Beyond technology agnosticism in P2X project development

A practical path to stronger P2X business cases and faster investment decisions



Whitepaper

ANDRITZ

Executive abstract

Power-to-X (P2X) projects are essential for decarbonizing hard-to-abate industries and creating new pathways to produce green hydrogen, e-methanol, e-ammonia, and other sustainable fuels. Yet despite strong market interest and increasing investment activity, many projects struggle to progress from concept to Final Investment Decision (FID).

The reasons are widely known. Developers face pressure from electricity costs, uncertain offtake markets, financing requirements, regulatory complexity, and rising capital expenditures. However, another factor receives less attention: the development methodology itself.

Many projects continue to follow technology-agnostic approaches during the early engineering phases. While these approaches can preserve optionality and competition, maintaining a broad technology field for too long may delay critical decisions about process integration and optimization. In a sector where project economics depend on the interaction of multiple technologies, this can increase uncertainty and weaken the business case.

This executive brief explores why P2X projects require a different development approach than traditional industrial investments. It outlines how early technology selection, integrated engineering, and alignment around a target Levelized Cost of Product (LCoP) can improve project viability and strengthen confidence on the path to FID.

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Key insights

- Project economics often present a greater challenge than technology selection. While technology continues to advance rapidly, electricity costs, financing conditions, regulation, and market expectations remain critical factors in determining whether a P2X project reaches FID.
- P2X projects require a different development approach than traditional industrial investments. Unlike refinery, petrochemical, and chemical projects, P2X developments must accommodate fluctuating renewable power supply, technology evolution, and complex value-chain interactions.
- Technology-agnostic approaches can delay optimization and business-case certainty. Maintaining broad technology optionality throughout multiple engineering phases may postpone integration and techno-economic assessments, increasing the risk of identifying business-case challenges late in the process.
- Technology selection should happen earlier than many developers assume. Early identification of suitable and bankable technology options enables more effective integration engineering, process optimization, and realistic economic evaluation throughout project development.
- Technology performance alone does not determine project economics. The economics of P2X projects also depend on how effectively electrolysis, renewable power, storage and downstream processes work together as an integrated system.
- Projects should be engineered around a target LCoP. Aligning technology choices, engineering decisions, and stakeholder collaboration around a defined Levelized Cost of Product can improve business-case certainty and support a successful path to FID.

Why many P2X projects struggle to reach FID

The promise of P2X is compelling. Renewable electricity can be transformed into green hydrogen and valuable derivatives that help decarbonize transportation, chemicals, fertilizers, refining, and heavy industry. Yet project developers across the industry continue to face significant challenges in bringing projects to commercial reality.

Together, these interconnected factors create a Gordian Knot for P2X developers: improving one part of the business case can influence several others, making early techno-economic optimization increasingly important.

Off-takers often seek lower product prices before committing to long-term offtake agreements. Financial institutions typically require these offtake commitments before providing financing. Electricity costs represent a significant share of operating expenses, while capital expenditures and financing costs continue to place pressure on project economics. Regulatory requirements introduce further complexity and uncertainty.

The result is a familiar challenge: projects may be technically feasible but commercially difficult to justify. As costs increase and uncertainty grows, investment decisions are delayed, projects are scaled back, or development efforts are paused altogether.

For project developers, the challenge is no longer simply about selecting technologies. It is about establishing a business case that can satisfy their customers, financiers, investors, and regulators simultaneously.

Why P2X requires a different development approach

Traditional industrial project development practices were established in sectors such as refining, petrochemicals, and chemicals. These industries benefit from decades of operational experience, mature technologies, extensive reference installations, and relatively predictable operating environments. P2X projects operate under different conditions.

Renewable electricity availability and pricing can fluctuate significantly. Regulations can influence operating strategies. Electrolysis plants must interact efficiently with downstream synthesis processes, storage systems, and other technologies across the value chain. Successful operation often depends on managing transient conditions rather than maximizing stable base-load performance. These differences create a new challenge for project development.

The key question is no longer which individual technology appears strongest in isolation. The real question is how all technologies interact as an integrated system to achieve the desired economic outcome.



Integrated P2X value chain

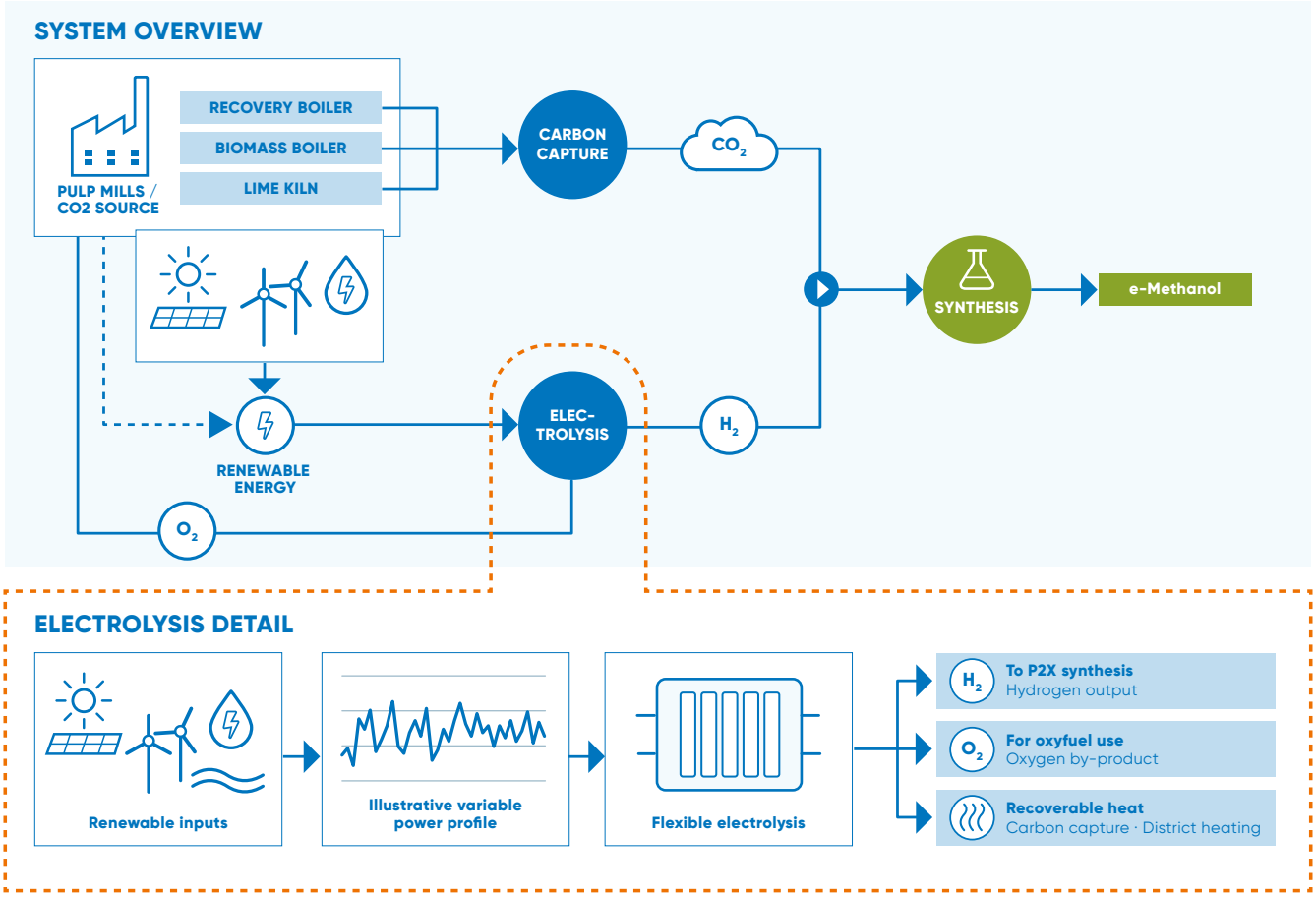

Figure 1: Example of P2X project development, where electrolysis, carbon capture, methanol synthesis and distillation are collocated next to a pulp mill as a source for biogenic carbon dioxide

1. **LCOE reduction** by flexible plant operation, to enable (i) grid-services, (ii) demand-side mgmt., (iii) arbitrage, (iv) use of curtailed power at low cost

2. **Regulatory Compliance** by revealing the latest requirements and considering in technical concept

3. **Product & by-product demand driven operation optimization** – with consideration of power supply, buffer integration and demand profiles

4. **Additional revenues from by-product use or cost savings from operational mode:**
   i. O2 for oxyfuel application
   ii. Off-heat use for CO2 Amine Wash Desorption

3. **Cost base improvement via value eng.'g**
   i. Inside battery limits (ISBL) / Outside battery limits (OSBL) integration
   ii. Integration eng.'g along full P2X value chain to determine best CapEx / OpEx options incl. buffer / storage requirements

3. **Additional funding exploiting from EU** by implementing more innovative edges

The hidden cost of technology agnosticism

To manage uncertainty, many project owners adopt a technology-agnostic approach in the early engineering phases. The intention is understandable: maintain flexibility, compare multiple technology providers, and encourage competition before making important investment decisions. However, flexibility can come at a cost.

When major technology decisions are delayed, opportunities for optimization are delayed as well. Process integration, simulation of transient operating conditions, storage concepts, utility balancing, and value-chain optimization often remain conceptual rather than becoming engineering-driven activities.

In complex P2X projects, value is rarely created by optimizing a single technology package. Instead, it emerges through the interaction of electrolysis, renewable power supply, carbon capture, synthesis technologies, utilities, storage systems, and plant operation strategies.

When these interactions are not sufficiently evaluated during the early engineering phases, project teams risk discovering commercial limitations later in the development process. By that point, valuable time and resources may already have been invested.

The challenge is therefore not technology choice itself. The challenge is understanding how technology choices affect project viability as early as possible.

Selecting the right technology earlier

One of the key challenges in P2X development is the growing number of technology options available to project developers. While competition and optionality can create value, they can also delay the engineering decisions needed to evaluate project viability. The longer key technology selections are postponed, the later integration and optimization can begin.

Rather than carrying a broad range of technologies through multiple engineering phases, developers should narrow the field early to technologies that are technically suitable, commercially credible, and bankable. This enables project teams to focus their efforts on optimizing the complete value chain and achieving the targeted project economics

Early technology selection does not necessarily mean committing to a single solution from the outset. Depending on the project and the maturity of the technology selection, different development approaches can be applied. Where uncertainty remains between a limited number of credible and bankable options, a dual front-end loading (FEL) approach can provide a structured framework for comparison. By evaluating selected technology pathways in parallel during the early engineering phases, developers can compare technical, integration, and economic performance against the targeted Levelized Cost of Product (LCoP). This supports informed decision-making while maintaining development momentum toward a bankable project. For many large-scale green hydrogen applications, we consider pressurized alkaline electrolysis the preferred technology, combining commercial maturity, scalability and competitive economics. The key reasons are summarized in the following figure and explored further in our latest blog article.

Electrolysis type	Alkaline Electrolysis (AEL)	Proton Exchange Membrane (PEM)	Solid Oxide Electrolysis Cell (SOEC)	Anion Exchange Membrane (AEM)
Cell-Temp.	80-90 °C	50-60 °C	500-900 °C	50-80 °C
Technology readiness level	Commercial			Research
System CapEx	Relatively low	Relatively high	Relatively high	TBD / lab-scale
System OpEx	Moderate	Moderate	Lower than AEL	TBD / lab-scale
Degradation	Low to moderate	Comparable to AEL	Higher than AEL	Higher than AEL / PEM
Noble metals	None / limited	Specific materials required	Technology dependent	Lower than PEM, higher than AEL

Figure 2. Comparison of the four main electrolysis technologies, highlighting differences in maturity, operating temperature, cost, degradation and material requirements.

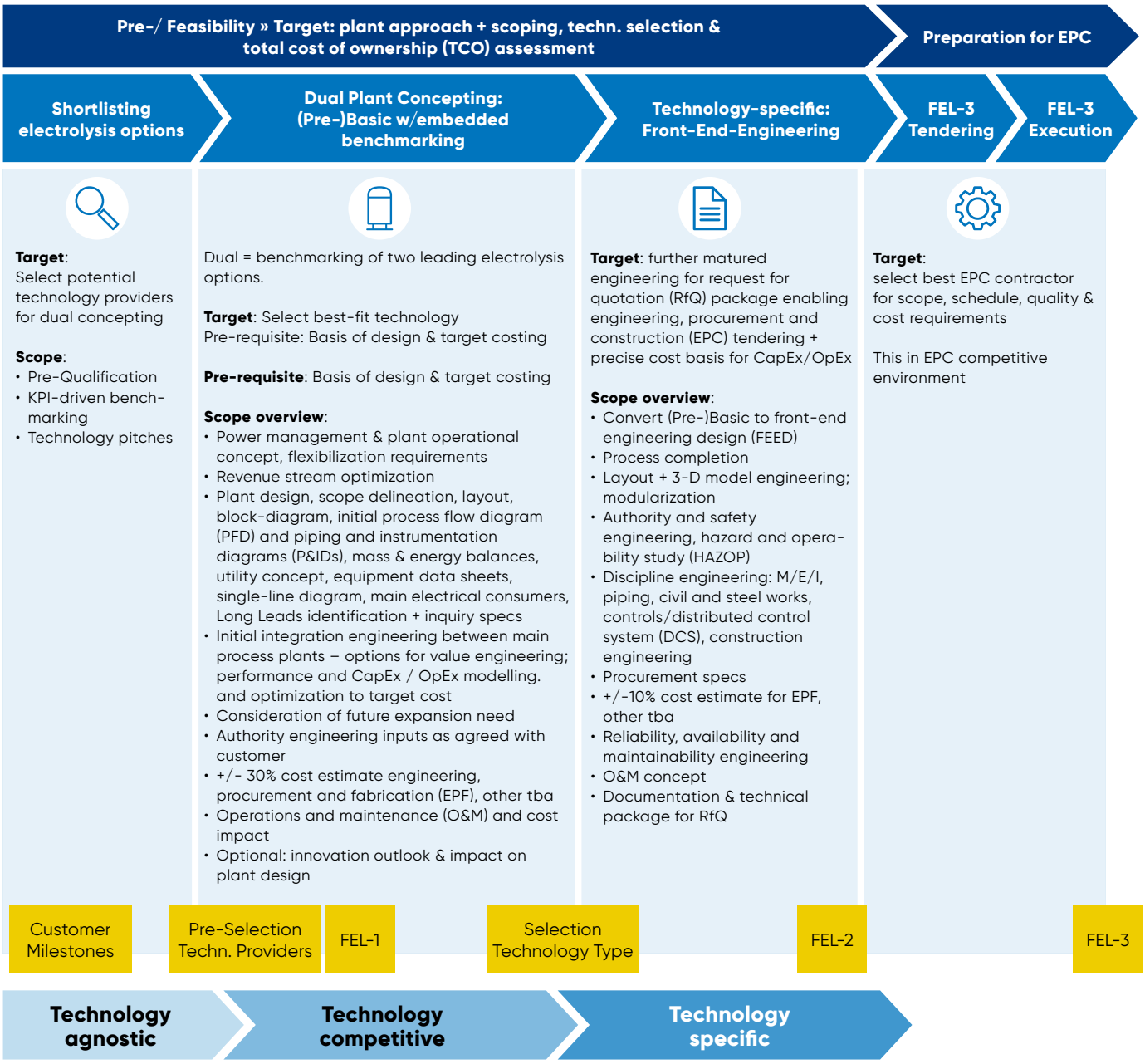

Figure 3: Dual FEL maintains competition while enabling earlier technology-specific evaluation and optimization.

1. **LCoP-oriented**: during this phase benchmarking, where specific technology advantages can be investigated for P2X value chain (instead of agnostic approach where differentiation is nor possible)

2. **Sound engineering basis**: operational clarity (e.g. intermittent power profile), where real tech behaviors are considered; transparent decision criteria for plant optimization, e.g. load factors, O&M, scale

3. **Sound financial decision basis**: technology specific cost insights, without losing the competitive character for downstream phases of EPC tendering

4. **Kick-start-readiness**: eng.'g packages based on tech truth, and suitable for seamless carry-over to next phase (FEL-2 / -3 / FEED)

5. **Still ensuring EPC bidding under competitive environment**: with a sound technology driven engineering package, all renown EPC contractors can bid on the scope for the next phase

Designing projects around target LCoP

Every successful P2X project must ultimately answer one question:

Can the project produce its intended product at a cost the market is willing to accept?

This is where the concept of target LCoP, or Levelized Cost of Product, becomes critical. Rather than asking suppliers what their individual packages will cost, project teams should first determine the product cost required to support long-term commercial success. This target then becomes the guiding principle for engineering, technology selection, and optimization efforts throughout project development.

Establishing a target LCoP requires realistic assumptions about:

- Product pricing and market demand
- Offtake requirements
- Renewable electricity costs
- Load profiles and intermittency
- Regulatory requirements
- Capital investment and operating costs

Once these parameters are understood, project participants can focus on a more meaningful challenge: identifying how the overall value chain can achieve the required economics.

This shifts the conversation from procurement to performance. Instead of evaluating technologies independently, developers evaluate how the complete system contributes to business-case success.

Collaboration as a competitive advantage

No individual organization possesses all the expertise needed to optimize a modern P2X project.

Technology providers understand their proprietary solutions. EPC companies bring engineering and execution expertise. Project developers understand market requirements and financial objectives. Success depends on bringing these perspectives together early enough to influence project outcomes.

A collaborative development approach allows project teams to:

- Assess realistic economic targets early
- Optimize integration across the value chain
- Reduce uncertainty in project assumptions
- Improve confidence in business-case viability
- Strengthen readiness for financing and FID

Rather than relying on competition alone to solve project economics at a later stage, collaboration focuses expertise on achieving a common objective from the beginning: a bankable, viable project.

For investors and project developers, this creates greater certainty. For lenders, it supports confidence in project economics. For the industry as a whole, it provides a more effective pathway from concept to commercial operation.

Executive summary

The next generation of successful P2X projects will be defined by commercial viability as much as technological innovation.

While renewable electricity, electrolysis, carbon capture, and synthesis technologies continue to evolve, the fundamental challenge remains unchanged: creating projects that can achieve competitive economics and secure investment.

Project development methodologies established in mature industries have proven their value over decades. However, P2X projects operate under different conditions. Variable renewable energy, evolving technologies and highly interconnected value chains require greater attention to early integration, optimization and technology-specific engineering.

Projects that establish clear economic targets from the beginning, align stakeholders around a target LCoP, and make informed technology decisions early are better positioned to improve project viability, strengthen bankability, and shorten the path to FID.



The most important question is no longer: *"What does each technology cost?"*

The question that matters is: *"How can we achieve the levelized cost of product needed for commercial success of the project?"*

Organizations that answer this question early, and align engineering, integration, and execution around it, will be best positioned to convert ambition into investment-ready projects.

ANDRITZ perspective

ANDRITZ combines early engineering, technology expertise and integration capabilities to lead P2X projects from concept development through EPC and operation. Our approach is built around understanding the complete value chain and working collaboratively with technology partners and licensors to optimize project performance and economics.

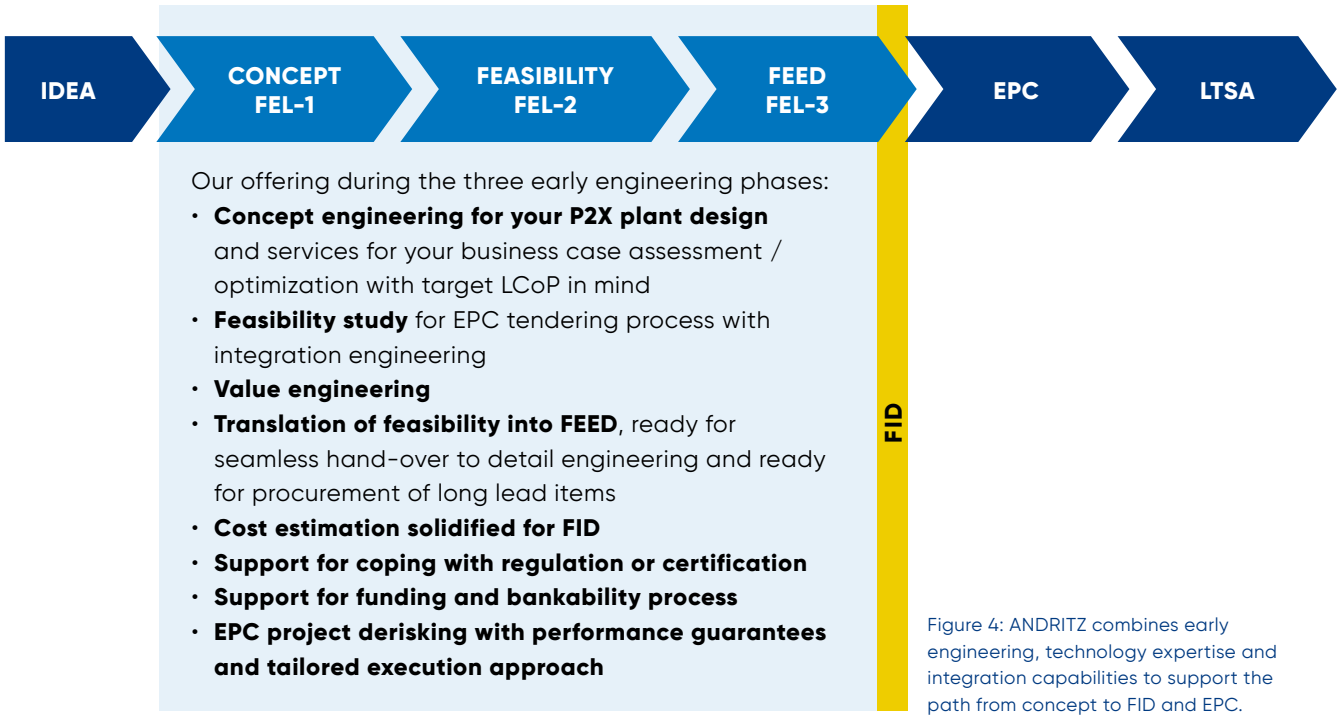

Figure 4: ANDRITZ combines early engineering, technology expertise and integration capabilities to support the path from concept to FID and EPC.

We enable the green transition

ANDRITZ P2X SOLUTIONS

ANDRITZ responds to the urgent need for decarbonization and green transition. We provide integrated P2X solutions for the production of green hydrogen, e-methanol and e-ammonia – ranging from consulting to EPC projects with full performance guarantees. Our long-term service agreements are based on our proprietary digital solution.

EXPLORE OUR P2X SOLUTIONS

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