Scientific Report

concerning the implementation of the project

ROmanian MArine Renewable solutions - ROMAR

in the period January – December 2019

In the second stage of the project implementation (E2) carried out in the period above mentioned, the specific objectives of the project were considered for investigation, as follows:

2.1 – Establish the performance of individual WECs for the Black Sea (onshore, nearshore and offshore). Analyse the performances of an offshore wave farm (Act 2.1).
2.2 – Identify an optimal layout of WEC array for the Black Sea environment, in order to increase the energy output (Act 2.2).
2.3 – Prepare the inputs for the local SWAN simulations, by running the numerical model for the western part of the Black Sea (Act 2.3).
2.4 – Evaluate the impact of various wave energy converters onto the local wave field reported close to the Romanian environment (Act 2.4).
2.5 – Dissemination of the results.

2.1. Establish the performance of individual WECs for the Black Sea (onshore, nearshore and offshore).

The wave energy represents one of the most promising sources, capable to cover the energy demand from the coastal areas. It is well known that a significant percentage of the world population lives in such regions, being estimated that almost 44% reside within 150 km of the coastline. In 1799, was registered the first patent involving a Wave Energy Converter (WEC) and since then hundreds of concepts were developed. Almost 150 projects (concept or tested) are reported on a global scale, and from them, almost 50% are being implemented in Europe.

Compared to the offshore wind industry, the wave sector is still in an infancy stage, and several technical-economic aspects will need to be solved in order to become a competitive market. The EU strategy also aims to accelerate the development of this marine sector, being predicted that a successful project will report a Levelized Cost of Energy (LCOE) of 15ct€/kWh by 2030 which needs to be reduced to 10ct€/kWh by 2035.

The sites located between 30 and 60 degree latitude in both hemispheres reveal the best wave energy resources, especially the ones located on the western coasts of the continents and islands. We may expect average wave power flux of 50 kW/m close to southern regions of Australia, Africa or South America, while a lower value of 25 kW/m seems to define the northern coasts of Madagascar. As for the Black Sea, during the recent years, various studies were implemented, most of them being focused on the calibration of the wave models or on the characterisation of these resources from a meteorological point of view. Several studies focused on the hybrid/mixed wind-wave projects emerge, this type of project being considered more suitable for the enclosed seas.

Figure 1 presents the distribution of the reference sites, which were grouped around three reference lines, namely A (north), B (centre) and C (south). The relation between the distance from the shoreline and wave resources will be also investigated, by taking into account several distances (5 km, 15 km and 30 km). For the present work, the information provided by the ERA-Interim dataset with a spatial resolution of 0.75°×0.75° was processed, obtaining results for a 20-year time interval (from January 1998 to August 2017). The wave parameters considered for evaluation are the significant wave height (*Hs* in meters) and the wave period (*Te* in seconds).

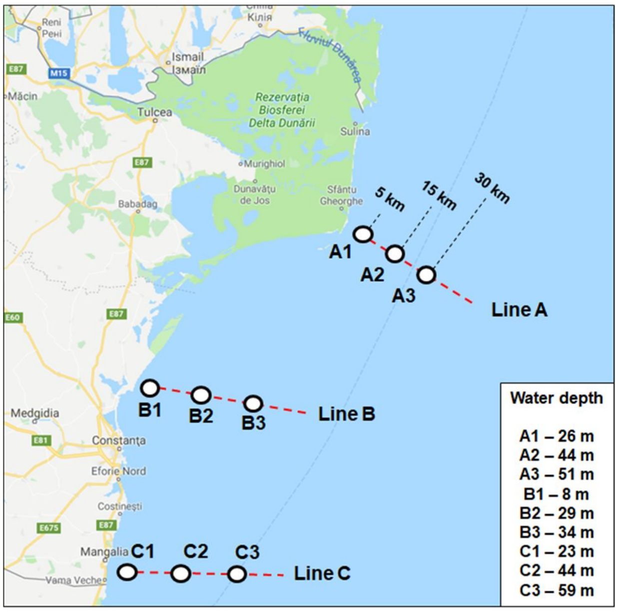


Figure 1. The target area and the reference sites considered for evaluation.

The wave energy flux (*Jwave* in W/m), of a particular site can be expressed as:

$$J_{wave} = \frac{\rho_{water} g^2}{64\pi} T_e H_s^2, \tag{1}$$

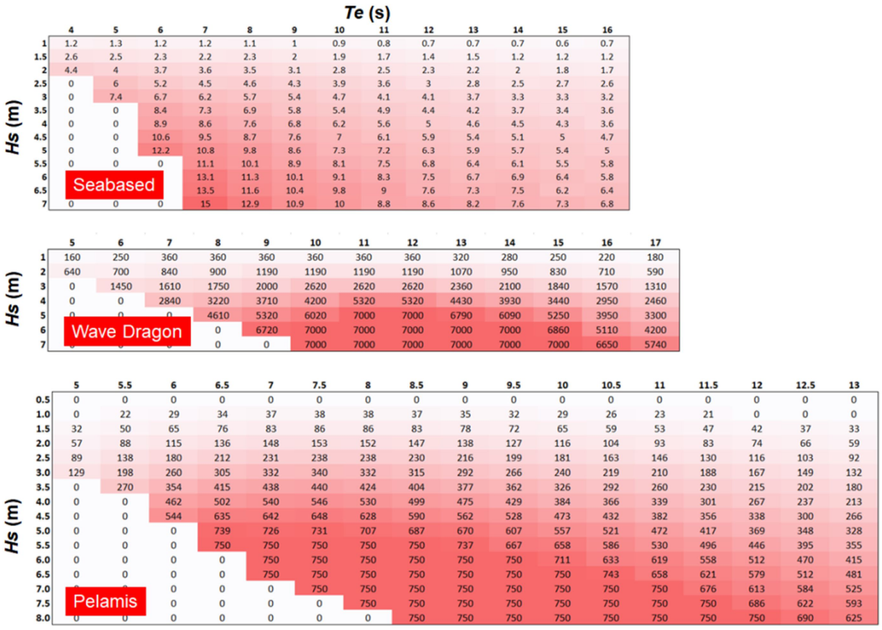
where ρ_{water} (kg/m^3) – seawater density and g (m/s) – gravitational acceleration.

The expected electric power output of a WEC generator can be determined by combining the bivariate distributions (*Hs* × *Te*) with the power matrix of each WEC, as follows:

$$P_E = \frac{1}{100} \cdot \sum_{i=1}^{n_T} \sum_{j=1}^{n_H} p_{ij} \cdot P_{ij}, \tag{2}$$

where p_{ij} is related to the energy percentage associated to the bin defined by the line i and column j, where as P_{ij} is the expected electric power output defined in the power matrix of each WEC for the same bin (defined by line i and column j).

For the present work, three WECs (Seabased, Pelamis and Wave Dragon) are considered, their power matrices being presented in Figure 2. By using these systems was possible to cover a full range of rated powers, which start from 15 kW and reaching a maximum of 7000 kW in the case of the Wave Dragon system. The wave energy exploitation has many difficulties and it is possible that some wave project will no longer be operational. This is the case of the Pelamis project, which for the moment is shut down due to some financial issues. Nevertheless, this system was used in the world's first commercial wave energy project located near Portugal.



Seabased

Hs (m) \ Te (s)	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.2	1.3	1.2	1.2	1.1	1	0.9	0.8	0.7	0.7	0.7	0.6	0.7
1.5	2.6	2.5	2.3	2.2	2.3	2	1.9	1.7	1.4	1.5	1.2	1.2	1.2
2	4.4	4	3.7	3.6	3.5	3.1	2.8	2.5	2.3	2.2	2	1.8	1.7
2.5	0	6	5.2	4.5	4.6	4.3	3.9	3.6	3	2.8	2.5	2.7	2.6
3	0	7.4	6.7	6.2	5.7	5.4	4.7	4.1	4.1	3.7	3.3	3.3	3.2
3.5	0	0	8.4	7.3	6.9	5.8	5.4	4.9	4.4	4.2	3.7	3.4	3.6
4	0	0	8.9	8.6	7.6	6.8	6.2	5.6	5	4.6	4.5	4.3	3.6
4.5	0	0	10.6	9.5	8.7	7.6	7	6.1	5.9	5.4	5.1	5	4.7
5	0	0	12.2	10.8	9.8	8.6	7.3	7.2	6.3	5.9	5.7	5.4	5
5.5	0	0	0	11.1	10.1	8.9	8.1	7.5	6.8	6.4	6.1	5.5	5.8
6	[illegible]	[illegible]	[illegible]	13.1	11.3	10.1	9.1	8.3	7.5	6.7	6.9	6.4	5.8
6.5	[illegible]	[illegible]	[illegible]	13.5	11.6	10.4	9.8	9	7.6	7.3	7.5	6.2	6.4
7	0	0	0	15	12.9	10.9	10	8.8	8.6	8.2	7.6	7.3	6.8

Wave Dragon

Hs (m) \ Te (s)	5	6	7	8	9	10	11	12	13	14	15	16	17
1	160	250	360	360	360	360	360	360	320	280	250	220	180
2	640	700	840	900	1190	1190	1190	1190	1070	950	830	710	590
3	0	1450	1610	1750	2000	2620	2620	2620	2360	2100	1840	1570	1310
4	0	0	2840	3220	3710	4200	5320	5320	4430	3930	3440	2950	2460
5	0	0	0	4610	5320	6020	7000	7000	6790	6090	5250	3950	3300
6	[illegible]	[illegible]	[illegible]	0	6720	7000	7000	7000	7000	7000	6860	5110	4200
7	0	0	0	0	0	7000	7000	7000	7000	7000	7000	6650	5740

Pelamis

Hs (m) \ Te (s)	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13
0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.0	0	22	29	34	37	38	38	37	35	32	29	26	23	21	0	0	0
1.5	32	50	65	76	83	86	86	83	78	72	65	59	53	47	42	37	33
2.0	57	88	115	136	148	153	152	147	138	127	116	104	93	83	74	66	59
2.5	89	138	180	212	231	238	238	230	216	199	181	163	146	130	116	103	92
3.0	129	198	260	305	332	340	332	315	292	266	240	219	210	188	167	149	132
3.5	0	270	354	415	438	440	424	404	377	362	326	292	260	230	215	202	180
4.0	0	0	462	502	540	546	530	499	475	429	384	366	339	301	267	237	213
4.5	0	0	544	635	642	648	628	590	562	528	473	432	382	356	338	300	266
5.0	0	0	0	739	726	731	707	687	670	607	557	521	472	417	369	348	328
5.5	0	0	0	750	750	750	750	750	737	667	658	586	530	496	446	395	355
6.0	0	0	0	0	750	750	750	750	750	750	711	633	619	558	512	470	415
6.5	0	0	0	0	750	750	750	750	750	750	750	743	658	621	579	512	481
7.0	[illegible]	[illegible]	0	0	0	750	750	750	750	750	750	750	750	676	613	584	525
7.5	[illegible]	[illegible]	0	0	0	0	750	750	750	750	750	750	750	750	686	622	593
8.0	0	0	0	0	0	0	0	750	750	750	750	750	750	750	750	690	625

Figure 2. Power matrices of the considered wave generators, which include Seabased – 15 kW (rated power), Pelamis – 750 kW and Wave Dragon – 7000 kW.

One way to assess the reliability of a particular system is to evaluate the capacity factor (C_f), which is defined as:

$$C_f = \frac{P_E}{R_P}, \tag{3}$$

P_E is the electric power expected to be generated by each system, and R_P represents the rated power of each system according to the values presented in Figure 2.

A detailed evaluation of the wave resources (indicated in kW/m) is presented in Figure 3, where was also included the winter season (from October to March). For this target area, a maximum value of 4.3 kW/m is reported for the C-sites during winter, while a 2.8 kW/m is representative for the total distribution. In general, the variations reported during the winter and total time are very small and, therefore, only the total values were indicated (in percentages). The variations reported for the A-sites seem to be more important, reaching a maximum of 378% (A3 reported to A1). By looking on these results we can notice that the site A1 seems to be least suitable for a wave project, reporting values of 0.09 kW/m and 0.14 kW/m during the total and winter time interval. For the rest of the sites, the wave power may vary with a maximum of 7.7% for the B-sites, while a 3.3% is expected along the C line.

Going to the wave energy converters, in Figure 4 are presented the performances of the Seabased generator that may operate in the Romanian area. By looking on these values, we may exclude the A-sites since the power output will be insignificant (close to zero). During the winter season, we may expect a maximum of 0.68 kW close to B3, which represents an increase with 6.51% compared to the site B1 (reported to winter value). For the C-sites, the reported values do not exceed 1 kW, being reported a maximum variation of 5.04% for the site C3.

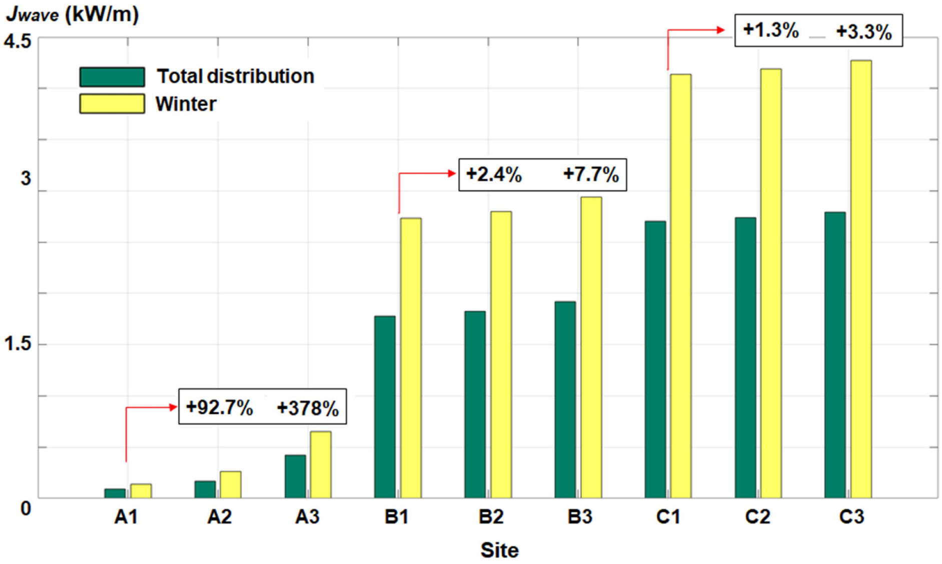


Figure 3. Distribution of the wave energy flux (average values) reported for the total distribution and winter season. The percentage represents the variations of the values reported to the sites located at 5 km from shore (A1, B1 and C1).

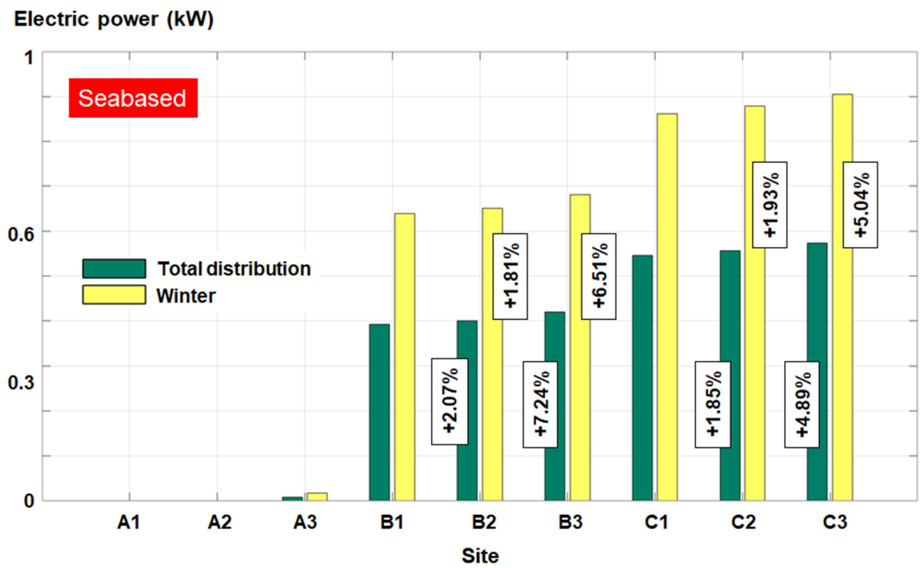


Figure 4. Power output and variations expected from the Seabased wave generator.

A more detailed evaluation of the WEC performances is presented in Figure 5, where the power variation is assessed on a monthly level. In general, more significant variations are being reported during the summer time and some important values can be found during November. For the Seabased system, a maximum variation of 14% may be expected in May for the site B3, while a 6.86% and 8.26% are reported by the site C3 in June and November, respectively.

For the Pelamis generator, the months May and August seem to be more dynamic in the case of B3, a similar pattern being observed in the case of C3 for June. It is important to mention that, for this system are reported negative values (or close to zero). Negative values are also noticed in the case of Wave Dragon, a minimum of 1.93% being accounted for C3.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Seabased	B2	1.707	2.373	1.894	1.063	5.249	1.431	2.859	5.512	2.627	1.773	1.088	1.654
	B3	6.527	6.09	8.187	8.292	14.06	8.854	10.71	11.1	6.986	5.382	5.567	5.169
	C2	1.928	2.339	1.934	0.6085	3.609	1.33	2.557	0.9701	1.763	0.7542	2.67	1.784
	C3	5.067	4.48	4.823	4.835	4.622	8.269	4.805	1.081	4.228	3.611	6.86	4.388
Pelamis	B2	4.488	4.275	4.951	4.168	16.94	0	12.64	15.34	8.191	3.642	6.425	4.746
	B3	13.75	13.71	14.76	15.05	31.9	12.21	23.24	32.53	18.99	13.14	18.9	14.87
	C2	1.861	1.156	0.436	-0.06	-2.042	5.231	1.231	2.141	1.282	0.3035	2.238	0.9771
	C3	4.389	1.79	1.51	0.832	-2.665	15.14	3.043	2.558	2.7	1.989	6.721	2.585
Wave Dragon	B2	4.591	7.051	6.527	6.31	25.75	3.69	5.768	18.88	13.82	5.365	9.587	5.77
	B3	12.8	13.68	14.94	13.15	32.34	31.38	16.97	30.51	20.28	13.67	17.89	15
	C2	1.606	1.611	0.846	-1.046	0.5747	1.174	1.019	0.7499	0.6258	-0.1946	1.782	0.7905
	C3	3.708	2.553	2.938	0.08165	-1.936	5.771	1.712	-0.4913	1.909	0.8662	6.214	0.9862

Figure 5. Monthly variations of the power output considering as a reference the sites located at a 5 km distance from the shore (A1, B1 and C1).

2.2 - Identify an optimal layout of WEC array for the Black Sea environment, in order to increase the energy output

Taking into account that at this moment there is interest to develop mixed wind-wave projects, probably that a project like this will represent a starting point. Figure 6 present the layout of wind-wave farm located near the Sardinia Island. The scenarios were built by taking as a core the structure of an offshore wind farm, more precisely the Kentish Flats project, which includes thirty Vestas V90-3.0 generators. The distance between the turbines in the gird is close to 0.7 km (along x and y directions), this being close to eight rotor diameters.

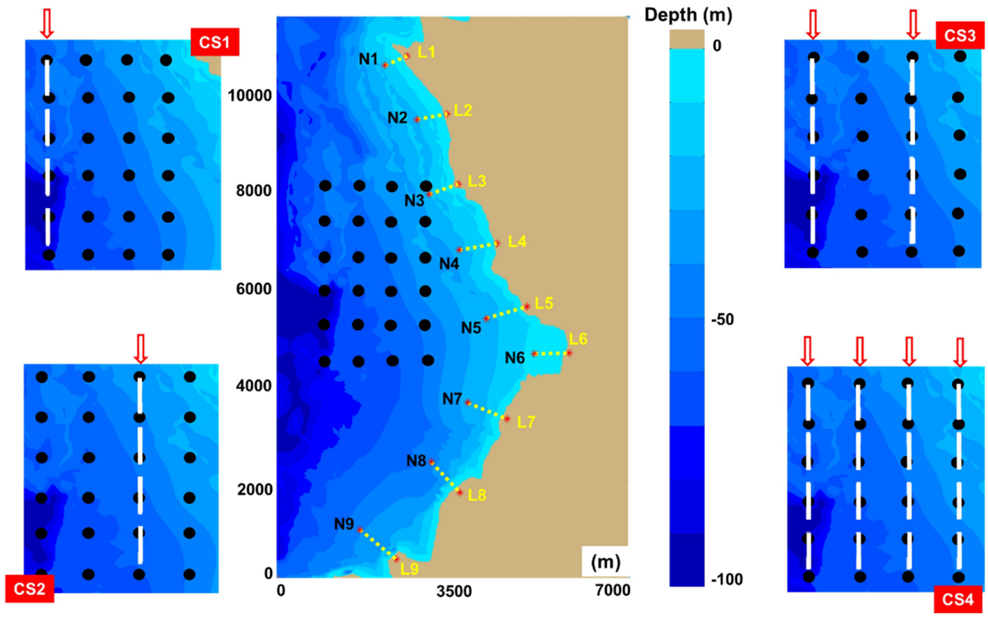


Figure 6. Computational domain of the target area (bathymetric map), including the wind farm configuration, the main scenarios (CS1, CS2, CS3 and CS4).

Nevertheless, for the present work only 24 systems were considered (6 × 4 turbines), in order to fit in the computational domain. Several scenarios were defined, each involving at least one generic wave farm defined by a 25% absorption characteristic. This means that 75% of the incoming waves will not be affected by these obstacles.

2.3 - Prepare the inputs for the local SWAN simulations, by running the numerical model for the western part of the Black Sea

The wind data used in the present section are produced by the U.S. National Centers for Environmental Prediction-Climate Forecast System Reanalysis (further denoted with NCEP), and cover a 30-year time interval (1987-2016). In this case, a dataset that is defined by a spatial resolution of 0.32 degree was processed, for which eight values per day were extracted for a 3-hour time step (0-3-6-9-12-15-18-21 UTC). These wind fields are defined by a reference height of 10 m, and therefore the wind speed will be indicated as *U*10.

Regarding the wave conditions, these info were obtained after the implementation of the SWAN (Simulating WAves Nearshore) wave model in the Black Sea basin. The simulations were carried out by using as input the NCEP wind fields, and therefore the obtained wave data cover the same interval (1987-2016) with the following characteristics: resolution = 0.08° and eight data per day.

Figure 7 provides a first perspective of the *Hs* distribution, by taking into account only the wave heights reported above 1 m and 2.5 m, respectively. As expected, the central part of the sea is defined by much higher values, this geographical environment is defined by two distinct areas, located in the west and east.

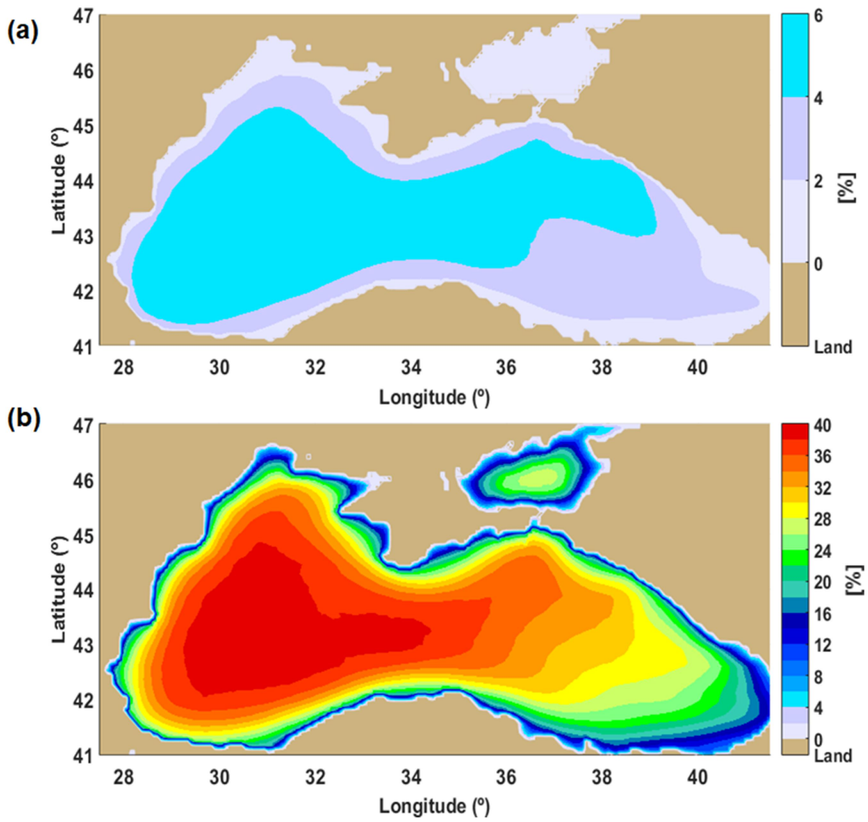


Figure 7. The spatial distribution of the significant wave height (*Hs*), as resulted from the 30-year SWAN simulations (1987-2016). Results reported for: (a) *Hs* > 2.5 m (in %); (b) *Hs* > 1m (in %).

The conditions reported in the western part are significantly much higher, this aspect being more visible in the case of the Hs values located above 1 m/s, for which a maximum of 40% is reported. These value decrease in the vicinity of the coastline, being expected a distribution in the range of 20% and 28% for the western regions, while in the east the values can go up to 24%. A much smoother distribution is reported for the 2.5 m threshold, were the values located between 4% and 6% are dominant in west, compared to the interval 0% and 2% that may be expected in east.

A more detailed assessment of the wave conditions is provided in Figure 8, considering this time the seasonal distribution of the *Hs* values located above 1 m. Four main seasons were considered, as follows: a) winter – December/January/February; b) spring – March/April/May; c) summer – June/July/August; d) autumn – September/October/November. During the winter time, the maritime activities will be limited in almost 60% of the time (offshore areas), being expected a minimum of 30% in the case of the coastal areas from the south–east. More energetic conditions can also occur during autumn, when the western part of the Black Sea report adverse weather windows in the range of 28% and 44%. The best season to initiate a project is during summer, when it is possible to have no adverse windows, especially in the case of the regions located close to the Turkish coastline (in the south–west).

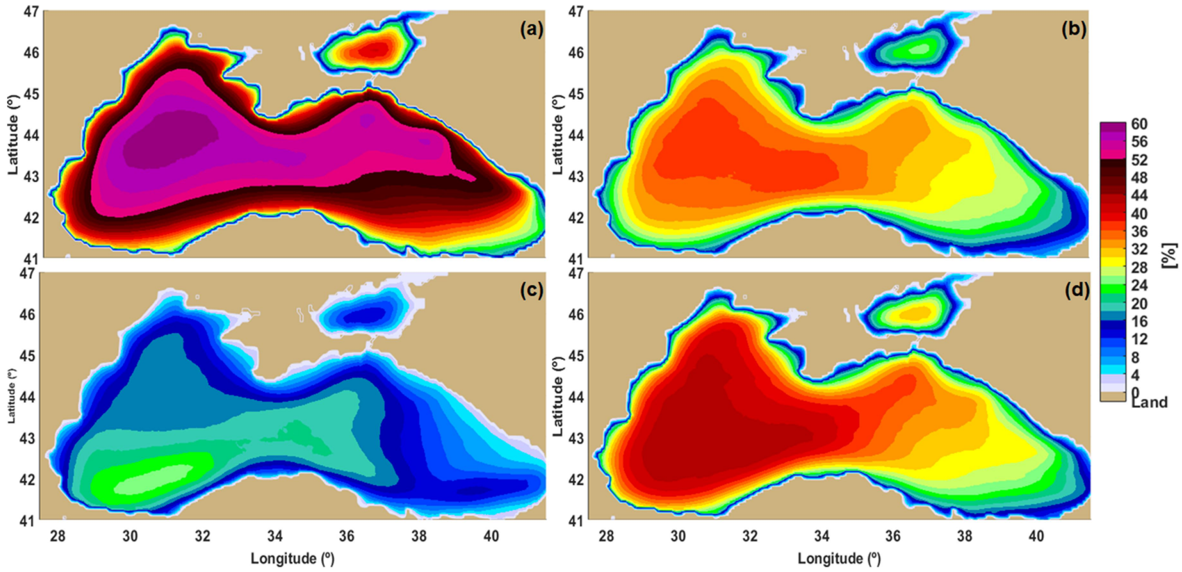


Figure 8. Seasonal distribution of the *Hs* parameter higher than 1 m considering the entire 30-year SWAN simulations (1987-2016), where: (a) winter; (b) spring; (c) summer; (d) autumn.

Going to more extreme conditions, in Figure 9 is presented the seasonal distribution by using as a reference a *Hs* value of 2.5 m. During the spring and summer, there is almost no restriction from this point of view, especially in the case of the coastal areas.

These values decrease in the case of the autumn season, with a restriction of 8% in the south-western areas, while in the vicinity of the shoreline a maximum limitation of 4% may be noticed. In the case of the winter season, two hot-spots (south-west and north-east) of 14% are more visible, with the mention that in the Azov Sea the weather conditions will have no influence on the maritime operations.

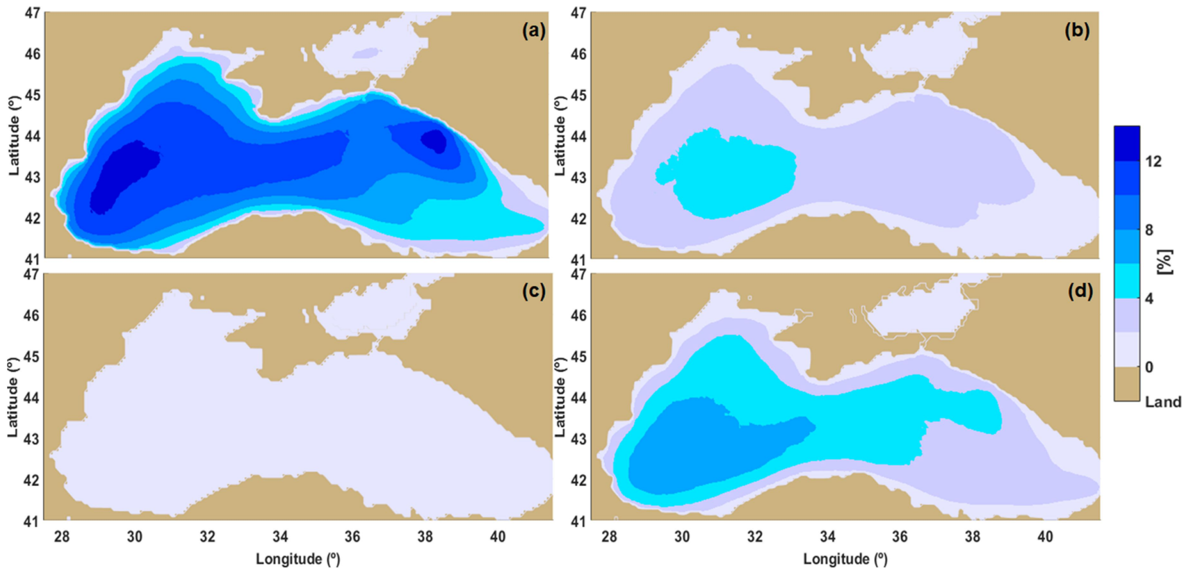


Figure 9. Seasonal distribution of the *Hs* parameter higher than 2.5 m considering the entire 30-year SWAN simulations (1987-2016), where: (a) winter; (b) spring; (c) summer; (d) autumn.

2.4 - Evaluate the impact of various wave energy converters onto the local wave field reported close to the Romanian environment

Figure 10 is designed to illustrate the evolution of the wave conditions from the Saint George sector (Danube Delta, Black Sea), by taking into account a generic wave farm and an extreme event.

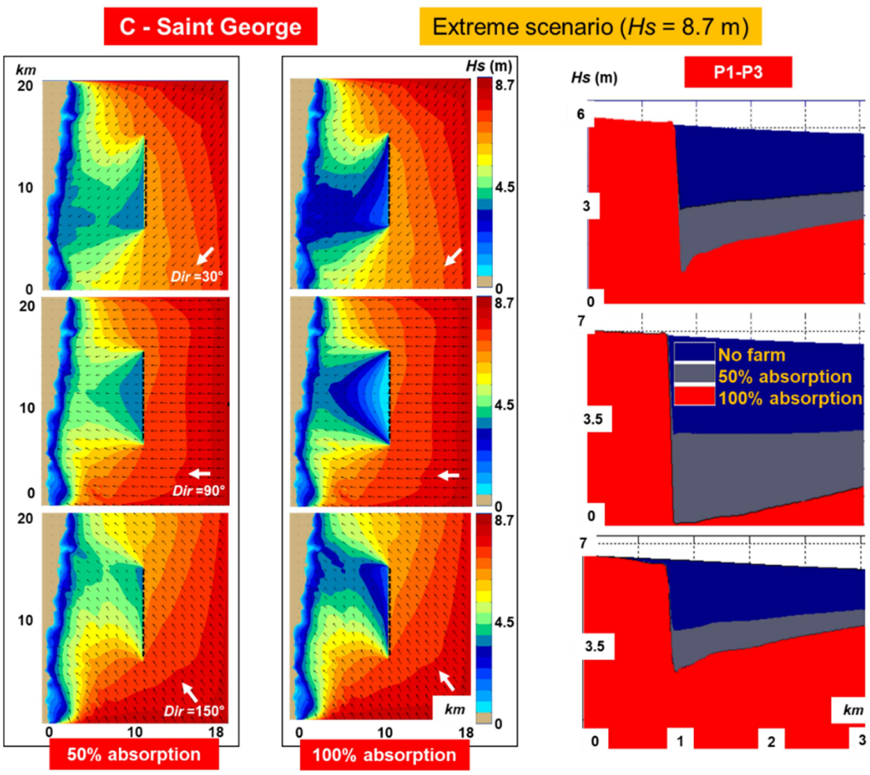


Figure 10. Saint George case study (generic wave energy farm) – variation of the significant wave height and wave direction corresponding to an extreme event and considering various scenarios (wave directions and absorption values).

Close to the point P1 (central part), an *Hs* value of 6 m is reported. At contact with the WEC line, the *Hs* value can decrease up to 3 m for the T2 scenario (50% absorption) or to a minimum of 1.2 m if we discuss about T4 scenario. As expected, the sheltering effect is visible in the area located between shoreline and wave farm as it relates to the direction of the wave conditions. For example, in the case of the waves related to the eastern sector, the waves can decrease up to 3.5 m on the contact with the farm in the case of T2 scenario, or to 0.4 m for the T4 scenario (100% absorption). From the analysis of the wave profiles defined between the points P1 and P3, we can notice that the waves are starting to regenerate as they pass the WEC line.

Going from offshore to nearshore, Figure 11 presents the variations (in %) of the *Hs* and *Dir* parameters as they are reflected by the NP-points. The positive values indicate an attenuation of the conditions, while the negative ones reflect the opposite. From the analysis of the *Hs* values we can notice that the best coastal protection provided by a configuration (WEC line parallel to the shoreline) may be expected in the case of the waves coming from north-east (10.06% - NP4/T4 scenario), while for waves coming from the south-east a maximum of 4.35% may be expected near the sites NP2 and NP3, respectively. The efficiency of the farm gradually increases as we adjust the absorption property from T1 to T4, with a small increase of the *Hs* parameter (NP1 and NP2 – waves from east) being expected in some cases.

C - Saint George

Hs variations; waves from north-east

Absorption	NP1	NP2	NP3	NP4	NP5	NP6	NP7
T1	0	0.46	2.06	1.83	0.7	0.07	0.05
T2	0	0.8	4.17	4.48	2.17	0.07	0.05
T3	0	1.06	5.97	8.07	4.66	0	0
T4	0	1.14	6.76	10.06	6.21	0	0

Hs variations; waves from east

Absorption	NP1	NP2	NP3	NP4	NP5	NP6	NP7
T1	-0.07	-0.53	0.04	0.16	0.23	0	0.05
T2	-0.14	-1.11	0.61	0.95	0.69	0	0.05
T3	-0.17	-0.08	3.25	2.88	1.24	0	0.05
T4	-0.14	1.19	5.35	4.25	1.47	0	0.05

Hs variations; waves from south-east

Absorption	NP1	NP2	NP3	NP4	NP5	NP6	NP7
T1	0.04	0.89	0.95	0.71	0.12	0	0
T2	0.04	2.11	2.23	1.45	0.2	0	0
T3	0	3.51	3.66	1.99	0.24	0	0
T4	0	4.27	4.35	2.19	0.27	0	0

Dir variations; waves from east

Absorption	NP1	NP2	NP3	NP4	NP5	NP6	NP7
T1	0.79	0.7	0.12	-0.56	-0.14	-0.18	-0.04
T2	1.59	2.78	1.33	-1.48	-0.66	-0.36	-0.07
T3	2.23	6.91	4.79	-3.02	-1.51	-0.51	-0.1
T4	2.41	9.39	6.96	-4.05	-2.04	-0.58	-0.1

Reference points

* T1=25% absorption; T2=50% absorption; T3=75% absorption; T4=100% absorption

Figure 11. Saint George case study (generic marine farm) – variation of the wave conditions (in %) corresponding to the NP-points under different scenarios. The results are reported to the no farm situation and include *Hs* and *Dir* parameters.

From the analysis of the *Dir* parameter (right down panel) reported for the waves coming from east (90^{o}), two main patterns can be observed. The group points NP1-NP3 report an attenuation of the values by a maximum 9.4% while for the points NP4-NP7 it is possible to notice an increase of the attenuation by a maximum of 4%. Nevertheless, these variations gradually attenuate as we move from the centre to the extremity of the target area.

2.5 Dissemination of the results.

Publications in international journals (2)

1. **Onea F**, Rusu L, 2019. *Long-term analysis of the Black Sea weather windows.* J. Mar. Sci. Eng. 2019, 7, 303, (WOS:000487981700023, IF=1.732). https://www.mdpi.com/2077-1312/7/9/303

2. **Onea F**, Rusu L, 2019. *A study on the wind energy potential in the Romanian coastal environment*. J. Mar. Sci. Eng. 2019, 7, 142, (WOS:000470965000022, IF=1.732). https://www.mdpi.com/2077-1312/7/5/142

Participation in international conferences (5)

1. **Onea F**, Rusu L, 2019. *An overview of the Black Sea weather downtime*. IISES International Academic Conference, September 23-26, 2019 Barcelona, Spain. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=2ahUKEwiQnLjmyOnlAhUB6aQKHWyOCRAQFjAAegQIAxAC&url=https%3A%2F%2Fwww.iises.net%2Fproceedings%2Finternational-academic-conference-barcelona%2Ftable-of-content%3Fcid%3D99%26iid%3D049%26rid%3D12126&usg=AOvVaw018Du9F_xPlw6lHZmcLNDC

2. **Onea F**, Rusu L, 2019. *Assessment of the Romanian onshore and offshore wind energy potential*. 2nd International Conference on Renewable Energy and Environment Engineering (REEE 2019), August 19-22, 2019 Munich, Germany. https://doi.org/10.1051/e3sconf/201912201003

3. Hobjila A, **Onea F**, Rusu L, 2019. Assessment of the weather windows availability related to the Black Sea maritime operations. CSSD-UDJG 2019, 13-14 June 2019, Galati, Romania. http://www.cssd-udjg.ugal.ro/index.php/abstracts-2019

4. **Onea F**, Rusu L, 2019. *Offshore wind energy and the Romanian energy future*. 4th International Conference on Advances on Clean Energy Research (ICACER 2019), April 5-7, 2019 Coimbra, Portugal https://doi.org/10.1051/e3sconf/201910301004

5. **Onea F**, Rusu L, 2019. *Wave power variation near the Romanian coastal waters*. 4th International Conference on Advances on Clean Energy Research (ICACER 2019), April 5-7, 2019 Coimbra, Portugal https://doi.org/10.1051/e3sconf/201910301006

Training schools and annual assembly (2)

1. 1st WECANet Training Course on Wave Energy from 18-22 March 2019 in Varna, Bulgaria https://www.researchgate.net/profile/Florin_Onea/project/ROmanian-MArine-Renewable-solutions-ROMAR/attachment/5cb8083e3843b01b9b9ad514/AS:748906392608769@1555564606778/download/Onea_Course+certificate.pdf?context=ProjectUpdatesLog

2. 1st WECANet Annual Assembly from 11-12 February 2019 in Thessaloniki, Greece https://www.wecanet.eu/meeting-thessaloniki

*****At the ICACER conference (paper 5), the author received the Best presentation award https://www.researchgate.net/project/ROmanian-MArine-Renewable-solutions-ROMAR

2.6 Conclusions

By looking on the expected results proposed for this stage of the project (2 ISI articles; 5 conferences), we can notice that the author fully completed his objectives. In addition to this it is important to mention that the author was already completed a workshop focused on the wave energy, this activity being planned to be carried out in final stage of the project (stage 3). By looking on the obtained results until now, we can notice that a significant part of the research is devoted to the offshore wind studies taking into account that at this moment there is interest to implement such projects in semi-enclosed basins.

For the next stage of the project, we expect to finish the studies focused on the coastal protection, to cover the remaining objectives (1 ISI article and 1 international conference) and to close the present project (deadline: 30.04.2020).

<u>Budget (2019) 124.890,00 lei (approx. 26.180 EUR)</u>

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21 November 2019

Project Director
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