LiftWEC

DEVELOPMENT OF A NEW CLASS OF WAVE ENERGY CONVERTER BASED ON HYDRODYNAMIC LIFT FORCES

Deliverable D9.1

Identification of potential technology stressors and environmental receptors of the LiftWEC technology

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EXECUTIVE SUMMARY

LiftWEC is a collaborative research project funded by the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 851885. The LiftWEC project aims at identifying promising configurations of a Wave Energy Converter operating through the use of one or more rotating hydrofoils that generate lift as the primary interaction with the incident waves.

Under the project *Work Package 9* (WP9) - *Environmental Impact Assessment*, four Tasks will be carried out to ensure the LiftWEC device development is made under the most suitable environmentally friendly criteria from an early design phase. The present document constitutes the first Deliverable of WP9: *D9.1 – Identification of potential technology stressors and environmental receptors of the LiftWEC technology*.

This Deliverable is divided into five Sections: Section 1 describes the current configurations (preliminary configurations) defined for the LiftWEC installation. These configurations were generated during the LiftWEC Workshop organized in 2020 by the LiftWEC project Consortium and will form the basis for further research conducted throughout the project; Section 2 provides an overview of the Environmental Impact Assessment process for the Marine Renewable Energy sector, with focus on Ocean Energy projects; Section 3 presents the key stressors associated with MRE projects and its effects on environmental and socioeconomic receptors; Section 4 identifies the stressors and receptors that might be associated with the LiftWEC installation and suggests possible mitigation measures to the effects; Section 5 provides final remarks about the interaction between the MRE sector and environmental and socioeconomic receptors, including the role of LiftWEC.

LIST OF ACRONYMS

EIA	Environmental Impact Assessment
EMF(s)	Electromagnetic Field(s)
MRE	Marine Renewable Energy
OE	Ocean Energy
PTO	Power Take-Off
SEIA	Socioeconomic Impact Assessment
WEC(s)	Wave Energy Converter(s)

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1 LiftWEC CONCEPT AND PRELIMINARY CONFIGURATIONS

During the first LiftWEC project workshop (25-27 May 2020), 79 potential LiftWEC ideas were generated by different working groups of 3-5 participants from different project partners in each group. The ideas generated included information for each of 10 options: whole system, hydrodynamics, hydrofoil, power train, control, load transmission, reaction source, marine operations, installation, and other. The concepts were saved in an *Ideas Catalogue*. After, each working group generated 3-6 configurations covering a wide range of concepts and saved them in a *Configurations Catalogue*.

At the end of the workshop, 15 preliminary LiftWEC configurations were generated and, together with the Atargis Jack-Up CycWEC configuration and the configuration described in the LiftWEC proposal, formed 17 configurations for consideration and scoring by each working group (Table 1.1)**Error! Reference source not found.**.

The description of the 17 LiftWEC preliminary configurations is provided in the LiftWEC Deliverable 2.3[1]. As it was mentioned in that document, a significant commonality among most of the different configurations was found with many of the proposed ideas being shared among configurations.

Table 1.2 presents the ideas mentioned more frequently among configurations, and those relevant to environmental components even if mentioned less frequently.

Table 1.1: Scores for the LiftWEC preliminary configurations

Scoring order	Configuration	Min. score	Max. score	Mean score
1	"LiftWEC proposal configuration"	40	100	65
2	"Radius control focused configuration"	40	99	63
3	"Slack moored LiftWEC semi-sub with multiple rotors"	10	99	62
4	"Planetary gear end plates "	25	94	60
5	"Hydrofoil mounted turbine PTO"	37	75	58
6	"Twin-moored buoyant structure with Minesto PTO"	0	90	58
7	"Spar buoy with phase-free rotor"	10	100	58
8	"Single strut hydrofoil with Minesto-type turbine"	10	100	57
9	"Struts based single rotor with submergence control"	5	100	56
10	"Direct hydrofoil rotor PTO"	10	90	55
11	"Hubless wing with mounted turbines"	7	85	54
12	"Jack-up CycWEC"	10	90	53
13	"Parabolic with flaps and stiff single-point v-mooring"	10	86	51
14	"Hydraulic PTO on main rotational shaft"	0	98	49
15	"Phase-locked contra-rotating"	3	90	48
16	"Adaptable/Reconfigurable WECs"	0	86	41
17	"Tethered mono-hydrofoil with wing mounted turbine"	0	75	34

[1] LiftWEC project *Deliverable 2.3 – Review of Current Lift-Based WEC Concepts and Specification of Preliminary Configurations*, available at https://liftwec.com/d2-3-review-of-current-lift-based-wec-concepts-and-specification-of-preliminary-configurations.

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Table 1.2: List of relevant ideas shared among the LiftWEC preliminary configurations.

Idea			No. of mentions (out of 17 configurations)
Operation mode	Phase locked		7
	Phase independent		6
Control of submergence			8
Collapsible system for transportation			3
Passive survival mode			5
No. of hydrofoils	2 hydrofoils (ranging between 1-5)		9
Mooring system	Bottom-based device	Jack-up struts (up to 4 mooring points)	3
		Pilling/Micro piling	1/1
		Gravity-based	1
	Floating device	Single point (undefined) with slack mooring/Single point V-shaped/2 single points (V-shaped + Y-shaped)/T-shaped with slack mooring/Central strut with taut mooring	1/1/1/1/1
Synthetic lines for mooring			5
Requirements for waves and lift force forecasting			4
Fundamental reaction source	Seabed (undefined)/ Support structure (undefined) on seabed		6/1
	Jack-up strut structure/Telescopic legs/Tethers/Inertia		1/1/1/1
Hydrofoil reaction source	Support structure (undefined)		3
	Seabed (undefined)		2
	Radial struts/Telescopic legs		1/1
Power capture	Hydrofoil-mounted turbine(s)		4
	Shaft-based generator		5
	Permanent magnet generator		2
	Direct drive generator/Hydraulic PTO/'Traditional' generator		1/1/1
O&M	Take the device back to port/sheltered location for maintenance operations		2
	Bring the device to the surface for maintenance operations at site/Use a chevron to produce a calmer area for access during maintenance		3/1

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Other aspects of the LiftWEC were discussed during the workshop, namely where it should operate (for example, nearshore or offshore). After the workshop, it was assumed that the installation would consist of a wave farm of arrays of devices with an operational lifetime of 25 years and that the electrical cable would have a minimum capacity of 100 MW. The farm would be positioned in sandy seabed at a bathymetry of 50 m, with average tidal range of 2 m and a current velocity of maximum 0.1 m/s. The deployment site would distance 10 km from the electrical grid on the shore, 20 km from a port suitable for service vessels and 50 km from a port suitable for installation vessels.

2 The Environmental Impact Assessment process

In the European Union, Environmental Impact Assessment (EIA) must abide to the EIA Directive (EU, 2001, 2014) which identifies the projects subject to mandatory EIA (defined in Annex I of the Directive), and those for which EIA can be requested at the discretion of the Member States (defined in Annex II of the Directive).

Although there is a significant variation in EIA procedures which is related with legal, policy and institutional frameworks in different countries, the EIA process can be summarized into seven main steps (**Error! Reference source not found.**):

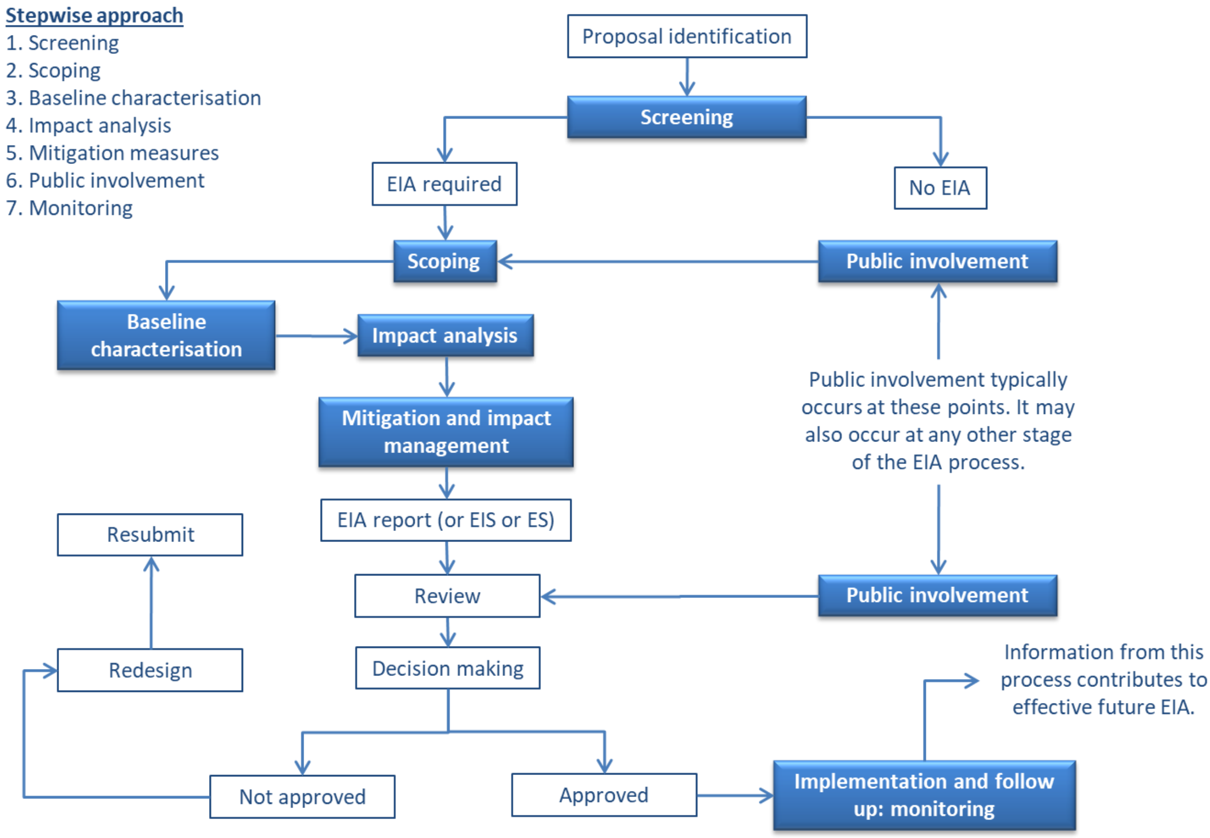

Figure 2.1: Environmental Impact Assessment (EIA) process flow chart (adapted from: UNEP, 2002).

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During the first step, *Screening*, the national authorities decide whether or not an EIA is needed, considering the following criteria i) project's characteristics (e.g., cumulation with other projects, use of natural resources, risks to the environment and to human health), ii) project's location (e.g., environmental sensitivity of the area, existing historical/cultural/archaeological features), and iii) the type and characteristics of potential impacts (e.g., nature, magnitude, probability, reversibility of the impacts). If an EIA is required, the next step would be the Scoping.

Scoping provides the foundations for an effective and efficient EIA process. The aim is to identify the key issues (for example environmental) to be considered in the EIA, the appropriate time and space boundaries of the EIA study, and what information is necessary for decision making.

Baseline characterization gathers information on environmental and socioeconomic baseline conditions in the impact area, which will be the basis to predict potential impacts and to develop effective mitigation and monitoring programmes.

The *Impact Analysis* deepens the screening and scoping steps through the assessment of the scale of potential impacts. It allows to identify which impacts are associated to each project development phase and predict the main impacts (for example, considering their nature, magnitude, extent, and reversibility), thus contributing to delineating mitigation measures.

Mitigation measures refers to the actions needed to prevent, minimize, and/or compensate for the predicted adverse effects of projects or to enhance their positive effects. Such measures should be implemented during the impact management stage which aims, among others, at ensuring that mitigation measures are implemented, monitoring the effectiveness of mitigation measures, and undertaking any necessary action when unforeseen impacts occur.

Monitoring is a key step to validate and expand the findings of the initial EIA. A monitoring plan should be drawn for all project phases (preparation, construction, operation, and decommissioning) considering all the information obtained in the previous steps. Monitoring of effects or impacts means that the monitoring plan must be designed to measure change against baseline conditions or management objectives.

Public involvement throughout the whole process ensures all stakeholders are actively participating in the EIA process and contributing to decision making.

2.1 Environmental Impact Assessment for Ocean Energy

Marine Renewable Energy (MRE) projects are considered within Annex II of the EIA Directive, under the category *Energy industry: a) Industrial installations for the production of electricity (...)*. Ocean energy (OE) technologies, including those of wave energy, are in an early stage of development compared to, for example, Offshore Wind. Owed to the great heterogeneity of OE technologies, namely concerning its operation principles and location, the EIA of OE projects is a challenging task given the uncertainty regarding the potential negative impacts and especially those with cumulative effects (Frid et al., 2012; Willsteed et al., 2017). While many effects are expected to be shared across OE projects (for example, seabed disturbance by drilling activities, noise created by vessels and machinery), most effects will be specific to the project, for example depending on the duration of preparation and construction activities, the type of equipment used in such activities, and on site-specific characteristics such as local hydrodynamics. Consequently, the EIA becomes project specific and uncertain for other places or devices due to the scarcity of deployments and monitored projects (Greaves et al., 2016; Mendoza et al., 2019).

Some important aspects concerning wave energy projects need to be considered for each of the different development phases of projects (preparation, construction, operation, decommissioning), namely Stressors, Receptors, Effects (or impacts), Mitigation (and/or Compensation) and Monitoring (e.g., Boehlert and Gill, 2010; Greaves et al., 2016; Iglesias et al., 2018; Mendoza et al., 2019):

- *Stressors* are features of the environment that may change, in this case, with the implementation of wave energy projects.
- *Receptors* are individual components with potential for some form of response to stressors.
- *Effects*, or impacts when severity, intensity or duration of the effect needs to be quantified, can be described as the change in a parameter (for example environmental), which results from a particular activity or intervention, i.e., they are the consequences of the stressors on the receptors;
- *Mitigation* refers to the actions needed to prevent, minimize, and/or compensate for the predicted adverse effects of projects or to enhance their positive effects.
- *Monitoring* refers to the methods and techniques used to validate the preliminary analysis of impacts.

WavEC is currently developing a tool[2] for EIA and socioeconomic impact assessment (SEIA) aiming at easing the EIA process for nearshore wave energy installations allowing developers, managers, and regulators for better decision-making. The tool is based on a comprehensive literature review on EIAs for nearshore installations (for example, wave energy projects and aquaculture cages), leading to the identification of a set of receptors and stressors potentially related to the development of nearshore wave energy projects and on impacts (positive and negative) already identified for similar nearshore installations.

In accordance to the reviewed literature (e.g., Boehlert and Gill, 2010; Simas et al. 2013a; Thomsen et al., 2015; Greaves et al., 2016; Iglesias et al., 2018), in the EIA and SEIA tool 12 key receptors are grouped into three main categories (factors) (Table 2.1). The tool presents the potential stressors and their effects on each receptor during each phase of a project development (**Error! Reference source not found.**), and provides information on mitigation measures to those effects and relevant monitoring parameters and techniques.

While the WavEC EIA/SEIA tool development has been directed to nearshore wave energy projects, most aspects will be shared by the LiftWEC configuration. Hence, the literature reviewed for developing the EIA/SEIA tool, together with more specific literature, will be the basis to describe the technology stressors and environmental/socioeconomic receptors associated to MRE projects (section 4) and to the LiftWEC technology (Section 5).

[2] MegaRoller project *Deliverable 2.6 – Environmental Impact Assessment (EIA) and Socioeconomic Impact Assessment (SEIA) models*, available at https://zenodo.org/record/3372479#.Xw3KtyhKi70.

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Table 2.1: Factors and receptors included in the EIA and SEIA tool.

Factor	Receptor
Physical	Hydrodynamics Water column Seabed Shoreline
Biological	Benthic habitats and communities Fish and Turtles Marine mammals Birds
Socioeconomic	Local communities Archaeological/protected sites Landscape/seascape Economic activities

Table 2.2: Short list of potential stressors and associated positive/negative effects included in the EIA and SEIA tool. Positive effects are highlighted in grey.

Development phase	Stressors	Factors affected	Key effects
Preparation	Surveying: Sampling; Vessel activity; Sonar/seismic surveys Site preparation: Dredging and seabed levelling activities Noise	Physical	Increase in turbidity.
		Biological	Productivity reduction.
		Socioeconomic	Noise disturbance; Disruption of fisheries.
Construction	Installation of wave device and support structures: Installation of WEC; Piling/drilling activities; Vessel activity; Presence of machinery/equipment Noise	Physical	Increase in turbidity; Disruption of pelagic habitats.
		Biological	Productivity reduction.
		Socioeconomic	Spatial restrictions for sea users; Noise disturbance; Disruption of fisheries.
Operation	Device deployment: Physical presence of WEC and support structures; Energy extraction Noise EMFs Renewable electricity production	Physical	Change in sediment resuspension/deposition rates;
		Biological	Risk of collision, entanglement, entrapment; Reef effects: Increase in productivity and biodiversity, increase in food availability; Enhancement of reproduction and nursery areas; Proliferation of invasive species.
		Socioeconomic	Loss of shoreline amenities.
Decommissioning	Removal of device and structural components:	Physical	Disruption of pelagic habitats; Increase in turbidity.

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	Vessel activity; Presence of machinery/equipment Noise	Biological	Loss of biomass and biodiversity enhanced locally; Harm to or death of organisms
		Socioeconomic	Noise disturbance.
All phases	Chemical/oil/fuel spill Loss of equipment or structural components: Drifting/sinking of equipment Blue Economy and Blue Growth development	Physical	Littering; Deterioration of water and sediment quality; Disruption of seabed morphology.
		Biological	Toxic response; Disruption of behaviour; Harm to or death of organisms.
		Socioeconomic	Spatial restrictions for sea users; Pollution of public and private spaces; Hazards to navigation; Risk of collision with sea users; Disruption of economic activities; Disruption of preserved traces; Visual impact; Regional development: New opportunities for company creation and development, employment enhancement; Reduction of fossil fuel dependence and tackling climate change; Perception of energy cost reduction.

3 STRESSORS FROM MRE PROJECTS AND ASSOCIATED RECEPTORS

In the *Deliverable 2.3* (under the *Specifications for Social and environmental impact* section), how the different configurations may have different environmental (and social) impacts was not strongly identified. A few examples of stressors and effects associated with OE installations were mentioned.

This Section develops on the key environmental and socioeconomic effects associated with MRE projects.

3.1 PHYSICAL RECEPTORS

3.1.1 Hydrodynamics and water quality

During preparation, construction, and decommissioning activities, which generally mining, drilling, piling, and/or anchoring (or removing of all structures in the case of decommissioning), there can be adverse effects on water quality. Together with cable laying on the seabed, such activities will result in increased turbidity although temporarily (days, depending on wave and current dynamics). Also,

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they may cause the release of contaminants such as heavy metals, trapped in the sediments (where existing) to the water column.

During the operation phase, devices extract potential or kinetic energy from waves as they pass. The presence of the device and the energy extraction may result in wave heights being reduced behind arrays of devices (Venugopal et al., 2017). This may influence the availability and transport of gases and nutrients, turbulence levels, as well as the sediment transport and deposition and consequent change in the seabed configuration (for example, changing the grain size composition and associated retention of organic matter).

While most insights into potential changes in hydrodynamics come from numerical modelling, few studies exist that have acquired and compared data from before and after MRE installations. The lack of data in turn hampers the validation of models (Copping and Hemery, 2020). Some studies mention that tidal single MRE devices or small MRE arrays (~20 MW or less) are likely to cause minor changes to hydrodynamics compared to the natural variability of the system (Petrie et al. 2014; Robins et al., 2014), variability which is expected to further increase with future sea-level rise. Other studies modelling the effect of different configurations of wave WEC arrays have shown significant wave height reduction downstream of the WEC array and farther down the coastline. The possibility of recovery in wave height with increasing distance from the arrays towards the shoreline is uncertain, with different models showing different trends (Iglesias and Carballo, 2014; Venugopal et al., 2017).

Regarding water quality, in all stages of an MRE project, substances such as fuel, mineral oil-based coolants, hydraulic fluids, and antifouling/anticorrosive paintings/coatings of vessels and MRE devices can be released to the ocean by accidents and/or lack of equipment maintenance and consequent equipment damage. Such substances can be rapidly dispersed in the immediate water column (Conley et al., 2013).

3.1.2 Seabed

The physical impacts on seabed are expected to be greater during construction and decommissioning (also, but in lesser extent, during preparation) phases.

Construction activities generally require mining, drilling, piling, and/or anchoring which, together with the installation of mooring systems and transmission cables to land, will disrupt the seabed, as well as increase sediment suspension and turbidity levels. Cable laying, either for bottom-based or floating devices, is expected to be less impacting to the seabed than other human activities, such as bottom fishing or deep-sea mining (Taormina et al. 2018). Depending on the methods for burying cables in the soft sediment (jetting and especially ploughing seem the less-disturbing), resuspended sediment tends to settle in a matter of days (Taormina et al., 2018).

During operation, the frequent sweeping of the seabed by the moorings/cables used to secure floating devices in site, driven by wave action, may have adverse effects on the seabed morphology and composition, disrupt benthic habitats, and harm or kill marine organisms directly through physical damage of benthic organisms and/or indirectly by the increase in turbidity which will affect pelagic organisms.

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3.2 BIOLOGICAL RECEPTORS

The structure of communities is conferred by the way organisms in a community are connected in food webs, where any change can impact the community's dynamics (Valiela, 2013). The introduction of wave energy developments represents several stressors to the surrounding marine environment, as described in the following subsections.

3.2.1 Physical presence of equipment

3.2.1.1 Change in benthic habitat and communities

During the preparation and construction phases, portions of the seabed are removed for the placement of the device itself (bottom-fixed type) or the anchors/supports (floating type), and to deploy the submarine cables that transport electricity to the onshore substation. As mentioned in Sections 3.1.1 and 3.1.2, this might result in a localized habitat loss and crushing, damaging, or displacement of benthic organisms. Additionally, increased levels of turbidity due to suspension of sediments during the activities undertaken in preparatory and construction phases might decrease light availability and affect photosynthetic organisms, reducing primary productivity and affecting the food web locally. The magnitude of these effects on the benthic community depends on the duration and intensity of disturbance and the resilience of the local infauna (Drabsch, 2001). The recovery timeframe for benthic communities is difficult to distinguish from natural variability (Dunham et al. 2015; Kraus and Carter 2018; Sheehan et al. 2018) and in some cases recovery has taken one to eight years after cable laying (Kraus and Carter, 2018; Sheehan et al., 2018; Taormina et al., 2018).

During the operational phase, if hydrodynamic conditions are affected by the presence of devices, it may influence the transport of food for some species and interfere with the distribution of others with dispersive juvenile stages reliant on transport by currents (Greaves et al., 2016). Depending on the depth at which devices are set to operate, the turbulence and forces generated above the equipment will increase water mixing which affect the water temperature, dissolved oxygen, and nutrients content, as well as may impact plankton communities (Dannheim et al., 2019). On the other hand, if the equipment is set close to the seabed, turbulence and forces generated below the equipment might cause resuspension of sediments and affect the seabed composition and the organisms that live there. Sediment suspension and transport may also cause abrasion to the device, affecting its performance, and may compromise its anchoring system (Laws and Epps, 2016).

Any artificial structure placed at sea, such as those from the MRE sector, will create a variety of habitats available for a range of organisms, acting as artificial reefs. Positive effects are anticipated with an increase of local biomass and biodiversity (Coolen et al., 2020), for example by providing a hard substrate for macroalgae settlement, colonization by many marine invertebrates, and attracting/aggregating organisms from higher trophic levels, such as fish and marine mammals (Langhamer, 2016; Taormina et al., 2018; Birchenough and Degraer, 2020). Often, these structures show greater diversity and abundance of organisms compared to surrounding areas that are generally made of sandy seabed (Coates et al., 2014).

However, artificial reefs might also lead to negative ecological and economic effects. It may allow for the settlement and propagation of non-native species, which can use the artificial structures as stepping stones (Adams et al., 2014; de Mesel et al., 2015) and may spread across the oceans. The

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colonization of artificial structures by non-native species may affect local organic matter loading, habitat structure and native community composition, with consequences on local biodiversity and food web structure and subsequently on ecosystem services (Coates et al., 2014; Dannheim et al., 2019). The possibility of partial removal instead of full removal of MRE structures/equipment upon decommissioning has been debated recently. Although the OSPAR Decision on the Disposal of Disused Offshore Installations (OSPAR Commission, 1998) requires that artificial structures be fully removed from the maritime space (with some exceptions), the removal of artificial structures (including for example scour protection rocks) will cause a loss of the biodiversity created by the artificial reef effect during the operational phase and will have other detrimental effects to environmental components, in common with preparatory and construction phases (for example, from increased seabed disturbance, turbidity, and pollution) (Coolen et al., 2020).

Altough several MRE, and especially OE, projects have been implemented in the last decade, they have not stayed in the water long enough (i.e., several years) to allow monitoring long-term changes caused in the seabed by the projects (Copping and Hemery, 2020).

3.2.1.2 Risk of collision

Collision risk will be present during all stages of an MRE project development. First, owed to the increased traffic in vessels which are used to transport the equipment and perform maintenance activities. Second, because the physical presence of equipment and anchoring, mooring and cables may create the possibility of collision, impingement or entrapment by mainly marine mammals and fish, but also by turtles and diving birds (Cada et al., 2007; Wilson et al., 2007). Collision with the pressure field created by the devices might also occur.

However, there is limited information about real numbers of collisions with OE installations and the likely consequences of collisions are greatly unknown (Copping and Hemery, 2020). Collision with equipment or its pressure field and entanglement with cables is rare (Laws and Epps, 2016; Sudderth et al., 2017; Copping and Hemery, 2020). Sudderth et al. (2017) mentions that a hydrofoil technology (oscillating wing-shaped hydrofoil) moves at a slower pace when compared to turbines, the fastest speed of the hydrofoils being similar to the flow rate of the water, and that the hydrofoil presents a low risk of strike for fish and other marine animals. The authors also mention that having an operational speed of the moving parts below the 4.5 m/s should cause minimal harm to animals (except possible to early larval fish; Jacobson et al. 2012). Furthermore, using blunt/thick hydrofoil edges would reduce the harm and mortality on animals caused by potential collision. According to Copping and Hemery (2020), using adequate configurations for electrical cables (suspended in the water column using floats, becoming more easily visible to animals) and moorings (reasonably taut) in MRE projects would reduce the probability of entanglement to very low.

3.2.2 Underwater noise

MRE installations generate noise and vibrations, both in the air and underwater, mainly through preparatory and construction activities (from mining, drilling, and pilling) and vessels movement. During the operation phase, the noise levels will be very much reduced in comparison to the other phases, coming from the moving components in the project (WEC, mooring, cables).

Considering that acoustic signals can travel longer distances underwater, some marine animals might be affected by noise pollution coming from kilometres away (Frid et al., 2012; Greaves et al., 2016). Mammals and fish particularly take advantage of sound propagation conditions in marine

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environments for communication, social interaction, orientation, predation, and evasion. Hence, noise disturbance might increase the likelihood of these organisms to collision with OE installations (Wilson et al., 2007).

In marine mammals, the main effects expected from noise pollution are changes in behaviour (for example, avoidance, attraction, foraging, and prey hunt), injury of sensitive hearing tissues and, in severe situations, death (Southall et al., 2007; Iglesias et al., 2018). Fish populations might be affected by noise as fish use the acoustic environment for orientation and behavioural responses such as communication (Wilson et al., 2007; Boehlert and Gill, 2010; Gill et al., 2012; De Backer and Hostens, 2017). Marine birds might also be affected by noise disturbance, changing their behaviour on landing, roosting, breeding, and migrating patterns (Wilson et al., 2007; Greaves et al., 2016).

Although during preparatory and construction phases high noise levels are expected, it is expected to have short duration. On the other hand, the operational noise of the WEC will be frequent throughout the project life, but in levels which might only exceed ambient noise[3] at short distances from the source (tenths of metres) (Cruz et al., 2015; Copping and Hemery, 2020). Several works have found that the noise generated by MRE installations should have minimal impact (if any) to marine animals (Cruz et al., 2015; Thomsen et al., 2015; Tougaard, 2015; Sudderth et al., 2017; Copping and Hemery, 2020), even during the construction phase except possibly in cases where pile driving is used (Thomsen et al., 2015). Further studies are needed to ascertain the existence of detrimental effects (and its magnitude) from noise generated by MRE installations to marine animals, especially considering arrays of devices (Copping and Hemery, 2020).

3.2.3 Electromagnetic fields

The electricity generated by MRE devices is carried to land substations by submarine cables which produce and emit electromagnetic fields (EMFs), the intensity of which depends on the amount of electricity running through the cables (i.e., the cable rating). The ability to sense and respond to EMFs is characteristic of many marine organisms that sense either electric fields (E-fields), magnetic fields (B-fields), or both. Cetaceans, migratory fish (for example, salmon and eel), turtles and some crustaceans use Earth's natural geomagnetic fields for undertaking large-scale migrations or orientation (Lohmann et al., 2008; Gill et al., 2012; Newton et al., 2019). Other organisms such as elasmobranchs (sharks, rays, and skates) and agnathans (lampreys) have a sensory apparatus to detect and respond to very low-frequency bioelectric fields emitted by prey or mates and for orientation (Collin and Whitehead, 2004).

The EMFs created at MRE installation areas may attract or repel both magneto-sensitive and electro-sensitive organims (Boehlert and Gill, 2010; Huveneers et al., 2013; Gill et al., 2014) and might affect the development, physiology, and/or behaviour of sensitive fish and invertebrate species (Hutchinson et al., 2018; Iglesias et al., 2018). Although some authors have found changes in the behaviour of bottom-dwelling organisms (in foraging and resting) they could not ascertain to what component of the EMF, intensity, and frequency they have responded to (Hutchison et al., 2020). To date, there is not enough evidence to determine if there are significant negative impacts, especially long-term physiological, biochemical, or behavioural effects, as a consequence of interaction

[3] Ambient noise is the background noise in the environment coming from multiple sources (for example, waves, animals, ships), generally measure measured prior to the preparatory and construction phases, and distinct from the noise emitted by a marine renewable energy device.

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between organisms and EMFs generated from MRE installations (Gill et al., 2014; Hutchison et al., 2018; Copping and Hemery, 2020). Nonetheless, data about environmental impact from EMFs are scarce, therefore, investigation is needed focusing on different groups of organisms (for example, fish and crustaceans) and life-stages (for example, embryonic and adult stages), especially considering that an increase in MRE installations and, consequently, increase in number of EMFs fields in the marine environment is expected in the next decades (Copping and Hemery, 2020).

3.3 SOCIOECONOMIC RECEPTORS

The introduction of OE installations raises several socioeconomic concerns, especially in coastal areas which provide a wide range of services to local human populations (UNEP-WCMC, 2011). The potential negative and positive socioeconomic effects expected from such installations are described in the following sub-sections.

3.3.1 Local communities and economic activities

The main economic activities in coastal regions are usually fishing, navigation, tourism, industry, and services (Simas et al., 2013a, b). While some of these sectors may be negatively affected by MRE installations (for example, the fishing and tourism sectors), other sectors may benefit from such kind of projects (for example, industry and services).

During the construction phase, the sea use is completely interdicted to avoid vessel accidents and for safe deployment of devices, restricting other activities in a delimited area. These interdictions will have a temporary nature. However, during the whole project exclusion zones are created and possible fishing areas, which are many times the primary income of local communities, are reduced. While this may benefit local populations (for example of fish and crustaceans) and potentially allow for their recovery in the MRE installation area (Krone et al., 2017; van Hal et al., 2017), it may lead to an increasing fishing pressure in nearby areas because of redistribution of fishing effort (Berkenhagen et al., 2010; Stelzenmüller et al., 2011). During the operational phase, an MRE installation will still occupy a large area of maritime space and although exclusion zones are much smaller than in earlier phases they are still implemented. Hence, the fishing sector remains with loss of exploitation areas. Only after decommissioning a restoration of the excluded zones is predicted, allowing for the entire use of maritime space by other coastal users. Then, some negative impacts stated during the construction and operation phases can be reverted, for example eliminating the potential conflict of uses by the local population and increasing job opportunities for the transport and dismantlement of the device and structural components.

Besides the impact on fishing, other concerns raised by local stakeholders include impacts on navigational safety, marine recreation, tourism, and property values (Bonar et al., 2015). The development of MRE projects generally imply coastal restrictions to carry out construction activities such as the cable laying to the onshore substation, and such interdiction zones will temporally prevent inhabitants and tourists from the practice of beach sports and leisure activities. In addition, the works for the cable path and the substation itself may disturb residents by increase of noise and traffic, and by potential loss in aesthetics and decrease of property value.

Positive effects are foreseen as a consequence of MRE projects implementation, especially concerning to an enhancement of industries and services locally and potentially at Regional and National levels. Opportunities for new businesses and services, such as transport operations,

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placement of equipment, manufacture of components, and export markets should arise together with creation of jobs (Dalton et al., 2015). Nonetheless, there might be the possibility that the skills required are highly specialised and not found locally, leading to the recruitment of people from abroad instead of local work force.

The public is broadly supportive of developing alternative energy sources namely for offshore projects, especially if they have reduced visual impact (DONG Energy et al., 2006; Ladenburg, 2008; Dalton et al., 2015). Public acceptance will probably be achieved if a strong public participation is allowed and if communication among local inhabitants, technology developers, decision makers and scientists is promoted, previous to and during the development of projects (Bonar et al., 2015).

3.3.2 Archaeological/protected sites

A preliminary project site survey should inform the eventual presence of cultural patrimony sites. In case of identification of such sites, any intrusive action in land or submersed sites of archaeological or biodiversity conservation interest might put these preserved areas at risk. Generally, project developers are able to avoid archaeological or protected sites intentionally.

3.3.3 Landscape/seascape

Every MRE installation includes terrestrial and maritime components, therefore potential impacts on the visual amenity in natural sceneries might overcome. Visual impact should be most significant during preparatory, construction and decommissioning activities owed to disruption of seascapes/landscapes of relevant interest and to the increase in vessel activity. However, that impact should be of temporary nature. During the operational phase, some maritime components might represent visual pollution but only if they are deployed visible to users (for example, nearshore and not submerged in seawater). Visual pollution on land might be expected from terrestrial infrastructures such as the electrical substation.

4 LIFTWEC TECHNOLOGY STRESSORS AND ASSOCIATED RECEPTORS

In Section 3 were identified key stressors from MRE projects and the associated physical, biological, and socioeconomic receptors. This Section identifies potential stressors from LiftWEC and its effects on receptors and, where applicable, suggests mitigation measures to those effects.

4.1.1 Hydrodynamics and water quality

As mentioned in Section 3.1.1, MRE devices and especially arrays of devices may affect the hydrodynamics (sedimentation rates, wave height) behind them, which would also be expected from LiftWEC. Optimizing spacing of devices within a farm might aid in mitigating potential effects (Nuernberg and Tao 2018; O'Dea et al., 2019).

With regards to water quality, the turbulence generated by preparatory and construction (and in lesser extent decommissioning) activities, for example, mining, anchoring, and cable laying should be reduced and eliminated days after the activities. Potential effects caused by leakage of oils or lubricants from vessels and devices can be avoided by ensuring adequate Operations & Maintenance plans and performing regular maintenance activities. Vessels should carry the tools and material to stop accidental spills and contain the discharged substances.

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Effects from the use of antifouling paints or coatings can be minimized by employing more environmentally-friendly biocide-free solutions that have been developed in recent years. These include silicone-based foul release coatings (for example, Intersleek 900) capable of acting against both micro- and macrofouling organisms due to their amphiphilic surface nature, and hydrogel paints (e.g., Hempasil X3) which form a water-absorbent polymeric network over the coated surface and make the fouling organisms perceive the coated surface more as a liquid rather than a solid surface (Ciriminna et al. 2015). However, to date, the more environmentally friendly antifouling solutions seem of difficult and expensive application in MRE structures and equipment. And even probably the most environmentally friendly method to control biofouling, which is mechanical cleaning, may have some sort of impact in the marine environment, for example with potential detrimental effects to seabed organisms caused by reduction in oxygen used in the decomposition of dead organisms in the area. Perhaps, acoustic methods (Legg et al. 2015) or mechanical grooming (e.g., Tribou and Swain 2015), which are quite efficient in the shipping sector, performed regularly could be a more environmentally friendly option to be considered in the MRE sector.

Some ideas mentioned in Table 1.2 might help reduce the impact of LiftWEC on water quality. Namely, making the device collapsible could allow using smaller and less specific vessels for transportation (during installation, maintenance, and decommissioning) possibly leading to reduced fuel consumption and antifouling substances released to water. Using synthetic lines for moorings could also require smaller vessels, as they are lighter than chains. Having ways of forecasting waves and lift forces could allow to predict and avoid extreme waves (for example, with temporary shut-down or submergence to close to the seabed) and damage on the device, thus preventing potential leaks of lubricants or hydraulic fluids caused by the damage.

4.1.2 Seabed

As presented in Table 1.2, the different configurations encompassed ideas that could be used either for seabed-based or floating devices, or both. Techniques used for securing devices require drilling the seabed, for example impact piling, representing greater impact on the seabed (and its biology). In those cases, vibratory piling/drilling could be an alternative to impact pilling. Less impacting are the gravity-based or suction bucket foundations, and thus should be considered in the first place. Seabed morphology in offshore (and other) areas changes naturally in a day-to-day basis, and changes associated to cable sweeping on the seabed might be cancelled quickly. To reduce the impact to the seabed, during preparatory and construction activities it should be considered, for example, reducing the seabed area to be cleared and restrict it to immediate vicinity of the project, establishing a limit depth to mine and choosing anchors based on a minimum practical depth into the sediment, and usage of silt screens to limit the dispersion of suspended sediments.

4.1.3 Change in benthic habitat and communities

Despite the seabed configuration and composition may recover in a short period, benthic habitats and communities should take much longer. As mentioned in Section 4.1.2, the impacted area of seabed could be reduced by different manners which will also reduce the impact on the benthic habitats and communities, namely reducing the area to be cleared, establishing minimum practical depth for anchoring, and using silt screens to limit the dispersion of sediments.

Colonization of the LiftWEC and other equipment by encrusting organisms may aid in faster recovery of the communities impacted during preparatory and construction phases. The prevention on non-

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native species propagation could be prevented by ensuring an adequate biosecurity risk management plan and regular biofouling-related maintenance activities (Vinagre et al., *unpublished*).

4.1.4 Risk of collision

In all stages of LiftWEC implementation, there will be some risk of collision by marine animals with vessels used for the different activities inherent to the project. The probability of collision with vessels can be reduced by lowering its speed when going to the implementation site, giving an opportunity to animals to evade the area.

Collision with equipment or its pressure field and entanglement with cables is unlikely to occur. Having a low operational speed, for example <4.5 m/s as mentioned by Sudderth et al. (2017), and if applicable, using adequate configurations for electrical cables (becoming more easily visible to animals) and moorings (reasonably taut), should reduce the probability of collision or entanglement to very low. Using blunt/thick hydrofoil edges should reduce the harm and mortality on animals caused by potential collision.

4.1.5 Underwater noise

With regards to seabed disturbance, piling and drilling techniques represent greater impact to the seabed compared to using for example gravity-based foundations. Piling and drilling also represent greater impact in what concerns to the noise generated during the activities. If pilling is necessary to implement LiftWEC, the noise from those activities can be reduced at the source for example by using vibratory hammers and sound dampers and reduced in the water column for example using bubble curtains.

4.1.6 Electromagnetic fields

Data about impacts from EMFs generated in MRE installations are lacking, seeming that significant negative impacts from EMFs are not expected. Nonetheless, EMFs emission from cables can be reduced for example using adequate cable configuration and sheath/armouring and increasing the distance from the cable to the overlying water whenever possible by burying the cables in the seabed and covering them with boulders, concrete mattresses or other cover material.

4.1.7 Local communities and economic activities

Socioeconomically, the LiftWEC project might represent more positive impacts than negative.

The main receptors affected negatively should be the local communities and businesses that rely on fishing as their sole or primary income. To these, it could be suggested after discussions with local Government representatives and authorities a nearby fishing area to the LiftWEC project area which will be restricted to other users. Also, it could be subject to a monetary compensation to make up for the reduced income from fishing.

Positive impacts foreseen include local development (new companies across industries) and creation of jobs, and of course, providing awareness of clean energy supply and perception of a possible reduction in energy cost reduction. In any case, public participation (meetings, enquiries, and general dialog) must be ensured with the local population and stakeholders to minimize negative perception of the project.

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As summarised by Fernandez Chozas et al. (2010), the public is having its first acquaintance with wave energy and thus, the sooner there is an effective approach by individual developers, the more opportunities will there be for the sector in general. Research shows there are different techniques of addressing the public. According to the experience of several offshore renewable energy projects developed in Europe and USA and the achieved results, different approaches as to whom, when and how developers should address have been investigated. The experience proves that early information dissemination to all interested parties via two-way communication methods contributes to achieving public acceptability most effectively.

To achieve public acceptability, a good planning participation strategy shall be in place, where dialogues with many kinds of interest groups, in particular neighbours and NGOs can generate a widespread understanding for and social acceptance of the project, including the chosen location, chosen technology and layout of the array. In public hearings, issues such as noise impact, visual impact, and risk of collisions of the LiftWEC wave array shall be carefully addressed. Visual impact is usually addressed through a visualisation campaign, where two images are shown: one showing the seascape without the wave array, and another one showing the seascape with the array. Hence, a direct comparison can be made.

4.1.8 Archaeological/protected sites

No impact from LiftWEC is foreseen to archaeological or protected sites if surveys are performed previously to preparatory activities to assess the presence of such sites and if they are avoided when implementing the project.

4.1.9 Landscape/seascape

Issues related to landscape might be minimized by ensuring that the site aesthetics is compromised at minimal levels, for example maintaining the site clean and ensuring its restoration after the construction activities. Furthermore, construction activities should be avoided during sensitive periods such as busy tourist seasons.

Regarding seascape, although greater visual impact is expected during preparatory, construction and decommissioning activities, that impact will be temporary. During the operational phase, no impact from LiftWEC to the seascape is foreseen if the project is implemented far away from the coastline and if all equipment (except for marking buoys necessary to identify the project area) is placed submerged.

5 CONCLUDING REMARKS

This deliverable aims at identifying potential technology stressors and environmental receptors of the LiftWEC technology. However, given the early stage of the project, it is still not possible to have all specifications that will be inherent to the LiftWEC final configuration. Besides the specificities of the device itself, further considerations include, for example, how and where it will be positioned in seawater, the amount of devices and the materials used in the project, and plans for operations and maintenance activities such as frequency, number and type of vessels used and the possibility to perform the activities *in situ*. Nonetheless, as mentioned throughout this document, many of the LiftWEC stressors and associated receptors should be greatly common among OE installations in general.

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This document presented the main effects coming from MRE, and particularly OE, projects and those potentially associated with the LiftWEC. Main effects include possible changes to local hydrodynamics and decreased water and sediment quality, displacement/death to benthic communities as a consequence of changes on the physical receptors, disturbance to marine mammals, fish and birds as a consequence of the noise and EMFs generated (as well as potential risk of collisions with the device or other components), and on socioeconomic aspects that relate to restrictions/jeopardies to local communities and related to public acceptance. While a number of effects are deemed negative, many positive effects are also foreseen, for example environmental effects with potential increase of biodiversity through the artificial reef effect with benefits to fisheries in surrounding areas, and socioeconomic effects with businesses and services development and job enhancement.

One should note that there are many gaps in knowledge particularly about environmental impacts (for example, related with disturbance by noise and EMFs and with seabed disruption), and that many effects mentioned throughout this document (and broadly acknowledged by the relevant scientific community) are perceived effects on receptors and are not measured effects. As a consequence, it might lead to conservative approaches in implementing MRE projects and hamper MRE development.

Taking the lessons learnt from previous MRE projects (and from the Oil & Gas sector), the LiftWEC could represent improvements to the OE sector, not only from the engineering or components development perspective, but also in developing good practices for environmental impact mitigation.

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