LAMINARIA

Deployment of a Shallow Water Wave Energy Converter at the EMEC Billia Croo Test Site

Project Information Summary

April 2018

Content

1 Introduction

The Project Information Summary of Laminaria will support the Marine Licence application for the Laminaria Wave Energy Converter (WEC) deployment at the wave energy test site Billia Croo of the European Marine Energy Centre (EMEC). The deployment period is planned to start with the WEC installation in August 2018 and will end with the decommissioning of the WEC in September 2019. The Project Information Summary will give detailed information about the working principle of the WEC, the main dimensions, a project description, the installation, operation, maintenance and decommissioning phases of the deployment and the project schedule.

Laminaria is a private company founded in October 2011 and based in Belgium. The company has a shallow water WEC under development which can be installed in water depth of 30 m to 70 m. The main focus on the company is to create innovative solutions that offer a high return on investment and show increased productivity compared to the leading technologies in the sector. Since its foundation, the company employed a combination of activities that prioritized experimental proof of concept, focusing its research and development efforts in rapid prototyping, wave tank testing and real in-sea validation of the predicted performance.

The WEC consists of a unique storm protection system to ensure survivability of the WEC during severe environmental conditions. The storm protection system will submerge the WEC in the water column to decrease the wave energy loads on the main floater and the mooring lines. The submergence continuous until the pre-defined nominal load threshold is reached again. Therefore, the submergence level is corresponding to the actual sea state at the deployment location. Further information on the survivability strategy of the Laminaria WEC can be found in section 2.1 of this document.

To de-risk the deployment of the WEC at EMEC, a tank testing campaign in November 2017 was conducted. The survivability strategy of the 1:30 scale model was tested in the wave tank of Plymouth University under conditions similar to the ones occurring at the wave energy test site Billia Croo. The survivability strategy and functionality of the scale model was validated and the model survived significant wave heights (Hs) of up to 16 m and maximum wave heights of 24 m. The limiting factor of the survivability test in extreme conditions was the capacity of the wave tank.

The Laminaria WEC deployment at EMEC is the first full-scale deployment of the technology. A previous 1:5 scale test was conducted 1 km offshore of the costs of Belgium in real sea conditions. The deployment of the fully functional prototype in March 2015 validated the Laminaria load management strategy to be highly efficient and the scale model survived a real sea storm with waves up to 2.7 m Hs which corresponds to wave heights of 13.5 m Hs in full scale conditions.

2 Device information

This section will give an overview of the working principle of the Laminaria WEC, the main dimensions, construction material and a small comparison of the Laminaria WEC compared to other wave energy technologies.

2.1 Device description

The Laminaria WEC consists of one main floater which is connected by four individual mooring lines to the gravity base anchor. The main floater can absorb energy of incident waves from all wave directions, heights and periods simultaneously. As a result of the horizontal movement in the water, the WEC is subjected to a tilting and translating motion. These motions are transferred through the mooring lines to the Power Take Off (PTO) chambers located at the bottom of the WEC. Each PTO chamber consists of a drum-system, a gearbox, an electrical motor and an asynchronous generator mounted on a main shaft.

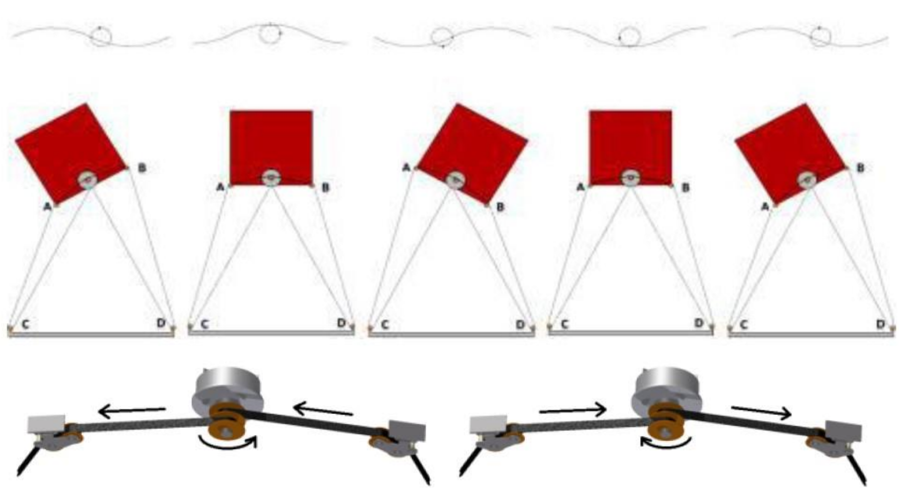

Figure 1: Schematic sketch of the WEC movement (pitch), the changing mooring line layout and the movement of the mooring lines on the drum system

The WEC is connected to the anchor system by four individual mooring lines, which results in four-time redundancy and protection against device loss. The mooring lines are designed in a W-shaped layout for the absorption of wave energy from all directions. The two V-shaped parts which create the W-shaped layout of the mooring ropes, are changing the shape due to the movement of the device as indicated in Figure 1. If the device is tilting towards the left site, the right V-shaped part of the mooring line increases in length and the left V-shaped part decreases in length. This change in shape results of the reeling in and reeling out of the mooring ropes. The mooring ropes are designed as flat ropes consisting steel wire ropes embedded in a rubber matrix. Laminaria developed flat ropes to increase the lifetime of the mooring lines. The increase in lifetime can be obtained by the reduced thickness of the rope (factor six) since the ratio between rope thickness and sheave diameter determines the longevity of the rope. Additionally, the costs for the PTO systems are reduced. An additional factor contributing to the longevity of the mooring lines is the incorporation of the height adaptation system. This solution allows to spread the cyclical movement that cause fatigue in the ropes over a longer distance (18 m instead of 3 m rope). The amount of cycles for the heaviest loaded fibres in the mooring lines is reduced by a factor of four, which results in a fourfold life expectancy for the ropes. The mooring lines are connected at the bottom centre of the WEC (central rope connection point), guided by pulleys through the anchor connection points and result in an assembly with two drum systems, which are coupled to two electrical generators.

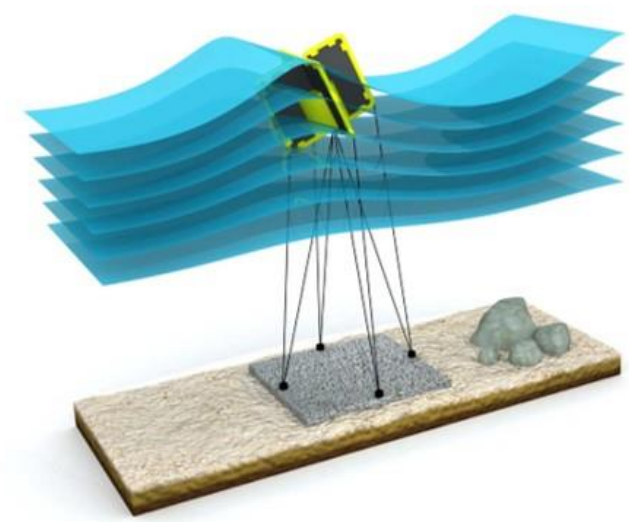

Figure 2: Artistical illustration of the Laminaria WEC

The drum-systems of the Laminaria wave energy converter consist of two drums each, which can be locked relative to each other. During the operation of the device, the two drums are locked and due to the movement of the mooring lines, the drums are moving back and forth. With the activated storm protection mode, the two drums are unlocked to each other which results in the on-spooling of mooring lines on one drum to decrease the WEC in the water column. When the device reached the submerged position, the drums will again be locked to each other to generate electricity.

The reliability of the mooring ropes is increased by the front-end PTOs of the Laminaria device which have a built-in system based on a differential to distribute load along the four mooring lines. With this system, minimum load is applied to each rope at all time and snatch loads due to slack of the mooring lines are avoided. Another major advantage of the rope driven front-end PTO is the lack of end stops. This means there is no mechanical blockage of movement when an excessive load is applied. In many technologies, end stops create very high instantaneous loads which are detrimental for reliability and survivability. Due to the lack of end stops, the Laminaria WEC can move more freely during freak waves. This strategy is called “PTO overdrive” and is governed by a programmable maximum torque setting for the PTO. Whenever the PTO torque exceeds the programmed maximum torque, the PTO increases the speed which results in a decreasing PTO torque and WEC loading. This increase of speed of the PTO results in the ability of the WEC to move more freely.

The unique survivability strategy of the Laminaria WEC consist of the load management strategy and the height adaptation system. The height adaptation allows the control of the WEC immersion by retracting the mooring lines and lowering the height of the WEC in the water column. Therefore, the WEC exposure to incident wave energy can be controlled. Load cells mounted on the mooring lines will identify the loads occurring and compare these to the pre-defined load threshold of the WEC. In case of an exceeding of the load threshold, the WEC will activate the height adaptation system and increases the submergence to lower energy parts of the water until nominal loads are reached again. With an identification of an undercut of the load threshold, the submergence of the WEC will decrease step by step into higher energy parts of the water.

With this concept, Laminaria provides a solution for economically viable wave energy extraction whilst being able to survive storm conditions due to the continuous and steady electricity production. The height adaptation system allows the device to produce continuous electricity output even in storm conditions and during the survivability position of the WEC. The survivability during storm conditions is the key factor to be successful at wave energy exploitation and has been a prime design consideration throughout the entire Laminaria technology development. The energy exposure of the WEC and mooring ropes can be regulated due to the height adaptation in the water column accordingly to the actual sea state. For common small waves (typically up to 3 – 3.5 m of significant wave height), the WEC is held near the water surface to maximise the energy exposure. With increasing wave height and therefore increasing exposure, the WEC is lowered in position to reach the required condition for nominal power production again. In this way, the energy exposure of the WEC can be adapted for a continuous nominal power production without the exposure to excessive forces. This peculiarity makes Laminaria the first and only technology to be able to survive even the most violent storms and still operate at high efficiency in common smaller waves.

In normal operation, the device can protrude the sea surface by up to one meter and the lowest position in the water column, in which the device is still generating electricity, is at 17.50 m (below the average water level). A maximum submergence of 22 m can be obtained during extreme storm conditions.

The WEC consists of two ballast chambers which can be filled with ocean water. This allows the device to float inverted, which is used for maintenance purposes. The mechanical components located at the bottom of the WEC can be easily accessed when the WEC is floating inverted. With this technique, the operations and maintenance costs are lower compared to other strategies since no crane vessel is needed to lift the WEC out of the water. The PTOs as well as the energy exposed hardware are in separate chambers and a small crane can lift the designated chamber in case of a replacement or repair.

The Laminaria WEC will re-use the umbilical connected to the subsea cable of berth two for the electric connection of the WEC to the local grid. The connection between the umbilical and the WEC is made by a cable terminator

The following figures will give an overview of the Laminaria main floater, gravity base anchor and the assembly for the towing:

Figure 3: Drawing of the main floater with attached PTO chambers

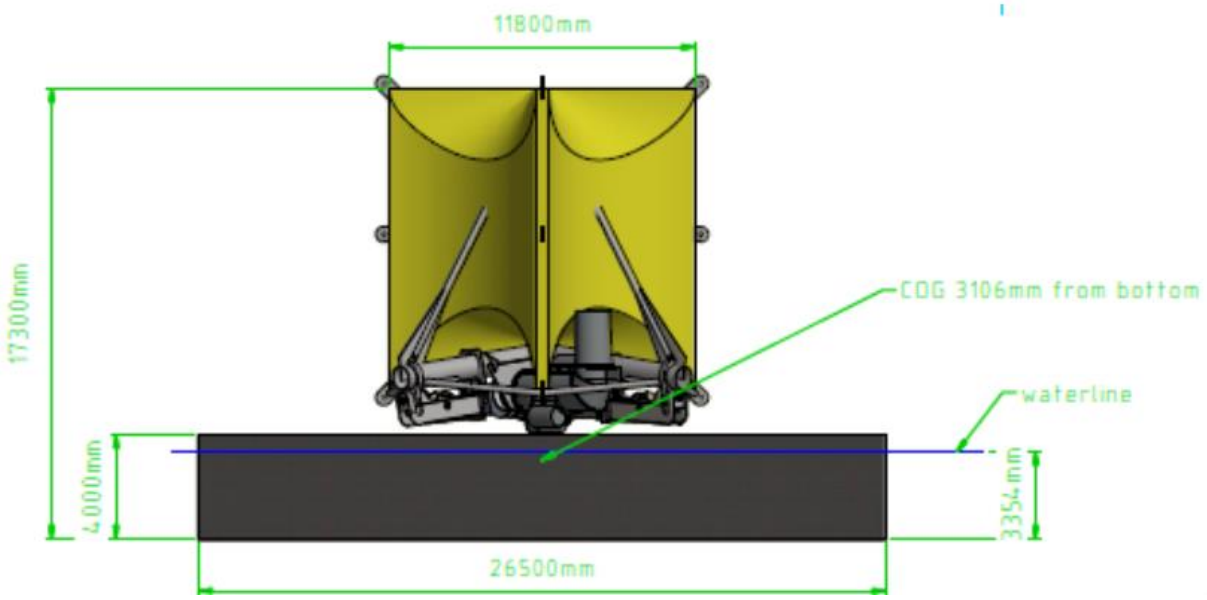

Figure 4: Drawing of the WEC assembly during the towing

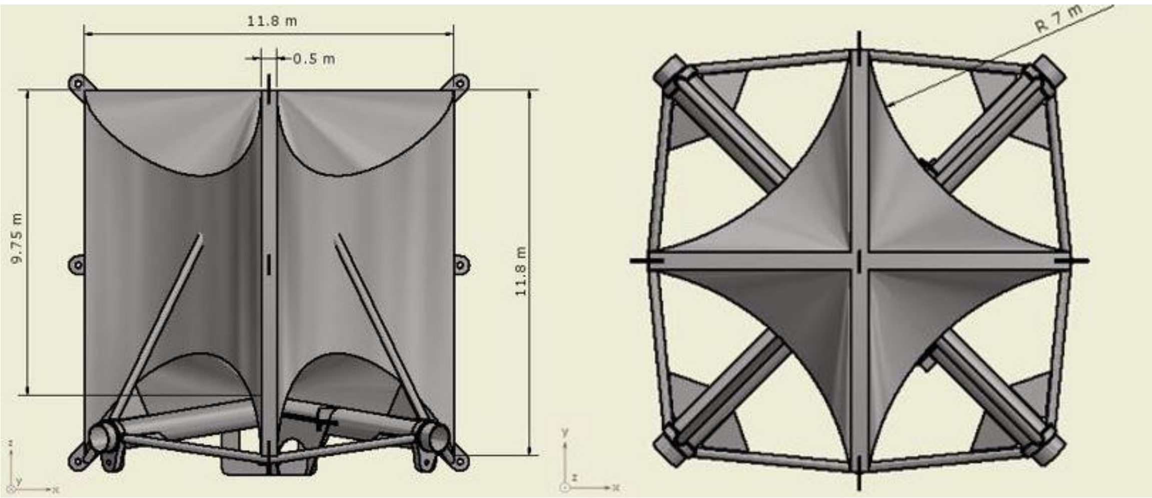

Figure 5: Laminaria WEC design with dimensions

Figure 6: Front and site view of the WEC

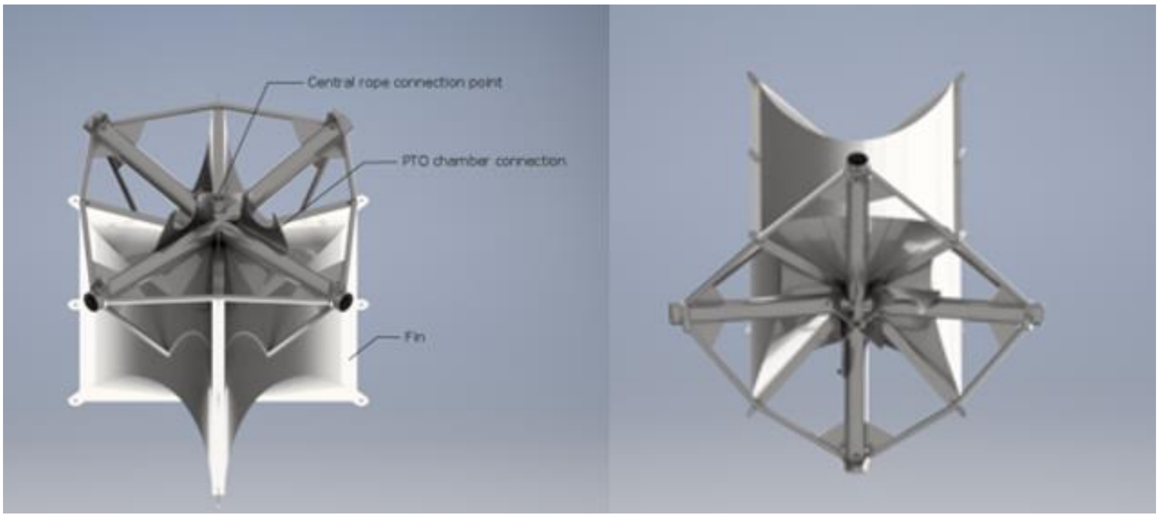

Figure 7: Bottom view of the WEC

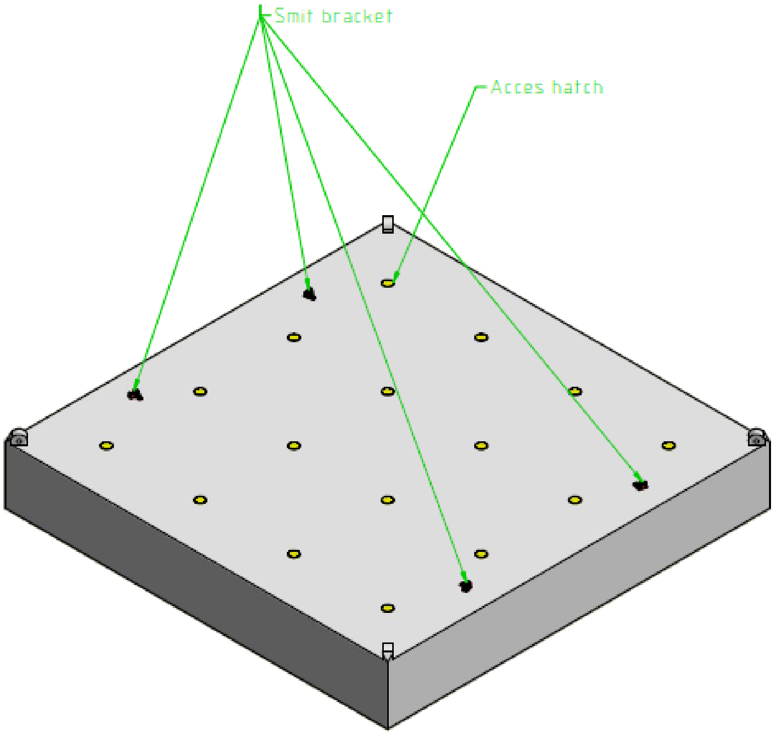

Figure 8: Drawing of the gravity base anchor

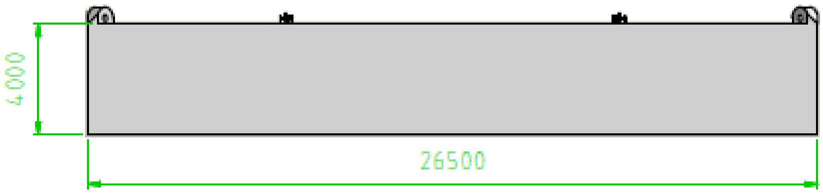

Figure 9: Drawing of the gravity base anchor (front view)

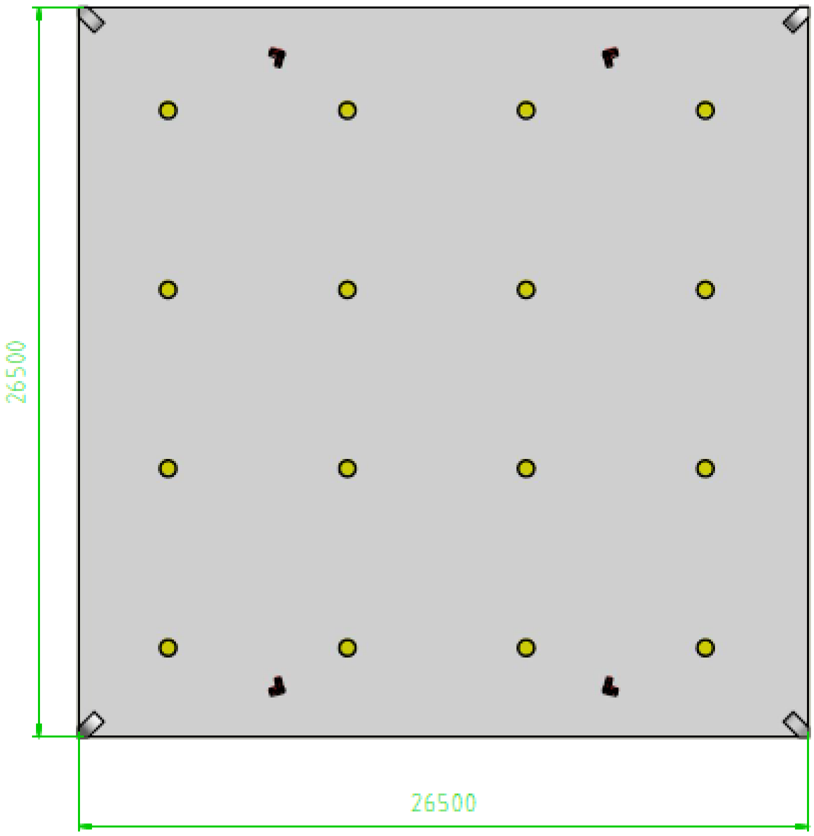

Figure 10: Drawing of the gravity base anchor (top view)

To decrease the potential environmental impacts of the WEC as much as possible, Laminaria developed a gravity base anchor design. The variable buoyancy gravity base anchor will allow towing of the whole structure to the deployment location. The anchor will include chambers which will be filled with air or water during the towing of the WEC to regulate the buoyancy of the anchor. With a steady negative buoyancy and the off-spooling of the mooring lines, the anchor will be submerged to the seabed.

The following table shows the key dimensions of the Laminaria WEC:

Table 1: Main Dimensions of the Laminaria WEC

Part of the WEC	Dimensions
Overall height of the WEC	13.30 m
Overall width of the WEC	11.80 m
Height of the fins	11.80 m
Width of the fins	0.5 m
External radius of the hull	7 m
Centre of Gravity	6.35 m
Estimated mass	250 t
Anchor footprint	26.5 m x 26.5 m
Anchor height	4 m
Estimated anchor mass	2,200 t

Table 2 shows the construction materials of the Laminaria WEC for the deployment at the Billia Croo wave energy test site.

Table 2: Construction material of the main floater and the anchor system

Components installed	Materials to be used	Approx. weight / volume
Main floater		
Mooring line	Steel wire rope in rubber matrix	4 x 200 kg
Sheaves	Ertalyte (PET-P)	8 x 200 kg
Sheaves	Nylacast Oilon	8 x 200 kg
Wet bearings	Feroform T14 by Tenmat	8 x 8.5 kg
Pulley bracket	Steel	8 x 420 kg
Drum	Super duplex stainless steel	2 x 1300 kg
Main shaft	Super duplex stainless steel	2 x 2100 kg
Main hull	Steel s355	250 tons
Paint	Hempadure Multi-Strength 45703	170 L
Umbilical electrical cable	Rubber and copper	4000 kg, 150 m
EMEC's subsea cable		
Roller bearings	Steel	4 x 150 kg
Gearbox	Steel	4 x 2.5 tons
Gearbox and rollerbearing oil	Offshore Environmental Oils HDEO EP	4000L
Gearbox and rollerbearing oil	Offshore Environmental Oils EO220	4000L
Generator	Steel, copper, magnets	2 X 800 kg
Electric induction motors	Steel, copper	2 X 600 kg
Electric switch gear		
PLC		
Power electronics		
Anchor		
Structure	Concrete	1000 m^3

2.2 Developer details

During the deployment period of the Laminaria WEC, the CEO of Laminaria, Steven Nauwelaerts, will be present at the test site at EMEC. This enables a fast decision-making process in case of unplanned activities in relation to the WEC and ensures the accurate configurations at all times. Anything related to the WEC during the deployment period can be addressed to Laminaria NV. Steven Nauwelaerts will be the emergency contact person:

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3 Project description

This section of the Project Information Summary will provide more information on the project to be deployed at EMEC. Laminaria NV plans to install their first full-scale WEC of 200 kW rated power at the Billia Croo wave energy test site at EMEC from August 2018 to September 2019. The Laminaria main floater will be constructed in Zeebrugge and the concrete anchor will be manufactured in Antwerp. The assembly of both will be conducted at the port of Zeebrugge and the WEC will be towed by a multi-cat vessel to Scotland.

The key aims of the testing at EMEC will be:

- Up-scaling of the WEC to full scale: performing research on the metal fatigue of the main floater, the ideal PTO (gearing ratio to pole number), ropes, grid connection and power electronics
- Monitoring of potential environmental impact of the WEC
- Monitor survivability, life expectancy, efficiency and stability

The installation of the WEC will be conducted as soon as weather windows allow and details about the installation method can be found in section 3.3. Several recoveries and re-instalments of the WEC are planned to optimise the installation process for future projects.

3.1 Location

The Laminaria WEC will be deployed in berth two of the Billia Croo wave energy test site. Table 3 and Table 4 are indicating the coordinates of the boundaries of the Billia Croo area, the berth two location and the proposed boundaries for the Laminaria WEC during the deployment period.

Table 3: Billia Croo navigational cardinal buoy and berth two location

Location	Latitude	Longitude
North cardinal buoy	59° 00.000’N	003° 24.330’W
West cardinal buoy (1)	58° 58.529’N	003° 24.638’W
West cardinal buoy (2)	58° 59.500’N	003° 25.330’W

Location	Latitude	Longitude
South cardinal buoy	58° 57.431'N	003° 23.028'W
East cardinal buoy	58° 58.386'N	003° 22.399'W
Berth two	58° 58.586'N	003° 23.335'W

Table 4: Laminaria proposed licence boundary coordinates

Location	Latitude	Longitude
North west corner	58° 58.753'N	003° 23.354'W
North east corner	58° 58.592'N	003° 22.928'W
South west corner	58° 58.444'N	003° 23.358'W
South east corner	58° 58.598'N	003° 23.768'W

The following figures indicate the Billia Croo wave energy test site (Figure 11) which can be clearly identified by the indicated marker buoys. The yellow square in Figure 12 roughly indicates the deployment location of the Laminaria WEC in berth two.

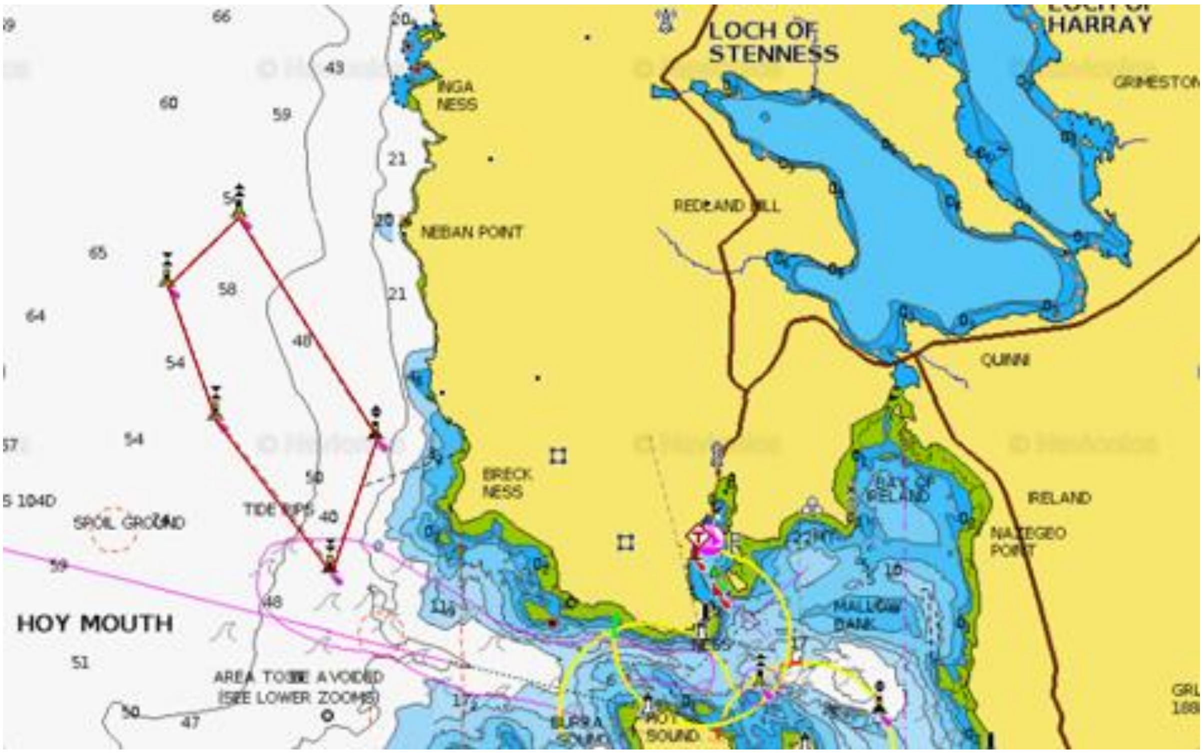

Figure 11: Indication of the Billia Croo wave energy test site[1]

[1] Chart from Navionics: https://webapp.navionics.com/?lang=en#boating@9&key=%7Df%7DfJb_%60S [09.03.2018]

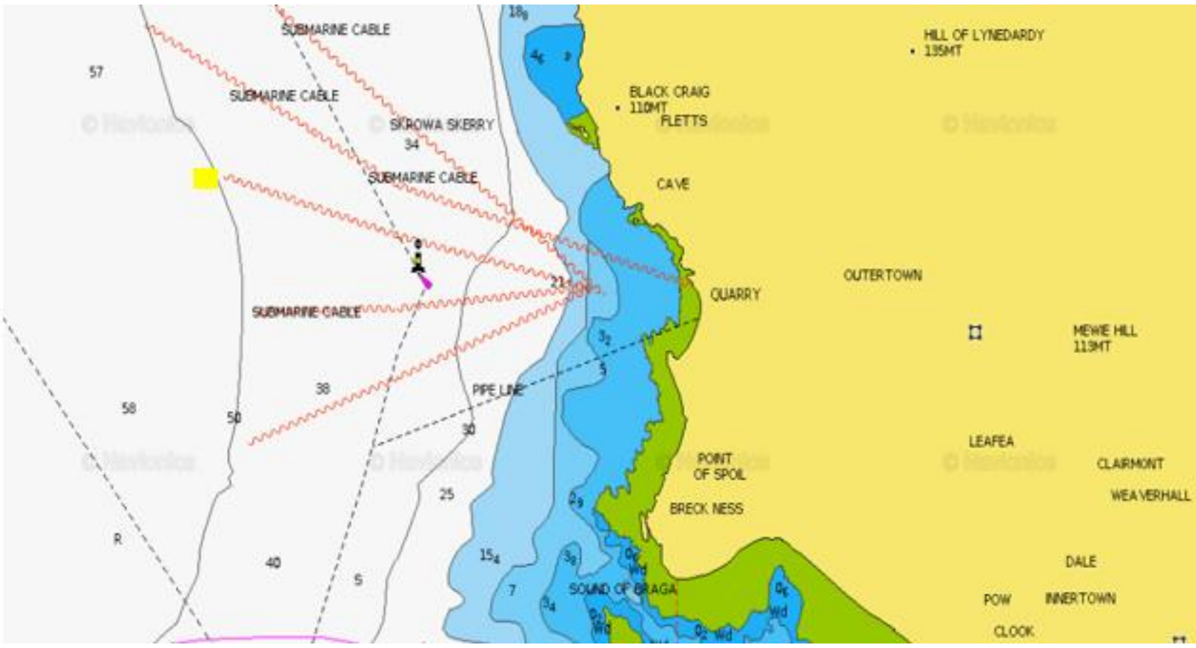

Figure 12: Indication of the deployment area of the Laminaria WEC[1]

3.2 Licensing process

Under the Marine (Scotland) Act 2010, it is necessary to obtain a marine licence to deploy infrastructure in the marine environment. Laminaria propose to apply for a marine licence to deploy, operate, recover and decommission their shallow water WEC at berth two at Billia Croo. The marine licence application will be submitted with the following supporting information:

- Project Information Summary: detailing the device description, berth and deployment location, installation, maintenance and decommissioning methodologies, timeline for deployment and decommissioning and key milestone dates.
- Project-Specific Environmental Monitoring Plan / Environmental Report: outlining the assessment process undertaken on the potential environmental impacts and proposed mitigation and monitoring measures.
- Device-Specific Addendum to the EMEC Wave Energy Test Site Navigational Risk Assessment: evaluating any project-specific navigational risks and mitigation actions associated with the deployment, operation and removal of the device.
- Decommissioning Programme: reviewing the planned decommissioning methodology and associated information.
- Third Party Verification: verifying the integrity of the structural design of the device and mooring system, for conditions experienced at Billia Croo.

In addition to these project-specific documents, site-wide documents produced by EMEC for the Billia Croo test site will also be submitted to support the application. These will be as follows:

- Billia Croo Navigational Risk Assessment (NRA, 2014)

- Billia Croo Environmental Description (Aurora, 2004)

The marine licence application is expected to be submitted to MS-LOT in April 2018.

3.3 Installation

The WEC can be installed in sea states of up to 2 m significant wave height (Hs) and when weather windows allow the installation, the WEC will be towed by a multi-cat vessel to the deployment location in berth two at Billia Croo. When the deployment position is reached, the chambers of the anchor will be filled slowly with water to decrease the WEC in position until the main floater will be in slightly submerged. Due to the positive buoyancy of the main floater, the whole WEC structure can be balanced without the need of the air included in the anchor. To bring the anchor towards the seabed, the chambers will be filled with water or air to reach a steady negative buoyancy. A small work vessel will transport an air compressor which will be connected to the anchor by a marine air hose. The mooring lines of the main floater will unspool during the process of submerging the anchor. The instalment process will be fulfilled when the anchor is successfully submerged and steady located at the seabed. The marine air hose will be attached to a marker buoy closely above the seabed which will be retrieved for the recovery of the WEC.

After the installation of the anchor, the mooring lines will spool on and decrease the main floater in the water column to a water depth of 17.2 m to 22 m to test the safety features installed. During this commissioning process, the movement of the WEC and the loads in the mooring lines and on the main floater will be identified and compared to the designed / expected movements and loads during this state of submergence. Additional, the thermal, mechanical and electrical properties of the PTO systems will be identified and compared with the previously defined threshold. After the identification of the safety system of each individual part, the failure algorithms will be tested to ensure a correct behaviour of the WEC. With a successful testing of the safety measures, the main hull will be gradually exposed to higher wave energy by decreasing the submergence. The height adaptation of the WEC will be tested and the WEC will be released for energy capture and electricity production.

The marine vessel required will be mobilised from the harbour in Kirkwall. More information about the marine vessels can be found in Annex One of the *Device-Specific Addendum to the EMEC Wave Energy Test Site Navigational Risk Assessment* of Laminaria.

3.4 Operation

During the operational phase, the Laminaria WEC will only move inside the anchor footprint and the submergence will correspond to the actual sea states at Billia Croo. With more severe environmental condition during storms, the WEC will be further submerged and with more calm conditions, it is more likely that the WEC will be closer to the water surface.

3.5 Maintenance

During the deployment at EMEC, no scheduled maintenance is planned, but the WEC will be recovered and re-installed several times during the deployment period. The aim of the re-instalments is to obtain more knowledge of the process itself to improve the procedure as well as the time needed for the instalment and receiving of the WEC. The instalment methods will be monitored by INNOSEA. For overall maintenance periods, the device will be towed to the harbour of Lyness and due to the ballast tanks, the WEC can flip over to float inverted. This feature enables easy access to the PTO chambers outside and the electronics inside the main floater, which can be accessed via a hatch. The advantage is that there is no need for a crane vessel to remove the device from the water. The PTO chambers are designed to be dismantled in one part from the WEC which ensures a fast and easy replacement.

The WEC is connected by four mooring lines to the gravity base anchor which result in four-time redundancy of device loss. Loads on the mooring lines and the main floater will be measured constantly and in case these loads are exceeding a pre-defined threshold, the storm protection system of the WEC will be activated automatically. Additional, a minimum tension will always be kept on the mooring lines to avoid slack. In case of a severe damage or failure of one mooring line, the WEC will increase the submergence to lower energy regions to avoid the damage of additional mooring lines. The broken mooring line will be spooled on the corresponding drum to avoid entanglement. During the deployment period at EMEC, the WEC will keep the position until it will be recovered manually to decrease the risks of free floating to a minimum. The Laminaria WEC is designed to continue electricity production even with two mooring line failures.

In case of a severe misalignment or a detected failure of parts of the WEC (for example the mooring lines, electrical motor, water ingress, electrical failure), the WEC will automatically activate the storm protection system to submerge the WEC to a lower energy region of the water column. The Laminaria team will try to solve the misalignment or failure remotely without removal of the WEC from the water.

3.6 Decommissioning / recovery

The decommissioning of the main floater and the anchor will be executed in the reverse order than the installation process. The Laminaria WEC will be decommissioned by one multi-cat vessel and one small work vessel. The decommissioning process will be in reverse order compared to the installation process, but the main floater will be at the water surface. The small work vessel will recover the marker buoy at the end of the marine air hose and the end of the air hose will be connected to an air compressor. This compressor will fill the chambers of the anchor with air to achieve a buoyancy of around zero. This process will take between 2.5 to 3 hours. With the slightly increasing anchor, the mooring lines of the WEC will be spooled on. After the anchor is surfaced, the mooring lines will be locked to ensure a safe transport position. The WEC will be towed from the deployment site back to the base port of Lyness. The multi-cat vessel will attach two towing lines at the Smith brackets of the gravity base anchor. The decommissioning will be fulfilled during one day.

3.7 Monitoring

During the deployment period at EMEC, monitoring will be conducted to identify potential environmental effects due to the presence, installation, operation and decommissioning of the Laminaria WEC. Included in the monitoring are:

- Noise monitoring: noise of the WEC will be measured with three microphones located in the main floater. The main source of the produced noise is estimated to be waves interacting with the WEC.
- Camera monitoring: a camera attached to the bottom of the WEC will monitor the drum systems, PTO systems and the upper part of the mooring lines to identify possible interactions or potential entanglement of marine species. The video will be a live-feed which enables immediate action in case of unforeseen events.
- Temperature monitoring: the temperature of the individual parts of the main floater will be measured to identify potential misalignments.
- Water ingress monitoring: monitoring of potential water ingress is in place to immediately identify water in the main floater or the PTO chambers.
- Water depth monitoring: to ensure a successful operation of the height adaptation system, the water depth of the main floater will be measured by pressure transducers.
- Load and input torque monitoring: loads cells will monitor the loads on the mooring lines and the main floater which will be used for the activation of the storm protection system. The load cells will ensure tension on all mooring lines at all times which reduces the risk of entanglement with marine species.
- Electrical connection monitoring (including grid voltage, current and DC bus voltage): the electrical connection will be monitored to identify potential misalignments or damages.
- GPS monitoring: the WEC will be equipped with a GPS tracker to identify the position. This is an additional safety feature for the unlikely case of drifting or free floating of the WEC and can identify the WECs position after the unlikely occurrence that the ballast tanks have been flooded.

Additionally, to the monitoring measures, the WEC will be connected to the Supervisory, Control and Data Acquisition (SCADA) system of EMEC to ensure a safe working environment. Laminaria will conduct video surveys of the complete WEC prior to each recovery of the WEC. To identify the potential level of scour at the anchors, video surveys will be undertaken before and after the installation of the WEC and before and after the decommissioning of the WEC.

4 Summary of the key environmental impacts

This section gives a summary of the identified potential key environmental impacts which have been identified during the Environmental Appraisal process. More details on the environmental impacts can be found in the *Project-Specific Environmental Monitoring Plan / Environmental Report* of Laminaria.

The following impacts have been identified to have a moderate impact on the environment:

- Hazard to navigation due to WEC presence: the WEC represents an additional structure in the water which could result in a hazard to navigation. The deployment of the WEC will take place in a wave energy test centre which should be avoided by marine vessels at all times. Additionally, Laminaria will release a Notice to Mariners to inform all marine stakeholders of the location of the WEC, the installation, operation and decommissioning works and times to be done and maintenance or recovery phases. The WEC will be lighted and marked accordingly to the standards of NLB to reduce risks of the WEC to become a marine hazard.
- Disturbance to wildlife due to underwater noise and vibration of increased vessel traffic: Due to the active wave energy test site of Billia Croo, the marine vessel traffic is already increased with a peak during the installation, maintenance and decommissioning periods. The vessels required by Laminaria will use indicated marine transport routes as much as possible to reduce the additional noise and vibration in the area. The increased vessel traffic will be temporary in nature. Due to smart vessel management, the time of maintenance vessels at site will be keep to a minimum.
- Disturbance to pelagic habitats due to underwater noise of increased vessel traffic: The underwater noise of the vessels will be keep to a minimum due to a smart vessel management plan of Laminaria and reduced time at site. The noise disturbance will be temporary in nature with a peak during installation, maintenance and decommissioning phases.
- Disturbing/Damaging/Destroying of seabed habitats and ecosystem due to the anchor system: The presence of the gravity base anchor will disturb the seabed habitats during the deployment period of the WEC. The WEC will be micro-sited in berth two to reduce the potential impact on the seabed habitat and the ecosystem. The effects of the anchor will be investigated during the regularly conducted video surveys.
- Entanglement of marine megafauna with the mooring system: The four mooring lines of the WEC will be keep in tension at all times to decrease the risks of entanglement with marine megafauna. Additionally, a live feed of a camera installed at the bottom of the WEC indicates potential interaction of marine species with the drum system and will be used for an evaluation of potential measures to decrease the entanglement risks of the WEC for future deployments.

Additional to the potential key environmental impacts of the WEC deployment at EMEC, the following activities could lead to minor residual impacts on the environment:

- Displacement of habitat due to the presence of the WEC: There are no significant changes in the habitats anticipated, but the potential environmental effect cannot be mitigated completely. Environmental monitoring will be in place to identify significant environmental changes.
- Change in distribution due to the presence of the WEC: The WEC may attract marine species like fish due to the potential shelter and occurring marine growth. Increased presence of fish may increase the presence of predators such as marine mammals and may increase the risk of entanglement. A camera mounted at the bottom of the WEC will provide a live-feed which will give information about potential increased marine species presence at the WEC.
- Disturbing of pelagic species and changes in wildlife distribution due to underwater noise and vibration of parts of the WEC (motors, electronics): The acoustic signature of the WEC is estimated to be low compared to the overall background noise. Therefore, the noise is not expected to propagate to a distance that it could cause significant displacement effects. If additional funding is found, an acoustic survey will take place during the deployment period at EMEC.
- Disturbing of pelagic habitats and distribution effects of marine wildlife due to underwater noise regarding the presence of the WEC: It is estimated that the major noise contribution will be the interaction of the WEC with the waves. The sound is expected to increase with increased roughness of environmental conditions, but the WEC will be expected to submerge further during rougher sea states.
- Disturbance to pelagic species and habitats and effects on wildlife distribution due to underwater vibrations of the WEC: The vibrations of the WEC are not expected to be a significant impact on the surrounding environment.
- Disturbance to wildlife and pelagic habitats due to underwater noise of increased vessel activity: Operational planning will reduce the time needed at sea. The noise disturbance of marine vessels required by Laminaria will be only temporary in nature. It is expected that species are avoiding the area during the periods of maintenance and the corresponding higher noise level.
- Disturbing/Damaging/Destroying of seabed habitat and ecosystems due to the anchor: Micro-siting in the test berth will be conducted to decrease the level of interaction as much as possible. Seabed surveys will be included during the deployment period at EMEC to identify the level of impact. A loss of seabed communities is expected in the footprint of the anchor.
- Entanglement with marine megafauna due to the mooring system: The mooring lines will be taught at all times to decrease the level of risk for entanglement of marine species. Loadcells mounted on the WEC will ensure this also during stormy conditions.

5 Summary of key navigational impacts

This section gives a summary of the identified navigational risks which have been identified in relation to the deployment of the WEC. More details on the navigational risks and the mitigation and monitoring measures can be found in the *Device-Specific Addendum to the EMEC Wave Energy Test Site Navigational Risk Assessment*.

The main risks identified and effects and results are the following:

Table 5: Identified navigational risks of WEC deployment

Risks identified	Effects / Results
Collision of WEC with other marine vessels or operator vessel	a. Damage of WEC b. Damage of marine vessel (→possible vessel sinking) c. Water ingress in device (→ WEC sinking possible) d. Man over board e. Mooring line damage/destruction (→ disconnection from the anchor possible; severe: free floating of WEC, becomes hazard for marine vessels) f. Damage electric cable g. Destruction of electric cable h. Disconnection WEC from electric cable
Man over board	a. Life threatening situation
Disconnection of tug line from marine vessel or WEC	a. Free floating of the WEC (WEC becoming hazard) b. Tug line becoming hazard (→ entanglement of tug line with marine vessel)
Entanglement of marine vessels with tug line	a. Marine vessels becoming hazard at sea (→ no navigational control over the vessel anymore; severe: collision of vessel with other marine users) b. Damage to ships
Significant drifting of the anchor	a. Misplacement of the WEC (not align with the coordinated given in Notice to Mariners
Uncontrolled surfacing of anchor	a. Main floater damage b. Entanglement of marine vessels in loose mooring lines c. Vessel damage (→ severe: sinking of marine vessel)

6 Project schedule

This section shows the project schedule of the one-year deployment project of the first full-scale WEC of Laminaria. It will be updated accordingly during the project.

Table 6: Project schedule

	Mar 18	Apr 18	May 18	Jun 18	Jul 18	Aug 18	Sep 18	Oct 18	Nov 18	Dec 18	Jan 19	Feb 19	Mar 19	Apr 19	May 19	Jun 19	Jul 19	Aug 19	Sep 19
Manufacturing																			
Third Part Verification (Risk Analysis)																			
Third Party Verification (Structural Analysis)																			
Third Party Verification (End Results)																			
Manufacturing WEC																			
Manufacturing anchor																			
Assembly (WEC and anchor)																			
Permits and Licensing																			
Marine Licence Application																			
Project Information Summary																			
Project-Specific NRA																			
Project-Specific MP / ER																			
Vessel Management Plan (VMP)																			
Construction Method Statement (CMS)																			
Deployment preparation																			
Mobilisation of marine vessels																			
Towing of WEC to Scotland																			

	Mar 18	Apr 18	May 18	Jun 18	Jul 18	Aug 18	Sep 18	Oct 18	Nov 18	Dec 18	Jan 19	Feb 19	Mar 19	Apr 19	May 19	Jun 19	Jul 19	Aug 19	Sep 19
Installation / Operation phase																			
Installation of WEC																			
Cable connection																			
Commissioning																			
Video Survey																			
Recovery and re-installments of the WEC																			
Decommissioning phase																			
Disconnection of cable																			
Decommissioning of the WEC																			
Towing of the WEC to next deployment location																			