EUROSTARS

Eurostars (Eureka) SME Innovation Project

AI-Driven Predictive Maintenance for Distributed Wind Turbine Fleets

WINDSAGE

Field	Value
Call Identifier	Eurostars Call 2026
Type of Action	Eurostars (Eureka) SME Innovation Project
Duration	36 months
Lead SME	Nordic Turbine Analytics AS (Norway)
Countries	Norway, Germany, Netherlands
Time to market	18 months after project end (month 54 from project start)
Total Budget	EUR 2,400,000
EU Contribution	EUR 1,300,000

Abstract

WINDSAGE develops and validates a commercially deployable edge-plus-cloud predictive maintenance platform for onshore and offshore wind turbine fleets. The platform fuses vibration, SCADA and acoustic-emission sensor data with physics-informed machine learning models - incorporating real-time aeroelastic simulation - to predict drivetrain and blade failures four to eight weeks in advance. This prognosis lead time is two to four times longer than current commercial condition-monitoring systems achieve, enabling planned interventions that eliminate the majority of unplanned downtime events. The consortium unites three complementary and experienced SMEs from Norway, Germany and the Netherlands: Nordic Turbine Analytics AS (platform software and AI, project lead), Ventus Sensors GmbH (ruggedised edge hardware and firmware) and Delft Dynamics BV (aeroelastic modelling and digital-twin integration). WINDSAGE targets a SaaS revenue model with a per-turbine monthly subscription, reaching commercial availability within 18 months of project completion. The global wind O&M software market is valued at approximately EUR 3.2 billion in 2026 and growing at 12% CAGR; WINDSAGE addresses a clearly defined and underserved segment within that market. Total project cost is EUR 2,400,000 over 36 months, with EUR 1,300,000 of requested public funding across the three Eureka countries.

SECTION 1 - PROJECT AND INNOVATION

1.1 The Innovation and Objectives

WINDSAGE delivers a hybrid edge-plus-cloud predictive maintenance platform that predicts drivetrain and blade failures in wind turbines four to eight weeks before occurrence - a prognosis horizon that is two to four times longer than the state of the art in commercial condition-monitoring systems. The platform continuously fuses three complementary data streams - triaxial vibration signals, SCADA operational data and acoustic-emission waveforms - with outputs from a real-time aeroelastic digital twin running on the edge device. A proprietary physics-informed machine learning (PIML) architecture combines first-principles structural dynamics with data-driven anomaly detection, dramatically reducing the labelled-fault data required for model training and enabling reliable prognosis on turbine populations as small as ten units. The system is designed for retrofit deployment on any IEC-compliant turbine without OEM dependency.

The primary project objective is to develop, integrate and field-validate the WINDSAGE platform across a representative mixed fleet (onshore and offshore turbines, multiple OEM makes) by month 30, achieving a false-positive rate below 5% and a missed-detection rate below 3% for the six most commercially significant failure modes: main bearing, gearbox, generator, rotor blade trailing-edge delamination, pitch system and tower base fatigue. Secondary objectives include: (i) design and qualification of a low-power (<8 W) edge processing unit capable of operating in IEC 61400-25 environments; (ii) development and open-source release of an aeroelastic surrogate model API enabling third-party integration; and (iii) demonstration of a cost-per-avoided-failure below EUR 3,000 across the pilot fleet, establishing a bankable business case for wind farm operators.

1.2 Degree of Innovation vs the State of the Art

Current commercial condition-monitoring systems (CMS) - such as those offered by SKF Enlight, Schaeffler OPTIME and Brüel & Kjaer Vibro - rely predominantly on vibration-only or SCADA-only signal chains with purely data-driven statistical models. Their typical actionable warning horizons range from two to fourteen days, which is insufficient for offshore O&M logistics where vessel procurement and technician mobilisation require three to six weeks of lead time. Physics-informed approaches exist in academic literature but have not been commercialised into a deployable edge product that operates without cloud connectivity during adverse-weather disconnections. No commercially available solution today integrates live aeroelastic simulation as a real-time conditioning input to the anomaly-detection layer.

WINDSAGE introduces three distinct innovations beyond the state of the art. First, the PIML architecture embeds a surrogate aeroelastic model - calibrated per turbine from design load case data and continuously updated with SCADA inflow measurements - as a physics prior within the neural network, reducing model uncertainty and extending prognosis lead times. Second, the edge-cloud split architecture enables autonomous on-device inference during connectivity outages while leveraging cloud compute for fleet-level transfer learning and model retraining, a capability absent in all surveyed competitors. Third, the acoustic-emission channel provides sub-millimetre crack detection sensitivity in composite blades at a sensor cost below EUR 200 per turbine, enabling cost-effective blade health monitoring without rope-access inspections. These three combined innovations constitute a non-trivial and protectable technical advance, with a freedom-to-operate analysis confirming no blocking prior art in the specific PIML-aeroelastic fusion configuration.

1.3 Technical Approach and Risks

The technical approach proceeds in three sequential phases. Phase 1 (months 1–12) covers requirements, architecture and component development: Ventus Sensors GmbH develops and qualifies the edge hardware module, including sensor fusion firmware and IEC 61400-25 protocol stack; Delft Dynamics BV builds the aeroelastic surrogate model library and its real-time API; Nordic

Turbine Analytics AS develops the PIML model architecture, cloud platform backbone and edge-cloud synchronisation protocol. Phase 2 (months 13–24) covers system integration and laboratory validation: the full stack is integrated and tested against a hardware-in-the-loop turbine emulator using historical SCADA and vibration data from a reference fleet of 40 turbines; model accuracy is validated against confirmed historical fault records. Phase 3 (months 25–36) covers pilot deployment and field validation on a live mixed fleet of at least 15 turbines across two Eureka countries, generating independent evidence of commercial-grade performance.

The main identified technical risks and mitigation strategies are as follows. Risk 1: insufficient labelled fault data for PIML training - mitigated by the physics prior, which allows generalisation from small datasets, and by a data-sharing agreement with a Norwegian fleet operator secured prior to project start. Risk 2: edge compute constraints limiting model complexity - mitigated by a model compression and quantisation workstream led by Ventus Sensors GmbH, targeting deployment on an ARM Cortex-M55 class processor. Risk 3: aeroelastic surrogate accuracy degrading under site-specific turbulence conditions - mitigated by an online Bayesian update loop that recalibrates the surrogate using measured tower-top accelerations. Risk 4: regulatory and cybersecurity requirements for OT-network-connected devices - mitigated by IEC 62443-compliant secure-by-design firmware architecture developed from month 1. A go/no-go decision point at month 18 (end of integration phase) will assess whether the PIML model meets the pre-defined accuracy thresholds before committing pilot fleet access costs.

SECTION 2 - MARKET AND COMMERCIALISATION

2.1 Market Need and Size

Wind energy is the fastest-growing source of electricity generation in Europe and globally. As of 2025, over 255 GW of wind capacity is installed across EU member states, representing approximately 125,000 individual turbines. Offshore wind capacity is projected to reach 300 GW in Europe by 2030 under the REPowerEU plan. Operations and maintenance expenditure accounts for 20–35% of the total lifetime cost of a wind asset; for offshore turbines this figure reaches EUR 35–55 per MWh. Unplanned corrective maintenance - the segment WINDSAGE directly addresses - constitutes approximately 35% of total O&M cost and can trigger revenue losses exceeding EUR 150,000 per turbine per unplanned downtime event when offshore vessel mobilisation costs are included.

The global wind O&M software and condition-monitoring market was valued at approximately EUR 3.2 billion in 2026 (MarketsandMarkets, Wood Mackenzie) and is projected to grow at 11–13% CAGR to reach EUR 5.8 billion by 2031. The serviceable addressable market (SAM) for WINDSAGE - advanced AI-based predictive maintenance software for utility-scale onshore and offshore fleets of 10 turbines or more in Europe, North America and East Asia - is estimated at EUR 780 million in 2027, rising to EUR 1.4 billion by 2031. The serviceable obtainable market (SOM) for the consortium in years 1 to 5 post-launch is conservatively estimated at EUR 28 million cumulative ARR by year 5, based on penetration of 0.8% of the European installed base and a blended per-turbine annual subscription of EUR 4,200 plus hardware amortisation. This represents a realistic and well-bounded commercial target for three SMEs operating with focused go-to-market execution.

2.2 Customers and Competition

Primary target customers are independent power producers (IPPs) and utility wind operators managing fleets of 20 or more turbines - including Equinor, RWE Renewables, Ørsted, Vattenfall and mid-market operators such as Alternus Energy and Cero Generation. A second customer segment comprises independent O&M service providers and asset managers (e.g., SGRE service division independents, Engie Green Operations) who manage multi-OEM fleets and have a strong incentive to reduce corrective maintenance call-outs. A third segment consists of wind turbine OEMs seeking to

enhance their service contract offering with third-party AI analytics. Nordic Turbine Analytics AS has existing commercial relationships with three Norwegian IPPs who have confirmed willingness to participate in the pilot and engage in early-adopter agreements upon commercial launch.

The competitive landscape comprises four main categories: (i) OEM-bundled CMS (Siemens Gamesa, Vestas, GE Vernova) - strong installed base but closed ecosystems, no multi-OEM compatibility and limited prognosis horizons; (ii) independent CMS hardware and software vendors (SKF, Schaeffler, Brüel & Kjaer) - vibration-centric, limited AI depth, no aeroelastic integration; (iii) pure AI analytics platforms (SparkCognition, Envision Digital) - cloud-only, dependent on third-party sensor hardware, limited physics grounding; and (iv) academic spin-outs at pre-commercial stage. WINDSAGE's differentiation is the combination of OEM-agnostic retrofit hardware, physics-informed AI with extended prognosis horizons and a proven edge-cloud architecture - a combination no current competitor offers in a single integrated product. Barriers to entry for future competitors are high, given the proprietary PIML-aeroelastic fusion IP and the fleet training data network effects that accumulate post-launch.

2.3 Business Model and Route to Market

WINDSAGE operates a hybrid SaaS-plus-hardware business model. Revenue stream 1 is a per-turbine monthly subscription for the analytics platform, priced at EUR 280–420 per turbine per month (blended EUR 350), which includes cloud processing, model updates, alerting and reporting dashboards. At a 50-turbine fleet, this generates EUR 210,000 ARR per customer. Revenue stream 2 is a one-time edge hardware unit sale at EUR 1,800 per turbine, with an estimated 60% gross margin after manufacturing cost. Revenue stream 3 is optional professional services for fleet onboarding and digital-twin calibration at EUR 8,000–15,000 per fleet. Unit economics at scale: customer acquisition cost (CAC) is estimated at EUR 22,000 per fleet customer (driven by technical sales cycle); customer lifetime value (LTV) at a 5-year average contract is EUR 1,050,000 for a 50-turbine fleet - an LTV/CAC ratio of 48:1, indicating a highly attractive SaaS business once the product is commercialised.

The go-to-market strategy leverages Nordic Turbine Analytics AS's existing operator relationships in Norway and the Nordic market as the primary early-adopter channel, targeting signed commercial contracts within 18 months of project completion. A second channel activates German and Dutch independent O&M service providers through Ventus Sensors GmbH's established distribution network in the DACH and Benelux markets. From year 3 post-launch, the strategy expands to a partner reseller model targeting the UK, Spain, Denmark and the US offshore market via Eureka network connections and industry events (WindEurope, AWEA). The consortium will seek to close a Series A investment round of EUR 4–6 million in the 12 months following commercial launch to fund international scale-up, with the WINDSAGE platform IP and validated field performance as the primary investment thesis.

SECTION 3 - CONSORTIUM AND IMPLEMENTATION

3.1 Consortium and Complementarity

The WINDSAGE consortium is composed of three SMEs from three Eureka member countries, each bringing a distinct and non-overlapping competence that is essential to the technical and commercial success of the project. Nordic Turbine Analytics AS (Norway) is the project coordinator and platform integrator. Founded in 2018, the company has 14 employees and specialises in machine-learning-based condition monitoring software for renewable energy assets. It brings existing IP in anomaly detection algorithms, a proprietary cloud data pipeline for SCADA ingestion and commercial relationships with Norwegian wind operators. Ventus Sensors GmbH (Germany) is the edge hardware partner. Founded in 2015, the company has 22 employees and a track record in ruggedised IoT sensor nodes and industrial edge computing for energy and process industries. It contributes certified hardware design, EMC and IEC 61400-25 compliance experience, and a manufacturing

supply chain for unit costs below EUR 800 at volumes above 500 units. Delft Dynamics BV (Netherlands) is the aeroelastic modelling partner. Founded in 2009, the company has 18 employees and is internationally recognised for its work on wind turbine structural dynamics, digital twins and load simulation, with prior participation in two Horizon 2020 wind energy projects.

The consortium structure satisfies all Eurostars eligibility requirements: the lead partner is an R&D-performing SME from a Eurostars country; all three partners are SMEs; partners are from three distinct Eureka countries (Norway, Germany, Netherlands); no single partner or country accounts for more than 70% of the project budget; and the aggregate SME Eurostars-country budget exceeds 50% of total project cost excluding subcontracting. The complementarity is genuine and verifiable: no two partners have overlapping technical roles, and the absence of any one partner would critically impair the project's ability to deliver the integrated platform. The international collaboration adds specific value: it combines the Nordic market access and software leadership of the lead SME with German hardware industrialisation capability and Dutch aeroelastic scientific depth, a combination that no single country-based consortium could replicate.

Partners

Partner	Country	Type	Role
Nordic Turbine Analytics AS	Norway	SME (Software)	Project coordinator; PIML platform development; cloud architecture; system integration; pilot coordination
Ventus Sensors GmbH	Germany	SME (Hardware)	Edge hardware design and qualification; sensor fusion firmware; IEC 61400-25 protocol stack; manufacturing
Delft Dynamics BV	Netherlands	SME (Aeroelastic Modelling)	Aeroelastic surrogate model library; digital-twin API; structural load simulation; validation methodology

3.2 Work Plan

The work plan is structured into five work packages (WPs) spanning 36 months, with a clear progression from requirements and component development through integration, validation, pilot deployment and dissemination. WP1 covers project management, coordination and reporting throughout the full project duration, led by Nordic Turbine Analytics AS. WP2 covers edge hardware development and qualification (months 1–18), led by Ventus Sensors GmbH, with tasks including sensor node hardware design, firmware development, EMC testing and IEC 61400-25 certification. WP3 covers aeroelastic surrogate model and digital-twin API development (months 1–20), led by Delft Dynamics BV, with tasks including load case database curation, surrogate training, API specification and integration testing. WP4 covers PIML platform development and system integration (months 6–28), led by Nordic Turbine Analytics AS, encompassing the PIML architecture, edge-cloud synchronisation, dashboard and alerting module, and hardware-in-the-loop laboratory validation. WP5 covers field pilot validation and exploitation (months 25–36), led by Nordic Turbine Analytics AS, encompassing pilot deployment, independent performance assessment and go-to-market execution.

Key milestones include: M1 (month 6) - system architecture and interface specifications frozen (go/no-go gate); M2 (month 12) - edge hardware prototype v1.0 delivered and aeroelastic API v1.0 released internally; M3 (month 18) - full platform integration complete and laboratory validation results reviewed (go/no-go gate for pilot); M4 (month 30) - pilot deployment on minimum 15

turbines complete; M5 (month 36) - independent validation report published and first commercial contract signed. Deliverables include technical specifications, software releases, hardware qualification reports, validation datasets and a final exploitation plan. All milestones are defined as go/no-go decision points with pre-agreed quantitative acceptance criteria.

Work packages

WP	Title	Lead	Months
WP1	Project Management and Coordination	Nordic Turbine Analytics AS	1–36
WP2	Edge Hardware Development and Qualification	Ventus Sensors GmbH	1–18
WP3	Aeroelastic Surrogate Model and Digital-Twin API	Delft Dynamics BV	1–20
WP4	PIML Platform Development and System Integration	Nordic Turbine Analytics AS	6–28
WP5	Field Pilot Validation and Exploitation Preparation	Nordic Turbine Analytics AS	25–36

3.3 Budget and Resources

The total project cost is EUR 2,400,000 over 36 months, with EUR 1,300,000 of requested public funding, representing a blended public funding rate of approximately 54%. Budget allocation by partner: Nordic Turbine Analytics AS - EUR 1,020,000 (43% of total, covering 8.5 FTE-years of software engineers, ML scientists and a project manager, plus cloud infrastructure costs); Ventus Sensors GmbH - EUR 840,000 (35% of total, covering 6 FTE-years of hardware engineers and firmware developers, plus prototyping materials and certification fees); Delft Dynamics BV - EUR 540,000 (22% of total, covering 4 FTE-years of aeroelastic engineers and a scientific advisor, plus simulation software licences). No single partner exceeds 50% of the total budget, and no single country exceeds 70%, ensuring eligibility compliance under Eurostars rules. Subcontracting is limited to independent pilot-site instrumentation services (estimated EUR 60,000 total) procured at arm's length; no inter-partner subcontracting is included.

The primary cost driver across all partners is personnel, representing approximately 74% of total costs, consistent with a software- and engineering-intensive R&D project. Each partner confirms that its share of project financing is secured: Nordic Turbine Analytics AS will self-finance its co-funding contribution from existing revenue and a pre-agreed revolving credit facility; Ventus Sensors GmbH has confirmed co-funding from retained earnings and a conditional regional innovation grant from the state of Baden-Württemberg; Delft Dynamics BV will co-fund its contribution from ongoing service contract revenue. All three partners have previously received national public R&D funding and have established financial management and reporting procedures compatible with Eurostars requirements.

SECTION 4 - IMPACT

4.1 Economic Impact for the SMEs

WINDSAGE is projected to generate significant and verifiable economic impact for all three SME partners within five years of commercial launch. For Nordic Turbine Analytics AS, the platform is expected to become the company's primary product line, replacing project-based consulting revenues with recurring SaaS ARR. Revenue projections: EUR 1.2 million ARR by end of year 2 post-launch (approximately 285 turbines under contract), growing to EUR 8.4 million ARR by end of year 5 (approximately 2,000 turbines), implying a 5-year cumulative revenue contribution from WINDSAGE of EUR 22 million. Headcount is projected to grow from 14 to 38 employees by year 5, with 18 of those roles directly attributable to WINDSAGE commercialisation. For Ventus Sensors GmbH,

WINDSAGE creates a new product line in the wind energy vertical, with projected hardware unit sales of 3,500 edge modules by year 5 generating EUR 6.3 million in cumulative hardware revenue and a contribution margin of EUR 3.8 million. Four to six new engineering and production roles are projected. For Delft Dynamics BV, the project creates the foundation for a commercial digital-twin licensing model; the aeroelastic API developed in WINDSAGE is expected to be licensed to two to three additional industrial partners by year 3, generating EUR 480,000 in additional licence revenue and supporting three new research-to-commercialisation roles.

Return on investment for the consortium as a whole: total project investment (including partner co-funding of EUR 1,100,000) against projected 5-year cumulative WINDSAGE-attributable revenue of EUR 29 million yields a conservative ROI multiple of 26x on the private investment component. This is a compelling and independently verifiable business case that confirms the market-driven character of the WINDSAGE project and its alignment with Eurostars programme objectives.

4.2 Wider European Impact

Beyond the direct economic benefit to the three SME partners, WINDSAGE will generate broader impact at the European level across three dimensions. First, it directly supports the EU's REPowerEU and European Green Deal objectives by improving the cost-competitiveness and reliability of wind energy - the single largest source of renewable electricity in Europe. By reducing unplanned O&M costs by an estimated 25–40% for early-adopter fleets, WINDSAGE contributes to lowering the levelised cost of electricity (LCOE) for wind, accelerating the financial viability of new installations and supporting the EU target of 510 GW of wind capacity by 2030. Second, WINDSAGE strengthens European industrial competitiveness in wind energy technology. The global wind O&M software market is currently dominated by US-based AI analytics platforms and OEM service divisions; WINDSAGE positions three European SMEs as genuine technology leaders in physics-informed predictive maintenance, with protectable IP and a scalable SaaS model capable of competing globally. Third, the project generates knowledge spillovers through the open-source release of the aeroelastic surrogate API, enabling the broader European research and industrial ecosystem to build upon the digital-twin methodology developed in WINDSAGE. The project results are exclusively civilian in purpose and raise no ethical concerns, fully complying with Eurostars eligibility requirements in this regard.