ALTRIUS | APQP4WIND

Quality to de-risk capital-intensive projects

APQP for Wind · Are we managing risk or just reacting to it?

09 June 2026

Across the offshore wind value chain

aLTrius

01

SECTION

Context & objectives

Offshore wind's economic equation is struggling visibly. The cause is not macro — it is quality, gate by gate.

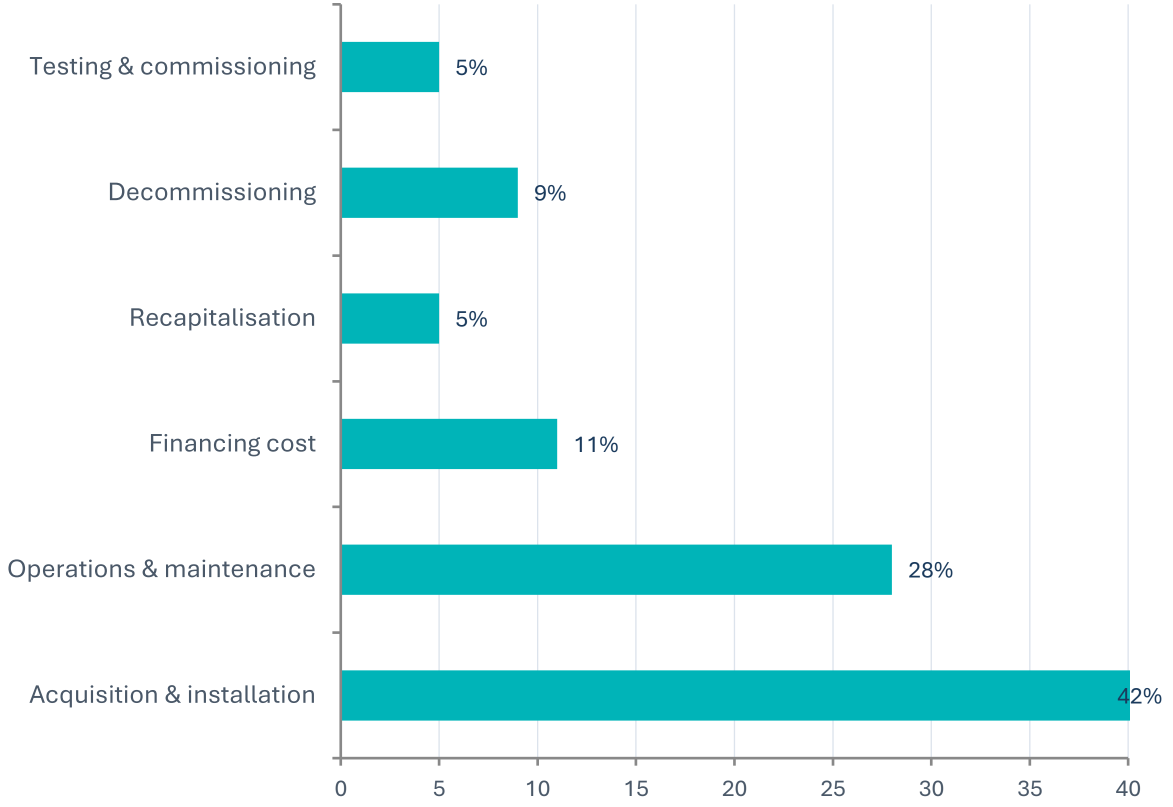
CONTEXT | THE ECONOMIC EQUATION

Offshore wind only closes the equation if every gate holds

THE INVESTMENT CASE

Revenue over 25 years must cover acquisition, installation, O&M, recapitalisation, financing and decommissioning.

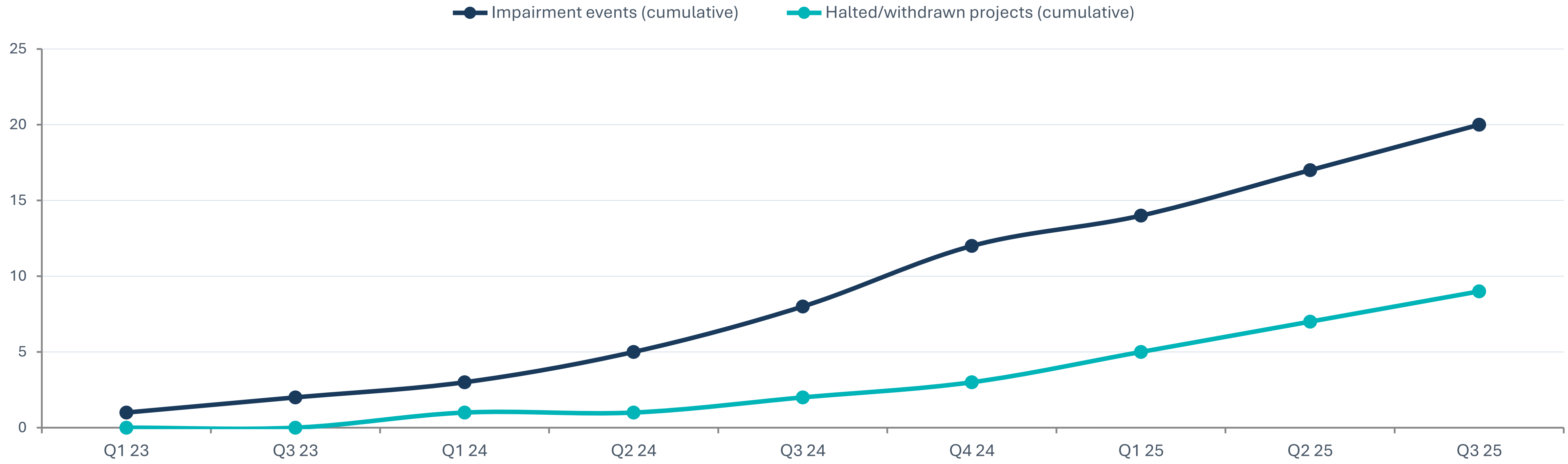
- Government-backed price guarantees are limited in time and price — the asset must perform across its full life to close the equation.
- Every cost line is governed by a complex validation chain — gates where quality assurance is meant to confirm fitness for purpose.
- When validation is weak at any gate, the cost cascades exponentially — and the project economics fail downstream, not at the gate that failed.



Sources: BVG Associates 'Guide to a UK offshore wind farm'; Dogger Bank financial close documents; Ørsted 2024 annual report.

CONTEXT | THE EVIDENCE

The equation is breaking visibly — in published earnings and halted tenders



Insight Ørsted booked DKK 12.1bn (EUR 1.62bn) impairment on Sunrise Wind in Q4 2024 (monopiles); halted Hornsea 4 in May 2025; Denmark's December 2024 North Sea tender attracted no bids; Vattenfall withdrew a 140-turbine project on +40% cost. The headlines blame macro — the root cause is quality debt accumulating across project gates.

CONTEXT | OBJECTIVES

Six questions to address

01 **Where is quality assurance failing today?**

Across the offshore wind project lifecycle — and at which gates does it cost the most when it fails?

02 **What does APQP-for-Wind look like?**

Adapted from automotive and aerospace, fit for marine construction, multi-tier suppliers, 25-year asset life.

03 **What must change in short-term?**

To de-risk the current pipeline and protect the economics of projects.

04 **What are the scope and boundaries?**

Hardware and software; from requirements through decommissioning; capability across skills, processes and tools.

05 **What this presentation is about?**

Six findings anchored in cross-industry cases, six recommendations, an industry-wide roadmap.

02

SECTION

Approach & methodology

A gate-based quality framework across the full lifecycle, paired with a three-dimensional capability maturity assessment.

APPROACH | GATE-BASED LIFECYCLE

Five strategic phases, nine quality gates

01 **Requirements & design**

Concept, FEED, detailed design, interface management — hardware and software treated symmetrically.

02 **Procurement & manufacturing**

Supplier qualification, sub-tier flow-down, production part approval, FAT, traceability.

03 **Transport, installation & commissioning**

Load-out, marine warranty, site acceptance, energisation, performance testing, taking-over certificate.

04 **Operations & maintenance**

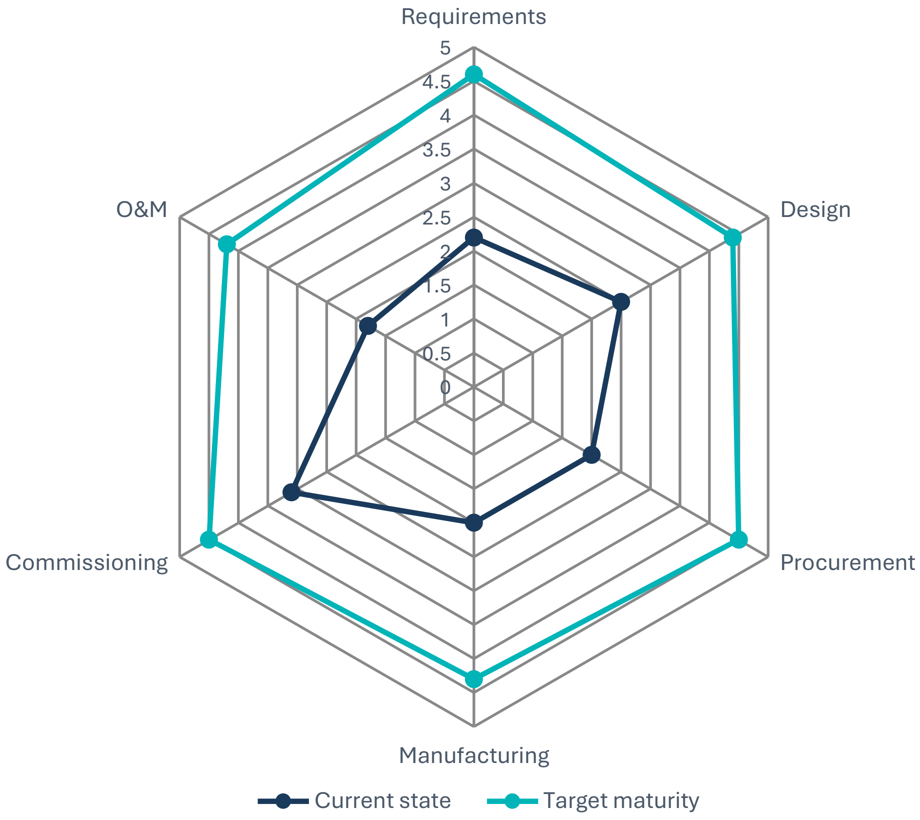
Condition monitoring, reliability-centred maintenance, warranty management.

05 **Recapitalisation & decommissioning**

Mid-life inspection, component replacement, re-certification, dismantling, financial assurance.

APPROACH | CAPABILITY MATURITY

Three-dimensional capability maturity assessment



ASSESSMENT FRAMEWORK

Skills, processes and tools across nine lifecycle gates

- Skills — engineering, quality, supplier development, marine operations, commissioning, asset management.
- Processes — documented, repeatable, measured, continuously improved against a 5-level maturity scale (Initial → Optimising).
- Tools — PLM, QMS, supplier portals, NCR/CAPA systems, digital twin, reliability databases.

> *The gates only work if the organisation behind them can execute — this is what the radar profile measures.*

Framework: adapted from CMMI Dev v2.0 and AS9145 APQP; scored 1–5 across nine lifecycle gates.

03

SECTION

Key findings

Six findings, each a structural quality gap, each anchored in a documented cross-industry case where the same gap produced visible economic damage.

FINDINGS | SUMMARY

Six structural quality gaps, six cross-industry parallels

01 **Requirements management**
Berlin Brandenburg Airport

02 **System design & FMEA**
Boeing 737 MAX (MCAS)

03 **Sub-system contracting**
NYC Subway CBTC

04 **Product delivery & process quality**
Airbus A350 (Qatar Airways)

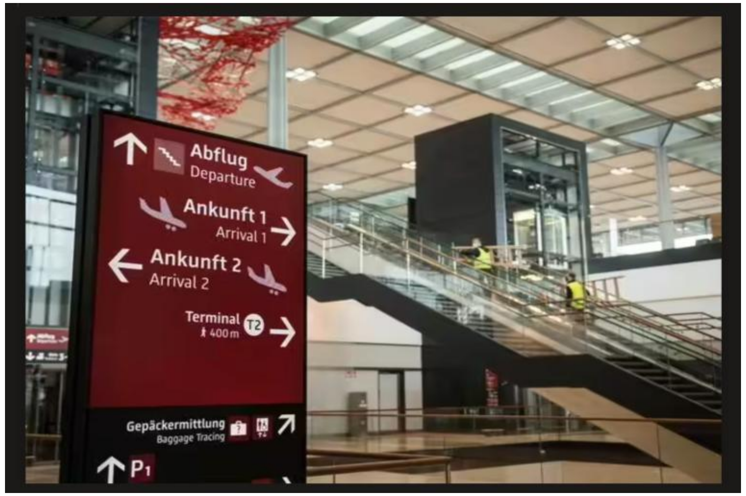
05 **System testing & commissioning**
Amtrak Acela / Avelia Liberty

06 **Operations & maintenance**
European ETCS rolling stock

FINDING 01 | REQUIREMENTS MANAGEMENT

Incomplete and conflicting requirements cascade across every gate

Berlin Brandenburg Airport opened nine years late at €7bn — nearly three times the initial €2.5bn estimate. The fire safety system blew smoke into the halls instead of extracting it. The defect was not workmanship; the fire-safety, building-control, and HVAC requirements were never reconciled, and no general contractor owned the overview.



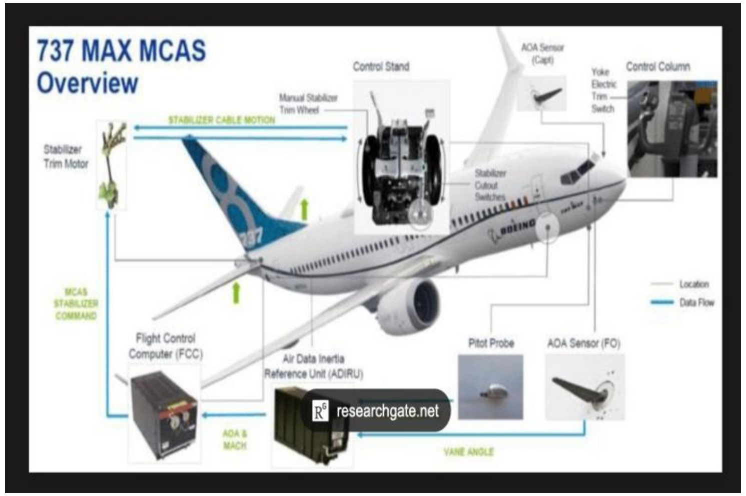
Berlin Brandenburg Airport (BER) — completed 2020

Sources: BER 2012 committee of enquiry; Oxford Saïd Business School; McKinsey 100-project study (44–50% over budget, 65% time overrun average).

FINDING 02 | SYSTEM DESIGN & FMEA

System design declared complete without testing critical requirements or modes

MCAS was designed to take a reading from a single angle-of-attack sensor, when the 737 MAX had two; could move the tail four times farther than the initial safety analysis stated; and was triggered repeatedly because the analysis failed to model the system resetting itself. Two crashes, 346 deaths, the entire 387-aircraft fleet grounded. The safety analysis described a different system from the one that was built.



Boeing 737 MAX MCAS — Lion Air 610, Ethiopian Airlines 302

Sources: Seattle Times investigation; FAA / EASA findings; academic analysis of performance-based safety requirements.

FINDING 03 | SUB-SYSTEM CONTRACTING

One-way cascade of requirements, no joint sign-off, no joint risk register, penalty regime suppresses early disclosure

NYC SUBWAY CBTC

Suppliers optimise for paperwork compliance, not for the integrated system actually working.

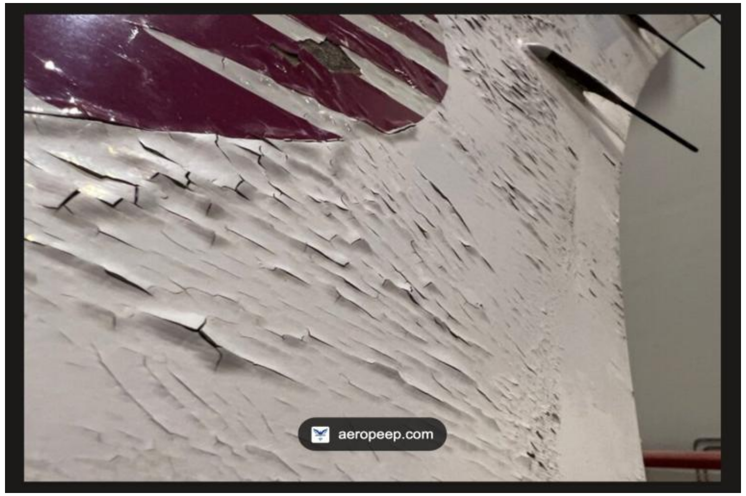
- MTA awarded parallel CBTC contracts to Siemens ($156.2m) and Thales ($49.6m) — two of the world's leading signalling primes. The Queens Boulevard programme grew from $663m to $734m (+11%) with completion pushed back 18 months due to "software-related reliability issues."
- On the Brooklyn section, a sub-contractor measurement error in fabrication caused cascading delays across the wider programme — the precise failure mode that front-end process audits exist to catch.
- The penalty regime triggered, but the underlying process gap remained. Penalising the outcome did not produce earlier disclosure or faster recovery — it produced daily meetings.

Sources: MTA Capital Programme records via THE CITY (2022); Crain's New York Business (2024); MTA Construction & Development public statements.

FINDING 04 | PRODUCT DELIVERY & PROCESS QUALITY

QA against the product, not the process — latent defects survive every inspection

Airbus's own pleaded defence in the High Court: the surface degradation "is effectively bound to occur at some point in the lifetime of an A350 aircraft because it results from a different coefficient of expansion as between the composite fibre reinforced polymer of the airframe and the expanded copper foil layer bonded to it." 29 aircraft grounded by Qatar's regulator; cracks exposed the lightning protection sub-system; remediation requires up to 900 patches per airframe; $2bn dispute.

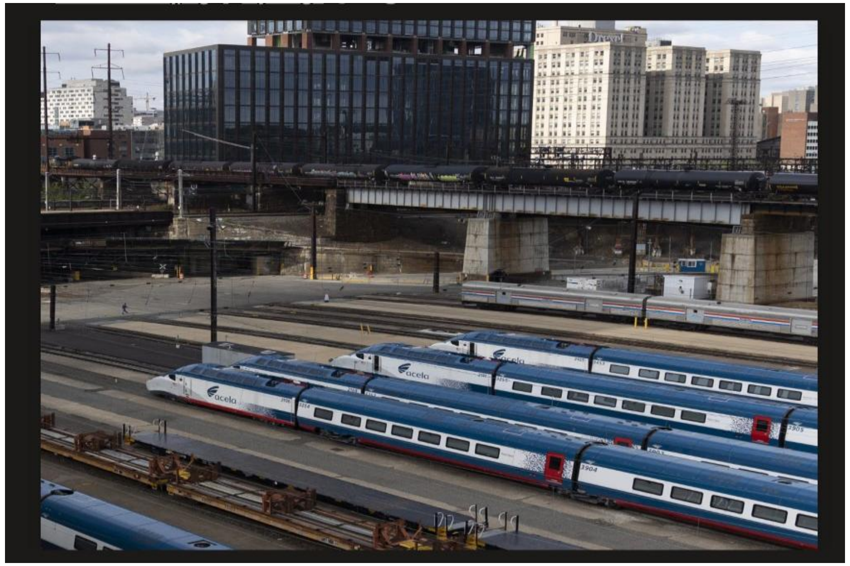


Airbus A350 / Qatar Airways — Mr Justice Waksman, High Court of England and Wales, 2022

Sources: High Court ruling; Airbus pleaded defence; EASA continued airworthiness surveillance; press reporting on settlement (2023).

FINDING 05 | SYSTEM TESTING & COMMISSIONING

Integration tested on site, not in lab — consuming schedule and budget upstream



Insight Amtrak's $2bn Avelia Liberty order, originally to enter service in 2021, finally launched 28 August 2025 — almost four years late. 90,000 miles of on-track testing because the simulation could not predict pantograph-catenary and wheel-rail dynamics. 14 of 28 trainsets delivered but in storage, awaiting acceptance. Site became the validation environment; weather, vessels and infrastructure access set the schedule.

FINDING 06 | OPERATIONS & MAINTENANCE

O&M absorbs the accumulated quality debt of every prior gate

The Association of European Rail Rolling Stock Lessors, March 2025: under the present ETCS rollout, “costs outweigh its advantages,” and “the current situation is even worse than before the introduction of ETCS.” Quantitative reliability requirements remain missing across Europe. Recurring on-train failure modes (balise not read, GSM-R faults, unexpected braking, mode transitions, frozen DMI) drive unscheduled service interruptions. The reliability case is being retrofitted onto an asset class already in service.

European ETCS rolling stock — AERRL open letter to EU Commissioner, March 2025

Sources: AERRL public statement (Railtech, March 2025); IRJ January 2025; UK industry incident resolution guide; academic reliability modelling literature.

04

SECTION

Implications

Quality gaps at each gate propagate through the project's risk register into the financial model — and end as written-down assets and refinancing events.

IMPLICATIONS | THE CASCADE

From quality gap to write-off, in nine steps

THE PATTERN IS NOW VISIBLE

Quality gaps at each gate compound into financial events. The pattern is now in published earnings.

- Poor gate-level risk management → weak mitigation & trade-offs → very late findings, difficult recovery → project delay, higher acquisition costs → lower revenue across lifetime → higher O&M costs → earlier, dilutive recapitalisation → ROI compressed by rising cost of capital → write-offs and refinancing.
- Ørsted Q4 2024: DKK 12.1bn (EUR 1.62bn) impairment on Sunrise Wind. Hornsea 4 halted May 2025. Denmark December 2024 tender attracted no bids. Vattenfall withdrew on +40% cost.
- Dogger Bank baseline IRR 5.6%, sensitivity 3.2pp to CAPEX overrun. Q4 2024 saw a 75bp WACC increase against the US portfolio. The IRR sensitivity is asymmetric: quality investment at design adds single-digit % CAPEX; quality failure at commissioning destroys double-digit % NPV.

Sources: Ørsted Q4 2024 annual report; Reuters & FT coverage; Dogger Bank financial close documents; BVG Associates.

05

SECTION

Recommendations

Six recommendations forming a single operating system — each closes one finding directly; together they shift the cost-to-fix curve to the left.

Six recommendations — one operating system

01

Requirements & risk management at every gate

End-to-end baseline coupled with joint risk register; economic equation as the live trade-off engine.

02

System design tested across all modes

System engineering authority with gate-stop power, residual risk driven to zero before gate closes.

03

Joint contractor engagement

Joint baselining, joint risk register, named ownership of interface risks, lab integration before site delivery.

04

Process QA in contracts — hardware & software

Process specifications, process maturity scoring, sub-tier flow-down, right of audit at defined cadence.

05

Upstream lab testing and system modelling

Move validation from asset to lab for testing on benches or simulation, engage certifiers early

06

predictive maintenance

FMEA-anchored; calibrate models with operational data.

RECOMMENDATION 01 | REQUIREMENTS & RISK

Implement end-to-end requirements management coupled with risk management at every gate

WHAT THIS MEANS

Two faces of one instrument: requirements baseline and risk register, owned by an empowered function, updated at every gate against the economic equation.

- Single lifecycle-spanning baseline (hardware + software). Bilateral sign-off at every interface (developer / EPC / OEM / contractor). Joint risk register updated at each gate, scored S×O×D, with named mitigation owners.
- Economic equation as the live trade-off engine — no requirement change, risk acceptance or design trade-off approved without numerical impact on CAPEX / schedule / AEP / OPEX / IRR.
- Impact: high (closes the largest avoidable risk). Effort: medium-high (new function + tooling + contract change)

Closes Finding 01 (Requirements management). Provides the spine for every subsequent recommendation.

RECOMMENDATION 02 | SYSTEM TESTING

Test system design against critical requirements across every mode of operation and the full asset lifetime

WHAT THIS MEANS

System design treated as a hypothesis to be falsified, not a once-validated engineering deliverable. Drive system-level residual risk to zero before the gate closes.

- Test plans built from requirements, not from design. All modes in scope: nominal, start-up, shut-down, sensor faults, comms loss, partial power, asymmetric loading, grid fault, extreme metocean, fallback states, post-fault restart.
- System-level FMEA owned by an empowered system engineering authority with gate-stop power. Every failure mode: eliminated by design, mitigated by redundancy/detection, or formally accepted in writing with named executive and economic-equation impact attached.
- Impact: high (largest lever on commissioning slippage). Effort: high (test infrastructure, simulation, system engineering capability)

Closes Finding 02 (System design & FMEA). Substantially mitigates Findings 05 (commissioning) and 06 (operational surprises).

RECOMMENDATION 03 | JOINT CONTRACTOR ENGAGEMENT

Re-engineer contractor engagement around joint definition, joint risk, joint peer-to-peer testing

WHAT THIS MEANS

Replace the one-way cascade with a model that obliges both parties to think together before they build apart. Interface risks have named owners on both sides.

- Joint baselining of sub-system definition before contract signature, with structured bilateral requirements analysis. Joint risk register, owned bilaterally, updated at every gate. Defined protocol for unallocated interface risks: shared ownership, cost-sharing formula, escalation path.
- Peer-to-peer integration testing in representative lab environments before site delivery. Incentive structure that rewards process quality and early problem disclosure, supplementing penalty regimes. Pre-qualification on process maturity, not only product capability.
- Impact: high (eliminates structural information-suppression of penalty-only contracts). Effort: medium-high (legal & commercial redesign + cultural shift).

Closes Finding 03 (Sub-system contracting). Required contractual mechanism for Recommendations 01 and 02 to reach the supply chain.

RECOMMENDATION 04 | PROCESS QA IN CONTRACTS

Embed process quality assurance for hardware and software into supplier contracts as a binding deliverable

WHAT THIS MEANS

Move QA from end-of-line product inspection to in-line process verification — contractually mandated, symmetrically for hardware and software.

- Process specifications (not only product specifications) in main contract body. Process maturity scoring (CMMI / AS9145 / APQP-equivalent) baselined at signature, re-assessed at milestones, with contractual consequences. Right of process audit at defined cadence.
- Software treated symmetrically: ISO/IEC 12207, IEC 61508/61511 for safety, IEC 62443 for OT cybersecurity. Process gates: defined → capable → qualified → in full production. Production ramp gated on these transitions, not on calendar.
- Impact: high (largest source of latent defects). Effort: medium-high (supplier development capability is the binding constraint).

Closes Finding 04 (Product delivery & process quality). Converts Recommendations 01 and 02 from intent into supply-chain reality.

RECOMMENDATION 05 | UPSTREAM LAB TESTING

Move the centre of gravity of system testing from the asset to the lab

WHAT THIS MEANS

Invest in peer-to-peer integration rigs and high-fidelity multi-physics simulation across all modes of operation. Limit on-site testing to an irreducible minimum. Engage certifiers early so simulated evidence carries validation credit.

- Shared HIL infrastructure (third-party operated, consortium-funded, IP-protected) for turbine controller / substation protection / SCADA / pitch system / floating-platform motion integration. Multi-physics system models qualified for validation credit by DNV, TÜV, Fraunhofer IWES, ORE Catapult.
- Default at every test-planning review: “simulate unless proven otherwise.” Continuous-improvement loop from site back to lab: every site finding the lab didn’t predict upgrades the simulation environment. The lab gets better project by project.
- Impact: high (most direct lever on commissioning duration). Effort: high capital, high capability (mitigated by shared infrastructure).

Closes Finding 05 (System testing & commissioning). Provides the technical infrastructure that Recommendations 02 and 03 depend on.

RECOMMENDATION 06 | PREDICTIVE MAINTENANCE

Build predictive maintenance into the asset by design, anchored on an enhanced system-level FMEA

WHAT THIS MEANS

Continuously recalibrate the underlying models against actual operational data so the O&M strategy improves project-by-project and the loop back to design closes.

- Predictive maintenance specified at requirements stage (Rec 01), not retrofitted. Each failure mode has a defined detection signature, predictive model, data source, warning threshold and intervention. Continuous model recalibration against operational data on a defined cadence.
- Heavier-than-design duty cycles formally re-baselined into the financial model. Mid-life recapitalisation planned from year one. Formal feedback loop from O&M to requirements function for the next-generation project — the rail industry's mistake (ETCS reliability retrofitted onto an installed fleet) avoided.
- Impact: high & compounding (only recommendation whose value accrues across the full 25-year life). Effort: medium-high (data infrastructure + reliability engineering + integration with design).

Closes Finding 06 (Operations & maintenance). Converts the engagement from a one-time intervention into a permanent capability.

06

SECTION

Roadmap

A long-term industry-wide roadmap with all stakeholders

ROADMAP | IRIS AS THE REFERENCE

A 36-month industry-wide programme, modelled on rail's IRIS → ISO 22163 trajectory

Insight IRIS reference: UNIFE-led, launched 2006;
Rev.01 (2008) added maintenance;
Rev.02 (2009) strengthened First Article Inspection;
ISO/TS 22163 (2017) added safety & project management;
full ISO 22163:2023 + Rev.04 (2024).

Today: 1500+ certificates, 50+ countries, lender & insurer-referenced.

Compressed APQP-for-Wind cadence:
Phase 0 Foundation (months 0–3, trade-body sponsorship, founding coalition);
Phase 1 Rev.01 (months 3–9, Recs 01–02, first pilots re-gated);
Phase 2 Rev.02 (months 9–18, Recs 03–04, first supplier audits, shared joint risk register);
Phase 3 Rev.03 (months 18–30, Recs 05–06, lab infrastructure operational, feedback loop established);
Phase 4 ISO Track (months 30–36+, lender & insurer embedding, continuous-improvement cadence).

Rail had 18 years to mature — offshore wind does not.

07

SECTION

Expected impacts

A more predictable investment case

EXPECTED IMPACT

Left-shifting quality work converts wind from a sector of impairments into one of predictable returns

FIVE LEVERS

Quality investment moves up the value chain. Defects move down the cost-to-fix curve. Risk moves from unmanaged to managed. Returns become predictable. Cost of capital follows.

- Lever 1: CAPEX overrun reduction — eliminates the dominant source of impairment events. Lever 2: Commissioning duration compression — months recovered from the highest-burn phase. Lever 3: Year-one-to-five availability protection — the fragile early period of the financial model becomes predictable.
- Lever 4: Lifetime OPEX reduction & recapitalisation governance — mid-life capex becomes planned and financeable, not dilutive. Lever 5: Cost of capital improvement — lenders and insurers re-price construction-phase risk as the sector accumulates an auditable quality track record. Largest absolute NPV lever; slowest to materialise.
- From current state (project-by-project impairments, IRRs sensitive to 75bp WACC moves) to end state (impairments as outliers; reliability comparable to mature infrastructure; cost-of-capital convergence). The difference between developing-technology pricing and infrastructure pricing.

Indicative magnitudes based on APQP automotive Tier-1 benchmarks, AS9145 aerospace, IRIS rail; project-specific figures vary.

08

SECTION

Main risk and mitigation

Quality assurance framework will smoothen system migration for upgrades driven by demand, regulation and technologies

RISKS & MITIGATIONS

The dominant risk is system migration over a 25-year life — the proposed regime is the mitigation

Insight
Every asset in service today will be a different system from the one commissioned.
Sub-systems change at different paces (technology, demand, regulation), but the asset must remain certifiable, financeable, insurable, safe and performing throughout.

Rail cybersecurity is the live precedent: TS 50701 (2021) → IEC 63452 (mid-2026), being retrofitted onto 30-year-old interlocking systems via “compensating controls” rather than patches.

The same wave is hitting wind: NIS2, evolving grid codes, software-defined controllers, component obsolescence.
The proposed regime is the mitigation: Rec 01 (requirements baseline) becomes the spine of migration governance;
Rec 02 (zero residual risk) becomes regression assurance;
Rec 03 (joint risk register) governs supplier-driven change;
Rec 04 (process QA) prevents process drift;
Rec 05 (lab testing) validates changes before they reach the asset;
Rec 06 (operational data feedback) detects regression after.

Implementation risks: executive sponsorship erosion, supplier resistance, certifier acceptance lag, lab investment timing.

Mitigation: lock the regime contractually with lenders and offtakers, anchor-tenant supplier strategy, engage certifiers as design partners from Phase 1, use third-party facilities while building owned infrastructure.

09

SECTION

Next steps

Quality assurance framework will smoothen system migration for upgrades driven by demand, regulation and technologies

NEXT STEPS

An industry-wide quality assurance programme

01 **Convene the Founding Coalition**
Major developers, system suppliers (turbine, HVDC), foundation/installation primes, certifiers, technical advisers, insurers, financiers,...

02 **Publish the sector position paper**
Findings + recommendations issued as a 15 to 20-page co-signed document, establishing the agenda publicly.

03 **Founding Group convening meeting**
Agree scope, governance, IRIS-style roadmap and contracting-model workstream as priority. Sign terms of reference with named workstream leads.

04 **Stand up contracting workstream**
Joint legal-and-commercial group drafts joint requirements analysis protocol, joint risk register template, process quality clauses, peer-to-peer testing obligations.

05 **Four credibility deliverables**
Pilot project identification (one per developer); shared lab infrastructure agreement, certifier and lender alignment on validation-credit framework; APQP-for-Wind Rev.01 published.

THANK YOU

Questions & discussion

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Across the offshore wind value chain

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