,** and **(iii) feasible allocation of technology and construction risk.**



Priority Support Mechanisms to Unlock Bankability for Green Chemistry

Identified high-impact support mechanisms for improving the bankability of green chemistry projects are outlined in the table below. Support mechanisms shown in blue are most targeted towards resolving the core bankability constraints described above. This selection is based on existing TNO studies [1] [2], expert interviews, the combined findings from the discussions during the Financing Roundtables and the business case modelling. Focus is placed on support mechanisms that can complement rather than replace private financing by addressing clearly identifiable market failures and residual risks.

Support Mechanism	Risk Addressed	Effect
Market Creation		
Offtake mandates	Offtake and willingness to pay risk	Creates demand and enables revenue generation
Government as a launching customer & strategic public procurement	Offtake and willingness to pay risk	Secures offtake and revenue streams
Direct Financial Support		
CfD mechanisms	Willingness to pay risk	Provides revenue stabilization
Capex subsidy	FOAK capital risks	Lowers required debt and equity funding
Liquidity facility	Operating performance risk	Provides liquidity during ramp-up and decreases risk of default on debt repayments
Guarantees		
Loan guarantee on project-level	FOAK capital risks	Reduces repayment risk for lender
Loan guarantee on portfolio-level	FOAK capital risks	Reduces repayment risk for lender
Technology performance guarantee	Technology and construction risk	Enables provision of technology performance guarantees (from EPCs) and reduces repayment risk for lender
Risk sharing fund	Technology and operating performance risk	Creates a market-based financial buffer and collective interest in successful project delivery
Case-Specific Policy Support		
Case-by-case support	Value chain risk, policy/regulatory risk	Targeted government support to absorb residual risks on a case-by-case basis

The Financing Roundtables allowed for findings to be validated and to jointly identify and prioritise the highest-impact support mechanisms for further development. Actionable support mechanisms for the Nehterlands are further discussed below:

Bridging revenue stabilization through CfD-like support

Revenue certainty is an essential determinant of bankability. CfD mechanisms aim to subsidize the gap between market price and production cost, where sustainable alternatives, like bio-methanol and PLA, typically have higher production costs and are unable to compete with fossil-based products in traditional markets. This type of instrument covers the unprofitable margin and creates revenue certainty. Existing CfD-like instruments in the Netherlands, like SDE++ and the NIKI subsidy scheme, could be expanded to provide more comprehensive support for the green chemistry sector.

Impact: Allows sustainable products to be absorbed in existing markets through subsidizing the unprofitable margin, thereby reducing market risk and improving long-term revenue stability for project developers and financiers.

Government-backed liquidity facility

FOAK projects face substantial uncertainty during the ramp-up phase, where facilities are operational but undergoing optimization to reach high-yield and stable production. Delays in reaching operational milestones can create cost overruns and liquidity shortages, while commercial lenders and equity investors are often reluctant to provide additional financing at this stage. A dedicated ramp-up liquidity facility run by public finance institutions or public intermediaries could provide temporary financing to bridge this gap. Structured as a loan or revolving credit line, the facility could offer flexible repayment terms, be subordinated to senior debt, and carry below-market interest rates. This would enable projects to cover cost overruns and working capital needs during ramp-up to bridge unexpected funding gaps. Access should be limited to fundamentally viable projects that have passed robust technical, financial, and commercial due diligence. To maintain aligned incentives, project sponsors should be required to co-invest alongside the facility.

Impact: Prevents short-term liquidity issues from derailing otherwise viable projects to reduce project failure risk, thereby protecting both private and public capital already committed.

Capex support + technology performance guarantee fund

A Capex subsidy combined with a technology performance guarantee fund can create a complementary de-risking package that addresses both upfront financing constraints and downstream technology performance and EPC participation risk. Capex support improves project economics by reducing upfront investment needs, while a technology performance guarantee fund enables EPC participation by backstopping residual technology performance risk that exceeds the EPC contractor’s acceptable risk exposure. A technology performance guarantee fund could operate as a pooled risk-sharing mechanism, where multiple projects access a shared facility. EPC contractors would retain a meaningful first-loss position, while the fund covers residual performance liabilities beyond a predefined threshold, enabling EPC participation. Public capital could take a subordinated position alongside private financiers and insurers, with EPCs paying a risk-based premium to maintain aligned incentives and support partial cost recovery.

Impact: Reduce upfront investment needs and enable EPC participation in performance guarantees, thereby lowering overall project costs and improving project risk profile.

Case specific policy support for strategic FOAK projects

Case-by-case support mechanisms can be designed specifically for select strategic FOAK projects that are close to a viable, but not yet bankable, business case. Support is based on residual risks that remain after standard risks have been allocated to market parties and may include both financial and non-financial support mechanisms. This arrangement could follow an orchestrating format, namely policy makers, various financiers, and industry actors work together towards bespoke support instruments that address the main bottlenecks for specific cases. In practice, public institutions can place targeted financial support, such as guarantees, tailored subsidies, or subordinated financing at precise points in the capital stack, aligned with the project's risk profile across development, construction, and early operational phases. Under this model, private parties remain leading in financing, while government takes a balancing role by only stepping in where absolutely necessary, with minimal capital, and only alongside existing and new private financiers. Non-financial support may focus on increasing investor confidence through resolving policy or regulatory bottlenecks and connecting value chain segments and stakeholders. The aim of the case-by-case approach is to shorten the lead time between technology development and project deployment by enabling critical milestones to be achieved earlier, reduce key risks more quickly, and capture market opportunities in a timely manner.

Impact: Accelerates FID by resolving project-specific bottlenecks.

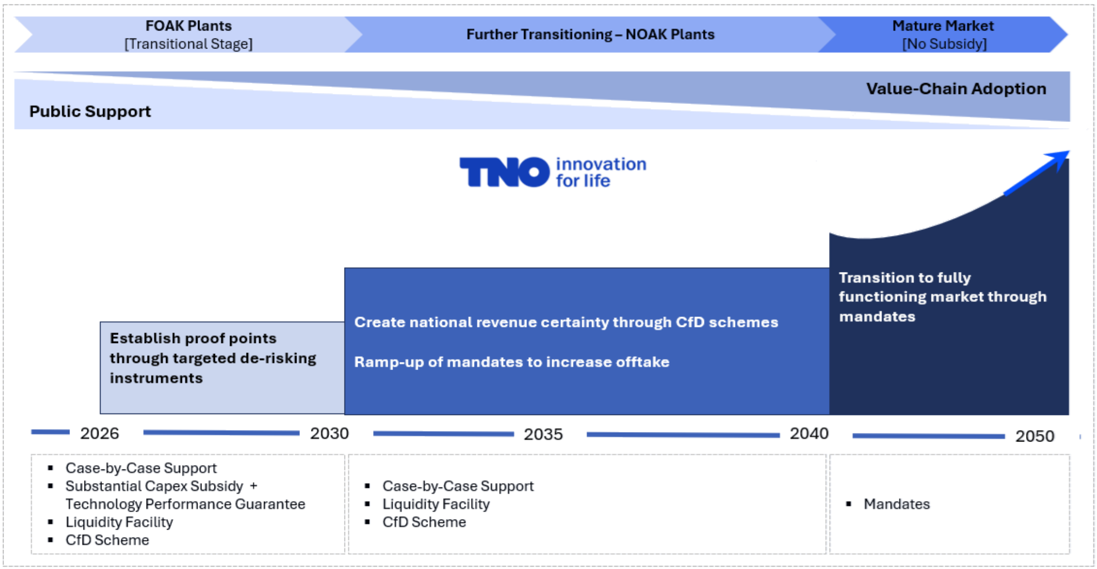
Public Support Need Decreases as FOAK Proof-Points are Developed

The high-priority support mechanisms described above could play different roles at different stages of project deployment and value chain development, from FOAK projects to NOAK projects to a fully functioning market.

In the short-term, targeted public funding support will be needed to address FOAK-specific technology, ramp-up, and market risks. Technology risk and ramp-up support for initial projects should create proof-points and benchmarks to reduce the risk profile of subsequent projects. Initial revenue stability can be bridged through targeted CfD-like mechanisms, double-sided auction mechanisms, or guaranteed offtake from state-backed entities..

After initial FOAK projects come online and NOAK projects begin planning, targeted derisking instruments may still be required. However, as NOAK projects benefit from the learnings and reference points created by FOAK projects, this will be required to a lesser extent. Public capital should play an increasingly smaller role as NOAK project deployment increases. As market regulation and subsequent visibility improves, more comprehensive CfD-like schemes could be deployed to allow larger volume of products to be absorbed by the market while offtake mandates continue to ramp-up.

In a fully functioning market in which multiple NOAK projects are operating and new value chains are established, projects should be commercially viable without direct public funding support. Offtake mandates create sufficient demand and willingness to pay. At this stage, private capital should be able to finance projects on standard market terms.



Moving Forward

As a next step following the Financing Roundtables and study summarised above, the Ministry of Economic Affairs and Climate Policy, together with Invest-NL and key stakeholders from the financial sector, will further develop the identified high-priority support mechanisms. The focus will be on translating the identified support mechanisms into concrete and actionable instruments that can effectively address the key bankability barriers facing FOAK green chemistry projects.

This next phase will involve evaluating how the proposed support mechanisms can best fit within existing and upcoming policy frameworks, financing instruments, and public investment structures. Particular attention will be given to implementation feasibility, institutional ownership, required public-private coordination, and alignment with broader societal objectives.

Contents

1 Background to Financing Green Chemistry and Aim of Study

Under the Clean Industrial Deal (CID), the EU is seeking a new balance between achieving climate goals for 2050 and maintaining industrial competitiveness and strategic autonomy. To meet European and national climate neutrality targes and conform to the strengthening of the EU ETS, fossil-based resources need to be displaced by sustainable resources in the chemical sector through mobilizing new industrial assets and repurposing brownfield infrastructure. This calls for large-scale deployment and financing of innovative technologies for converting biomass, waste, and CO_2 resources into sustainable commodity chemicals, like sustainable methanol, Fischer Tropsch liquids, ethanol, pyrolysis oil, and their derivatives, as well as sustainable plastics, like bio-PET, PEF, and PLA. This reduces Europe's fossil input while reinforcing industrial resilience.

Europe is relatively advanced in innovation and early demonstration. Technologies for biomass gasification to methanol and PLA (bioplastics) production are largely proven at small to medium scale pilot and demonstration projects. What is now needed are effective mechanisms to accelerate large-scale deployment and mobilise financing for those technologies that are largely already proven [1].

The Netherlands is well positioned to become a leading hub for green chemistry in Europe. The country benefits from highly developed port infrastructure, extensive pipeline networks, inland waterways, and rail networks, with strong connectivity to Germany and Belgium. In addition, the Netherlands hosts several highly integrated industrial clusters and substantial legacy infrastructure. Together, these strengths provide a strong foundation for the transition towards a green chemistry hub, leveraging existing logistics infrastructure for the import of sustainable feedstocks and export of products, while utilising existing industrial infrastructure for the production of green molecules.

However, next generation green chemistry production assets are typically highly capital intensive and face significant risks along the value chain. This creates a barrier for accessing large-scale, low-cost financing and stalls the installation of production capacity needed to meet European and national goals [1].

1.1 Securing Financing is a Key Bottleneck for Scaling Sustainable Technologies

This transformation of the industrial system from fossil-based feedstock to sustainable feedstocks requires large-scale deployment and financing of multiple first-of-a-kind (FOAK) commercial-scale projects and value chains to build momentum and pave the way towards meeting European goals and protecting national interests. FOAK projects create data and replicability, reducing the perceived risks for subsequent projects and enabling Next-of-a-Kind

(NOAK) project development [1]. Leveraging private capital will be instrumental to a successful transformation, as private capital is foreseen to finance ~70% of the pipeline of Dutch investment plans, as per the Wennink report [3].

Three main pathways have been identified in the transition towards sustainable carbon-based chemistry [4], as shown in Figure 1.1 and Table 1.1 below.

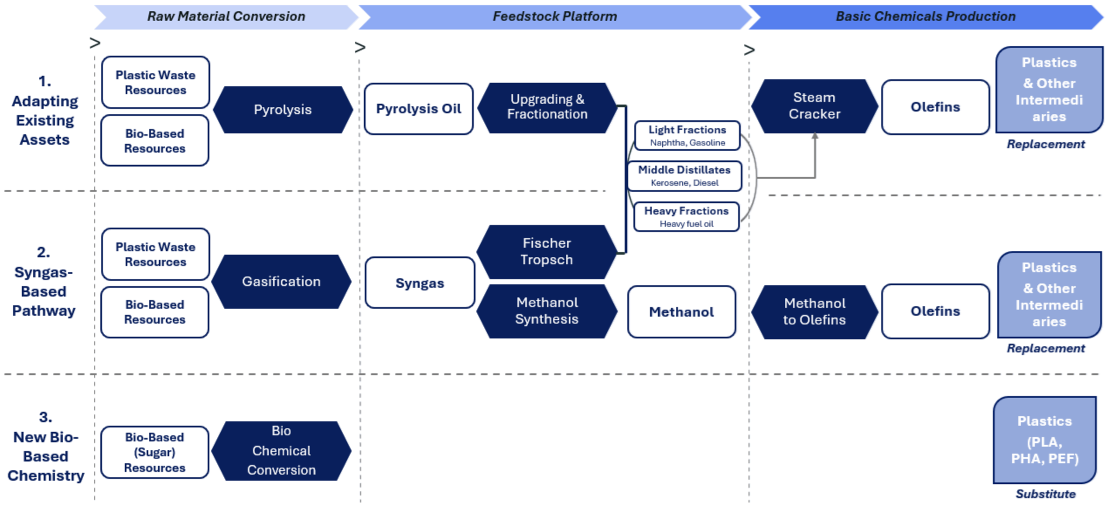


Figure 1.1: Summary schematic of the three main pathways towards sustainable carbon-based chemistry

Despite the urgent need for FOAK projects, these projects face significant challenges in reaching Final Investment Decision (FID) and attracting private capital. FOAK projects are inherently capital-intensive and high-risk, as they require large-scale deployment of new technologies or value chains [1]. The technologies and processes presented in Table 1.1 typically struggle to secure funding for the FOAK phase [4], creating a bottleneck for project scaling and the broader industrial transformation.

Table 1.1: Overview of three main pathways towards sustainable carbon-based chemistry

1. Adapting existing petrochemical assets for sustainable feedstock	2. Syngas based chemistry	3. New bio-based chemistry
High volume	High volume	Lower volume
Focus on adapting existing upstream refining and petrochemical assets	Focus on repurposing and reusing of existing downstream infrastructure, with new upstream infrastructure requirements	New infrastructure required for converting biomass, waste, and CO2 feedstock into replacement or substitute chemical products

1. Adapting existing petrochemical assets for sustainable feedstock	2. Syngas based chemistry	3. New bio-based chemistry
Pyrolysis as a central enabling technology to displace fossil-based crude and naphtha - converts plastic waste or bio-based resources into a fossil naphtha replacement for use in existing steam crackers Steam crackers produce basic chemicals used for plastics and specialty chemicals	Gasification as the core enabling technology for methanol and Fischer-Tropsch platforms - syngas is produced through the gasification of plastic waste or bio-based feedstocks Both methanol synthesis and the Fischer-Tropsch process can result in sustainable plastics and building blocks for specialty chemicals (while also having applications for fuel sector)	PLA, PEF, and PHA as key products - this route relies on converting bio-based resources (mostly sugar) into bio-based plastics that can act as substitutes for traditional plastics
Given that this route relates to adapting/repurposing existing assets – there is a strong role for existing, incumbent industrial players that will likely pursue balance sheet financing	Given that this route will require new upstream production infrastructure – there is growing interest from newer entrants and therefore a need for accessing project finance	Given that this route will require new production infrastructure but is currently smaller scale – there is growing interest from newer entrants not able to rely on balance sheet financing

Pathway 1 involves (complex) retrofits of existing petrochemical assets and Pathway 2 requires new, large-scale gasification infrastructure, both demanding significant upfront investment. Limited operational references and a high CAPEX profiles makes conventional project finance difficult to access, creating a structural financing challenge for FOAK chemistry projects. This challenge affects independent project developers, innovative entrants without an extensive track record, more acutely than existing industrial players who can leverage balance sheet financing and existing operational cash flows. Independent project developers will in many cases need to pursue a project finance structure. Project finance depends primarily on the certainty of cash flows, a criteria that FOAK projects are often not able to meet [1]. As per the Wennink report, € 9,3 billion will be required for greening Pathways 1 and 2 (greening steam crackers, gasification, and methanol to olefins). Projects under pathway 3 are expected to be smaller scale and therefore have a lower CAPEX profile. Pathway 3 projects will also require new production infrastructure combined with limited operational references and new value chains, thereby experiencing similar challenges in accessing low-cost finance. An estimated, € 3,1 billion will be required for Pathway 3 (biobased circular economy) [3].

1.2 Research Aim & Approach

The objective of the research is to identify business case risks and high-priority support mechanisms for addressing business case challenges for green chemistry projects. The research is based on two representative case studies, namely, i) biomass gasification to bio-methanol and ii) PLA production. This provides a structured basis for policymakers and financiers to jointly assess and discuss the effectiveness and feasibility of potential support mechanisms. By explicitly linking interventions to identified risks and bottlenecks, the study is intended to support informed decision-making on how targeted public measures can unlock private investment in projects that serve strategic and national interests.

The research approach centered around the orchestration of ‘’Financing Roundtables’’ that bring together policy makers and various financiers from the private sector from commercial banks, private equity, venture capital, impact debt, and the European Investment Bank (EIB) conducted in collaboration with the Ministry of Economic Affairs and Climate and InvestNL.

The first Financing Roundtable focused on identifying the key financing bottlenecks for FOAK green chemistry projects and mapping potential support mechanisms that could address these challenges. This was based on existing TNO studies on financing and bankability barriers for FOAK chemicals and fuels projects [1] [2].

The second Financing Roundtable focused on prioritising and further working out high-potential support mechanisms in greater depth, including their feasibility and implementation requirements. This built on TNO analysis, bilateral expert interviews and insights from the first Financing Roundtable, with the aim of refining the most promising financial and policy support mechanisms and assessing their impact on the selected case studies. The assessment consisted of i) qualitative analysis based on bilateral expert interviews with stakeholders across the financing ecosystem to validate and refine the identified barriers and potential support mechanisms, and ii) quantitative analysis through the development of a business case and financial model to evaluate the impact of support mechanisms on key investment metrics, like cash flows, Internal Rate of Return (IRR), Net Present Value (NPV), Debt Service Coverage Ratio (DSCR). A business case was modelled for each of the selected case studies based on a techno-economic assessment (TEA) of each conversion process, see Appendix A.1.

The Financing Roundtables allowed for findings to be validated and enabled policymakers and financiers to jointly identify and prioritise the highest-impact interventions for further development.

1.3 Case Studies: Bio-Methanol & PLA

Two case studies form the analytical basis for the study, as illustrated in Figure 1.2 and Figure 1.3:

1) Lignocellulosic biomass gasification to methanol
2) Polylactic acid (PLA) production from first generation sugars

These cases were selected to represent distinct parts of the chemical value chain: bio-methanol as an upstream platform chemical and PLA as a downstream polymer. Together, they form a representative view of the financing challenges in the green chemistry transition. The case studies prioritize larger-scale facilities capable of achieving strong economies of scale to ensure efficient project economics and enhancing market competitiveness. The case studies were selected based on their societal relevance, the scale of the financing bottleneck, technology maturity (TRL), and the degree to which targeted interventions can address identified risks.

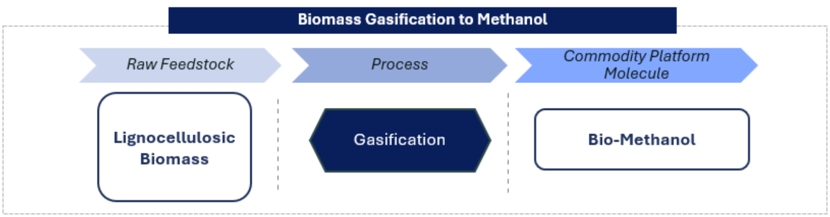


Figure 1.2: Illustration of biomass gasification to methanol process

The domestic production of platform molecules is a key enabler and foundation for a sustainable and competitive industrial system. Methanol is a versatile platform molecule with strategic importance across multiple sectors. It serves as a key building block for sustainable fuels, including maritime fuels and sustainable aviation fuel (via Methanol-to-Jet pathways), as well as for a wide range of chemical value chains, such as olefins (via Methanol-to-Olefins), formaldehyde, and acetic acid. Biomass gasification can displace fossil feedstock from early stages in the chemical supply chain through converting (local) difficult to process lignocellulosic feedstocks into methanol. Securing domestic production capacity for methanol therefore has direct implications for strategic autonomy, as it diversifies and reduces dependence on imported fossil-based feedstocks and supports critical downstream industries.

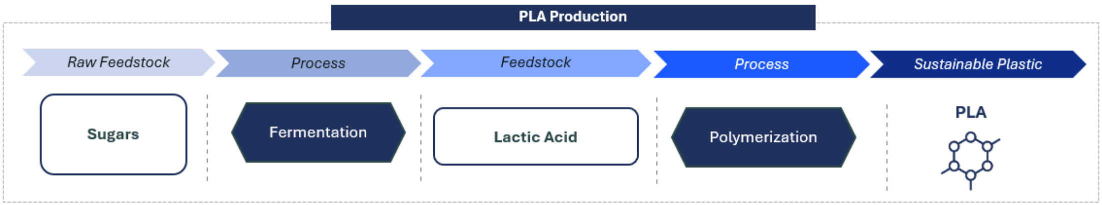


Figure 1.3: Illustration of PLA production process

PLA serves as a key enabler for substituting fossil-based plastics and subsequently displacing fossil-based resources from production chains. PLA can be applied within bulk markets, as a sustainable substitute for fossil-based plastics, as well as in niche markets capitalizing on it's biodegradable properties for specialized uses in the medical and agricultural sectors.

The figure below summarizes the key characteristics of the two selected cases and the parameters used in the business case analysis:

Lignocellulosic Biomass Gasification to Methanol	Sugar Fermentation to PLA
Case Description	**Case Description**
Function: upstream fossil-feedstock replacement for chemicals & sustainable fuel **TRL:** 7-8 **Potential financiers**: commercial & public banks, infrastructure PE funds, asset managers, pension funds **Example projects (NL):** PerpetualNext (220kt @ ~€800m), Gidara Energy (90kt @ ~€250m estimate) **FOAK status:** FOAK for biomass feedstock to methanol	**Function:** downstream fossil-plastic substitute **TRL:** 8-9 **FOAK status:** FOAK for EU, proven at scale in Thailand **Example projects (global):** Total/Corbion (75kt @ ~$140m estimate), Futerro (75kt @ ~€500m) **Potential financiers:** VC, infrastructure PE funds, impact debt funds, venture debt funds, asset managers, pension funds, banks
Case Characteristics and Assumptions	**Case Characteristics and Assumptions**
Case Characteristics and Assumptions: **System boundary:** gasification of biomass, methanol synthesis from syngas **Facility size:** 200kt bio-methanol **Capex:** €822m **Lifetime:** 20 years **Construction period:** 2 years **Ramp-up period:** 25% Y1, 30% Y2, 35% Y3, 90% Y4	**System boundary:** lactic acid production (from 1G sugars), PLA formation **Facility size:** 75kt PLA **Capex:** €257m **Lifetime:** 20 years **Construction period:** 2 years **Ramp-up period:** 30% Y1, 35% Y2, 60% Y3, 90% Y4

Figure 1.4: Summary of case study parameters and assumptions. See Appendix A.1 for techno-economic calculations behind the case characteristics.

The relevance of the selected case studies therefore extends beyond their individual applications. The identified financing barriers are structural in nature and are applicable to a wider set of FOAK projects in green chemistry, sustainable fuels, and circular value chains, especially those developed by independent project developers. The proposed interventions and insights can be considered generalizable across emerging industrial technologies, where similar challenges around FOAK deployment and value chain development affect access to financing.

1.4 Investments in Green Chemistry Require an Interplay Between Public and Private Funding

FOAK green chemistry projects face significant risks across the value chain, from feedstock supply, to construction, to ramp-up, to product offtake. Stakeholders across the value chain, namely feedstock suppliers, original equipment manufacturers (OEMs), engineering procurement and construction (EPC) contractors, project developers, equity providers, debt providers, and government, must each assume a defined share of responsibility. For FOAK technologies and value chains, these risks are often difficult to allocate and residual risks remain, hindering project bankability and often resulting in a risk-allocation stalemate.

This creates a clear role for government to act as a catalyst, using targeted risk sharing and market creating interventions to absorb residual FOAK risks that exceed private sector appetite and thereby unlock the scale of private capital required to accelerate large-scale FOAK rollout. FOAK success creates data, confidence, and replicability, reducing the perceived risks for all subsequent projects and enabling NOAK project development and full industrial rollout.

Government support will be required to create a feasible investment environment for local, sustainable industry projects through i) funding support to derisk investments, ii) creating markets for higher cost, sustainable products, and iii) setting boundary conditions that enable the commercial viability of business cases. When government support is strategically deployed to create enabling conditions and absorb risks that exceed the risk appetite of market participants, FOAK projects can transition beyond pilot phases and attract large-scale private financing [1].

Public capital and government intervention should not be viewed as substitutes for private investment, but rather as catalytic instruments that reduce uncertainty and enable market participation. Well-designed tools can effectively bridge the gap between what the market is willing to finance and the risk profile of early commercial projects. By selectively assuming these residual risks, governments can unlock financing from private lenders and institutional investors, significantly increasing the total capital available for deployment [1].

The transition to green chemistry also presents an opportunity for private financiers: bio-based chemical assets, such as bio-methanol and PLA, require large investment tickets, operate as long-lived, strategically important industrial assets, and, when supported by the right mandates and offtake structures, can deliver stable, infrastructure-like cash flows.

Table 1.2: Summary of opportunities for private investors

Key Opportunity	Description
Large ticket sizes	Bio-methanol and PLA production facilities are highly capital-intensive assets, with individual projects often requiring investment tickets in the hundreds of millions of euros. The high capex intensity requires the deployment of large-scale, long-duration investments aligning with the investment profile of institutional investors seeking sizeable, long-term allocations.
Strategic production assets with long lifetimes	Bio-methanol and PLA plants are capital-intensive, long-lived industrial assets that form the backbone of multiple key chemical products. Once fully operational, they can generate stable, infrastructure-like cash flows over longer time horizons.

Key Opportunity	Description
Stable demand from large, credible industrial offtakers	With the right mandates and incentives in place, long-term offtake contracts can underpin predictable revenues and cash flows. Demand will be driven by basic and specialized chemicals for packaging and consumer goods seeking to decarbonise supply chains, as well as fuel for shipping and aviation in the case of bio-methanol.
Public support to lower risk profile	When targeted public risk-sharing instruments are deployed, residual first-mover risks associated with early projects could be partially absorbed by the public sector. This improves the project's risk profile and enhances risk-adjusted returns for private investors, thereby boosting the commercial feasibility and attractiveness of the business case.

Against this backdrop, the Financing Roundtables for green chemistry has been organized to create and unlock impactful investment opportunities in the chemical sector. The central aim is to identify and design financial and policy interventions that address the financial bottlenecks currently preventing FOAK green chemistry projects that serve strategic and national interests from reaching Final Investment Decision (FID). While bio-methanol and PLA are used as illustrative case studies in this analysis, the identified barriers and proposed support mechanisms are not limited to these specific value chains. The findings in the report are broadly applicable to a wider range of investments in green chemistry, particularly for FOAK and early commercial-scale projects facing similar challenges around market creation, risk allocation, and access to financing.

2 Risks Along the Value Chain

The main financing bottleneck for projects in green chemistry, as with the selected case studies, arises during the transition from demonstration to the commercialization stage. During this stage, both the investment requirement and risk profile are high, leading to bankability challenges and a financing gap. FOAK projects in green chemistry face risks across the value chain, from feedstock supply, to technology risk of the conversion facility, to offtake certainty, as summarized in the figure below. These characteristics make FOAK projects difficult to structure under conventional project finance models, which rely on proven performance and stable cash-flow generation [1].

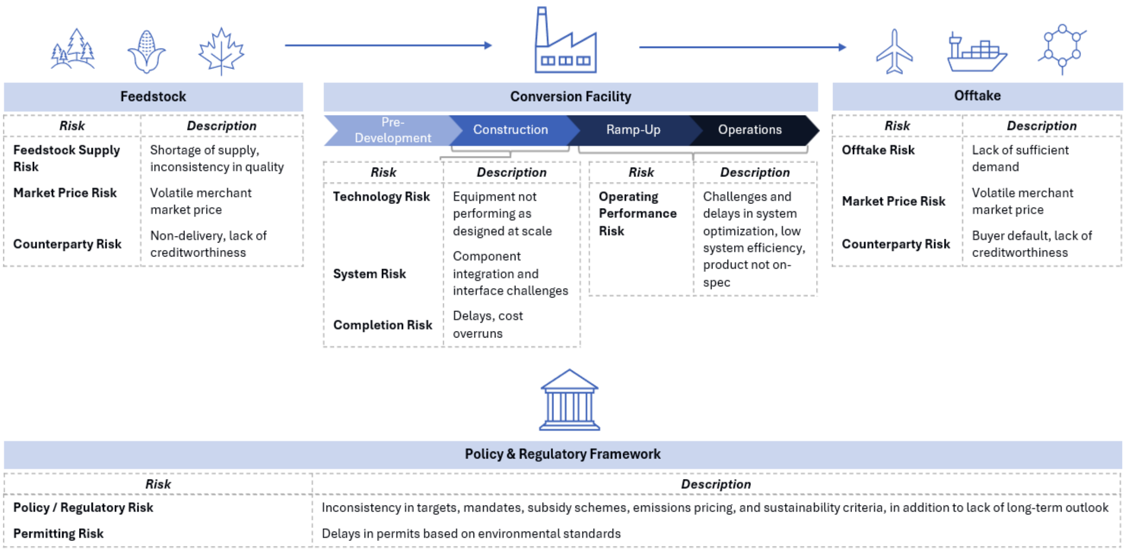


Figure 2.1: Overview of main business case risks across the value chain. Adapted from TNO (2025). Bankability of Defossilised First-of-a-Kind Chemicals & Fuels Production Projects [1].

As a result, FOAK projects in green chemistry face a variety of financing challenges:

- Limited access to large-scale, low cost debt financing, with banks requiring greater equity contributions from credit-worthy project sponsors or project developers ("skin in the game").
- Higher required returns to offset unproven performance and value chain risks.
- Stricter collateral and guarantee requirements from key stakeholders along the value chain to improve certainty of cash flows, with guarantee contracts for FOAK projects typically coming at a higher price than for proven projects with benchmarks.
- Prolonged due-diligence and credit approval cycles, delaying final investment decision and construction.

2.1 Business Case Risks: Biomass Gasification to Methanol

The following section specifies the broad risks from Figure 2.1 to the case of biomass gasification to methanol.

Feedstock supply uncertainty

Biomass gasification will be able to make use of a diverse range of second generation lignocellulosic feedstocks, like wood chips and wood pellets, agricultural residues, forestry residues. Many feedstock supply chains, like for agricultural and forestry residues, are in early development, creating uncertainty around consistency of the supply, quality of biomass, and price of biomass, and leading to a lack of long-term feedstock supply agreements. In contrast, the supply chain for wood chips and wood pellets are more established, with wood pellets already being a globally traded commodity. Scarcity, and therefore pricing, for preprocessed wood pellets from established supply chains as feedstock may rise in the future as demand for bio-based products increases.

Technology risk at conversion facility

Gasification of lignocellulosic biomass feedstock is largely unproven at commercial scale. Potential delays, overruns and a prolonged ramp-up phase for the FOAK projects may be encountered, resulting in higher associated costs. The lack of operating reference plants further increases investor caution, as well as hesitation from EPCs and OEMs to cover technology risks and provide guarantees on equipment and system performance.

Achieving economic production costs for bio-methanol requires large-scale facilities to benefit from economies of scale. Constructing such facilities requires high upfront capital investments. For example, the TEA data developed for this case study estimates that the construction of a 200kt FOAK bio-methanol facility requires approximately ~€823 million in CAPEX. These capital requirements significantly raise the financing threshold and limit the amount of investors able to participate in such large investment tickets.

Offtake and willingness to pay uncertainty

Conventional, fossil-based methanol is already a traded commodity product in large-scale global markets. However, despite bio-methanol being a direct replacement for conventional methanol based on physical qualities, this comes at a higher production cost and is largely unable to compete with fossil-based methanol in these markets. The current bio-methanol market is small in comparison, driven by European greenhouse gas reduction mandates like FuelEU Maritime and voluntary drivers subject to macroeconomic forces that influence the price and offtake potential. The market for bio-methanol remains at an early stage of development, resulting in limited visibility on stable and sufficient demand.

Unlike the fuel sector, which has greenhouse gas based offtake obligations and blending mandates in the form of REDIII, ReFuelEU Aviation, and FuelEU Maritime, the chemical sector has no binding offtake targets for sustainable feedstocks and products, like bio-methanol. The absence of binding substitution requirements leads to a lack of clear demand for sustainable products and uncertainty on price premiums for sustainable chemicals. There is therefore significant uncertainty around long-term, concrete demand and willingness to pay for higher cost sustainable methanol in the chemical sector, as well as in the early phases of the fuel sector where mandated volumes are small and mandates can be met through green molecules beyond bio-methanol.

Key potential offtakers, such as shipping companies, chemical producers, and fuel distributors, are currently hesitant to commit to long-term offtake agreements, a key requirement for investors. This reluctance is driven by uncertainty around future regulatory requirements, the pace of market uptake, and the long-term supply volumes and pricing of bio-methanol. Willingness to pay is limited, as conventional, fossil-based methanol is significantly cheaper. While bio-methanol production costs are expected to decline over time through technology learning, scale-up, and improved feedstock logistics, the current cost differential remains substantial. As a result, fossil-based methanol is expected to remain more cost-competitive, constraining the willingness of offtakers to accept long-term price premiums for bio-methanol without an incentive or obligation to do so.

The current market price of fossil-based methanol is around €598/ton (Contract Price Europe averaged over 2024) [5]. The levelised cost of bio-methanol from gasification illustrated through the TEA in this study (Appendix A.1) is approximately €1279/ton, indicating a substantial cost differential and the resulting business case "as is" not being bankable in existing markets. This leads to a significantly negative net present value (NPV) for the case study.

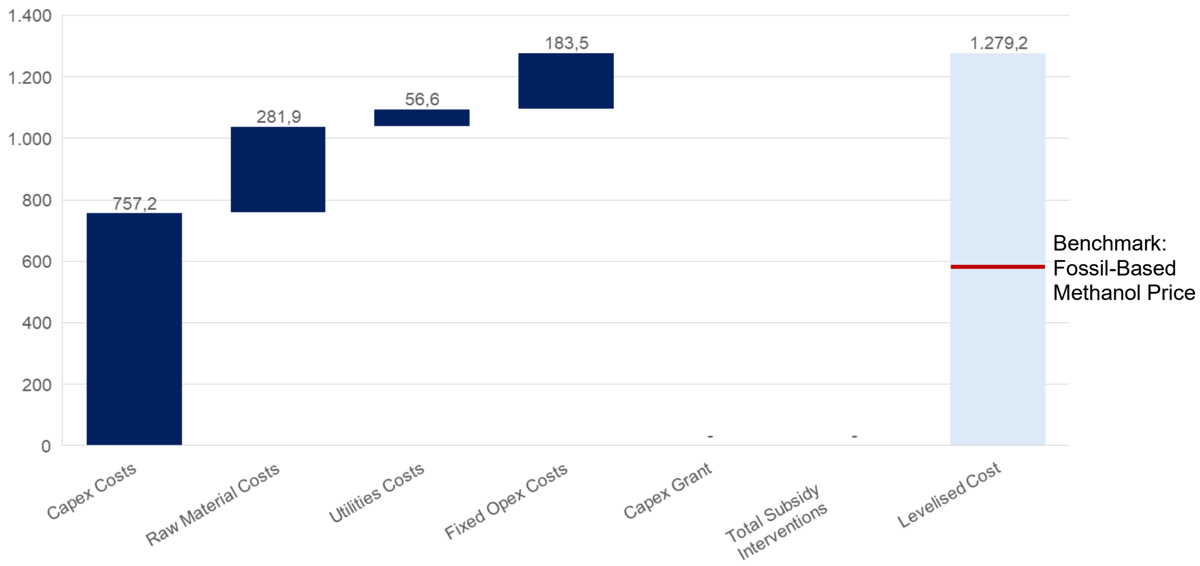


Figure 2.2: Breakdown of the estimated levelised cost of production (LCOP) for the biomass gasification to methanol asset modelled in this study. Note that LCOP is sensitive to feedstock pricing, which can vary highly based on market conditions.

2.2 Business Case Risks: PLA Production

The following section specifies the broad risks from Figure 2.1 to the case of PLA production.

Feedstock supply uncertainty

PLA production currently relies mainly on first generation sugar-based feedstocks, like corn, sugarcane, or sugar beets. While these supply chains are relatively mature and well-established, they are subject to seasonal price fluctuations and broader agricultural market dynamics. Sugar prices in Europe are generally high due to competing demand from different sectors. The lactic acid intermediate for PLA follows the same trend due to having multiple uses, including food additives and pharmaceuticals, which can tighten supply and increase prices. In addition, the large-scale use of first generation, food-competitive feedstocks for industrial purposes, specifically for the transport sector, is currently discouraged at EU level, where the use of waste and advanced feedstocks are being promoted under RED III, creating potential regulatory risk over the long term. This creates uncertainty around feedstock cost stability and long-term project economics.

Technology risk at conversion facility

PLA production form first generation sugars has already been proven at scale in cases outside of Europe. It has been commercially produced and scaled to industrial plants (>~100 kt/year) by NatureWorks based on corn in USA[1] and Total Corbion based on sugarcane in Thailand[2]. Therefore it is considered to be close to NOAK, while not having been proven at scale in Europe. PLA is therefore expected to have comparatively lower technology risk than biomass gasification.

Offtake and willingness to pay uncertainty

PLA has differing physical properties to conventional plastics, mainly biodegradability (under industrial conditions) and lower heat resistance. Biodegradability allows PLA to serve specific use cases in, for example, the biomedical and agricultural sectors, where a price premium for improved performance compared to conventional plastics is typically accepted. PLA can also serve as a substitute for conventional plastics in low temperature packaging applications. However, the large-scale use of PLA as a substitute for cheaper, conventional plastics is associated with uncertainty in terms of offtake volumes and willingness to pay. PLA currently faces a price premium of approximately 1.5–2.0x compared to conventional fossil-based plastics [6] [7]. While demand for sustainable materials is growing, market willingness to pay remains uncertain and fragmented across end-use sectors such as packaging and disposable consumer goods. In the absence of binding mandates, potential offtakers may be reluctant to commit to long-term offtake agreements at price levels required for bankability. This lack of firm, long-term demand visibility increases revenue risk for PLA projects.

While PLA does not have a direct fossil-based substitute, to provide a benchmark, the current market price of polyethylene, a comparable fossil-based plastic, is around €1330/ton (Price Europe September 2025) [6], while the levelised cost of PLA illustrated through the TEA in this study (Appendix A.1) is approximately €2464/ton. The current business case “as is” is therefore not bankable in the absence of firm, long-term green premium certainty for PLA and results in a significantly negative NPV.

[1] NatureWorks operates a 150,000 tonnes per year PLA plant in Blair, Nebraska, USA.
[2] Total Corbion operates a 75,000 tonnes per year PLA plant in Rayong, Thailand.

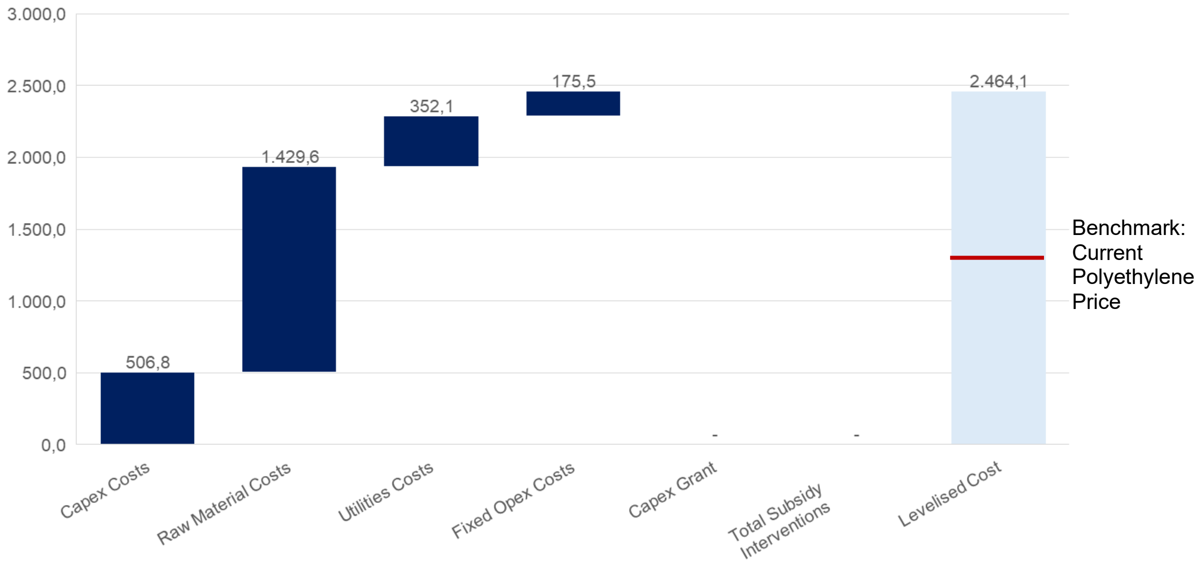


Figure 2.3: Breakdown of the estimated levelised cost of production (LCOP) for the PLA production asset modelled in this study. Note that LCOP is sensitive to feedstock pricing, which can vary highly based on market conditions.

2.3 Effects of Value Chain Risks on the Business Case

The risks outlined above lead to specific financing challenges, as described below:

Increased Capex requirements resulting from FOAK nature

The FOAK nature of green chemistry projects further increases capital requirements relative to NOAK plants. Design immaturity, technology scale effects, system interface challenges and higher contingency allowances all contribute to a FOAK cost premium. As a result, the Capex of a FOAK facility is materially higher than that of a comparable mature or NOAK plant, reducing project returns and increasing financing risk. From the Capex projections in this study, the FOAK nature for bio-methanol leads to a ~1.75x increase in Capex, while for PLA this leads to a ~1.43x increase in Capex, details can be seen in Appendix A1. This highlights the significant cost premium for FOAK projects compared to NOAK facilities.

Prolonged ramp-up for FOAK projects

After the facility has reached mechanical completion and commissioning and start-up has taken place, risks remain around ramping-up the facility to reach desired full load hours and produce on-spec products within the desired timeframe. As a result there is a risk that the ramp-up phase consumes more funds and time than planned and revenue from initial product sales is delayed or below expectation due to sub-spec quality or low uptime. This can lead to liquidity stress for the project developer and hinder debt repayment capacity for the lender. For bio-methanol, the assumed capacity utilization in the first year of production is ~25%, 30% in year 2, and 35% in year 3. Given that PLA production is more proven than biomass gasification, for PLA this is assumed at ~30% in year 1, 45% in year 2, and 60% in year 3. These figures illustrate the prolonged and uncertain ramp-up profile typical for FOAK sustainable green chemistry projects, where delayed stabilisation of operations further amplifies financing risks and working capital requirements.

High financing costs

The combination of technology risk, market uncertainty, and high capital intensity leads to FOAK green chemistry projects facing elevated financing costs. Commercial lenders apply higher risk premiums or are unwilling to provide debt financing altogether, forcing projects to rely disproportionately on (more expensive) equity or subordinated capital. This results in a higher weighted average cost of capital (WACC), reducing project attractiveness and viability.

3 Support Mechanisms to Improve Green Chemistry Business Cases

As described above, typically, the business case for green chemistry projects face residual risks and strained project economics. Support mechanisms were therefore developed based on existing TNO studies [1] [2], expert interviews and the findings from the discussions during the first Financing Roundtable. Support mechanisms are categorised according to i) market creation, ii) direct financial support, iii) guarantees, and iv) case-specific policy support. All support mechanisms are targeted at fundamentally viable projects that are constrained by bankability challenges, rather than being used to support projects with structurally weak business cases.

The table below provides a summary of the risk addressed and effect of each support mechanism on business case metrics. During the second Financing Roundtable, support mechanisms considered to have the most significant impact on improving bankability were selected. In the sections below, these high impact support mechanisms are highlighted in **blue.**

Table 3.1: Summary of support mechanisms, with high-priority support mechanisms highlighted in **blue**

Support Mechanism	Risk Addressed	Effect
	Market Creation	
Offtake mandates	Offtake and willingness to pay risk	Enables revenue generation
Government as a launching customer & strategic public procurement	Offtake and willingness to pay risk	Provides reliable revenue streams
	Direct Financial Support	
CfD mechanisms	Willingness to pay risk	Provides revenue stabilization
Capex subsidy	FOAK capital risks	Lowers required debt and equity funding
Liquidity facility	Operating performance risk	Provides liquidity during ramp-up overruns and decreases risk of default on debt repayments
	Guarantees	
Loan guarantee on project-level	Value chain risk	Reduces repayment risk for lender
Loan guarantee on portfolio-level	Value chain risk	Reduces repayment risk for lender
Technology performance guarantee	Technology risk	Enables provision of technology performance guarantees (from EPCs) and reduces repayment risk for lender

Risk sharing fund	Technology and operating performance risk	Creates a financial buffer and collective interest in successful project delivery
Case-Specific Policy Support		
Case-by-case support	Value chain risk, policy/regulatory risk	Targeted government support to absorb residual risks for specific cases

3.1 Market Creation

Creating stable, predictable demand that allows projects to derive revenue for their sustainable chemical products in the market is foundational for positive project economics and a bankable business case. Long-term offtake at predictable pricing must be secured to improve access to private sector finance. The results indicate that there are multiple methods for creating a market across EU and national levels.

Offtake Mandates:
Main risk addressed: offtake and willingness to pay risk

Regulatory requirements that create demand through obligating market parties to absorb minimum shares of sustainable alternatives, such as blending mandates, creates structural demand and long-term market visibility. This encourages willingness to pay for more expensive, sustainable products and enables businesses to derive value for their products from the market. Mandate mechanisms should be enforced by stringent penalties that are higher than the cost of compliance and underpinned by clear regulatory timelines. This allows investors to plan around the duration and phasing of mandated volumes.

Mandate frameworks are currently being put in place for the transportation sector. These are in the form of greenhouse gas emission intensity reduction targets, as with the maritime sector, or volume based blending mandates, as with the aviation sector. As mandated volumes and obligations ramp-up in the coming years, more substantial market uptake will be created for sustainable fuels. See examples below:

- FuelEU Maritime sets binding GHG reduction targets that ramp-up towards 2050 (2% by 2025, 6% by 2030, and 80% by 2050). These targets and associated penalties create a market for low-carbon shipping fuels, like bio-methanol, ammonia, or bio-LNG.
- ReFuelEU Aviation sets binding blending mandates for SAF, which ramp-up towards 2050 (2% by 2025, 6% by 2030 and 70% by 2050).
- REDIII requires that EU member states must achieve 29% renewable energy in transport or 14.5% GHG-intensity reduction in transport fuels by 2030.

Mandated volumes can also be fulfilled through imports. To support domestic production capacity, Made in EU mandates as proposed in the Industrial Accelerator Act or anti-dumping policies could also be considered in conjunction with enforceable mandates.

While the chemical sector does not currently have direct mandates in place as with maritime or aviation fuels, initiatives are in place that can create indirect market pull through increasing transparency and sustainability requirements. See examples below:

- Packaging and Packaging Waste Regulation (PPWR) introduces requirements for recycled content and recyclability of plastic products. This strengthens the demand for recycled content in polymers by, for example, requiring 30% recycled content in PET packaging products by 2030. This regulation does not include requirements for bio-based content.
- Ecodesign for Sustainable Products Regulation (ESPR) establishes sustainability requirements of products on the EU market, including aspects like recycled content and carbon footprint. Product-specific requirements will be introduced through delegated acts, expected gradually from 2026 onwards.
- Digital Product Passport (DPP) requires disclosure of product information under ESPR, like material composition and recycled content. This is an enabling mechanism that promotes visibility of sustainable feedstocks in products, with mandatory passports applying to specific products, like EV batteries, from 2027 onwards.

This may create demand in the long-term as delegated acts and stringent penalties are put in place, but does not address short-term demand certainty challenges.

<u>Government as a Launching Customer and Strategic Public Procurement</u>:
Main risk addressed: offtake and willingness to pay risk

Government as a launching customer or strategic public procurement, where government or a public intermediary takes on the role of offtaker and provides the required long-term offtake agreements to projects, provides offtake certainty to projects and investors. By acting as the main offtaker, the government reduces market and counterparty risk for project developers, stabilizes revenues, and improves cash flow predictability. Under a strategic procurement scenario, a government-led framework ensures offtake of the full production volume at a price above breakeven. This provides sufficient revenue certainty to enable project profitability and financing. To feasibly pass the product through to the market, government can potentially match products with strategic state-based offtakers, particularly where early demand is insufficient to support commercial deployment. The product could be directed toward strategic domestic applications, such as maritime fuels, precursors for aviation fuels, or as input for chemical value chains (e.g. olefins, formaldehyde, or acetic acid) that support critical sectors like construction or defense applications. Government as a launching customer and strategic procurement can therefore be used as a tool to support domestic production.

Instruments like government as a launching customer can act as a bridging mechanism for creating a market while mandates ramp-up to support early projects until sufficient market demand is established. This can therefore serve as a temporary market-creation tool, either in the absence of regulatory demand or as a bridge while mandates (e.g. FuelEU Maritime or RED III) scale-up over time.

3.2 Direct Financial Support

Direct financial support through subsidies or buffer schemes can target specific risk areas, such as revenue stability or ramp-up overrun unpredictability, or reduce the investment sizes required.

CfD Mechanisms:
Main risk addressed: willingness to pay risk

Contract for difference (CfD) mechanisms aim to subsidize the gap between market price and production cost, where sustainable products typically have higher production costs and are unable to compete with fossil-based products. This type of instrument covers the unprofitable margin and creates revenue certainty. By stabilising revenues through a guaranteed product price, CfD mechanisms allows sustainable products to be absorbed in existing markets, reducing market risk and improve long-term price stability for project developers. While CfD mechanisms improve price uncertainty, offtake risk still remains. This is particularly relevant for sustainable chemicals, where there is no clear market demand.

The Netherlands currently runs two subsidy mechanisms with CfD-like components, namely, the SDE++ subsidy scheme and the NIKI subsidy scheme.

The SDE++ subsidy scheme in the Netherlands [8] is a CfD-like instrument aimed abating GHG emissions within the boundaries of the Netherlands and operates on a euro per ton emissions avoided basis. This operating subsidy covers the gap between a predetermined benchmark for production cost of the sustainable product and the current market price, thereby enabling sustainable products to compete in existing markets with more economic, fossil-based products.

This framework is mainly designed with the goal of emissions abatement, thereby being more applicable for energy-based applications like fuels. Its current applicability for materials-based applications, like bio-methanol as a building block for chemical products, is therefore limited. It covers direct emission reductions that occur within national boundaries and does not count for emission reductions that may occur elsewhere. This makes it complicated for commodity chemicals. At present, SDE++ supports biomass gasification to methanol when used as a fuel for inland transport. However, this excludes applications in the chemical sector (e.g. formaldehyde, acetic acid, methanol-to-olefins), where bio-methanol can play a critical role in displacing fossil carbon. This reflects a broader structural gap for products with dual applications like bio-methanol, which can be used as a fuel as well as a platform chemical.

Moreover, given that the SDE++ subsidy distribution is based on a competitive bidding process, advanced lignocellulosic pathways, like biomass gasification to methanol, may be more expensive than other emission reduction measures covered under the scheme, thereby not often able to access sufficient subsidy volumes. The competitive nature of SDE++ allocation potentially poses a barrier for large projects based on advanced lignocellulosic pathways, such as biomass gasification to methanol. While recent changes such as earmarked budgets and technology-specific categories have been introduced to ensure that higher-cost but strategic pathways can access support, competition within and across categories remains largely cost-driven.

The NIKI subsidy scheme in the Netherlands [9] provides a combined Capex and Opex subsidy to high TRL, strategic FOAK industrial transformation and innovation projects that cannot be covered by SDE++. Projects can fall under either Category A – fixed emission reduction per unit of output for projects for energy/fuel applications where there are specific baselines, or Category B – emission reduction based on displacement of fossil carbon from the product chain over a certain operating period for materials-based projects. The Opex component of the

subsidy scheme covers 10 operating years and functions as a CfD-like mechanism to cover the gap between production cost and market price. The NIKI subsidy scheme can support PLA projects under Category B.
An additional CfD mechanism or extension of the CfD-like mechanisms described above targeting dual-use basic molecules, like bio-methanol, that are included under SDE++ for fuel applications, but not for chemical feedstock applications, could support the displacement of fossil-based feedstock from the chemical sector, which currently remains largely unsupported.

CfD mechanisms could also be combined with market facilitation mechanisms, like the EU double-sided auction instrument for eSAF [10]. This is designed to connect and aggregate supply and demand and bridge the gap between conventional jet fuel and more expensive eSAF. Double-sided auctions aim to provide producers with long-term offtake certainty and airlines with short-term competitive contracts, compensating for the price difference between supply and demand.

Capex Subsidy:
Main risk addressed: FOAK capital risks

Capex subsidies reduce the scale of upfront investment required. In the Netherlands, the DEI+ scheme currently provides CAPEX support of up to €30 million for demonstration-scale projects, including technologies such as gasification to bio-methanol production. This support is directed at demonstration plants, the available subsidy levels may be limited in their ability to influence the financing structure of FOAK commercial-scale facilities. Large industrial projects in this space often involve total capital expenditures in the hundreds of millions of euros, and in some cases approaching or exceeding one billion euros. At this scale, a €30 million subsidy represents a relatively small share of total project costs and therefore has a limited effect on project economics from the perspective of lenders and investors.

An expansion of the current Capex support for early commercial-scale facilities could therefore be considered as a potential mechanism to address this gap. Higher subsidy levels could be selectively targeted at projects that demonstrate strategic relevance, potential for replication, or the ability to generate learning effects that may reduce costs for future projects. To ensure efficient use of public funding and maximize additionality, such support should be restricted to new and advanced technologies, particularly FOAK and early commercial-scale applications where market failures are most pronounced and private financing remains constrained. By aligning subsidy volumes more closely with the capital intensity of these projects, public support may contribute to materially lowering upfront financing requirements and improving the feasibility of attracting private investment.

Liquidity Facility:
Main risk addressed: operating performance and cost overrun risk

A liquidity facility could provide financial runway for projects experiencing ramp-up phase underperformance of production. This could address a critical financing gap that may arise after mechanical completion, when projects enter the commissioning and ramp-up phase. At this stage, facilities are operational, but have not yet achieved stable production or planned capacity utilisation. Delays in reaching operational milestones can lead to unexpected cost overruns and delayed revenue generation, particularly for FOAK projects where ramp-up periods are often longer than anticipated.

These additional costs are inherently difficult to predict and create a trade-off between including sufficient contingencies and maintaining acceptable business case metrics. If ramp-up periods extend beyond the financial capacity or risk tolerance of shareholders, projects risk becoming stranded before technical performance is fully demonstrated. In these situations, commercial lenders are typically reluctant to provide additional debt, as the project has not yet demonstrated stable cash flows. At the same time, equity providers may be hesitant to inject additional capital beyond their initial commitments, creating a funding gap at a critical stage of the project development cycle.

A liquidity facility run by public finance institutions or public intermediaries could provide temporary financing to bridge this gap. Structured as a loan or revolving credit line, the facility would offer flexible repayment terms, be subordinated to senior debt, and carry below-market interest rates. This would enable projects to cover cost overruns and working capital needs during ramp-up, with repayment once stable operations and predictable revenues are achieved. The duration of the facility should be of adequate length to ensure that projects are not forced into premature repayment before reaching stable operations and sufficient cash flow generation, thereby avoiding additional financial stress during the ramp-up phase.

Given the risk profile of such support, it is essential to set clear access criteria and closely monitor long-term technical outlook to avoid loan defaults based on deep-rooted technological challenges. A comprehensive technical, financial and commercial due diligence should be conducted by expert independent parties prior to granting access to the facility. The instrument should be targeted at fundamentally viable projects that are temporarily constrained by liquidity issues during ramp-up, rather than being used to support projects with structurally weak business cases. Access to the liquidity facility should be secured upfront before FID to cover potential unforeseen risks.

To ensure proper incentive alignment, access to the facility should be conditional on additional commitment from equity investors and project sponsors. Additional equity contributions could also be required alongside drawdowns from the facility. For example, drawdowns could be covered on a shared basis (e.g. 50/50) between the liquidity facility and additional equity contributions from the private sector, ensuring that project sponsors retain exposure and remain incentivized to manage costs and performance.

In case of project failure or bankruptcy, public support could be safeguarded through mechanisms similar to the Dutch Innovatiekrediet [11], whereby the government obtains preferential rights or first claim on intellectual property, patents, or other key project assets. This helps protect public investment and allows for potential value recovery.

Compared to grant-based support, a liquidity facility may require lower net public capital outlay, as funds are expected to revolve as initial projects reach steady-state operations. At the same time, the instrument can significantly reduce the risk of project failure caused by short-term liquidity shortages, thereby protecting both private and public capital already committed.

3.3 Guarantee Mechanisms

Guarantee mechanisms assist with softening overall default risks and improving investment palatability.

Loan Guarantee on Project-Level:

Main risk addressed: value chain risk

Loan guarantees cover value chain risks and effectively assuming project performance risk within the project Special Purpose Vehicle (SPV), thereby reducing lenders' exposure to project risks. Under such arrangements, the government or public finance institutions can commit to covering a portion of the project's debt if the SPV is unable to meet its repayment obligations. This additional layer of security can increase lender confidence and the palatability of the investment.

Evidence from international case studies suggests that guarantees can be an effective instrument for mobilising private capital for cases where technologies already have initial proof points, as with the US DOE loan guarantees program covering where large guarantees were provided to HEFA SAF projects [12]. The effectiveness of this instrument generally depends on the share of debt covered by the guarantee and the conditions under which projects can access the program. If the guaranteed portion of the loan is too limited, lenders may still face substantial residual risk, reducing the effectiveness of the instrument. In addition, eligibility criteria typically need to reflect the realities of early commercial or FOAK projects, which do not yet meet the bankability standards required by commercial lenders. Moreover the process for obtaining a loan guarantee will require a comprehensive technical, financial, and legal due diligence process, whereby successfully passing the review serves as a strong signal of a project's technical feasibility, commercial viability and creditworthiness.

Loan guarantee facilities can be structured to be partially cost-recovering. In such structures, project developers pay a risk-based premium to access the guarantee facility. This structure can help attract private investors to invest in the guarantee fund itself. Public investment in the fund should hold a first loss position to incentivize private investment and ensure that the premium paid by projects does not become so high that it undermines project viability.

The Netherlands already operates a loan guarantee instrument through the GO (Garantie Ondernemingsfinanciering) facility [13], which supports corporate lending by providing partial guarantees on bank loans. A similar approach could be considered for large-scale industrial decarbonisation projects, potentially by establishing a dedicated guarantee program tailored to capital-intensive transition projects.

Loan Guarantee on a Portfolio-Level:

Main risk addressed: value chain risk

A portfolio guarantee mechanism could share risk at the portfolio level rather than on a project-by-project basis. Under this approach, a public entity provides a guarantee covering a defined share of losses across an investor's portfolio of projects, rather than underwriting individual assets. These guarantees reduce a financier's risk exposure by diversifying risks across portfolio of assets, minimizing exposure to any single asset. This in turn lowers the capital costs and enables financiers to deploy a larger volume of financing into higher-risk or innovative projects. This can enable financing of projects that may be marginally too high risk for loan guarantees on a standalone basis, but viable within a diversified portfolio.

This model could take inspiration from existing European structures such as InvestEU, where the European Commission provides portfolio guarantees covering up to 80% of the value of the loan for innovation projects to the EIB and other selected public finance institutions [14] [15]. Apart from increasing the palatability of innovative projects, this also enables these public finance institutions to have lower capital consumption per loan, thereby setting aside smaller contingencies internally across the portfolio of loans, where capital consumption is generally more significant for higher-risk projects. This increases overall debt availability for innovative projects.

Second, the mechanism can further increase debt availability as portfolio level guarantees may allow financiers to spread the risk of default over a greater number of projects, thereby potentially allowing more projects to meet credit requirements. This can enable a higher share of debt in the capital structure, reducing reliance on more expensive equity and improving overall returns. Applied to industrial FOAK projects, a portfolio guarantee could allow public or commercial lenders to bundle multiple FOAK or early commercial projects into a single risk pool. Losses are then absorbed at the portfolio level, rather than requiring each project to meet strict criteria in isolation.

Third, portfolio level guarantees (as seen in EU-level structures from the EIB [15]) can lower capital requirements for lenders, namely earmarked capital reserves acting as internal contingency against loan exposure as per the EU Capital Requirements Directive. A portfolio guarantee can therefore expand lending capacity, enabling larger participation from banks and public financiers to participate in FOAK and early commercial projects.

Portfolio guarantees could be structured in two ways:

- Capped portfolio guarantees, where losses are covered up to a predefined maximum at portfolio level, limiting the public sector's total exposure.
- Uncapped portfolio guarantees, where a predefined share of losses is covered for every eligible loan in the portfolio without an overall portfolio loss cap.

Depending on guarantee designs and capital consumption requirements, guarantee structures may achieve a substantial multiplier effect, as they will only be called upon in the event of losses or defaults across the project or portfolio rather than requiring upfront capital deployment.

Technology Performance Guarantee Fund:

Main risk addressed: technology risk

The allocation of technology performance risk is a key bankability constraint in FOAK industrial projects. In project finance structures, lenders typically require EPC contractors to provide comprehensive performance guarantees on the construction, installation, and initial functioning of the facility. For early commercial projects, the required guarantees may create significant liabilities that exceed the EPC's expected profit margin. This creates hesitation from EPCs for participating in FOAK projects and leads to challenges in fully covering and allocating this risk. Commercial lenders prefer to work with established EPC's, who are generally limited in the flexibility they can provide for a project.

A Technology Performance Guarantee Fund from government or public finance institutions aimed at covering the residual risk beyond the EPC breakeven point could address this constraint to enable feasible risk allocation. Under a potential fund structure, the EPC would remain responsible for providing performance guarantees up to a defined share of its expected

project margin and would retain a first-loss position. This ensures that incentives remain aligned for EPC contractors to continue to carry meaningful risk exposure and remain strongly incentivized to deliver the project on time and according to performance specifications. The Technology Performance Guarantee Fund would then provide a backstop guarantee covering residual performance risk beyond the EPC's break-even point, up to a predefined limit. In practice, the fund could be structured to cover cost overruns or performance-related financial losses that arise after a certain % of the EPC's margin has been exhausted.
The facility could operate as a pooled guarantee mechanism, where multiple projects contribute to and access the fund. To maintain discipline in risk pricing and support partial cost recovery, EPC contractors could pay a risk-based premium to access the fund, calculated based on expected loss rates. Public capital could take a subordinated position within the capital structure of the facility, matched alongside contributions from private financial institutions and potentially insurers, making the mechanism attractive for private sector participation while leveraging public resources to absorb higher-risk exposures.

By limiting coverage to residual risks for the EPC while maintaining EPC first-loss exposure, the structure seeks to support feasible risk allocation without distorting incentives. Additionally, reducing the level of performance guarantees required directly from EPC contractors may lower overall project costs, as the liabilities associated with extensive guarantees are typically priced into EPC contracts.

This instrument is specifically targeted at addressing EPC participation and technology performance risk, and does not directly mitigate other value chain risks such as feedstock availability, market demand, or offtake uncertainty. In contrast to broader loan guarantee mechanisms, a Technology Performance Guarantee Fund is designed to enable EPC participation in FOAK projects by addressing the residual performance risks that may otherwise exceed an EPC contractor's risk appetite. A conventional loan guarantee would likely still require a turnkey full-wrap EPC contract, as the risk tolerance of the guarantee provider is often closely aligned with that of the underlying lenders. As a result, loan guarantees alone may have limited ability to reduce the level of performance commitments required from EPC contractors or materially expand EPC willingness to participate in high-risk FOAK projects. In cases where technology performance risk represents the primary barrier to financing, such a mechanism could help unlock project finance for FOAK projects while allowing EPC contractors and technology providers to build operational experience that supports the development of subsequent NOAK facilities.

It was highlighted during the second Financing Roundtable that combining a Capex subsidy with a Technology Performance Guarantee Fund can create a complementary de-risking package that addresses both upfront financing constraints and downstream technology performance and EPC participation risk. A Capex subsidy primarily assists the initial business case by reducing upfront investment requirements. The Technology Performance Guarantee Fund address the downstream technology performance risk by redistributing residual performance risk that would otherwise sit with EPC contractors or financiers, enabling a more balanced risk allocation structure. This combination not only lowers total project costs but also increases lender confidence and EPC participation, thereby enhancing the likelihood of reaching FID.

Risk Sharing Fund from Market Parties:

Main risk addressed: technology and operating performance risk

A project-level risk sharing fund could be established as an additional contingency buffer across the project development lifecycle, including construction and ramp-up, with contributions from key stakeholders such as project developers, OEMs, EPCs, financiers, and potentially public actors. Higher risk projects face higher contingency needs across the conversion process and balance of plant system. The risk sharing fund acts as a collective residual risk holder to cover cost overruns, where the coverage of a specific risk does not depend only on a single party for absorbing a risk they cannot manage well, instead all parties contribute a limited amount into a common pool that absorbs predefined residual risks. A risk sharing fund adds value in situations where there is a risk allocation stalemate that results in projects being unlikely to otherwise proceed. The facility should therefore absorb predefined risks that cannot be efficiently allocated through conventional contracts, such as technology underperformance, commissioning delays, ramp-up shortfalls, or unexpected cost overruns during critical project phases. Successful project development allows OEMs and EPCs to get reference projects and future contracts and investors to capture returns. Access to the fund should be triggered only under clearly predefined conditions and milestones. The risk sharing fund guarantees that at least a portion of potential cost overruns can be covered by market-based project stakeholders.

By requiring contributions from all key value chain participants, the mechanism seeks to align incentives, reduce moral hazard, and create a collective interest in successful project delivery. Participation ensures that all parties retain meaningful “skin in the game” throughout the project lifecycle, with each stakeholder contributing proportionally to its role, expected upside, and risk exposure. For value chain actors, the incentive to participate lies in enabling projects that may otherwise not reach financial close due to unresolved risk allocation challenges, thereby increasing the likelihood of project realization, commercial deployment, and future market opportunities.

Contributions could be structured proportionally to each party’s role and risk exposure, with higher relative participation from developers and equity investors in early phases, and increasing involvement from EPC contractors, technology providers, and financiers as the project progresses into construction and early operations. The size and structure of the fund can vary by phase, reflecting the evolving risk profile from development through construction to early operations.

Participation in later stages would be conditional on contributions in earlier phases, ensuring all parties retain “skin in the game” throughout the project lifecycle. The fund would act as a targeted buffer to absorb predefined losses, such as technology underperformance, ramp-up delays, or commissioning-related cost overruns, thereby supporting more balanced and feasible risk allocation.

For a risk sharing fund to improve bankability, it must be sufficiently capitalized, cover a meaningful share of downside risk, have participation from credit-worthy parties, and for lenders to sit in a position where they clearly benefit from the fund. Public participation in the risk sharing fund could create additional risk-bearing capacity and allow for difficult to cover risks to be transferred, not just redistributed.

An important design consideration is the funding structure of the vehicle. Given the long project timelines and capital intensity, requiring full upfront cash contributions may create a barrier to participation. As such, the fund could be structured based on capital commitments rather than immediate funding, where stakeholders commit to provide capital when required (via capital calls) rather than placing the full amount on their balance sheet from the outset. This approach, can significantly lower the threshold for participation, while still providing funding certainty when risks materialize. Governance arrangements would determine how and when funds are deployed, for example through a joint decision-making structure involving key contributors and potentially an independent party to ensure objectivity.

3.4 Case Specific Policy Support

Business case risks can also be addressed through project-specific interventions, in contrast to instruments that target an entire sector or subsector.

Case-by-Case Support:
Main risk addressed: value chain and policy risk

Case-by-case support mechanisms can be designed specifically for selected strategic FOAK projects that are close to a viable, but not yet bankable, business case. This approach focuses on identifying the specific residual risks that remain after standard risks have been allocated to market parties. These risks often prevent promising individual projects from reaching FID, where a case-by-case approach can address these with bespoke public support instruments, tailored to the case, instead of deploying sector-wide public funding support. This approach recognizes that FOAK and early commercial-scale projects often face unique combinations of technology, financing, market, and regulatory risks that may not be adequately addressed through market contracts and standardized subsidy mechanisms alone. This arrangement could follow an orchestrating format, namely policy makers, various financiers, and industry actors work together towards bespoke support instruments that address the main bottlenecks for specific cases. This may include both financial and non-financial support mechanisms.

In practice, public institutions can place targeted guarantees, tailored subsidies, or subordinated financing at precise points in the capital stack, aligned with the project’s risk profile across development, construction, and early operational phases. For example, support mechanisms could selectively address feedstock, offtake and early-stage development risk, construction completion risk, or initial technology performance risk during ramp-up. By assuming only clearly defined and limited portions of risk gaps, specifically those that private parties are unable to absorb, public institutions can help consolidate fragmented and unallocated risks, aligning with private financiers risk reward mandates to unlock access to finance. The role of government is therefore to take a residual position, structuring support in such a way that private financing is maximized first, and public intervention is only deployed where necessary to complete the financing package alongside existing and new private investors.

Non-financial support may focus on increasing investor confidence through resolving specific policy or regulatory bottlenecks, connecting value chain stakeholders, and further developing value chain segments to improve feedstock or offtake certainty.

A case-by-case approach can be most effective when implemented in close coordination with regional and national stakeholders, including industrial clusters, provinces, municipalities, and investment agencies. Beyond financial support, this enables the resolution of non-financial bottlenecks, such as site development, infrastructure connections, permitting, and coordination across funding sources, through a focused, joint effort, thereby increasing the overall likelihood of project success.

Next to this case-by-case support model, establishing a single, centralized contact point for new sustainable industry project developers is essential. Projects could be supported by a dedicated account manager, backed by a multidisciplinary team of technical, financing, and policy experts who coordinate across the relevant public instruments and institutions. This structure would reduce complexity for new sustainable industry developers, improve coordination between different public support mechanisms, and ensure that interventions are coherent, targeted, and aligned with the actual bankability challenges of each project.

Targeted public support can help crowd in additional private capital and improve financing conditions. In doing so, it unlocks financing and market access that would otherwise not materialize, or only at a later stage. This improves the project's negotiating position, reduces risk, and enhances long-term continuity. Case-by-case approach can therefore accelerate FID by shortening the time between technology development and project deployment. Public support is used to enable critical steps to be taken earlier, reduce key risks more quickly, and allow projects to capture market opportunities in a timely manner. This helps prevent delays or project stagnation caused by liquidity constraints, long lead times, or uncertainty among offtakers and financiers.

3.5 Timeline for Support Mechanisms

The various support mechanisms described above could play different roles at different stages of technology deployment and value chain development, from FOAK projects to NOAK projects to a fully functioning market, as outlined in Figure 3.1.

Short-Term:
Deploy public funding support to enable FOAK projects to reach financial close and execution through deploying targeted de-risking instruments to alleviate FOAK-specific technology and value chain risks. Technology risk and ramp-up support for initial projects should demonstrate technical performance, establish benchmarks, and build initial value chains, thereby reducing the risk profile of subsequent projects and paving the way for subsequent NOAK projects. FOAK projects operate in early-stage markets and will require offtake certainty in the short-term to improve bankability. Initial revenue stability could be bridged through targeted CfD-like mechanisms or guaranteed offtake from state-backed entities while mandates ramp-up and the market becomes more established. Double-sided auctions for the first projects could be considered as an alternative. This matches supply with demand and covers the price gap in between, thereby creating an impression of market clearing price in the early-stages where benchmarks are limited as well as providing offtake clarity.

Instruments: Case-by-Case Support, Substantial Capex Subsidy, Liquidity Facility, Loan Guarantee on Project Level, Loan Guarantee on Portfolio Level, Technology Performance Guarantee Fund, Risk Sharing Fund, Government as a Launching Customer / Strategic Procurement

<u>Medium-Term</u>:
After initial FOAK projects come online and NOAK projects begin planning, targeted derisking instruments may still be required. However, as NOAK projects benefit from the learnings and reference points created by FOAK projects, this will be required to a lesser extent. Public capital should play an increasingly smaller role as NOAK project deployment increases. As market regulation and subsequent visibility improves, the adequacy of benchmarks can improve and more mature and comprehensive CfD-like schemes could be deployed, potentially alongside government as a launching customer if still required. This will allow larger volumes of products to be absorbed by the market as offtake mandates begin to create sufficient demand and continue to ramp-up. This establishes revenue certainty to provide long-term visibility on pricing and potential offtake, thereby lowering financing risk and supporting the transition from isolated FOAK projects to replicable deployment.

Instruments: Case-by-Case Support, Loan Guarantee on Project Level, Loan Guarantee on Portfolio Level, CfD Scheme, Risk Sharing Fund, Government as a Launching Customer / Strategic Procurement, Ramp-Up of Mandates

<u>Long-Term:</u>
In the final transition to a fully functioning market in which multiple NOAK projects are operating and new value chains are established, projects should be commercially viable without direct public funding support to absorb residual risks or create artificial markets. Offtake mandates create sufficient demand and willingness to pay. At this stage, proven technologies, established value chains, and mature demand mechanisms enable private capital to finance projects on standard market terms.

Instruments: Mandates

Figure 3.1: Potential roll-out of support mechanisms until 2050. Adapted from TNO study on Barriers to Advanced Biofuels [2]

4 Impact of Support Mechanisms on Business Case

Selected support mechanisms across i) market creation, ii) direct financial support, and iii) guarantee mechanisms were quantitatively tested in a business case model to assess their effectiveness for improving commercial viability. The business case model was used to assess the impact of these support mechanisms on key investment metrics, like IRR, NPV, cash flow available for debt service (CFADS), free cash flow (FCF), and DSCR. This process was supported through bilateral expert conversations with financiers to further discuss the material impact of support mechanisms and validate assumptions and findings. The section below describes the impacts the selected support mechanisms had on investment metrics and the assumptions behind the analysis.

Please note: *The data, assumptions, calculations, and figures presented in this section only serve to illustrate orders of magnitude, not absolute values. This is intended to provide an initial directional view of how the business case could develop under certain conditions. The outcomes are sensitive to underlying assumptions and input data, many of which are subject to uncertainty. This includes, but is not limited to, market prices, cost estimates, technology performance, and the financial assumptions leading to the impact of the proposed interventions. As such, the results should be seen as an analytical framework to support further discussion and more detailed evaluation.*

4.1 Market Creation

The market creation scenarios adopted in the business case model for bio-methanol and PLA and their impacts are described below.

4.1.1 Bio-Methanol

Two illustrative scenarios in which a market for bio-methanol is created were considered, where willingness to pay may be created at prices near to production costs. This is compared to a fossil-based reference case. For a 20 year outlook, price increases of 2% annually were assumed from baseline to account for inflation. No further assumptions were made to maintain simplicity.

1. Mandated market

Given that there are currently no offtake mandates in place in the chemical sector for bio-methanol, illustrative offtake pricing under a mandated market was taken from FuelEU Maritime. Under FuelEU Maritime, binding GHG intensity reduction targets and associated penalties create a market for low-carbon maritime fuels, including bio-methanol. Under this mandate, willingness-to-pay is expected to be around ~€1,193/ton for bio-methanol [16]. This approaches the LCOP of €1,279/ton indicated in this study, enabling project viability. In this scenario, it is assumed that full production volumes are absorbed by the market at these price levels, although in practice offtake ramp-up could be more gradual and staged. Additional instruments such as CfDs may be required to bridge early-stage gaps.

2. Strategic government procurement

Under a strategic procurement scenario, a government-led framework ensures state-backed offtake of the full production volume at a price above LCOP, for modelling purposes assumed at LCOP + 20% margin (approximately ~€1,339/ton). This should provide sufficient revenue certainty to enable project profitability and improve access to finance. The product could be directed toward strategic domestic applications, such as maritime fuels, precursors for SAF, or as input for chemical value chains (e.g. olefins or downstream derivatives, formaldehyde, or acetic acid) that support critical sectors like construction or national security. Strategic procurement can therefore serve as a temporary market-creation tool, either in the absence of regulatory demand or as a bridge while mandates (e.g. FuelEU Maritime) scale-up over time. For modelling simplicity, it is assumed that the full production volume is absorbed at the defined price level.

3. Competing in fossil market (reference case – no dedicated market)

In the absence of regulatory and government support or sufficient voluntary demand, sustainable methanol will compete with fossil-based alternatives. Current market prices (~€598/ton [5]) are significantly below LCOP, resulting in a structurally unviable business case. This scenario illustrates that FOAK bio-methanol projects cannot operate profitably in existing fossil markets without market creation mechanisms or significant CfD support.

The analysis in this study applies a base case in which a functioning market for bio-methanol exists, while also comparing this to a “no-market” scenario to illustrate the critical importance of demand creation for project viability. Without a market able to absorb volumes at or above LCOP, the business case is negative and will not materialise. In this context, instruments such strategic procurement and CFDs can act as bridging mechanisms to support early projects until sufficient market demand is established through offtake mandates.

4.1.2 PLA

One illustrative scenario for PLA is considered in which willingness to pay is created at prices near to production costs. This is compared to a fossil-based reference case. A 20-year outlook is applied to estimated PLA prices, with a 2% annual price increase to account for inflation, while no additional market dynamics are assumed to maintain comparability across scenarios.

1. Sufficient voluntary market

PLA can access voluntary markets for specific applications (e.g. sustainable packaging), with an average of 2025 PLA prices of ~€2,658/ton [7], which exceeds the LCOP of €2,464/ton estimated in this study. This enables business case viability, but demand remains dependent on corporate and public sustainability commitments and broader market conditions.

2. Competing in fossil market (reference case - no dedicated market)

Without regulatory support encouraging sustainability commitments, PLA may have to compete with fossil-based alternatives, like polyethylene which is priced around ~€1330/ton in Europe of September 2025 [6], for applicable bulk commercial uses like packaging. This remains below LCOP and results in an unviable business case for large-scale deployment.

4.2 Direct Financial Support

The impact of multiple direct financial support mechanisms for reducing specific risks is described below.

Capex Subsidy:

While Capex subsidies improve the capital stack through reducing private financing requirement and improves the Project IRR and Equity returns, Capex subsidies do not directly address key bankability barriers, such as technology performance risk, ramp-up risk, or value chain uncertainties (e.g. feedstock and offtake). As a result, their impact on unlocking large-scale private debt financing may be limited. Capex support can make projects more palatable by lowering investment needs, but, unless the Capex subsidy convers a considerable portion of the upfront costs, a Capex subsidy on its own is generally considered insufficient to materially change the financing dynamics of FOAK projects.

A Capex subsidy can involve significant public capital outlay. For a 20% subsidy of total Capex costs, this is estimated to correspond to around €150 million in public funding for the 200kt bio-methanol case and around €50m for the 75kt PLA case.

Despite this substantial contribution to the capital stack, the impact on overall bankability may be limited as Capex subsidies do not directly address the key risk drivers that constrain access to conventional project finance. As a result, the intervention may improve project economics, but may not be sufficient to unlock financing on its own.

Given the combination of high fiscal cost and relatively limited impact on core bankability constraints, Capex subsidies may be less effective in improving and creating bankability compared to more targeted instruments, like a liquidity facility, that directly address specific risks in the financing structure.

CfD Mechanisms – Example of NIKI combined Capex/Opex subsidy for PLA[3]:

PLA production may be supported under Category B of NIKI subsidy scheme (replacement of primary fossil carbon in the product chain). This makes NIKI one of the few available instruments that directly targets materials-based defossilisation, where emissions are largely embedded in the end-of-life strategy rather than captured in direct scope 1 and 2 emissions.

For modelling purposes, it is assumed that a third of the full available subsidy volume of €211m is allocated to a single PLA project (~€70m). In practice, NIKI operates as a competitive tendering mechanism, and the actual allocation may differ depending on the number and quality of applications within a given round. The available subsidy volume is assumed to be

[3] Given that biomass gasification to methanol for use in the chemical sector is not currently eligible under existing subsidy schemes, this was not tested quantitatively in the business case model. For CfD mechanisms, focus was placed on PLA production as this is eligible for the combined Capex/Opex NIKI subsidy scheme.

split between 40% Capex support (~€28m) and 60% Opex CfD-like support (~€42m), which is available over 10 operating years. This blended structure allows the instrument to address both upfront investment requirements and operational revenue gaps.

Overall, the NIKI scheme, through its combined Capex and Opex support, has the potential to more effectively improve the business case for PLA compared to single-instrument approaches. However, its effectiveness will depend on allocation outcomes, subsidy levels, and long-term policy certainty, particularly given the reliance on competitive tendering.

Liquidity Facility:

If ramp-up periods extend beyond the financial capacity or risk tolerance of shareholders, projects may become stranded before technical performance is fully demonstrated. A liquidity facility, provided by government or public finance institutions, could address this gap by offering temporary funding to cover 50% of cost overruns and working capital needs during ramp-up, where the other 50% must be sourced from the project sponsor or additional private investors to incentives project performance. The liquidity facility can be used to cover cash flow shortages, including implementing design corrections or repaying a portion of the project loan. This reduces revenue risk by providing additional contingencies, similar to project insurance. Such an instrument is therefore essential to encourage initial debt financing, as it reduces the risk of project failure in this critical phase.

Given the scale and capital intensity of FOAK projects, a liquidity facility would need to be sufficiently sized to have a meaningful impact, potentially in the order of €50 to a €100 million per project. To illustrate, for the 200kt bio-methanol case, when assuming a ramp-up period of approximately three years, total additional liquidity needs could reach around €140 million, of which approximately 50% could be drawn from the liquidity facility. These funds would be repaid over the project lifetime once stable operations and cash flows are achieved.

4.3 Guarantee Mechanisms

The impact and assumptions around guarantee mechanisms for improving the business case are described below.

Loan Guarantee on Project-Level

A loan guarantee covering 50% of the debt exposure, in line with the current Go Facility [13], is assumed in the business case to reduce the credit risk premium component proportionally, resulting in an estimated interest rate reduction of 175 to 275 basis points on the term loan facility, leading to lower financing costs. For modelling purposes, in the bio-methanol case a 275 basis points reduction is assumed, for PLA a 175 basis points reduction is assumed. Given that the bio-methanol project faces higher technology risk and subsequently higher credit risk premiums from the debt provider, the effect of the loan guarantee on the credit risk premium portion of the interest rate is therefore larger for bio-methanol than for PLA.

These values are illustrative, in practice, the actual impact will depend on a large range of factors, including lender risk perception, overall project risk profile, market conditions, and the specific structure and terms of the guarantee. The public capital required to support such guarantees will depend on national regulatory frameworks, including banking regulations and capital treatment of guaranteed exposures. In the 200kt bio-methanol case, the total assumed loan amount would be ~€415m, with a 50% guarantee this would imply an exposure of ~€210m in case of 0% recovery rate. In the 75kt PLA case, the total assumed loan amount would be

~€120m, with a 50% guarantee this would imply an exposure of ~€60m in case of 0% recovery rate.

While this improves financing conditions and may increase lender comfort, the impact on lending decisions may be more limited. This improves the palatability of the investment, but does not target underlying technology or cost overrun risks that may cause loan repayments to default. Even with partial guarantees, the residual risk exposure for banks can remain significant, particularly in FOAK projects with multiple unresolved risks across the value chain, with ramp-up risk being emphasized during expert interviews as a material barrier. As a result, loan guarantees alone may not be sufficient to unlock debt financing, but can play an important role as part of a broader risk-mitigation package.

Loan Guarantee on Portfolio-Level:

As with a loan guarantee on the project level, a portfolio guarantee does not directly improve project revenues or reduce CAPEX. However, it can improve the financing terms and strengthens the overall business case.

First, by reducing lender exposure and lowering loss given default, a portfolio guarantee can lead to a lower cost of debt. This reduces interest expenses over the life of the project, improving key financial metrics such as NPV, IRR, and DSCR. Based on the input collected, a loan guarantee fund is assumed to lead to a 150-300 basis point reduction in the term loan facility cost in the business case. For modelling purposes, for bio-methanol a 225 basis point reduction is assumed while for PLA a 150 basis point reduction is assumed based on expert discussions. These values are illustrative, in practice, the actual impact will depend on a large range of factors, including lender risk perception, overall project risk profile, market conditions, and the specific structure and terms of the guarantee.

Technology Performance Guarantee Fund:

A Technology Performance Guarantee Fund may improve the business case primarily through a reduction in EPC-related costs. By introducing a Technology Performance Guarantee Fund that covers residual risk beyond the EPC's margin, the EPC's exposure is capped at a more manageable level. This has several effects:

- Lower risk premium in EPC contracts: With reduced downside exposure, EPC contractors can reduce contingency buffers and price contracts more competitively, reducing overall project Capex.
- Increased willingness of EPCs to participate: More contractors may be willing to bid on FOAK projects, increasing competition and further reducing pricing.

Under a Technology Performance Guarantee, this is achieved without fully transferring risk away from the EPC, as the contractor retains a first-loss position.

Based on expert interviews the EPC costs are estimated to be around 20-25% of total Capex. The total exposure for the EPC is estimated to be around 65% of its margin based on:

- The assumed amount of exposure for the EPC under a lump sum turnkey is equal to 40% of the total loan value.
- The additional premium charged by the EPC to provide a lump sum turnkey for a FOAK facility is estimated to be 40% of the total exposure.

If EPC exposure is assumed to be 40% of the total loan value, a Technology Performance Guarantee could cover 50% of the EPC exposure, thereby reducing EPC exposure to 20% of the total loan value. As a result the additional premium charged by the EPC to provide a lump sum turnkey should decrease by 50%. In the case of the 200kt bio-methanol facility, this would lead to a ~€35 million decrease in EPC costs, while for the 75kt PLA facility this would lead to a ~€10 million decrease. While the absolute business case impact of the mechanism is relatively limited, the primary advantage of the instrument is to enable EPC participation in the risk allocation structure.

4.4 Impact of Support Mechanisms on Business Case NPV

The figures below illustrate the potential stand-alone effects of the selected support mechanisms on the business case. This serves to create a first impression of the magnitude of the quantitative impacts of support mechanisms on improving project economics.

NPV represents the total discounted value of future unlevered project cash flows over the project lifetime, after accounting for upfront investment costs, and is therefore an indication of project profitability. A positive NPV indicates that the project is expected to generate value above the required return threshold (in this study an original WACC rate prior to the implementation of support mechanisms of 11,1% is assumed for the bio-methanol case and 9,2% for the PLA case. Given that the bio-methanol project contains higher technology risk, it faces both a higher asset specific risk adjustment factor as well as higher credit risk premiums from the debt provider leading to a higher overall WACC Rate, see Appendix B for an overview of financial assumptions). In the figures below, the effect of different support mechanisms on the NPV indicate a transition towards a more economically viable business case. The willingness of investors to provide capital will primarily depend on project risks that impact cash-flow predictability, which is not reflected in the NPV metric. NPV should therefore be viewed as an indication of project economics, but not necessarily an indication of investor perception or willingness.

As can be seen from the figures for both bio-methanol and PLA, the NPV of both projects are significantly negative (NPV below the red line) without a stable mandated or voluntary market demand that can absorb product volumes at a price above production cost (LCOP). Based on these estimates from the financial model and insights form the expert discussions, **market creation has the largest positive impact on bankability and project economics**. The absolute effect of other selected support mechanisms are therefore calculated on a stand-alone basis in the baseline scenario that a market is in place for the case study products, where full production volumes can be absorbed by the market at prices at or above LCOP as described in Section 4.1. The baseline scenarios also assumes that debt is accessible and constitutes 60% of the capital stack. For the other financial assumptions please refer to Appendix B.

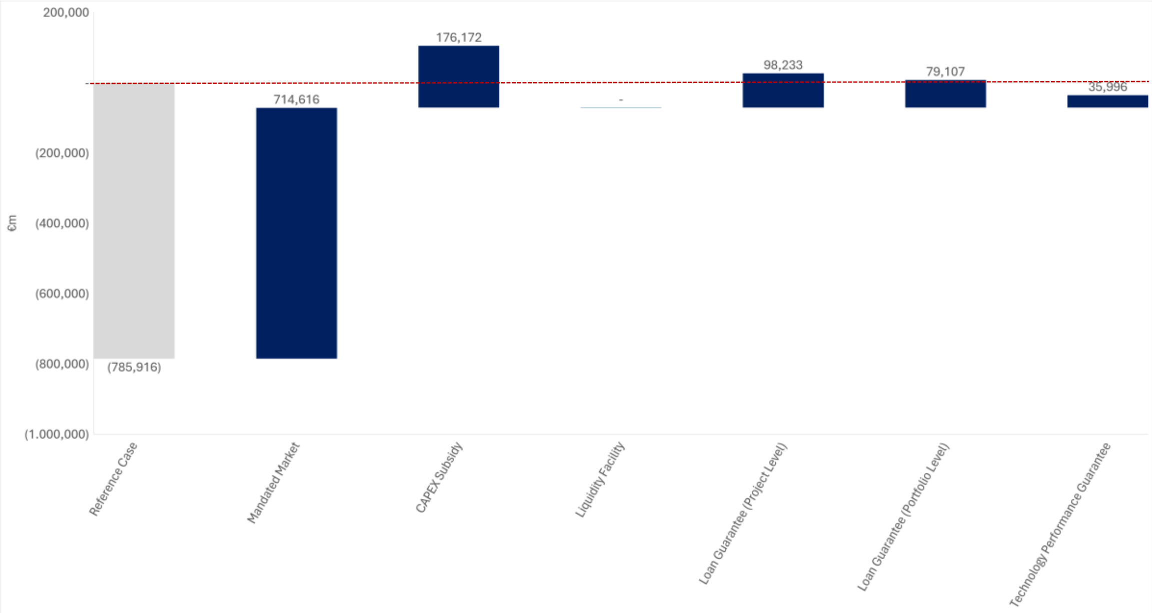


Figure 4.1: For bio-methanol, NPV effects of selected support mechanisms. Red line demarcates positive and negative NPV. NOTE: Support mechanisms are calculated on a stand-alone basis in the baseline scenario of a mandated market being in place.

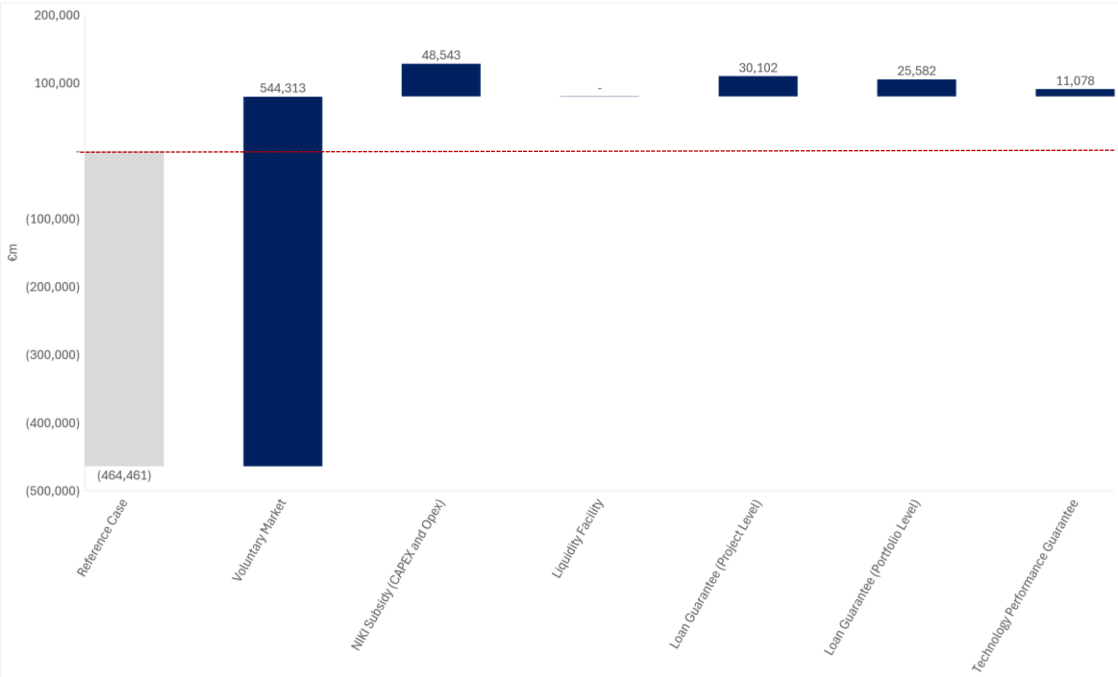


Figure 4.2: For PLA, NPV effects of selected support mechanisms. Red line demarcates positive and negative NPV. NOTE: Support mechanisms are calculated on a stand-alone basis in the baseline scenario of a mandated market being in place.

The Capex subsidy for bio-methanol and combined Capex/Opex NIKI subsidy for PLA have a large absolute effect in terms of NPV on the business case, as the subsidy is assumed to be of significant size (10-20% of Capex requirements). However despite its significant contribution to the capital stack and as a result positive impact on the NPV, it was indicated during expert discussions that the impact on improving access to debt may remain limited as Capex subsidies do not address the underlying risk drivers constraining access to project finance. As a result, **Capex subsidies may improve project economics, but are unlikely to be a key driver in unlocking conventional project financing for FOAK projects.**

Both loan guarantee schemes also display a substantial effect on NPV for both business cases. The loan guarantee improves the cost of financing and decreases the WACC. While this can improve the NPV of the project and lender comfort, it was indicated during expert discussions that its influence on actual lending decisions may be limited. Residual risks often remain significant for FOAK projects, and risk of loan defaults continue to remain material if key risks are unaddressed. **Loan guarantees alone are therefore unlikely to unlock debt financing, but can contribute as part of a broader risk-mitigation package.**

A liquidity facility does not display a direct impact on NPV estimations. This serves as an indirect backstop during times of project distress rather than directly improving upfront NPV project economics[4]. The primary value of the liquidity facility is that it directly targets a core bankability constraint, namely unpredictable cost overruns during a prolonged ramp-up period that are not easily absorbed by key project stakeholders. **Although the liquidity facility does not directly improve upfront NPV project economics, it targets a critical source of potentially significant investor exposure, thereby reducing perceived risk and strengthening investor confidence.**

4.5 Main Takeaways

Achieving bankability for FOAK green chemistry projects requires core risks to be mitigated to improve certainty of cash flows and thereby enable access to debt, in conjunction with feasible project economics and positive NPV.

Improving access to debt requires a combination of high-priority support mechanisms that address three critical bankability conditions simultaneously: (i) creation of a reliable market for green chemistry products, (ii) feasible allocation of technology and construction risk, and (iii) coverage of unpredictable ramp-up risks. It is therefore essential to focus on support mechanisms that help alleviate these three bottlenecks across the value chain. This can consist of a combination of the following support mechanisms:

Firstly, the **creation of a viable market** that enables stable offtake for higher-cost green chemistry products is a prerequisite for any bankable business case in the green chemistry sector. In practice, sufficient mandated offtake is still in development. As such, in the short-term it is critical to focus on alternative market-supporting mechanisms. Instruments such as government as a launching customer and **CfD mechanisms** can serve as bridging solutions to create revenue certainty in the short-term while EU-level mandates (e.g. ReFuelEU) gradually create structural demand in the long-term. Although CfD mechanisms improve revenue stability and reduce price risk for produced volumes, revenue risk associated with the facility not ramping-up to sufficient production capacity within the planned timeframe still remains.

A second structural barrier therefore relates to potential cost overruns and delayed performance during the **ramp-up phase**, which cannot be fully anticipated or contractually

[4] In both the business case models for bio-methanol and PLA, the use of the liquidity facility was anticipated and modelled upfront. The envisioned loan-based nature of the liquidity facility implies that it will not present a direct impact on NPV, as this is calculated as a function of unlevered cash flows. If the liquidity facility were structured as a subsidy rather than a loan, it would present a direct positive NPV impact.

allocated. As a result, project developers are unable to plan for these risks, and private investors and lenders are generally unwilling to underwrite open-ended exposure with unpredictable cash flows. A dedicated **liquidity facility** will therefore be a key enabling instrument, providing temporary cash flow support to bridge this phase and prevent otherwise viable projects from failing before reaching stable operations.

Thirdly, the analysis highlights a fundamental tension in **the allocation of technology and construction risk**. There is a structural mismatch between lender requirements and ability of the required market parties, specifically EPCs, to absorb these risks. Addressing this gap requires alternative risk-sharing mechanisms, like a **technology performance guarantee fund**, as selected during the Financing Roundtables, or a risk sharing fund, the development of third-party technology insurance solutions that can partially underwrite performance risk, or EPC co-investment ("skin in the game").

In addition, a more targeted **case-by-case support approach** can potentially play a complementary role in **addressing residual risks that are not effectively covered by standardized instruments**. Such an approach allows public institutions to selectively address risk gaps for strategic cases that private parties are unable to absorb. This may include both financial and non-financial regulatory-based support mechanisms.

Finally, while instruments such as **Capex subsidies and loan guarantees** can improve project economics and reduce financing costs, they generally do not resolve the underlying challenge of cash flow uncertainty. These instruments may make projects more palatable for investors, but **do not fundamentally change the underlying risk profile**. As a result, they are **unlikely to be sufficient** on a standalone basis for unlocking large-scale private financing for FOAK projects. Targeted support mechanisms, like a liquidity facility or technology performance guarantee, are therefore required to resolve core bankability constraints and **create bankability**, while Capex subsidies and loan guarantees improve investment palatability and **enhance bankability**.

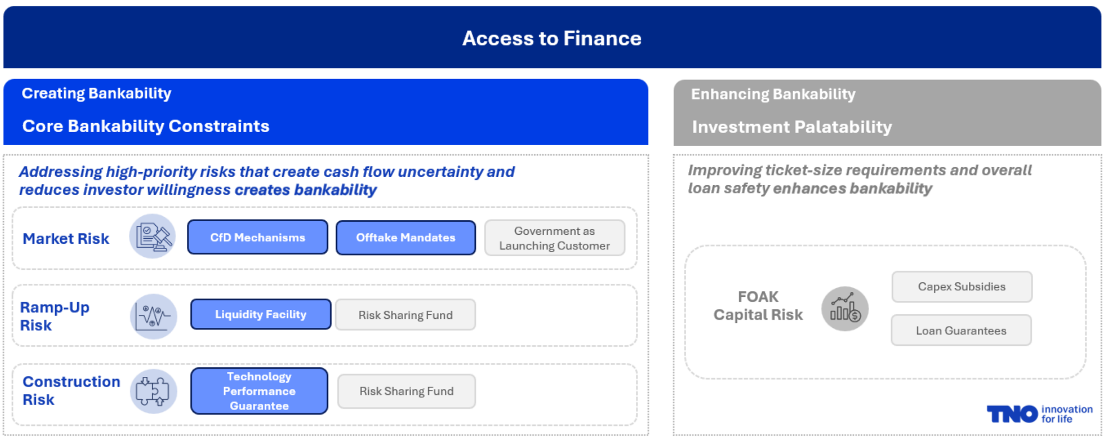


Figure 4.3: Summary of impact of support mechanisms on access to financing

The key support mechanisms proposed above are considered to be applicable to a wider set of FOAK projects in green chemistry, sustainable fuels, and circular value chains, especially those developed by independent project developers. These insights can be applied across emerging industrial technologies, where similar core challenges around FOAK deployment and value chain development affect bankability.

4.6 Next Steps & Further Research

As a next step following the Financing Roundtables and TNO study, the Ministry of Economic Affairs and Climate Policy, together with Invest-NL and key stakeholders from the financial sector, will further develop the identified high-priority support mechanisms. The focus will be on translating the identified support mechanisms into concrete and actionable instruments that can effectively address the key bankability barriers facing FOAK green chemistry projects. This next phase will involve evaluating how the proposed support mechanisms can best fit within existing and upcoming policy frameworks, financing instruments, and public investment structures. Particular attention will be given to implementation feasibility, institutional ownership, required public-private coordination, and alignment with broader societal objectives.

While this study provides a comprehensive overview of support mechanisms to improve the bankability of green chemistry business cases, further research in the following areas could provide a more complete perspective on access to finance and add further nuance to inform policymaking:

- **Deep-dive on 2-3 support mechanisms:** Further develop eligibility requirements, potential tendering procedures, execution strategies with milestones, required stakeholder collaborations, and develop a roadmap for implementation through market consultations with financiers, project developers, and supporting actors like EPCs.
- **Investigate the equity-side for FOAK projects and scale-up companies:** Before debt access and bankability is a consideration, equity must be secured to scale-up new industrial companies, further develop innovative technologies, and finance project pre-development activities (e.g., FEED studies). The creditworthiness and track-record of the equity investor are essential in the credit assessment of the institutional lender, oftentimes being a major contributor to unlocking debt financing. Attracting high-caliber equity investment with an understanding of FOAK realities and patience in crucial design phases is therefore key to a successful technology development process, improving access to debt, and enabling the larger rollout of FOAK. However, equity investment in these companies and projects is still lagging and oftentimes not well aligned with the timelines and realities of FOAK projects. Further exploration is therefore needed on main barriers and investment opportunities for equity investment in next generation industrial companies developing FOAK projects, as well as potential government and market-based support mechanisms that create opportunities and upside to attract equity investors with the right characteristics for FOAK projects.
- **Quantitative assessment of public funding needs:** Develop short-term estimates of public funding requirements for applying the high-impact support mechanisms highlighted in this study to the scaling of selected production pathways. Providing public funding estimates will support the further development and implementation of chosen support mechanisms. This analysis should include a baseline assessment of how much public funding is currently allocated by ministries to selected production pathways and where public funding is directed towards other production pathways instead. Such an analysis should include multiple scenarios (low, medium and high): what is the minimum public budget required, what could be achieved with a medium budget, and what could be achieved with a more substantial budget, as well as an indication of how subsidy requirements may differ between selected production pathways. This quantitative analysis could be used to support decision-making on whether additional public funding is required and, if so, how much, compared with the current level of support.

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Annex A
Techno-Economic Assessment of a First-of-a-Kind Biomass Gasification to Methanol and PLA Facilities

This annex focuses on Capex estimation details, including First-of-a-Kind (FOAK) cost estimation method, process description, techno-economic data of a nth-of-a-kind (NOAK) facilities, and the conversion of NOAK-based PLA and bio-methanol data to FOAK-based PLA and bio-methanol data.

The source and origin of woody biomass feedstock for bio-methanol and sugar feedstock for PLA was out of scope for this study and below analysis.

A.1 FOAK Techno-Economic Analysis

A FOAK Techno-Economic Analysis (TEA) is a specialized, in-depth evaluation used to assess the commercial viability, technical risks, and cost drivers of a new, unproven technology when it is first deployed at a small commercial or demonstration scale (see Figure A.1). Unlike standard TEAs, which often model mature, optimized NOAK plants, a FOAK analysis specifically accounts for the high risks, capital intensity, and performance uncertainties associated with bringing a technology out of the laboratory. Thus, to take account of these risks and uncertainties, cost escalation factors or learning curves are used for FOAK capex analysis.

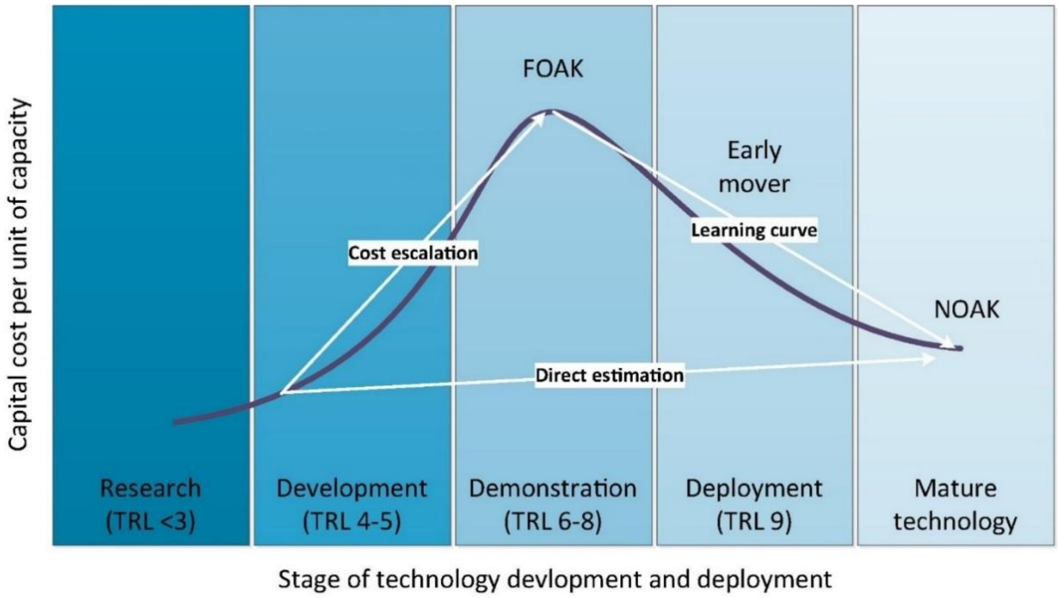

Figure A.1: FOAK vs. NOAK cost comparison throughout the technology development of a process[5]

Key reasons for cost escalation in FOAK plants are:
1) High contingency because of high risks and technical uncertainties, leading to FOAK projects requiring much higher contingency percentages in their cost estimation
2) Limited data on equipment cost and cost estimates are often not fully defined, requiring estimates to be updated for low accuracy
3) Process knowledge is limited and as the accuracy of the cost estimations heavily depends on the depth of the design, with lower-level of process knowledge for FOAK design often leading to significant cost overruns

FOAK cost estimation involves, often, using a detailed bottom-up engineering approach to calculate capital costs for new technologies. The RAND method (also known as the pioneer plant cost estimation method) is an empirical approach for estimating the costs and performance of FOAK facilities[6] [7]. Developed in 1981 by Edward Merrow et al. at the RAND Corporation, it uses statistical regression analysis to adjust optimistic "bottom-up" engineering estimates into "pioneer plant" cost estimates.

The RAND method treats FOAK cost estimation as a function of technological uncertainty and project definition. It typically follows three steps: (1) detailed TEA of a NOAK plant design; (2) applying cost growth factor estimated through empirical equations to "inflate" the total capital investment (TCI) based on specific risk variables; (3) followed by adjusting the plant performance factor (operational reliability) “downward” to account for early-stage technical and plant start-up issues.

The RAND model uses six critical factors, as shown in Table A.1, to calculate a cost growth factor; i.e., degree of definition (i.e., how much of the engineering and design or front-end loading is complete), technological innovativeness (i.e., the percentage of the plant's capital

[5] M. Van Der Spek, A. Ramirez, and A. Faaij, “Challenges and uncertainties of ex ante techno-economic analysis of low TRL CO_2 capture technology: Lessons from a case study of an NGCC with exhaust gas recycle and electric swing adsorption,” *Appl. Energy*, vol. 208, pp. 920–934, Dec. 2017

[6] R. E. Horvath, *Pioneer plants study user’s manual*. in [Report] / Rand, no. R-2569/1-DOE. Santa Monica, Calif: Rand, 1983. [Online]. Available: https://www.rand.org/pubs/reports/R2569z1.html

[7] T. K. Poddar and C. D. Scown, “Technoeconomic analysis for near-term scale-up of bioprocesses,” *Curr. Opin. Biotechnol.*, vol. 92, p. 103258, Apr. 2025, doi: 10.1016/j.copbio.2025.103258.

cost dedicated to new and unproven technologies), impurity problems (i.e., the level of difficulty expected in handling feedstock or waste streams), complexity measured by the number of separate process steps or units in the facility and project site characteristics (i.e., specific local challenges or lack of infrastructure). In addition to the cost escalation, the operating performance of a FOAK plant impacts the working capital needs. The "on-stream factor" (which is the ratio of actual operating time of a plant to the total possible operating time) for a FOAK plant is typically lower than a mature plant in its first years due to limited knowledge on start-up, process operations and process safety. These performance uncertainties are considered in the RAND method using four variables defined in Table A.1.

Table A.1: Variables and their definition in the RAND method [8] [9]

Variables		Definition
Cost growth variables	Percentage of new equipment (PCTNEW)	The installed cost of all commercially undemonstrated equipment as percentage of total installed equipment cost.
	Issues from impurities, corrosion & abrasion (IMPURITIES)	Represents the potential process issues that may arise due to impurity build-up from recycling streams, equipment corrosion or abrasions. The value ranges from 0 to 5, with 0 given for processes with no impurities or recycle or corrosion issues.
	Process complexity (COMPLEXITY)	The number of continuously linked process steps. The value ranges from 1 to 11 according to the data from the reference plant used in developing the RAND model.
	CAPEX calculation rigor (INCLUSIVENESS)	Percentage of pre-startup inventory, pre-startup personal and land purchase cost considered. Enter a whole number between 0 & 100, corresponding to the percentage. For example, if two of these factor have been rigorously considered, the variable would be given a value of 67%.
	Commercial status (C)	Use a value of -0.04011 for commercial or precommercial plants. Use a value of -0.06361 for processes with substantial R&D component like in pre-development or research phase.
	Project status (PROJECT DEFINITION)	A numerical value between 2 & 8 is used, based on the level of engineering completed and site readiness at the time of cost estimation. The level of engineering completeness is defined as: 1- Engineering completed, 2- Moderate or extensive engineering, 3- Limited engineering, 4- Design stage. The value of site-specific information is assigned as: 1- Definitive or completed work, 2- Preliminary or limited work, 3- Assumed or implicit analysis, 4- Not used in cost estimation at all. A value of 2 means that the engineering & site preparation work is completed and a value of 8 means that the project is at design phase without considering site-specific costs.
Plant performance variables	New process steps (NEWSTEPS)	The number of steps in the process that have not been proven commercially. The value ranges from 0 to 11 according to the data from the reference plant used in developing the RAND model.

[8] R. E. Horvath, *Pioneer plants study user's manual*. in [Report] / Rand, no. R-2569/1-DOE. Santa Monica, Calif: Rand, 1983. [Online]. Available: https://www.rand.org/pubs/reports/R2569z1.html
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Variables		Definition
	Process validation (BALEQS)	The percentage of mass and energy balance equations used in the plant design that are validated with commercial scale data. A value ranging from 0 to 100 can be used corresponding to the percentage. Some weight can be given to rigorous theoretical modelling based on RAND report.
	Difficulty of waste handling (WASTE)	Potential problems that may be associated with waste handling. A value between 0 & 5 can be used, with 0 meaning no waste handling issues and 5 meaning significant waste handling issues.
	Solid handling in the process (SOLIDS)	The scale used is 0 or 1. A value of 1 if the plant is expected to handle solids either as feedstock, intermediate or as products. Value of 0, otherwise.

Using the empirical correlation as shown in equation (1), equation (2) and definitions provided in Table A.1, the cost growth factor and plant performance factor for the FOAK plant is estimated. The total cost of investment and plant capacity of the FOAK plant is calculated using the factors and equation (3)-(4).

$$\begin{aligned} Cost\ growth\ factor &= 1.12196 - (0.00297 * PCTNEW) - (0.02125 * IMPURITIES) \\ &- (0.01137 * COMPLEXITY) + (0.00111 * INCLUSIVENESS) + (C \\ &* PROJECT\ DEFINITION) \end{aligned} \quad (1)$$

$$\begin{aligned} Plant\ performance\ factor &= 85.77 - (9.69 * NEWSTEPS) + (0.33 * BALEQS) - (4.12 * WASTE) \\ &- (17.91 * SOLIDS) \end{aligned} \quad (2)$$

$$Total\ cost\ of\ investment_{FOAK} = \frac{Total\ cost\ of\ investment_{NOAK}}{Cost\ growth\ factor} \quad (3)$$

$$Plant\ capacity_{FOAK} = Nameplate\ capacity * Plant\ performance\ factor \quad (4)$$

A.2 NOAK Techno-Economic Analysis

NOAK TEA is an evaluation method used to determine the cost, performance, and financial viability of a technology that has reached a mature, commercial, and standardized stage. Unlike FOAK analysis, which accounts for the high costs of initial design, engineering, and operational issues of a new technology, NOAK assumes the technology has been deployed multiple times resulting in lower, stable costs due to learning-by-doing, optimized construction, and supply chain efficiencies. The CAPEX of a NOAK plant can be calculated from bare equipment cost using the lang factor as shown in Table A.2.

Table A.2: Breakdown of NOAK lang factor[10]

CAPEX breakdown		NOAK Lang factor		
		Solid	Solid-fluid	Fluid
Total direct costs	Equipment purchase	1	1	1
	Equipment delivery	0.1	0.1	0.1
	Equipment installation	0.45	0.39	0.47
	Instrumentation and controls	0.18	0.26	0.36
	Piping	0.16	0.31	0.68
	Electrical systems	0.1	0.1	0.11
	Buildings	0.25	0.29	0.18
	Yard improvements	0.15	0.12	0.1
	Service facilities	0.4	0.55	0.7
	Land (if purchase required)	0.06	0.06	0.06
Total indirect costs	Engineering & supervision	0.33	0.32	0.33
	Construction expenses	0.39	0.34	0.41
Overhead fee	Legal expenses	0.04	0.04	0.04
	Contractor's fee	0.17	0.19	0.22
Contingency	Contingency	0.35	0.37	0.44
Working capital	Working capital	0.7	0.75	0.89
Sum		**4.83**	**5.19**	**6.09**

The NOAK Lang factors contain various categories of CAPEX including direct, indirect, overhead, contingency and working costs for solids, solid-fluid, and fluid based processes. Table A.2 details the factor used and the direct costs considers equipment purchase, delivery, installation, instrumentation, piping, electrical systems, buildings, yard improvements, service facilities, and land acquisition. Indirect costs are also outlined, covering engineering and supervision, construction expenses, legal fees, contractor's fees, contingency, and working capital. Each item is assigned a specific Lang factor, indicating its proportion of the total cost for each process type. The summed Lang factors for solids, solid-fluid, and fluid processes are 4.83, 5.19, and 6.09 respectively, illustrating the relative cost intensity of each category. A Lang factor of 5.19 is used in this study as it is assumed the PLA and bio-methanol plants are a solid-fluid based process.

The Capex expenditure is assumed to happen in two years with assumption of expenditure as shown in Figure A.2. This staged investment approach ensures that funds are allocated efficiently throughout the development and scaling phases of the production plants to calculate the cash flow analysis.

[10] G. Towler and R. Sinnott, "Capital Cost Estimating," in *Chemical Engineering Design*, Elsevier, 2013, pp. 307–354. doi: 10.1016/B978-0-08-096659-5.00007-9

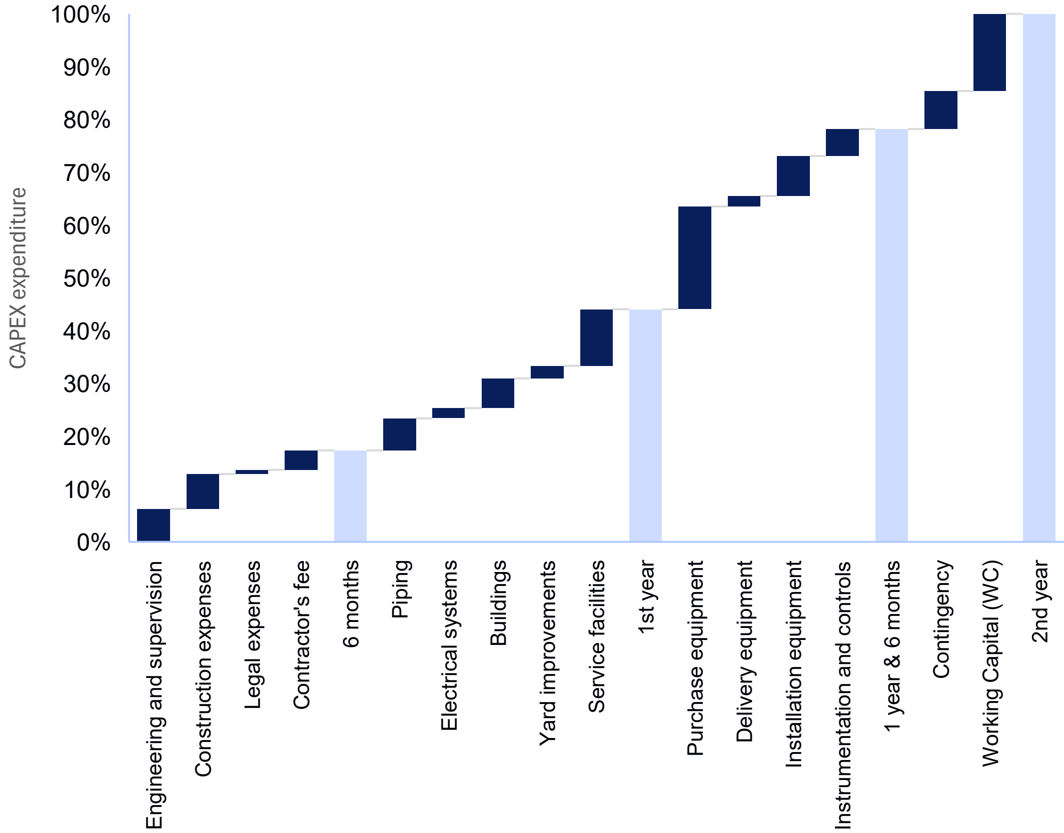

Figure A.4: Assumed timeline of the CAPEX expenditure

The PLA and bio-methanol production plants were scaled to the required production capacities (explained in Case-1 and Case-2) and the Capex was scaled using six-tenths rule as shown in equation 5.

$$New\ CAPEX = Previous\ CAPEX * \left(\frac{New\ capacity}{Previous\ capacity}\right)^n \quad (5)$$

The exponent n is typically 0.8 to 0.9 for processes that use a lot of mechanical work or gas compression (e.g., methanol, paper pulping, solids-handling plants)[11]. For typical petrochemical processes, n is usually around 0.7. For small-scale, highly-instrumented processes, such as specialty chemical or pharmaceuticals manufacture, n is in the range 0.4 to 0.5. Averaged across the whole chemical industry, n is around 0.6, and hence equation-5 is commonly referred to as the "six-tenths rule."[12] Thus, based on the above heuristic values, the scaling factor of 0.7 (for PLA) and 0.8 (for Bio-methanol) were used in this study. All the CAPEX were harmonised to the base year 2022/2023 using CEPCI and are reported in Euro (2022/2023).

[11] G. Towler and R. Sinnott, "Capital Cost Estimating," in *Chemical Engineering Design*, Elsevier, 2013, pp. 307–354. doi: 10.1016/B978-0-08-096659-5.00007-9

[12] G. Towler and R. Sinnott, "Capital Cost Estimating," in *Chemical Engineering Design*, Elsevier, 2013, pp. 307–354. doi: 10.1016/B978-0-08-096659-5.00007-9

A.3 Case-1: Bio-Methanol Production

The global renewable and low-carbon methanol landscape is expanding rapidly, driven by decarbonisation targets and regulatory incentives. According to GENA's Project Navigator Methanol, globally there are 246 plants and projects in the pipeline with an expected methanol production capacity of ~50 million tonnes[13]. Most biomass gasification based methanol production projects are at demonstration phase, with observed TRL between 7-8. They are located mostly around western European countries like Sweden, Finland, Netherlands and Spain with market players like Sodra (Sweden), Enerkem (Spain/Netherlands), VTT (Finland), Veolia (Finland), and Gidara (Netherlands)[14] [15].

Biomass gasification to methanol process

In this study, woody biomass is assumed as the feedstock, which is subsequently converted into syngas and then methanol. The incoming woody biomass is first processed through a belt dryer, reducing its moisture content from 45% down to 15%, before it enters the gasification stage. Within direct gasification-based facilities (see Figure A.5), the gasifier used is a pressurised circulating fluidised bed (CFB), supplied with both steam and oxygen. The process is thermally maintained by partially oxidising the biomass using oxygen sourced from an air separation unit (ASU). The majority of the carbon from the feed ends up in the nitrogen-free syngas as CO, CO_2 and CH_4, while a smaller portion is removed from the bed as unconverted char. These gasification methods produce syngas that is free from nitrogen but contains considerable levels of tar and methane. Downstream from the gasifier and a high temperature filtration unit, a catalytic autothermal reformer (ATR) is installed to transform methane and tar into CO and H_2. The ATR receives oxygen generated by an ASU with 95% molar purity, and utilises catalysts suitable for raw syngas operation. A restricted equilibrium calculation for the ATR presumes 90% conversion of methane and total conversion of higher hydrocarbons. Following reforming, the syngas requires further conditioning, cleaning and compression ahead of product synthesis and purification. A water scrubber is used to extract soluble impurities from the syngas, such as ammonia and chlorine. Bulk sulphur is removed using a liquid redox unit (the LO-CAT process), wherein H_2S is transformed into elemental sulphur and water via reaction with an iron oxygen carrier. Upstream of the final compression stage at approximately 50 bar in methanol production plants an activated carbon bed and sulphur scavenging units are employed to eliminate trace contaminants.

[13] Gena solutions, "Renewable Methanol Update (July 2025)." Accessed: Oct. 16, 2025. [Online]. Available: https://www.genasolutions.com/analysis_and_insights/49
[14] I. Landalv, "Status- Renewable Bio-methanol production," Fuels & Energy Consulting, 2020
[15] A. Brown et al., "Advanced Biofuels - Potential for Cost Reduction," 2020

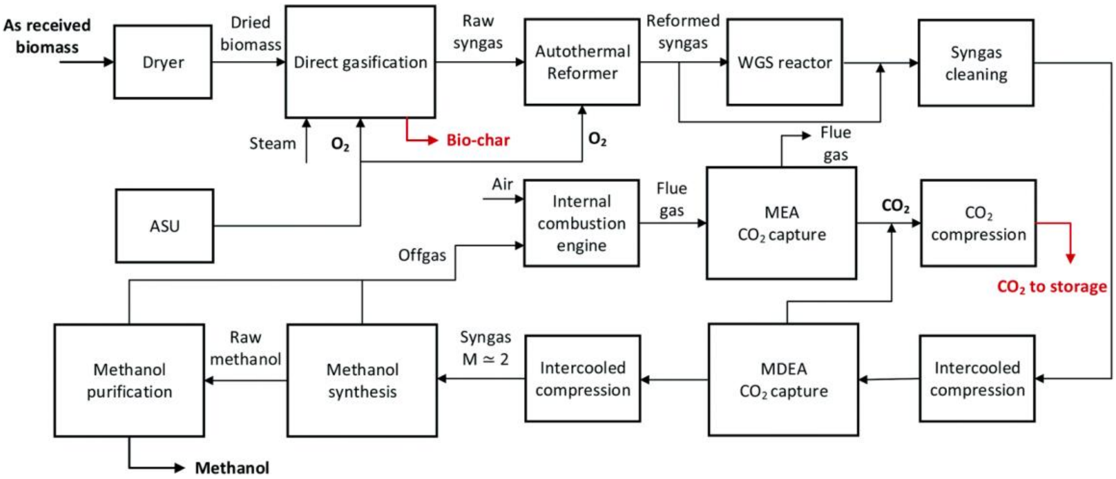

Figure A.5: Block flow diagram of a direct gasification based Bio-methanol plant[16]

For methanol production, the plants require syngas with a module M = (H_2 + CO_2)/(CO + CO_2) of approximately 2. This ratio is achieved by conditioning the syngas using a water-gas shift (WGS) reactor and/or a CO_2 removal system. After passing through the autothermal reformer (ATR), the syngas is cooled to 220 ºC, with roughly 27.4% of the total flow directed to an adiabatic sour WGS reactor. This step fine-tunes the syngas composition ahead of CO_2 removal. The WGS reactor operates at the lower end of the raw gas shift temperature spectrum (200–500 ºC). It is worth noting that typical cobalt-molybdenum sour WGS catalysts need sulphur compound levels in the dry gas of at least 100–1500 ppm to remain active. Under the biomass and gasification conditions considered in the reference study, the sulphur level in the sour WGS after direct gasification is about 100 ppm. Following bulk cleaning, the syngas is compressed to 30 bar using a four-stage intercooled compressor. The outlet temperature after each stage is 40 ºC, with a pressure ratio of roughly 2 per stage, keeping the gas temperature below 115 ºC at each step. A pre-combustion CO_2 removal system, based on MDEA scrubbing at 30 bar, extracts CO_2 from the syngas, with 95% of the CO_2 separated to achieve the desired module before methanol synthesis.

In methanol facilities, a two-stage intercooled compressor boosts the pressure of the conditioned syngas to around 90 bar, which matches the operating pressure of the methanol synthesis reactor. After purification, conditioning, and compression, the fresh syngas (with a module value of 2.05) is sent to the methanol synthesis unit. The fresh syngas is mixed with recycled gas that was not converted, then preheated in a feed/effluent heat exchanger before entering the methanol synthesis reactor. The reactor output is cooled to 40 ºC and passed through a flash unit, separating light gases which are recycled back to the reactor. Methanol is synthesised in a multi-tubular fixed bed reactor loaded with commercial Cu/ZnO/Al_2O_3 (CZA) catalyst pellets, and externally cooled by boiling water (boiling water reactor). The reactor features tubes that are 6 m long and 40 mm in diameter, with boiling water maintained at 238 ºC. The crude product, which is rich in methanol and water plus trace components (such as light boiling substances and ethanol), is sent to the purification section at 2 bar and roughly 40 ºC after pressure reduction. Two distillation columns are used in series: the first removes most of the non-condensable gases, while the second concentrates the methanol to a purity of 99.85% by weight. Methanol recovery exceeds 99.5% by mole in both columns. The stabilising column uses 20 trays for separation, and the concentration column employs 40 trays. The

[16] A. Poluzzi, G. Guandalini, and M. C. Romano, “Flexible methanol and hydrogen production from biomass gasification with negative emissions,” *Sustain. Energy Fuels*, vol. 6, no. 16, pp. 3830–3851, 2022, doi: 10.1039/D2SE00661H.

purge stream from the methanol synthesis and purification units contains significant light gases, which are used in a co-generative internal combustion engine (ICE) to produce electricity and steam.

The mass flows, energy flows, and economic data of a bio-methanol production plant were collected from a recent TNO study by de Leeuw den Bouter et al. In this study, a bio-methanol production capacity of 200 kt/y is assumed based on the production capacity of a similar plant by Gidara[17].

Table A.3: Mass flows, energy flows, and economic data of a NOAK bio-methanol plant[18]

Mass	**Mass in (kt)**		**Mass out (kt)**	
	Dry biomass	404	Methanol	200
	Water (steam fluidization, boiling water feed)	160	CO_2	324
	Oxygen reformer	36	Flue gas	170
	Oxygen gasifier	94		
Energy	**Energy in (TJ/y)**		**Energy out (TJ/y)**	
	Electricity	296		
	Cooling water	406		
Economic	**NOAK CAPEX (Million EUR)**		**Basis year**	
	468		2022	

The NOAK plant Capex was converted to a FOAK plant Capex using the RAND method described above. The values and assumptions used to estimate the variables is provided in Table A.7.

Table A.4: Values assumed for the FOAK calculation of the Bio-methanol plant using RAND method

RAND method variables		**Values assumed**	**Notes**
Cost growth factor	PCTNEW	25	Some equipment are commercially proven like compressors and columns while some are new like biomass gasifier
	IMPURITIES	5	The recycle streams in the process are: 1) Gasifier catalyst recycling from filters and cyclones 2) Scrubber liquid recycle 3) Activated char bed regeneration recycle 4) Waste water recycling in quench section 5) MDEA recycling in CO_2 scrubber 6) Syngas recycling in methanol reactor Thus, high value assumed due to solids and gas recycling

[17] Gidara Energy, "HTW®2.0 Gasification: A proven path towards Advanced Biofuels," 2022. Accessed: Dec. 02, 2026. [Online]. Available: https://www.ieabioenergy.com/wp-content/uploads/2022/10/2-3_Moghaddam-GIDARA.pdf

[18] A. W. N de Leeuw den Bouter, S Luzzi, J. W Dijkstra, M. Weeda, and R. J. Detz, "The potential role of renewable hydrogen and negative emission credits in renewable methanol production. (under review)".

RAND method variables		Values assumed	Notes
	COMPLEXITY	8	Continuously linked process steps are: 1) Air separation Unit 2) Biomass drying unit 3) Biomass gasification unit 4) Syngas cleaning unit 5) Syngas conditioning unit 6) Syngas to methanol unit 7) Methanol purification unit 8) Off gas handling and CHP units
	INCLUSIVENESS	0	Among pre-startup personnel costs, pre-start-up inventory cost and land purchase; only one factor is assumed to be considered in this work. It is assumed that the land for the plant is available in the Port of Rotterdam area and the cost is included in lang factor
	C	-0.04011	Biomass gasification plant is assumed to be at pre-commercial stage and syngas to methanol at commercial stage
	PROJECT DEFINITION	7	Level of completeness: (1) engineering completed, (2) moderate or extensive engineering, (3) limited engineering, and (4) screening design stage. (assumed 4 for bio-methanol via gasification in Europe as there is no commercial plant in Europe) Site-specific information: (1) definitive or completed work, (2) preliminary or limited work, (3) assumed or implicit analysis, and (4) not used in the cost estimation at all. (assumed 3 for bio-methanol as site preparation is considered in Lang factor)
Plant performance factor	NEWSTEPS	3	1) Air separation Unit (Commercially proven) 2) Biomass drying unit (Commercially not proven) 3) Biomass gasification unit (Commercially not proven) 4) Syngas cleaning unit (Commercially not proven) 5) Syngas conditioning unit (Commercially proven) 6) Syngas to methanol unit (Commercially proven) 7) Methanol purification unit (Commercially proven) 8) Off gas handling and CHP units (Commercially proven)
	BALEQS	50	The mass and energy balance used for the CAPEX calculation of this study was based on a TEA journal paper. Thus, 50% accuracy assumed

RAND method variables		Values assumed	Notes
	WASTE	3	The waste associated with the bio-methanol via gasification process are: 1) Waste water 2) Ash + char 3) Entrained gasifier catalyst 4) CO_2 from syngas conditioning 5) Entrained MDEA 6) Purge gas, off gas, combustion flue gas These wastes are assumed to be moderately difficult to handle
	SOLIDS	1	Biomass, gasifier catalyst, activated char, ash + char from syngas are solids in the process

Based on the assumption given in Table A.7, the cost growth factor is calculated as 0.57 and plant performance factor is calculated as 43% for a FOAK bio-methanol plant in the Netherlands. Thus, the Capex of a FOAK based bio-methanol plant escalated from €468m to €823m based on the assessment.

Bio-methanol plant with 200 kt methanol production capacity	NOAK Capex	FOAK Capex
	€468m	€823m

The table below provides indicative price estimates used in this study to estimate Opex for the 200kt FOAK bio-methanol facility. This is largely illustrative for executing the business case. Opex is highly sensitive to changes in price values, which vary based on location, source, and short-term market movements.

Table A.5: Indicative price estimates for bio-methanol mass and energy flows to illustrate Opex

Indicative Price Estimates for Mass and Energy Flows (Opex)			
Component	**Price**	**Unit**	**Source**
Dry Biomass (Woodchips)	77	EUR/t	S. Lensink and E. Eggink, “Eindadvies basisbedragen SDE++ 2025,” Planbureau voor de Leefomgeving (PBL), 2025.
Water (steam fluidization, boiling water feed)	35	EUR/t	Estimated in: A. W. N de Leeuw den Bouter, S Luzzi, J. W Dijkstra, M. Weeda, and R. J. Detz, “The potential role of renewable hydrogen and negative emission credits in renewable methanol production. (under review)”.
Electricity (Euro/kWh)	0.0836	EUR/kWh	
Cooling water (CW) (Euro/m^3)	0,0712	EUR/m^3	

A.4 Case-2: PLA Production

PLA is a bio-based polymer used in certain single-use packaging (such as plates, cutlery, straws, balloon sticks, and cotton buds) as well as medical and healthcare applications. [19] It can be produced from a range of sugar-rich crops, such as sugarcane, sugar beet, corn, and cassava. Currently, most PLA is manufactured from sugarcane (e.g. Corbion) or corn (e.g. NatureWorks).

The global PLA production is estimated to be approximately 320 ktonnes, according to harmonized data from nova-Institute for the years 2020-2024[20]. Key players in this market include Corbion (Netherlands), NatureWorks (US), TotalEnergies-Corbion (Thailand), Cargill Incorporated (US), Galactic (Belgium), Henan Jindan Lactic Acid Technology (China), Unitika ltd (Japan), Sulzer (Switzerland), Mushashino Chemical (Japan), Vigon International (US), Toray Industries INC.(Japan), and Danimer Scientific (US)[21].

Diluted sugar to PLA

PLA is produced by the fermentation of sugar (glucose) to lactic acid followed by esterification and ring-opening polymerisation, as shown in Figure A.3..

Figure A.3: Block flow diagram of PLA production from sugar

The fermentation process starts by combining process water with the carbon source and essential nutrients, such as nitrogen and minerals, in vessel V_{PLA}-201 to achieve a sugar concentration of 213 g/l. The mixture then undergoes continuous heat sterilisation via two heat exchangers and a holding tube (E_{PLA}-201 to E_{PLA}-203), where it is sterilised at 140 °C and subsequently cooled to 37 °C, which is the fermentation temperature. This prepared media is then transferred to bioreactors (F_{PLA}-204), with 10% (v/v) inoculum of fermentation broth introduced per bioreactor. During fermentation, the pH is regulated at 6.7 by adding 10 M NaOH solution, and calcium carbonate is used to neutralise the process, resulting in the formation of calcium lactate. The downstream purification of L-lactic acid, with optical purity exceeding 99.4%, follows a three-stage approach. Initially, bacterial biomass is separated from the fermentation broth by centrifugation (CF_{PLA}-201), after which calcium lactate reacts with 50% sulphuric acid at 30 °C for one hour (R_{PLA}-201), producing dilute lactic acid and solid calcium sulphate. The calcium sulphate is then removed by another centrifugation step (CF_{PLA}-202), and the concentration of lactic acid in the liquid stream is increased to roughly 50% (w/w) through evaporation (EV_{PLA}-201). Any lactic acid lost during evaporation is recovered by recycling the vapour effluent. The second stage involves the esterification of the lactic acid-rich stream with methanol (99.6%) in a continuously stirred tank reactor (R_{PLA}-202) to yield methyl lactate and water, with the resulting stream heated to 105 °C (E-206). In the third stage, polymer-grade L-lactic acid is produced via hydrolysis of methyl lactate in a reactive distillation

[19] Global Bio-Based Polymer Market to Grow 13% Annually Through 2029, Led by Asia and North America," *Renewable Carbon*, 2025. Accessed: Dec. 23, 2025. [Online]. Available: https://renewable-carbon.eu/news/global-bio-based-polymer-market-to-grow-13-annually-through-2029-led-by-asia-and-north-america/

[20] Global Bio-Based Polymer Market to Grow 13% Annually Through 2029, Led by Asia and North America," *Renewable Carbon*, 2025. Accessed: Dec. 23, 2025. [Online]. Available: https://renewable-carbon.eu/news/global-bio-based-polymer-market-to-grow-13-annually-through-2029-led-by-asia-and-north-america/

[21] "Global Lactic Acid and Polylactic Acid 2023-2028: Europe Leads the Polylactic Acid Market with 33.4% Market Share, Driven by Sustainable Solutions," *GlobeNewswire*, 2023. Accessed: Dec. 23, 2025. [Online]. Available: https://www.globenewswire.com/news-release/2023/08/22/2729303/28124/en/Global-Lactic-Acid-and-Polylactic-Acid-2023-2028-Europe-Leads-the-Polylactic-Acid-Market-with-33-4-Market-Share-Driven-by-Sustainable-Solutions.html

column (T_{PLA}-201). Methanol and excess water are separated as distillate and methanol is recycled back to the esterification stage through distillation (T_{PLA}-202). The downstream process achieves an overall yield of 97.7%, resulting in the production of polymer-grade lactic acid.

The pre-polymerisation phase can be broken down into two main sections: prepolymer production and lactide synthesis. Lactic acid from AREA 200 is directed into the prepolymer reactor (R_{PLA}-301), where it undergoes continuous condensation, with water removed at 120 °C for one hour. This condensation reaction forms low molecular weight poly(lactic acid), known as prepolymer. The vapour produced contains volatilised lactic acid and traces of low molecular weight oligomers, which are separated from water in column T_{PLA}-301 and recycled back into the process. The prepolymer is then introduced into the lactide reactor (R_{PLA}-302) along with stannous octoate catalyst, enabling the oligomers to cyclise and form lactide rings (cyclic dimers of lactic acid). Heat is applied to vaporise the lactide, which is continuously withdrawn as vapour. Any remaining liquid, containing unreacted oligomers, is recycled back to the reactor. The vapour stream also contains unreacted lactic acid, lactic acid oligomers, and water. Lactide purification is accomplished through two vacuum distillation columns (T_{PLA}-302–303); the first removes water from the lactide stream, while the second separates residual lactic acid. It is important to note that all three distillation columns produce overhead streams rich in lactic acid, which are collected and recycled to the lactic acid recovery stage.

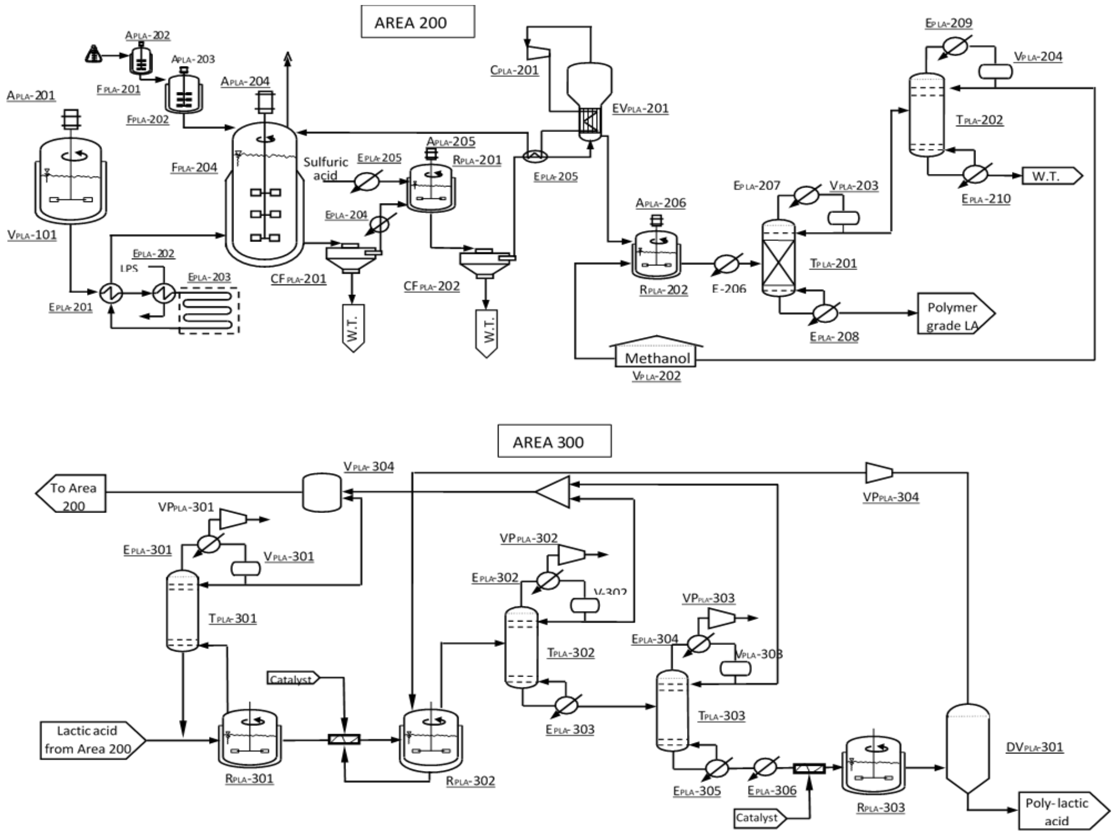

Figure A.4: Process flow diagram of the PLA production process [22] (Equipment tag description: A-Agitator, C-Compressor, CF- Centrifugal separator, CR- Crystallizer, DR- Dryer, DV- Devolatizer, E- Heat exchanger, EV-Evaporator, F- Fermenter, M- Pre steamer, P- Pump, R-Reactor, T- Distillation Column, V-Vessel, VP- Vacuum pump)

[22] S. M. Ioannidou *et al.*, “Techno-economic risk assessment, life cycle analysis and life cycle costing for poly(butylene succinate) and poly(lactic acid) production using renewable resources,” *Sci. Total Environ.*, vol. 806, 2022, doi: 10.1016/j.scitotenv.2021.150594.

In the final stage, the purified lactide is combined with stannous octoate catalyst and introduced into the polymerisation reactor (R_{PLA}-303), where high molecular weight PLA is formed through ring-opening polymerisation of lactide. The output stream contains a significant proportion of unreacted lactide, which is separated under vacuum in the devolatiliser (DV_{PLA}-301) and recycled back to the reactor. The finished PLA stream is then pelletised (this step is outside the scope of the present study) and stored.

The mass flows, energy flows, and economic data of the PLA production plant from sugar (glucose) were collected from Ioannidou et al.[23]. In this study, a PLA production capacity of 75 kt/y is assumed based on the production capacity of a similar PLA plant in Thailand[24].

Table A.6: Mass flows, energy flows, and economic data of a NOAK PLA production from C6 sugars [25]

Mass	Mass in (kt)		Mass out (kt)	
	Sugar	97	PLA	75
	Water	453	Calcium sulphate	71
	Yeast extract	9	Methyl lactate	0.1
	NH_4Cl	0.5	Methanol	0.01
	H_2SO_4 (50% concentration)	102	CO_2	23
	$NaNO_2$	0.5	Waste sludge	7
	$CaCO_3$	64	Waste water	549
	Stannous octoate	0.1		
	Methanol	0.1		
Energy	**Energy in (TJ/y)**		**Energy out (TJ/y)**	
	Electricity	180		
	LP Steam	660		
	MP steam	167		
	Cooling water	1414		
Economic	**NOAK CAPEX (Million EUR)**		**Basis year**	
	180		2023	

The NOAK plant Capex from the reference data was calibrated using the lang factor (5.19) as given in Table A.2 for this study. The NOAK plant Capex was converted to a FOAK plant Capex using the RAND method described above. The values and assumptions used to estimate the variables are provided in Table A.7.

[23] S. M. Ioannidou *et al.*, “Techno-economic risk assessment, life cycle analysis and life cycle costing for poly(butylene succinate) and poly(lactic acid) production using renewable resources,” *Sci. Total Environ.*, vol. 806, 2022, doi: 10.1016/j.scitotenv.2021.150594.

[24] Totalenergies, “Thailand: Total Corbion PLA starts-up its 75,000 tonnes per year bioplastics plant.” 2018. Accessed: Nov. 02, 2026. [Online]. Available: https://totalenergies.com/media/news/press-releases/thailand-total-corbion-pla-starts-its-75000-tonnes-year-bioplastics-plant

[25] S. M. Ioannidou *et al.*, “Techno-economic risk assessment, life cycle analysis and life cycle costing for poly(butylene succinate) and poly(lactic acid) production using renewable resources,” *Sci. Total Environ.*, vol. 806, 2022, doi: 10.1016/j.scitotenv.2021.150594.

Table A.7: Values assumed for the FOAK calculation of the PLA plant using RAND method

RAND method variables		Values assumed	Notes
Cost growth factor	PCTNEW	0	All equipment in the process has been commercially demonstrated in other countries like Corbion plant in Thailand
	IMPURITIES	4	The recycle streams in the process are: 1) water recycle from lactic acid evaporator, 2) Methanol recycle in lactic acid recovery section 3) Lactic acid has recycle in 3-stages during polymerisation steps 4) The usage of fermentation bacteria also add complexity to the build-up of impurities Thus, a higher value is used
	COMPLEXITY	5	Continuously linked process steps are: 1) Sugar dilution 2) Sugar fermentation to lactic acid 3) Lactic acid recovery 4) Lactic acid polymerisation 5) PLA recovery
	INCLUSIVENESS	0	Among pre-startup personnel costs, pre-start-up inventory cost and land purchase; it is assumed that no factor is considered.
	C	-0.04011	PLA plant is already commercially running in Corbion plant in Thailand. Thus, it is assumed that the design is in commercial stage
	PROJECT DEFINITION	7	Level of completeness: (1) engineering completed, (2) moderate or extensive engineering, (3) limited engineering, and (4) screening design stage. (assumed 4 for PLA in Europe as there is no commercial plant in Europe) Site-specific information: (1) definitive or completed work, (2) preliminary or limited work, (3) assumed or implicit analysis, and (4) not used in the cost estimation at all. (assumed 3 for PLA as site preparation is considered in Lang factor)
Plant performance factor	NEWSTEPS	0	All the steps in the PLA process have been proven commercially
	BALEQS	50	The mass and energy balance used for the CAPEX calculation of this study was based on a TEA journal paper. Thus, 50% accuracy assumed

RAND method variables		Values assumed	Notes
	WASTE	2	The waste associated with the PLA process are: 1) Waste water 2) Waste sludge (containing bacteria) 3) Entrained methanol 4) CO_2 5) Solids like Calcium sulphate 6) Liquids like methyl lactate These wastes are assumed to be moderately easy to handle
	SOLIDS	1	Sugar, $CaCO_3$ and sludge are solids in the process

Based on the assumptions given in Table 7, the cost growth factor is calculated as 0.7 and plant performance factor is calculated as 76% for a FOAK plant in the Netherlands. Thus, the Capex of a FOAK based PLA plant escalated from €180m to €257m based on the assessment. This value is in line with the estimated investment of $140m for the 75kt Total/Corbion PLA facility[26] in Thailand from 2016, but conservative when compared to the recent investment requirement estimate of €500m for the upcoming 75kt PLA Futerro project in Normandy[27]. Current real-world values therefore may likely exceed the €257m estimate in this study.

PLA plant with 75 kt polymer production capacity	NOAK Capex	FOAK Capex
	€180m	€257m

The table below provides indicative price estimates used in this study to estimate Opex for the 75kt FOAK PLA facility. This is largely illustrative for executing the business case. Opex is highly sensitive to changes in price values, which vary based on location, source, and short-term market movements. The sugar feedstock for PLA is assumed to be raw sugar and the average EU reference price is used. It is assumed that the raw sugar feedstock is compatible with the glucose based PLA process in the reference case.

[26] Corbion, ''Total Corbion PLA Joint Venture – Investor Presentation. Corbion N.V. and Total S.A.'', 16 November 2016. Accessed: July 08, 2026. [Online]. Available at: https://www.corbion.com/-/media/corbion/files/pla-pdfs-1-of-24/20161116-totalcorbion-final_566905.pdf?utm

[27] Futerro, ''Futerro closes its first external fund-raising for its biorefinery project in Europe.'', 2024. Accessed: July 08, 2026. [Online]. Available: https://www.futerro.com/futerro-closes-its-first-external-fund-raising-for-its-biorefinery-project-in-europe/

Table A.8: Indicative price estimates for PLA mass and energy flows to illustrate Opex

Indicative Price Estimates for Mass and Energy Flows (Opex)			
Component	**Price**	**Unit**	**Source**
Sugar	400	EUR/t	European Commission, Directorate-General for Agriculture and Rural Development. “Sugar Dashboard,” [Online]. Available: https://agriculture.ec.europa.eu/document/download/166100ca-001d-4a6c-9c96-52af7d0e78c5_en?filename=sugar-dash-board_en.pdf
Water	0,37	EUR/t	Intratec. “Process water cost in the Netherlands,” [Online]. Available: https://www.intratec.us/solutions/industry-economics-worldwide/utility/process-water-cost-netherlands
Yeast extract	1387	EUR/t	2017 price from “S. M. Ioannidou et al., “Techno-economic risk assessment, life cycle analysis and life cycle costing for poly(bu-tylene succinate) and poly(lactic acid) production using renewa-ble resources,” Sci. Total Environ., vol. 806, 2022, doi: 10.1016/j.scitotenv.2021.150594.”
NH4Cl	314	EUR/t	Zauba. “Ammonium chloride import data,” [Online]. Available: https://www.zauba.com/import-ammonium-chloride-hs-code.html
H2SO4 (50 wt% concentrated)	92	EUR/t	Intratec. “Sulfuric acid prices,” [Online]. Available: https://www.intratec.us/solutions/primary-commodity-prices/commodity/sulfuric-acid-prices
NaNO2	1073	EUR/t	Intratec.”Sodium nitrate prices,” [Online]. Available: https://www.intratec.us/solutions/primary-commodity-prices/commodity/sodium-nitrate-prices
CaCO3	176	EUR/t	Intratec. “Calcium carbonate prices,” [Online]. Available: https://www.intratec.us/solutions/primary-commodity-prices/commodity/calcium-carbonate-prices
Stannous octoate	8628	EUR/t	Zauba. “Stannous octoate import data,” [Online]. Available: https://www.zauba.com/import-stannous+octoate-hs-code.html
Methanol	518	EUR/t	Intratec. “Methanol prices,” [Online]. Available: https://www.in-tratec.us/solutions/primary-commodity-prices/commodity/metha-nol-prices
Electricity	0,16	EUR/kWh	Intratec. “Electricity price in the Netherlands,” [Online]. Avai-lable: https://www.intratec.us/solutions/energy-prices-mar-kets/commodity/electricity-price-netherlands
LP Steam	22	EUR/t	Intratec. “Industrial steam cost in the Netherlands,” [Online]. Available: https://www.intratec.us/solutions/industry-economics-worldwide/utility/industrial-steam-cost-netherlands
MP steam	27	EUR/t	Intratec. “Industrial steam cost in the Netherlands,” [Online]. Available: https://www.intratec.us/solutions/industry-economics-worldwide/utility/industrial-steam-cost-netherlands
Cooling water	0,07	EUR/t	Intratec. “Cooling water cost in the Netherlands,” [Online]. Avai-lable: https://www.intratec.us/solutions/industry-economics-worldwide/utility/cooling-water-cost-netherlands

Annex B
Financial Assumptions in the Business Case Analysis

This appendix summarizes key financial assumptions underlying the financial model. This includes the main assumptions related to capital structure, financing terms, discount rates, operations, depreciation, taxation, and project cash flow modelling. These assumptions form the basis for the analysis presented in Section 4, where they were used to develop an initial directional view of how the business cases may change under different conditions and to illustrate the potential impact of the selected support mechanisms.

B.1 Financial Assumptions for Case 1 - Bio-Methanol Production

The tables below provide an overview of the assumptions related to facility operations, including facility capacity and ramp-up estimates, as well as assumptions related to the financing structure, including capital stack estimates, repayment scheduling, and WACC rate. The estimated parameters below relate to the unaltered baseline scenario, prior to the application of support mechanisms.

Table B.1: Operational and financial assumptions used in the bio-methanol case

	Operational Assumptions		
	Component	**Value**	**Notes**
	Nameplate Capacity	200 KT	
	Capacity Utilization Factor Ramp-up Y0	25%	Based on the techno-economic analysis conducted under Appendix A
	Capacity Utilization Factor Ramp-up Y1	30%	
	Capacity Utilization Factor Ramp-up Y2	35%	
	Capacity Utilization Factor Operational	91%	
	Depreciation Period	20 Years	
	Corporate Income Tax	25,8%	

	Financial Assumptions		
	Component	**Value**	**Notes**
Debt	Term Loan Facility Repayment Period	15 Years	
	Term Loan Facility Interest	10,87%	Based on Expert Discussions
	% Debt Funding as % of Private Funding	60,00%	
	Funding Priority	Pro-Rata	

	Interest Expenses During Construction	Capitalized	
	Amortization of Capitalized Interest Period	20 Years	
	Term Loan Facility First Repayment	Y4	
Equity	Risk Free-Rate	2,98%	10Y Dutch Government Bond
	Market Risk Premium	5,25%	KPMG, "Equity Market Risk Premium Estimate for the Netherlands," [Online]. Available https://indialogue.io/clients/reports/public/5d9da61986db2894649a7ef2/5d9da63386db2894649a7ef5
	Beta	0,49	Damodaran, A. "Levered and Unlevered Betas by Industry," 2025. [Online]. Available https://pages.stern.nyu.edu/~adamodar/New_Home_Page/datacurrent.html
	Asset Specific Risk Adjustment Factor	10,00%	Based on Expert Discussions
	Unlevered Equity Rate	15,55%	
WACC	WACC Rate	11,06%	Given that the bio-methanol project contains higher technology risk, it faces both a higher asset specific risk adjustment factor as well as higher credit risk premiums from the debt provider leading to a higher overall WACC rate than the PLA case

B.2 Financial Assumptions for Case 2 - PLA Production

The tables below provide an overview of the assumptions related to facility operations, including facility capacity and ramp-up estimates, as well as assumptions related to the financing structure, including capital stack estimates, repayment scheduling, and WACC rate. The estimated parameters below relate to the unaltered baseline scenario, prior to the application of support mechanisms.

Table B.2: Operational and financial assumptions used in the PLA case

	Operational Assumptions		
	Component	**Value**	**Notes**
	Nameplate Capacity	75 KT	
	Capacity Utilization Factor Ramp-up Y0	30%	
	Capacity Utilization Factor Ramp-up Y1	45%	
	Capacity Utilization Factor Ramp-up Y2	60%	

	Capacity Utilization Factor Operational	91%	Based on the techno-economic analysis conducted under Appendix A
	Depreciation Period	20 Years	
	Corporate Income Tax	25,8%	

	Financial Assumptions		
	Component	**Value**	**Notes**
Debt	Term Loan Facility Repayment Period	15 Years	
	Term Loan Facility Interest	8,87%	Based on Expert Discussions
	% Debt Funding as % of Private Funding	60,00%	
	Funding Priority	Pro-Rata	
	Interest Expenses During Construction	Capitalized	
	Amortization of Capitalized Interest Period	20 Years	
	Term Loan Facility First Repayment	Y4	
Equity	Risk Free-Rate	2,98%	10Y Dutch Government Bond
	Market Risk Premium	5,25%	KPMG, "Equity Market Risk Premium Estimate for the Netherlands," [Online]. Available https://indialogue.io/clients/reports/public/5d9da61986db2894649a7ef2/5d9da63386db2894649a7ef5
	Beta	0,49	Damodaran, A. "Levered and Unlevered Betas by Industry," 2025. [Online]. Available https://pages.stern.nyu.edu/~adamodar/New_Home_Page/datacurrent.html
	Asset Specific Risk Adjustment Factor	7,50%	Based on Expert Discussions
	Unlevered Equity Rate	13,05%	
WACC	WACC Rate	9,17%	

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