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ROMANIA'S OFFSHORE WIND ENERGY RESOURCES

Natural potential, regulatory framework, and development prospects

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Romania's Offshore Wind Energy Resources:

Natural potential, regulatory framework, and development prospects

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Executive summary

Offshore wind power is regarded as a likely pillar in reaching net-zero greenhouse gas (GHG) emission by 2050, as envisioned by the European Green Deal. Europe is home to some of the world's most significant offshore wind resources. Better tapping into this potential will be addressed in the Commission's upcoming 2020 Offshore Wind Strategy, expected to bolster a rapid expansion of offshore wind on the continent, from the current 20 GW installed capacity to 450 GW by 2050. Offshore wind generation can offer numerous advantages: high full-load hours, high operating hours, rather low variability and, consequently, greater predictability and lower forecast errors, as well as lower balancing power needs compared to onshore wind and solar PV.

The present study assesses the natural and technical potential of Romania's offshore wind sector, finding an estimated total potential natural capacity of **94 GW**, out of which **22 GW** could be installed as fixed turbines, leading to a total Annual Energy Production (AEP) of **239 TWh**, with 54,4 TWh from fixed turbines. The data analysed in this report show that wind speeds increase with the distance to the shore, with only the central part of the deep-water sector having more sizeable mean wind speeds (close to 7 m/s). A large part of Romania's Exclusive Economic Zone (EEZ) consists of a deep-water area (>50 m) that is more suitable for floating platforms. Nonetheless, several offshore wind farms in Europe have been recently built at about 60 km from shore, a distance that is just within the Romanian transition area from shallow to deep water.

The study identifies **two potential clusters** with most favourable conditions for a first stage of offshore wind development, based on fixed turbines: one with capacity factors between 33-35%, in water depths below 50 m at 40-60 km from the shore – an area that strikes the right balance between wind resources and costs of the required offshore network, given the possibility to inject the output in the Constanța Sud electrical substation and the proximity to the Port of Constanța. The other area presents marginally better wind resources, but the existing onshore power transmission line is further inland and the connection grid would have to be extended through the Danube Delta, which is a protected area.

To develop its wind potential in the Black Sea, Romania needs to address a number of key issues, the most significant being overcoming **grid challenges**. Any new offshore wind farm developed in Romanian waters will have to be connected to the grid in Dobrogea, where a large part of the country's power generation assets are already located and additional renewables are planned to be developed, alongside two new nuclear units at Cernavodă, to the effect of almost doubling the installed capacity in an area with quite limited local energy demand. A separate issue is the offshore grid connections. As project size and distance from shore increase, higher voltage lines are used to minimize electrical losses. Large projects built farther away from shore may use a connection for high voltage direct current (HVDC), leading to higher up-front costs.

To avoid unnecessary spending and optimise offshore infrastructure costs, advanced coordinated planning is paramount, starting with the phase of maritime spatial planning. The government should prepare, with close and early involvement of the relevant stakeholders, the national Maritime Spatial Plan (MSP), as required under the MSP Directive. The MSP is critically important in advancing state interests and lowering the risk of conflict between potential activities and policy priorities: shipping, military zones, fishing, environmental and biodiversity impact, archaeological sites, as well as other facilities and economic activities.

Collaboration and investment by wind farm developers must be encouraged with the purpose of facilitating timely construction and maximising common utilisation of offshore connections.

The offshore wind electricity production will have beneficial effects for the Romanian **power markets**. The energy system would benefit from a more constant power output and increased forecast accuracy, which reduces costs related to power management and balancing. Then, less volatile electricity production increases the offshore producers' odds to compete on futures markets, with medium and long-term delivery products, which have lower commercial risk than the products offered by their onshore peers. Assuming increased interconnectivity of the regional market, the additional clean electricity will limit the room for fossil fuel-based generators on the spot markets.

Development of offshore wind farms should also be planned to facilitate an accelerated decarbonisation of key sectors such as transport and industry, either through direct electrification using renewable energy, or through the use of **hydrogen**. Creating demand for clean hydrogen will also help ease the difficulties of evacuating the electricity produced by offshore wind farms out of the Dobrogea region. If Romania makes efficient use of the available EU financial instruments for clean energy development, it is well positioned to become a premier producer of clean hydrogen in Southeast Europe and can develop into a regional exporter. The Dobrogea region, in particular, has all the prerequisites for hosting a hub of hydrogen development, as it has both exceptional prospects to produce clean hydrogen by means of onshore and offshore renewable sources, and potential for significant local demand from refineries and steel making industry, district heating, decarbonised port activities, as well as naval transport.

Expanding **port capacity** is paramount. A well-equipped port facility within economic distance from the offshore wind development areas is a key prerequisite, considering that components such as foundations, platforms or substations are manufactured directly at the nearest port facility, which also plays a key role in operations and maintenance (O&M). This highlights the need to encourage and support the modernisation of port facilities and infrastructure to host larger turbines, ramp up volumes, cater to operation and maintenance, develop training facilities and decommissioning centres for fixed and floating turbines. Ports are also important for integrating the energy output of offshore power generation, either as direct energy consumers or by potentially becoming hubs for clean hydrogen. The Port of Constanța can, therefore, expand its strategic position in the Black Sea and grow into a regional pole of decarbonisation, while providing the basis for offshore wind development in the entire Black Sea region.

Romania also needs to pursue the strategic aim of attracting a significant share of the **new supply chains** that are being created across Europe's offshore wind industry. The sector creates significant added value to the EU economy beyond just in the energy system, including in sectors such as electrical equipment, machinery, metals, construction works, telecommunications, etc. When it comes to the **jobs** that the offshore wind industry creates, a significant number is required for the installation, building of foundations, planning and O&M processes, which can mostly be covered with national workforce. In longer term, reasons of cost efficiency will lead to relocating part of the manufacturing chain, potentially towards Romania and the region.

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1. Introduction and context

In the midst of the energy transition and planning for a post-Covid 19 economic recovery, offshore wind power is regarded as a would-be pillar in reaching net-zero greenhouse gas (GHG) emission by 2050, as envisioned by the European Green Deal. As emphasised by the European Commission, Europe is home to some of the world's most significant offshore wind resources. Better tapping into this potential will be addressed in the European Commission's upcoming 2020 Offshore Wind Strategy. Given that all the member states are currently planning measures and stimulus packages for economic recovery, the strategy is expected to bolster a rapid expansion of offshore wind on the continent by also tapping into these newly available financial resources.

The Commission's strategy will build upon previous work that shows the importance of offshore wind in the context of decarbonisation. For example, with its Long-Term Strategy (LTS), the Commission explored several pathways to reduce GHG emissions, from scenarios that address the target well below 2°C to those that pursue efforts to limit temperature growth to 1.5°C (EC 2018b). The latter goal is forecast in modelled by the 1.5LIFE and 1.5TECH scenarios. The total power generation capacity in the two 1.5 scenarios ranges from around 2,300 GW to 2,800 GW in 2050, with the share of renewables in gross electricity generation reaching more than 80% and – within renewables – with wind representing the dominating renewable energy technology (>50%). According to this document, the decarbonisation of the EU economy will require up to 451 GW of offshore wind capacities by 2050. By then, the Commission estimates that up to 30% of electricity demand could be supplied by offshore wind. In the 1.5LIFE scenario, offshore wind is projected to reach an installed capacity of 396 GW by 2050, and of 451 GW in the 1.5TECH scenario. This represents a challenge of gargantuan proportions, given the fact the EU currently has around 20 GW of installed offshore wind capacity (IEA 2019). Deploying 450 GW of offshore wind in Europe would require a considerable increase in the annual installation rate, starting from around 3 GW per year today to some 7 GW per year by the second half of the 2020s and to over 20 GW per year by the mid-2030s (WindEurope 2019).

There are multiple reasons for pursuing such a significant expansion in offshore wind capacity. Offshore wind comes with desirable properties that onshore wind and solar photovoltaics (PV) do not currently have: high full-load hours, high operating hours, rather low variability and, consequently, greater predictability, including correspondingly lower forecast errors and balancing power requirements. Due to these features, offshore wind's system value is generally considered to be higher than that of onshore wind and more stable over time than that of solar PV (IEA 2019). Whereas solar PV and onshore wind power generation are assumed to reach up to 2,300 and 3,700 full-load hours in the highest potential sites, IRENA (2018) showed that the global weighted average capacity factor for offshore wind amounted to 43%, i.e. nearly 3,800 full-load hours.

When it comes to system adequacy, offshore wind can contribute around 30% of its installed capacity to the ability of the power system to match generation with consumption at all times, thereby reducing the need for investment into dispatchable backup power plants. In the future, offshore wind could also provide flexibility services (Stiftung Offshore 2017).

Offshore wind also increasingly represents a cost-effective option for power generation. The levelized cost of electricity (LCOE) generated by offshore wind declined from about 0.15 USD/kWh to 0.13 USD/kWh between 2010 and 2018 (IRENA 2018). Moreover, strike prices in recent auctions in Europe have fallen to almost 0.05 USD/kWh for delivery in the mid-2020s, and the confidence of investors into offshore wind is growing, thereby reducing financing costs even further and minimising the risks of nonrealization.

Offshore wind may also unlock significant opportunities for the hydrogen economy. Electrolysers for hydrogen production are most cost-efficient when operated on a continuous basis. Efficient green hydrogen production thus needs a renewable energy source that can deliver a high number of full-load hours, a requirement that can be met by offshore wind. Consequently, offshore wind deployment goes hand in hand with greater hydrogen production in numerous decarbonisation scenarios. For example, the “optimised gas scenario”, commissioned by the “Gas for Climate” consortium, projects total installed offshore wind capacity of 1010 GW in order to achieve net-zero GHG emissions in the EU by 2050. Half of this capacity would be dedicated to green hydrogen production (Navigant 2019), that is hydrogen produced through electrolysis using electricity sourced from renewables. In producing green hydrogen, offshore wind will compete with exceptionally inexpensive solar PV and onshore wind at very good sites around the globe. However, given the high costs associated with long-distance hydrogen shipping – whether as liquid hydrogen, ammonia, or in liquid organic hydrogen carriers – offshore wind located in Europe might have a competitive advantage.

Given all these recent developments and the role it will play in the decarbonisation process, Romania needs to also tap into its offshore wind potential present in the Black Sea. Currently, while Romania is a leading country in Southeast Europe in terms of onshore wind development, with an installed capacity of 3 GW and another 2.4 to 3 GW planned by 2030 according to the National Energy and Climate Plan (NECP) 2021-2030 (NECP 2020), there is more limited support for the development of offshore capacities in the Black Sea. Currently, both precise information of offshore wind potential and an adequate regulatory and financial framework for supporting such developments are missing.

Recently, the European Commission published its assessment of the NECPs and the recommendation for Romania is to increase its level of ambition regarding the share of energy from renewable sources from 30.7% in 2030 to at least 34%. In the latest communications regarding the 2030 targets, the Romanian Ministry of Economy, Energy and Business Environment (MEEMA) mentioned an ambition of 3 GW of additional wind capacity by 2030, including offshore capacities, compared to the approximately 2.3 GW included in the NECP. Hence, offshore wind could potentially represent the solution for covering the gap between the current level of ambition and Romania’s renewable energy potential. Besides, the upcoming revision of the EU 2030 GHG emissions to potentially 55% will also require a higher level of ambition when it comes to Romania’s renewable energy target.

Against this background, this study seeks to contribute to the development of Romania's Black Sea offshore wind potential by providing early-stage data and analysis, relevant for both the national and EU-levels. The study is structured as follows:

Section 2 assesses the natural and technical potential of the country's offshore wind sector, based on reanalysis of data provided by the ERA5 project from European Centre for Medium-Range Weather Forecasts (see subsection 2.1), providing estimations for the maximum yearly power output as well as total capacity.

Section 3 tackles a host of regulatory aspects that must be addressed in order to create a competitive and incentivising investment environment for the sector – a discussion largely led in reference to the recent Romanian Senate's bill of a wind offshore law – especially with regard to maritime spatial planning, grid access, and EU-wide regulatory harmonisation.

Section 4 of the study discusses the opportunities and pathways for offshore wind energy in view of the EU's ambitious net-zero carbon emissions by 2050, and in the context of other, already published strategy papers of the European Green Deal – EU Hydrogen Strategy, EU System Integration Strategy, and EU Industrial Strategy – notwithstanding the upcoming EU Offshore Renewable Energy Strategy, due to come out towards the end of 2020.

Section 5 concludes with a number of policy recommendations meant to support a swift and sustainable development of offshore wind power in Romania, in line with the EU targets and strategy. Focus is also given to the opportunities that enhanced regional cooperation can unlock for the development of the Black Sea's offshore wind potential.

2. Assessment of Romania’s offshore wind potential

2.1 Method of analysis

Several previous publications have focused on the assessment of Romania’s wind offshore resources, as indicated in Table 1 below. Against that background, the current study brings several elements of novelty:

- An analysis of a new wind database (ERA5);
- Wind speed reported to a hub height of 100 m (*U*100), as obtained from ERA5 data centre;
- Inclusion on 24 values per day;
- Evaluation based on state-of-the-art wind turbine**:** MHI Vestas V174 9.5;
- Maps of the Romanian exclusive economic zone (EEZ) differentiated by water depth (less than 50 m – fixed structures; more than 50 m – floating systems).

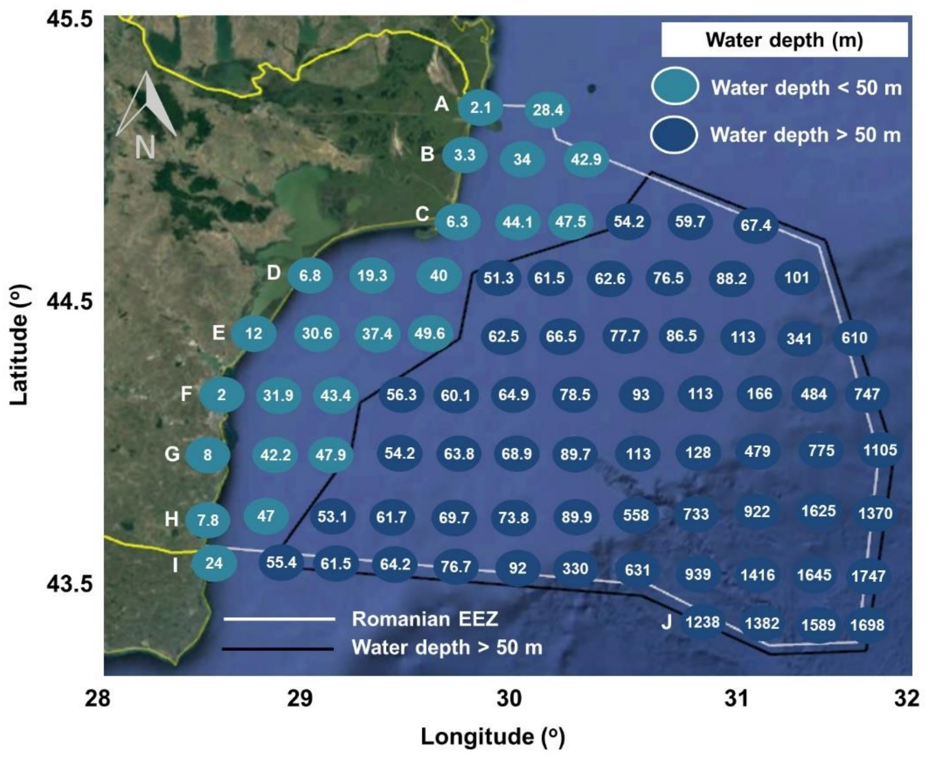
Table 1. Previous studies on the Romanian wind offshore resources

Wind data							
No.	Data	Time interval	Height (m)	Spatial resolution	Temporal resolution (per day)	Turbine	Reference
1.	NCEP	1987-2016	U10	0.32°	8 values	-	Onea et al. (2019a)
2.	ERA-Interim	1998-2017	U80	0.125°	4 values	GE Energy 2.5xl SWT-2.3-93 Areva M5000-116	Onea et al. (2019b)
3.	ERA-Interim	2009-2017	U80	0.125°	4 values	V90-3.0 MW Areva M5000-116 Senvion 6.2M126 V164-8.8 MW V164-9.5 MW	Onea and Rusu (2018)
4.	ERA-Interim	1997-2009	U10; U80	0.125°	4 values	Siemens 2.3	Onea and Rusu (2014)
Current study							
-	ERA5	2000-2019	U100	0.25°	24 values/day (1/hour)	MHI Vestas V174 9.5	-

A grid of 84 points was considered, as shown in Figure 1, distributed along parallel lines, marked A to J, with the distance between them set at 20 km along longitudinal and latitudinal lines. Figure 1 also shows the differences in water depth across Romania’s EEZ. Close to the extremity of the continental shelf, the depth is about 600 m, dropping to a maximum of 1,747 m at the end of the EEZ zone.

As shown in Figure 1, a significant part of the EEZ is a deep-water area (>50 m) that is more suitable for floating platforms. A look at the European offshore wind market (WindEurope 2020) indicates that, in 2019, the average distance to the shore for projects under construction was close to 60 km, which is just within the Romanian transition area from shallow (<50 m) to deep water (>50 m). However, as explained below in section 3.2, wind farms at more than 50 km from the shore should be connected to grid through high voltage direct current connections (155 kV HVDC), in order to significantly reduce electrical losses. Such connections, though, require higher upfront investment costs.

Figure 1. Romanian exclusive economic zone (EEZ) and water depth



Source: National Oceanic and Atmospheric Administration (Bathymetric Data Viewer).

Note: The reference lines (marked A to J) include points of a grid at an approximate distance of 20 km from each other along the x and y axes.

The wind data are part of the ERA5 portfolio that is maintained by the European Centre for Medium-Range Weather Forecasts (ECMWF) (Guillory 2019). It is important to underscore that the ECMWF provides wind speed values directly related to 100 m height (denoted by $U100$), to the effect that no further data processing was needed, such as the use of logarithmic/power law to adjust the wind speed from 10 m height to 100 m. Thus, it was possible to remove uncertainties related to the adjustment of wind conditions from much lower heights, where local velocity is lower due to boundary layer mean velocity distribution.

According to the ERA5 documentation (ECMWF Confluence Wiki 2019), the $U100$ parameter is interpolated from the ERA5 model level winds based on a combination of methods between different layers (e.g. quadratic and linear interpolation). Importantly, the ERA5 is a reanalysis product, which means it combines a model with weather observations – wherever such information is available.

Based on comparisons with *in situ* measurements, the ECMWF wind data appear to somewhat underestimate the wind conditions from the north-western part of the Black Sea, especially for the onshore area. This aspect requires *in situ* empirical confirmation, by including in the analysis other measurement stations, such as historical data from the Gloria oil and gas platform, which was decommissioned in 2019. For example, by comparing the wind conditions from the ECMWF with satellite measurements for some European offshore sites (Rusu and Onea 2019), it was found that variations were in the range of 22.3-33% for the 50 percentile index, while a variation between 5.0-16.9% may be expected for the 95 percentile values. Indeed, a report by the European Commission's Joint Research Centre (Dalla Longa et al. 2018) confirms the underestimations of the wind energy resources that may emerge when using data derived from similar sources as the present study. Thus, wind conditions can be underestimated by 25% compared to *in situ* conditions for measurements in simple terrain conditions.

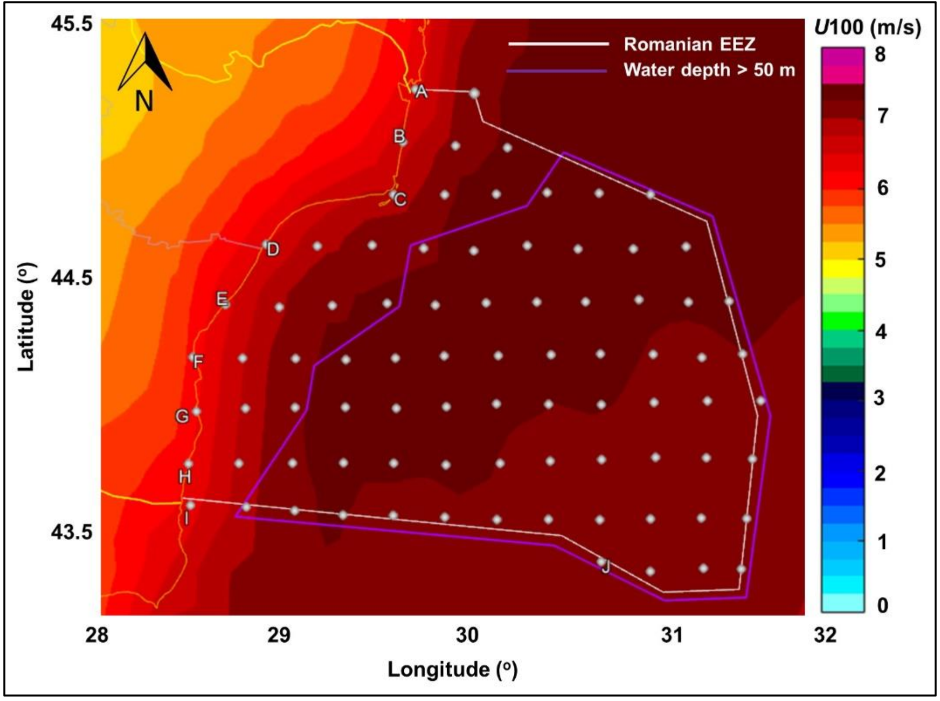
More technical detail on the how the ERA5 data have been processed, the definitions and calculation of the relevant magnitudes – expected power output per turbine, capacity factor, and average electricity production (AEP) – are presented in the Annex.

2.2 Results

Figure 2 presents the spatial distribution of the average wind speed ($U100$) based on data reported for the time interval 2000-2019, while the Annex (Figure A1) adds similar distributions for the four seasons. These maps clearly show that the wind speeds increase the further they are measured from the shoreline. Nevertheless, the data shows that only the central part of the deep-water sector has more sizeable mean wind speeds (close to 7 m/s), compared to the South-Eastern part of the Romanian EEZ, where the wind speed decreases. Regarding the seasonal distribution, the marine areas have wind speeds in the range of 8-9 m/s in winter, compared to a maximum of 7 m/s in the North-Eastern part of the EEZ in summertime. The average wind speed value is a relevant indicator in this context, since it indicates what type of wind turbine is suitable for the analysed coastal environment.

The *capacity factor*, which is used to calculate the efficiency of a particular generator, is presented in Figure 3 for the MHI Vestas V174 9.5 MW turbine, considering all the available data. Closer to the shore, a single turbine's capacity factor is in the range 24-28%, which can reach up to 35% close to the 50 m contour line. As for the deep-water area, the north-east sector frequently evinces capacity factors of more than 35%, while the central part of EEZ is defined by values around 34%. The seasonal distributions are presented in the Annex (Figure A2). In winter, the capacity factor reaches 47% in the offshore areas, and up to 40.5% near the shoreline, close to Sacalin peninsula (south of the Danube Delta). Once again, it should be mentioned that the wind measurements used for these calculations may underestimate the wind potential when compared to in situ measures.

Figure 2. Average wind speed measured at 100 m height (U100)



Source: Calculations based on ERA5 dataset for the Romanian EEZ, 2000-2019.

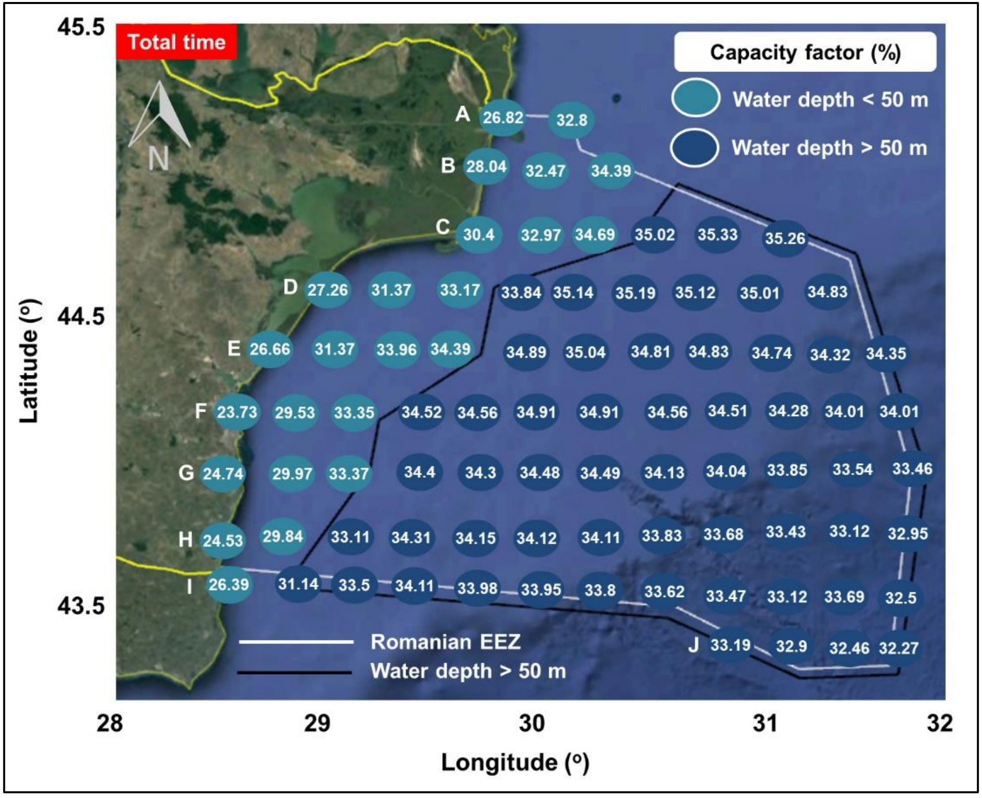
It should be noted that these figures were calculated for a single turbine that could be installed in any point of the grid, not for a fully developed windfarm. Correspondingly, no additional effects were taken into consideration, such as the wake effect. The effect of wakes will, nonetheless, be discussed in section 2.3.

The estimation of the Annual Energy Production (AEP) is presented in Figure 4 (Figures A3 in the annex shows the seasonal AEP distribution, as well). The analysis of the total time data show that, in general, a turbine such as the MHI Vestas V174 9.5 MW will not exceed an output of 30 GWh/year, while the wintertime alone would result in a theoretical output of 39 GWh/year for a single unit, showing the significantly higher production potential for the winter months.

Another important indicator, the inter-annual variability index (IAV), is frequently used in climatological analysis. IAV is defined as the ratio between the standard deviation of a particular dataset and the absolute mean.

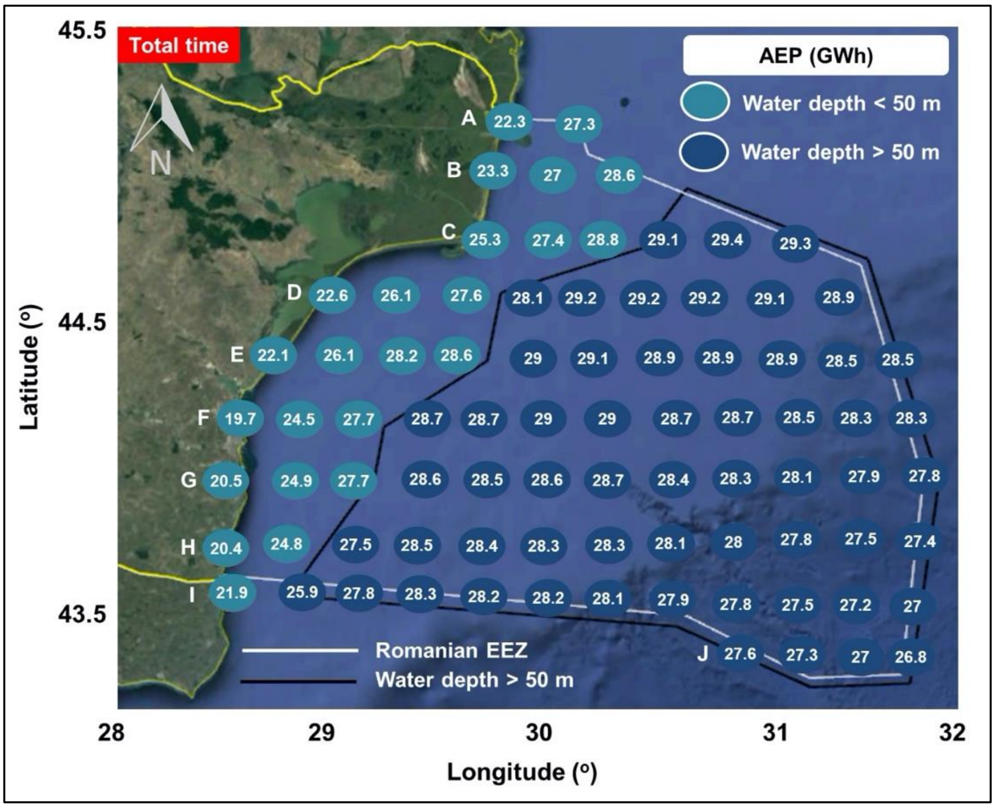
Figure 4 illustrates the IAV values computed for each point. In can be observed that the values increase from 5.52% (A-points) to a maximum of 7.15% (J-points). This means that a site with a lower IAV is characterised by less wind speed fluctuation, which may better recommend it for the characteristics of a particular sort of turbine. In this respect, the best sites are located in shallow water areas, especially in the middle and northern parts of the Romanian EEZ.

Figure 3. Average capacity factor (%) of MHI Vestas V174 9.5 MW turbine, U100, 2000-2019, corresponding to the grid points inside the Romanian EEZ



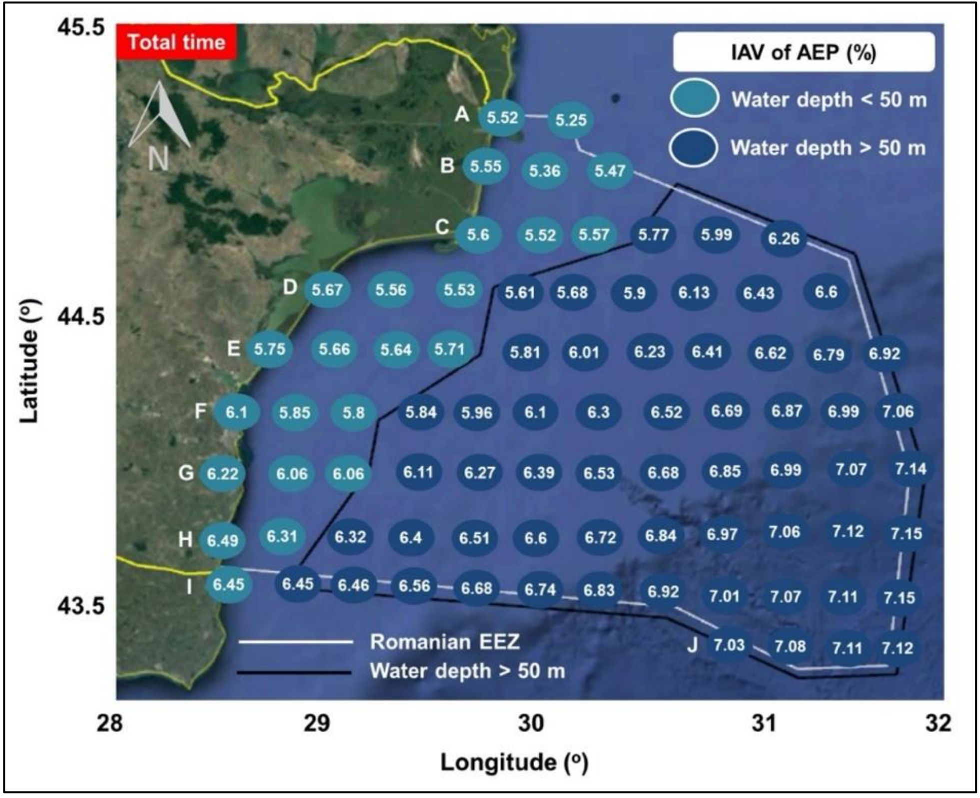
Source: Calculation by Dunărea de Jos University and EPG

Figure 4. Annual energy production of MHI Vestas V174 9.5 MW turbine, U100, 2000-2019



Source: Calculation by Dunărea de Jos University and EPG

Figure 5. Inter-annual variability (IAV) of AEP MHI Vestas V174 9.5 MW, U100



Source: Calculation by Dunărea de Jos University and EPG

Most of the Romanian EEZ has a depth that exceeds 50 m, which makes it more suitable for wind projects based on floating platforms. While deep-water areas are increasingly accessible for floating wind turbines, given the progress of technology and their cost reduction, in water depth of more than 150 m the cost of mooring increases significantly, whereas at shore distances beyond 50 km, expensive high voltage direct current (HVDC) connections to the grid are preferable.

Table 2 sums up the total Romanian offshore wind resources physical potential estimations of this study, both in terms of total potential natural capacity and average annual expected production based on the full development of this potential. Much of the estimated potential lies in floating turbines, since most of Romania's maritime space is deeper than 50m. Nonetheless, up to 22GW can be installed in the form of fixed turbines. Table 3 shows the AEP for the Romanian maritime space, calculated by summing up the estimated installed capacities per 400 km^2 square of the grid.

Table 2. Total offshore wind physical potential of Romania

	TOTAL	Fixed	Floating
AEP (GWh)	239,037	54,435	184,602
Total capacity (GW)	94	22	72

Source: EPG calculation.

Note: The total installed capacity estimates are based on a power density of 5.0 MW/km^2. The literature reviews conducted both by JRC (Dalla Longa et al. 2018) and Deutsche Windguard (2018) suggest that this is a suitable value for estimating offshore wind potentials in Europe, while ensuring both the use of adequate technological options and keeping the wake effect to a minimum. This study excluded from calculation all grid squares within 20 km from the coastline, as well as those of water depth greater than 150 m, where the increase in the total mass of the mooring systems lead to an accelerated ramping up of costs, and thus make the investment uneconomical (JRC 2017). Areas with average wind speeds are lower than 7 m/s were also excluded on account of the low economic opportunity for wind farm development in such conditions. Lastly, areas of analysis that could not be fully contained within the Romanian EEZ were also excluded. For the estimation of the AEP, the calculations assumed losses of 15% due to factors such as icing, down time, park effects, transformer losses, etc. (see Dalla Longa et al. 2018). As previously mentioned, satellite data may underestimate actual wind potentials, yet this was not accounted for in the calculations. Hence, it is expected that estimations based on in situ measurements will likely produce higher values.

Table 3. Average Annual Expected Production (GWh) for 400 km^2 squares

	AEP (GWh)											
Distance to shore (km)	0	20	40	60	80	100	120	140	160	180	200	220
0		4885										
20		4832	5118									
40		4903	5172	5207	5261	5243						
60		4671	4939	5046	5225	5243	5225	5207	5189			
80		4671	5064	5118	5189	5225	5189	5189	5172	5118	5118	
100			4975	5136	5154	5207	5207	5154	5136	5100	5064	5064
120			4975	5118	5118	5136	5136	5082	5064	5046	4993	4975
140			4939	5118	5082	5082	5082	5046	5011	4975	4939	4903
160		4635	4993	5082	5064	5064	5028	5011	4993	4939	4867	4849
180									4939	4903	4832	4814

Source: EPG calculation.

Note: Figures in white represent areas suitable for fixed onshore development (i.e. less than 50 m water depth), figures in pink represent areas suitable for floating offshore development, and figures in yellow represent areas excluded from the estimation of total offshore wind potential, as explained in Table 2. Losses of 15% were assumed.

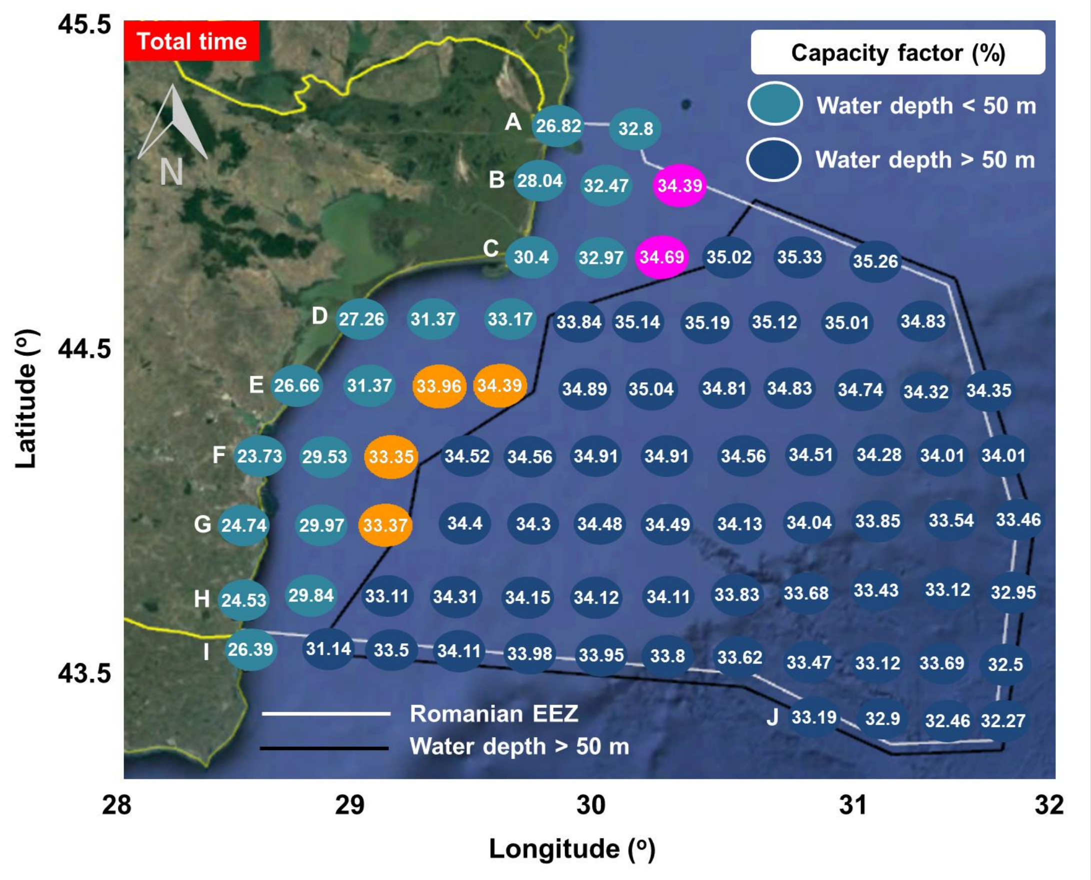
On balance, considering the wind speed and water depth conditions, the most suitable area for development seems to be located close to the 50 m contour line, which makes it possible to avoid most interferences with shipping routes and port activities. Nevertheless, the selection of any particular site is a multi-criterial process, and therefore the selection of the Romanian offshore wind power sites must be done by means of particularised project planning. The figures indicated for the capacity factor are in line with other values reported at European level– circa 30-40%. Nevertheless, for a complete picture, a full portfolio of offshore wind turbines ought to be analysed in order to identify the most representative systems for this geographical region.

As shown in Figure 6, based on the calculations presented in this study, two potential clusters are identified that offer the most favourable conditions for a first stage of offshore wind development, based on fixed turbines:

a) *Orange cluster* – containing four 400 km^2 squares, each with capacity factors between 33-35%, in water depths below 50m and situated between 40-60 km from the shore, it should provide the best available balance between wind resource and cost of the offshore grid, particularly given the possibility to inject the output in the Constanța Sud electrical substation, as pointed out in the TSO's TYNDP. Moreover, the proximity to the Port of Constanța and its facilities make this cluster relevant in terms of accessibility for both the development process and O&M activities, as well as for its hydrogen production potential. Due to its positioning, the cluster can also host cross-border offshore wind projects involving Bulgaria.

b) *Pink cluster* – marginally the best offshore wind development area with respect to the wind resource, with two 400 km^2 squares averaging a capacity factor above 34% and located at ca. 40 km from the shoreline. However, the good wind resource is offset by the fact that the existing onshore transmission line is further inland and to make the connection, the grid would have to be extended in the Danube Delta, which is a protected area.

Figure 6. Most promising development areas based on average capacity factor (%)



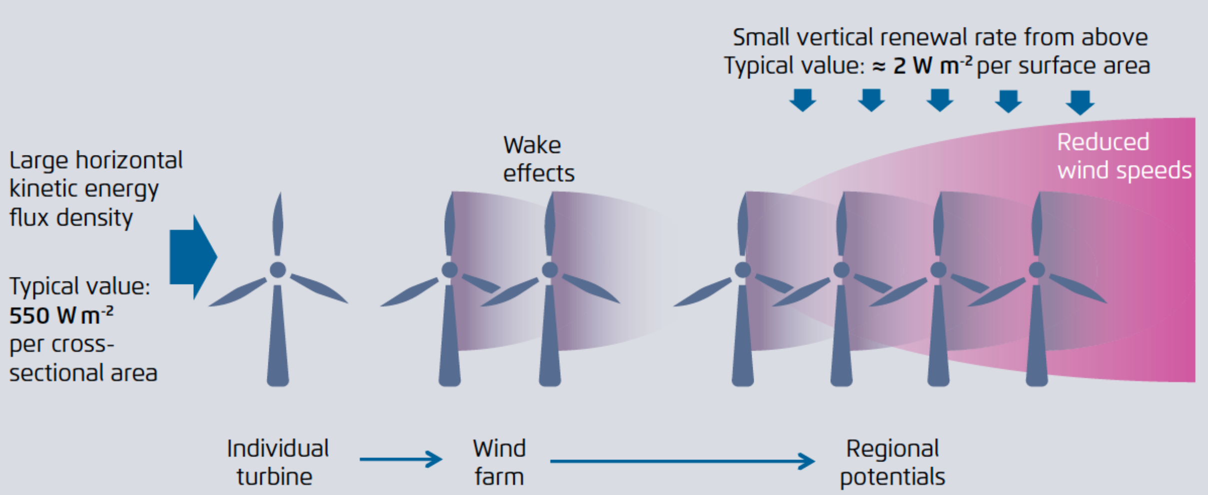
Source: EPG assessment

2.3 The wake effects and their implications

A study commissioned in 2020 by Agora Energiewende to the Max Planck Institute for Biochemistry and Technical University of Denmark reveals the importance of *wakes*, which are ‘mean wind speed reductions behind the turbine, together with increased turbulence levels’ (Agora 2020). The diminished wind speed after passing the turbine, as a result of kinetic energy transformation into electricity and friction, is an effect that must be taken in consideration by spatial planners and wind farm operators, since the aggregated power output of a wind farm will be very different – and significantly lower – than the arithmetical sum of the individual wind turbines. ‘The more the surrounding horizontal air flow is affected, the greater the reduction in downstream wind speeds, because additional kinetic energy can effectively only come from higher atmospheric layers, and the vertical renewal rate from above is limited’ (Agora 2020) – see Figure 7.

Wakes are a common phenomenon in onshore and offshore wind farms alike, yet the offshore effects are much more pronounced. The reason is that in order for wakes to recover, a certain minimal distance is needed behind the wind turbine for the wind energy to be replenished through atmospheric turbulence. But the onshore wakes are much shorter (7-8 km at most), due to the absorption and emission of energy from sunlight and the many different terrestrial obstacles that cause turbulence, whereas offshore wakes are replenished almost only from above, which explains why offshore wakes have been measured to reach 40-50 km in length (Platis et al. 2018).

Figure 7. Illustration of wake effects



Source: Agora (2020). The indicated typical value is based on the yearly average for the North Sea

Maritime spatial planning for wind farm concessions has so far had a virtually exclusive national focus – and, as discussed in section 3, the Romanian legislative initiative meant to put in place a regulatory offshore wind framework makes no exception. Nevertheless, factoring in wake effects is imperative for a successful development of the offshore wind sector. This also requires planning based on the broader regional wind dynamics and cross-border coordination in order to avoid unnecessary losses of production potential.

As underscored in the Agora (2020) study, ‘sufficiently large spaces between wind farms should be preserved in order to ensure replenishment of wind speeds. These replenishment areas could potentially be reserved for other purposes, such as shipping corridors or nature conservation. […] In order to maximize the efficiency and potential of offshore wind, the planning and development of wind farms – as well as broader maritime spatial planning – should be coordinated across national borders.’

2.4. Tapping into the offshore wind potential: fixed vs. floating turbines

The evolution of offshore wind technology in the last 15 years has been substantial. By 2006, most of the installed offshore wind turbines had a rated power between 2.5 and 3 MW, while the average rated power over the following decade ranged between 3.5 and 4 MW and reached 7.8 MW in 2019, as pointed out by JRC (2017) and WindEurope (2020c). Moreover, rated powers larger than 10 MW are expected to become the norm for the offshore wind parks to be developed by 2030. The evolution in the rated power per turbine is complemented by the evolution of the average size of offshore wind farm projects, from 200 MW in 2009 to more than 600 MW in 2019.

WindEurope also shows that the average water depth increased from below 10 m before 2005, to almost 35 m in 2019, while offshore farms have started to be developed farther away from the shore, from less than 10 km before 2007, to an average of 60 km in 2019.

As offshore wind developments surged at continental level, costs have dropped by more than 60% in the last five years (WindEurope 2020). As already mentioned, two technology options emerged, aimed at maximising the wind energy potential of the European seas: fixed (or bottom-fixed) and floating offshore wind turbines.

Fixed offshore turbines are used in shallow waters, with depths up to 50-60 m. At depths greater than this threshold – where 80% of the European offshore wind resources are located – floating turbines are the solution of choice. Compared to fixed offshore turbines, floating installations are less dependent on factors such as weather, soil and sea conditions. However, such turbines require the development of a different kind of infrastructure for their installation, since components are generally assembled onshore and then towed to the offshore site. For some key operations and maintenance (O&M) activities, floating turbines are brought back to ports. Consequently, any uptake of this type of offshore wind turbine is dependent on the availability of suitable port facilities in the area, as pointed out by WindEurope (2017a).

In this respect, Romania’s Port of Constanța can play a significant role in the development of floating wind turbines in the Black Sea region. This can represent an enabling factor for tapping into unexploited offshore areas and allow for larger installed capacities, thus creating new business opportunities and jobs.

As underscored by WindEurope (2017b), the fixed offshore wind technology has become quite competitive over the last years, with costs dropping from about €150/MWh in 2014 to €60-65/MWh in 2020. The cost of floating offshore wind facilities is significantly higher today, but on a steeply decreasing curve, with continuous investment in R&D being required for sustained cost reductions. While in 2018 the costs were around €200/MWh, recent auctions have announced target prices of €110-120/MWh for projects that will be operational by 2026, and it is expected that an LCOE similar to the one of fixed offshore wind (€55-65/MWh) will be achieved by 2030, as the industry benefits from visibility in terms of volumes, policy and strategy to develop an offshore value chain.

Nonetheless, as the mass of the mooring system for floating turbines increases with water depth beyond approximately 150 m, and hence the investment costs, the economics of offshore wind farms is still restricted within waters not too deep, and mostly within 50 km from the coastline, because of the higher costs of HVDC connections – although recent years have seen large-scale wind farms built 110 km away from the shore[1]. Besides, the Black Sea contains hydrogen sulphide in high concentration at depths surpassing 200 m, which is highly corrosive for steel equipment, and thus special, protected carbon steel is required.

As of 2019, the only operational large-scale floating wind farm was the 30 MW Hywind project in Scotland (IRENA 2019). At present, four floating wind farms are under development in Grand Canaria, totalling a capacity of 200 MW (Evwind 2020).

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[1] As indicated in JRC (2017, 22), 'Nine projects located in Germany, which were fully commissioned by the end of 2015, used this type of connection. Currently, the projects Gode Wind 1 and 2, Sandbank, Nordsee One, Veja Mate and Borkum Riffgrund 2 under construction in Germany also plan to use HVDC connection.' Meanwhile, the latter projects have also been commissioned.

3. Creating an incentivising regulatory framework for offshore wind

3.1 The legislative proposal of the Romanian Senate on offshore wind

In July 2020, the Romanian Senate passed a bill on the 'needed measures for operations to exploit offshore wind energy'. The legislative proposal came in response to a spike of interest in public discussion about the offshore wind potential of the Black Sea, and a generally heightened EU-wide promotion of this technology. In this respect, considering the almost total lack of regulatory background for such operations, the initiative served a clear purpose. Indeed, the comprehensive document endeavours to tackle the licensing procedures of offshore wind parks, authorisation for construction and exploitation, land access, expropriation, subsidy schemes and bonuses for offshore wind power generation (though source of funding is not mentioned), allocation of costs for the offshore power networks, decommissioning obligations, as well as penalties and fines.

However, the hastiness and lack of public consultation have, unfortunately, resulted in a legislative proposal insufficiently thought-out and abounding in unclarity and controversial implications. The current study only highlights a few such concerns.

Importantly, the bill introduces two distinct procedures for awarding wind offshore concessions: (1) the *competitive bidding* procedure, consisting in a tender process organised by the government for predefined offshore perimeters and wind power capacities, in which projects are awarded based on the lowest price offer in a contract for difference – thus ensuring the lowest level of subsidy that the state would support; (2), the *open* procedure, in which the project developer requests a licence for a chosen location and capacity.

For the open procedure, Art. 31 of the bill establishes a premium of up to €0.025/kWh on top of the market price, but the resulting value cannot exceed €0.060/kWh – case in which the premium is to be diminished accordingly. In addition to the premium, €0.020/kWh is supposed to be provided by the state for up to 20 years from the moment of grid connection for 'balancing of costs.' There is no annex of quantitative analysis to explain the chosen monetary values proposed for these subsidies, neither is there any explanation of what 'balancing of costs' means.

For the offshore wind parks developed through open procedure, Art. 13 introduces the questionable provision that the owners of parks within less than 16 km from the coastline must 'offer the option that 20% of ownership shares are acquired by local residents that reside within 4.5 km from the wind park or in a locality that has coastlines within 16 km from the wind park.' The apparent arbitrariness of such figures and the lack of clarity about the pricing mechanism for the sale of shares – as well as about what happens if said residents are not interested in the offer – raise a suspicion of haphazardness or, worse, self-serving rulemaking.

The government is required to prepare an offshore spatial planning for the perimeters to be tendered competitively, and to asses, based on a ‘broad set of criteria’, the adequacy of the perimeters proposed for development through the open procedure.

Another significant difference between the two types of projects is that, according to Art. 36, the owner of open-procedure wind parks will have to cover the costs of all facilities and infrastructure necessary to transport the electricity from the offshore connection point to the shoreline. Meanwhile, for offshore wind parks developed through the competitive procedure, the wind park owner is responsible only for the internal network, while the TSO will ensure the facilities needed for the transmission of power to the shore. Such additional costs for projects awarded through the open procedure can significantly tilt the interest of investors towards the latter form of selection.

Another crucial issue concerns land access for the construction and maintenance of the needed onshore facilities and infrastructure. Art. 19 of the bill states that, for private lands, the licence holder will have a right of servitude for land access, against payment of an annual rent to the landowners. However, if the quantum of the rent cannot be agreed upon, it is to be settled in a court of justice. This can imply, in practice, years of litigation, in which the right of access cannot be exerted, having the consequence of effectively stalling the grid connection works for the duration of the trial. This is not merely a speculative scenario, as shown by the experience of the oil and gas industry. Access to private lands has often been blocked for years on account of disagreement between landowners and oil and gas companies. Therefore, it would be preferable that the right of access will be enforced through a specific provision in the law, separate from the issue of the amount of the rent, whose settlement could be pursued separately in court.

The issue of land access is compounded by a separate piece of legislation, recently promulgated, which introduces major restrictions to the ownership right on agricultural land and the possibility of changing its purpose, even for the small parts that may be required for the operations of energy companies. Not only does such legislation disincentivise investment in key energy projects, but it also conveys a general environment of strategic incoherence in the making of laws and regulations.

While some of the above-mentioned problems may be dealt with through more careful legal and strategic pondering, others require careful preparatory research and analysis of the offshore sector, including measurements of wind resources and proper mapping of perimeters, environmental impact, biodiversity, military considerations, shipping lanes, fishing, other economic activities, etc. Indeed, there is a well-established tool that is essential in dealing preventively with potentially conflicting priorities among these uses and domains: the national Maritime Spatial Planning, as required by Directive 2014/89/EU[2].

Art. 5 (2) of the MPS Directive clearly states that ‘Through their maritime spatial plans, Member States shall aim to contribute to the sustainable development of energy sectors at sea, of maritime transport, and of the fisheries and aquaculture sectors, and to the preservation, protection and improvement of the environment, including resilience to climate change impacts. In addition, Member States may pursue other objectives such as the promotion of sustainable tourism and the sustainable extraction of raw materials’.

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[2] The MPS Directive requires that all member states prepare and submit their national Maritime Spatial Plans to the European Commission by March 31, 2021, for examination and Strategic Environmental Assessment (SEA).

Moreover, in taking such a multi-use approach, the member state should ensure at an early stage *public participation* (Art. 9) by involving all the interested parties, relevant stakeholders and authorities.

It is, therefore, imperative that a well-designed MSP for the Romanian Black Sea precedes any other action in term of zoning and carving out perimeters for offshore wind activities.

3.2 Overcoming grid challenges

In offshore wind development across Europe, onshore grid access and infrastructure pose serious challenges, the situation in Romania being no different. Any offshore wind farm developed in the Romanian waters will have to be connected to the grid in Dobrogea, where a significant part of the country's power generation assets is already situated. Indeed, most of the country's 3 GW of onshore wind is installed there, in addition to 1.4 GW from the Cernavodă nuclear power plant's two nuclear reactors. Besides, according to the NECP, some additional gigawatts of renewable energy, mostly wind power, are expected to be developed in the same congested south-eastern region of Dobrogea, alongside two new nuclear reactors at Cernavodă, to the effect of almost doubling the installed capacity in the area, in an area with limited local energy demand.

That notwithstanding, in the recently published Network Development Plan (PDRET) for 2020-2029 of Transelectrica (2020), the Romanian electricity TSO, the assumed uptake of RES is not aligned with the targets in the NECP and the latest version of the Energy Strategy. In fact, PDRET's "green" scenario is at least 50% more conservative in terms of renewable energy sources (RES) than the capacities required to reach the country's 2030 targets. In addition, the grid infrastructure projects announced for the next decade do not add sufficient grid capacity to even evacuate the existing onshore energy produced in the Dobrogea region, with only two major power lines planned to be commissioned by 2029. In its baseline scenarios, the PDRET does not mention any offshore wind developments and associated infrastructure, albeit the TSO has recently become markedly more interested in the topic. It is expected, though, that the next revision of the PDRET will at least include more details on this subject. Otherwise, the development of any addition wind energy capacity in the region will be impaired.

It should be mentioned, however, that after receiving feedback from the renewable industry, the TSO added a brief analysis of the scenario based on the 2030 targets presented by the NECP. In effect, Transelectrica considers about 500 MW of offshore wind in the Black Sea, which is to be connected to the onshore grid in the Constanța Sud power substation. Although the updated PDRET does not offer an in-depth system adequacy analysis of this scenario, the conclusions are encouraging regarding the grid's capacity to integrate additional variable power generation, under certain conditions.

At EU level, the wind industry is currently expecting a high-level strategy for the necessary grid development to achieve up to 450 GW of offshore wind that would be needed to meet the 2050 net-zero GHG emissions target. Such investments in the European grid already have various funding sources available, such as the new InvestEU programme, Next Generation EU, Connecting Europe Facility, as well as other instruments that will be available for the Central and East

European member states starting in 2021, such as the Modernisation Fund. Besides, EIB financing will also be available. Therefore, Transelectrica's access to funding does not seem to be the main issue when it comes to investing in further measures for RES integration, but rather a lack of sufficient strategic clarity and coherence at governmental level in terms of investment subsectors and grid development.

A separate issue, already touched upon, is the offshore grid connections. As underscored by JRC (2017), 'as project size and distance from shore increase, higher voltage levels (mainly 132 kV, 150 kV or 155 kV) are used in order to minimize electrical losses. […] Nevertheless, the longer distances, higher transmitted power (i.e. more installed capacity) and voltage levels are, the higher the capacitive effect is in AC submarine cables, which generates additional currents and electrical losses. Thus, large projects, which are farther away from shore, use high voltage direct current connection (155 kV HVDC), which requires higher up-front costs.'

In order to secure timely investment, avoid unnecessary spending and minimise offshore infrastructure costs, strategic planning is paramount, starting with the maritime spatial planning phase. Romania ought to ponder all the relevant economic, technical, security, environmental, archaeological and other strategic factors in order to carve out perimeters for concession. The TSO and the government should plan for the necessary offshore infrastructure design and optimal landing points. The planning process, however, should also involve the wind farm developers (WFDs), which are naturally interested in seeing that such critical infrastructure is built in time and at optimised costs.

Indeed, the very ambitious pace set by the European Commission for offshore wind power deployment, with a target of 100 GW installed by 2030 and 450 GW by 2050, translates in about 7 GW/year of new offshore wind farms up to 2030. Sustaining such an investment effort may constitute a challenge for national governments and TSOs. Therefore, the regulatory framework could also include the offshore WFDs in planning and building the offshore grid connections. The TSOs would thus be spared the massive upfront capital needed to sustain the investments, whereas the WFDs are intrinsically motivated to eliminate the main risk to their business plans: considerable delay or utter lack of offshore connectivity to the grid. Involvement of all these stakeholders can also mitigate any potential for conflicting incentives between wind park developers and infrastructure operators.

There are, in this respect, several possible regulatory models to follow, but generally it is important that the WFDs participate, in some capacity, in the construction of the offshore network. The latter is to be transferred thereafter either to a third-party – a so-called Offshore Transmission Owner (OFTO), as in the British model – or to the TSO itself, against a *transfer value* settled though a competitive tender process.[3]

Finally, it is important that the TSOs of Romania and Bulgaria cooperate to facilitate the deployment of cross-border *hybrid* offshore projects,[4] thus allowing the offshore

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[3] At least for some particular offshore projects, the operational control may justifiably be kept by the WFD itself, based on exemption from the EU's ownership unbundling regime.

[4] The next development step would be offshore *meshed grid*, similar to the onshore power grid system, where the electricity flow can take many directions. For the Black Sea, though, the move from hybrid project to a meshed system could only be justified when, at some point, non-EU countries such as Ukraine and Turkey will be able to join by adhering to the same norms of governance.

power sources to feed into either power market, as well as multiple uses, such as Power-to-X projects, which can bring a valuable flexibility dimension. Moreover, the TSOs cooperation should extend to the modernisation and optimisation of the existing onshore grid.

3.3 Relevant authorities in the offshore wind development in Romania

According to the Senate's bill on offshore wind, 18 institutions are to be involved in the sector, including four ministries: the Ministry of Economy, Energy and the Business Environment (MEEMA), the Ministry of Public Works, Development and Administration (MDLAP), the Ministry of Culture, and the Ministry of External Affairs (MAE).

For the process of policy making in general, and for the permitting process in particular (e.g. Chapter II of the bill, Authorisation to build and operate offshore wind farms), MEEMA's role is crucial. MEEMA coordinates the authorisation process with all relevant public authorities for four key licenses:

- conducting preliminary investigations;
- wind farm construction;
- electricity production;
- authorizations for electricity production, required for power plants with a capacity over 25 MW.

The land access is authorized by MEEMA, for the entire operation lifetime of the offshore wind farm. In addition, considering that wind turbines with an area exceeding 200 m^2 must be certified as a project, MEEMA is also in charge with selecting and approving the companies responsible for issuing the certificates for the wind turbines. Such certificates will be valid for a specific project and location for the entire lifetime of the turbines.

A dedicated *Committee for Wind Energy* is to come into existence to ensure that the establishment of wind farms in specific areas will not have a significant negative impact on other maritime activities. Therefore, the committee, within a strategic environmental assessment plan, will be responsible for the forthcoming spatial planning of offshore wind farms. The committee has not been set up yet, but the likely members are MEEMA, ANRE, the Maritime Hydrographic Directorate, the National Research and Development Institute for Energy ICEMENERG and Transelectrica – the electricity transmission system operator in Romania. No details are provided about the governance of this structure, and the ways it would work with other relevant stakeholders.

City halls and county councils do not have distinct responsibilities in the process in this form, their responsibilities only covering urbanism certificates and technical documentation. In order to protect the local cultural heritage while conducting offshore operations, some additional steps will need to be followed, with the involvement of three other institutions, namely the Ministry of Culture, the Zonal Commission of Historical Monuments and the National Institute of Heritage.

4. Opportunities and pathways for offshore wind development in Romania

This section builds the case for developing Romania's Black Sea offshore wind resources, given the beneficial impact this would have on the climate, domestic power market, prospect for energy system integration, increased role for the port of Constanța, as well as potential for job creation, economic growth and development of parts of the industry's value chain in Romania.

4.1 Power markets

Offshore wind projects will have a significant impact on the Romanian power markets, both for spot transactions and medium and long-term contracts. The whole energy system would benefit from a relatively constant power output and increased forecast accuracy, which reduces costs related to energy management and balancing. At the same time, less volatile electricity production increases the offshore producers' odds to compete on futures markets, with medium and long-term delivery products, which have lower commercial risk than the products offered by their onshore peers. Moreover, considering these characteristics, offshore wind farms are suitable for coupling mechanisms – e.g. virtual power plants, VPPs – not only with gas PPs, but also with onshore wind parks, solar PV capacities or storage facilities.

In such a scenario – to wit, higher RES power traded on the futures market, to the detriment of volumes traded on the day-ahead market (DAM) – the sold RES power (both as stand-alone offshore production and through VPP aggregators of offshore and onshore RES production will cause the merit order on DAM to "push out" some electricity producers that are currently closing the spot market (i.e. the price makers). Therefore, volumes traded volumes on the DAM, as well as their closing prices should undergo downward pressure.

The development of offshore wind power capacity will also provide benefits for the balancing market, as it would have significant impact on the volumes traded thereon through the diminishing demand for "short" positions. Then, less intermittent power would increase competitiveness on the markets for balancing and ancillary services. Finally, higher participation of onshore RES producers in VPPs alongside offshore ones decreases the former's need to balance their market positions, both on the DAM and the balancing market, thus reducing the costs associated with portfolio balancing.

Probably the biggest challenge for new power sources in southeast Romanian, onshore and offshore alike, is related to the grid's capacity to take up and evacuate high electricity outputs at the same time, as the Dobrogea region is home to most of the country's onshore wind farms and some large-scale solar PV power plant, developed between 2008 and 2016, in addition to units 1 and 2 of the Cernavodă nuclear power (1,400 MW). The region's chronical congestion is also caused by the geographical distribution of the energy demand, concentrated in the centre and Western part of the country. This turns any new generation capacity into a challenge for the TSO, especially absent any existing storage capacities in the area.

On the other hand, the additional clean electricity, provided by the region's offshore capacities, will call for increased regional market integration. To this purpose, legal provisions need to be reconsidered, to effectively allow Romanian power producers and traders to sell abroad, on regional wholesale markets. In addition, the upcoming regional integration of spot markets, planned for July 2021, when the Bulgarian DAM power market is expected to couple with the Romanian one, thus joining the regional 4M Market Coupling of Romania, Hungary, Slovakia and Czechia. In April 2021, 4M and the Polish energy exchanged are due to join the EU-wide Multi Regional Coupling (MRC) (Dimitrov 2020). This will add even more to competitive DAM prices, which will limit the participation of fossil fuel-based generators on the spot markets.

4.2 Sector integration and hydrogen

Developing offshore wind to become a consistent part of the Romanian energy mix will open up the way for an accelerated decarbonisation of key sectors such as transport and industry, either through direct or indirect electrification using RES, and potentially even heating and cooling. In the conventional power generation sector, various companies have publicly announced investments of at least 1.6 GW worth of gas-fired power generation for the coming five-six years. Such assets, along with any additional gas transport infrastructure, should already be designed to be "future proof" in terms of readiness to accommodate hydrogen, in order to lower the risk of becoming stranded assets

A smart deployment of charging infrastructure, along with a well-targeted policy and regulatory framework that should encourage electrification of rail and public transport, as well as maritime and long-haul road transport, apart from passenger vehicles, would also allow for offshore wind power to be used for decarbonising the transport sector.

Industry is a key sector for Romania's decarbonisation efforts. Clean hydrogen (i.e. produced through electrolysis using renewable electricity), potentially produced using offshore wind, can be a decisive enabler of the industrial transition effort. Creating demand for clean hydrogen at national level will also help ease the difficulties of evacuating the electricity produced by offshore wind farms to the shore and then further from the Dobrogea region. In addition, if Romania makes efficient use of the available EU financial instruments for clean energy development, it could even become a premier producer of clean hydrogen in SEE and even develop into a regional exporter.

The Dobrogea region in particular has all the prerequisites for hosting a pole for hydrogen development as it has both exceptional capacity to produce clean hydrogen (onshore and offshore renewable energy), and potential significant demand from existing refineries and steel making industry, use in district heating, decarbonizing port activities as well as naval transport.

4.3 Role of ports

While some of the components of an offshore wind farm may be manufactured inside or near the facility site, most of them are built onshore, shipped to a port and then to the site, generally requiring special vessels, as explained by IRENA (2018). Very large components, such as foundations, platforms or substations, are manufactured directly at the nearest port facility; even for maintenance operations, some components or even entire floating turbines are brought back to the port. Both the platform and the substation are too heavy to be transported by land, so the viable option is for it to be manufactured in the dock nearest to the planned site, then transferred to the offshore farm on completion. A port is a key asset as long as it can accommodate discharge and storage of turbine parts. Absent a well-equipped port within economic distance, large-scale projects, long-term operation and maintenance activity require construction of a new one.

This highlights the need for member states to encourage and support the modernisation of port facilities and infrastructure to host larger turbines, ramp up volumes, cater to operation and maintenance, develop training facilities, as well as decommissioning and centres for fixed and floating turbines. At the same time, ports will need expansion of premises, quay reinforcement, deep-sea harbour enhancement, and other civil works (WindEurope 2020b).

Programmes on certification and standardisation should be unitary and adopted by as many member states as possible, with the EU playing a coordination role. In fact, there is valuable know how to be built upon from the oil and gas companies regarding training and safety measures, as well as offshore operations more generally.

Ports are also important for integrating the energy output of offshore wind farms, either as direct energy consumers or by potentially becoming hubs for clean hydrogen based on offshore wind energy. The Port of Constanța can, therefore, expand its highly strategic position at the Black Sea and grow into a regional pole of decarbonisation, while providing the basis for offshore wind development in the entire Black Sea region. Encouragingly, the Port of Constanța is already exploring the possibility of playing a significant role in the energy transition, after it showed interest in becoming part of the EU Clean Hydrogen Alliance, which opens up the way for synergy with the growth of the offshore wind sector in the Black Sea.

4.4 Economic impact, job creation and development of new value chains

As indicated by WindEurope (2020b) report, the wind energy industry alone contributed more than €37 billion to the EU's GDP (about 0.26%), with almost €23 billion as direct contribution and more than €14 billion indirectly, from wind developers, turbine manufacturers, service providers etc, for both onshore and offshore activities. Per GW of installed wind power, onshore wind in Europe generates €2.5 billion of value added to the EU economy, while offshore creates €2.1 billion, meaning that every new offshore turbine installed is adding no less than €16 million to the EU economy. Wind turbine manufacturers and developers have the highest share of the contribution to the GDP, followed by manufacturers of parts and components, offshore substructures and service providers. In terms of indirect economic impact, the report also argues that every €1,000 of revenue in wind energy creates an additional €241 of economic activity in other sectors of the economy: electrical equipment, machinery, metals, construction works, telecommunications etc.

Further investments to boost industrialisation may be the key, considering that in the last five years the offshore wind sector has attracted average investments of ca. €11 billion a year, according to WindEurope (2020c), putting offshore wind at the forefront of renewable technology investments in the EU. Annual investments in offshore wind alone are expected to rise significantly starting with 2020 and reach close to €30 billion by 2030, more than double compared to onshore wind at that time.

In its latest report, WindEurope (2020b) highlights that wind energy alone was responsible for more than 300,000 jobs at EU level in 2019, with about 160,000 being direct jobs, and the rest indirect. Out of the total number of jobs, it is estimated that offshore wind covers around 25%, with 77,000 people involved in this subsector. However, as the EU countries are ramping up their efforts towards decarbonisation, it is estimated that the total number of offshore wind jobs could increase to as high as 200,000. The estimate of jobs created per GW of offshore wind developed in Europe reveals a total number of 5,677 direct jobs (2,049 in manufacturing, 1,875 in installation, 1,366 in foundations, 188 in planning and 198 in O&M), along with 5,780 indirect jobs, for a total of 11,457. Meanwhile, at global level, IRENA (2018) estimates that the wind industry sector can grow from 1.1 million jobs in 2017 to more than 2 million by 2050, noting that, in general, a 500 MW offshore wind farm requires approximately 2.1 million person-days of work.

A key question is how many of these jobs will Romania be able to create nationally, given that the process requires economic and industrial planning, long-term vision and significant political and administrative ambition. A closer look at the figures, however, raises doubts on the prospect for the jobs in manufacturing, considering that most of the offshore wind industrial value chain is still located in Western Europe. Nonetheless, a large share of the jobs required for the installation, foundation building, planning and O&M processes can be covered with national workforce.

In terms of manufacturing facilities, Romania is not hosting any turbine manufacturer yet, but as the dwindling technology cost puts pressure on the cost of labour in Western Europe, relocating part of the manufacturing chain towards the Eastern Europe becomes a solution. At the moment, Romania is only hosting manufacturing facilities for bearings and forgings, along with ones for generators and electrical control systems for turbines. However, on the O&M side, Romania can benefit from the experience of a wind turbine technician training centre in Constanța, that has been producing experts covering the needs of multiple regional markets and is already preparing offshore technicians.

Employment levels will also depend on the EU's ability to maintain a competitive wind energy supply chain in a context of international competition and cost reductions in other parts of the world. Education, skills and know how will play a central in role, since almost 82% of the professionals in the wind sector are qualified workers. With the considerable set of means provided by the EU, leading in technology development and solutions for system integration with large shares of wind energy, the job creation rate for wind energy across EU is poised to increase.

Especially in times of economic recovery, combined with a smart and targeted use of the available funding instruments, Romania can tap into the positive economic impact and job creation potential that offshore wind offers. Moreover, a target of the Romanian authorities should be to attract a significant share of the new value chains that are being unfolded in support of Europe's decarbonisation process and transition to a sustainable economy.

Apart from the wind industry's value chain, it is important to focus on hydrogen and batteries, since they can also create economic value and quality jobs, while aligning regional efforts with the European Green Deal. If Romania is able to attract at least part of the offshore wind value chain, the premises will be met for the country to benefit from part of the exports that the wind energy industry generates in the form of goods and services worth more than €8 billion annually.

5. Policy recommendations

Regulatory and investment frameworks

- Romania should include plans for developing offshore wind capacities in the NECP 2021-2030, as well as the National Energy Strategy for 2030 and 2050, with a clear set of measures in support of deployment, such as a long-term calendar for auctions and development of grid infrastructure, as well as the development of port facilities. The TSO's network development plans should also be updated to better account for the deployment of offshore wind capacities. For an efficient auction design, capable of producing competitive prices, the authorities should involve the stakeholders in a transparent and substantial consultation process.
- Offshore wind implies high upfront costs. A clear, stable, and predictable regulatory framework is vital to attract investment and scale up capacity. A competitive, auction-based CfD (*contract-for-difference*) mechanism is suitable for incentivising investments in RES and obtaining the lowest cost for consumers. It provides long-term price stabilisation, thus bringing down the cost of capital, while also protecting consumers from over-compensation of investments. In order to decrease the burden on final consumers a fund can be created, for example by using resources form the Modernisation Fund, to ensure a financial buffer for covering the price that needs to be paid to the developer when the prices they are obtaining on the market are too low. In such a way, the full burden of covering the CfD expenses is shifted away from the consumer, who would no longer have to bear the full price through electricity bills.
- To advance state interests and lower the risk of conflict between potential activities and policy priorities (shipping, military aspects, fishing, environmental and biodiversity impact, archaeological sites, as well as other facilities and economic activities), the government should prepare, with close and early involvement of the relevant stakeholders, the national Maritime Spatial Plan (MSP), as required under the MSP Directive.
- Any mapping of offshore wind perimeters, designs for offshore infrastructure and facilities, should be based on the MSP. This should also include a clear dimension of cross-border cooperation and coordination.
- Corporate PPAs, based on long-term bilateral contracts, are fundamental, as they decrease the investment risk and offer a revenue stream stabilization. While allowed under EU law (Regulation 943/2019), PPAs had been forbidden under Romanian law, a situation that changed only in May 2020, when the Government Emergency Ordinance 74/2020 allowed for PPAs to be concluded for new power generation capacities commissioned after June 1, 2020.
- An extended definition of *virtual power plants* (VPPs) needs to accommodate offshore wind capacities, too. This is required for reasons of market integration and efficiency gains, as well

as for improvements in system adequacy, since commercial synergies may also stabilise the physical power outputs at peaking load.

- The government should ensure *strategic coherence* in the use of upcoming EU funds, such as the new InvestEU programme, the Modernisation Fund, the national Recovery and Resilience Fund (RRF), Connecting Europe Facility, as well as private finance and funding from the development banks. The offshore wind sector needs an integrated approach to investment in wind farms and infrastructure, regulatory framework, and development of industrial value chains. This also needs to be coordinated with the development of storage and hydrogen technologies in the region.
- In particular, funds such as InvestEU, the Just Transition Fund, the Modernisation Fund, and certainly RRF are particularly well suited for investment in the requisite skilled workforce in the offshore wind sector, as well as for bolstering the institutional capacity in government, the energy regulator, TSO and other associated institution with key functional roles.

Technical and market integration

- Standards and procedures for network integration are needed, especially in conjunction with VPP development, in order to maximize the available generation potential and decrease network congestions.
- Offshore wind farms can bring benefits to Romania’s wholesale markets. To this purpose, equal access to competitive tenders for ancillary services should be granted, both for individual offshore producers and VPP associations.
- To ensure timely and cost-efficient development of the offshore grid infrastructure, the authorities should involve the wind park developers (WFDs) in building and possibly operating offshore connections. If built by the WFD, the latter is to be transferred either to an Offshore Transmission Owner (OFTO), as in the British model, or the TSO itself, against a transfer value settled though a competitive tender.
- The prospect to generate a significant amount of offshore wind power should become a cornerstone in Romania’s plans for clean hydrogen production, flexibility options, and sector coupling, given that Dobrogea is an ideal location for the development of such technologies.

Regional cooperation and integration

- There is an opportunity for cross-border maritime cooperation between Romania and Bulgaria. The two member states’ TSOs should cooperate on facilitating grid connectivity for cross-border hybrid offshore wind projects and allowing wind parks to feed into either power market. Such cooperation is also important in order for project operators to be able to deal optimally with wake effects.
- Increased electricity markets integration is needed between the two countries, but also within the region more generally. To this end, the regional DAM markets should become fully integrated – which is expected to happen by July 2021 – while Romanian and Bulgarian

electricity producers' ability to trade in neighbouring countries based on medium and long-term contracts should be unambiguously provided by national legislation.

- Given the higher wind resources in northern area of Romania's EEZ, Ukraine may also become a partner in developing joint projects. Cooperation with a non-member state in the EU's close neighbourhood may also benefit from additional support at EU level.
- Regional cooperation could prove valuable not only for wind farm development, but also for overcoming shortcomings of the power systems in the C&SEE: landlocked countries such as Hungary, Serbia or Moldova may also be able to benefit from the development of Romania's offshore wind, provided that adequate interconnections are in place. The upcoming review of the TEN-E Regulation offers an opportunity to address this issue. Regional coordination could be further pursued through other instruments, such as ENTSO-E's Ten-Year Network Development Plan (TYNDP) and the Regional Coordination Centres (RCCs) established by the recast Electricity Regulation. Moreover, regional cooperation platforms such as Central and South Eastern Europe Energy Connectivity (CESEC) and the Energy Community could provide a governance structure.
- Regional harmonisation of subsidies, auctioning and grid access may provide for the most-cost-effective offshore network design, avoiding duplication of spending and greatly reducing projects' uncertainty.

Annex

The wind dataset was downloaded from the ECMWF server in the form of a NetCDF file. First, the spatial data are used to generate wind maps showing the distribution of the mean wind speed for the full-time distribution (i.e. total time) and for the four seasons, respectively. Another important objective is to assess the performance of a state-of-the-art wind turbine (MHI Vestas V174 9.5) that seems to be suitable for the Black Sea wind conditions. To this purpose, for each reference point in Figure 1 a time series was processed – 84 time series in total – that was obtained from the interpolation of information available in the NetCDF file.

Next, the time series are used to determine the expected power output of this turbine type by using the following equation (Răileanu et al. 2019):

$$P = \int_{cut-in}^{cut-out} f(u)P(u)du, \tag{1}$$

where *P* is defined in MW; *f(u)*—Weibull probability density function; *P(u)*—power curve of a turbine*; cut-in* and *cut-out*—the turbine characteristics.

The Weibull PDF (probability density function), is defined as follows:

$$f(u) = \left(\frac{k}{c}\right)\left(\frac{u}{c}\right)^{k-1} exp\left[-\left(\frac{u}{c}\right)^{k}\right], \tag{2}$$

where *u*—wind speed; *k*—the shape parameter; *c*—the scale parameter (in m/s).

Once the expected power output is obtained for each individual point in the grid, some additional parameters, such as the capacity factor (C_f) or the Annual Electricity Production (AEP) can be estimated. According to Răileanu et al. (2019), the capacity factor is defined as:

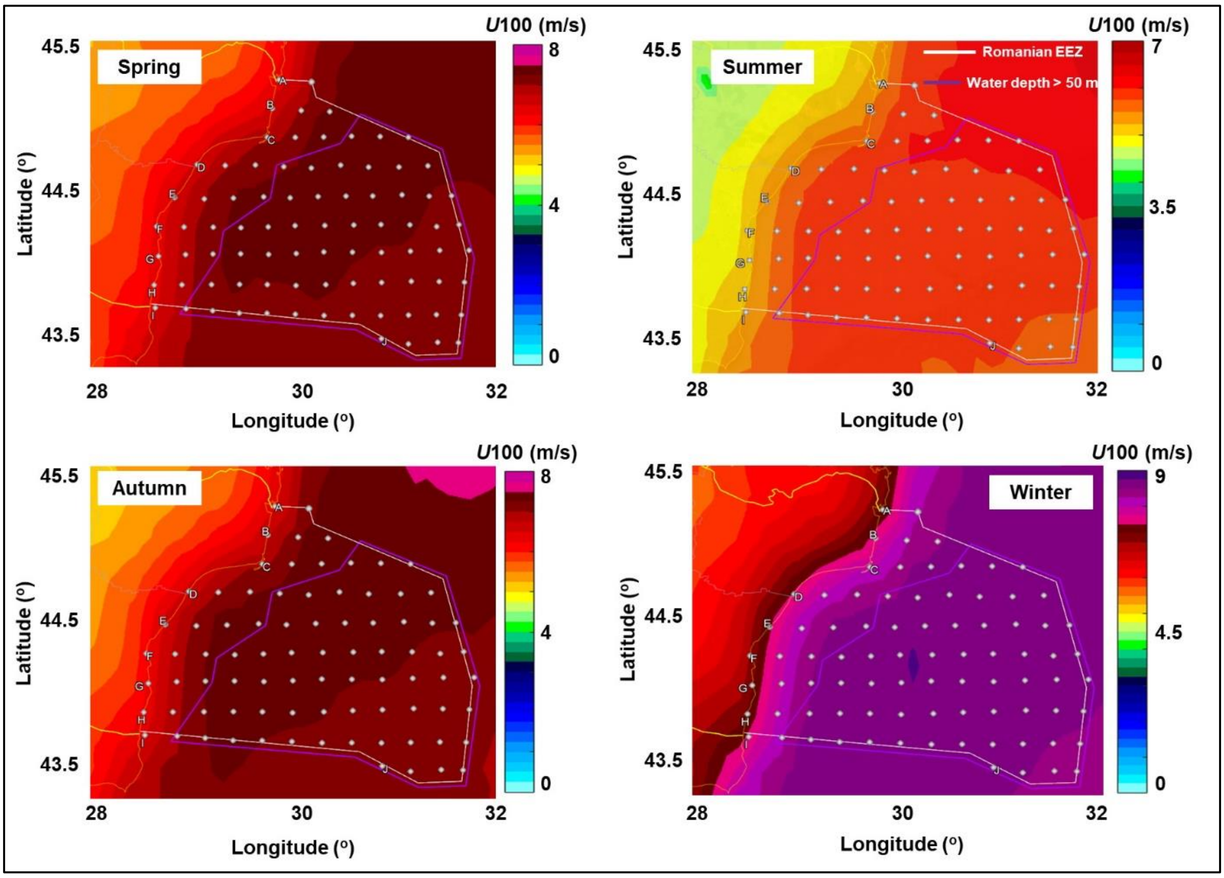
$$C_f = \frac{P_{turbine}}{Rated_{power}} \times 100, \tag{3}$$

where: $P_{turbine}$ is the electric power produced by each system, and $Rated_{power}$ is the rated power of a turbine (9.5 MW in this case). The AEP parameter is obtained by multiplying the power production (P in MW) with the average number of hours per year (8760 h/y), the final results being expressed in GWh. The results associated to this turbine will be represented as numerical values on the spatial maps that represent the Romanian EEZ and the two main water domains (<50 m and >50 m).

It is important to underline that the results are reported just for an individual wind turbine that may operate in a particular grid point (e.g., point A1 - 29.78° E/45.20° N; B1 - 29.65° E/45.01°N, etc). The idea was to screen this area in order to identify some hot spots in terms of the wind energy and for future analysis to consider some promising points, for which the time series can be evaluated in more details. Taking into account that the restricted areas associated to the

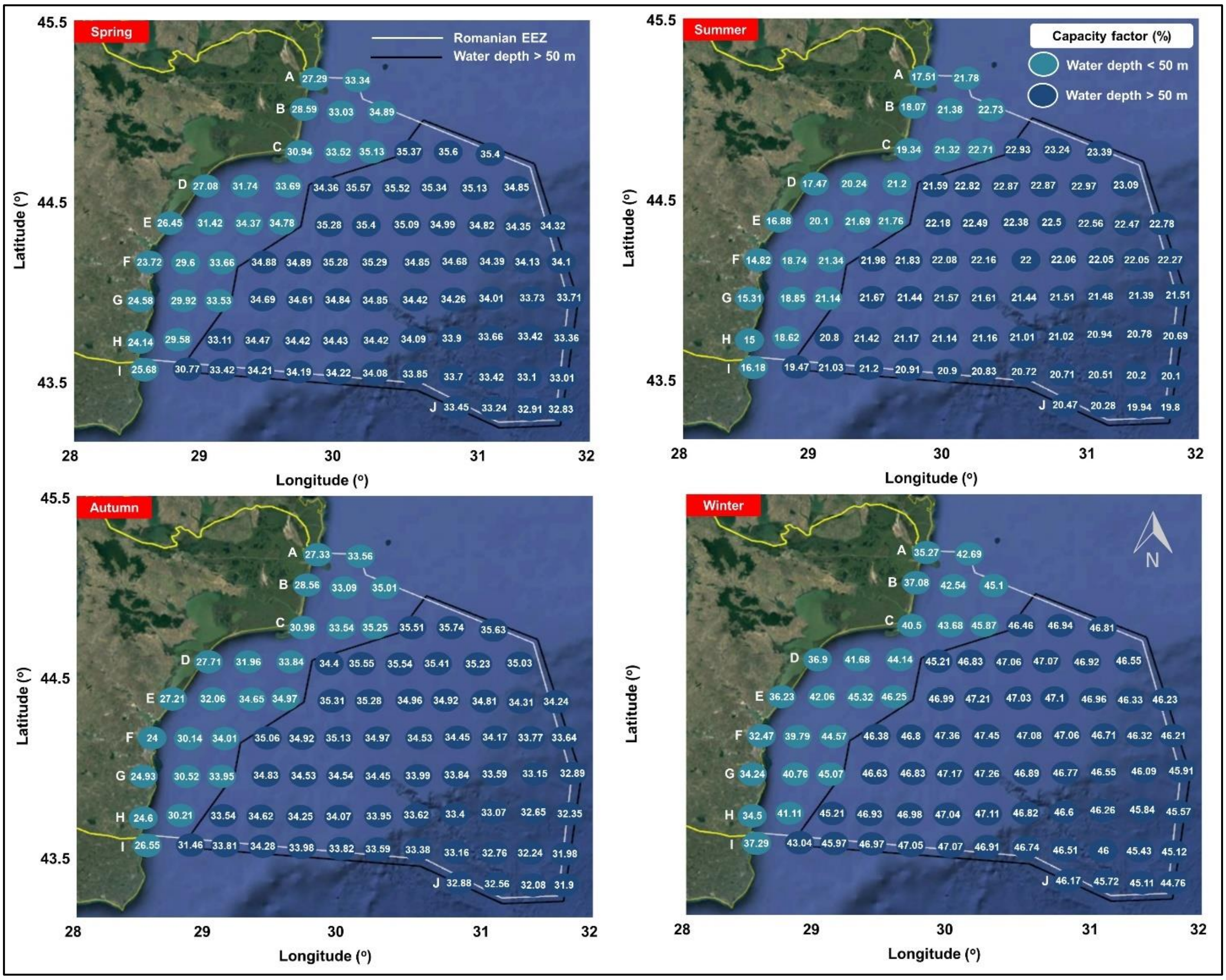
Romanian nearshore are not taken into account, an analysis of a wind farm configuration will be just speculative at this moment and definitely will require a more in-depth analysis.

Figure A1. The seasonal averaged wind speed as indicated by the ERA5 dataset for the Romanian EEZ over the time interval 2000-2019. From top to bottom the following seasons are presented: (a) spring – March-April-May; (b) summer – Jun-Jul-Aug; (c) autumn – Sept-Oct-Nov; (d) winter – Dec-Jan-Feb. In the background are represented the reference points considered for evaluation.



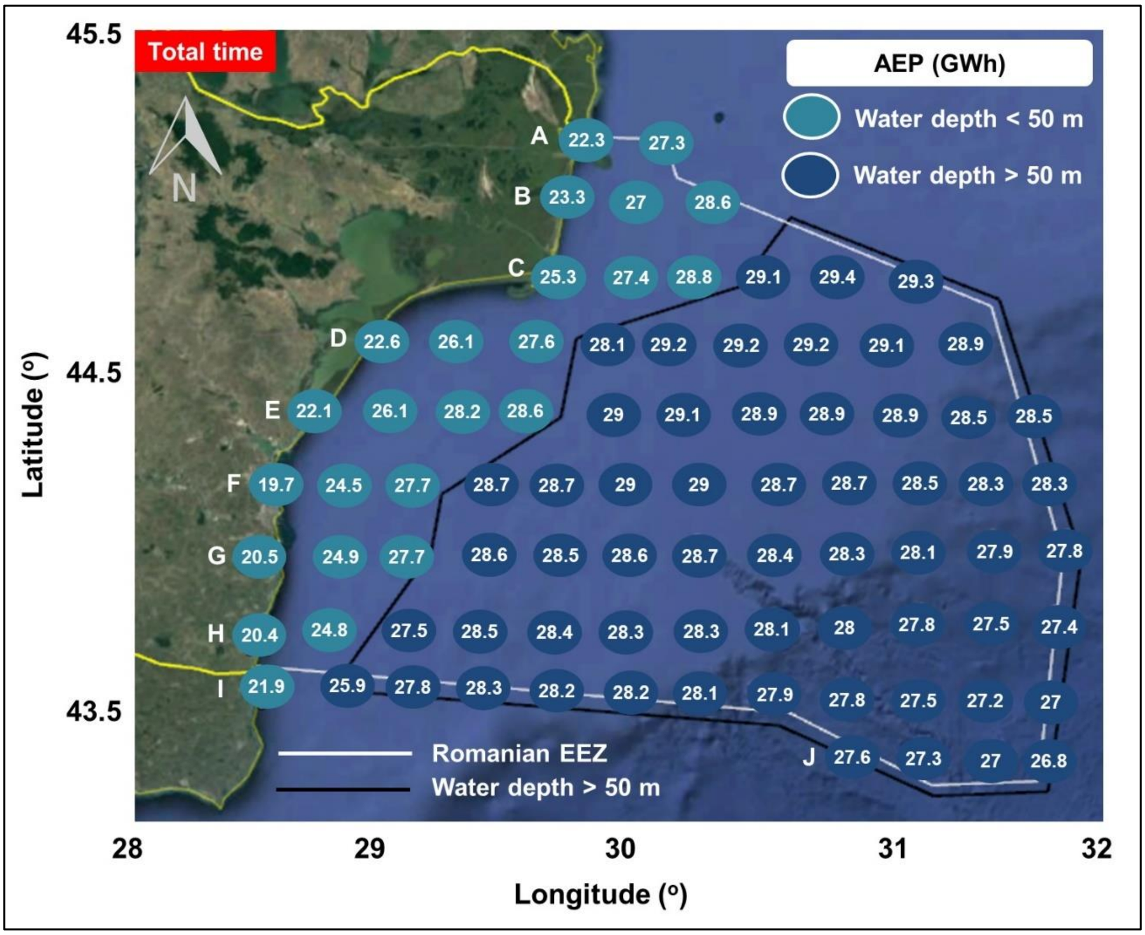
Source: Calculations based on ERA5 dataset for the Romanian EEZ, 2000-2019.

Figure A2. Seasonal distribution of the capacity factor (%) of the MHI Vestas V174 9.5 MW. The results (U100) are evaluated for the time interval 2000-2019 and correspond to: (a) spring; (b) summer; (c) autumn; (d) winter.



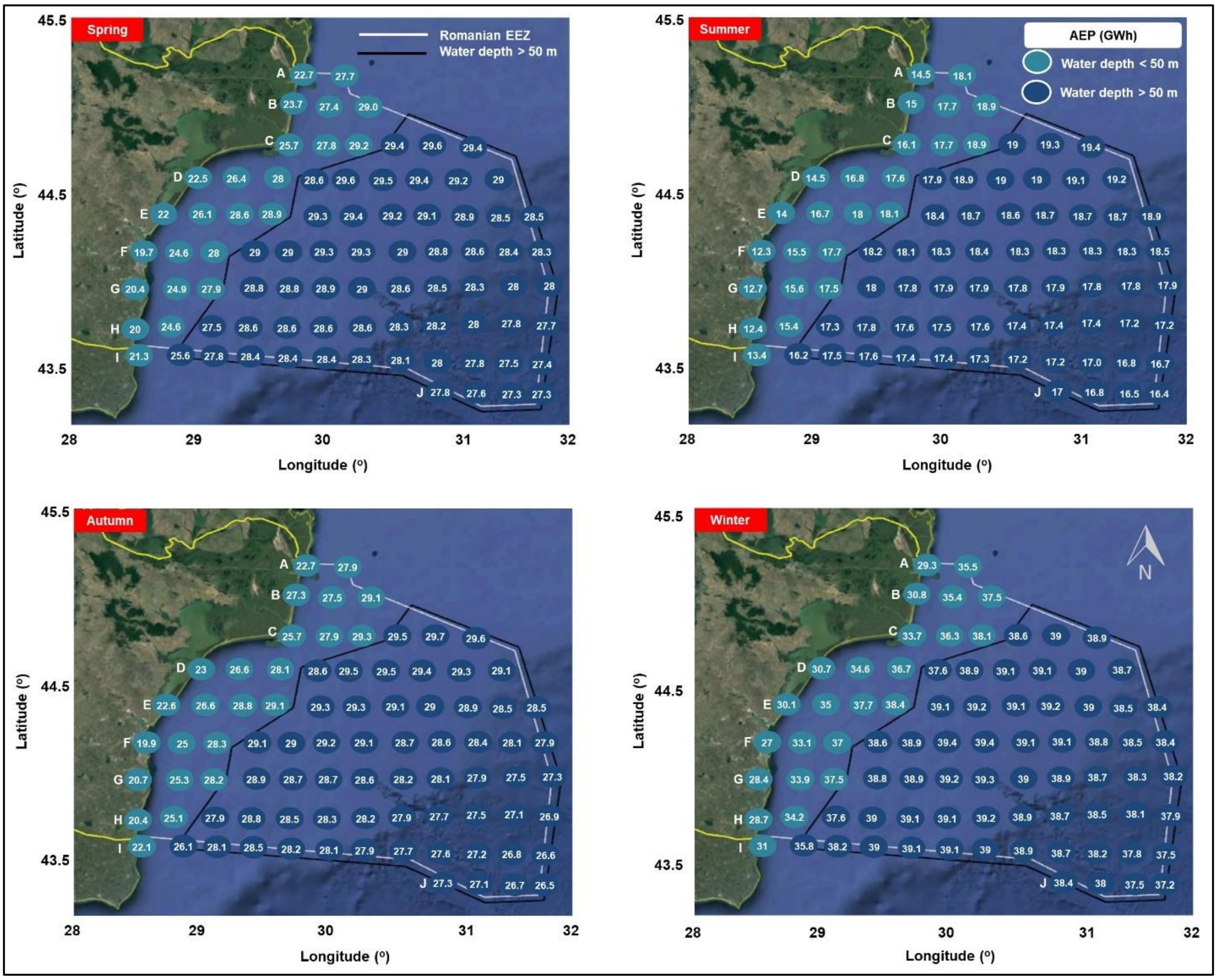
Source: Calculation by Dunărea de Jos University and EPG

Figure A3. MHI Vestas V174 9.5 MW – annual energy production computed for total time interval (U100).



Source: Calculation by Dunărea de Jos University and EPG

Figure A4. MHI Vestas V174 9.5 MW – seasonal distribution of the AEP values (U100).



Source: Calculation by Dunărea de Jos University and EPG

Abbreviations

4M	4M Market Coupling for electricity of Romania, Hungary, Slovakia and Czechia
AEP	Annual Electricity Production
ANRE	National Authority for Energy Regulation
CESEC	Central and South East European Energy Connectivity High Level Group
CEF	Connecting Europe Facility
DAM	Day-Ahead Market
EEZ	Exclusive Economic Zone
EPG	Energy Policy Group
HVDC	High Voltage Direct Current power line
IAV	Inter-Annual Variability index
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
JRC	Joint Research Centre, the European Commission's science and knowledge service
LCOE	Levelized Cost of Electricity
LTS	Long-Term Strategy – *A Clean Planet for All. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy* COM (2018) 773 final
MRC	Multi-Regional Coupling
MSP	Maritime Spatial Planning
NECP	National Energy-Climate Plan
OFTO	Offshore Transmission Owner
PCI	Project of Common Interest
PDRET	10-year Network Development Plan of Transelectrica S.A., the Romanian electricity TSO
PP	Power Plant
PPA	Power Purchase Agreement
RCC	Regional Coordination Centre
RED	Renewable Energy Directive (EU) 2018/2001
RES	Renewable Energy Sources

RRF	Recovery and Resilience Facility
SEA	Strategic Environmental Assessment
TEN-E	Trans-European Electricity Networks Regulation (EU) 347/2013
TSO	Transport System Operator
TYNDP	Ten-Year Development Plan, done by ENTSO-E and ENTSO-G, respectively
VPP	Virtual Power Plant
WFD	Wind Farm Developers

References

Agora Energiewende (2020), *Making the most of offshore wind. Re-evaluating the potential of offshore wind in the German North Sea* – Study by Technical University of Denmark and Max Planck Institute for Biochemistry, March 2020

Bathymetric Data Viewer, https://maps.ngdc.noaa.gov/viewers/bathymetry/ (accessed on June 17, 2020)

Dalla Longa, F., Kober, T., Badger, J., Volker, P., Hoyer-Klick, C., Hidalgo, I., Medarac, H., Nijs, W., Politis, S., Tarvydas, D. and Zucker, A. (2018), Wind potentials for EU and neighbouring countries: Input datasets for the JRC-EU-TIMES Model, EUR 29083 EN, Publications Office of the European Union, Luxembourg.

Deutsche Windguard (2018), Capacity Densities of European Offshore Wind Farms, https://vasab.org/wp-content/uploads/2018/06/BalticLINes_CapacityDensityStudy_June2018-1.pdf

Dimitrov, L. (2020), Bulgaria-Romania Day Ahead Power Market Coupling Due July 2021, Depends on ICP, ICIS, September 28, https://www.icis.com/explore/resources/news/2020/09/28/10557576/bulgaria-romania-day-ahead-power-market-coupling-due-july-2021-depends-on-icp

ERA5: How are the 100m winds calculated?, Copernicus User Support Forum – ECMWF Confluence Wiki, https://confluence.ecmwf.int/pages/viewpage.action?pageId=155343870 (accessed on Sep 30, 2020)

ESMAP (2019), Going Global: Expanding Offshore Wind to Emerging Markets. Washington, DC: World Bank, http://documents1.worldbank.org/curated/en/716891572457609829/pdf/Going-Global-Expanding-Offshore-Wind-To-Emerging-Markets.pdf

European Commission (2018b), European Commission: In-Depth Analysis in Support of the Commission Communication. A Clean Planet for All. A European Strategic Long-Term Vision for a Prosperous, Modern, Competitive and Climate Neutral Economy, COM(2018) 773

Evwind (2020), Wind power in the Canary Islands, Greenalia plans four offshore wind farms in Gran Canaria, September 24, https://www.evwind.es/2020/09/24/wind-power-in-the-canary-islands-greenalia-plans-four-offshore-wind-farms-in-gran-canaria/77340

Guillory, A. ERA5, https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era5 (accessed on May 31, 2019)

IEA (2019), Offshore Wind Outlook 2019, IEA, Paris https://www.iea.org/reports/offshore-wind-outlook-2019

IRENA (2018), Renewable energy benefits: leveraging local capacity for offshore wind

Navigant (2019), Gas for Climate. The optimal role for gas in a net-zero emissions energy system

NECP (2020), *Planul Național Integrat în domeniul Energiei și Schimbărilor Climatice* 2021-2030

Onea, F. and L. Rusu (2014), An Evaluation of the Wind Energy in the North-West of the Black Sea. *Int. J. Green Energy*, *11*, 465–487, doi:10.1080/15435075.2013.773513

Onea, F. and L. Rusu (2018), Evaluation of Some State-Of-The-Art Wind Technologies in the Nearshore of the Black Sea. *Energies*, *11*, 2452, doi:10.3390/en11092452

Onea, F. and L. Rusu (2019), A parallel evaluation of the wind and wave energy resources along the Latin American and European coastal environments. *Renewable Energy*, doi: 10.1016/j.renene.2019.05.117

Onea, F. and L. Rusu (2019), A Study on the Wind Energy Potential in the Romanian Coastal Environment. *Journal of Marine Science and Engineering*, *7*, 142, doi:10.3390/jmse7050142

Onea, F. and L. Rusu (2019), Long-Term Analysis of the Black Sea Weather Windows. *JMSE 7*, 303, doi:10.3390/jmse7090303

Platis, A., Siedersleben, S., Bange, J. et al. First in situ evidence of wakes in the far field behind offshore wind farms. Sci Rep 8, 2163 (2018). https://doi.org/10.1038/s41598-018-20389-y

Răileanu, A.B., F. Onea and E. Rusu (2020), Implementation of Offshore Wind Turbines to Reduce Air Pollution in Coastal Areas – A Case Study of Constanța Harbour in the Black Sea. *Journal of Marine Science and Engineering*, *8*, 550, doi:10.3390/jmse8080550

Transelectrica, *Planul de dezvoltare a RET 2020-2029*, August 2020

V174-9.5 MW Archives. *MHI Vestas Offshore*

WindEurope (2017a), Local impact, global leadership: The impact of wind energy on jobs and the EU Economy

WindEurope (2017b), Wind energy in Europe: Scenarios for 2030

WindEurope (2019), Our energy, our future, How offshore wind will help Europe go carbon-neutral

WindEurope (2020a), The EU Offshore Renewable Energy Strategy

WindEurope (2020b), Wind energy and economic recovery in Europe

WindEurope (2020c), Offshore wind in Europe – key trends and statistics 2019