Final report

1. Project details

Project title	AI-powered Lean Wind Turbine Installation
File no.	64021-2033
Name of the funding scheme	EUDP
Project managing company / institution	Claviate Aps
CVR number (central business register)	40247114
Project partners	Siemens Gamesa RE & Siemens Gamesa Renewable Energy GmbH & Co. Kg
Submission date	23 July 2025

2. Summary

Project summary:

- **The purpose of the project**
  - The purpose of the project was to adapt, improve and expand the existing Claviate operational tracking technology to create a fully functioning AI-powered monitoring system for onshore wind turbine installation projects.
  - The developed solution should lower construction costs for wind turbines, ultimately reducing the cost of renewable energy.

- **Results, conclusions and perspective**
  - The project has been able to achieve both the stated project purpose and goal. This means that a fully functioning AI-powered monitoring system for onshore wind turbine installation projects, complete with co-developed reporting formats, has been developed.
  - The solution has been developed to a level where it has been possible to commercialize the product after the project completion.
  - The project has been able to demonstrate significant reductions in administration time for the construction site management leading to both reductions in costs and ensuring that key personnel were able to use more of their time on the project's critical challenges. Findings:
    - In the final pilot project, SiemensGamesa registered a 50% reduction in administrative time for both SiemensGamesa site management and their subcontractor.

    - Improvement in processes and evaluation of ways of working were enabled by the AI-powered cameras.
    - Claims and settlements between parties were resolved at once as claims were documented with the cameras. This resulted in significantly reduced costs and time used on claim discussions between the construction parties.
  - The project is therefore considered a success by all partners. Siemens Gamesa has after end of this project decided to use the solution on their future projects in Germany, the Nordics and Middle East.

Projektresumé

- **Formålet med projektet**
  - Formålet med projektet var at tilpasse og forbedre den eksisterende Claviate løsning til at skabe et fuldt fungerende AI-drevet kamera-overvågningssystem til installation af vindmøller på land.
  - Den udviklede løsning har til formål at sænke installationsomkostninger for vindmøller, hvilket i sidste ende reducerer prisen på vedvarende energi.

- **Resultater, konklusioner og perspektiv**
  - Projektet har opnået projektformålet. Et fuldt fungerende AI-drevet overvågningssystem til installationer af vindmøller på land er blevet udviklet.
  - Løsningen er udviklet til et niveau, hvor produktet kan kommercialiseres.
  - Projektet har påvist store reduktioner i administrationstiden for byggepladsledelsen, hvilket har reduceret omkostningerne og sikret, at nøglepersoner i højere grad kunne fokusere på projektkritiske udfordringer.
  - Konkrete resultater
    - På det sidste pilotprojekt registrerede SiemensGamesa en 50% reduktion i administrationstiden for både SiemensGamesa's byggepladsledelse og deres underleverandør.
    - Forbedringer i processer og evaluering af arbejdsmetoder blev muliggjort af AI-drevne kameraer.
    - Parterne kunne ved hjælp af kameradokumentationen løse krav og forlig straks. Dette reducerede omkostninger og tidsforbrug på kravdiskussioner betydeligt.
  - Projektet betragtes af alle parter som en fuld succes, og Siemens Gamesa har efter projektafslutning besluttet at bruge løsningen på deres fremtidige vindmølleprojekter i Tyskland, Norden og Mellemøsten.

3. Project objectives

- The purpose of this project was described in the original application as follows:
  - *The overall objective of this project is to further adapt, improve and expand the* [existing Claviate] *operational tracking technology to cover the entire onshore wind turbine installation*.
- Three primary sub-goals were defined to achieve the above:
  1. Developing and integrating new hardware
  2. Developing new reporting formats for the data that meets the needs of the project managers
  3. Maturing the system so that it is prepared for scale-up
- To achieve the above the project carried out two test campaigns/demonstrations on large Siemens Gamesa onshore installation projects.
- The expected result of the project was described as follows in the approved application:
  - *The expected result of the project is a fully functioning AI-powered monitoring system for onshore installation projects, complete with co-developed reporting formats, ready to be commercialised by Claviate*
- On a societal level the above purpose and result will aid reducing the costs in onshore wind turbine construction as well as reduce the construction time. In turn, this will reduce the cost of renewable energy and speed up the transition to renewable energy.
- The following technology was developed and demonstrated:
- An AI-powered camera solution with a complete software platform. The solution captures all relevant activities on an onshore wind turbine project either via cameras, an app, GPS sensors, weather data or an online portal. This enables a full project reporting tool that contains all information and can generate relevant reports for site management, supplier, the Siemens Gamesa back office and their customers.
- In the following the hardware developments, the software developments and the reporting formats will be described in detail

Development of hardware installed on onshore cranes and functioning in all weather conditions

Several different hardware activities were completed during the project:

1. Trailer Solution

A new trailer camera solution was created. The purpose of the 'Solar Trailer' was to create a camera solution that:

- Captured installation activities independently of the Installation Cranes
- Could run on own power in all weather conditions
- Was mobile and could be moved to relevant hard stands to capture different turbine installations

The solar trailer is pictured below. As can be seen the trailer has when positioned an extendable mast so that cameras could be placed in 6 meters height:

Solar trailer with mast extended. Picture is from the first pilot project (Björnberget). Cameras can be seen at top of the mast.

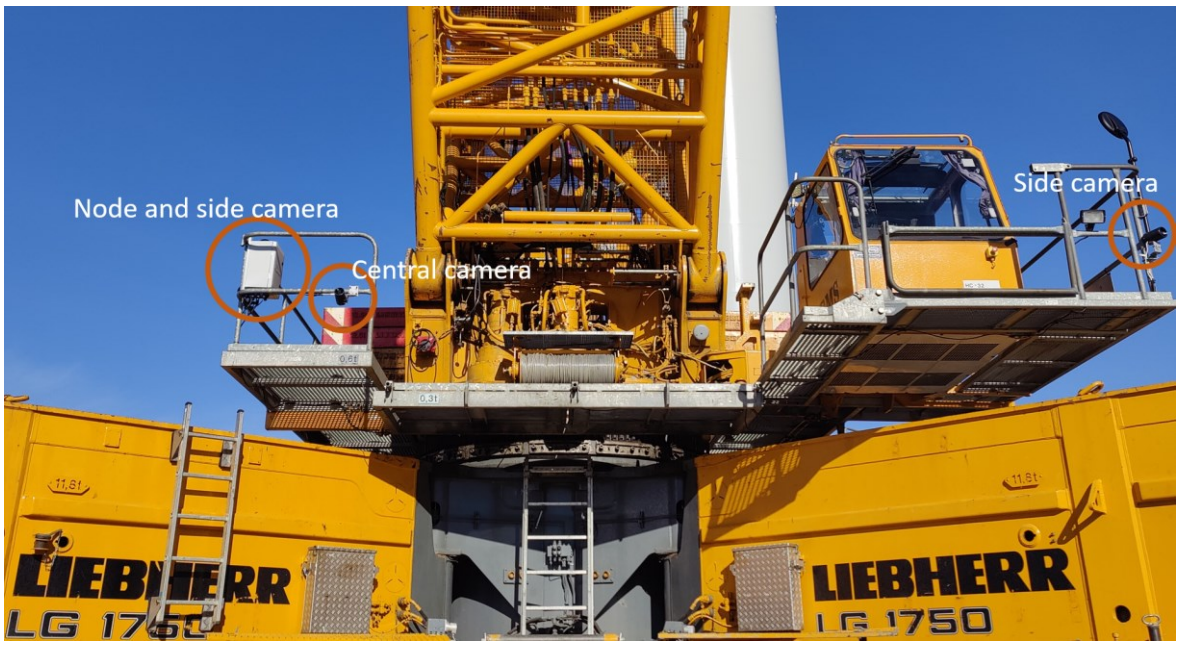
The pictures from the solar trailer enabled capturing all activities at the turbine hard stands independently of the main crane. Below is an arial shot of the position of the solar trailer on a hard stand.

Aireal view of the position of the solar trailer on a wind turbine hardstand

The solar trailer demonstrated unique insights into activities at the hard stands and enabled the project to test and evaluate if critical activities had to be captured from multiple angles independently of the main crane.

2. Updates to computer nodes

An updated solution of the nodes and cameras was developed to work with the onshore crawler cranes.



Picture of Node and cameras installed on a Liebherr LG1750 crawler crane on the first pilot project

During the project the hardware was improved based on learnings from each test project. Primary improvements related to power connections, improved antenna designs, redesign and repositioning of nodes and cameras to continue working during crane demobilization and repositioning from turbine to turbine, development of battery guards and improvements to the GPS sensor.

The hardware was tested and improved iteratively over the three pilot projects. The result was a node with two cameras placed next to the crane driver house with direct power connection. This ensured a stabile solution that captured all relevant data and did not require any work between demobilization and relocations of the crane. The solution was tested in extreme weather conditions (less than minus 20 degrees), and the design was changed to ensure that it could handle these conditions.

3. MiniNode

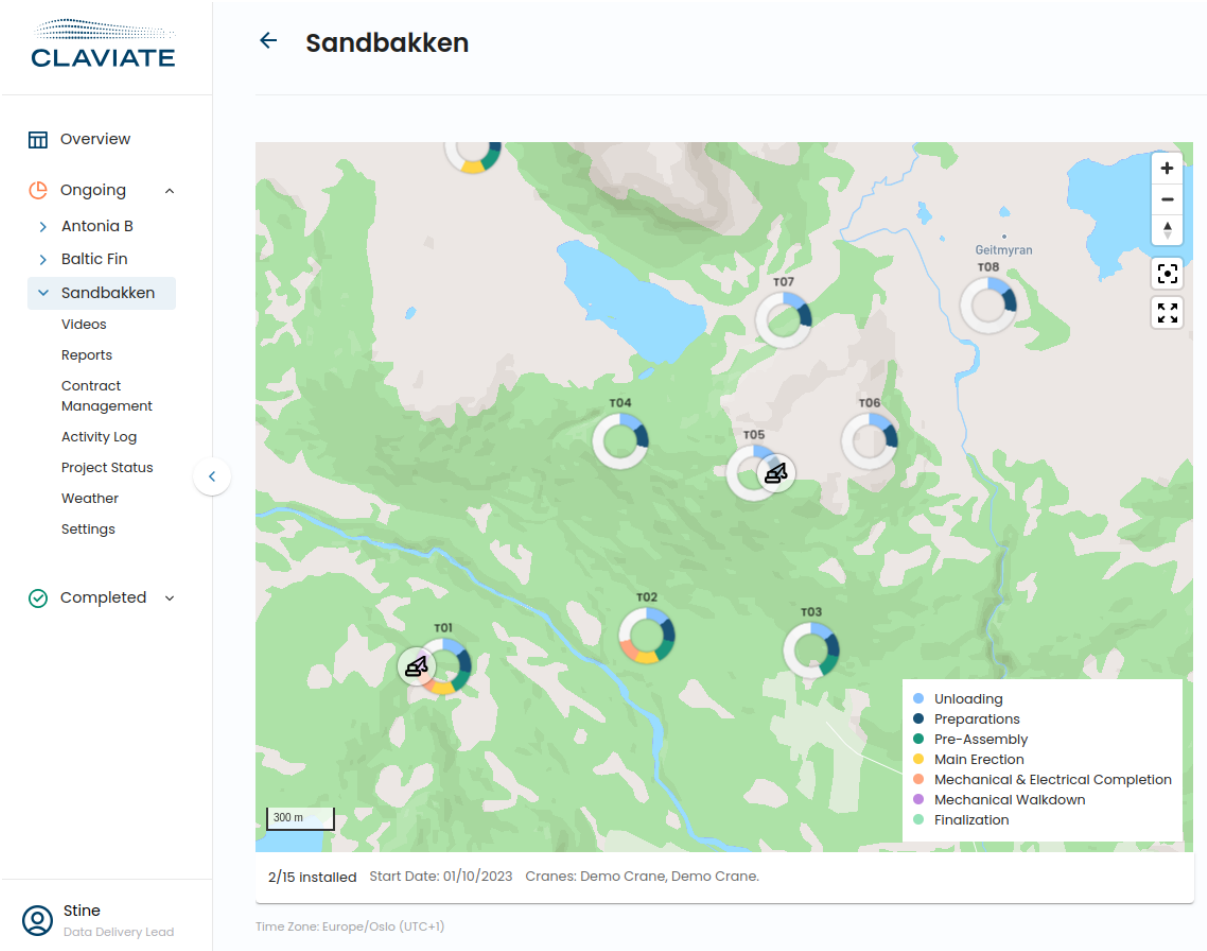
At the very end of the project, a simpler and smaller node with an integrated camera was developed and tested at Hovsøre. This node is significantly smaller and was developed with easier implementation in mind. The test was successful but further development of the MiniNode will continue after project completion.

MiniNode with integrated camera seen up close

MiniNode positioned left of crane driver house

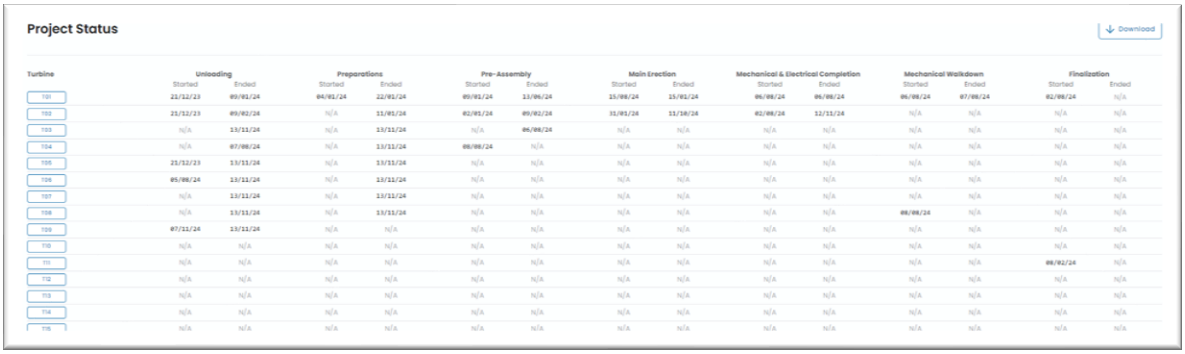
- **Development of a software platform that can capture and show all relevant project progress information based on both app registrations and automatically captured activities.**

  Several new developments were made to the Claviate software portal to ensure that site management and back office got the project status and information they needed.
  Below are examples of pages developed with this purpose.



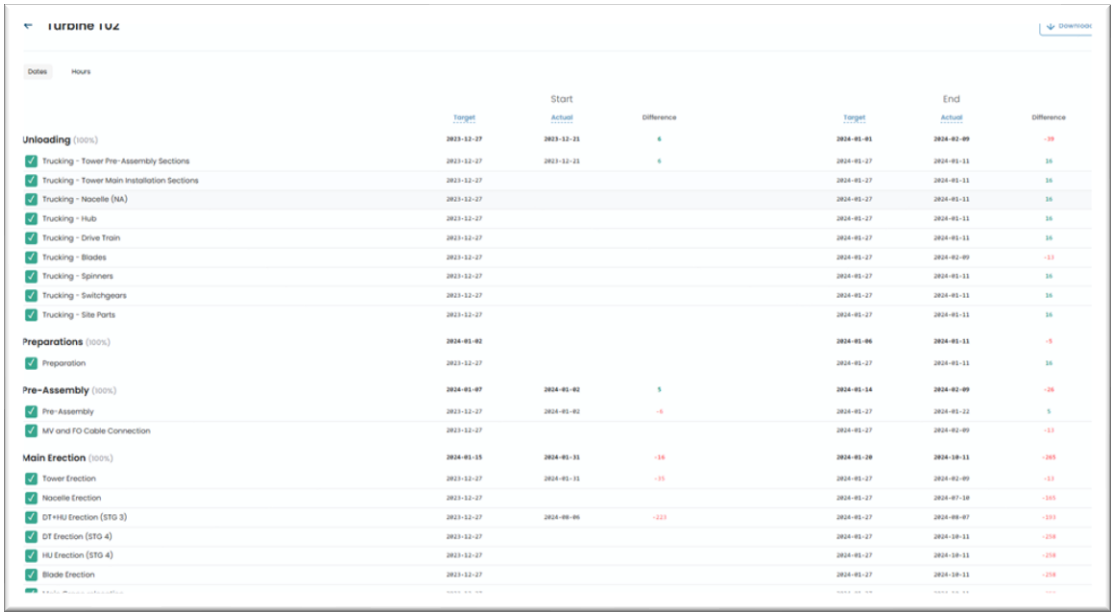
The project overview page shows the installation status of all turbines immediately together with a live update of where all cranes are located:

Additionally detailed information on turbine installation progress was created:



The project status page shows dates for all turbine installation phases

This enables project managers to compare installation progress with forecasted and planned dates. The data can be extracted to reports and it's possible to drill down and see further details on individual turbine level:

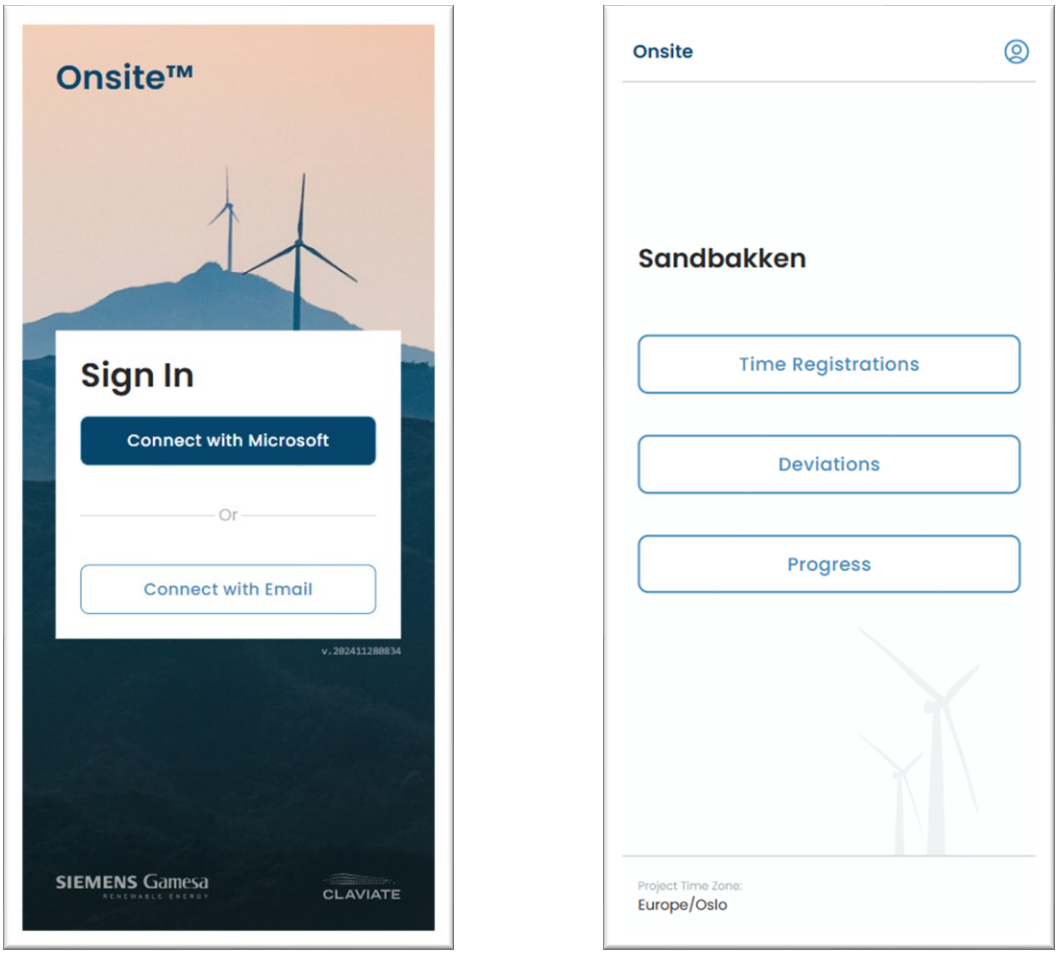


The Turbine page shows planned and actual dates for all phases and sub-tasks

When cameras capture the installation events, the status is automatically updated.

- **Development of an app that enables manual registration of all activities that cannot be automatically captured by the AI-powered cameras.**

  When cameras cannot capture the events, a different method to capture data was needed. The Onsite app was developed to enable site personnel to effectively input data in these cases:

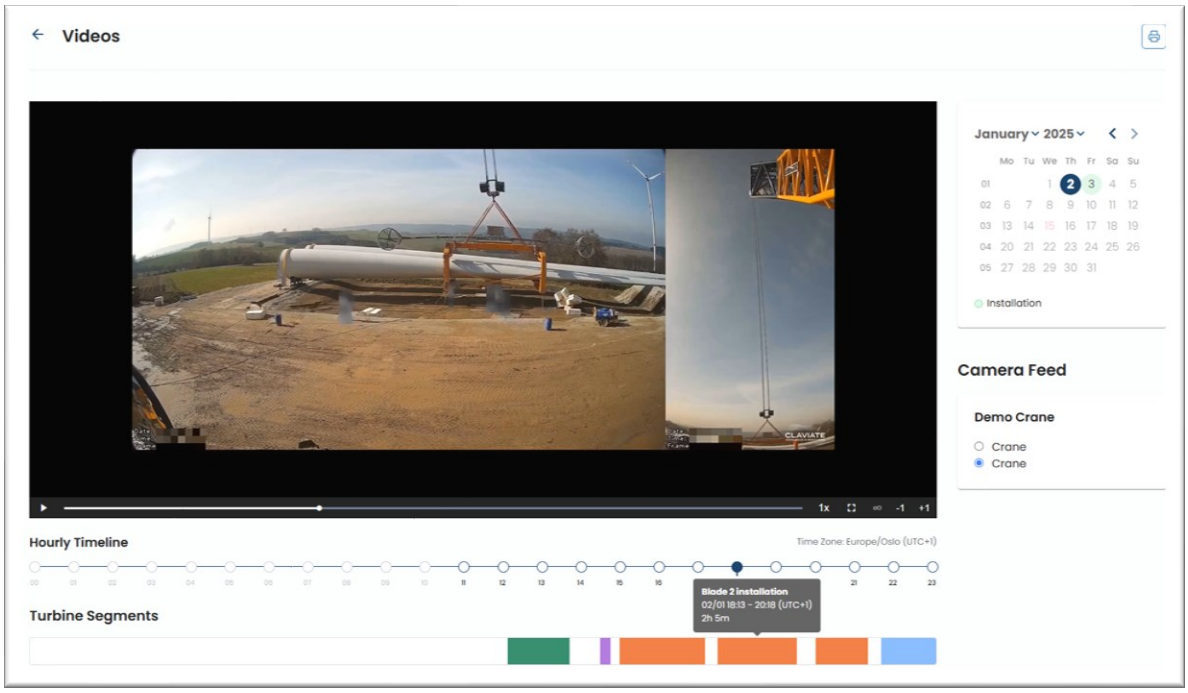


Views of the sign in page and project overview page on the app

  The app allows site personnel to input time registrations, deviations and installation progress. All this data is then fed into the portal and connected with the camera data to give a full overview of installation progress.

- **Development of the AI Software to identify onshore activities and effectively anonymize all site personnel.**

  A key software development was the update to the existing neural networks in Claviate to ensure that onshore installation activities could be recognized by the AI and that all site personnel were recognized and anonymized. Based on the images captured at the three test projects, it was possible to get enough data to update the training models in the neural networks so that events and people were effectively recognized by the AI. An example of the result can be seen in the below.

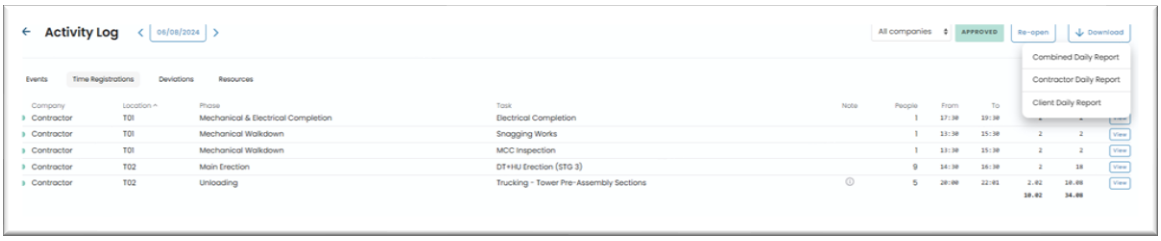


Video example from the Portal where two cameras capture activities on the ground and the crane tip in a mosaic view

Note the blurred people as well as the bar in the bottom of the screen that shows what process is occurring.

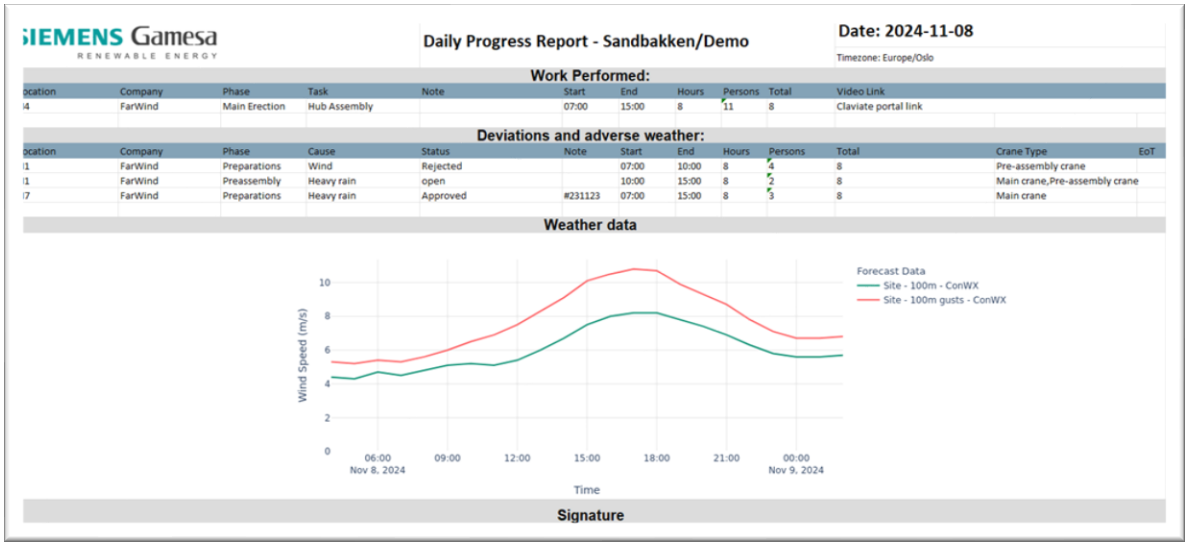
- **Development of project reporting for site management to all relevant stakeholders**

  With all relevant data captured and registered, detailed reports covering backoffice needs and site management needs were created.



Daily Progress Report page where different reports can be downloaded

The reports were automatically generated based upon the registered data:



Example of a Daily Progress Report

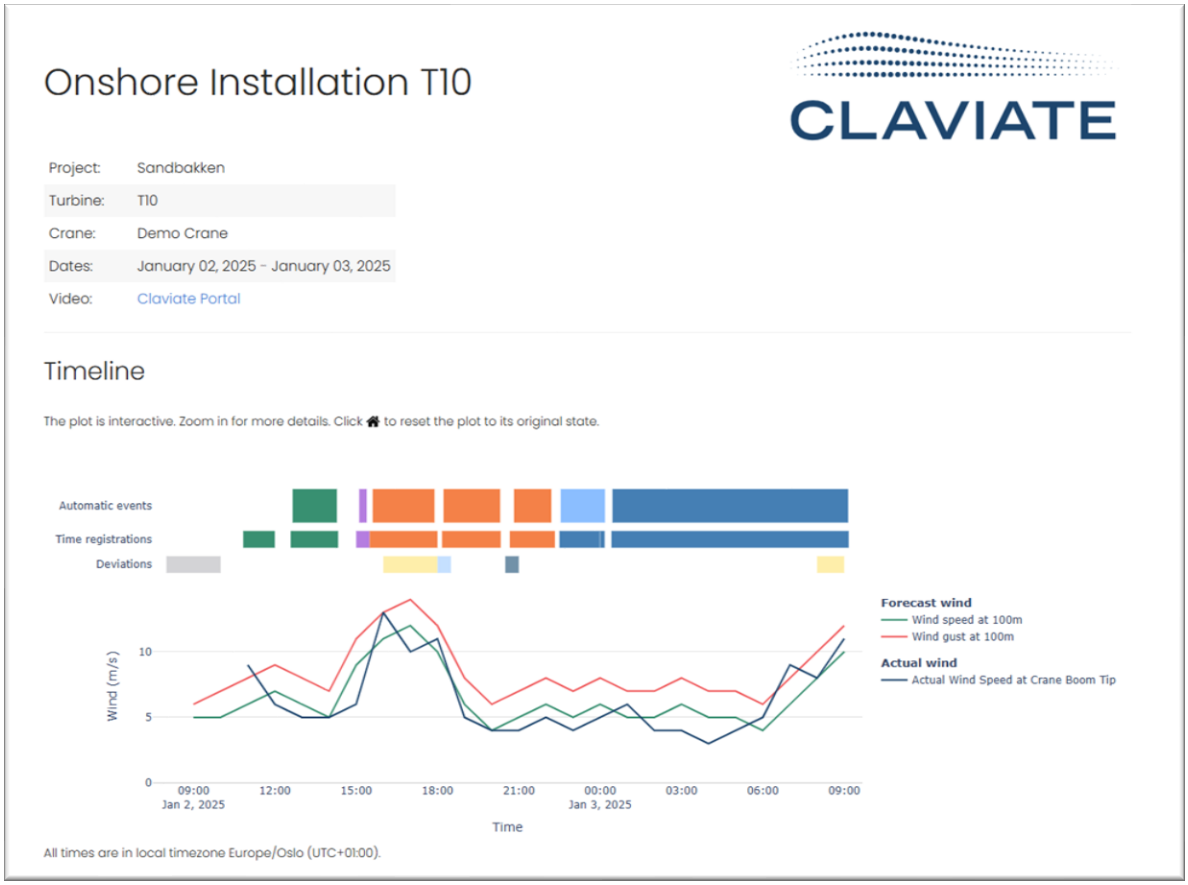
- **Integration with crane weather sensors and Weather forecast services**

Integrations with both the actual datalogger from the crane and external weather forecast services were made. This enabled both planning of installation activities based upon weather forecasts and evaluation of deviations and delays due to weather.

Example of the weather module where weather windows are automatically calculated based upon both forecasted and actual wind data

- **Development of specialised reports that combine video data and automated activity tracking with weather data and app registrations**

  Combining the weather analysis, the time registrations, the deviations and the video data allows for generating unique reports for each turbine installation which enables customers to analyse process improvements and verify claims:



Example of a specialized turbine installation report where all data is shown on a synchronized time-line

4. Project implementation

- The project developed the solution and tested it applying an iterative approach where two Siemens Gamesa wind turbine test projects were defined to test the solution. Findings from the tests where then used to improve and mature the project.
- During the project it was found that an additional test project was needed to finalize the solution. The third test was executed within the original project plans and timelines.
- The risks that occurred during the project related to finding and getting access to relevant pilot projects, ensuring approval from subcontractors that needed to approve the cameras on site. In addition, a considerable risk was identified related to developing the hardware to be able to withstand the harsh weather conditions on sites. Temperatures can drop to below -30 degrees on sites in Finland and Sweden during winter. One of the reasons for a third test project was to improve the hardware to ensure no data was lost no matter the location and conditions.
- The project followed the overall project plans and deliverables. However, a need for a simpler hardware solution was identified and the project therefore requested an extension of the project for 3 months to test this solution. This test was conducted within the 3-month period and the project was completed in accordance with the new approved plan.
- The biggest, unexpected problem that occurred was that the Siemens Gamesa project manager left the company during the project. This had the effect that his activities with tool suppliers regarding integration with their sensors were terminated. The solution was instead developed without these integrations and focus on integration with crane sensors was done instead. This change did not change the outcome of the project or reduce the value of the final solution.

5. Project results

- The original objective of the project was fully achieved. Below are some of the obstacles that were encountered.
- During the pilot projects it was found that the construction activities were so dispersed that it was both impossible and inefficient to cover everything with cameras. A new software solution was therefore developed that enabled technicians to manually register all activities in an app. This ensured that the Claviate solution could capture everything enabling the site leads from Siemens Gamesa to get a full overview of everything in the Claviate solution. Cameras were then strategically placed on main cranes and supporting cranes to ensure that the most important and costly activities (the critical path) were automatically captured by the Claviate AI-powered cameras.
- In the first pilot projects the camera solution was modified to ensure that it worked on the cranes, and it was tested that it could work both under the harsh weather conditions and be able to continue working as cranes were demobilized and transferred from hardstand to hardstand during the main erection installation phases.
- In the extension of the project (from July to September 2024) a new and simpler camera solution was tested. The purpose of this test was to investigate if a simpler hardware solution could simplify the installation of the hardware so that it would not require a certified crane electrician. This new simpler camera solution has been installed on a main crane in Høvsøre without any electrician. The test was therefore a success. Further maturation of the solution is still required, but a proof-of-concept has been achieved.

- Two patents that cover the developed solution are currently pending. The first covers in broad terms the ability to use AI-powered cameras to automatically capture all relevant events in the unique working environment that exists when constructing wind turbines. The second covers in broad terms the ability to settle disputes on the wind turbine sites between contractual parties using the fact-based evidence that the AI-powered cameras can create.
- The most unexpected findings during the first pilot tests were that based upon site feedback the primary need was a solution that was robust and easy to use. First iteration had too detailed reporting requirements based upon back-office needs, this hindered user adoption of the solution and resulted in lacking and wrong data. By simplifying the solution, the data quality and user adoption was markedly improved.
- The final pilot test demonstrated the following commercial results:
  - Reduction by administration time for both Siemens Gamesa site management and subcontractors of 50%. This exceeded the expectations of the project.
  - Claims were supported by the AI-powered cameras which gave Siemens Gamesa a significant cost reduction per turbine.
  - The developed solution was able to cover all project reporting needs and therefore demonstrated that it was viable as a solution that could replace earlier solution
- The biggest commercial result is as mentioned that Siemens Gamesa after conclusion of the EUDP project has chosen to buy the solution for future projects in Germany, the Nordic countries and the Middle East for the next year.
- The companies that will benefit from the solution and therefore be interested in procuring are wind turbine developers, wind turbine manufacturers and subcontractors providing technicians, cranes and other supporting services.
- The solution will contain all relevant site reporting. The primary users of the solution will therefore be site management, site personnel, contractors and general management.
- No scientific papers have been published in relation to this project. The results from the pilot projects have been shared in articles in relevant industry news sites. Links to articles have been provided in the last section

6. Utilisation of project results

- The project results will be utilised as described in the original application:
  - *The expected result of the project is a fully functioning AI-powered monitoring system for onshore installation projects, complete with co-developed reporting formats, ready to be commercialised by Claviate*
- The solution was at end of project ready to be commercialised and used on site during onshore wind turbine construction.
- This was directly proved after this project end as the developed solution has been sold to Siemens Gamesa for all their projects in Germany, the Nordic countries and the Middle East.
- The developed solution is unique as there are no solutions that use AI-powered cameras to automate the project reporting. However multiple solutions exist that provide a software only solution for site reporting. These software solutions are standard project planning and overview solutions that are customized to the wind industry. Some of the main providers of such a software only solution are Sumit and Lautec.
- A primary entry barrier is reaching the right stakeholders among the potential customers. The customer organizations are large, and relevant stakeholders often have a primary focus on project deliveries and not on improving ways of working with new technological solutions.

- The AI-powered solution results in higher costs than software only alternatives. A barrier to entry is therefore to explain how this new solution generates value that is higher than the relative cost difference.
- The developed solution has proven reduced administrative costs and reduced costs related to claims and settlements. Siemens Gamesa expects to find additional process improvements by using the developed solution, but this is something that will be demonstrated over time and cannot be quantified reliably in year 0.
  These are significant costs in the turbine construction and therefore the developed solution supports in reducing the costs for wind energy.

7. Project conclusion and perspective

- Upon project completion we can conclude that we have successfully transferred the Claviate solution from offshore to cover the unique needs in the onshore wind turbine construction industry. This was the primary goal of the project.
- The project has enabled a new solution that automates project reporting in an industry that has relied exclusively on ‘manual’ documentation.
- The solution created covers the full installation scope from trucking of site parts to final commissioning of the turbines.
- Next steps for the developed technology are to mature and improve it further. Possible improvements have been identified as well as additional features that will bring value to the onshore construction sites. However, the developed solution is already covering business needs and has a proven product-market fit. Thus, next steps will also include going to market and selling the developed solution.
- The simpler hardware solution will be further matured during the next year. It is the plan that it is thereafter offered as a product for future onshore wind turbine construction projects.
- During the project Claviate and Siemens Gamesa have identified multiple areas that the developed solution can be expanded to. This includes activities related to servicing the turbine after construction and the supply chain handling logistics of all turbine components from factory to site.
- The project has not only enabled the creation of a product that covers current needs. It has also uncovered additional areas where the wind industry can benefit from an improved automated AI-powered camera solution.

8. Appendices

- Publications to relevant industry news sites have been made. These cover activities and findings from the first and second pilot campaign. The publications have been picked up by multiple different industry relevant news sites (more than 18 different articles can be found online). All publications refer to EUDP and how EUDP has enabled the development of the solution. Below are examples from six different news outlets:
- https://www.energy-supply.dk/article/view/882404/timelapse_videoer_skal_optimere_opsaetningen_af_vindmoller

Energy Supply

Nyheder News in English Køb & Salg Job Energiøerne

Time-lapse videoer skal optimere opsætningen af vindmøller

Claviates teknologi anvendes i forbindelse med opstillingen af 60 Siemens Gamesa-møller i det nordlige Sverige

- https://energiwatch.dk/Energinyt/Renewables/article16487337.ece

EN DEL AF WATCH MEDIER

ENERGIWATCH

ENERGISELSKABER OLIE & GAS RENEWABLES CLEANTECH POLITIK & MARKEDER

RENEWABLES

Siemens Gamesa tester dansk software: Sparer tid i møllebyggeri

Softwareselskabet Claviate hjælper Siemens Gamesa med at spare op mod 80 pct. af den tid, som typisk bliver brugt på at holde øje med og registrere forløbet under opførelsen af svensk vindmøllepark.

Billede fra opførelsen af en tidligere opført vindmøllepark i Sverige, Björnberget | Foto: Claviate / Pr

AF JESPER ELKJÆR JENSEN

5. OKTOBER 2023 KL. 11.01

- https://stiften.dk/erhverv/aarhus-firma-leverer-banebrydende-teknologi-i-gigantisk-vindmoellepark-over-300-000-husstande-forsynes-med-energi
- https://altomteknik.dk/nyheder/2023/07/25/dansk-ai-frontloeber-sparer-tid-og-penge-i-nyt-svensk-vindmoelleprojekt/
- https://www.energy-supply.dk/article/view/1057096/kunstig_intelligens_giver_siemens_gamesa_store_tidsbesparelser
- https://itwatch.dk/ITNyt/Brancher/kunstig_intelligens/article16485289.ece
- A project website has been created and can be found here: https://www.claviate.com/eudp
- In addition different social media posts on LinkedIn have been made during the project lifetime
- Access to a demo version of the developed solution can be provided upon request. Please reach out to Project Manager Mathias Kaastrup-Olsen (mathias@claviate.com) to request access.