Final report

1. Project details

Project title	Power Buoy – Offshore solution for green marine charging
File no.	64020-1056
Name of the funding scheme	EUDP / Energy efficiency / Udvikling Demonstration
Project managing company / institution	Stillstrom A/S
CVR number (central business register)	42487651
Project partners	N/A
Submission date	30/11/2025

2. Summary

Project summary

The purpose of the project

The maritime sector emits ~3% of global GHGs and is hard to decarbonize. Stillstrom develops offshore charging for electric vessels. Offshore wind farms show immediate demand: Service Operation Vessels (SOV) spend long hours onsite and must refuel onshore. This project focuses on enabling direct decarbonized charging at sea, boosting efficiency and resilience.

Results, conclusions and perspective

Project results:

- Reached TRL 7 (near-commercial readiness)
- Completed detailed engineering design and built key components
- Executed full-scale trials proving safety, reliability, and efficiency
- Spun out Stillstrom as a standalone company focused on commercialization
- Expanded the technical team and capabilities, accelerating delivery
- Established partnerships with vessel operators and wind developers

Future use:

Offshore wind farms in the UK and EU show immediate demand. SOVs spend long periods onsite and currently return to refuel; with Stillstrom they can charge offshore, cutting cost, time, and emissions. We now offer four tailored applications, each matching site constraints and developer needs:

- Wind Turbine Generator (WTG) — mounted directly on the wind turbine
- Substation — integrated on the offshore substation
- Monopile — installed on a dedicated monopile
- Buoy — floating unit offering maximum flexibility

Broader impact:

- Supported creation of a new “Zero Emissions Anchorage Zones” business line: shore power ready vessels at anchor can switch off engines, cutting CO_2, NOx, and noise while reducing GHG related costs
- Accelerates maritime electrification; rising competitor activity confirms strong market momentum
- De-risks investment in electric vessels by demonstrating that offshore charging infrastructure will be available
- Contributes to EU/UK climate targets, improves port-area air quality, and fosters resilient, locally sourced clean-energy jobs

Projektresumé

Formålet med projektet

Den maritime sektor står for omkring 3 % af de globale drivhusgasudledninger og er en af udfordrende branche at omstille til en mere klimavenlig drift. Stillstrom udvikler offshore-ladeløsninger til elektriske fartøjer. Offshore vindparker viser et umiddelbart behov: servicefartøjer (SOV) opholder sig i lange perioder i området, men skal sejle i havn for at tanke. Dette projekt fokuserer på at muliggøre direkte dekarboniseret opladning til søs, hvilket øger effektiviteten og driftssikkerheden.

Resultater, konklusioner og perspektiv

Projektresultater:

- Opnåede TRL 7 (næsten kommerciel parathed)
- Færdiggjorde detaljeret ingeniørdesign og byggede centrale komponenter
- Gennemførte fuldskalatests, der bekræftede sikkerhed, driftspålidelighed og effektivitet
- Sætte Stillstrom op som et selvstændigt selskab med fokus på kommercialisering
- Udvide det tekniske team og kompetencer, hvilket accelererede leverancen
- Etablerede partnerskaber med rederier og udviklere af offshore vindparker

Fremtidig anvendelse:

Offshore vindparker i Storbritannien og EU viser et umiddelbart behov. SOV'er opholder sig længe på stedet og sejler i dag i havn for at optanke; med Stillstrom kan de oplade offshore, hvilket reducerer omkostninger, tid og udledninger. Vi tilbyder nu fire skræddersyede løsninger, som hver matcher lokale forhold og udviklernes behov:

- Wind Turbine Generator (WTG) — monteret direkte på vindmøllen
- Substation — integreret i offshore transformerstationen
- Monopile — installeret på en dedikeret monopæl
- Bøje — flydende enhed, der giver maksimal fleksibilitet

Bredere impact:

- Understøttede etableringen af en ny forretningslinje for "Zero Emissions Anchorage Zones", hvor landstrømsklare skibe på anker kan slukke motorerne og reducere CO_2, NOx, støj samt omkostninger knyttet til udledninger
- Fremskynder elektrificeringen af skibsfarten; voksende konkurrenceaktivitet bekræfter et stærkt markedsmomentum
- Reducerer risikoen ved investering i elektriske skibe ved at demonstrere, at offshore ladeinfrastruktur vil være tilgængelig
- Bidrager til EU's og Storbritanniens klimamål, forbedrer luftkvaliteten i havneområder og styrker robuste, lokalt forankrede grønne arbejdspladser

3. Project objectives

The original project objectives were adjusted in response to rapidly evolving market demand. While the initial focus was on providing idling power at offshore wind farms, it became clear that the greater need lies in offshore vessel charging. In 2024, Stillstrom submitted a detailed scope change request reflecting this shift, which was subsequently approved.

3.1. Original objectives:

The overall objective of the Power Buoy project was to seize a novel market opportunity through the development, demonstration, and commercialization of a buoy that acted as a mooring point while also providing access to clean energy. These buoys were intended to power stand-by vessels without the need to berth onshore or run their engines/alternative generators. At the time, ships relied on onshore power facilities, which were often unavailable or inefficient for offshore operations.

To develop the Power Buoy, the project aimed to overcome several operational challenges and achieve technical breakthroughs. Each work package was assigned specific objectives, milestones, and deliverables, summarized as follows:

- Technical: to develop a robust, safe, and versatile design capable of meeting different energy requirements from ships and power generation facilities under offshore conditions.
- Commercial: to present a cost-effective buoy providing offshore access to clean power.

3.2. Revised objectives:

Following the scope change, the project shifted from developing a buoy solution to focusing on the Hang-Off Stillstrom Offshore electric Charger (SOeC). The new objective was to design, demonstrate, and commercialize a compact charging system mounted on offshore wind infrastructure, enabling vessels to connect directly to clean energy while at sea.

Key aims included:

- Technical: create a robust, safe, and versatile charger adaptable to varying vessel energy needs and offshore conditions.
- Commercial: deliver a cost-effective solution that accelerates electrification of offshore operations.

Planned outcomes were a functional Hang-Off prototype, a pilot demonstration to validate performance and cost-effectiveness, and subsequent design improvements to maximize flexibility and scalability across vessel types and offshore facilities

3.3. Reasoning for objectives change:

During 2023–2024, several external factors significantly influenced the project's direction. The planned pilot build and test at Ørsted's wind farm was halted, and changes in test site, vessel availability, and supplier base added complexity and cost. At the same time, market demand evolved rapidly, showing stronger interest in offshore charging solutions integrated with wind farm infrastructure rather than buoy-based idling power alone.

To reduce the risk of delivering a non-market-fitting product, Stillstrom and Ørsted agreed to refine the project direction. Project learnings were incorporated into the development of the Hang-Off SOeC offshore charger, which better addresses immediate customer needs while retaining the core mission of decarbonizing maritime operations. This design delivers higher emission reductions: up to 6 tons of CO_2 per day for a fully electric SOV, around 200% more than the initial idle power buoy concept and offers a more scalable path to commercialization

4. Project implementation

4.1. Project evolution:

4.1.1. Timeline overview

2020	EUDP grant approved while Stillstrom was part of Maersk Supply Service (MSS).
2021	Stillstrom established as a standalone company; cooperation agreement signed with Ørsted for Race Bank pilot.
2022	Design and manufacturing contracts awarded; Ørsted relocates test site; early shift toward charging focus
2023	Revision of product offering to offshore charging; market competition intensifies.
2024	Team expansion; EUDP scope change approved; vessel and yard trials executed.
2025	Final design adjustments; commercial equipment ordered; new grants applied.

4.1.2. Detailed overview

The Power Buoy project originated within Maersk Supply Service (MSS), where the initial concept was developed and the EUDP grant application was submitted in 2020. That same year, EUDP approved funding, providing both financial support and external validation of the project's innovative potential. The award played a decisive role in convincing Maersk to spin off Stillstrom as an independent company in 2021, enabling dedicated focus on offshore charging technologies.

The official collaboration with Ørsted, established in 2021, marked the true start of technical implementation. The initial deployment site was designated as Ørsted's Race Bank Wind Farm in the UK. In early 2022, Stillstrom contracted Orwell Offshore to design and construct the buoy, while additional subcontracts were signed for key components such as the carousel, subsea cable, and electrical systems.

In March 2022, Ørsted's decision to relocate the test site coincided with emerging market insights: offshore wind developers were expressing growing interest in charging capabilities for electric Service Operation Vessels (SOVs) rather than static "idling power." Redesigning the buoy for idling alone would have added cost without real market value, so Stillstrom began shifting focus toward charging-oriented applications, anticipating where demand would grow.

During 2023, the company formally began revising its product offering, pivoting from the buoy to new offshore charger configurations, including the Hang-Off SOeC. This strategic shift aimed to reduce costs, increase competitiveness, and directly address the needs of offshore wind developers. The appearance of new competitors during this time confirmed that market demand was maturing, validating Stillstrom's direction.

In 2024, Stillstrom entered a period of rapid expansion, significantly increasing its workforce and strengthening its internal R&D and engineering capacity. That year also marked an important regulatory milestone with EUDP's approval of the formal scope change request, officially updating the project's objective to the development of offshore charging solutions. Stillstrom conducted vessel and yard trials later in the year, demonstrating the feasibility and readiness of the new system.

As the project advanced into 2025, activities focused on final design optimization and commercial readiness. Key equipment such as winches, cables, connectors, and electrical systems was procured to support the first commercial deployment. In parallel, Stillstrom applied for two new grants, one valued at approximately EUR 12 million (Innovation Fund), aimed at transitioning from R&D to full-scale implementation.

The EUDP Power Buoy project was completed in November 2025, marking the culmination of the development phase and the beginning of commercialization.

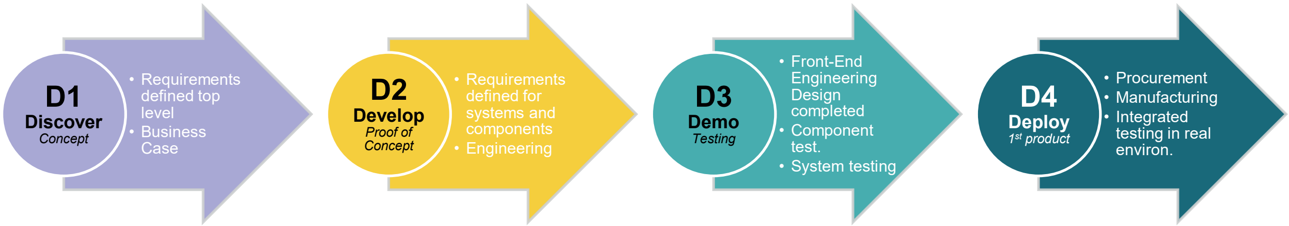
The evolution of the project reflects Stillstrom's agility and strategic foresight, adapting to changing market conditions, strengthening technological capabilities, and laying the groundwork for a new era of offshore vessel electrification that directly supports Europe's green transition.

4.2. Alignment with milestones

The Power Buoy project has progressed in close alignment with its key milestones, despite external changes that required a mid-course rescoping from a buoy-based prototype to the SOeC Hang-Off. The revised implementation maintained all technical and innovative objectives while strengthening market relevance and commercial potential.

Milestone 1 – Full list of specifications and feasibility study – linked to WP1 - WP4

During 2022–2023, Stillstrom defined the full system specification for an offshore power connection system. It defined a connection over 690 V at 650 kW. This was designed for the original Power Buoy; however, it could be transferred to the new Hang-off design. After rescoping in 2024, activities covered the D1 – D3 stages of the internal development process, including functional and interface requirements, electrical and mechanical designs, and feasibility studies for offshore power distribution and charging operations. The output formed the foundation for the initial front-end engineering design package and guided subsequent prototype activities. The rescoping also included upscaling of the power connection as the demand shifted from supplying idling vessels with hotel load power, to charging battery powered electric and hybrid-electric vessels. This meant changing the electrical philosophy and aligning with existing shore power standards, in this case IEC 80005-1. This prescribed a power connection over 11 kV. Stillstrom system is originally designed to charge vessels at 6.5 MVA, however, this can be further upscaled up to around 8 MVA before more significant design changes have to be considered. This specification was completed on time in September 2024. This specification was completed on time in September 2024.



Caption – Product Development Process

Milestone 2 – Prototype SOeC built and ready for installation – linked to WP4

Through 2023, the company developed the first prototype design: a power-buoy-style cable management and charging system. Hardware elements such as the provisional Vessel Connection Unit (VCU) with pull-in winch and the carousel-style umbilical cable reel including cable and connector head, which was supposed to be installed on top of the charging buoy were prepared for bench assembly and functional dry-run testing. Assumption was that these can be similarly reused for the Hang-off system. This work validated key mechanical and electrical interfaces and prepared for the first integrated prototype evaluation.

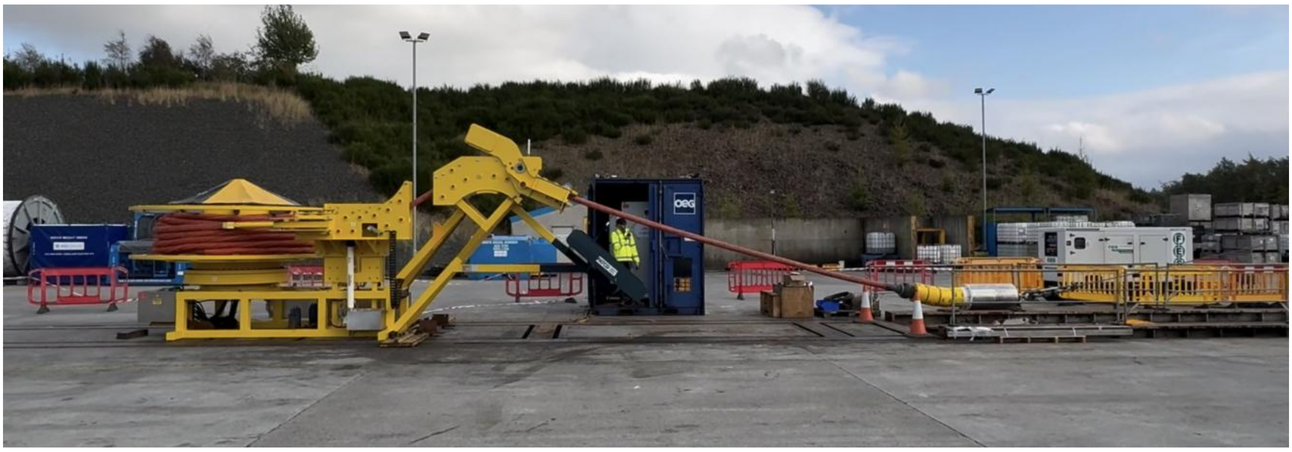
<u>Milestone 3 – SOeC functioning in test conditions</u> – linked to WP5

In 2024, several component-level and subsystem tests were completed, demonstrating basic functionality under controlled conditions. These included the cable-transfer tests, control-system logic checks, and the yard trial held in Aberdeen, Scotland (October 2024).

The trial verified and confirmed

- Synchronization between winch systems based on tension control philosophy
- The breaking load of the weak link between the connector head and the messenger line, and recoil of the system
- Operations of the catenary control of the carousel cable reel, allowing fine-tuning prior to the harbour trial

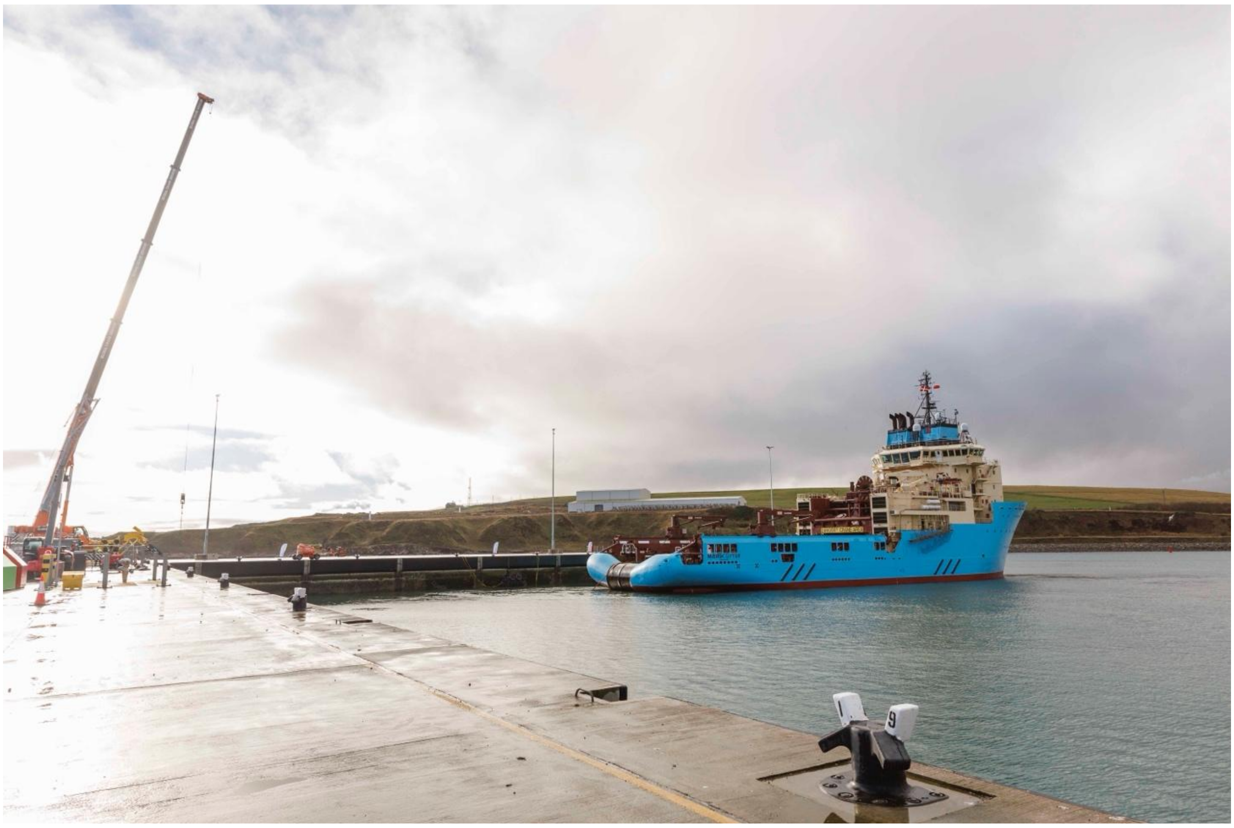
The results were used to refine control parameters and validate the mechanical design against operational loads and safety interlocks. They were also used to fine-tune the harbour trial parameters and operations.



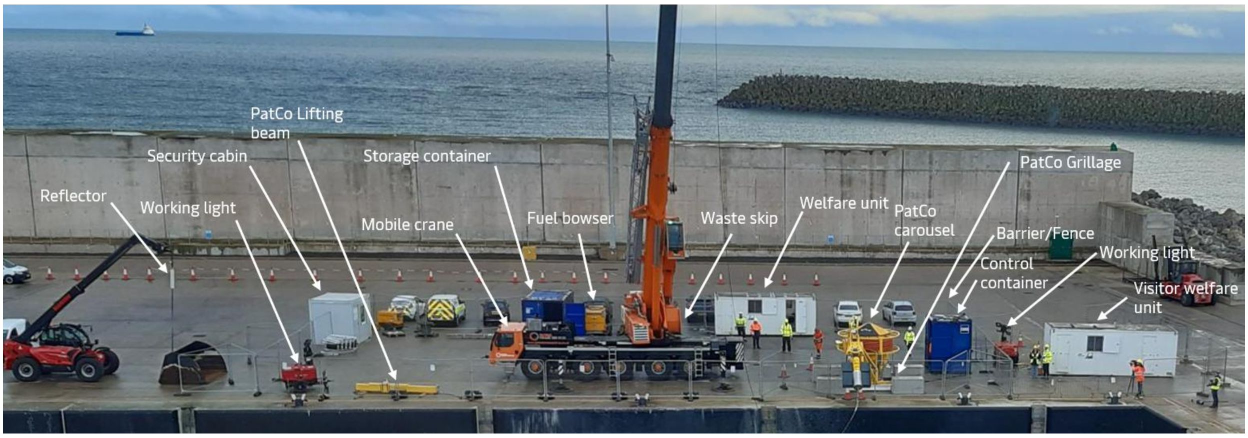
Caption: Yard Trial 2024

<u>Milestone 4 – SOeC validated in operational conditions & key optimization parameters defined</u> – linked to WP5

Following the successful yard trial, preparations were made for the harbour-scale validation in Aberdeen, Scotland (November 2024). This activity constituted the project's operational demonstration phase and included logistics such as vessel rental, port-area test site establishment, mobile crane and infrastructure support, and deployment of the test team and service personnel. The harbour trial served to confirm performance under controlled sea-state and handling conditions, providing data for optimization and readiness for full-scale system integration. Maersk Lifter, an offshore support vessel of anchor handling type was selected for this. Provisional VCU with pull-in winch were installed on the aft deck of the vessel and platform units with mobile crane were present at the quayside. The test successfully validated the operational philosophy of SOeC system, generated feedback on the training requirements, control philosophy, connection philosophy and manual handling optimization.



Caption: Harbour Trial 2024



Caption: Quayside layout of the Harbour Trial 2024

Milestone 5 – Final design for an SOeC functioning in field conditions – linked to WP7

During 2025, optimization efforts focused on translating the prototype into a market-ready Hang-Off SOeC design, corresponding to Stillstrom's D4 stage. Activities included design improvements and establishment of the supply chain partnerships for manufacturing, testing and delivery of the connection, electrical, controls, and digital systems. A comprehensive bench test was performed to validate functionality of communication interfaces between the control and digital systems. Connector system's mechanical testing, including drop, abrasion, vibration, and sealing were performed. Additionally, durability tests were performed to verify the connector's system's resilience to frequent mating and disconnections. DNV Technology Qualification Plan has been fully endorsed, containing a list of activities to be performed to derisk future system operations and validate safe functioning offshore. Several of these activities were executed before project's end, mainly through control and digital system bench test and the connector system mechanical testing. Final verification steps are to be completed in yard and vessel trials before end of 2025 and during the 2026 system integration trial.

Alignment summary

Although the project underwent a major scope revision in 2024, milestone completion remained largely on schedule. The shift from the original buoy concept to the Hang-Off SOeC configuration ensured that EUDP funding supported a more impactful and commercially viable solution. Each milestone has delivered measurable technical outcomes that directly feed into the continued product maturation towards deployment and commercialization.

4.3. Risk management

Risk management has been an integral part of the Power Buoy and SOeC projects from their initiation.

Risk categories and general overview

The main risk categories monitored throughout the project included:

- Technical design risks – relating to component functionality, integration of the control system, and qualification of new electrical and mechanical interfaces.
- Operational and safety risks – particularly in relation to cable handling, connector operations, and high-voltage interfaces during testing and future offshore use.
- Manufacturing, schedule, and supply-chain risks – concerning timely component procurement, fabrication of large mechanical systems, and electrical hardware lead times.
- Business case and market risks – mitigated substantially through the project's rescoping, ensuring alignment with market demand for wind farm integrated charging solutions.

The rescoping to the Hang-Off SOeC eliminated many operational and hydrodynamic risks associated with the original buoy concept. However, it introduced new design risks, namely the need for more complex integration of SOeC equipment on fixed wind farm infrastructure. Furthermore, operational risks linked to the boom crane and messenger line handling philosophy were introduced, which required design additional validation through test campaigns.

Procurement related risks evolved over time: while general lead times for electrical and control components improved during 2025, the availability of high-voltage transformers remains a challenge. Stillstrom mitigates this by collaborating with wind farm operators who procure transformers at scale.

Risk management process during SOeC development

A formal enterprise risk register was established at the project outset, using TECOP analysis. This analysis produced the top 10 risks detailed later in this section, and also formed the basis for the product risk register.

After the first product development stage gate was passed, and on an ongoing basis thereafter, the product risk register was revisited to add successive levels of detail and granularity to identified technical and operational risks.

As the project advanced into the D3 and D4 stages, the approach was strengthened through the use of formal risk analyses including HAZID (Hazard Identification), FMEA (Failure Modes and Effects Analysis), with the latter providing the basis for independent Technology Qualification (TQ) of SOeC by DNV.

In addition to the formal risk analyses detailed above, Stillstrom conducted the additional risk management activities as part of the product development process:

- Product Design Reviews
- Vessel integration workshops with several Service Operation Vessel owners and operators
- Product tests and trials

Technology qualification

As a means of validating both compliance with recognised engineering standards, and threats to successful deployment of the technology, Stillstrom engaged DNV to provide TQ support during the latter stages of product development. Technology qualification is a rigorous process of independent quality assurance, driven by a systematic assessment framework. TQ required Stillstrom to develop a plan to ‘qualify’ all identified threats / risks through a combination of tests, trials and further risk analysis to the satisfaction of the Classification Society (i.e. DNV). Risk reviews were conducted jointly with DNV, ensuring alignment between engineering, certification, and qualification activities. Each major test campaign (bench test, yard trial, and harbour trial) included pre-test risk assessments and post-test updates to ensure lessons learned were captured and residual risks were documented.

Alignment with wind industry legislation and good practice

As a means of further strengthening risk management within product development and based on feedback from potential customers and end users of the technology, Stillstrom elected to align its product development process with ‘Safe by Design Good Practice Guidance’ published by the G+ organization.

This alignment enables Stillstrom to take a more proactive approach towards wind farm operators through the identification of issues of mutual concern, such as technical integration risks, vessel operational risks, and certification / compliance requirements.

As a further pre-emptive step, Stillstrom has readied SOeC for entry into the UK offshore market by incorporating elements of the Construction and Design Management (CDM) Regulations (2015) into the product development process. These elements include a Design Decision Log (DDL) and Design Residual Risk Register (DRRR), which are legal requirements for offshore construction projects in UK waters.

Key risks addressed and mitigated in the project

Technical

- Failure / fault propagation from or into client or vessel systems, unplanned downtime
- Insufficient power delivered to charge vessel
- Lower TRL of novel system components
- Unclear route to Class approval of offshore charging technology
- Ability to withstand harsh environmental conditions

Commercial / Financial

- Lack of purchasing power of offshore charger provider compared to offshore wind developers
- Cost / availability of umbilical cable that can withstand anticipated environmental loads
- Business case for electrification versus MGO or alternative fuels

Operational

- Improper handling of connector, resulting in reduced operating life
- Connector sinking and contacting seabed after emergency disconnection

Evolution of the risk profile

Risk management remained dynamic throughout the project lifecycle. Following the rescoping in mid 2024, the overall technical risk exposure decreased, while complexity shifted toward system integration and qualification.

Early-phase risks around offshore operability, station keeping, and buoy fatigue were archived and will be used for future development of the buoy concept, shall the market steer in this direction.

New focus areas emerged around mechanical integration with turbine foundations, control-system robustness, and digital connectivity.

The DNV qualification process ensured that each critical technical risk was linked to a verification activity within the Technology Qualification Plan, ensuring traceability between identified risks and mitigation testing.

Given the extended duration and complexity of the D4 phase, risk reviews were held quarterly in addition to the standard stage gate checkpoints. Design reviews were also institutionalized to maintain traceability between design changes and associated risk updates.

Outcomes and next steps

The structured risk management process ensured that all major technical and operational risks have been addressed through testing, simulation or other kind of engineering validation. Remaining residual risks are now confined to system integration and offshore deployment activities, which will be verified during the System Integration Trial and Service Operations Vessel Trial in 2026.

4.4. Unexpected challenges

During the project implementation, several unexpected challenges arose, primarily connected to the transition from the original Power Buoy concept to the Hang-Off SOeC configuration in mid 2024, as well as to supplier changes necessitated by new technical requirements. While these shifts introduced schedule and cost implications, they were essential to ensure long-term feasibility, technical robustness, and alignment with the evolving offshore charging market.

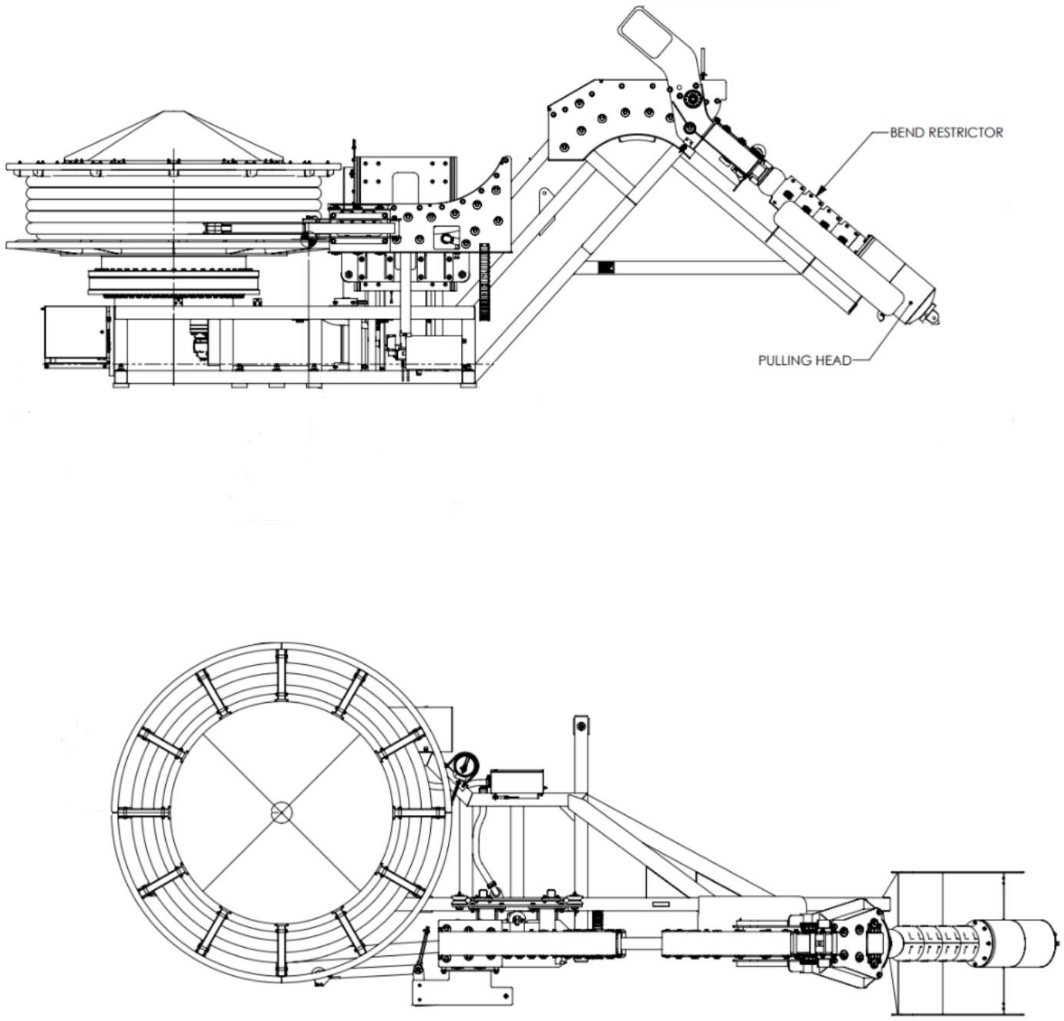
Transition from Buoy to Hang-Off concept

The original Power Buoy prototype was based on a floating platform design integrating a large horizontal carousel cable winch. Although technically sound for idle power delivery, subsequent feasibility studies and customer dialogues demonstrated a stronger need for charging solutions directly integrated with existing wind farm infrastructure rather than standalone buoy systems.

This finding led to a major technical and architectural shift, resulting in the revision of this project in July 2024. The project was rescoped to develop the Stillstrom Hang-Off SOeC, mounted on turbine foundations, offshore substations or standalone monopile structures. The new design reduced offshore operability risk, improved energy efficiency, and enabled simplified logistics, but also introduced several new engineering challenges. These included structural integration with existing platforms, a completely new cable handling philosophy, and the addition of a boom crane system to manage connection and disconnection operations safely.

Cable management redesign and supplier changes

The transition rendered the original carousel winch unsuitable for the Hang-Off configuration. To meet the new mechanical and operational requirements, Stillstrom engaged two new European suppliers to develop and validate alternative vertical cable reel designs capable of controlled umbilical deployment and retrieval within the platform envelope.

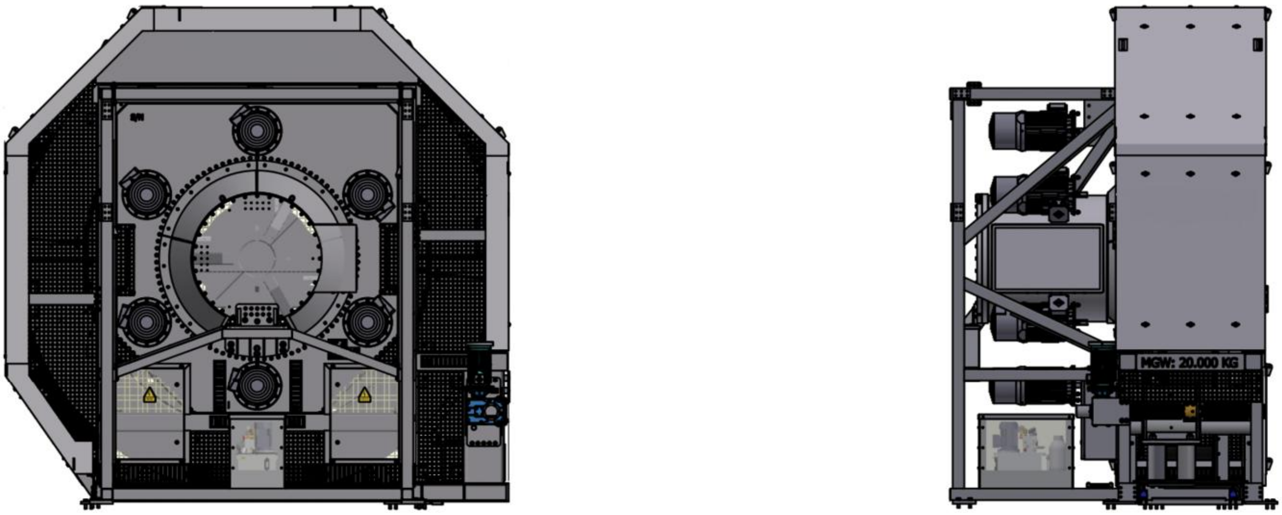


Caption – Original carousel cable reel for Power Buoy

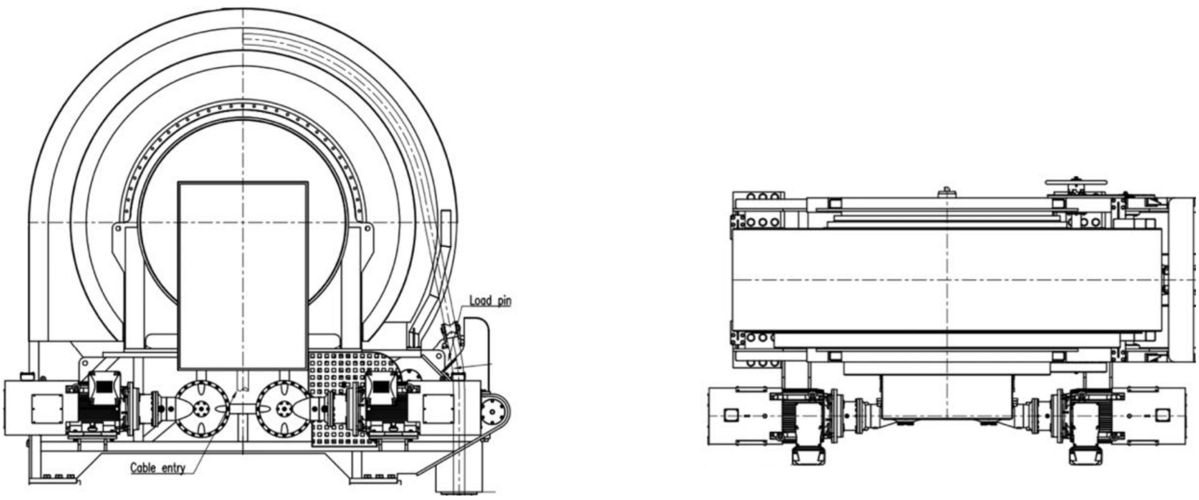
Selecting two independent suppliers served a deliberate dual purpose:

- To ensure competitive design and avoid reliance on a single source supplier for a core subsystem
- To benchmark alternative technical solutions for performance, cost, and maintainability

While this dual track approach strengthened the final design basis and long-term supply resilience, it added engineering-coordination complexity across interfaces.



Caption – Cable reel option 1



Caption – Cable reel option 2

<u>Electrical and control system Integration</u>

In parallel, the electrical and control architecture evolved beyond the initial project scope. Stillstrom originally contracted a consultancy supplier for the electrical and control systems, which were replaced by another supplier after the rescoping. The change was driven by the need for holistic system integration between:

- High-voltage (HV) and low-voltage (LV) control systems
- Core and auxiliary electrical systems
- The cable management control system (CMCS)
- The digital platform, IT/OT communication, cybersecurity, and networking

The new supplier, an experienced industrial and offshore systems integrator, was selected to consolidate these domains into a single, interoperable control and automation architecture. Although this transition introduced additional onboarding and design transfer efforts, it has provided a significantly more robust and certifiable system baseline.

Summary

While the combination of design rescoping, supplier changes, and parallel subsystem development created unplanned complexity, these challenges were effectively managed through risk tracking, supplier coordination, and DNV oversight. The outcome is a technically stronger and more commercially viable product platform that builds directly upon the lessons learned from each challenge encountered.

4.5. Collaboration and stakeholder engagement

Collaboration has been a cornerstone of the project's success from the very beginning. Stillstrom's approach has always relied on strong partnerships across the value chain, from offshore wind developers and vessel operators to specialized engineering and manufacturing partners. These collaborations ensured that the project evolved in line with market needs while maintaining technical excellence and commercial realism.

The partnership with Ørsted, established at the project's outset, played a defining role. As the selected offshore wind developer, Ørsted provided the planned test site and served as a key partner in validating operational concepts. Initially, the project aimed to deploy the Power Buoy at Ørsted's Race Bank Wind Farm, and design and manufacturing activities were already underway with Orwell Offshore, the contracted buoy manufacturer.

However, Ørsted's decision to relocate the test site in 2022 coincided with a broader market shift. Operational and weather conditions at the new site differed significantly, requiring extensive redesign and added engineering cost. At the same time, Stillstrom observed that market interest was moving beyond "idling power" supply toward charging capabilities for fully electric vessels. Together with Ørsted, the project team concluded that continuing with the original buoy concept would no longer represent an efficient use of resources. Instead, Stillstrom decided to pivot the project's focus toward developing the Hang-Off SOeC, an offshore charger better suited to the market's future needs.

This decision, jointly informed by partners and supported by real market feedback, ultimately strengthened the EUDP Power Buoy project's relevance and commercial potential. Buoy remains part of Stillstrom's product portfolio but has evolved into a charging buoy concept, now offered alongside other applications. Several customers are already considering this configuration for future offshore projects.

In parallel, Stillstrom has built a robust collaboration network within the Danish and European supply chain. The company developed its mechanical systems together with MacArtney (Denmark) and the electrical design in close cooperation with Semco Maritime (Denmark), contributing directly to Denmark's industrial base and engineering expertise. For its first commercial project, Stillstrom has also contracted EU-based suppliers for key components, including cables and winches, ensuring high quality, European origin, and supply chain sustainability.

Beyond direct partnerships, Stillstrom maintains close dialogue with major offshore wind developers across Europe, including RWE, EnBW bp, Ørsted, SSE, Vattenfall, and others. These engagements focus on understanding site specific constraints, operational requirements, and long-term electrification strategies, ensuring that offshore charging can be integrated into both brownfield (existing) and greenfield (new) wind farm projects. Stillstrom also collaborates actively with Service Operation Vessel (SOV) owners to ensure that offshore charging solutions are developed as part of a complete, integrated offering, combining vessels, energy infrastructure, and operational procedures into a unified system.

This collaborative approach has been essential in maintaining project momentum, aligning resources effectively, and ensuring that the technology addresses real operational challenges. It has also positioned Stillstrom and its partners at the forefront of a new clean energy market segment, one that will drive maritime electrification and support Europe's transition to sustainable offshore operations.

5. Project results

5.1. Achievement of objectives

Project has achieved its objective, and all project work packages and milestones have been completed in line with the revised scope approved by EUDP in 2024. Activities were delivered as planned, and the results meet both the technical and commercial goals defined under the updated framework. An overview of each work package, including milestones and completion status, is provided in Appendix #1.

5.2. Technological results

Overview

The Power Buoy has resulted in the successful design, development, and testing of a first-of-a-kind offshore high-voltage charging system: the Stillstrom Offshore eCharger (SOeC).

Over the course of the project, the concept evolved from a floating buoy type prototype into a Hang-Off charger system designed for direct integration with existing offshore wind infrastructure, or as a standalone charging system on an offshore structure.

This evolution enabled the technology to achieve higher technical readiness, improved safety, and greater emission-reduction potential.

Design development

The initial Power Buoy concept was centered around a floating platform on a buoy of a Catenary Anchor Leg Mooring (CALM) type, with an integrated horizontal cable carousel and mooring or anchoring arrangement.

While technically feasible, analyses and customer dialogue revealed several challenges:

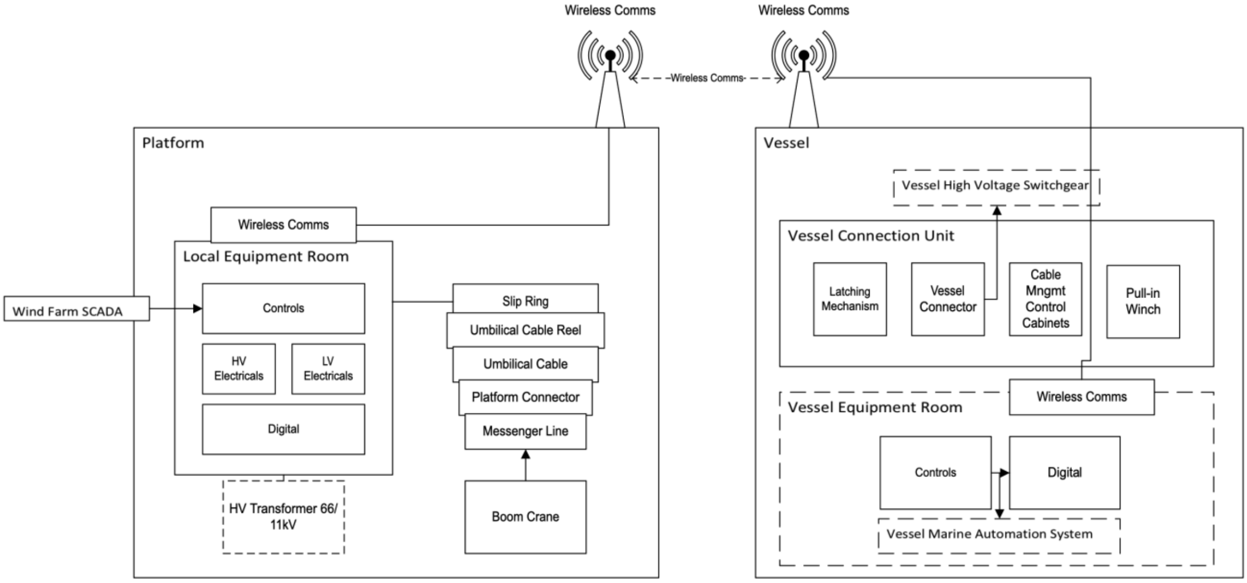
- High mechanical loads and fatigue on the buoy structure and dynamic loads on components contained in it
- Complex station-keeping and service logistics
- Limited compatibility with turbine layouts
- Limited deployment options in shallower waters

In 2024, the design was rescoped to a Hang-Off configuration, mounted directly on existing wind turbine platforms, offshore substation platforms or standalone offshore structures.

The new architecture introduced:

- A vertical cable reel system integrated within a compact Hang-Off frame
- A boom crane and messenger line handling system for safe connection
- Modular high-voltage and low-voltage switchgear in a local equipment room, and
- Integrated digital and control systems for monitoring, automation, and remote access

This change simplified marine operations, optimized maintenance needs, and enabled faster adoption at wind farm sites.



Caption – SOeC Block Diagram

<u>Manufacturing and assembly</u>

Manufacturing and assembly of the prototype systems were carried out across several international suppliers, reflecting the evolving technical scope from the original PowerBuoy concept to the final Hang-Off SOeC configuration. The initial pilot version of the PowerBuoy was manufactured in Spain, while the carousel winch, connector head, and prototype cable were produced in the United States. The pull-in winch used during early yard and harbour trials was leased from suppliers in the United Kingdom.

For the final Hang-Off SOeC system, manufacturing activities were consolidated within Europe and the UK to ensure supply chain resilience, compliance with EU/UK offshore standards, and improved integration oversight. The connector system and the Vessel Connection Unit are being manufactured in Denmark, while the cable management system, including the vertical cable reel and the dedicated pull-in winch, is produced within the European Union. Parts of the sensor system are sourced from a UK supplier with extensive experience in offshore navigation technologies. The electrical and control systems are integrated in Denmark using components from established European manufacturers such as Siemens and Schneider Electric, enabling compatibility with offshore-wind infrastructure standards.

All manufacturing activities are supported by factory acceptance tests, supplier audits, and interface control procedures aligned with the DNV Technology Qualification Plan.

Summary of testing and validation activities

The project executed a comprehensive multi-stage validation program combining simulations, laboratory tests, and full-scale field trials.

Test	Description	Outcomes
Simulation & Modelling	Dynamic loads cable analysis, offshore structure loads, fluid dynamics, charging simulation with battery assumptions	Validated feasibility of 11 kV, 6-8 MW charging with compliant cable dynamics
Yard Trial 2024	Mechanical testing of catenary and tension cable controls, weak link breaking validation and recoil test. Validate subsystem communication, mechanical robustness and safety interlocks	Functionality confirmed under controlled conditions
Harbour Trial 2024	System assembly test including cable management, tension control philosophy, connection and disconnection operations, structural vessel integration, vessel dynamic positioning operations	Functionality confirmed and feedback collected for connection and disconnection procedures and vessel operations
Connector System Test	Connector qualification – mechanical and electrical testing – pressure, pull-force, mating cycles, high voltage, full load current, abrasion, submersion and sealing	Mechanical properties and requirements verified, functionality of mating verified. Electrical tests to be completed later this year due to limited availability of a test lab.
Control & Digital Systems Bench Test	Control and digital systems communication interfaces, protocols, network, security and signal exchange test	Confirmed successful network setup, firewall settings, IP-addressing, and validated signal exchange between all control and digital systems of SOeC.

Each test phase provided input for subsequent design optimization and risk reduction.

Yard Trial 2024

The Yard Trial conducted in 2024 served as the first integrated functional test of the original carousel based cable management system combined with an electric pull-in winch. The test was carried out in Aberdeen, Scotland and represented the final validation step of the buoy style configuration before the transition to the Hang-Off SOeC concept. The setup consisted of a single integrated test arrangement including the carousel, the pull-in winch, provisional vessel side rigging, and the connection cable.

The technical objective of the trial was to validate the operational methodology for controlled cable deployment and retrieval, confirm the working principles and settings of the carousel equipment, and gather insights that would inform the subsequent harbour scale validation. Additional focus areas included verifying the behavior of the weak link and observing how the cable and messenger line would respond in the event of a deliberate break. Conducting these activities in a static environment allowed the team to reduce operational uncertainty prior to performing dynamic trials offshore.

Three tests were executed. The first test confirmed the breaking characteristics of the weak link and monitored the recoil behavior of both the charging cable and the messenger line. The weak link operated as intended, and the charging cable exhibited no recoil, significantly reducing the risk profile for the planned harbour trial. The second and third trials focused on tension-control and catenary control operation respectively, enabling fine tuning of carousel behavior. Both tension controlled and manual modes were tested. Manual mode proved smoother and more predictable when operated in combination with the pull-in winch. As a result, it was selected as the preferred operating mode for the harbour trial. The trials also allowed identification of suitable pull-in winch speed settings.

The Yard Trial met its objectives by validating system behavior, identifying operational preferences, and eliminating key uncertainties. The test results directly informed planning for the harbour trial and provided a safe platform for evaluating cable management behaviour prior to full-scale vessel operations.

Caption: Weak link breaking and cable recoil test during Yard Trial 2024

<u>Harbour Trial 2024</u>

The Harbour Trial took place in November 2024 in Aberdeen, Scotland, using the Maersk Lifter as the host vessel. Maersk Lifter is an anchor handling tug supply vessel (AHTS), which offered a spacious open deck, suitable for this scale of testing. The objective of this trial was to validate the practical offshore style operations for deploying, retrieving, and handling the charging cable using a provisional vessel connection unit installed on the aft deck. The trial followed the Yard Trial and served as the first opportunity to observe the cable handling methodology under realistic operational conditions with a full marine crew.

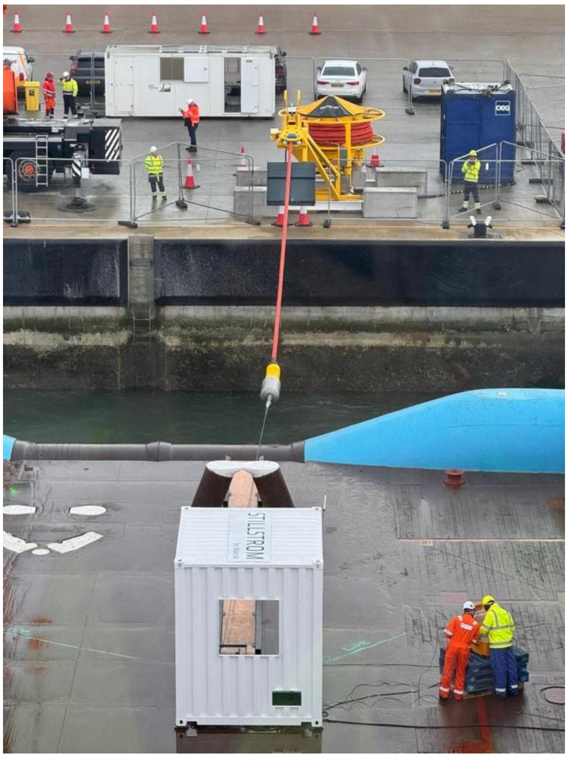
The messenger line transfer from quayside to vessel was performed multiple times and functioned reliably. The Maersk Lifter crew provided valuable operational feedback based on their typical handling routines, allowing refinement of procedures in later development stages. Once the connector head reached the vessel, the testing team observed the need for a properly engineered chute system to ensure consistent capture of the connector and to avoid snagging on sharp vessel structures. This requirement has since been incorporated into the updated vessel side interface design.

A key operational learning was the importance of a clear visual overview of the connection cable catenary for both deck crew and bridge operators. Effective catenary awareness proved critical for maintaining safe geometry during the operation, especially when the cable reel was operated in manual mode. This observation directly contributed to the development of a new automated control functions scheduled for validation during the Yard Trial in December 2025.

All deployment activities were performed safely and efficiently. Messenger line transfer and connector head deployment took approximately ten minutes. The trial demonstrated that both deployment time and operational workload can be further reduced by increasing pull-in winch speed and shortening the vessel side guiding structure. Tensions during deployment were notably lower than the conservative estimates used in the detailed design, confirming robust operational margins.

Several operational considerations were noted. Significant manual handling was required for spooling the messenger line and winch wire, and shackle placement remained a manual process. Clear contingency procedures were developed for weak link or messenger line breakage and for recovering the connection cable in the event of cable reel power loss. The trial confirmed that automation of both the pull-in winch and the cable reel is feasible, as the necessary are available for future use. This automation functionality will be tested in subsequent trials.

The Harbour Trial successfully validated the operational methodology, confirmed safety and handling principles, and provided essential input for system optimization and the 2025 Yard Trial.



Caption: Connector Head Transfer during Harbour Trial 2024

<u>Connector system test</u>

Connector system testing is being completed through a sequence of mechanical, electrical, and functional tests performed during the final project period. Mechanical testing was carried out after completion of factory acceptance tests (FATs) and manufacturing activities at the supplier facilities in October. Additional third-party mechanical and environmental testing was performed in November, and high-voltage electrical testing will be conducted at a specialist laboratory in Germany in January, due to laboratory availability.

<u>Control & digital systems Bench Test</u>

A comprehensive bench test campaign was conducted to validate the control, digital, and communication architecture of the SOeC Hang-Off. The tests took place in Esbjerg at the telecommunications and automation test facility of one of the suppliers. The test environment consisted of a rack mounted hardware setup combined with multiple rows of system tables wired with the necessary programmable logic controllers (PLCs), remote terminal unit (RTU), servers, network equipment, positioning units, and display interfaces. Several external inputs were emulated to simulate system behavior, allowing testing of all critical interfaces without requiring the physical equipment to be offshore.

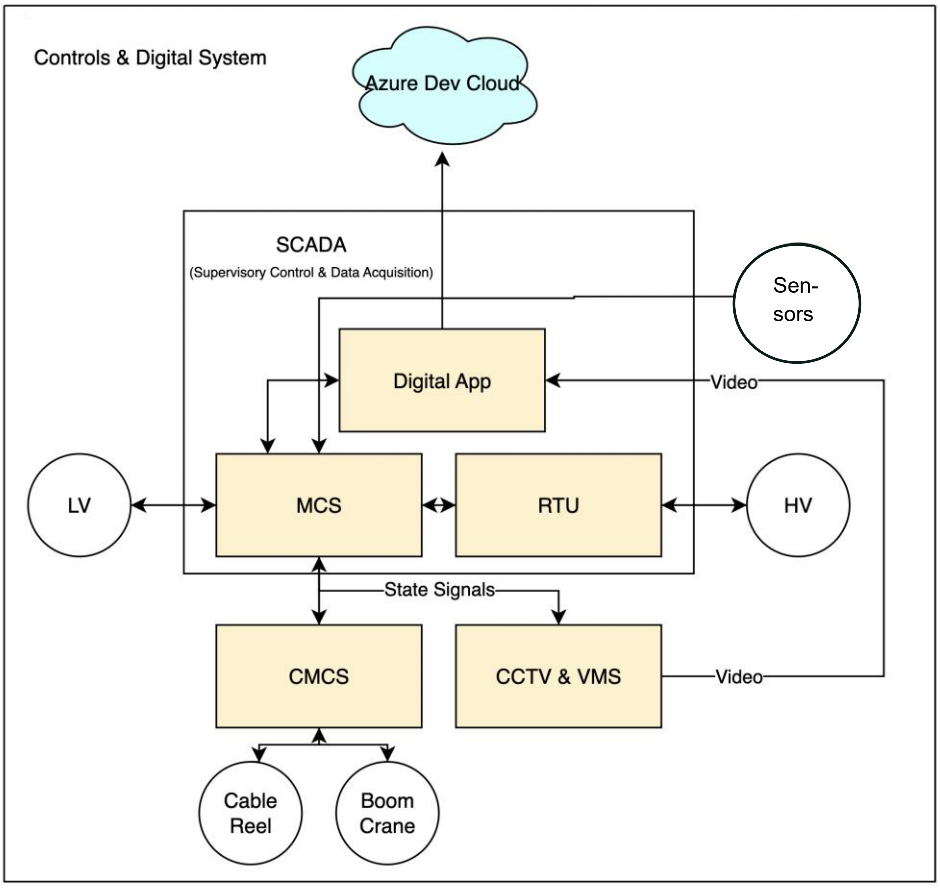
The bench test represented the first full integration of software and hardware sourced from five suppliers. The setup included the master control system and the cable management control system running on PLCs, the high-voltage SCADA system running on RTU, the CCTV and video management system (VMS) hosted on a dedicated server, the digital user application to be used on vessel infotainment screens, and the positioning system using antennas and processing units. Additional infrastructure consisted of firewall, network switches, cabling, and a dedicated internet link enabling real-time synchronization with the cloud development environment.

Preparation for the bench test required several months of coordination, during which Stillstrom, the system-integration partner, and subsystem suppliers jointly aligned on signal lists, communication protocols, addressing schemes, cybersecurity configurations, network design, and interface specifications. A structured interface test matrix was co-created by Stillstrom and managed by the system integration partner, ensuring that every interface, data exchange, and operational mode was validated in a controlled sequence.

The three day execution covered network setup and validation, system configuration, and detailed point-to-point signal transfer tests. All major interfaces were successfully validated. These included communication between the cable management control system and the master control system in both directions, integration of the positioning system with the master control system, streaming of CCTV feeds into the VMS, two-way communication between the digital application and the VMS, health status reporting from the VMS to the master control system, two-way data exchange between the high voltage SCADA and the master control system, and full digital app connectivity to the master control system and the cloud. Cloud synchronization was tested using the Azure development tenant and demonstrated stable real time data transfer.

Minor issues encountered during the campaign were limited to variable name mismatches, small inconsistencies in signal mapping, and minor network configuration errors. All issues were resolved during the test window. The bench test confirmed that the digital and control architecture is robust, interoperable across suppliers, and ready for integration into the full system during the 2026 integration trial.

Caption: Bench test setup



Caption: Bench Test Control & Digital System Setup

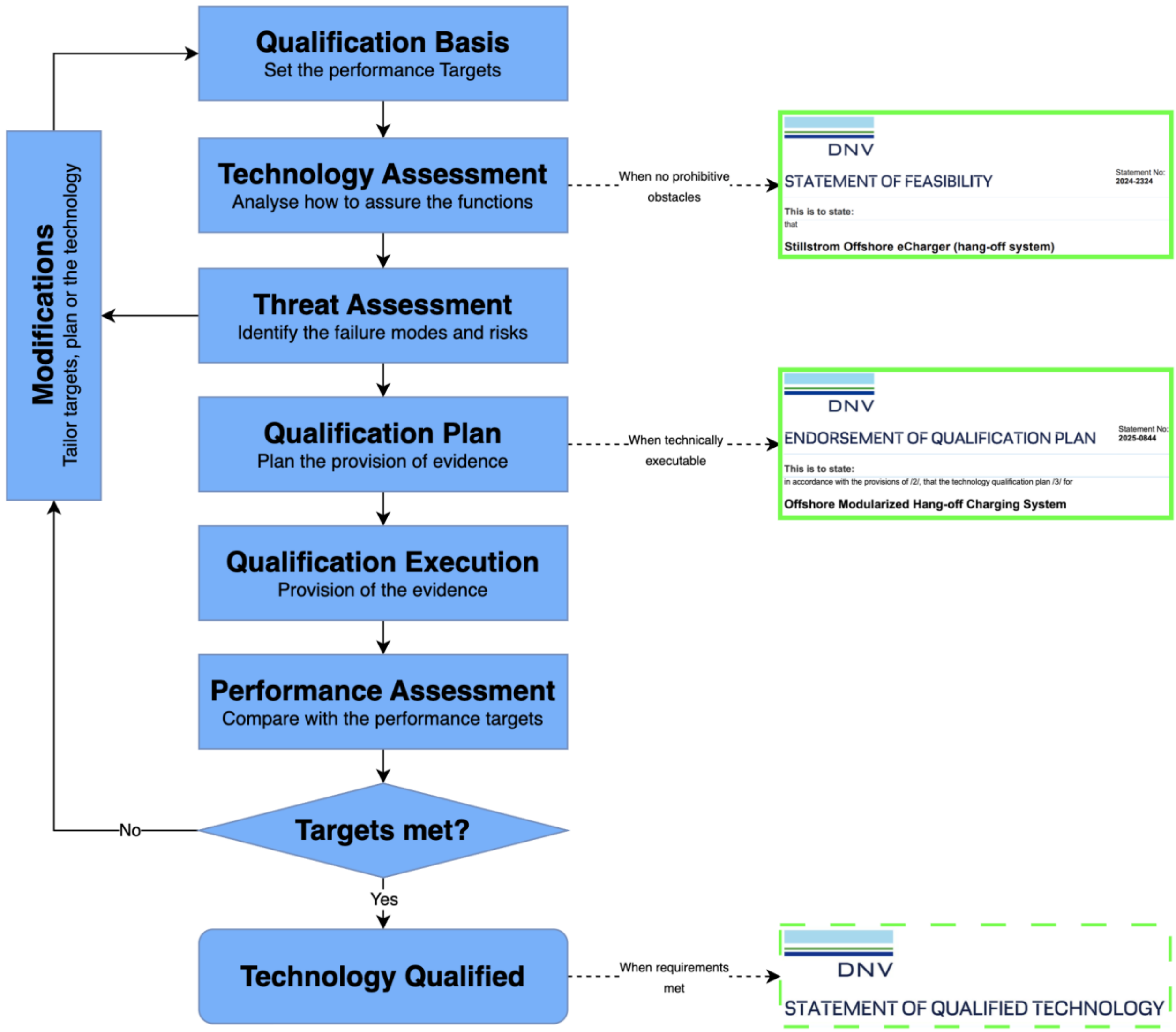
<u>DNV technology-qualification process</u>

All validation activities were conducted under the framework of a DNV Technology Qualification (TQ) Plan, developed and endorsed as part of the project.

The TQ process covered the first two DNV stages:

- Feasibility Statement: issued Q1 2024, confirming that the Hang-Off SOeC concept meets fundamental safety and functional principles
- Qualification Plan Endorsement: achieved Q3 2025, establishing verification steps, success criteria, and traceability between identified risks and test evidence

The next phase, Technology Qualification Execution, will be completed during the 2026 System Integration Trial, finalizing the verification of the complete system in operational configuration.



Caption – DNV Technology Qualification Process DNV-RP-A203

<u>Technical learnings and innovations</u>

The project produced several new and unexpected technical insights:

- Integration with offshore structures: Mechanical analysis confirmed that turbine platforms can safely accommodate the Hang-Off SOeC loads with minor reinforcement and main access platform (MAP) design adjustment, opening a scalable deployment path
- Cable handling innovation: The vertical reel configuration, combined with automated tension control, provides lower wear rates and improved fatigue performance, while reducing the footprint significantly compared to horizontal carousel systems
- Digital architecture: The integrated IT/OT network design established a secure data link between charger and vessel, demonstrating real-time monitoring wirelessly
- Control-system interoperability: The modular PLC and SCADA framework successfully interfaced with vessel automation systems via standardized and safe communication protocols confirming compatibility with industry standards (IEC 62443) and DNV's recommended practices (DNV-RP-0575)

- Operational efficiency: The Hang-Off SOeC enables fast, safe connection and high-power charging directly at wind farm sites or outside of major ports with suitable seabeds and water levels, supporting emission reductions of up to 5.000 tons of CO_2 per year for fully electric vessels (assuming an average annual consumption of approximately 1,600 tons of MGO, and an emission factor of about 3.2 tons of CO_2 per ton of MGO consumed).

Validation outcome

- By the end of 2025, individual subsystems of the Hang-Off SOeC have been validated at prototype level.
- The system has reached Technology Readiness Level 7, verified through DNV's qualification framework.
- The remaining step, full system integration and offshore demonstration in 2026, will complete the qualification and readiness for commercial deployment.

5.3. Commercial and organizational results

The idea for offshore power and charging began as a lean innovation program within a Maersk division. The EUDP support created significant traction with a key offshore wind developer and enabled the team to design and develop its technology, operational philosophy, and market interest. Fast forward to today, the market has shifted significantly, with a pull from clients for this novel technology. Stillstrom is now a fully carved out, dedicated company of 30+ professionals. The majority of the offshore wind market is now investigating offshore charging for its new wind farms, and it is just a matter of time before the first orders begin getting placed.

Stillstrom now has a matrix of products (in different stages of development) that cater to most SOV/wind farm requirements. Building out this new industry includes engagement with offshore wind developers, vessel designers, municipalities, class societies, standard bodies, power providers, and technology suppliers. Stillstrom has engaged much of this landscape and helped set a foundation for the industry. To date, Stillstrom has completed numerous feasibility and FEED studies for major offshore wind developers such as RWE, EnBW bp, Ørsted, SSE, Vattenfall, and others. These studies are providing the technical and commercial basis for future offshore charging deployments.

In addition to offshore wind developers, Stillstrom has also built strong collaboration with key port and canal authorities. This includes feasibility work and Memorandums of Understanding with the Port of Skagen and the Panama Canal Authority, supporting the development of our next-generation product aimed at Zero Emissions Anchorage Zones solutions.

5.4. Applications and target groups

Stillstrom's offshore charging products target two main markets: Offshore Wind and Zero Emissions Anchorage Zone .Each market is solving for a unique problem, rooted within the 'decarbonization' journey. For Offshore Wind, SOVs will decarbonize their full operations by turning to batteries. These vessels will however require charging infrastructure in field, which Stillstrom can now provide. For the Zero Emissions Anchorage Zones market, we will be providing 'green parking spaces' to larger vessels (cruise liners, container ships, tankers, etc.), allowing for the full decarbonization of idle loads.

While these markets and vessels differ significantly, there are many overlapping cases based on vessels (i.e. smaller vessels requiring some charging power), and geography (northern Europe where anchorages and offshore wind farms are relatively close to each other). Most importantly, however, is that the underlying offshore power and charging technology, developed within the EUDP program, is widely applicable across markets. Power transformation, mooring structures, and operations require similar philosophies and solutions. Stillstrom has developed modular systems that can be applied to these different use cases. In hindsight, this matrix of solutions was developed due to the Ørsted site change and project issues faced a couple years back. This, coupled with the use case change (from idle to charging) has impacted the industry in a positive way, and has accelerated several sub-markets.

The value proposition is two-fold: decarbonize idle or propulsion emissions in a clean, cost-effective way, while not being subject to large-scale supply build of green molecules. Green methanol, ethanol, ammonia, LNG, etc, has proven to be both very expensive and largely unavailable. This plus the falling price of batteries and energy storage has brought hybridization and full electrification into the mix as a viable and cost-competitive pathway.

While full electrification is not applicable to large, ocean-going vessels, there is still a use case to utilize offshore power when at anchorage. Even if vessels are sailing on green fuels, they will be economically incentivized to use offshore power when idle, as green fuels are expected to cost anywhere from 2-5x green electricity.

5.5. Dissemination of results

Project results have been widely disseminated through digital platforms, industry memberships, conferences, and direct stakeholder engagement. A dedicated company website (http://www.stillstrom.com) was launched to communicate objectives, milestones, and results to a broad audience. In parallel, Stillstrom has actively used LinkedIn to share updates and insights, including a widely viewed video of the 2024 offshore trials, which generated strong engagement from the maritime community.[1]

Through memberships in Wind Europe, Waterborne TP, Green Power Denmark, Danske Maritime, Maritime Battery Forum, EOPSA, IMCA, and others, the company has contributed to sector knowledge sharing and policy dialogue. Notably, Stillstrom engaged with the IEEE organization to influence the adaptation of existing standards so that offshore charging can be formally recognized. This positions the company not only as a technology provider but also as a contributor to the regulatory framework shaping future electrification.

Conferences and exhibitions have been another key channel for dissemination. Results were presented at leading industry events such as WindEurope, WindEnergy Hamburg and Renewable UK - Global Offshore Wind. At WindEurope, WindEnergy and Renewable UK, Stillstrom hosted its own stand, enabling direct dialogue with developers, vessel operators, regulators, and supply chain actors. In addition, press coverage, interviews, and media releases have extended visibility beyond the immediate industry, while targeted workshops with developers and regulators ensured alignment with customer needs and policy requirements.

These combined efforts have raised awareness of offshore charging, built market credibility, and helped establish the foundations of a new segment in maritime decarbonisation.

5.6. Broader impact and added value

The project contributes significantly to maritime decarbonization and offshore wind integration at a time when the EU's shipping sector accounts for 3-4 % of total EU CO_2 emissions (over 124 million tonnes in 2021).[2] By delivering offshore charging solutions, the Hang-Off SOeC and related applications reduce reliance on fossil fuel generators and idling engines, enabling emission reductions that can scale as offshore wind capacity grows. In 2024, Europe connected 2.6 GW of new offshore wind capacity; by 2030 the EU is expected to install 23 GW/year on average offshore to meet REPowerEU targets.[3]

[1] https://www.linkedin.com/posts/stillstrom_we-are-excited-to-share-another-major-step-activity-7264883920138108929-G4tC?utm_source=share&utm_medium=member_desktop&rcm=ACoAAB0TlOwB5Ceik6SdUB3_amBSiuSalG92bwA

[2] https://climate.ec.europa.eu/eu-action/transport-decarbonisation/reducing-emissions-shipping-sector_en?utm_source=chatgpt.com

[3] https://windeurope.org/data/products/wind-energy-in-europe-2024-statistics-and-the-outlook-for-2025-2030/?utm_source=chatgpt.com

Strategically, the project enhances alignment with EU/UK climate goals such as net zero by 2050. It supports policies like FuelEU Maritime, which mandates a well-to-wake GHG intensity reduction that starts around 2 % in 2025 and rises toward 80 % by 2050.[4] The work also strengthens the innovation ecosystem: the growing interest from new entrants, increased expectations among investors, and regulatory discussions all boost market credibility and catalyze further investment.

On jobs and skills, the offshore wind sector in the EU already supports approximately 47.000 full-time equivalent (FTE) roles in 2024, of which around 28.000 are direct positions. [5]Stillstrom has contributed to this growth by creating at least 20 highly skilled jobs during the project, strengthening expertise in engineering, design, and project management. With commercialization ahead, many more positions are expected to follow, both within Stillstrom and across its supply chain, adding to the sector's wider employment and skills development.

Other added value includes enhancing energy security through reduced dependency on imported fossil fuels, especially for remote operations. The ability to use clean electricity directly offshore supports more stable operational costs and less exposure to fuel price volatility, which is important for long-term planning by vessel operators and wind farm developers.

[4] https://www.dnv.com/maritime/insights/topics/fueleu-maritime/?utm_source=chatgpt.com
[5] https://blue-economy-observatory.ec.europa.eu/eu-blue-economy-sectors/marine-renewable-energy_en?utm_source=chatgpt.com

6. Utilisation of project results

This EUDP supported project has directly enabled Stillstrom to establish the technological foundation for a new generation of offshore high-voltage charging systems. The project outcomes will be utilised both technologically and commercially through the continued development, qualification, and deployment of the Hang-Off SOeC.

Stillstrom is the sole commercial owner and developer of the SOeC technology and will continue its advancement beyond the EUDP project through further engineering, technology qualification, and full scale pilot deployments. The results of the project are expected to contribute significantly to the electrification of offshore wind operations and to support the decarbonisation of the global offshore maritime sector.

The technological and commercial utilisation pathways are detailed below.

6.1. Future technological use

The technology development results obtained from the project form the backbone of Stillstrom's offshore charging product line, comprising of multiple deployable variants. The SOeC solution has reached prototype maturity and will be developed through Technology Readiness Levels 8 and 9 in the next project phase, This will be achieved by further testing, documentation, analysis and simulation and, finally, an offshore deployment that will serve as a long-term validation of Stillstrom's product.

<u>SOeC Hang-Off</u>

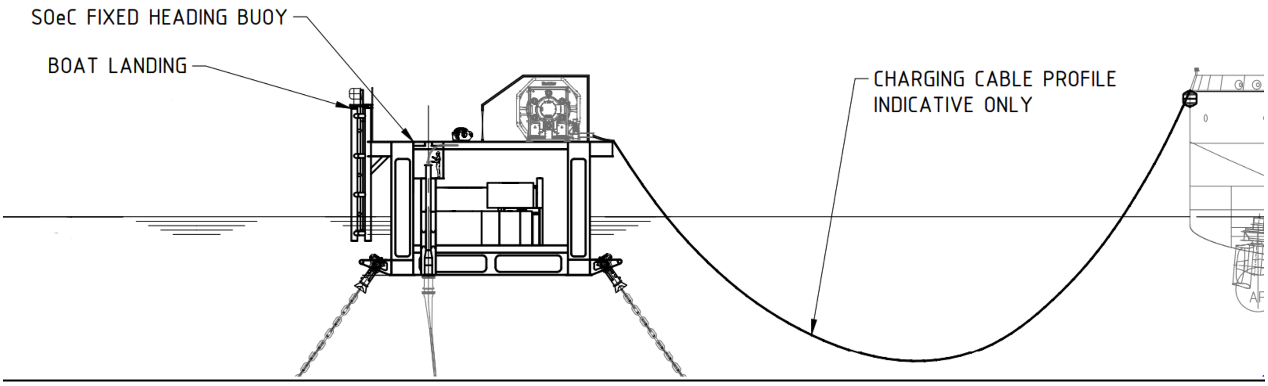
The Hang-Off is the primary commercial product resulting from this project. It is designed for direct installation on fixed offshore structures and can be deployed in several variants:

- Wind Turbine Generator (WTG) Integration: mounted on the main access platform of offshore wind turbine
- Standalone Foundation Integration: installed on a separate monopile or jacket foundation with custom platform design, near a wind farm or transit corridor
- Offshore Substation Integration: implemented on larger platform, typically in the center of wind farms or hubs

This architecture leverages existing offshore wind infrastructure, significantly reducing installation complexity and enabling scalable deployment across different sites.

<u>Fixed heading buoy</u>

A fixed heading buoy variant of the Hang-Off was investigated and basis for the design of it was developed. This variant remains technically feasible for specific applications and environmental conditions. Its further development will depend on market demand, which currently favors the Hang-Off configuration due to its direct compatibility with wind farm or hubs assets, allowing significantly reduced costs, simplified deployment including installation, operations & maintenance and commissioning, as well as simplified certification pathway.



Caption – Fixed Heading Buoy Variant

Future roadmap

Stillstrom will continue developing and validating the technology according to the following plan:

Phase	Key Activity	Expect. Completion
Yard Trial 2025	Demonstration of new and improved cable control philosophy, digital system maturation, vessel deployment and operational procedures	December 2025
System Integration Test	Full integration and verification of mechanical, electrical, control, and digital systems, as well as training programs and marine operations	Q2-Q3 2026
Technology Qualification (TRL 8)	Execution of final DNV qualification activities, documentation of evidence, certification	Q3 2026
Operational Demonstration (TRL 9)	First full-scale operation and long duration testing in target environment.	Q4 2026 – Q2 2027
Commercial Deployment	System installed & commissioned in Project	Project dependent

The main users and collaborators expected to utilise the developed technology include:

- Offshore wind farm developers and operators, who will host the chargers on existing assets
- Vessel operators, who will benefit from access to high-power offshore charging
- Vessel designers and shipyards, to integrate compatibility in newbuild electric and hybrid vessels
- Port authorities and offshore regulators, for application of the technology in near coastal charging and electrified logistics or anchorage zones

Stillstrom will commercialise the Hang-Off SOeC through direct sales and turnkey delivery, ensuring unified responsibility for design, integration, and service. Memoranda of Understanding have been signed with several prospective offshore wind developers, ports, collaborators, and multiple SOV operators.

Through these partnerships and continued R&D, the project results will form the technological and commercial foundation for Stillstrom's next phase of growth, contributing to the large-scale decarbonisation of offshore operations.

6.2. Commercialisation and economic impact

Stillstrom's matrix of solutions are at various stages of commercial readiness. Offshore Wind's SOV solutions, for example, are now available to wind farms, with the caveat that they will require some adaptation to each wind farm and SOV. The Zero Emissions Anchorage Zones solutions are less mature and will require additional research and development in the coming years.

Stillstrom views itself as an important facilitator of offshore charging, developing the industry through stakeholder collaboration and education. Over the last few years, Stillstrom has worked closely with DNV and IEC on standards setting, and has worked with offshore wind developers, vessel designers and owners, and other offshore power companies. Market consensus and standard setting are vital for the large-scale adoption of this new technology.

With offshore wind as the early adopters of this technology, Stillstrom is focused on a simple 'Sell & Service' business model. This includes the sale of the equipment, the support in ensuring that interfaces between the vessel, power supply, and charging infrastructure run safely and seamlessly, and a long-term service contract to ensure system performance. This model may pivot in the future, but it is the simplest for both technology providers and wind farm owners.

The main geographical markets in scope today are in Europe and the UK. These areas are continuing to expand offshore wind efforts, with new tenders coming up on an annual basis, and with decarbonization increasingly becoming an important part of the tender itself. We expect this to continue to be our core market in the coming years, with potential expansion to other niche cases across the globe.

6.3. Competitive landscape

Competitors in offshore charging do exist, many of them also focused primarily on offshore wind. The growing number of players reflects strong market demand and increasing investor interest momentum that our own development and progress have helped accelerate. Several competitors operate as innovation units within larger organizations, while Stillstrom has advanced its technology and approach around offshore charging as a holistic, system-level solution rather than a standalone product.

As an early mover and thought leader, Stillstrom has helped shape the direction of the industry and has engaged with all major developers in space. This position enables continued expansion of our offering and the development of solutions that address core challenges across the offshore ecosystem.

6.4. Market barriers and mitigation

6.4.1. Overview

The introduction of offshore vessel charging represents a fundamental shift in the way maritime operations are powered. While the environmental and operational benefits are clear, the pathway to market is shaped by several regulatory, technical, and economic challenges. As a pioneer in this field, Stillstrom has worked proactively to identify these barriers early and to define strategies that enable safe, cost efficient, and scalable deployment of its technology.

6.4.2. Key barriers

- Regulatory and permitting challenges

Offshore charging is a new concept within an already complex regulatory environment that governs offshore energy and maritime operations. Approval pathways are not yet established, and permitting processes can be lengthy and fragmented. Collaboration between developers, vessel operators, and authorities is therefore essential to ensure that offshore charging becomes recognized within existing frameworks.

- Safety standards and training

As offshore charging involves high-voltage systems in harsh marine environments, new safety standards and operating procedures must be developed. Crew members will require additional training, certification, and operational guidance. Stillstrom recognizes that building this framework is critical to long-term adoption and is actively involved in shaping these standards through international organizations such as the IEEE and classification societies.

- Upfront investment and cost structure

Although offshore charging reduces lifetime operating costs, initial capital expenditure remains a barrier. Infrastructure on wind assets, vessel modifications, and battery systems represent significant upfront investments. However, these are balanced by lower OPEX, as electricity is cheaper than fossil fuels and reduces exposure to emission penalties under IMO, EU ETS, and FuelEU Maritime. Stillstrom evaluates each business case using a net present value (NPV) approach, factoring in both costs and long-term savings. Over time, economies of scale, supplier competition, and technology standardization are expected to reduce overall system costs substantially.

- Customer adoption and perceived risk

As a first of its kind technology, offshore charging faces typical early market hesitation. Developers and vessel operators are cautious about new systems that require changes to operations and infrastructure. Demonstrating proven value, reliability, and safety is therefore essential to secure adoption and confidence among early customers.

6.4.3. Strategy to overcome the barriers

- Partnerships and collaboration

Stillstrom's approach is built on strong collaboration across the value chain. Partnerships with offshore wind developers help ensure site integration and risk sharing. Engagement with SOV owners, battery suppliers, and equipment manufacturers ensures technical compatibility, cost optimization, and alignment with real operational needs.

- Certification and standards development

To address the regulatory and safety barriers, Stillstrom actively participates in workshops and working groups aimed at establishing clear certification pathways for offshore charging. By collaborating with international standardization bodies, the company helps define safety and interoperability criteria that will accelerate global market acceptance.

- Alignment with policy and regulation

Close collaboration with the Maersk Group and other maritime stakeholders allows Stillstrom to remain fully aligned with emerging regulatory requirements under IMO, EU ETS, and FuelEU Maritime. This proactive engagement ensures that system design and business cases remain compliant with evolving climate and emission-reduction policies.

- Cost reduction and market readiness

Stillstrom's cost strategy combines design optimization, modular manufacturing, and supplier diversification. As the technology scales, both capital and operational costs will decrease. The company also pursues targeted pilot projects to demonstrate operational savings and build a proven return on investment track record, lowering the perceived risk for future adopters.

6.4.4. Overall impact and outlook

Through this combined strategy, Stillstrom not only mitigates key market barriers but also contributes to shaping the wider offshore charging ecosystem, creating a foundation for safe, standardized, and economically viable electrification of the maritime sector.

6.5. Contribution to energy policy objectives

The project is well aligned with EU/UK and global climate policy, particularly IMO, EU ETS, and FuelEU Maritime, by offering an electrification path that can help meet ambitious emission-reduction targets. The IMO's 2023 GHG Strategy calls for at least a 40% reduction in CO_2 intensity of international shipping by 2030 (vs 2008) and aims for zero or near-zero GHG emission energy sources to make up 5–10% of fuel use by 2030. FuelEU Maritime, part of the EU's Fit for 55 package, mandates gradually stricter well-to-wake GHG intensity limits for maritime fuels, starting with a 2% reduction in 2025, 6% by 2030, accelerating afterwards to reach up to an 80% reduction by 2050.

By developing reliable offshore charging (Hang-Off SOeC) and Zero Emissions Anchorage Zones solutions, Stillstrom provides a way to electrify vessel operations, avoiding use of fossil fuel generators or idling engines. This directly supports the IMO's push for zero or near zero energy sources, aligns with EU ETS policies (which penalize emissions and increase costs for fossil fuel use), and meets FuelEU Maritime's requirement to lower emissions intensity onboard ships.

Moreover, electrification via renewably powered offshore chargers helps reduce dependency on fossil fuel supply chains and volatile fuel prices, adding energy security and resilience to maritime operations. The solution enhances offshore wind utilization by enabling more of its power to be dispatched or stored for use by maritime operations rather than being curtailed or wasted, integrating clean power more tightly into maritime infrastructure.

Taken together, the project contributes concretely to achieving the UK/EU target of net zero by 2050, supports intermediate targets for 2030 (under IMO and EU regulation), and helps move the maritime sector along the deepest decarbonization pathways (full electrification, clean fuels, energy efficiency).

7. Project conclusion and perspective

7.1. Conclusions

The project has demonstrated adaptability and resilience in response to rapidly changing market conditions. What began as the development of the Power Buoy evolved into the creation of the Hang-Off SOeC offshore charger, a more relevant, scalable, and impactful solution that directly addresses the emerging needs of offshore wind operations and the wider maritime sector.

Through this journey, Stillstrom achieved a high level of technological maturity, validating the feasibility of offshore charging through design advancements, prototype testing, and operational trials. The project also laid the foundation for a strong organization: Stillstrom grew into a standalone company with a highly skilled technical team and a clear commercial roadmap.

The results confirm that offshore charging is both technically viable and commercially attractive, offering tangible pathways to decarbonize one of the hardest to abate sectors in the global economy. The project's outcomes have not only advanced technology but also shaped market awareness, regulatory dialogue, and industry readiness for large scale implementation.

Importantly, this progress would not have been possible without the support of the EUDP program. The grant provided the initial momentum, credibility, and resources needed to transform an early stage concept into a viable commercial venture. It is fair to conclude that without EUDP's investment, Stillstrom as an independent company might not exist today. The funding enabled the transition from idea to execution, creating lasting value for Danish innovation, green employment, and global maritime decarbonization.

7.2. Next steps

Stillstrom's journey has been significantly buoyed by the EUDP grant. Since its access to funding, the company has been carved out, has grown substantially, has created standards in a new market, and has developed its technology. While a full scale commercial system has not yet been deployed, the market is beginning to pull for information and economic investigations. Stillstrom hopes to secure its first commercial sale in 2026, proving both the technical and commercial feasibility in a European wind farm.

In parallel to selling the first product, further development into tangential products, optimization, and supply chain build will all take place in the coming years. These complementary applications include turbine and substation hang-off systems, monopiles, and additional buoys. Stillstrom will continue to optimize for safety and quality when it comes to its solution set.

With the strengthening of the EU ETS and FuelEU, we expect a significant uptake of offshore charging systems in the coming years, facilitated by a push to decarbonize operations.

7.3. The future of offshore charging

Based on insights from this project, Stillstrom initiated a new business segment: "Zero Emissions Anchorage Zones". Stillstrom envisions a future where idle vessels outside of ports (over 6.000 commercial vessels globally at any given point), will be required to reduce or eliminate emissions near populated areas. A couple of feasibility studies have been conducted and look to be promising in the future. Stillstrom will take its core learnings from this program to be applied to this future market.

Additionally, and further into the future, the electrification of more vessels is a possible scenario. This will occur if battery technology continues to improve, the battery pricing continues to fall, and if future fuels continue to face high prices and challenging supply chains. Stillstrom's ambition is to be ready to deploy offshore, fast charging networks for these electric vessels. This concept will merge the offshore wind and Zero Emissions Anchorage Zones solutions.

These solutions can play a significant role in contributing to EU/UK decarbonization goals, while presenting a scalable export market for Danish clean-tech. This project not only delivered on its revised objectives, but was a significant stepping stone and facilitator to this future.

8. Appendices

- Appendix #1: Work Package status and achieved Milestones
- Stillstrom homepage: https://stillstrom.com/

Appendix #1

to the Final EUDP Project Report for the Power Buoy project (file no. 64020-1056), dated 28 November 2025

Work Package status and achieved Milestones

Project Completion Summary

#	Work Package / Milestone	Objective	Status	Short Description of how it was achieved	Detailed description
			Work Packages		
1	WP 1. Prototype study I – Technical, Research & Sustainability aspects	To establish technical feasibility and sustainability foundations for offshore charging concepts through research, modelling, and preliminary design work.	Completed	Conducted early-stage feasibility studies, lifecycle assessments, and concept modelling to define technical and environmental baselines.	Page #7, Section 4.2. Page # 12, Section 4.2. Page #18, Section 5.2. Page #22, Section 5.2. Page #24, Section 5.3.
2	WP 2. Prototype study II – Regulation & Safety aspects	To identify applicable regulatory frameworks, safety requirements, and certification pathways for high-voltage offshore charging systems.	Completed	Mapped IEC and DNV requirements, performed preliminary risk and safety assessments, and defined compliance roadmap.	Page #7, Section 4.2. Page #10, Section 4.3. Page #22, Section 5.2.
3	WP 3. Prototype study III – Environmental research	To evaluate potential environmental impacts and establish mitigation principles for offshore charging installations.	Completed	Completed environmental screenings, evaluated cable handling, installation effects, and integrated safeguards into design.	Page #7, Section 4.2. Page #10, Section 4.3. Page #22, Section 5.2.
4	WP 4. Hang-Off solution development - SOeC (Stillstrom Offshore electrical Charger)	The main purpose of this work package is to prepare all necessary designs, equipment, and resources to ensure the SOeC solution is ready for the testing phase.	Completed	Produced detailed design packages for the prototype, manufactured and assembled subsystem components, and prepared test configurations.	Page #7, Section 4.2. Page #18,19, Section 5.2. Yard Trial 2024 Harbour Trial 2024

#	Work Package / Milestone	Objective	Status	Short Description of how it was achieved	Detailed description
5	WP 5. Pilot test – Installation and piloting	In summary, the key objectives of the testing are: - Validation of the connector system design (including control system) - Validation of the operational procedures for connection/disconnection - Obtain learnings for further development and optimization of the system - Preparation for future offshore trials of the system	Completed	Executed test program consisting of yard trials, harbour trial, component and sub-system tests.	Page #8, Section 4.2. Additional details in Section 5.2. (Page #16)
6	WP 6. Assessment – Pilot test assessment	To assess and document performance of prototype systems and define improvement areas.	Completed	Analyzed test data, compared results with design models, established key optimization parameters for final design and DNV TQ.	Page #18, Section 5.2. Summary of Testing and Validation Activities
7	WP 7. Prototype optimizations towards a marketable product	To refine and optimize the Hang-Off SOeC design into a market-ready configuration with improved reliability and manufacturability.	Completed	Implemented mechanical, electrical and control system improvements, performed connector and other sub-system qualification tests, and prepared documentation for commercial deployment.	Page #9 Section 4.2. Page #16, Section 5.2. Page #29, Section 6.2.
8	WP 8. Commercial study & Market strategy	To investigate market opportunities, define key customer segments, and develop a commercial strategy for offshore charging solutions.	Completed	A full business case, financial and valuation models were developed, key industry relationships established, and a clear commercial strategy defined.	Page # 24, Sections 5.3. and 5.4. Page # 29, Sections 6.2., 6.3. and 6.4.
9	WP 9. Project Management and Dissemination activities	Ensure effective coordination, quality control, and dissemination across the project through structured project management and active stakeholder engagement.	Completed	The project was successfully managed and controlled throughout its duration, all milestones were delivered, and results were broadly disseminated through industry collaboration, conferences, website and LinkedIn outreach, and engagement with standardization and regulatory bodies.	Project Management: Activities, highlighted throughout the document Dissemination: Page # 25, Section 5.5.
			Milestones		
10	Milestone 1. full list of specifications and feasibility study	To define complete technical specifications and verify the feasibility of offshore charging operations.	Completed	Consolidated system requirements, completed feasibility studies, for the PowerBuoy concept, new generation Charging Buoy concept, and full-design of SOeC Hang-off	Page #7, Section 4.2. Additional details in Section 5.2. (Page #16)

#	Work Package / Milestone	Objective	Status	Short Description of how it was achieved	Detailed description
11	Milestone 2. Prototype SOeC built and ready for installation	To complete fabrication and assembly of the prototype system for initial testing.	Completed	Manufactured and integrated prototype subsystems, verified functionality, and prepared the unit for yard-level commissioning and tests.	Page #7, Section 4.2. Additional details in Section 5.2. (Page #16)
12	Milestone 3. SOeC functioning in test-conditions	To demonstrate operational performance of key subsystems under controlled conditions.	Completed	Conducted component and yard trials confirming cable-handling, control-system communication, and mechanical performance.	Page #8, Section 4.2. Additional details in Section 5.2. (Page #16)
13	Milestone 4. SOeC validated in operational conditions, working as expected, and key optimization parameters defined	To validate prototype functionality in near-operational conditions and establish optimization targets for final design.	Completed	Executed harbour-scale test preparation and validation activities, confirming system operation under realistic conditions and defining parameters for final optimization.	Page #8, Section 4.2. Additional details in Section 5.2. (Page #16)
14	Milestone 5. Final design for a SOeC functioning in field conditions	To finalize the optimized Hang-Off SOeC design suitable for offshore deployment.	Completed	Completed bench and connector qualification tests, issued final design documentation, and initiated component procurement for 2026 system-integration trial.	Page #9, Section 4.2. Additional details in Section 5.2. (Page #16)