Floating Wind

Challenges and Opportunities

11/05/2023

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Summary

1. SSER Position
2. Why Floating Wind?
3. FOW Technology and Status
4. FOW Projects and Locations
5. Challenges and Opportunities
6. Concluding Remarks

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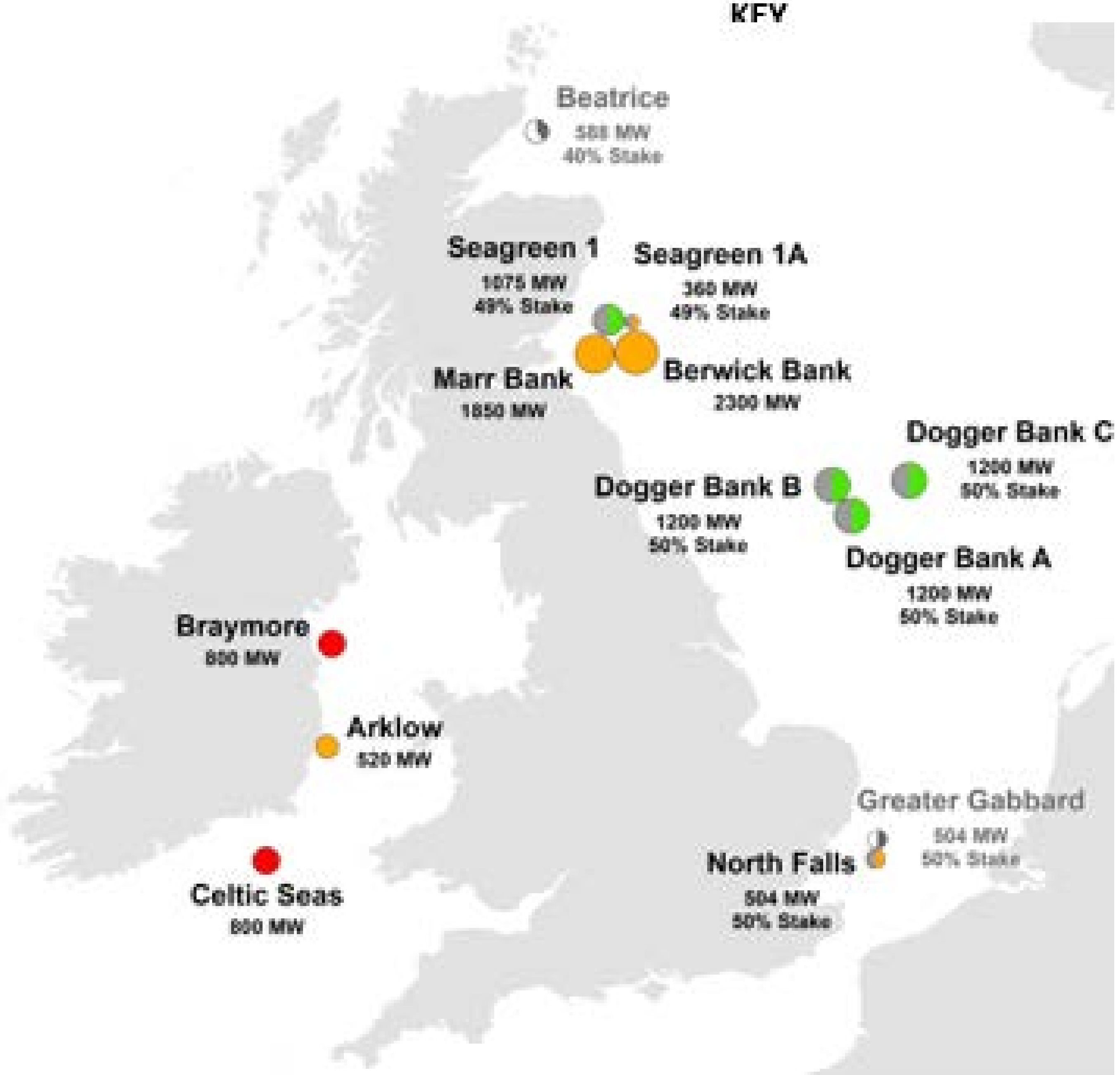
SSER Position – Bottom-fixed

- SSER is developing offshore wind for over 15 years
- Over 1459MW of installed offshore wind capacity
- Currently own and operate >1GW of offshore wind
- >3GW in construction
- >6GW of offshore wind in development
- Largest portfolio (operational, construction & development) of UK fixed bottom offshore wind projects



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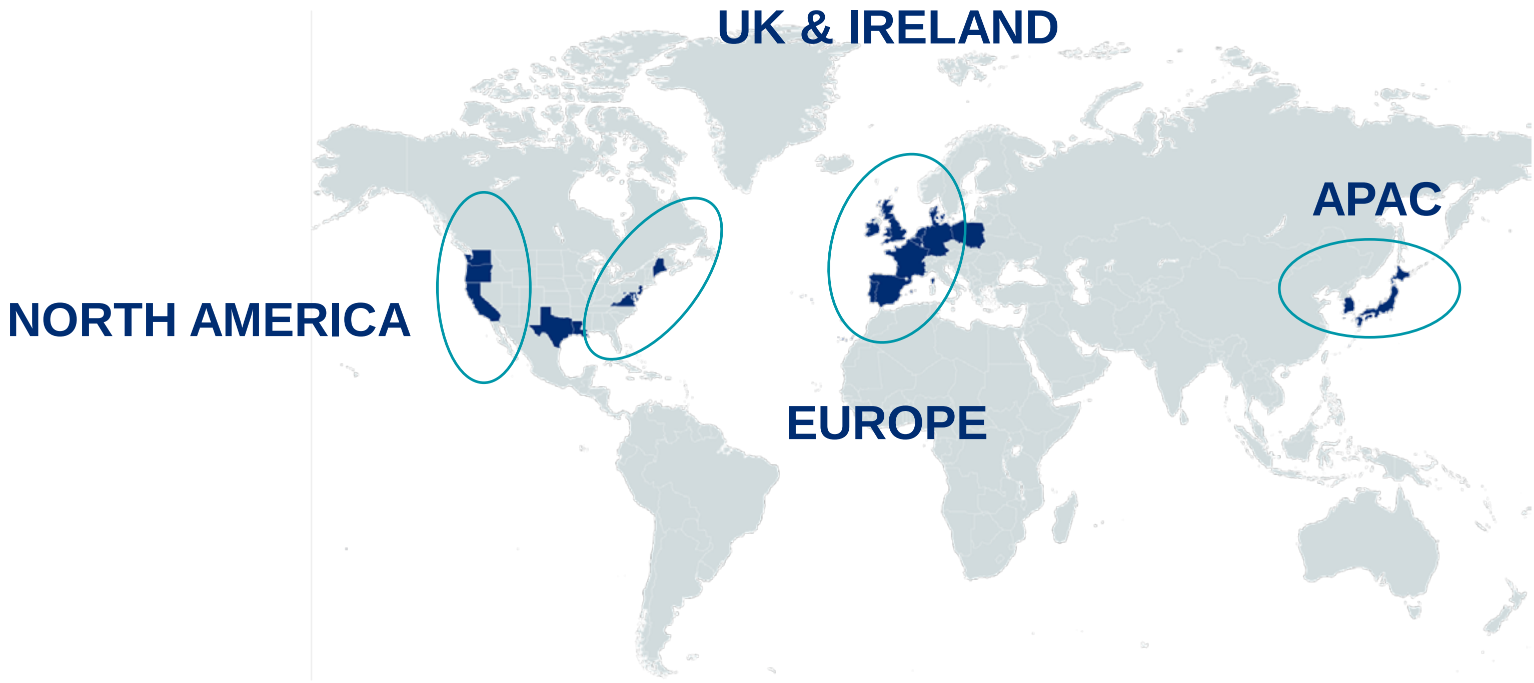
SSER Position – Floating Wind

- Over 80% of potential offshore sites are in deep waters
- FOW projected to make-up 10-20% of offshore build-rate by 2030
- FOW unlocks offshore wind potential globally
- SSER has secured 3.6GW FOW pipeline
- Target >5GW pipeline by 2030/31



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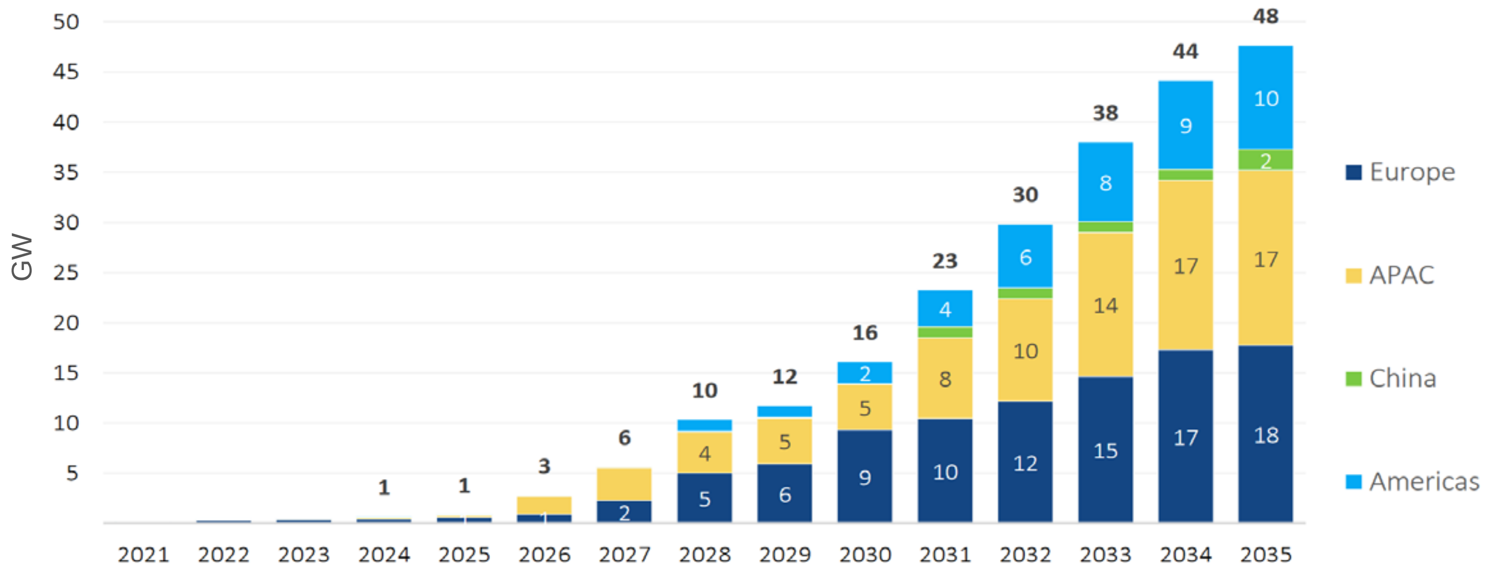
Why Floating Wind?

- Bottom-fixed wind becomes exponentially more challenging with greater depth
  - Current (2022) max depth is ~65m for bottom-fixed
- ~80% of global offshore wind resources are in locations **suited for floating,** with opportunity for larger capacity
- FOW enabler to decarbonisation for key regions (e.g. Japan, California) with very **limited continental shelf**
- Long term, many industry analysts believe FOW can deliver greater cost reductions than bottom fixed offshore wind

Cumulative Floating Wind Capacity Forecast



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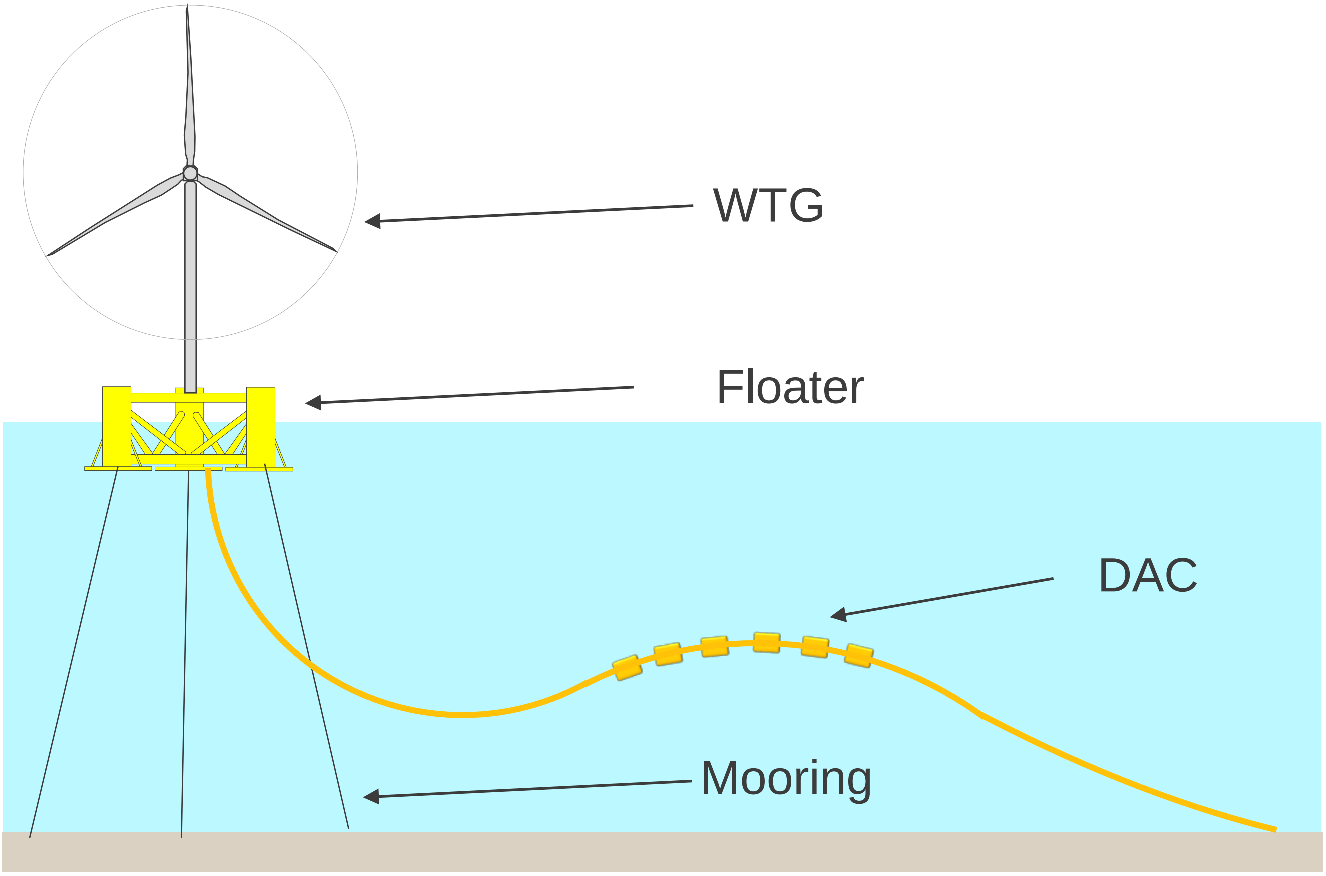
FOW Technology and Status

Floating Wind System



- Floating wind installations are complex systems requiring an integrated view
- Holistic approach required for the definition of:
  - Floater (Sub-structure)
  - Mooring system
  - Anchors
  - Dynamic Array Cable (DAC)
  - Transportation and Installation (T&I)
- No "one size fits all" solution - several options available, depending on project reqs and conditions

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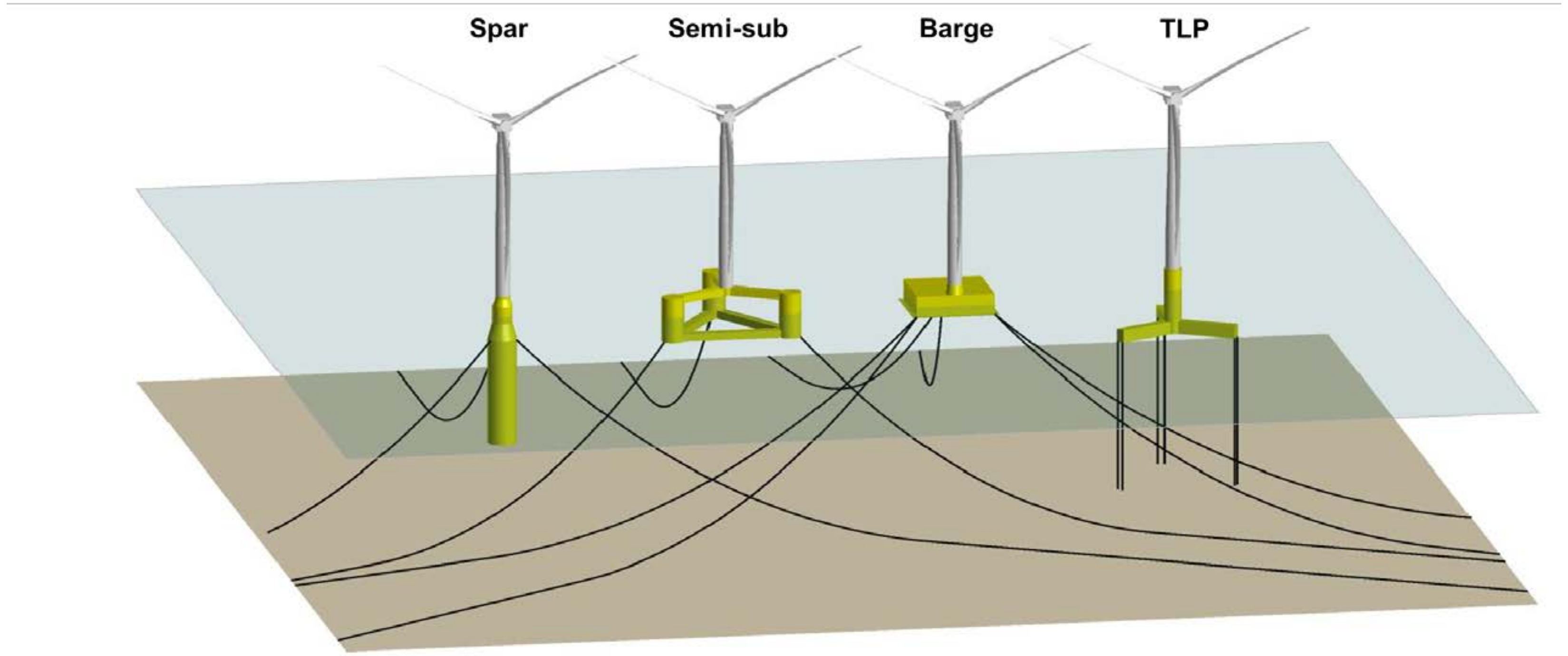
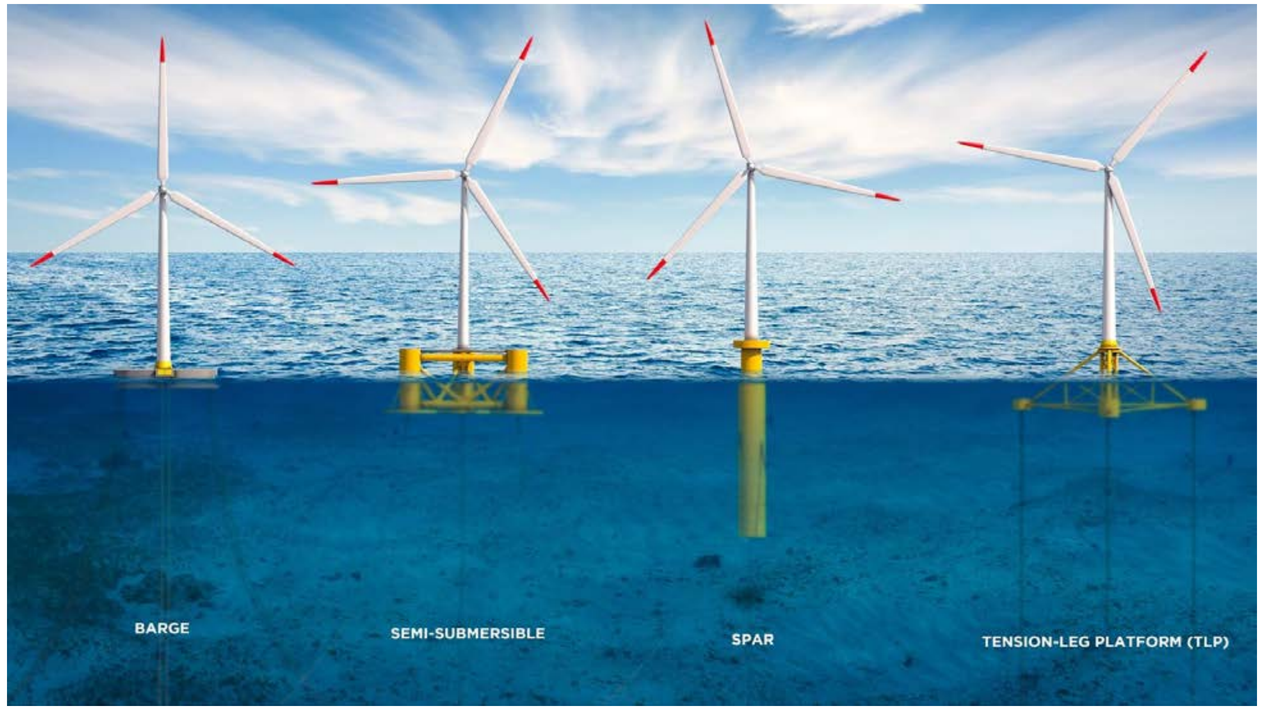
FOW Technology and Status

Floating Sub-Structures





Floaters are classified into four types

- **Spar:** Simple & proven design, but restricted to deeper waters (>100-200m)
- **Semi-sub:** Most widely developed/adopted and flexible design (many variants), but often requiring large and heavy structure
- **Barge:** Geometrically simple design but prone to poor dynamic and sea-keeping performance
- **TLP**: Alternative design with superior dynamic performance but lower maturity and complex design considerations

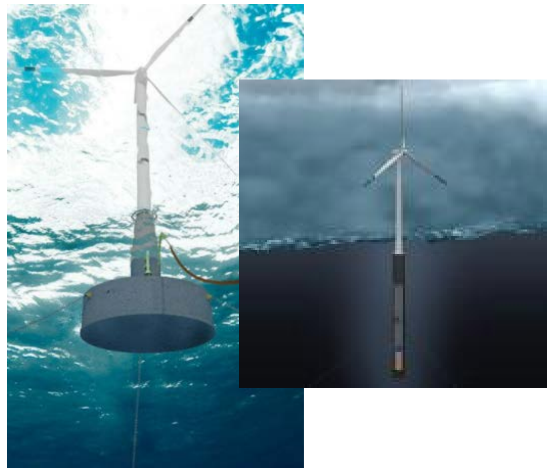
FOW Technology and Status

Floating Sub-Structures

Over 40 different foundation designs commercially available

Potential selection considerations:

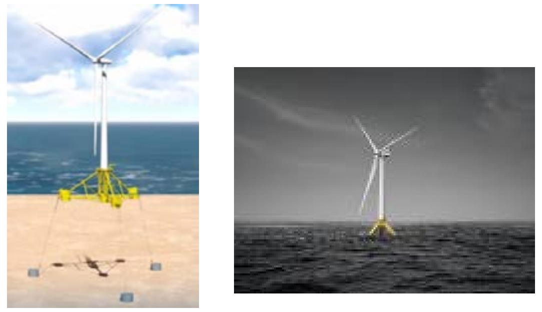
- Floater type (Spar, Semi, Barge, TLP …)
- Material (steel, concrete)
- Dimensions (e.g. draft for port?)
- Footprint
- Qualification and TRL (Technology Readiness Level)
- Fabrication and Logistics
- T&I
- Access and O&M



Spar

Semi-sub

Barge



TLP

FOW Technology and Status

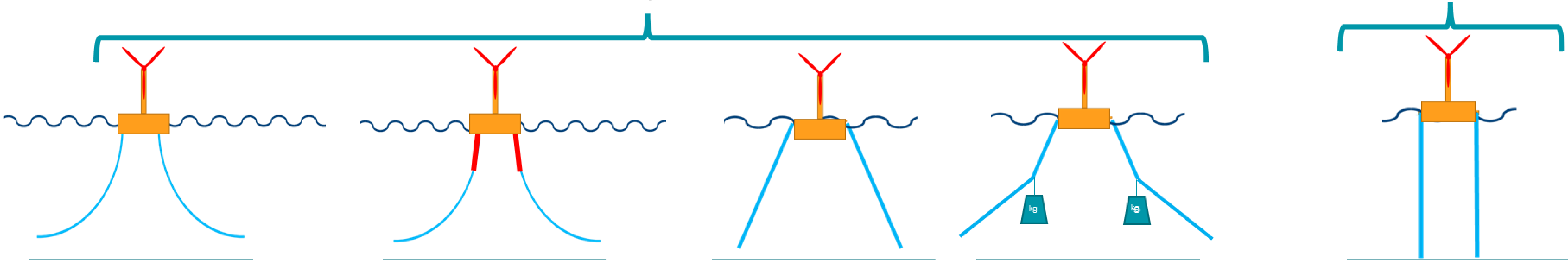
Mooring Systems

Several types of mooring systems available – design often site-specific and dependent on floater

Industrialisation and footprint constraints are an opportunity for semi-taut and taut synthetic fibre

Compliant

Restrained



Catenary

- Widely accepted
- Established modelling
- Limited fatigue/reliability
- Logistics/supply chain

Hybrid/semi-taut

- Removes chain from splash zone
- Increased operating envelope
- More interfaces

Taut

- Reduced peak tensions
- Improved supply chain
- Reduced CAPEX
- Not length stable
- Robustness issues

Geometric compliance

- Optimisation of catenary & taut (EA < nylon)
- Increases interfaces & install challenge
- Limited class acceptance (low reliability)

TLP

- >>criticality than compliant
- Robustness common with compliant
- Install & hook up challenge

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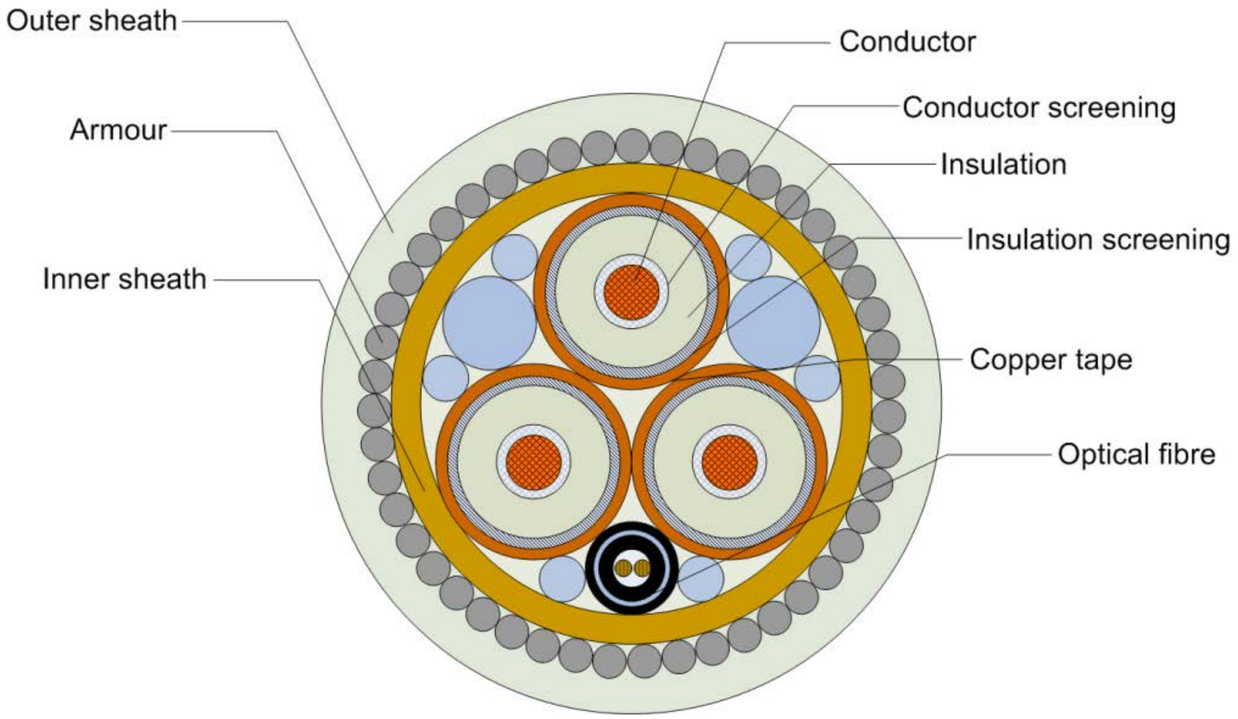
FOW Technology and Status

Cabling and Connection

- Range of cable suppliers but dynamic cables may require bespoke development for HV
- Inter-Array Cables subject to significant motions with fatigue issues
- Ancillary components for cable layout (buoyancy elements, stiffeners etc.)
- Subsea connectors for dynamic applications still novel developments



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FOW Technology and Status

Construction, Transportation and Installation

- Scaling up the manufacturing is a significant challenge for industrialisation
- Limited facilities can allow WTG integration
- Wet tow vs. dry tow options
- Full-scale farms may require appropriate logistic considerations (e.g. wet storage)

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FOW Projects and Locations

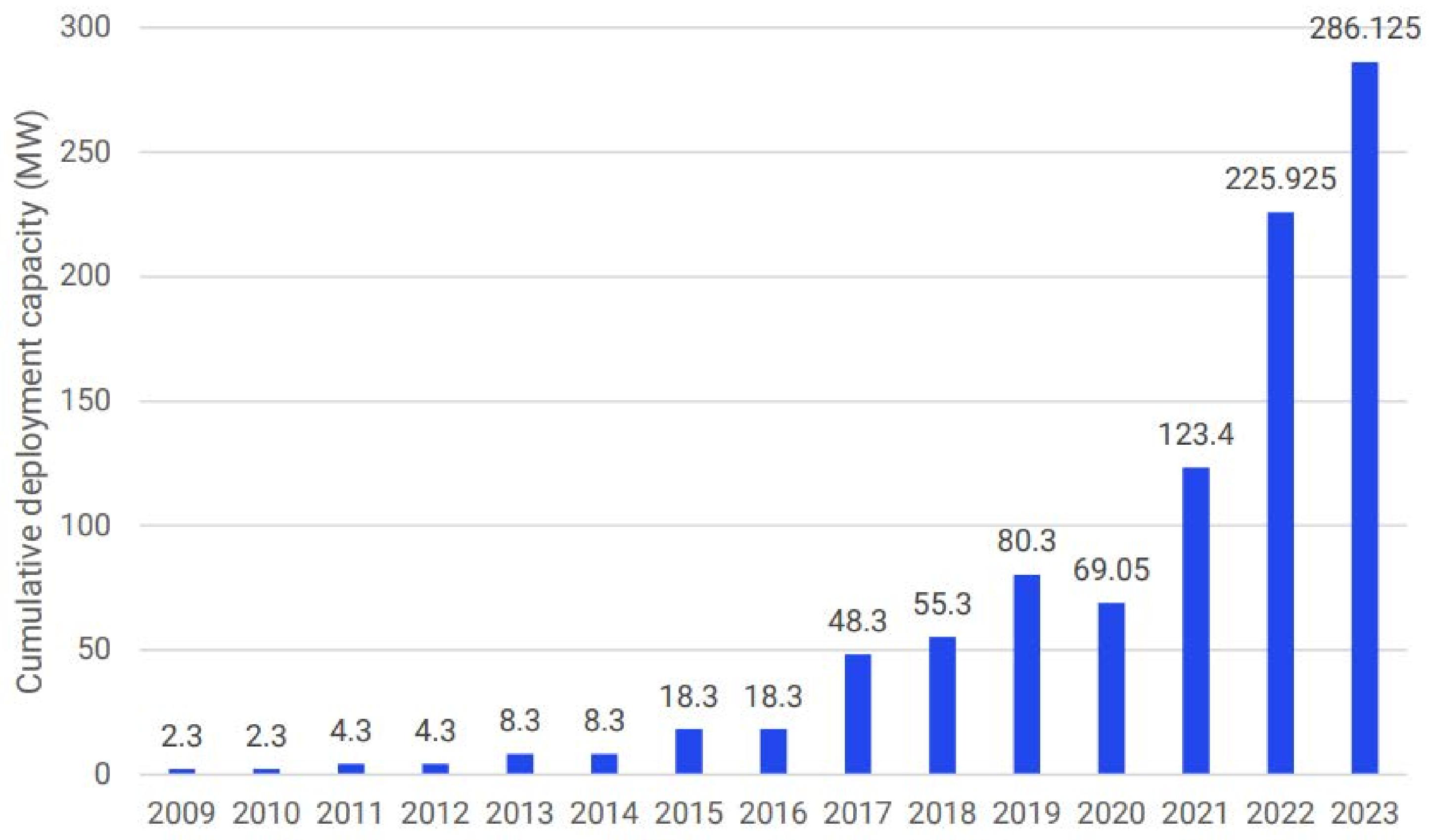
Three steps in path to commercialisation:

1. **Proof of Concept Phase** (2009 – 2016), Prototypes ranging from 2MW to 7MW

2. **Pre-commercial Phase** (2017 – 2025), Arrays of multiple turbines with installed capacity between 12MW and 50MW

3. **Utility-scale Floating Arrays** (2026 and beyond), Large-scale wind farms of >400MW

The floating wind industry is still at pre-commercial stage with several concepts undergoing demonstration in real sea



Global cumulative floating offshore wind capacity, according to 4C Offshore database, 2022

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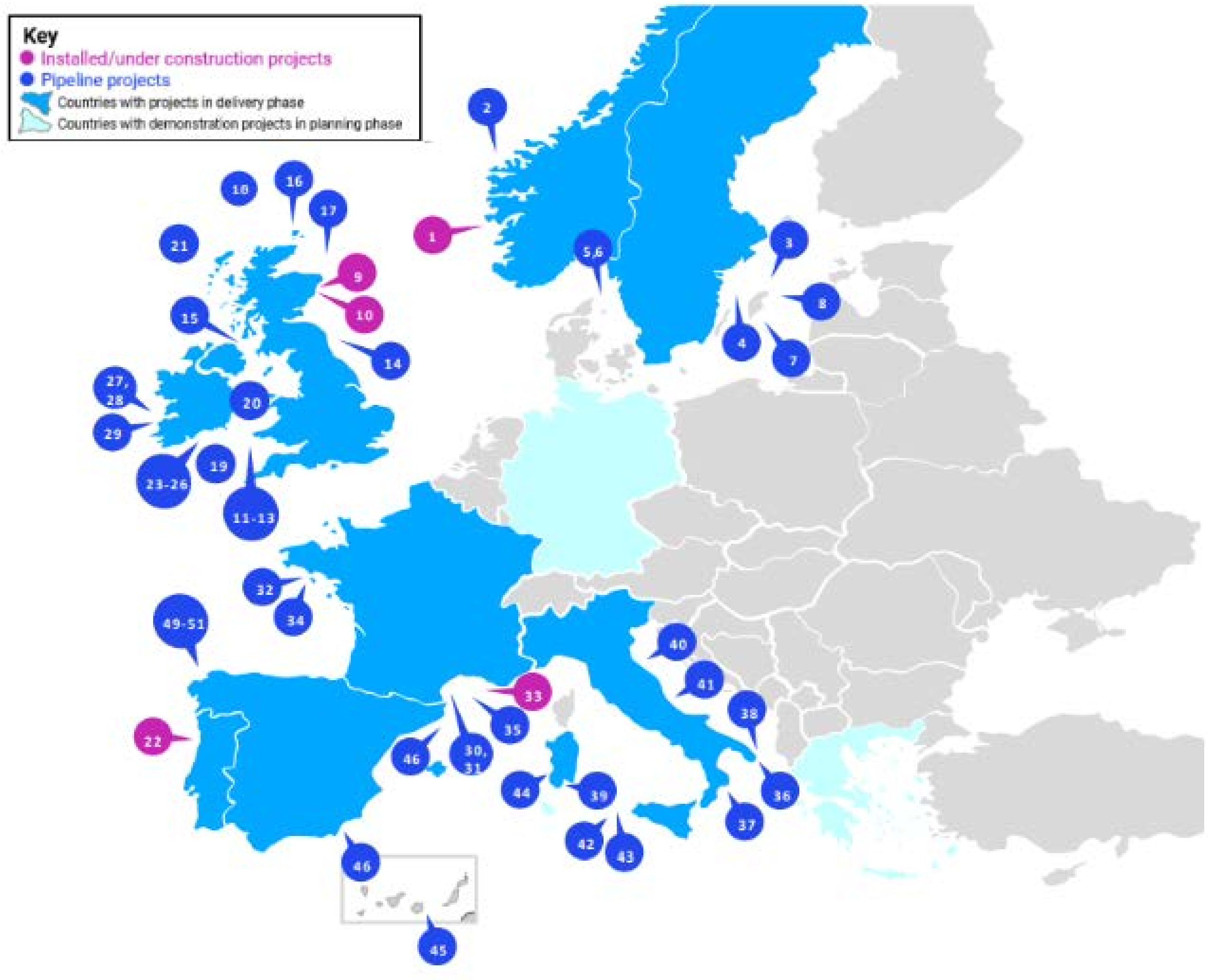
FOW Projects and Locations



Project	MW
Norway	
1. Hywind Tampen	88
2. Frøyabanken	500-1500
Sweden	
3. Dyning	2000
4. Kultje	2150
5. Mareld	2300
6. Poseidon Nord	1000
7. Skidbladner	2000
8. Herkules	2750
United Kingdom – floating target 5 GW by 2030 *	
9. Hywind pilot park	30
10. Kincardine	50
11. Erebus (commercial)	600
12. Petroc	300
13. Celtic Deep	398
14. Blyth	58.4
15. North Channel Wind	400
16. Dolphyn project	2000
17. Green Volt	480
18. Cerulean North Sea	3000
19. Crown Estate Test & Demonstration	400
20. Celtic Sea Floating	4000
21. Scotwind	15,000
Portugal	
22. WindFloat Atlantic	25

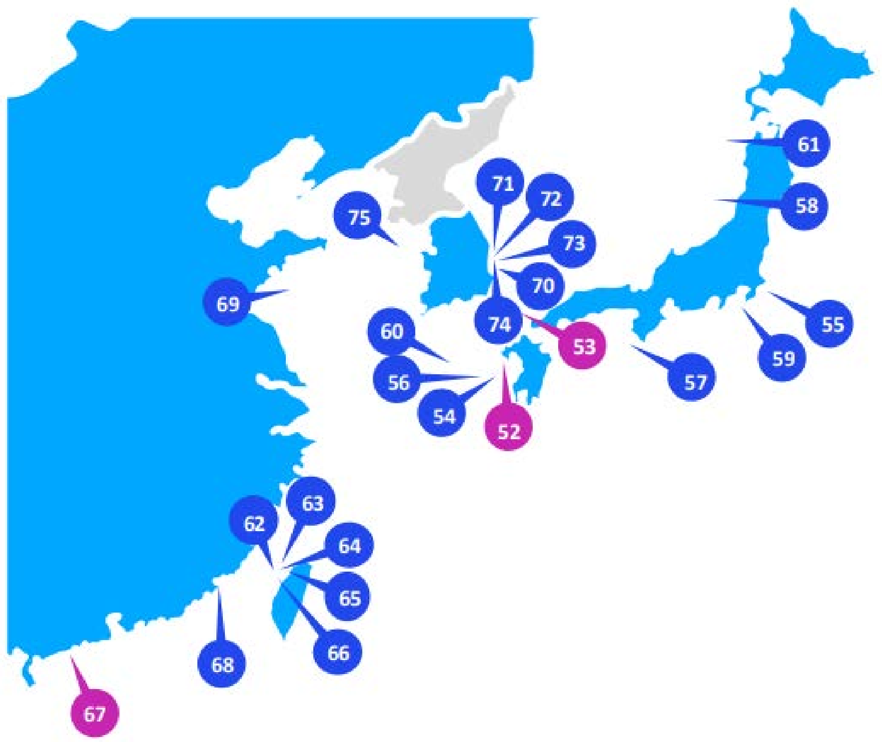
Project	MW
Ireland	
23. Emerald	1300
24. Inis Ealga	1000
25. Blackwater	1500
26. SSE Celtic Sea	800
27. Clarus	1000
28. Western Star	1350
29. Moneypoint	1000-1500
France – floating target 3 GW by 2030 **	
30. EOLMed	30
31. Gulf du Lion	30
32. Groix & BelleÎle	28.5
33. Provence Grand Large	25.2
34. Triskéol	250
35. Méditerranée I-IV	1500
Italy – floating target 5 GW by 2040 **	
36. Odra Energia	1500
37. Minervia Energia	675
38. KailiaEnergia	1200
39. Nora Energia	1395
40. Marche	840
41. Abruzzi	1760
42. MedWind	2800
43. Marsala	750
44. Sardegna Sud Occidentale	504

Project	MW
Spain – floating target of 1-3 GW by 2030 *	
45. Canarray I & II	180
46. Mar de Agata	300
47. Parque Tramuntana I	500
49. Parque Nordes I	525
50. San Brandan	490
51. San Cibrao	490

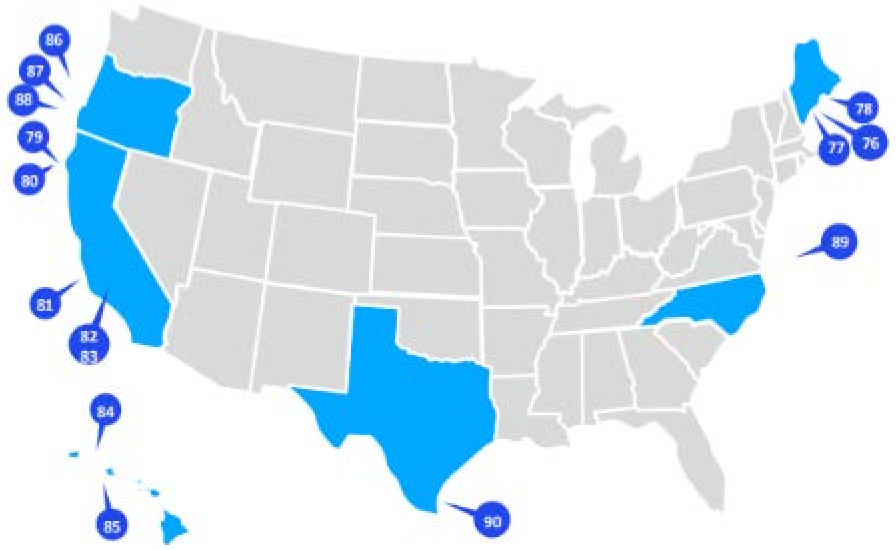
* target government set
** target set by industry

* Taken from Carbon Trust Joint Industry Project – Phase4 report - July 2022

FOW Projects and Locations



Project	MW
Japan	
52. Sakiyama	2
53. IDEOL Kitakyshu demo	3
54. Goto City	17
55. Sakura	520
56. Kyushu	1000
57. Kishuu	450
58. Toki I & II	1100
59. Progression Energy Floating	800
60. Goto Sakiyama Oki Oki	500
61. Seihoku-ouki	600
Taiwan	
62. Eolfi Taiwan	500 - 2000
63. Chu Tin I & II	1300
64. Huan Ya	1400
65. Laifeng	950
66. Hai Shuo	1350
China	
67. CTGNE Yangjiang Shapa	5.5
68. Longyuan Nanri Island	4
69. Qingdao	2000
South Korea	
70. Ulsan Prototype	5
71. Donghae Sites	500 - 4500
72. Firefly	804
73. Munmu Baram	420 - 1500
74. Ulsan Floating	1000 - 2500
75. Incheon	1600



Project	MW
Maine	
76. Aqua VentusI	12
77. Maine Research Array	144
78. Future Floating *	450 - 1500
California	
79. Redwood	150
80. Humboldt WEA *	1600
81. Morro Bay *	700-1000
82. Lompoc/CADEMO	60
83. Castle Wind *	1000
Hawaii	
84. Oahu Northwest *	400
85. Oahu South *	400
Oregon	
86. Coos Bay *	10,000
87. Bandon *	2,800
88. Brookings *	3,400
North Carolina	
89. Central Atlantic E *	1000
Texas	
90. Gulf of Mexico *	2000

** = call areas*

* Taken from Carbon Trust Joint Industry Project – Phase4 report - July 2022

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Challenges and Opportunities

Challenge

- **Sub-structure Capital Cost**
  - Variety of sub-structure concepts
  - Limited technological proof
  - WTG integration still uncertain

Opportunity

- **Potential for cost reduction**
  - Room for disrupting innovations
  - Demo projects to establish processes
  - Interface with OEM for bespoke design

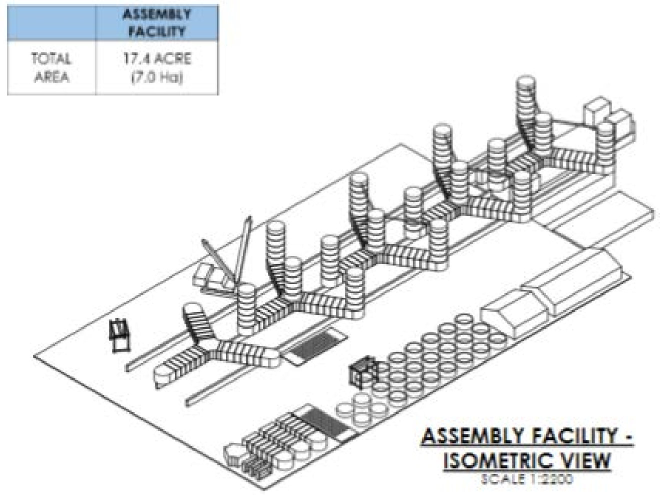
Challenges and Opportunities

Challenge

- **Industrialisation for large-scale arrays**
  - Limited supply chain for construction
  - Slow assembly rates for existing yards
  - Limited capability of existing ports

Opportunity

- **Development and Scaling-up**
  - Consider local capabilities (e.g. concrete)
  - Optimise fabrication processes (novel joints)
  - Build / expand dedicated facilities



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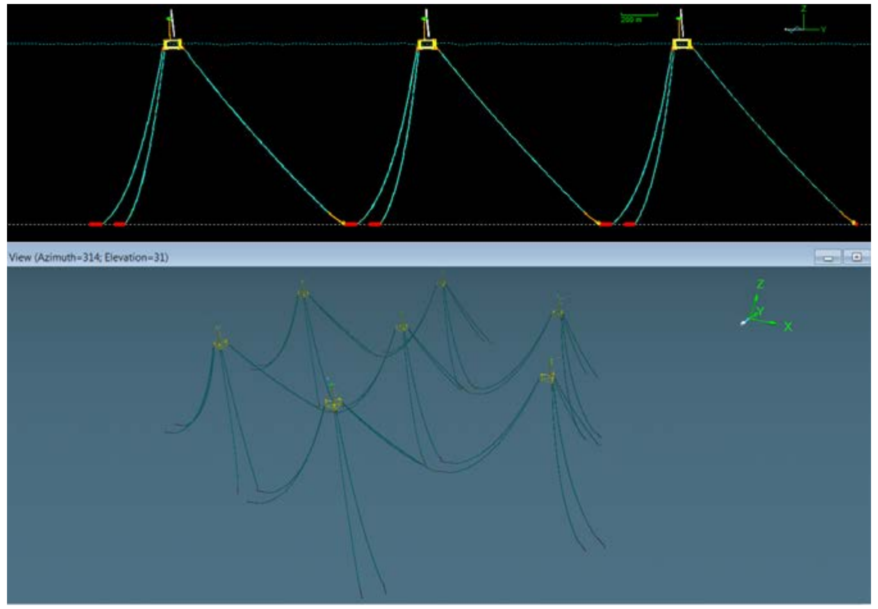
Challenges and Opportunities

Challenge

- **Moorings qualification and supply**
  - Limited supply for offshore chains
  - Sensitivity to high loads and fatigue
  - Complex and expensive anchors

Opportunity

- **Development and Scaling-up**
  - Adopt novel synthetic rope (e.g. nylon)
  - Innovative load reduction systems
  - Shared anchor arrangement



Challenges and Opportunities

Challenge

- **Stream-lined T&I**
    - Floater constrains on T&I options
    - Installation rate weather-sensitive
    - Limitation of vessels and equipment

Opportunity

- **Bespoke T&I procedures**
    - Improve floater design
    - Include wet storage options
    - Fortify installation vessel supply

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Concluding Remarks

- Floating wind represent an immense opportunity (80% of the global offshore wind resources suited to floating technologies)
- Floating wind installations are complex systems with many components, requiring an integrated view of the wind turbine, sub-structure, moorings, anchors, dynamic cable as well as consideration of construction, assembly, transportation, installation and operation phases
- Although significant experience has been cemented over the past decade, there is still a large variability of concepts and technologies and it is likely that different solutions may be feasible depending on project location and conditions
- Floating offshore wind projects are expected to reach utility-scale by 2026, after full completion of the ongoing demonstration projects
- Larger offshore wind turbines have led the way for lower cost in offshore wind, however opportunities for cost reduction exist in floating wind by addressing the challenges of sub-structure design consolidation, industrialisation of the fabrication process, moorings component supply chain, and development of suitable T&I procedures and tools

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