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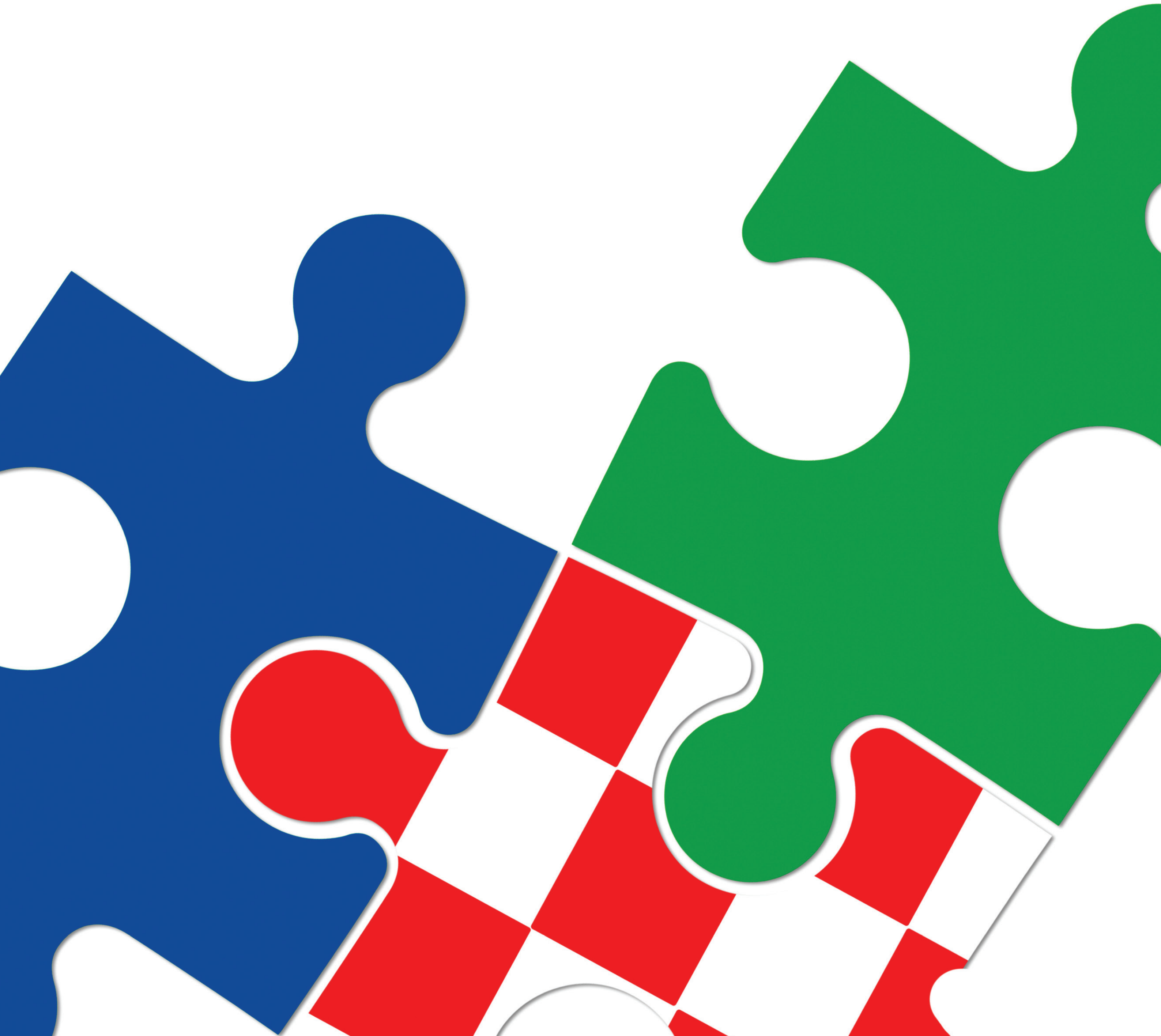
ACTION PLAN FOR THE UPTAKE OF OFFSHORE RENEWABLE ENERGY SOURCES IN CROATIA



DISCLAIMER

This report was funded by the European Bank for Reconstruction and Development (EBRD) and written jointly by the Faculty of Mechanical and Naval Engineering (FSB), University of Zagreb, OIKON Ltd. – Institute of Applied Ecology, and Island Movement.

The report analyses the existing framework and conditions for the development of offshore renewable energy sources and proposes an Action Plan that would help in their uptake. This high-level publication provides recommendations for offshore areas for further investigations but nothing in this report should be taken as legal, technical, or professional advice or services. This document does not provide the determination of go-to renewable areas as proposed in REPowerEU.

Neither the European Bank for Reconstruction and Development, nor the Renewable Energy Sources of Croatia, nor the authors shall be responsible for any loss whatsoever sustained by any person or a third party who relies on this publication.

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EXECUTIVE SUMMARY

The development of offshore renewable energy sources depends on a number of factors. After analysing the major sectors that would be impacted by the development of offshore renewables, this publication has identified more than 29,000 km^2 of available area for offshore renewables. This includes areas for offshore wind (both bottom-fixed and floating wind) and for floating photovoltaic power plants.

In the low-impact zone in the northern part of the Croatian part of the Adriatic Sea, the identified offshore area could accommodate up to 25 GW of offshore wind capacity. This identified area is the most preferred option as it would have the lowest environmental and visual impact. Furthermore, this could be expanded to medium-impact zones, where the potential offshore wind capacity increases by an additional 32 GW.

The central and southern parts of the Croatian part of the Adriatic Sea have more than 26,000 km^2 of available area for offshore renewables. Due to greater water depths, this area is preferred for floating offshore wind and floating photovoltaic power plants.

In order to start the development of offshore renewables, there are a number of points that need to be addressed by the Croatian Government.

The most important step is the development of the National Maritime Spatial Plan, which is the first step in establishing renewable go-to areas for offshore renewables. It is important to plan for a multi-use development of offshore renewables (e.g. co-location with hydrogen production, utilising existing oil and gas infrastructure, food production from mariculture activities, etc.). However, the Croatian Government should ensure a large number of available areas for the development of offshore renewables so that developers can identify the most cost-efficient sites.

The Republic of Croatia has a chance to include offshore renewables in the next revision of the integrated National Energy and Climate Plan, which is planned to start in 2023. Furthermore, this could also be used as an opportunity to identify the Croatian Hydrocarbon Agency as a single contact point for guiding developers in the permitting process of offshore renewables, as the agency has significant experience in managing concession tenders for the oil and gas sector and the geothermal sector provided that the legal framework for such role is ensured through changes of relevant laws and bylaws.

In order to see the first projects for offshore renewables commissioned in the early 2030s, it is important that, as soon as possible, agencies are identified that would start facilitating continuous measurements and the monitoring of offshore data sets, such as wind speed and frequency at higher altitudes, hydrographic surveys, and environmental surveys.

The development of offshore renewables also depends on the development of both offshore and onshore power networks. The ten-year network development plans of system operators need to plan for the integration of large-scale offshore renewables as well. This will require investments in the onshore network, which is already under pressure from the rapid development of onshore renewables.

The offshore renewable energy sector is relatively new and requires specific skills and expertise. It will take time to build the pool of necessary skills and expertise. Therefore, the Croatian Government should develop an *Offshore Renewable Energy Sector Deal*, and explore the inclusion of non-price criteria in auctions, which would award developers' commitments to invest in training and education programmes, as well as the local supply chain.

During the construction period of offshore renewables, the activities of other sectors (e.g. fishing) are usually restricted. Therefore, developers should engage fishermen early on in the site-selection phase and explore hiring or working together with them throughout the lifetime of the project.

Once a project is commissioned, it can operate in co-existence with fishing, biodiversity protection, military and civil aviation, etc. Identified agencies should be responsible for publishing offshore data (e.g. location of submarine cables) that can be used by other sectors to perform their activities in a safe way. Furthermore, in order to have uniform rules for all offshore renewable sites, the Croatian Government should define general rules of access. The general rules of access should precisely define which activities are allowed within the offshore renewable site and in its proximity.

Lastly, it is important to ensure a high level of community involvement in the development of offshore renewables. The identified agencies should develop an offshore renewables communication strategy, which will identify key stakeholders, and how best to communicate with them. The identified agencies should also identify the most suitable business model for involving local communities, conduct campaigns on awareness raising, and organise roundtables with stakeholders.

LIST OF ABBREVIATIONS

Abbreviation	**Full description**
AoI	Areas of Interest
CEEAG	Guidelines on State aid for climate, environmental protection and energy
CEF	Connecting Europe Facility
CfD	2-sided Contract for Difference
DEA	Danish Energy Agency
EIA	Environmental Impact Assessment
EC	European Commission
EPC	Engineering, Procurement, and Construction
EU	European Union
HVAC	High-Voltage Alternative Current
HVDC	High-Voltage Direct Current
LCOE	Levelised Cost of Electricity
MSP	Maritime Spatial Plan
NECP	National Energy and Climate Plan
NGOs	Non-Governmental Organizations
O&M	Operation and Maintenance
OEM	Original Equipment Manufacturer
ORES	Offshore Renewable Energy Sources
PV	Photovoltaic
TSO	Transmission System Operator
R&I	Research and Innovation
RES	Renewable Energy Source
ZPDML	The Act on Maritime Property and Sea Ports
ZPU	The Act on Spatial Planning

1. INTRODUCTION

Even though there is a growing share of onshore renewable energy sources, mainly onshore wind and photovoltaic (hereinafter: PV) power plants, the share of renewable energy sources (hereinafter: RES) in the European Union (hereinafter: EU) in 2021 reached only 21.8%.

In order to reach the EU's ambitious 2030 RES target of 42.5-45% and ultimately carbon neutrality by 2050, offshore renewable energy sources (hereinafter: ORES) will also need to contribute in generating renewable energy.

ORES are already contributing to decarbonising the power sector in other parts of Europe. Out of all ORES technologies, bottom-fixed offshore wind power plants are the most mature technology with, 30 GW installed in Europe. The United Kingdom has 14 GW of offshore wind, followed by Germany with 8 GW and the Netherlands with 3 GW (WindEurope, 2023).

However, in the Mediterranean Sea there is a significantly lower uptake of ORES due to the higher costs as compared onshore renewables. There are fewer than 35 MW of ORES installed in the Mediterranean Sea, with Italy having 30 MW of bottom-fixed offshore wind and 3.4 MW of tidal and wave power. However, the number of bottom-fixed offshore and floating offshore wind projects in Italy, Greece, France, and Spain is rapidly increasing.

In addition to decarbonising the existing power demand, ORES could help in covering the increase in electricity demand due to the direct electrification of the economy (electrifying transport, buildings, and industry). Large-scale ORES projects in northern and north-western Europe are also planned for dedicated hydrogen production, which will be needed for decarbonising hard-to-abate sectors, such as high-temperature industrial processes, aviation, and shipping.

The need for ORES has been growing in Europe over the past few years. Europe has faced high gas and power prices due to the war in Ukraine. However, ORES projects have a significantly longer lead time compared to onshore RES due to their size and complexity. In order to utilise the ORES potential in Croatia in the early 2030s, it is important to start developing the ORES framework as soon as possible.

2. STRATEGIC AND LEGAL FRAMEWORK FOR THE DEVELOPMENT OF OFFSHORE RENEWABLE ENERGY SOURCES

2. 1. EU FRAMEWORK

The *Guide for the Development and Implementation of Renewable Energy Projects in Croatia* already identified the strategic and legal framework for renewable energy sources, which also refers to offshore renewable energy sources (EnergoVizija, 2022).

The most important strategic framework for ORES is the European Union's strategy on offshore renewable energy (*European Commission, An EU Strategy to harness the potential of offshore renewable energy for a climate neutral future, COM (2020) 741*), which sets a target of 60 GW of offshore wind and 1 GW of ocean energy by 2030. By 2050, these figures would increase to 300 GW of offshore wind and 40 GW of ocean energy. The European Commission (hereinafter: EC) identified the main challenges regarding, and proposals to address, the uptake of ORES:

- maritime spatial planning should provide for the sustainable management of space and resources;
- a new approach to offshore renewable energy and grid infrastructure should include the possibility of so-called hybrid projects;
- mobilising private-sector investment in offshore renewables is required, with EU funds having a role in supporting the sector;
- boosting research and innovation is an important precondition for the large-scale deployment of offshore renewable energy;
- a stronger supply and value chain across Europe is required.

Following Russia's invasion of Ukraine, the EC presented the REPowerEU Plan (*European Commission, REPowerEU Plan, COM (2022) 230*) to reduce the EU's dependency on Russian fossil fuels. The REPowerEU plan highlighted the need to diversify the EU's energy sources (including installing more offshore wind capacity and hydrogen production capacity) and the need to accelerate the permitting of RES.

The Maritime spatial planning directive (*Directive 2014/89/EU on establishing a framework for maritime spatial planning*) establishes a framework for maritime spatial planning and integrated coastal management by Member States aimed at promoting the sustainable growth of maritime economies, the sustainable development of marine areas and the sustainable use of marine resources. The directive also obliges Member States to develop national Maritime Spatial Plans, which must include:

- land-sea interactions;
- an ecosystem-based approach;
- coherence between the maritime spatial plan and other processes such as integrated coastal management;
- the involvement of stakeholders;
- the use of best available data;
- transboundary cooperation between Member States; and
- cooperation with third countries.

The TEN-E Regulation (*Regulation (EU) 2022/869 on guidelines for trans-European energy infrastructure*) sets the framework to develop better-connected energy networks and provides funding for new energy infrastructure. The regulation also aims for offshore infrastructure planning to be moved away from an individual project to a coordinated comprehensive approach of integrated offshore grids.

In light of the high energy prices resulting from the war in Ukraine, the Council of the European Union presented a regulation to address high energy prices (*Council Regulation (EU) 2022/1854 on an emergency intervention to address high energy prices*). The regulation capped market revenues from selected energy sources (including ORES) at €180/MWh.

Although this temporary measure lasts until 30 June 2023, a potential revenue cap should be considered when developing ORES, as this measure could be extended.

In late 2022, the Council of the European Union also presented a regulation to accelerate the permitting of RES (*Council Regulation (EU) 2022/2577 on laying down a framework to accelerate the deployment of renewable energy*). This regulation establishes rules for projects that start with permitting as of 22 December 2022 for a period of 18 months, but Member States may apply this regulation to projects that are currently in the permitting process. The regulation has a review clause and it can be extended if necessary. Chapter 4.2 Permitting procedures in Europe shows in more detail the impact of this regulation on ORES development.

Furthermore, at the time of writing this publication, the European institutions were working on the revision of the Renewable Energy Directive and the reform of the EU's electricity market design.

2. 2. NATIONAL FRAMEWORK

The Croatian strategic framework that was identified in the *Guide for the Development and Implementation of Renewable Energy Projects in Croatia* (Energy Development Strategy, National Energy and Climate Plan, and Low-Carbon Development Strategy) does not include targets and measures explicitly for ORES. However, the Low-Carbon Development Strategy does mention offshore wind farms as one of the technologies that could contribute to the decarbonisation of Croatia's power system.

Although the Republic of Croatia needs to develop its Maritime Spatial Plan (hereinafter: MSP) as prescribed by the MSP Directive, there is no single MSP for the Croatian maritime area. Currently, any development of ORES in Croatia depends on the inclusion of ORES areas in county spatial plans.

On top of the legal framework for RES, ORES has to comply with the procedures and requirements set out in the Act on Maritime Property and Sea Ports, the Act on Spatial Planning, and the Act on Concessions.

The Act on Maritime Property and Sea Ports (*OG, No. 158/03, 100/04, 141/06, 38/09, 123/11, 56/16, 98/19*) regulates the ways of using maritime areas, as well as the procedure needed for their concession. The Act is being amended at the time of writing this publication.

The Act on Spatial Planning (*OG, No. 153/13, 65/17, 114/18, 39/19, and 98/19*) regulates the spatial planning system, including the creation, adoption, and implementation of spatial plans. The Act is also being amended at the time of writing this publication.

The Act on Concessions (*OG, No. 69/17, 107/20*) regulates the procedure for obtaining a concession, including for a maritime area.

Developers should also comply with the Maritime Code (*OG, No. 181/04, 76/07, 146/08, 61/11, 56/13, 26/15, 17/19*), which stipulates activities of vessels in maritime areas.

Chapter 4.3 – Permitting procedures in Croatia shows in more detail the ORES permitting procedures from the afore-mentioned Acts.

2. 3. CROSS-BORDER ORES PROJECTS

Although there is only one operational cross-border ORES project (*Kriegers Flak* offshore wind farm in the Baltic Sea), the number of cross-border ORES projects under development is growing. Most interest is being seen in offshore wind farms, that connect two or more countries, as seen in Figure 1.

The European Green Deal (*European Commission, The European Green Deal, COM (2019) 640*) identified the fact that increasing ORES production will be essential, building on regional cooperation between Member States.

The TEN-E regulation sets the framework for ‘unique points of contact’ that will enable more cross-border ORES projects. The TEN-E also stipulates that the European Network of Electricity Transmission System Operators (ENTSO-e) shall prepare plans to develop an integrated offshore grid by establishing five priority offshore grid corridors. Croatia falls under the South and East offshore grid corridor, connecting with Bulgaria, Greece, Italy, Cyprus, Romania, and Slovenia. As part of the TEN-E regulation, the seven countries agreed on a non-binding agreement target of 25.9 GW of ORES capacity by 2050 (with Croatia having a target of 0.51 GW by 2030, 1.2 GW by 2040, and 3 GW by 2050) (European Commission, 2023).

2. 4. JOINT ORES PROJECTS IN EUROPE

Although the Renewable Energy Directive (*Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources (recast)*) and the implementing regulation on renewable energy financing mechanism (*implementing Regulation (EU) 2020/1294 on the Union renewable energy financing mechanism*) set out the framework for joint RES projects in Europe, there has been limited development of joint projects.

There have been a number of cooperation agreements signed for the development of energy islands in the North Sea. However, only Latvia and Estonia are working on a joint offshore wind project – ELWIND since 2020, with commissioning being expected as of 2030 (ELWIND, 2023).

Figure 1. Cross-border offshore wind projects in Europe (WindEurope, 2022)

3. TECHNOLOGY OVERVIEW OF OFFSHORE RENEWABLE ENERGY SOURCES

3. 1. OFFSHORE RENEWABLE ENERGY SOURCES

ORES can be divided into offshore wind, ocean energy, floating photovoltaic (PV) power plants, energy derived from marine geothermal resources, and bioenergy derived from marine algae. Ocean energy is further divided into five categories: wave energy, tidal current (stream), tidal range, thermal gradient (Ocean Thermal Energy Conversion – OTEC), and salinity gradient. All these technologies have potential in different parts of the world, but this study focuses on technologies that can be scaled up to a utility-scale within the next few years.

Table 1 shows an overview from a recent study by the European Commission that identified the technical resource potential for ORES in the Mediterranean Sea. In it, Croatia has more than 1,158 km^2 of available area for bottom-fixed offshore wind farms and 18,104 km^2 for floating offshore wind farms. Translated into capacity and annual electricity production figures, this would mean that Croatia has the potential for more than 8.1 GW of bottom-fixed wind farms (which could produce more than 17.9 TWh), and 126.7 GW of floating offshore wind (which could produce more than 313 TWh per year). The increased available area potential is assumed to increase from 2030 to 2050 due to the higher hub heights of offshore wind farms – resulting in utilising less windy sites. The study also observed that due to the lack of technical resources, there is almost no potential for wave and tidal power plants in Croatian waters (European Commission, Directorate-General for Energy, Staschus, K., Kielichowska, I., Ramaekers, L., et al., 2020).

The floating PV potential was never mapped for Croatia due to the abundant available area and unclarity on the possible power capacity per area since the technology is less mature than offshore wind.

While the Republic of Croatia does not have any explicit capacity targets for ORES in its strategic documents, countries such as France, Greece, Italy, and Spain have capacity targets for ORES by 2030.

The following paragraphs will give a more detailed description of the most promising ORES technologies in Croatia.

Table 1. Technical resource potential for ORES in Croatia (European Commission, Directorate-General for Energy, Staschus, K., Kielichowska, I., Ramaekers, L., et al., 2020)

	Bottom-fixed offshore wind (2030)	Bottom-fixed offshore wind (2050)	Floating offshore wind (2030)	Floating offshore wind (2050)	Wave energy (2030 and 2050)	Tidal energy (2030 and 2050)
Available area potential (km2)	1,158	1,468	18,104	18,414	0	0
Generation potential (TWh/a)	17.9	22.9	313.2	325.3	0	0
Capacity potential (GW)	8.1	10.3	126.7	128.9	0	0

*taking into account:

1) minimum distance from shore of 12 nautical miles
2) maximum dept of 50m dept for bottom-fixed and 1,000m floati
3) maximum distance to shore of 200 km

Bottom-fixed offshore wind

When comparing ORES technologies, bottom-fixed offshore wind is the most developed as many countries in Europe, and also globally, have installed significant capacity already. In the last decade, the yearly average of newly installed offshore wind turbine capacities doubled, from 3.9 to 8 MW. The average size of commercial offshore wind farms has grown in capacity from approximately 200 MW in 2009 to 800 MW in 2020 (ETIP Wind, 2021). In 2022, new wind installations in Europe amounted to 19.1 GW, out of which 2.5 GW were offshore. Most of the installations were in the UK with 1.2 GW, followed by France with 480 MW, and the Netherlands by 369 MW (WindEurope, 2023).

Offshore wind turbines have many advantages over onshore wind turbines. The main advantage is that the wind speeds offshore are higher and more frequent, allowing for more stable electricity production. This is because there are no land obstacles, which cause higher surface roughness and lower wind speeds.

Furthermore, offshore wind farms usually have a larger available terrain than onshore technologies. The world's largest offshore wind farm is comprised of 165 wind turbines, amounting to a total of 1.3 GW (Orsted, 2022).

Since offshore wind farms are generally further away from populated areas, there are fewer complaints concerning noise and visual impact.

The disadvantages include higher capital costs due to higher installation costs (installation of underwater cables, substructures, offshore substations, etc.), which require the involvement of several offshore vessels. Offshore Operation and Maintenance (hereinafter: O&M) can be time-consuming (Green Coast, 2019) and harsh sea conditions can result in high maintenance costs (Dreyer, 2017).

On the other hand, bottom-fixed offshore wind farms have a higher capacity factor than onshore wind turbines. This is due to the better wind conditions offshore but also because offshore wind turbines are larger and taller than onshore wind turbines. Capacity factors in Europe increased from 39% in 2010 to 48% in 2021 (IRENA, International Renewable Energy Agency, 2022).

One reason for this increase is that projects are moving further offshore to harness better wind conditions. Figure 2 shows that bottom-fixed offshore wind projects in Europe are moving into deeper waters (almost up to 60 m depth), while other projects are being located further away from the shore (120 km from shore). Depending on seabed conditions, offshore wind developers usually choose between monopiles and jacket foundations. Monopiles are the most common, accounting for about 81% of all offshore wind foundations in Europe, followed by jacket foundations (WindEurope, 2020).

In addition to lowering capital and operational costs, the offshore wind sector in Europe has also benefited from economies of scale, as the average offshore wind farm in Europe increased its size from 25 MW in 2000 to 591 MW in 2021. All of this has resulted in a lower Levelised Cost of Electricity (hereinafter: LCOE). The LCOE in Europe fell from €139/MWh in 2010 to €55/MWh in 2021 (IRENA, International Renewable Energy Agency, 2022).

Floating offshore wind

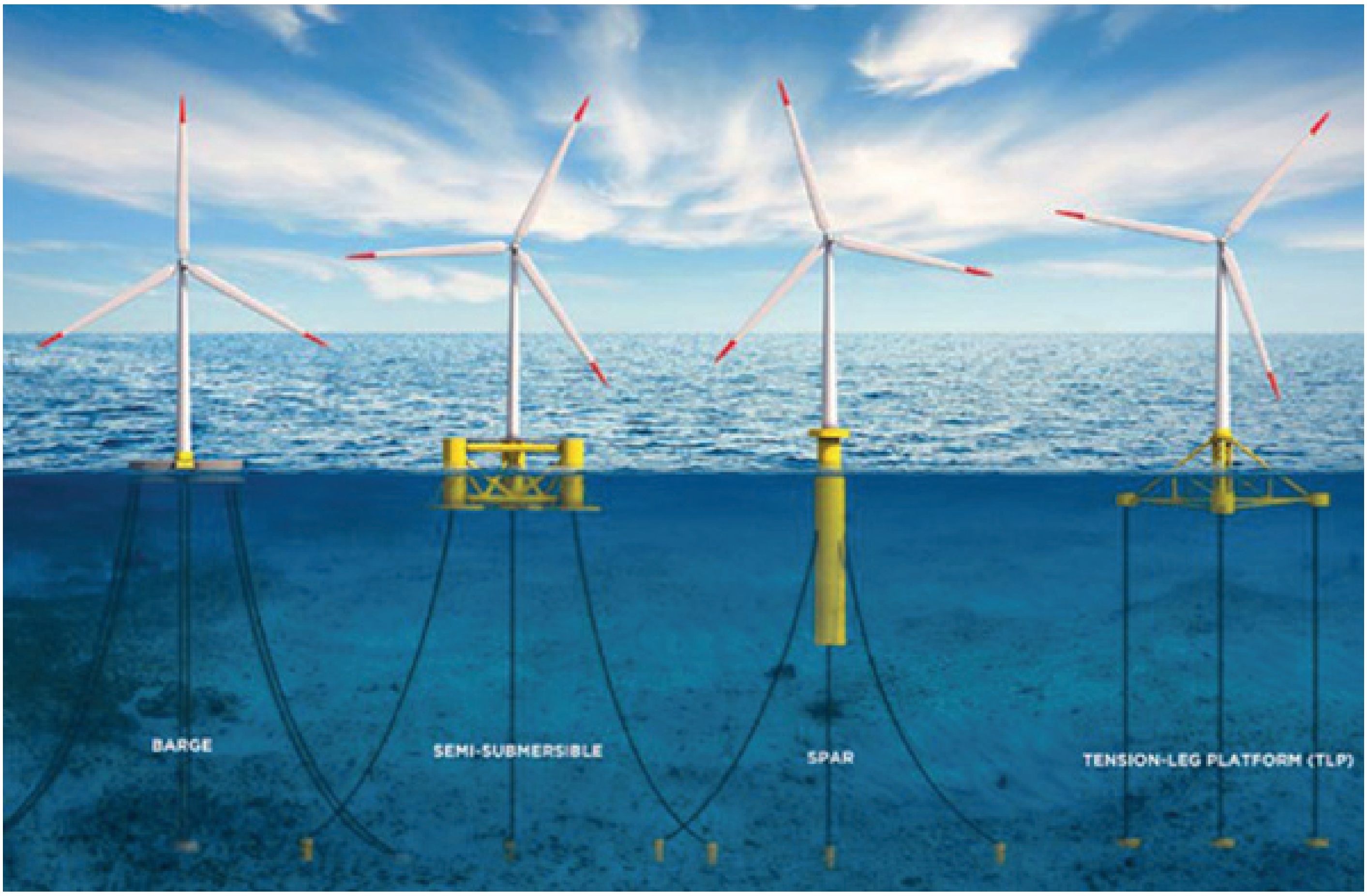
Floating offshore wind farms have an advantage over traditional bottom-fixed offshore wind farms when it comes to being limited to shallow waters. Going further offshore (into depths from 50 to 1,000 meters) allows for the capture of even higher and more stable winds than nearer the shore.

From an installation and O&M point of view, floating offshore wind can offer additional benefits over bottom-fixed offshore wind. Floating wind turbines can be assembled onshore and towed to the location of the wind farm – allowing for lower installation costs. O&M activities can also benefit from towing floating offshore wind turbines back to shore for maintenance. However, floating offshore wind farms are more expensive than bottom-fixed due to the lack of economies of scale and the lack of utility-scale projects in Europe (WindEurope, 2021).

There is no standard foundation structure for floating offshore wind turbines. The foundations are studied based on wind conditions, turbine size, sea depth, waves, currents, geology, etc. (Thomson & Harrison, 2015). Figure 3 shows four different types of floating offshore wind turbine foundations. Barge, semi-submersible, and spar are loosely moored to the seabed, while the tension leg platform is firmly connected to the seabed.

Figure 2. Average distance from shore and water depth for offshore wind, 2000-2021 (IRENA, International Renewable Energy Agency, 2022)

Figure 3. Types of floating offshore wind foundations (WindEurope, 2018)



As of 2021, Europe has 113 MW of floating wind capacity. The largest wind farm is Kincardine in the UK with 50 MW. Portugal, Norway, Spain, and France have floating offshore capacities as well (WindEurope, 2022).

Floating PV

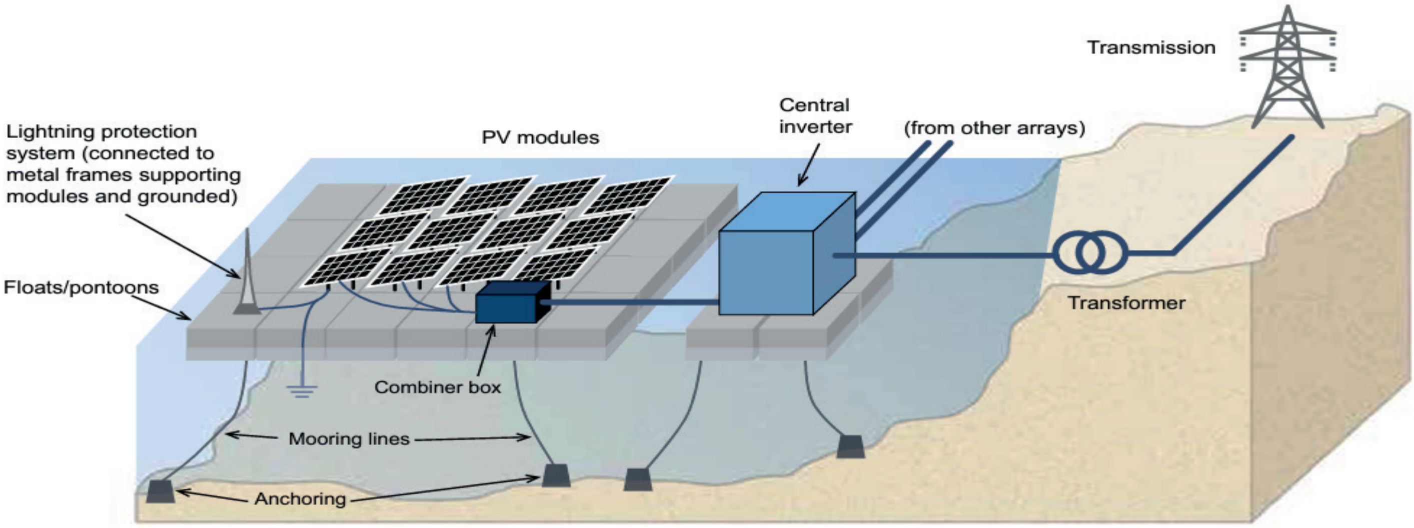
Although it started as a niche technology for reservoirs and lakes to prevent water evaporation, floating PV has been an emerging technology globally as more than 2.6 GW had been installed by 2020 (IRENA, International Renewable Energy Agency, 2021). Most of the capacity was installed in inland waters, led by installations in Asia.

Floating PV has started moving to coastal areas (lagoons and bays) and open seas as well to create additional locations for PV deployment. Exposure to the open sea can result in the higher efficiency of the PV system due to the cooling effects of the sea and open winds (World Bank Group; Energy Sector Management Assistance Program; Solar Energy Research Institute of Singapore, 2019). Figure 4 shows a schematic of a utility-scale floating PV system.

Several European companies are successfully operating offshore floating PV, which face high-wave environments. Oceans of Energy is operating the North Sea 2 power plant of 1 MW, which is 12 km offshore and faces high waves of up to nearly 14 meters (Oceans of Energy, 2022). Ocean Sun is operating a 0.5 MW floating PV system in a hybrid connection to an offshore wind farm (Ocean Sun, 2022).

In two separate offshore wind projects in the Netherlands, developers announced that they

Figure 4. Schematic of a utility-scale floating PV system (World Bank Group; Energy Sector Management Assistance Program; Solar Energy Research Institute of Singapore, 2019)



will also include floating PV projects. RWE will have a 5 MW system in its 760 MW *Hollandse Kust West* wind farm (PV magazine, 2022), while Shell and Eneco also announced floating solar and hydrogen production in their 759 MW *Hollandse Kust Noord* wind farm (Offshorewindbiz, 2020).

Offshore floating PV systems in Croatia could be used either co-located with offshore wind projects in open seas or near-shore areas to support the decarbonisation of remote islands. Floating PV can not only help in matching the increased power demand due to air conditioning and tourism peaks in summer but also be used to power desalination plants, which require electricity.

3. 2. SUPPORT SCHEMES IN EUROPE

Support schemes for ORES are a revenue-stabilisation mechanism, as ORES projects are CAPEX intensive and are in most cases financed via project finance. Lenders of CAPEX-intensive projects usually require some sort of revenue guarantee, which can be achieved through support schemes and/or corporate Power Purchase Agreements. This is especially important for projects that have an estimated lifetime of 20 years and above as the uncertainty of future power prices will increase their cost of financing.

National support schemes for RES in the EU are subject to EU State aid rules. Such support schemes need to receive prior approval from the European Commission under the *Guidelines on State aid for climate, environmental protection and energy (CEEAG)*, unless they can be exempted under the *General Block Exemption Regulation*.

In the early 2000s, Feed-in Tariffs were the main support scheme for ORES, but as EU Member States started implementing CEEAG, market-based support schemes through competitive bidding became the standard. Currently, the most common support scheme is the 2-sided Contract for Difference (hereinafter: CfD), which is awarded through auctions.

The 2-sided CfDs are the preferred option for both developers and Governments as they offer a fixed strike price for the electricity that they produce, but while depending on the wholesale market. When the market price is lower than the strike price in the auction, the Government pays the difference to the developer. When the market price is higher than the strike price, the developer pays the difference back to the Government.

Until recently, CfDs were awarded through auctions where the lowest price per MWh of produced electricity is the selection criteria. However, the latest changes to the CEEAG allow price-based auctions in Member States to now include up to 30% of non-price criteria as selection criteria. Such criteria can include:

- sustainability and biodiversity;
- system integration and innovation;
- supply chain development;
- benefits to communities; etc.

Furthermore, the latest developments in the energy market due to the war in Ukraine have shown that CfDs are preventing high wholesale power prices, while preventing windfall profits (which is common in 1-sided CfDs).

Some countries have seen very strong cost reductions of ORES, which have made them explore the subsidy-free development of ORES. However, ORES auctions are very country-specific and the strike prices depend on: seabed properties, wind resource, length of support scheme, indexation, cost of capital, etc. The following paragraphs present an overview of several European support schemes for ORES, which is important in understanding the differences in auction prices.

Denmark

Denmark differentiates two types of ORES projects: nearshore wind farms and tendered offshore wind farms. The near-shore projects are identified and developed by developers. Nearshore wind farms compete in the same pay-as-bid auction scheme as onshore wind and solar PV. The last auction under this scheme took place in October 2021, when a 429 MW auction did not receive any bids due to low ceiling prices (Enerdata, 2021).

The support scheme for tendered offshore wind farms is a 2-sided CfD for a pre-identified area. In the most recent tender, RWE won the 30-year concession for the 1 GW Thor offshore wind farm through a lottery system. The lottery system had to be used because multiple bidders offered the lowest bidding price of €0.0013/MWh. After paying the pre-defined concession cap payment of €375m to the Danish Government, RWE will receive income by selling electricity in the power market (Clean Energy Wire, 2021).

Germany

The German support scheme has been continuously evolving. The Government initially allowed developers to choose their areas for developing projects (decentralised model), but then shifted to centralise the process by tendering pre-determined areas (which in some cases are areas that are under development by a developer under the decentralised model).

The latest changes to German offshore wind legislation will now enable both centralised and decentralised offshore wind development.

Under the centralised development model, the German Government will pre-develop the planned site and tender it annually – where developers will compete for 20-year, non-indexed, 2-sided CfD contracts. The selection criteria will be based on a catalogue of qualitative criteria:

- 60 out of 100 possible points will be based on the bidding price; and

- 40 on the following criteria: the use of green electricity and green hydrogen in the project, an education and training quota, the conclusion of a power purchase agreement, biodiversity and nature protection in the project.

Under the decentralised model, developers will identify potential sites and once the Government decides to open an auction for offshore wind capacity, the developers will compete solely based on price – which now also allows for negative bidding. This will result in developers needing to pay for the right to build an offshore wind farm (WindEurope, 2022).

The Netherlands

The Netherlands Enterprise Agency (RVO) awards building rights for offshore wind farms in pre-determined sites under the zero-subsidy model. "*Site VII*" of the *Hollandse Kust West* was tendered using non-price criteria for system integration. RWE was awarded the right to build a 760 MW offshore wind farm, including 600 MW of onshore electrolysers for the production of renewable hydrogen, 225 MW of e-boilers for district heating and industrial application, batteries, and floating PV. All of these technologies will enable higher capacity factors of wind farms and provide less variable electricity to the grid (WindEurope, 2022).

The right to build the 756 MW "Site VI" of the *Hollandse Kust West* wind farm was awarded to Ecowende (a joint venture between Shell and Eneco). Developers had to compete in demonstrating that the offshore wind farm can mitigate or restore maritime biodiversity. The Ecowende project will have one section of the wind farm designed with wider spaces between wind turbines to allow birds to fly in the area. The developers will also use piling techniques to minimise the impact on marine habitats during construction. And they will add artificial reef structures on the seabed after the construction (WindEurope, 2022).

The challenge with non-price criteria is the design and implementation of clear, comparable, and easy-to-measure rules. If those rules leave any room for misinterpretation, appeals by other developers could significantly delay the commissioning of ORES.

Poland

The Polish Government granted administratively set 2-sided CfDs of €70.8/MWh to 5.9 GW of offshore wind projects (Windpower monthly, 2021). After awarding contracts to the first round of developed projects, the Polish Government plans to hold two more auctions of 2.5 GW each, in 2025 and 2027. The 25-year 2-sided CfD contracts are subject to indexation.

The United Kingdom

The UK's CfD auction scheme is probably the most well-designed support scheme for ORES in Europe, as it has delivered constant cost reductions, while having strong oversubscription rates. The UK Government will hold annual auction rounds as of March 2023.

The Government sets an overall budget for each allocation round (in the most recent round it was €345m) and capacity and strike price caps for three different technology pots (similar to the Croatian onshore support scheme). Then developers compete for a 15-year 2-sided CfD with their permitted projects. The pay-as-clear auction closes when the capacity cap or a budget cap is reached.

The most recent round (AR4) awarded 11 GW of projects, including 7 GW of offshore wind (at €43.86/MWh), 32 MW of floating wind (at €102.5/MWh), and 44 MW of tidal stream (at €209.7/MWh). The bids are inflation-indexed to 2012 prices (GOV.UK, 2022).

3. 3. COST BREAKDOWN OF OFFSHORE WIND

In order to design the right support scheme for ORES in Croatia, it is necessary to estimate the investment cost of an ORES. Since offshore wind farms are the most popular ORES technology, this chapter will provide an indicative cost breakdown of a potential offshore wind farm in Croatia.

The most important factors when designing an offshore wind farm are the average wind speed and its frequency. However, there is a lack of wind speed measurement data in the Adriatic Sea. Indicative wind speeds could be estimated by the data generated from offshore oil and gas platforms, which are disclosing these and other datasets to the public authorities. However, they would need to be made publicly available to developers.

In addition to any environmental assessments, developers need to assess the morphology and the composition of the seabed, sea currents, seismic activity, etc.

In general, the cost of an offshore wind farm is comprised of:

- the capital expenditure, including development expenditure (CAPEX);
- the cost of finance for the CAPEX;
- the operational expenditure (OPEX); and
- the decommissioning expenditure (DECEX).

CAPEX

Offshore wind farms have seen a significant cost decrease per MW as the sector benefited from larger and more powerful turbines, larger wind farms, economies of scale, etc. The average total installation cost in Europe fell from €4,159/kW in 2015 to €2,364/kW in 2021 (IRENA, International Renewable Energy Agency, 2022).

However, these figures differ significantly by country as seen in Table 2. In addition to the afore-mentioned factors, an important factor in assessing CAPEX figures is the grid build-out

Table 2. Weighted average total installed costs for offshore wind, 2010 and 2021 (IRENA Renewable Cost Database)

	Costs in €/kW	
	2010	2021
Europe	**4,159**	**2,364**
Belgium*	5,395	3,019
Denmark	2,915	1,950
Germany*	5,740	3,185
Netherlands**	3,662	2,128
United Kingdom	4,048	2,604

*** Countries where data were only available for projects commissioned in 2020, not 2021.**

**** The Netherlands had no projects commissioned in 2010, so data for projects commissioned in 2015 are shown.**

responsibility, which differs between countries, as explained in Chapter 4.2 – Permitting procedures in Europe.

Installation costs represent a significantly higher share of the total costs in offshore wind than in onshore wind, as seen in Figure 5. Although the offshore wind sector is expected to have additional cost reductions, the sector is facing supply chain bottlenecks, logistic issues, and higher costs of finance in countries where there is a lack of revenue stabilisation mechanisms.

Depending on the grid build-out model in Croatia, the current CAPEX for offshore wind farms could range between €2,364/kW and €3,185/kW. Since Croatia will need several years to see the offshore wind projects, these figures could become even lower in light of the global cost reductions. Due to the lack of operational large-scale floating offshore wind farms, it is hard to estimate the CAPEX of such projects, which heavily depends on the scalability of the offshore wind farm.

The CAPEX costs of the offshore grid-connection depend on a number of factors (capacity of the offshore wind farm, length of the offshore cable, type of connection, and length of the onshore cable). For offshore transmission systems of 50 km offshore cable length and a 15 km onshore length, the costs range from €150m to €650m (depending on the size of the offshore wind farm) (DNV GL, 2019).

OPEX

The operational costs for offshore wind farms are O&M costs, which depend on the distance to shore, weather conditions, the availability of skilled personnel, and access to specialised

Figure 5. Wind farm CAPEX breakdown (ETIP Wind, 2021)

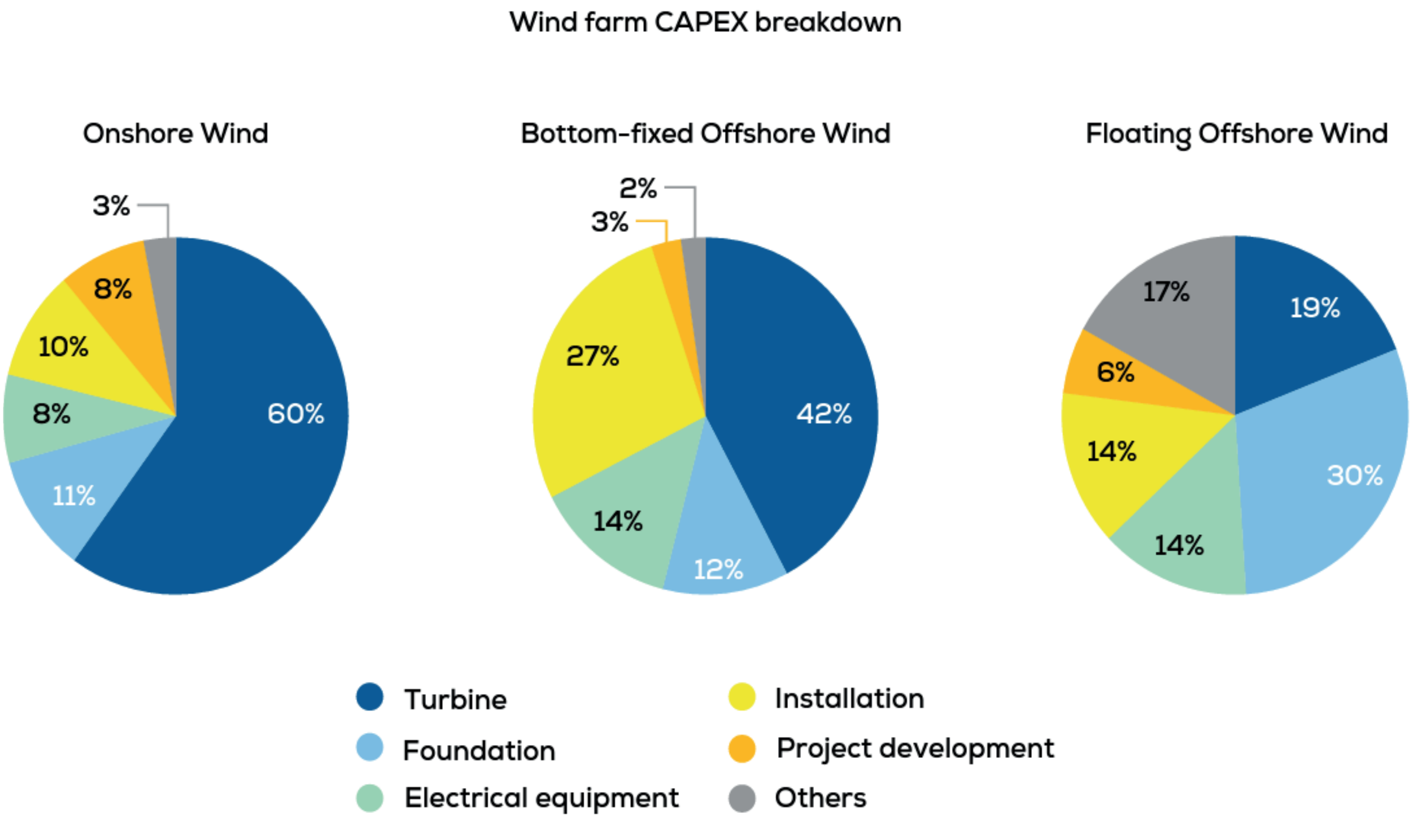


Figure 6. Contribution of each major cost element to LCOE of offshore wind in the UK (BVG associates, 2019)

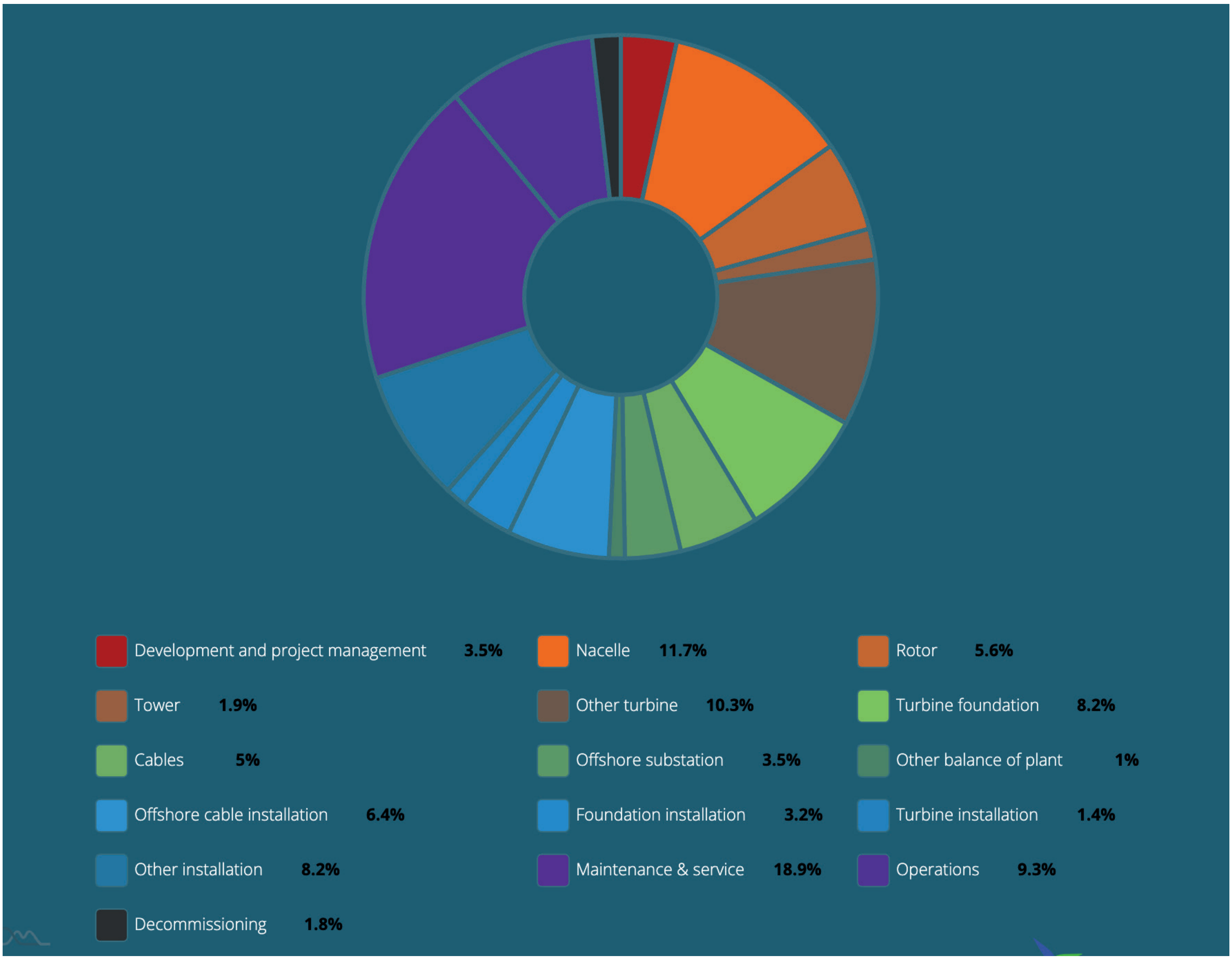


Table 3. Weighted average LCOE of offshore wind, 2010 and 2021 (IRENA Renewable Cost Database)

	LCOE in €/MWh	
	2010	2021
Europe	**139**	**55**
Belgium*	193	71
Denmark	92	35
Germany*	153	69
Netherlands	N/A	50
United Kingdom	179	46

* Countries where data were only available for projects commissioned in 2020, not 2021.

vessels. Globally, O&M costs usually constitute 16% to 25% of the LCOE of an offshore wind farm (IRENA, International Renewable Energy Agency, 2022).

In 2018, the O&M costs for offshore wind ranged between €60/kW/year and €110/kW/year. IRENA estimated that O&M costs in the past five years are about €14.5/MWh – €25.5/MWh (IRENA, International Renewable Energy Agency, 2022).

There is a potential for O&M cost reductions in the offshore wind sector as wind turbines of a higher power rating require less maintenance per kW, utilising O&M centres for several offshore wind farms, digitalisation and predictive maintenance.

DECEX

When developing offshore projects, developers in most cases need to plan for a full decommissioning of their project – which includes full removal of any equipment. Developers should follow the guidelines of the OSPAR commission on the development of offshore wind farms for better planning of decommissioning activities (OSPAR, n.d.). Depending on the scope of the decommissioning, the DECEX costs can be up to 1.8% of the LCOE or roughly €365,000/MW (BVG associates, 2019).

Levelised cost of electricity (LCOE)

The LCOE is a metric that includes the capital cost of constructing the project, the fuel price, O&M, as well as decommissioning costs. It shows the electricity revenue needed to operate a power plant in its lifetime. Figure 6 shows the contribution of each major cost element to the LCOE in the UK for a 1 GW offshore wind farm.

Since the offshore wind sector saw steep CAPEX cost reductions in the past decade, it resulted in LCOE reductions as well. As seen in Table 3, the LCOE in Europe fell from €139/MWh in 2010 to €55/MWh in 2021. In 2021, the LCOE for offshore wind in Europe ranged from €34.9/MWh to €70.7/MWh.

Future LCOE reductions will be primarily driven by CAPEX cost reductions, but also by to OPEX cost reductions, higher capacity factors, longer lifetimes, and decreased cost of capital. The LCOE for bottom-fixed offshore wind could fall to €38/MWh – €60/MWh by 2030. By 2050 the LCOE could further decrease to €28/MWh – €48/MWh (ETIP Wind, 2021).

EU Funding

There is a large variety of *EU funding for ORES*, including grants, loans, equity financing, etc. This paragraph presents an overview of the most relevant programs for offshore wind from which developers could benefit.

The *InvestEU* programme leverages mainly private investments and focuses on economically viable projects but also on demonstration projects. Debt and equity financing can be provided to offshore wind farms but also for energy grids, port upgrades, and cabling for offshore grids.

The *Modernisation Fund* provides grants and financial instruments to mature ORES technologies. However, developers cannot submit direct applications, instead, applications must be submitted by Member States to the European Investment Bank.

The *Innovation Fund* provides grants and project development assistance to innovative ORES. This can include offshore wind farms that will also feature battery storage or hydrogen production.

The most relevant EU instrument for cross-border and joint ORES projects is the *Connecting Europe Facility (CEF) Energy*. The CEF energy grants can be used to map potential offshore development sites, and fund the necessary studies and construction works, for projects between two or more Member States. However, for ORES to be eligible under CEF Energy, projects need to first receive the status of *Project of Common Interest* or cross-border project.

Lastly, the renewable energy financing mechanism can offer grants to ORES in an EU-wide tender. This mechanism aims to share the benefits of offshore energy projects with landlocked Member States by providing statistical benefits to them. The mechanism can also be combined with CEF and InvestEU, provided that rules on no double funding are maintained.

3. 4. CROSS-TECHNOLOGY IMPACT

Power production from ORES also creates an opportunity for other technologies. This can include the nearby localisation of electrolysers for hydrogen production, the possible reuse of the existing oil and gas infrastructure, generating renewable electricity for charging zero-emission vessels, desalination of seawater, etc.

Developers in several European countries started developing multiple ORES technologies at the same site (bottom-fixed offshore wind and floating PV) but there is also a growing number of ORES projects that include hydrogen production. The benefits of jointly developing several technologies include cost reductions for developers, the better exploitation of maritime areas, and a lower environmental impact (PELAGOS, 2017), (Karimirad & Koushan, 2016).

Algae are also a promising source of sustainable biofuels that merit further research and innovation.

Hydrogen production

In the medium- and long-term, the integration of offshore wind farms could help develop energy carriers such as hydrogen and ammonia. Hydrogen could be used to decarbonise the industry and transport sectors but also to integrate additional RES.

For ORES, the most interesting hydrogen production is via electrolysers, which when using renewable electricity can produce renewable hydrogen. This can be done through dedicated hydrogen production from an ORES or by using excess electricity from ORES for hydrogen production.

There are three options for hydrogen production from ORES:

- integrated production – Siemens Gamesa and Siemens Energy are developing a solution where an electrolyser is integrated into an offshore wind turbine (Siemens Gamesa, n.d.);
- onshore production – RWE is developing a 760 MW offshore wind farm in the Netherlands with 600 MW of onshore electrolysers (Hydrogen Insight, 2022); and
- offshore production – in France, Lhyfe commissioned an offshore hydrogen production platform that is powered by a floating wind turbine (offshoreWIND.biz, 2022).

Hydrogen that is produced offshore can be transported to shore by pipeline or by ship. For hydrogen that would be transported back to the Croatian shore, the International Renewable Energy Agency estimates that the most cost-effective transport method is by pipelines (IRENA, 2022).

In Croatia, the most interesting method would be utilising existing, non-operational offshore oil and gas platforms for hydrogen production, which could be then transported back to shore through retrofitted gas pipelines or newly built hydrogen pipelines.

When back on shore, the renewable hydrogen can be used in refineries that use it for the desulphurisation of fuel and for the production of ammonia and e-fuels.

Ammonia and e-fuels

When renewable hydrogen and renewable nitrogen (from air separation) are fed into the renewable electricity-powered Haber process, renewable ammonia is produced. Ammonia is needed to produce fertilisers and is also used as a refrigerant gas, and for plastics, nylon, and acrylics.

Ammonia has a higher energy density than hydrogen and it can be easily liquified. This is also why for long-haul hydrogen exports shipping via ammonia ships is the most cost-efficient solution. Therefore, renewable ammonia can help in decarbonising deep-sea shipping or large cargo journeys.

E-fuels are hydrogen-based fuels that have a higher energy density than hydrogen or ammonia. They require the combination of hydrogen and CO_2 with the aid of Fischer-Tropsch synthesis. The outcome product can be used as e-gasoline, e-diesel, e-heating oil, e-kerosene, and e-gas (eFuel alliance, n.d.).

The most interesting e-fuel for decarbonising the aviation sector is e-kerosene, which can be combusted in a conventional jet turbine and requires only minimal or no modifications (Transport&Envrionment, 2020).

Energy islands

Several European countries plan to connect their ORES to energy islands. Such islands will be a landing point for array cables from ORES and connect to several countries with fewer export cables (WindEurope, 2022).

Energy islands can enable the system integration of ORES and storage into a high-voltage grid. They could host electrolysers that would produce renewable hydrogen, energy storage facilities, and charging infrastructure for vessels.

Other impacts

Croatia could also benefit from thermal energy for heating and cooling purposes in coastal areas which are consuming electricity. There are already commercial and prototype examples of seawater heat pumps across Croatia's coastline located in Dubrovnik, Makarska, Petrčane, Split, and Novi Vinodolski. Smaller systems of seawater heat pumps are highly efficient, with high coefficients of performance. They can be used for residential, commercial, and industrial purposes (Blue Deal, n.d.).

Lastly, several remote Croatian islands currently receive their freshwater supply via ships and face freshwater shortages. Desalination of seawater is an energy-intensive process but with reverse osmosis it can utilise renewable electricity from ORES and create freshwater in a sustainable manner (IRENA, n.d.).

3. 5. RESEARCH AND INNOVATION

The EU's Offshore Renewable Energy Strategy observed that boosting research and innovation is necessary for the large-scale deployment of ORES. The Research and Innovation (hereinafter: R&I) investments in the clean energy sector in Europe are mostly driven by the private sector (77%), followed by national governments (17%), and EU funds (6%). R&I programmes for offshore wind were granted about €496m from 2009 to 2019, focusing on wind turbine design, infrastructure development, circular advanced materials, and digitalisation (European Commission, 2020).

Future R&I activities should focus on larger and more sustainable ORES, their transportation and installations, O&M, decommissioning and recycling. Furthermore, R&I activities will also include offshore grid development, focusing on high-voltage direct current (hereinafter: HVDC) multi-terminal connections, as HVDC can present an alternative to high-voltage alternative current (hereinafter: HVAC) in ORES projects that are further offshore. Other R&I activities could include digitalisation in the ORES value chain as well as the cumulative impacts of RES on the marine environment.

R&I for ORES can be supported through several EU funding mechanisms. The most notable ones are: *InvestEU*, *Horizon Europe Cluster 5*, and *European Innovation Council*.

National funding

The National Energy and Climate Plan (hereinafter: NECP) for the Republic of Croatia for the period 2021-2030 addresses research, innovation, and competitiveness. The NECP includes the measure *Co-financing industrial research and experimental development projects aligned with the National Development Strategy,* which promotes research and development of products and services relevant to low-carbon development by co-financing research projects under priority topics. Tenders for this measure will be announced on an annual basis for research projects to be carried out within Croatia. For the application of this fund, approximately €6m a year is needed. This is one of the national objectives and targets, but it has not yet been implemented (Republic of Croatia, 2019).

The United Kingdom Research and Innovation (UKRI) is a good example of encouraging R&I. UKRI is the national funding agency investing in science and research in the UK, with a combined budget of more than £6bn. This national funding agency is an executive non-departmental public body, sponsored by the Department for Business, Energy & Industrial Strategy, supported by seven agencies and public bodies. Such a national agency could finance RES research, but also other areas that are needed in the country (UKRI, n.d.).

3. 6. ORES SUPPLY CHAIN

Any renewable energy supply chain can be split into three phases: development and planning, installation and manufacturing, and operation (Joint Research Centre, European Commission, 2017). Decommissioning and recycling are also emerging as phases of the supply chain – but this is only relevant for countries that have had offshore wind capacity for more than 15 years.

Developers need to contract a large number of suppliers for their ORES projects. In the UK, Ørsted (an offshore wind developer) has placed major contracts with over 200 UK companies in the past five years (Ørsted, n.d.). The following paragraphs present a more detailed overview of an ORES supply chain.

Development and planning

In the development and planning phase, the main actors in the supply chain will be developers and subcontractors specialised in conducting various surveys (environmental impact assessments, geotechnical surveys, grid impact, etc.).

Installation and manufacturing

Installation and manufacturing refer not only to the specific energy generator provided by the Original Equipment Manufacturer (hereinafter: OEM) (such as an offshore wind turbine or floating PV), but also to foundations and grid connection.

OEMs (such as Vestas, Siemens Gamesa, GE) will produce components for their energy generator in their various facilities (blades, nacelles, etc.) and transport them to an installation centre – which is, in most cases, a port. Many other components in the energy generator can come from subcontractors (towers, gearboxes, bearings, etc.).

Developers are inclined to tender Engineering, Procurement, and Construction (hereinafter: EPC) contracts to a single contractor or split the EPC into several contracts to several contractors.

One part of EPC activities is linked to foundations (or in the case of floating technologies – floaters and mooring lines). The choice of technological solutions will depend on engineering results and the parts for foundations are often produced locally.

Cables are also a part of EPC activities. These can be offshore array cables (cables that connect an energy generator with an offshore substation) and the cables that connect the offshore substation with the onshore substation.

Operation

During the operation phase, O&M activities will require constant monitoring and inspection – both remotely and in-person. This provides more job opportunities for local communities as O&M centres are located relatively close to the power plants in order to reduce down time.

Croatian supply chain

Although turbine manufacturing depends on a global supply chain, many Croatian companies participating in the onshore RES supply chain will be able to be part of the ORES supply chain as well.

Some Croatian companies already have experience of being part of the ORES supply chain. Končar Power Transformers (a joint venture of Siemens AG and Končar) produced offshore transformers for Iberdrola's East Anglia ONE wind farm (Končar, 2017). Brodosplit has built a data collection buoy for a floating offshore wind zone in France. The buoy will allow simultaneous measurements campaigns, including aerial and underwater biodiversity monitoring (Brodosplit, 2022).

In the future, the shipbuilding sector could benefit from ORES development as they both involve mainly steel and welding, forming, bending, and casting processes. Croatian shipyards have production capacities (large workshops, cranes, etc.) that can support the construction and assembly of offshore wind turbines and building vessels that are needed (jack-up vessels, cable laying vessels, floating installation vessels, etc.).

Offshore wind generates €2.1bn/GW of economic activity to the EU. Applying the same methodology to Croatia, 3 GW of offshore wind capacity would generate €6.3bn of economic activity in Croatia (WindEurope, 2020).

In 2021, the Polish Government and the wind industry signed the *Polish Offshore Wind Sector Deal*, which aims to maximise local content to at least 50% by 2030. The Sector Deal also aims to upgrade the port infrastructure and the identifying of installation terminals and service ports for offshore wind. Similarly to the Polish example, Croatia should also aim to develop an ORES Sector Deal where the shipbuilding sector could benefit from firm commitments by developers and the Government (WindEurope, 2021).

There is a large number of Croatian companies that could participate in the ORES supply chain. However, at this stage it impossible to assess all of the companies in a non-discriminatory way.

3. 7. SKILLS REQUIREMENTS

A skills shortage is already being identified as a possible bottleneck in the ORES sector in Europe (K2 Management, 2021). Europe's largest offshore wind market, the United Kingdom, had 10,000 employees in the offshore wind industry in 2018, a number which is predicted to grow to 36,000 by 2032 (Energy & Utility Skills , 2020). Guided by the UK's experiences, the following paragraphs outline the necessary skills and knowledge for the future development of ORES projects in Croatia.

Development and planning

In the early development phase, any investor will necessarily need engineers and experts in the field of biological studies such as marine biology, oceanography, chemistry, geology, earth observation and GIS spatial analytics to create studies and analyses of the environmental impact.

Furthermore, carrying out a feasibility study requires the involvement of experts from Science, Technology, Engineering, and Mathematics (STEM) disciplines, project management, finance and economics, and related fields.

Legal and regulatory experts are needed for permitting and legal matters, such as for reviewing and negotiating contracts and agreements, advising on issues related to property rights and leasing, liability for environmental damage or accidents, etc.

In order for ORES projects to have a high level of community engagement, developers will need to plan for experts in community building, public regulations professionals, cooperative managers, event organizers, social media managers, and graphic designers.

Installation and manufacturing

When it comes to the manufacturing and installations of an ORES, developers and contractors need to be guided by principles of safety, efficiency, and sustainability.

The installation phase of on ORES project requires individuals with high academic qualifications in shipbuilding, mechanical engineering, and civil engineering, as well as high voltage electricians, welders, electricians, etc.

In addition, there is also a need for other human resources, such as health and safety personnel, technicians who operate cranes and other essential machines, height workers, professional divers, team coordinators, and administrative and accounting staff.

Operation

The maintenance and monitoring of a power plant are complex tasks that require a team of skilled and trained personnel to ensure that the equipment operates safely and efficiently. This team typically includes engineers, electricians, and other specialised technicians with the knowledge and experience necessary to perform regular inspections, troubleshoot problems, and carry out repairs as needed. The skills required for such personnel include:

- knowledge of ORES technology;
- electrical systems, including high voltage systems;
- offshore environment and safety regulations;
- welding, electrical, and mechanical repair;
- computer control systems and SCADA systems;
- physical fitness and ability to work at heights;
- ability to work in a remote, offshore environment.

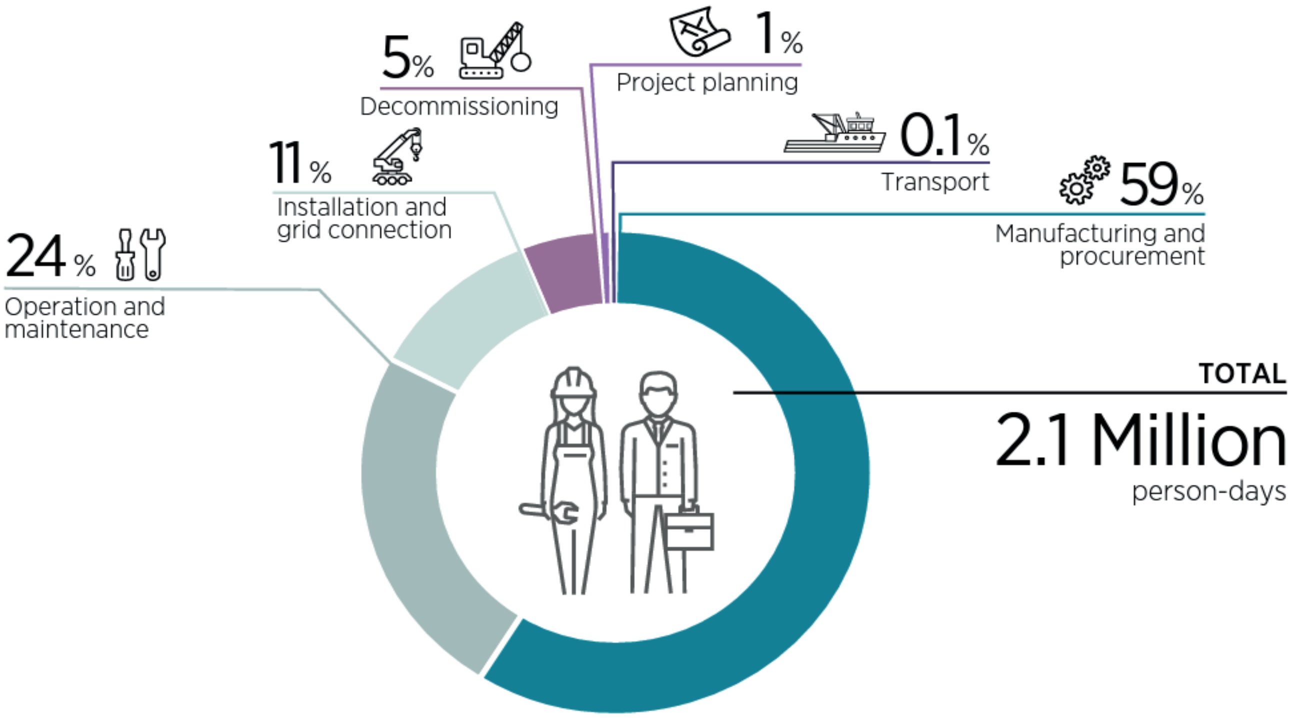
Skills requirements for offshore wind

The International Renewable Energy Agency estimates that a total of 2.1 million person-days is needed to develop an offshore wind farm of 500 MW. Figure 7 shows that about 59% is needed for manufacturing and procurement, while O&M represents 24% (IRENA, 2018).

Gender gap in ORES

The share of women in the wind energy sector in Europe and North America is only 26%. They are only well represented in adminis-

Figure 7. Distribution of human resources required along the value chain for the development of a 500 MW wind farm (IRENA, 2018)



tration roles – where 52% of jobs are held by women. There is a big gender gap in all other activities of the wind sector (IRENA, 2020). Similar trends can be observed with other ORES. Therefore, it is necessary to take gender gaps into account when proposing measures for identifying and reducing skills shortages in the ORES sector.

4. ENVIRONMENTAL IMPACT AND PERMITTING OF OFFSHORE RENEWABLE ENERGY SOURCES

4. 1. ENVIRONMENTAL IMPACT OF ORES

The development, construction and the use of ORES can have a significant impact on marine biodiversity. Therefore, ORES projects must be carefully planned and managed so that they have a low impact on nature.

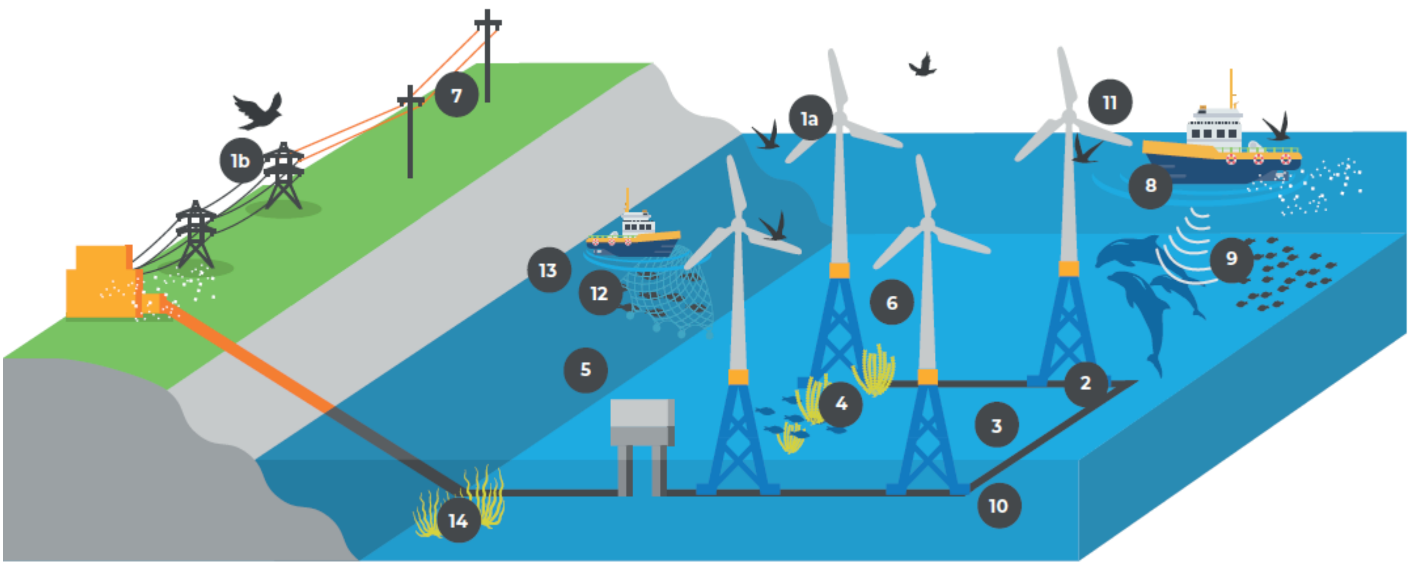
In order to achieve the greatest possible sustainability of ORES projects in relation to biodiversity, the EC issued a *Guidance document on wind energy developments and EU nature legislation* in 2020. The purpose of this document is to provide guidance on the best way to ensure compliance of wind energy projects with the Birds Directive and the Habitats Directive.

For future developers it is very important to be aware of such risks and the necessary measures for the project that arise from such risks. For this reason, IUCN and The Biodiversity Consultancy (TBC) created *Guidelines for project developers for Mitigating biodiversity impacts associated with solar and wind energy development (2021)*. Figure 8 shows the potential impact from bottom-fixed offshore wind farms.

Protected areas of Nature

As far as natural protection is concerned, it is worth noting that 266 Natura 2000 marine sites have been established in Croatia (257 Sites of Community Importance (SCI) and 9 Special Protection Areas (SPA)) over a total of about 16% of the country's marine area. There are no marine protected areas (MPA) as defined by the Nature Protection Act, but there are many protected areas that include marine

Figure 8. Potential impacts on biodiversity and the associated ecosystem services due to bottom-fixed offshore wind developments (IUCN & TBC, 2021)



1. Bird and bat collision with, a) wind turbines and b) onshore transmission lines
2. Seabed habitat loss, degradation and transformation
3. Hydrodynamic change
4. Habitat creation
5. Trophic cascades
6. Barrier effects or displacement effects due to presence of wind farm
7. Bird mortality through electrocution on associated onshore distribution lines
8. Mortality, injury and behavioural effects associated with vessels
9. Mortality, injury and behavioural effects associated with underwater noise
10. Behavioural effects associated with electromagnetic fields of subsea cables
11. Pollution (e.g. dust, light, solid/liquid waste)
12. Indirect impacts offsite due to increased economic activity and displaced activities, such as fishing
13. Associated ecosystem service impacts
14. Introduction of invasive alien species

areas over a total of 1.5% of the country's marine area (National Parks Brijuni, Kornati and Mljet, Nature Parks Lastovo Isles and Telašćica). Figure 9 shows an overview of offshore protected areas in Croatia (European Commission, 2022).

In consideration of its high ecological value, in 2014 the Jabuka/Pomo pit was declared an "*Ecologically or Biologically Significant Marine Area*" (EBSA), according to the criteria adopted by the 9th COP of the Convention on Biological Diversity (CBD). In 2017 the General Fisheries Commission for the Mediterranean (GFCM) adopted the EU proposal for the establishment of a Fisheries Restricted Area (FRA) in the Jabuka/Pomo pit banning demersal fisheries. A marine area of at least 2,700 km^2, recognised as an essential nursery and spawning ground for several marine species, is placed outside the territorial waters of Italy and Croatia (FAO, 2017).

Habitats

The marine habitats of Croatia were mapped in 2004 and cover only the territorial waters of Croatia. Given that the existing map of marine habitats is mostly modelled using bathymetric and sediment maps, historical data, and a limited amount of in situ data, the creation of a new, much more detailed and precise map of marine habitats is underway. Therefore, a map of marine habitats from the European Marine Observation and Data Network (EMODnet) was used for this publication (EMODnet, 2023).

Figure 9. Offshore protected areas and Natura 2000 sites in Croatia (Bioportal, 2023)

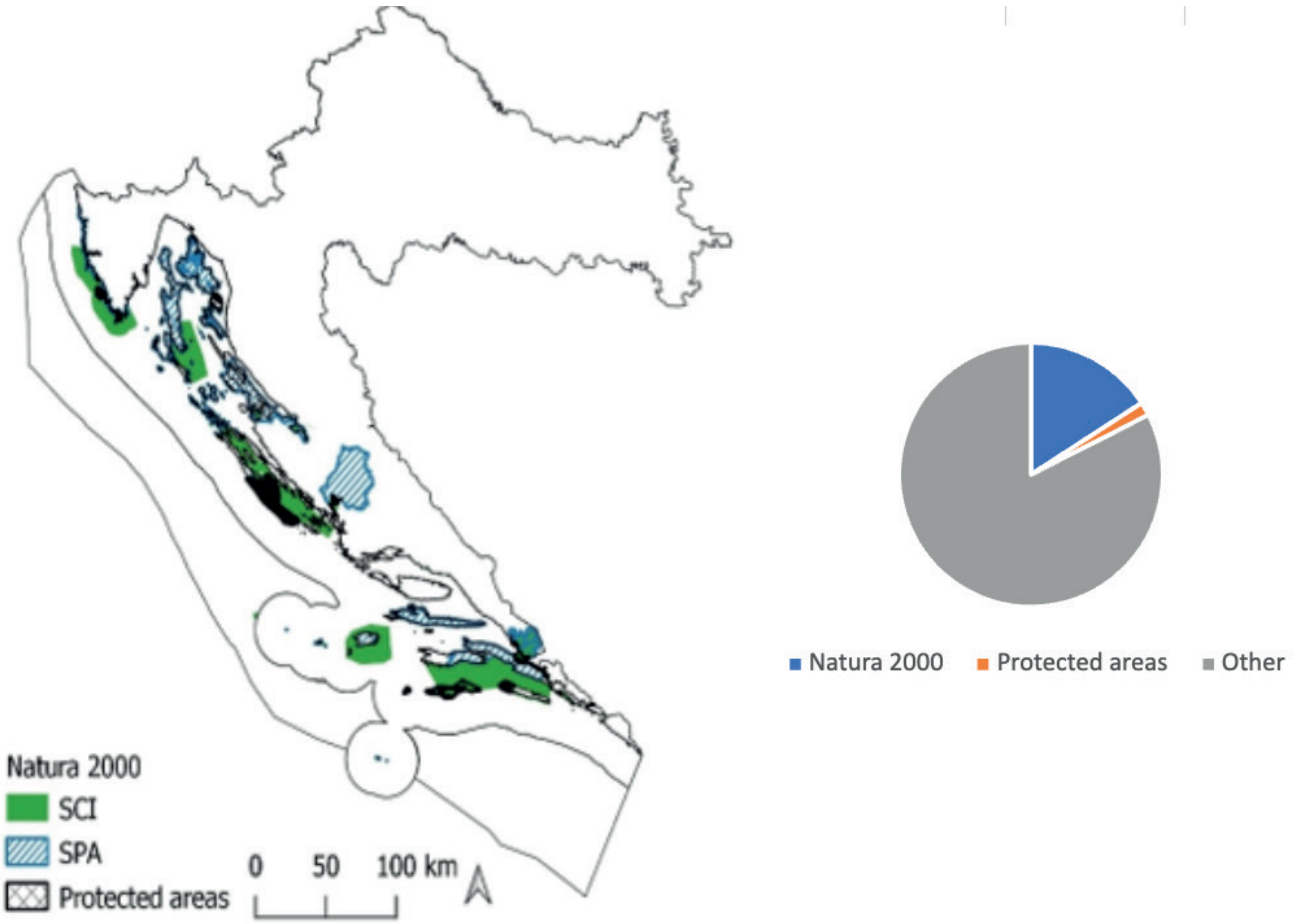
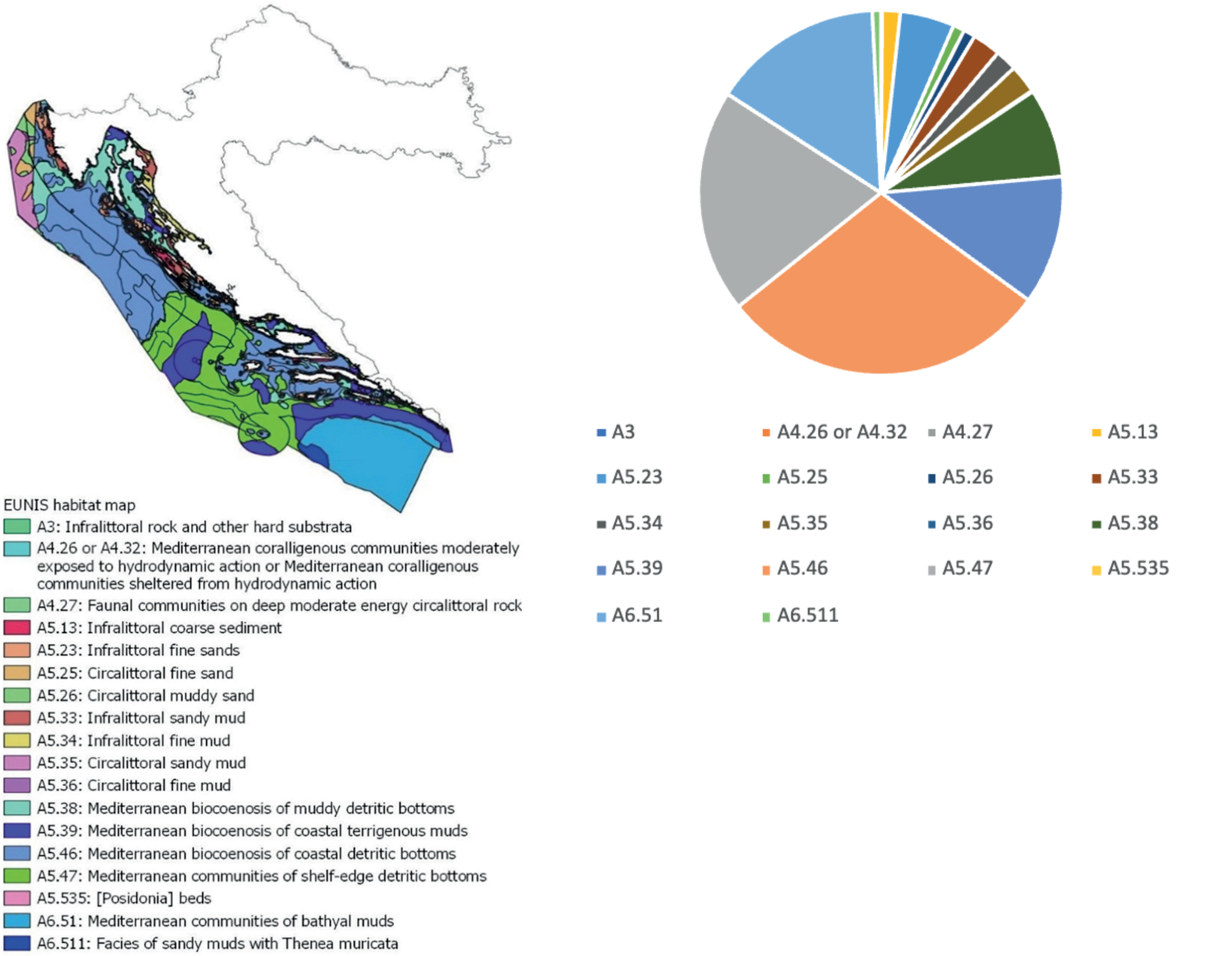


Figure 10. EUNIS habitats map (EMODnet, 2023)



As seen in Figure 10, habitats that cover most of the sea under Croatian jurisdiction are A5.46: Mediterranean biocoenosis of coastal detritic bottoms (29%), and A5.47: Mediterranean communities of shelf-edge detritic bottoms (19%).

The main potential habitat impacts of ORES are habitat loss, disturbance of habitats and contaminant release. Intertidal and subtidal habitats can be affected through: habitat loss under the footprint of ORES and associated infrastructure including cables, disturbance as a result of sediment dispersion/sedimentation arising from different activities, which can lead to the smothering of the seabed, altering the physical structure of habitats, temporary disturbance from vessel anchors, etc. Long-term effects on habitats include the introduction of new artificial substrates that can attract benthic and other organisms (European Commission, Directorate-General for Environment, 2018).

Marine habitats that are potentially vulnerable to effects from offshore wind energy development are also listed in Annex I list of the Habitats Directive: ‘sandbanks which are slightly covered by sea water all the time' [1110], 'reefs' [1170], and Posidonia beds [1120]. Posidonia beds are at risk from direct physical destruction, sedimentation changes in hydrographic regimes and shading from floating PV. Finally, the Annex I of the Habitats Directive can be affected by the exclusion of other activities that previously took place, such as fisheries. Benthic habitats, which have been seriously degraded due to bottom-trawling activities, could recover as ORES require the restriction of bottom-trawling fishing because of the potential damage to offshore infrastructure (European Commission, Directorate-General for Environment, 2018).

Fish, marine mammals, and turtles

ORES can have a negative impact on certain species of marine fish, mammals, and sea turtles. According to *Guidance document on wind energy developments and EU nature legislation* the impacts of offshore wind energy projects can occur in four main phases of the development:

- pre-construction phase (e.g. meteorological tests, research studies on sediment stability and seabed preparation);
- construction (e.g. transportation of materials by vessels and construction of foundations, grid connection cables, etc.);
- operation (including maintenance); and
- end-of-life activities such as life-time extension and decommissioning (removal of a wind farm or individual turbines).

Most of the impact on fish is manifested through the action of electromagnetic fields of cables that carry electricity from the power plant to shore, the emission of anthropogenic underwater noise, and the creation of new habitat conditions by the formation of artificial reefs on the substratum seabed.

The majority of the impact on marine mammals is manifested through the loss and/or deterioration of marine habitats in the areas of the foundation and anchoring of power plants or the route of the submarine cables, noise emissions from geophysical and geotechnical investigations during location selection (sonars, seabed drilling and test blasting), the foundation of wind turbines (driving pylons) and the vessels themselves during construction. These can lead to damage to hearing organs and interference with communication, collision with vessels, obstacle impact, change in water quality (pollutants and waste), effects of electromagnetic fields on navigation, effect of artificial reefs and indirect effects. A positive impact can be expected through the reduction of fishing pressure.

The above-mentioned impacts can be manifested in other marine species as well. In addition to these, the thermal impact due to the heating of energy cables could lead to the settlement of species that are not typical for that habitat, as well as non-native and invasive species.

Concerns about the effects of electromagnetic fields are usually eliminated by covering the cable with protective sheaths and sinking the cable into the seabed to a depth of one metre or more. This method also excludes the influence of heat from the cable to the marine environment.

In late 2022 the Republic of Croatia created *Guidelines for assessing and mitigating the impact of anthropogenic noise on marine mammals and sea turtles in environmental impact assessment procedures, strategic environmental impact assessment procedures of strategies, plans and programs, and assessment of acceptability for the ecological network*. These guidelines define the species of marine mammals and sea turtles that are permanently or occasionally present in the Adriatic Sea and are subject to the impact of anthropogenic noise, the assessment of the impact of activities that produce anthropogenic noise, and the mitigation of the negative impacts of anthropogenic noise on marine mammals and sea turtles.

The species of marine mammals that are permanently or occasionally present in the Adriatic Sea and to which these guidelines apply are: whales (*Cetacea*), Bottlenose dolphin (*Tursiops truncatus*), striped dolphin (*Stenella coeruleoalba*), Risso's dolphin (*Grampus griseus*), Cuvier's beaked whale (*Ziphius cavirostris*), Fin whale (*Balaenoptera physalus*), Common dolphin (*Delphinus delphis*), Sperm whale (*Physeter macrocephalus*), False Killer Whale (*Pseudorca crassidens*), Long-finned pilot whale (*Globicephala melas*), Humpback whale (*Megaptera novaeangliae*) and seals (*Pinnipedia, Phocidae*): Mediterranean monk seal (*Monachus monachus*). Three species of protected sea turtles have been recorded in the Adriatic Sea: Loggerhead Sea turtle (*Caretta caretta*), Green Sea turtle (*Chelonia mydas*), and the Leatherback sea turtle (*Dermochelys coriacea*).

Animals exposed to long-term and strong anthropogenic noise in the sea can experience passive resonance (partial movement) that can result in injury ranging from superficial (hematoma) to organ rupture and death (barotrauma). Noise can cause a permanent or temporary shift in the hearing threshold, reducing the animal's ability to communicate and perceive a threat and ultimately affect the rate of reproduction (Ministry of Economy and Sustainable Development, 2023).

There is not much experience related to measures taken solely to avoid or reduce impacts on fish species. Seasonal restrictions on pole driving are being considered, but the possible range of noise disturbance itself is not clear.

For the protection of marine mammals, measures are being considered to exclude certain areas (macrolocation selection), to avoid sensitive periods such as the mating season (timing), by selecting turbine foundations (foundations with low noise levels), measures to limit noise, monitoring (visual and sound) the presence of marine mammals in safety zones, and measures by which animals are actively deterred from these areas.

Birds

According to *Guidance document on wind energy developments and EU nature legislation,* offshore wind farms have the potential to impact birds by:

- displacing individuals from foraging areas;
- through collisions of birds in flight with the rotating turbine blades;
- barrier effects that increase energy needed to transit between sites;
- habitat loss and degradation through the removal or fragmentation of the supporting habitat that birds would otherwise use and be attracted to (e.g. roosting sites).

These interactions are mostly discussed in the context of seabird populations in breeding colonies. However, there is also the potential to interact with a wide range of species that migrate through the Adriatic Flyway corridor. These include seabirds, gamebirds, waders, passerine birds, and raptors. Important breeding grounds for birds and seabirds can be seen in Figure 11.

The Adriatic Flyway is an important migratory corridor for waterbirds from central, northern, and eastern Europe, which fly in large numbers

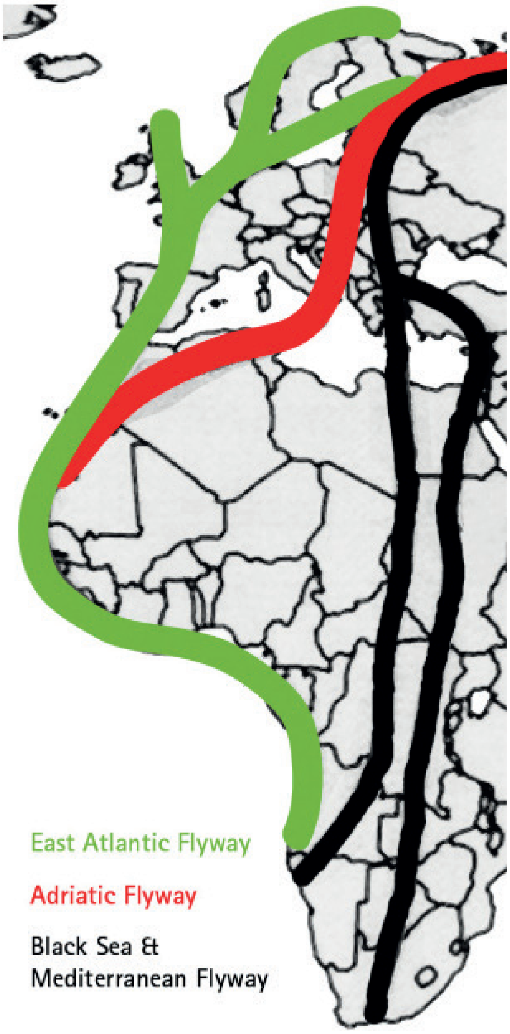
Figure 11. Important breeding grounds for raptors and seabirds

twice a year (in autumn and spring) along the eastern coast of the Adriatic Sea and southern Italy to northern Africa, as seen in Figure 12. Although there have been observations that some birds follow the coastline (raptors and storks), especially during bad weather and cold spells, most seem to fly only over the Southern Adriatic Sea, at a distance of 80-200 km from the coast (Schneider-Jacoby, 2008).

As the coastline is long and there are several potential sites for crossing the Adriatic, during the autumn migration the birds leave the eastern Adriatic coast from various places, such as the southern tip of Istria, the islands of Cres and Lošinj, the archipelago between Split and Apulia, the islands of Lastovo and Palagruža, or further south towards Albania.

Wetlands around the Mediterranean provide suitable stopovers for long-distance migrants to feed, rest, and moult. Some of the most important wetlands around the Adriatic Sea are: Škocjanski zatok (Slovenia), Po Delta (Italy), Vransko jezero (Croatia), Neretva Delta (Croatia), Livanjsko polje (BiH), etc. The Adriatic area is particularly important because the rugged and shallow coastline allows for various lagoons and bays that are important feeding areas during migration (salt pans, marshes, deltas). In addition, some of the islands in the Adriatic are important breeding grounds for raptors and seabirds (Cres, Krk, Rab, Pag, Silbanski greben, Dugi otok, Kornati, Lastovo otočje, Svetac, Biševo, Jabuka, Vis, Sušac, Palagruža).

Figure 12. Migrations corridors of birds (AEWA, 2016)



The main concern in relation to these species is collision with the turbine blades. Therefore, important nesting areas and bottlenecks in the corridors of the Adriatic migration routes must be taken into account when planning potential sites for the construction of offshore wind farms.

Visual impact of ORES

The visual impact of ORES on the landscape and seascape depends on several factors, including the height of the components, the distance from shore, and the surrounding topography. On average, a wind turbine with a height of 150 metrss can be visible from the coast up to 20-30 km away on a clear day.

However, in the Adriatic Sea, visibility can be affected by particular topographical features and weather conditions such as clouds and fog. Some studies have shown that wind turbines can be visible up to 60 km from the coast in certain conditions, but this is very rare.

As tourism is a significant contributor to the Croatian economy, the following visibility factors need to be considered:

- the Croatian coast has many islands and rocks that can block, open, or narrowly direct the view of the open sea. Microclimatic conditions can also greatly restrict or enhance visibility, e.g., rain, fog, wind, and turbidity of the atmosphere from free-hovering particles;

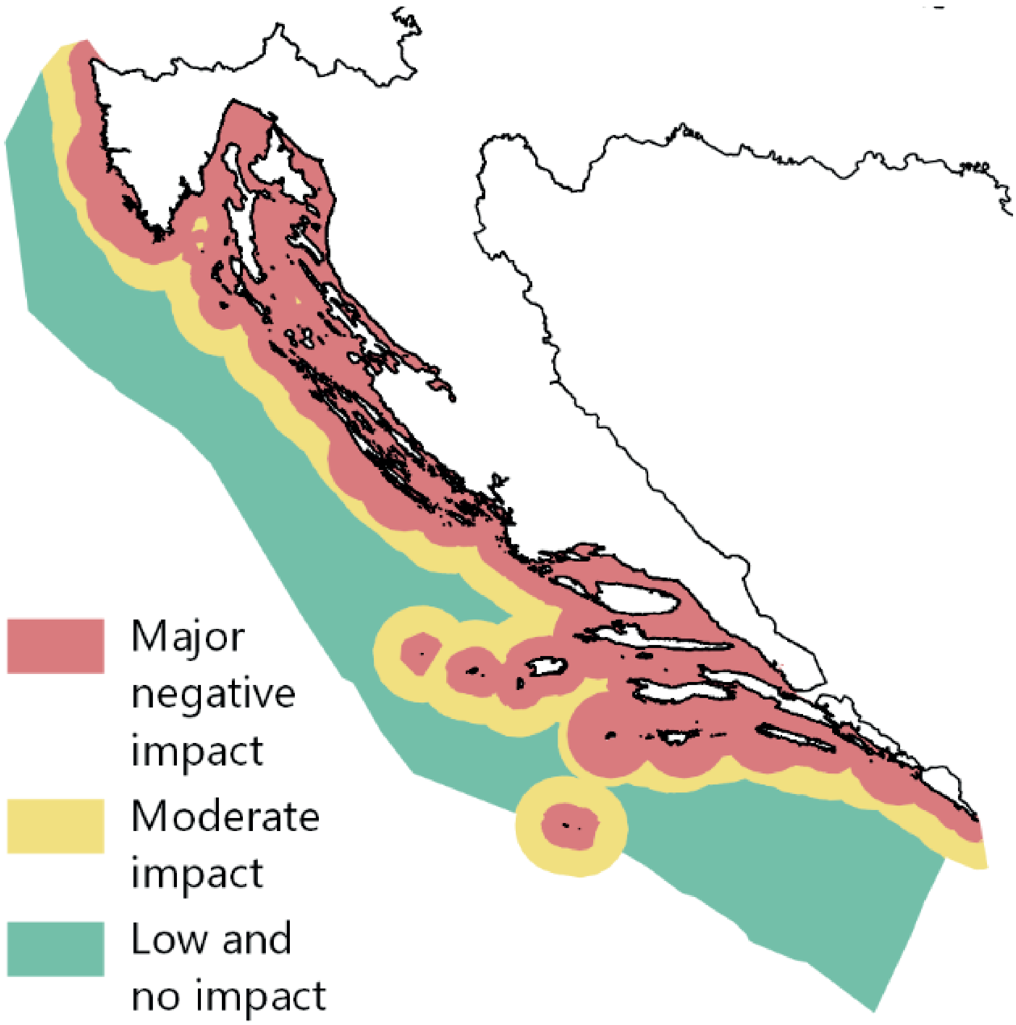
- the visual impact of ORES is lower if viewed from north to south than those from the south due to the reflection of the sun on the water surface; and
- visibility is clearer in the morning than in the afternoon because there is less atmospheric turbulence. At night, the wind turbines are not visible, but their lights can be seen from a great distance.

As the most mature ORES technology is offshore wind, Figure 13 shows a map of the visual impacts of offshore wind based on the following parameters:

- the major negative impact zone is up to 10 km from the coast along the entire length with an additional buffer zone of 20 km around national parks, nature parks and other highly visited places such as Dubrovnik, Split, Hvar Island, Pula, Rovinj, etc.;
- the moderate impact zone is up to 12 nautical miles (22.22 km) from the coast. Offshore renewable energy facilities are likely to be visible from the coast, but the image will probably be blurred and it will not be easily noticed from the shore; and
- the low and no impact zone is the area from 12 nautical miles to the line of the EEZ. The area is considered far enough from the coast that potential visual impacts on the landscape are minimised or non-existent.

However, when developing ORES in the area of central Adriatic close to unpopulated off-

Figure 13. Visual impact of offshore wind farms in Croatia



shore islands and rocks, the above listed parameters should be reconsidered in the course of maritime spatial planning and project related Environmental Impact Assessments (hereinafter: EIA).

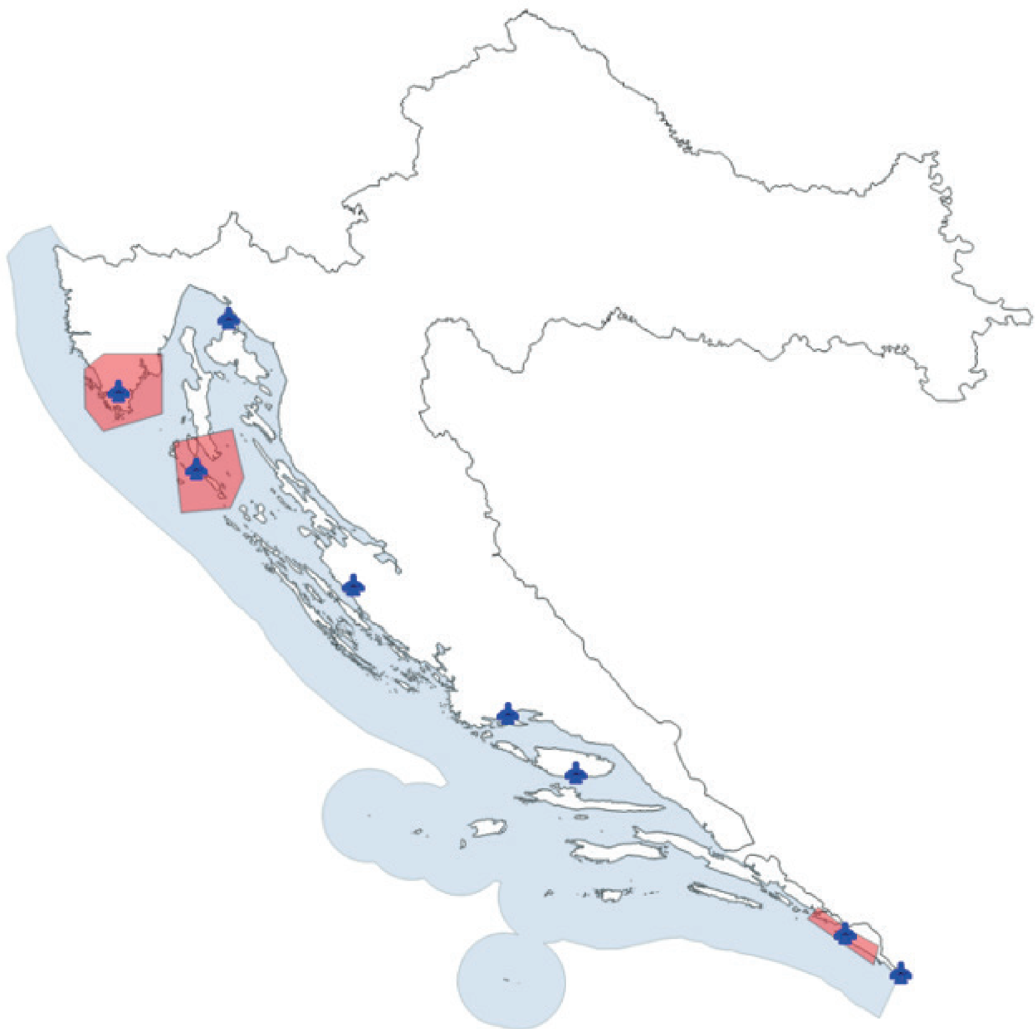
Lastly, the visual impact of floating PV should be considered significantly lower due to its flat layout.

Air traffic and special purpose zones

Offshore wind turbines, due to their height, which is approaching 300 meters with the tendency to be higher in the future, represent potentially dangerous objects for air traffic. Therefore, they must be properly marked, both during the day and at night. The situation is more complex if they are located near or within airport zones (CTR – Control Tower Region), regardless of the airport category. There are seven coastal airports in Croatia, from north to south: Pula, Rijeka (island of Krk), Mali Lošinj, Zadar, Split, Brač, and Dubrovnik. Furthermore, Tivat airport in Montenegro is located right next to the border with Croatia and should also be taken into account. Out of the afore-mentioned airports, only the airports of Pula and Mali Lošinj have a control traffic zone that significantly extends over the sea and represents a potential restriction zone as seen in Figure 14.

Another challenge is the influence of the rotating turbine blades on civil flight control radars

Figure 14. Coastal airports (blue markings) with marked CTR of Pula, Mali Lošinj, and Dubrovnik airports (red polygons)



because they see them as low-flying planes that appear at one moment and disappear after a short time. This can be solved by calibrating the radar.

Wind turbines, as artificial obstacles at sea, must be marked with maritime markings prescribed by law, both during the day and the night, which will need to be harmonised with aviation markings.

The Croatian Air Force has pre-defined locations for hedgehops, and the Croatian Navy has areas for target practice and the disposal of expired ordnance. Therefore, when determining the location of offshore renewable energy sources, the conditions of the Ministry of Defence should be included to avoid unnecessary conflicts in a timely manner.

Developers should also engage in an early development phase with the Civil Aviation Agency to identify any restrictions for ORES development.

Areas of sunken ammunition and weapons

In the Adriatic Sea, there are areas where unused weapons and ammunition have been discarded throughout recent history (from World War I to the Croatian Homeland War and NATO operations in Serbia). There is no publicly available data or maps with such areas registered, as well as accurate information on the type and quantity of weapons or ammunition. According to data from the European Marine Observation and Data Network (EMODnet), in the Croatian part of the Adriatic, including the continental shelf, there are 21 such areas with a total area of more than 386,000 ha, as seen in Figure 15 (EMODnet, 2023).

The potential impacts of such discarded weapons and ammunition on ORES can be devastating. In order to avoid any accidents during the construction phase, developers should engage early on with the Ministry of Defence in order to safely detect and avoid risky areas.

Underwater cultural heritage

The UNESCO Convention on the Protection of Underwater Cultural Heritage (Paris, 2001) defines underwater cultural heritage as every trace of human existence, cultural, historical or archaeological character that was partially or completely underwater, occasionally or permanently, for at least one hundred years. All underwater cultural heritage in Croatia is protected by the Protection and Preservation of Cultural Property Act.

According to the Ministry of Culture, there are 206 registered archaeological sites/zones in the Croatian part of the Adriatic Sea, as seen in Figure 16. Spatially, they are most concentrated around the islands and in the sea towards the shore. It is assumed that there is a large number of unregistered localities or zones in the open sea that have not yet been found or explored.

ORES could damage the historic environment during the construction, anchoring, and cable laying phases. Similar impacts can be expected closer to shore and within the inter-tidal zones where the sites and materials comprising the historic environment are likely to be particularly dense and complex. In addition to the primary impacts, indirect impacts on archaeological zones and sites located at a certain distance from the project can be expected, as well as cumulative impacts with other projects. Positive impacts on the underwater cultural heritage can be expected through the registration and protection of new archaeological sites and zones, especially in the case of

Figure 15. Areas according to EMODnet where unused weapons and ammunition have been discarded in the Adriatic Sea (EMODnet, 2023)

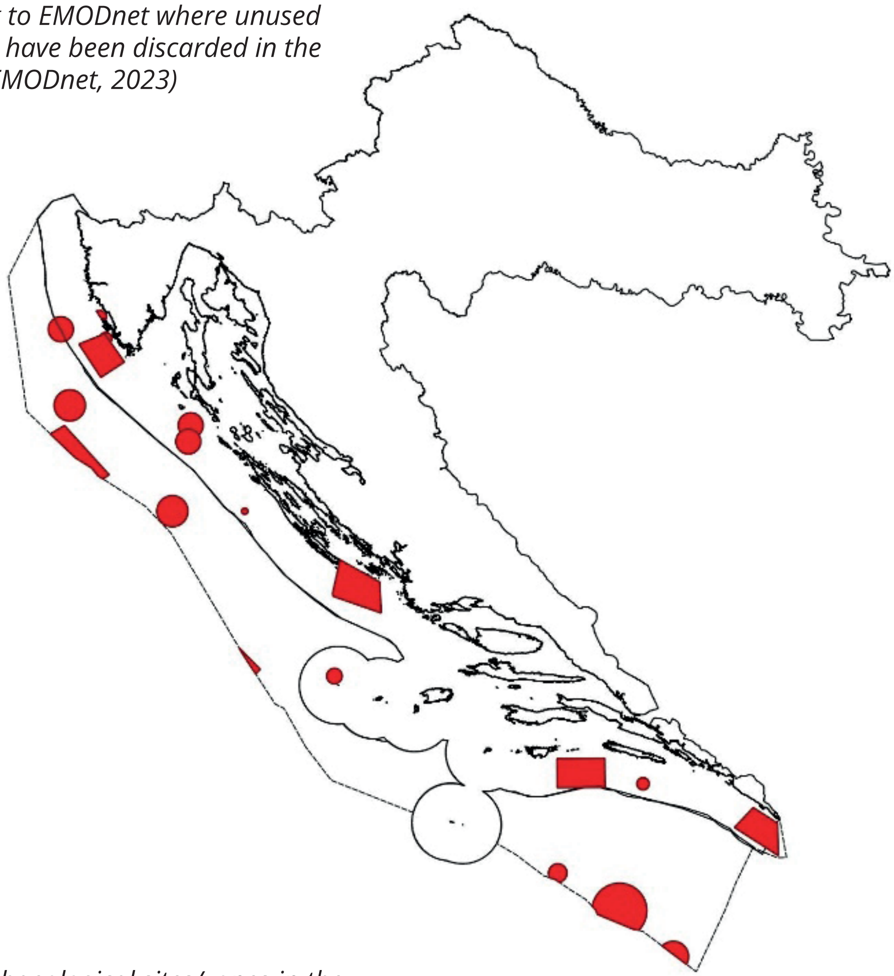


Figure 16. Registered archaeological sites/zones in the Croatian territorial part of the Adriatic Sea

in situ protection. Archaeological inspections and protection measures should take place at the project level.

4. 2. PERMITTING PROCEDURES IN EUROPE

The permitting process for ORES is very complex and a long process as many different bodies and layers of the administration are involved. The main differences of ORES permitting across Europe are:

1. Seabed concessions:
   a) Centralised model –Government identifies offshore sites for ORES development;
   b) Decentralised model – developers identify offshore sites.

2. Grid build-out responsibility:
   a) Transmission System Operator's (hereinafter: TSO) responsibility;
   b) Developers' responsibility;
   c) Mixed responsibility .

Figure 17 shows an example of the responsibilities between Government bodies, wind farm developers, and the TSO in the case of offshore wind in several European markets.

The grid build-out responsibility between stakeholders in the case of offshore wind development is shown in Figure 18.

The following paragraphs present an overview of ORES permitting procedures in several European countries, with a focus on seabed concessions and grid build-out responsibilities.

Denmark

As explained earlier, Denmark differentiates between two types of ORES projects – nearshore wind farms and tendered offshore wind farms.

Nearshore projects are permitted under the open-door procedure, where the developer initiates the project development by submitting an application for a license to carry out preliminary investigations in the area (except for zones that are pre-defined). The developer pays for the grid connection to land.

The Danish Energy Agency (hereinafter: DEA) is the designated one-stop shop. As a first step, DEA identifies any major public interests that could block the project, after which the application can be processed. DEA then issues an approval to the developer to carry out preliminary investigations, including an EIA. If the investigation results are positive, the developer can obtain a licence to establish the project (Danish Energy Agency, 2022).

Tendered offshore wind farms are pre-defined and permitted by DEA. In the most recent example, DEA identified the *Thor* site and assessed the site as being able to accommodate offshore wind capacity between 800-1000 MW. DEA also carried out and published a number of preliminary investigations, including data on the wind resource, environmental assessments, reports on environment, seabed investigations, and geotechnical investigations (Danish Energy Agency, 2022).

DEA was in charge of completing a Strategic Environmental Assessment and additional environmental surveys and studies that are needed for the EIA. The winner of the 30-year concession is in charge of completing the EIA of the offshore part of the project, while DEA completes the EIA for the onshore part of the project (Danish Energy Agency, 2019).

Figure 17. Responsibilities for offshore wind development in Europe (WindEurope, 2022)

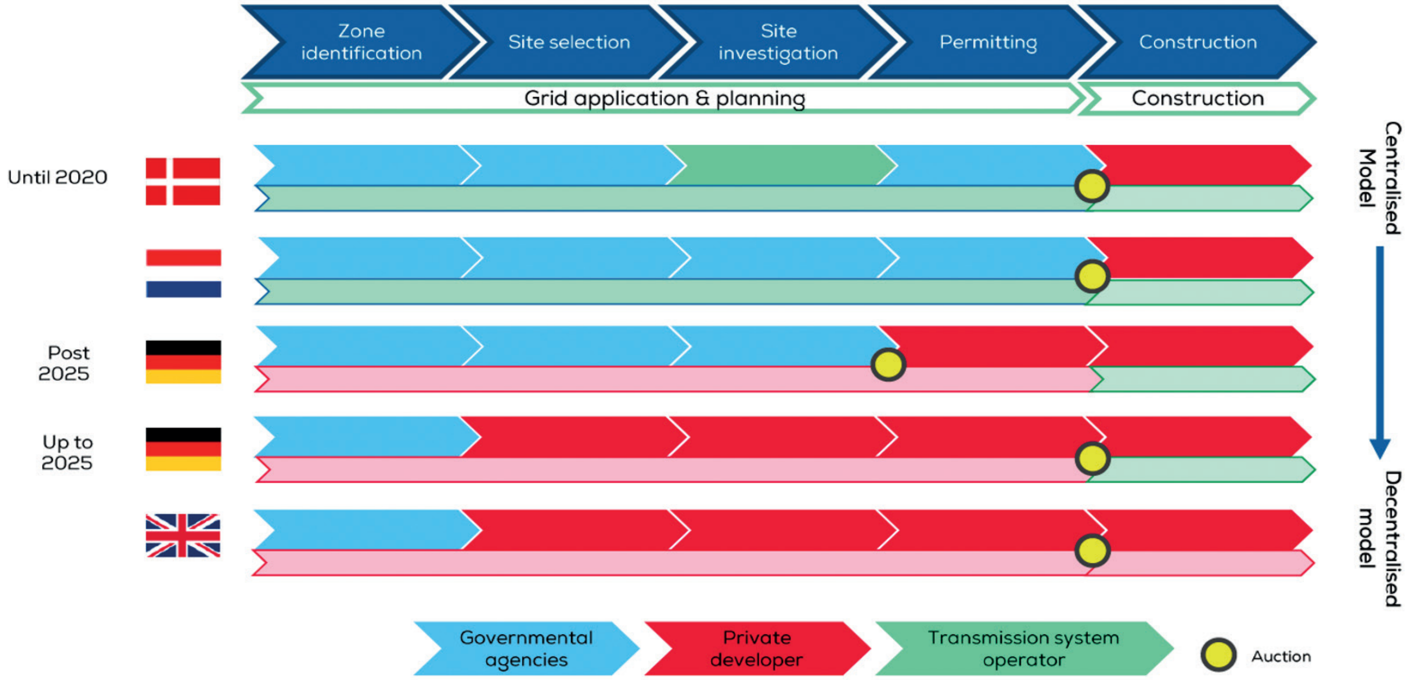
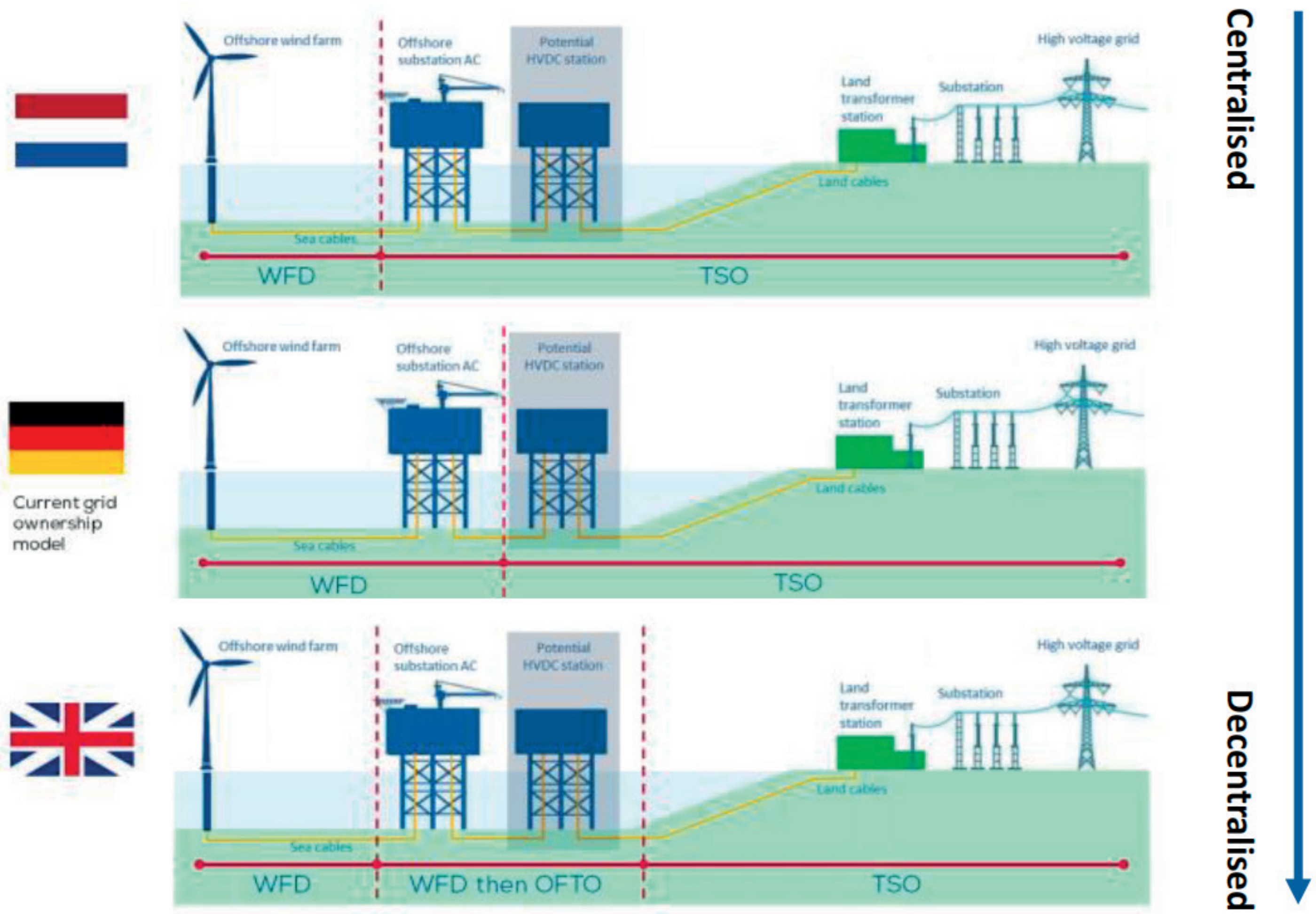


Figure 18. Grid build-out responsibility for offshore wind development in Europe (WindEurope, 2022)



Furthermore, the developer is responsible for developing and constructing the grid connection from the wind farm to the transmission grid, while the TSO is responsible for building the onshore grid connection.

Lastly, the developer is responsible for dismantling and decommissioning the offshore wind farm. The developer has to allocate 10% of the estimated construction cost of the project as a decommissioning guarantee no later than 15 years after commissioning and two years before planned decommissioning (Danish Energy Agency, 2021).

Germany

After initially allowing developers to identify their projects, Germany will pre-develop future sites, providing grid connections and other administrative development such as site surveys.

The Federal Maritime and Hydrographic Agency (BSH) is the designated one-stop shop. BSH starts with marine spatial planning, ensuring balanced interests by the various users of the maritime area. After that, BSH carries out the investigation of the marine environment, subsoils, wind and oceanographic conditions. If BSH finds a suitable site, an executive order is sent to the Federal Network Agency (BNetzA), which decides whether to go through the tendering procedure. After a developer wins the tender rights to a site, the developer is responsible for the permitting (including the EIA, spatial and technical overview report, analysis of military, aviation, and shipping matters, etc.) (Jack, 2022).

In the latest changes to the to the German Offshore Wind Energy Act, the Government implemented faster approval and permitting rules, including a faster offshore grid connection (which is awarded immediately after the area is included in the development plan), environmental assessments and participation rights being bundled together, deadlines for planning approval, etc. (Cabinet of Germany, 2023).

Due to the large number of offshore wind farms in Germany, BNetzA believes that the most cost-effective grid development for offshore wind farms will be with direct current coupling via multi-terminal platforms, instead of individual point-to-point connections. The three German TSOs will be responsible for nine offshore wind connections with the latest 2 GW, ±525 HVDC technology (REGlobal, 2022).

The Netherlands

The Netherlands also transitioned from a decentralised to a centralised model for site selection of offshore wind farms in 2018.

The process starts with identifying offshore wind zones in the National Water Plan by the Ministry of Economic Affairs and Climate Policy and the Ministry of Infrastructure and Environment. After that, the Government decides on the rollout sequence in which the offshore sites will be developed, the generation capacity of each site, and finally the planned timeline of tendering, installation, and commissioning. All of this is done as part of the Offshore Wind Energy Roadmap. So far, the Government has issued the 2015-2023 roadmap and the 2023-2030 roadmap.

The Netherlands Enterprise Agency is responsible for commissioning the EIA, as well as the site studies (soil, wind, and water conditions, archaeological survey, etc.), free of charge.

The Dutch TSO – TenneT, is responsible for the offshore grid connection. Tennet was installing AC substations for projects that are close to the shore, while for new projects that are 70 km off the Dutch coast, Tennet is installing HVDC substations. The developer is responsible for the inter-array cables that connect the wind turbine to the substation (Wind & Water Works, 2022).

After RVO concludes a tender for the site under the zero-subsidy model, the winning developer will receive the permit for the construction, operation, and removal of the wind farm, which allows the developer to immediately start construction. The permit is valid for a maximum of 40 years and the developer has to provide a decommissioning guarantee of €120,000/MW to RVO, which the developer can use only after 12 years of operation (TNO, 2020).

The United Kingdom

Under the UK's decentralised model, the Crown Estate (covering England, Wales, and Northern Ireland) and the Crown Estate Scotland designate specific zones for ORES development and are responsible for permitting as a one-stop-shop. This is followed by a tender for seabed leasing rights, where developers identify selected sites for which they compete.

In one of the most recent rounds, the Crown Estate awarded seabed leasing rights to 8 GW of offshore wind projects (including 480 MW for a floating wind farm) through a tender in 2021. Developers were competing based on a price criterion. The successful developer commits to pay at least three years of option payments and an annual option fee for each project until the project is ready to enter into a lease agreement (WindEurope, 2021).

Separately for offshore wind projects in Scotland, the Crown Estate Scotland awarded 25 GW (7,000 km^2) of offshore wind projects (60% for floating and 40% bottom-fixed). Developers will have to pay a one-off fee of up to £43,000/ MW (OffshoreWind.biz, 2022).

During the option period, the developer can carry out surveys and install measurement equipment within the option area in order to develop the project.

The developer is responsible for obtaining the necessary licenses and permits such as the EIA, a marine license from the Marine Management Organisation, permission for the construction of the wind farm from the Department for Business, Energy and Industrial Strategy (BEIS) and a grid connection agreement from National Grid.

The developer is responsible for financing and constructing the offshore wind transmission assets to shore. The offshore substation and export cables are transferred to an Offshore Transmission Owner (OFTO), who owns and operates it. Alternatively, the developer can opt for a "OFTO build" model, where an OFTO will be appointed to construct and operate the offshore transmission asset.

Lastly, prior to licencing ORES, developers have to submit a decommissioning program, which explains how the site will be decommissioning and dismantled, as well as the costs for those activities (DecomTools, 2019).

Permitting acceleration measures in the EU

The REPowerEU Plan identified several measures for accelerating the permitting of RES. These rules will be implemented in two pieces of legislation – the Renewable Energy Directive (which was under negotiations during the writing of this publication) and the Council Regulation (EU) 2022/2577 on laying down a framework to accelerate the deployment of renewable energy.

The REPowerEU measures that will most likely be addressed in the revised Renewable Energy Directive are:

- defining the administrative processes that fall under the permitting deadlines and the start of the permitting process;
- Member States to set up a contact point that would guide developers through the permitting process and ensure the fulfilment of deadlines for permit-granting;
- Member States will need to identify areas for renewable sources needed to meet the EU RES target;
- identifying 'renewables go-to areas' where the permitting will not exceed one year;
- exempting RES projects in 'renewables go-to areas' from an EIA.

The Council Regulation (EU) 2022/2577 on laying down a framework to accelerate the deployment of renewable energy establishes temporal rules for projects that start with permitting as of 22 December 2022 such as:

- overriding public interest for RES, grids, and storage assets;
- applying a population-based approach to biodiversity;
- possibility for exemptions of an EIA for RES, grids, and storage assets for projects in a dedicated renewable or grid area that has been subjected to a strategic environmental assessment.

4. 3. PERMITTING PROCEDURES IN CROATIA

Developers of offshore RES have to follow the development steps that are already identified for onshore RES in the *Guide for the Development and Implementation of Renewable Energy Projects in Croatia*, however, there are a few differences in development in the process (EnergoVizija, 2022).

The first step for ORES would be identifying ORES zones in spatial plans. In Croatia there are different levels of spatial planning. The main documents for spatial planning is the Strategy of Spatial Development of the Republic of Croatia and the National Spatial Development Plan. Unfortunately, the National Spatial Development Plan is not finished. Lower level of spatial plans are county spatial plans. County level of planning takes into account only the maritime area inside territorial waters of Republic of Croatia, so the exclusive economic zone of the Adriatic Sea is under the jurisdiction of the Croatian Government and the Croatian Parliament as well as the territorial sea under the governance of the Ministry of Maritime Affairs, Transport and Infrastructure for objects of national interest. The objects of the county levels of interest are under jurisdiction of each county assembly.

However, the current procedure for exploiting maritime areas in Croatia is highly complex and, in principle, does not guarantee certainty that the investor will succeed in achieving the goals within the desired period. In the case of exploiting maritime areas that require construction (which requires additional permits), then the procedure is even more complicated. At the time of writing this publication, two pieces of umbrella legislation regulating the use of maritime areas are being amended:

- the Act on Maritime Property and Sea Ports (hereinafter: ZPDML), which regulates the ways of using the maritime domain, as well as the procedure needed for their concession; and
- the Act on Spatial Planning (hereinafter: ZPU) which defines the first step in obtaining a concession – the process for obtaining a location permit and detailed procedures for development in the area.

The new Maritime Property and Sea Ports Act will soon be adopted and it is expected that it will not undergo any profound changes to the version analysed in this publication. The ZPU is in the phase of amendments, and until its adoption, changes will potentially take place that directly affect the development of ORES projects.

In addition, the National Spatial Development Plan which includes the possible development of the exclusive economic zone of the Adriatic Sea, is under development and should be finalised and adopted by the end of the year. Once completed, the spatial plans od areas of special characteristics (such as spatial plan of Exclusive Economic Zone) should be made in corelation with National Spatial Development Plan. The Decision on the preparation of the State Spatial Development Plan was delivered at 93rd session of the Government of the Republic of Croatia. The holder of the National Spatial Development Plan is the Ministry of Physical Planning, Construction and State Assets, and the expert drafter is the Croatian Institute for Spatial Development. The National Spatial Development Plan is drawn up and adopted for the territory of the Republic of Croatia with the specific focus on the projects of the national and regional importance.

Planning

The area of the Exclusive Economic Zone (EEZ) is defined by the Maritime Code and includes the sea areas from the outer border of the territorial sea in the direction of the open sea to its outer border permitted by general international law (Article 32). In its economic zone, the Republic of Croatia exercises sovereign rights in order to (Article 33):

- research and exploitation, preservation and management of living and non-living natural resources;
- energy production using the sea, sea currents and winds.

Article 35 of the Maritime Code stipulates that the Republic of Croatia has the exclusive right in the economic zone, to build, permit and regulate the construction, operation and use of artificial islands, devices and devices at sea, on the seabed and in the seabed. The corresponding regulations of the Republic of Croatia apply to the construction, operation and use of afore-mentioned facilities.

The ZPU envisages that, in the development of spatial plans covering the maritime area, efforts should be made to contribute to the sustainable development of tourism, maritime transport, the fishing and mariculture sector, and the energy sector in the maritime area. Additionally, it should also contribute to the preservation, protection and improvement of the natural scenery and the environment, including resilience to the effects of climate change, as well as the protection and preservation of cultural goods.

Based on the current proposal of the ZPU, the maritime area includes the internal sea waters of the Republic of Croatia, the territorial sea of the Republic of Croatia, the airspace above them, the seabed, and the subsoil of these maritime areas. They represent the Exclusive Economic Zone (EEZ) of the Republic of Croatia in the Adriatic Sea.

Article 44 of the ZPU identifies maritime areas as areas of economic use, allowing for the development of ORES in maritime areas. However, an exception is the Protected Coastal Sea Area, a restricted area for construction, which represents an onshore (and island) area 1,000 m away from the coastline and the maritime area of 300 m from the coastline.

The ZPU states that the maritime area is planned by either: the National Spatial Development Plan, the Spatial Plan of the Exclusive Economic Zone of the Republic of Croatia, the spatial plans of national parks and nature parks that include the marine area, the spatial plans of the counties that have the marine area, and the spatial planning plans of cities and municipalities, and general urban and development plans that include the maritime area. The ZPU is based on vertical integration, meaning that documents and plans of a higher order must be incorporated into plans and documents of a lower order. Thus, these state-level plans and documents allow construction even if they are not included in lower-order plans.

After inclusion in the spatial plans, energy approval, and the grid connection contract, the developer will need to obtain the necessary environmental approvals (as described in the *Guide for the Development and Implementation of Renewable Energy Projects in Croatia*).

Procedure for obtaining the location permit and the concession

The procedure for obtaining a concession in a maritime area is regulated by the Act on Concessions, which does not have any territorial restrictions and includes the entire maritime area in the Adriatic Sea, while the ZPDML regulates activities in the maritime area of the territorial sea. Therefore, if the ORES project is planned in the area of the Exclusive Economic Zone, the Croatian Government should bring a specific decision of obtaining the legal interest. The legal interest is the first step for the location permit and consequently the building permit.

Non-existence of the National Spatial Development Plan is the first obstacle, because during the location permit procedure it is necessary to be aligned with spatial plans of the specific area. Generally, Ministry of Physical Planning, Construction and State Assets and the Ministry of Maritime Affairs, Transport and Infrastructure are responsible for that area, but lot of details remains unclear under the which Law and which of the Ministries should be responsible for each step. For example, the construction permit for oil platforms were issued by the Ministry of Physical Planning, Construction and State Assets under the Mining Act which is not replicable for ORES projects.

Consent or preliminary studies and research in the area of the Exclusive Economic Zone as well as the concession on the cables and transportation of the electricity from the territorial sea to the mainland will be issued by the Ministry of the Sea, Traffic and Infrastructure.

The ZPDML stipulates that ORES can be installed under the economic activity provisions, provided that a concession for the area is obtained.

ZPDML also states that maritime goods and any buildings or objects permanently connected to it cannot be privately owned or leased, and they cannot acquire any other real rights, as they are outside legal circulation and belong to the state. It is therefore important to point out that all built infrastructure becomes the Republic of Croatia's property upon construction completion and is used economically during the concession period.

Furthermore, ZPDML states that a concession in the maritime domain is granted for purposes planned in the spatial plan, (e.g., wind energy production, fishing and aquaculture, etc.).

The first step in obtaining a concession for a maritime domain is to obtain a legal interest from the grantor of the concession to start the location permit procedure, which is determined by the level of the spatial plan that governs its usage. If there isn't a National Maritime Spatial Plan, then the county in question is responsible for granting the concessions outlined in the county-level spatial plan.

A developer that has expressed interest and obtained all the necessary documentation (including the location permit) still needs to compete in a tender for the concession. This introduces a certain legal amount of uncertainty, especially considering the time required to obtain the necessary permits.

For concessions at the state level, the longest duration is 50 years. In exceptional cases, with the consent of the Croatian Parliament, the concession can be granted for a period longer than 50 years, which depends on the depreciation period of the building. Counties can grant a concession for a maximum period of 20 years. The Croatian Parliament gives state-level concessions, and regional-level concessions are given by a representative body (county assembly). Developers that compete for a concession must meet the following conditions:

- the developer has to be registered to carry out the economic activity for which it is requesting a concession;
- all obligations from previous concessions have been settled by the day of submission of the bid or request; and
- the developer has not violated the provisions of the Act or the relevant by-laws.

The developer competes in the concession tender based on a proposed concession fee, which consists of a fixed and a variable part. The fixed amount is determined according to the size of the area (land and sea area) given in the concession. The variable part is defined as a percentage of the revenue generated by performing the activity for which the concession was granted.

The Regulation on the procedure for granting concessions in a maritime area defines the minimum prices for the fixed and variable parts of the concession fee. However, there is no guidance on the minimum variable fee for power plants. Until the regulation is changed, the initial values of the price per square metre in the tender, and the variable part, are the decision of the concession grantor.

Upon completion of the concession process, the selection of the concessionaire, and the signing of the concession contract, construction can begin, and the concession contract is considered a legal interest in obtaining a building permit.

Lastly, developers should also comply with the Maritime Code, which stipulates that maritime activities (such as measurements, monitoring, etc.) need prior approval by the Ministry of Maritime Affairs, Transport and Infrastructure.

4. 4. MARITIME AREAS FOR OFFSHORE RENEWABLES IN CROATIA

Maritime areas for ORES are determined based on a number of factors. The following paragraphs present an overview of the most important factors, with a focus on identifying zones for bottom-fixed offshore wind farms.

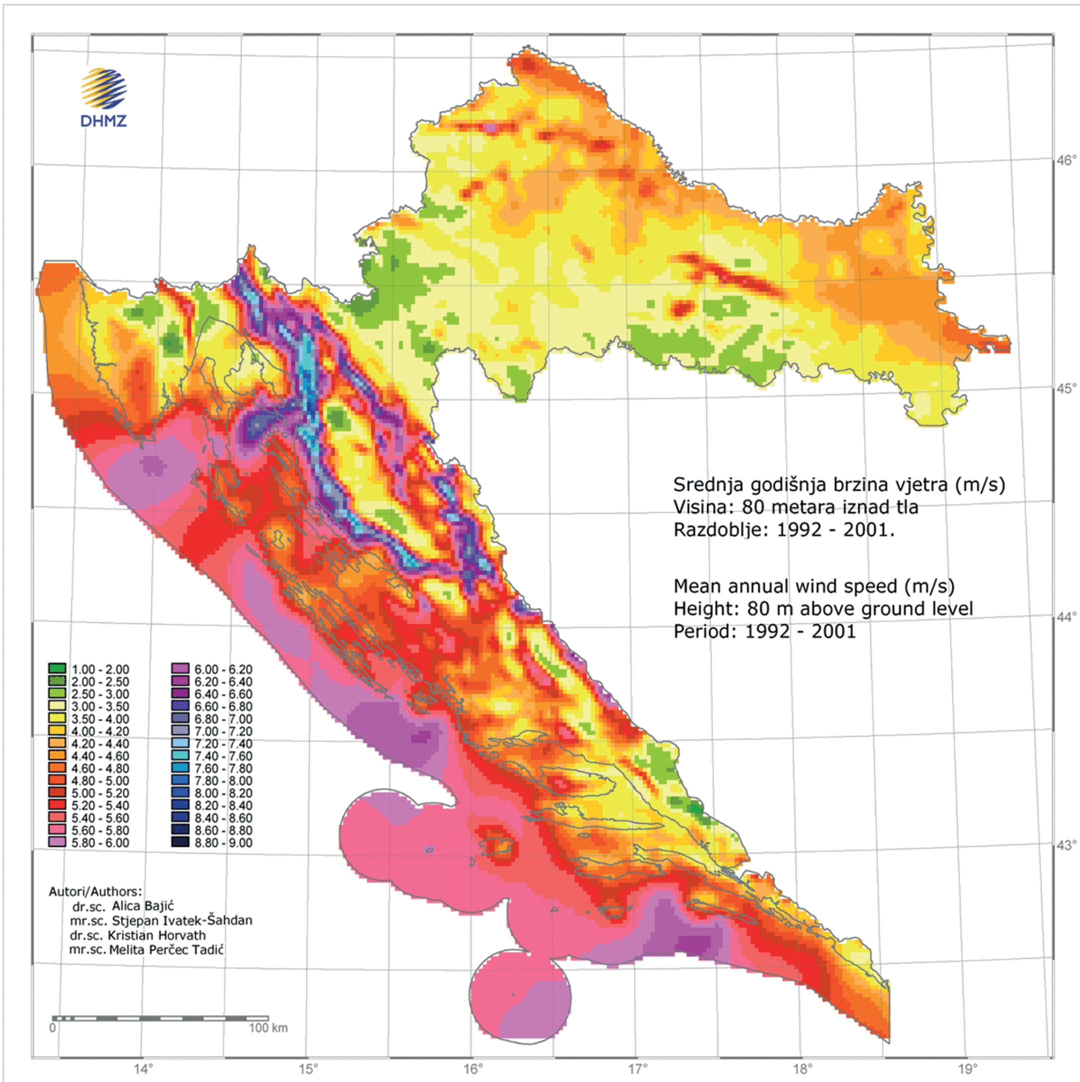
Winds in Croatia

There are two main winds in the Croatian part of the Adriatic Sea: the Bora and Scirocco.

The Bora is a strong, dry, and cold wind with an average velocity of 15 m/s. Wind gusts can reach up to 70 m/s. It is developed in high coastal mountains (Velebit, Mosor, Biokovo etc.), mostly common in the winter, and blows in gusts (directions: N, NE, E).

The Scirocco's average velocities are between 10 m/s and 30 m/s (directions: S, SE). It is strongest in the open sea, where it creates big waves. It blows for several days, more often in winter than in the warm part of the year. In summer it usually lasts no longer than 3 days, and in winter it can last up to 10 days, and sometimes with minor interruptions up to 3 weeks. It usually develops in the southern part of the Adriatic during winter, and in the northern part of the Adriatic during spring. In addition, the numerous Croa-

Figure 19. Mean annual wind speed at 80 m above ground level (DHMZ, n.d.)



tian islands form additional obstacles, which decreases wind velocity and enhances atmospheric turbulence (Marović & Herak Marović, 2007), (Duplančić Leder, Leder, & Lapine, 2007).

Figure 19 shows the mean annual wind speed at 80 m above ground level. However, with the increasing hub heights of offshore wind farms, there is a need for additional wind measurements.

Several different studies on wind speed in the Adriatic are underway. One of the latest is from the Croatian oil company INA, which this year started measuring wind speed on two gas platforms in the Adriatic, Izabela North and Ivana A (northern Adriatic).

Geology of the Adriatic

From a geological point of view, the Adriatic Sea lies on the Adriatic Carbonate Platform, as seen in Figure 20. The karstified carbonate platform is inconsistently overlain by clastic pliocen, pleistocen and holocen sediments varying in thickness from 0 m to 4,000 m in the Croatian part of the Adriatic.

The thickness of the PlioQuaternary deposits within the Adriatic foreland basin are shown in Figure 21.

Seabed properties

The Adriatic Sea is divided into two different parts, separated by the Palgruški Prag. The northernmost part of the Adriatic is shallow (up to 100 m), and has a flat, sandy or muddy bottom. The exception is the Kvarner canals, which are deeper than 100 m. The second section of the northern part has an average depth of 200 m and stretches 130 km along the longitudinal axis and 40 km in width, all the way to the Palagruški Prag. The southern part of the Palagruški prag descends steeply to the deepest point in the Adriatic Sea, which is 1233 m. The deepest – the South Adriatic Basin – is located between the Palagruški prag and Otranska vrata (743 m). Otranska vrata is also the exit from the Adriatic Sea. The bottom structure of this part is mixed sedimentary (Kučica, 2013). The bathymetry and the seabed sediments map of the Adriatic Sea are shown in Figure 22 and • possibility for exemptions of an EIA for RES, grids, and storage assets for projects in a dedicated renewable or grid area that has been subjected to a strategic environmental assessment..

Sea current

In the Adriatic Sea, there is a current that comes as a branch of the Mediterranean current from the Ionian Sea. It flows along the Croatian coast from south to northwest, i.e. it circles the entire Adriatic and returns to the Ionian Sea along the Italian coast as seen in Figure 24.

The main current is affected by currents of sea changes (tides) and currents created under the influence of the wind. Tidal and strong southerly currents with rain strengthen the main current along the Croatian coast. The speed of the current along the Croatian coast is higher in winter than in summer. In general, in winter, the sea current is stronger along the Croatian coast, and in summer along the Italian coast. The average speed of currents is from 0.25 to 0.5 m/s. Through canals, straits and near river mouths, it can reach up to 2 m/s. In general, sea currents are not strong (Duplančić Leder, Leder, & Lapine, 2007).

Figure 20. The Adriatic Carbonate Platform (Vlahović, Tišljar, Velić, & Matičec, 2005)

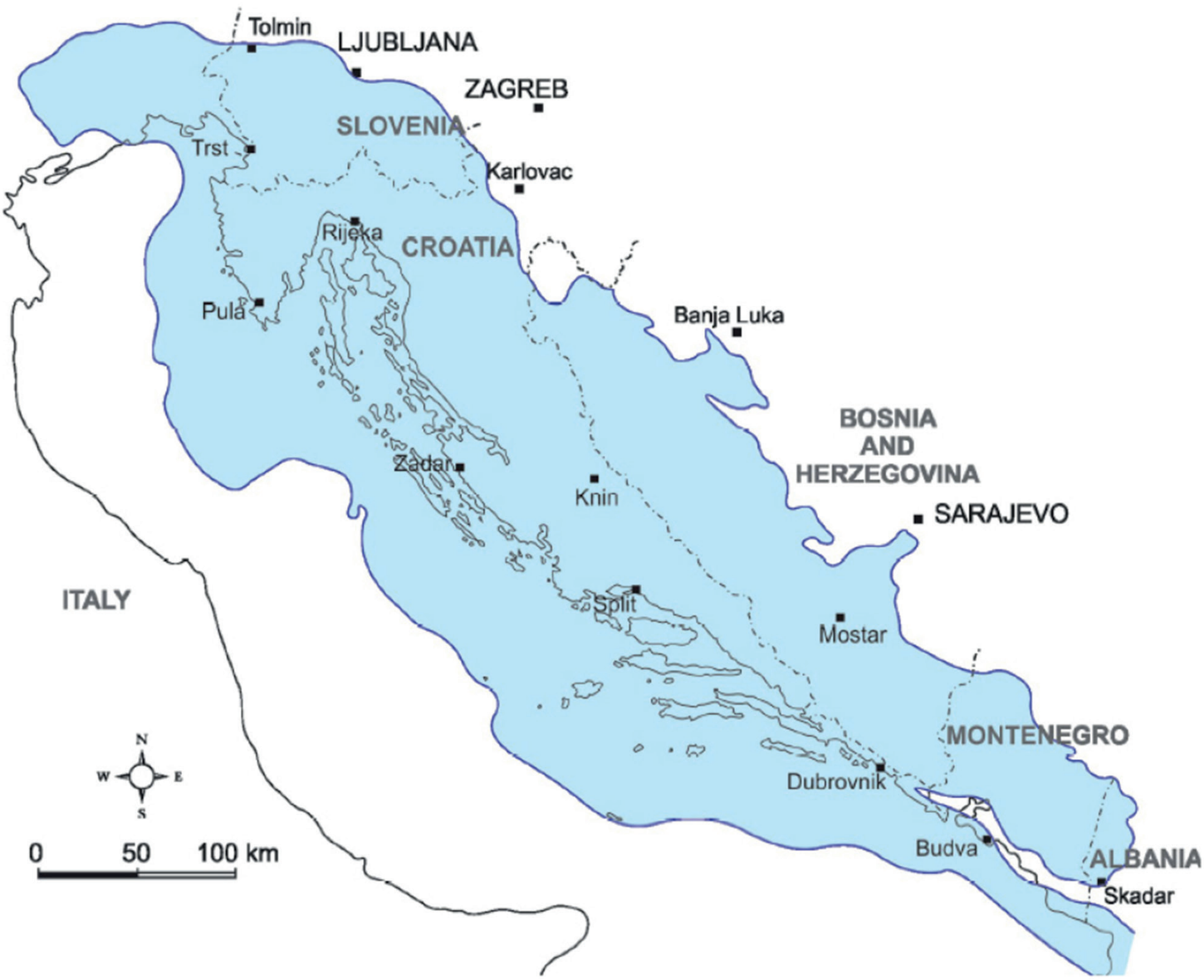


Figure 21. The thickness of PlioQuaternary deposits within the Adriatic foreland basin (Cattaneo, Correggiari, Langone, & Trincardi, 2003)

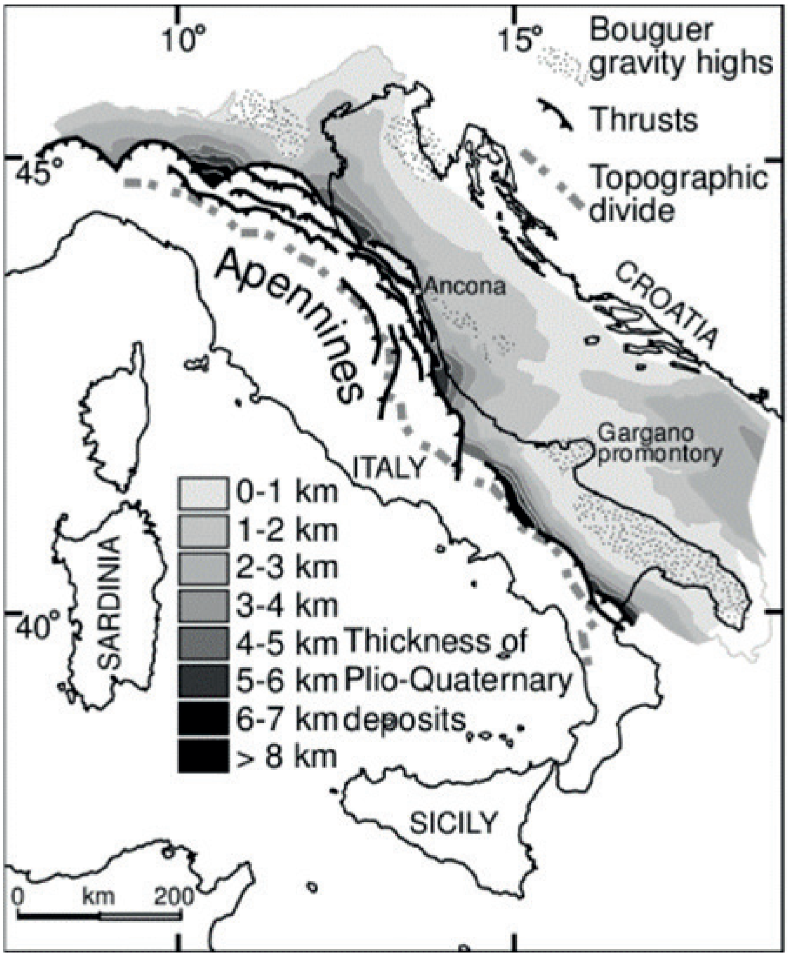


Figure 22. Bathymetry of the Adriatic Sea (UNEP/MAP-RAC/SPA, 2015)

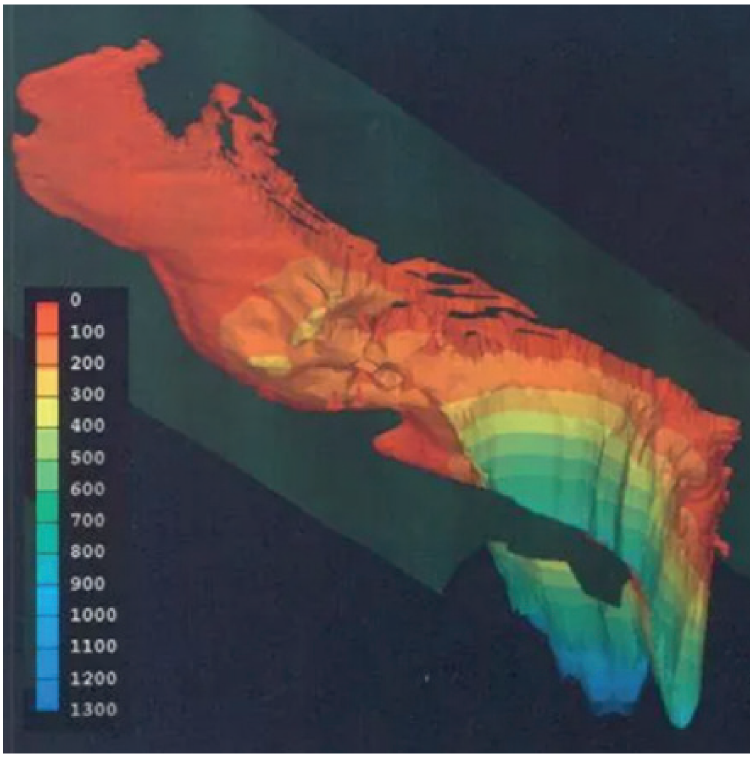


Figure 23. Seabed sediments map (HIJRM, 1985)

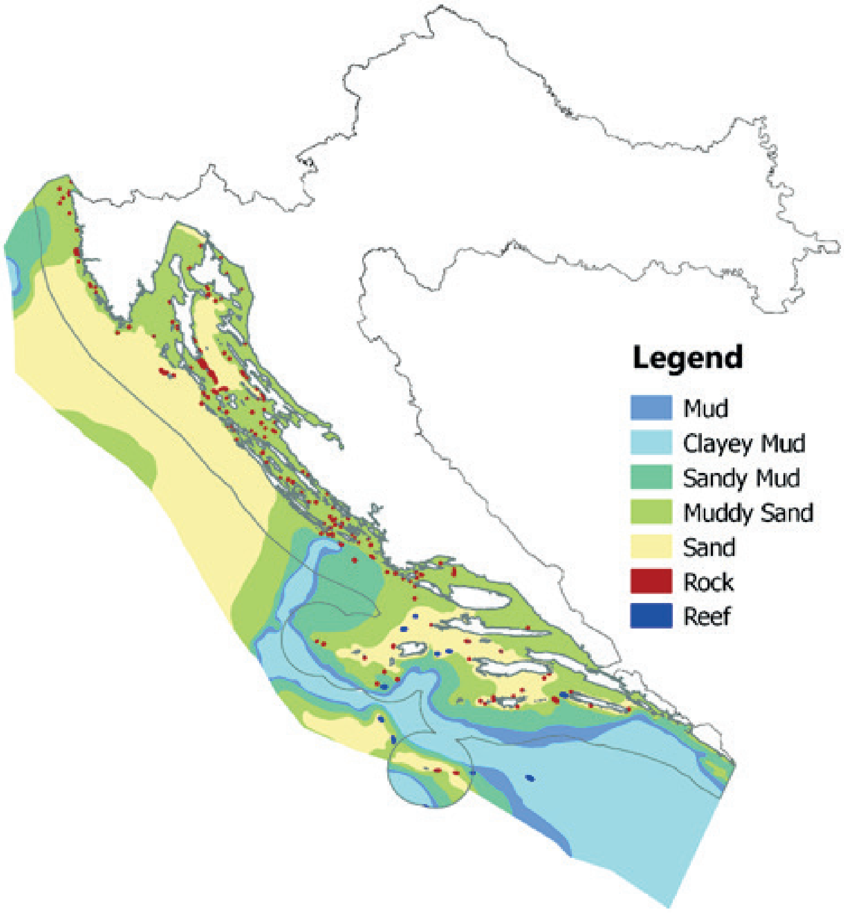
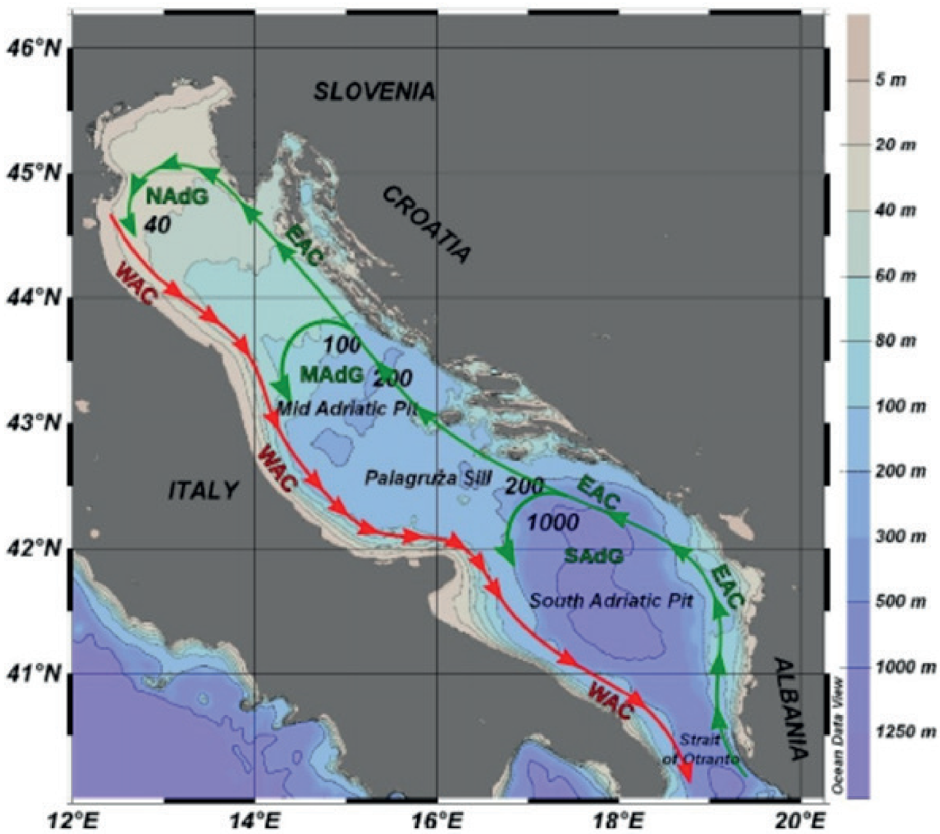


Figure 24. Currents in the Adriatic Sea (Lipizer, Partescano, Rabitti, & Giorgetti, 2014)



Spatial analysis of offshore areas in Croatia

Spatial analysis of potential areas of interest (hereinafter: AoI) for ORES in Croatia was focused on the analysis of bottom-fixed offshore wind farms due to the fact that they have higher spatial constraints compared to other renewables. Those are mainly related to the maximum depth for which construction is possible, the required minimum distance from the shore, and potential impacts on the environment.

The spatial analysis of possible AoI for bottom-fixed wind farms took into consideration the following constraints and limitations:

- the maximum sea depth feasible for the construction of bottom fixed wind-farms of 60 m;
- possible AoI need to be outside of existing hydrocarbon exploitation concession areas;
- zones of directed navigation need to be avoided to reduce the impact on existing shipping routes;
- protected marine areas and Natura 2000 sites need to be avoided;
- important bird migratory corridors need to be avoided; and
- possible AoI need to have a low impact on the landscape and seascape, or be placed 12 nautical miles from the shoreline.

An additional important constraint that was set was the exclusion of the area of the channel sea of Croatia. The reason for this was the intensive use of the channel sea waters for maritime transport, fishing, marine tourism, as well as the higher degree of biodiversity and the heterogeneity of marine habitats and the higher number of priority species and habitats present and expected in this area. However, these areas should remain open for limited ORES development if needed by the local communities on remote islands with inadequate infrastructure.

Conducting a high-level spatial analysis of possible ORES AoI required a wide range of spatial data sets which were gathered from different sources. The data source for the bathymetric map of the Adriatic Sea was the European Marine Observation and Data Network (EMODnet, 2023). The Croatian Hydrocarbon Agency (AZU) provided data about existing hydrocarbon exploitation concession fields and existing oil and gas platforms. The directed navigation shipping routes were adopted from official nautical charts. The data source for the spatial distribution of Natura 2000 sites and protected marine sites was the Nature Protection Information Service – Bioportal hosted by the Ministry of Economy and Sustainable Development of Croatia and its Department for Nature Protection.

Figure 25 shows the analysed maritime area. It should be noted that due to the high-level nature of this document the numbers and calculated areas that are the results of this spatial analysis should be viewed as approximated and are expected to change in more focused and localized studies. Furthermore, the proposed areas could be further reduced if they are in close proximity to dumped munitions, have a significant impact on aviation, or destroy cultural heritage.

The northern part of the Adriatic Sea under Croatian jurisdiction, from the southern part of Mali Lošinj island to the northern tip of the Istria peninsula, was recognized as the only acceptable area of interest when taking into consideration the maximum depth and the minimum distance from the shoreline. Due to this, further analysis was localised and focused on the defined area seen in Figure 26.

Taking into consideration the constraints in depth and the distance from the shoreline as well as the need to avoid the existing hydrocarbon exploitation concession fields and directed navigation shipping routes, four distinct areas of interest

Figure 25. Analysis of possible AoI for the construction of bottom-fixed offshore wind farms

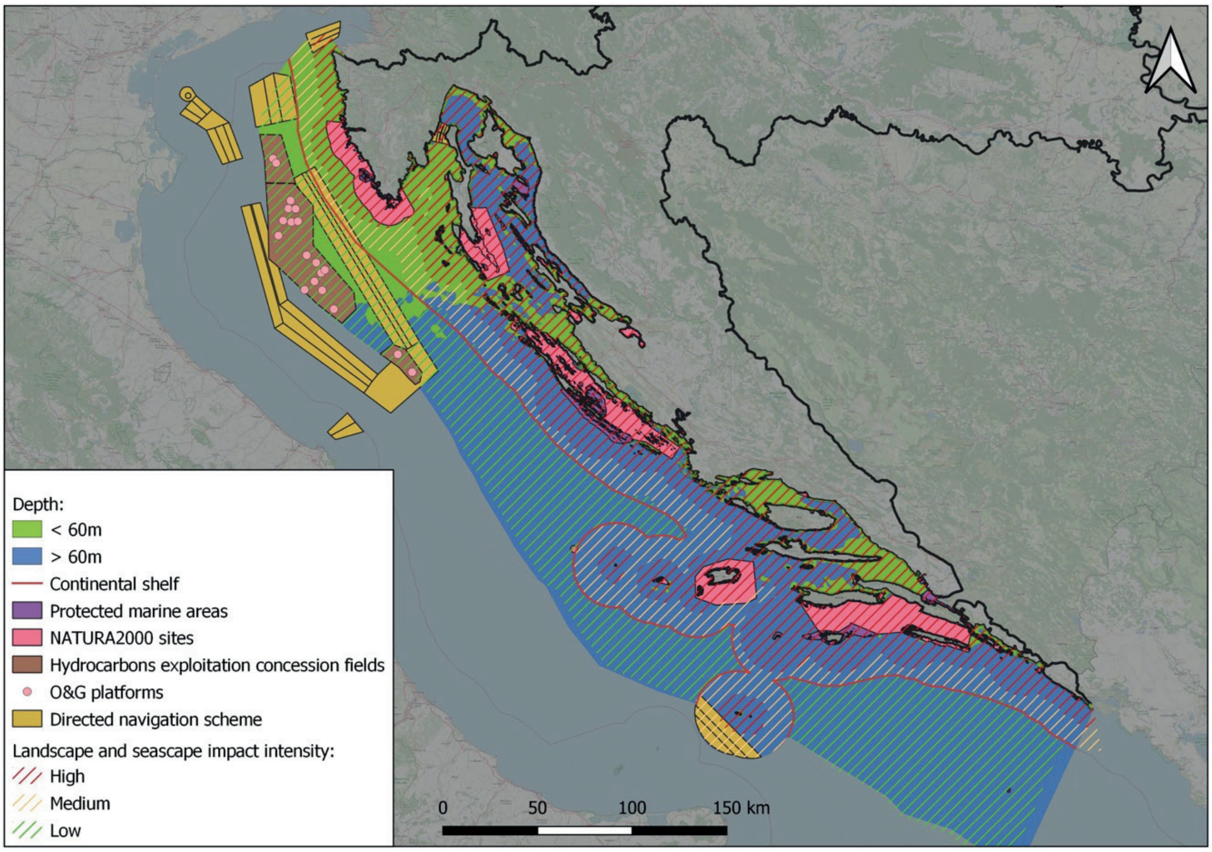
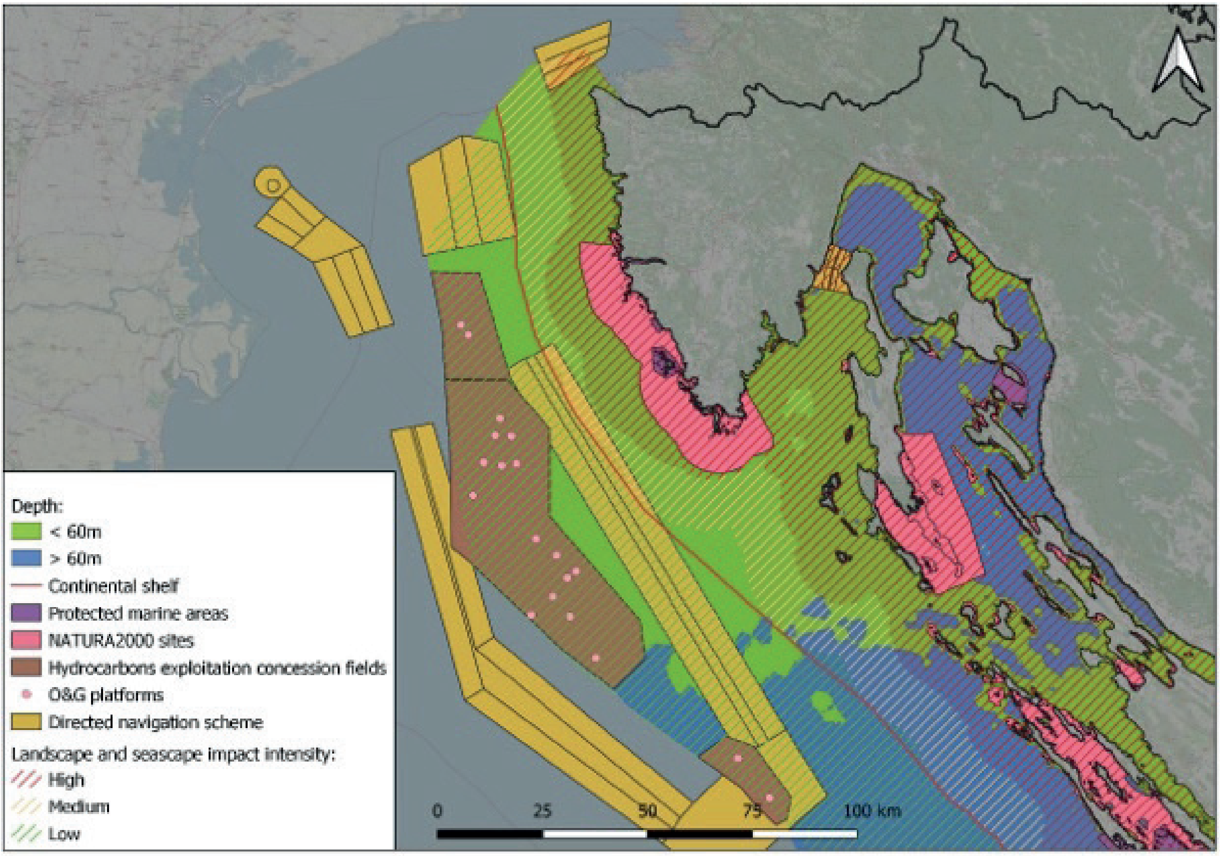


Figure 26. Area of the focused analysis of possible AOI for bottom-fixed offshore wind farms



have been identified, as seen in Figure 27.

It should be noted that due to the low spatial resolution and accuracy of the bathymetric data, depths of up to 60 meters were approximated from the available data.

The overall area of the detected five zones of possible AOI for bottom-fixed wind farms are approximately 1,260 km^2 and the approximate specific area per zone is listed in Table 4. The power density of offshore wind farms in Europe is between 3.3–20.2 MW/km^2, which would translate up to 25 GW of potential offshore wind capacity (Enevoldsen & Jacobson, 2021).

A solution in which areas of medium impact on the landscape and seascape are considered as possible areas of interest was also explored. In that case, an additional 1,602 km^2 of possible

Figure 27. Zones of possible AOI for bottom-fixed offshore wind farms with low impact on landscape and seascape

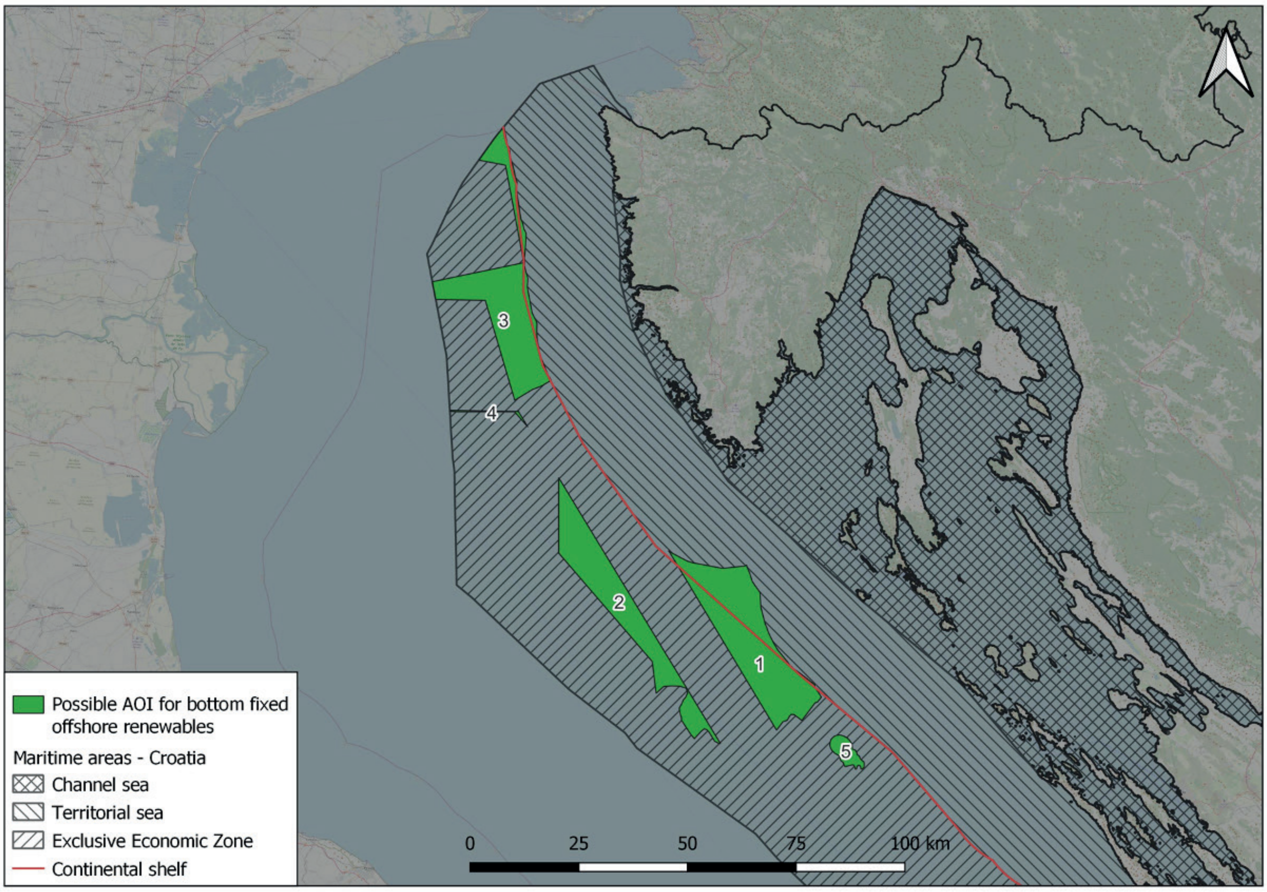


Table 4. Identified zones of possible AoI for bottom-fixed wind farms in Croatia (low impact)

AOI ID	Overall area [km^2]	Inside the territorial sea [km^2]
1	471	175
2	348	0
3	403	29
4	5	0
5	33	0
Total	**1,260**	**204**

areas for the construction of floating PV and bottom-fixed wind farms were identified, as seen in Figure 28. This could accommodate up to 32 GW of offshore wind capacity. The overall area detected as suitable for bottom-fixed offshore wind is shown in Table 5.

Further studies should also take into account the results of the ongoing project of benthic and coastal marine habitats, ordered by the Ministry of Economy and Sustainable Development of Croatia, as those results might have a strong impact on environmental constraints in the possible areas of interest for bottom-fixed wind farms. Therefore, the areas of medium impact should remain opened for further considerations, depending on the results of other more detailed studies and public acceptance.

An additional offshore zone can be the already awarded concession areas for hydrocarbon exploitation (approx. 2,181 km^2 with the exclu-

Figure 28. AoI zones for bottom-fixed offshore wind with low and medium impact on the landscape and seascape

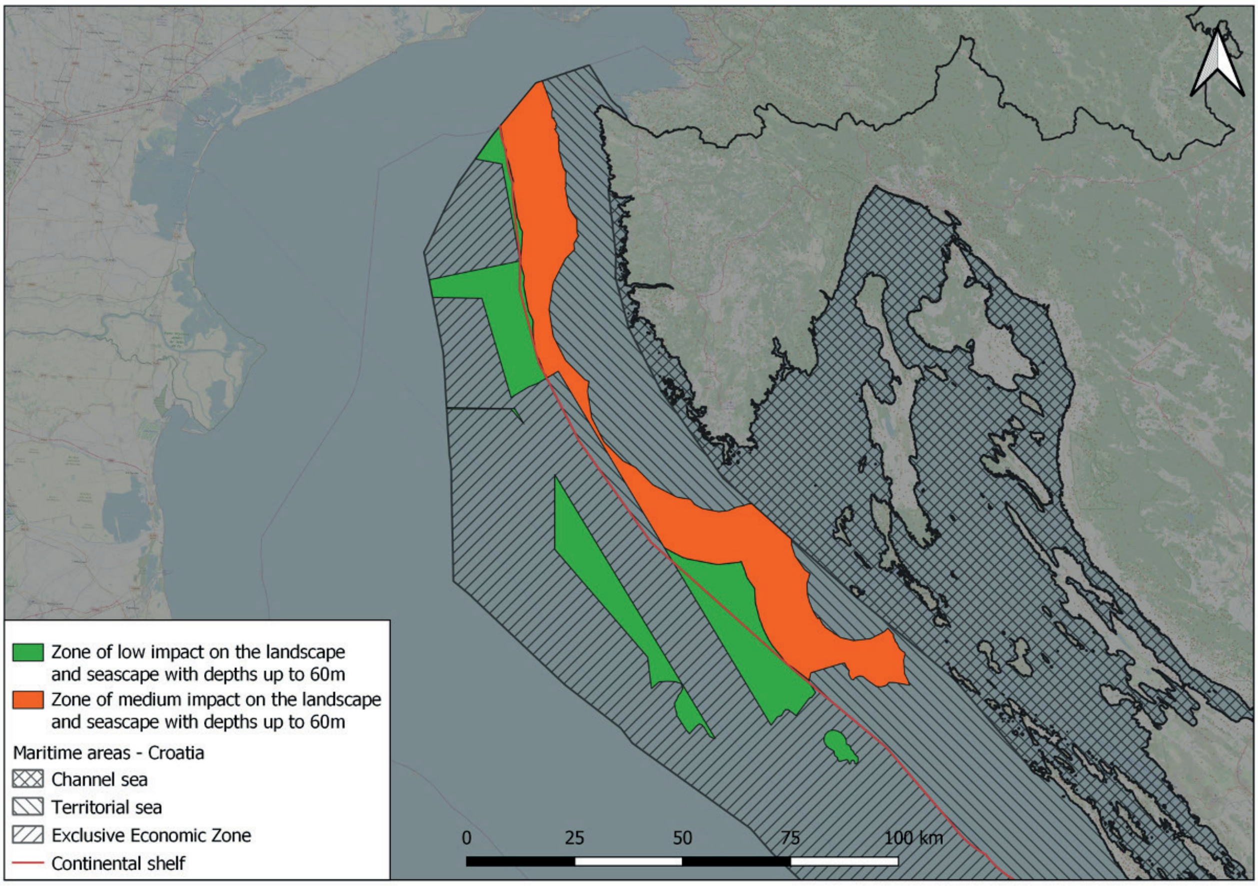


Table 5. Suitable areas for bottom-fixed offshore wind

Type of impact	Teritorial sea [km^2]	Exclusive Economic Zone [km^2]	SUM [km^2]
Low	205	1,055	1,260
Medium	1,602	-	1,602
SUM [km^2]	**1,807**	**1,055**	**2,862**

sion of the 500 m safety zone around the existing and planned hydrocarbon exploitation platforms.). This could translate up to 44 GW of potential offshore wind capacity. The development of bottom-fixed offshore wind in these zones depends on concession agreements between INA and the Republic of Croatia.

Areas for possible ORES development in the central and southern Adriatic are likely to focus on floating offshore wind farms and floating PV due to higher water depths. Floating offshore wind farms should be developed in areas of low impact on landscape and seascape, while floating PV can be developed within the offshore wind farm areas or separately in medium impact zones. This is due to the smaller size of floating PV, which has a lower visual impact. Spatial analysis of areas suitable for floating ORES was conducted with the same constraints and parameters as the analysis of bottom-fixed areas with the difference of the maximum

Figure 29. Zones of possible floating ORES development with low and medium impact on landscape and seascape

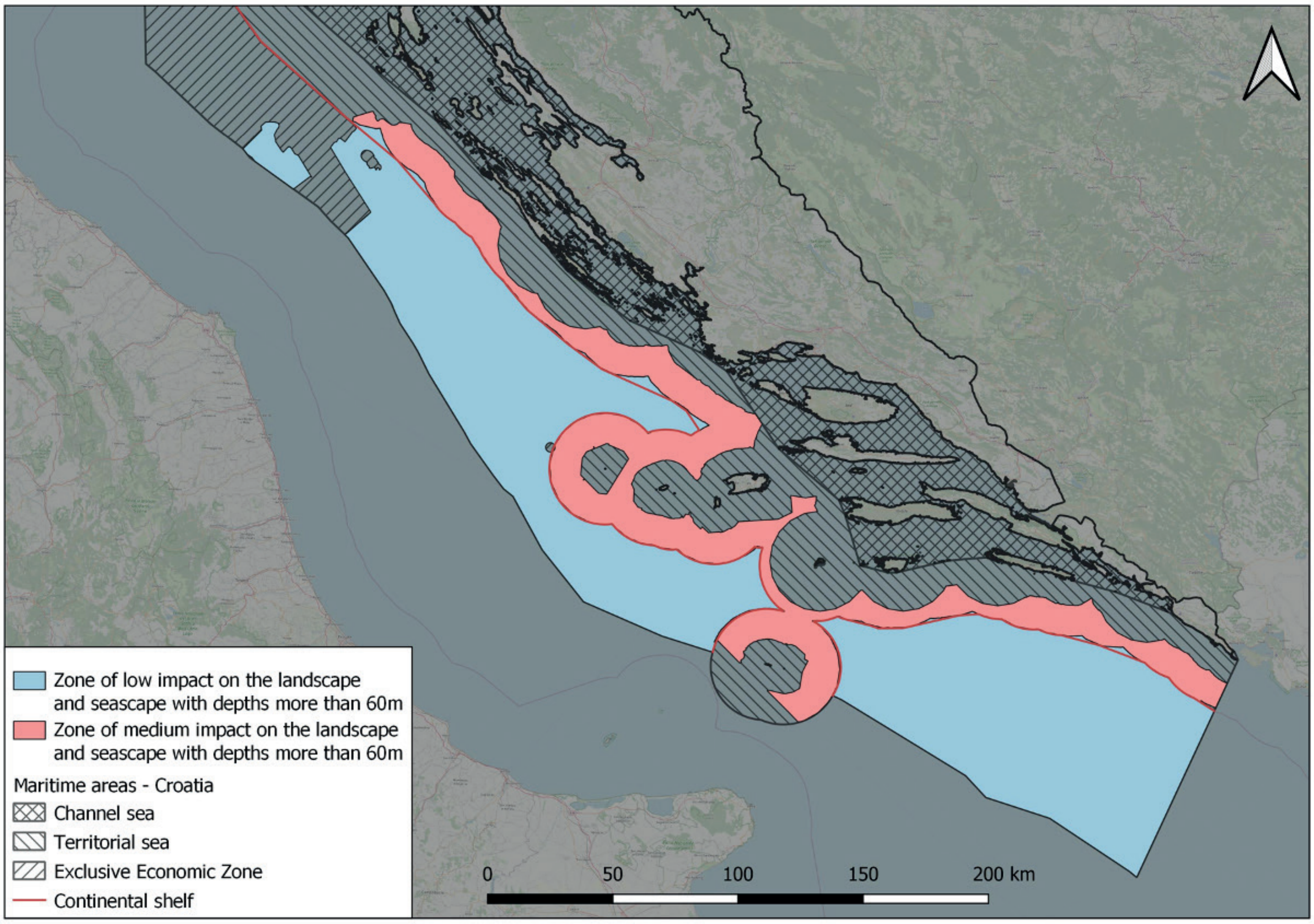


Table 6. Suitable areas for floating ORES in central and southern Adriatic

Type of impact	Teritorial sea [km²]	Exclusive Economic Zone [km²]	SUM [km²]
Low	286	18,775	19,061
Medium	7,251	22	7,273
SUM [km²]	**7,537**	**18,797**	**26,334**

depth constraint, which was disregarded. The result of the analysis are areas of low and medium impact on the landscape and seascape suitable for floating ORES in the Territorial Sea and the ecological and fisheries protection zone of Croatia and are shown in Figure 29.

It should be noted that the level of detail in the analysis of areas for floating ORES was lower than the analysis for bottom-fixed ORES. Due to this, there is a greater level of approximation and uncertainty in the total areas reported in Table 6 than those reported for bottom-fixed areas.

In all of the ORES development areas future multipurpose usage should be considered, both in energy production (e.g. hydrogen production) or food production (mariculture of all kinds suitable for offshore conditions).

4. 5. GRID-CONNECTION FOR ORES

Offshore energy infrastructure

In addition to the required offshore energy infrastructure for ORES, there is also a need for onshore infrastructure, as shown in Figure 30. As Croatia is facing a low grid availability for new RES, investments in the onshore network need to significantly increase.

Currently, offshore grid developments are mostly developed as radial connections of ORES. In addition to these single-purpose solutions, in the future there will be an increasing number of dual-purpose solutions that connect the ORES with multiple countries (offshore hybrids).

The European Network of Transmission System Operators for Electricity (ENTSO-E) identified and compared five different grid delivery models for future offshore systems. Figure 31 shows an overview of the five models.

Since there is still a lack of offshore wind measurement data, the first ORES projects will likely be smaller pilot projects. Therefore, it is recommended to adopt the Competitive Light model as in the UK.

Once there is a larger number of ORES projects in the pipeline, including a growing number of offshore hybrids, the Onshore TSO model should be explored to optimise the amount of new offshore grid infrastructure and reduce the number of onshore landing points.

Figure 30. Energy infrastructure for offshore wind in the UK (Ørsted, n.d.)

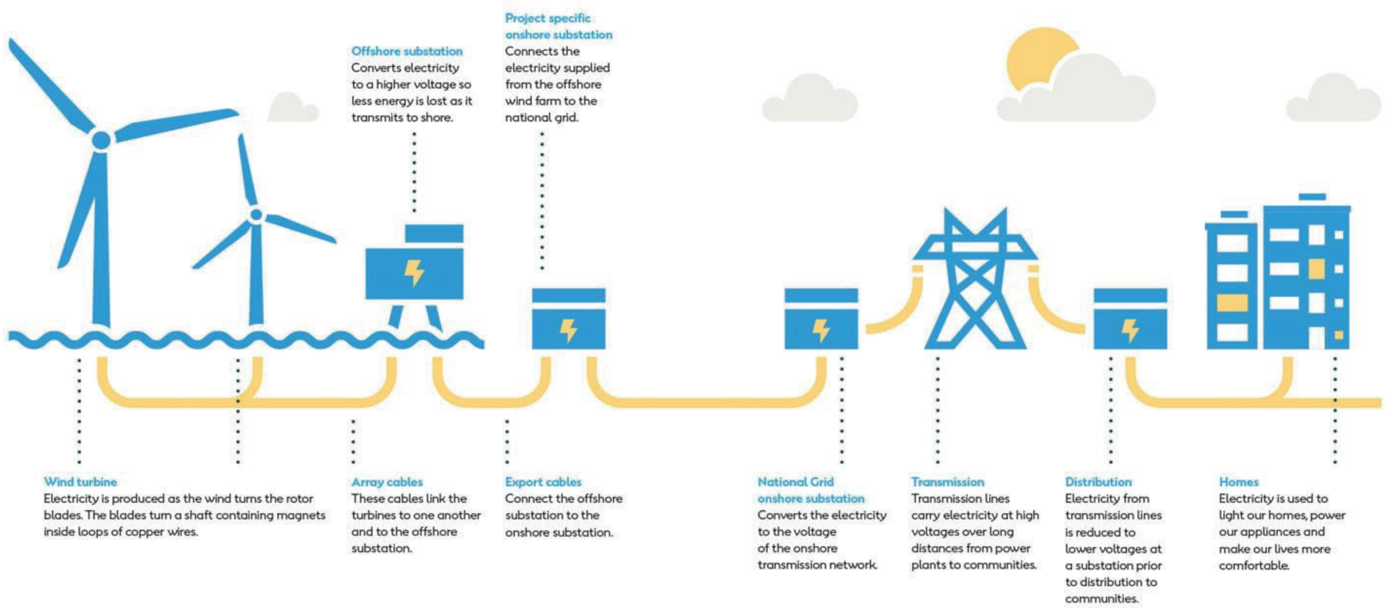


Figure 31. Grid delivery models for ORES (ENTSO-E, 2022)

Models	Network planning	Asset design & building	Ownership	Maintenance	Operation
Onshore TSO	Onshore TSO	Onshore TSO	Onshore TSO	Onshore TSO	Onshore TSO
Offshore TSO	Offshore TSO Onshore TSO	Offshore TSO	Offshore TSO	Offshore TSO	Offshore TSO
Competitive Light	Onshore TSO	Third party	Onshore TSO	Onshore TSO	Onshore TSO
Competitive	Onshore TSO	Third party	Third party	Third party	Onshore TSO
Competitive ISO	ISO Onshore TSO	Third party	Third party	Third party	ISO

HVDC vs HVAC

Utility-scale ORES can be connected to the power grid either through a HVAC or HVDC connection. The choice between the connection type depends on several factors, but the two most important ones are distance to shore and transmission capacity.

HVAC connections are mostly used for projects closer to shore, but their costs and losses rapidly increase with distance (Larsson, 2021).

HVDC connections not only need a lower number of power lines, but they also do not require power compensation as no reactive power is generated, which can be better controlled by system operators. HVDC connections are more cost efficient than HVAC connections when the distance to shore is larger than 50km (Csanyi, 2014).

Onshore landing points

As already analysed in the *Action Plan for Power Grid Strengthening to Support the Integration of Renewable Energy Sources in Croatia*, the major electricity consumption centres in Croatia are in the continental part of the country. However, most of new onshore RES capacity is under development in southern Croatia. This will directly impact the availability of onshore landing points for ORES, which will need to compete with onshore RES.

The Croatian TSO – HOPS provided an overview of possible locations for connection to the transmission network. In the coastal part of Croatia, only the north-western region – Istria, was identified as having additional grid connection capacity. Capacity in the hubs of Poreč, Raša, and Rovinj is still limited, up to 50 MW per hub (HOPS, 2022).

The currently available capacity is acceptable for pilot projects, but in order to integrate large-scale ORES, available onshore grid connection capacity will need to significantly increase.

5. PUBLIC ACCEPTANCE AND COMMUNITY INVOLVEMENT

5. 1. KEY STAKEHOLDERS AND PARTICIPANTS

Following the experience of mapping and connecting key stakeholders for the island energy transition in Croatia, it is recommended to use the Quadruple Helix Model, which serves as a framework for understanding and addressing complex societal challenges such as innovation, sustainability, and social inclusion through collaboration between different sectors and stakeholders. It is an extension of the Triple Helix Model, which focuses on government, industry, and academia interactions. The Quadruple Helix Model adds the fourth helix, which represents the role of civil society, including Non-Governmental Organizations (hereinafter: NGOs), community groups, and individuals.

In the EU community, successful examples are seen in cases such as Germany and the Netherlands, countries with strong collaboration between the government, society, industry, and academia. The German Federal Ministry for Economic Affairs and Energy has implemented various programs involving cooperation between government, industry, academia, and citizen groups in developing and deploying renewable energy technologies. The Smart Cities program is an excellent example of quadruple helix collaboration in the Netherlands. The program brings together government, industry, academia, and citizen groups to develop and implement innovative solutions for urban challenges such as energy efficiency, mobility, and waste management. The program also involves citizen participation and engagement to co-create sustainable solutions for their cities (European Commission, 2017).

The four helixes in the Quadruple Helix Model are:

Government

Representing the state's traditional role in shaping policy and regulation. It is crucial to include decision-maker representatives on three different levels: national, regional, and local, to understand and implement the complex processes, procedures, and regulations necessary for the development of ORES.

Industry

Represents the private sector and its role in economic development and innovation. Different public companies, technology providers, subcontractors, vessel operators, grid operators, consultants, and engineers should be included from the beginning to achieve common goals and reduce potential development risks, but also local companies who are going to be influenced by the development of a project.

Academia

Representing the knowledge sector and its role in producing and disseminating knowledge while ensuring change and the adaptation of the existing educational industry, which needs to back up the transition process with new professionals and expertise. In addition to research and consultancy, academic representatives should learn from the process and improve the educational system to answer future challenges in the ORES sector.

Civil society

Represents the role of citizens, NGOs, and community groups in shaping public policy and driving societal change. Their role is crucial as, besides the social impact, cooperation will result in public support and acceptance of projects, meaning faster development, lower risks, and more certain goals achievement.

The development of ORES projects in Croatia must take into account the principle of the Quadruple Helix Model and all stakeholders who are directly affected. The government and relevant public institutions are important stakeholders in this context as they play a crucial role in shaping the policy, regulation, and investment decisions related to energy, spatial planning, environmental protection, and maritime affairs. The Croatian stakeholder group should include relevant Ministries, such as the Ministry of Economy and Sustainable Development, the Ministry of Physical Planning, Construction and State Assets, and the Ministry of the Maritime Affairs, Transport and Infrastructure, as well as other key stakeholders such as the Institute for Environmental and Nature Protection, the Croatian Electricity Distribution System Operator, regional development agencies, local governments, investors, small entrepreneurs, local action and fishery groups, as well as civil society organizations representing environmental, community, and consumer interests. Engaging these stakeholders in a transparent and inclusive manner is crucial to ensure that ORES projects align with national priorities, address environmental and social impacts, and contribute to sustainable economic development.

Fisheries

The co-existence of ORES with fishery groups will be needed in many offshore areas. There is the potential for synergy between such sectors, which needs to start through constructive dialogues.

Fishing can play a crucial role in employment in some coastal communities, which will be impacted by the construction and operation of an ORES. Although floating PV will provide little space for fishing activities, there is a potential for fishing activities in offshore wind areas.

During the construction activities of an ORES, fishing activities are usually restricted, therefore, developers should consult fishermen in the site identification phase. Developers may offer compensation schemes if local fishing activities were disrupted or offer temporal work opportunities.

Once in operation, bottom trawling and other fishing activities that disturb the seabed should be avoided due to the potential damage to submarine cables by fishing gear or anchors. In order to reduce the risk of accidents, it is important to transparently share data on submarine cable locations and exclusion zones.

However, the lack of seabed-disturbing activities often results in a growing number of fish stocks that are available for less invasive fishing activities. Such limited fishing activities can take place within and nearby ORES.

Lastly, ORES may also offer alternative or part-time employment to fishermen to help with safety patrols, or other services, depending on the size and condition of their vessels (WindEurope, 2020).

5. 2. PUBLIC ACCEPTANCE OF OFFSHORE RENEWABLES

Although ORES have the potential to significantly decarbonise Europe's economy, public acceptance is a crucial factor in the development and deployment of these technologies.

When the public supports a project, they are more likely to advocate for it and pressure other stakeholders to support it. This can help overcome bureaucratic obstacles and ensure that a project is completed in a timely and cost-effective manner. Unfortunately, Croatia doesn't have this kind of public acceptance for infrastructure projects so often. When RES projects are developed, communities and NGOs are often not included in the planning, development, or investment process.

One of the great positive examples is the Grimsby project in the UK – once the largest fishing port in the world, Grimsby experienced the effects of post-industrial decline as its main economy slowed. Working with industry, the coastal town has developed a new vision focused on offshore wind and the renewable energy sector (Orsted, n.d.).

When public acceptance is low, on the other hand, it can lead to significant delays and increased costs for a project. Furthermore, a low acceptance level can lead to less private investment in a project because investors may be hesitant to invest in a project that faces significant public opposition, as there's a higher risk of failure and the return on investment could be compromised.

The transition to renewable energy needs to be inclusive and bring all stakeholders along. This is particularly valid for ORES as it is a new industry, and the public may need to become more familiar with the technology. Efforts to promote public acceptance of ORES should be an integral part of the development process, including public engagement, transparency, and education, to ensure that these technologies can contribute to meeting global energy demand.

Addressing public acceptance concerns

Many people support renewable energy, but they may have concerns about the visual impact of offshore turbines, the potential impact on wildlife and marine habitats, and the potential for noise pollution.

To address these concerns, involving the public in offshore renewable energy projects' planning and development processes is crucial. This can include holding public meetings and consultations and providing information about the benefits of ORES, such as their potential to reduce carbon emissions, create jobs, and different models of how to participate in the investments. Preparing environmental and social impact studies and providing concrete and transparent data is also important. Social impact assessment can also help identify potential adverse impacts and help mitigate them.

It will be extremely important for the first ORES projects to engage early with the local community. Onshore wind and solar PV projects have been developing all over the country in the last decade and their experience could be used as an example. However, in the pioneering ORES projects there will be an additional need engage local stakeholder as they are less familiar with the technology and will have additional concerns about minimizing any negative impacts.

Developers should plan for more time and tools for the communication campaign, which will include all interested parties and create positive public activities. Furthermore, developers should prepare a concrete strategy to include communities and gain support by raising awareness, educating, and involving citizens in the whole process.

A group of European organizations concerned about climate and policy have formed a group called POLIMP to answer the challenges. It has aimed to identify the knowledge gaps to improve existing policies and formulate new policies in the future for every stakeholder involved in renewable energy technologies. In their 1st Policy Brief, POLIMP presented five essential elements of public acceptance of renewable energy resources:

1) Awareness;
2) Sense of Fairness;
3) Trust toward Stakeholders;
4) Evaluation of Costs, Risks, and Benefits; and
5) Local Context.

Awareness

Public awareness consists of three sub-factors: knowledge of the need for renewable energy, knowledge of the practical aspects of renewable energy technology, and familiarity with renewable energy technology (Hofman & van der Gaast, 2014).

There is evidence of a positive relationship between people's awareness of the need for renewable energy, their acceptance of sustainable or renewable energy resources, and their willingness to act/support (Strazzera, Mura, & Contu, 2012).

With the ongoing energy crisis, people's awareness of the need to switch to renewable energy sources is increasing even more.

An excellent example of successful public awareness is the energy cooperative Apsyrtides from the islands Cres and Mali Lošinj. The project was started in 2019 by local stakeholders. Active education, consultation, and involvement of leading stakeholders from the island and beyond resulted in the energy cooperative's funding in 2021 with 30 founders from all four pillars – local authorities and public companies, entrepreneurs and hotel companies, schools, as well as citizens and citizen organizations. The next big step happened in 2022 when the cooperative bought land to develop a community solar park (Island Movement, 2021).

Sense of Fairness

The second element of public acceptance is sense of fairness, which comprises three-sub-factors; public involvement, public interests, and transparency. Public interests are most often related to the economy, legislation, and location of a renewable energy resource and transparent management of the projects – in other words, investors need to approach the community.

There are several onshore wind and solar projects in Croatia that were not positively accepted because of the non-transparent and non-inclusive development. Although most of the projects were developed, some of the projects were completely abandoned.

The development of ORES projects should aim to satisfy all stakeholders, taking into consideration the principle of sustainability Financing – Environment – Society. After all, the *European Climate Law* aims to reach climate neutrality by 2050, though in a socially balanced, fair and cost-efficient manner.

Trust towards Stakeholders

In the development of onshore RES, negotiations are happening between local and regional authorities and developers. Citizens are legally included through the public changes of the spatial plans, but they are generally not active, or the information about public discussions is not transparently disseminated. Once the construction of the project starts, and the community finds out about through the media, the trust of the community is lost.

An excellent example of trustful and joint development is the Križevci project – the first project of citizens' investment in a city project, unique in Croatia, launched by the City of

Križevci and the Green Energy Cooperative in 2018 with an investment in the construction of a rooftop solar PV on a public building called Križevci sunroofs. Starting with building trust, awareness, and a sense of fairness since the first project, today, Križevci has an energy cooperative and an information office in the city centre, and the number of citizens' solar roofs has increased threefold. They continuously develop public RES projects, including the citizens in different business models, and are a leader and an example to other municipalities and developers (Greenpeace Croatia, 2018).

Evaluation of Costs, Risks, and Benefits

The costs, risks, and benefits of ORES should be related to:

- socio-economic aspects, such as the fact that ORES will create more job opportunities but also their potential impact on fisheries and tourism;
- environmental aspects such as visual impact, noise, biodiversity impacts, etc.

There are different examples of how ORES projects in Europe included citizens and minimized the social and environmental impact, which can be easily replicated in Croatia. Some examples are:

- through in-depth environmental research related taking care of specific birds and animals;
- co-funding or co-investing projects with community members;
- including the local economy in the value chain;
- opening new all-year jobs;
- educating people and developing new skills;
- investing in renovation or building new public buildings such as kindergartens, schools, educational centres.

Local context

Using locally available potentials for renewable energy, such as wind and sun in Croatia, can increase public acceptance. However, public acceptance can be deceptive, as locals may have opposing views towards a renewable energy project for personal reasons, such as being disturbed by the sound or appearance of wind turbines. This phenomenon is often referred to with the ancronym NIMBY – "not in my back yard", where locals oppose a project in their area as they are more visible and audible than non-renewable resources.

Perceiving the local context is important in project development because it allows for a better understanding of the community, culture, and environment in which the project will be implemented. This understanding can lead to more effective and sustainable solutions, as well as improved relationships with local stakeholders. Additionally, taking into account the local context can help to identify potential challenges and opportunities that may not have been considered otherwise, which can improve the overall success of the project.

5. 3. COMMUNITY INVOLVEMENT IN OFFSHORE RENEWABLES

Social acceptance plays a crucial role in a the successful development of renewable energy projects. If not addressed, it can become a significant barrier to achieving renewable energy goals.

There are two levels of social acceptance: general social acceptance and local social acceptance. General social acceptance refers to the broadest level of social approval, while local social acceptance pertains to the acceptance of renewable energy projects within a particular community.

One of the key factors in gaining local social acceptance is distributional justice. The financial participation model could increase the acceptability of wind parks by ensuring fairness in the distribution of costs and benefits among local residents. This could help increase public support and ultimately lead to a more successful and sustainable renewable energy future (Segreto, 2020).

Community involvement models

Voluntary share purchasing is an investment model based on voluntary share purchasing, also known as community ownership, and is a way for communities to invest in renewable energy projects and become stakeholders in the project. Under this model, the residents of a community can purchase shares in a renewable energy project. This allows them to become co-owners of the project and share in its benefits, such as reduced energy costs, increased property values, and a stable source of income from the sale of excess energy. Additionally, they can also have a say in the decision-making process, including the planning and development of the project.

This model has been successfully implemented in several countries in Europe, including Germany, Denmark, and the Netherlands. In Germany, for example, the citizens' energy movement has grown significantly, with over 800 energy cooperatives providing citizens with the opportunity to invest in renewable energy projects and to share in the benefits. The result is that 200,000 members invested a total of €3.2bn in renewable energies and generated around 8.8 TWh of clean electricity in 2020 (German Cooperative and Raiffeisen Confederation, n.d.).

The Crowd investing model is very similar to the voluntary share purchasing model but it does not need to be focused only on the narrow community where the project is developed. Crowd investing refers to a situation where a large number of individuals pool their money together to invest in a company or project, typically through an online platform. The return on investment from crowd investing can vary widely, depending on the specific company or project.

Bond purchasing is an investment model where investors can purchase bonds issued by renewable energy projects. The bonds pay a fixed or variable interest rate to the investors, and the principal amount is returned at the end of the bond's term.

This model has been successfully implemented in several countries in Europe, including Germany, Denmark, and the United Kingdom. In Germany, green bonds have become increasingly popular, with a significant portion of these bonds being issued to finance renewable energy projects, including offshore wind farms.

The Crowdlending model is quite similar to the bond purchasing model. Crowdlending, also known as peer-to-peer (P2P) lending or debt crowdfunding, involves lending money to a borrower, typically an individual or small business, in exchange for a fixed rate of return which is agreed upon at the time of investment. Crowdlending platforms connect borrowers with investors, who can lend small amounts of money to multiple borrowers, diversifying their investment and reducing their risk.

Energy transition fund (investment tax for local communities' projects) collects revenue from an ORES tax imposed on offshore energy developers and use that revenue to support local communities and individuals who may be affected by ORES development. The offshore resource tax is calculated based on the amount of energy that a developer generates from offshore sources. This compensation can take the form of direct payments, funding for community projects, or investments in renewable energy infrastructure, and public buildings.

Whether it is through the voluntary share purchasing model, the bond purchasing model, crowd lending or crowd investing – these models provide a way for individuals to take an active role in the transition to a more sustainable energy system. However, it is important to note that these investment models may not be suitable for everyone, and that they are subject to certain risks and limitations.

Examples of good practices in Europe

The *Borkum Riffgrund 2* wind farm in Germany was developed by the Danish renewable energy company, Ørsted. The company took a collaborative approach by engaging with local residents and stakeholders to gather their feedback and input on the project. This approach was important in shaping the final design and implementation of the project. Moreover, Ørsted also provided an opportunity for local residents to invest in the project, thereby allowing them to financially benefit from its success. This approach not only helped to gain the support of the local community but also helped to create a sense of ownership and investment in the project.

The *Westermost Rough* wind farm in the UK was developed by Dong Energy (now Ørsted). The company took a proactive approach to engaging with local residents and stakeholders throughout the development process, seeking their feedback and input to help minimize the project's impact on the local environment. To further support the local community, the company established a community fund, which provides funding for local projects and initiatives. By working closely with thelocal residents, the *Westermost Rough* wind farm project was able to achieve a positive outcome for both the environment and the local community (Ørsted, 2019).

The *Lillgrund* wind farm in Sweden is a 90 MW onshore wind farm located in the Oresund Strait, near Malmo in southern Sweden. It was developed by Vattenfall, a Swedish energy company, and was commissioned in 1997. The wind farm has created numerous jobs and provides economic benefits to the local area, including revenue for local businesses and taxes for the local government. Vattenfall has also been engaged in community outreach initiatives in the area surrounding the Lillgrund wind farm, including sponsoring local events and organizations, and providing educational resources on renewable energy to schools and community groups (Swedish Agency for Marine and Water Management, 2013).

6. ACTION PLAN

Develop the National Maritime Spatial Plan

Developing an MSP is an extensive and long process. It is the first step in establishing renewable go-to areas for ORES. When determining ORES zones, the relevant authorities should include all criteria that were analysed in this publication.

The identified low- and medium-impact zones provide a starting point for ORES development. The MSP should address the cumulative impacts of ORES, ensure stakeholder engagement, and allow multi-use within ORES zones (e.g. co-location with hydrogen production, utilising existing oil and gas infrastructure, food production from mariculture activities, etc.).

There is a lot of available areas for ORES, but it is up to developers to decide which are the most cost-efficient sites. The first low- and medium-impact ORES zones in the northern offshore areas, should be planned for bottom-fixed offshore wind and floating PV. In the central and southern offshore areas, the preferred technologies in the low- and medium-impact zones are floating offshore wind and floating PV.

This high-level analysis has assumed that in medium-impact zones the preferred technology would be floating PV due to its lower visual impact. However, this should not immediately exclude bottom-fixed and floating offshore wind from being developed in medium-impact zones, which could be developed in the medium-term provided a high level of local acceptance is achieved.

Until the National MSP is developed, ORES projects can have a maximum of a 20-year lifetime, which could be useful for pilot projects and additional measurements of resources and environmental surveys.

Introduce offshore renewables into strategic documents

Securing the space for ORES is just the first step. Croatia should aim to translate all these areas into clear targets in the NECP revision which is planned for 2023. Once Croatia develops targets for ORES, it should design an auction-based support scheme and a clear timeline of auctions, where developers can compete for 2-sided CfD contracts. Croatia should also utilise the inclusion of non-price criteria into the auction scheme.

Identify a public institution that will act as a contact point

As prescribed by the revised Renewable Energy Directive, Member States need to identify contact points in order to accelerate permitting and facilitate transparency of ORES development for other stakeholders. Developers should be guided through the permitting process by a single contact point.

The Law on the establishment of the Hydrocarbons Agency already includes such provisions that allow the Croatian Hydrocarbon Agency to support the development of ORES. The Croatian Hydrocarbon Agency has significant experience managing concession tenders for the oil and gas, and geothermal sectors, which could be translated to the ORES sector. Therefore, the Croatian Government should explore designating the Croatian Hydrocarbon Agency as a contact point for ORES provided that the role of the Croatian Hydrocarbon is ensured through changes of relevant laws and bylaw.

Continuous measurements and monitoring

During the spatial analysis of areas suitable for the construction of bottom-fixed offshore wind farms, several data sets were unknown and the bathymetric data did not offer accurate spatial resolution and accuracy. In order to attract ORES development, the Croatian Government should, as soon as possible, identify agencies that could start conducting additional measurements, in particular of wind speed and frequency at higher altitudes, hydrographic surveys, and environmental surveys.

The Adriatic Flyway is an area where a multi-continental environmental survey could allow for a more inclusive development of ORES. As this would be a large and long-lasting project, the Croatian Government should identify agencies that can initiate it and apply for EU funding in partnership with other stakeholders in Europe and North Africa. However, the development of ORES must not wait for the conclusion of such a multi-continental environmental survey, which is especially important for the first ORES projects in Croatia.

Additionally, the ongoing project of mapping benthic marine habitats in Croatia should be taken into consideration as it will provide extensive data about the possible ecosystem impacts of ORES projects.

Croatia should continuously collect marine data to guide responsive and adaptive decision-making, however, it will be on ORES developers to conduct project-based surveys.

Foster community involvement to increase public acceptance

Community involvement is the backbone for inclusive ORES development. The Croatian Government should identify agencies that would establish an expert working group based on the quadruple helix approach and with an inclusive and transparent process ensure the delivery of a detailed communication strategy, identify key stakeholders, and develop business models for involving local communities. The agencies should ensure public acceptance and involvement of all stakeholders through awareness raising campaigns and education activities, developing sense of fairness to all impacted by the ORES projects, building trust among all stakeholders, and delivering evaluation of the costs, risks and benefits according to the specific local context.

Start planning for offshore infrastructure development

The uptake of ORES depends on the development of both offshore and onshore networks. The ten-year network development plans of system operators need to plan for integrating large-scale ORES, which will require investments also in the onshore network.

Transmission system operators need to start the coordinated development of their ten-year network development plans with neighbouring system operators. In addition to the growing number of onshore wind and solar PV projects that are under development, the Croatian TSO – HOPS will need to take into account the growing number of ORES projects in neighbouring countries. This is especially the case for ORES projects in Italy and their impact on the Croatian power network.

Depending on the proximity of the ORES projects to shore, developers might prefer to develop their projects with HVAC or HVDC connections. As the first projects will likely be smaller pilot projects that are closer to shore, it is recommended to adopt the Competitive Light grid delivery model as in the UK. Once there is a larger number of ORES projects in the pipeline, including a growing number of offshore hybrids, the Onshore TSO model should be explored to optimise the amount of new offshore grid infrastructure and result in a lower number of onshore landing points.

Another crucial part of the offshore infrastructure for ORES, especially for large-scale offshore wind, is shipyards. Shipyards are most suitable to be a hub for production, assembly, maintenance, and general logistic. Croatia has several big shipyards in different parts of the Adriatic Sea but most of them are in existential problems. The Croatian Government should explore supporting them until the ORES industry becomes a sustainable source of their income.

Explore cross-border and joint development of ORES projects

Although more complex, Croatia should explore the possibility of a cross-border offshore hybrid, which could also be jointly developed with a neighbouring country. The Croatian Hydrocarbon Agency should be explored as the single contact point also for cross-border and joint projects, which could benefit from substantial EU funding – in particular the CEF programme. In addition to ORES development, the TEN-E regulation also creates the opportunity for the funding of hydrogen storage and electrolysers that have a cross-border impact.

Such a cross-border offshore hybrid should be explored with Italy. In such cases, the Offshore Bidding Zone is the most promising concept for future offshore hybrid projects and meshed HVDC projects.

Address the skills requirements for ORES

Croatia has experts with the skills to develop ORES as the country has a strong engineering and technical workforce and it has been investing in renewable energy in recent years. However, it's worth noting that the ORES sector is relatively new and requires specific skills and expertise. It may take time to develop the necessary skills and expertise, but it is possible. Special focus should be on O&M as these are expected to last for more than 30 years and be a generator of local employment.

Therefore, the Croatian Government should develop an *Offshore Renewable Energy Sector Deal* and explore the inclusion of non-price criteria in auctions which would award developers' commitment to invest in training and education programmes as well as the local supply chain.

Support research and innovation of ORES

As there are no significant funds allocated for research and innovation in the Croatian budget, Croatia should look for private-sector investments to invest in research and innovation centres. Such an R&I centre should utilise the Croatian academic community and provide a place where technological inventions can be tested.

Develop rules for the multi-use and co-existence of ORES with other sectors

During the construction period of ORES, the activities of other sectors (e.g. fishing) are usually restricted. Therefore, developers should engage fishermen early on in the site-selection phase and explore hiring or working together with them throughout the lifetime of the project.

After the ORES is operational, it can operate in co-existence with fishing, biodiversity protection, military and civil aviation, etc. The Croatian Government should identify the agencies that would be responsible for publishing ORES data (e.g. location of submarine cables) that can be used by other sectors to perform their activities in a safe way.

In order to have uniform rules for all ORES sites, the Croatian Government should define general rules of access to ORES sites. This would include prohibiting bottom trawling fishing and other activities that disturb the seabed in the ORES site or in its proximity. The general rules of access should precisely define which activities are allowed within the ORES site and in its proximity.

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