CATAPULT
Offshore Renewable Energy

FLOATING OFFSHORE WIND CENTRE OF EXCELLENCE

INTERNATIONAL MARKET OPPORTUNITIES

Summary Report

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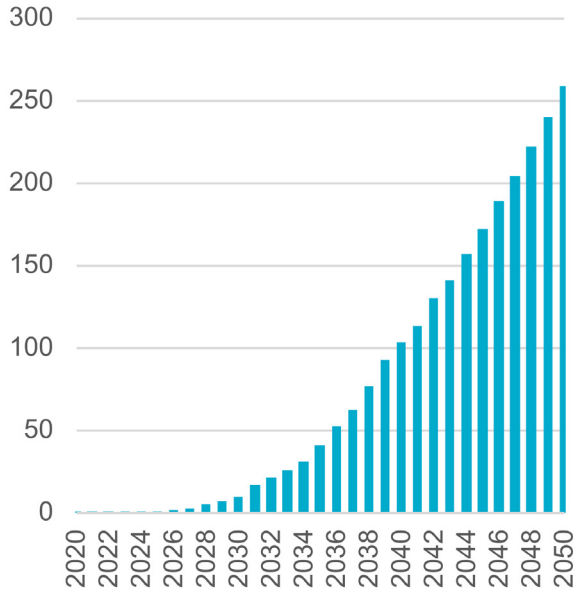
EXECUTIVE SUMMARY

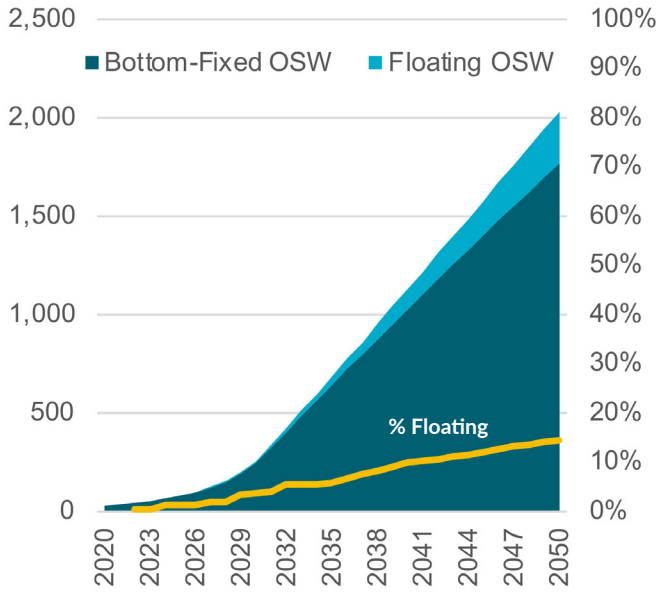
1.1 This Study

Floating offshore wind is rapidly transitioning from the demonstration stage to the pre-commercial phase and is poised to enter the global commercial phase this decade. Several floating offshore wind projects have been fully consented and are in advanced development across markets in Europe and Asia. The global pipeline of floating offshore wind, bolstered by increasing policy support, indicates that well over 10 GW is on track to be commissioned by the end of 2030. However, the momentum must accelerate. The International Renewable Energy Agency (IRENA) calls on 2,000 GW of offshore wind capacity to be installed by 2050 as part of its 1.5°C Scenario. [1] Floating offshore wind will be critical to offshore wind's role in the future energy generation mix; not only by unlocking vast untapped resources in existing offshore wind markets, but expanding to new geographies globally.



Source: OWC, based on DNV's Energy Transition Outlook[1]

Figure 0-1: Long-term Floating Offshore Wind Global Forecast (GW)



Source: OWC forecast, based on IRENA's 1.5°C scenario

Figure 0-2: Offshore Wind in a Net Zero Emissions by 2050 Scenario

In the near-term, growth of floating offshore wind will be consolidated in a handful of markets where demonstration projects have been deployed and a first wave of pre-commercial and commercial projects have secured site control. Notably, United Kingdom, South Korea, Japan, and France seek to deploy commercial scale projects this decade. However, longer-term growth of floating offshore wind will not be concentrated in a handful of markets; but distributed over several territories across that world that have strong technical potential, political ambition and social drivers to incorporate floating offshore wind into the power generation mix.

This study maps the international opportunities for floating offshore wind in the near-term (2022 – 2035) as well as the long-term horizon (2035 – 2050). A total of 54 global territories have been identified and categorised as near-term or long-term markets.

[1] DNV Energy Transition Outlook (2021, p. 65) forecast 264 GW floating offshore wind installed in 2050. OWC's forecast is based on achieving 264 GW.

1.2 Key Findings

The analysis identified 22 markets for near-term floating offshore wind and 32 longer-term markets. Each market was assessed using weighted criteria spanning technical and policy drivers, commercial investment landscape, and market facilitators. These factors were scored to evaluate the "readiness" of that market for offshore wind and the speed of market development. Each country listed in the tables below meets or exceeds the basic thresholds devised for floating offshore wind; however, not all will pursue commercial floating offshore wind. Some could be speculative future markets, depending on an investor's risk appetite. The results of the near-term / long-term markets analysis are shown below.

No.	Near-Term Markets	Weighted Scoring
1	United Kingdom	97.1
2	Japan	92.3
3	France	90
4	South Korea	88
5	Taiwan	87.6
6	Norway	85.3
7	United States	78.5
8	China	77.9
9	Portugal	76.7
10	Ireland	73.5
11	Italy	72.6
12	Spain	69.2
13	Vietnam	68.1
14	Greece	67.7
15	Poland	66.5
16	Sweden	66.1
17	Philippines	65
18	Brazil	62.1
19	Denmark	59.7
20	Australia	58.3
21	Canada	50.1
22	India	49.9

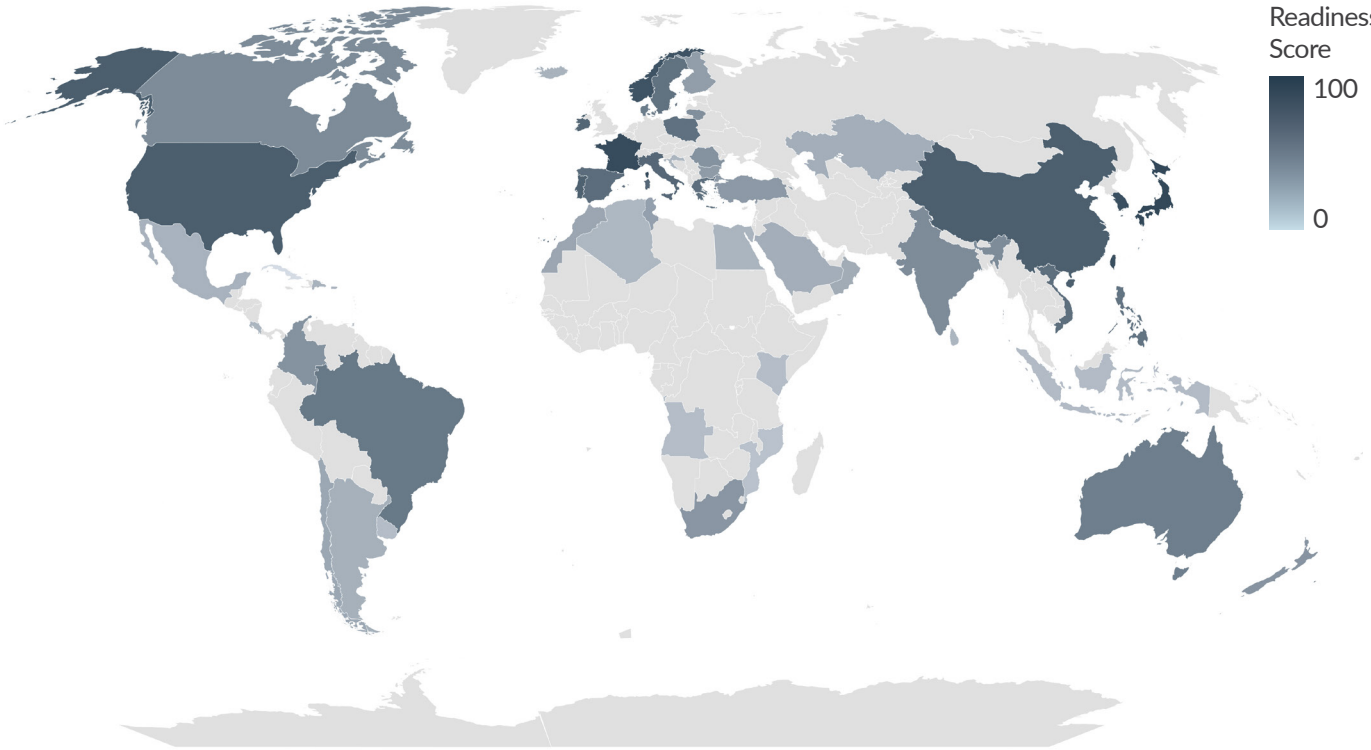
Figure 0-2: List of Near-Term Floating Offshore Wind Markets

No.	Long-Term Markets	Weighted Scoring
1	Lithuania	47.6
2	Romania	45.9
3	Colombia	45.8
4	New Zealand	44.9
5	South Africa	43.5
6	Turkey	41.8
7	Bulgaria	40.2
8	Finland	38.8
9	Azerbaijan	37.4
10	Tunisia	37.3
11	Morocco	33.4
12	Chile	32.5
13	Oman	30.1
14	Kazakhstan	28.6
15	Saudi Arabia	28.4
16	Argentina	26.7
17	Mexico	25.9
18	Iceland	25.6
19	Dominican Republic	25.5
20	Puerto Rico	25.2
21	Egypt	24.3
22	Costa Rica	23.7
23	Sri Lanka	23.7
24	Croatia	23.5
25	Algeria	22.2
26	Indonesia	20.5
27	Kenya	19.1
28	Trinidad and Tobago	19
29	Uruguay	18.9
30	Angola	18.9
31	Mozambique	16.1
32	Cuba	12.6

Source: OWC, 2022. As of March 31, 2022

Figure 0-3: List of Long-Term Floating Offshore Wind Markets

A map showing the “readiness” of floating offshore wind markets by 2050 is shown below.



Source: OWC analysis, 2022. As of March 31, 2022.

Figure 0-4: Map: Readiness of future floating offshore wind markets (2022 – 2050)

This map above depicts the various global territories that meet minimum technical and socio-economic thresholds for floating offshore wind development, although some markets may not pursue floating offshore wind. Each market’s “readiness” was assessed using several criteria.

Scale of future floating wind opportunities

A high-level assessment to understand the scale of the floating wind opportunity was also performed for the 54 markets identified in the study. Initial consideration of market scale for floating offshore wind opportunities was based on: (1) technical resource potential for floating offshore wind, and (2) power consumption within that market (shown as bubble size the graph below). The results of this high-level assessment indicate a high degree of readiness in many of the larger-scale markets (e.g., Japan, UK, USA, China). Longer-term markets may represent smaller scale opportunities, and as such, policies in these markets must seek to effectively attract sufficient investments in floating offshore wind.

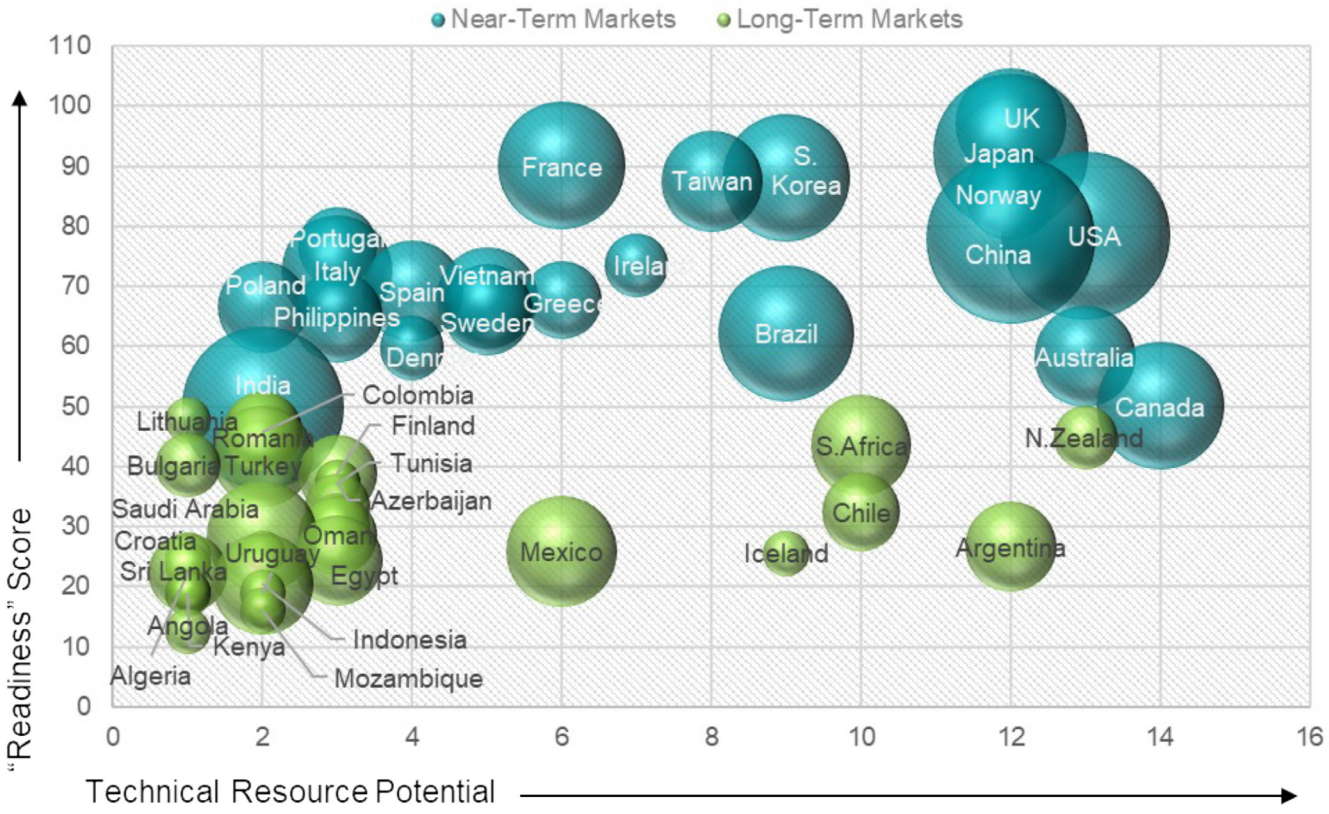


Figure 0-6: Potential Future Floating Offshore Wind Markets and the Scale of Opportunity

Technical potential scoring bands (X-Axis)

Technical Potential (GW)	Score Value
>5000	14
2500-5000	13
1000-2500	12
900-1000	11
800-900	10
700-800	9
600-700	8
500-600	7
400-500	6
300-400	5
200-300	4
100-200	3
50-100	2
10-50	1
10 or less	0

Source: OWC, 2022

Power consumption scoring bands (Bubble size)

Power Consumption (TWh/y)	Score Value
>2000	14
1000-2000	13
900-1000	12
800-900	11
700-800	10
600-700	9
500-600	8
400-500	7
300-400	6
200-300	5
100-200	4
50-100	3
25-50	2
10-25	1
10 or less	0

Source: OWC, 2022

Power-to-X and other routes-to-market

It is also recognized that floating offshore wind may have alternative and varying routes-to-markets than solely power generation and electricity sales. While we consider power-to-x markets such as green hydrogen, we have based the near-term / long-term market analysis and the scale of the opportunity on the assumption that electricity generation will remain the primary route-to-market driving commercial scale floating offshore wind development in this study's time horizon. We also recognize that advancements in transmission infrastructure, particularly those integrating or consolidating smaller demand clusters to larger demand clusters, may present future opportunities for new floating offshore wind markets.

1.3 Global Picture

The future trajectory and global growth of global floating offshore wind depends to a large extent on what happens in this decade. Within the second half of the 2020's, commercial scale floating offshore wind deployment is poised to accelerate in the United Kingdom, France, South Korea, Japan, and Norway. Capacity targets in the United Kingdom, as well as planned tenders specifically for floating offshore wind in France and Japan, are market building policies that will effectively accelerate the deployment of commercial floating offshore wind. Several new floating offshore wind markets will also emerge late in this decade. These are likely to include Spain, Portugal, the United States and Taiwan. By early the next decade, Greece and Italy will deploy commercial floating wind, followed eventually by Philippines, Vietnam, and potentially Brazil. The table below represents a projected timeframe of when each of these select territories may host a commercial floating offshore wind industry.

2022 - 2030	2030 - 2035	2035 - 2050
• United Kingdom	• Italy	• Colombia
• Japan	• Greece	• Bulgaria
• France	• Canada	• Morocco
• South Korea	• Sweden	• Tunisia
• Taiwan	• Vietnam	• Turkey
• Norway	• Philippines	• Finland
• United States	• Brazil	• Lithuania
• China	• Australia	• South Africa
• Portugal	• Romania	• New Zealand
• Ireland	• India	• Chile
• Poland		• Costa Rica
• Spain		• Kenya

Source: OWC, 2022. As of March 31, 2022

Figure 0-7: Select Floating Offshore Wind Markets by Decade

The scale and potential of floating offshore wind in these markets is significant. Developing just 1% of the technically achievable floating wind capacity in the markets identified in this study as near-term markets (2022 – 2035) would result in approximately 250 GW of floating offshore wind power generation capacity. Realising 5% of the technical resource potential in the near-term markets could translate to over 1,200GW of floating offshore wind capacity.

The methodology for identifying and assessing "readiness" of the future markets for floating offshore wind is detailed in the following section.

1 METHOD

1.1 Approach

An initial global territorial outlook was compiled to canvas 246 global territories for floating offshore wind potential. Countries and dependencies that meet the minimum technical threshold requirements for floating offshore wind (coastal access, offshore wind resources and bathymetry) were filtered through additional criteria for floating offshore wind development. These additional filters included key socio-economic thresholds assumed necessary to support investments in commercial scale floating offshore wind (e.g., political stability indicators, corruption index, rule of law, power consumption). Territories that passed all technical and socio-economic threshold filters (Figure 1-1) were then evaluated for near-term versus long-term floating offshore wind development using 11 custom evaluation criteria spanning three categories: technical and policy drivers, investment environment, and market facilitators (Figure 1-2).

Market Screening and Assessment Approach

Territory Screening Filters	Synergies With Other Sectors
Geographic	Coastal access
Technical	Resource Potential (wind speed and bathymetry)
Socio Economic	Power consumption
Governance	Control of Corruption
Governance	Rule of Law
Socio Economic	GDP / Capita
Socio Economic	Major political-economic instability (e.g., war, sanctions, etc.)

Figure 1-1: Market Screening Filters

Source: OWC, 2022

Figure 1-2: Market Readiness Assessors

Territories were allocated scores based on the strength of several criterion within each of these categories and given an overall weighted "readiness" score for floating offshore wind. Territories that scored the highest show the strongest near-term potential. Territories that passed all technical thresholds but scored lower on the "readiness" factors are considered potential prospects for longer-term floating offshore wind markets. It is recognized that some of the lowest scoring markets may not appear likely to pursue or implement commercial floating offshore wind market building policies. However, they may be potential markets of interest for speculative investors or developers with the right risk profile, and thus could be considered as future long-term prospective opportunities.

1.1.1 List of Territories Considered

The global territorial outlook was compiled using several sources. This was challenging from the onset due to a number of implications when finding a standard list due to contested boundaries within certain regions and making assumptions on whether to include grey areas regarding territories which are neither recognised as an independent nation-state or dependencies. In total, a master list of countries and dependencies totalling 246 was created.

1.1.2 Market Filtering

Technical and then socio-economic data was collected for each of the territories resulting from the global territorial outlook. To screen for markets with floating offshore wind potential, each territory was passed through seven (7) technical and socio-economic filters. Filter types ranged from the basic minimum technical thresholds, to meeting certain socio-economic thresholds or standards necessary to support project investment, financing, and economics..

Filter	Filter Type	Filter name	Threshold
1	Geographic	Coastal access	At least 75 km of ocean or sea access
2	Technical	Resource Potential	≥ 6 GW of floating offshore wind technical potential
3	Socio Economic	Power consumption	Power consumption of at least 10 TWh / year
4	Governance	Control of Corruption	Score of ≥ -1.5 on World Bank Index
5	Governance	Rule of Law	Score of ≥ -1.5 on World Bank Index
6	Socio Economic	GDP / Capita	≥ US $2,000/ day
7	Socio Economic	Instability	Major instability (war, sanctions, etc.)

Source: OWC, 2022

Figure 1-3: Minimum Technical and Socio-Economic Thresholds

Thresholds for control of corruption and rule of law were deliberately set low for this study. Only countries in the bottom 1/3 of the Global Corruption Index were excluded, and all countries with a World Bank “Rule of Law” index scoring -1.5 or above were passed. This flexibility was to allow for long-term institutional reform and / or development bank assistance for offshore wind sector planning. Results are shown in Figures 1-6 and 1-7.

1.1.3 Results of Market Filtering

In total, 54 territories were identified that meet the basic requirements for future floating offshore wind potential.

Count	Explanation / Validation
168	Number of territories with sufficient coastal access
119	Number of territories with technical floating wind potential ≥ 6 GW
61	Number of territories meeting above criteria and with annual power demand ≥ 10 TWh
54	Number of territories meeting above criteria and passing remaining thresholds

Source: OWC, 2022

Figure 1-4: Number of territories passing initial filtering

Source: OWC, 2022

Figure 1-5: Map of territories passing filters

Notes:
(1) Countries without ESMAP estimates for floating offshore wind resource potential did not pass Filter 2.[2]

[2] See Energy Sector Management Assistance Program (ESMAP) Offshore Wind Technical Potential

	Country Name		Country Name
1	Algeria	28	Kenya
2	Angola	29	Lithuania
3	Argentina	30	Mexico
4	Australia	31	Morocco
5	Azerbaijan	32	Mozambique
6	Brazil	33	New Zealand
7	Bulgaria	34	Norway
8	Canada	35	Oman
9	Chile	36	Philippines
10	China	37	Poland
11	Colombia	38	Portugal
12	Costa Rica	39	Puerto Rico
13	Croatia	40	Romania
14	Cuba	41	Saudi Arabia
15	Denmark	42	South Africa
16	Dominican Republic	43	South Korea
17	Egypt	44	Spain
18	Finland	45	Sri Lanka
19	France	46	Sweden
20	Greece	47	Taiwan
21	Iceland	48	Trinidad and Tobago
22	India	49	Tunisia
23	Indonesia	50	Turkey
24	Ireland	51	United Kingdom
25	Italy	52	United States
26	Japan	53	Uruguay
27	Kazakhstan	54	Vietnam

Source: OWC, 2022

Figure 1-5: 54 countries passing filters (in alphabetical order)

The below 54 territories pass the initial technical and socio-economic thresholds evaluated for floating offshore wind development.

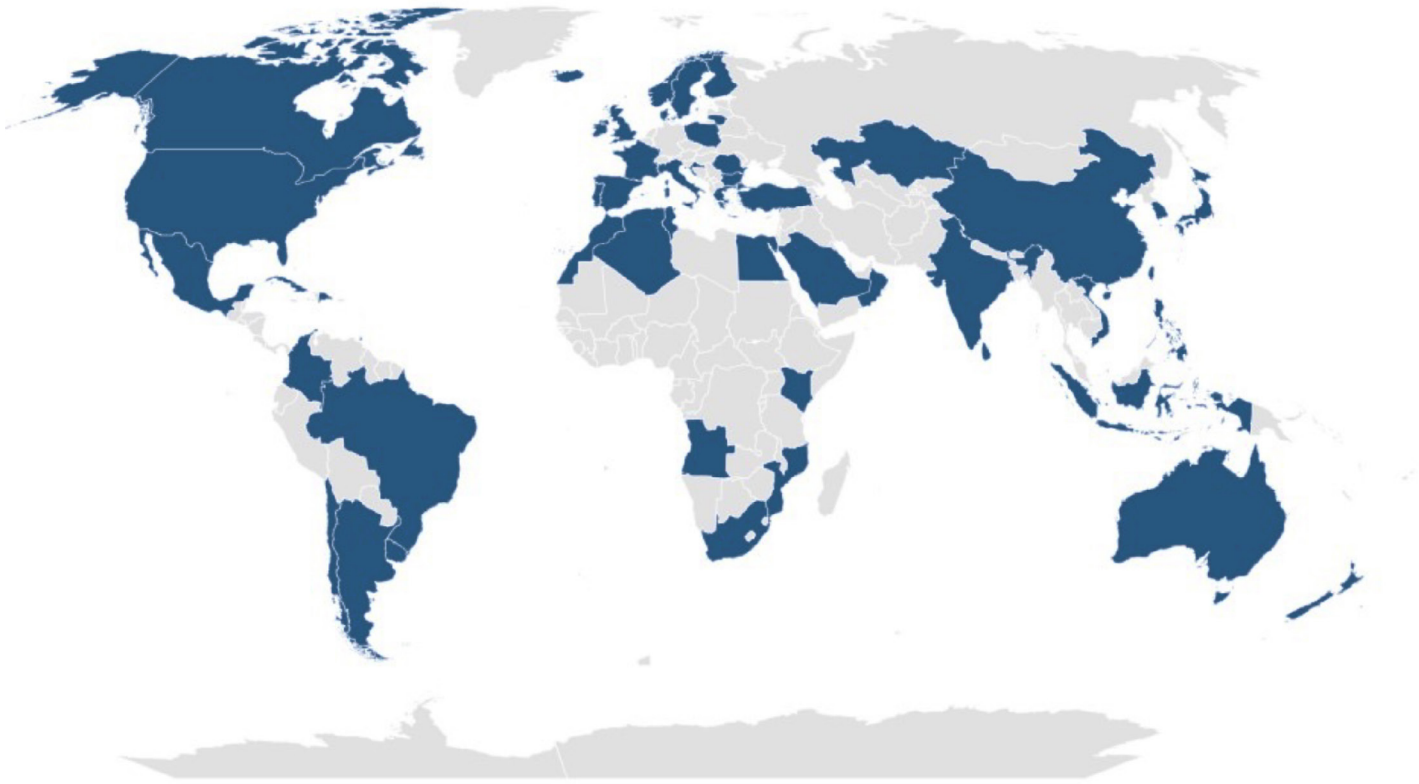


Figure 1-5: 54 countries passing filters (in alphabetical order)

Note: Countries without ESMAP estimates for offshore wind resource potential excluded.

1.2 Assessment Criteria – Speed of Market Development

1.2.1 General

To assess market readiness and the potential speed of commercial floating wind development, the filtered list of 54 territories was then further screened using the below custom evaluation criteria to assess markets for near-term or long-term commercial floating offshore wind readiness. A total of 11 different criterion were weighed across 3 different areas impacting pace of floating offshore wind market development. These are descried in Figure 1-9 below.

Market Speed Drivers	Assessment Criteria
Technical and Policy Drivers	Technical potential for floating offshore wind
	Power demand
	Policy targets for offshore wind
	Competitiveness of floating in energy mix
Investment Environment	Ease of Doing Business Score
	ESMAP RISE score
	Offshore wind players present in market
Market Facilitators	Offshore wind capacity already installed
	Floating pilot projects installed
	Defined regulations and procedures
	Seabed leasing processes for floating wind started

Medium Impact on speed of commercial floating wind market development

High impact on speed of commercial floating wind market development

Source: OWC, 2022

Figure 1-9: Market Speed Drivers and Criteria

1.2.2 Technical and Policy Drivers

Technical potential for floating offshore wind and power demand are both considered in the speed of market development assessment. Markets with higher power demand and large resource potential may have higher incentive to promote development of floating offshore wind. Markets that have similarly already established policy targets for offshore wind (fixed-bottom or floating) are further along the pathway towards realizing offshore wind. Finally, floating wind was deemed more likely to be competitive in countries with higher cost of energy. Each of these factors is deemed to have a medium impact on the speed of market development.

1.2.3 Investment Environment

The commercial investment environment crucial to assessing the speed of market development. The assessment of the investment landscape was comprised of three factors:

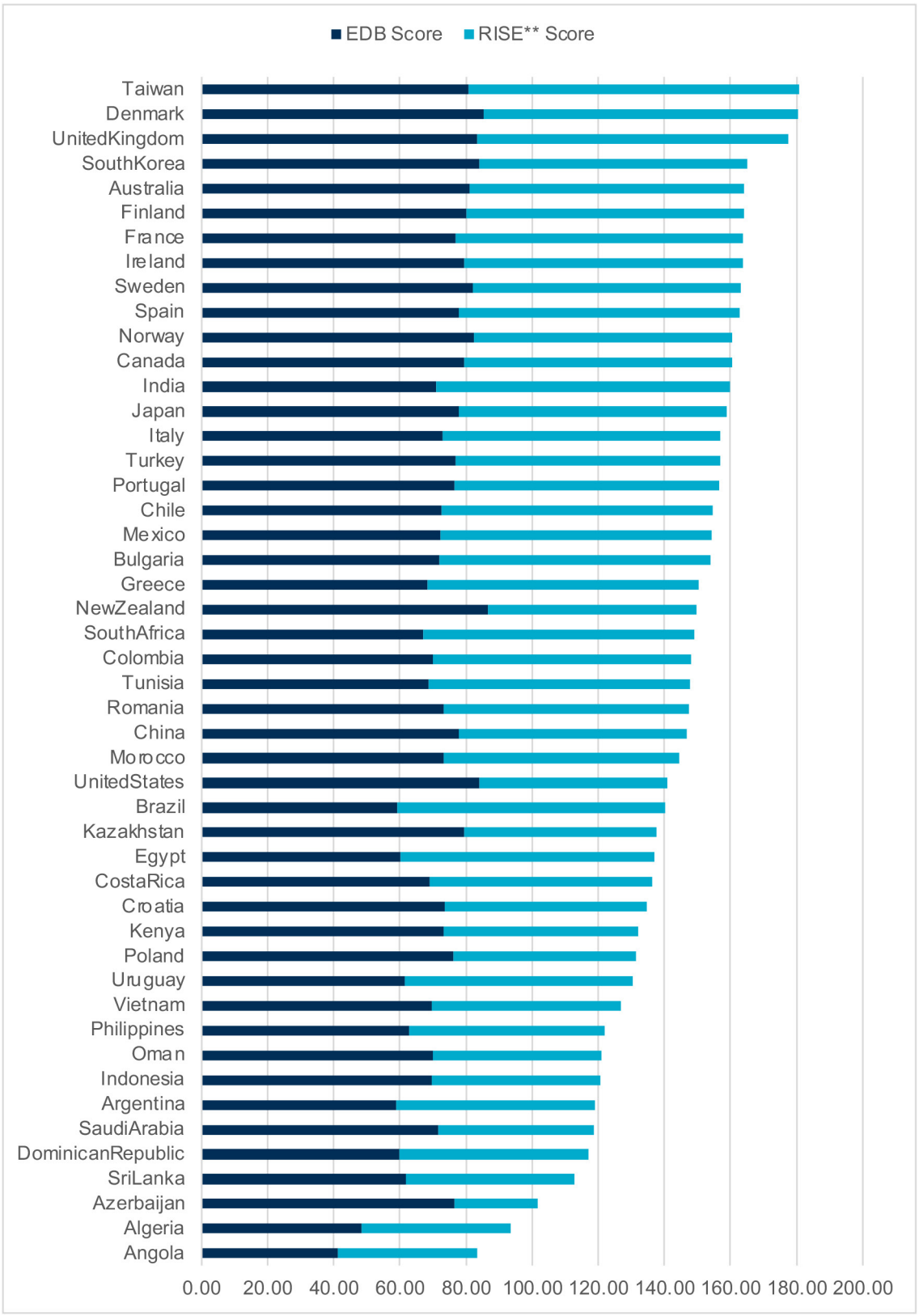
Scoring Factor	Description
Ease of Doing Business (EDB) Score	The World Bank's "Doing Business 2020" [2][3] report and the Doing Business (DB) database scores were assessed for each screened territory (where available). The "EDB" scores are based on the average of each country's ease of doing business across 10 topics that are evaluated in the ranking, including: **Starting a business, employing workers, dealing with construction and permits, getting electricity, registering property, getting credit, protecting minority investors and enforcing contracts.** The Ease of Doing DB ranking is seen as an important indicator for many independent power producers, supply chain companies, or contractors when evaluating whether to invest in floating offshore wind in a specific territory.
RISE Regulatory Indicators for Sustainable Energy	The assessment of the investment environment for renewables also takes into consideration the Energy Sector Management Assistance Program's (ESMAP) Regulatory Indicators for Sustainable Energy (RISE) Score [3]1F[4] for renewable energy in each of the territories (where available). The RISE score is ranked out of a maximum score of 100 and used to track progress for UN Sustainable Development Goal (SDG7) and assesses seven (7) factors of a country's renewable energy framework: • **Legal framework for renewable energy** • **Planning for renewable energy expansion** • **Incentives and regulatory support for renewable energy** • **Attributes of financial and regulatory incentives** • **Network connection and pricing** • **Counterparty risk** • **Carbon pricing and monitoring**
Ease of Doing Business (EDB) Score	The third criteria used to assess the investment landscape is the presence of commercial offshore wind industry players in that territory, with a focus on project developers (utilities, independent power producers) with stated ambition in offshore wind. As offshore wind has proliferated globally over the past half-decade, many prospective project developers have established operations in new markets. The existing presence of offshore wind developers in a prospective floating offshore wind market is a strong indicator that the investment environment is open and conducive to future floating offshore wind investments.

Figure 1-8: Factors for assessing investment environment

[3] World Bank. 2020. Doing Business 2020. Washington, DC: World Bank. DOI:10.1596/978-1-4648-1440-2. License: Creative Commons Attribution CC BY 3.0 IGO

[4] World Bank, RISE 2020. https://trackingsdg7.esmap.org

Depicted below is each of the markets' Ease of Doing Business (EDB) score with their RISE Score. Higher combined scores are a strong indication of a safer and more conducive investment environment, particularly for large-scale renewable energy projects. Lower scores do not eliminate the possibility but suggest more risk or uncertainty in the investment environment.



Source: OWC compiled from rise.esmap.org and data.worldbank.com
Note: Lithuania, Iceland, Trinidad, and Tobago omitted from chart as RISE score unavailable.
***RISE Score = Regulatory Indicators for Sustainable Energy. Assessing Renewable Energy Score Only.*

Figure 1-9: Combined RISE renewables scores and Ease of Doing Business score

1.2.4 Market Facilitators

The third category to assess market speed, market facilitators, assesses the current state of the offshore wind market and the steps the government has taken or is taking to facilitate the technology and market for floating offshore wind. It is assessed using four criteria:

Existing OSW Market	Floating Pilot Projects	Defined Regulations	Seabed Leasing Procedures
Markets with fixed-bottom offshore wind capacity already installed are likely to have established the necessary regulatory framework and procedures, including seabed leasing and site control, necessary to quickly facilitate floating offshore wind in the near-term. These markets also are more likely to have elements of the offshore wind supply chain in place, such as ports and harbours, and experienced contractors.	**Having already installed floating offshore wind pilot projects is a key step in facilitating a commercial floating offshore market.** Markets that have already deployed pilot projects and defined areas for floating offshore wind development zones are likely to develop floating offshore wind in the near-term.	**Well defined regulations and procedures, including planned solicitations for offshore wind power, power purchase agreement (PPA) structures, establishment of bankable subsidies or incentives, are all vital to accelerating the deployment of commercial scale floating offshore wind.** The project team assessed each of the 54 markets for the maturity of their offshore wind regulations and procedures.	**Spatial planning and seabed leasing procedures are critical to spurring floating offshore wind development.** Territories that have already defined floating offshore wind development zones and implemented well defined procedures and regulations for leasing and obtaining control of the seabed as well as required site studies and permits are well positioned to be near-term markets for floating offshore wind.

Source: OWC, 2022

1.2.5 Market Scoring Approach

To assess factors influencing the readiness and speed of development of floating offshore wind market development, scores ranging from 1 to 5 were assigned for each of the criterion evaluated for each of the 54 territories. These values were each multiplied by a weighing factor within the category. The total scores were added, and then the category was assigned an overall weighted value. The maximum potential weighted score is 100. Territories that had a weighted average of ≥50 are deemed to be markets that could likely be ready to deploy commercial offshore wind in the near-term (2022 – 2035). Territories that had a weighted average of ≤50 are markets that, although having the technical and socio-economic drivers from floating offshore wind development, are likely to be longer-term markets for floating offshore wind (2035-2050). The results are provided in the following section.

2 RESULTS

2.1 General

Results of the market filtering and readiness assessment are discussed below. The near-term markets are those with a weighted score ≥50 and longer-term markets are those with weighted score of ≤49. **The weighted scoring does not predict the chronological order in which markets will develop commercial floating offshore wind, but rather the relative "readiness" of the market for commercial scale floating offshore wind.**

2.2 Near-Term Floating Offshore Wind Markets (2022 – 2035)

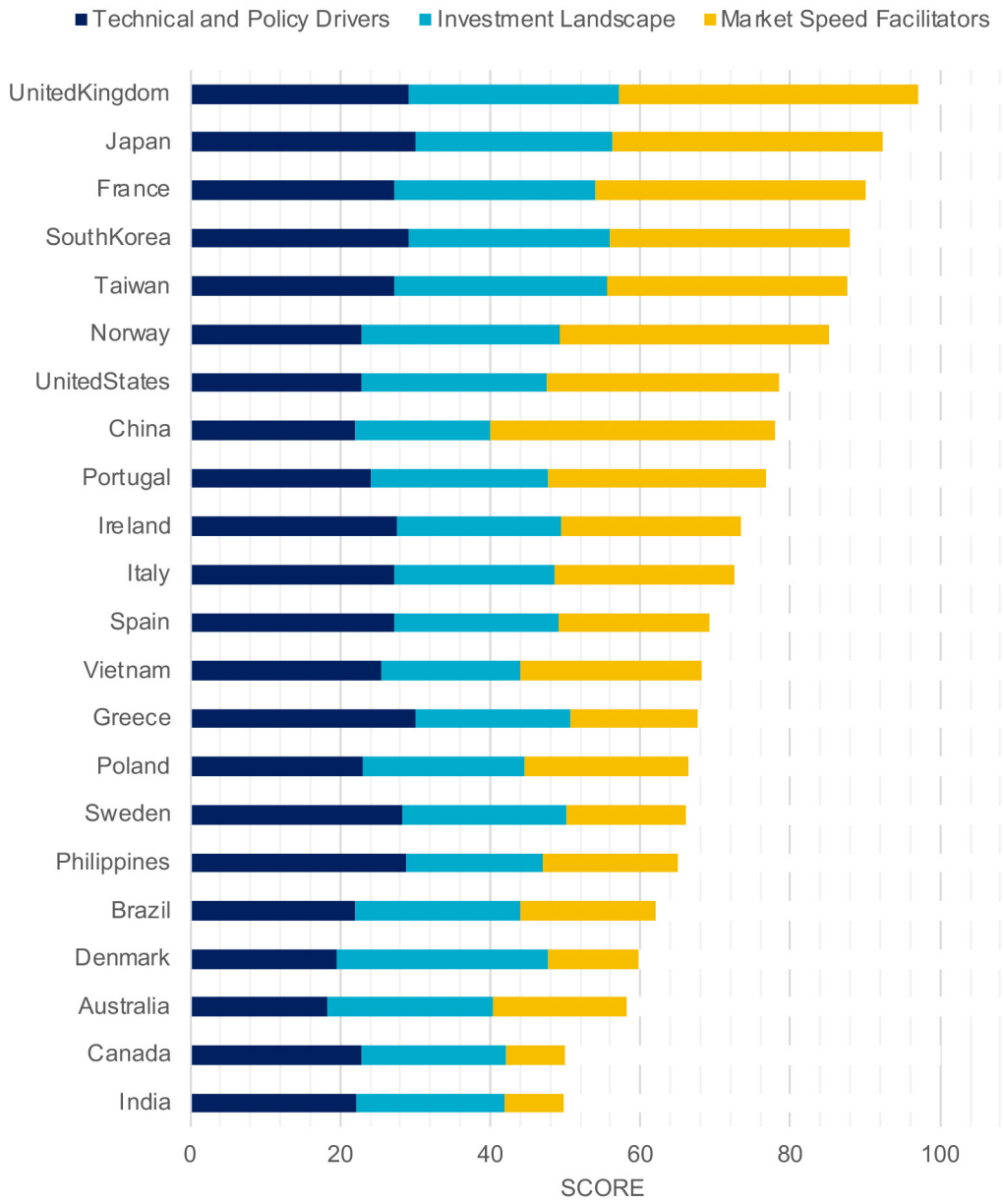
Near-term markets are predominately led by the markets with floating offshore wind pilot projects, as well as clear policy targets for floating offshore wind (e.g., United Kingdom, South Korea) and offshore wind power solicitations specific to floating offshore wind (e.g., France, Japan). Each of these territories also represent large power markets, where electricity generation and sales represent viable and commercially proven routes-to-market.

No.	Territory Name	Technical and Policy Drivers	Investment Landscape	Market Speed Facilitators	Weighted Score
1	United Kingdom	29	28	40	97.1
2	Japan	30	26	36	92.3
3	France	27	27	36	90.0
4	South Korea	29	27	32	88.0
5	Taiwan	27	28	32	87.6
6	Norway	23	26	36	85.3
7	United States	23	25	31	78.5
8	China	22	18	38	77.9
9	Portugal	24	24	29	76.7
10	Ireland	28	22	24	73.5
11	Italy	27	21	24	72.6
12	Spain	27	22	20	69.2
13	Vietnam	26	19	24	68.1
14	Greece	30	21	17	67.7
15	Poland	23	21	22	66.5
16	Sweden	28	22	16	66.1
17	Philippines	29	18	18	65.0
18	Brazil	22	22	18	62.1
19	Denmark	20	28	12	59.7
20	Australia	18	22	18	58.3
21	Canada	23	19	8	50.1
22	India	22	20	8	49.9

Source: OWC, 2022

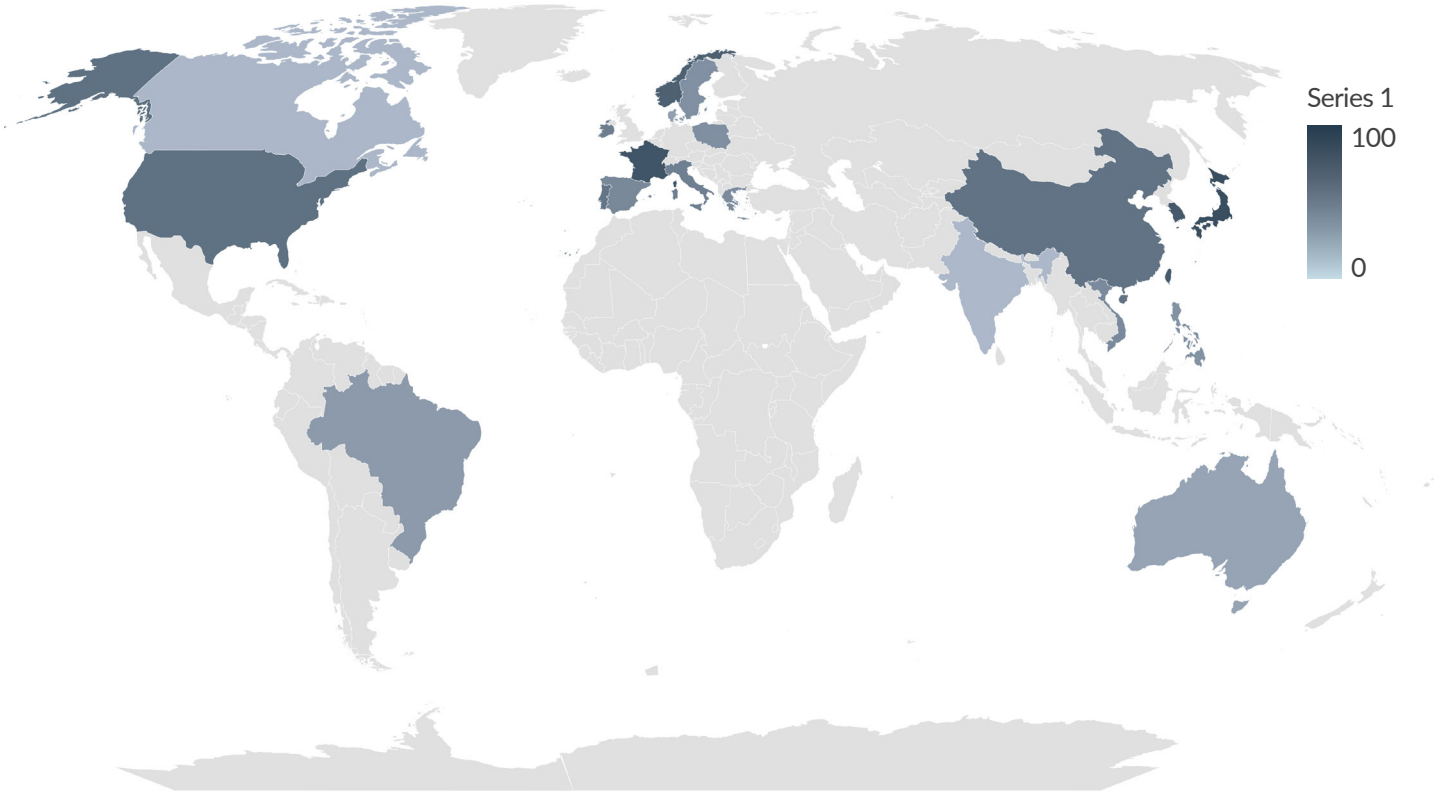
Figure 2-1: List of near-term floating offshore wind markets

The second band of near-term territories (territories 7-15) represent those with strong policy drivers and ambitious targets for offshore wind deployment and technical drivers to develop floating offshore wind. These markets have varying stage of fixed-bottom offshore wind development; however, each has substantial resource areas where floating offshore wind would be a competitive alternative in the territory's energy mix. Several of these territories have already begun spatial planning exercises for floating projects, and have seabed leasing procedures established. The remainder of territories in the near-term list are nascent offshore wind markets (with the notable exception of Denmark) but have strong technical and policy drivers for offshore wind. Notably, markets such as Greece and Philippines have substantially more resource potential in deeper waters conducive to floating offshore wind and will likely have to develop those resources in the near-term to meet renewable energy targets.



Source: OWC, 2022

Figure 2-2: Graph of near-term floating offshore wind markets



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Source: OWC, 2022

Figure 2-3: Map of near-term floating offshore wind territories (2022 – 2035)

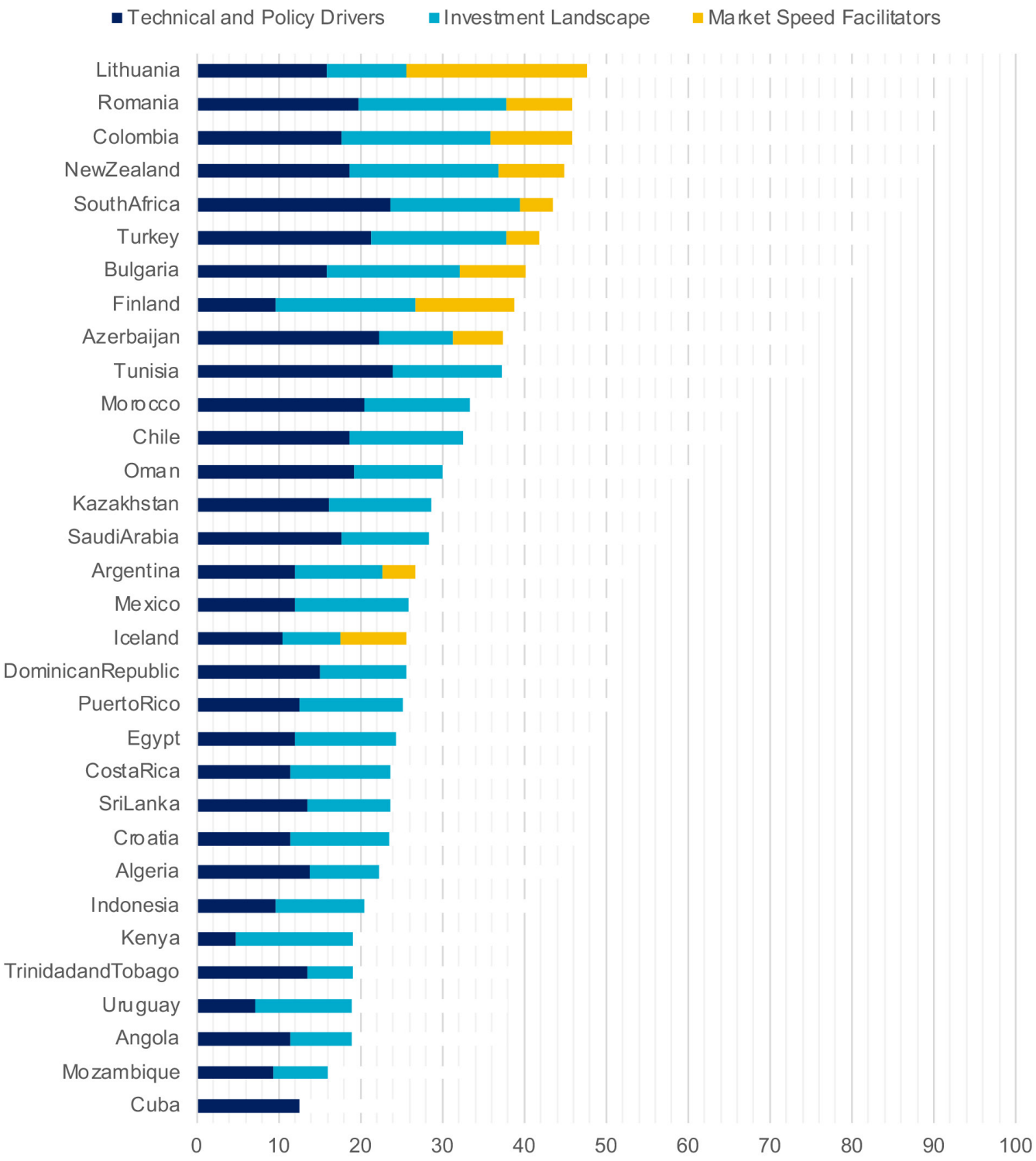
2.3 Long-Term Floating Offshore Wind Markets (2035 – 2050)

Long-term markets consist of several territories that have no stated policy targets for offshore wind. However, some of the territories on the list have publicly expressed interest in developing offshore wind, and a handful (Colombia, Turkey, Azerbaijan) have engaged with the World Bank ESMAP program for offshore wind roadmap studies. Nonetheless, several of the lower scored countries are highly speculative. These countries have sufficient technical resources for floating offshore wind but lack any specific market-building policy initiatives or market speed facilitators to encourage floating offshore wind. That notwithstanding, some of the lower ranked countries may present longer-term opportunities – and with the right combination of political and perhaps multilateral development support, could represent future markets for floating offshore wind.

No.	Territory Name	Technical and Policy Drivers	Investment Landscape	Market Speed Facilitators	Weighted Score
1	Lithuania	15.9	10	22	47.6
2	Romania	19.8	18	8	45.9
3	Colombia	17.7	18	10	45.8
4	New Zealand	18.6	18	8	44.9
5	South Africa	23.7	16	4	43.5
6	Turkey	21.3	17	4	41.8
7	Bulgaria	15.9	16	8	40.2
8	Finland	9.6	17	12	38.8
9	Azerbaijan	22.2	9	6	37.4
10	Tunisia	24	13	0	37.3
11	Morocco	20.4	13	0	33.4
12	Chile	18.6	14	0	32.5
13	Oman	19.2	11	0	30.1
14	Kazakhstan	16.2	12	0	28.6
15	Saudi Arabia	17.7	11	0	28.4
16	Argentina	12	11	4	26.7
17	Mexico	12	14	0	25.9
18	Iceland	10.5	7	8	25.6
19	Dominican Republic	15	11	0	25.5
20	Puerto Rico	12.6	13	0	25.2
21	Egypt	12	12	0	24.3
22	Costa Rica	11.4	12	0	23.7
23	Sri Lanka	13.5	10	0	23.7
24	Croatia	11.4	12	0	23.5
25	Algeria	13.8	8	0	22.2
26	Indonesia	9.6	11	0	20.5
27	Kenya	4.8	14	0	19.1
28	Trinidad and Tobago	13.5	6	0	19.0
29	Uruguay	7.2	12	0	18.9
30	Angola	11.4	7	0	18.9
31	Mozambique	9.3	7	0	16.1
32	Cuba	12.6	0	0	12.6

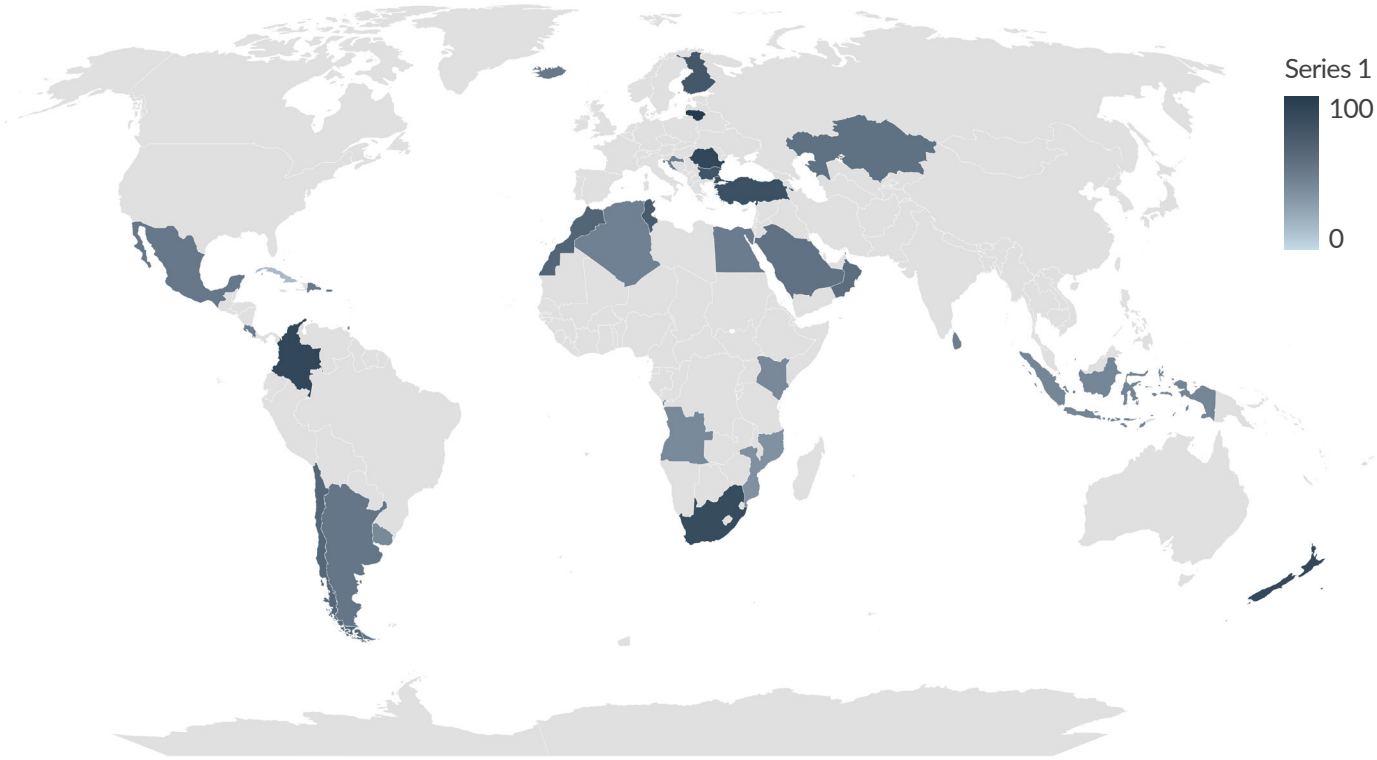
Source: OWC, 2022

Figure 2-4: List of long-term floating offshore wind markets



Source: OWC, 2022

Figure 2-5: Graph of long-term offshore wind markets



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Source: OWC, 2022

Figure 2-6: Map of long-term floating offshore wind territories (2035 – 2050)

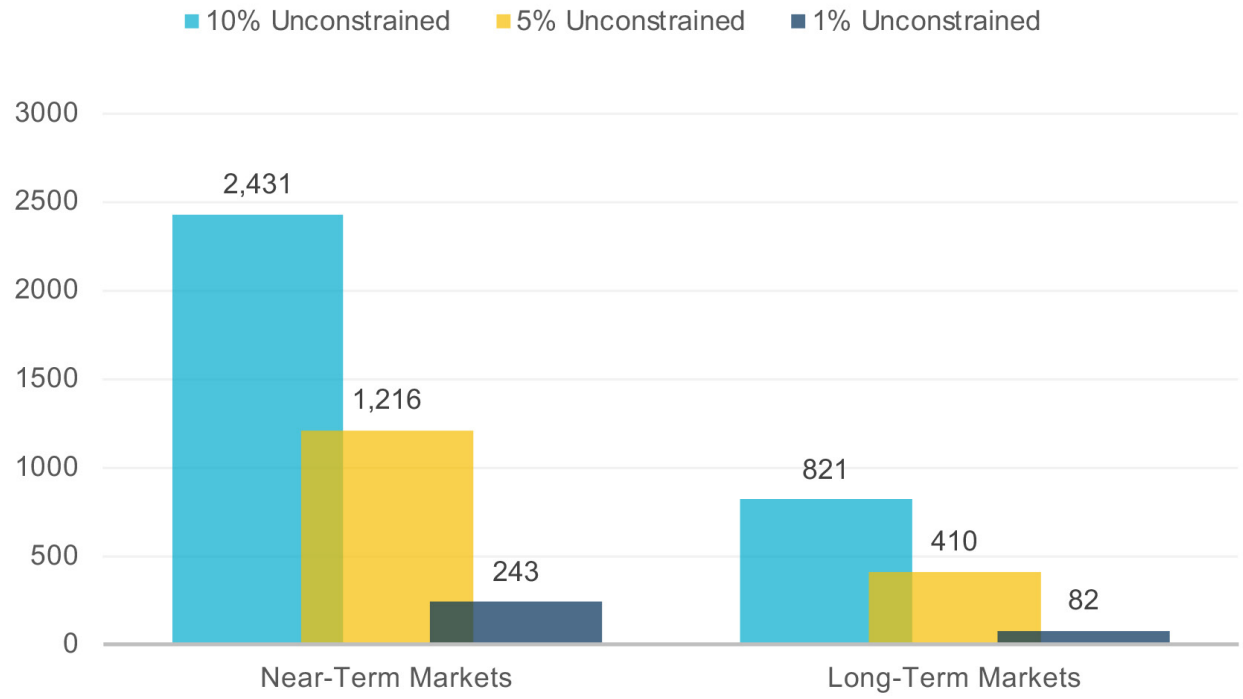
3 IMPLICATIONS

3.1 Scale of the Opportunity

3.1.1 Unconstrained and Constrained Potential

The 54 identified markets have a combined gross technical resource potential surpassing 32 TW (32,000 GW)[5]. Of this, the 22 near-term markets have an unconstrained (gross) technical resource capacity of 24 TW (24,000 GW), while the 32 longer-term prospective markets have a maximum floating resource potential of exceeding 8.2 TW (8,200 GW).

While not all of the technical achievable capacity could be feasibility developed due to conflicting maritime uses of the space and other environmental and social constraints, **developing just 1% of the technically available resources in the near-term markets would translate to over 240 GW of floating offshore wind renewable energy generation.**



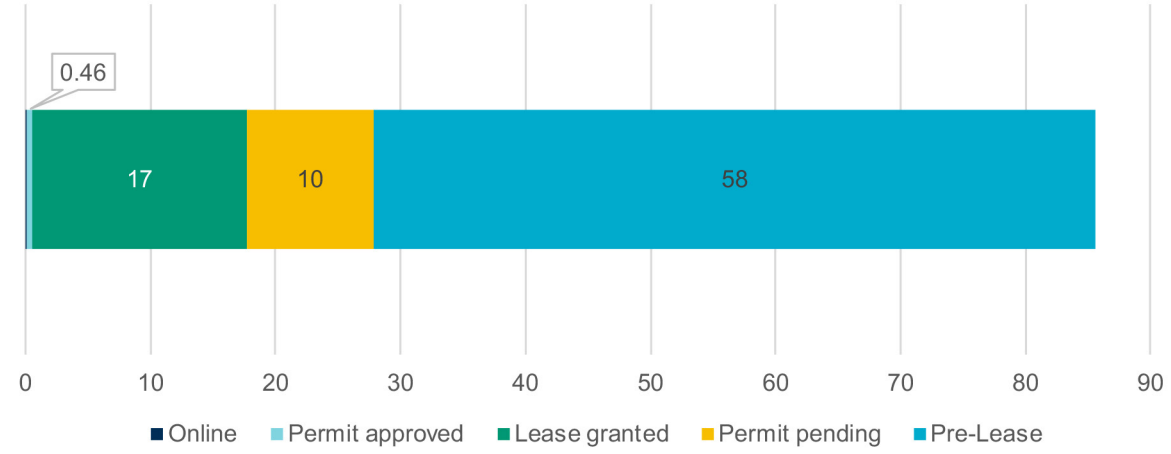
Source: OWC, 2022

Figure 2-1: Unconstrained capacity development scenarios (GW)

3.1.2 Pipeline of Projects

A solid pipeline of projects must be built in these near-term markets to reach net zero emissions targets. The floating offshore wind project pipeline has expanded rapidly in recent years and now totals up to 85 GW. This estimate includes approximately 17 GW of floating offshore wind farms in the pipeline that have secured site control or exclusivity (lease granted). However, of these, only ~0.5 GW have received full consent and are fully permitted. Several more projects have been announced (totalling approximately 58 GW),but have yet to secure site control. Examples include over 10 GW of announced projects in Europe (e.g., Italy, Greece), 12 GW of intended / announced projects in Australia and New Zealand, and up to 3 GW of potential floating offshore wind project areas being auctioned off California.

[5] According both to ESMAP analysis and OWC resource assessments for the areas compatible with floating offshore wind development

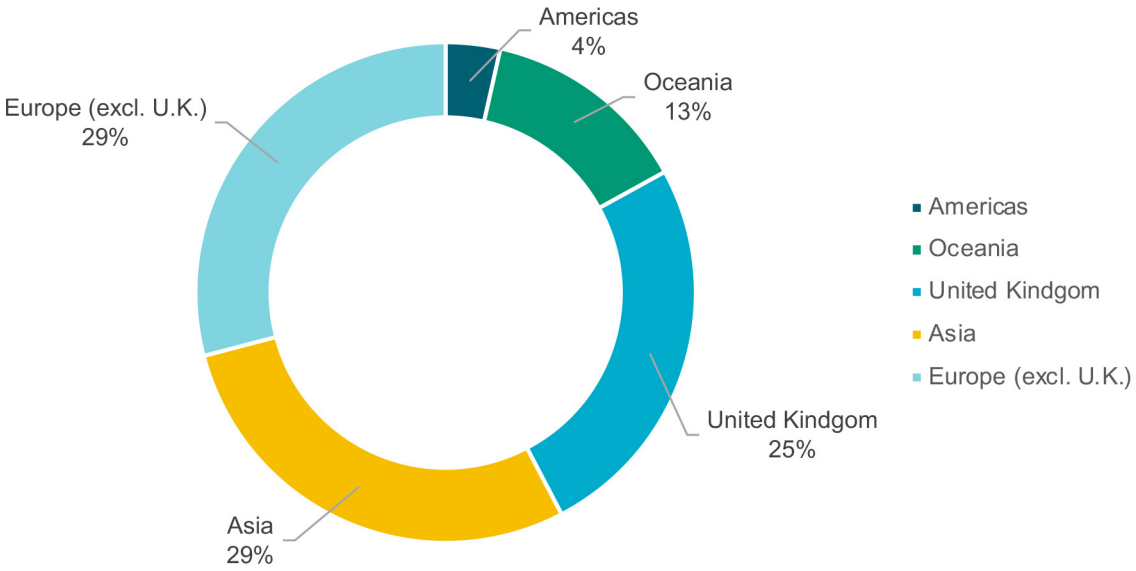


Category	Definition
Online	Projects that are currently online (commissioned)
Permit Approved	Projects that are fully consented and permitted
Lease Granted	Projects that have site exclusivity but are not fully permitted
Pre-Lease / Announced	Projects that have been announced but have not secured a site.

Source: OWC, 2022. Based on end-2021 data.

Figure 3-1: Global floating offshore wind pipeline (2022) – GW

The current pipeline for floating offshore wind projects is heavily concentrated in Europe + U.K. as well as East Asia (South Korea, Japan, Taiwan). The chart below represents the distribution of the nearly 80 GW of floating offshore wind projects in the pipeline.



Source: OWC, 2022. Based on announced floating offshore wind projects.

Figure 3-3: Global floating offshore wind pipeline by region (2022)

3.1.3 Growth Forecast

The IEA's Net Zero Emissions by 2050 scenario calls on annual capacity additions for offshore wind to reach 70 GW globally by 2030 and sustain up to 70 GW of annual of capacity additions through 2050. [4] As commercial floating offshore wind expands to new markets, floating wind farms are anticipated to account for approximately 15% of the global offshore wind market in the long term. [5] OWC anticipates that Floating Offshore Wind will need to reach current deployment rates of approximately 6 GW of annual new deployments by the second half of this decade, and accelerate to 12-15 GW of annual capacity additions longer-term to support capacity growth on par with Net Zero Emissions targets for offshore wind.

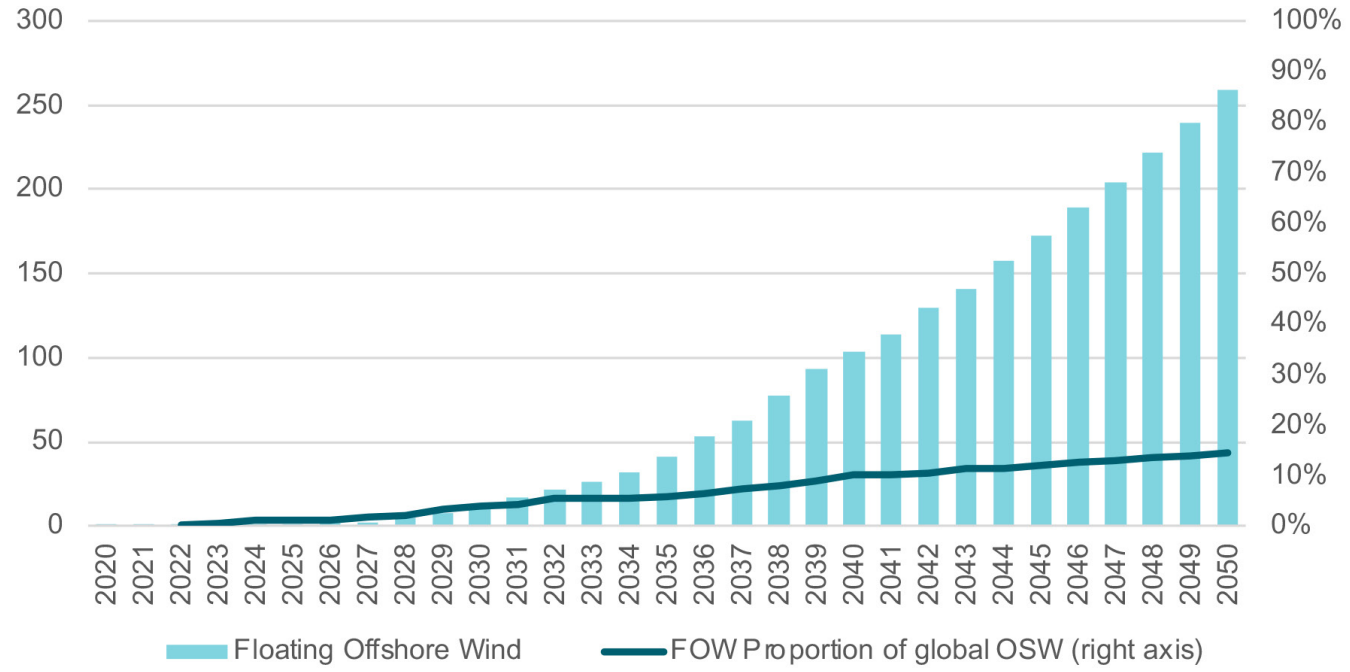
IEA Net Zero Emissions by 2050 Scenario			
Annual Capacity Additions (GW)			
	2020	**2030**	**2050**
Wind	114	390	350
of which Offshore Wind	5	80	70

*Source: IEA, 2021. *Floating wind estimated by OWC.*

Figure 3-4: Global floating offshore wind – annual capacity additions required

3.1.3.1 Long-Term Floating Market Development

Provided sustained policy momentum, long term cost of energy reductions, and global supply chain buildout that supports the aforementioned annual deployment scenarios, floating offshore wind is envisaged to exceed over 250 GW by 2050.



Source: OWC, 2022. As of March 31, 2022.

Figure 3-8: Global Floating Offshore Wind Capacity Forecast 2022 –2050 (GW)

Description of forecast:

- Based on the current global pipeline of projects, announced government targets and planned tenders for floating offshore wind, total global installed capacity is forecast to increase from approximately 200 MW by end-2022 to over 10 GW by the end of 2030.
- From 2030 – 2035, growth will accelerate rapidly, driven by multi-gigawatt growth of floating offshore wind in several major markets in Western Europe (United Kingdom, Ireland, France, Italy, Spain, Portugal), Asia (South Korea, Japan, Taiwan, China), and the United States. Global installed capacity is forecast to over triple, from 10 GW at the end of 2030 to nearly 40 GW by 2035.
- From 2035 – 2040, global installed capacity nearly doubles, surpassing 100 GW by the end of the next decade. This is driven by new markets adopting the technology and beginning to deploy multi-gigawatt of floating offshore wind installations. Annual deployment of new floating offshore wind farms increasing to approximately 10 GW per year.
- From 2040 – 2050, floating offshore wind continues to grow in mature markets in Western Europe and Asia, while gaining momentum in additional markets, notably in Latin America. The global supply chain is equipped to support 15 GW in annual deployment each year. By 2050, installed global floating offshore wind capacity is between 200 and 250 GW.

3.2 Readiness + Scale of Market Size

Below, the assessed "readiness" score and technical resources potential for floating offshore wind in each market, along with its annual power consumption (bubble size) are depicted. The results indicate a high level of readiness in many of the large-scale markets (e.g. Japan, UK, USA, China) which will likely develop in the near-term; whereas longer-term markets may in general represent smaller market opportunities from a size and scale perspective.

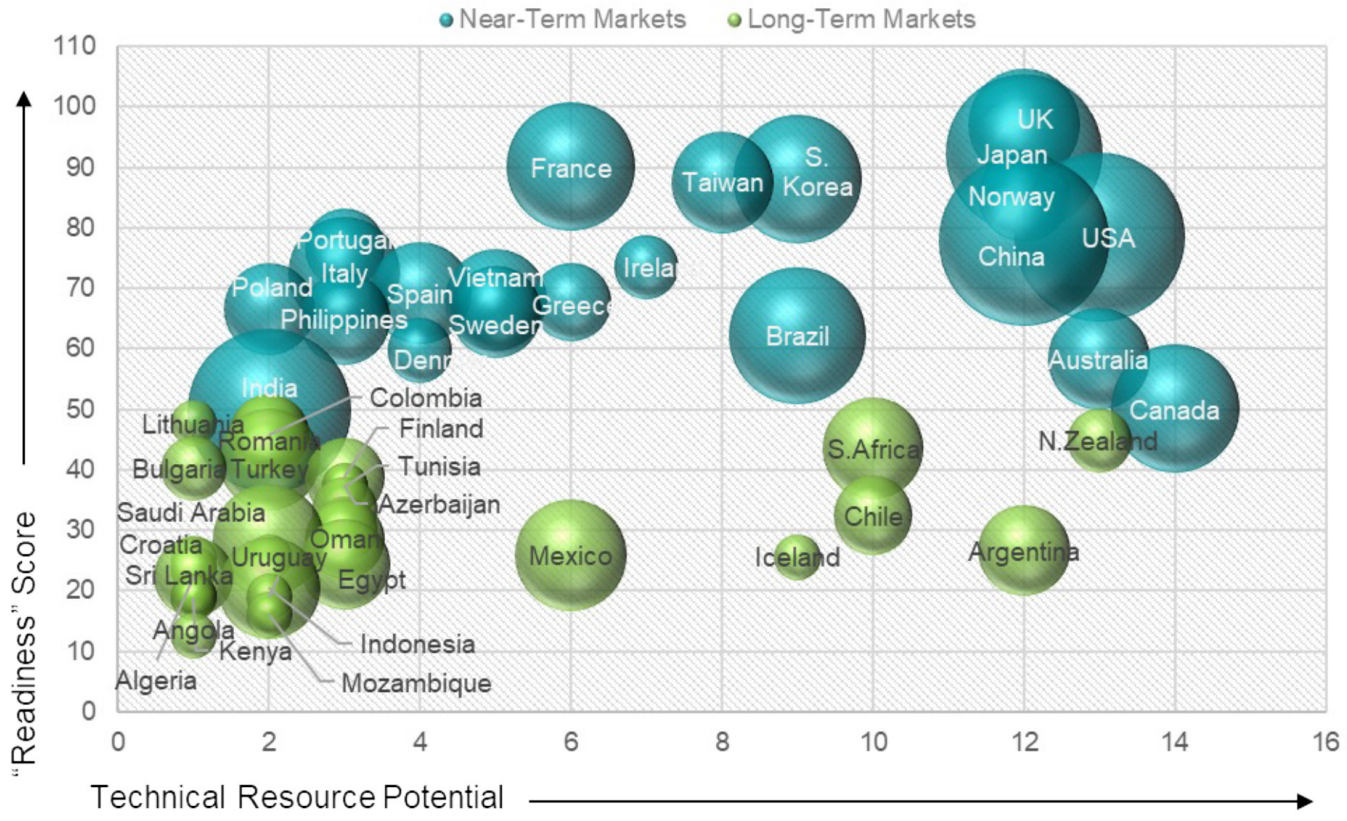


Figure 3-9: Readiness and Scale of Market Size

Technical resources and electricity consumption were plotted using the scoring values below.

Technical potential scoring bands (X-Axis)

Technical Potential (GW)	Score Value
>5000	14
2500-5000	13
1000-2500	12
900-1000	11
800-900	10
700-800	9
600-700	8
500-600	7
400-500	6
300-400	5
200-300	4
100-200	3
50-100	2
10-50	1
10 or less	0

Source: OWC, 2022

Electricity Consumption Scoring Bands (Bubble)

Power Consumption (TWh/y)	Score Value
>2000	14
1000-2000	13
900-1000	12
800-900	11
700-800	10
600-700	9
500-600	8
400-500	7
300-400	6
200-300	5
100-200	4
50-100	3
25-50	2
10-25	1
10 or less	0

Source: OWC, 2022

Those territories in the top half of the chart are most likely to represent the "low hanging fruit", and in particular those markets in the top right quadrant. Given the high "readiness" score of these markets, well as the large potential of technical resource and large power markets, it is anticipated these markets will develop in the near-term. Conversely, severely markets that still meet technical and socio-economic fundaments, are at a lower level of regulatory and commercial readiness, and typically also represent smaller scale opportunities.

3.3 Additional Considerations

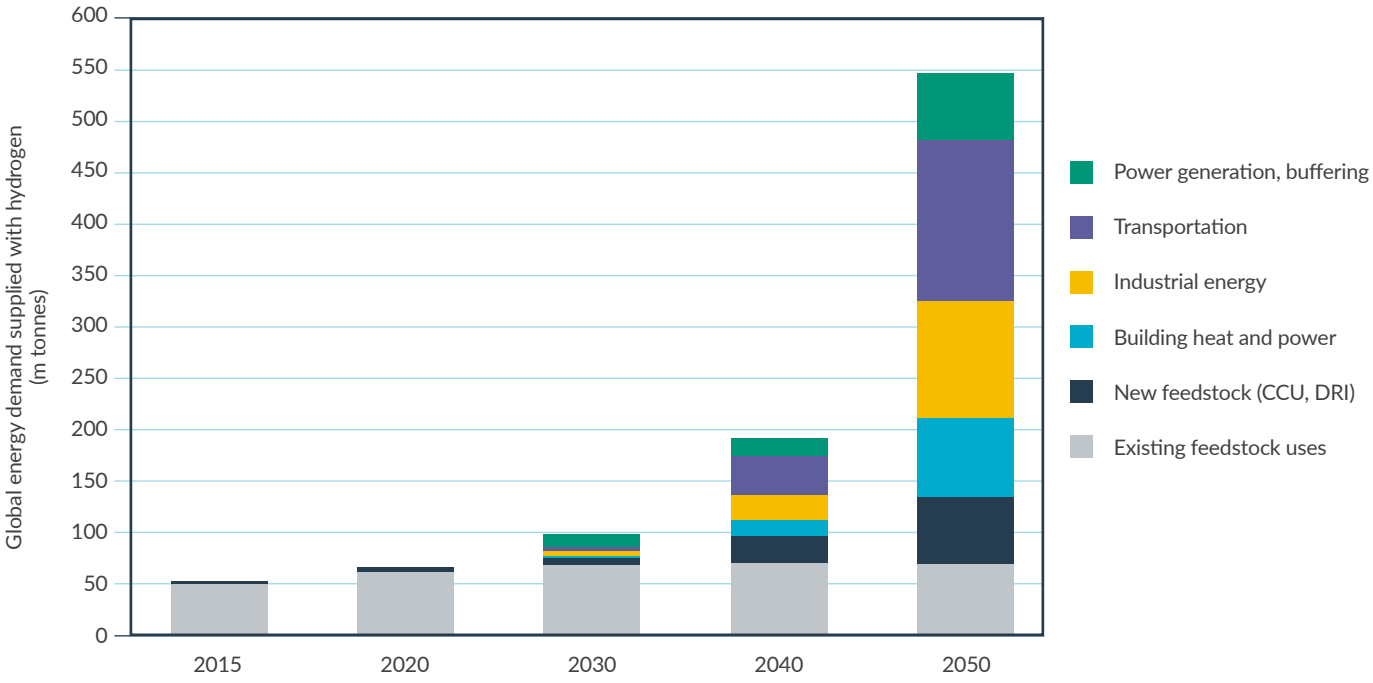
To-date, the primary route-to-market for offshore wind has been to generate and sell grid-connected electricity. However, we recognize that additional route-to-markets will be available for floating offshore wind – from powering offshore oil and gas platforms, to generating green hydrogen by electrolysis. Moreover, buildout of grid and transmission infrastructure may make previously unattractive power markets more capable of supporting scalable floating offshore wind. Below, we briefly review some of the additional possibilities for floating offshore wind.

3.3.1.1 Power to "X" Market Development – Green Hydrogen

As floating offshore wind moves further offshore, power transmission distances approaching 100 miles are seen to become less practical and HVDC systems may be required. This would require considerably larger and more costly offshore transformer and converter substations [6]. Additionally, the cost of the cables to shore will rise. All the remaining energy transport options identified are based on hydrogen, which as an energy vector has an advantage over electricity that it is also a means of storing energy [6]. An alternative to transporting hydrogen is to combine it with nitrogen to form ammonia. It is much easier to transport liquid ammonia in pipelines at relatively low pressures. Another alternative would be to export the ammonia by vessel, by piping the ammonia to a SALM (single anchored leg moor) for loading.

Although the hydrogen route to market for floating wind is promising (as presented in Table 3 7 below), there are several challenges with offshore production of hydrogen by electrolysis of sea water [7]. The foremost technical challenge for producing renewable hydrogen offshore is the development of electrolyser modules, which are compatible with that environment, while being sufficiently compact to achieve very high rates of hydrogen production per platform or per wind turbine, and able to survive long term when connected directly to an intermittent variable renewable power supply. Different specific conditions, including the marine environment, stringent safety requirements, commercial terms of existing delivery contracts and difficult accessibility make it very challenging.

Nonetheless, there has been an increase in global hydrogen demand in multiple use sectors as depicted in Figure 3-6 below, which has been co-produced by using vertical analysis in a completed project co-authored by an OWC's hydrogen team in 2020. There is every indication that the increasing long-term demand for hydrogen will further compel floating offshore wind developers to seek it out as a potential route-to-market.



Source: "Hydrogen Scaling Up." Hydrogen Council (2017). [9]

Figure 3-6: Global demand in hydrogen energy 2015 – 2050 [8]

With respect to installed floating offshore wind capacity required to support hydrogen demand, assuming that average capacity factor of floating wind is 45% and power energy input required to produce 1 tonnes hydrogen by water electrolysis is 52 MWh [10], we calculated the floating wind capacity needed to supply 1%, 5%, 10% and 20% global hydrogen demand by 2030, 2040 and 2050 as presented in Table 3 10 below.

Year	2030	2040	2050
Global hydrogen demand (million tonne) from Figure 4 1	98	196	546
Floating wind capacity (GW) for 1% global H2 demand	12.9	25.9	72.0
Floating wind capacity (GW) for 5% global H2 demand	64.6	129.3	360.1
Floating wind capacity (GW) for 10% global H2 demand	129.3	258.5	720.2
Floating wind capacity (GW) for 20% global H2 demand	258.5	517.1	1,440.5

Source: OWC, 2022.

Figure 3-7: Global floating wind installation to supply parts of hydrogen demand

In the long-term, green hydrogen production and sales may be a promising route-to-market to support large scale floating offshore wind. However, due to several technical and economic challenges and uncertainties, this study focuses on electricity sales as the primary route-to-market for supporting commercial scale floating offshore wind.

4 SELECT MARKET PROFILES

4.1 General

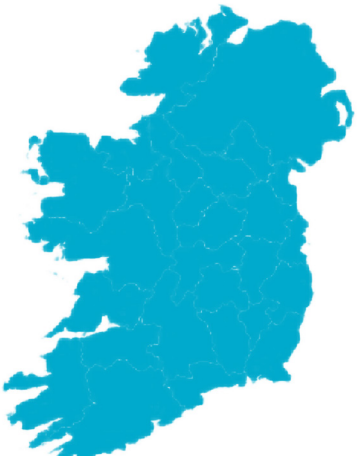
Select future floating offshore wind markets have been profiled below.

4.2 Select Near-Term Market Profiles

United Kingdom
5 GW by
2030 target

As part of the Build Back Greener initiative, the UK government set a target of 1GW of floating offshore power by 2030. To support this goal, the UK Contract for Difference's auction pot 4 allocated EUR 28 million to floating wind projects in 2021. Recently, the UK awarded EUR 31.6 million to support floating offshore wind technology through the competitive funding scheme, Floating Offshore Demonstration Programme, which funds 11 projects in total. As of now, the UK has two floating offshore wind projects installed, Hywind Scotland, Kincardine, and several more consented including the 95 MW Erebus floating offshore wind project. In 2022, the government increased its floating offshore wind ambition, up to 5 GW by 2030.

Ireland
5 GW OSW
by 2030



Ireland has identified 4 sites that have ideal conditions for floating offshore wind: Ireland's Northern Pacific Ocean has a water depth between 100-150 meters and wind speeds range from 10 to 11 m/s. In the southern and south-western areas by the Irish Sea, there are various coastal sites with ideal winds of 9 to 10 m/s. The Irish Government plans to develop floating offshore wind in these sites to help achieve their goal of 5 GW of installed offshore wind capacity. The government plans to host three offshore wind auctions to start offshore wind development in both these and other sites. With ideal environmental conditions in combination with favourable government initiatives, Ireland's floating offshore wind market has high potential. Stakeholders recognize this and have already made investments in several floating offshore wind projects off of Ireland's coast, building a pipeline of approximately 4 GW of projects by mid-2022.

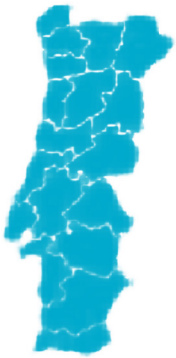
France
750 MW
by 2030

France is actively expanding its floating offshore wind industry with various new projects in sight. The government has a target of installing 5.2-6.2 GW of offshore wind capacity by 2028. To reach this target, France is scheduling to auction 750 MW of floating offshore wind power. France launched a competitive tendering procedure for the development of two 250 MW floating offshore wind farms in the Mediterranean. This follows the tendering of a 250 MW floating wind project offshore Brittany. France also has four floating offshore wind projects under development. In total, the country plans to spend up to EUR 300 million to advance development of the floating offshore wind industry.

Norway
Plans to auction
4.5 GW of Floating

Norway makes huge strides in the floating offshore wind industry as they develop the world's largest floating offshore wind farm, Hywind Tampen, with a capacity of 88GW, anticipated to be commissioned in 2022. Continuing offshore wind development, the government will be auctioning offshore wind in two coastal areas: Utsira (1.5GW) and Sørlige Nordsjø 2 (3GW). Utsira in particular is suitable for floating offshore wind due to average water depths of 267m. Development in this area is intended to expand offshore wind by 4.5GW. The government will host its next licensing round in 2025 with the aim to develop 30 GW of offshore wind capacity by 2040. Norway's high technical potential for floating offshore wind (1,416GW) and ideal conditions positions Norway as one of the top potential leaders in floating offshore wind industry. The Norwegian Offshore Wind Cluster aims to be the strongest global supply chain for floating offshore wind.

Portugal
1-3 GW Floating
OSW Target



Portugal has one of the first operational floating wind farms, the 25 MW WindFloat Atlantic, that has been operating since 2020. Working towards the country's target of generating 80% of electricity from renewable sources by 2030, Portugal will hold its first offshore wind tender potentially in 2023. The country intends to auction 3-4 GW of offshore wind power in the Portuguese Atlantic Ocean which they aim to have the projects operating by 2026. Most of these sites will be floating wind projects as floating offshore wind makes up 117GW of the country's 131 GW of technical potential.

Spain
Auctioning 3-4 GW
of Floating

Spain possesses a well-developed domestic supply chain for wind technology which could allow production to easily transition to floating offshore wind. The Spanish government recently set firm targets for floating offshore wind development by approving the Roadmap for Offshore Wind and Marine Energy, which aims to research, develop, and build 1-3 GW of floating offshore wind in Spain by 2030. The government will allocate EUR 200 million to fund the roadmap's goals by the end of 2023. Spain has 207GW of floating offshore wind technical potential.

Greece
2 GW Floating
OSW Target

Greece currently has a floating offshore wind technical potential of 413GW. In order to fulfil the goals of their National Energy and Climate Plan, as well as their target of 2 GW of offshore wind, the country is anticipated to release a new legal framework for offshore wind projects in late 2022, as well as potential marine spatial planning with fixed-bottom and floating zones potentially designated. . In preparation, several developers have announced planned projects in Greece.

Philippines
17 GW Floating
OSW Possible

The Philippines' Department of Energy (DOE) and the World Bank Group developed an Offshore Wind Roadmap for the Philippines which lays out the next steps for developing Philippines' offshore wind market. The roadmap outlines policies, infrastructure, financing and other recommendations needed to install 21GW of offshore wind power by 2040, 17GW of which will be floating. There are currently three areas of interest for floating offshore wind, one in close proximity to Manila. This area has sites with wind speeds up to 10-11 m/s creating ideal conditions for floating offshore wind. These sites being in close proximity to Manila is extremely advantageous as it holds the largest load centre in the country. Floating offshore wind in the Philippines has a technical potential of 160GW of the 178 total technical potential.

Vietnam
54 GW of offshore wind by 2050

Vietnam has great potential for offshore wind development due to its long coastlines and wind resources. The country has a floating offshore wind technical potential of 338 GW out of 599 GW total technical potential. Vietnam is finalizing approval of the amendments to their energy plan, Power Development Plan 8, to reach their goal of net-zero emissions by 2050. Offshore wind development will take off once the Power Development Plan 8 is finalized and their official offshore wind target is established. They currently aim to have 54GW of offshore wind capacity by 2045 and have set ideal sites for floating offshore wind development, one being off Ninh Thuan.

Brazil
First OSW projects under review

Brazil's commitment to having 48% renewables in its energy mix by 2030 drives the expansion of the country's offshore wind market. The government recently announced a decree which enables offshore wind research and generation projects. This is Brazil's first step in offshore wind development. In response, there has been an influx of proposals from stakeholders looking to develop, several of which are floating offshore wind developers. Brazil's environmental assessment and authorization body, IBAMA, is currently evaluating offshore wind projects totalling than more than 80GW of wind power. Brazil has the floating offshore wind technical potential of 748GW.

Australia
First floating projects under development

The first to take action in Australia is the state of Victoria announcing they aim to generate 3GW by 2035 and 9GW by 2040 through offshore wind power. The state will invest $40 million underneath the Energy Innovation Fund to the research and pre-construction of offshore wind projects. Australia currently has several offshore wind projects in the early development stages, including plans to develop three major offshore wind projects, two of which are floating offshore wind. A proposed floating offshore wind project is in the waters of Newcastle, New South Wales and will have a capacity of 1.4GW, and a second project is proposed off Wollongong, New South Wales with a capacity of 1.6GW. Although the country has yet to announce official floating offshore wind targets, Australia's market has lots of opportunity with a floating offshore wind technical potential of 3,391 GW.

China
Potentiall 100 GW
Floating OSW by 2050

China's offshore wind capacity is growing at impressive rates, and the country now accounts for 40% of the world's total offshore wind capacity with a total of 19.7GW of installed capacity (2021). China's new offshore wind development was supported by the country's feed-in tariff (FIT) but is being phased out in 2022. Continued new offshore wind installations are dependent to a large extent on the strength of provincial government support. Some plan to continue to subsidize projects. Each province implements their own plan with individual targets: Jiangsu (30GW OSW by 2030), Guangdong (30GW by 2030), Fujian (50GW over unknown time), Zhejiang (10GW by 2030), Shandong (10GW by 2025), Liaoning (3.25 by 2025). Floating offshore wind technology has more traction in Guangdong, Fujian and Zhejiang. China's first floating offshore wind turbine is located off Guangdong. The country is determined to develop, manufacture, and install the country's own floating offshore wind technology. China has major potential to expand its floating wind market due to its floating offshore wind technical potential of 1,582GW. DNV GL (2021) forecasts the size of China's floating offshore wind market to exceed 100 GW by 2050.

5 CONCLUSION

This decade is poised to see floating offshore wind enter a global commercial phase and start to emerge as a major contributor to carbon-free power generation. By 2030, floating offshore wind markets will begin to proliferate – expanding to additional offshore wind markets in Western Europe as well as markets in Asia and the Americas. In this study, we screened over 240 territories and identified 54 potential floating offshore wind markets. We assessed the "readiness" of those 54 markets to support commercial floating offshore wind based on 11 custom criteria spanning technical and policy drivers, commercial investment environment, and market facilitators for floating wind.

Our assessment categorized future floating offshore wind markets as follows:

2022 - 2030	2030 - 2035	2035 - 2050
• United Kingdom	• Italy	• Colombia
• South Korea	• Greece	• Bulgaria
• Japan	• Canada	• Morocco
• Norway	• Sweden	• Tunisia
• France	• Vietnam	• Turkey
• Ireland	• Philippines	• Finland
• Taiwan	• Brazil	• Lithuania
• China	• Australia	• South Africa
• Poland	• Romania	• New Zealand
• Spain	• India	• Chile
• Portugal		• Costa Rica
• United States		• Kenya

Source: OWC, 2022.

The extent and certainty to which many of these identified markets will emerge as future floating offshore wind markets depends foremost on policy: commitments, ambition, and implementing market-enabling policies, establishing firm growth targets and establishing procedures to facilitate private-sector investment and market growth.

With strong policy momentum and global expansion of floating wind, the size of the global floating offshore wind market could exceed 250 GW by 2050 – up from less than 0.2 GW now. However, achieving this scenario requires a massive step-up of annual capacity additions - to approximately 5-6 GW by the end of this decade and 10 GW or more within the next decade. As such, it is imperative that today's leading floating offshore wind markets set the foundation and a template for rapid deployment of floating offshore wind for both mature and emerging markets.

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