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Offshore wind – the enabler of Romania's decarbonisation

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About EPG:

Energy Policy Group (EPG) is an independent think-tank, specialized in energy and climate policies. Founded in 2014, EPG brings together experts working in international research projects. EPG is focused on the deeper context of European policies and global trends, and promotes constructive dialogue among decision makers, stakeholders, and the larger audiences, proposing concrete solutions for decarbonisation.

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Sumar executiv

Energia eoliană offshore are un rol major în cadrul obiectivelor europene de reducere a dependenței de importurile de combustibili fosili și de decarbonare până în anul 2050, într-un moment în care interesele Uniunii Europene (UE) privind securitatea energetică și obiectivele climatice sunt aliniate. Același principiu este valabil și pentru România, întrucât necesită dezvoltarea a 15GW de capacități de energie eoliană offshore în Marea Neagră, respectiv zona economică exclusivă (ZEE), pentru a atinge neutralitatea climatică până în anul 2050, conform unui exercițiu de modelare al Energy Policy Group (EPG). Aceasta ar deveni cea mai mare sursă de producție de energie electrică a țării, cu peste 40% din total. Dezvoltarea parcurilor eoliene offshore este realizată între cinci și zece ani, cu o medie a UE de șapte ani, ceea ce relevă faptul că există oportunități majore ca România să conecteze primele capacități de energie eoliană offshore la rețeaua de transport de electricitate înainte de anul 2030. Astfel, statutul actual al României, de importator net de energie electrică, s-ar putea schimba, oferind energie curată suplimentară necesară pentru decarbonarea sectoarelor precum industrie, transport și încălzire și răcire.

Acest raport este dezvoltat pe baza rezultatelor primului studiu al EPG care a estimat potențialul tehnic al energiei eoliene offshore din Marea Neagră și propune soluții inovatoare pentru provocările ce țin de rețeaua de transport de energie electrică. Instrumentele UE care sprijină energia regenerabilă, planificarea și dezvoltarea regională comună între România și Bulgaria pot stimula dezvoltarea accelerată a energiei eoliene offshore din Marea Neagră și implicit economiile de scară. Astfel, energia eoliană offshore poate deveni un catalizator al procesului de decarbonare din România și Europa de Sud-Est.

Abordarea provocărilor ce țin de rețelele de transport de energie eletrică cu care se confruntă atât România, cât și Bulgaria în implementarea potențialului de energie eoliană offshore poate fi realizată prin conceptul de insulă energetică (*energy island)* româno-bulgară (RO-BG). Aceasta ar fi o soluție eficientă pentru deblocarea dezvoltării energiei eoliene offshore la nivel de economii de scară, precum și pentru extinderea capacității de interconectare cu alte țări din bazinul Mării Negre (cum ar fi Turcia, Georgia, precum și Azerbaidjan, către Est), care va contribui la securitatea energetică și la stabilitatea prețurilor din regiune. Acest lucru va spori potențialul de energie eoliană offshore din întregul bazin al Mării Negre, iar cablul subacvatic High-Voltage Direct Current (HVDC) anunțat recent, care va fi construit de România, Azerbaidjan, Georgia și Ungaria va reprezenta un pilon important în acest proces.

Costul mediu de producere al energiei (LCOE) offshore pe bază de turbine fixe va fi de €71/MWh în zona României din bazinul Mării Negre, conform scenariului realist al EPG pentru 2030, în timp ce pentru dezvoltarea ulterioară a energiei eoliene offshore pe bază de turbine plutitoare, LCOE ar fi de €94/MWh. Pentru un proiect comun între România și Bulgaria, includerea costurilor unei conexiuni HVDC la stația Constanța Sud, precum este indicat în scenariul de referință pentru energia eoliană pe bază de turbine fixe, ar conduce la un LCOE total la €79/MWh pentru o capacitate instalată de 3GW. Mai mult, realizarea unei insule energetice RO-BG ar conduce la un LCOE total în valoare de €85/MWh, presupunând că investiția pentru dezvoltarea insulei este împărțită în mod egal între cele două state. Costurile totale de capital (CAPEX) alocate de România într-un proiect RO-BG, inclusiv parcurile eoliene offshore de 3GW, au fost estimate la €8,4 miliarde (€810 milioane, reprezentând partea României din insula energetică RO-BG), în timp ce producția anuală de energie rezultată a fost estimată la 9,8TWh.

Dezvoltarea parcurilor de energie eoliană offshore generează și beneficii socio-economice prin crearea de locuri de muncă în producția, construcția și operarea și întreținerea (O&M) proiectelor, cu efect de multiplicare asupra altor sectoare, inclusiv prin concentrarea activităților economice asociate energiei eletrice offshore în Portul Constanța. Pentru 1GW de capacitate instalată, energia eoliană offshore din Europa generează €2,1 miliarde în economie. În consecință, 3GW de capacitate instalată de energie eoliană offshore în România ar putea genera €6,3 miliarde, respectiv 2,6% din PIB-ul anului 2021. Mai mult, investițiile în 3GW de energie eoliană offshore ar putea crea un total de 22.000 de noi locuri de muncă pentru angajați cu normă întreagă (20.000 în faza de CAPEX și 1.800 în cea de operare și întreținere), dintre care 15.500 noi locuri de muncă ar putea fi create în mod direct la nivel național, presupunând că România ar atrage investitori în producția de componente pentru turbine eoliene, în construcția, instalarea și, respectiv, întreținerea infrastructurii parcurilor eoliene offshore.

Stabilirea unui cadru legislativ și fiscal adecvat este esențial în dezvoltarea energiei eoliene offshore, în contextul actual marcat de extinderea accelerată a acestor capacități de producție la nivel mondial. Un dialog al Uniunii Europene cu privire la obiectivele privind dezvoltarea energiei eoliene offshore din Marea Neagră ar facilita procesul pentru cele două state membre (România și Bulgaria), precum și pentru partenerii din afara UE. Mai mult, aceasta ar putea promova investițiile în insule energetice, precum și potențialele interconexiuni pe distanțe lungi. Din perspectiva cadrului legislativ și de reglementare, acest raport propune un mix de politici între un model centralizat, bazat pe stat și un proces deschis, bazat pe investitori, pentru dezvoltarea zonei României din bazinul Mării Negre, având ca scop valorificarea avantajelor menționate și diminuarea riscurile asociate pentru investitori. Dialogul permanent și consistent între autorități și investitori reprezintă o pre-condiție a planificării și dezvoltării cu succes a parcurilor eoliene offshore din zona României din Marea Neagră.

Executive Summary

Offshore wind power plays a key role in Europe's pathways to reducing dependency on fossil fuel imports and decarbonisation by 2050, in a moment when EU's energy security interests and climate objectives are fully aligned. The same goes for Romania, with a modelling exercise indicating that 15GW of offshore wind capacities need to be developed in Romania's Black Sea exclusive economic area (EEA) by 2050, in order to achieve climate neutrality. This would become the country's largest source of electricity production, with more than 40% of total, in some scenarios. Offshore wind farms take between five to 10 years to be developed, with an EU-average of seven years. This means that there is a good chance for Romania to connect its first wind offshore capacity to the grid before 2030. This could change Romania's current status of net electricity importer, as well as provide significant additional clean energy needed to decarbonise sectors such as industry, transport, and heating and cooling.

This report builds on the results of the first EPG study that estimated the technical potential of offshore wind in the Black Sea, proposing innovative solutions for overcoming grid-related challenges. Backed by EU instruments, joint regional planning and joint development between Romania and Bulgaria, offshore wind in the Black Sea can kickstart and achieve the needed economies of scale to make offshore wind a major enabler of decarbonisation in Romania and Southeast Europe.

To address the grid challenges that both Romania and Bulgaria face in deploying their offshore wind potential, a Romanian-Bulgarian (RO-BG) energy island would be an efficient and scalable solution to unlock large-scale offshore wind deployment, as well as bring valuable interconnection capacity with other Black Sea countries (such as Turkey, Georgia, as well as Azerbaijan, further east), drastically improving energy security and contributing to the regional price stability. This would also bolster the offshore wind potential of the entire Black Sea Basin. Indeed, the recently announced underwater HVDC cable to be built by Romania, Azerbaijan, Georgia, and Hungary will be a steppingstone in the process.

In a realistic scenario for 2030, the Levelized Cost of Energy (LCOE) for fixed offshore wind power in the Romanian region of the Black Sea will be €71/MWh, while for the later development of floating offshore wind the LCOE would be €94/MWh. In the case of a joint project between Romania and Bulgaria, including in the LCOE the costs of an HVDC connection to the Constanța Sud station, as indicated in the reference scenario for fixed offshore wind, would bring the total cost to €79/MWh for a 3GW installed capacity. Adding an artificial RO-BG Energy Island would bring the LCOE to €85/MWh, assuming the capital investment for the energy island is split equally between the two countries. The total CAPEX costs allocated to Romania in a RO-BG Energy Island project, including the 3GW offshore wind farms, would be €8.4 billion (€810 million representing Romania's share of the RO-BG Energy Island), while the resulting annual energy production is estimated at 9.8TWh.

Apart from the importance for energy supply and resilience, offshore wind deployment brings socio-economic benefits by creating jobs in the manufacturing, construction, and operation and maintenance (O&M) of projects, with a multiplying effect on other sectors – including a significant concentration in the Port of Constanța. Per GW of installed power, offshore wind in Europe generates €2.1 billion. Consequently, 3GW of installed offshore wind power in Romania would generate €6.3 billion, 2.6% of GDP (2021). This could also contribute to a total of 22,000 new FTE employees (20,000 in the capital phase and 1,800 for O&M), with 15,500 in direct new jobs at local level, assuming that Romania would attract investors in manufacturing of wind-turbine components and in construction, installation and balance of plant, respectively.

Setting up the proper legislative and fiscal frameworks for offshore wind developments is of critical importance, especially at present, at the beginning of massive deployments of offshore wind capacity worldwide. An EU-led conversation on the future of Black Sea offshore deployment would facilitate the process for the two member states (Romania and Bulgaria), as well as for non-EU partners. It would also promote the discussion and investment in energy islands, as well as potential long-distance interconnections. This report proposes a blend between a centralised, state-led model and an open-door, investors-led process for site-developing, aiming to capitalise on the mentioned advantages, while diminishing the downsides and associated risks for investors. As a prerequisite and as a rule for successful planning and development, a consistent and continuous dialogue between state authorities and private investors is paramount, already from the early stages.

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List of Acronyms

ANRE	National Energy Regulatory Authority
EC	European Commission
EEA	Exclusive Economic Area
ENTSO-E	European association for the cooperation of transmission system operators (TSOs) for electricity
EPG	Energy Policy Group
ETS	Emission Trading System
EU	European Union
GEO	Government Emergency Ordinance
GHG	Greenhouse Gas
HVAC	High Voltage Alternative Current
HVDC	High Voltage Direct Current
IEA	International Energy Agency
LCOE	Levelised Cost of Energy
LTS	Long-Term Strategy
PCI	Project of Common Interest
RES	Renewable Energy Sources
TSO	Transmission System Operator
NRRP	National Recovery and Resilience Plan
WPP	Wind Power Plant

1. Offshore wind's key role for Romania's decarbonisation

Offshore wind capacity in the EU totalled 14.6GW in 2021. The European Commission's offshore wind strategy (EC, 2020) would see this capacity increase to at least 60GW by 2030, aiming to reach 300GW by mid-century. The strategy identified the Black Sea as one of the five key basins for deploying these capacities. These deployment plans were accelerated in the wake of the Russian invasion of Ukraine and the resulting energy crisis. Driven by the imperative to wean off Russian gas by 2027, the European Commission proposed the REPowerEU Plan for diversifying the EU's energy sources, including by a rapid uptake of renewable energy sources. The plan highlighted the role of offshore wind as an energy resource that is stable, abundant and with a higher level of public acceptance (EC, 2022a). The plan would see an additional 41GW of wind to be installed compared to the previous estimation made for the Fit for 55 package (EC, 2022b).

In the current context, the EU's energy security and climate objectives are fully aligned. The large-scale deployment of renewable energy sources has become an imperative for both goals. The need for offshore wind capacities, which have higher capacity factors and do not face the same NIMBYism issues as onshore installations, is largely confirmed in modelling exercises. According to the European Commission's Long-Term Strategy – LTS (EC, 2018), reaching climate neutrality in the EU will require the deployment of up to 451GW of offshore wind capacities by 2050. By then, the Commission estimates that up to 30% of electricity demand could be supplied by offshore wind.

EPG has also shown a similar role for offshore wind in the case of Romania through a modelling exercise. This was done using the 2050 Pathways Explorer developed by CLIMACT and calibrated and adapted for the Romanian case study by EPG. The Pathways Explorer is a full-fledged simulation model at the national level for all European countries. It is a fully comprehensive and dynamic model, covering all sectors of the economy emitting GHG emissions and all energy vectors, connecting the sectors dynamically between one another. Using this tool, EPG has developed three distinct economy-wide decarbonisation scenarios (EPG, 2022):

(1) **Tech scenario**, which assumes rapid development of cutting-edge technology together with rapid cost reductions,

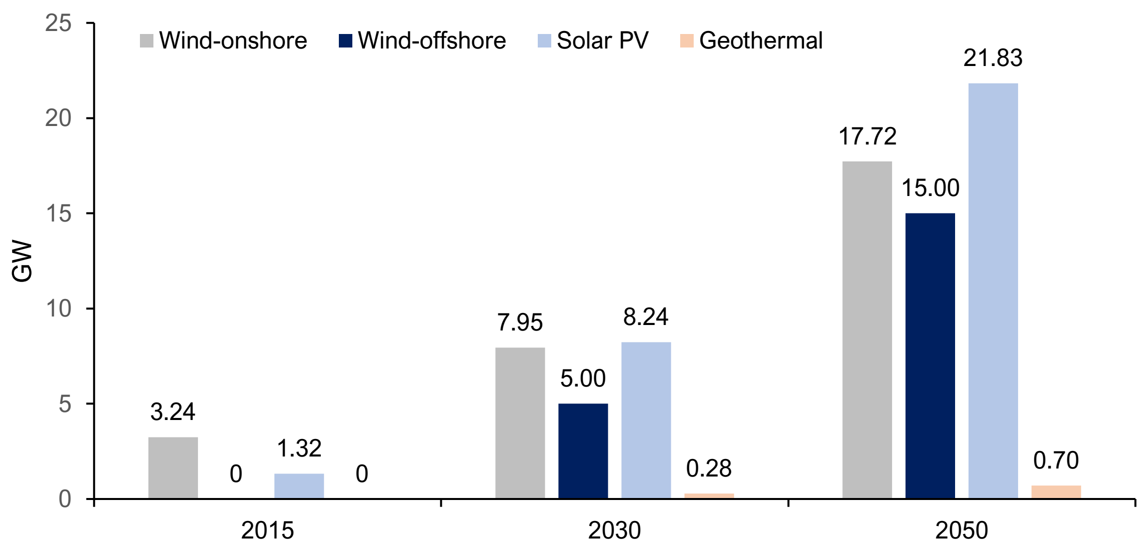
(2) **Life scenario**, which assumes full involvement of political leaders and general population in reaching climate neutrality, together with transformative changes in lifestyle choices and individual behaviour, and

(3) **EPG scenario**, which is a more balanced approach relying on a combination of more moderate transformation in terms of technological development and behavioural changes in the general population.

To ensure consistency with the Paris Agreement 1.5°C objective and the EU's long-term decarbonisation goals, all scenarios are set to achieve net-zero or net-negative GHG emissions in 2050.

The results of the modelling indicate that the decarbonisation of Romania's electricity supply will be mainly driven by a massive increase in solar PV and wind energy capacity. According to the modelled scenarios, Romania needs more than 53GW of renewable capacities by 2050. Importantly, all scenarios see some 15GW of offshore wind capacities developed in Romania's exclusive economic area (EEA) in the Black Sea by 2050, with 5GW already installed by 2030. In all scenarios, offshore wind becomes the largest source of electricity production by 2050 – more than 40% of total electricity production in some scenarios.

Figure 1. Installed renewable capacities in the EPG scenario (GW)



Source: Climact, 2050 Pathways Explorer, EPG calculations

Therefore, given the scale of renewable uptake that Romania needs to accomplish, tapping into its offshore wind potential is of critical importance. Timing is also of the essence. At present, while Romania is a leading country in Southeast Europe in terms of onshore wind development, with an installed capacity of 3GW and another 2.4-3GW planned by 2030, according to the National Energy and Climate Plan (NECP), there is rather limited support for the development of offshore capacities. There is no precise information about the offshore wind potential, and an adequate regulatory and financial framework to support such developments is missing. Offshore wind could cover the gap between the current level of ambition and Romania's renewable energy potential, especially considering the revision of the EU renewable targets for 2030.

2. Innovative solutions for overcoming grid challenges

2.1 The state of power grid infrastructure development in South-Eastern of Romania

The main barriers to untapping the potential of the Romanian offshore wind energy resources reside in two areas: planning and permitting, and the power grid – including the offshore connections. The first must be addressed by the Maritime Spatial Planning that Romania is yet to submit to the European Commission, while permitting aspects will also be regulated by future EU and national legal and regulatory frameworks.

The grid-related aspects must allow building the offshore grid and bringing the energy onshore, as well as evacuating the energy from Romania's South-East, where a large part of the country's power generation is already located, and where additional renewables are planned. Due to its large wind and solar potential, the Dobrogea region in the country's south-east, bordering the Black Sea, is the area of highest concentration of installed renewables capacities (mostly wind energy), with ca. 3,000MW already in place. In the same area, Romania's power system has another major energy production node, the Cernavodă Nuclear Power Plant, with installed capacity of 1,400MW, expected to be expanded to 2,800MW, according to the Government's stated plans. The region already has a strong surplus of energy production compared to consumption, most of which being evacuated towards the capital city of Bucharest and to the Moldova region, in the North.

After the significant development of RES capacities in the early 2010s, the transmission availability in Dobrogea area became limited, and has seen no substantial expansion until the last years when some important new power lines projects have started. Currently, no new MW of RES capacity can be installed there, according to Romanian TSO's (Transelectrica) new connection capacities availability of the transmission power grid map (Figure 2), until new grid capacities will be finalised. Two important new transmission power lines to be finished soon will increase the capacity in Dobrogea area by almost 1,000MW:

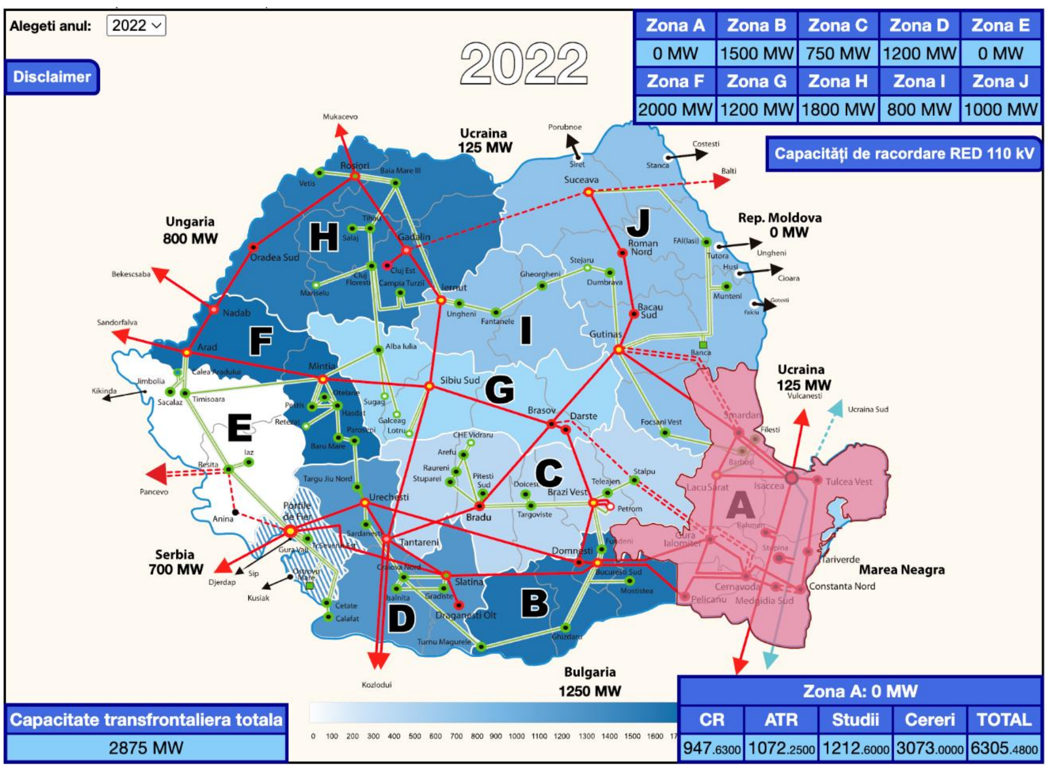
- The Cernavodă-Stâlpu 400kV HVAC (double-circuit, 159km) power line, which will contribute to the energy evacuation from Dobrogea to western Romania of an additional installed power of 452MW. The construction of this power line will be finished in the short term.
- The Gutinaș-Smârdan 400kV HVAC (double-circuit, 140km) power line, which will contribute to the energy evacuation from Dobrogea to north-western Romania of an

additional installed power of 424MW. The construction of this power line will be finished at the end of 2024 (Transelectrica, 2022a).

According to Transelectrica's Ten Years Development Plan (TYNDP) (2022-2031), the ongoing power grid development projects in Dobrogea will boost the integration of new wind capacities with a total of 2,008MW. Most of these projects will be commissioned between 2023 and 2026 (Transelectrica, 2022a).

Moreover, Transelectrica has recently signed financing contracts for nine strategic projects of EUR 424 million from the Modernisation Fund, which will increase the transmission capacity in the Romanian power system with 1,700MW through 480km of new power lines, refurbishment of electrical substations, and implementation of new technologies.

Figure 2. New connection capacities available to the transmission power grid in Dobrogea area (*Zona A*)



Source: Transelectrica (2022b)

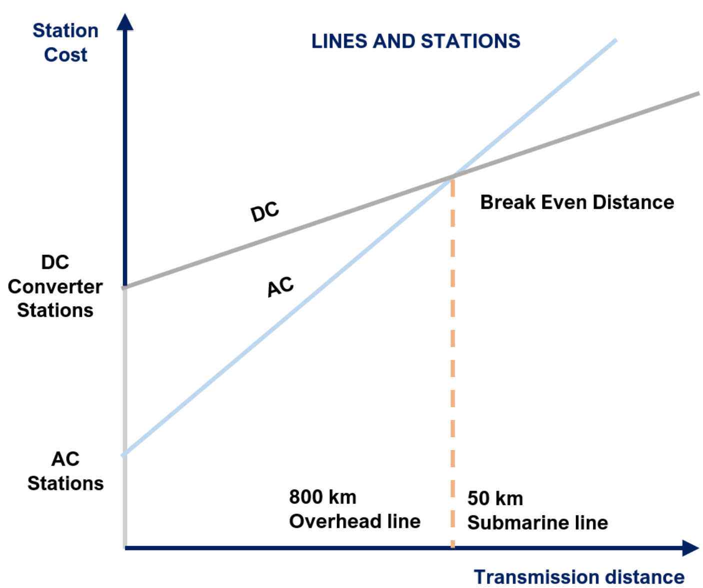
2.2 Connecting offshore wind to the power grid. HVAC vs. HVDC

An offshore wind power plant (WPP) can be connected to the power grid either through a HVAC (high voltage alternating current) or a HVDC (high voltage direct current) connection, depending on various economic and technical aspects, of which the most important ones are the distance of the WPP from the shore and the transmission capacity.

The HVAC connections are mostly used for short distances to the shore, due to the lower costs and losses compared to HVDC. However, the HVAC costs and losses increase rapidly with the distance (Larsson, 2021). For a given cable conductor area, the line losses with HVDC cables are about 50% less than for AC cables (Electrical Engineering Portal, 2014). Therefore, for most offshore WPP developments, the HVDC connections are mainly used, given advantages such as:

- lower number of power lines, resulting in lower total cost;
- reduced transmission losses at equivalent power levels;
- no need for power compensation, because the DC cable does not generate any reactive power, so it can be better controlled by the power grid operators.

Figure 3. Comparative HVDC & HVAC Transmission Costs



Source: Csanyi (2014)

As indicated in Figure 3, a HVDC connection becomes cost-effective for WPPs that are more than 50km away from shore.

All in all, the HVDC technology plays a major role in the energy transition towards clean and secure power systems, as it allows more efficient transfer of energy from the areas with high renewable potential to concentrated points of consumption. HVDC is not a mere alternative to HVAC, but a mature technology in its own right, which been in use for decades now, due to the following strongpoints:

- Power transmission for long distances;
- Connecting offshore wind power plants to National Transmission Grids;
- Interconnecting HVAC grids that are operating at different voltage frequencies or asynchronous grids;
- Power transmission through submarine cables.

HVDC power links have been developed all over the world starting with the first such transmission line covering the 98km distance between the island of Gotland and the Swedish mainland in 1954 (Heyman O., 2010), transmitting a power of 20MW at 100kV. More recent projects are much larger in size – the 1,100kV UHVDC Changji-Guquan, the world's longest and most powerful line, can transmit 12,000 MW over 3,293km of China's mainland.

Since the 1950s, European countries have been leading in research and development of new HVDC projects, that were mostly used to interconnect different islands or regions with the mainland, and to evacuate renewable energy from offshore wind power plants. As pointed out on ENTSO-E's Transmission System Map (Figure 4, magenta colour), most of these projects were developed in the North Sea and Baltic Sea.

Table 1 below presents some of the main HVDC projects developed in Europe and their total costs with the converter stations costs included. The resulting average cost of €3.31 million/km will be used further for the estimation of the HVDC connection between Romania, Bulgaria and possibly Turkey, Georgia in the Black Sea.[1]

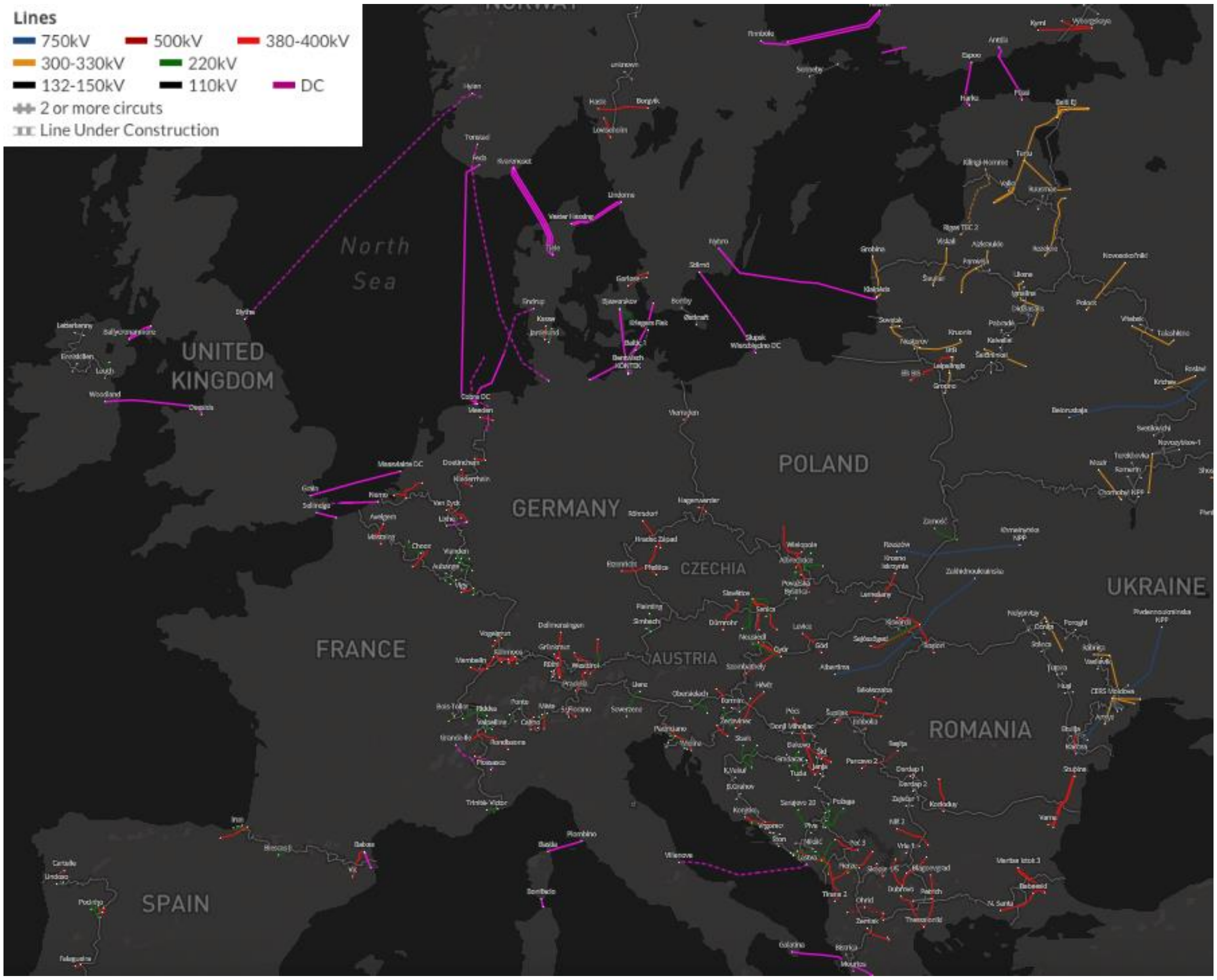
[1] As the price per km of the offshore varies, in the historical cases, from less than €1 million to almost €8 million, the main two factors that drive the costs are the system's voltage and power, to which other determinants add up, such as the depths, submarine relief, corrosivity etc. Besides, the technological complexity and the inflation over decades are included also in the above figures.

Table 1. Technical and economical characteristics of different national connection and interconnection projects in Europe (line and converters included)

No.	Project Name	Rated voltage +/- (kV)	Rated power (MW)	Line Length (km)	Line Cost (EURm)*	Price per km (EURm/km)
1	EstLink1	150	350	105	84.8	0.81
2	EWIC	200	500	261	421.7	1.62
3	NordBalt	300	700	450	438.6	0.97
4	Aland	80	100	158	99.1	0.63
5	Skagerrak4	500	700	242	258.9	1.07
6	NordLink	500	1400	623	1332.3	2.14
7	NorthSeaLink	515	1400	730	1298.9	1.78
8	COBRA	320	700	325	420	1.29
9	IFA2	320	1000	235	590.2	2.51
10	BorWin1	150	400	200	422.8	2.11
11	BorWin2	300	800	200	745.3	3.73
12	BorWin3	320	900	161	1250	7.76
13	HelWin1	250	576	130	745.3	5.73
14	HelWin2	320	690	130	845.3	6.50
15	DolWin1	320	800	165	682.4	4.14
16	DolWin2	320	916	137	832.6	6.08
17	DolWin3	320	900	162	1150	7.10
18	SylWin1	320	864	205	745.3	3.64
					Average Price	**3.31**

Source: EPG analysis using input data from Härtel et al. (2017)

Figure 4. ENTSO-E Transmission System Map



Source: ENTSO-E (2022)

The *energy island* concept

Energy islands refer to existing or artificial islands (constructed as caisson embankment or as steel platform) serving as a hub for energy evacuation from the surrounding offshore wind farms, as well as for interconnection with the neighbouring shore. It is a recent concept, the first such structures being developed by Denmark in the North Sea and Baltic Sea.

The energy islands have several advantages compared to conventional point-to-point connections of offshore wind power plants to the grid:

- The wind turbines can be placed further away from land;

- The energy island can distribute power from the offshore wind turbines between several countries more efficiently through higher load factors for the connection grids;
- The energy island can accommodate facilities for:
    - Energy storage for the situations when generation exceeds demand;
    - Electrolysis-based hydrogen production plants;
    - Other technologies for energy conversions.
- It is scalable for future offshore wind capacities.

Energy islands will support through their multiple advantages the energy transition in Europe and are rightly considered to be key elements of the future energy systems (Danish Energy Agency, 2022; State of Green, 2022).

The hub-and-spoke concept

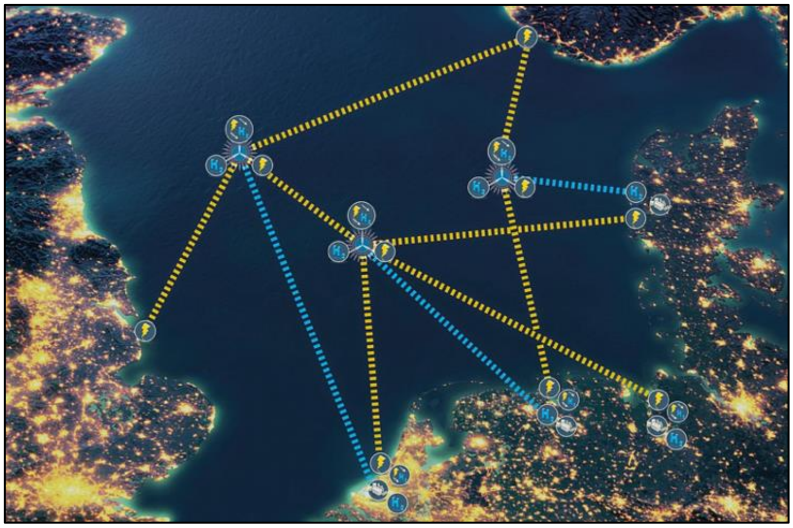
The *hub-and-spoke* concept refers to cutting-edge technology for offshore wind connections, that will play a major role for further offshore WPP developments, coming hand in hand with the *energy island* concept.

Hub-and-spoke involves an energy island, serving as a hub, being connected with HVDC submarine cables, which represent the "spokes" that link several countries to the island or between them. The main characteristic of a hub-and-spoke project is that it could enable at the same time the wide integration of offshore capacities to the national power grids and interconnecting regional power systems of multiple countries. In other words, the hub-and-spoke concept is the backbone of the energy island notion, being represented by the power grid infrastructure on the island and by all its connections with the shores.

The generated wind power is transported to the highest bidders or the countries with the greatest need for sustainable electricity at the time of production. The cables also serve as interconnectors between countries, especially when the WPPs do not produce electricity (Witteveen+Bos, 2022). The current utilisation of a connection between a wind farm and the mainland is around 40%, but with the links between countries as interconnections, the utilisation of the cable can reach almost 100%.

The most advanced projects that use the hub-and-spoke principle are in the North Sea, where wind electricity will be distributed and transmitted over HVDC cables to the North Sea countries: the Netherlands, the UK, Belgium, Norway, Germany and Denmark (Tennet, 2022a; Multi-DC, 2021). TenneT's hub-and-spoke project in the North Sea goes even further, introducing also green hydrogen production for some of the generated wind power, which will be piped to the shore using the existing gas infrastructure (Tennet, 2022b).

Figure 5. Hub-and-spoke representation in the North Sea



Source: TenneT (2022b)

Energy island costs based on the European experience

Given the incipient development phase of such projects, cost estimations are particularly challenging. Therefore, to estimate the costs of an energy island for the Black Sea, this report relies on the estimations made for the most advanced similar project developed by Denmark in the North Sea.

As indicated by the Danish Energy Agency, the energy island in the North Sea will be situated at approximately 100km from the coast and will be able to accommodate 3GW of power capacity installed in offshore WPPs. The total estimated cost, with the offshore wind farms and power transmission infrastructure included, is €7.93 billion, and the targeted year of commissioning is 2030. The energy island is scalable up to a capacity of 10GW, which would cost around €28.22 billion with an embankment solution, and around €29.57 billion with a steel platform solution for the island. Both options are capable to connect various other facilities such as energy storage, hydrogen conversion etc.

Thus, the total costs for the development of an energy island that includes the construction of the artificial island, the offshore wind power plants and the power transmission infrastructure linking the island to shore (Danish Energy Agency, 2022; State of Green, 2022) is ca. €3 billion/GW, [2]

[2] The figures are based on the estimation by the Danish Energy Agency for the North Sea Energy Island, with an approximate total cost of €29.57 billion (steel platform) for a capacity of 10GW. Thus, an estimate of €3 billion/GW

expected to drop with technology advances, as well as with CAPEX decreases for offshore wind turbines.

2.3 Romania-Bulgaria Energy Island

As mentioned in the Trans-European Networks for Energy (TEN-E) Regulation, the Black Sea Basin is a priority offshore grid corridor at EU level for offshore grid development. This basin has a substantial wind potential that could be maximized with the capabilities that an energy island project can bring to the benefit of the riparian EU (Romania and Bulgaria) and non-EU countries (Turkey, Georgia, Ukraine), as well as the EU internal market, more broadly.

To address the grid challenges that both Romania and Bulgaria face for deploying their offshore wind potential, a Romanian-Bulgarian (RO-BG) energy island can be an efficient and scalable solution to unlock large-scale offshore wind deployment, as well as bring an invaluable interconnection capacity with other countries at the Black Sea (such as Turkey, Georgia, as well as Azerbaijan, further on), drastically improving energy security and contributing to the region's decarbonisation.

Based on existing studies, the joint planning and development of offshore wind resources between Romania and Bulgaria can start by combining the two most promising areas:

- Romania: **The Orange cluster**, identified by EPG's study on the potential for offshore wind in the Black Sea, which provides the best available balance between wind resource and cost of the grid infrastructure (EPG, 2020).
- Bulgaria: **Area 1** (Shabla/ Romanian maritime border), mentioned in CSD's study on wind power generation in Bulgaria, which stands out due to the best wind resource and largest plot size (CSD, 2021).

A RO-BG energy island located between the two areas, each capable to host 3GW of offshore wind capacity, could link them together through VSC-HVDC submarine cables to the shores of both countries, as suggested in Figure 10 below.

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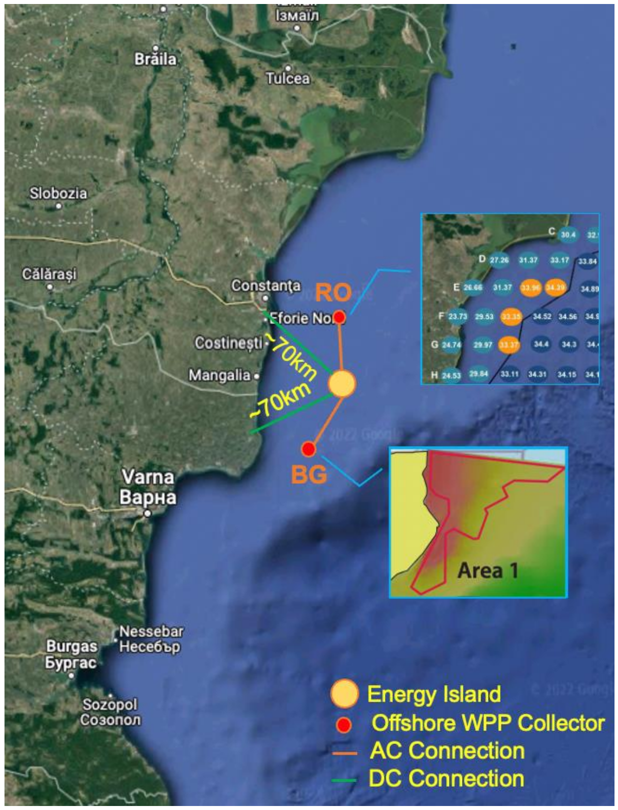
emerges, that can be roughly used for the Black Sea Energy Island case study, where a total capacity exceeding 3GW (Romanian and Bulgarian offshore wind capacities) is considered.

Figure 6. RO-BG Energy Island and HVDC submarine cable interconnection



Source: EPG (2020) and CSD (2021)

Based on other VSC-HVDC projects developed globally (Table 1), the length between these two potentials offshore WPP clusters, and considering the Romanian and Bulgarian national power grid, we estimate the main technical characteristics of the connections between the RO-BG Energy Island and their national power grids are:

- Total Cables Length: 140km;
- RO-BG energy island to Constanța Sud Substation: 70km;
- RO-BG energy island to Shabla Substation: 70km;
- DC Voltage Rating: 400kV;
- Power Rating: 3,000MW;
- VSC-HVDC Cable cost: €470 million in total, split between Romania and Bulgaria.

The locations of the offshore wind clusters were chosen based on the results of previous studies by EPG and CSD, respectively, with the selected areas standing out as having the highest offshore wind potential for each of the two countries. Thus, based on this feature, when selecting the location of the clusters and the location of the energy island halfway between the two power generation spots, the total HVDC cable length adds up to 140km.

The voltage level of HVDC links was set at 400kV based on the maximum standardised voltage level used the in Romanian and Bulgarian national power grids. It was deemed most suitable in terms of voltage conversion, and considering further offshore wind and interconnection developments, in order to match an energy capacity as big as possible.

The power rating was approximated at 700-1,000MW, and the cable cost was estimated at €470 million, based on comparison with other similar projects (see Table 1) – assuming a cost per km of €3.31 million/km, converters included.

Depending on the total power of the offshore WPP to be transmitted to the national power grid, the number of circuits of HVDC cables may grow and, correspondingly, the total cost of the power line will also go up. For example, if we are considering a total installed capacity of 3GW in offshore WPPs to be connected to the proposed RO-BG energy island, three circuits with the technical characteristics described above would be necessary to evacuate the energy to shore. For such a capacity, the total connection cost would increase to approximately €1 billion.

A configuration option for the power grid with the RO-BG energy island is represented in Figure 7. It is composed of a HVAC ring that would cover the hub on the island, with two types of connections to it:

- The offshore WPPs, connected through HVAC to the ring via an AC collector platform, if the WPPs are far from the island, and directly if they are close to the island.
- The interconnections to the Romanian and Bulgarian shores, which will first be connected to the HVAC-HVDC conversion stations, and then from the conversion stations to the HVDC submarine cables that will transport the energy to the shores. The infrastructure created by these links from energy island to both countries will also serve as interconnections between Romanian and Bulgarian power systems, when needed.

Based on the RO-BG energy island representation in Figure 6 for the Black Sea, a total cost emerges of **€2.6-3.4 billion/GW** for Romania's share of the RO-BG energy island, including the offshore WPPs and the HVDC power transmission infrastructure. This, again, is based on estimations from Denmark's Energy Island project (Danish Energy Agency, 2022; State of Green, 2022), and takes into account the distance from the shore – hence, the HVDC cable length from the island to Constanța Sud substation. This estimation is available for the proposed case, where the investment in the construction of the artificial island would be equally shared between Romania and Bulgaria. The range is given by WPP CAPEX values estimated from €2 to 2.8 billion/GW.

An in-depth feasibility study is required to analyse all technical and economic aspects of such a project, offering multiple solutions with other locations for the clusters, or with different location of the energy island, depending on the suitable areas for offshore wind capacities developments, their connection to the national power grids, protected areas, ports, etc.

RO-BG Energy Island financing options

The REPowerEU Plan launched this year to reduce the EU's dependence on Russian fossil fuels has some new important directions and goals to fast forward the clean transition. The Commission encourages the development of offshore grids, and an additional €29 billion will be invested in the power grids by 2030. This will be an important step benefiting both countries for cross-border PCIs (Project of Common Interest) that could interconnect the national power systems and help the future growth of offshore wind energy power in the Black Sea. Most such PCI projects required to deliver on the REPowerEU objectives will be supported through the Connecting Europe Facility-Energy (CEF-E), that has new calls for PCI proposals every year, with the next one in the early 2023 (EC, 2022b). It is essential that offshore DC cable projects be encouraged under these funding mechanisms, coordinated with the development of offshore wind farms in the region. Under an internationally coordinated approach to power grids infrastructure, the costs can be reduced, and additional benefits obtained from the facilitation of energy exchange between international markets (ABB, 2018).

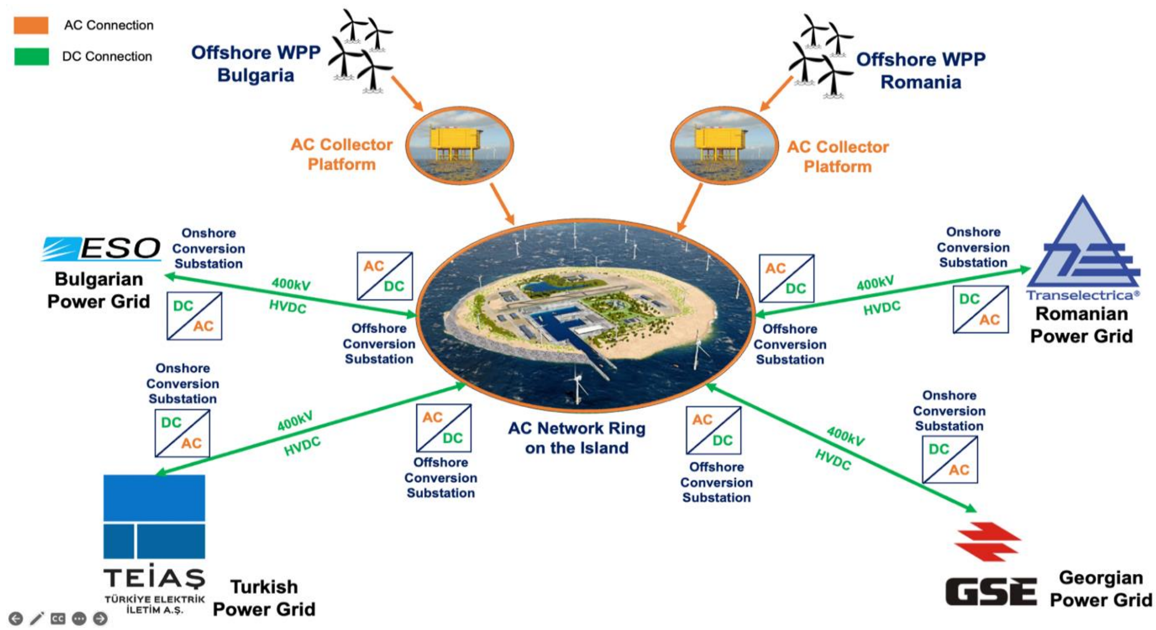
2.4 The development of potential HVDC cross-border interconnections in the Black Sea basin through the Energy Island

Transelectrica's TYNDP document (Transelectrica, 2022a) mentions the company has assessed the options for grid development for an additional installed capacity of 1,000-3,000MW in Dobrogea. The results of the study propose two options:

- An AC solution: a new 400kV power line from Constanța Sud to Bucureşti Sud substations, completed by the reconductoring of some of the power lines in the region;
- A DC solution: a new 876km 400kV VSC-HVDC power line to connect the new Constanța Sud substation with the existing Bucureşti Sud, Slatina and Arad substations.

If any of these two grid development solutions are developed in Dobrogea, they could solve the grid bottlenecks for future offshore wind developments in the Black Sea, and the energy island and hub-and-spoke concepts described above could become reality.

Figure 7. Energy island configuration in the Black Sea



Source: EPG analysis

The second option in the Transelectrica's study, describing a HVDC cable that goes from S-E to the west of the country and further to Hungary, is a solution with even better applicability for the energy island. This solution is basically a HVDC 400kV power cable that would cross the country from the Black Sea to the Hungarian border, like an „energy highway" for the Romanian power system, capable to evacuate high power from the south-east and deliver energy to the western Romania, which is the country's region of highest energy demand, and which lacks sufficient local power generation capacities.

Another technical advantage of this solution for the offshore developments is that the number of conversions is lower, and the power coming from the energy island will connect directly in HVDC through this 400kV cable. Although this solution would be several times more expensive than the AC solution (€2.694 billion compared to only €222 million) (Transelectrica, 2022a), the costs would be offset in time by the increased flexibility of the regional grid and the improved energy security.

In terms of regional cooperation, an important project that had been intensively discussed about 10 years ago is the undersea HVDC Romania-Turkey interconnector. For that project, a feasibility study was contracted by Transelectrica. The interconnector's construction should have started in 2014, but the two consecutive governments could not reach an agreement with the Turkish counterpart.

The Romania-Turkey interconnector proposal would still be a very welcome project, able to strengthen the region's grid for future RES developments in Dobrogea and in the larger Black Sea basin. If it was to be resumed in the coming years, the better option would be to link it to an energy island, which would bring the huge advantage of providing interconnectivity not only with Romania, but also with Bulgaria.

Another important regional project proposal that must be taken in consideration is the Georgia-Romania submarine cable that would interconnect Southeast Europe with the South Caucasus underneath the Black Sea. In 2019, the Georgian TSO (GSE JSC) performed a preliminary study on a Georgian-Romanian power systems interconnection, funded by the Energy Community. That study pointed out that a feasible interconnection would have the following specifications:

- Length: 1,170km
- Capacity: 1,050MW
- Voltage: 500kV HVDC
- Estimated cost: €2 billion
- Estimated date of commissioning: late 2029
- Connecting substations: Anaklia (GSE) – Constanța Sud (TEL)

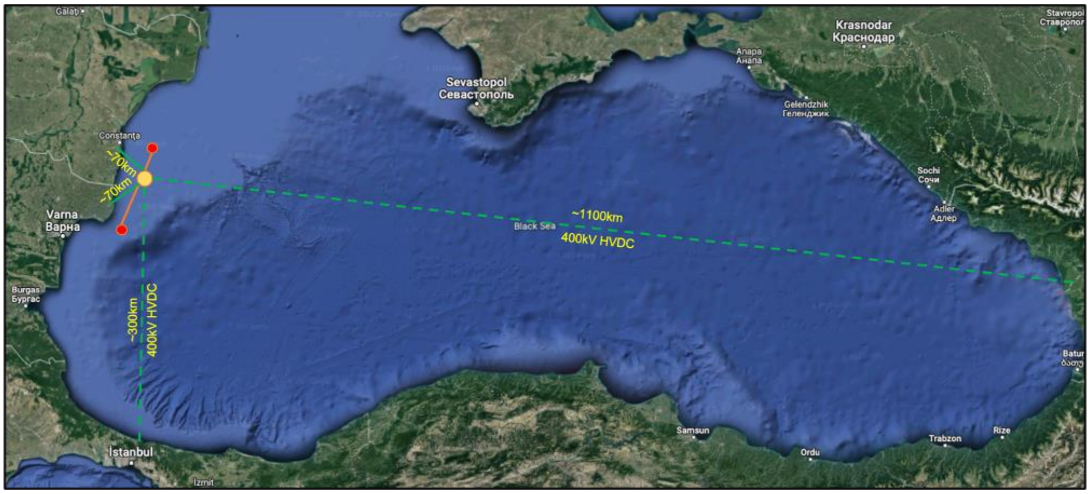
Based on this preliminary study, in 2021 the Georgian TSO ordered a more complex feasibility study that is still ongoing with the support of the World Bank, which will identify the main technical aspects of the project. The feasibility study is expected to be finished at the end of 2023. This project would mark a very important step in the Black Sea Basin in terms of regional cooperation, as it will bring significant gains for the security of supply, competitive energy prices and green energy development.

GSE has already included it in its TYNDP plan, and ENTSO-E included the Black Sea interconnector in its projections. Transelectrica is currently collaborating with GSE for the feasibility study and will subsequently decide whether the project will become part of its TYNDP (Transelectrica, 2022a; World Bank, 2020; GSE, 2021).

The most recent signal that this regional interconnection project across the Black Sea is getting closer to reality came on 17 December 2022, when Romania, Azerbaijan, Georgia, and Hungary signed in Bucharest an agreement to build the submarine HVDC power cable to link the Romanian and Georgian shores for the transmission of green energy.

The energy island proposal would certainly add an extra-advantage to the Georgian-Romanian HVDC interconnection, namely that Georgia, but also Romanian, Bulgaria and Turkey would benefit from of a larger interconnection using the hub's infrastructure.

Figure 8. Representation of the interconnection of Georgian power grid with the Romanian, Bulgarian and Turkish power grids through the RO-BG Energy Island



Source: EPG analysis

3 Cost assessment of the offshore wind power in the Black Sea and the implications for the energy market

An insight on the key economic indicators for the development of offshore wind in the Black Sea is essential for determining the viability of the investment and the role the technology will play in the future energy mix. Based on the wind resource data from the initial study, as well as estimated CAPEX and OPEX data from the industry, the LCOE for offshore wind in Romania will be calculated, in different scenarios, for both fixed and floating technology. This will help understand the level of public support required for developing offshore wind capacities, compared to other technologies, as well as the implications on the energy market.

3.1 Methodology

The Levelized Cost of Energy (LCOE) is a summary metric that combines the primary technology cost and performance parameters: capital expenditures, operations expenditures, and capacity factor (NREL, 2021).

Equation 1. Levelized Cost of Energy

$$\mathrm{LCOE} = \frac{\text{Total lifetime cost}}{\text{Total lifetime output}} = \frac{\sum_{t=1}^{n} \frac{I_t + M_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

It = investment and expenditures for the year t

M_t = operational and maintenance expenditures for the year (t)

E_t = energy output for the year (t)

r = discount rate

n = the expected lifetime of the project

For offshore wind, Capital Investment Expenditures (CAPEX) costs refer to project management, development and engineering expenditure, environmental, social, and coastal impact assessments, seabed surveys, technology equipment and installations, balance of plant components (CSD, 2021). The largest share of the costs comes from the wind turbines, approximately 30-35%, while variable operational costs (OPEX) are low due to the zero fuel costs.

OPEX costs mainly refer to Operation and Maintenance costs (O&M), which occur throughout the lifetime of the project and include maintenance, repairs, administration, but also port activities and sometimes license fees. Generally, the farther from the shore, the higher these costs are.

The capacity factor represents the number of hours a renewable generator can operate at full capacity in one year and therefore has a significant impact on the LCOE. Decommissioning costs at the end of the lifetime are also considered in assessing the LCOE of offshore wind technology.

Table 2. LCOE for fixed and floating offshore wind assumptions

Sensitivity	Fixed			Floating		
Capacity factor	0.35	0.40	0.45	0.35	0.40	0.45
CAPEX ('000 EUR)	2,000	2,200	2,800	3,200	3,400	3,700
WACC (%)	5.0	7.0	10.0	5.0	7.0	10.0
OPEX (EUR/MW/year)	73,500			119,000		
Project lifetime (years)	30			30		

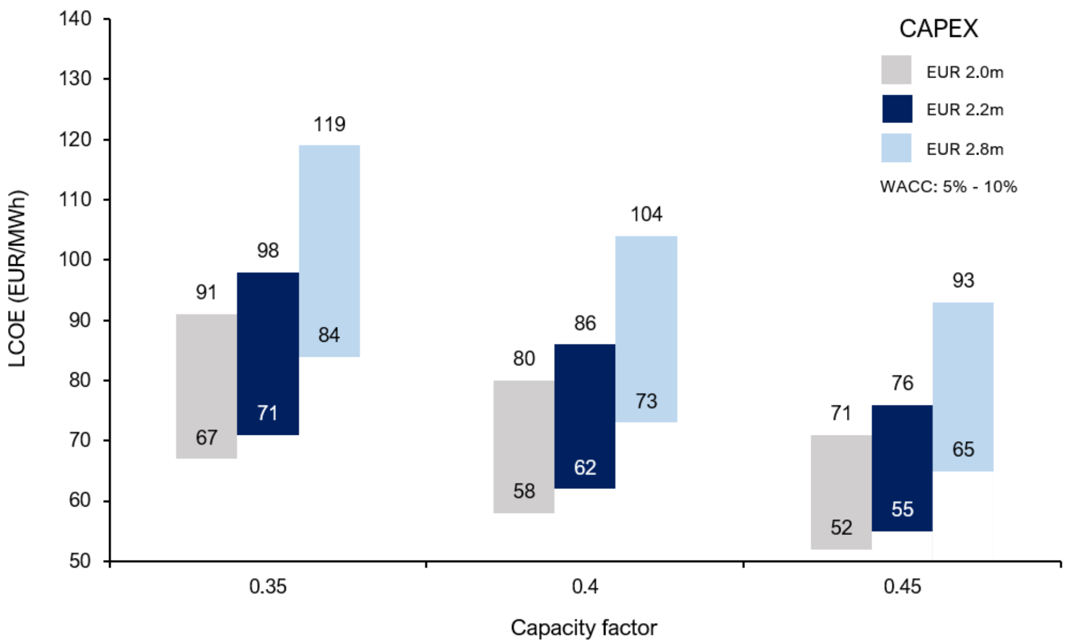
Source: EPG analysis using same input parameters as CSD (2021)

3.2 Results

A sensitivity analysis on the key parameters influencing the LCOE for offshore wind reveals a wide range for the LCOE of fixed offshore wind in the Romanian region of the Black Sea between €52 and €119/MWh. However, narrowing down to a realistic reference scenario for 2030, accounting for a CAPEX of €2.2 million/MW, a 0.4 capacity factor and a WACC of 7% leads to an LCOE of €71/MWh.

Despite recent cost reductions, floating offshore wind is still the more expensive technology, reflected by the results of the sensitivity analysis for the Romanian region of the Black Sea, with the LCOE ranging from €82 to €163/MWh. Since there is a substantial potential for placing fixed offshore wind farms, exploiting the floating potential only makes sense at a later point, when technology costs drop sufficiently, and to tap into areas of better wind resource. Therefore, the reference scenario is based on a CAPEX of €3.2 million/MW, a 0.45 capacity factor and a WACC of 7%, resulting in an LCOE of €94/MWh.

Figure 9. LCOE variation of fixed offshore wind in the Black Sea depending on CAPEX, capacity factor and WACC



Source: EPG analysis

While mostly global technology advances and optimisation will reflect in the CAPEX cost, at national level achieving the lowest possible costs for offshore wind energy can be done through:

- Identifying and exploiting the areas with the best natural potential, translated into the highest capacity factor (when considering for the same geological conditions in the case of fixed offshore technology and equivalent distance to shore connection points)
- Lowering political and financing risks through a stable legal and regulatory framework in the field of energy, as well as de-risking revenue stabilisation mechanisms such as two-way CfDs for offshore wind auctions, with a direct impact on the WACC.

Brining the energy output to shore is one of the key challenges for offshore wind, requiring complex and expensive infrastructure. However, it can also create new flexible interconnections with countries from the same sea basin, through HVDC grids and energy islands.

In the specific case of a joint project between Romania and Bulgaria as presented in the previous chapter, adding the costs of HVDC connection costs to the Constanta Sud station to the LCOE of the reference scenario for fixed offshore wind would bring the total cost to €79/MWh for a 3GW installed capacity.

Adding an artificial RO-BG Energy Island, as described by the previous chapter, tailored for the same 3GW installed capacity would only bring up the total levelized cost to €85/MWh, assuming that the capital investment for the energy island is split equally between Romania and Bulgaria.

In the reference scenario, the total share of the CAPEX costs allocated to Romania in the RO-BG Energy Island project, including the 3GW offshore wind farms would be €8.4 billion (€810 million representing Romania's share of the RO-BG Energy Island), while the annual energy production is estimated at 9.8TWh.

3.3 Energy market impact

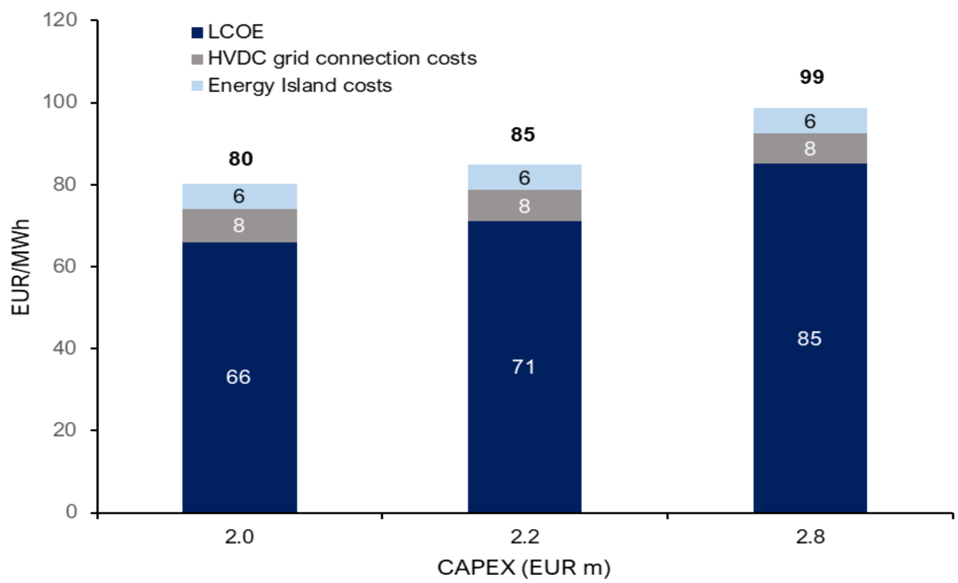
Offshore wind investments have a longer time to market compared to their onshore renewable counterparts, but shorter than conventional zero-carbon generation such as large hydro or nuclear power plants. Offshore wind farms take between five to 10 years to be developed, with an EU-average of 7 years, meaning there is a good chance for Romania to connect its first offshore capacities before 2030. This will contribute to addressing the net electricity importer status Romania has today, as well as provide a significant share to the additional clean energy required for decarbonising sectors such as industry, transport, and heating and cooling.

While difficult to estimate electricity market prices in 2030 and beyond, the LCOE for fixed offshore wind in the Black Sea in the reference scenario is lower than the one of conventional power generation capacities such nuclear, gas- and coal-fired power plants when considering the cost of CO_2 emissions. While not competing on price against onshore renewable capacities, offshore wind can offer the scale without the challenges related to land installation, and higher capacity factors. The higher capacity factor that offshore wind provides in the cold season and the stability of power production (EPG, 2020) open up for synergy with heat pumps in decarbonising the heating sector, thus reducing Romania's exposure to gas related vulnerabilities during the winter months.

Offshore wind energy can also contribute to hydrogen production and meeting Romania's targets of decarbonising industry and transport through RFNBOs. Dobrogea has all the prerequisites for becoming a clean hydrogen valley, due to an exceptional potential for producing hydrogen from offshore and onshore renewable energy, regional hydrogen demand in refineries, steel plants, and multiple transport modes, as well as a strategic role to be played by the Port of Constanța.[3] Given the LCOE estimations in this study, producing green hydrogen from offshore wind alone will not be cost-competitive against onshore wind and solar PV. However, to reach the highest cost-efficiency of hydrogen production plants by ensuring 4,500-5,500 electrolyser full-load hours, sourcing offshore wind energy on top of onshore wind and solar will be essential.[4]

The additional interconnection capacity that a joint RO-BG offshore wind project and a RO-BG Energy Island connected to Georgia and Azerbaijan, or possibly Turkey, would have a major impact not only on the overall energy security of the Black Sea Region, but also on the energy market prices, offering alternative import routes for clean energy, compared to the mostly fossil-based energy that is imported from countries such as Ukraine or the Balkans.

Figure 10. LCOE, HVDC grid connection costs and Energy Island costs for fixed offshore wind in the Black Sea



Source: EPG analysis

[3] https://www.enpg.ro/wp-content/uploads/2022/04/EN_18.11.2021_OP-ED.pdf

[4] https://www.enpg.ro/wp-content/uploads/2022/02/68-Clean-Hydrogen-in-Romania-Study-1.pdf

Table 3. LCOE for Fixed and Floating Offshore Wind in Romania

LCOE (EUR/MWh) for Fixed Offshore Wind

WACC = 5%

Capacity factor/ CAPEX (mEUR)	2.0	2.2	2.8
0.35	67	71	84
0.40	58	62	73
0.45	52	55	65

WACC = 7%

Capacity factor/ CAPEX (mEUR)	2.0	2.2	2.8
0.35	76	81	97
0.40	66	71	85
0.45	59	63	75

WACC = 10%

Capacity factor/ CAPEX (mEUR)	2.0	2.2	2.8
0.35	91	98	119
0.40	80	86	76
0.45	119	104	93

LCOE (EUR/MWh) for Floating Offshore Wind

WACC = 5%

Capacity factor/ CAPEX (mEUR)	3.2	3.4	3.7
0.35	106	110	116
0.40	93	96	102
0.45	82	86	91

WACC = 7%

Capacity factor/ CAPEX (mEUR)	3.2	3.4	3.7
0.35	121	126	134
0.40	106	110	117
0.45	94	98	104

WACC = 10%

Capacity factor/ CAPEX (mEUR)	3.2	3.4	3.7
0.35	146	153	163
0.40	128	134	143
0.45	114	119	127

Source: EPG analysis

4 Recommendations to stimulate local content and create a local value chain

4.1 Offshore wind value chain

Beyond the role for the energy supply and security of a country or region, offshore wind deployment has socio-economic benefits by creating jobs in the manufacturing, construction and operation and maintenance (O&M) of projects, with a multiplying effect on other sectors (World Bank, 2021). Hence, governments should consider offshore wind's long-term contribution to local economic and industrial strategies and chart areas of the supply chains where a country is likely to have competitive advantages.

National markets are typically too small to support a competitive local supply chain by themselves, compared to the United States or China, where, for example, employment at wind power companies depends especially on the strengths of the domestic market (BNEF, 2021). Although countries such as Germany and Spain have started to produce the full range of wind-turbine components consisting in nacelles, blades, towers, generators, gearboxes, and bearings (IRENA, 2021), employment there depends more on export markets (BNEF, 2021).

The manufacturing of wind turbines is highly concentrated in China, accounting for 45% of the ca. 800 factories worldwide, and Europe with 31%, followed by India (7%), Brazil (5%), the United States (4.5%), Canada and Mexico (WindEurope, 2020), as presented in Table 4.

Table 4. Wind-turbine components manufacturing footprint

#	Component	Manufacturing country/region
1	Nacelle	China, Denmark, Germany, India, and the U.S. hold a combined 98% of the world market
2	Blades and towers	China accounts for 40% of the manufacturing plants, Europe has a similar share (about 40%)
3	High-quality bearings	Companies in Europe, Japan, and the U.S. supply most of them
4	Gearboxes	More geographically dispersed compared to the above

Source: IRENA (2021) and WindEurope (2020)

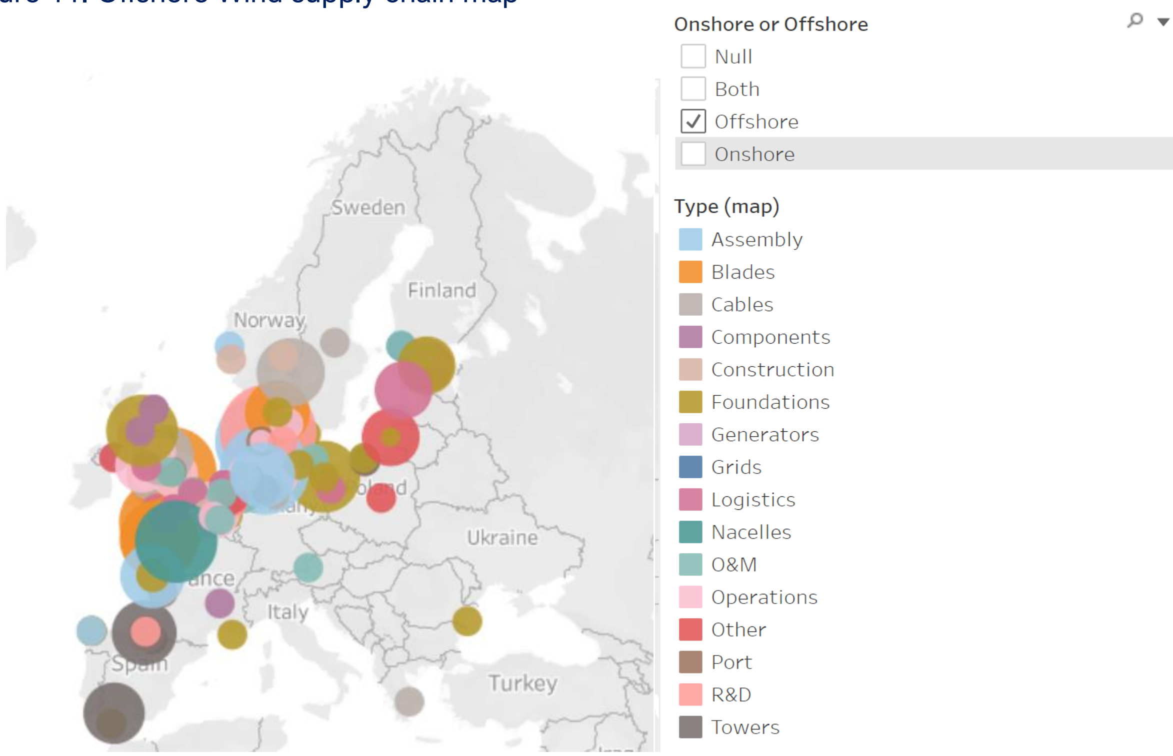
The sector's manufacturing footprint influences the locations where jobs are created. Thus, overall employment in onshore and offshore wind, estimated at 1.25 million jobs worldwide, is concentrated in China, with 44% of the global total, followed by Europe with 27% (21% in the EU) (IRENA, 2021).

Europe is the leader in installations and technology development in offshore wind industry, with a robust supply chain in the Nordic and Baltic countries, yet much less so in the Southern and especially the Eastern part of the continent, as presented in Figure 11. Even though in Romania a sole segment of the offshore value chain is currently active, namely foundations, through GSP (*Grup Servicii Petroliere Offshore*) – a company providing offshore integrated services, especially drilling rigs for the oil and gas industry – in September 2022, Damen Shipyards Mangalia, announced the development of a new class of vessel capable to support the rollout of large scale, floating offshore wind turbines – FOWT (Damen, 2022). Thanks to its geographical position, Damen's offshore construction facility will also be critical to the development of floating offshore wind, through the production of floating foundations on which the turbines will be mounted. Such investments will have a multiplying effect on other investments, with positive impact on the regional economy and infrastructure development.

Moreover, on the O&M side, Romania can benefit from the experience of the largest training centre for renewable sources in Southeast Europe developed by Monsson and located in Constanța, namely Renewable Energy School of Skills – RESS (RESS, 2022). The training centre has been producing experts covering the needs of the regional markets and is already preparing offshore technicians.

In 2020, the leading European manufacturers of offshore wind turbines (by the number of installed offshore wind turbines) were: (i) Siemens Gamesa Renewable Energy (3,670), with headquarter in Spain; (ii) Vestas Offshore Wind (1,290); (iii) Senvion (238); (iv) Bard Engineering (80); and (v) GE Renewable Energy (74) (WindEurope, 2021 and Statista, 2020). A clear commitment from Romania's authorities on the development of offshore wind will capture investors' attention, especially those already present in the country. For instance, Siemens has been doing business in Romania since 1991, currently having four factories and five R&D centres, with a total of 2,300 employees (Siemens, 2022), focusing on technologies for industry, including smart power grids, infrastructure, transport and healthcare. Therefore, Romania's Foreign Investment Agency (InvestRomania) might consider tailoring a strategic approach to attract Siemens Gamesa Renewable Energy through Siemens Romania.

Figure 11. Offshore Wind supply chain map



Source: Wind Europe (2022)

Offshore wind needs investment in new manufacturing facilities to continue to reduce LCOE, but individual suppliers often find it hard to justify such investments, especially in new markets. However, public support can incentivize investment decisions. For example, the UK developed an *Offshore Wind Manufacturing Investment Scheme* in 2020 (GOV.UK, 2020) aiming to speed up the offshore wind deployment. The scheme implied a competitive process to enable delivery of a single large coastal manufacturing site for the offshore wind industry, able to generate manufacturing clusters where several large-scale producers can co-locate. The competition is run by the Department for Business, Energy and Industrial Strategy (BEIS). Although the amount of the scheme was not fixed, the reference was GBP 70 million. The scheme continued in 2021. Siemens Gamesa and GRI Renewable Industries were among the beneficiaries of this scheme, to increase capacity for wind turbine and tower manufacturing in the Humber region (Edie, 2021).

Different countries have introduced different fiscal and financial mechanisms to support offshore wind investments, especially where they are made to deliver a single project. In general, as pointed out by World Bank (2021), such mechanisms include:

- Targeted competitive schemes, whether for capital support (GOV.UK, 2020) or research and development (R&D) support (NOWRDC, 2020).
- Tax incentives for offshore wind or for industry more generally (New Jersey Economic Development Authority, 2020).

In some countries the governments introduced local content requirement for offshore wind manufacturers as a form of protectionism for local offshore wind development – such examples are France and Taiwan (World Bank, 2021). The UK has no such requirements, but a target of 60% local content by 2030 has been agreed upon (GOV.UK, 2019).

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, as indicated by WindEurope (2020). Per GW of installed power, onshore wind in Europe generates €2.5 billion of value added to the EU economy, while offshore creates €2.1 billion. Applying this estimation to the Romanian economy, 3GW of installed offshore wind power could generate €6.3 billion, 2.6% of GDP[5] (Eurostat, 2021), yet the figures are just a broad indication, as there are significant structural differences between Romania's economy and the European one, including the level of offshore value chain development. 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 WindEurope report 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 (EPG, 2020).

4.2 Local employment opportunities

Offshore wind industry creates long-term sustainable jobs in manufacturing, construction and O&M. Offshore wind farms require more labour than onshore ones, because construction and installation are more complex, involving undersea foundations and installation vessels, as well as substations and undersea cables to bring electricity onshore, leveraging the capabilities found in the offshore oil and gas sector (GWEC, 2020).

The wind energy is responsible for more than 300,000 jobs at EU level (WindEurope, 2020), with about 160,000 direct jobs (as of 2019), 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

[5] According to Eurostat, Romania's GDP was €240 billion in 2021.

that the total number of offshore wind jobs could increase with 40,000 until 2025, namely a 52% increase in seven years (from 77,000 in 2019 to 117,000 in 2025).[6]

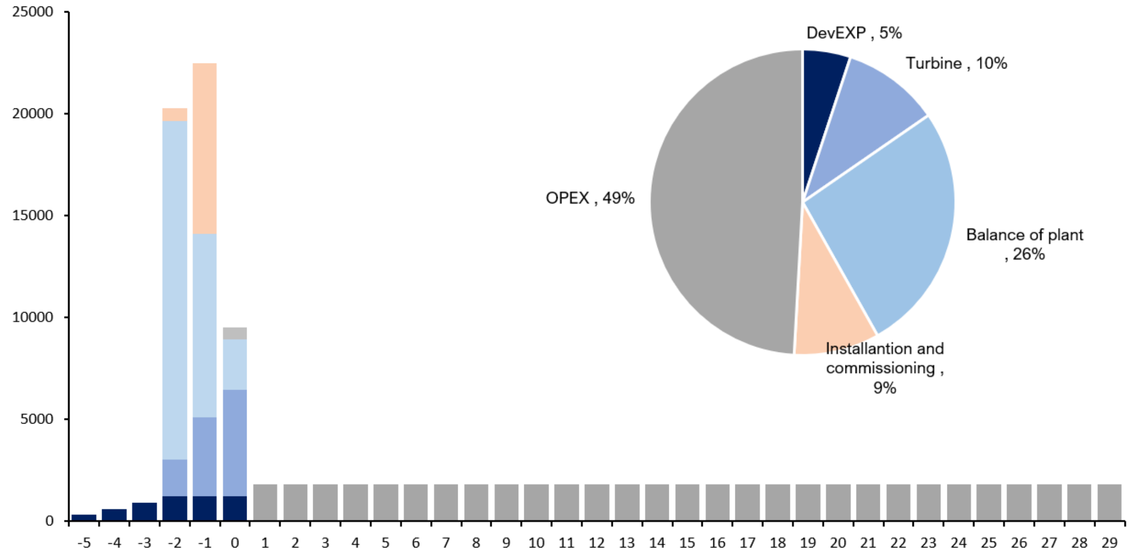
A key question is how many of these jobs will Romania be able to create locally, given that the process requires economic and industrial planning, long-term vision and significant political and administrative ambition. Although most of the offshore wind industrial value chain is located in Northern and Western Europe, as presented above, 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 national clear targets for offshore wind deployment could attract investors, as is the case in Poland, proving that investments in the manufacturing chain towards the Eastern Europe becomes an opportunity. In October 2022, Vestas announced building a nacelle factory in Poland for offshore wind turbines that will create up to 700 direct jobs. The Polish wind farm developer Orlen will, in parallel, build a port for offshore wind installations near the factory. Both investments will serve the 1.2GW Baltic Power offshore wind project in the Baltic Sea. Vestas will deliver, install, and commission 76 wind turbines for the project, and support the foundation designing (Wind Europe, 2022b). The investment follows the Offshore Wind Sector Deal signed by the Poland in September 2021. The deal aims to establish a leading offshore wind industry in Poland, where the industry commits to create up to 60,000 direct and indirect jobs by 2040, and the government promised to carry out competitive auctions for offshore wind as of 2025 (WindEurope, 2022b). The investment follows the Offshore Wind Sector Deal signed by the Poland in September 2021.

Developing a 3GW project of offshore wind power in Romania, the distribution of full-time equivalent employees (FTE) involves about 20,000 FTE in the capital phase, for project development, manufacturing, balance of plant and installation (two-three years before the commissioning of the project); and ca. 1,800 FTE per year for O&M activities (Figure 12). The reasoning is that at first, a new market will have a higher share of local employment in the operating phase than the capital phase of a project, but the contribution to the capital phase typically increases as local the suppliers mature. Therefore, the number of jobs associated with the development of an offshore wind project, especially in the capital phase is correlated with its value chain.

[6] EPG estimations based on GWO and GWEC forecasts (172,000 new offshore wind globally, out of which 21% in the EU).

Figure 12. Offshore Wind jobs distribution for a 3GW project in Romania



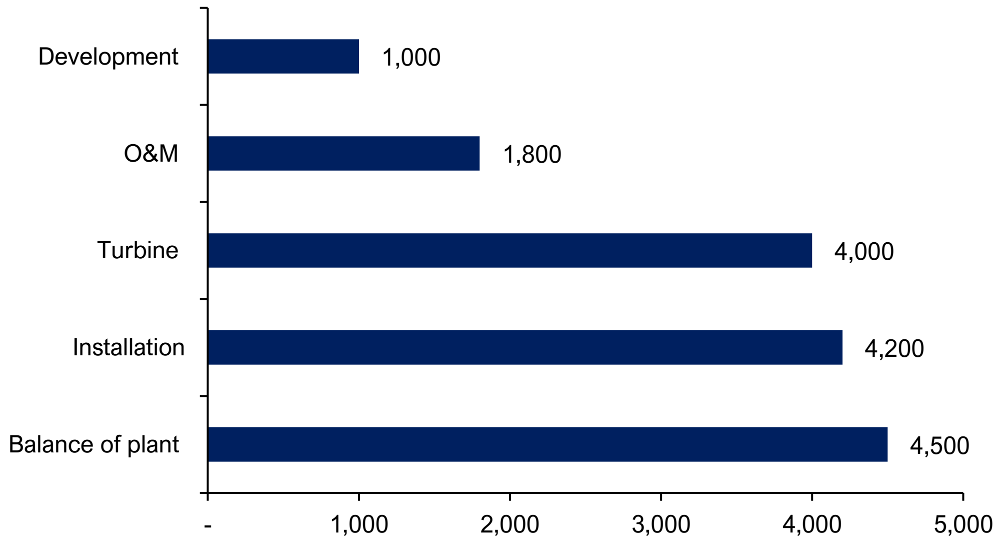
Source: Adapted from World Bank (2021)

Out of the total 22,000 new FTE employees: (20,000 in the capital phase and 1,800 for O&M), 15,500[7] could be direct new jobs created at local level (approximately 4,500 in the balance of plant, 4,200 in installation, 4,000 in turbine manufacturing, 1,800 in O&M and 1,000 in development and support functions), assuming Romania will attract investors in manufacturing of wind-turbine components and also in construction activities, installation and balance of plant, respectively as presented in Figure 13. The assumptions were that (i) 50% of turbine components will be manufactured locally, (ii) 50% of installations will be developed with local labour force, and (iii) 75% of the balance of plant employment will be developed will also involve local workforce. The estimation reflects a conservative approach, based on Romania's labour market dynamics (EC, 2022). National planning focused on access to training and education, including reskilling programs and vocational schools that form technical skills for offshore wind employment will increase Romania's attractiveness for investors in offshore wind manufacturing.

Romania's decarbonisation scenarios until 2050, presented in Section 1, indicate that 15GW offshore wind will be needed by 2050. Thus, we envisage five employment phases until 2050, as indicated in Figure 13 (scenario for 3GW).

[7] EPG estimations based on WindEurope (2020): The estimate of jobs created per GW of offshore wind developed in Europe reveals a total number of 5,677 direct jobs and World Bank (2021).

Figure 13. Offshore Wind new FTE created locally for a 3GW project in Romania



Source: EPG analysis

In times of challenging macroeconomic context (IMF, 2022), 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, an objective 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. A strategic approach could be developed through cooperation between InvestRomania and the Department for Industrial Policy and Competitiveness under the Ministry of Economy.

4.3 Ports: a key enabler for offshore wind

Ports must be prepared to support wind turbine manufacturing, foundation production, installation, operation and maintenance of wind farms across regions to serve several projects with the right investments and policies. Once the offshore wind power plants become operational, ports fulfil the function of operation and maintenance (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 7.5m (CSD, 2021).

The port infrastructure needs to provide high load capacity, and the docks should be about 200-300m long to provide access to vessels of at least 140m without restrictions. Installation ports need to be designed as deep seaports and 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 15-30t of material per m^2 and at least 80,000m^2 of storage space would be necessary for laying and assembling the equipment (EPG, 2020).

Large investments are needed in the needed port infrastructure for offshore wind. For reference, Siemens Gamesa Renewable Energy invested GBP 160 million in 2016 in the Port of Hull (UK) for the construction of a new harbour to enable the pre-assembly of turbines prior to installation in the North Sea. The investment, combined with an extra GBP 150 million from Associated British Ports, allowed the construction of the facility which will supply several offshore wind farms. Also, the new infrastructure for the development of floating offshore wind in the Mediterranean led to €230 million investments in Port La Nouvelle, France. This includes a reinforced quay of 200 x 50m; a specific area with a capacity of 30 t/m^2; and 10 ha with strengthen soil. The port has been working with EolMed windfarm and EFGL (Eoliennes Flottantes du Golfe du Lion) on two pilot projects of 28-30MW.

EU funding dedicated to ports infrastructure for supporting offshore wind deployment is available. According to the Connecting Europe Facility-Transport (2022), investments eligible for financing are the development of quays, berths and utilities installations for the pre-assembly, construction, operation, maintenance and decommissioning of offshore wind farms. Maritime ports on the TEN-T core and comprehensive network are eligible to apply for funding. Support will be provided both under the general envelope (maximum co-funding rate for studies, 50%; 30% for works) and under the cohesion envelope (maximum co-funding rate both for studies and works, 85%).

5 Framework to unlock the legal and regulatory status quo for offshore wind development in Romania

5.1 Regulatory framework. Role of authorities

The natural potential and structural conditions for offshore wind power differ across Europe, resulting in a range of investment options, yet the interest and investment in such assets have steadily increased steadily over the years, with countries using support schemes, de-risking instruments, and organising multiple tender rounds. The differences among them, though, including the capacity to organise competitive tenders and manage big infrastructure investments, resulted in different approaches to offshore wind investments.

According to the World Bank (2021), the European offshore wind practice favours two options for site-developing: a centralized, state-led model and an open-door, investors-led process.

- The former implies a hands-on management by the state authorities, with identification of priority areas, ensuring grid access, and organising auctions for perimeters.
    - The advantage of this approach consists in having a well-planned, strategic, deployment of offshore windfarms, in different investment stages, especially considering the need for cross-border cooperation.
    - The disadvantage consists in longer lead-times for assessing the priority areas, as well as in the limited confidence among potential investors in the accuracy of such technical measurements.
- The latter envisions measurements by prospective operators themselves, under exploration licenses, based on their investment intentions, which can later acquire exclusive rights for deploying and operating wind parks. In any event, the exploration results are kept by the state authorities for future investment stages.
    - The advantage of this approach is a more agile assessment process, thus faster measurements (which can be done at the same time, for different areas, by different operators) and, therefore, shorter lead-times.
    - The disadvantage comes from a less organised deployment, which may also lead to inefficiency in development (e.g., wake effects), as well as in a less or no coordinated approach with neighbouring countries.

As scholars and analysts have noted, offshore wind developments ought to be integrated in the national long-term energy strategies, with specific and extensive provisions in strategic plans.

Given Romania's natural wind potential in the Black Sea, as well as the seabed structure, the offshore cost is expected to become competitive with other forms of electricity generation in the region. For this reason, setting up the proper legislative and fiscal frameworks for offshore wind developments is of critical importance, especially at present, at the beginning of massive deployments of offshore wind capacity worldwide. To this end, the Romanian recovery and resilience plan (NRRP) features reforms to support offshore wind investments, while the World Bank is currently leading an in-depth study to facilitate the capacity scale-up.

Experts have advocated for a dedicated law for offshore wind regulation, arguing that this approach would avoid regulatory conflicts with other primary or secondary legislation. Nonetheless, the Romanian legislative record shows that while dedicated legislative frameworks offer a foundation for implementation, regulatory conflicts can still occur, stalling the deployment process. Therefore, a separate legislative act for offshore wind developments is no guarantee against regulatory bottlenecks. Indeed, a larger regulatory framework for new renewable generation capacities may be a better fit, as it would set the general rules for permitting and competitive bidding for all categories of renewable technologies, aligned with the latest EU developments. The disadvantage of a larger piece of legislation relates to its very developing process, since including other types of renewable generators would likely delay issuing the legislative act.

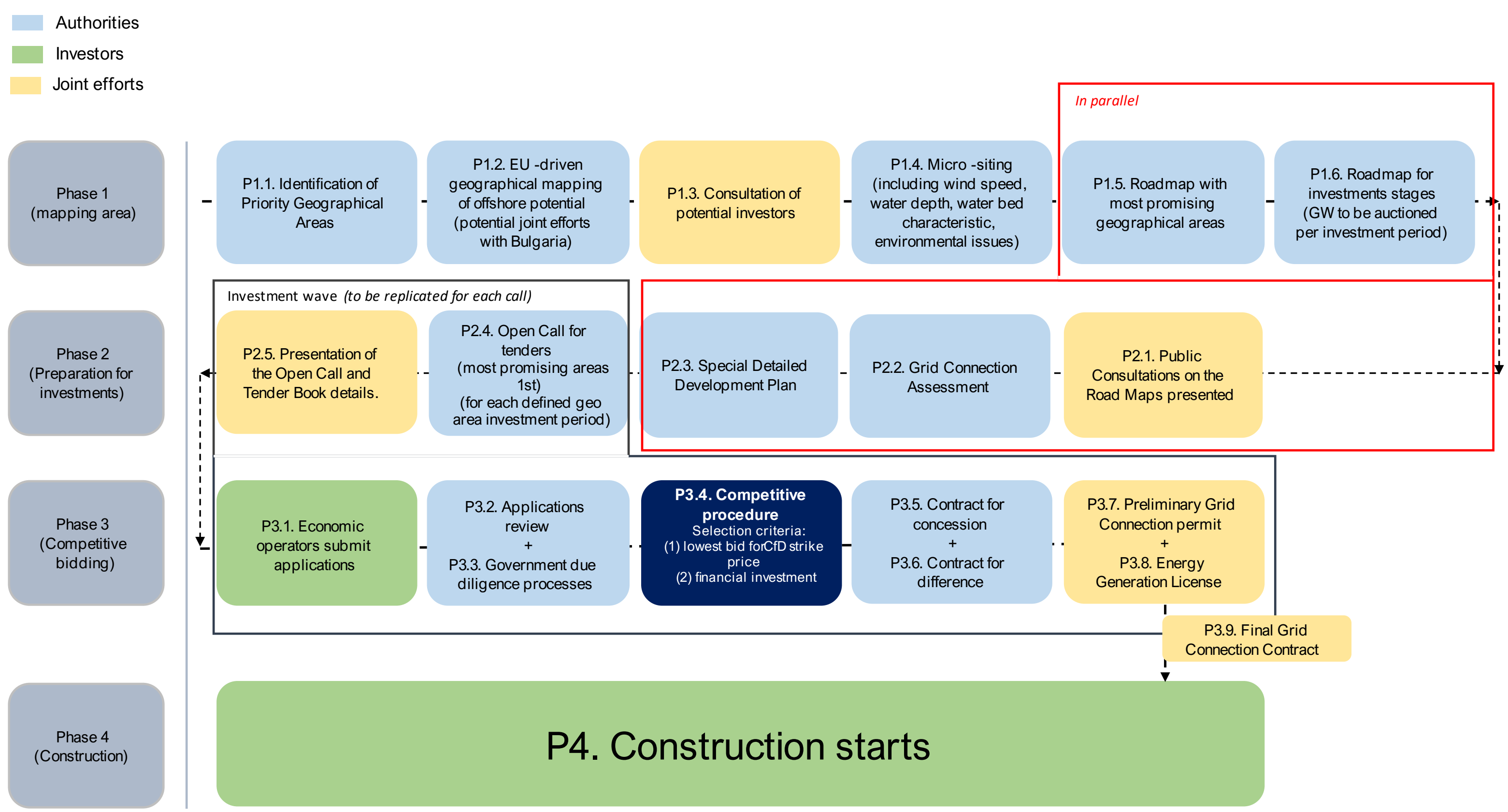
Apart from setting an adequate regulatory path ahead for offshore wind capacities, the legislative framework must establish clear roles and competences among the authorities and institutions. As in other countries of the region, the approval/development process is presently split between different central authorities (e.g., Ministry of Energy, Ministry of Environment, Ministry of Transportation, Ministry of Finance, etc.), several central executive bodies (e.g., National Regulatory Authority, TSO, Distribution System Operators) and, to some extent, local authorities next to the offshore perimeters. To this end, an inter-ministerial committee – with the role of managing the planning and developing process (Figure 14) – will go a long way ensuring a lean and bottleneck-free process in the years to come.

In addition, with the current geopolitical tensions in the region, developments in the Black Sea region ought to be assessed by the Romanian Supreme Council of Defence (CSAT). Strategic and military reasons call for a regional joint dialogue between Romania and Bulgaria, in a first stage, and other neighbouring countries in later stages. An EU-led conversation on the future of Black Sea offshore deployment may ease the process for the two member states and future non-EU partners. It would also facilitate the discussion and potential creation of energy islands, as well as potential long-distance interconnections.

5.2 Site Planning and Development Processes

Considering the above-described approaches to offshore wind investments, with their respective advantages and disadvantages, the current report presents a middle-ground solution (Fig 14), a blend between the two approaches, which aims to capitalize on the mentioned advantages, while diminishing the downsides and associated risks for investors. As a prerequisite and as a rule for successful planning and development, a consistent and continuous dialogue between state authorities (the inter-ministerial committee) and private investors is paramount, already from the early stages. For this reason, our approach includes several public consultations and dialogue opportunities between the parties

Figure 14. Site planning and development processes for offshore wind



Source: EPG analysis

The process above includes four phases, detailed in Table 5 below.

Table 5. Phases of the site planning and development processes for offshore wind

Phase		Description
Phase 1 **Mapping areas**	P1.1. Identification of Priority Geographical Areas	Based on existing studies and maps, the Committee determines high-level areas to be considered for the granular evaluation phase.
	P1.2. EU-driven geographical mapping of offshore potential (potential joint efforts with Bulgaria)	An EU-led process, aiming at granular map of the Black Sea seabed, for both Romania and Bulgaria, with the support of specialized technical institutes and experienced companies. Thus, the measurements will be consistent (the results will be based on the same measurement methodology) across the whole region and will be less likely to be contested by any developers in the region.
	P1.3. Consultation of potential investors	A first phase of consultations with potential investors stars in parallel with the micro-siting process. The consultation will feed the measurement methodology and reveal what kind of data is relevant for assessing the investment opportunities.
	P1.4. Micro-siting (including wind speed, water depth, waterbed characteristics, environmental issues)	Selected entities are performing technical measurements, revealing granular data for the respective offshore area.

	P1.5. Roadmap with most promising geographical areas	Based on the previous results, the Committee compiles a technical roadmap, containing the most promising areas.
	P1.6. Roadmap for investment stages (GW to be auctioned per investment period)	Similarly, different investment stages are determined, based on previous results and the long-term development strategy for the energy system.
Phase 2 **Preparation for investments**	P2.1. Public Consultations on the Road Maps	Based on the two Road Maps, a public consultation is held with interested investors and stakeholders, to optimise the Special Detailed Development Plan and the Competitive Bidding Phase.
	P2.2. Grid Connection Assessment	Based on the technical results available after P1A5, the TSO is providing high-level technical requirements for each determined area, for potential investors to include these costs in their bidding prices.
	P2.3. Special Detailed Development Plan	Based on the two Road Maps (P1.5 and P1.6), after the public consultation (P2.1.) and the technical provisions issued by the TSO (P2.2), a Special Detailed Development Plan is issued. It includes specifications (both natural potential and technical characteristics of the grid), as well as details on the investment stages.
	P2.4. Open Call for tenders, starting with the most promising areas (for each defined investment period in a geographical area)	Based on the Special Details Development Plan, a call for tenders is published. This phase and the remaining of the process is repeated for each investment stage.

	P2.5. Presentation of the Open Call and Tender Book details	Public presentation of the open call and Tender Book details are following. Based on this final consultation, last-minute procedural and administrative details may be adjusted.
Phase 3 **Competitive bidding**	P3.1. Economic operators submit applications	Considering the provided details, investors are submitting their applications.
	P3.2. Applications review	Applications are reviewed and those fitting the technical criteria of the Tender book, as well as the due diligence process (P3.3), are moving to the competitive procedure (P3.4)
	P3.3. Government due diligence processes	Due diligence of the investors that submitted proposals.
	P3.4. Competitive procedure	Bidding process for determined areas is being held. Selection criteria: lowest bid for CfD strike price, and non-price criteria.
	P3.5. Contract for concession	Based on the results from the previous stage, a contract for concession is issued for the winner.
	P3.6. Contract for difference	Based on the results from the previous stage, a contract for difference (CfD) is issued for the winner.
	P3.7. Preliminary Grid Connection permit	In-depth analysis by both the developers and TSOs representatives reveal the detailed technical requirements for the wind park. A temporary grid permit is issued.

	P3.8. Energy Generation License	Finalised approval process by the National Energy Regulator. Generation license is issued for operations.
	P3.9. Final Grid Connection Contract	Based on the technical solution and agreements approved by the TSOs through the preliminary grid connection permit, the final grid connection contract is signed.
Phase 4 Construction	The developer starts the construction phase of the determined offshore wind park	

Policy Recommendations

1. Joint regional planning and development of offshore wind between Romania and Bulgaria is paramount to deliver the scale that will enable cost-effectiveness and decarbonisation in the Black Sea basin. The additional interconnection capacity that a joint RO-BG offshore wind project and a RO-BG Energy Island connected to Georgia and Azerbaijan, and possibly Turkey, would have a major impact not only on the region's energy security, but also on energy market prices, offering alternative import routes for clean energy to the mostly fossil-based energy that is imported from the Ukraine or Serbia.
2. Achieving the lowest possible costs for offshore wind energy requires identifying and exploiting the areas of best natural potential, which translate into the highest capacity factor (assuming similar geological conditions for fixed offshore technology and equivalent distance to the shore connection points) and lowering political and financing risks through a stable legal and regulatory framework, as well as adopting de-risking, revenue stabilisation mechanisms such as two-way CfDs for offshore wind auctions, with a direct impact on the WACC.
3. The higher capacity factor that offshore wind provides in the cold season, with the associated stability of power production, is favourable to a widespread adoption of heat pumps, to decarbonise the heating sector and reduce Romania's exposure to gas related vulnerabilities during the winter months. This, along with offshore wind's contribution to decarbonising industry and transport, should be reflected in national strategic plans, such as the NECP, Long Term Strategy, Industrial Decarbonisation Strategy or the National Hydrogen Strategy.
4. The Port of Constanța needs a medium- to long-term vision for becoming a hub for offshore wind development in the Black Sea. Becoming the first mover in the Black Sea basin would allow it to host manufacturing capacities for the expansion of offshore wind to neighbouring countries, as well. To create a high number of local jobs, national planning should focus on training and education, including reskilling programs and vocational schools that form technical skills for offshore wind employment.
5. With a smart and targeted use of the available funding instruments, Romania could benefit from the positive economic impact and job creation potential that offshore wind offers. Moreover, a goal 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.

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