CENTER FOR THE STUDY OF DEMOCRACY

Wind Power Generation in Bulgaria

Assessment of the Black Sea Offshore Potential

WIND POWER GENERATION IN BULGARIA

ASSESSMENT OF THE BLACK SEA OFFSHORE POTENTIAL

CENTER FOR THE STUDY OF DEMOCRACY

Power generation from offshore wind resources brings forward a significant potential for energy system decarbonization and regional economic growth through the establishment of supporting activities, green employment opportunities and the development of port infrastructure. Moreover, marine energy technologies complement the variable character of other renewables such as solar photovoltaics, onshore wind and hydropower making them suitable for providing steady baseload power. Yet, Bulgaria is the only EU country with access to sea, which has not tried to take advantage of this low-carbon and competitive form of energy.

This study assesses the technical and economic potential of the Bulgarian Exclusive Economic Zone in the Black Sea identifying favorable deployment areas for offshore wind power generation. The data demonstrates that 26 GW out of total 116 GW technically feasible capacity could be utilized in shallow waters by mature bottom-fix technology concept with capacity factors in the range of 40 – 48 per cent. Even if a fraction of this threshold could be harnessed, offshore wind could play a transformational role in meeting and exceeding the 2030 national renewable energy targets. It would contribute to the establishment of a regional value chain part of a completely new industrial profile for the country in line with the goals for a low-carbon Europe in the European Green Deal. Based on expert interviews and desk research, the study discusses the main obstacles to the utilization of offshore wind energy and formulates recommendations for future policy actions. The analysis touches upon important pre-conditions such as availability of supporting infrastructure, regional cooperation, and the coexistence between offshore wind energy and all the other ecological, economic, and societal interests.

Authors:
Mariya Trifonova, Research Fellow, Economic Program, Center for the Study of Democracy;
Assistant Professor at Sofia University "St. Kliment Ohridski"
Martin Vladimirov, Director, Energy and Climate Program, Center for the Study of Democracy

This study is financed by the European Climate Foundation (ECF) and implemented by the Center for the Study of Democracy (CSD). The sole responsibility for the publication lies with CSD and the content may not necessarily reflect the positions of ECF.

Cover photo: Pixabay

ISBN: 978-954-477-428-8

ACKNOWLEDGEMENTS

This publication is a product of the multi-disciplinary work of CSD's Energy and Climate team after extensive consultations with various national and international stakeholders. The assessment benefited from the advice and geospatial competence of Vladimir Krumov, expert in offshore wind resource assessment and siting. The legal aspects of the study have been consulted with Ventsislav Benov, lawyer and business development manager of Applied Research and Communications Fund.

Valuable input, support and comments were provided by national experts, business representatives, local administrations, academic and non-governmental organizations at an online roundtable debate organized in partnership with the Faculty of Economics and Business Administration of Sofia University in February 2021.

CSD highly values the recommendations and the expertise of WindEurope on the offshore wind energy infrastructure, technology trends and market developments presented by its chief executive officer Giles Dickson to the Bulgarian government in February 2021 and shared with CSD for this publication. The team appreciates insights and comments on the national renewable policy and market integration provided by Miglena Stoilova, chairwoman of the Bulgarian Wind Energy Association. The interviews with Boyan Savov, chief executive officer of B.V.S. Consult, allowed our team to gain additional insights into the Black Sea costal, as well as seabed specifics and navigation regulations in the Bulgarian maritime zone. Valuable support and inputs about the energy system technical capacity and needs for future development were provided by the experts of the Bulgarian Electricity System Operator. Potential synergies with the oil and gas activities in the Black Sea were recognized and discussed with the management team of Petroceltic Bulgaria. The examination of the environmental aspects accompanying the potential offshore wind deployment benefited from the profound expertise and publications of Irina Kostadinova, EU policy officer with the Bulgarian Society for the Protection of Birds and Pavel Zehtindjiev, professor in the Bulgarian Academy of Science. The main findings of the study were presented and discussed during a high-level online conference in September 2021 carried out in collaboration with the British Embassy in Bulgaria. CSD expresses its warm gratitude to Ambassador Rob Dixon and his team.

The techno-economic data gained during the extensive work on the study and the analyses of social, environmental, logistical and legal aspects of offshore wind energy development in the Black Sea served as a base for the preparation of an offshore wind demonstration project proposal for the National Recovery and Resilience Plan. CSD would like to thank the team of the Central Coordination Unit of the Council of Ministers and its Director Ivan Ivanov and the Head of Unit Strategic Planning and Programming Anton Gladnishki for their guidance in this effort.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

CAPEX	Capital Expenditure
CF	Capacity Factor
CSD	Center for the Study of Democracy
EEZ	Exclusive Economic Zone
EC	European Commission
EIA	Environmental Impact Assessment
EU	European Union
GIS	Geographic Information System
GW	Gigawatt
HVDC	High Voltage DC Cable
JRC	Joint Research Center of the European Commission
km	Kilometer(s)
LCOE	Levelized Cost of Electricity
m	Meter(s)
MW	Megawatt
MWh	Megawatt Hours
NECP	National Energy and Climate Plan
NMSP	National Maritime Spatial Plan
NRRP	National Recovery and Resilience Plan
NGO	Non-Governmental Organization
O&M	Operation & Maintenance Costs
OPEX	Operating Expenditure
R&D	Research and Development
SEA	Strategic Environmental Assessment
TSO	Transmission System Operator
TWh	Terawatt Hours
WACC	Weighted Average Capital Cost
‘000	Thousand(s)

EXECUTIVE SUMMARY

REPORT HIGHLIGHTS

- Bulgaria has unutilized technical offshore wind potential of 116 GW.
- 26 GW could be realized by mature bottom-fix technology.
- Capacity factors in the range of 40 – 48 % are achievable.
- The average cost for a unit of generated electricity from bottom-fix installations is estimated at EUR 62-90/MWh.
- The average cost for a unit of generated electricity from floating installations is estimated at EUR 120-158/MWh.
- The offshore energy industry could have a significant contribution for local communities in terms of highly-skilled job creation as well as for the formation of new technological clusters.
- The transformation of the two largest Bulgarian ports (Varna and Burgas) to decarbonization hubs would support offshore wind industry formation.
- Current national strategic document roadmaps fail to recognize the potential of Bulgarian maritime territories for the decarbonization of the energy sector.
- The lack of strategic orientation towards offshore wind energy development reflects on maritime spatial planning and grid development roadmaps.
- Infrastructural improvements as well as administrative and regulatory changes are necessary for opening the door for future investors in the offshore wind energy sector.
- Financial mechanisms of the European Green Deal offer timely opportunity for financing the pre-conditions of the formation of a regional offshore wind energy industry in Bulgaria.

A key medium-term pathway for the better integration of renewable energy sources in the electricity generation sector in Bulgaria is the development of the country's **significant wind potential** in line with policy priorities in Europe. Large-scale deployment of wind energy in the Bulgarian territorial waters of the Black Sea coast could contribute to the implementation of the country's main energy transition objectives. Offshore wind will stimulate **low-carbon economic development**, the uptake of competitive and secure energy and the reduction of the country's dependence on energy imports. This will help reduce carbon emissions from coal and natural gas-fired power plants and will also ease the burden of balancing the electricity system. Offshore wind power might improve energy security by **strengthening the balancing capacity of the electricity system**, especially during off-peak hours, and by reducing the need to use baseload generation that has a higher emission factor.

The current study assesses the technical offshore wind energy potential in the Bulgarian section of the Black Sea at roughly 116 GW. Around a fifth of this capacity or 26 GW could be realized by mature bottom-fix technology concept and the rest via floating power plants. Although offshore wind remains relatively more expensive than other conventional and renewable power plants, the study estimates the cost for unit of generated electricity for bottom-fix installations at EUR 62-90/MWh, which is likely to be **competitive at the average power market prices in the next 10 years**. In peak demand periods, electricity prices already exceed EUR 90/MWh and average yearly prices are expected to reach around EUR 70/MWh by 2025 if not earlier.

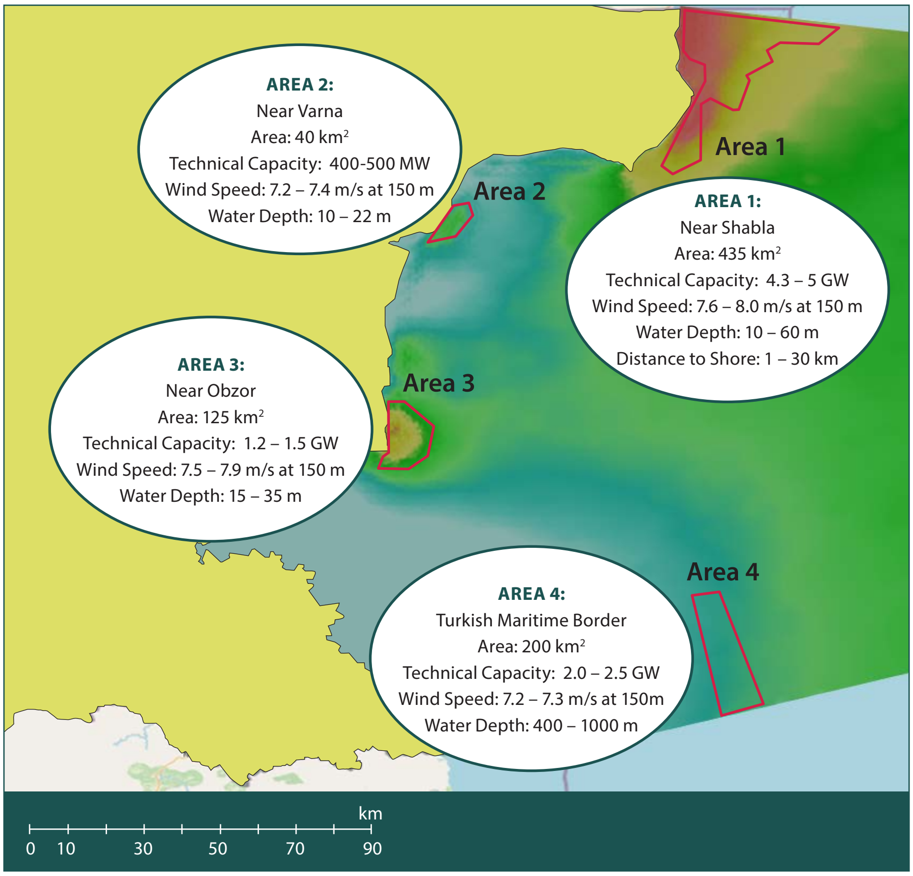
The study has **identified four areas as suitable for potential project development** of offshore wind energy in the Bulgarian Black Sea exclusive economic zone (EEZ):

- **Area 1:** Shabla/Romanian maritime border – close to the shoreline with a distance of up to 30 km to the coast of Shabla, a town and seaside resort in Northeastern Bulgaria. This Black Sea section is distinguished by the best wind resource and largest plot size (435 km^2) out of all four areas. Wind speeds hover between 7.6 and 8 m/s at a 150 m height.
- **Area 2:** Varna – the smallest area, only 40 km^2, but in the immediate proximity of the town of Varna, an important economic centre with two industrial zones, an airport, and a seaport. Because of the industrial power demand available near the area, offshore wind projects could be developed as part of a larger low-carbon industrial restructuring process. Although the initial technical potential has been calculated at 400-500 MW with wind speeds between 7.2 and 7.4 m/s, only a small fraction could be utilized due to the intense marine traffic in the area.
- **Area 3:** Obzor – located near the town of Obzor, which is about 30 km by sea to Burgas, the second largest town on the Black Sea coast in Bulgaria. The area is large, 125 km^2, suitable for fixed installations at water depth of 15-35 m. Based on wind speeds in the range of 7.5 and 7.9 m/s at 150 m, its technical capacity is assessed between 1.2 and 1.5 GW. Conflicts with current navigation routes reduce the technical potential of full deployment.
- **Area 4:** Turkish maritime border – it is far away from the shore located on the maritime border with Turkey. The main reason to pre-select this plot is its proximity to a planned high-voltage DC (HVDC) submarine cable connecting Romania and Turkey. The area itself occupies 200 km^2 up to 400-1000 m sea depth. The wind conditions are moderate with 7.2-7.3 m/s at 150 m height. It provides a potential opportunity for the development of floating-platform-based wind parks in the time horizon after 2030.

The deployment of offshore wind depends to a very high extent on the **availability of corresponding infrastructure**. Any potential new project would require connection to a high voltage transmission grid. According to this preliminary analysis, the national transmission grid has the available capacity to accommodate up to 4 GW in new energy projects in the region.

The financial mechanisms of the European Green Deal provide ample opportunities to finance new business strategies for the transformation of the two largest Bulgarian ports (Varna and Burgas) into **decarbonization hubs** based on offshore wind energy. Shipbuilding companies as well as industrial zones located near the harbors could benefit from low-carbon energy supply and later attract new renewable energy investors.

Pre-Selected Prospective Areas for the Deployment of the Offshore Wind Projects in Bulgaria



Source: *CSD.*

Despite the EU 2050 strategy and policy focus on offshore wind, the Bulgarian government has so far failed to develop an appropriate strategic, policy, regulatory and market framework for supporting offshore wind projects as part of the country's long-term energy documents. The utilization of the offshore wind energy potential outlined in this report and in the EU strategic outlook requires that Bulgarian policymakers implement a consistent and well-coordinated policy strategy and initiate a range of regulatory adjustments. The Bulgarian government should urgently **align the policy and regulatory framework to offshore wind development opportunities**, by addressing the unclear procedures for spatial planning, licensing, grid connection, subsequent decommissioning at the end of the facility's operational lifetime as well as the underwhelming economic incentives for potential investors. The adoption of specially designed and focused legislative and regulatory acts for offshore wind development following the example of Romania and Poland needs to be among the top priorities in the Bulgarian "Fit for 55" policy agenda.

INTRODUCTION

The development of a consistent, long-term **decarbonization strategy** in line with the European Green Deal has so far lacked political clarity and cohesion in Bulgaria. This has stalled efforts to promote the large-scale diffusion of renewables. Wind energy could play a major role for future energy system transformation in the country and the achievement of national **low-carbon energy** targets.

In 2021, Bulgaria has only 0.7 GW of installed **onshore** wind capacity. The National Energy and Climate Plan (NECP) foresees to raise it moderately to 0.89 GW by 2030.[1] **The NECP does not even consider any offshore wind additions**. The modelling assessment linked to the document envisions the addition of 3.35 GW of installed capacity in onshore wind parks until 2050. This is still **just** about 40 per cent of the full technical onshore wind potential estimated most recently by the Green X model**.**[2] The offshore potential in the exclusive economic zone of the Bulgarian Black Sea coast remains understudied, leaving **a critical gap in the country's long-term renewable energy strategy**.[3]

In November 2020, the European Commission unveiled the EU Strategy on Offshore Renewable Energy,[4] considered to be **one of the pillars of the European Green Deal**. The document sets high deployment ambitions estimating the potential of the European seas at 60 GW installed wind capacity by 2030 or five times higher than the currently realized projects. The total installed offshore wind capacity could reach 300 GW by 2050. These numbers suggest large volumes of low-carbon offshore electricity essential for the decarbonization of the European energy sector as well as a way to provide a variety of zero-carbon opportunities for industrial development.

The strategic document showcases a strong commitment for the development of the European marine energy sector and **recognizes the role of the Black Sea** with its natural potential for unlocking the enormous renewable energy potential in Southeast Europe. Concrete numbers and objectives are still missing in the EU prospects. Yet, these first steps in highlighting the Black Sea offshore wind potential offer direction for regional policy planning, for research activities, and for initial project opportunity screening in Bulgaria and Romania.

The World Bank assessed **the technically viable wind energy potential of the Black Sea** at 435 GW.[5] It reveals that 26 GW of offshore wind plants could be realized using a mix of fixed and floating platforms in the Bulgarian economic zone once the technology is cost-competitive and no physical constraints or

[1] Bulgarian Ministry of Energy, Ministry of Environment and Water, Integrated Energy and Climate Plan of the Republic of Bulgaria 2021–2030, 2020.

[2] Szabo, Laszlo et al., *SEERMAP Bulgaria country report*, September 2017.

[3] Ibid, the Green X model has provided a rough estimate for the offshore wind potential in Bulgaria of 1,2 GW without consideration of technical (power system) or water use limitations due to environmental restrictions.

[4] European Commission, EU strategy on offshore renewable energy, November 2020.

[5] World Bank, *Offshore Wind Energy Potential in the Black Sea*, Washington, D.C., March 2020.

logistical restrictions are in place. Indeed, seabed fixed wind power installations as mainstream technology could deliver **the cheapest electricity generation** as early as 2022.[6] Floating offshore wind turbines are still used only in pilot and demonstration projects[7] but due to continuous technology improvements and dynamic learning curves, offshore wind costs are declining at a fast pace and at greater magnitude.

The level of technology development determines the future tipping point at which marine energy would begin to attract the attention of investors and developers in Bulgaria as well. The World Bank assessment reveals that at the current stage just a few, small areas in the Northern part of the national sea shelf are feasible at sea depths of up to 50 m and locations close to the shore. Floating platforms could increase the average capacity factors[8] and improve access to additional wind resources at water depths exceeding 50 m. Different sources under varying assumptions evaluate **technical wind energy potential could go up** to as much as 62 GW.

This study aims to enrich the existing knowledge about offshore wind energy in Bulgaria by providing assessment of its technical and deployment potential considering nation-specific data. It seeks to identify key bottlenecks and recommends policy action for **tackling barriers before the future deployment of offshore wind** technology. The document consists of six sections (including the introduction) and appendixes. Section two describes the methodological approach applied and the complemented industry-average parameters which provide the base for the assessment. Section three justifies the selection of four potential deployment areas for which the technical and economic potential is evaluated based on public spatial and resource data and expert interviews with representatives of academia, national wind energy industry, regional and environmental NGOs as well as local planners. Expert consultations contributed to the identification of important challenges and hurdles which sections four and five address. Section six concludes the study with **a list of policy recommendations** meant to support a swift and sustainable development of offshore wind power in Bulgaria, in line with national renewable energy targets and the EU strategy.

---

6 World Bank, *Going Global: Expanding Offshore Wind To Emerging Markets*, Washington, D.C., November 2019.

7 IEA, *ETP Clean Energy Technology Guide*, 2020.

8 The capacity factor defines the ratio of an actual electrical energy output over a given period to the maximum possible electrical energy output under the assumption that the particular installation operates continuously at full capacity. The ratio provides a base for the calculation of the productivity of the potential offshore wind farms in the observed climate and geographic areas.

METHODOLOGICAL FRAMEWORK

Review of Existing Data and Assessments

The **technical potential** is the upper limit of the maximum power that can be generated in a certain region with a chosen technology and given land use. In this report it refers to all territorial waters within the exclusive economic zone of the Republic of Bulgaria. The technical potential does not consider economic feasibility considerations, conflicts of use or environmental regulations. Its main determinants in the case of offshore wind are wind speed, turbine height and water depth.[9] Only a portion of the technical potential will translate into actual investment projects in territories, where developers can obtain a consent to build. This is called **locational potential** and it represents areas of the seabed that are available and suitable for offshore wind development. The next step of the assessment would be to estimate the **economic potential,** identifying the available resources within the boundaries where offshore wind can be developed at a competitive cost. If additional regulations such as distance to shipping lines, gas and oil pipelines/platforms or submarine cables are considered, the assessment calculates the **actual deployment potential**. The latter is a small fraction of the overall technical potential.[10]

Table 1. Results and Assumptions of Previous Studies on Technical Wind Offshore Potential in Bulgaria

Source	Year	Assumptions	Fixed (GW)	Floating (GW)	Total Potential (GW)
World Bank[11]	2019	• Only selected areas considered • Water depth up to 50 m – fixed • Water depth up to 1000 m – floating • Distance from shore – up to 200 km • Wind speed at approx. 7 m/s	2	24	26
JRC, ENSPRESO Database[12]	2019	• Low restrictions • Sea depth up to 60 m – fixed • Water depth up to 1000 m – floating • Capacity Factor > 25%	24.4	38.4	62.8
Bulgarian NECP[13]	No prospects for development, no potential estimated				
GREEN-X Model	1.2 GW in fixed-platform offshore wind potential based on GIS modelling without consideration of technical (power system) constraints but with sea use limitations				

9 Additional assumed restrictions on water use could lead to large variations in the technical potential.

10 World Bank, *Going Global: Expanding Offshore Wind to Emerging Markets*, Washington, D.C., November 2019.

11 World Bank, *Offshore Wind Energy Potential in the Black* Sea, Washington, D.C., March 2020.

12 Ruiz Castello, P. et al., "ENSPRESO – an open, EU-28 wide, transparent and coherent database of wind, solar and biomass energy potentials," in *Energy Strategy Reviews*, Vol. 26 (2019) 100379, ISSN 2211-467X (online), JRC112858.

13 Bulgarian Ministry of Energy, Ministry of Environment and Water, Integrated Energy and Climate Plan of the Republic of Bulgaria 2021–2030, 2020.

Table 1 summarizes the results and the underlying assumptions found in the available studies on the offshore wind energy potential of Bulgaria, namely the Joint Research Centre (JRC) database ENSPRESO, the offshore wind map of the World Bank and the GREEN-X GIS based model.

Estimates of the Technical Potential

So far, **a full feasibility study** of the Black Sea's offshore wind potential for Bulgaria based on variable air density as a function of temperature, pressure or water content has not been done. While the North and the West of the Black Sea have been evaluated to have the strongest wind potential, new studies[14] concluded that location selection criteria other than wind speed must be considered for successful utilization of wind power potential. This section builds upon existing research considering public climate and spatial data as well as the knowledge of local experts in order to analyze economic feasibility of offshore projects in Bulgaria. Potential technical, economic and regulatory obstacles are subsequently discussed.

The methodological approach adopted by the study corresponds to the one described by Breiter et all.[15] First, the entire geographic area within the Bulgarian EEZ boundaries is measured using GIS/ Global Wind Atlas.[16] The following technology exclusion filters are applied on the **estimated gross potential resource:**[17]

1. Exclusion of areas with wind speeds less than 7 m/s measured at 150 m. Both previous studies assumed a 100 m turbine height and correspondingly cut off larger areas where the minimum of 7 m/s wind speed is not present and net capacity factors higher than 30 per cent cannot be achieved. Considering the technology development trend, a turbine height of 150 m is suitable in this assessment.
2. Fixed foundation offshore wind is considered technically viable where there are average wind speeds of more than 7 m/s and water depths less than 60 m.[18]
3. Floating wind energy is considered viable where there are wind speeds of over 7 m/s and water depths – between 60 m and 1,000 m.
4. Zones without 150 km from the shore are excluded based on average distance to the coast of installations put into operation in the last 20 years.[19]

---

[14] Agrin, M., and Yerci, V., "Offshore wind power potential of the Black Sea region in Turkey," in *International Journal of Green Energy*, vol. 14, issue 10, 2017, pp. 811-818.

[15] Beiter, P. et al., *Terminology Guideline for Classifying Offshore Wind Energy Resources* (Technical Report), 2016, NREL/TP-6A20-65431.

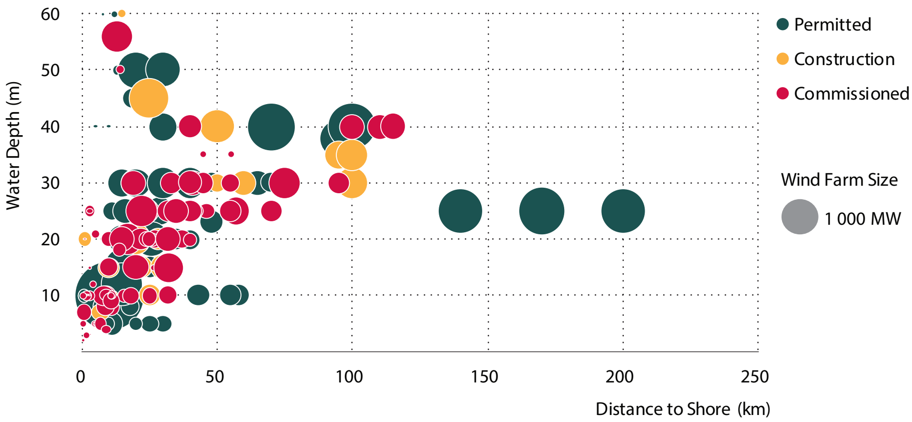
[16] Global Wind Atlas 3.0, a free, web-based application developed, owned and operated by the Technical University of Denmark (DTU). The Global Wind Atlas 3.0 is released in partnership with the World Bank Group, utilizing data provided by Vortex, using funding provided by the Energy Sector Management Assistance Program (ESMAP).

[17] Gross resource potential refers to the total recoverable resource potential within the boundaries of the Bulgarian EEZ without considering environmental, logistical and technology limitations as well as conflicts with other maritime activities.

[18] IEA, *ETP Clean Energy Technology Guide*, 2020.

[19] Fraunhofer IEE, Windmonitor, Online database, 2020.

Figure 1. New Turbine Installation by Average Distance from Coast



Source: *IEA (2019).*

Further **restrictions** are applied on the resulting geographic area due to conflicting use, such as:

- Restrictions due to **security and logistical issues**: Some areas need to be excluded because they comprise national marine sanctuaries, marine protected areas, shipping and towing lanes, subsea cables, as well as offshore platforms and pipelines. The study has assessed existing navigation charts[20] to exclude areas with military bases, heavy marine traffic due to a proximity to shipping lanes, offshore platforms, and pipelines.[21] According to the national maritime spatial planning navigation routes are subject to future relocation, however, their area size is assumed to remain the same which would not impact the assessment.
- Restriction due to **environmental protection:** The total protected area of the Bulgarian maritime territory is 2477 km^2.[22] Over 80 per cent of the extra-settling areas along the coastline are also under environmental protection. Furthermore, it is highly likely that the selected areas will be located on the path of migratory birds or to represent wildlife refuges, which might require a detailed biodiversity impact assessment, as well as the installation of radar devices that will alert the plant operator of incoming bird flocks. Nevertheless, wind risk assessment maps are not existent for the Bulgarian maritime territories, thus limitation have been applied on the **technical offshore resource capacity'** calculations only considering Natura 2000 protected zones.[23]
- Finally, any potential offshore wind areas need to be reduced following the conducting of a study of the seabed for the **presence of man-made objects** such as undersea cables, pipelines or the existence of archeological artefacts and coral reefs (e.g. mussel colonies in the case of the Black Sea).

[20] Screenshots of Navionics electronic charts, based on official data as well as on other sources, have been used as layers for the creation of the maps under Appendix III and IV. The obtained maps are not for navigation purposes. For more information visit Navionics.

[21] In general, offshore wind platforms could be situated close to marine navigation routes with at least 500 m of separation.

[22] Bulgarian Ministry of Environment and Water, General information about Natura 2000 Network, 2021.

[23] The electronic charts of Natura 2000 Network Viewer by the European Environment Agency have been obtained for the localization of zones protected under Natura 2000.

T**he technical offshore wind resource capacity** is calculated as function of the restricted area, wind turbine density and turbine's nominal power generation capacity. Optimum spacing will vary with atmospheric conditions. For projects realized in European seas, capacity density is highly dependent on policy frameworks and offshore regulations, space resource and wind speed. For recently built turbines it varies within the band 10-15 MW. Considering nominal density averages of wind farms commissioned after 2015[24], this study assumes nominal array power density equal to 10 MW/ km^2 in further calculations. **Table 2** outlines total technical offshore wind resource capacity in the Bulgarian EEZ, while section 3 of the document investigates in more detail suitable areas for its utilization.

Table 2. Technical Offshore Resource Capacity in the Bulgarian EEZ

	Limitations	Wind speed > 7 m/s at 100 m	Wind speed > 7 m/s at 150 m
Bottom-fix and floating platforms	Military bases, shipping lanes and areas at water depth > 1000 m	77.5 GW	116 GW
Only bottom-fix platforms	Military bases, shipping lanes and areas at water depth between 10 m and 60 m		26 GW

Source: *CSD.*

Input Parameters for the Economic Feasibility Assessment

Based on international benchmarks for offshore wind capital expenditures, this assessment aims to provide an approximate estimate for the levelized cost of electricity (LCOE) and the size of the total investment considering the above-calculated potential. The analysis includes a general discussion of feasible technological solutions, and their potential costs.

Offshore wind capital investment expenditures (CAPEX) include project management, development and engineering expenditure, environmental, social, and coastal impact assessments, seabed surveys, technology equipment and installations, balance of plant components and (de)commissioning.

The wind turbines represent the most essential component of the technical equipment with a one-third share of the CAPEX. Early offshore installations used turbines that had been adopted from the onshore wind energy sector. Starting from turbines of 0.45 MW demonstrated at the first offshore wind park Vindeby[25], today's standards suggest 10 MW and even more powerful turbines specially designed for offshore deployment. Dominant market manufacturers are currently offering turbines with rated power over 10 MW with the first turbines at this capacity expected to become operational in 2022.[26]

---

[24] Deutsche WindGuard, *Capacity Densities of European Offshore Wind Farms*, March 2018.

[25] Offshore Windfarm at Vindeby: Cordis Fact Sheet.

[26] IRENA, *Offshore renewables. An action agenda for deployment offshore. A contribution to the G20 presidency*, 2021, p. 31.

The capital investment expenditures have increased from EUR 2 200/kW in 2007 to EUR 2 490/kW in 2008 and even reach EUR 4 500/kW in 2015. Since then, the costs have been falling but remain high. The main driver of the higher CAPEX levels is the inflated cost of new generation offshore wind turbines. At the same time, with expanding deployment in the European seas, wind farms growing in size and moving further from shore, site investigation is becoming more cost-intensive and access to promising locations more difficult. With technology evolution, the average water depth has also increased from below 10 m to almost 35 m in the past 15 years, as has the distance to the shore surpassed 60 km for newly developed offshore wind farms. The emergence of the floating technology raises the expectation that deployment sites further off the coastline are becoming economically viable.

The table below represents comparison of **CAPEX values for offshore wind farms** (both fixed and floating) as of 2019/2020 according to different source and future projections.

Table 3. CAPEX Variations and Future Projections (Euro/kW)

CAPEX	2019/2020	2030	2050
IRENA (2019), 5th percentile	2450		
IRENA (2019), average	3230		
IRENA (2019), 95th percentile	5080		
Lazard, 2020, low case	2210		
Lazard, 2020, midpoint	3124		
Assumption for EU installations, "A Clean Planet for All”		2048	1929

Source: *FSR (2020).*[27]

The CAPEX of floating offshore farms could be estimated to be more than double the amount necessary for fixed foundations. However, the technology is developing quickly, and costs are falling with 7 pre-commercial projects (147 MW in total) commissioned in Europe by the end of 2020, and 6 (217 MW) announced and planned by the end of 2022. In sum, by the end of 2022 there will be 300 MW of floating offshore capacity operational. France and Norway are also developing larger projects. Together with the investment intentions of Spain and the UK, 7 GW of floating offshore wind capacity is expected to be online in Europe by 2030.[28]

Operation & Maintenance costs (O&M) are those occurring throughout the lifetime[29] of the turbine. Port activities and license fees could also be incorporated in the annual O&M costs covering regular annual maintenance visits and remote monitoring, repairs, administration and other back-office tasks.

---

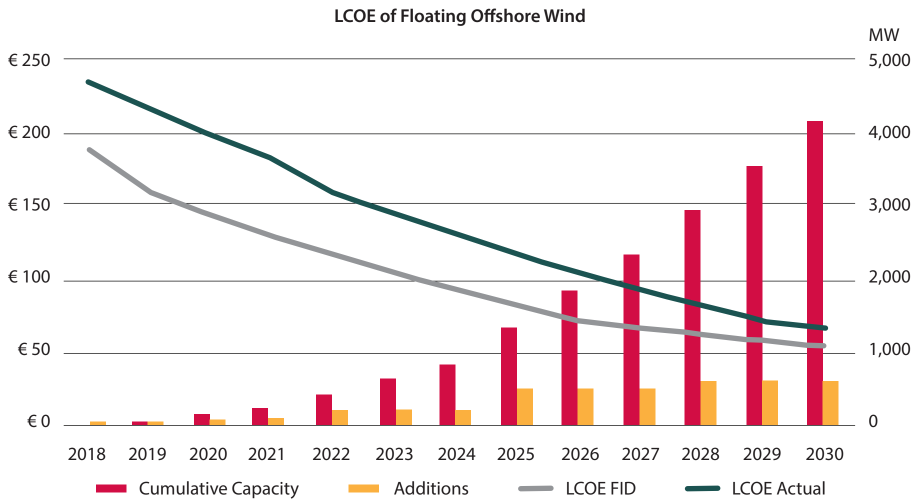
27 Piebalgs, A. et al., *Cost-Effective Decarbonisation Study* (Research Report), European University Institute, November 2020.

28 WindEurope, *Offshore wind in Europe – key trends and statistics 2020*, 2021.

29 The lifetime of offshore wind farms is usually considered in investment calculation 20 years for early projects, increasing to 30 years recently due to the technology development.

O&M costs could be estimated at EUR 15 – 33/MWh with an average of EUR 20/MWh in early UK farms. Higher levels of O&M costs are associated with the increased costs of getting access to the turbines and maintaining the necessary port logistical infrastructure.[30] Therefore, companies are working specifically on wind farm designs that aim to reduce maintenance requirements given the relatively high cost of marine access. Usually, large modern wind turbines enable lower O&M which vary with the number of turbines and in general decline over the years of operation.[31]

Figure 2. Floating Wind Energy Cost Reduction Pathways



Source: *WindEurope (2018).*

The levelized cost of electricity (LCOE) is calculated as the cost of unit energy generated by the wind farm during its lifetime. LCOE for fixed-platform wind parks varies significantly across Europe, but generally falls within the range of EUR 50-75/MWh.[32] LCOEs of the European pre-commercial floating wind projects indicate values of EUR 180-200/MWh.[33] These values are projected to decline to EUR 80-100/MWh when commercial projects utilizing proven technologies emerge in 2023-2025 and might further **decrease to under EUR 60/MWh by 2030** as the technology matures. On the basis of the rapid development, leading offshore wind energy developers are confident they can bring down the cost even further to between EUR 40/MWh and EUR 60/MWh by 2030. In the long run, floating concepts might prove to be more cost advantageous because of the savings potential embedded in the installation process. The easier assembly of floating wind structures significantly reduces the need for operational handling at sea and the use of costly large jack-up and installation vessels. The time required for installation along with the vessel type hired are a key cost driver in offshore projects.

[30] Arántegui, R.L., *Wind Energy Technology Development Report 2018*, EUR 29914 EN, European Commission, Luxemburg, 2019, ISBN 978-92-76-12536-5, doi:10.2760/073032, JRC118315.

[31] Peak Wind, *OPEX Benchmark – An insight into operational expenditures of European offshore wind farms*, 2019.

[32] BVGAssociates, Wind farm cost, 2020.

[33] WindEurope, *Floating offshore wind energy: A policy blueprint for Europe*, 2018.

ASSESSMENT OF THE OFFSHORE WIND DEPLOYMENT POTENTIAL IN BULGARIA

The current study has identified **four areas in the Bulgarian Black Sea EEZ** (**Figure 3**) as suitable for potential project development based on the technical and economic criteria described in the section above. The following **criteria** have been relevant **for the pre-selection**:[34]

- the wind resource metrics and water depths;
- distance to shore (particularly availability of harbors and electrical substations);
- avoidance of dense navigation routes;
- avoidance of possible environmental restrictions (e.g., Natura 2000) and conflicts with maritime bases for other economic purposes.

For each area capacity factors are calculated based on the wind resource and the technical assumptions, explained in Section 2. The table in *Appendix V* provides an overview of the size of the pre-selected areas before and after the application of restrictions according to the selection criteria.

Area 1: Shabla/ Romanian maritime border

Area 1 is located in the Northern-most part of the Bulgarian EEZ along the border line with the Romanian territorial waters. It is close to the shoreline with a distance of up to 30 km to the coast of Shabla, a town and seaside resort in Northeastern Bulgaria.[35] This Black Sea section possesses **the best wind resource and the largest plot size (435 km^2)** of all four options. Wind speeds hover between 7.6 and 8 m/s at a 150 m height. The deepest part of the area is 60 m, but most of it is under 50 m depth. Therefore, the installation of fixed platforms will be viable also considering the reduction of technological costs.

As evident on the corresponding map in *Appendix II: Water Depths at the Pre-selected Areas*, the area could be separated as follows:

- Section 1, under 40 m water depth, covering 96 km^2, with estimated technical potential of 1 GW
- Section 2 40 – 50 m water depth, covering 190 km^2, with estimated technical potential of 1.9 GW
- Section 3 is above 60 m water depth, covering 149 km^2, resulting in additional 1.4 GW estimated technical potential.

The **total technical offshore wind resource capacity** of Area 1 is calculated **in the range of 4.3-5 GW**. Accounting for known restrictions due to navigation routes and submarine cables as shown in *Appendix III: Navigation Routes and Submarine Infrastructure at the Pre-selected Areas*, the area is redefined and reduced to 420 km^2 keeping its technical capacity above 4 GW (Area 1 B). The

---

34 The pre-selection does not substitute professional site investigation methods and does not exclude other possible sites.

35 The Northeastern region of the country is characterized by the best onshore wind potential. 17 onshore wind power plants with total capacity of 40 MW are already operational in the municipality of Shabla alone. Considering the neighboring municipalities of Balchik and Kavarna 460 MW of wind power (or 2/3 of the Bulgarian total installed wind capacity) are connected to the national grid.

western part of the pre-selected Area 1 located close to the shore is in conflict with small portion of sites which are protected under the Habitats Directive[36] and Birds Directive[37].[38] The overlapping territories are marked in *Appendix IV*. After their exclusion, the deployment potential of Area 1 results in the size of 405 km^2 (Area 1 C). The gross capacity factor is estimated at between 45-48 per cent.

Area 2: Varna

Area 2 is **the smallest option, only 40 km^2**, but it is in the immediate proximity of the town of Varna, the third largest in Bulgaria with a population of almost 400,000. It is an important economic center with two industrial zones, an airport and a seaport, operating facilities for public transport of national importance. Because of **the industrial power demand** available near the site, the area is considered important for further investigation as offshore wind projects could be developed as part of a larger industrial restructuring project that involves large private industrial producers investing in electricity generation capacity for self-consumption.

This offshore area is surrounded by shallow waters with depths of 10-22 m. Although the initial technical potential has been calculated at 400-500 MW with wind speeds between 7.2 – 7.4 m/s, only a small fraction could be utilized due to the intense marine traffic in the area. Taking into account currently indicated navigation routes, the territorial scope is reduced to 26 km^2 resulting in **technical capacity of 250-300 MW**. The gross capacity factor is estimated at 40 per cent.

Area 3: Obzor

Area 3 is located near Obzor, which is about 30 km by sea to Burgas, the second largest town on the Black Sea in Bulgaria. **Burgas** is also **the first municipality in the country that has set its own renewable energy target** of 32 per cent by 2030. The area is large, 125 km^2, suitable for fixed installations at water depth of 15-35 m. Based on wind speeds in the range of 7.5-7.9 m/s at 150 m, the **technical capacity is assessed between 1.2-1.5 GW**. However, the identified area conflicts with current navigation routes and the technical potential cannot be deployed in full under the provisions in place. Coordination and consultation with maritime authorities is needed to explore options for deconflicting potential projects with marine traffic routes. The relatively flexible rules for the distance between shipping routes and offshore wind farms (around 500 m) could enable the utilization of part of the area. However, the existence of sites[39] protected under Natura 2000 Regulations could potentially further limit it, which requires planners and potential developers to undertake more exact micro-siting. Possible Gross Capacity factor for Area 3 is 44-45 per cent.

---

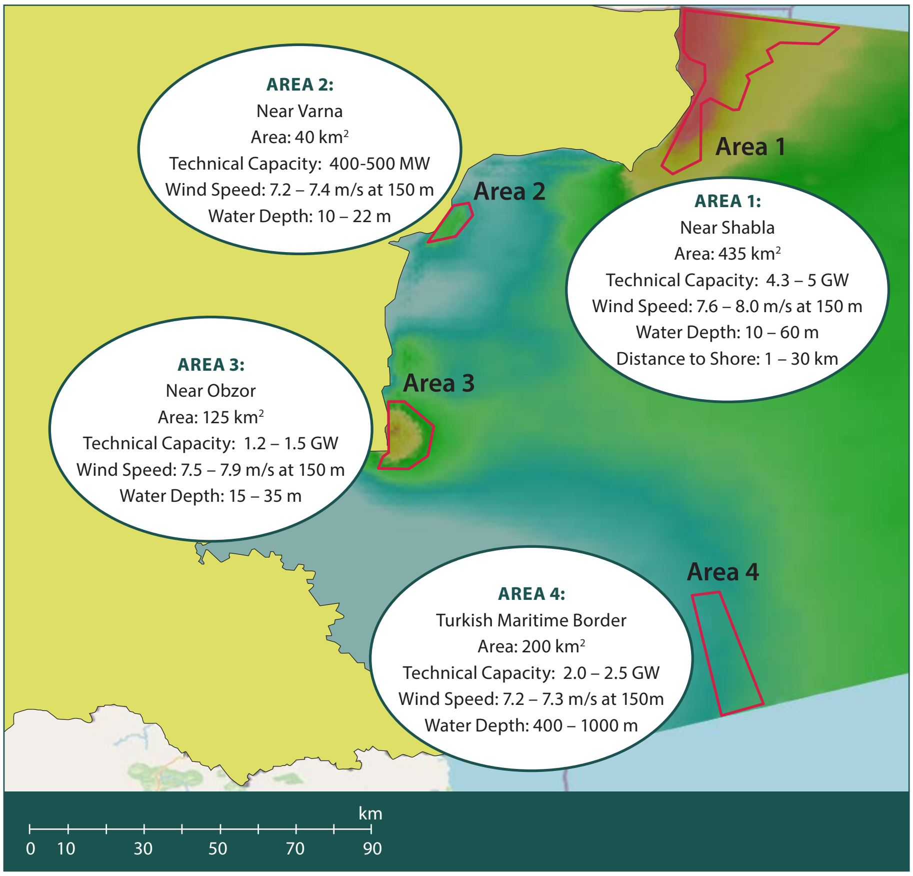
[36] EUR-lex, Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.

[37] EUR-lex, Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds.

[38] The two environmental protected sites which Area 1 comes in conflict with are Kaliakra Complex (Birds Directive Code BG0002051, Habitats Directive Code BG0000573) and Ezero Durankulak (Habitats Directive Code BG0000154).

[39] Site Kamchiyska planina with Birds Directive Code BG0002044, sites Emona and Emine-Irakli with Habitats Directive Codes respectively BG0001501 and BG0001004.

Figure 3. Pre-Selected Prospective Areas for the Deployment of the Offshore Wind Potential in Bulgaria



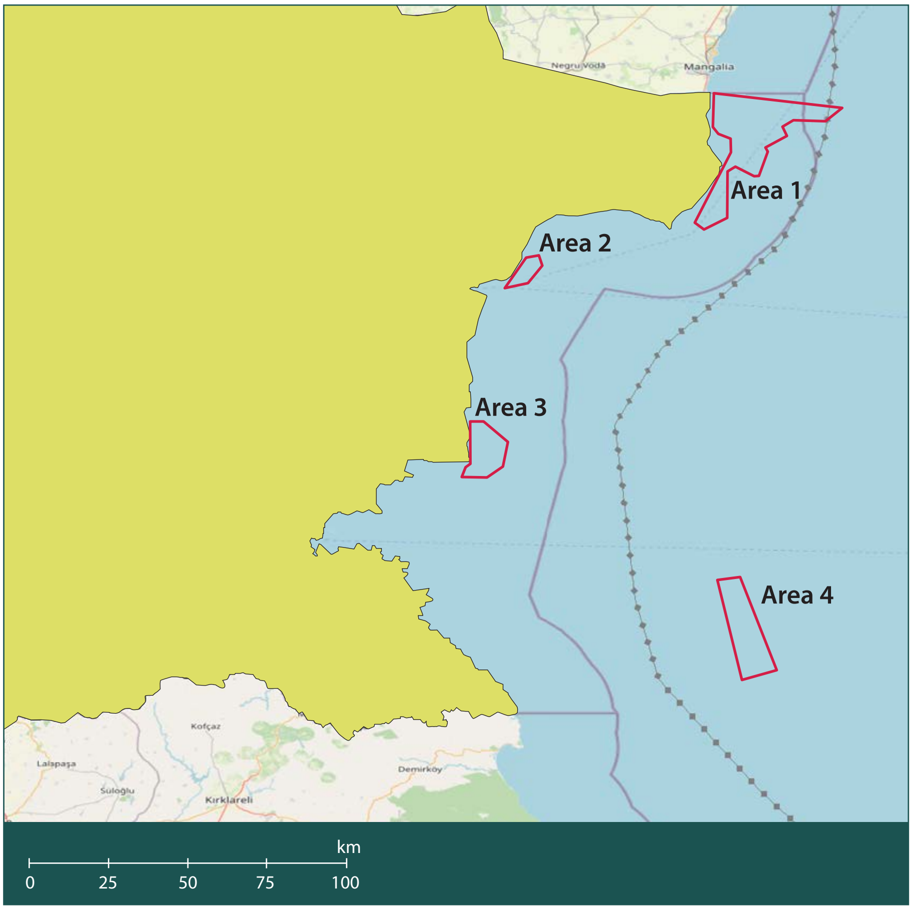
Source: *CSD based on Global Wind Atlas data.*[40]

Area 4: Turkish maritime border

Area 4 is far away from the shore located on the maritime border with Turkey. The main reason to pre-select this plot is its **proximity to a planned high-voltage DC** (HVDC) **submarine cable** connecting Romania and Turkey. The development of deep offshore wind energy in the Black Sea would require the corresponding infrastructure. The exact distance between Area 4 and the location of the prospective undersea cable is 20 km. The area itself occupies 200 km^2 at 400-1000 m sea depth. The wind conditions are moderate with 7.2-7.3 m/s at 150 m height. From the current technological and cost framework, the area is not highly attractive. However, it is a **potential opportunity for the development of floating-platform-based wind parks** in the time horizon after 2030. The Gross Capacity factor projected for area 4 reaches 43-44 per cent.

[40] Data obtained from the Global Wind Atlas 3.0, a free, web-based application developed, owned and operated by the Technical University of Denmark (DTU). The Global Wind Atlas 3.0 is released in partnership with the World Bank Group, utilizing data provided by Vortex, using funding provided by the Energy Sector Management Assistance Program (ESMAP).

Figure 4. High Voltage DC Undersea Cable Planned to Interconnect Romania and Turkey



Source: *CSD.*

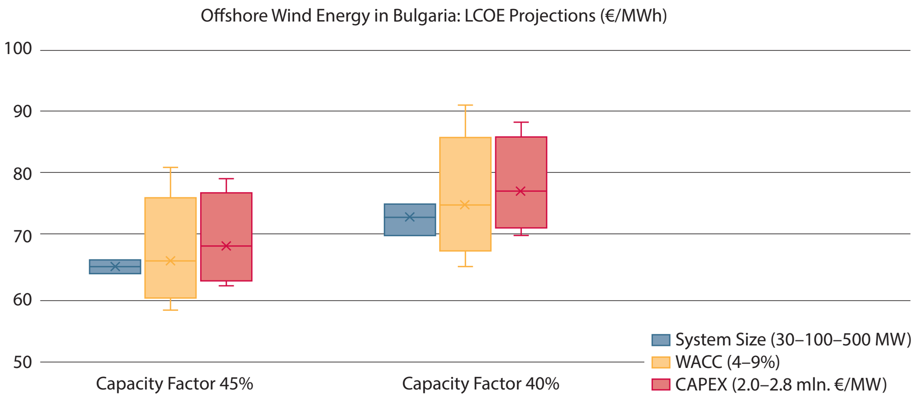
ECONOMIC, TECHNICAL AND ENVIRONMENTAL OBSTACLES

Cost of generated energy

The initial evaluation of the pre-selected areas indicates the feasibility of wind energy projects in area 1 and area 2 under the existing conditions. For both of them, the sensitivity cost analysis has estimated **LCOEs in the range of EUR 62-81/MWh** for gross capacity factor of 45 per cent (area 1) and EUR 79-91/MWh for gross capacity factor of 40 per cent (area 2). The weighted average cost of capital impacts strongly the LCOE values' variation due to the high ratio of capital to operational costs (see **Figure 5** and *Appendix VI: LCOE Calculations and parameters sensitivity*, which summarizes the assumed input parameters and the results of the sensitivity analysis).

Investment expenditures are calculated obtaining public information about projects that have already been implemented or are under construction. It should be taken into account that each project has strictly specific characteristics due to the climatic and geographical features of its location, the chemical composition of the water as well as the seabed topography and biodiversity among other factors.[41] Investment and O&M expenditures increase with distance to the shore, which modifies the underlying assumptions. **Figure 6** visualizes the results of the sensitivity analysis conducted based on the assumptions for floating installations.[42] With a capacity factor of 45 per cent **LCOE in the range of EUR 110-133/MWh** could be **achieved for floating wind projects**, while at sites with lower wind availability the cost per generated MWh from such a farm would be between EUR 124 and EUR 150.

Figure 5. LCOE Calculations for Bottom-Fixed Offshore Wind Farms in Bulgaria

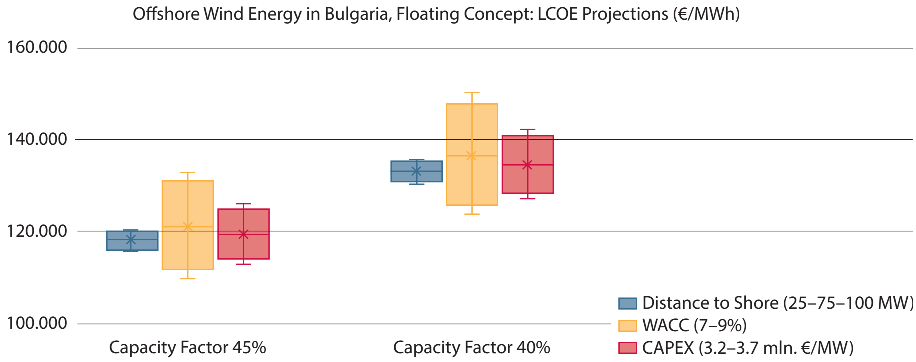


Source: *CSD.*

[41] The study assumes the installation of offshore wind turbines with capacity of 10 MW. The gross capacity factor is converted into net value at the rate of 91%, accounting for wake, electrical and availability losses. The lifetime of the projects usually exceeds 30 years, although the underlining assumption for the current analysis is 30 years. In the reference case a simplified constant WACC rate of 6% and inflation of 2% are modelled.

[42] For the same capacity factors (40% and 45%) und under assumption of constant system size of 100 MW, LCOEs are projected for floating wind energy concepts.

Figure 6. LCOE Calculations for Floating Offshore Wind Farms in the Bulgaria



Source: *CSD.*

Infrastructure

The deployment of offshore wind depends to the highest extent on the availability of corresponding infrastructure. Any potential new project would require connection to a high voltage transmission grid. Transmission injection points are available in the north eastern part of Bulgaria at the substations Dobrudzha (approx. 50 km to the shore) and Varna (approx. 70 km). Another 440 kV substation is currently under development near Shabla (15 km to the shore). In the Southern part of the country, connection is possible at the substation Burgas. According to a preliminary analysis and consultations with experts from the power transmission system operator (TSO), **the national transmission grid has the available capacity** to accommodate up to 4 GW in new energy projects in the region. In the latest version of the National Recovery and Resilience Plan, the Bulgarian government foresees the complete digitalization of the national high and medium voltage network, which will expand the interconnection capacity with neighboring countries by additional 200 MW, allowing the investors to sell electricity from renewable energy sources outside the country on power exchanges after the finalization of the regional market coupling.

A much more problematic aspect than the capacity of the Bulgarian transmission network is the **time-consuming and administratively heavy procedure of grid connection** examination and permitting which each investor must undergo. To manage the offshore grid interconnection, the renewable energy resource zone concept[43] of planning would be suitable. The concept emerges as a planning tool for mapping areas targeted for transmission development in order to support renewable energy generation. Consequently, the assessments for plant connections would be finalized during the investment planning period and the installation of needed transmission infrastructure would be implemented during the construction of the wind parks.

Not only the capacity of the network is essential, but also the **port infrastructure**, which is critical for the storage, unloading and installation of the equipment. By assembling as much of the turbine as the nearest port allows, construction companies save time restricted by seasonal weather window as well as minimize cost. Once the offshore wind power plants become operational,

[43] Lee, N. et al., *Renewable Energy Zone Transmission Planning Process: A Guidebook for Practitioners*, National Renewable Energy Laboratory, Golden, Colorado, 2017.

ports fulfill the function of O&M bases for equipment storage and regular fast and reliable service of the power generation facilities. Suitable ports must satisfy the requirement to accommodate offshore wind construction and O&M vessels with draft of over 7.5 m. The port infrastructure needs to provide high load capacity, and the port docks should be about 200-300 m long and provide access to vessels with a length of at least 140 m without restrictions. Installation ports need to be designed as deep seaports and to provide a large area for the storage and assembly of the offshore wind components. Heavy loading key sides reinforced with steel are required so that the cranes would lift up 15 – 30 t of material per m^2.[44] At least 80,000 m^2 of storage space would be necessary for laying and assembling the equipment.[45]

Currently, the main ports in Bulgaria (Varna and Burgas) fulfill the conventional role to support the delivery and shipment of cargo. The Varna East Port Terminal is the largest harbor in the country, located in the north part of the Black Sea coast. It offers the necessary lifting equipment and 10 berths with length over 140 m, allowing distance from water level to the top of cargo hatch of max 15 m.[46] The total open storage space is 73 150 m^2 (including the storage base), and the total area of warehouses is 35 340 m^2.[47]

The financial mechanisms to be deployed in the framework of the European Green Deal are well timed providing **ample opportunities to finance new business strategies for the transformation of both ports** into decarbonization hubs. Shipbuilding companies as well as industrial zones located near the harbors could benefit from low-carbon energy supply and later attract new renewable energy investors. On the other hand, offshore wind parks could supply electricity to an electrolyzer developed close to the port infrastructure that would enable hydrogen supply (a critical fuel of the future according to EU plans) to the big industries in the region.

Environmental aspects and biodiversity

The coexistence between offshore wind energy and all the other ecological, economic and societal interests is key for the **social acceptance** of new offshore wind investments. The **compatibility** of economic, archaeological and other activities with ecosystems, geological and hydrogeological characteristics, cultural and historical heritage at the bottom of the sea until 2035 is to be mapped out by the National Maritime Spatial Plan (NMSP).[48] The draft version document has been published in February 2021, but its content does not suggest any future prospects for offshore wind energy development.[49] According to the NMSP the Black Sea is characteristic of its limited biodiversity except for the adjacent coastal areas which are inhabited by a variety of species.[50]

44 Akbari. N. et al. (2017) "A multi-criteria port suitability assessment for developments in the offshore wind industry," in *Renewable Energy*, Vol. 102, Part A, March 2017, pp. 118-133.

45 WindEurope, *Ports: a key enabler for the floating offshore wind sector*, 2020.

46 These metrics are relevant for the loading/ uploading activities.

47 Varna East Port Webpage.

48 Ministry of Regional Development and Public Works, Bulgarian National Maritime Spatial Plan, 2021.

49 The NMSP's GIS database has been considered in this analysis for the identification of areas which restrict the technical potential of offshore wind energy utilization.

50 Ministry of Regional Development and Public Works, Bulgarian National Maritime Spatial Plan (Section Biodiversity), 2021.

The **Eastern European migration route**, second largest in Europe, passes over the Bulgarian coast and marine territories. Accordingly, dozens of coastal sites have been declared as protected areas under the Biodiversity Act. Those areas are highlighted on **Figure 7** below and regarded as strict restrictions for investment activities.

Any investment prospect for the development of offshore wind energy facilities and infrastructure must assess the impact on species as provided in the EU Nature Directives.[51] [52] The potential risks include death or injury that could be caused by the potential project, or deliberate disturbance during breeding, rearing, hibernation and migration, or the deterioration or destruction of breeding sites or resting places of species protected under the Birds[52] and Habitats Directive[51], as well as under EIA[53] or SEA[54] Directives. However, as the 15 years long experience with onshore wind development in Bulgaria proves the negative impact can sometimes be effectively mitigated. The assessment of significance needs to be done on a case-by-case basis and in light of the species and habitats potentially affected. The loss of a few individuals may be insignificant for some species but may have serious consequences for others. Population size, distribution, range, reproductive strategy and lifespan will all influence the significance of the effects.[55]

Wind risk assessment maps mark areas of importance to birds that should be avoided or approached with caution by wind energy developers. It should be considered at the earliest stage of the investment decision process because next to the detrimental impact to biodiversity, wrong planning could also be associated with negative consequences for the wind farm's profitability due to systemic suspension of the operation of the park in order to reduce the risk of collision of birds with turbines. Currently, studies researching bird migration, nesting, and feeding on Bulgarian territory cover onshore zones but little attention has been given to marine areas far from the coast. A highly conservative evaluation reveals that 90 per cent of the Bulgarian land suitable for wind energy development is unacceptably risky for bird populations.[56] Additional in-depth impact assessment is vital for the offshore wind energy sites locating. However, the latest Ornithological Monitoring in the Integrated System for Protection of Birds in the area of highly dense-situated wind parks of Kaliakra confirmed the **installations do not have an effect on sensitive bird species** using migratory upward airflows (thermals) to move over long distances during the Fall migration period.

---

51 EUR-lex, Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.

52 EUR-lex, Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds.

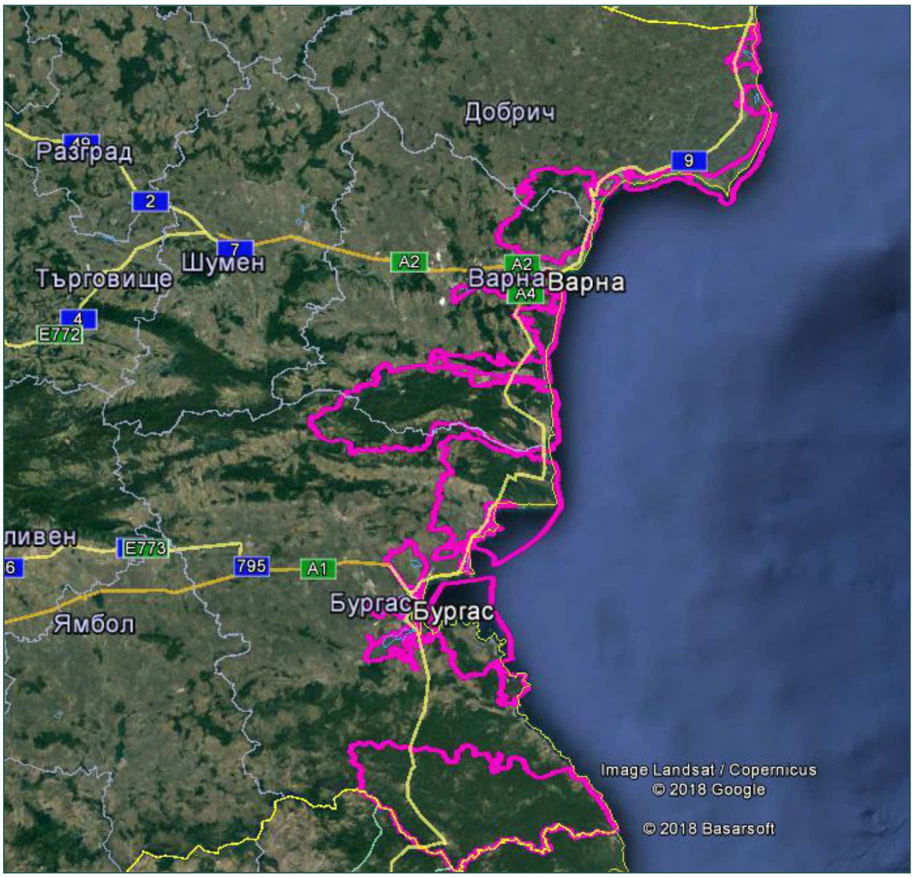
53 EUR-lex, Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment Text with EEA relevance.

54 EUR-lex, Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment.

55 See also EC, Guidance on Energy Transmission Infrastructure and EU nature legislation, 2018.

56 Zehtindjiev, P., *Report on data assessment and control, Technical report on GIS model and wind risk mapping*, conducted by EKONEKT consortium for the Bulgarian Ministry of Environment and Water, 2013.

Figure 7. Protected Areas for Wild Birds Along the Black Sea Coast



Source: *Bulgarian National Maritime Spatial Plan (2021).*

REGULATORY AND POLICY BOTTLENECKS

The renewable energy policy which is in place in Bulgaria steps mainly on the provisions of the Renewable Energy Sources Act[57] and the 2030 National Energy Strategy[58] (currently only a draft version). Both set out a **broad legal and policy framework** without specifying support instruments or separate national or cross-border mechanisms for the facilitation of wind energy investments. Since 2019, any power trading deals with operators of renewable energy plants with a total installed capacity of 1 MW and above have been required to be conducted via the Bulgarian power exchange. Moreover, under the current legislation, power generation from utility-scale plants such as an offshore wind power facility must be connected directly to the electricity transmission grid preventing the option to sell electricity via long-term purchasing power agreements to locally based large-scale industrial consumers. Policy and technical measures such as the introduction of **transparent grid capacity planning** for new renewables deployment or auctioning mechanisms are not implemented in the country, reducing predictability and secure cash flows' prediction for large investors in low-carbon energy.

The support scheme for renewable energy currently in place in Bulgaria was introduced in line with the European Commission's Guidelines on State Aid for environmental protection and energy[59]. It provides a subsidy to renewables through a technology-specific sliding feed-in premium scheme. A premium payment adds on to the wholesale market price, when it is lower than a technology-specific reference tariff, determined by the energy regulator every year. Feed-in-tariffs are applicable only for small power plants up to 30 kW and only if they are used for own consumption of the generated power.

The utilization of the offshore wind energy potential outlined in section 3 of this study requires that policymakers **implement a consistent and well-coordinated policy strategy** and initiate a range of regulatory adjustments. Efforts aimed at aligning the policy and regulatory framework with offshore wind development should address the issue of the **missing policy milestones**, **the unclear procedures for spatial planning**, licensing, decommissioning and grid connection as well as the **underwhelming economic incentives**. The adoption of specially designed and focused legislative acts following the example of Romania[60] and Poland[61] represents an optimal solution but is not yet on the Bulgarian policy agenda.

---

57 Lex.bg, Закон за енергията от възобновяеми източници [Renewable Energy Sources Act of Republic of Bulgaria], promulgeted in SG No. 35 of 3 May 2011, last amended in SG No. 21 of 12 March 2021.

58 Bulgarian Ministry of Energy, Draft Strategy for Sustainable Energy Development of the Republic of Bulgaria until 2030 with a horizon until 2050, 2021.

59 EUR-lex, Communication from the Commission — Guidelines on State aid for environmental protection and energy 2014-2020, 2014.

60 Energy Policy Group, *Romania's Offshore Wind Energy Resources: Natural potential, regulatory framework, and development prospects*, November 2020.

61 SKS Legal, "The Polish Offshore Wind Act," *Legal Alert*, February 2021.

The missing policy milestone

Despite the EU policy focus on accelerating the decarbonization of the energy system on the back of utilizing the offshore wind potential of European seas, the Bulgarian government has so far **not developed a policy framework for supporting offshore wind projects** as part of the country's long-term energy strategic documents.

The National Energy and Climate Plan (NECP) envisions to increase the onshore wind capacity only moderately from around 0.7 GW to 0.89 GW by 2030.[62] The document does not consider any offshore wind additions although the modelling assessment linked to the document envisions the addition of 3.35 GW of installed capacity in onshore wind parks until 2050. Large-scale deployment of wind energy in the Bulgarian territorial waters of the Black Sea could contribute to the implementation of the main objectives set in the NECP, namely stimulating low-carbon economic development, the uptake of competitive and secure energy sources, and the reduction of the country's dependence on fossil fuels imports.

The National Recovery and Resilience Plan (NRRP)[63], another key strategic document to guide the long-term decarbonization of Bulgaria, has also missed the opportunity to open a window for new industrial development while accelerating low-carbon regional growth and modernizing the port infrastructure. The first draft version of the Plan, submitted to the European Commission in early March 2021, received **widely acknowledged criticisms towards its insufficient contribution to climate-friendly spending**.[64] The country's caretaker government in office since mid-May 2021 published a revised version for public consultation in July 2021, which includes low-carbon transition measures worth EUR 6.45 billion. Although the document aims to improve the renewable energy investment environment, the applied approach is biased against innovative and emerging technology solutions such as offshore wind or reforms that would unlock the potential for its future development.

Unclear procedures of planning and licensing

The lack of political support and strategic orientation towards offshore wind industry development has been reflected by the **absence of appropriate spatial and infrastructural planning**. In terms of the maritime spatial planning, the country missed the opportunity to define suitable areas for offshore wind development in the latest version of its NMSP as of March 2021.[65] The next opportunity for its modification cannot happen until 2024. NMSP could be an essential coordination instrument for the planning of future projects without contradictions with other marine activities. The TSO's grid development plan also does not account for the potential deployment of offshore wind capacities, which is a prerequisite for ensuring investment security and predictability.

[62] Bulgarian Ministry of Energy, Ministry of Environment and Water, Integrated Energy and Climate Plan of the Republic of Bulgaria 2021–2030, 2020.

[63] Council of Ministers of Republic of Bulgaria, National Plan for Recovery and Resilience (as of August 2021 not officially submitted to the EC), 2021.

[64] The Green Recovery Tracker assesses the green spending share at 27% compared to the targeted level of 37%.

[65] WindEurope, "Maritime Spatial Planning: most countries late, offshore wind must remain a priority," *Newsroom*, April 19, 2021.

In addition, there is a **lack of clarity** about the consistency of offshore wind investments in the Bulgarian national law on concessions for permitting the exploration, construction, installation, and operation of offshore wind farms in areas with already granted concessions for other activities such as oil and gas exploration and production. The Concession Law[66] applies strictly to the management of national resources and should not be used to limit the scope for the utilization of the wind potential in a given area. Private companies are allowed to request a permit to use a specific territory of the Black Sea that should be granted by the Black Sea Basin Directorate, which should also regulate any construction activities in the Bulgarian territorial waters.

Currently, the Bulgarian legal framework does not provide any **rules or procedures for exploiting under concession sea areas for offshore energy project** development. Moreover, two of the areas pre-selected in Section 3 fall within the scope of territories which are under concession for oil and gas exploration and production activities. The existing legal framework would not mandate offshore wind investors to apply for a separate concession grant from the Bulgarian state. However, a conflict may arise if the owner of a concession agreement demands that the territory under question is not used for any other purposes outside the remit of the agreement, e.g., oil and gas companies in the Khan Asparuh block may protest the installation of offshore wind platforms as this could prevent them from completing their exploration surveys (2D/3D seismic studies that require full shipping access to the territory under survey).

However, an additional legal analysis would be needed to establish whether a potential conflict with the owner of a concession exists in the case the latter aims to use the whole area of a concession. There are examples in other EU countries for collaboration between operators of offshore wind plants and oil and gas field developers. In addition, synergies already exist between offshore wind and offshore oil and gas activities. It is also worth noting that some of the largest oil and gas companies (Shell, Total, Statoil, ENI) are increasingly becoming important players in the offshore wind market, therefore further opening opportunities for shared use of the marine space and its resources.

Underdeveloped economic incentives

The gradual electricity market liberalization in Bulgaria since 2016 has led to an increase in the volatility of electricity prices, the overall market liquidity, and the regional market integration. As a result, the forecast of the wholesale market price for renewable energy producers is very complex although prices are expected to follow a general upward trend[67]. Until recently, support policies applied in Bulgaria such as the feed-in-tariff offered guaranteed price certainty and a low-risk investment profile. With the transition to more competitive renumeration schemes new financial risks have emerged for investors. Especially in the situation of renewable power procurement based on actual market price, the predictability of the amount of future cash-flow represents additional hurdle leading to higher costs of financing. As renewable energy investments are mainly composed of upfront capital costs, their economic

---

[66] Lex.bg, Закон за концесиите [Concession Act of Republic of Bulgaria], promulgeted in SG No. 96 of 1 December 2017, last amended in SG No. 17 of 26 February 2021.

[67] Szabo, Laszlo et. al., *South East Europe Regional Report 2017*, SEERMAP: South East Europe Electricity Roadmap September, 2017.

feasibility is more sensitive to higher price risk. Accounting for all the other missing elements of the regulatory framework and the policy risks, the poor predictability of the future wind farm projects' revenues increases the value of the debt capital. Particularly for capital-intensive complex technology projects with complicated process of development and longer pay-back period such as offshore wind energy, future market price trajectories are not reliable enough.

Therefore, economic incentives for future offshore wind investors in the form of **access to a fixed remuneration** or **an add-on to the wholesale electricity price** within a predefined cap would better define the project financing conditions decreasing further the cost of dept capital. When combined with auctions, these elements (e.g., premium tariffs, contracts for differences, etc.) could secure fixed levels of competitive prices for renewable power procured by the state. Further aspects, such as attitudinal quality appreciation, information provision and regional cooperation represent additional challenges, that may turn into opportunity if addressed timely.

Social acceptance and local community benefits

The level of social acceptance and the attitudes of the local community towards wind energy can have a significant impact on the development of offshore wind projects, as it can be blocked by organized social opposition. Citizens living in Northeastern Bulgaria, where the bulk of onshore wind power plants would be located, **show higher levels of awareness and readiness to support renewable energy technology deployment** than the rest of the country.[68] However, history has shown that the installation of wind turbines in the European seas often raises concerns among local communities about the industry's environmental footprint and the impact on local tourism.[69] Social acceptance can vary greatly from project to project. Bulgarians have so far not embraced the development of renewable energy sources in the country enthusiastically.

The development of renewable power plant projects in Bulgaria began in the mid-2000s fueled by the involvement of large, well-established power sector investors. At the time, **public opinion**, also prodded by different incumbent industry sources, coalesced around the notion that alternative energy technologies are too expensive, are only driven by centralized EU policy and are a yet another opportunity for high-level corruption by well-connected private interests. The decarbonization myth that renewable energy projects benefit only large international investors and local **corruption schemes have long dominated the public discourse**. The organization of detailed information campaigns and active stakeholder engagement to showcase the positive relationship between the offshore wind energy and local tourism could have a positive impact on the social acceptance of the technology in coastal areas.

---

68 Trifonova, M., *Social acceptance of renewable energy sources in Bulgaria*, Sofia University "St. Kliment Ohridski", 2021.

69 Local communities in Greece economically active in the tourism industry are not particularly keen to accommodate wind parks on their islands. Greek islands are not well integrated into the national power grid and wind power plants could provide sustainable competitive advantages to those communities over other tourist destinations in the hot summer months. See: Zafeiratou. E., and Spataru, K., *Transforming the Greek Cycladic islands into a wind energy hub*, ICE Publishing, 2015.

The deployment of any large-scale, renewable energy technology should be realized in **partnership with local stakeholders** including municipalities, businesses and civil society organizations as to ensure that the projects have wide-reaching local community benefits. One good practice to be introduced in Bulgaria could be the allocation of green shares of the planned projects to local communities. The Northeastern Bulgarian region has much to offer in terms of the **development of local supply chains** for the engagement of small business and the creation of new green job opportunities. Well-trained maritime specialists graduate from the Bulgarian Maritime University, based in Varna. A subsidiary of the largest European manufacturer, installer and service provider for the wind turbine industry, VESTAS, has a subsidiary company operating in the region, providing a skilled workforce for the maintenance of the onshore wind farms in Bulgaria and Romania. Hence, local employment opportunities are expected to grow in all phases of the project lifecycle, particularly in the construction & installation of the wind park (over 1000 local employees per GW installed capacity) and Operations & Maintenance (approximately 250 workers per GW) as well as project development and management (again approximately 200 workers per GW).[70]

Regional Cooperation

A regional approach to the unlocking of the offshore wind energy potential in the Black Sea would trigger the development of new supply chains, cost reductions and the development of technical competencies. **Regional synergies** are possible **with Romania and Turkey** as both countries have already announced plans for the development of offshore wind projects.[71]

Most of the regional offshore wind potential has been under development in Romania. The state-owned Hidroelectrica company has included in its investment plan the addition of 600 MW of wind power capacity by 2026, including a 300 MW offshore wind farm – the first to be built in the Black Sea.[72] The project estimated to cost around EUR 590 million can generate about 1 TWh per year, at an average capacity factor of 38 per cent and an estimated project development period of three years. The Turkish section of the Black Sea also has very good wind speeds of 7–8 m/s and the country announced plans for launching an offshore wind tender in 2018 that were later cancelled. The expectation was for the tender to focus on a maritime zone in the Kıyıköy area of the Black Sea.[73]

In addition, Black Sea offshore wind development could revive the discussion for a **high voltage undersea DC cable between Romania and Turkey**. The findings from the current assessment of the offshore wind energy potential can be utilized to support the debate for a Black Sea HVDC infrastructure serving primarily future offshore wind investments and connecting the pow-

[70] Energy & Utility Skills Ltd., *Skills and Labour Requirements of the UK Offshore Wind Industry*, 2018.

[71] The Ex-Energy Minister of Romania publicly encourages Bulgaria to develop offshore wind partner-project, see Gocheva, R., "България не обръща внимание на потенциала за офшорни инсталации" [Bulgaria does not pay attention to the potential for offshore installations], *Capital.bg*, November 30, 2020.

[72] Balkan Green Energy News, "Hidroelectrica plans to install first offshore wind park in Black Sea," March 6, 2020.

[73] Foxwell, D., "Local content a key to Turkish offshore wind tender," *Riviera*, June 20, 2018.

er transmission grids of several countries in the region. Such a project could receive political and financial support in the context of the Three Seas Initiative that aims to channel public and private investment into strategic projects improving regional cooperation in Central and Eastern Europe with the energy sector seen as a key priority.

NEXT STEPS

Unlocking the offshore wind energy potential in the Bulgarian section of the Black Sea requires a much-needed strategic vision for removing the socio-economic, regulatory and governance obstacles preventing large-scale investment in the sector:

- Bulgaria should **set clear offshore wind deployment targets** in the country's National Energy Strategy and the NECP, which will send a clear signal to potential investors that policy-makers are committed to laying the right policy and governance groundwork.
- Bulgaria should **leverage the vast EU and national financial instruments** at its disposal to finance feasibility studies, pilot projects, port infrastructure development, R&D activities, training of wind engineers and power grid upgrades so as to provide an efficient investment environment serving as an economic incentive for private investors.
- Bulgaria should **update the Maritime Spatial Plan**, as required under the MSP Directive[74], by including a dedicated chapter on offshore energy development that will determine the mechanisms for managing potential conflicts between offshore wind construction and operation and other maritime activities including shipping, fishing, and the functioning of naval bases. There needs to be a clear delimitation of the maritime areas where offshore wind projects could have an impact on the ecosystem and could risk the destruction of archeological artefacts.
- There is a need for a **detailed development plan** for offshore wind deployment that includes the necessary maritime area investigations, a capacity density plan that sets the requirements for the optimal positioning and deployment of wind farms, the different impact assessments, the national, regional and local coordination activities and a site-specific implementation strategy. Besides coordination, such a plan can contribute to the reduction of project development time and can help build up the administrative capacity of the relevant institutions.
- There is a need for a **legal gap analysis** based on in-depth consultations with all stakeholders and relevant institutions so as to identify the necessary changes to the legal and regulatory framework with a focus on the State Property Act, the Water Act, the Renewable Energy Act, the Environmental Protection Act and others.
- Bulgaria should **introduce financial support schemes** for offshore wind investment through the organization of power auctions and the institution of contracts for difference and corporate power purchase agreements[75] that have proved to be an efficient way of incentivizing renewable energy investment in a predictable time framework while minimizing the cost of the generated electricity for final consumers.

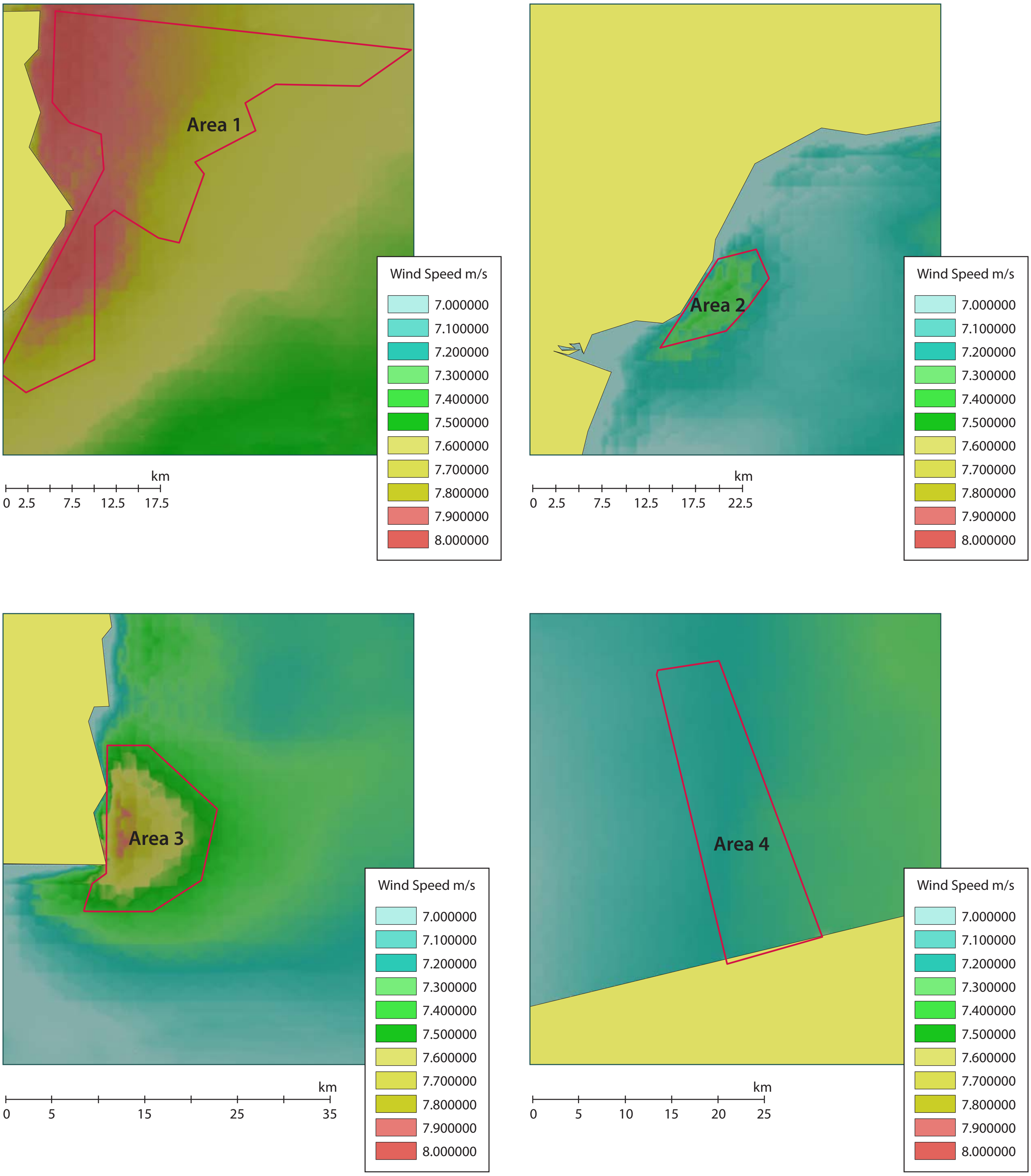
---

[74] EUR-lex, Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning.

[75] The power purchase agreements are bilateral contracts, which are signed for purchasing the generated power at pre-defined conditions and for longer periods. They represent suitable solutions for establishing power purchasing long-term relationships with locally based industrial consumers.

- Contracts for difference and power purchase agreements **guarantee predictable remuneration for wind investors** that will enable them to achieve more cost-effective financing terms. In a market environment with rising wholesale power prices, auctions can serve as a price cap in the long run. The Energy System Security Fund that is used to facilitate the payment of premiums to renewable energy companies with long-term power purchasing agreements with the state-owned National Electricity Company can also be the preferred vehicle for managing the contractual relationship with new offshore wind investors.
- The introduction of corporate power purchase agreements for offshore wind investment can, in the long run, contribute to the low-carbon transformation of the energy mix of large, industrial, energy consumers, especially in the Varna region, which is characterized by a low electricity transmission capacity undermining the **security of supply** of regional consumption centers.
- Power auctions should not only be limited to Bulgaria but should expand across the whole Black Sea region. **Cross-border auctioning mechanisms** are recommended for the establishment of offshore wind energy partnerships, as well as technology and know-how transfer with neighboring countries.
- Bulgaria should introduce open-door procedures for the provision of **economic incentives** to offshore wind investments. Open-door procedures, common in Denmark, provide the wind developers with the initiative to choose a specific project site and then apply for an exploration license to conduct all the required site-specific assessments.
- The production of electricity from offshore wind farms should be supported as part of the development of **the hydrogen industry** and in particular the production of green hydrogen, as outlined in the European Green Deal. Green hydrogen can facilitate the deep decarbonization of key sub-sectors in energy, transport, and industry, and could serve as a key tool in regulating energy systems. Green hydrogen can satisfy the energy needs of large enterprises in the planned industrial zone, Varna, as well as become a raw material for the large chemical industry in the region.

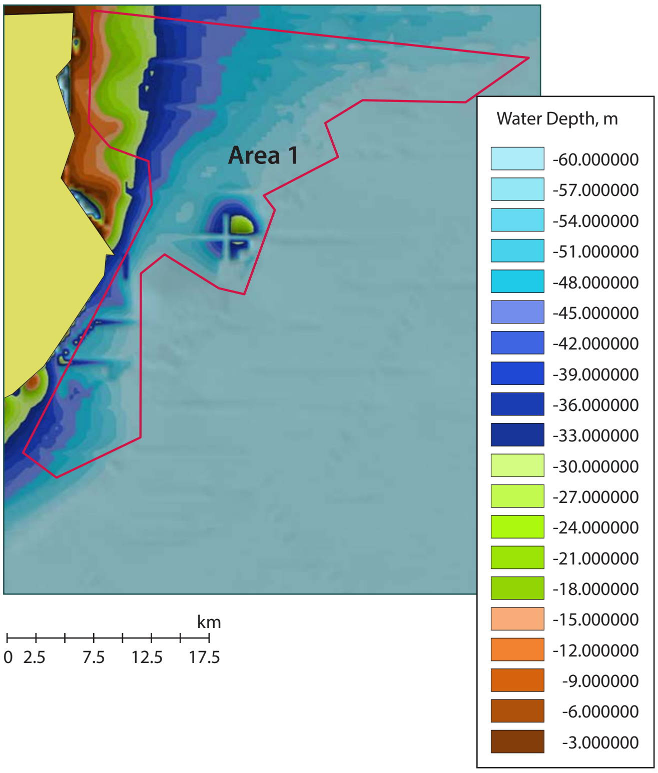
APPENDIX I: Wind Resource of Pre-Selected Areas (150 m height)

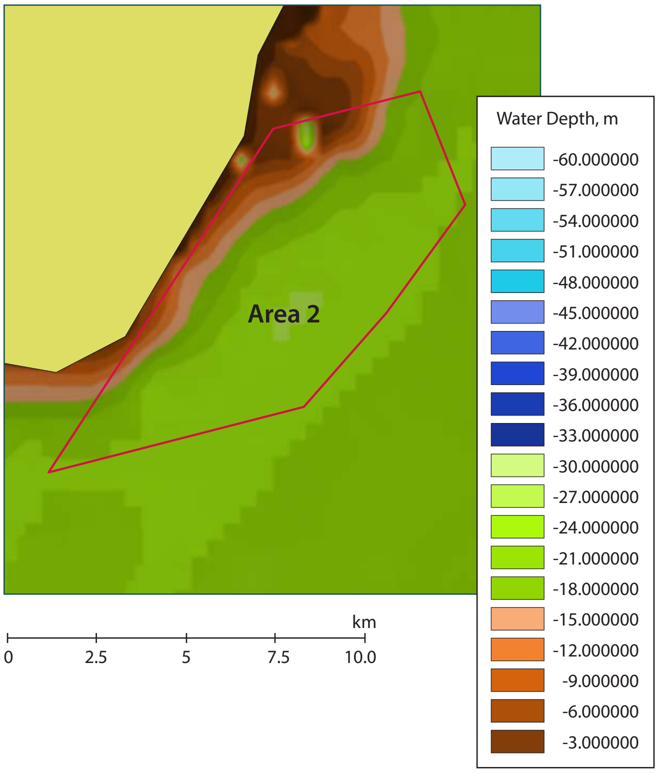


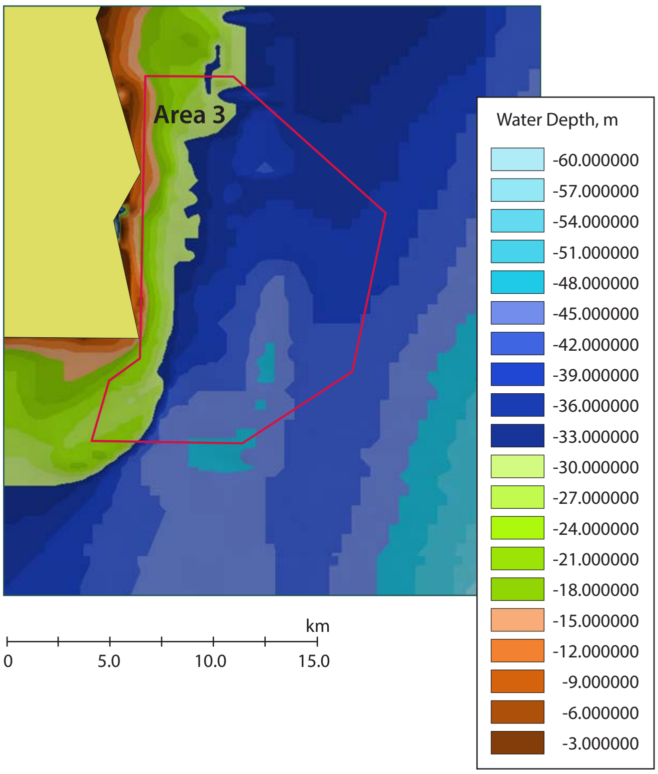
Source: *CSD based on Global Wind Atlas data.*

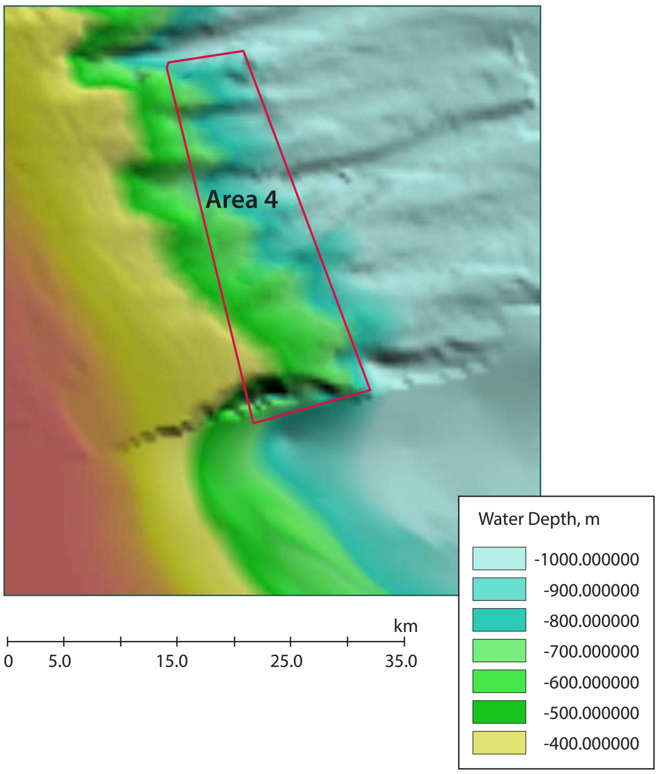
Global Wind Atlas 3.0, a free, web-based application developed, owned and operated by the Technical University of Denmark (DTU). The Global Wind Atlas 3.0 is released in partnership with the World Bank Group, utilizing data provided by Vortex, using funding provided by the Energy Sector Management Assistance Program (ESMAP). For additional information: https://globalwindatlas.info

APPENDIX II: Water Depths at the Pre-Selected Areas





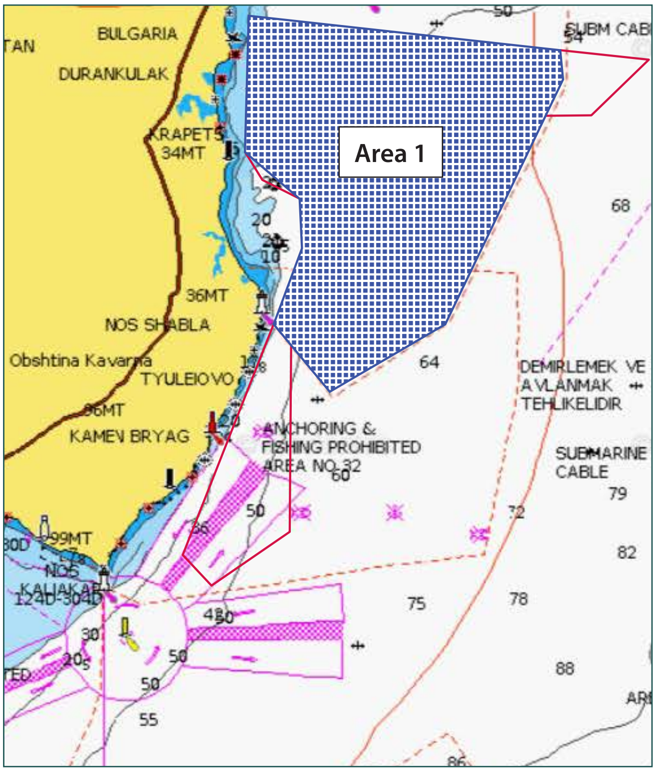


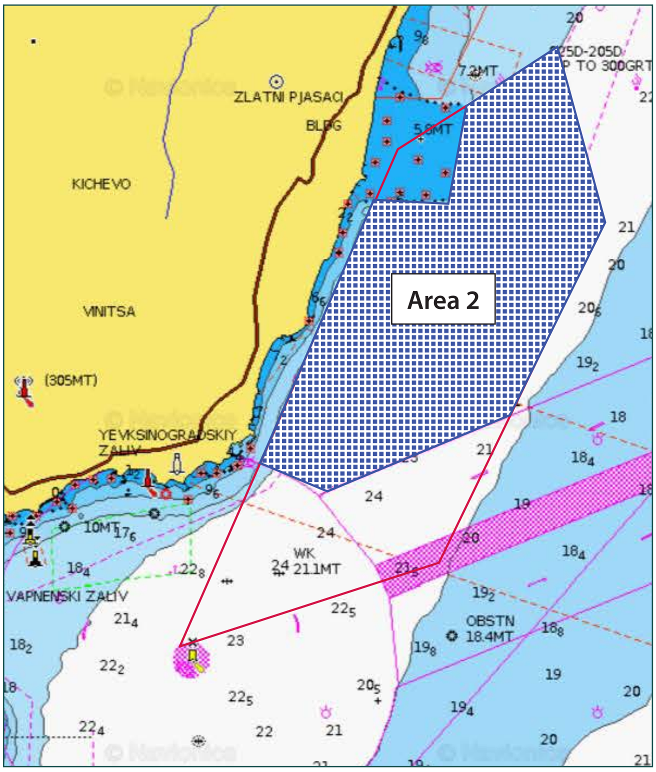


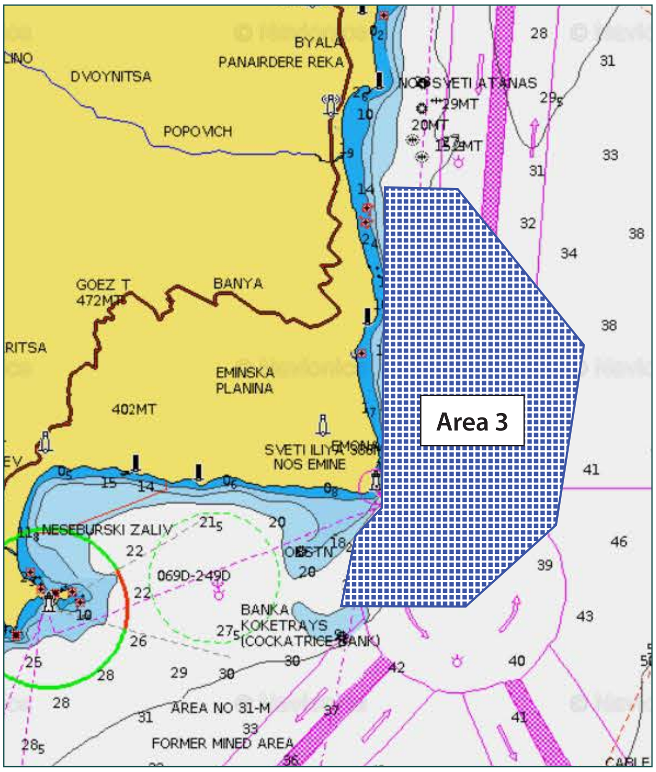
***Source**: CSD based on Global Wind Atlas data.*

Global Wind Atlas 3.0, a free, web-based application developed, owned and operated by the Technical University of Denmark (DTU). The Global Wind Atlas 3.0 is released in partnership with the World Bank Group, utilizing data provided by Vortex, using funding provided by the Energy Sector Management Assistance Program (ESMAP). For additional information: https://globalwindatlas.info

APPENDIX III: Navigation Routes and Submarine Infrastructure at the Pre-Selected Areas







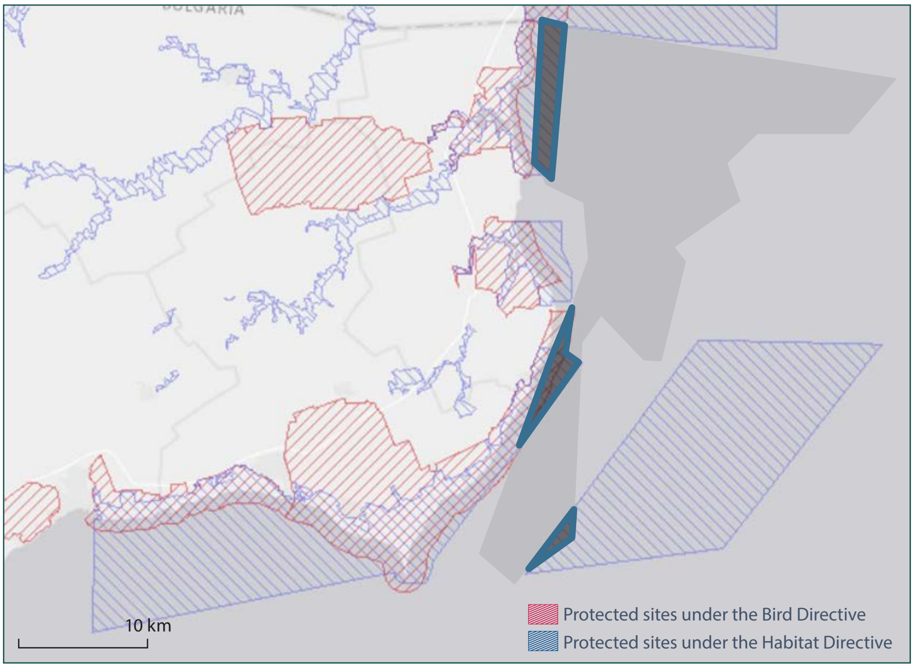
Source: *CSD based on Navionics Base Map.*

The obtained electronic maps are not intended for navigation.

NAVIONICS
A Garmin Company

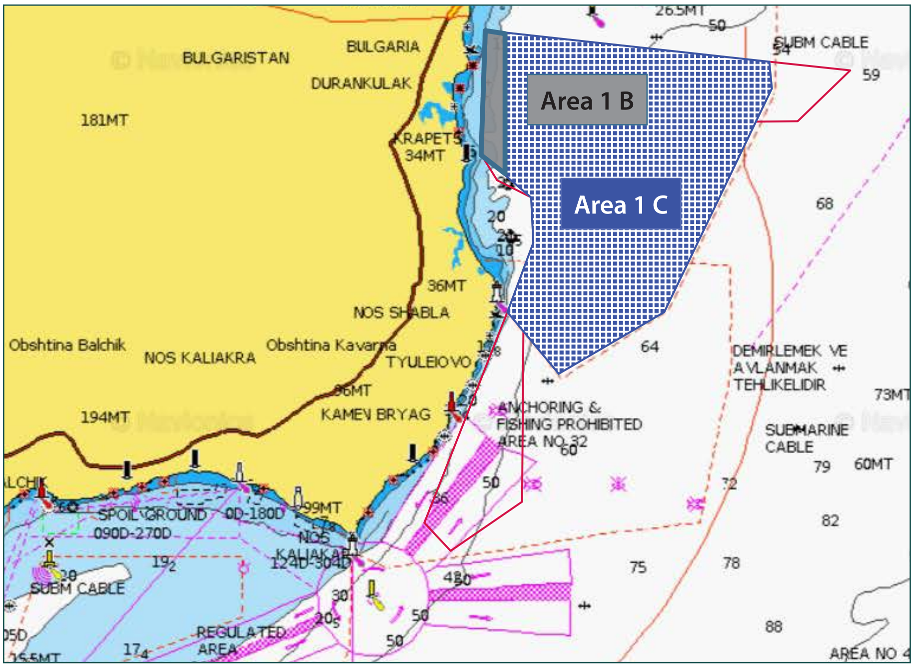
APPENDIX IV: Environmental Protected Territories in Area 1

Natura 2000 Network near the Shabla Coast



Source: *CSD based on Natura 2020 Network Viewer by the European Environment Agency.*

Offshore Wind Energy Deployment Area near the Shabla Coast



Source: *CSD based on Navionics Base Map.*

The obtained electronic maps are not intended for navigation.

APPENDIX V: Size of the Pre-Selected Areas Before and After Applied Restrictions (km^2)

Area No	Total	Conflicts with maritime routes and military bases	Area B	Conflict with zones under NATURA 2000 found in Area B	Area C (Deployment Potential Area)
Area 1	435	15	420	15	405
Area 2	40	14	26	0	26
Area 3	125	125	0	–	0
Area 4	200	0	200	0	200

APPENDIX VI: LCOE Calculations and Parameters Sensitivity

Input parameters – assumptions		Sensitivity	Reference case	Sensitivity
Wind system size	MW	10	100	500
Turbine units	Unit	1	10	50
Gross Capacity Factor	%		**45%**	
Net capacity factor, gross to net conversion 91 %	%		**40.95%**	
Wind energy production per year	Net capacity factor x System size x (24*365)			
CAPEX (net) per MW, bottom-fixed concept	'000 €/MW	**2,000.00**	**2,200.00**	**2,800.00**
CAPEX (net) per MW, floating concept	'000 €/MW	**3,200.00**	**3,400.00**	**3,700.00**
Decommissioning cost per MW	'000 €/MW		**384.00**	
Project lifecycle	Years		30	
OPEX (O&M), bottom-fixed concept	€/MW/year		**73,500.00**	
OPEX (O&M), floating concept	€/MW/year		**119,000.00**	
OPEX annually decrease	%		**-0.2289%**	
Inflation	%		2%	
WACC (real)	%	**4%**	**6%**	**9%**
WACC (real), floating concept		**7%**	**8%**	**9%**

$$LCOE = \sum_{i=0}^{n=30} \frac{\textit{annual discounted expenditure}}{\textit{annual discounted wind energy generation}}$$

Capacity factor 45%						
Bottom-fixed Concept	**Reference Case**					
Parameter Variation (%)		-9%	0%	9%	27%	
CAPEX ('000 €/MW)		2000	2200	2400	2800	
LCOE (€/MWh)		62	66	70.5	79	
Parameter Variation (%)		-60%	0%	400%		
System Size		40	100	500		
LCOE (€/MWh)		65	66	64		
Parameter Variation (%)	-33%	-17%	0%	17%	33%	50%
Real WACC (%)	4%	5%	6%	7%	8%	9%
LCOE (€/MWh)	58	62	66	71	76	81

Capacity factor 40%						
Bottom-fixed Concept	**Reference Case**					
Parameter Variation (%)		-9%	0%	9%	27%	
CAPEX ('000 €/MW)		2000	2200	2400	2800	
LCOE (€/MWh)		70	75	79	88	
Parameter Variation (%)		-60%	0%	400%		
System Size		40	100	500		
LCOE (€/MWh)		73	75	70		
Parameter Variation (%)	-33%	-17%	0%	17%	33%	50%
Real WACC (%)	4%	5%	6%	7%	8%	9%
LCOE (€/MWh)	65	70	75	80	85	91

Capacity factor 45%				
Floating Concept	**Reference Case**			
Parameter Variation (%)	-5%	0%	5%	10%
CAPEX (‘000 €/MW €/MW)	3210	3380	3550	3720
LCOE (€/MWh)	113	117	122	126
Parameter Variation (%)	-50%	0%	+50%	+100%
Distance to shore (km)	25	50	75	100
• Effect on CAPEX (‘000 €/MW)	3340	3380	3420	3460
• Effect on OPEX (‘000 €/MW)	11.7	11.9	12.1	12.3
LCOE (€/MWh)	116	117	119	121
Parameter Variation (%)	-13%	0%	13%	25%
Real WACC (%)	7%	8%	9%	10%
LCOE (€/MWh)	110	117	125	133

Capacity factor 40%				
Floating Concept	**Reference Case**			
Parameter Variation (%)	-5%	0%	5%	10%
CAPEX (‘000 €/MW)	3210	3380	3550	3720
LCOE (€/MWh)	127	132	137	142
Parameter Variation (%)	-50%	0%	+50%	+100%
Distance to shore (km)	25	50	75	100
• Effect on CAPEX (‘000 €/MW)	3340	3380	3420	3460
• Effect on OPEX (‘000 €/MW)	11.7	11.9	12.1	12.3
LCOE (€/MWh)	130	132	134	136
Parameter Variation (%)	-13%	0%	13%	25%
Real WACC (%)	7%	8%	9%	10%
LCOE (€/MWh)	124	132	141	150