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COASTENERGY
EUROPEAN UNION

Port o f Ancona: Onshore Wave Energy Converters

Pre-feasibility study

Deliverable D4.3.1

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INTRODUCTION

In the framework of the INTERREG Italy-Croatia COASTENERGY project funded by EU, University of Camerino – UNICAM appointed the Italian company ECOPRO S.R.L. to implement a pre-feasibility study to understand social - environmental benefits and technical issues related to the production of renewable energy from a wave energy power station in the port of Ancona. Figures already gathered by UNICAM research group have been taken for granted and – where possible – verified with the manufacturer of the technology.

This pre-feasibility study about a Wave Energy Converter located in the port of Ancona (specifically in the seafront Fincantieri shipyard section) includes the following sections: technical pre-feasibility, economic and financial pre-feasibility, social and environmental impact analysis. The workgroup has the aim of considering physical, legal, technological, economic, and social contexts in order to highlight advantages, or critical aspects, related to the installation of a system harvesting energy from the waves.

The findings in this pre-feasibility study suggest that there is a good exploitability potential of onshore wave energy converters in the central Adriatic area and specifically in the Port of Ancona. Moreover, it is noticeable that the Port Authority is a large energy consumer and renewable energy solutions would obviously be the most sustainable opportunity to self-consumption, sustainability and energy cost reduction. Particularly, the majority of energy consumption takes place because of two main reasons: consumption by third parties and consumption related to infrastructures managed by Ports Authority.

It is very important to notice that before any economic evaluation takes place, energy potential data need to be gathered by a monitoring of the selected area with a wave-recorder so that those real figures can be considered in the business plan.

Specific data on the technology selected by the University of Camerino for this pre-feasibility are lacking because the manufacturer did not disclose those figures. Especially in the technical and economic pre-feasibility please consider that important information could not be included nor considered, even though they could possibly affect the resulting payback period in terms of cashflow and operation costs.

ECOPRO / June, 28 2021

1. LOCATION: THE AREA OF THE PORT OF ANCONA

1.1. PORT OF ANCONA: FINCANTIERI AREA

Ancona is the Regional County Seat of Le Marche. The city is located in the Western-central coast of the Adriatic Sea and has a population of averagely 99.000 inhabitants as of 2019.

The port of Ancona covers a surface of over 1.4 million square meters, including general cargo and container facilities, international ferry and passenger terminals to Greece, Croatia and Albania. The ancient Roman Port of Ancona was founded in the 4th Century BC by Syracusans and because of the natural elbow-shaped inlet – which gave the name to the city, Ancona comes from the Greek term *ankon* ("elbow") – it became a very important port for commercial purposes when Romans completed the construction of the port. It still remains important today after the Post-WWII renovation works, because it is registered as EU international port and included in the TEN-T Scandinavian-Mediterranean route. It is definitely the main port in the Adriatic Sea in relation to number of shipping and regular lines. Over 6,500 people work every day at the port of Ancona, the traffic of goods is 11 million tons per year and over 1 million passengers per year use the port of Ancona on ferries and cruise ships, linking to the Eastern coast of the Adriatic Sea and the Aegean Sea. Container traffic has grown to more than 150,000 TEUs per year . Since the year 2003 the port of Ancona has undergone the implementation of infrastructures with employment benefits and ongoing studies on strategies to improve the competitiveness of the port.

In order to make easier logistics and traffic routes to the port of Ancona, the Regional Council of Le Marche in 2021 has appointed a commissioner who will deal with the building of a new freeway to better connect the port of Ancona with A14 highway, the airport and the Interporto (i.e. the local intermodal and logistics centre) . This is to say that the provisional future strategies referring to the port of Ancona are actually positive: it is definitely necessary to include renewable energy solutions – including blue energy technologies, such as wave energy systems – to reduce energy costs, improve sustainability of energy needs in the port of Ancona.

Figure 1 – Italian Military Geographical Institute - Map of table118 Ancona

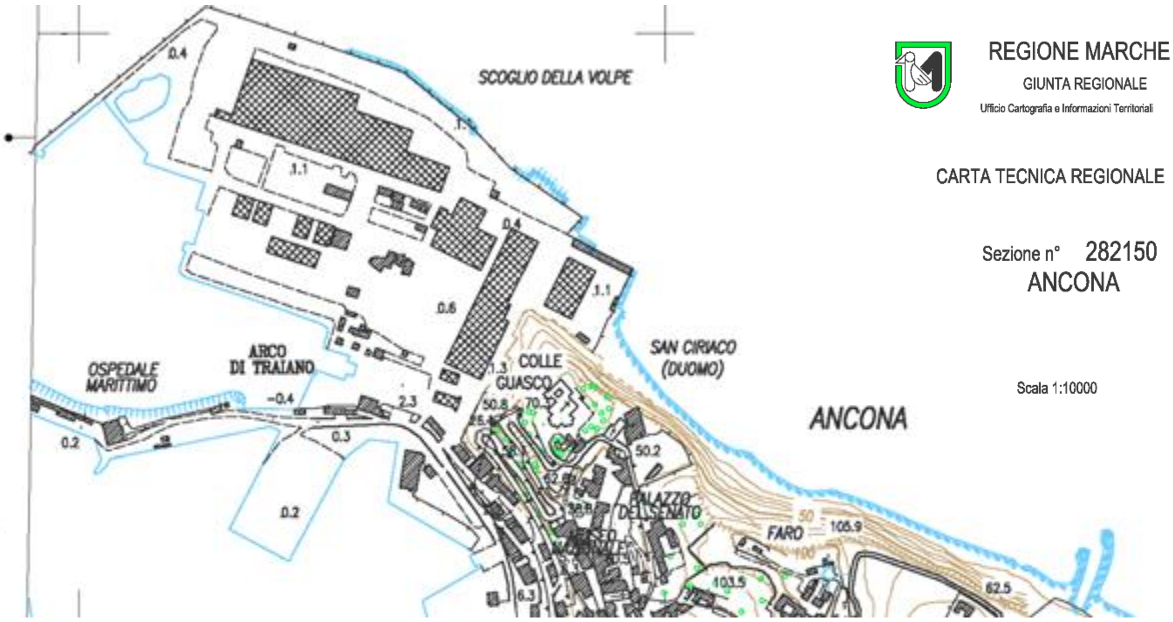

Figure 2 - Regional technical Map of the Port of Ancona Section 282150 ANCONA

1.2. SELECTED AREA – FINCANTIERI SHIPYARDS AT THE PORT OF ANCONA

The supposed location has the following WGS84 GPS coordinates from GoogleMaps:

43.63118081532939, 13.504182942740403

Figure 3 - Photogrammetric view of the Port of Ancona

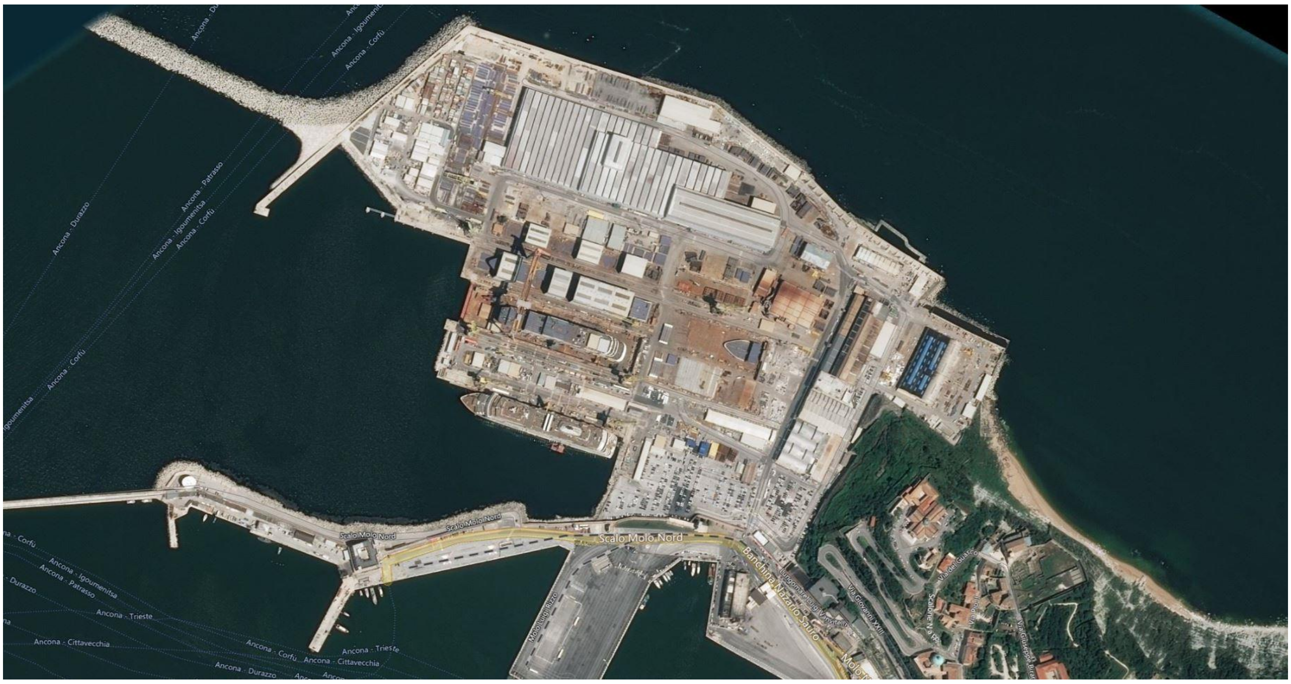

Figure 4 - Bird's-eye view of the Fincantieri Shipyards

Figure 5 - Cadastral Map of the Port of Ancona – bird's-eye view of the Fincantieri Shipyards

1.3. SELECTED AREA: IMAGES OF THE SUPPOSED LOCATION – WALL AT FINCANTIERI SHIPYARDS

The location selected for the installation of an on-shore wave energy converter system composed of 50 floaters is the sea-front wall of the Fincantieri area of the Port of Ancona. The criteria for the choice of the location were basically:

- the absence of tetrapods, which actually would make more cost-effective the installation process of the floaters, and also because of the low environmental and social impacts of such an installation
- availability of the area which is subject to concession of the port of Ancona
- the protection walls would benefit from the structure of the floaters which would also make the wall much more solid in case of storms[1]

Here are few pictures to better understand the area where the supposed system could be installed.

[1] As suggested by the manufacturer of the WECs.

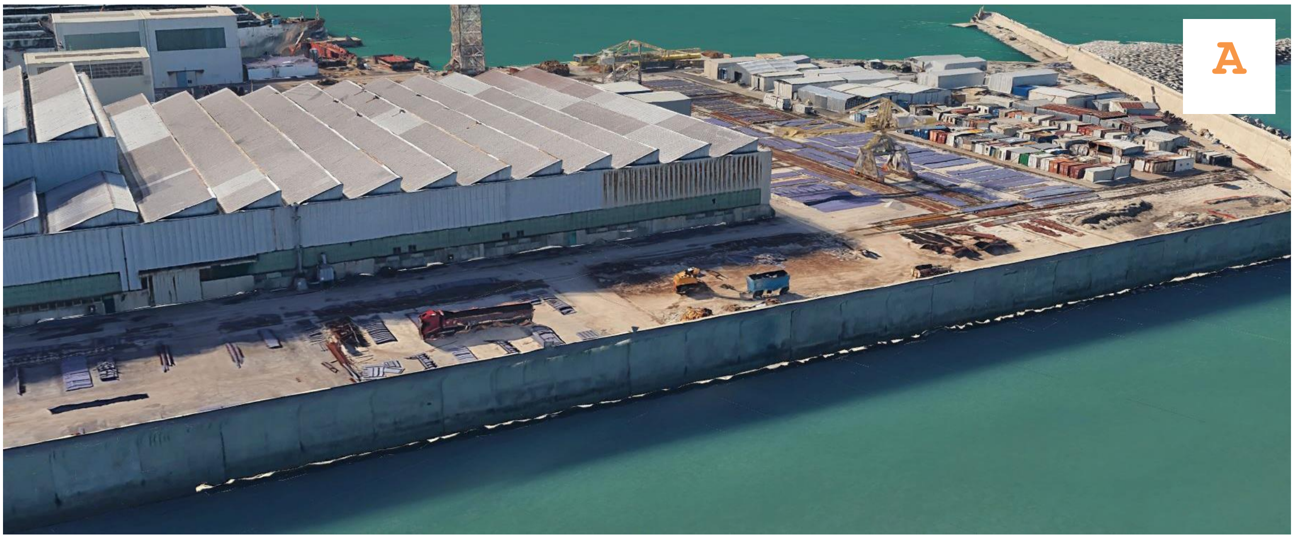

Figure 6 - Fincantieri shipyards in the port of Ancona - supposed location for the WEC / bird's-eye view A

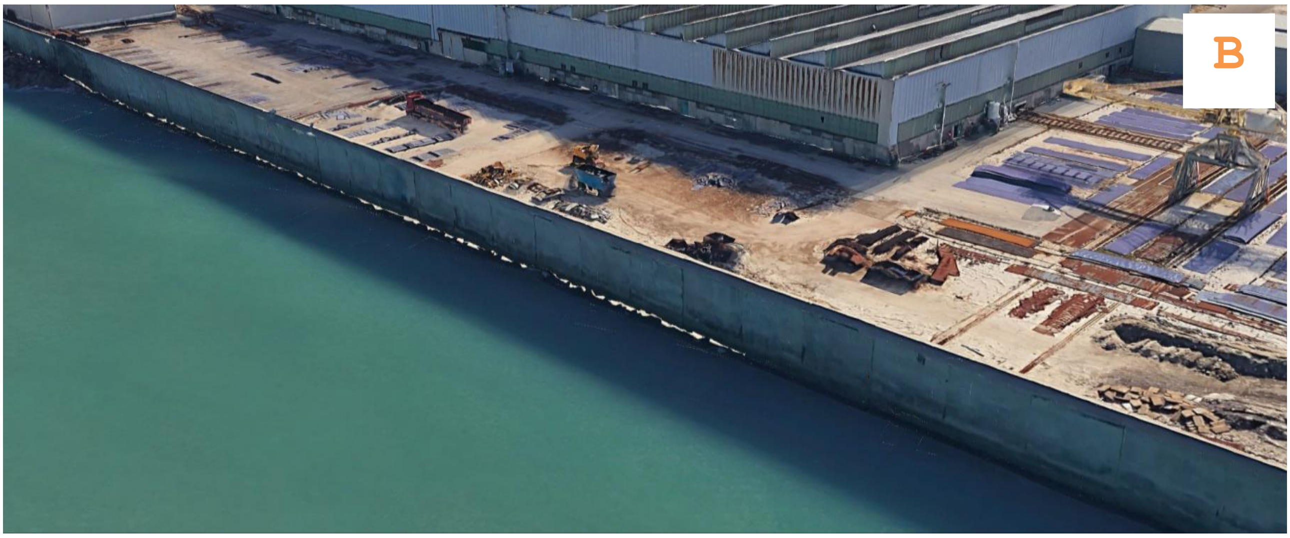

Figure 7 - Fincantieri shipyards in the port of Ancona - supposed location for the WEC / bird's-eye view B

Figure 8 - Fincantieri shipyards in the port of Ancona - supposed location for the WEC / bird's-eye view C

1.4. WAVE ENERGY POTENTIAL ANALYSIS IN THE PORT OF ANCONA

The EU Renewables Directive addresses two of the biggest challenges of our time, i.e. energy security and climate change. The recent energy targets of the European Commission for 2030 are set to at least 32% renewable: it has become crucial not only for securing the energy supply in the EU, but also for the mitigation of the climate change consequences and the enhancement of the competitiveness of the economy. The energy sector must turn to new energy sources and more efficient technologies, in order to fill the energy demand with clean energy, such as onshore renewable energy sources. It has the potential to help reduce CO_2 emissions and alleviate the global climate change threat. Nevertheless, it is also critically important that the development of new ocean energy technologies does not harm the marine environment[2].

It is herewith necessary to define that wave energy (offshore and onshore) is a technology, which can be embedded on manmade structures, such as ports and wave-breakers, or on floating buoys. In our pre-feasibility study, we considered an onshore wave energy converter as the technology to generate clean energy for the port of Ancona. In addition to more consolidated and widespread renewable energy systems already commissioned – such as CHP and solar PV – wave energy converters offer the opportunity to take advantage of an infinite source that is locally available in the port of Ancona: sea wave energy. On-shore WECs can be installed in areas where no other facility can be equally profitable, and their

2 R. PELC, R.M. FUJITA, *Renewable energy from the ocean,* 2002

structure would also give benefits in terms of solidity and security of the area against flooding in case of stormy weather[3].

There are very few sources to analyse the potential of blue energy in the Port of Ancona, though this paper highlights the opportunities of developing such solution to generate renewable energy from the waves by the installation of an on-shore wave energy converter system composed of 50 floaters in the Fincantieri area.

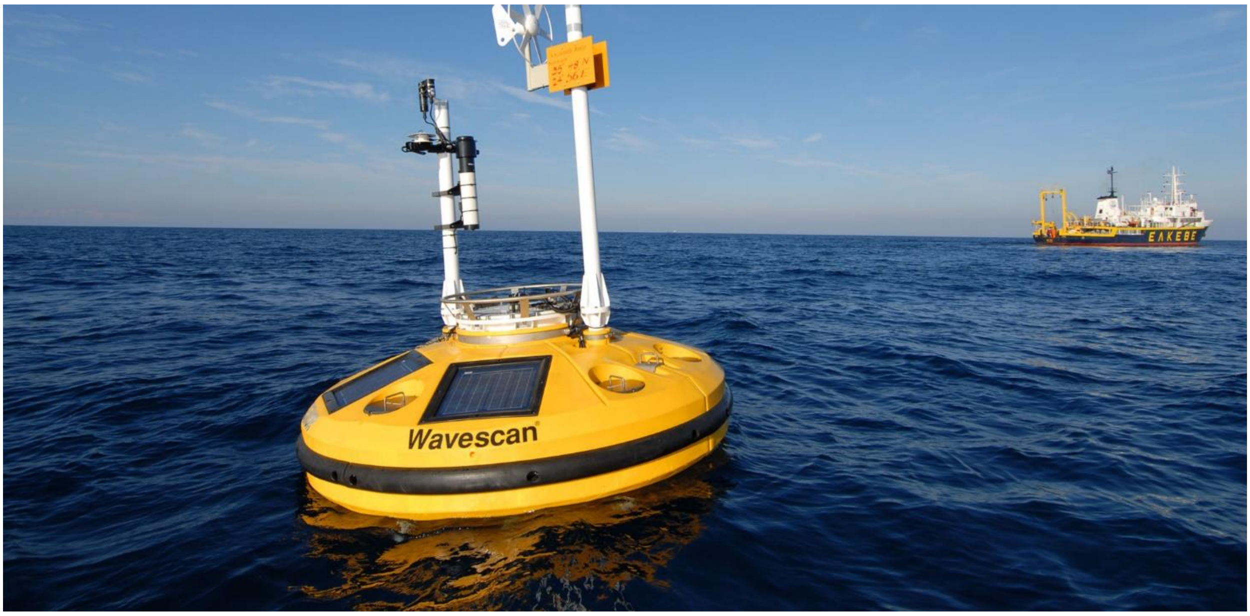

Figure 9 - Wave scanner: a measuring system to gather specific information and figures about waves in supposed locations for WECs

Our suggestion as engineering consultants is that any further interest in this technology has to be followed by the monitoring of the area using a wave-recorder, which would give much more specific data about waves and potential of blue energy, in order to gather projection and scalable data in the business plan of a possible future feasibility study. Wave height and intensity records are necessary information to study the location, just because the choice of the right location is extremely important for wave energy converters. Sensors and a monitoring system would give precious figures on a year-long period.

[3] See footnote 4.

Regarding the wave characteristics, there is a specific study about the sea and waves on the Port of Ancona[4] requested by the Central Adriatic Ports Authority and developed by AcquaTecno: this study gathers data on the waves by the Fincantieri docks in the commercial area of the port of Ancona, in order to check operation conditions of moorings in the new quays of Molo Clementino. It is not actually the same location that it is analysed in this pre-feasibility study, but the said study gives useful information in order to understand what characteristics the waves have in the vicinity of the port of Ancona. In particular, the sea-weather study[5] has been considered for its specific data gathered from the wave-meter (that is installed off the coast of Ancona, as one of the meters of the National Wave-meter Network managed by APAT).

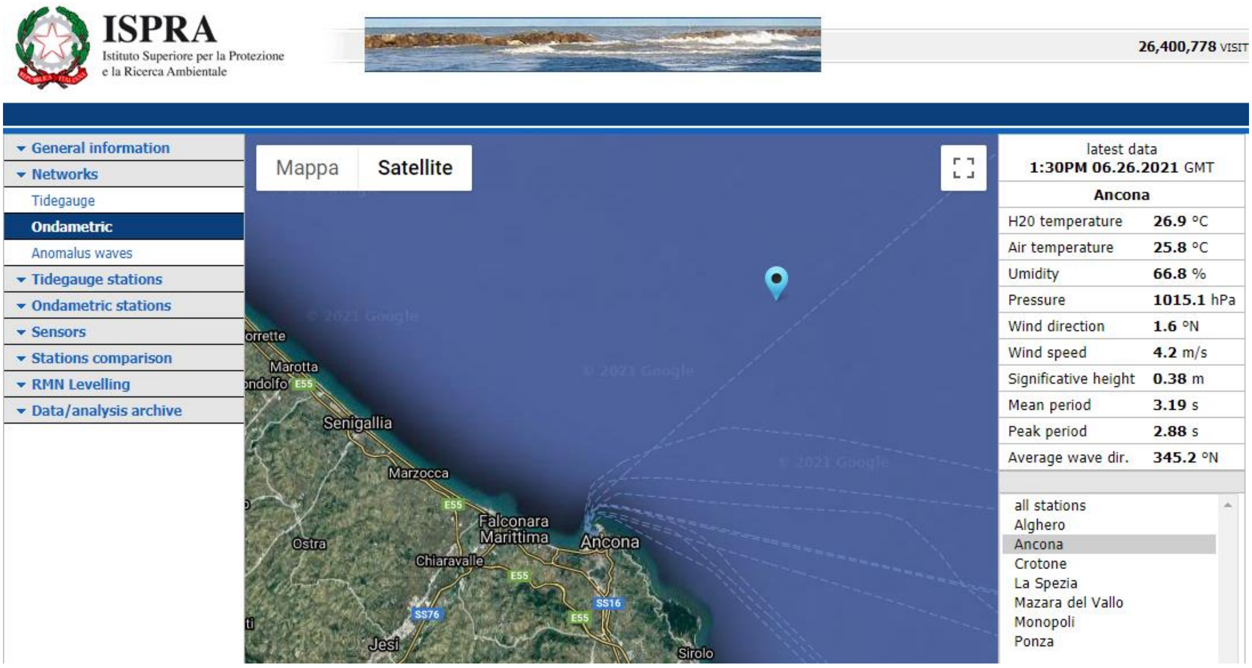

Figure 10 - Location of the Wave-meter (Buoy) off the coast of Ancona – ISPRA website

[4] *Studio specialistico idraulico-marittimo Determinazione dei livelli di agitazione ondosa del banchinamento del fronte esterno del molo clementino*, project developed by AcquaTecno for the Central Adriatic Ports Authority in May 2018.

[5] *Studio meteo-marino*, Variante al P.R.P. di Ancona, study developed by AcquaTecno and Modimar for the Port Authority. Please note that all figures and tables in this section are takes from this source.

ondametric network	
latest data 1:30PM 06.26.2021 GMT	
water surface temperature	26.9 °C
air temperature	25.8 °C
relative humidity	66.8 %
atmospheric pressure	1015.1 hPa
wind average direction	1.6 °N
wind average speed	4.2 m/s
spectral significant height	0.38 m
spectral mean period	3.19 s
peak spectral period	2.88 s
average wave direction	345.2 °N

Figure 11 - Information gathered by the wave-meter – ISPRA website

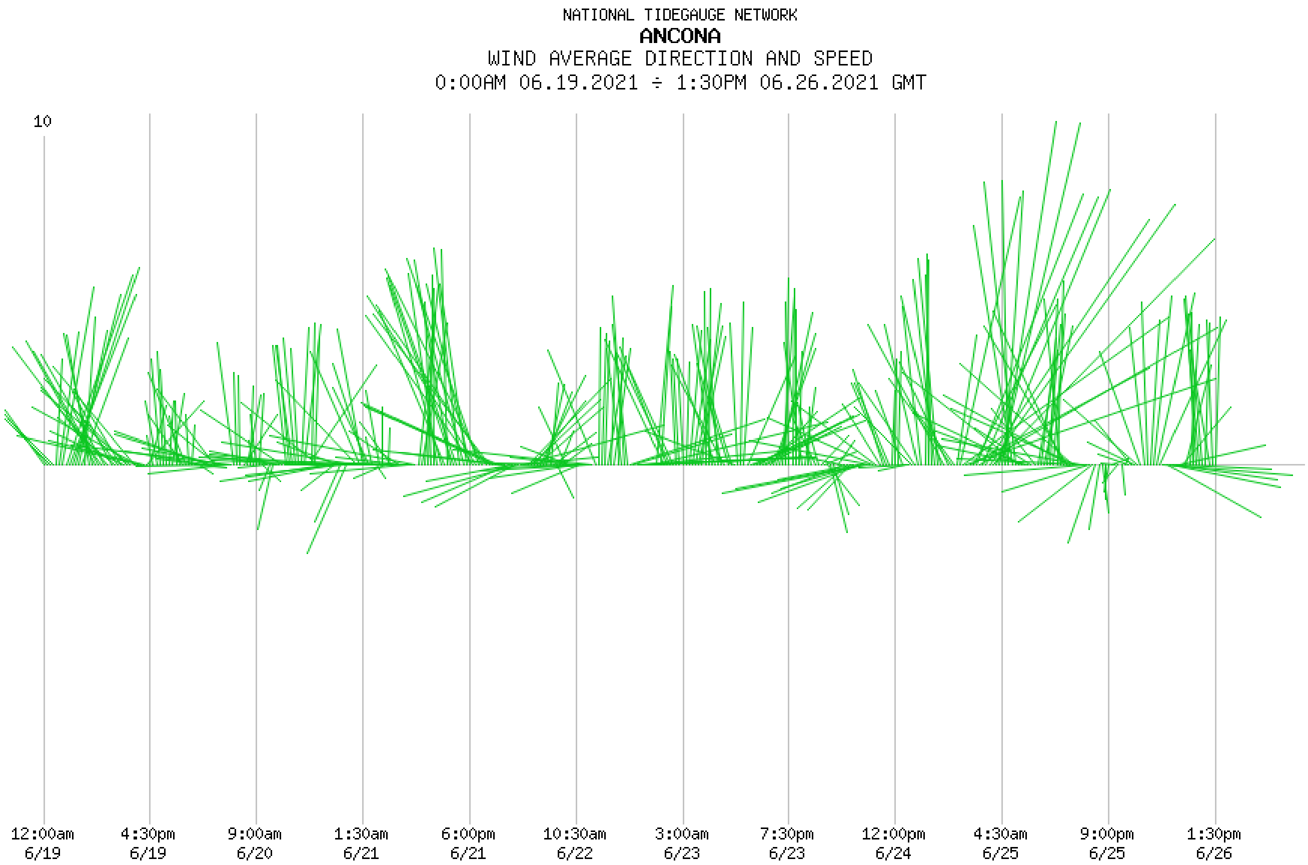

Figure 12 - Data about wind direction and speed - week June, 19 to 26

The analysis of the offshore wave characteristics offers the opportunity to define main parameters such as the typical waves and potential energy production of the WECs.

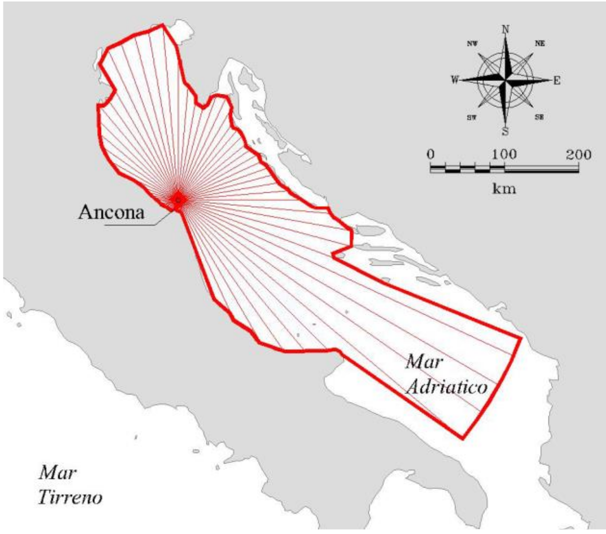

Figure 13 - Geographical fetches off the coast of Ancona

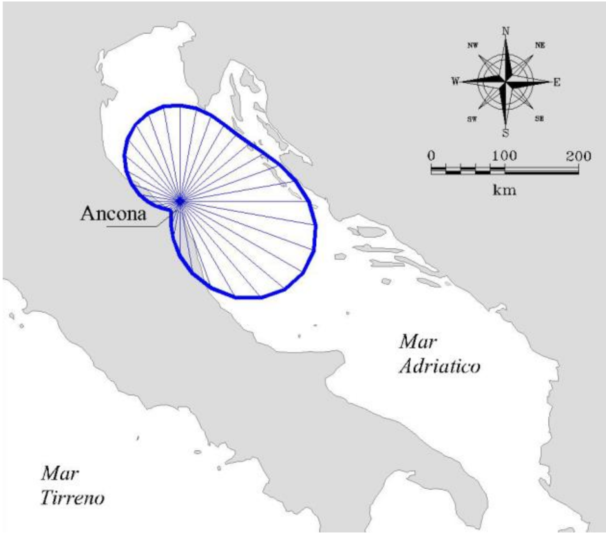

Figure 14 - Effective fetch off the coast of Ancona

Direzione media settore di traversia (°Nord)	Fetch Geografico (km)	Fetch Efficace (km)	Deviazione direzione vento-mare (°)	Direzione media settore di traversia (°Nord)	Fetch Geografico (km)	Fetch Efficace (km)	Deviazione direzione vento-mare (°)
0	192.76	130.19	-1.0	180	14.26	72.94	-30.0
10	133.43	127.76	-4.0	190	13.43	51.13	-34.0
20	150.81	123.95	-6.0	200	12.06	34.53	-38.0
30	144.39	120.35	-7.0	210	15.80	23.98	-43.0
40	124.44	119.27	10.0	220	16.89	18.90	-46.0
50	119.06	122.69	20.0	230	17.22	18.05	-50.0
60	123.52	131.15	20.0	240	18.42	20.58	41.0
70	128.58	143.98	17.0	250	21.20	25.82	38.0
80	137.12	159.37	14.0	260	24.63	33.42	35.0
90	167.47	174.51	10.0	270	28.54	43.41	31.0
100	236.82	186.50	6.0	280	36.77	55.66	28.0
110	223.85	193.11	2.0	290	48.05	69.47	24.0
120	498.40	192.88	-2.0	300	107.48	83.84	20.0
130	500.00	185.13	-7.0	310	138.57	97.74	16.0
140	265.02	170.21	-11.0	320	167.39	110.10	13.0
150	221.14	149.35	-16.0	330	211.53	119.97	9.0
160	141.99	124.53	-21.0	340	226.21	126.71	5.0
170	15.71	98.20	-25.0	350	230.95	130.06	2.0

Figure 15 - Geographical and effective fetches off the coast of Ancona

Useful for our pre-feasibility study is the section of analysis of the waves by the coastal area of the port of Ancona, as of the following Figures.

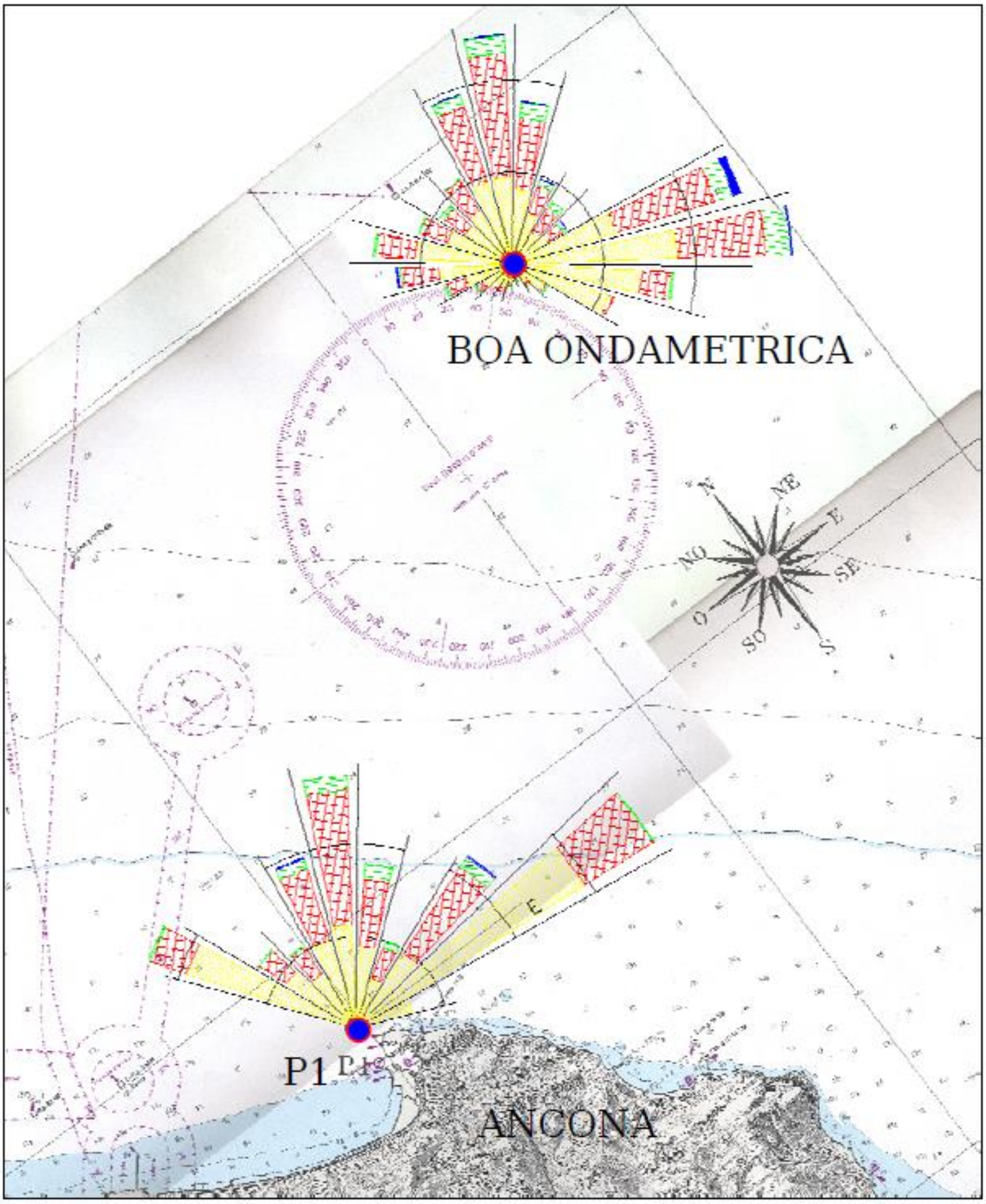

Figure 16 - Geographical location and annual wave behaviors off- and on-shore

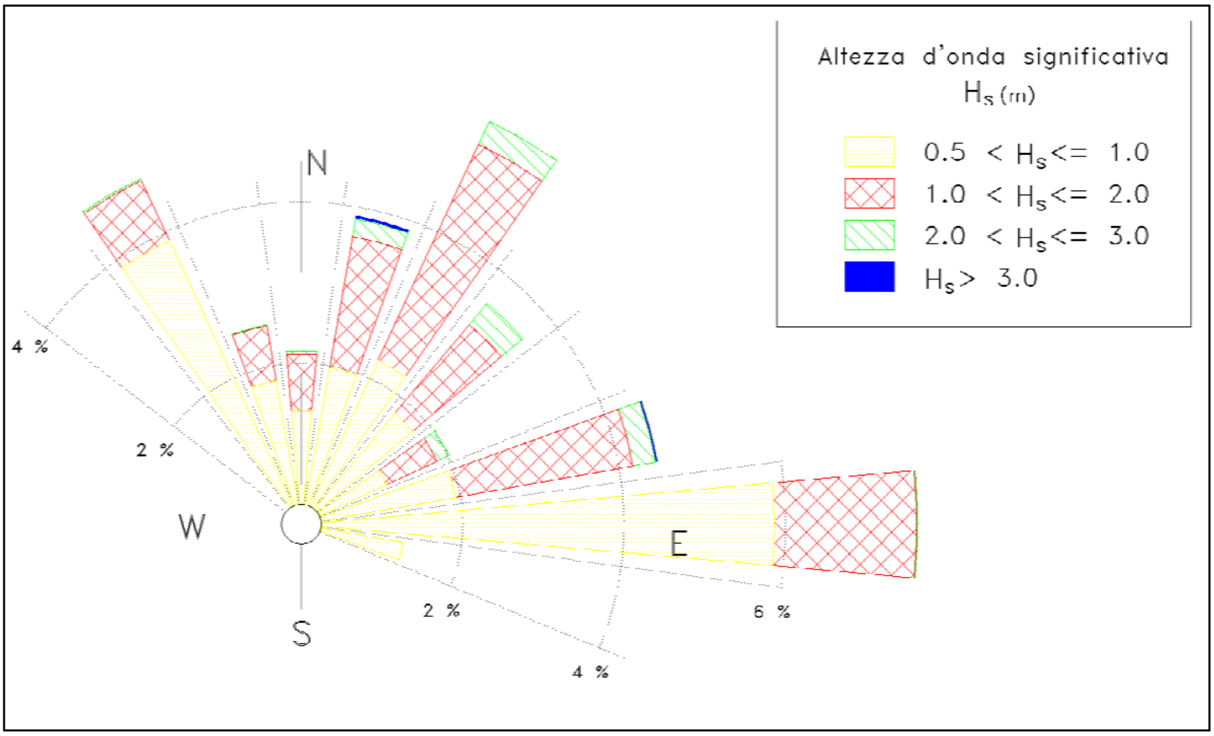

Figure 17 - Direction and distribution of waves on the cost, referring to P1 that is closer to the supposed location for the installation of WECs

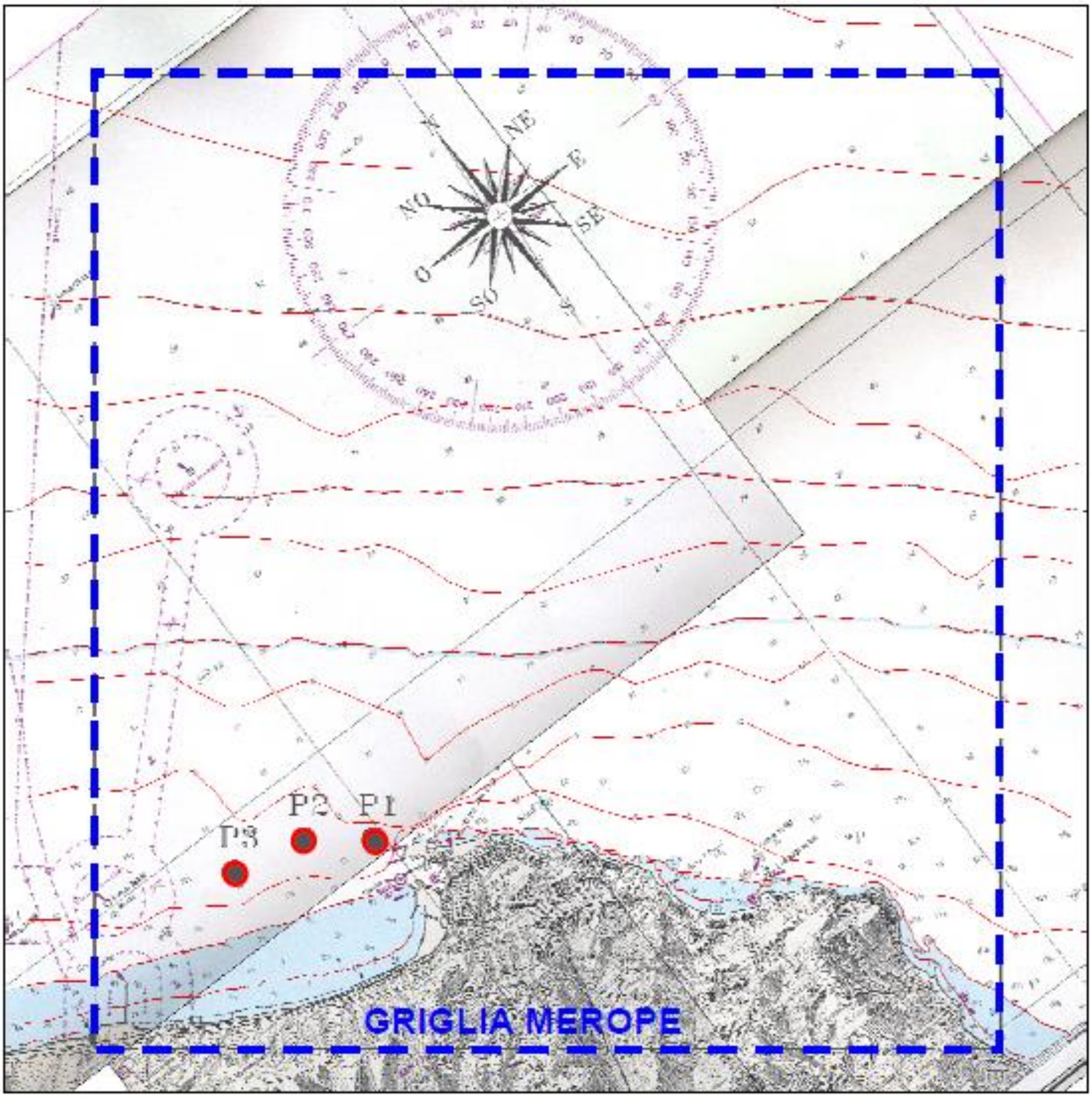

Figure 18 - Chorography of the area and calculation grid with selected points at the entrance to the port of Ancona

Distribuzione percentuale degli eventi ondosi, per classi di Hs e direzione di provenienza.

Ancona largo - Periodo di riferimento gennaio 2002 - dicembre 2004

DIR	CLASSI DI ALTEZZA D'ONDA SIGNIFICATIVA Hs (m)															
(°N)	<.25	.25÷0.5	0.5÷1.0	1.0÷1.5	1.5÷2.0	2.0÷2.5	2.5÷3.0	3.0÷3.5	3.5÷4.0	4.0÷4.5	4.5÷5.0	5.0÷5.5	5.5÷6.0	6.0÷6.5	>=6.5	TOT.
10	0.39	0.73	0.98	0.63	0.27	0.04	0.03	0.01								3.09
20	0.51	0.69	1.37	0.97	0.42	0.15	0.07					0.01				4.19
30	0.43	0.63	1.33	1.21	0.64	0.21	0.06	0.01								4.52
40	0.31	0.51	1.00	1.01	0.40	0.22	0.07	0.01								3.55
50	0.36	0.45	1.13	0.52	0.31	0.12	0.03									2.92
60	0.45	0.34	0.76	0.25	0.12	0.10		0.01								2.04
70	0.40	0.46	0.55	0.16	0.19	0.06										1.83
80	0.34	0.45	0.51	0.34	0.19	0.10	0.01	0.01								1.97
90	0.51	0.51	0.48	0.12	0.09	0.03										1.73
100	0.54	0.85	1.06	0.72	0.31	0.16	0.01									3.65
110	0.67	1.18	2.12	1.03	0.55	0.25	0.15	0.16	0.01	0.03	0.01					6.17
120	0.81	1.67	2.34	1.01	0.46	0.16	0.21									6.67
130	0.84	2.12	1.98	0.40	0.16	0.07	0.03									5.61
140	0.84	2.07	1.98	0.24	0.03											5.16
150	1.07	2.48	1.51	0.07												5.13
160	0.60	1.45	0.75	0.03	0.01											2.83
170	0.70	0.76	0.40	0.04	0.01	0.03										1.95
180	0.39	0.45	0.27	0.04	0.01											1.16
190	0.28	0.36	0.19	0.03	0.01	0.01										0.89
200	0.33	0.25	0.12	0.04	0.01	0.01										0.78
210	0.18	0.27	0.22	0.01		0.01										0.70
220	0.22	0.28	0.24	0.04	0.01	0.01										0.82
230	0.19	0.43	0.34	0.04												1.01
240	0.39	0.33	0.27	0.10	0.01											1.10
250	0.22	0.42	0.43	0.16	0.03											1.27
260	0.24	0.52	0.28	0.06												1.10
270	0.33	0.67	0.51	0.10	0.06		0.01									1.69
280	0.36	0.75	0.58	0.13	0.03											1.85
290	0.52	1.00	0.81	0.33	0.09	0.03										2.77
300	0.46	1.18	1.10	0.49	0.15	0.03	0.01	0.01								3.45
310	0.43	1.19	1.34	0.43	0.13	0.03										3.56
320	0.57	1.09	1.34	0.40	0.09	0.01										3.50
330	0.46	1.34	1.07	0.39	0.06	0.01										3.34
340	0.34	0.97	0.81	0.31	0.07	0.03										2.54
350	0.49	0.87	0.78	0.22	0.06	0.01	0.04									2.48
360	0.45	0.92	0.97	0.42	0.18	0.01										2.95
TOT.	16.61	30.62	31.93	12.56	5.22	1.97	0.76	0.25	0.01	0.03	0.01	0.01				100.00
Tot. cumul.		47.23	79.16	91.72	96.94	98.91	99.67	99.93	99.94	99.97	99.99	100.00	100.00	100.00	100.00	

Numero eventi validi : 6705

Figure 19 - Annual events of waves classified in height and direction

Important results from the analysis is that more frequent and higher waves come from east-southeast (80°-170°), and 47% of events are waves at 0,5 m.

Especially for the calculation of the potential energy generation of the WECs the data in this section are considered, and in addition to those figures also the following table[6] is useful:

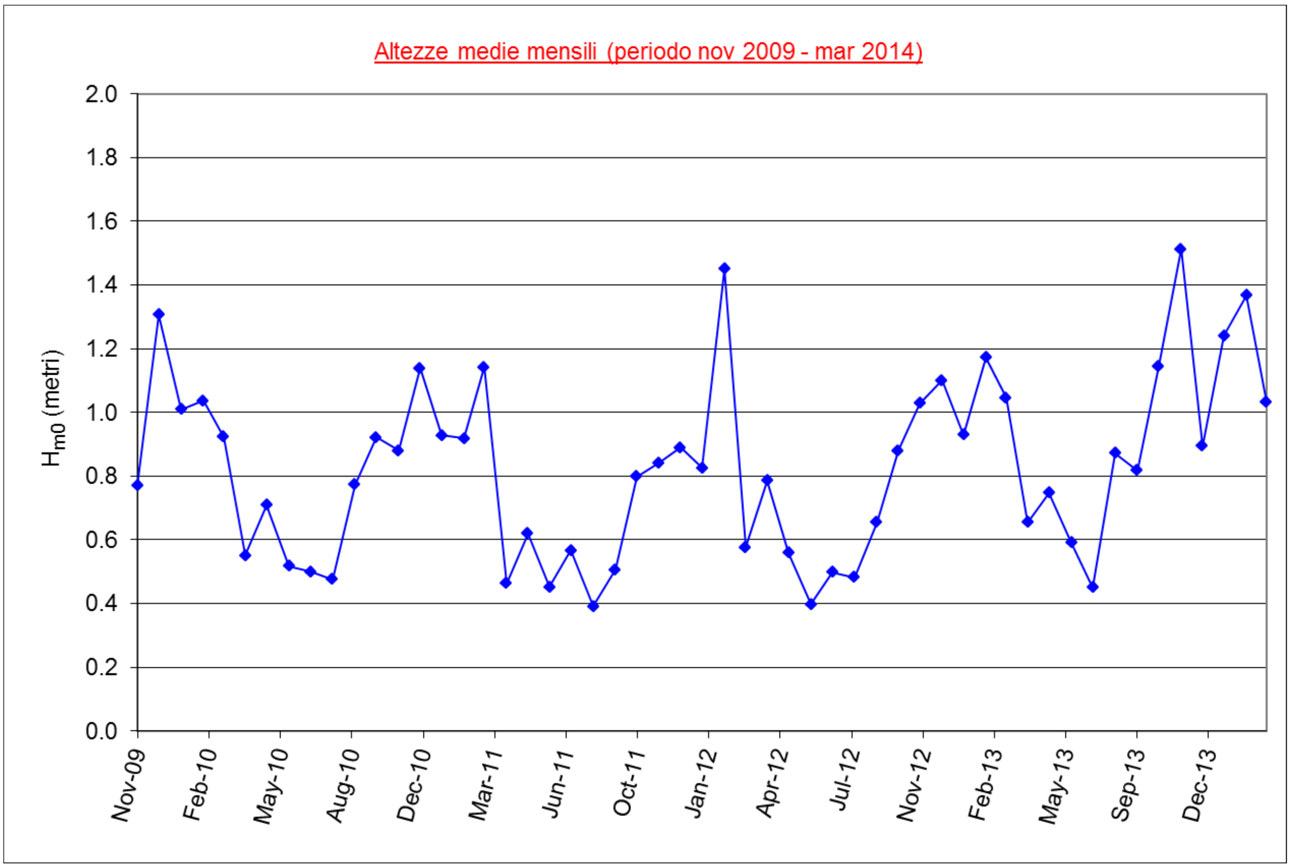

Figure 20 - Wave heights on a monthly scale, evaluated every half hour by the wave-meter offshore the port of Ancona from Nov. 2009 to Mar. 2014

[6] *Convenzione per lo studio dell'agitazione ondosa interna al nuovo di Ancona*, Università Politecnica delle Marche 2014.

1.5. REGULATIONS IN FORCE

The port of Ancona is under control of the Central Adriatic Ports Authority[7]. The Authority fosters competitiveness and further development of the port of Ancona by a review of the Port Master Plan in force, in order to increase the operation capacity of the port.

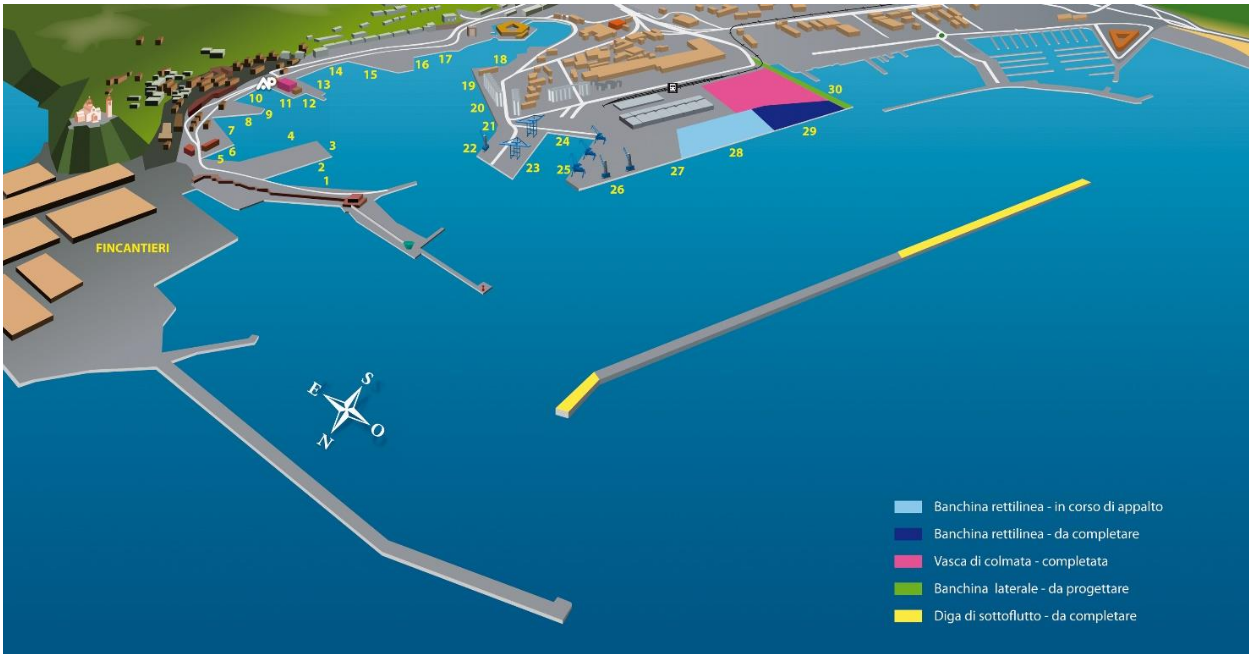

Figure 21: map rendering of the extension works in the new Port Master Plan

The new Master Plan will include the building of port aprons and facility areas over a surface of 220,000 square meters, a 900 meters-long and 14 meters-deep quay, 776 meters-long breakwaters. No particular obligations for the bureaucratic authorization of an onshore wave energy system shall occur.

The construction of WECs is regulated also by renewable energy legislation and in terms of incentives or feed-in tariffs it is necessary to understand if the Ports Authority is interested in self-consumption or in selling the energy. Self-consumption is obviously always suggested and in the following months a new regulation will probably offer incentive opportunities for WECs, while at present you can get advantage

[7] For further information see footnote 2.

of the so-called **SCAMBIO SUL POSTO** (for self-consumption) or even the so-called RITIRO DEDICATO (you can sell the energy to the national grid) managed by GSE SpA.

Here is a list of regulations in force that have to be considered in case of any project development in the area of the port of Ancona:

- Legislative decree No. 169, August 4 2016 – Ports Authorities need to develop an Energy and Environmental Masterplan of Pots (the so-called DEASP – Documento di Pianificazione Energetica e Ambientale del Sistema Portuale[8]) according to guidelines from Ministeries of Sea and Infrastructures. It is herewith important to notice that Ports Authorities have to take into account energy and environmental sustainability, lowering CO_2 emissions, improving energy efficiency and renewable energy solutions also implementing a monitoring system of consumption;
- *Green Guide. Towards excellence in port environmental management and sustainability* published by European Sea Ports Organisation (ESPO);
- *National Strategic Plan for Ports and Logistics* (the so-called PSNPL – Piano Strategico Nazionale della Portualità e della Logistica) adopted by Decree of Prime Minister on August 6 2015 – especially chapter 7 is on Sustainability, and aims to offer enhancement of smart use of energy, energy efficiency, fostering use of renewable energy sources, reducing environmental impact in ports;
- *EU Directive 2014/94/EU on implementation of infrastructures for alternative fuels* (DAFI – Deployment of alternative fuels infrastructure) and Legislative decree No. 2574, December 16 2016 in relation to LNG and electricity utilities for mooring ships.

[8] This document is available on the website of the Ports Authority at http://www.assoporti.it/media/6855/deasp-adsp-mare-adriatico-centrale.pdf.

2. TECHNICAL PRE-FEASIBILITY

2.1. TECHNOLOGY: WAVE ENERGY CONVERTER

The selected technology for this project is the Wave Energy Converter designed and manufactured by the Israeli-Swedish company ECO WAVE POWER GROUP[9], because it is the only grid-connected wave energy array in the world. Eco Wave Power holds several patents (17 and some more pending patents) on its proprietary technology. In the past years many wave energy converters used to locate their systems offshore, while Eco Wave Power offered a new approach by installing its systems onshore and attaching machines to breakwaters. This approach is based on recent studies about the exploitation level of power in the onshore systems.

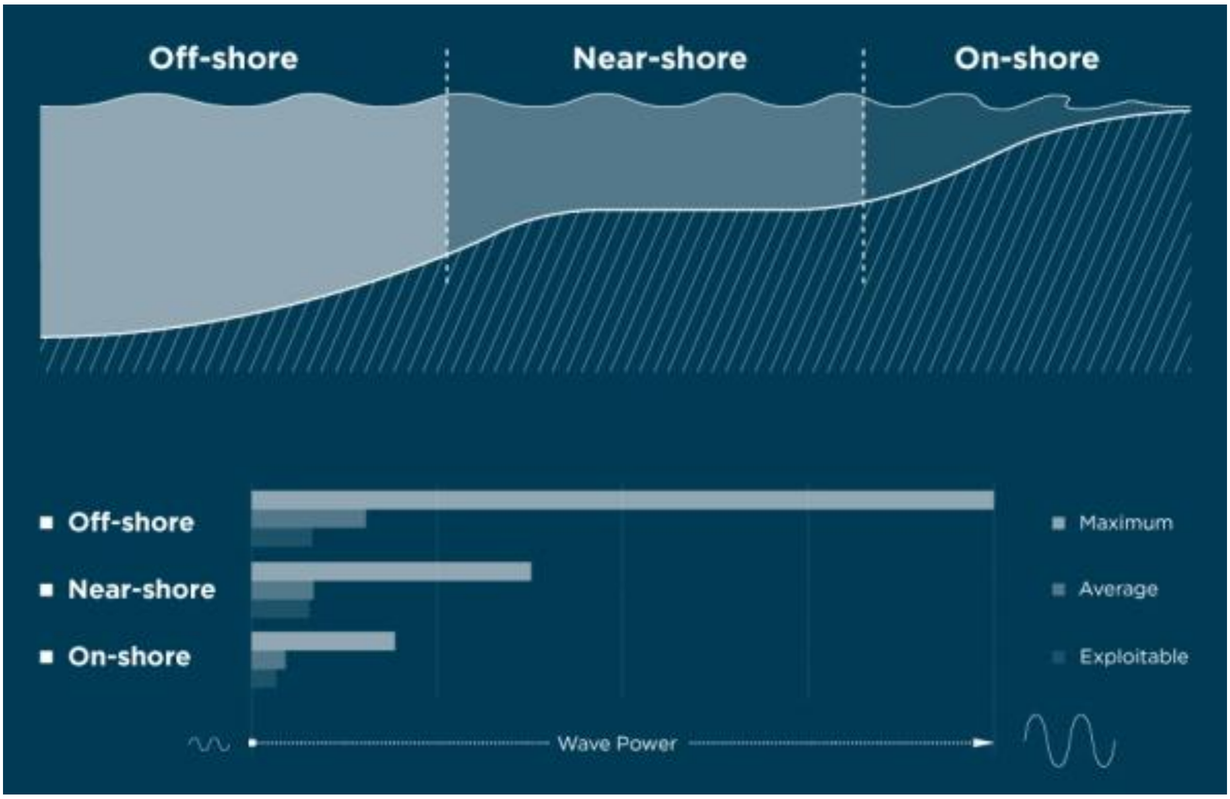

Figure 22 - Table taken from study published by TEXAS A&M UNIVERSITY

[9] General and technical information are mainly taken from the website of the company https://www.ecowavepower.com/, June, 21 2021.

According to research studies, WECs (i.e. wave energy converter) positioned in near-shore locations encounter waves coming from the same direction and more stable sea, thus boosting the amount of captured energy. Onshore technologies also have lower power transmission losses and lower infrastructure costs. As a consequence, wave energy resources on onshore and near-shore systems are far more exploitable compared to off-shore systems[10].

The aim of the onshore wave energy converter designed by Eco Wave Power is to produce clean energy using floaters that are attached to existing man-made structures, such as in the case of the port of Ancona, where the supposed location is composed of a sea-front wall. Installation and maintenance are simple and cost-effective[11].

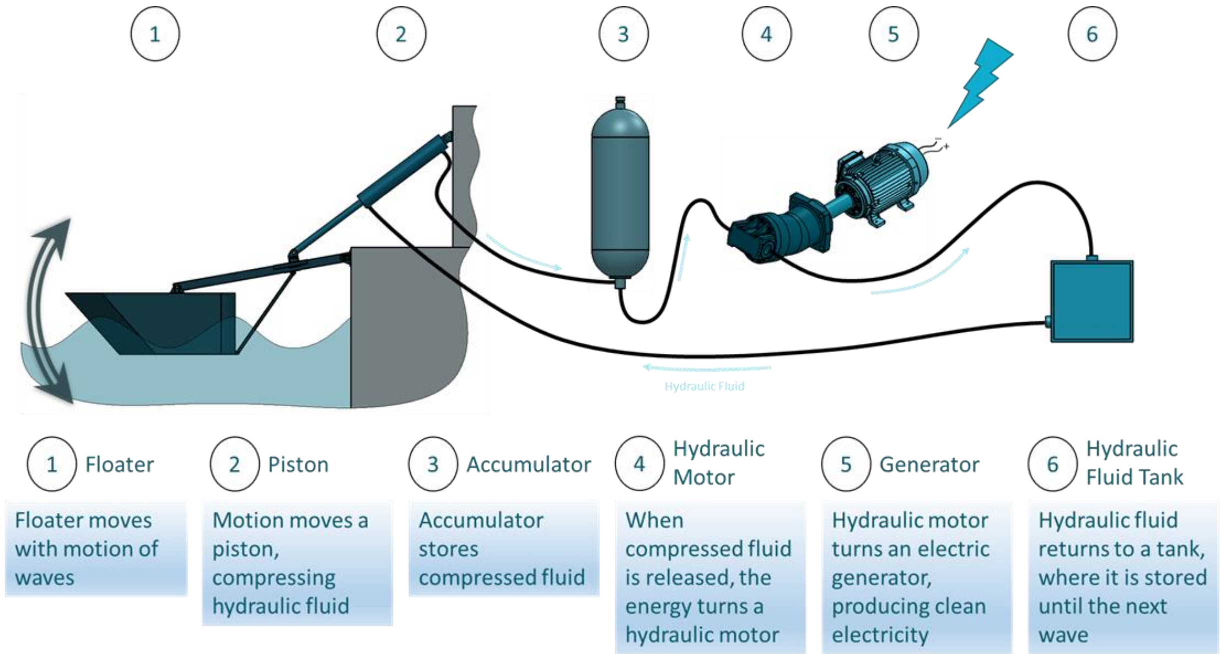

Figure 23 - Energy generation process of the ECOWAVE floaters - picture taken from the company website https://www.ecowavepower.com/our-technology/how-it-works/

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[10] Research resources taken from TEXAS A&M UNIVERSITY, *Theory of Wave Energy & Availability*, published on the website https://waveenergyconversiontamu15.weebly.com/theory-of-wave-energy--availability.html

[11] As declared by the manufacturer of the WECs, i.e. Eco Wave Power, yearly maintenance costs are 10% of cost of floaters

The plant is composed of floaters, which are attached to the wall, and the rising and falling motion of the waves against the floaters are converted into clean energy. The movement of the floaters compresses and decompresses hydraulic pistons, which transmit bio-degradable hydraulic fluid into land-land located accumulators. Pressure is built in the accumulators and rotates a hydraulic motor, and subsequently rotates the generator. The electricity is then transferred into the inverter, and into the national electricity grid. The process is a closed circular system because, after decompression, fluid flows back into the hydraulic fluid tank, where it is re-used by the pistons. Production of electricity from waves begins at a 0.5 meters wave height. Monitoring is granted by a smart automation system, which also suspends operation and prevents damages to the system by rising the floaters above sea level in case of storm.

2.2. ENERGY NEEDS AND CAPACITY OF THE PLANT

The potential wave power generation in the selected area – as identified in section 1.4. – would be averagely 13.400 kW of energy converted for each floater. The supposed location is a 200 meters long wall so that 50 floaters could be installed.

Ripartizione percentuale per classi di altezze d'onda significative e periodo di picco
Ancona largo - Periodo di riferimento gennaio 2002 - dicembre 2004

	CLASSI DI PERIODO MEDIO Tp (s)								
Hs (m)	T_p<4	4 ≤T_p<6	6 ≤T_p<8	8≤T_p<10	10≤T_p<12	12 ≤T_p<14	T_p>14	Tot	Tot. cumul.
0.25 <	12.07	4.16	0.33	0.01	0.01		0.03	16.61	16.61
0.25 ÷ 0.75	43.64	5.43	0.43	0.10	0.06	0.01		49.68	66.29
0.75 ÷ 1.25	11.60	8.77	0.40	0.01				20.79	87.08
1.25 ÷ 1.75	0.43	7.10	0.48					8.01	95.09
1.75 ÷ 2.25		2.45	0.39					2.83	97.93
2.25 ÷ 2.75		0.97	0.43					1.40	99.33
2.75 ÷ 3.25		0.19	0.30					0.49	99.82
3.25 ÷ 3.75		0.01	0.10					0.12	99.94
3.75 ÷ 4.25									99.94
4.25 ÷ 4.75			0.04					0.04	99.99
4.75 ÷ 5.25									99.99
>5.25			0.01					0.01	100.00
Tot.	67.74	29.08	2.92	0.13	0.07	0.01	0.03	100	
Tot. cumul.	67.74	96.82	99.75	100.00	100.00	100.00	100.00		

Figure 24 - Waves classified in relation to height and period (in percentage)

Here is a power Matrix for an Eco Wave Power wave energy power station with an installed capacity of 500 kW with 50 floaters:

Wave height (m)	Wave period (s											
	4	5	6	7	8	9	10	11	12	13	14	15
0.51	39.74	31.8	26.5	22.71	19.87	17.66	15.9	14.45	13.25	12.23	11.35	10.6
1	158.99	127.19	105.99	90.85	79.49	70.66	63.59	57.81	52.99	48.92	45.42	42.39
1.5	357.72	286.18	238.48	204.41	178.86	158.99	143.09	130.08	119.24	110.07	102.20	95.39

2	500	500	423.97	363.40	317.97	282.64	254.38	231.25	211.98	195.68	181.70	169.58
2.5	500	500	500	500	496.84	441.63	397.47	361.33	331.22	305.74	283.91	264.98
3	500	500	500	500	500	500	500	500	476.96	440.27	408.82	381.57
3.5	500	500	500	500	500	500	500	500	500	500	500	500
4	500	500	500	500	500	500	500	500	500	500	500	500

The audit on energy consumption of the port of Ancona give us specific information about the electrical and thermal consumption.

Capacity of the plant

50 floaters = **500 kW**

Potential energy generation

50 floaters x 13,400 kW each = **670,000 kWh/y**

Average electricity consumption for lighting system in the port of Ancona

2016 consumption: **1,800,000 kWh/y**[12]

Average electricity cost – port utility – street lighting

0.180 €/kWh13

Annual cost reduction

670,000 kWh x € 0.180 = **€ 120,600 /year**

Annual CO_2 emissions reduction

- 220 tons/year

[12] Data taken from AUTORITA' DI SISTEMA PORTUALE DEL MARE ADRIATICO CENTRALE, *Documento di Pianificazione Energetico Ambientale del Sistema Portuale*, December 2019.
[13] See previous footnote.

2.3. DESIGN OF THE PLANT

During our survey on site we were able to scan the area for the supposed location of the wave energy converters. In the following figures some results from the survey using the laser scanner.

Figure 25 - Resulting scans from the survey on site (onshore area of the Fincantieri shipyards)

The Eco Wave Power wave energy power stage is supposedly composed of 50 floaters attached to the wall (on the opposite side of the wall you see in Figure 25).

A rendering of the plant is in the following pictures:

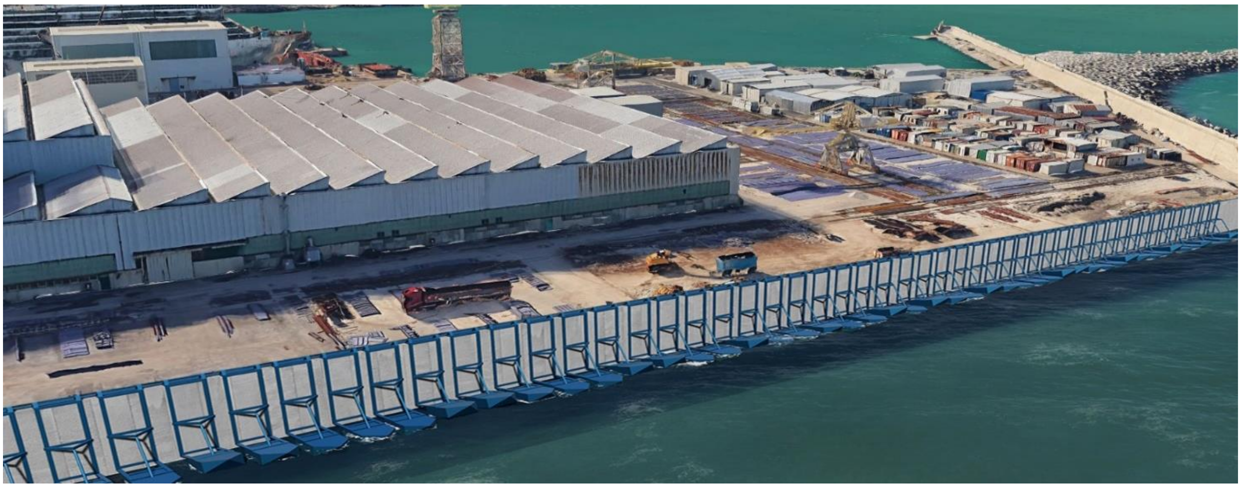


Figure 26 - Birds'eye view from the sea of the power plant

Figure 27 - View of the floaters from the north side


Figure 28 - View from the sea

It seems particularly important to design a specific installation structure for the power station, because it needs to fit into the selected location and guarantee security in operation and in defensive operation of the wall.

3. ECONOMIC PRE-FEASIBILITY

3.1. INVESTMENT COST

Investment costs for the installation of an onshore wave power station in the port of Ancona would have the figures in the following table. Please note that specific data are lacking because they are not available, so exclusions from the costs are listed in the following section 3.3.

TOTAL INVESTMENT COST: *Costs are supposed according to similar plants (fluids not included)*	€ 1,008,000*
Cost of 50 floaters	€ 503,000**
Cost of installation and structure for 50 floaters. Special painting and anti-corrosive manufacturing, 2x cranes x 30 days	€ 290,000
Project development – security on building site:	€ 65,000
Transformers, inverters, cabin:	€ 150,000***

3.2. OPERATION AND MAINTENANCE

Maintenance costs (per year) manufacturer declares that yearly maintenance costs is 10% of cost of floaters	€ 60,000****

3.3. RETURN ON INVESTMENT – PAYBACK PERIOD

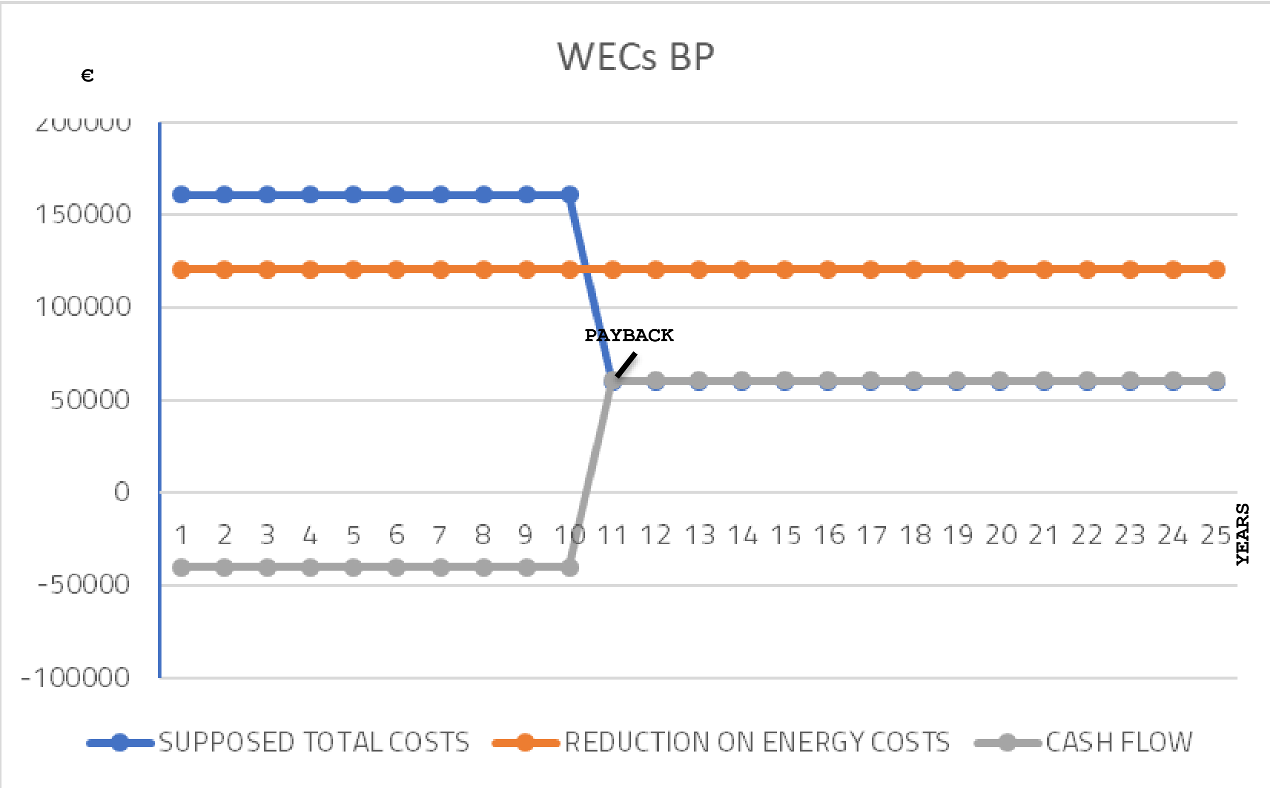
Life of Plant	25 years
Energy cost reduction (per year)	€ 120,600*****
Supposed average payback period	**11 years**

Excluded from costs evaluation:

*   investment at a 0% flat rate
**   hydraulic fluids
***   bureaucratic authorization, electrical wiring and connection to the national electricity grid
**** wave-recorder monitoring, operation cost and insurance cost
***** specific data on energy generation on the supposed site have to be assessed by monitoring with wave-recorder and sensors

3.4. BUSINESS PLAN

Here is a business plan with available data – please note exclusions as identified in the previous section. It is herewith calculated an investment over a 10 years period + maintenance costs over a 25 years period of life of plant. Earning actually come from cost reduction which could be calculated in € 120,600 per year, taking for granted an average cost of 0.18 €/kWh.



4. SOCIAL AND ENVIRONMENTAL IMPACT: LIFE CYCLE ASSESSMENT

4.1. SOCIAL, ENVIRONMENTAL AND ECONOMIC IMPACTS OF WAVE ENERGY PRODUCTION

Wave energy has many advantages compared to other renewable energies: it is reliable and its production is predictable, it has minor negative environmental impacts, it is cost-effective and its deployment potential and energy density are higher than solar and wind energy. Moreover, electricity power extraction from wave energy systems is continuous for 90% of the day, while the ratio for solar energy is usually 30% and wind energy is 20%[14]. Electricity generated by ocean energy (including wave and tidal energy) is expected to increase to 300 TWh of installed capacity by 2050, according to 2018 Ocean Energy Outlook published by the International Energy Agency[15].

Wave power generation is considered as having lowest greenhouse gas emission and most favourable social impacts. It is considered as one of the most sustainable renewable energy sources, followed by wind energy, hydropower, solar photovoltaic, and then geothermal. As these resources are considered as clean energy resources, they can be helpful for the mitigation of greenhouse effect and global warming effect.

Renewable energy sources can contribute to social and economic development and can help reduce the negative impacts of energy provision on human health and the environment. Wave energy might play a significant role in meeting energy requirements in an industrial level to reach sustainable development, because the installation of the supposed wave energy plant in the port of Ancona would generate a reduction in terms of energy costs, for instance for the lighting of the area in self-consumption mode. It is widely known that renewable energy helps social and economic development of regional areas because of local employment and job opportunities, reduction of external dependency and improvement of life standard. Community development can be achieved by the proper usage of wave energy systems.

[14] M. FADAEENEJAD et al., *New approaches in harnessing wave energy: With special attention to small islands*, 2014.
[15] Data taken from the website of the International Energy Agency https://www.iea.org/ - June, 16 2021.

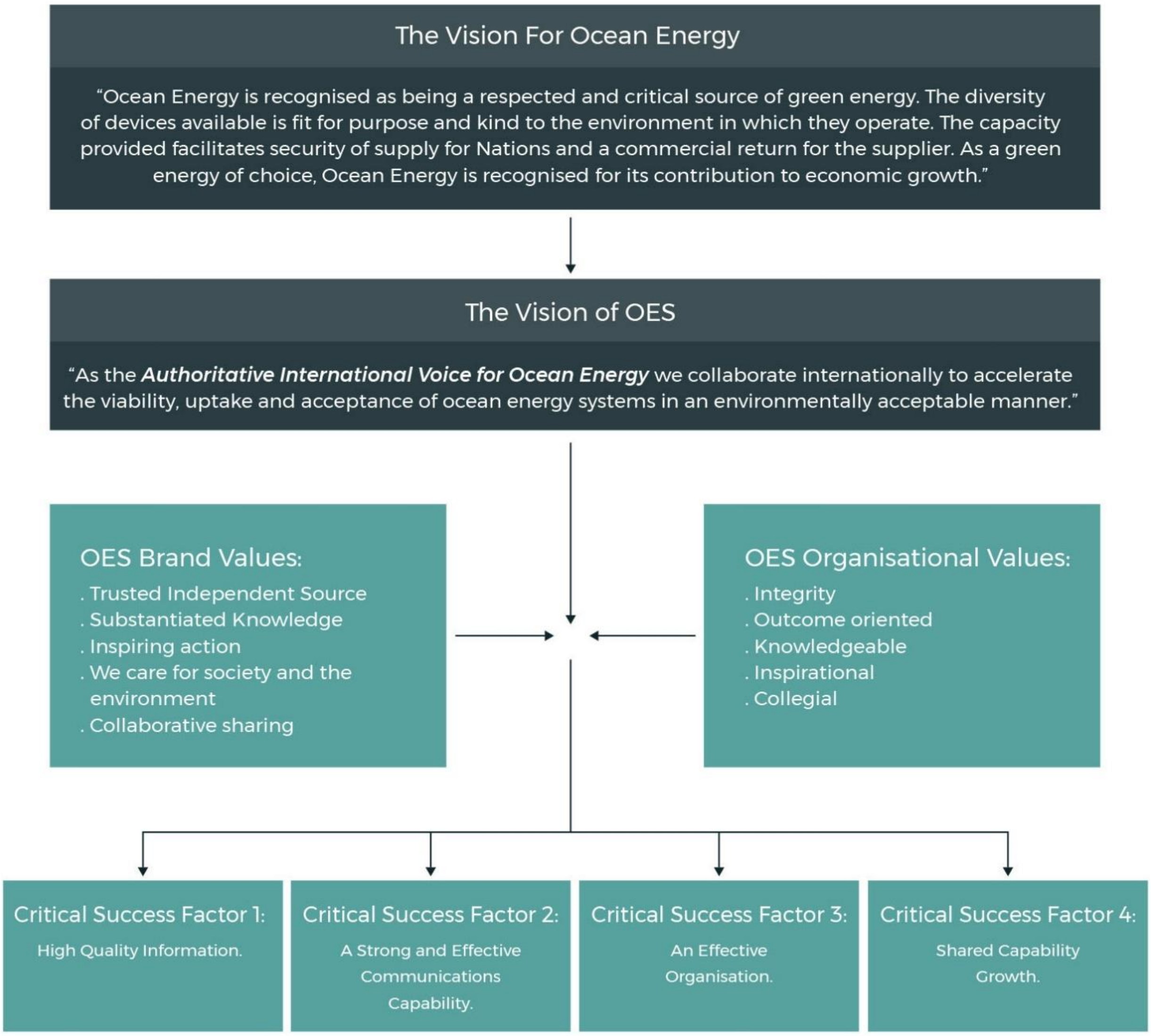


Figure 29 - Ocean Energy Technology critical success factors https://www.ocean-energy-systems.org/about-us/vision-mission-/

Wave energy power is enormous and more reliable than other renewable resources such as solar and wind energy because its density (2-3 kW/m^2) is greater than wind (0.4-0.6 kW/m^2) and the solar (0.1-0.2 kW/m^2)[16].

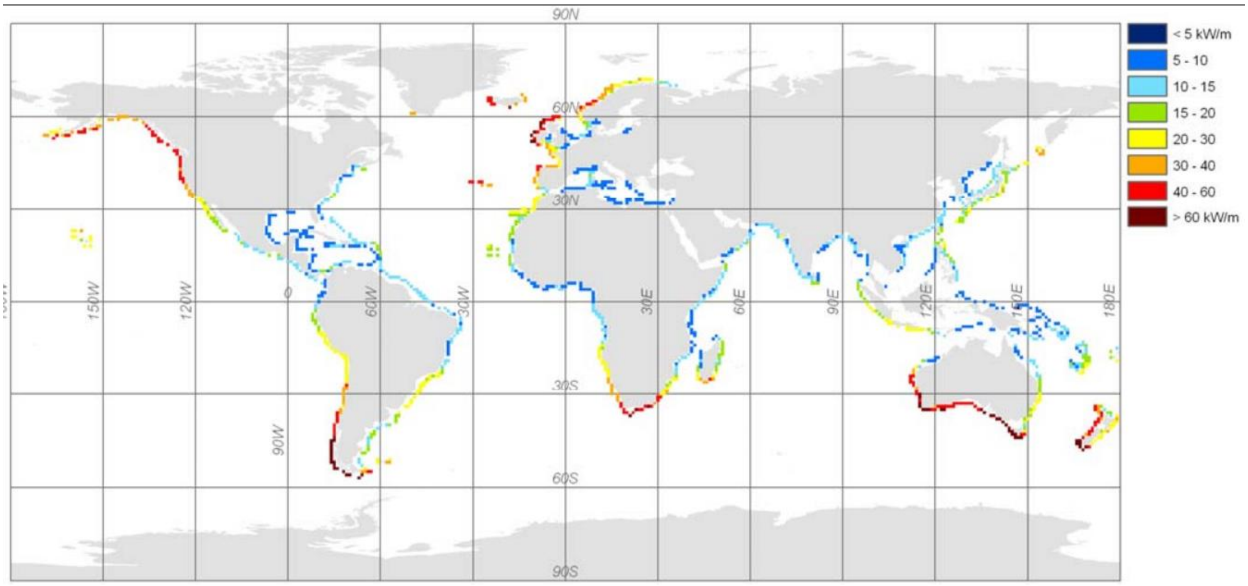


Figure 30 - Annual net wave power worldwide, map taken from GUNNAR MØRK et al., Assessing the global wave energy potential, 2010

Capital cost comparison with renewable energy sources[17]:

Energy source	Cost as primary source (100MW)	Cost as secondary source (1MW)
Coal plants	1,500-3,500	-
Fuel cells	-	5,000
Wind/solar	4,000	8,000
Wave	2,300	6,200

16 LOPEZANDREU, 2013, p. 414
17 Source from VINIGAND MUETZE, 2009

Wave energy is sustainable and clean, unlimited and environmentally friendly. In fact, it does not destroy favourable agricultural areas: in this pre-feasibility study we analyse the social and environmental impacts of on-shore wave energy systems, which are typically installed in areas that are not used for any other purpose, or – as is the case of the port of Ancona – areas that are used as protection from the sea waves.

Water is the most concentrated source of renewable energy on Earth, so wave energy has an unlimited potential. Since WECs are not widespread, its effects on habitats is not known exactly[18]. In order not to affect fishing and other uses of the sea, it is very important to choose carefully the installation site, and monitor WECs environmental effects in the five-year period after construction. On the other hand, it is widely recognised that all marine renewable energy devices represent a clear and significant resource, thus have potential to generate low carbon energy.

Wave energy applications have positive impacts on the tourism industry, because there is successful sustainable development and maintain high-quality environment. The chosen location to install the WECs in the Fincantieri shipyards area of the port of Ancona is actually not visible from tourists on mainland, not even from the uphill belvedere of the Ancona Cathedral. The floaters would be visible from the ships, though the landscape would not be worsened because the background is a shipyard with industrial facilities that are quite common for ports. WECs also have important and positive impacts on tourism, since the energy generation system is installed by the sea, and the agricultural areas will not be used for energy production. Moreover, because of deployment, operations, maintenance and decommissioning, wave energy would certainly be one of the most environmental-friendly electricity-generation technology[19].

Wave energy has positive and negative environmental impacts[20]:

Type of environmental impact	Rate of impact
Land use	Weak
Construction and maintenance	Weak
Coastal erosion	Weak or medium
Noise	Weak
Fish	weak

[18] S. AKAR, D. A. AKDOĞAN, *Environmental and Economic Impacts of Wave Energy: Some Public Policy Recommendations for Implementation in Turkey* (Ch. 13) in M. M. ERDOĞU et al., *Handbook of Research on Green Economic Development Initiatives and Strategies,* 2016

[19] BEDARD, 2007

[20] M. FADAEENEJAD et al., 2014

The social benefits of wave energy include:

- Providing a new, environmentally friendly and easily assimilated grid;
- Avoiding plague so many infrastructure projects;
- Reducing dependence on imported energy supplies and the risk of future fossil fuel price volatility;
- Reducing emissions of greenhouse gases;
- Promoting local job creation and economic development.

Subsequently, wave energy devices do not produce gases harmful to environment when they operate electricity production. Wave energy technology could help to reduce the emission of these gases.

Wave energy offers important economic opportunities. The minor investment by governments could stimulate the energy industry to increase economic output and employment. Furthermore, compared with wind and solar energy, wave energy is potentially more easily assimilated into the grid. Wave energy ensures substantial contribution to an affordable electricity price in the long run. A country's high dependence of fossil fuel imports leads to energy diversity.

Wave energy technology stimulates employment (especially, it ensures local job creation), economic development and output. Wave energy has a significant potential for positive economic impact and job creation. Wave energy's potential impact on fisheries and fish habitats are evaluated within the socioeconomic category. The closing of a wave energy area may enhance fishing activities. It may provide fish breeding and growing. Thus, this could have spillover impacts onto other areas. These devices may help recuperate ethnic regions.

Here's a summary of drivers and barriers related to wave energy[21]:

Driver	**Onshore**
Guaranteeing economically viable prices	S.P.D.
Guaranteeing security of supply	S.P.D.
Climate protection	S.P.D.
Enforced direct market support	S.P.D.
R&D spending	P.D.
Very high potentials worldwide	S.P.D.
Sea use competition	P.D. / S.I.
Aiming at conflict neutral technologies	P.D.
Increasing demand for local added value	P.D.
Potential for technology export from Europe	P.D.

[21] Source Sorensen and Naef, 2008. S.P.D. = strong pushing driver; P.D. = pushing driver; S.I.D. = strong inhibiting driver; I.D. = inhibiting driver; S.I. = small impact

Short-term objective of least costs of electricity	I.D.
Preferring non-intermittent electricity suppliers	P.D.
Advanced side applications and side products	S.P.D.
Restricted production capacities	S.I.D.
Development in perception and network building	P.D.

Energy production has positive and negative impacts that must be considered in the total energy cost. This issue is known in the literature as externalities. Renewable energy sources have had a minor environmental impact due to minor externalities. In order to determine energy costs, externalities should be internalized. Therefore, the positive and negative impacts of energy production must be determined. For instance, carbon emissions in wave energy are estimated at about 6 gCO_2/kWh, but the rate for conventional energy sources are about 250 gCO_2/kWh. Thus, decline of 244 gCO_2/kWh would be achieved by wave energy production. This should be included in the energy price of wave energy production. Furthermore, wave energy production supplies new jobs and these positive externalities should be considered separately.

Environmental externalities of energy production could be divided into two net costs categories[22]:

- Costs of the damage caused to health and environment by emissions of pollutants;
- Costs resulting from the impact of climate change. Thus, the argument of "polluter pays principle" would be to internalize as many of the externalities of energy generation in theory as possible.

When considering wave energy installation, it also should be discussed with stakeholders. Potential negative externalities could be avoided or minimized.

[22] OWEN, 2006

4.2. LIFE CYCLE ASSESSMENT

Very few studies have attempted to quantify the environmental impacts of a wave energy converter LCA. (Life Cycle Assessment) is a technique for evaluating the inputs, outputs and potential environmental impacts of products and services.

The typical process of a life cycle is illustrated in the following Figure, and it involves analysing resources use and pollutant emissions at each stage of the product or service life cycle, i.e. from extraction of raw materials, through manufacture and operation to decommissioning and disposal. This methodology allows to find identifiable consequences or "impact potentials"[23].

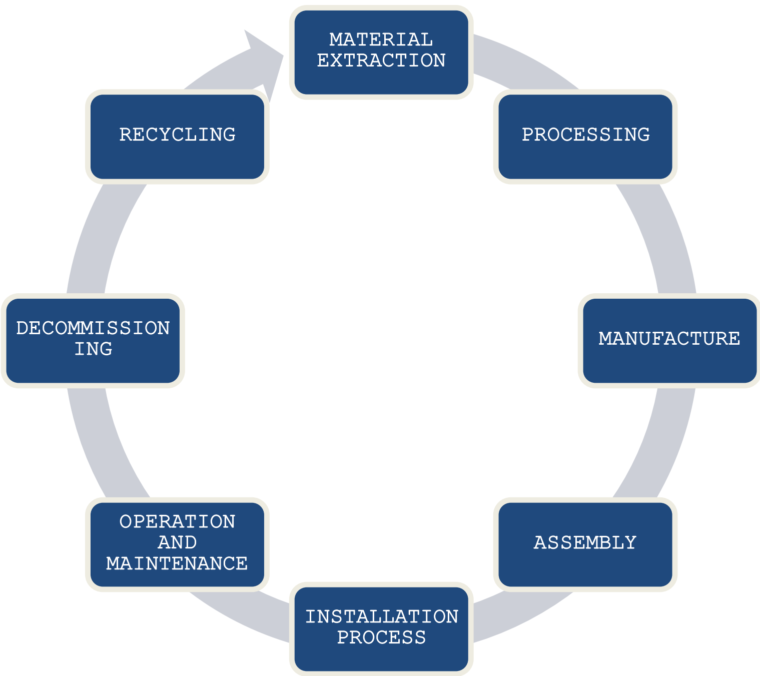


Figure 31 - Life Cycle of Eco Wave Power WECs

This pre-feasibility study is intended to expand earlier work produced by the University of Camerino to provide an assessment of the environmental, social and economic impacts of Eco Wave Power WEC. The analysis includes the floaters, the structure and the electrical components. The whole system is composed

[23] Life Cycle Assessment is governed by ISO 14040 series

by 50 WECs and each wave energy converter unit is 10 kWp of nominal power, power generation of the whole system is 670.000 kWh per year, considering a 20-year life of the system. It is herewith assumed that the main components of the system are manufactured in Israel, its installation would take place in the port of Ancona. In order to calculate the carbon payback, it is assumed that the electricity offset by the device will be the average of Italian national electricity grid, with a CO_2 intensity of 0.347 kg/kWh[24].

The Life Cycle Inventory involves detailing all resource use and pollutant emissions at each life cycle stage. Where data are not available, we have made justifiable assumptions. Typically for renewable energy projects, the most significant impacts take place during the manufacturing stage. The carbon dioxide and energy consumption for the life cycle stage of materials and manufacturing of the wave energy converters shall be higher compared to other stages, especially because the manufacturing materials request particular protection stages in order to prevent corrosion and a special painting / protection layer is requested. Together with assembly and installation processes, operation, operation, maintenance and disposal after decommissioning would have emissions close to 25 gCO_2/kWh and 300 kJ/kWh in energy consumption. These data have been calculated under comparison to other similar technologies, to the recycling ratio, to the fluids necessary for the energy generation process and the materials used for the installation on site of the WECs.

While wave energy sources are low-impact, energy is consumed and pollutants are emitted during the construction, operation and decommissioning of the wave energy converters. In order to identify the life cycle environmental impacts of WECs, we have carried out an analysis of research studies and published papers that could support the information we are delivering in this pre-feasibility study. Because of the importance of site of installation and specific design selection, we believe that it is necessary to collaborate with manufacturer in order to disclose several information that cannot be shared at the moment, because of 17 patented processes and because the company is going to turn into a public company in the near future.

[24] Data taken from ISPRAMBIENTE website:
https://www.isprambiente.gov.it/files2018/pubblicazioni/rapporti/R_283_18_NIR2018.pdf

CONCLUSIONS

With technological improvements, and – hopefully – public support for the early stage of development, the blue energy sector can develop a similar scale as offshore wind over time. Wave energy is in fact less developed than other technologies for harvesting energy from renewable sources. Since the cost of wave energy is competitive with other sources when it is used as a primary power source, it has the highest energy density, minor negative environmental impacts, it is predictable, and it satisfies electricity demand changes, it is suggested to enhance the use of this technology for the generation of clean energy in onshore locations, especially in the proximity of ports.

Wave energy does not create pollution in the stage of energy production. Operating and maintenance costs are very low, equal to 10% of the initial investment cost. In this pre-feasibility study, we have considered several advantages of this technology: it is a stable resource, it has low visual and acoustic impact and no fuel input or carbon emissions or price volatility. Moreover, wave energy may increase domestic energy supplies and it may help to reduce current account deficits.

The analysis on social impacts has also demonstrated that wave energy production creates new job areas. It may contribute to regional development and the tourism sector. The manufacturing, transportation, installation, operation and maintenance of wave energy facilities will generate revenue and employment. On the other side, there are some externalities to analyse: performance of WECs should be observed, input–output and cost benefit analysis should be done with real data and real figures, the adverse effects of WECs should be observed and assessed and local governments should promote partnership agreements with the wave energy industry.

The economic figures show how the payback period of a 50 floaters' wave energy power station is 11 years, so further analysis on a feasibility stage could be useful to check the information and understand how a wave energy converter could be useful to reduce energy costs for ports authorities.

Since specific data on the technology selected by the University of Camerino for this pre-feasibility are lacking because the manufacturer did not disclose those figures, we recommend monitoring and specific data gathering before any further development and feasibility study takes place in order to evaluate the project using real figures. Especially in the technical and economic pre-feasibility please consider that important information could not be included nor considered, even though they could possibly affect the resulting payback period in terms of cashflow and operation costs.