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White Paper 2021
Offshore wind power and ‘green’ hydrogen: discovering new limits of Ukraine’s generating capacity

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FIRST INSPIRATION OF OFFSHORE WIND POWER

A Dutch proverb says '*Who harvests the wind, harvests the future.*' Indeed, the horizons of wind power are so endless that it is of paramount importance today and will be an advanced technology in the future. Wind power is one of those technologies that give confidence in the future, both from an environmental and economic perspective.

With every passing year, wind energy becomes increasingly used to meet the growing demand for reliable and environmentally friendly energy sources. In the world that is actively implementing the 'green' energy transition, wind energy is considered the safest and most environmentally friendly renewable energy source (RES). In addition, it has proved to be the most resilient in the post-COVID-19 reality and new living environment *(MEA, 2020)*.

From the first days of the wind power sector, **offshore (marine-based) wind power is considered as the next logical step** of the sector's development, which has huge technical, economic and social potential.

Compared to other types of RES, offshore power is considered a new technology. Denmark was the pioneer in the development of offshore wind projects. In 1991, the country built in the Baltic Sea the world's first Vindbey offshore wind power plant (WPP) (known as Ravnosborg) with a total generating capacity of 5 MW. The power plant consists of 11 wind turbines of 0.4 MW each. The first turbines that started generating electricity from offshore wind were supplied by Bonus Energi, which is now part of Siemens Gamesa. In 2017, the Danish Dong Energy started dismantling the first offshore WPP after 26 years of its operation.

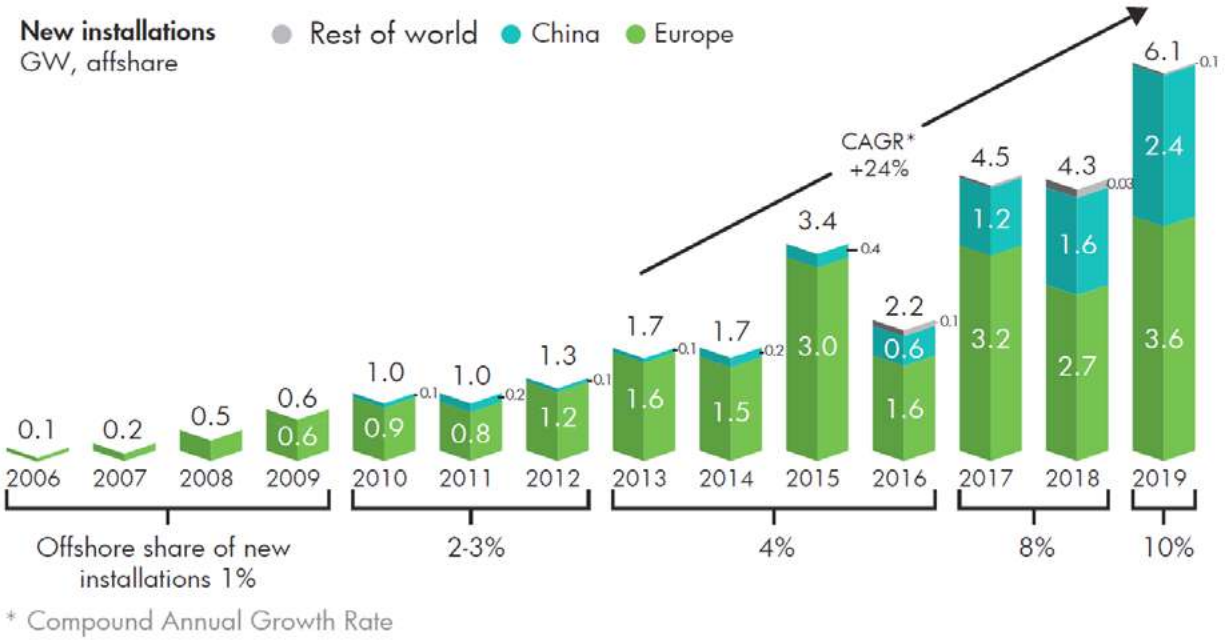
> *'The Vindeby Offshore Wind Farm is almost miniature-sized in comparison with the giant projects which are now being implemented. But without the experience gained from it, we wouldn't be where we are today. It's fair to say that Vindeby is the cradle of the offshore wind industry, and that this is where the industry was born,'* says Leif Winther, who is responsible for offshore power projects at Dong Energy.

Twenty years after the launch of the world's first offshore wind farm, nine European countries installed 2,946 MW wind generating capacities at 45 offshore wind farms by the end of 2010, which together supplied 10.6 TWh of 'green' electricity to the European grid. Generally, since the beginning of the decade, each new year has seen the presentation of new offshore wind capacities, while pioneering the development of offshore wind projects has allowed European producers and developers to expand beyond the European seas. In April 2010, the Cape Wind offshore wind farm in Massachusetts, USA, obtained the first-ever construction permit from the US federal regulatory authority—the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE). The United States was followed by China, which commissioned its first commercial 102 MW offshore wind farm Donghai Daqiao in June 2010 and developed the world's third-largest offshore wind market with a total capacity of 7,058 MW in 11 years (as of late 2020).

The large-scale development of the global offshore wind power sector began in 2014. Before that time, about 6,400 MW of offshore wind capacities were operated in the world. All projects were built near the shore, mostly by European countries, and their installed capacity did not exceed 100 MW. This trend was explained by the high cost of offshore wind equipment and the lack of geospatial research, assessment of sea wind potential and relevant government policies.

The offshore power market started gaining momentum in parallel with the transformation of the energy paradigm and business strategies of leading energy companies, the large-scale transition of countries to renewable energy sources, and the massive reduction in the cost of 'green' technologies. According to the Global Wind Energy Council (GWEC), the offshore wind power market has grown by an average of 24% each year since 2013, reaching a total capacity of offshore installations of 29,100 MW or 5% of global offshore wind capacity as of the end of 2019.

Chart 1. Offshore wind capacities installed in 2006 to 2019, GW

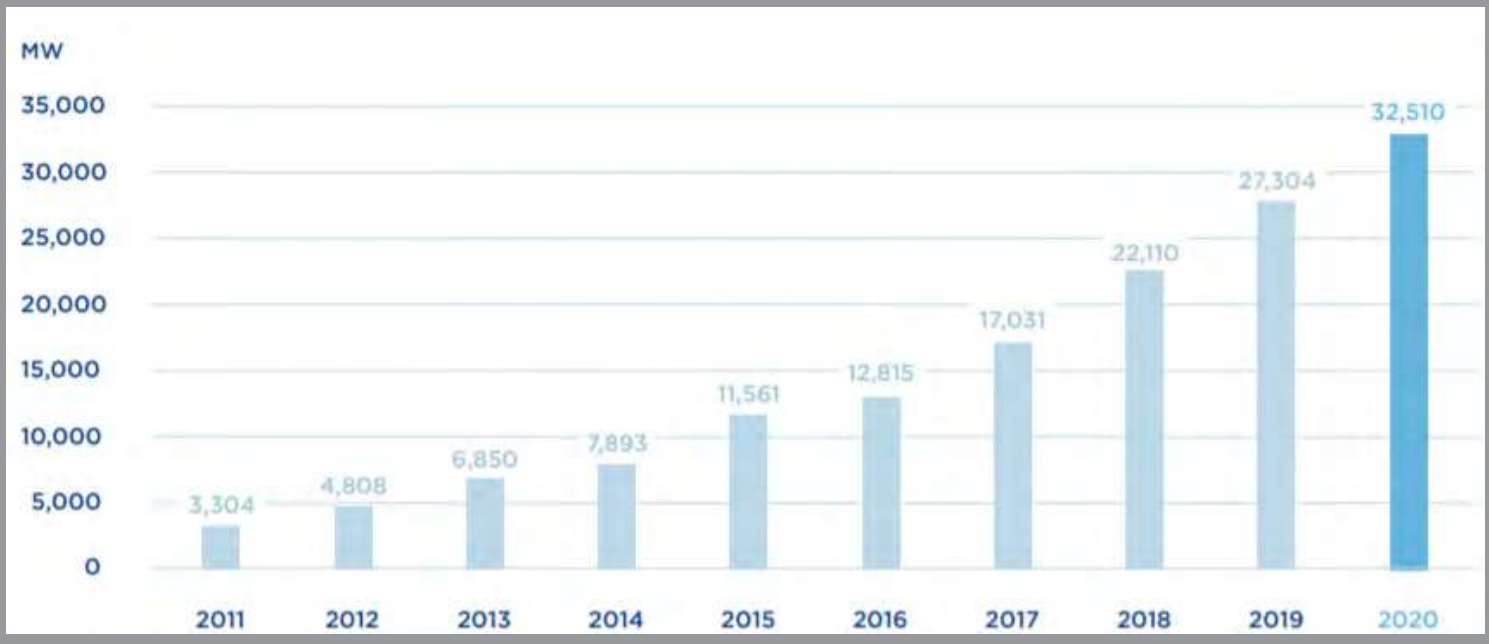


Source: GWEC, 2020

OFFSHORE WIND POWER TECHNOLOGY SINCE 30 YEARS?

Thirty years after the commissioning of the first offshore wind farm in Denmark, the global installed wind capacity reached **32,500 MW** in late 2020. Today, **162 offshore wind farms**, powered by ocean and sea energy, generate 'green' electricity in Europe, Asia, and the United States.

Chart 2. Increase in the global offshore wind capacities from 2011 to 2020, MW



Source: WFO, 2020

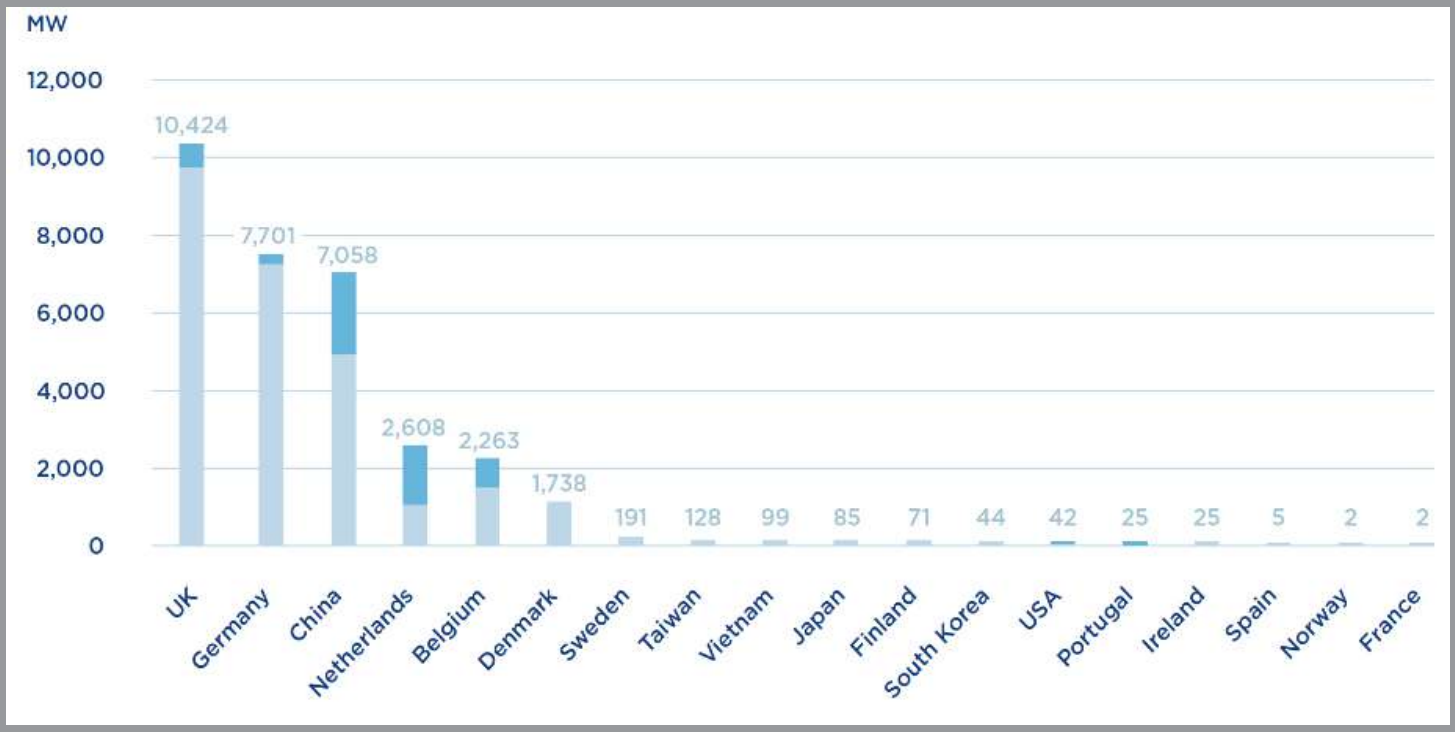
Despite the COVID-19 pandemic, 2020 proved to be the best year ever for the offshore wind power sector reaching 5,200 MW of new capacities commissioned in one year. Fifteen new offshore WPPs were launched in the wind power markets of the USA, Portugal, Denmark, the United Kingdom, the Netherlands, Belgium, and China.

That same year (2020), China sets its own record by installing 2,100 MW of offshore wind capacities, 700 MW of which was commissioned in the second half of 2020 alone. Today, China's offshore wind capacity has reached a total of 7,058 MW, being close on the heels of Germany with its 7,701 MW.

The Dutch offshore power market was also significantly successful last year. In one year, the Netherlands has overtaken Belgium and Denmark with 1,500 MW of new offshore wind installations commissioned and has reached a total generating capacity of 2,600 MW.

Thus, 30 years after the implementation of the first offshore wind power project, the top five leaders in the development of the offshore wind power sector are the United Kingdom (10,424 MW), Germany (7,701 MW), China (7,058 MW), the Netherlands (2,608 MW), and Belgium (2,263 MW).

Chart 3. Total offshore wind capacity installed in certain counties in 2020, MW



Source: WFO, 2020

Europe remains a key offshore wind power market, which is accounted for 75% of the global energy mix of offshore wind projects. It is expected that this share will continue to grow as Europe plans to achieve a total of 60 GW and 300 GW of offshore wind power capacity by 2030 and 2050, respectively, according to the EU strategy on offshore renewable energy. This is supported by, among other things, the United Kingdom's Ten Points Plan for Green Industrial Revolution, which aims to reach 40,000 MW of offshore wind capacities by 2030; or the Offshore Wind Act passed by the Polish Government in November 2020, under which Poland has committed to install 8,000 MW of offshore wind capacities by 2030; or consultations launched in Greece on 1 February 2021 to develop legislation necessary for establishment of the offshore wind power sector in the country.

Moreover, the offshore wind power sector is developing at such a rapid pace that the countries across the world are not only increasing their ambitions for new offshore wind projects, but also developing hybrid offshore systems *(for example, in 2020 Danish TSO Energinet and German TSO 50Hertz built the first interconnector in the North Sea connecting, for the first time ever, an offshore wind farm to the grids of two countries simultaneously.)* and implementing *(for example, Germany and the Netherlands)* zero-subsidy projects, under which electricity generated by an offshore WPP is sold in a wholesale market with no reliance on any support schemes.

Today, a total of **10,000 MW** of new offshore wind energy capacities are being built globally, 44% of which is being implemented in China. The average unit size of future projects reaches 381 MW.

Table 1. Offshore WPPs, which construction is in progress as of early 2021.
Source: WFO, 2020

Offshore WPP	MW	Turbine	Country
Borssele 5	19	MHI-Vestas V164-9.5	Netherlands
Windpark Fryslan	383	Siemens Gamesa SWT 4.0-130	Netherlands
Kriegers Flak	605	Siemens Gamesa SG 8.0-167 DD	Denmark
Southwest Offshore Demonstration Phase I	60	7 WinDS 3000/100, 13 WinDS 3000/134	South Korea
Fujian Fuqing Haitan Strait	154	Mingyang MYSE 7.0-158	China
Fujian Putian City Flat Bay (Zone F)	200	Siemens Gamesa SWT 7.0-154	China
Daishan 4	234	18 SG 4.0-130, 36 EN148-4.5	China
Fuqing Xinghuawan Offshore Wind Phase II	280	Goldwind ГВт 175-8.0	China
Datang Jiangsu Binhai	300	MingYang SCD 3 МВт	China
Tangshan Area 6	300	Siemens Gamesa SG 4.0-130	China
Phase II	200		
Sheyang H1	300	Envision EN148-4.5	China
CTGNE Yangjiang Shapa Phase I	300	Mingyang MYSE5.5-155	China
Yangjiang Nanpengdao	300		
Jieyang Shenquan	400		
Three Gorges Renewables YangXi II	400		
Shanwei Houhu Offshore Wind Phase I	500		
Pingtan Changjiangao	204		
Zhuhai Jinwan	300		
Changhua Phase I	109	Hitachi 5.2 МВт	Taiwan
Yunlin	640	Siemens Gamesa SG 8.0-167 DD	Taiwan
Kincardine (floating WPP) Phase II	48	MHI-Vestas V164-9.5	United Kingdom
Triton Knoll	857		
Moray East	950		
Hornesea 2	1 400	Siemens Gamesa SG 8.0-167 DD	United Kingdom
Neart na Gaoithe	450		
Total: 9 893			

KEY CHALLENGES TO OFFSHORE WIND ENERGY TECHNOLOGY

The analysis of the history of establishment of the offshore wind power markets in the world's leading countries makes it clear that the story of success of each individual country is unique. However, their development trends can be traced to common challenges that arose at the beginning of harvesting marine wind and can be faced by any country that plans to develop offshore wind projects.

1. DESIGN, AFFORDABILITY, INSTALLATION AND MAINTENANCE OF OFFSHORE WIND TURBINES

Generally, offshore wind turbines are produced using the same technology and by the same manufacturers as onshore wind turbines. However, there are some difficulties that countries face in launching their offshore wind power markets:

a) the cost of offshore wind turbines is much higher than that of onshore ones due to a higher unit capacity, and, accordingly, a higher output; the use of additional components in the production of turbines, such as reinforced foundation, anti-corrosion coating, etc. As of 2018, the average cost of building a 1,000 MW offshore wind project, including connection costs, was about USD 4 billion. However, experts from the International Energy Agency expect it to fall by more than 40% in the next decade;

b) a longer production time of installations due to an increased demand for onshore wind turbines;

c) lack of local competent staff. Although the manufacturers of wind power equipment have gained sufficient experience in offshore wind turbines over 30 years, the countries face the problem of lack of companies' experience in the development of such projects, lack of staff willing to work offshore, and proper transportation of turbines to the site, when launching this market; and

d) lack of companies that build special foundations for offshore WPPs and provide appropriate equipment such as marine cables.

2. CONNECTION TO THE GRID

The major part of the costs of installing and operating an offshore WPP is accounted for electrical connection between the turbines at the power plant and the power plant and the onshore grid. While the electrical cables connecting wind turbines do not necessarily have to be laid on the seabed, the laying of the cable connecting the offshore WPP to the onshore grid is another story. Such cables must be buried in the seabed to prevent obstruction to fishing and navigable waterways and can be more than 50 km long. Laying and maintaining such cables requires competent staff, which adds difficulties for newcomers in the offshore wind power sector. After the connection of the offshore WPP to the onshore grid, a new problem arises with the consistency between the quantities of electricity generated at sea and the level of onshore demand. As we have already mentioned, offshore wind generation is always an order of magnitude higher than that of onshore WPPs due to stronger wind resources (a 10% increase in average wind speed implies a 30% increase in electricity generation). Therefore, at times when an offshore WPP generates more electricity than needed by population, the transmission system operator must take measures to limit its generation, including the forced shutdown of the power plant.

3. ENVIRONMENTAL IMPACTS OF WPPS

Although offshore wind turbines are completely safe for the general and marine environment as such, their installation can pose some threats to reservoirs. For example, fixing the foundation and laying marine cables can disrupt the sedimentary component of the reservoir and create significant noise and vibration, which can adversely affect marine life. As far as human activities are concerned, the developer of a wind farm should ensure that appropriate changes are made to navigation devices and radar stations in air and water transport to prevent collisions and accidents.

On the other hand, the global story of success of offshore wind projects shows that only right, sound and predictable legislation and the existence of a specific national strategy for the deployment of offshore power can provide effective solutions to the above problems.

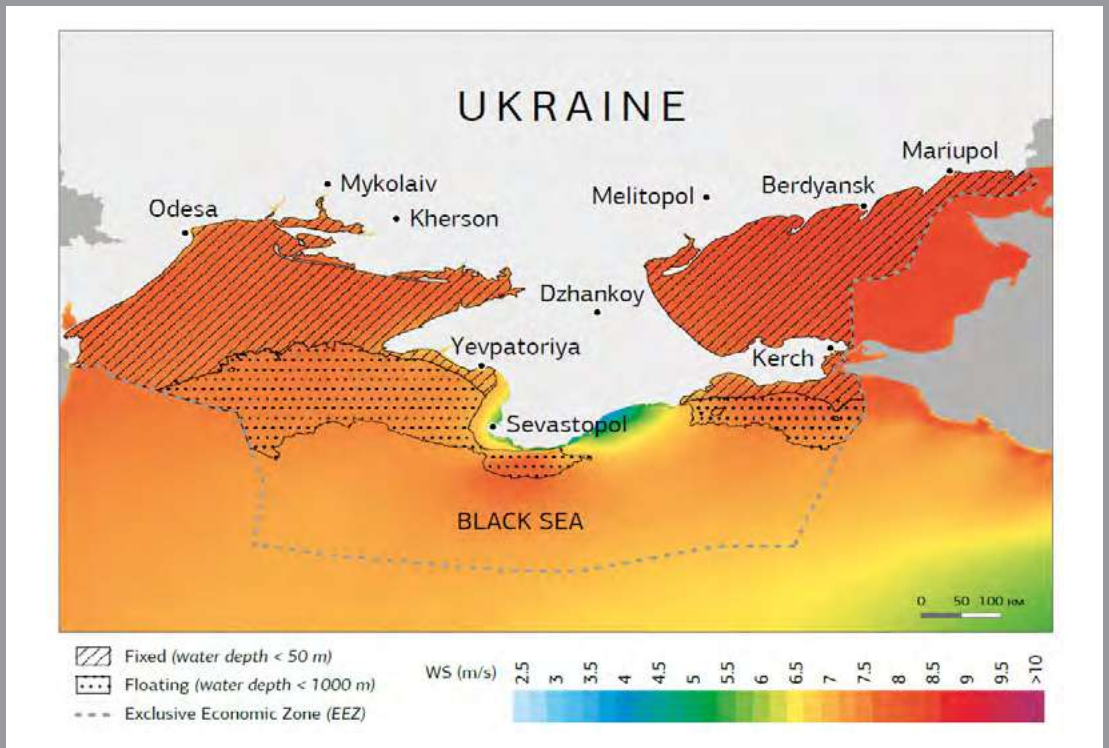
PRACTICAL STEPS TO IMPLEMENT OFFSHORE WIND ENERGY IN UKRAINE

As indicated in *the EU Strategy to harness the potential of offshore renewable energy for a climate neutral future* which is a part of the *European Green Deal* the Black Sea offers a good natural potential for offshore wind (bottom-fixed and floating) and localised potential for wave energy.

Regional cooperation already takes place in the context of the Common Maritime Agenda for the Black Sea of which Ukraine is a participant. The Black Sea strategic research and innovation agenda lists as one of its priorities to stimulate emerging blue economy sectors, such as offshore wind and wave technology.

When looking at the EU and Energy Community members in the Black Sea, offshore wind may well be the region's best bet to meet the objectives of the *European Green Deal.* A recent World Bank analysis estimated the technical offshore wind potential for Ukraine in the waters of Black and Azov seas in total of 251 GW. Although it includes the territory of the occupied Crimea.

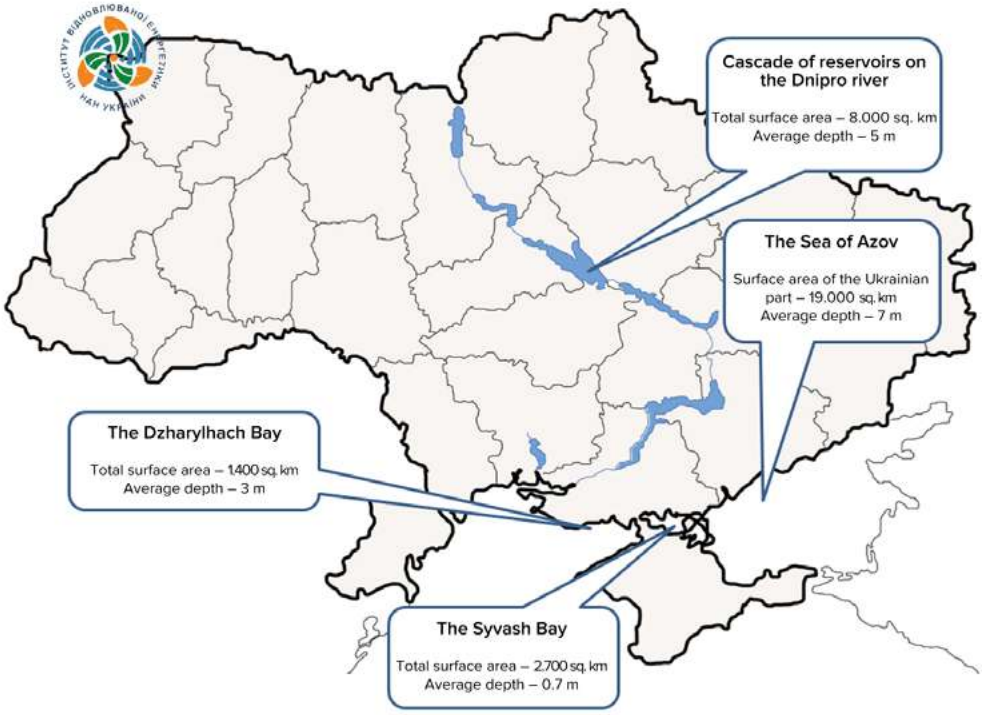
Map 1. Technical potential of offshore wind power in the Black and Azov Seas (including the Autonomous Republic of Crimea)



Ukraine has significant technical potential for the development of offshore power generation in shallow areas of large water areas—the Azov and Black Seas, the Syvash Bay, the reservoirs of the Dnipro HPPs, and estuaries (Map 2).

According to the research of the National Renewable Energy Laboratory (NREL), the United States, the territory of the shallow areas allows for building offshore WPPs with a total capacity of GW 146 in Ukraine [5].

Map 2. Key shallow water areas of Ukraine



The Wind Power Department of the Renewable Energy Institute (REI) of the National Academy of Sciences (NAS) of Ukraine has calculated the specific values for the potential of offshore WPPs in Ukraine. The findings are presented in Table 2.

Table 2. Inputs and outcomes of assessment of installed capacity potential of offshore WPPs in Ukraine (according to the Renewable Energy Institute of the NAS of Ukraine)

Water areas	Shallow area, km^2	Expert assessment of percentage of area suitable for WPPs, %	Area for WPPs, km^2	Density of installation, MW/km^2	WPP capacity, GW
Azov and Black Seas (Ukraine)	19000	30	5700	35	199.5
Syvash Bay	2500	25	625	30	18.8
Dnipro HPPs	6888	15	1033	25	25.8
Estuaries	1500	15	225	25	5.6
Total	**29888**	**25**	**7583**		**249.7**

According to the assessment of the Renewable Energy Institute of the NAS of Ukraine, the potential of offshore WPPs in Ukraine amounts to almost 250 GW. Given the real, average installed capacity factor of 0.45 for Ukraine's offshore WPPs, the corresponding annual electricity generation will be 984 billion kWh, which is more than six times the current annual electricity consumption in Ukraine. It should be noted that, according to WindEurope (the European Wind Energy Association), the installed capacity factor may reach 0.6 for new offshore turbines of 10 MW+ each. In this case, the generation of electricity by offshore WPPs in Ukraine may exceed the estimates of the REI of the NAS of Ukraine.

Today, the green hydrogen power sector, which produces hydrogen by electrolysis of water, is defined by significant rate of electricity loss. One of the most efficient ways to produce green hydrogen in Ukraine is to use wind energy.

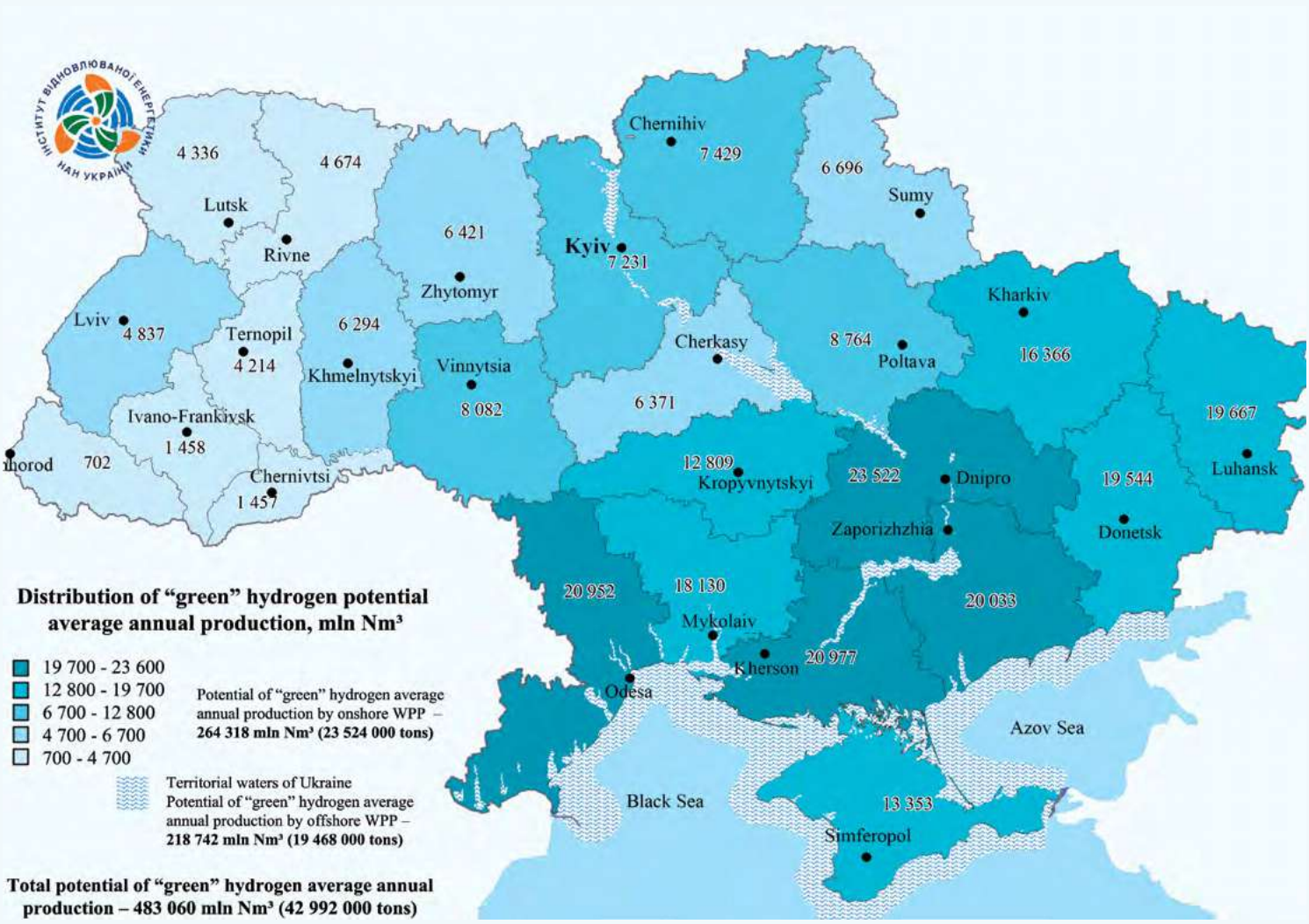
The below scenarios for the deployment of green hydrogen in Ukraine (Table 3) are based on research by the international energy agencies—International Renewable Energy Agency (IRENA) [6] and National Renewable Energy Laboratory (NREL) [5], the United States—and the Wind Power Department of the REI of the NAS of Ukraine [7]. To calculate the potential production of green hydrogen by electrolysis, a specific consumption of electricity of 4.5 kWh / mn3 H2 or 50.56 kWh / kg H2 has been assumed for modern electrolysers.

Table 3. Assessment of wind power potential of Ukraine and equivalent electrolysis of green hydrogen

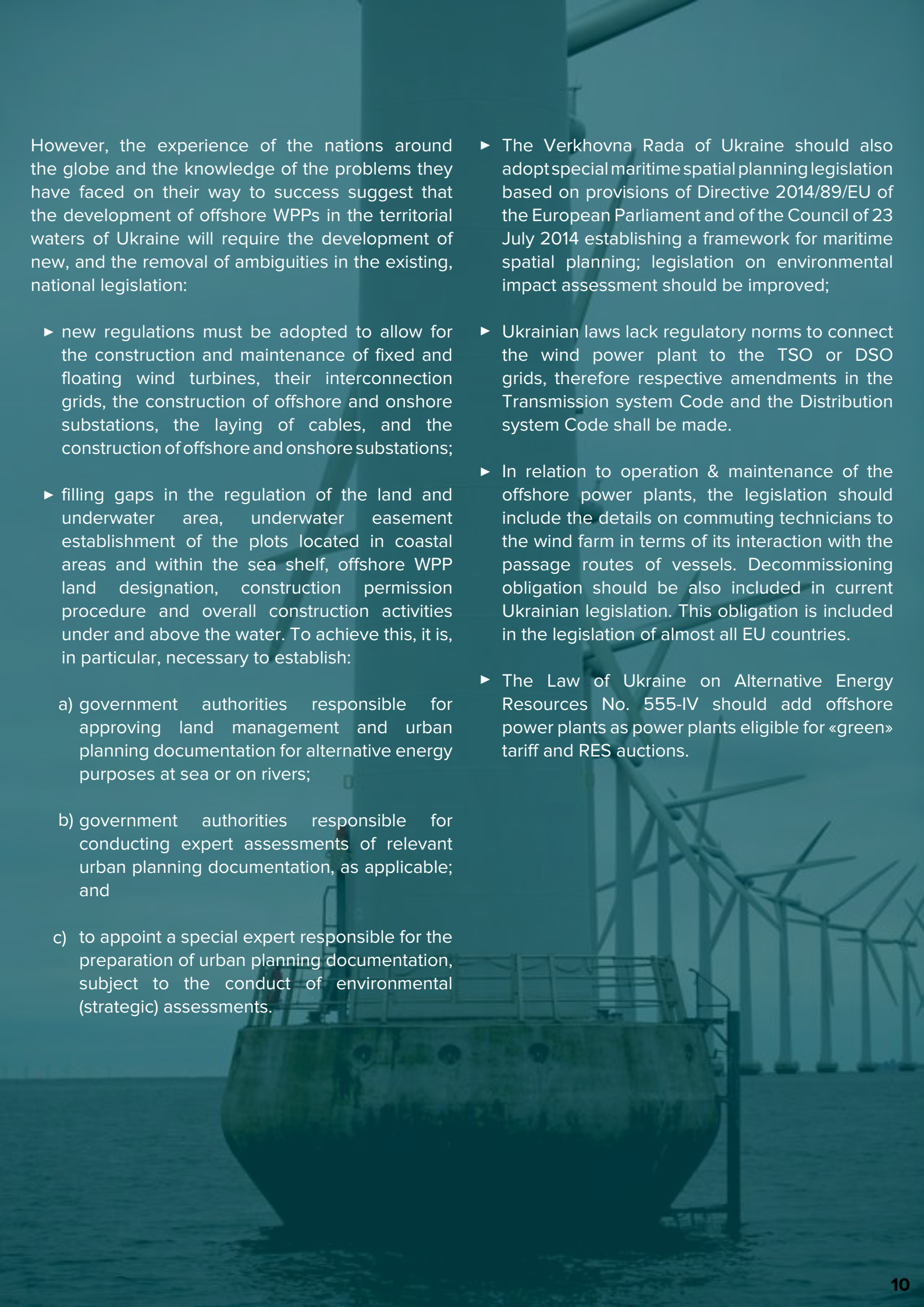
WPP	Information source	Capacity, GW	Average annual production of electricity, billion kWh	Average annual Production of H_2, billion mn^3	Average annual production of H_2, million tonnes
onshore	IRENA	320	858	191	17
offshore	NREL	146	570	126	11
Total		466	1428	317	28
onshore	REI of the NAS of Ukraine	438	1190	264	23.5
offshore	REI of the NAS of Ukraine	250	984	219	19.5
Total		688	2174	483	43

The distribution of of ‘green’ hydrogen potential average annual production from wind and solar energy in Ukraine is shown on Map 3 below.

Map 3. Distribution of ‘green’ hydrogen potential average annual production in Ukraine [8]



According to research conducted by the REI of the NAS of Ukraine, Ukraine has the potential to establish 250 GW offshore WPPs in its territory with an average annual electricity production of 984 billion kWh and can provide an average annual production of 219 billion mn3 (19.5 million tonnes) of green hydrogen by electrolysis.



However, the experience of the nations around the globe and the knowledge of the problems they have faced on their way to success suggest that the development of offshore WPPs in the territorial waters of Ukraine will require the development of new, and the removal of ambiguities in the existing, national legislation:

- new regulations must be adopted to allow for the construction and maintenance of fixed and floating wind turbines, their interconnection grids, the construction of offshore and onshore substations, the laying of cables, and the construction of offshore and onshore substations;

- filling gaps in the regulation of the land and underwater area, underwater easement establishment of the plots located in coastal areas and within the sea shelf, offshore WPP land designation, construction permission procedure and overall construction activities under and above the water. To achieve this, it is, in particular, necessary to establish:

  a) government authorities responsible for approving land management and urban planning documentation for alternative energy purposes at sea or on rivers;

  b) government authorities responsible for conducting expert assessments of relevant urban planning documentation, as applicable; and

  c) to appoint a special expert responsible for the preparation of urban planning documentation, subject to the conduct of environmental (strategic) assessments.

- The Verkhovna Rada of Ukraine should also adopt special maritime spatial planning legislation based on provisions of Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning; legislation on environmental impact assessment should be improved;

- Ukrainian laws lack regulatory norms to connect the wind power plant to the TSO or DSO grids, therefore respective amendments in the Transmission system Code and the Distribution system Code shall be made.

- In relation to operation & maintenance of the offshore power plants, the legislation should include the details on commuting technicians to the wind farm in terms of its interaction with the passage routes of vessels. Decommissioning obligation should be also included in current Ukrainian legislation. This obligation is included in the legislation of almost all EU countries.

- The Law of Ukraine on Alternative Energy Resources No. 555-IV should add offshore power plants as power plants eligible for «green» tariff and RES auctions.

BENEFITS OF OFFSHORE WIND POWER FOR UKRAINE

The benefits offered by the development of offshore wind projects in Ukraine can hardly be underestimated. Marine-based WPPs will **significantly contribute to Ukraine's climate policy**, carbon emissions reduction *(for example, CO2 emissions from the global energy sector are expected to be reduced by five to seven billion tonnes over the next two decades)*, the country's performance of its obligations under the Paris Agreement and transition to a carbon-free economy, i**mproving its energy security due to a reduced dependence on imported fuels**.

A huge benefit of the offshore wind industry is **the creation of new jobs**, which number will be much higher than in any other RES sector due to the scale of work associated with the construction and operation of offshore wind farms. In addition, tax revenues from offshore wind power **will replenish the country's local and national budgets**.

The high cost of the offshore technology is offset by **the amount of investment raised**. In recent years, the offshore wind sector has attracted a record amount of investment, in particular, more than USD 20 billion in 2018, which is equivalent to almost a quarter of total investment in the wind power sector and accounts for 6% of the total investments in renewable energy sources. The world's total offshore wind capacity is expected to increase more than 15 times by 2040 and, consequently, to become a USD 1 trillion business.

The development of the offshore wind energy technology is directly related **to the development of Ukraine's energy potential**. Today, the installed capacity utilization factor for new offshore wind projects exceeds 50%. At this level, the efficiency of offshore wind installations is comparable to coal-fired or gas-fired power plants and is almost four times higher than the installed capacity utilization factor for solar photovoltaic installations.

Finally, offshore wind power provides a platform for establishing another market in Ukraine—**the hydrogen technology market**, creating new potential ways for cooperation with European countries.

The carbon-free generation of electricity, high installed capacity factor and reduced capital costs make **offshore wind power an attractive technology for producing 'green' hydrogen**—a flexible product that can be used for decarbonising the heavy engineering, housing and transport sectors. For example, an offshore wind farm with a capacity of 1,000 MW can produce enough 'green' hydrogen to heat 250,000 households. The growing demand for 'green' hydrogen leads to a sharp increase in the market potential of offshore wind projects in the world. While Poland has ambitious plans to build a 'hydrogen' pipeline to transport 'green' electricity and H2 from offshore WPPs in the Baltic Sea to the south, Belgium and the United Kingdom are working on connecting their offshore WPPs to a single power system of the North Sea WPPs. Denmark plans to create offshore power hubs for the production of 'green' hydrogen with a total capacity of 12,000 MW, which can be connected to the grids of other European countries.

THE ABOVE INFORMATION HAS BEEN PREPARED BASED ON THE FOLLOWING DATA:

1. Global Wind Energy Council: https://gwec.net/wp-content/uploads/2020/12/GWEC-Global-Offshore-Wind-Report-2020.pdf

2. World Forum Offshore Wind: https://wfo-global.org/wp-content/uploads/2020/06/WFO_Global-Offshore-Wind-Report-2020.pdf

3. European Wind Energy Association (presently known as WindEurope): http://www.ewea.org/fileadmin/files/library/publications/reports/Offshore_Report.pdf

4. World Bank: http://documents1.worldbank.org/curated/en/709391586844502062/pdf/Technical-Potential-for-Offshore-Wind-in-Ukraine-Map.pdf

5. Improved Offshore Wind Resource Assessment in Global Climate Stabilization Scenarios. Technical Report. National Renewable Energy Laboratory (NREL), 2012.

6. IRENA. Cost-Competitive Renewable Power Generation: Potential across South East Europe. 2017.

7. Reasons for and findings of review of potential of Ukraine's wind power plants, S.O. Kudria, N.M. Mkhitarian, B.H. Tuchynskyi, O.O. Riepkin, I.V. Ivanchenko, K.V. Petrenko. Vidnovliuvana Enerhetyka. 2020. No. 1. Pages 6 to 16. https://doi.org/10.36296/1819-8058.2020.1(60).6-16

8. Atlas of energy potential of Ukraine's renewable energy sources / S.O. Kudria, V.F. Rieztsov, I.V. Ivanchenko, K.V. Petrenko, et al. / Edited by: S.O. Kudria. Kyiv: IRE NAS of Ukraine, 2020, p. 82.

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About UWEA

Public Union Ukrainian Wind Energy Association is the largest renewable energy industry association in Ukraine. It's a non-profit organization that serves as the principal communication and cooperation platform for large-scale adoption of wind technologies in the country and further advancing the "green" transformation of the Ukrainian energy system.

The UWEA founded in 2008 to protect the interests and support the activities of both, the national and international stakeholders of the Ukrainian wind energy market, which as of the end of 2020 unities 80 companies including 100% of wind electricity producers and investors in Ukraine, wind farm developers, equipment manufacturers and suppliers, utilities, construction, consulting and logistic companies, lawyers and environmentalists involved in the wind industry.

Throughout its history the Ukrainian Wind Energy Association has been closely cooperating with various national, regional and local authorities, and such international institutions and organizations as International Energy Agency, BloombergNEF, Wood Mackenzie, REN21. The UWEA is a full member of the World Wind Energy Association and the WindEurope.

Numerous awards and distinctions have proven high-level professionalism of the association. Thus, the UWEA has been twice recognized as the choice of the year – in 2017 it was awarded with the Honorary award "Choice of Ukraine 2017" and in 2019 – the Honorary award "Choice of the Country 2019".

About Asters

Asters is the largest Ukrainian law firm by the number of lawyers, having its offices in Kyiv, Washington, Brussels, and London. Since 1995, the firm has been providing services to large international organisations, government agencies and key transnational and Ukrainian companies operating in various industries. Throughout its existence, the firm has been one of the key players in the Ukrainian legal market.

Asters has one of the largest and strongest energy and construction teams in Ukraine. Asters is highly recommended for energy and natural resources by Chambers Europe 2020 and The Legal 500: EMEA 2020. The firm has been recognised as one of the top three energy and natural resources law firms by Ukrainian Law Firms 2020.

About Ukrainian Hydrogen Council

Energy Association 'Ukrainian Hydrogen Council' is the first and only one hydrogen energy association in Ukraine aiming to develop green hydrogen power as an integral part of the production and supply of alternative energy sources and to promote hydrogen technologies in various industries and business sectors to improve their energy efficiency.

The association was established in 2018 to consolidate the efforts of representatives of energy businesses, investment institutions, scholars, and public and government authorities to implement energy independence of the country, to improve energy efficiency and to sustainably implement the roadmap for Ukraine's hydrogen power sector.