Development and demonstration of an automated, modular and environmentally friendly multi-functional platform for open sea farm installations of the Blue Growth Industry

D7.4 – Health and Safety Manual

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LIST OF ACRONYMS AND ABBREVIATIONS

AIS	Automatic Identification System
AUV	Autonomous Underwater Vehicles
BGF	Blue Growth Farm
DAU	Data Acquisition Unit
EC	European Commission
ERP	Emergency Response Plan
ESSS	External Surveillance and Security System
GA	Grant Agreement
GUI	Graphical User Interface
HMI	Human Machine Interface
HVAC	Heating, Ventilation, and Air Conditioning
ISSS	Internal Surveillance and Security System
MSDS	Material Safety Data Sheet
O&M	Operation and maintenance
PPE	Personal Protective Equipment
PTZ	Pan, Tilt and Zoom
R&D	Research and Development
ROV	Remote Operated Vehicle
SHM	Structural Health Monitoring
SIMOPS	Simultaneous Operations
TCP/IP	Transmission Control Protocol/Internet Protocol
UPS	Uninterruptible Power Supply
WEC	Wave Energy Converter
WP	Work Packages

APPLICABLE DOCUMENTS

[AD1] European Commission, Directorate-General for Research & Innovation, Grant Agreement Number 774426 The Blue Growth Farm (GA-2018-774426), 2018.

[AD2] Technical Annex I to the Grant Agreement Number 774426: "Description of Work", April 2018, Part A and Part B.

1. INTRODUCTION

The present report has been produced in the framework of Task 7.4 (WP7) activities of the Blue Growth Farm contract [AD1], [AD2].

Within the scope of WP7, is to produce design of the Blue Growth Farm multi-purpose platform, taking advantage of return of experience from the experimental campaign carried out on the outdoor prototype, , technical input and indications coming from the environmental assessment as well as suggestions and recommendation resulted from workshops with marine users and interested stakeholders, the assessment of the Health and Safety procedures for safe use of the Blue Growth Farm and related production systems is the object of the present document to report about.

In particular, Health and Safety Engineering (HSE) and management is a vital function in modern industrial plant and it has to be established to handle HSE-related issues across the Project Lifecycle, in close collaboration with other functions such as Engineering, Procurement, Construction, Commissioning / Start-Up, Maintenance. Health and Safety requirements and recommendations for the Blue Growth Farm are here identified and characterised for the operative tasks planned to be carried out during the operative life of the BGF multipurpose platform. In particular, H&S requirements and solutions to be adopted involve use of onboard technologies, from energy harvesting devices O&M tasks, to aquaculture production and maintenance, to logistic and shipping operations, making reference to international norms, codes and standards.

1.1.1 System overview

The main composition of the BGF full scale configuration infrastructure is reported in Figure 1-1. In particular the infrastructure is composed of:

- A semi-submersible type floating platform based on industrialized modular concrete caissons' technology suitably joined to form a monolith assembly. This floating platform is 210 m long by 162 m wide. The platform is kept in position in typical water depth of 100 m (max 200 m) by multiple sea-bed anchors, occupying approximately 0.9 x 0.9 km (≈ 80 ha). A Structural Health Monitoring (SHM) system installed at critical areas of the platform enables a continuous monitoring of structural deformation leading to a better knowledge of environmental loading history experienced through the entire life.
- An industrial aquaculture system, based on 6 net cages (50 x 50 m), which are protected over three edges of the concrete caisson platform, being the fourth more transparent to waves to enable an appropriate internal re-circulation and dispersion of waste from the pool. The 6 cages guarantee a fish production of 2.000 tonnes/year of salmon, sea-bass or sea-bream (depending on environment). The net cages, which are hung on the structure, are kept in position and open by weights at their bottom. Net cages extend to 35 m below sea-level, being the first 20 m protected by the monolithic infrastructure. The presence of the protective service platform opens opportunities for system automation and management not normally available to offshore fish farms. As well, all activities that are carried out manually on current systems by operators staying on workboats aside the aquaculture plant are sited on the BGF platform with the support of service cranes. Other routine operations, such as net cleaning and repair, fish grading and vaccination, and the fish harvesting, processing, packing and storing, are greatly simplified by automation.
- A complex set of offshore energy production system is equipping the BGF platform. It is composed of a DTU 10 MW wind turbine technology, different WEC technology devices (evolution of REWEC patented solution) and PV panels located on the roof of the infrastructure operations building located in the aft side of the platform. As the BGF platform is conceived to be oriented along a predominant wave streaming, both wind tower and WEC are installed on the front side of the platform. Additional WECs

can be also considered for installation over the two longitudinal sides of the floating platform, depending on the wave characteristics of the installation site, as well as on economic considerations. The WECs are embodied in the reinforced concrete caissons, so they are integral part of the monolithic structure. Whilst protecting the internal pool of the structure from the incoming waves by absorbing part of their energy and transforming it into electric energy, WECs also protect the water sheet into the platform (for fish cages) from green water and overtopping. The produced electric energy makes the infrastructure energetically independent. Electric energy services for battery recharge of service vessels are also provided. The excess of energy left from the BGF operations is transferred to the land grid via the umbilical cable.

- An Automation & Control system interfaces the different systems of the multipurpose platform. The system provides real time interaction with the instrumentation for monitoring water and environmental parameters, electrical energy production systems, fiber-optic sensors for monitoring structures, the complete automation of fish feeding system, the surveillance and navigation safety system. With specific reference to the aquaculture automation and control, modern aquaculture automation technology is asked to enable real time estimation of total number of fish and size distribution, biomass control, selective breeding in parallel to environmental monitoring and biological indicators. In particular, the aquaculture automation enables a) a better feed management, including performance monitoring, including benchmark cage / population data; b) continuous automated monitoring to optimize farming operations & fish welfare, based on continuous automatic environmental monitoring (i.e. oxygen, chlorophyll, algae, etc.) in order to assess fish reaction to different farming operations and environmental influences; c) data measurement to quantify juvenile quality (morphology, physiology, health, stress); d) monitoring of anomalies and deviations from desired standard; e) data measurement to improve disease diagnosis. All information coming from sensors and cameras are directed to the Local Control Room, placed on BGF infrastructure operations building. The Control Room System is composed of servers and terminals to enable local supervision and control when the platform is manned. The Remote-Control Room, which hosts a copy of information available onboard, allows a real time monitoring of all functions running onboard when the platform is not man-operated (e.g., when access to platform is not safe due to exceptional weather conditions). Overall subsystems control by means of machine learning techniques (BGF_AQUARES) enables early alerting on anomalous trends of specific parameters under monitoring.
- An offshore electric substation provides with all the power conversion equipment to collect wind turbine, wave devices and PV panels produced energy and suitably transform it in order to distribute and adequately supply all electric loads installed onboard and to dispatch to onshore the electricity excess.
- A set of capabilities to enable shipping operations required to accomplish the following tasks: a) daily operations carried out by a regular staff assisting the onboard production; b) periodic controls and maintenance activities to all systems onboard; c) fish feed stock loading; d) fish production and harvesting; e) other functions like waste recovery to land, transport of produced microalgae to Clients, hosting specialised activities by suppliers' (e.g., assisted diving operations of inspection to the mooring and anchors on seabed, etc.). An assisted docking / undocking facility is placed along the aft side of the platform, thus benefitting from the calmer sea conditions. This platform is equipped with a charging system to serve full electric or hybrid propulsion-based vessels / boats providing services to the platform.
- A logistic sub-infrastructure to enable all platform operations, represented by the two-levels aft side building, sized 110 m length x 12 m width x 6m height, to allocate three distinct functional zones: a) living (manned area); b) functional area; c) electric substation area. The living (manned area) hosts all

human operations, including the supervision and control activity deployed at the Local Control Room located in the Control Tower. The functional area accommodates a composition of specific volumes and related devices to support the BGF infrastructure fish production and management, in terms of Fish feeding, Fish feed storage (silos), Fish health monitoring, including a clinical diagnostic laboratory, Oxygen production and distribution, and micro-algae production. Operations support functions are deployed in terms of: potable and sanitary water production, Fire-fighting pumping, Ballasting pumping, HVAC conditioning, workshops (including a divers store, equipment store, net store, spares parts store, and electro-mechanical laboratory for maintenance and repairing tasks). The platform deck operations are mainly limited to the fish farming tasks (net maintenance, fish harvesting, etc.) by means of deck cranes, maintenances of energy harvesting devices, off platform operations based on ROVs (BGF installation environmental monitoring, inspection and survey to the submerged structures, maintenance to the navigation safety devices, etc.) and on small boats lifted by vertical landing structure placed on the right side of the platform (for instance to enable small operations by staff within the pool).

- An integrated set of Surveillance and Security system (SSS) in charge of ensuring the physical integrity of the platform and of the people involved in its operations / maintenance. In particular, a) the External Surveillance and Security System (ESSS), combining surveillance Radars, AIS and long-distance cameras to produce a real time picture of navigation traffic far from the BGF installation and in particular vessels approaching the platform to monitor eventual unexpected events (accidental or deliberate actions) and to provide prompt or early alert; and b) the Internal Surveillance and Security System (ISSS) integrating a smart security network of cameras to implement access control of operators and surveillance of accuracy in carrying out tasks in safe conditions, thus promoting adequate behaviour during platforms operations. Navigation safety devices, according to applicable normative and to conform to the National Maritime Authority competent for the installation area are implemented in the BGF infrastructure design. Data managed at Local Control Room level are transmitted to the Remote Local Control (onshore) by redundant means: a) Fiber optic line (through the umbilical cable); b) Data transmission system (radio link). In particular, the Local Control Room monitoring videos are predominantly transmitted "through the umbilical" connection and only some information is replicated on the radio link, via satellite, thus enabling an overall traffic of 500 Mbit / s.

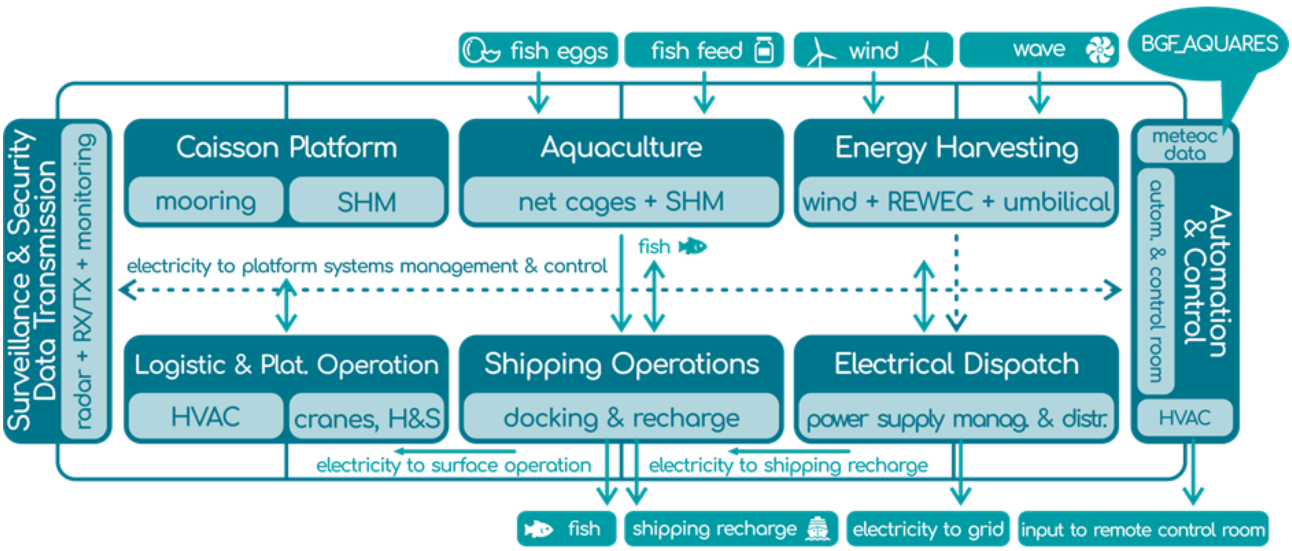

Figure 1-1. The BGF full scale configuration architecture

1.1.2 BGF infrastructure 3D model

The snapshots of the overall 3 D infrastructure model, which describe how the overall infrastructure looks like, are given in the following Figure 1-2.

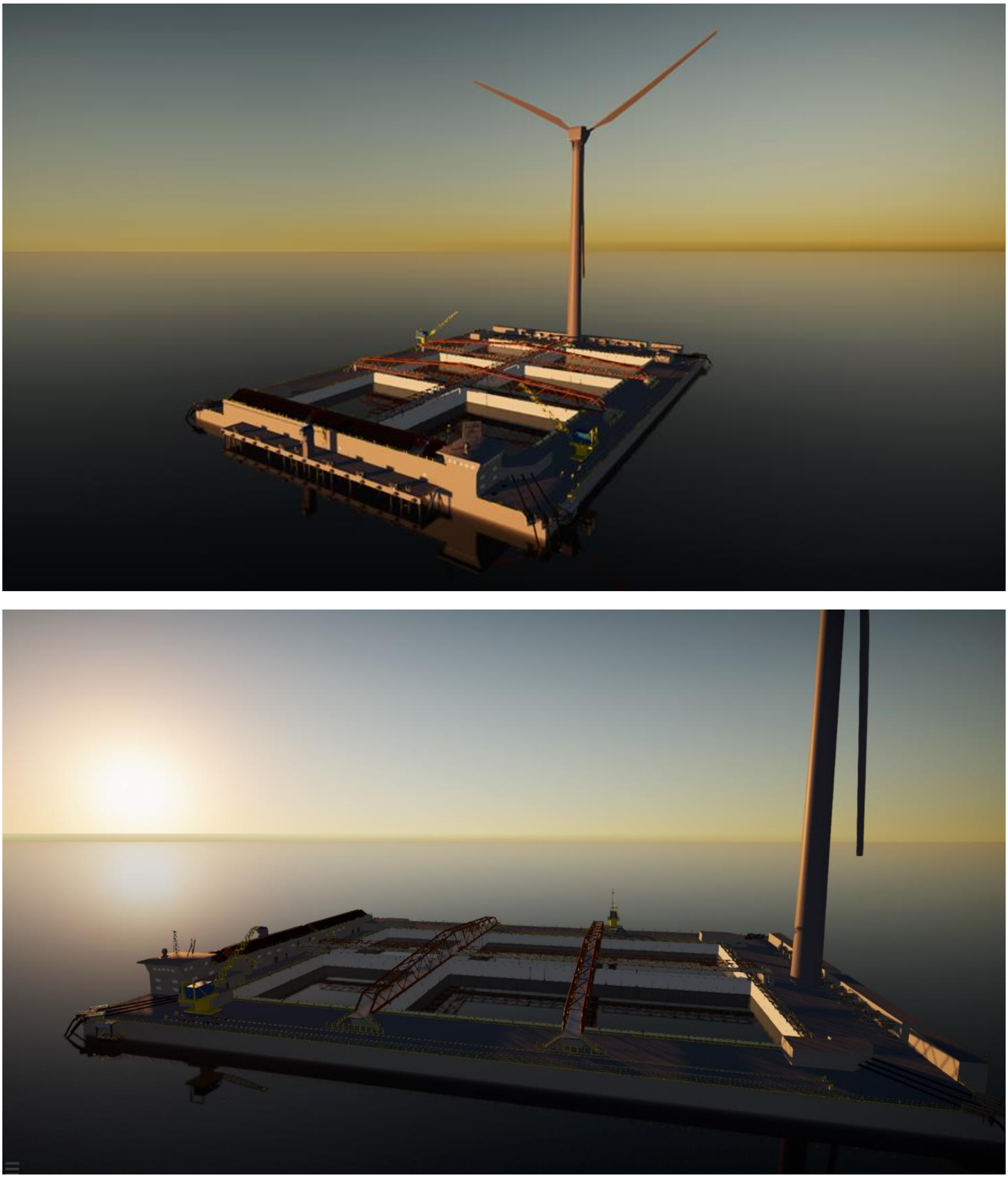

Figure 1-2. The BGF full scale 3D model (snapshots)

1.2 Interfaces of the Blue Growth Farm System

A map of the overall sub-systems interface is described in Table 1-1.

Table 1-1. Sub-systems interface matrix

	STEEL CAISSONS PLATFORM	AQUACULTURE	ENERGY HARVESTING	AUTOMATION AND CONTROL	ELECTRIC DISPATCH	SHIPPING OPERATIONS	LOGISTICS AND PLATFORMS OPERATIONS	SURVEILLANCE AND SECURITY DATA TRANSMISSION
STEEL CAISSONS PLATFORM		X	X		X	X	X	X
AQUACULTURE	X						X	
ENERGY HARVESTING	X			X	X		X	X
AUTOMATION AND CONTROL			X		X			X
ELECTRIC DISPATCH	X		X	X			X	X
SHIPPING OPERATIONS	X							
LOGISTICS AND PLATFORMS OPERATIONS	X					X		
SURVEILLANCE AND SECURITY DATA TRANSMISSION	X			X	X		X	

1.3 Identification of the document and its structure

The present document is identified as Deliverable D7.4 "*Health and Safety Manual*" of the Blue Growth Farm Contract [AD1], [AD2].

The contents of the document are organized according to the following sections:

- Section 1 contains the introduction to the present document;
- Section 2 reports a summary of BGF integrated functions description;
- Section 3 gives an overview of the applicable legislation on occupational health and safety and of the main hazards present at the Blue Growth Farm infrastructure;
- Section 4 reports about health and safety practices and provisions;
- Section 5 reports the conclusion of the document;
- Section 6 lists the quoted references.

2 SUMMARY OF BGF INTEGRATED FUNCTIONS DESCRIPTION

A synthetic description of subsystems functions as integrated in the BGF infrastructure is provided in the following paragraphs:

- § 2.1 BGF infrastructure production;
- § 2.2 BGF infrastructure services.

2.1 BGF Infrastructure production

2.1.1 Aquaculture and harvesting systems

2.1.1.1 Automated feeding system

The fish feed in the form of pellets is contained totally in eight silos (HxLxW 14.45 m x 4.5 m x 9.1 m), separated by feed size and nutritional characteristics (juveniles and adult fish) for an overall amount of up to 2.000 tons. The silos will be filled by fish feed boats, either using a bulk-bag and crane lifting system, or by pumping feed by a dedicated air blower and hose from the supply vessel.

The feeding system architecture is based on (Figure 2-1):

- a feed blower, which generates the air pressure to transport the feed from each silo;
- a cooling system, which guarantees to cool down the compressed (1 bar overpressure max) air as well as surrounding components from a max 120°C to a minimum (25°C) acceptable before it reaches the dosers;
- dosers, which are used to transfer feed into the air flow. According to the need, both feed doser valves and feed augers with gate valves are provided;
- selectors, which represent the connection point for the HDPE feeding pipes;
- rotor spreader, which guarantees correct feed spread in cages. It is composed of lightweight aluminium rotor pipes that allow for lower air speed for start-up and rotation;
- air control system, which is installed between the air cooler and the feed doser. It allows for real time measurement of airflow, back pressure and temperature, ensuring optimal feed handling, as well as reduced risk of malfunctions (the lower the speed, the higher the risk of pellet breakage and pipe blockage; the higher the air speed, the higher the dust formation and pipe blockage);
- smart control, which is based on a control SW tool (Figure 2-2) enabling a remote monitoring of the feed system, on the basis of the environmental sensors data and videos from the feeding cameras;
- cleaning feed pipes, represented by an injector installed between the air control and the first doser in the feed line. It works as an entrance for the cleaning plugs that collect condense and feed parts and general waste out through the feed hoses.

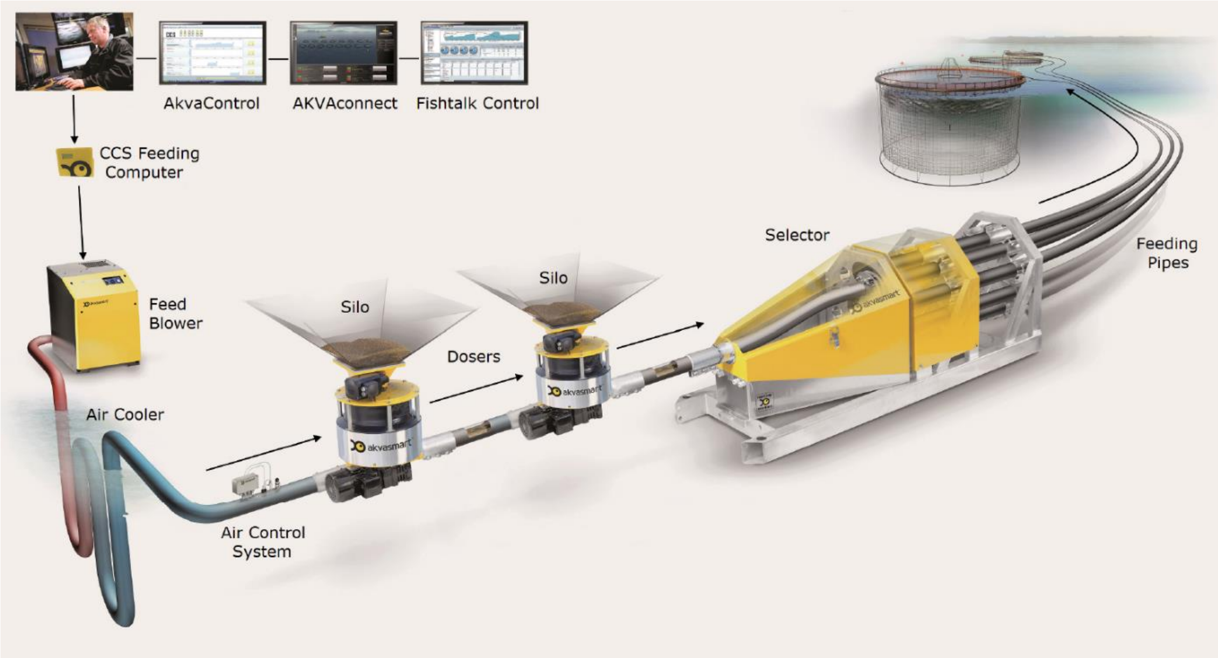

Figure 2-1. Feeding system characteristics

Figure 2-2. Feed levels management SW graphical interface

Ambient conditions inside the caisson and silo (moisture) (Figure 2-3) are normally monitored, in terms of temperature and humidity. The feeding system is programmed on a daily basis for the optimal amount of feed at each feeding time. The system can handle a certain number of feed lines running in parallel to supply a different number of net pens. All operations are automatically managed from the automation and control system, but the operator may switch the process to manual mode from the Local Control Room whenever appropriate.

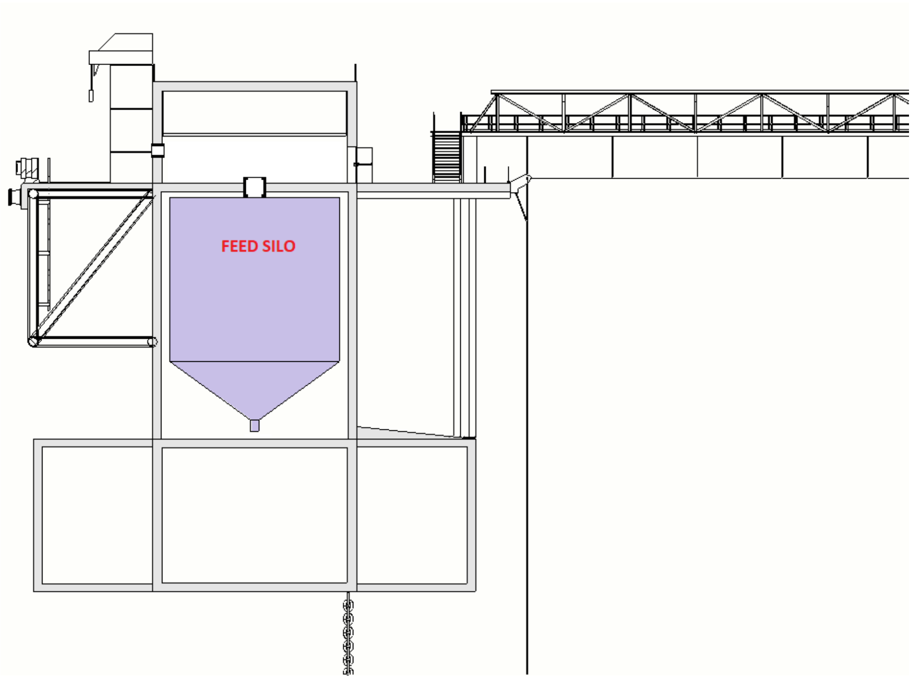

Figure 2-3. Feed Silo positioning

Feed Dozer Valves (FDV) are used to transfer feed into the air flow (Figure 2-4). These components are similar to rotary valves used in solids storage and transport, but they are specifically designed to carefully and accurately transfer the pellets down to the feed pipe, minimizing the dozer clogging risk and causing minimum pressure contact and pellet damage. The pellets are transported in controlled separate doses from the silos to the feeding pipe below, and then they are blown out to the cages.

Figure 2-4. Feed dozer valve

Feed Selector Valve (Figure 2-5) is the connection point from the HDPE feeding pipes and the hoses that distributes feed to the cages and allows selection of cage to be fed.

Figure 2-5. Feed selector valve

One rotor spreader (Figure 2-6) distributes the feed on cage surface. The rotor is constituted by an inflatable buoy, a bottom stability weight attached to a subsea pole, and the distributor pipe that rotates moved by air pressure. Smooth rotation is ensured by a stainless-steel ball bearing.

Figure 2-6. Feed distribution system – Rotor spreader

The feed system software foresees the feeding regime based on accurate monitoring of fish average weight, numbers, appetite (by cameras monitoring) and environmental data (oxygen, water temperature, current).

2.1.1.2 Net cleaning

The net system is automatised thanks to a ROV based assembly (Figure 2-7). Filtered high pressure sea water is used to remove marine fouling on the nets, using rotating cleaning discs mounted on support frames in various shapes and combinations. High pressure pumps are used to drive the cleaning discs.

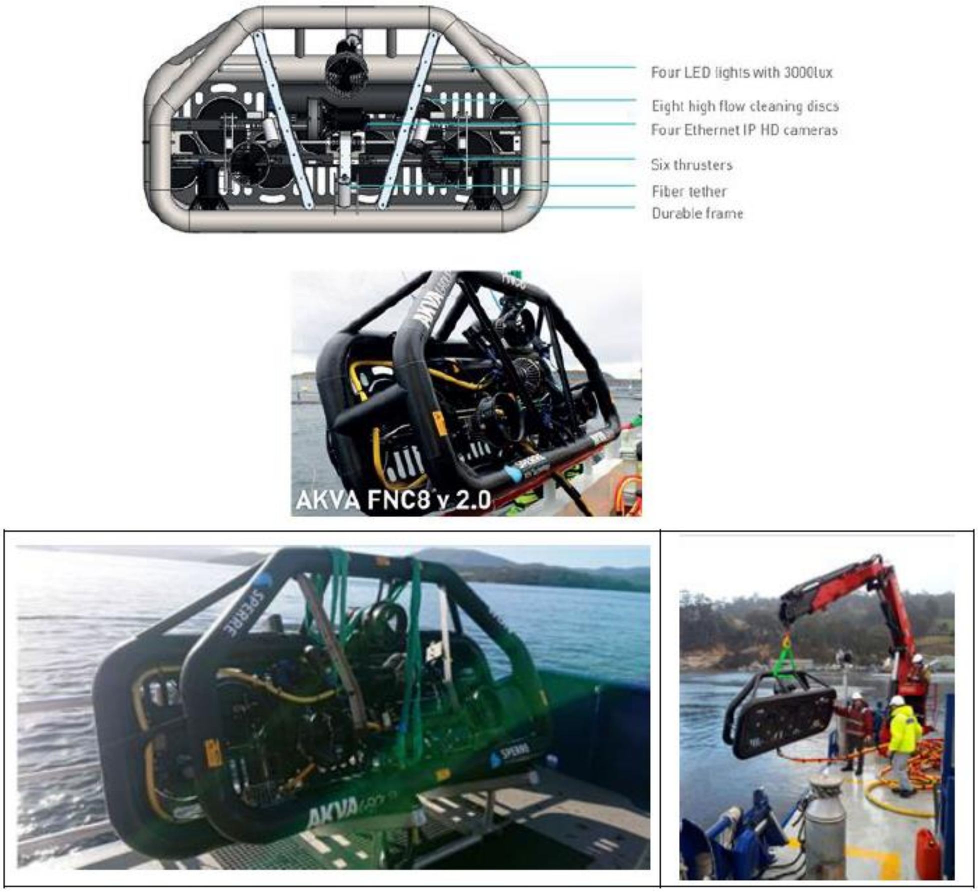

Figure 2-7. Feed distribution system – Rotor spreader

2.1.1.3 Fish state monitoring system

A continuous automated monitoring system is provided to ensure the maximum fish welfare, based on the control of biometric variables and management of safety devices for the fish farm. The system can log all the collected data showing real-time status of fish farm and the history trend of the observed variables. Artificial Intelligence (AI) solutions are available to correlate fish welfare to the ambient and fish specific conditions. These solutions are easily integrated with existing hardware at the site for fish and water state monitoring.

All real-time data (values, device status, alarms) is collected and presented to the operator with a graphical overview of the current fish welfare status to enable prompt intervention.

2.1.1.4 Sea Lice Treatment

The BGF pool is protected by the concrete caissons-based platform, which offers a primary barrier, considering that the natural habitat of sea lice is in surface waters, from around 0 to 10 m depth. Nevertheless, a risk remains so systems need to be in place bot reduce that risk and, in case of occurrence mitigate its severity.

One such solution is provided by a pump, which filters large quantities of seawater through a specialized filter. Water is sucked through the holes in the top of the device and lice and algae are caught in the filter bag below (Figure 2-8). It captures lice at every stage of the organism' life cycle – from larvae to mature lice. During crowding and delousing, it collects any lice that detach from the fish, thus preventing the louse from finding a new host. Furthermore, the device also collects algae and other particles, e.g., debris from net cleaning, ensures increased circulation inside the cage and filters seawater, which promotes good gill health.

Figure 2-8. Sea lice collector

The BGF platform is equipped with sensors (pool cameras) that can help identifying lice eggs on the surface thus, to enable prompt reaction by the collector. The collector system also provides real-time information on the filter's condition, thus providing useful information on the presence of lice eggs from start of filtering following the alert received by the BGF sensors.

Artificial intelligence can help in better addressing by risk mapping of sea lice eggs formation in the concerned area based on ambient characteristics. In case of sufficient data for the concerned site are available and a correlation between causes and effects (sea lice eggs) are established, the collector system can also be used continuously during the most critical periods identified by the sea lice risk mapping.

If, despite the above, sea lice levels exceed those recommended for good fish welfare, then the preferred treatment option is to the pump the fish to a wellboat for in-tank bathing in a proprietary treatment product or by warm water bath, and then pumping them back to the holding cage. To achieve this, the fish will be concentrated in one half of the pen by lifting it from one side and the empty half of the net dropped back into the water to make a receiving section for treated fish.

Should any other parasitic infections occur e.g., AGD in salmon, Sparicotyle chrysophrii in sea bream, Dactylogyrus in bass, the treatment regime would be like similar to the above i.e., pumping to wellboat tanks for bath treatment.

The risk of the most common bacterial and viral diseases in salmon, bream and bass can be avoided by stocking only fully vaccinated juveniles. However, should any bacterial infections occur, they can usually be resolved by in-feed antibiotic treatment which can readily be programmed into the automatic feeding system.

2.1.1.5 Fish position sensors

A system reporting net positioning underwater under the effect of wave/current is required to address the fish behaviour under the different conditions they may experience in the BGF pool (Figure 2-9). A series of acoustic beacons are positioned at the net bottom and connected to a submerged acoustic receiver on the platform. This latter records the signal from beacons and transmit it to a 2.4 GHz hub that will dispatch them to a SW processor, which provides sensor positioning over a 3-D map. In particular, the surface camera (1), underwater stereo **video camera** (2) and **sonar system** (3) produce data on the fish within a sub-volume in the cage (delimited by dashed lines for each system), the **acoustic telemetry** system (4) collects data on the individual fish carrying acoustic transmitters regardless their location in the cage.

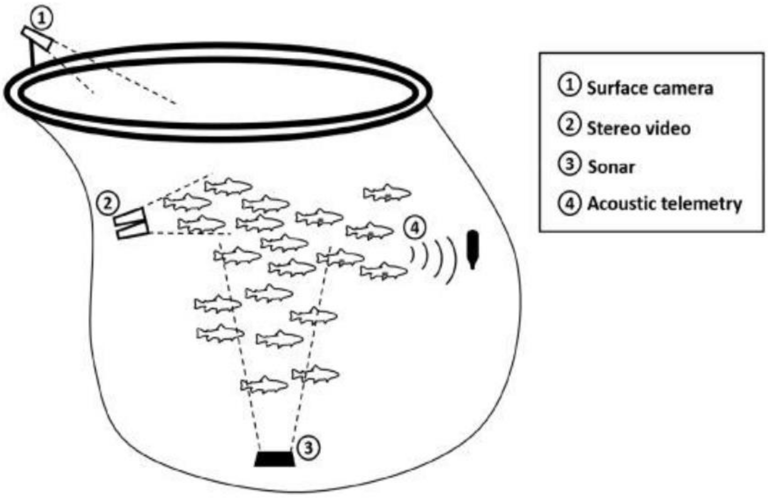

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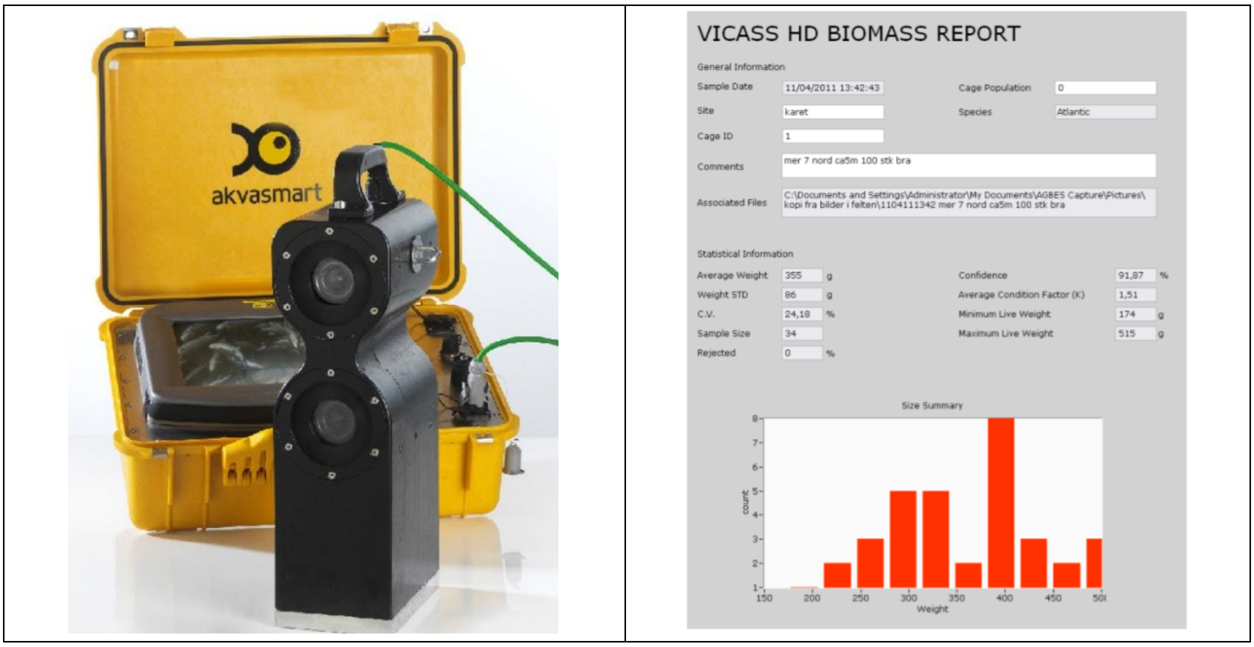
Figure 2-9. Fish position sensor scheme

2.1.1.6 Fish Sizing Systems

Biomass estimation is carried out through Video Image Capture and Sizing System (Figure 2-10). This camera measures live fish average weight; it is accurate fast and does not cause stress to the fish. A stereoscopic video image measures the height and length of each fish while it is swimming in the cage. Advanced geometry algorithms specific for the particular fish species accurately estimate the live weight of the fish and provides a detailed biomass report which includes accurate size distribution graphs. The output from the sensors is fed directly into the fish feeding control system to allow the quantities and sizes of feed fed to each population to be constantly updated in real time.



Camera Fish sizing report

Figure 2-10. Fish sizing system characteristics

2.1.1.7 Cage monitoring cameras (on platform)

Cameras with a high optical zoom capability are mounted at the 4 corners of the platform to monitor water surface from air predators (birds), fish appetite and feeding visual control, the correct operation of the feeding system, fish swimming and jumping behaviour, sea lice or other sickness sign, as well as the human activities and safety of staff working around the cages.

2.1.1.8 External anti-predator nets

Six top nets are deployed to provide a continuous protection from external aerial predators, especially pelagic birds. They are anchored at bridge level from one side and at deck level from the opposite side. They are easily retractable to enable operations on fish nets.

The net rolling and unrolling task is automated in order to reduce human effort, with specific rail guides being placed at the interface with bridge and deck. A switch sensor communicates the Local Control Room about the state of opening and closing of the net panels.

2.1.1.9 Dead Fish collecting system

A conical bowl (mort cone) provided with a ballast weight is used to collect dead fish from the bottom of each cage (Figure 2-11).

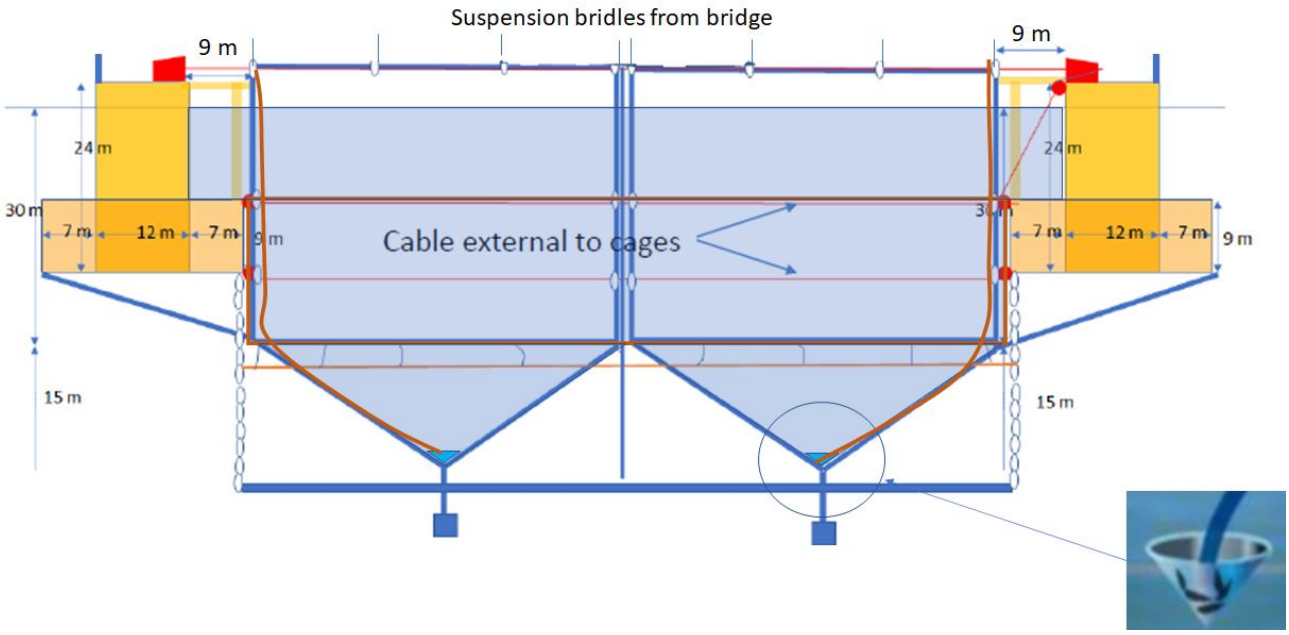


Figure 2-11. Dead fish collecting system characteristics

The collection system is operated by sending pressurised air through a hose into the top of the mortality collection cone assembly. As in an airlift pump, the air mixes with the water in the up-pipe lowering its density so this low density water/air mix rises to the top of the pipe creating suction which pulls water and dead fish from the cone into the pipe and upwards with the rising water to the dewatering separator at the surface. At this interface a simple automatic count records the number of mortalities removed from the cage and transfers this information to the local control room.

This mortality handling system can be used continuously, avoiding the accumulation of any mortalities within the cage thereby reducing the risk that predators damage the net whilst attempting consume the morts. It also reduces the risk of parasites and diseases that may have contributed to the mortality from being readily transferred via cannibalism to other fish in the cage.

A container for ensiling the dead fish is housed at platform level. This system features: 1) a rotating knife grinder for reducing the size of the dead fish, designed to handle the whole fish; 2) a plastic material acid tank with dosing pump to keep pH around 4 or below and two storage tanks (the first is used whilst the second is being emptied or awaiting emptying, capacity 8000 l) made in stainless steel. All components are connected by a stainless-steel piping and managed through a control panel.

Figure 2-12. Dead fish treatment system characteristics

2.1.1.10 Harmful organisms

The BGF multipurpose platform is conceived for offshore installations (in the range of 10-12 nautical miles). In this environment in some typical coastal marine, as well as eutrophic areas, threats like toxic algae and blooms are not considered applicable because the basic hydrological conditions for their priming and development do not occur, and the basic condition of water confinement is also missing. As well, the open sea condition eliminates the risk of being contaminated by other compounds of pharmaceutical origin, sulphonamides, other antibiotics, disinfectants etc..

2.1.2 Onboard energy production systems

The BGF infrastructure represents a single marine infrastructure using combined wind and wave generation with the objective of optimize the utilization of the resources of WEC and wind turbine and the energy implementation, such to become a self–sustaining farm. In order to maximise the energy produced on site a PV farm has been also considered to be placed on top aft side, where it is unlike to be reached by sea waves.

The electric flow scheme generated by BGF infrastructure is described in Figure 2-13.

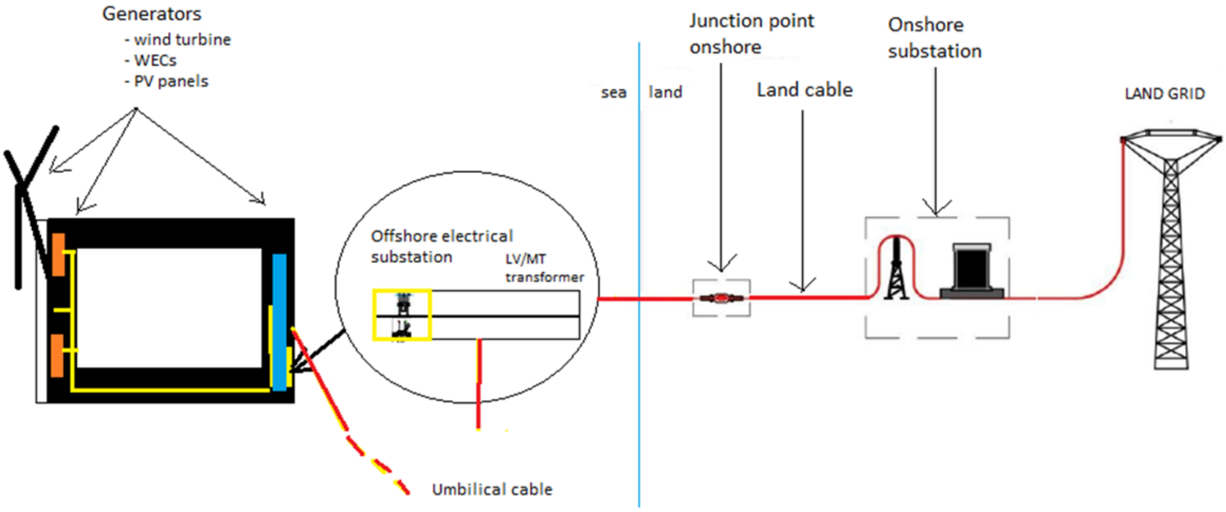


Figure 2-13. Electric flow scheme of the BGF infrastructure own energy production

2.1.2.1 Wind Energy system

The wind energy generation is designed to obtain the real power from the wind resources of the prevailing wind direction, and it represents the main energy production of the platform. For the reason of the present investigation, the application case of the 10 MW DTU turbine reference (Figure 2-14) has been considered in order to be exploit all information already published and available on the subject, otherwise impossible is making reference to a commercial technology.

Description	Value
Rating	10MW
Rotor orientation, configuration	Upwind, 3 blades
Control	Variable speed, collective pitch
Drivetrain	Medium speed, Multiple stage gearbox
Rotor, Hub diameter	178.3m, 5.6m
Hub height	119m
Cut-in, Rated, Cut-out wind speed	4m/s, 11.4m/s, 25m/s
Cut-in, Rated rotor speed	6RPM, 9.6RPM
Rated tip speed	90m/s
Overhang, Shaft tilt, Pre-cone	7.07m, 5° , 2.5°
Pre-bend	3m
Rotor mass	229tons (each blade ~41tons)
Nacelle mass	446tons
Tower mass	605tons

Figure 2-14. Key parameters of the DTU 10MW RWT

The DTU 10-MW reference turbine assumes a medium-speed permanent-magnet generator (PMSGs) with an estimated efficiency of 94%. In terms of power conversion, several options are available, yet it is anticipated that direct-drive turbines with permanent-magnet generators will have the greatest applicability offshore.

Nevertheless, since the evolution of commercial wind turbine is well progressing also on the offshore sector and production efficiency is growing whilst roughly maintaining similar geometric characteristics, the BGF infrastructure will accommodate any best technology available in the near future according to the market opportunities (see for instance SIEMENS GAMESA and XALIADE-GELECTRIC 14 MW wind turbine solutions, which offer an increase in Annual Energy Production (AEP) more than 25% compared to its predecessor (10 MW) in similar conditions).

2.1.2.2 Wave Energy system

The technology used in the BGF project to capture wave energy is the Oscillating Water Columns (OWC). Their major advantage when compared with other technologies is the simplicity of the energy conversion mechanism: waves induce oscillations of the water column into the semi-submerged chamber and thereby force a reciprocating airflow through an orifice located in the air chamber. This airflow is transformed into electricity by means of a turbine-generator group.

The REWEC3 technology employed in the BGF multipurpose platform covers the wave-to-electricity chain in three stages (Figure 2-15). The primary conversion is from wave to pressurized air. The secondary stage is transforming the mechanical energy to rotatory energy of the turbine shaft, and the last stage is converting the mechanical rotation into electric power through electric generators.

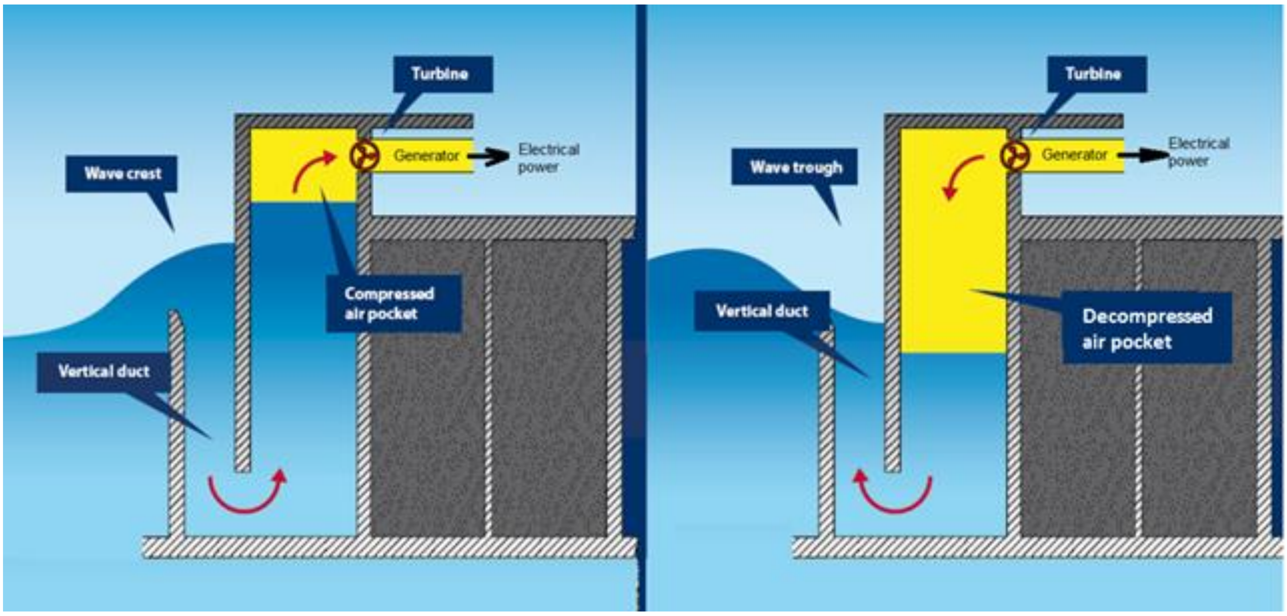


Figure 2-15. REWEC3 technology scheme for floating applications

Since the air alternately flows from the chamber to the atmosphere and back, self-rectifying air turbines, whose rotational direction is independent of the direction of the air flow, are usually employed. Different types of self-rectifying turbines have been developed over the years. The turbine is used to drive the shaft of the electric generator, with generator producing variable frequency and variable amplitude AC voltage.

2.1.2.3 Photovoltaic system

A contribution to the solar energy generation onboard BGF infrastructure has been considered to support electric consumption of the microalgae production system and the sea water desalination. The photovoltaic panels (N_p= 700, Panel type: SPR-220-BLK-U Solar Panel from SunPower) are installed on the aft building roof, along its entire length.

2.1.3 On site oxygen generation and distribution

To cope with temporary dissolved oxygen scarcity in the pool water due to extreme adverse weather conditions in the summer time, a oxygen stock availability is secured onboard (Figure 2-16), ready to be pumped within the first 5-10 m of water depth (Figure 2-16) to improve fish welfare.

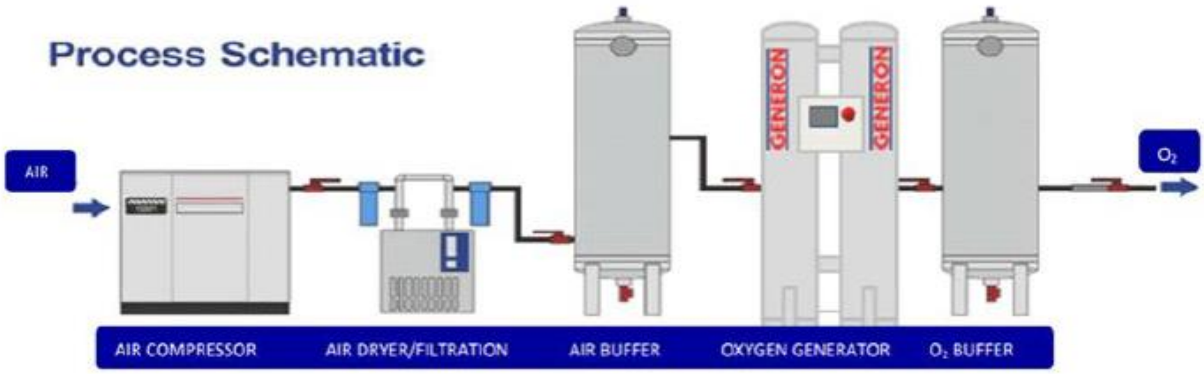


Figure 2-16. Oxygen generation process characteristics

Figure 2-17. Oxygen distributor

2.1.4 Microalgae production system

Production of microalgae at aquaculture sites, although presently ongoing in 13 European countries, is still at an early stage of development in Europe in terms of production volumes and number of production units. Nevertheless, containing not only high levels of protein and essential fatty acids, microalgae also offer great potential as an ingredient in formulated aquaculture feeds, and for direct use in hatcheries for rearing live feed organisms (zooplankton) or for greening larval tanks.

The case of BGF application, one technology solutions is to install photobioreactors systems (PBR's) supplied in containerised form (20" or 40" foot (6,10m or 12m x 2,44m x 2,59m) as shown in Figure 20. Here all the equipment necessary for the cultivation of microalgae under optimized conditions of light, temperature, and pH (main factors) are integrated in a turn-key module. The algae produced will be held in a chilled tank ready for transport back to shore for processing. These PBR packages offer high productivity in a controlled environment, preventing or minimizing contamination in the culture media, while reducing the required labour and modulating the nutritional composition of biomass produced.

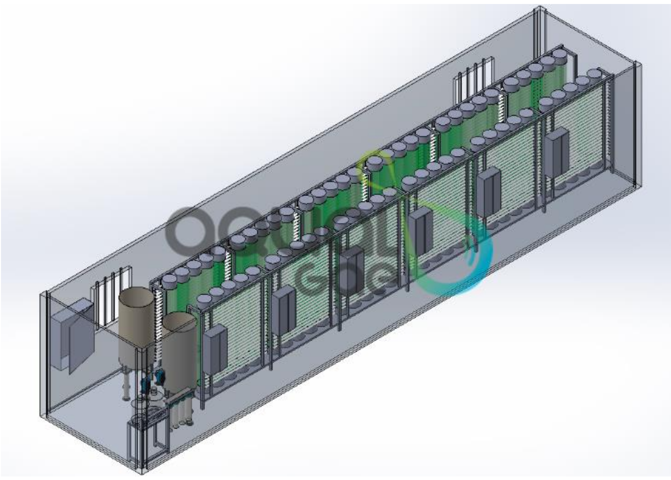


Figure 2-18. Photobioreactors integrated container

2.1.5 Desalinated water production system

Reverse Osmosis (RO) desalination system is employed onboard the BGF infrastructure to obtain fresh water from the sea (Figure 2-19). The reverse osmosis unit separates the salts still present in the water, generating a certain percentage of fresh water (permeate) and discharging the remaining concentrate. The ratio of permeate to concentrate provides a measure of the efficiency of the entire process, which increases as the size of the treatment plant increases.

The pre-filtration at the inlet eliminates all particles suspended in the water and reduces water turbidity, by passing through filters that physically retain them. This preventive process, with which a first improvement in the quality of the water is achieved, also has the important function of preventing the suspended particles, flowing directly to the reverse osmosis unit, could compromise its efficiency and effectiveness through time.

When necessary, a chemical pre-treatment section is added to prevent the formation of incrustations and inorganic fouling in the membranes of the reverse osmosis unit thanks to the use of appropriate chemical additives (anti-precipitants). This pre-treatment can be carried out with different solutions based on the type of water to be treated, having as its main objective that of making the raw water suitable for passing over the osmotic membranes.

The High Pressure (HP) pump gives the water the correct pressure required to access the reverse osmosis section. Pump characteristics and performances depend on the type of water to be treated (sea or brackish) and on the required production capacity.

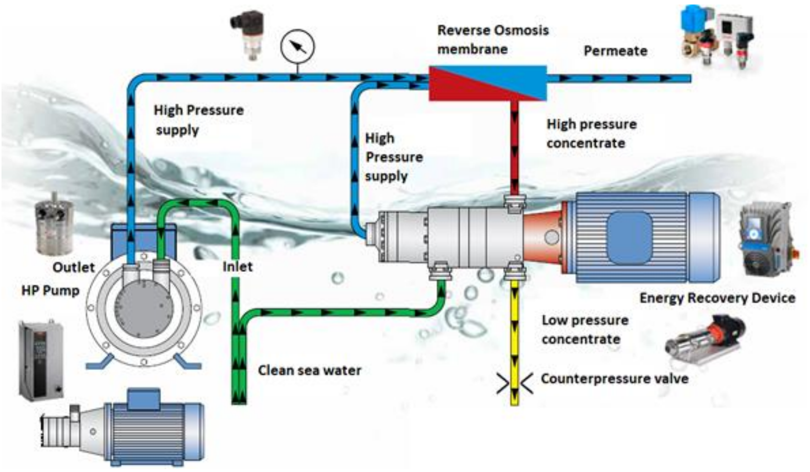


Figure 2-19. Reverse Osmosis process system architecture characteristics

The fresh water thus obtained can be further treated, if necessary, with a UV sterilization, which definitively reduces the bacterial and pathogenic load in general, followed by with a post-filtration with activated carbon, to improve the organoleptic characteristics or by a chemical post-treatment (chlorination, for example), for greater safety of conservation in storage tanks.

The entire process is managed by an electronic control unit and by a command & control instrumentation panel. The process can also be automated.

For the BGF application a potable / clean water production of 5 m^3/h (700÷1800 rpm, 13,7 kW at maximum pressure of 80 bars) is fitting the purpose of infrastructure operations, that includes use for the following needs: a) crew living areas; b) cleaning of surfaces / equipment; c) laboratory activities; d) microalgae production; e) cleaning of PV panels.

2.2 BGF infrastructure services

2.2.1 Mooring and anchoring system

The mooring system is composed of 12 mooring lines (3 lines per each platform corner) of 1,000 m length, connected to anchors at the opposite extreme. An optimisation analysis has considered the possibility to reduce this length up to 500 m, depending on the seabed characteristics. The maximum mooring tension in the chain line is 772 t, in intact condition.

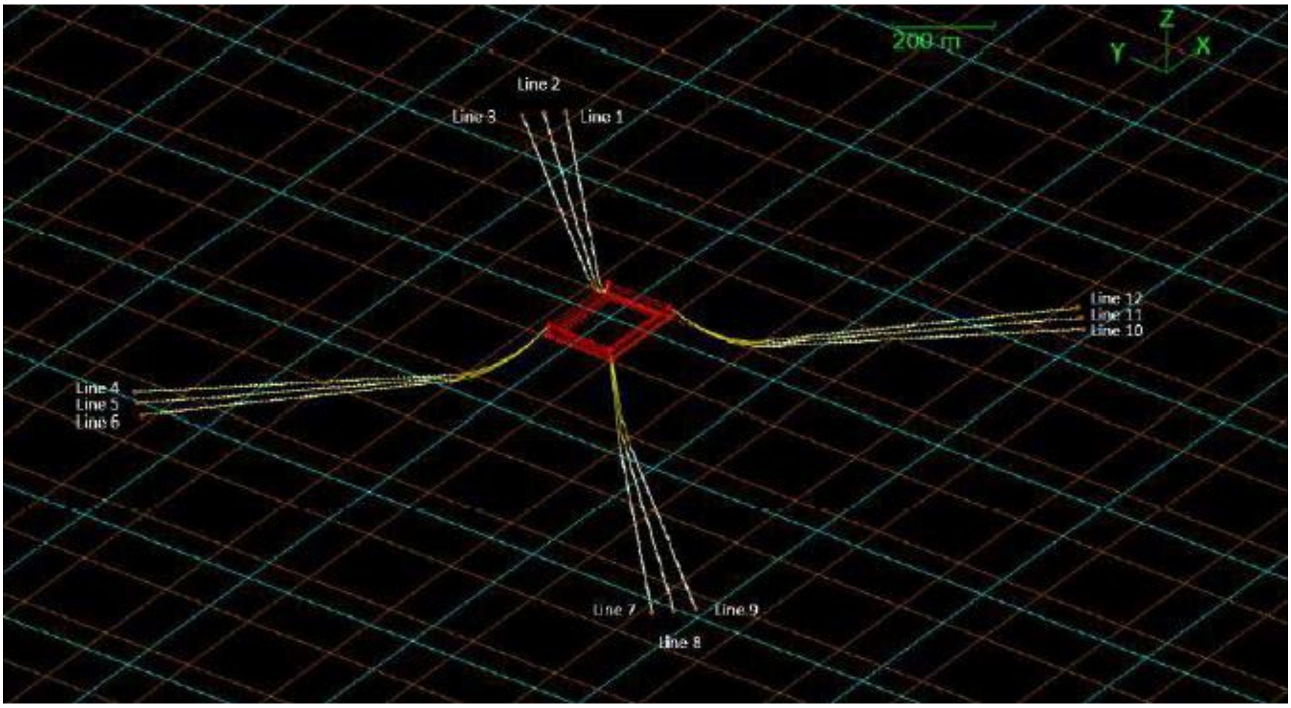


Figure 2-20. General mooring layout for the 12 mooring lines of the BGF platform

Two different anchoring systems are defined based on the seabed characteristics. The 30 t Stevpris Mk5 drag anchor is selected for typically sandy soils (Figure 2-21). Specific modular dead man anchor system is to be preferred when interfacing rocky soils.

Figure 2-21. Stevpris Mk5 drag anchor characteristics

2.2.2 Ballasting system (optional)

The water ballast system manages the water quantity inside the platform ballasting cells. Modalities to manage it are matter of platform customisation. The platform ballasting system is composed of a certain number of invertible pumps to balance the resulting 41,477 t resulting from the design. Because of the cost implications, the final decision about the nature of the ballasting function (passive or active) is left to the Customer decision.

2.2.3 Water state monitoring system

Water conditions are monitored both inside and outside the cage by means of dedicated sensors. In particular, the following variables are object of analysis: sea temperature, Dissolved Oxygen (DO), pH, salinity, Turbidity, Current speed and direction, Wave frequency and height.

Multiprobe sensors (Figure 2-22), pH and conductivity (Figure 2-23) and turbidity (Figure 2-24) are distributed at different points of the pool area as local water state measurements stations (Figure 2-25).

Figure 2-22. Multi probe sensor characteristics

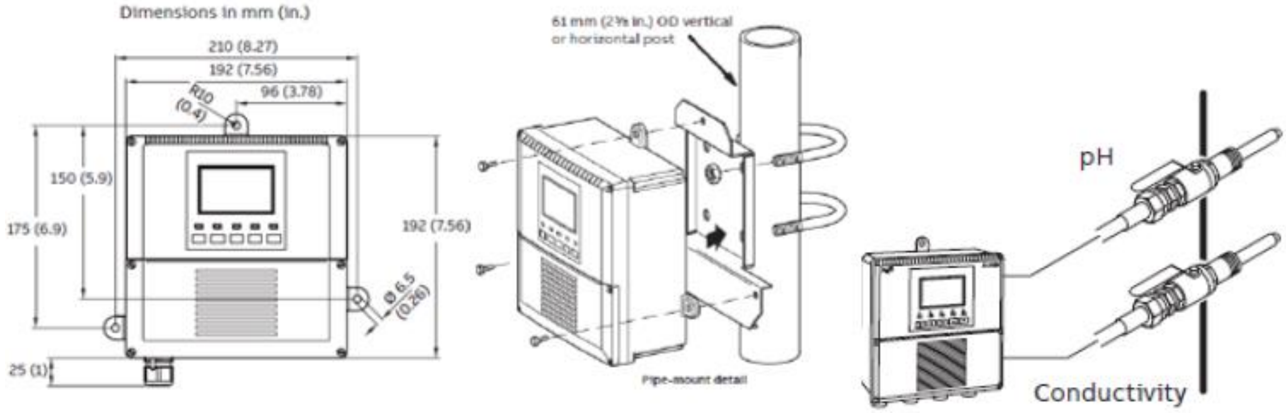


Figure 2-23. pH and conductivity sensor characteristics

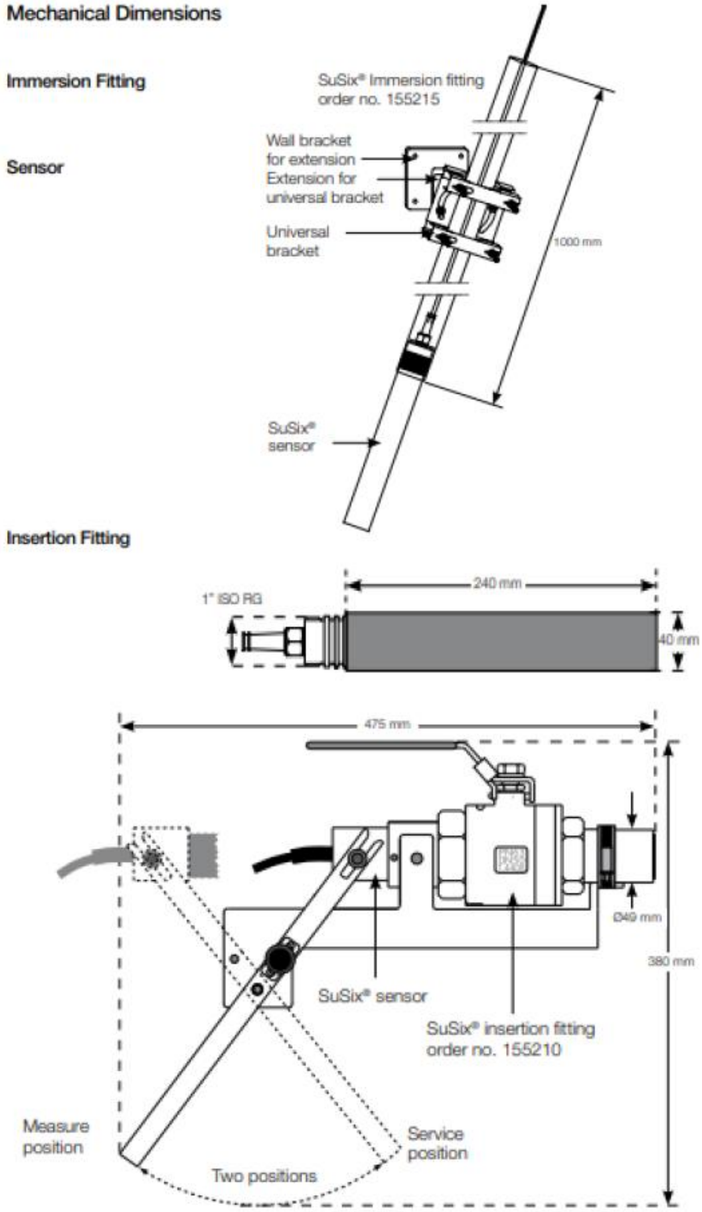


Figure 2-24. Turbidity sensor characteristics

Acoustic doppler current profilers as well as wave height, current and speed direction sensors are placed at specific points to measure the water movement within the pool.

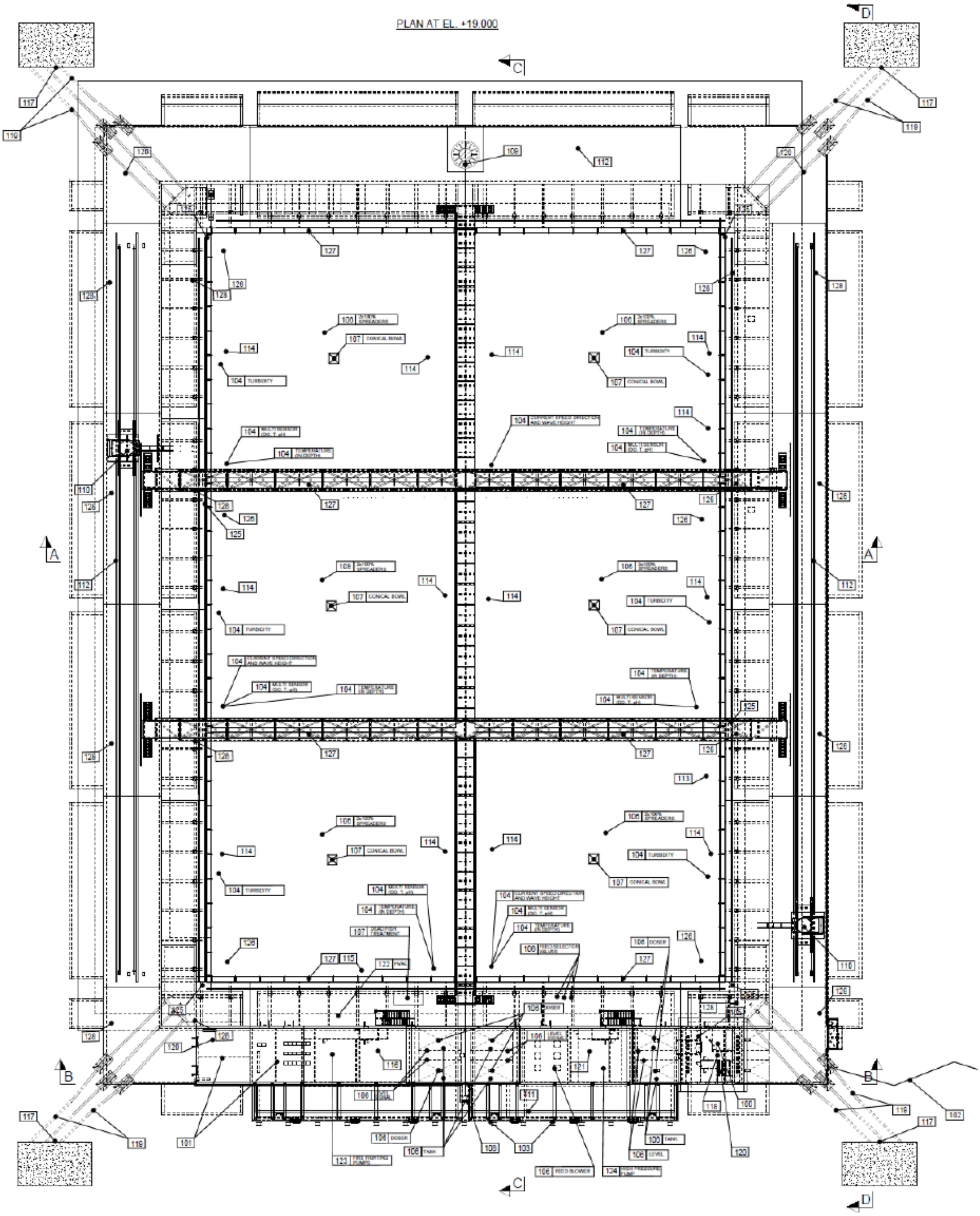


Figure 2-25. Water sensing distribution on the BGF pool

2.2.4 Recirculation system (optional)

The BGF platform configuration foresees a transparent aft edge to enable natural water surface recirculation once the platform is aligned parallel to the prevalent sea wave current. As well, deeper natural recirculation is expected to occur at 20 m depth of the platform draft. Nevertheless, in given circumstances the desired three water exchanges per hour in the pool needed to maintain healthy water conditions especially at the sea surface level that may not be guaranteed by natural water exchange alone. Water re-circulation pumps can be envisaged to guarantee a buffer capacity, for instance in case of less energetic waters. This system is considered then as optional, given that the dissolved oxygen replenishment (§ 2.1.3) is assumed to be sufficient for the majority of BGF infrastructure potential installations.

2.2.5 ROV (Remote Operated Vehicles)

In addition to the robotic device used for net cleaning, the BGF platform is equipped with two Remote Operated Vehicles (ROVs): a) one dedicated to underwater activities within the BGF pool and outside it, b) the second employed to broad inspection tasks related to the environmental monitoring.

The ROV considered for the above two applications is a portable device that can be managed by an operator from the Control Room. Remote control is carried out through copper or fibre optic cables. The device can be equipped with several built-in features, including advanced camera systems and sensors to perform various monitoring tasks, as shown in Figure 2-26.

Figure 2-26. Remotely operated vehicle (ROV) system characteristics

2.2.5.1 ROV for underwater platform activities

ROV for cleaning operations is equipped with a) one camera to visualize the net and the lower parts of the concrete caissons, b) navigation sensors, c) a scanning sensor for the seabed analysis around the anchors.

The ROV for inspection has also hydraulic manipulators used for simple jobs, like net checking, etc.

Additional device's capabilities include:

1. mechanical arm for specimens' collection. Collected specimens may be analysed directly onboard, within the control room if the necessary instruments are available or may be transferred onshore for laboratory analysis. Nevertheless, considering the significant presence of automatic instruments already installed in the proximity of the cages, this type of practice should be implemented only occasionally, for instance to meet regulatory requirements or where other specific information is needed;
2. acoustic sensors (e.g.: hydrophones), which can detect sound levels in the area of the BGF platform and can support an improvement of knowledge about noise emissions generated by the BGF installation, including the operation of its energy generation systems;

3. instruments (e.g.: probes) that measure water clarity, water temperature, water density, light penetration, and temperature to be used to perform measurements outside the cages and at the distance foreseen by the monitoring plan, where currently installed sensors cannot be effective.

2.2.5.2 ROV for environmental monitoring

ROV for environmental monitoring is managed via a service boat, which provides the required power supply through the umbilical cable. Main details about each inspection performed with the ROV are to be systematically recorded in an Excel file, including personnel performing the inspection, location of the inspection, time of inspection and main parameters observed (qualitative and quantitative) in order to carry out an exhaustive high-level monitoring database, especially of benthic communities, as foreseen by the monitoring plan. In addition to this high-level kind of data processing, a more specific analysis of images/videos recorded during the inspection is systematically implemented.

Data transfer from the ROV can be done either manually, by plugging the internal memory of the ROV to the desired laptop, or remotely by the dedicated software, in case the instrument is set for remote data transfer. However, in general, due to limitations in wireless technologies, communication is usually fed through the umbilical. The transmission mediums for communications are metallic conductors or fibre optics. The latter are beginning to become more prevalent in inspection-class ROVs.

2.2.6 Concrete caissons biofouling monitoring and removal system

Concrete caisson biofouling is monitored through ROV periodically (see §2.2.5). Whilst uniform settlement of biofoulers covering an entire concrete surface can protect the structure from deterioration, a nonuniform deposit can lead to severe localized pitting corrosion. Despite the concrete surface at direct contact with water is pre-treated with a protecting anti-biofouling thickness, the contrast to this phenomenon do not eliminate the corrosion problem but it can reduce it.

Control and biofouling removal is processed via ROV as well (Figure 2-27). It rapidly, safely and thoroughly cleans even damage-prone surfaces without clogging, or performance degradation regardless of water depth. Because of the regularity of the BGF submerged infrastructure, the ROV guidance is such to enable an automated accurate cleaning of concrete pre-treated surface. Nevertheless, compatibility of the rotary stress and friction mobilised by the technology with pre-treated surface characteristics has to be accurately verified in order not to endanger the treatment efficiency in reducing the attack from fouling.

Figure 2-27. ROV based technology for biofouling removal from submerged surfaces

2.2.7 HVAC and fire-fighting system

2.2.7.1 HVAC system

The Technical Building and the silos room are permanently ventilated / conditioned (temperature and humidity), whilst the Local Control Room is normally conditioned only when operators are onboard, with the exception of the server room.

The Air Flow System Control is in place to maintain the correct volumetric ratio of return air to fresh air.

Silos and Warehouses humidity is controlled via a desiccant dehumidification package.

2.2.7.2 Fire-fighting system

The automatic safety system intervenes in case of a fire event in conjunction with the fire-fighting system.

At Control Room level, a Fire Alarm Control Panel (FACP) displays the potential presence of a fire in each controlled area. Fire detection devices are provided in relevant areas of the platform for an early detection of any fire initiation and to suitably provide warning either at the local control room or at the remote-control room.

The following types of fire detectors are provided: a) Heat Detection Systems – Heat Sensitive Cable Type, b) Smoke Detection Systems – Optical High Sensitivity Temporized Type, c) Heat Detection Systems – Rate of Rise, d) Flame Detectors.

Manual call points are provided throughout the platform areas, connected in a common loop. Activation of any manual call point shall initiate a fire alarm. Manual alarm call points are installed at all passages corners.

The detection of a confirmed fire causes an emergency alarm status in the immediate area, as well as in the control room, and the activation of the sprinkler fire-fighting system.

2.2.8 Structural health monitoring (SHM) system

The SHM system enables real-time monitoring of the following structural platform parameters: a) local strain of the platform in the most critical sections; b) strain at modules joint level; c) inclinations (for measurement of the platform rotations); d) differential displacement (for global measurement of the platform deformability); e) accelerations and vibrations in three directions.

Typical sensors are shown in Figure 2-28.

Temperature sensor Tri-axial accelerometer

Figure 2-28. Typical SHM sensor characteristics

2.2.9 Electric dispatching system

The substation of the floating platform will collect the energy generated by the Wind Turbine (10 MW), Wave Energy Converters (1.2 MW max) and the Solar Energy Plant (0.154 MW) and will also power the platform itself and the electric boat recharging system.

An output at 33 kV is assumed but the details of the onshore connection point would require an in-depth analysis, so it is assumed that this voltage level is reached on the coast and the floating platform would be connected:

a) to an existing substation;
b) to a new substation.

The umbilical cable devoted to the excess electric energy transmission to shore presents the following characteristics:

- Voltage drop and power losses around 2%.
- Submarine cable data from ABB-Submarine Cable Systems[1] (Figure 2-29).

Cross-section of conductor	Diameter of conductor	Insulation thickness	Diameter over insulation	Cross section of screen	Outer diameter of cable	Cable weight (Aluminium)	Cable weight (Copper)	Capacitance	Charging current per phase at 50 Hz	Inductance
mm²	mm	mm	mm	mm²	mm	kg/m	kg/m	μF/km	A/km	mH/km
Three-core cables, nominal voltage 30 kV (Um = 36 kV)										
70	9.6	8.0	28.0	16	100.6	16.9	18.2	0.16	0.9	0.46
95	11.2	8.0	29.6	16	104.0	17.7	19.5	0.18	1.0	0.44
120	12.6	8.0	31.0	16	107.0	18.4	20.7	0.19	1.0	0.42
150	14.2	8.0	32.6	16	110.5	19.3	22.1	0.21	1.1	0.41
185	15.8	8.0	34.2	16	114.0	20.1	23.6	0.22	1.2	0.39
240	18.1	8.0	36.5	16	118.9	21.4	25.9	0.24	1.3	0.38
300	20.4	8.0	38.8	16	123.9	22.6	28.2	0.26	1.4	0.36
400	23.2	8.0	41.6	16	129.9	24.6	32.0	0.29	1.6	0.35
500	26.2	8.0	45.0	16	137.3	26.7	36.0	0.32	1.7	0.34
630	29.8	8.0	48.6	16	145.1	29.2	40.9	0.35	1.9	0.32
800	33.7	8.0	52.5	16	154.4	32.2	47.2	0.38	2.1	0.31

10-90 kV XLPE 3-core cables		
Cross section mm²	Copper conductor A	Aluminium conductor A
95	300	235
120	340	265
150	375	300
185	420	335
240	480	385
300	530	430
400	590	485
500	655	540
630	715	600
800	775	660
1000	825	720

Figure 2-29. 36 kV Cable data

[1] https://new.abb.com/docs/default-source/ewea-doc/xlpe-submarine-cable-systems-2gm5007.pdf

2.2.10 Offshore electric substation

The main components in the offshore electric substation are represented by:

- Five 36kV/630A Switch Unit for power cable inputs from Wind Turbine, WECs Clusters and the Solar Plant.
- One 36 kV/630A Circuit Breaker Unit connected to the Ancillary Services Transformer.
- One 33/0.42 KV 1250 kVA Ancillary Services Transformer.
- One 36 kV/630A Circuit Breaker Unit connected to the Reactive Power Compensation System.
- One 36 kV/630A Circuit Breaker Unit connected to the Energy Storage System.
- One 36 kV/630A Current and Voltage measurement Unit to control the energy flow between the onshore grid and the floating platform.
- One 36 kV/630A Circuit Breaker Unit to protect the submarine cable that connects the floating platform with onshore network.

2.2.11 Shipping operation systems

Shipping operations are required to accomplish the following tasks:

- Periodic controls and maintenance activities to all systems onboard;
- Fish feed stock loading;
- Fish harvesting.

Specific services to accomplish these functions are given by the:

- docking / undocking system;
- electric recharge system.

2.2.11.1 Docking / Undocking system

The BGF docking / undocking facility is placed along the aft side of the platform, as it is less exposed to predominant sea wave’s impact and, as well, easier to be accessed thanks to its lower-level protective wall. On the other hand, under this configuration the approaching vessel is subject to the sea water outflow from the aft windows.

Different typologies of vessels are expected to dock / undock from the Blue Growth Farm multipurpose platform, including Live Fish Carrier, Fish harvesting Vessel, Forage Carrier, and Support Vessel for logistics and maintenance. Additionally, a certain number a number of recreational electric engines-based vessels that could take advantage of the availability of the sea electric recharge station to recharge their batteries necessitate to find docking opportunities.

Six docking robot systems have been accommodated (Figure 2-30) to host a variety of service and specialised vessels approaching the platform. In particular, 25 m to 80 m length vessels are served through the different mobilisation of the docking elements (n. 2 for the shortest vessel, n.6 for the longest one). Combinations of docking approach are possible, depending on the vessel size and functions deployed, along the docking area length.

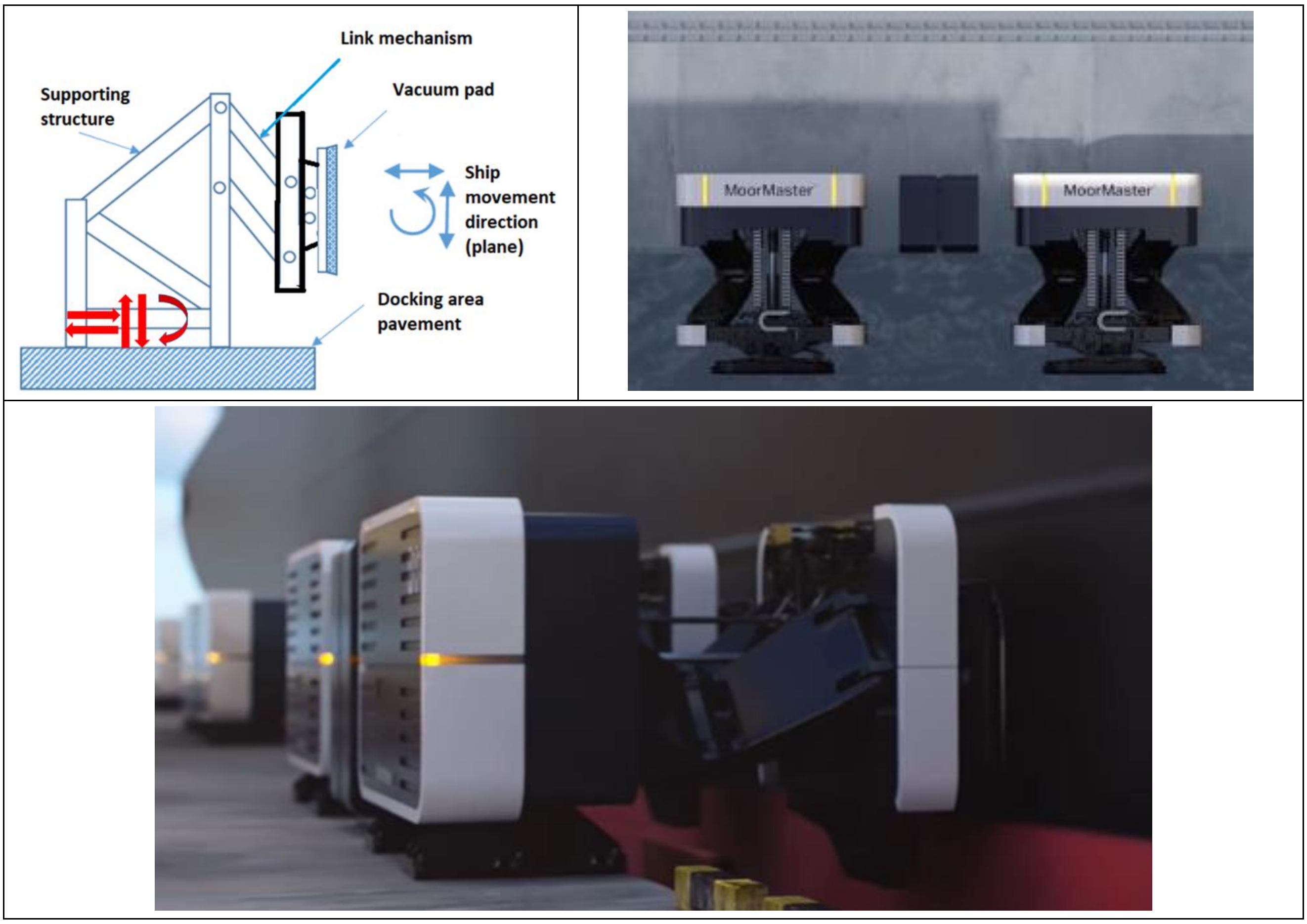


Figure 2-30. Docking robots' system

2.2.11.2 Electric recharge system

The electric recharge system enables electric or hybrid engine-based service vessels to recharge batteries when in safe docking conditions (Figure 2-31). The energy supply is supervised by the platform Energy Management System, which controls how much energy could be released without endangering the energy consumption needs for ongoing platform operations.

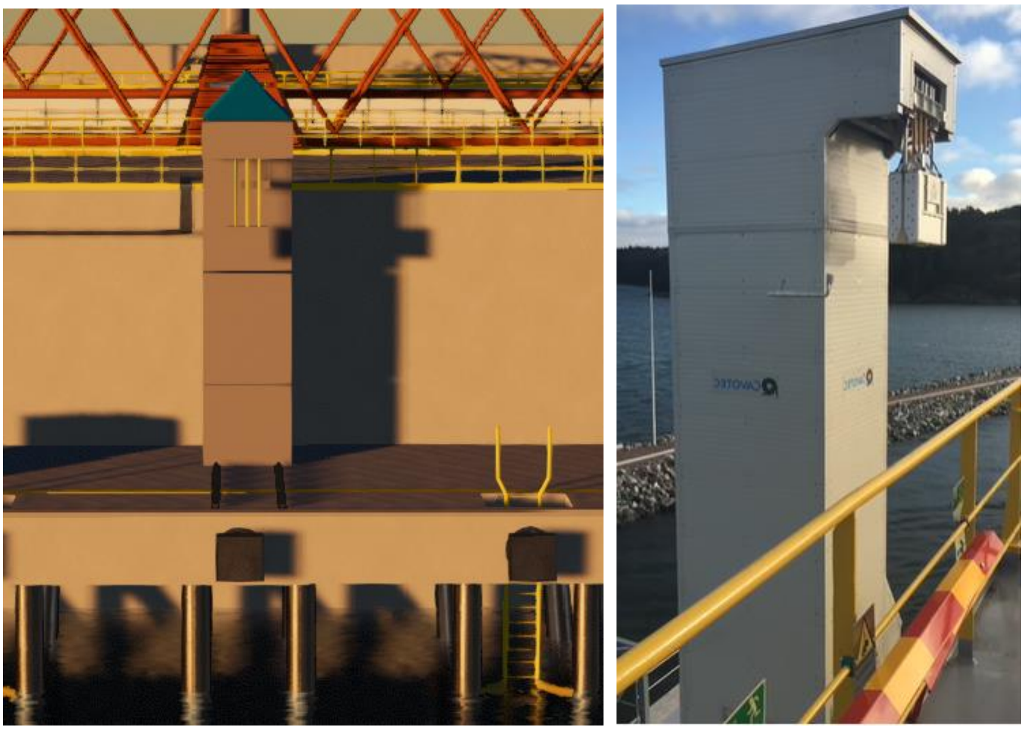
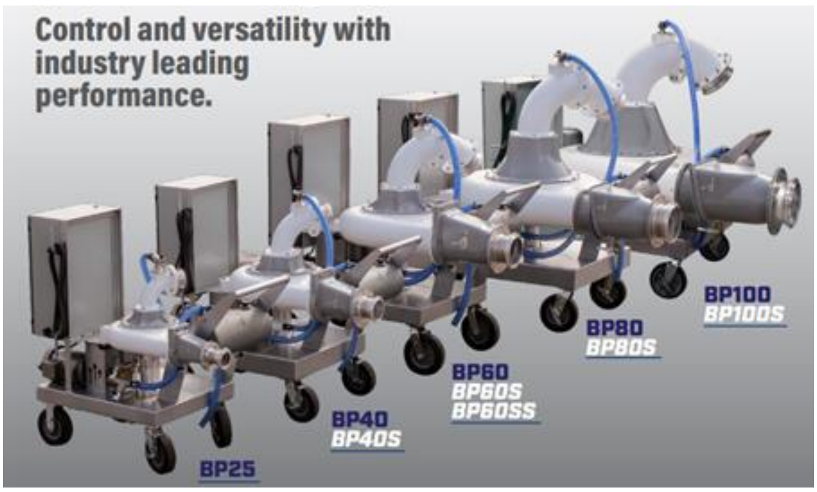


Figure 2-31. Electrical recharging tower

2.2.11.3 Fish loading / unloading

The loading or unloading system for fry and fish in / from the pool is carried out by using an articulated piping and dampers system with dedicated suction pumps.

Each cage is provided with a submergible flexible pipe that is immersed in the water during the loading / unloading operation. The flexible pipe is collected to the rigid pipe positioned on the inner edge of the platform and connects the pool area with the ship docking zone. Here, flexible tubing enables loading / unloading from ship by means of a transportable suction pump available on the platform or by a fixed pump placed on ship. Depending on the type of harvesting, downstream the pump, a fish / water separator as well as a fish weighting system is included (Figure 2-32).



	BP25	BP40 - S	BP60 - S - SS	BP80 - S	BP100
Intel/Outlet Size	2.5 in (65mm)	4 in (100mm)	6 in (150mm)	8in (200mm)	10in (300mm)
Main Pump Drive	2hp	3hp & 7.5hp	5hp - 7.5hp - 10hp	15hp & 20hp	25hp & 30hp
Priming Pump Drive	1hp	1hp	1.5 hp	1.5hp	1.5hp
Fish Pumping Cap	4 t/hr	8 t/hr	16 t/hr	24 t/hr	55 t/hr
Pump Output Max	170 gpm	480-807 gpm	800-1200-1500 gpm	2400-2700 gpm	3300-3900 gpm
Maximum Head	24.6 ft (7.5m)	29.5-46 ft (9-14m)	29.5-36-46 ft (9-11-14m)	29.5-36 ft (9-11m)	29.5-36 ft (9-11m)
Maximum Distance	300m	800m-3000m	600m-1500m-2700m	800m-2000m	700m-1500m
Maximum Avg Fish Size	95g	300g	600g	1.5kg	2.7kg

*limits and specifications vary depending on the application, species and setup. Specifications cannot be achieved simultaneously.

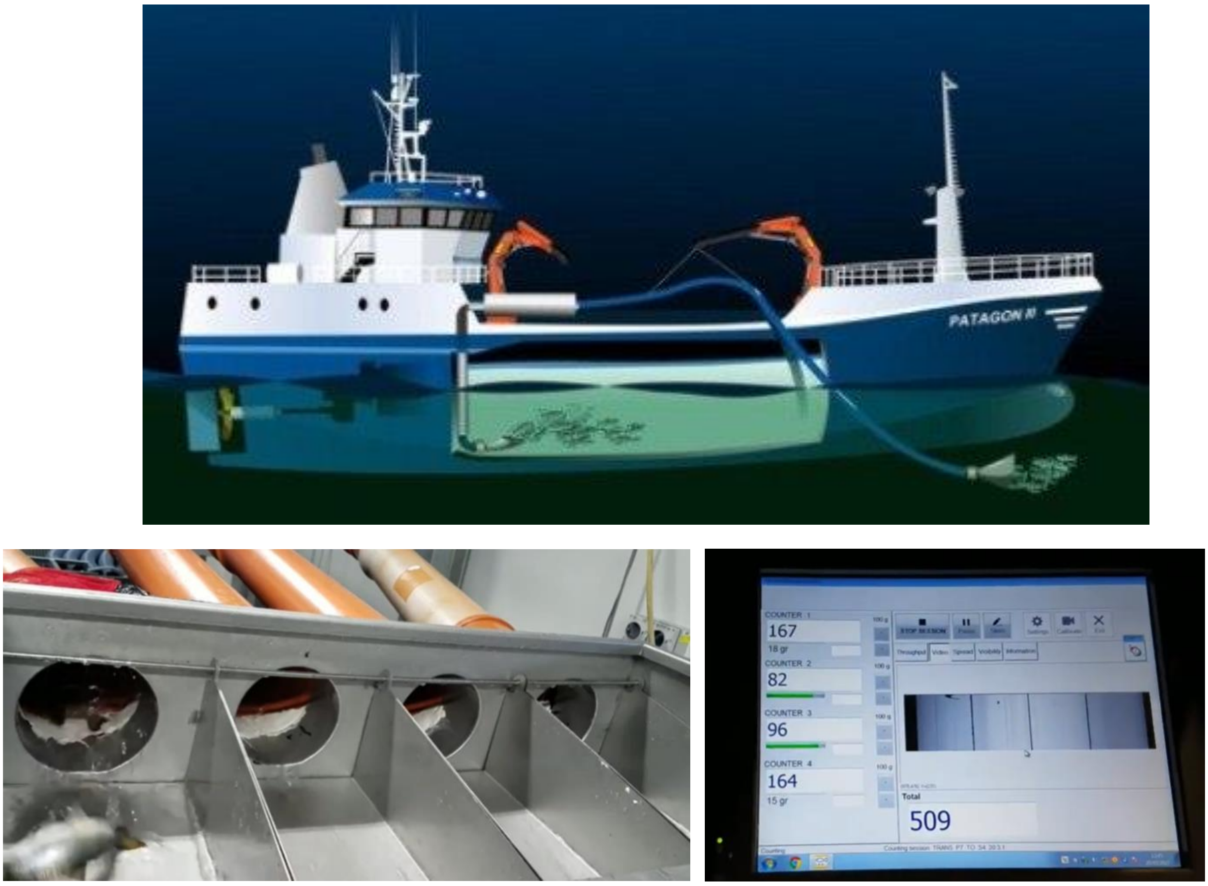


Figure 2-32. Fish pump system characteristics

2.2.12 Surveillance and Security systems

Surveillance and security systems are key elements for a multipurpose offshore platform as the BGF, which is not subject to a full-time human presence, but thanks to automatization and remote surveillance, it can be operated with less risk to humans.

Surveillance and security data are managed by the Local Control Room, under the monitoring of the Remote-Control Room (located on mainland), which receives processed data in real time. The aim is to ensure that the platform is always managed even when human access to the platform is not safe, for instance in case of harsh weather conditions.

Connection between the two control rooms is provided by means of the following links:

- the fibre optic cable which runs parallel to the umbilical cable;
- the BGF infrastructure radio channel.

An integrated system of radar and cameras enables the achievement of a real time picture of activities and vessels approaching the platform. The Surveillance and Security system oversees the physical integrity of platform and people involved in its operations and maintenance. In particular, a twofold technological approach has been defined:

- **External Surveillance and Security System** (ESSS), exploiting the integration of information of the surveillance Radars, AIS and long-distance cameras to provide an accurate surveillance of maritime traffic and to identify eventual unexpected events (accidental or deliberate actions).
- **Internal Surveillance and Security System** (ISSS), based on a smart security network of cameras to implement access control of operators and surveillance of accuracy in carrying out tasks under safe conditions, thus promoting adequate behaviour during platforms operations.

In the context of the ESSS, the long-range radar is responsible for detecting any vessel in the proximity of the platform as well as its movement pattern. This information is exploited to focus the PTZ long-range camera in such a way that the vessels are clearly visible and traceable.

On the other hand, the ISSS is focused to the security of the platform. For this reason, is designed as a more traditional video-surveillance /perimeter protection system. The key requirements are relevant to people safety, as well as critical structural components (such as wind tower).

2.2.12.1 Surveillance systems

Surveillance and transmission antennas that enable surveillance of the navigation system and the transmission of data to the remote-control room (onshore) are located on the roof of the Local Control Tower. They are constituted by:

- Surveillance radar.
- Long distance cameras.
- AIS (Automatic Identification System).

In particular, the radar system works in combination with long-distance cameras. This integration provides an accurate surveillance of maritime traffic, capable to include identification of potential intrusion by small boats approaching the platform.

2.2.12.1.1 Surveillance radar

The surveillance radar is responsible for detecting any vessel in the area around the platform, as well as its movement pattern. This information is used to guide the PTZ long-range cameras, towards the target, in such a way that the vessels become clearly visible and traceable (within the Line of Sight) (Figure 2-33).

Figure 2-33. Marine radar system characteristics

2.2.12.1.2 Long distance cameras

The external surveillance function is complemented by long distance cameras (Figure 2-34). They have PTZ (Pan, Tilt and Zoom) capability to be able to track a specific target selected by the operator based on alerts provided at control and surveillance console. In particular, the integration with the radar allows to obtain a higher level of maritime traffic surveillance capability, with identification of potential intrusion by small boats approaching the platform.

Both IR and video cameras feature powerful optical zoom lens allowing the operator to both detect and then zoom into the area of interest. Both thermal and video outputs are provided simultaneously. The aluminium housings are rated to IP67 and with appropriate anodization and powder coated to withstand harsh environmental conditions. Optical encoders ensure positional accuracy and are coupled to a self-correction system that automatically keeps the cameras in the desired position. The harmonic drive train is virtually zero backlash, eliminating image bounce as the camera pans between pre-sets.

Figure 2-34. Long range camera

2.2.12.1.3 AIS (Automatic Identification System)

The purpose of the AIS is to provide identification information relevant to the vessels that are present in the specified area. These mainly include Vessel Maritime Mobile Service Identity (MMSI code), unit type, position, course, speed. This information is displayed on the operator screen and used by the system to give an automatic alarm in the event of a potential collision risk is acknowledged. The transmitted data also allows maritime authorities to monitor the movements of the concerned vessels.

The AIS consists of a VHF transceiver connected to a positioning system, such as a LORAN or a GPS receiver, jointly with other electronic navigation sensors. The transmission takes place on two channels (87B and 88B) of the band intended for radio transmissions between vessels. The data are transmitted periodically using algorithms that allow avoiding the interference among the transmissions of the various units.

The symbol for every significant vessel within the radio range is visualized on a Radar screen or Electronic Chart Display system. Each symbol is characterized by a velocity vector (indicating speed and heading). Each vessel "symbol" can reflect the actual size of the ship with position to GPS or differential GPS accuracy. Ship name, course and speed, classification, call sign, registration number, MMSI and other information are discoverable simply by clicking on the vessel symbol. Manoeuvring information, Closest Point of Approach (CPA), Time to Closest Point of Approach (TCPA) and other navigation information, more accurate than information available from an automatic radar plotting aid, are also made available (Figure 2-35).

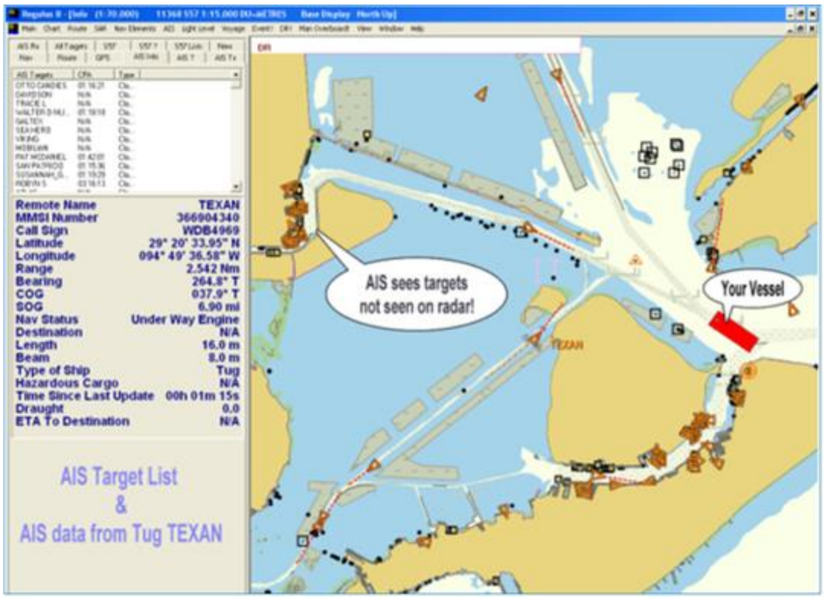


Figure 2-35. Target not visible to the Radar

2.2.12.2 Security systems

The internal surveillance of the platform is carried out by means of CCTV Camera system which include different type of sensors:

- PTZ Cameras Indoor/outdoor;
- Fixed Cameras Indoor/Outdoor
- camera in the visible spectrum;
- IR camera.
- Underwater cameras.

Each camera is connected, via Ethernet/optical fibre, to a network switch able to transmit a redirect the signals to the elaboration and recording unit.

ISSS is designed as a more traditional video-surveillance /perimeter protection system. The key requirements are relevant to people safety, as well as critical structural components (such as wind tower).

2.2.12.3 Access control

The access control is granted only to people with a specific badge provided by the BGF infrastructure operator. Everyone will have access only to the rooms necessary to carry out their work on the basis of the "Need to work" principle. Given the security needs of the platform, it is advisable to choose badges of the "Mifare" type at 13.56 MHZ.

When the badge approaches the reader, entering the radiofrequency field emitted by this, the two devices begin a secure communication session using shared encryption keys. When communication is established, the card transmits its data, after which the dialogue is completed.

2.2.13 Navigation safety

The Navigation Safety System is designed according to IALA Recommendation O-139 on Marking of Man-made Offshore Structures, which includes the offshore aquaculture farms in national waters. The marking is proposed to the National Maritime Authority, competent for the area, to obtain the authorization for the installation (formal communication).

According to its position with respect to the marine traffic, the special marks can be mounted in integration with Beacon radar through an anchored positioning at relevant position of in correspondence of the main sides of the platform. For the BGF installation a Radar beacon (short racon) is integrated in the fixed navigational mark, which works as a transmitter-receiver. When triggered by a radar, it automatically returns a distinctive signal that appears on the display of the triggering radar, providing range, bearing and identification information (Figure 2-36).

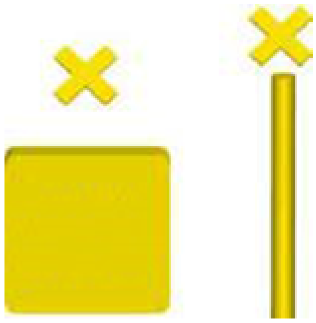


Figure 2-36. Special marks positioning with respect to the platform location

2.2.14 Data transmission system

Data managed at Local Control Room level are transmitted to the Remote Local Control (onshore) by redundant means:

- Fibre optic line (umbilical)
- Data transmission system (radio link).

2.2.14.1 Fibre optic cable connection

Taking advantage of the umbilical cable that electrically connects the BGF infrastructure with the grid on land, a fibre optic connection is easily deployed through this line to enable data transmission to the Remote Control Room. Therefore, basically, the monitoring of the videos of the control room is predominantly transmitted on the "umbilical" connection and only some information is replicated on the radio link.

Cabled data transfer for BGF infrastructure is based on a single-mode fibre as it has a significantly greater bandwidth than the multi-mode fibre. The single-mode cable supports connections over a much greater distance than the multi-mode cable reaching up to 40 Km and is therefore perfectly suited to the BGF application. It is, in fact, used in applications that require large bandwidth and in long-range network connections distributed over large areas, such as cable television and the creation of backbones.

VPNs is configured to control, at Remote Control Room level, equipment and devices within the Local Control Room. Virtual Private Network (VPN) technology routes the internet traffic through a VPN tunnel, which is an encrypted connection between the device and the destination on the web. A VPN tunnel not only encrypts the data, but it also hides the IP address and location. Like an armoured van, it takes a person from point A to point B in total secrecy, protecting the person against any danger lurking outside. It is necessary to install and update Antivirus software on Remote and Local locations. It is also advisable, in relation to the exchange of sensitive information, to use hashing and digital signature algorithms to be sure of the identity of the senders of the communications.

2.2.14.2 Radio link

The Radio link is designed considering 2 Mbps for each video flow to transmit (including Video radar). Considering that each video stream provided, as per design specifications, does not exceed 2 Mbit / s, it can reasonably be estimated that the overall video stream will not exceed 500 Mbit / s.

Therefore, the chosen antennas, in transmission and reception, has to respect the listed requirements. Based on this, the following design solutions for the BGF infrastructure is identified:

- SATCOM Systems: the connection is through a satellite link which, however, must allow overall traffic of 500 Mbit / s. The need to encrypt various information, in fact, weighs down the traffic produced.

3 OVERVIEW OF PRINCIPAL HAZARDS

3.1 Legal framework

This section outlines the principal acts and regulations that address the overall framework for health and safety management in aquaculture projects.

Many aspects of health and safety are subject to EU directives, the requirements of which are generally transposed and enforced into National legislations. The EU Framework Directive 14 on Safety and Health at Work, adopted in 1989, set out to guarantee minimum health and safety standards throughout Europe, while still allowing member states to maintain or establish more stringent conditions. Key EU health and safety directives, and the associated regulations, are listed in Table 3-1. Note that only the most relevant regulations are listed, as each directive may affect multiple sets of regulations.

Table 3-1: Key EU occupational health and safety directives and regulations

EU Legislative reference	Name	Scope
Framework Directive **(89/391/EC)**	Council Directive of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work	Introduce measures to encourage improvements in the safety and health of workers at work. It applies to all sectors of activity, both public and private, except for specific public service activities (e.g., armed forces, police or certain civil protection services).
Safety and health requirements for the workplace **(89/654/EEC)**	Council Directive of 30 November 1989 concerning the minimum safety and health requirements for the workplace	To lay down minimum requirements for safety and health at the workplace (given in Annex I and Annex II).
Work equipment **(2009/104/EC)**	Council Directive of 16 September 2009 concerning the minimum safety and health requirements for the use of work equipment by workers at work	This Directive lays down minimum safety and health requirements for the use of work equipment by workers at work.
Personal Protective Equipment (89/656/EEC) **Repealed by Regulation (EU) 2016/425**	Council Directive of 30 November 1989 on the minimum health and safety requirements for the use by workers of personal protective equipment at the workplace	This Directive lays down minimum requirements for personal protective equipment (PPE) used by workers at work.
Regulation (EU) 2016/425	Regulation (EU) 2016/425 of the European Parliament and of the Council of 9 March 2016 on personal protective equipment	The aim is to ensure common standards for personal protective equipment (PPE) in all Member States in terms of protection of

	and repealing Council Directive 89/686/EEC	health and the safety of users, while enabling the free movement of PPE within the Union. The Regulation applies to all sorts of PPE except, for example, for those used by armed forces, certain private uses of PPE, and the ones subject to other rules (e.g., PPE on seagoing vessels, motorcycle helmets, etc.).
Manual Handling of loads **(90/269/EEC)**	Council Directive of 29 May 1990 on the minimum health and safety requirements for the manual handling of loads where there is a risk particularly of back injury to workers	Minimum health and safety requirements for the manual handling of loads where there is a risk particularly of back injury to workers
Noise **(2003/10/EC)**	Directive 2003/10/EC of the European Parliament and of the Council of 6 February 2003 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise)	Define minimum requirements for the protection of workers from risks to their health and safety arising or likely to arise from exposure to noise and in particular the risk to hearing
Vibration **(2002/44/EC)**	Directive 2002/44/EC of the European Parliament and of the Council of 25 June 2002 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration)	Ensure health and safety of each worker and at creating a minimum basis of protection for all Community workers by timely detection of adverse health effects arising or likely to arise from exposure to mechanical vibration, especially musculo-skeletal disorders.
Temporary or Mobile Construction Sites **(92/57/EEC)**	Council Directive 92/57/EEC of 24 June 1992 on the implementation of minimum safety and health requirements at temporary or mobile constructions sites	Define minimum safety and health requirements for temporary or mobile construction sites i.e. any construction site at which building or civil engineering works are carried out and intends to prevent risks by establishing a chain of responsibility linking all the parties involved.

Safety and / or health signs **(92/58/EEC)**	Council Directive 92/58/EEC of 24 June 1992 on the minimum requirements for the provision of safety and/or health signs at work	Lay down minimum requirements for the provision of safety and/or health sign at work.
Medical treatment on board vessels **(92/29/EEC)**	Council Directive 92/29/EEC of 31 March 1992 on the minimum safety and health requirements for improved medical treatment on board vessels	Improve medical assistance at sea since a vessel represents a workplace involving a wide range of risks.
Machinery **(2006/42/EC)**	Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast)	This Directive applies to machinery; interchangeable equipment; safety components; lifting accessories; chains, ropes and webbing; removable mechanical transmission devices; partly completed machinery.
Risks related to chemical agents at work. **(98/24/EC)**	Council Directive 98/24/EC of 7 April 1998 on the protection of the health and safety of workers from the risks related to chemical agents at work	To lay down minimum requirements for the protection of workers from risks to their safety and health arising, or likely to arise, from the effects of chemical agents that are present at the workplace or as a result of any work activity involving chemical agents.
Carcinogens or mutagens at work **(2004/37/EC)**	Directive 2004/37/EC of the European Parliament and of the Council of 29 April 2004 on the protection of workers from the risks related to exposure to carcinogens or mutagens at work.	This Directive covers the protection of workers from health and safety risks from exposure to carcinogens or mutagens at work.

3.2 Hazards related to production systems

Once operational, the BGF infrastructure is daily operated and maintained by a reduced crew, taking advantage of the large use of automation and control capabilities, as well as the availability of mechanical means onboard. When the ambient conditions are such to make access unsafe, the BGF infrastructure is monitored and operated by remote. All the mentioned measures significantly contribute to reduce the exposure of BGF workers to hazards.

3.2.1 Aquaculture

The principal hazards can be divided over five categories according to [R4]:

1) physiological (work design),

2) physical,
3) chemical,
4) biological,
5) psychological.

These categories are described in Table 3-2.

Table 3-2: Occupational hazards associated with aquaculture

Categories	Exposures	Potential Consequences
Physiological (work design)	Heavy lifting, prolonged standing, awkward postures, repetitive motion, overexertion, lack of visibility	Low back pain, neck and shoulder pain, bursitis, tendonitis, tenosynovitis, carpal tunnel syndrome
Physical	Slips and trips, falls from height, falls overboard, transport and trucking, machinery, electricity, fire, heat and cold, diving, noise, vibration, confined spaces, entanglement, underwater entrapment, solar radiation	Injuries, cuts, burns, broken bones, amputation, hypothermia, hyperthermia, drowning, electrocution, injury-related death, asphyxiation, decompression illness, sprains and strains
Chemical (toxic, flammable, corrosive, explosive)	Disinfectants, parasiticides, piscicides, fungicides, antifoulants, anaesthetics, antibiotics, radon gas from water sources, hydrogen sulphide, carbon monoxide, sulphites, dusts, fumes, styrene, needlesticks, flammability's, battery explosion	Respiratory illness, burns, cancer, central nervous system effects, birth defects, reproductive effects, poisoning, hematopoietic effects, and lung, eye, or skin irritations
Biological	Sharp teeth, spines, aerosolized proteins, bacteria, parasites, skin contact with shellfish and finfish tissues and fluids, enzymes, airborne proteins and endotoxins, fish feed dust	Bites, cuts, punctures, and related infections; allergy, asthma, eczema, urticaria (hives), chapped skin, itching.
Psychological	High demand and low control situations, remote locations away from family, potential for large fish kills, abusive social environment	Work-related stress

Physical and biological hazards on the BGF infrastructure are related to the fish handling. Such operation can involve numerous hazards, including limbs, clothing, hair or jewellery getting caught in equipment, falling off the platform while working with fish, and handling large, powerful fishes.

BGF aquaculture workers shall receive adequate training on the proper techniques and precautions required to remain safe and healthy while performing any appointed tasks. Work surfaces shall always be cleaned and disinfected upon usage (e.g., after working on any fish or after using chemicals, such as inoculants).

Risks from contact with organophosphorus and other medicines are reduced by choosing the least hazardous alternative that will do the job and using a system which avoids or reduces operator contamination. Use of PPE, operator training and supervision are also enforced to reduce risks.

BGF aquaculture operators are also trained on the correct method of administering vaccinations and associated procedures to reduce the risk of accidental self-injection (since certain oil-based vaccines can result in serious tissue damage leading to amputation or in rare cases, anaphylaxis). The use and safe storage of veterinary medicines is regulated according to the product label instructions. Proper disposal of the empty veterinary medicine containers is also enforced.

A further list of aquaculture-specific hazards is reported in Table 3-3, together with the risk mitigation measures foreseen for the BGF infrastructure. Worksheets of the HAZID specifically carried out for the BGF infrastructure are reported in Annex C.

Table 3-3: Summary of hazards and BGF specific risk mitigation measures for particular activities

Task	Hazards	Specific risk mitigation measures
Fish feed unloading and storage	Dropped objects Slips, trips, falls Lifting operations Dust exposure Noise exposure	Operator training and certification. Use of PPE. Unloading procedures. Noise survey. Medical checks. The silos will be filled by fish boats, either using a bulk-bag and crane lifting system, or by pumping feed by a dedicated air blower and hose from the boat. Continuous silo level monitoring BGF's silos are equipped with compressed dry air injectors to avoid feed clogging by moisture.
Fish feed distribution	Slips, trips, falls Lifting operations Dust exposure Noise exposure Electrical shock due to static charges from air fluxes	BGF' fish feeding system is completely automated. Feed is transported pneumatically via three HDPE pipes, one line for each silo. The air blowers are installed in silencer cabinets. Blower pipe tips are earthed. All sensor data are displayed in real time and logged for further analysis and integration with

		machine learning algorithms, allowing for optimal feeding at all times.
Fish state monitoring	Slips, trips, falls Drowning (diving operations)	Continuous automated monitoring system is provided. Use of artificial Intelligence solutions to correlate water quality parameters to fish welfare.
Mort fish collection	Slips, trips, falls Drowning (diving operations) Biological (finfish handling) Lifting of loads Contacts with carcasses	Automated collection system operated by pressurized air. Further treatment (size reduction of dead fish) is carried out by automated system in a dedicated container at platform level. Adequate washing and disinfecting procedures. Mass mortality events included in the scope of emergency preparedness.
Cage monitoring	Slips, trips, falls Drowning	No operator activities foreseen. Cameras with a high optical zoom capability mounted at the 4 corners of the platform to monitor water surface, fish appetite and feeding visual control, the correct operation of the feeding system, fish swimming and jumping behaviour.
Fish net positioning/removal	Use of hazardous tools Noise exposure Vibration exposure Navigational hazards Lifting operations Slips, trips, falls Drowning	Mobile winches and cranes used to lay nets on BGF platform deck or directly on the service vessel moored outside the platform. See also Paragraph 3.3.8
Fish net cleaning	Use of pressure washers Electrical hazards Hazardous substances	No operator activities foreseen. Net cleaning is automatised by using a subsea ROV based

		assembly.
Fish net repairs	Use of sharp tools Drowning (diving operations)	Use of adequate and certified tools. Operator training. Work instructions/procedures. Use of PPE. Repairing failure in net can be achieved by divers or by dedicated tools now available on ROV.
Laboratory activities	Hazardous substances Electrical hazards Biological	See Paragraph 3.3.14 (hazardous substances / biological hazards)
Cleaning and disinfection of equipment	Hazardous substances	See Paragraph 3.3.14 (hazardous substances).

3.2.2 Energy production

Any technical or procedural failures relating to electrical systems can expose the working personnel to a variety of hazards including electric shock and internal burns due to heating when an electrical current passes through body tissues. These phenomena could lead to a range of different kind of injuries, respiratory failure, cardiac arrest, and death.

Other electrical hazards are related to arc flash, which releases high levels of UV radiation, causing skin and eye damage, and potentially very severe burns if a person is enveloped by the arc. Furthermore, fire and smoke caused by the overheating of overloaded components, or explosions, such as the rupture of switchgear or other equipment due to an internal fault, or the ignition of a flammable atmosphere due to a spark can cause serious harm to exposed workers.

To mitigate the risks to which BGF workers can be exposed, all electrical installations and equipment onboard the BGF facility are constructed, installed, operated, protected and maintained to prevent the risk of danger from electric shock or burns. Weather conditions and the corrosive marine environment in which energy producing installations operate are also taken into account.

General validity precautions included in the BGF safe system of work for managing the electrical risks include, but are not limited to:

- All handheld power tools and appliances are connected through a residual current device;
- Equipment is grounded/earthed at all times unless it is double insulated;
- Wiring, equipment, leads and plugs are to be kept in good repair. Check prior to using the equipment;
- Handheld power tools, leads and plus are tagged for maintenance checking every 3 months;
- Use of electrical equipment that has damaged casing or wiring is prohibited;
- All wires around ponds and dams are encased in metal conduit and/or PVC piping;
- Waterproof outlets and fittings must be used in wet areas and outside;
- All cages' workers must leave the fish cages before a newly installed aerator is tested;
- When workers are working in the cages, electrical power to aerators must be switched off;
- Access to the electrical technical building and to the platform electrical substation is restricted to authorized personnel only

In the following paragraphs, a summary of system-specific hazards and adopted risk mitigation measures is given.

3.2.2.1 Wind turbine system

Under nominal conditions, BGF wind turbine operations are mainly based of inspections. Given that several variables are monitored at the Local Control Room level, physical inspections on equipment and sub-systems are limited to the minimum. In particular, planned periodic inspections are planned to occur every one (drive train inspection) or two (condition control of the rotor blades) years.

Maintenance activities include common tasks such as cleaning blades, lubricating parts, full generator overhaul, replacing components and repairing electrical control units. These may be more repetitive tasks, which mean that maintenance technicians become, in general, more familiar with the risks and the procedures in place for working at heights, interacting with electricity and working in confined spaces. Nonetheless, maintenance operations on wind turbines can be demanding and present a number of OSH hazards.

Throughout the wind turbine there are a number of areas that can be defined as confined spaces, such as nacelles, blades, rotor hub, tower, tower basement and pad mount transformer vaults. These spaces have adequate size and configuration for worker entry but have limited means of access and egress and are not designed for continuous worker occupancy.

In addition to risks linked to hazardous substances and lack of oxygen in confined spaces, further issues such as ergonomics and musculoskeletal disorders linked to awkward, static postures need to be taken into consideration. Hot temperatures can also be an issue, for example when working within the nacelle, especially in summer, and this may also present a cardiovascular challenge.

To reduce to exposure of BGF workers to the mentioned hazards, visual inspection to the tower and blades, in addition to the insight already provided by the monitoring system embedded in the wind technology (typically strain gauges sensors, accelerometers, etc.), is performed using a small drone guided by operator standing on the BGF deck.

Inspections are carried out by qualified personnel, either as part of the primary turbine maintenance works or by a team of independent inspectors. Mandatory training covering both technical aspects and health and safety skills and awareness regarding the wind turbine operation is required for the maintenance operators. The technical training involves the specific operations of the turbine model and include operational safety practises for high voltage switching.

A number of OSH certificates are required by personnel likely to be present on the BGF infrastructure, including:

- Emergency first aid and advanced medical training;
- Offshore survival training, including marine transfer;
- Working at height;
- Working in confined spaces;
- Wind turbine rescue;
- Manual handling;
- Lifting and hoisting;
- Electrical safety awareness.

A confined space entry permitting system could also be put in place when serious hazards are foreseen. This system requires that a written permit to enter must be issued by the employer. This permit will provide details on the steps that need to be taken to make the space safe before and during the entry.

To mitigate residual risks connected with wind turbine inspection and maintenance activities, BGF operators are provided with suitable PPE, such as gloves, safety boots, and hard hat, ear defenders and safety eyewear.

A checklist for the prevention of accidents and damage to health relevant for wind energy production [R5] is reported in Annex A.

3.2.2.2 WEC System

The WEC solution identified for the BGF energy is based on a modification of the REWEC3 patented solution for fixed installation to comply with floating conditions.

Regular maintenance is to be carried out monthly and annually depending on the degree of wear of each component and covers both mechanical and electrical components. Typical maintenance operations are characterized as being either inspections, services, repairs or replacements. Maintenance also includes the removal of accumulated fouling in the WEC chambers; this activity must be performed having plugged the WEC chambers opening to avoid water entrance and by sucking the water left in the chamber by acting through a dedicated opening at the level of the platform deck. From there the removal of fouling is facilitated by means of water jets. Final removal of other obstructing objects eventually entrapped in the chamber is feasible by employing adequate on-deck means. Under normal conditions, maintenance operations for the WEC system can be performed with the help of automated systems, without the direct intervention of workers and they do not foresee the presence of BGF operators inside the WEC chambers, thus preventing the hazards related to drowning and confined spaces entry.

3.2.2.3 PV System

PV systems installed on board the BGF infrastructure supply electricity to the microalgae production system and the sea water desalination. The photovoltaic panels are installed on the aft building roof, along its entire length.

Periodic inspections and cleaning operations are at the base of the PV system efficiency. Such activities may expose maintenance operators to electrical and work at height hazards (as the panels are installed on a roof). The design and installation of the BGF PV system is such to prevent frequent cleaning operation. Nevertheless, this routine operation can be performed using a robotized cleaning system to eliminate the risks of fall and work at height.

Other maintenance operations include the regular checks on the electrical equipment (junction boxes, electrical protection devices, cables and wiring. Protective devices such as residual current devices and solar array isolators are installed on the system. BGF workers shall also follow the provided O&M instructions and written procedures.

Operator training and the use of adequate PPE (such as fall-arrest systems) is required to mitigate the residual risks linked to operation and maintenance of this system.

A checklist for the prevention of accidents and damage to health relevant for the PV system [R5] is reported in Annex B.

3.2.3 Oxygen Production

The oxygen generator installed on the BGF infrastructure is an on-site oxygen-generating machine. It is coupled with the air compressor, refrigeration air dryer and filtration system, it takes air and separates the oxygen from other gasses. The separation is accomplished with an inert ceramic material (molecular sieve) that does not require replacement (when maintained and used according to this instruction manual). The process is completely regenerative which makes it reliable and virtually maintenance free.

The Oxygen generator system is designed to accept compressed feed air into its filter assembly (at 6.0 – 10.0 bar(g) and deliver 90-95% oxygen when supplied with a minimum feed air pressure of 6.0 bar(g)., or at 11 – 14 bar(g), according to different models.

Exhaust gas from the oxygen generator contains only 8-21 % oxygen. Exhaust gas must be piped out of the room to the outside. The room must always be well ventilated.

The main hazards to which workers can be exposed during operation and maintenance of the oxygen generation system are related to the use of electrical equipment and work with pressurized equipment.

Electrical risk mitigation measures implemented on the BGF infrastructure are covered in Section 3.2, while a list of basic precautions adopted on the BGF infrastructure to reduce the risks related to pressure vessels is given below:

- following a major repair and/or modification on a pressure vessel, the whole system is re-examined before being brought back into use;
- definition of operating and maintenance instructions for all of the equipment in the pressurized system and for the control of the system as a whole, including in emergencies;
- inspections and maintenance on pressurized equipment are carried out by a competent and appropriately trained person. Inspection results are logged;
- pressurized equipment is to be always operated within the safe operating limits;
- instruction and relevant training for the workers who operate on the pressure equipment are provided, also including what to do in an emergency.

3.2.4 Microalgae Production

The microalgae production system installed on the BGF aquaculture hatchery is mainly intended to provide value products for industry but a part of it is directed to the nutrition of juvenile stages of fish. Dedicated ISO-type containers, fully equipped with industrial culture growing systems, are placed on top of the aft side building and some of them (smaller size) inside the building too.

Maintenance tasks for industrial type of photobioreactors is reduced to minimum thanks to the controlled ambient that protect the culture. In addition to work at height hazards, workers of the BGF facility can be exposed to hazards arising from the use of pressure washing equipment for the outside cleaning of the photobioreactor tanks. When water is pressurized, it can easily generate forces resulting in serious injury when the water jet comes into contact with skin or eyes. The impact of a high-pressure nozzle, leaky hose or being hit by wash debris (rocks, etc.) can cause potentially life-threatening injuries.

BGF workers involved in pressure washing activities have to wear adequate PPE such as a heavy-duty raincoat to keep technicians dry and to help provide a barrier in the event there is contact with flying debris from washing. Safety goggles, heavy duty waterproof gloves (insulated, if running hot water) are to be worn in addition to rubber boots with metatarsal guards. Hard hats are used in environments where falling objects are a potential hazard.

Additionally, work at height safety precautions already reported are applied to minimize the risks during maintenance operations carried out at the third level of the BGF infrastructure.

3.2.5 Sea water desalination Production

Potable water for human, sanitary and operation needs on board the BGF platform is produced starting from fresh seawater using a Reverse Osmosis (RO) desalination system.

The Reverse Osmosis equipment consists of a rotating isobaric pressure exchanger and a booster pump driven by the same electric motor. Maintenance activities mainly involve the electric motor. All inspection and installation works are performed by authorized, qualified specialist personnel, thoroughly familiar with the O&M manual.

Electrical safety precautions reported are applied; furthermore, the power must be shut off and the starting device be locked before any intervention on the system.

3.3 Other Common Hazards

An overview of the most common hazards related to aquaculture activities is given in the following sections. For each topic addressed, a summary of the activities and connected hazards is given, with the main focus on health and safety risks. Examples of risk mitigation measures, safe procedures or best practices adopted on the BGF installation are also provided.

3.3.1 Navigational Hazards

The installation of a moored structures into a previously unobstructed area of sea introduces new collision hazards, bringing obvious risks to people aboard vessels.

In addition to the effects on commercial shipping and fishing, the effects on recreational sea users should be considered, including addressing concerns about the effects of wind turbine wakes on sailing vessels and kite surfers.

Collisions with ships may result in damage to the facility as well as increase risks to workers that are onboard.

The Navigation Safety System, together with the Automatic Identification System (AIS) and the long-range offshore cameras installed on the BGF infrastructure, are intended to prevent unintentional and intentional collision hazards. The AIS provides identification information relevant to the vessels that are present in the covered area to the operator screen. AIS information includes the Vessel Maritime Mobile Service Identity (MMSI code), unit type, position, course, speed which can provide the operator useful data to determine the intention of approaching vessels and take appropriate actions (e.g., alert competent authorities, raise an alarm or state abandon platform). Long-distance cameras, also provide an additional accurate surveillance of maritime traffic and the identification of potential intrusion by small boats approaching the platform.

BGF surveillance and monitoring system can detect and identifying any vessel passing even different kilometres from the BGF installation site. Any ship which is not expected to moor at the BGF infrastructure, as part of the planned maintenance or harvesting purposes, will be analysed in its actual route trajectory compared to the route planning. Any tendence to deviate from that route, and with a risk to enter the safety area around the BGF platform, will be recognised as potential for collision, then an alarm will be raised accordingly.

This information is made available to the local and remote operator. Manual action is required to be mobilised to enable any direct contact with the ship captain via radio kinks. Automatic control is established at platform radar level, which gives raise the alarm, and at cameras level, that are guided to focus on the ship view line for the identification analysis.

3.3.2 Transfers To And From Vessels

A worker undertaking routine offshore operations aboard the BGF infrastructure, potentially on a daily basis over the lifespan of the multipurpose installation, is likely to undertake many thousands of transfers during their career.

Every transfer exposes the people involved to a number of significant hazards; given the expected frequency of transfers, extremely robust and repeatable systems are required in order to ensure that the overall risk remains at a tolerable level.

Health and safety hazards related to vessel to platform transfers can include:

- Falling down onto the vessel, or into the sea, or being suspended by a fall arrest system;
- Crushing or entrapment due to relative movement between the vessel and the ladder;
- Serious injury from any objects that may drop from the offshore structure during transfer operations;
- Stranding – if metocean conditions change, such as weather or sea state deteriorating, or if very low tides prevent access in areas of shallow water;
- Whole Body Vibration during transfer in rough sea conditions.

For transfers involving a vessel, the master of the vessel assesses the conditions, and authorises the transfer. Each individual who is to transfer has to make their own assessment of their capability to transfer safely and inform their supervisor of any concerns. The precise criteria for transfer decisions, and site-specific safety management systems, should take account of the particular characteristics of the access systems and vessels being used.

The BGF personnel is properly trained, medically and psychologically fit to undertake vessel transfers, taking account of site-specific equipment and conditions.

Typical measures to mitigate the risks of transfer have been considered in the BGF infrastructure design and have included:

- Design of the vessel / boat landing interface aimed at minimizing the risk of a fall and eliminate the potential for a person to be crushed or entrapped between the vessel and boat landing;
- Provision of suitable lighting to allow safe transfer at darkness;
- Provision of fall-arrest systems compatible with the foreseeable demands of transfer from a vessel;
- Provision of suitable equipment to permit effective communication between the bridge, deck crew and personnel being transferred.

Furthermore, the BGF docking / undocking facility is placed along the aft side of the platform, as it is less exposed to predominant sea wave's impact and, as well, easier to be accessed thanks to its lower-level protective wall.

Access to the BGF platform is allowed through an internal metallic spiral stair inserted in the vertical cabinet for the electric recharge. In its parking configuration, the cabinet remains fixed to the vertical wall of the caissons. The internal staircase leads to the docking level (+ 4 m ASL) at a height of +10 ASL. The respective entrance doors at the two levels are locked and can only be opened with a special pass.

3.3.3 Slip, Trip and Fall Prevention

A number of aquaculture injuries occur as a result of slips, trips and falls. These often can result in muscle strain, broken limbs and contusions and can even cause death.

- Slips happen when there is insufficient traction between footwear and the surface being walked on (e.g., wet, oily or icy surfaces, slick flooring);
- Trips can occur when there is an obstructed view, cluttered or poorly lit working area, uneven walking surfaces or there are lines and cables to walk over;
- Falls from an elevation (i.e., ladders, stairs, jumping into the boat from the dock) can occur when balance is lost, or faulty equipment is used.

To prevent such kind of risks, safe working surfaces are provided on board the BGF platform. Protective handrails on deck, bridges and ladders are installed. Suitable and secure walkways are also provided around the exterior of each fish cage.

Footrails are fitted at the inside edge of cage walkways to provide bracing and to prevent workers' feet slipping from the walkway when nets are being hauled up.

Floors and other surfaces on which people walk are free-draining, non-slip and sufficiently firm and continuous to allow safe walking and transport of materials. They should be kept free of obstructions and splinters, protruding nails, bolts etc.

Stairways and ladders are provided with a secure handhold at the top of any stairway.

Furthermore, the risks of operator falling at sea is reduced by means of access control at the platform critical areas and remote-control consensus release (video camera) to check operator is wearing appropriate PPE.

3.3.4 Weather Hazards

Metocean factors comprise the combination of weather and sea conditions. Working in stormy or inclement weather on the water can put workers and asset at risk. Adverse conditions increase both the probability of incidents and errors occurring, and the severity, by hampering recovery or containment actions.

In addition to wind, wave and tidal conditions, including currents:

- Cold temperatures can cause hypothermia, and icy surfaces can prevent safe movement;
- Lightning is also a hazard to people on offshore structures;
- Rain, hail, snow and fog can all affect visibility, and also impede vision through safety spectacles or similar PPE; and
- Warm air temperatures can cause heat stress, whether as a consequence of working in hot enclosed spaces such as wind turbine nacelles, or climbing an access ladder while wearing a survival suit.

Adverse metocean conditions can cause significant operations delay in addition to represent a hazard for workers. The BGF infrastructure is equipped with a weather forecasting system and its structure is designed to withstand weather extremes. When required, the platform automated system is capable to disconnect the umbilical and WECs and to shut down the wind turbine. The BGF wind turbine is fitted with lightning protection. In case of emergency, operators working onboard are required to evacuate via safety boat.

3.3.5 Remoteness

Remote operations are likely to be carried out with minimal direct supervision; this may introduce risks to the quality of work, the condition that the workplace is left in, or the adherence to approved methods of working.

When considering maintenance operations carried out onboard the BGF facility, the workers team will be deployed by using access vessels and it will be therefore remote from immediate support and supervision from the onshore base. The physical remoteness of the aquaculture facility from a place of safety (generally the onshore base) and the risk that metocean conditions may further limit access will influence the emergency response arrangements as a whole. On this basis, the degree of remoteness can change significantly if weather conditions and sea state change. In an extreme case, if egress from the offshore facility were to become impossible, then any people on the structure would be stranded, and work in progress on the facility would have to be suspended, as there would no longer be the means of evacuating a casualty.

Possible hazards directly related to the remoteness of the facility include the considerable time that can be required for additional help to arrive in the event of an incident and the challenges in the provision of supervision and auditing activities. This is the reason why the BGF infrastructure offers an area for personnel accommodation and living under sanitary conditions, including availability of the infirmary, to support the occurrence of a sudden change of weather conditions and to enable even a long permanence onboard (one week) until the sea conditions become more affordable.

3.3.6 Workplace conditions

Even though the BGF infrastructure is not H24 operated, it is anyway subject to H8 based activity, at least all times the access to the platform is safe on the basis of the specified docking conditions.

Working conditions affect the health and safety of employees in relation to the risk of accidents, illnesses, and development of longer-term health conditions. The risk of accidents is increased in a workplace that has inadequate lighting, is dirty or untidy, or has inadequate access for the tasks to be undertaken. A lack of ventilation or control of temperature leads to discomfort, loss of concentration, and a tendency to rush tasks so that the worker can move to a more comfortable environment.

If workers are unable to maintain appropriate hygiene standards, then this introduces a risk of illness or infection. Suitable facilities for sanitary, eating and refuge requirements are also provision on the BGF platform.

The BGF living area guarantees adequate accommodation and living conditions on a daily basis in general, and over a long permanence should unplanned worsening of sea conditions impede workers to recover in time to the base on land.

3.3.7 Ergonomics

Ergonomics looks at the relationship between the demands of the workplace and the ability of the worker. Redesigning the workplace or reorganizing tasks can increase productivity and lessen down-time due to injury-related absences.

Common hazards that contribute to workers experiencing injuries include, but are not limited to:

- Improperly laid out work areas,
- Work that must be completed at a fast pace,
- Activities that do not allow workers to change tasks,
- Activities that restrict the flexibility of the body's position (e.g., prolonged standing in a stooped position, repetitive reaching and twisting of the body, working with arms elevated),
- Standing on a hard floor and having limited ability to sit down while working,
- Working in excessive or prolonged heat, humidity, cold or vibration,
- Working with worn or improperly maintained tools that increase the amount of force required to carry out the task,
- Activities that require force to be concentrated on small parts of the body (i.e., wrist).

Where work is carried out on open decks of the facility, such as preparing loads for lifting, the people involved may be working in cold, wet conditions, wearing a combination of PPE to provide insulation, waterproofing and buoyancy, but which may also be bulky. The use of gloves (or having cold hands) will reduce dexterity, making otherwise simple tasks, such as pressing the correct buttons on a handheld radio, more difficult.

Operation and maintenance procedures for the BGF facility take into account the environment in which the work is to be carried out. Work equipment is selected accordingly, and tasks are designed thoughtfully.

3.3.8 Lifting

Maintenance activities foreseen for the aquaculture facility involve a wide range of lifting operations, ranging from the routine lifting of tools and equipment between support vessels and the offshore structure, to complex lifts of major components. In many cases, further lifting within the structure will be necessary in order to bring the load to the precise location where it is needed, which may also involve moving the load in very restricted spaces.

The two BGF platform cranes working on rails are manually operated. Use of cranes covers different tasks, such as:

- facilitating nets maintenance and repair;
- enabling platform side operations with laterally docked barges;
- easing fish harvesting (raising nets during fish pumping out);
- supporting deployment of ROVs, small boats and other ancillaries within the pool.

The main hazards to workers arise from dropped objects, which may be caused by failure of lifting equipment or attachment points on the load itself. As well as the high potential risk to any people beneath the suspended load, the consequences of any such event are increased offshore, particularly if it causes a vessel to be damaged or destabilised, thereby endangering all personnel on board.

The offshore environment greatly increases the technical and organizational complexity of lifting since:

- The marine environment will accelerate the deterioration of structural and mechanical components of lifting equipment, or of attachment points on loads;
- Vessels and their crews may be from a number of different countries, bringing the potential for difficulties arising from communication problems or differences between regulatory systems;
- Proximity hazards are increased, as a consequence of the restricted space on vessels or structures;
- Swinging of load, with potential for impact against adjacent structures / objects / people;
- Metocean conditions may change rapidly and unexpectedly, affecting both equipment and personnel.

Particular attention is devoted to the fish nets that will occasionally have to be removed for repair, local maintenance needs, or exchanged for nets with a larger mesh size as the fish grow. Specific procedures are adopted and validated for each lifting activity to operate safe and correctly. Mobile winches are used to lift the nets around the perimeter (along platform walkways and on the bridges), then the mobile cranes are employed to lay them on BGF platform deck or directly on the service vessel moored outside the platform. The mobile cranes are also used to raise the last 15 m net cone.

Feedback about the cranes' status and main operating parameters is returned to the platform local control room to allow real time monitoring of the lifting operations by the operators. Specific training is required for workers performing lifting activities.

3.3.9 Work at height

Work at height can expose people to a range of hazards such as severe injuries or death. Any injury that incapacitates a worker offshore will lead to a more complex evacuation being required than would be the case onshore. Additionally, if a person is suspended in an upright position for a period of time, as may occur after a fall has been arrested, suspension trauma or syncope may lead to loss of consciousness.

On the BGF platform, the steps taken to avoid the risks of work at height followed a clear hierarchy:

1. Avoid work at height;
2. Where work at height cannot be avoided, use work equipment or other methods to prevent falls from occurring;
3. Where the risk of falls cannot be eliminated, take suitable measures to minimise the distance and consequences of a fall.

Adoption of measures at the lowest level of this hierarchy, such as fall-arrest systems, reduces but does not eliminate the risk of serious injury.

3.3.10 Vibration

Workers can be exposed to different forms of vibration in the course of maintenance activities performed aboard the facility. Hand-arm vibration is most commonly related to the use of certain tools, whilst whole body vibration may arise from shocks and jolts during transit on vessels in rough sea conditions.

Hand-arm vibration can cause damage to blood vessels, nerves and joints, resulting in permanent pain and disablement. The risk depends on the level of exposure to vibration, both in terms of magnitude and duration. Vibration-related health problems can permanently impair a worker's capability, including becoming unable to carry out fine work with small components, sensitisation to cold or wet conditions, and reduced grip strength, which may affect activities such as ladder climbing. Whole body vibration can lead to back pain, either due to unusually high levels of exposure, or more commonly in combination with other risk factors such as muscle strains caused by heavy physical activity. A small vessel, at high speed, in rough sea conditions can subject those aboard to severe impacts. Even if no injury occurs, a rough passage will contribute to physical and mental fatigue.

Where prevention of exposure to the vibration hazard is not feasible, the exposure of BGF workers is limited following measures such as:

- Limiting the exposure duration, by changing methods of work to reduce the need for processes which give rise to hand-arm vibration, and by rotating the work amongst different members of a team.
- Ensuring that tools are properly maintained, and suitable for the task;
- Use of improved tools, mounting arrangements and consumables.

Mitigation of the risk associated with whole body vibration aboard vessels requires a combination of an appropriate vessel design and selection (to minimise impact forces at service speed in the intended operating conditions) and the careful detail design and set-up of engineered mitigations, such as suspension seating.

3.3.11 Noise

Prolonged exposure to high levels of noise may result in people suffering permanent or temporary hearing loss or damage. Hearing damage may also result from sudden, extremely loud noises. Such incidents may cause temporary hearing loss but could also cause longer lasting or permanent hearing damage.

A noisy working environment also impairs communication, while the safety of operations may be affected if personnel involved are unable to hear safety alarms.

Noise exposure may occur from a range of activities including:

- Use of noisy power tools such as impact tools or angle grinders;
- Use of temporary power sources such as generators or compressors;
- Offshore transfers on vessels.

The noise exposure is likely to be more severe when tools are used in restricted spaces within the facility such as the wind turbine tower. Divers can also be exposed to noise arising from subsea operations.

Activities and O&M tasks carried out on the BGF platform are planned and performed in accordance with the applicable Noise at Work regulations to reduce the noise exposure and risk to the employees so far as is reasonably practicable, even if a specific exposure limit is not exceeded. The noise-related risk is mitigated according to a hierarchy of controls:

1. Elimination of the source of loud noise;
2. Modification of equipment to reduce noise and vibration emission (e.g., silencers fitted on air tool exhaust outlets);
3. Limitation of workers' exposure to noise.

In case workers are found to be still exposed to noise levels that exceed specified thresholds, after the implementation of the foreseen technical and organisational control measures, the BGF management is committed to:

- Make sure that no employee is permitted to be exposed to noise exceeding the Exposure Limit Value;

- Provide hearing protection and make its use mandatory if the upper Exposure Action Value is likely to be exceeded;
- Provide hearing protection if requested when the lower Exposure Action Value is likely to be exceeded. In such case the use of protection is discretionary.

In all cases, employees who are exposed to noise at work are properly trained and instructed about the risks, and about the use of work equipment and PPE to reduce their noise exposure.

3.3.12 Diving operations

Diving is a highly hazardous activity that depends upon specialist personnel with a high level of training and experience to plan, support and carry out diving operations in a safe manner. Working under the surface of the water can pose special hazards. Divers are always exposed to the risk of drowning, respiratory or circulatory problems, hypothermia or physical injury. The correct management of breathing air or gas mixtures (depending on the depth) and decompression is fundamental to avoid acute physiological effects (such as decompression sickness), or longer-term harm.

Divers may be vulnerable to a wide range of hazards which include, but are not limited to:

- Limited visibility created when sediment is stirred up in the water;
- Divers getting caught away from the boat in inclement weather or strong currents;
- Experiencing mechanical difficulties with the SCUBA gear;
- Getting caught or tangled in the aquaculture gear;
- Getting hit by the dive boat, aquaculture gear or other boat traffic in the area.
- Underwater noise can impede communication, or, in extreme cases, cause hearing damage;
- Electricity;
- Entrapment or severing of divers' umbilical by vessel thrusters, cables or other equipment;
- Breakdown in communication, either due to language or equipment issues.

The unforgiving subsea environment, combined with decompression requirements preventing immediate evacuation, can rapidly escalate the severity of any accident or health issue.

To avoid the risks involved in diving activities, a series of routine operations on the BGF infrastructure are performed by using Remotely Operated Vehicles (ROVs). In particular, the BGF platform, as per current design, is equipped with two ROVs:

1. one dedicated to underwater activities within the BGF pool and outside it (in addition to the robotic devise used for net cleaning);
2. a second one dedicated to broad inspection tasks related to the environmental monitoring (as already described in [R6].

The ROVs considered for the above two applications are portable device that can be managed by an operator from the Control Room.

However, some diving operations may still be required for certain O&M activities.

3.3.12.1 Implemented safe diving procedure

For all other cases in which diving operations cannot be avoided, it is required that all divers have received proper training and have valid First Aid and diving certificates.

BGF's diver operators are instructed in the work procedures they will be required to carry out and are trained how to safely operate other equipment they are required to use.

Diving operations are never performed alone and when the diver is in any way unfit to do so (e.g., ill, fatigued, impaired, injured, etc.).

Diving activities are suspended if weather or water conditions are hazardous or likely to become hazardous in the area of the planned dive.

When necessary, deep diving (depths greater than 20 m) and night diving are contracted to professional divers knowledgeable of the special procedures and hazards involved with these activities. When this occurs, the person in charge on the BGF facility must require that the operation is carried out in compliance with all applicable health and safety regulations.

Divers must not stray from the posted dive site.

Only equipment/vessels that will be used in connection with the dive should be brought within the dive site boundaries.

Divers are provided with a lamp or other suitable device during periods of darkness.

The dive site or underwater work site will be adequately illuminated if the nature of the dive allows to do so.

Snorkel divers will use the buddy system when diving and be equipped with a whistle, weight belts (if required) with quick release closures, and thermal protection.

Cage guards are placed on all propellers, and props on boats must be disengaged and locked out while being used as a dive base.

Divers conducting a dive in open water without a lifeline must carry an audio or visual signalling device.

Dives are to be avoided when a health or safety hazard may be caused by equipment at or near the dive site, such when vessels are scheduled for approaching the platform, unless the divers are protected from the hazard.

A written dive plan is prepared before a dive is conducted at a dive site. This includes:

- A description of the tasks to be performed at the site
- Work procedures for each type of dive
- Diving equipment to be used
- Estimated maximum time to be spent at each depth
- Decompression tables and procedures to be used
- Procedures to identify and address health or safety hazards at the dive site
- A list of industrial plants and water control facilities in the immediate area of the dive site
- Instructions for getting medical assistance
- Instructions for evacuating an ill or injured diver from the dive site
- Emergency procedures for responding to any loss of communication
- Emergency procedures for responding to diving equipment malfunction
- Emergency procedures for responding to hazardous weather or water conditions
- Emergency procedures for aborting a dive
- Emergency procedures for responding to any difficulties in keeping the dive base stationary.

Before the dive, the diving team is briefed on the following:

- Dive plan including the planned location of all dives
- Work to be carried out
- Possible hazards that may be encountered
- Intended duration and maximum depth of the dive(s)
- Decompression table to be used
- Communication signals to be used
- Planned location of all divers
- Any emergency procedures to be followed in the event of an accident or unsafe conditions.

A dive Log must be kept updated with all data referring to any dive and divers involved in it.

Logbooks will include:

- Operator's name
- Buddy name
- Surface operator's name
- Equipment used
- Gas used
- Qualification
- Dive time
- Decompression time
- Surface time
- Operation carried out
- Sea state
- Difficulty encountered
- Data download from dive computer, including depth, intervals, gas consumption, gas residuals in tissues, no-fly time

Logbook must be periodically inspected and signed by divers' Supervisor.

3.3.13 Confined spaces

A confined space is defined as a space of any volume which is not intended as a regular workplace and has restricted means of entry and exit. It may also have inadequate ventilation and/or an atmosphere which is either contaminated or oxygen deficient.

Typical hazards that may endanger people in confined spaces include:

- Loss of consciousness due to an increase in body temperature, as a result of working in a hot environment such as a compartment;
- Loss of consciousness, or asphyxiation, due to the presence of hazardous substances, or lack of oxygen, in the atmosphere of a confined space
- Inhaling an atmosphere that contains no oxygen can result in loss of consciousness within a few seconds;
- Inert gases such as nitrogen, can cause dangerous oxygen depletion if released;
- Drowning, due to ingress of water to subsurface structures
- Injury arising from fire or explosion of substances.

Due to the limited exchange of air in a confined space, a hazardous concentration of a substance may occur from a relatively small release, that would not endanger people in an open-air situation.

BGF design measures foreseen to reduce the risk due to unavoidable confined space entries include:

- Provision of monitoring systems to detect hazardous conditions prior to entry (e.g., presence of water, release of gases or liquids, fire or smoke, presence of hazardous substances, or oxygen depletion);
- Physical separation of compartments that may contain identified hazards, such as oxygen-depleted atmospheres, from those where work will be undertaken;
- High integrity seals to prevent water ingress into compartments below the waterline;
- Provision of internal lighting, with due consideration to how it is to be maintained;
- Provision of robust isolations, to provide safety from hazards such as substances, electricity and movement of equipment;
- Ensuring that access and egress routes have suitable dimensions and characteristics for use when wearing all necessary PPE (which may include a breathing apparatus set), and for the rescue of a casualty;
- Provision of appropriate anchor / mounting points in suitable locations for rescue equipment and PPE.

A list of precautions included in the BGF’s safe system of work for confined space work includes, but is not limited to:

- Follow applicable Occupational Safety & Health Regulations when working in a confined space;
- Prior to any person entering a confined space, atmospheric testing and monitoring is carried out to identify hazards and risk assessment;
- Use of a Permit to Work system;
- Access to a confined space restricted only to personnel trained to do so;
- The confined space is withdrawn from service prior to entry and isolated, de-energised and locked out;
- Cleaning and purging of the confined space are carried out prior to entry to remove hazards;
- Exhaust extraction and ventilation of the confined space must be in place prior to entering;
- A stand-by person must be present at the entrance when there is a possibility of:
    - Unsafe level of oxygen
    - Atmospheric contaminants with concentrations above the exposure standards
    - Risk of explosion or fire
    - Risk of entrapment or engulfment
    - Conditions outside of the confined space threaten the safety of the people inside.
- Suitable PPE is provided, including respirators, harnesses and lines;
- Rescue and first aid procedures must be in place and equipment at hand;
- Rescue of a person inside a confined space can only by carried out by trained operators wearing self-contained breathing apparatus.

3.3.14 Hazardous substances

Hazardous substances can be in solid, liquid or gaseous form and may always be present in a device, such as coolants or lubricants or they can be introduced during specific operations, such as cleaning fluids. Hazardous substances can also be generated as a by-product of work activities, such as fumes from welding, paints and glass fibre repair compounds.

In some cases, hazardous substances may not be readily visible, such as dusts and vapours in the air.

People may be harmed by any form of contact with hazardous substances, including skin contact or puncture, ingestion, absorption, and inhalation. The severity and duration of the effects range from minor, temporary irritation, to chronic illness and death, and the onset of symptoms may range from an immediate reaction to years after exposure. The potential combination of delayed onset and serious illness means that any use of hazardous substances requires careful management.

The BGF design philosophy is aimed at avoiding the use of hazardous substances, by selecting less hazardous alternatives when feasible. When it is not possible to use a less harmful substitute, hazardous substances quantities are minimized and systems for containment / separation / handling are provided to minimise workers' exposure.

During the O&M phase, periodic replacement of substances such as lubricating oils (compressors, net cleaning robots, ROVs, etc…) and greases may be required; additional care may be necessary as used fluids may be more hazardous than when equipment was first manufactured.

Hazards presented by non-routine repairs, which may involve hot work such as welding or grinding, should also be assessed, both in terms of the substances directly involved (such as fumes from welding) and any reaction products, such as fumes that may be released from surface coatings if exposed to excessive heat from these operations.

Some of the measures adopted on the BGF platform for managing risks entailing from hazardous substances exposure are:

- Availability of Material Safety Data Sheet (MSDS) for every chemical and hazardous substance kept on board;
- All hazardous substances are stored according to the MSDS and the applicable legislation covering dangerous goods. All containers are labelled. The storage area is kept well ventilated, free from direct sunlight and safety signs are well displayed to indicate the type of hazard which is present;
- Ensure the first aid kit contains the correct antidote for each substance, and that a readily supply of water is available when using chemicals to enable washing off of chemicals or flushing out chemicals from the eyes;
- All substances are handled in a safe manner and by following the MSDS;
- Hazardous substances and empty containers are disposed of in a safe manner;
- Ensure that correct personal protective equipment and clothing is used at all times when handling/using hazardous substances, as instructed by the MSDS;
- Exclusive use of chemicals approved for aquaculture uses;
- All employees working with either veterinary or agricultural chemicals are properly trained to do so;
- Flammable goods are stored at a safe distance from any running engine or naked flame;
- Gas fuels are only handled by qualified persons, identified by a certificate of competency;
- All gas cylinders must be handled/transported:
    - Carried in an upright position
    - Well secured during transportation
    - Not tampered with at either the cylinder or valve level
    - Located a minimum of 20 m from a source of ignition if they are thought to be leaking from the safety valve
    - Fixed, when empty, if there is a belief that there may be a fault

  - Kept away from source of ignition or heat
  - Safety valves and gauges are kept free of grease
  - Secured to a trolley at all times
  - When free standing, must be held in place by chainage to ensure cylinder cannot fall over.
- All pressure gauges and supply and applicator hoses must be checked before each usage;
- Hazardous goods are stored in a safe area well above the sea surface;
- Appropriate fire extinguishers and firefighting equipment are situated near the storage area.

3.3.15 Fire Hazards

Fires and explosions on aquaculture facilities can be caused by a number of things including fuels, faulty wiring, overheating equipment and welding. These hazards can cause damage to structures, equipment and machinery as well as serious injury or death. The offshore positioning of the BGF infrastructure makes the mentioned hazards even more challenging.

The main fire-related hazards to people are:

- Smoke inhalation that may cause people to suffer asphyxiation and death, even if they are not in the immediate vicinity of a fire, particularly if the materials that are burning release toxic combustion products;
- Flames and hot surfaces can cause burns;
- Glowing fires may release toxic carbon monoxide as a consequence of incomplete combustion;
- Explosions and arc flashes from electrical faults can lead to immediate serious injury;
- Fire suppression systems may introduce hazards to people, depending on the gases /substances used.

The BGF infrastructure is a normally not manned structure, so there is only a direct risk to people during maintenance activities. Concerning maintenance operations on the wind turbine generator, this should be stopped during major maintenance, and temporary generators may be used, introducing an additional initiator and fuel source.

Some common fire hazards related to aquaculture operations include:

- Improper storage of flammable and combustible materials
- Faulty/damaged electrical wiring (coating on wires are susceptible to salt water and can corrode or rot over time);
- Malfunctioning or overheating equipment/machinery;
- Sparks from welding;
- Smoking around flammable/combustible materials;
- Overloaded outlets;
- Improper ventilation of enclosed spaces that contain fuel;
- Leaking propane or oxygen tanks;
- Improper storage of oily rags.

BGF platform is equipped with a fire-fighting system that acts in conjunction with the automatic safety system in case of a fire event developing on board. At Control Room level, a Fire Alarm Control Panel (FACP) displays the potential presence of a fire in each controlled area. Fire detection devices are provided in relevant areas of the platform for the early detection of any fire initiation and to suitably provide warning either at the local control room or at the remote-control room.

The following types of fire detectors are provided in all areas where a fire may occur for fire alarm purpose only:

- Heat Detection Systems – Heat Sensitive Cable Type
- Smoke Detection Systems – Optical High Sensitivity Temporized Type
- Heat Detection Systems – Rate of Rise
- Flame Detectors

Manual call points are also provided throughout the platform areas, connected in a common loop. Activation of any manual call point initiates a fire alarm. Manual alarm call points are installed at all passages corners and the maximum travel distance between two alarm points does not exceed 150 m.

Detection of a confirmed fire causes an emergency alarm status in the immediate area, in the control room and the activation of the sprinkler fire-fighting system.

Further fire safety provisions adopted on the BGF platform are listed below:

- All extinguishers are in service and tagged, clearly marked for the type of fire they shall be used for;
- Extinguishers are checked and maintained at regular intervals in compliance with applicable legislation;
- All employees receive appropriate training in fire prevention and firefighting strategies;
- Building exits are kept clear of all obstructions;
- Emergency evacuation procedures must be put in place;
- Fire drills are carried out on a regular basis;
- Materials are stored properly to reduce the risk of a fire starting;
- Flammable debris and rubbish are removed regularly to ensure no additional fire hazard exists;
- All hazardous goods and substances are stored correctly, in accordance with MSDS provisions, to reduce the fire risk;
- All combustion engines must have adequate exhaust systems or spark arrestors.

3.3.16 Lone working

As per UK's HSE definition, a lone worker is *someone who works by themselves without close or direct supervision*, [R7]. Considering the operations carried out onboard the BGF facility, the possibility of lone working may arise during cleaning and netting of exposed surfaces (e.g., power washing of microalgae production equipment), extraordinary maintenance activities on the WEC system or wind turbine generator requiring operator intervention, and fish net positioning/removal or repairing activities.

Specific risks for lone workers will be included in the risk assessment document to implement the appropriate preventive and mitigation measures and to help evaluate the right level of supervision for lone workers. Besides the common risks arising from the previously mentioned working activities/conditions, lone working can negatively impact on employees' work-related stress levels and their mental health. For example, the lack of relationships with, and support from, other workers and managers could lead to work-related stress since good support is more difficult to achieve.

To minimise the risk to which lone workers on the BGF infrastructure may be exposed, an individual evaluation of the employee's fitness for carrying out a specific task on its own is required also considering the individual's age and skill set.

The risk assessment document will identify the level of supervision required (which will depend on factors such as the risk level of the specific task foreseen, the amount of training received by the lone working employee and their experience level).

Appropriate means of supervision will be defined on a case-by-case basis depending on the job task to be performed by lone workers. In case the use of dangerous machinery cannot be avoided, operator supervision is enforced whilst hazardous machinery is in use to provide guidance in times of uncertainty. Although not constant, supervision can be granted remotely (e.g., mobile phone or radio communication, etc.). The risk assessment will also set out the procedures under which the lone worker reports to base.

As general practice, lone working on BGF facility is reduced to the minimum and is only tolerated in exceptional circumstances where there is a serious or imminent safety reason that could justify it. Some high-risk activities for which lone working is not permitted and at least one other person needs to be present include:

- Diving operations;
- Confined space activities;
- Operations near exposed live electricity conductors.

Employees will receive appropriate training for carrying out their work activity even under limited supervision or control. Workers will be adequately trained to be able to recognize when to seek advise from elsewhere. In case lone workers are new to a job, dealing with a new situation, or still completing their training, they will be accompanied at first by an experienced co-worker to be supervised.

The Internal Surveillance and Security System (ISSS) (refer to Section 2.2.12) installed on the BGF facility allows to continuously monitor the activities performed onboard, thus facilitating intervention in case of accidents involving lone workers.

4 HEALTH AND SAFETY ONBOARD

4.1 Health and Safety managerial measures

4.1.1 Workforce engagement

Employers have a legal duty to consult with employees in matters relating to their health and safety; in addition to this, successful health and safety management needs the shared commitment of all personnel involved.

The requirements set by the EU Framework directive on safety and health at work impose specific duties in relation to employee consultation for matters concerning changes that may affect workforce health and safety, including matters such as provision of information, competent people for safety-related roles, and allowing employees who are serving as safety representatives to have sufficient time during their contracted working time, and use of facilities, in order to undertake their duties or necessary training.

Further legal duties regarding the workforce engagement in the safety management system may derive from the applicable local legislation.

4.1.2 Ergonomics, Human Factors and Behavioural Safety

This paragraph focuses on the contribution of ergonomic and human factors to initiating and escalating incidents, and how design and behavioural safety approaches can be used to reduce the risks that human errors introduce.
Ergonomics is the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system.
A list of factors that can contribute to the occurrence of a human error is presented below. This includes, as example:

- <u>Environmental factors</u>
  - Quality of lighting;
  - Noisy, unpleasant or poorly maintained workplace;
  - Extremes of temperature;
- <u>Organizational factors</u>
  - Effectiveness of communications, including at shift changeovers;
  - Health and safety culture;
  - Quality of training and supervision;
- <u>Job-related factors</u>
  - Design of equipment and control / warning systems;
  - Workload / time pressure;
  - Interruptions during complex multi-stage tasks;
  - Physical and mental match between the job and the individual;
- <u>Human and individual characteristics</u>
  - Personality and attitudes;
  - Habits, which can either have positive or negative effects;
  - State of health and fatigue;
  - Competence;
  - Boredom.

Such factors have different impacts on the possibility of incurring into human error depending on the type of error that can occur. Human errors can be divided into different types, as reported below:

- Deliberate deviation from procedures, which can be of different types:
  - Routine, (e.g., due to incorrect or impractical procedures);
  - Situational (e.g., attempting to meet conflicting or unrealistic demands);
  - Exceptional (e.g., in response to abnormal circumstances)
- Errors of action, which may either be:
  - Lapses or omissions;
  - Slips (e.g., an action is performed incorrectly);
- Errors of thinking (e.g., due to inadequate knowledge or training).

The consequences of errors can affect both operations and safety and can range widely in severity.

Two different strategies are followed by BGF's management to reduce the risks due to human errors:

1. Taking account of human factors in the design process, to identify ways to reduce the probability of errors occurring, and their safety implications (ergonomic design);
2. Use of behavioural safety approaches to improve human reliability.

Behavioural safety programs typically involve workplace observation of unsafe acts or conditions, supported by follow-up work to resolve identified issues, and a reporting system, in order to address the different types of human failure. Programmes should also involve observation of, and positive feedback on, safe practices in order to identify and be able to disseminate and reinforce safe behaviour.

4.1.3 Occupational Health and Medical Fitness to Work

Employers need to identify and assess workplace hazards to health and monitor and review the health of the workforce. Occupational health therefore needs to be integrated into health and safety management strategies, so that employers have a clear understanding of the state of health of their workforce, in terms of short- and long-term physical health and wellbeing.

According to the applicable local legislation, BGF's management put in place a health surveillance system capable of:

- Early detection of health problems, so that improved controls can be introduced to prevent worsening;
- Provide data to enable health risks to be evaluated, and the effectiveness of control measures to be assessed;
- Enabling employees to highlight concerns about health effects of their work and reinforcing training and education on health-related hazards and protective measures.

Medical fitness for work evaluations is also carried out when necessary. These are specific checks to assess whether an individual is fit to undertake the work they will be doing without unacceptable risk to themselves or to others.

While good ergonomic design principles are applied in all situations, the need for, and scope of, fitness for work checks, should be based on the outcomes of a risk assessment.

4.1.4 Management Systems

In accordance with relevant legal duties, employers shall assess the health and safety risks presented by the activities of their organisation, and to have appropriate arrangements for the effective planning, organisation, control, monitoring and review of the preventive and protective measures" identified in the risk assessment.

The health and safety management system provides a framework and instruments to enable the organisation to achieve the aims of its health and safety policy.

The BGF health and safety policy records management commitment aimed at the prevention of injury and ill health and at the achievement of continuous improvement in health and safety management arrangements and performance.

The policy provides a framework for setting and reviewing health and safety objectives; it is formally documented, implemented (by means of the health and safety management system), and reviewed and maintained as necessary to ensure that it remains appropriate, with particular respect to changes in legal duties, performance standards and the activities of the organisation. The BGF health and safety policy is communicated to all personnel (including both employees and contractors) working under the control of the organisation, in order to ensure that they are aware of their responsibilities, and it is also made available to others as required.

4.1.5 Risk Management

The risk management is a hierarchical process. The BGF's management has implemented the following actions (ranked by priority):

1. Eliminate hazards where possible, for example by design changes, elimination of a hazardous operation, or selection of a different method;
2. Reduce the potential of those hazards that cannot be eliminated;
3. Reduce the exposure of people to hazards, by means of collective protection measures such as fixed guards;
4. Where fixed guards or similar are not possible, protective systems such as interlocks are used; these are designed such that if they fail, the machine will default to a safe state; and then mitigate residual risks by adopting safe systems of work and using PPE.

As many designs and tasks related to offshore aquaculture installations development are novel, there is little historical data on which to base risk assessment studies, so other approaches will be needed in order to provide evidence of the level of risk presented. The added complexity of marine operations also increases the risk, compared to equivalent operations onshore.

The fundamental aim of the risk management process is to ensure that all reasonably foreseeable risks are adequately assessed.

For this goal, different risk assessment techniques can be used depending on the project lifecycle stage, as illustrated in Figure 4-1.

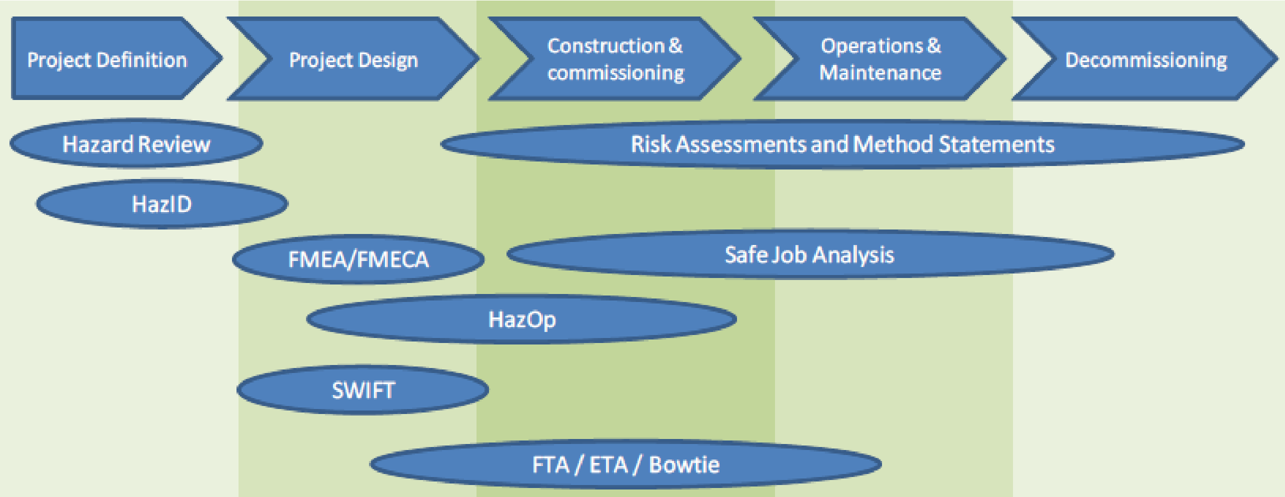


Figure 4-1: Example of different risk assessment techniques that can be adopted during the project lifecycle.

Preliminary to risk assessment, the hazard identification is a required step. Different structured identification methodologies can be applied depending on the stage in project development, and the resulting level of project-specific detail. An example of available techniques include:

- Hazard Review;
- Hazard Checklists, Structured What-If checklist Technique (SWIFT);
- Hazard Study / HazOp (Hazard and Operability Study;
- Failure Modes, Effects (and Criticality) Analysis (FMEA / FMECA);
- Safe Job Analysis (SJA)

Following the identification of possible hazards, for which an overview is reported in Section 3, qualitative or quantitative risk assessment methodologies can be applied to define hazards probability and severity, thus estimating the risk level of the operations performed.

Outputs of a qualitative risk assessment method can be in the form of a Risk Priority Number, which is generally the product or sum of numerical values assigned to probability and severity, or inside a Risk Matrix, with probability and severity on its axes.

On the other hand, the most common quantitative are the Fault Tree Analysis (FTA), Event Tree Analysis (ETA), and Bow Tie diagrams. The quality of results for these techniques is dependent on the quality and availability of failure and event data.

4.1.6 Training and Competence

Residual risks are those remaining after all risks have been eliminated as far as reasonably practicable. The BGF's management is required, under different applicable legislations, to provide information, instruction, training and supervision as is necessary to address the residual risks.

A worker can be considered competent if they have:

- Sufficient understanding of the risks and safe systems of work that are relevant to the location where they are working;
- Sufficient knowledge of the specific tasks to be undertaken, and the risks that they entail; and
- Sufficient training, experience and ability to undertake their assigned duties, and sufficient understanding to recognize their own limitations.

Different levels of training are required to develop specific competence:

- Entry level (typically required for new employees, newly appointed contractors, and visitors): health and safety training for any person newly exposed to a relevant health and safety risk;
- Basic Level: specific health and safety training for any employee undertaking a defined role or task on a project, in any life cycle phase;
- Advanced or specialist training: for example, training related to peculiar technical operations or usage of a particular equipment item, or a role within a safe system of work.

4.1.6.1 Safe procedure for training

New BGF's workers are required to perform their tasks under the supervision of a trained, responsible person prior to allowing them to attempt the work alone.

- Keep written records of the training workers receive. Document:
  - Who provided the training,
  - Who received training,
  - When the training occurred,
  - What training occurred.
- Documentation can include a photocopy of any certificates the workers have acquired;
- Make sure that the workers are aware of their legal rights and responsibilities under the applicable Occupational Health & Safety laws.
- Instruct the workers where they can find assistance and any emergency numbers.
- Correct any unsafe work habits and reward safety conscientiousness.
- Monitor new and young workers to ensure that the task is being carried out properly and answer any questions that they might have.
- Monitor workers to ensure that the safety standards/protocols are being maintained.
- Remember that employers and supervisors are also responsible for the worker's health and safety.

4.1.7 Safe systems of work

A safe system of work is required to establish and maintain systems of work that do not present risks to health as far as reasonably practicable. This is achieved through the control of work activities (both normal operation and maintenance activities), and by managing the interaction between different activities.

The abovementioned functions are fulfilled through a combination of supervision and control of operations, supported by BGF's management systems:

- Normal (or Routine) Operating Procedures define tasks that are part of normal operation, and where operation of the equipment does not expose the people undertaking the task to health and safety risks;
  - Explain to the worker any hazard, safe work procedures and any personal protective equipment that is required to complete the work task.
  - Provide a copy to the worker (or make sure that one is readily available) of the written safe work procedures for the task as per the BGF's Operation and maintenance manual [R3]. A copy of the Occupational Health and Safety manual must be available for all workers to review.
- A Permit to Work (PTW) system covers all other activities.

Awareness of the need for PTWs is covered in a site safety induction, while further training and competence assessment are required for people carrying out work under the system.

4.1.8 Simultaneous Operations (SIMOPS)

The need for Simultaneous Operations (SIMOPS) to be carried out during different lifecycle stages of the BGF infrastructure (e.g., maintenance) increases the risk of interference between different operations. In case such interference may lead to adverse effects, such as unsafe situations or asset damage occurring, a SIMOPS process should be used to manage the operations. This process can be summarized as:

- SIMOP cause identification, for example due to intentional scheduling, or a result of factors such as task durations differing from the original plan.
- Planning phase, typically consisting of:
    - Kick-off meeting, involving all parties to the operation, in order to:
        - Define the scope of the SIMOP; and
        - Identify and assess risks and mitigation measures.
- Execution phase, including:
    - Initial briefing of all parties;
    - Ongoing communications for the duration of the SIMOP; and
    - Monitoring of operations against the plan, and ensuring effective control of change;
- Close-out review to identify any learning for future operations.

The level of effort in this management process will be determined by the level of risk that the expected SIMOP presents, and whether similar operations have previously been undertaken on the BGF facility.

4.1.9 Management of Change

Different types of change are unavoidable over the lifecycle of offshore aquaculture installations, despite the quality of the initial design of the facility. Unexpected or unforeseen events or situations may arise requiring changes to be implemented quickly, which if not managed effectively, may significantly increase health and safety risks. Potential impact on health and safety are properly assessed, so that hazards or risks associated with technical or procedural changes and their implementation are identified and managed effectively.

The Management of Change process foreseen for the BGF platform considers:

- The need for the change;
- How the change will affect the health and safety risks posed by the BGF aquaculture facility;
    - In general, modifications should reduce risks; if the assessment indicates increased risk, then the design should be reconsidered;
- The risks that will occur during the installation and commissioning of the modification, including any additional equipment or materials that will be used;
- Requirements for follow-up activities, such as:
    - Provision of training and information for those who will be affected, updating of drawings, and changes to spares inventory;
    - Review, and revision of existing risk assessments (where necessary), safe systems of work, method statements and work instructions;
    - Any additional control measures – organisational, procedural, engineering controls and / or PPE;

- Issuing modified information and instructions to relevant people, and the withdrawal of information and instructions that are superseded;
- The allocation of sufficient time and resources to implement the change.

Personnel changes shall require careful management too. These changes can refer to a change of contractor, the introduction of new people to established work groups, or to the loss of experienced people to other duties or employers.

Thorough induction processes should be in place, supported by formal systems to provide increased supervision and support for new employees, ideally differentiating between those who are new to a site, and those who are new to the industry.

4.1.10-Emergency response & preparedness

In the event of an emergency occurring onboard the BGF facility, the operator is responsible for leading the initial response, which will normally follow predetermined procedures detailed within the facility's Emergency Response Plan (ERP). The BGF's management shall:

- Develop procedures for dealing with emergencies (e.g., sinking, fire, person overboard) and ensure that the crew receives the appropriate training.
- Ensure that all workers are aware of the ERP developed for responding to emergencies. They must be capable to call the appropriate emergency numbers and to communicate relevant incident details (e.g., GPS position, number and type of injuries/casualties, etc.) to the emergency responders. In the event of an emergency, it is essential that all personnel involved are fully familiar with their roles and responsibilities, which may vary depending on the nature of the emergency and their location at the time.

Emergency information will be displayed at suitable locations within the BGF platform, so that it is available to personnel when required.

4.1.11 First Aid and Emergency Medical Response

Despite the aim of health and safety management is to reduce the risk of people suffering injury or illness at work, the risk cannot be entirely eliminated. Suitable arrangements are put in place on board the BGF infrastructure, in order to minimise the severity of the effects on a person who is ill or injured.

First aid provision is integrated with the Emergency Response Plan for the aquaculture facility. Such provisions include successive levels of support:

- The immediate response is likely to be provided by the casualty's colleagues who will raise the alarm, and where it is safe to do so, rescue the casualty from immediate danger and provide initial first aid within competencies acquired during their training;
- Other personnel within the BGF platform may provide further assistance in the care of the casualty, particularly where they have more advanced first aid or medical training and may also assist with evacuation to a support vessel or helicopter; and
- Support vessels within the facility may be needed both to transport assistance to the casualty, and evacuate the casualty, and may also provide access to further equipment and supplies.

Each level of support is capable of taking care of the casualty until the next level of support is available, until the casualty is handed over to full medical care, in a place of safety such as a hospital or ambulance.

An example of general precautions concerning first aid is given below:

- Ensure that the required number of workers hold valid emergency, standard, or advanced First Aid certificates from a recognized training agency.
- Keep a record of all injuries, even minor ones, and note any First Aid care that was given.
- Ensure that First Aid service is accessible to all workers during all working hours.
- Ensure that transportation is available at all times to transport an injured worker.
- Ensure workers understand the need for First Aid kits, that the kit is adequate for the number of workers and located in the current work area.

4.1.11.1 Safe procedure for first aid

Before beginning any activity, each worker is:

- Instructed in the proper and safe procedures
- Aware of the potential hazards of all job functions
- Instructed in the proper use, care and limitations of protective clothing and equipment
- Instructed in the location of the First Aid supplies
- Aware of the appropriate procedures for obtaining medical attention

A sufficient number of people will receive the appropriate level of First Aid training from a recognized training agency. The first aid procedure also prescribes to:

- Provide an adequate number of the appropriate First Aid kits.
- Clearly mark the First Aid kits and store them in an accessible area. Workers must know where all First Aid kits are located.
- Keep the First Aid kits current by regularly checking the contents' expiry date and that replacements have been added to the kit after use
- Grant that casualty evacuation is available at all times to transport an injured worker to a medical facility
- Make means of communication available to workers
- Keep the required distress, boat safety and emergency equipment in a dry, easily accessible area.
- Keep a record of all injuries and note any First Aid that was administered.

5 CONCLUSIONS

The present document has been identified as Deliverable D7.4 "*Health and Safety Manual*" of the Blue Growth Farm Contract [AD1], [AD2]. This document has presented an overview of the applicable occupational health and safety legislation together with a review of the main hazards related to the equipment and activities present or carried out on the Blue Growth Farm infrastructure. Example of best practices, safe procedures or preventive measures have also been given.

Occupational health and safety organizational requirements have been reported, summarizing the minimum employer's duty and priorities.

6 REFERENCES

[R1] BGF Deliverable, 2021, "D7.2 – Aquaculture automation & security design, design for integration with renewable energy production systems report", Rev. 0.0, 29th October.

[R2] BGF Deliverable, 2021, "D7.3 – Integration system design for the farm technologies report", Rev. 0.0, 30th December.

[R3] BGF Deliverable, 2021, "D7.5 – Operation and Maintenance Manual", Rev. 0.0, 28th February.

[R4] Melvin L. Myers and Robert M. Durborow (2012). Aquacultural Safety and Health, Health and Environment in Aquaculture, Dr. Edmir Carvalho (Ed.), ISBN: 978-953-51-0497-1, InTech, Available from: http://www.intechopen.com/books/health-and-environment-in-aquaculture/aquacultural-safety-and-health

[R5] E-Fact 80: Hazard Identification Checklist: Occupational Safety and Health (OSH) risks in the wind energy sector | Safety and health at work EU-OSHA (europa.eu)

[R6] Deliverable D4.3, 2019," D4.3 – Environmental monitoring measures and data elaboration report", Rev.0.0, 30th September.

[R7] UK HSE, 2020. Protecting lone workers: How to control the risks of working alone. https://www.hse.gov.uk/pubns/indg73.pdf.

Annex A. Hazard identification checklist for wind turbine generator

Questions		Yes	No
1	**Site management (references: 1, 2, 3, 4, 5, 6 and 7)**		
1.1	**Safety Co-ordination onsite**		
1.1.1	Has a competent safety coordinator been appointed to coordinate and oversee safety actions and to update disseminated safety information?		
1.1.2	Has the safety coordinator received appropriate training to carry out his duties?		
1.1.3	Do supervisors provide leadership in addressing and promoting OSH in the wind farm? For example, do they conduct inspections and act quickly to deal with hazards?		
1.1.4	Is access to the site controlled and/or appropriate levels of supervision in place?		
1.2	**Emergency Procedures**		
1.2.1	Are there written emergency procedures and plans in place that consider any major incident within a wind turbine, how the rescuing of workers will be undertaken and the co-ordination with the emergency services?		
1.2.2	Do these procedures take into consideration the remoteness of onshore wind farms or if the facility is offshore? For example what to do in the event of: • Person overboard when being transferred to and from the wind turbine. • Vessel collision. • Helicopter crush. • Fire, explosion or collision on turbine or accommodation module. • Stranded workers on turbines due to weather conditions. • Diving emergencies.		
1.2.3	Do all personnel, contractors and visitors receive training and information on the emergency procedures?		
1.2.4	Have competent fire marshals been appointed to coordinate evacuations and communicate with any emergency services that may attend an incident onsite?		
1.2.5	Are there effective and reliable ways of raising the alarm for all employees? Are emergency numbers displayed in the wind turbine?		
1.2.6	Are emergency drills carried out at the wind farm as a minimum twice a year?		
1.3	**First Aid**		
1.3.1	Has an appropriate number of first aiders been appointed? Have the following been considered when determining this number: • Size of the wind farm (e.g. number of persons on		

	site simultaneously). • Location of the wind farm. • Response time for emergency services to reach the wind farm. • Type of work carried out in the wind turbine. • Presence of vulnerable groups (e.g. young workers, pregnant women, visitors, people with special needs etc.) • Wind farm being in a remote site. • Lone working. • Requirements for travel. • Other parties / subcontractors working on the wind farm. • Records of previous incidents. • Adequate coverage by first aiders at all times.		
1.3.2	Are the first aiders' identities displayed in the wind turbine?		
1.3.3	Are there sufficient first aid kits available?		
1.3.4	Is the content of the first aid kit in date and complete?		
1.3.5	Are all workers made aware of the accident reporting system?		
1.4	**OSH Management**		
	Hazard Management		
1.4.1	Are there defined systems, procedures and documentation in place to manage Health and Safety? For example do they cover: • The objectives and goals for health and safety being set for the project. • An organization structure that clearly defines health and safety roles and responsibilities of all responsible persons and site personnel. • Description of the defined systems, procedures and documentation in place to manage health and safety. • Procedure for the development of method statements, risk assessments and safe systems of work for all activities throughout the entire life cycle of the wind turbines, for example construction, operation, maintenance, demolition etc. • The resources that have been allocated to ensure all necessary OSH information, instruction and training is being provided.		
1.4.2	Are there clearly defined methods and procedures in place for conducting risk assessment? Is a system in place that ensures all risks to all persons working in the wind turbine have been identified, assessed and are adequately controlled?		

1.4.3	Have workplace hazards linked to the organization of the work and work-related stress been assessed as part of the work-place risk assessment? Do these cover: • Workload. • Deadlines. • Support from supervisors and colleagues. • Autonomy. • Monotony. • Working offshore. • Working day/night rotating shifts. • Working at height for several hours at a time either in harness or confined within the nacelle. • Work-life balance.		
1.4.4	Are there measures in place to avoid a high work load and tight deadlines?		
1.4.5	Have the specific needs and risks of the different worker groups (for example migrant workers, young and older workers or female workers) been addressed?		
1.4.6	Is there a procedure in place that allows employees to report hazards in the wind turbine as soon as they are detected?		
1.4.7	Are all workers aware of these risk management mechanisms and procedures? Do workers have easy access to a site-specific safety manual and task-specific risk assessments?		
1.4.8	Is the use of sub-contractors appropriately managed? Are contractors/visitors to the wind turbine briefed on workplace hazards before entering? For example is the following information provided before work commences: • Wind farm layout. • The hazards they can encounter in the wind turbine. • Information on site rules and safety procedures including incident reporting process. • What PPE is required when working in the turbine. • Any special equipment that needs to be used onsite. • What to do in the event of an emergency. • Clearly understand their responsibilities and restrictions. Are procedures in place (for example are contractors escorted) to ensure the management and supervision of sub-contractors whilst they are onsite?		
1.4.9	Is lone working avoided or are there adequate procedures in place to protect lone workers? Are employees working on their own / remotely issued with personal first aid kits and personal communicators /		

	mobile phones etc.?		
1.4.10	Is appropriate Personal Protective Equipment (PPE) available and being used and maintained correctly? For example: eye, head, ear, and hand protection or safety harnesses when working at heights.		
	Training		
1.4.11	Are training needs for staff at all level identified?		
1.4.12	Is OSH training made available to all employees?		
1.4.13	Are all employees fully trained in the skills required to work in a wind turbine?		
1.4.14	Are training records maintained?		
	Communication and Employee participation		
1.4.15	Are relevant safety rules and regulations including information from wind associations or federations appropriately communicated to the workers including temporary workers, sub-contractors and visitors? For example OSH information should be communicated and passed on to: • Site personnel and the management team. • Third parties. • The public. • Shared workplaces. • Emergency services.		
1.4.16	Are any safety critical turbine faults communicated to the industry and are turbine manufacturers/the industry consulted regularly to share good practice and identify potential issues?		
1.4.17	Does a health and safety committee exist?		
1.4.18	Are workers consulted on all workplace changes that may affect the OSH of employees in the wind turbines? For example are workers consulted in the development of: • Safety rules and procedures. • Risk assessments including their results and method statements. • The introduction of any measure which may substantially affect workers health and safety at work. For example the introduction of new equipment or new systems of work. • Information you must give your employees on the risks and dangers arising from their work, measures to reduce or get rid of these risks and what employees should do if they are exposed to a risk. • The planning and organization of health and safety training. • Changes within the workplace.		
	Welfare		

1.4.19	Is there a suitable way to access the site e.g. suitable roads and walkways? Is there a system in place to check for the safe access to the wind turbine?		
1.4.20	Are adequate welfare facilities/amenities provided for all employees?		
1.4.21	For offshore wind farms have appropriate accommodation platforms or vessels been provided?		
1.4.22	Are lighting levels in and around the wind turbine suitable? The lighting must: • Allow people to notice hazards and assess risks. • Be suitable for the environment and the type of work (for example, it is not located against surfaces or materials that may be flammable). • Provide sufficient light (illuminance on the task). • Allow people to see properly and discriminate between colors, to promote safety. • Not result in excessive differences in illuminance within an area or between adjacent areas. • Not pose a health and safety risk itself. • Be suitably positioned so that it may be properly maintained or replaced, and disposed of to ensure safety. • Include, when necessary, suitable and safe emergency lighting.		
1.4.23	Are workers protected from extreme weather and extreme temperatures?		
1.4.24	Are relevant safety signs displayed in the wind turbine?		
2	Manufacturing (references 7, 8, and 9)		
2.1	**Hazardous substances**		
2.1.1	Is there a system that identifies all hazardous substances used in the manufacturing of wind turbine components? Have risk assessment been carried out?		
2.1.2	Are exposures to chemicals and dust eliminated or, if not possible, reduced to the minimum, giving priority to measures at source according the hierarchy of control measures as indicated in the legislation on hazardous substances? Please note that national legislation on dangerous substances may have stricter provisions and should be checked)		
2.1.3	Are material safety data sheets obtained for all the substances used and are these made available to all workers?		
2.1.4	Is mechanical ventilation provided throughout the fabrication area at sufficient rate?		
2.1.5	When risk reduction measures at source are not sufficient, is personal protective equipment (PPE) provided, used, and maintained whenever necessary?		
2.1.6	Are workers trained to use the PPE provided?		

2.1.7	Are flammable or toxic chemicals stored in appropriate containers in a well-ventilated area, when not in use?		
2.1.8	Are there procedures in place for safe maintenance and cleaning of manufacturing installations where exposure to chemicals and dust could occur?		
2.1.9	Is the control of exposure to hazardous substances monitored in the workplace? Is the quality of the air and exhaust air monitored?		
2.1.10	Is the health surveillance of workers carried out in the workplace?		
2.1.11	Do workers have access to information on safe working procedures?		
2.2	**Manual handling**		
2.2.1	Is work arranged so that manual handling operations such as lifting and carrying or repetitive manual handling of even light items are avoided, and where not possible, reduced to a minimum?		
2.2.2	Have workers been trained on safe manual handling techniques?		
3	**Transportation (Reference 3, 11, 12, 13, 14 and 15)**		
3.1	**Onshore – General**		
3.1.1	Has a route survey that describes the transport route and points of transfer been carried out? The survey should have highlighted: • If vehicle routes are sufficiently wide for the purpose. • If there are any restricted access routes, steep gradients, confined road corridors, road traction, or limited turning points. • If ground conditions on which vehicles operate are suitable for the purpose, properly constructed and well maintained. • If vehicle routes are free from obstructions and other hazards. • If there are poor sight lines or visibility problems on the route. • The form of communication that is best suited.		
3.1.2	Are clear and appropriate hazard warning signs prominently displayed in the vicinity where vehicles manoeuvre e.g. directional, speed limit, give way, no public entry?		
3.1.3	Are additional safety controls provided e.g. provision of escorts? Escorts should be used: • To provide and apply an element of control on road users along particular section of the route, for example when a load must impinge upon the centre like if a road or move along the wrong side of a roundabout.		

	• To provide an element of warning and information for other road users about the imminent proximity of the convoy. • Assess and warn of potential hazards such as clearance, low hanging branches, junctions etc.		
3.2	**Onshore – Vehicle suitability and selection**		
3.2.1	Are assessments carried out to ensure that suitable vehicles and attachments have been selected for transporting wind turbine components? Has the assessment considered: • Height, weight and width of the turbine components to be transported. • Weight and dimensions of the vehicle. • The maximum working load of the vehicle to be used. • How will the components be secured. • Maintenance record of the vehicle. • How far will the vehicle travel. • Conditions the vehicle will be used. • Vehicle route conditions, for example access routes to the site, gradients, road restrictions. • The need for additional equipment such as trailer units with hydraulic dynamically balanced suspension system.		
3.2.2	Do vehicles have good direct visibility or devices for improving vision where reversing cannot be eliminated and where significant risk still remains?		
3.2.3	Do vehicles have effective service and parking brakes?		
3.2.4	Do vehicles have seats and seatbelts where necessary?		
3.2.5	Are there guards to prevent access to dangerous parts of the vehicles, e.g. power take-offs, chain drives, exposed exhaust pipes?		
3.2.6	Do drivers have protection against bad weather conditions, or against an unpleasant working environment, i.e. the cold, dirt, dust, fumes and excessive noise and vibration?		
3.2.7	Is there a safe means of access to and exit from, the cabs and other parts that need to be reached?		
3.2.8	Are surfaces, where people walk on vehicles, slip resistant?		
3.2.9	Are there measures in place that offer protection to drivers against injury in the event of an overturn or being hit by falling objects?		
3.2.10	Is there a vehicle preventative maintenance programme in place whereby vehicles are inspected at predetermined intervals of usage or mileage? Does the programme consist of: • Checklist of maintenance service tasks		

	performed. • Maintenance service interval or frequency to perform tasks. • Driver written-up inspections and/or complaints. • An automotive facility with trained professional automotive technicians — either in-house or outsourced. • Scheduling and recordkeeping, either manual or electronic.		
3.2.11	Is there a vehicle defect reporting system in place?		
3.3	**Onshore – Driver competence & training**		
3.3.1	Have drivers received adequate training, instruction and supervision to carry out their duties safely?		
3.3.2	Are drivers fully aware of the company's safe systems of work and their responsibilities in maintaining a safe workplace?		
3.3.3	Are driver's standards regularly monitored and are they recorded?		
3.4	**Offshore – Vessel suitability and selection**		
3.4.1	Has a suitability assessment been carried out to ensure that the vessel selected is suitable for the intended operation? Has the suitability assessment been verified through a fit for purpose assessment? The selection of a Fit for Purpose vessel should take into account a wide range of operational factors including: • The activity it will be carrying out - type, frequency, scale and complexity. • The conditions likely to be encountered at the site of the activity and during transit to/from the site. • The duration of the work. • Station keeping requirements. • Area of operation. • Number of project crew. • Vessel endurance / time offshore. • Crew comfort factors e.g. fatigue, vibration, and other occupational health aspects. • Transit times. Sea, tide and wind operational limits.		
3.4.2	Is there an inspection regime in place that ensures that the vessel is fit for purpose for the life cycle of its operations? This regime should cover: • Pre operation – Including selection of the vessel, mobilisation of equipment and personnel to the vessel. This may include installation of equipment onto and/or modification of the vessel.		

	• During operations – Carrying out the activity e.g. surveys, installation of meteorological monitoring equipment and masts, transits, emergency support. • Post operation – De-mobilisation of equipment and personnel including returning the vessel to its pre-hire configuration.		
3.4.3	Have passage plans and navigational risks been assessed to determine the existing densities and type of marine traffic in the wind farm development area?		
3.5	**Offshore – service vessel passengers**		
3.5.1	Has offshore working been considered in an appropriate risk assessment? The assessment should consider: • Transfer from vessel to boat landing ladder and vice versa. • Emergency response arrangements, including the provision of first aid equipment, rations and equipment in the event of stranding. • Provision of appropriate navigation aids. • Practicality of access by helicopter. • the need to remotely stop turbine blades in the appropriate formation to allow for access by helicopter		
3.5.2	Do all service vessel passengers have in their possession valid certification as appropriate to their access requirements? As a minimum all service vessel passengers should have in their possession valid certification as appropriate to their access requirements such as: • First aid. • Sea survival. • Helicopter Underwater Escape Training (HUET). Working at height.		
3.5.3	Are the names of all the service vessels passengers that have authorisation to undertake work within the wind turbines recorded in a database?		
3.5.4	Is a procedure in place to addresses visitors who do not hold the required certificates?		
3.5.5	Are all vessels passengers provided with PPE? For example: • Safety footwear. • Safety helmet. • Harness. • Safety belt and lanyard. • Fall arrest systems. • Life jacket. • Personal locator beacon. • Survival suit.		

3.5.6	Are vessels specific safety inductions carried out?		
3.5.7	Are rescue and emergency procedures in place?		
3.5.8	Are weather conditions and the tides monitored and appropriate interventions made? Do these consider: • The weather limitations of the activity taking into account the site and duration of the work. • The selected vessel must be capable of operations within the expected prevalent conditions with a safety margin to allow for changes in environmental conditions. • The time to transit to/from the site and distance from a safe haven. • Site specific and up to date weather forecasts need to be reviewed to allow planning of the operation. • Local weather, wind, tide and sea state characteristics data must be taken into account at the time of carrying out the activity. • Local conditions should dictate when operations are safe to continue.		
4	**Construction / Demolition (references 3, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26 and 27)**		
4.1	**Communication and coordination**		
4.1.1	Has the frequency and methods of communication between all parties involved in the wind farm project been considered and agreed?		
4.1.2	Does this include arrangements for emergency response?		
4.1.3	Is everyone involved in the project aware of the equipment to be used to post or deliver OSH communication information?		
4.1.4	Have specific measure been put in place to coordinate marine operations and vessel movements?		
4.1.5	Can contact be maintained with key personnel, e.g. by mobile phones or radios, at all times?		
4.1.6	Are there procedures in place for persons working alone in a tower or in remote areas?		
4.1.7	Are instructions and information made available and understood by workers regardless of their native language?		
4.1.8	Are there procedures in place for the management of vessel movements, especially when several may need to be in the vicinity simultaneously?		
4.2	**Weather conditions**		
4.2.1	Is there an adverse-weather policy in place?		
4.2.2	Does this policy cover: high winds, effects on workers of inclement weather, risk of being snowed in or cut off, lack of visibility, risk of lightning strike, hot sunny		

	weather, cold weather and additional weather-related PPE?		
4.2.3	Are all workers aware of when work will cease due to high winds, poor weather, or significant sea states?		
4.2.4	Are all vessels and equipment used capable of being made safe and/or are able to reach sheltered waters in adverse weather conditions?		
4.2.5	Are the cranes used offshore capable of withstanding abnormal wind loadings when not in use?		
4.3	**Temporary facilities**		
4.3.1	Have the location of temporary structures been assessed so as to consider ground conditions or the need to secure against strong winds?		
4.3.2	Have safe unloading and loading areas been identified?		
4.3.3	Is the installation of temporary services such as electricity or Liquefied Petroleum Gas (LPG) adequate and safe?		
4.4	**Working at Heights**		
4.4.1	Has working at height been considered in an appropriate risk assessment?		
4.4.2	Can working at heights activities be eliminated?		
4.4.3	Have activities such as use of ladders, access into tower and hub, working in nacelle, rope access activities, etc. all been taken into consideration?		
4.4.4	Has the assessment considered the various places of work and their means of access at height? Have the following been assessed? • They are stable and of sufficient strength. • Have sufficient dimensions to permit the safe passage of persons and the safe use of any plant or materials. • Include suitable and sufficient means for preventing any falls of workers or objects.		
4.4.5	Are fall prevention provisions such as guard rails, suitable and sufficient and are they regularly inspected?		
4.4.6	Are fall arrest equipment suitable and sufficient? Has a risk assessment been undertaken that demonstrates that the work at heights can be performed safely while using such systems?		
4.4.7	Has the approval of the use of ladders been as a result of a risk assessment that has demonstrated that the use of more suitable work equipment is not justified because of the low risk of the activity, because the duration of use is short, or because of existing features on site which cannot be altered?		
4.4.8	Are rescue procedures in place to recover workers who may become trapped or suspended at height?		
4.4.9	Are workers appropriately trained?		

4.4.10	Are tools or other objects / materials fitted with safety straps to prevent them being dropped?		
4.4.11	Are working areas free from slip and trip hazards?		
4.4.12	Are access areas directly beneath work at height restricted?		
4.5	**Lifting Operations**		
4.5.1	Are all lifting operations subjected to a full risk assessment?		
4.5.2	Do the risk assessments consider the activity, the load and the environment?		
4.5.3	Has a lifting plan been carried out?		
4.5.4	Has a lifting supervisor been appointed?		
4.5.5	For Onshore lifting operations that use mobile cranes have the following been considered? • Condition of access roads and if they are strong enough to withstand. the axle load of the crane. • Presence of underground or overhead services. • Ground conditions - no potential for shifting or settling of outriggers. • Wind conditions.		
4.5.6	For Offshore lifting operations have the following been considered? • Type of construction vessel to be used - Vessel design. • The impact of the vessel being subjected to different motions such as rolling or pitching. • Vessel stability. • Wind conditions. • Tidal conditions. • Lifting of larger components • Crane position. • Rated capacitor indicator to be set for appropriate sea-state. • Visibility of vessel deck. • Lifting done over the vessel deck. • Personnel working near loading/unloading area.		
4.5.7	Is EN13000 (the requirements for limiting and indicating devices on mobile cranes) been applied to correctly calculate the drag coefficient (Cw) of loads?		
4.5.8	Are workers involved in lifting operations appropriately trained?		
4.5.9	Is lifting equipment regularly inspected and suitable for the specific task?		
4.5.10	Are there effective means of communication (e.g. signals or radio) between the crane operator and banksman and/or those working at height?		
4.5.11	Are weather conditions monitored and appropriate interventions made if, for example, high winds or		

	lightning are expected?		
4.6	**Diving Operations**		
4.6.1	Have risk assessments been carried out for all diving activities that use site specific information and that takes into consideration the diving activity and its location? For example: • Turbine/cable maps, details on port of operations, • Tidal restrictions, • Facilities available to diving contractors, • Access and egress arrangements to/from vessels, or contact details.		
4.6.2	Has the elimination of the diving operation been considered? Is it possible to use alternatives like remotely operated vehicles?		
4.6.3	Has a dive plan been produced that indicates the resources required to undertake the diving work safely? For example: • Interface with crane operations, transition piece works, or barge operations. • Tooling requirements and quality assurance requirements. • Anticipated boundaries of the dive site. • Historical information (technical and safety). • Environmental conditions.		
4.6.4	Has the dive contractors' competence and capability been assessed?		
4.6.5	Is the dive team size sufficient for the project?		
4.6.6	Has a person been appointed to supervise the dive?		
4.6.7	Is there suitable and sufficient plant available to carry out the dive?		
4.6.8	Is there additional plant to address first aid and foreseeable emergencies connected with the diving project?		
4.6.9	Are checks carried out to ensure that weather conditions and the strength and depth of tides are suitable for diving to be undertaken?		
4.6.10	Is an 'A' (alpha) flag deployed or appropriate marine lighting used to show that a trial is in place?		
4.6.11	Can a diver be deployed safely into the water and recovered, including in an emergency?		
4.7	**Noise and Vibration**		
4.7.1	Have noise and vibration risk assessments been carried out for activities that expose workers to levels at or above the daily exposure action limit?		
4.7.2	Has the type level and duration of the exposure been considered?		
4.7.3	Has the work activities been designed with appropriate		

	work schedules and adequate rest periods to limit the exposure durations?		
4.7.4	Have all workers been provided with suitable and appropriate hearing protection?		
4.7.5	Are suitable and sufficient information and training provided to employees to ensure that work equipment is used correctly and safely?		
5	**Operation and maintenance (references 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, and 41).**		
5.1	**General issues**		
5.1.1	Have all operational and maintenance activities been risk assessed?		
5.1.2	Are all operational monitoring activities clearly defined?		
5.1.3	Are all operators appropriately trained and equipped to do their job safely and effectively?		
5.1.4	Is there a suitable preventative maintenance schedule in place to avoid catastrophic failures and to minimise the need for reactive maintenance?		
5.1.5	Are maintenance activities appropriately coordinated and supervised and are responsibilities clearly defined?		
5.1.6	Are maintenance workers appropriately inducted and trained with respect to the work they are expected to undertake?		
5.2	**Electricity-related risks**		
5.2.1	Is there safe system of work procedures in place to manage work activities on or near live electrical systems?		
5.2.2	Is there a permit to work procedure in place for electrical work?		
5.2.3	Is electrical work being carried out by a qualified and competent electrical engineer?		
5.2.4	Are effective safety measures and procedures for electrical isolation and earthing? LV isolation should be by the withdrawal of fuse links or other Isolating. Devices. Time switches, float switches, thermostats, sequence switching devices or similar automatic switching devices are not Isolating Devices. Are approved insulation tools being used?		
5.2.5	Is there an appropriate management system for the use and maintenance of switchgear?		
5.2.6	Has the fault level of the generator, transformer and cable layout been appropriately calculated and adequate circuit breakers installed?		
5.2.7	Are methods of frequency and voltage control suitable and sufficient?		
5.2.8	Are wind turbines and their associated hardware compatible with the relevant Distribution Network Operator's distribution code and their technical		

	recommendations and safety rules?		
5.2.9	Have common standards for warning signs and for labelling and annotating electrical plans been agreed and is all equipment clearly and accurately labelled?		
5.2.10	Are the electrical tools/equipment approved for work in wet areas?		
5.2.11	Are workers provided with suitable PPE when risk reduction measures at source are not sufficient? For example rubber gloves / insulating gloves.		
5.3	**Fire prevention**		
5.3.1	Are turbines equipped with comprehensive lightning and surge protection, which is appropriate for the individual type of turbine and based on risk assessment or set in accordance with the International Standard for Protection against lightning, IEC 62305 LPL 1? For example: • Compact circuit breakers. • Semiconductor protection fuses. • Differential current monitoring devices. • Residual-current devices.		
5.3.2	Is appropriate fault protection in place to selectively disconnect faulty components?		
5.3.3	Are combustible materials kept to a minimum and are hydraulic and lubricant oils non-combustible or have significantly higher flash points than operating temperatures?		
5.3.4	Where hot work cannot be avoided, are fire precautions taken prior to, during and after it is carried out? Are hot work permits in place?		
5.3.5	Are smoke detectors and fire alarms installed and regularly tested?		
5.3.6	In case of fire or strong winds, are the shutdown procedures and engineering controls suitable and sufficient?		
5.3.7	Are suitable fire extinguishers regularly checked and appropriately located, and are workers trained to use them?		
5.4	**Ice throw/blade failure / tower collapse**		
5.4.1	Are systems in place, such as vibration sensors, to assess the condition of rotor blades and detect the presence of ice build-up?		
5.4.2	Are systems in place to alert workers of the threat of ice/blade throw and ice fall from the nacelle?		
5.4.3	Are there adequate exclusion zones (at least 150m in all directions from the wind turbine) that will become effective when the threat of ice /blade throw is detected?		
5.4.4	Are the turbines designed to cope with foreseeable		

	weather conditions?		
5.4.5	Are blades equipped with lightning protection systems?		
5.4.6	Are systems in place to prevent the turbine being restarted with the blades locked in a hazardous position after maintenance work?		
5.4.7	Are there redundant "fail-safe" control systems in place to avoid wind turbine operation under over-speed conditions?		
5.4.8	Is there a suitable and sufficient inspection and preventative maintenance regime in place? For example to check integrity of the tower fastening system or the condition of blades.		
5.5	**Harmful substances**		
5.5.1	Are the hierarchy of controls defined in Council Directive 98/24/EC on the protection of the health and safety of workers from the risks related to chemical agents used to ensure worker exposure to harmful substances is reduced to a minimum and within the relevant national Occupational Exposure Limits (OEL)?		
5.5.2	Are Safety Data Sheets provided and are harmful substances risk assessment carried out?		
5.5.3	Is appropriate storage provided for gas cylinders and flammable or toxic chemicals?		
5.5.4	Are there provisions for the neutralisation or disposal of spills or overflows of hazardous chemicals?		
5.5.5	Are adequate washing facilities provided and has the need for eyewash stations and emergency showers been considered?		
5.5.6	Has the need for mechanical ventilation been considered and if in use, is its effectiveness regularly checked?		
5.5.7	Are all workers made aware of the exposure risks of for all hazardous substances used? Are they informed of the precautions they need to take?		
5.5.8	If used, are respirators inspected, cleaned, sanitised, and maintained regularly?		
5.5.9	Is air quality monitored and appropriate gas detectors used in confined spaces?		
5.6	**Musculoskeletal issues - manual handling / awkward postures / static postures / repetitive movements**		
5.6.1	Have manual handling, repetitive movements and awkward postures been considered in an appropriate risk assessment?		
5.6.2	Is work arranged so that the heavy lifting is kept to a minimum?		
5.6.3	Are workers trained in safe handling techniques and are aware of the risks associated with awkward (i.e. non-neutral) postures?		
5.6.4	Are loads easy to lift or are mechanical assists available?		

5.6.5	Can the task be done without lifting of the arms above shoulder level?		
5.6.6	Are provisions in place to ensure workers avoid static postures (i.e. being in the same posture for long periods)?		
5.6.7	Are tools ergonomically designed and comfortable to use?		
5.6.8	Are tool belts provided and used when climbing and descending the wind turbine ladder?		
5.7	**Confined spaces**		
5.7.1	Have all the confined spaces in the wind turbine been identified? For example nacelle or inside blades.		
5.7.2	Is there a record of all identified confined spaces?		
5.7.3	Have all workers been informed of the existence of these confined spaces and warned of the possible hazards?		
5.7.4	Has a risk assessment been conducted to identify, evaluate and control all risks arising from entry or work in confined spaces?		
5.7.5	Are safe work procedures established for all confined space work, both routine and non-routine in the wind turbine?		
5.7.6	Do the safe work procedures for confined space cover the following key areas? • Evaluation of the need to enter or carry out work in the confined spaces identified. • A confined space entry permit. • The types of atmospheric testing required and the interpretation of test results. • The safety and health precautions to be taken during entry into the confined space and during an emergency situation. • The provision and safe use of safety equipment and personal protective equipment. • The means to prevent unauthorised entry into the confined space including the display of warning signs.		
5.7.7	Are the following information provided in the confined space entry permit? • The location and identity of the confined space. • The purpose of entry into the confined space. • The results of the gas testing of the atmosphere of the confined space. • The validity of the confined space entry permit.		
5.7.8	Are safe means of access and egress provided for movement of workers to and within the confined space?		
5.7.9	Are all confined space openings effectively covered to prevent objects from falling through?		

5.7.10	Is there sufficient and suitable lighting provided for entry into and work in confined space?		
5.7.11	Are all moving parts and equipment inside the confined space locked out and tagged?		
5.7.12	Has a written rescue plan been established for work activities in confined spaces in the wind turbine?		
5.7.13	Have sufficient supplies of rescue equipment been provided/made readily available? Are the rescue equipment properly maintained?		
5.7.14	Are regular drills conducted?		
5.7.15	Have the persons entering the confined space received adequate safety and health training pertaining to the hazards associated with entry/work in the confined space?		
5.7.16	Have all appointed rescue personnel received adequate training in rescue operation, including first aid and proper usage of personal protective equipment and other rescue equipment?		
5.8	**Working at height**		
5.8.1	Have all the relevant points raised above, in Section 4.4, been considered from an operational and maintenance perspective and have these activities been risk assessed?		
5.9	**Lifting operations**		
5.9.1	Have all the relevant points raised above, in section 4.5, been considered form an operational and maintenance perspective and have these activities been risk assessed?		
5.10	**Exposure to noise**		
5.10.1	Have all the relevant points raised above, in Section 4.7., been considered from an operational/maintenance point of view?		
5.11	**Slips, trips and falls**		
5.11.1	Have slips, trips and falls been considered in an appropriate risk assessment?		
5.11.2	Are walkways clean, even, and free from clutter and potholes?		
5.11.3	Are floor surfaces adequately slip resistant, bearing in mind the possible contaminants or wet surfaces that may be present, the type of work being undertaken and the angle of any slopes?		
5.11.4	Are there suitable provisions in place to minimise and/or clean up floor surface contaminants, e.g. suitable cleaning equipment and cleaning regimes?		
5.11.5	Are changes in level (i.e. small slopes and steps that could present a trip hazard but cannot practicably be removed) clearly defined by using contrasting floor colours?		
5.11.6	Are lighting levels sufficient?		
5.11.7	Are suitable handrails provided on stairs and are step		

	dimensions reasonable and consistent?		
5.11.8	Are contrasting stair no sings installed to define the edge of each step?		
5.11.9	Is appropriate slip resistant footwear provided and if so, is its condition regularly checked?		
5.11.10	Is the condition of footwear and flooring regularly checked?		
5.11.11	Are workers conscious of slip and trip hazards and work responsibly?		
7.1	**Disposal and recycling**		
7.1.1	Is worker's exposure to airborne dangerous substances, micro –organisms or the generation of dust and aerosols avoided?		
7.1.2	Are these exposures reduced to a minimum giving priority to control measures at source according to the hierarchy of control measures indicated in the legislation on hazardous substances?		
7.1.3	Are adequate washing facilities available for all workers?		
7.1.4	Is the exposure to noise eliminated, or if not possible reduced to a minimum and kept within the limit of 85 dB(A) by implementing control measures at source?		
7.1.5	Is appropriate PPE provided, properly maintained, and are workers trained in their correct use?		

Annex B. Checklist for the prevention of accidents and damages to health in the solar energy sector

Questions		Yes	No
1. Manufacture			
Exposure to dangerous substances			
1.1	Is worker exposure to chemicals and dust eliminated or, if not possible, reduced to the minimum, giving priority to measures at source according the hierarchy of control measures as indicated in the legislation on hazardous substances? (EU Directive 98/24/EC on the risks related to chemical agents at work, and EU Directive 2004/37/EC on carcinogens or mutagens at work; Please note that national legislation on dangerous substances may have stricter provisions and should be checked)		
1.2	Is mechanical ventilation provided throughout the fabrication area at a sufficient rate?		
1.3	When risk reduction measures at source are not sufficient, is personal protective equipment (PPE) provided, used, and maintained whenever necessary?		
1.4	Are workers properly trained to use the PPE provided?		
1.5	Are flammable or toxic chemicals stored in appropriate containers and in a well-ventilated area, when not in use?		
1.6	Are hazardous gas cylinders (e.g. silane) stored adequately, i.e. outside in an isolated secure area or in purged gas cabinets?		
1.7	Are there procedures in place for the safe maintenance and cleaning of manufacturing installations where exposure to chemicals and dust could occur?		
1.8	Is the quality of air in the workplace and of exhaust air monitored?		
1.9	Are Safety Data Sheets provided?		
1.10	Have the workers access to information on safe work procedures?		
1.11	Is an emergency plan available?		
1.12	Is work arranged so that manual handling operations, such as lifting and carrying operations and repetitive manual handling of even lighter items are avoided and, where not possible, reduced to the minimum?		
1.13	Have workers been trained on safe manual handling techniques?		
2. Installation, maintenance, decommissioning			
Work organisation, psychosocial risks			
2.1	Is information on the solar system, the electrical installation and the building that is required to perform the work safely available to the workers?		
2.2	Is training provided on safe working procedures?		
2.3	Is there sufficient cooperation, communication and exchange of information among the different actors involved (for example building owner, site manager and the workers) in order to allow the safe performance of the work, especially if different companies and sub-contractors are involved?		
2.4	Are workers involved in the workplace risk assessment?		

2.5	Have workplace hazards linked to the organisation of the work and work-related stress been assessed as part of the workplace risk assessment?		
2.6	Are there measures in place to avoid a high workload and tight deadlines?		
2.7	Have the specific needs and risks of the different worker groups (migrant workers, young and older workers, female and male workers, etc.) been assessed?		
2.8	Are there measures in place to ensure communication of information to (e.g. migrant) workers who may not have a good command of the working language in order to allow them to perform their work safely?		
Working at height, slips and trips, falls			
2.9	Can work at height in general, and in particular on slanting roofs be avoided?		
2.10	When work at height is necessary, are there mobile elevating work platforms (MEWPs) and scaffolding available if needed?		
2.11	When ladders are used to reach the place of work at height, has the appropriate ladder been chosen and is it used safely?		
2.12	When roof work is necessary, has the condition of the roof been assessed to ensure that the roof is dry and free from slipping and tripping hazards such as moss, snow, ice, vent pipes, equipment lying around, etc.?		
2.13	In the case of skylights or holes/cavities, are they safeguarded?		
Electricity-related risks (PV), burns/scalds			
2.14	Are only qualified persons allowed to work on electrical equipment?		
2.15	Is a safe distance kept for workers, tools and materials from high voltage power lines during maintenance/repair activities?		
2.16	Is the work area at the power inverter dry?		
2.17	Are workers aware that low voltages can cause surprise shocks and thereby falls?		
2.18	Are workers aware that small amounts of sunlight can produce a voltage potential in the PV system and shock or arc-flash hazards?		
2.19	In the case of STP, is the solar thermal collector cooled off?		
2.20	Are workers provided with suitable PPE when risk reduction measures at source are not sufficient?		
Hazards of musculoskeletal disorders (MSDs)			
2.21	Is work arranged so that manual handling operations, such as lifting and carrying are avoided and, where not possible, reduced to the minimum?		
2.22	In case lifting or carrying operations are necessary, including lifting tools, equipment and material from the ground to the roof and vice-versa, are mechanical aids provided?		
2.23	In case a crane is used, are workers operating the crane properly trained?		
2.24	Are measures in place to avoid or, when not possible, to reduce to a minimum the need for workers to perform repetitive movements or to work in sustained postures?		
2.25	Are measures in place to avoid or, when not possible, reduced to a minimum the need for workers to work frequently or in prolonged kneeling or squatting positions?		
3. Integration into infrastructure, operation			

Electricity-related risks (PV)			
3.1	Are only qualified persons allowed to integrate the system to the mains?		
3.2	Is the local electric power company contacted to turn the power off when connecting/separating the PV plant to/from the grid or working within a certain distance of high voltage power lines?		
3.3	Are workers accompanied always by at least one colleague when working on electrical systems, thereby eliminating lone working?		
3.4	Are workers aware of PV shingles bearing electric risks in case they are damaged e.g. during cleaning activities?		
4. Disposal/recycling			
Exposure to dangerous substances and noise			
4.1	Is workers' exposure to airborne dangerous substances such as Volatile Organic Compounds, micro-organisms and the generation of dust and aerosols avoided or, if not possible, are there measures in place to reduce workers' exposure to the minimum, giving priority to control measures at source according to the hierarchy of control measures indicated in the legislation on hazardous substances?		
4.2	Are there adequate washing facilities available for all workers?		
4.3	Is the exposure to noise eliminated or, if not possible, reduced to the minimum and kept within the limit of 85 dB(A) by implementing control measures at source according to the hierarchy of control measures?		
4.4	When risk reduction measures at source are not sufficient, is appropriate PPE provided, properly maintained, and are workers trained in their correct use?		
4.5	Manual handling issues		
4.6	Is manual handling, in particular lifting or carrying heavy items or repetitive handling, even of lighter items, avoided or where not possible, reduced to a minimum?		
4.7	In the case of manual handling work, can the task be done without lifting the arms above the shoulder level?		
4.8	Are workers trained in safe handling techniques?		
5. Fire emergency			
Electricity-related risks (PV), burns/scalds			
5.1	Are there measures in place to ensure that emergency services would be informed about the presence and type of solar power system (STP or PV or both)?		
5.2	Are emergency services aware of the safe distances to be kept to the (possibly) voltage carrying parts of the system, similarly to the safe distances they have to observe when intervening at electrical plants?		
5.3	Are emergency services aware that electric arcs can be caused by high direct current voltages from PV systems (also building integrated systems)?		
5.4	In the case of STP, can the existence of hot solar heat modules be excluded?		
Collapses and falls, falling pieces			
5.5	Is information readily available for emergency services on the fire resistance and fire spread characteristics of the solar panels?		

5.6	Can building-integrated PV shingles bearing slipping risks be unequivocally identified?		

Annex C. HAZID worksheet

Node: **Aquaculture** Date: 27/08/2021 Time: 9.15 - 10

Category	HAZID Guideword	Top Event (Hazard Release)	Consequence (Hazard Effect)	Existing Control Measures	Recommendation		
					Action	Responsible	Comments
1. Equipment	1.1 Equipment - failures	Lifting equipment failure leading to swinging load or dropped object	Health effect for operators and asset damage				
		Failure of net cleaning system	Impossibility to carry out the operation				
		Failure of mortality removal system	Impossibility to carry out the operation				
		Failure of oxygenation system	Potential oxygen leak onboard with consequent risk of fire				Liquid/compressed oxygen storage vs oxygen production system currently under discussion
	1.2 Control System failures	No hazard for operator identified					
	1.3 Electrical system failures	Loss of power supply	Stop of operation				
		Generic failure of electric component	Potential for electrocution for operations	- Safety system automatically disconnects power supply			
	1.4 Utility failures	Loss of communication between bridge and aquaculture maintenance personnel	Potential for misoperation, health effect for operators and asset damage		- Investigate communication system within the platform	RINA	
2. Location/ Environment	2.1 Location Hazards	Net fouling/ damages (presence of external debris, local predators etc)	Potential for net damages with increased need for cleaning and maintenance				
	2.2 Other activities	No hazard for operator identified					

	2.3 Ambient Conditions	Adverse weather conditions (high wind, high wave, current etc.)	Man overboard during people transfer and/or potential for swinging load or dropped object during lifting operation		- Define safe working envelopes for offshore operation	RINA	
3. Materials	3.1 Flammable/ Oxidizing materials	Accumulation of explosive dusts in feeding silos	Explosion with health effect for operators and asset damage	- Prevention of spark (earthing) - Good ventilation - PPE and procedures			
	3.2 Toxic materials	Chemicals for fish treatment	Minor health effect for operators	- PPE and procedures according to MSDS - MSDS will be made available onboard			
	3.3 Acid materials	Chemicals for mortality treatment (mildly acid)	Minor health effect for operators	- PPE and procedures according to MSDS - MSDS will be made available onboard			
	3.4 Inerts	Not applicable					
4. Operating Parameters	4.1 Temperature	No hazard for operator identified					
	4.2 Pressure	Net cleaning system	Sudden release of pressure from the system leading to health effect for operators	- Net cleaining system is semi-automatic and it will be operated from boat			
	4.3 Flow	Not applicable					
	4.4 Level	Not applicable					
5. Operating Modes	5.1 Operation at Sea	Diving (45-50 m maximum depth)	Health effect for operators	- Use of ROV instead of divers			
		People transfer from external boat (e.g., net cleaning boat) to platform and viceversa	Man overboard		- Safe procedure for people transfer	RINA	

	5.2. Other Operations	Confined space entry (cleaning and maintenance inside feed silos)	Potential for asphyxiation	- PPE - Procedures	- Develop a confined space entry procedure in safety maintenance	RINA	
6. Operation and Maintenance	6.1 Operation						
	6.2 Maintenance						
	6.3 Other						

Tentative list of tasks:
- Net cleaning
- Net changing
- Rise docking
- Harvesting fish
- Monitor net mooring system
- Monitor fish health
- Bridge winch maintenance
- Fish feeding (automatic)
- Maintenance of feeding system
- Refill of feeding silos and silos maintenance
- Bring juvenile fishes
- Removal of dead fish (semi-automatic)
- Water quality measurement (automatic)
- Treating the fish for disease
- Mortality treatment system (automatic)

Node: **Energy production systems** Date: 27/08/2021 Time: 10.00 - 10.40

Category	HAZID	Top Event	Consequence	Existing Control Measures	Recommendation

	Guideword	(Hazard Release)	(Hazard Effect)		Action	Responsible	Comments
1. Equipment	1.1 Equipment - failures	Failure of sealing elements in coupling room leading to water leak	Need for human intervention inside coupling room (replacing of sealings) with potential for health effect in case of misoperation				
		Failure of wind turbine blade	Projectiles with health effect for operators and asset damage				
	1.2 Control System failures						
	1.3 Electrical system failures						
	1.4 Utility failures						
2. Location/ Environment	2.1 Location Hazards						
	2.2 Other activities						
	2.3 Ambient Conditions	Ice accretion on wind turbine blades	Projectiles with health effect for operators and asset damage				
		Adverse weather condition (wave height)	Sea water on electrical system	- Electrical system will be water proof			
		Lightning strike on wind turbine	Health effect for operators	- Definition of working envelop to avoid maintenance during storms (Refer to Action ###)			
3. Materials	3.1 Flammable/ Oxidizing materials	Leak from oil insulate transformer	Potential for fire event				

		Hydrogen release from battery under charge	Potential health effect for operators accessing the battery room		- Depending on battery typology, develop appropriate battery room access procedure	RINA	
		Lube oil system - no specific hazards identified					
	3.2 Toxic materials						
	3.3 Corrosive materials						
	3.4 Inerts						
4. Operating Parameters	4.1 Temperature						
	4.2 Pressure						Verify if pressure inside OWC can pose any threaths for maintenance operators
	4.3 Flow						Verify if air flow out of OWC can pose any threaths for maintenance operators
	4.4 Level						
5. Operating Modes	5.1 Operation at Sea	Cable repair - intervention of divers	Potential for health effect for operators				Cable repair is not under the responsibility of BGF

		Maintenance of OWC chambers - intervention of divers (inspection, maintenance and cleaning of chamber valves)	Potential for health effect for operators				
	5.2. Other Operations	Confined space entry (maintenance in the coupling room)	Potential for asphyxiation	- PPE - Procedures - Inspection will be performed remotely			
		Maintenance on cable electrical connection onboard	Risk of electrocution for operators	- Possibility to switch off the power supply from land and isolate from platform			
		Transformers maintenance	Risk of electrocution for operators	- Switchers to isolate transformers under maintenance - PPE			
		Batteries maintenance	Risk of electrocution for operators	- Proper PPE and procedures (from batteries manufacturer)			
		Maintenance on LV load and UPS	Risk of electrocution for operators	- Possibility to isolate systems under maintenance - PPE			
		Maintenance of wind turbine/ OWC electrical generator	Risk of electrocution for operators	- Possibility to isolate systems under maintenance - PPE			
		Working at height for wind turbine maintenance	Slips, trips and falls	- PPE	- Develop working at height procedures	RINA	
		Working at awkward positions (small deck around the turbine for maintenance)	Slips, trips and falls	- PPE			

6. Operation and Maintenance	6.1 Operation						
	6.2 Maintenance	Aggressive corrosion of materials due to marine environment. Intervention of divers for maintenance (maximum connector depths is designed - 40 m) - replacement of sacrificial anodes	Potential for health effect for operators	- Normal depth of cable connection is estimated in the range -0m to -10m			
	6.3 Other	Bolt slackening	Potential health effect for operators and asset damage	- Bolts continuous automatic remote monitoring			

Tentative list of tasks: physical power supply connection to land (inspection)

monitoring of mechanical loads for cable connection (done remotely)

visual inspection of coupling room (done remotely)

transformer for wind turbine

transformer for wave energy

transformer for other services

battery

maintenance of OWC system chamber

UPS

LV loads (lights, control systems etc.)

Node:	**Marine systems (including maintenance of structural equipment)**	Date:	27/08/2021	Time:	10.50 - 11.30

Category	HAZID Guideword	Top Event (Hazard Release)	Consequence (Hazard Effect)	Existing Control Measures	Recommendation		
					Action	Responsible	Comments
1. Equipment	1.1 Equipment - failures	Lifting equipment failure leading to swinging load or dropped object	Health effect for operators and asset damage				Lifting equipment details to be defined
		Failure of mooring cables	Sudden release of tension with health effect for operator and asset damage	- Periodic monitoring of mooring system			
		Failure of watertight access to platform inside	- Water ingress to platform inside. Wet floor leading to slips trips and falls. Asset damage. - Potential for stability issues (if one door remains fully open in adverse sea state - long term effect)		Include in safety manual requirements to keep watertight doors always closed	RINA	
	1.2 Control System failures						
	1.3 Electrical system failures						
	1.4 Utility failures						
2. Location/ Environment	2.1 Location Hazards						
	2.2 Other activities						

	2.3 Ambient Conditions	Adverse weather conditions (high wind, high wave, current etc.)	Man overboard during people transfer and/or potential for swinging load or dropped object during lifting operation				
		Adverse weather conditions (ice formation on deck)	Slips, trips and falls				
3. Materials	3.1 Flammable/ Oxidizing materials	Bunkering of diesel (and other flammable materials)	Potential for fire event				Verify if bunkering equipment for diesel (and other flammables) have been already defined.
	3.2 Toxic materials						
	3.3 Corrosive materials						
	3.4 Inerts						
4. Operating Parameters	4.1 Temperature						
	4.2 Pressure						
	4.3 Flow						
	4.4 Level						
5. Operating Modes	5.1 Operation at Sea	Anchor monitoring - involvement of divers (approx water depth 90 m)	Health effect for operators	- ROV will be used to avoid intervention of divers			
		People boarding/unboarding through gangway	Potential for man overboard				
		Diving for platform cleaning (20 m maximum depth)	Health effect for operators		Include in safety manual minimum requirement for emergency response for	RINA	Verify medical appliances foreseen onboard

					diving operations		
		Maintenance and operation in the boat landing	Health effect for operators due to mooring equipment and potential movements of moored boat				
	5.2. Other Operations	Working at awkward positions (small deck around the turbine for maintenance)	Slips, trips and falls	- PPE			
		Working at awkward positions (mooring connector monitoring); proximity to equipment under tension (anchor line)	Slips, trips and falls leading to man overboard; risk of sudden rupture of mooring leading to health effect for operator				
		Working at awkward positions (mooring connector monitoring); motion of anchor chain inside the mooring connector chute	Health effect for operators due to moving elements				
		Confined space entry (spaces inside platform)	Potential for asphyxiation	- PPE - Procedures			
		Inspection and maintenance of structural equipment (tensioning equipment for concrete caisson)	Loss of platform integrity				

		Maintenance of electrical equipment for anchor line tensioning	Risk of electrocution for operators	- Proper PPE and procedures - Possibility to isolate the electrical equipment for maintenance			
6. Operation and Maintenance	6.1 Operation						
	6.2 Maintenance						
	6.3 Other						

Tentative list of tasks: anchor line monitoring and tensioning

anchor monitoring

anchor line replacement

mooring connector monitoring

Node: **Safety and security devices** Date: 27/08/2021 Time: 11.25 - 11.35

Category	HAZID Guideword	Top Event (Hazard Release)	Consequence (Hazard Effect)	Existing Control Measures	Recommendation		
					Action	Responsible	Comments
1. Equipment	1.1 Equipment - failures	Generic failure of safety devices	Unavailability of safety device	Periodic inspection and maintenance			Verify if safety devices are provided with self detection and alarm for failures
	1.2 Control System failures						
	1.3 Electrical system failures						
	1.4 Utility failures						
2. Location/ Environment	2.1 Location Hazards						
	2.2 Other activities						
	2.3 Ambient Conditions						
3. Materials	3.1 Flammable/ Oxidizing materials						
	3.2 Toxic materials						
	3.3 Corrosive materials						
	3.4 Inerts						
4. Operating Parameters	4.1 Temperature						
	4.2 Pressure						
	4.3 Flow						
	4.4 Level						
5. Operating Modes	5.1 Operation at Sea						

	5.2. Other Operations	Maintenance of electrical equipment	Risk of electrocution for operators	- Proper PPE and procedures - Possibility to isolate the electrical equipment for maintenance			
6. Operation and Maintenance	6.1 Operation						
	6.2 Maintenance	Maintenance on safety devices	Working with safety device in override position. Impossibility to rely on safety device		Include in the Safety manual recommendations for redundant system or contingencies to be put in place during safety systems maintenance	RINA	
	6.3 Other						