Floating Offshore Wind Cost Optimization Strategy to Enable a Rapid Energy Transition

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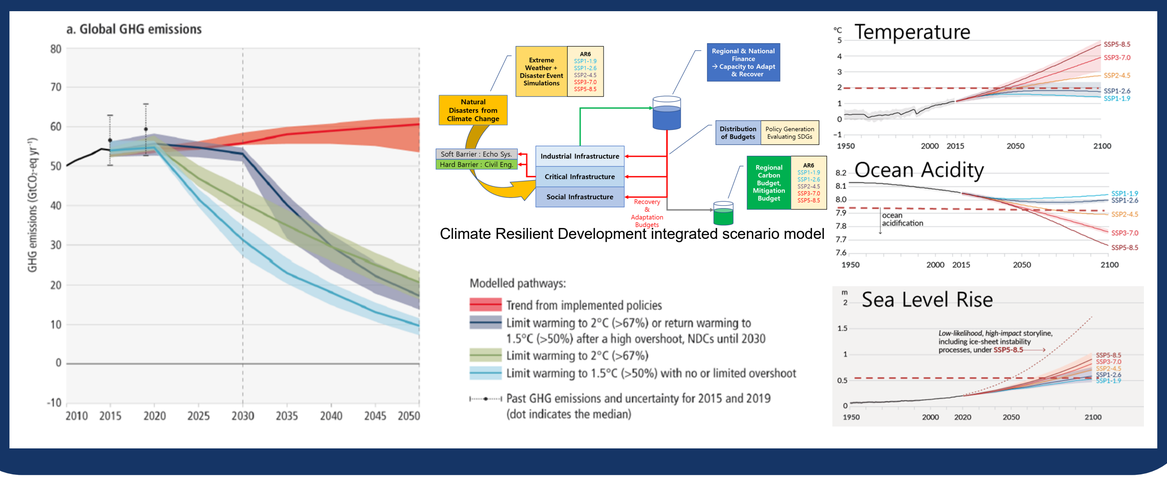
Background

It is still possible to reach carbon zero and less than 2 degree celcius global temperature increase by 2050 but need unprecedented transition speeds after 2030:

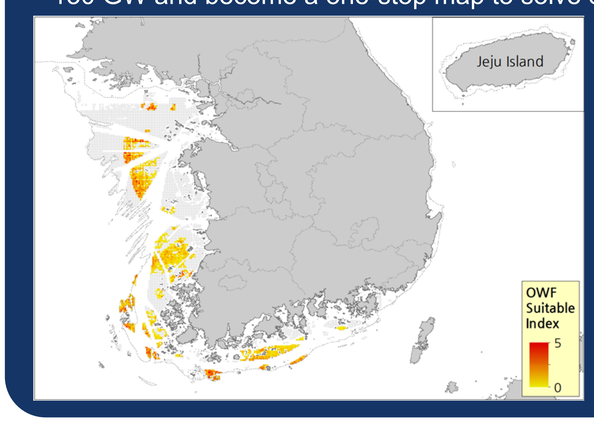
- The worldwide carbon reduction objectives after 2030: 1.5 billion tons per year after ’30
- The South Korea carbon reduction objectives after 2030: 27 million tons per year after ’30
- The reduction 27 million tons of carbon per year can be realized by 16 GW renewables
- The yearly offshore manufacturing capacity of South Korea is more than 9 million tons in displacement weight of the vessel, which correspond to about 5 GW of floating wind/yr
- Adaptation effort should be accompanied for climate resilient development based on scenario study

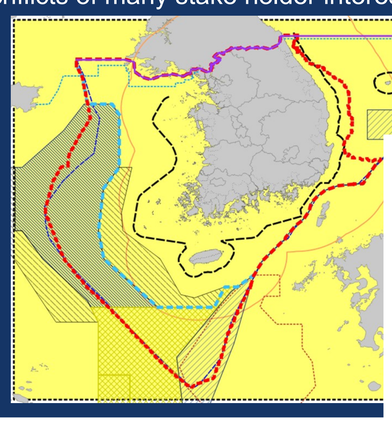


Introduction

Marine spatial map for offshore wind is being expanded from limited depths of up to 60 m to up to 1,000 m and EEZ areas to find enough marine space for large scale deployment of offshore wind.

- The 1st stage offshore MSP map project only resulted in 25 GW
- The 2nd stage offshore MAP aims to find enough space for large scale deployment up to more than 130 GW and become a one-stop map to solve cnflicts of many stake holder interests

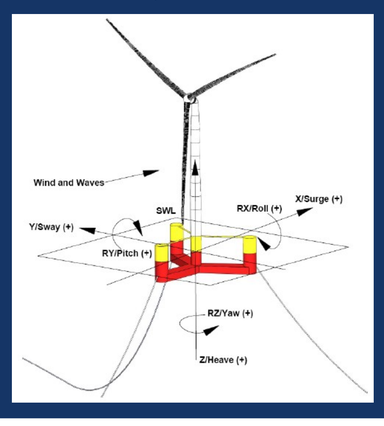




Assumptions for the System

IEA Wind U-Maine Volturn US-S 15 MW Reference Turbine is utilized for floater cost estimations. Three systems which will be manufactured in South Korea will be considered

- Doosan Enerbility 10 MW
- Unison 10 MW
- VESTAS 15 MW (OEM manufactured in S. Korea)



Parameter	Units	Value
Turbine Rating	MW	15
Hub Height	m	150
Platform Type	-	Semisubmersible
Freeboard	m	15
Draft	m	20
Total System Mass	t	20,093
Platform Mass	t	17,839
Tower Mass	t	1,263
RNA Mass	t	991
Water Depth	m	200
Mooring System	-	Three-line chain catenary
Hull Steel Mass	t	3,914
Mooring Length	m	850

Assumptions for Key Parameter

As a preliminary study, key values are calculated based on simple formulations with assumptions.

Cost of Turbine

Item	Unit price
Turbine Manufacturing	$ 1.5 m/MW

Floating Substructure Cost

Turbine	Steel Unit Price	Weight	Cost	Unit price/MW
10 MW	$ 3.6 k/ton	3,565 ton	$ 12.9 m	$ 1.90m/ MW
15 MW		3,914 ton	$ 14.3 m	$ 1.13m/MW

Mooring Cable Cost

Turbine	Unit Price	Length	No.	Cost	Unit price/MW
10 MW	$634/m (steel chain) $417/m (polyester)	700 m	3	$ 1.33m	$166k /MW
15 MW		850 m		$ 1.62m	$107k /MW

Cost of anchor

Turbine	Unit Price	Weight	No.	Cost per turbine	Unit price/MW
10 MW	$ 8.69k/ton	17 ton	3	$ 443k	$ 55k / MW
15 MW					$ 30k /MW

Transportation and installation cost

Item	Cost
Transportation and installation after assembly at port	4.2 100k $ /MW

Floating offshore substation cost

Item		Price	
Floating offshore substation cost	Relay distance less than 100km	1.56	100k $/MW
	Relay distance more than 100km	3.12	100k $/MW

Grid Connection Cost

Item		Unit Price
Internal Grid	10 MW	{1.74 + (dynamic cable length) X 0.0315} 100k $/MW
	15 MW	{1.10 + (15.69 km) X 0.0315} = 1.59 100k $/MW

Turbine	Type	400 MW Plant per unit length	Distance between Turbines	Turbine Arrangement (Row, Column)	Cable Length	Unit price per MW
10 MW	Static	9.80 100k $ /km	1,351 m	10, 5	71.07 km	1.74 100k Won/MW
15 MW		9.80 100k $/km (450 MW)	1,680 m	10, 3	50.40 km	1.10 100k Won/MW

Turbine	Type	Price per unit length	Price per MW
10 MW	dynamic	12.60 100k m/km	{(Cable Length) X 0.0315} 100k $ * (Cable Length) = $(125 + \sqrt{125^2 + (Depth)^2}) \times 0.099$ km
15 MW			15.69 km

External Grid Connection Cost

Item	Unit Cost
External Grid	$\{0.1046 \times (External\ Grid\ Length) + 0.2006\}$ 6.48 100k $/MW (60 km)

OPEX

Item	Unit cost
OPEX Cost	1.21 100k m/MW

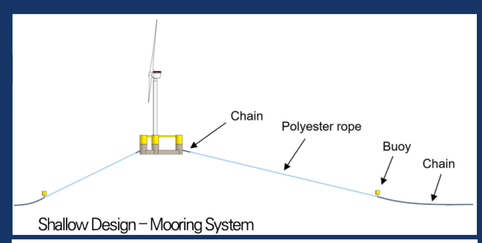
Designs for Different Depths by IEA Wind Task 49 WP2

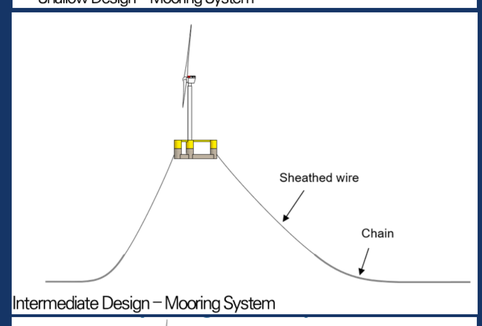
The overal mooring layout for different depths were adapted from IEA Wind Task 49 WP2 : reference array designs for three different representative depths

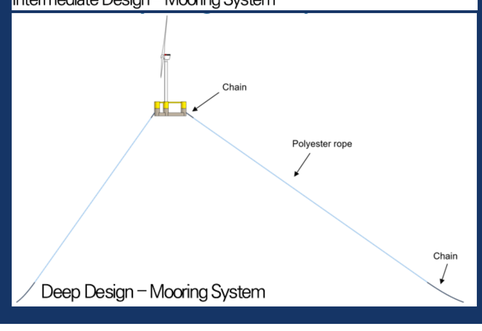
	Shallow Mooring Design
Number of lines	3
Water depth (m)	60
Anchoring radius (m)	1070
Fairlead radius (m)	58
Fairlead depth (m)	14
Pretension (kN)	1150
Line section 1 type	130 mm R4 stud chain
Line section 1 length (m)	80
Line section 2 type	203 mm polyester
Line section 2 length (m)	754.9
Line section 3 type	130 mm R4 stud chain
Line section 3 length (m)	80

	Intermediate Mooring Design
Number of lines	3
Water depth (m)	300
Anchoring radius (m)	937.6
Fairlead radius (m)	58
Fairlead depth (m)	14
Pretension (kN)	1180
Line section 1 type	150mm sheated steel wire
Line section 1 length (m)	288
Line section 2 type	165 mm R4 studless chain
Line section 2 length (m)	716
Peak offset (m)	35%

	Deep Mooring Design
Number of lines	3
Water depth (m)	800
Anchoring radius (m)	1400
Fairlead radius (m)	58
Fairlead depth (m)	14
Pretension (kN)	3380
Line section 1 type	135 mm R4 studless chain
Line section 1 length (m)	40
Line section 2 type	210 mm polyester
Line section 2 length (m)	1451
Line section 3 type	135 mm R4 studless chain
Line section 3 length (m)	40

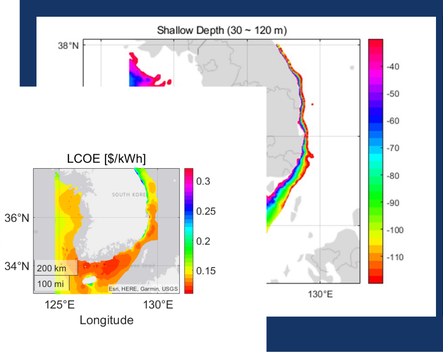


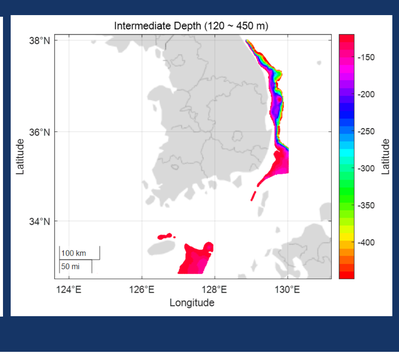


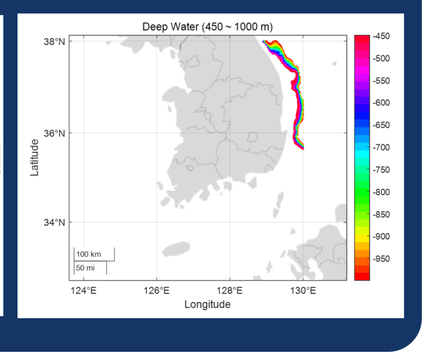


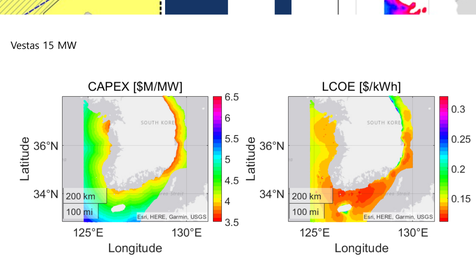
Extrapolation for Different Depth Ranges

The water depth around Korea varies significantly, ranging from shallow areas to depths exceeding 1,000 meters. A floating offshore wind map is currently being developed for depths spanning from 30 meters to 1,000 meters. These depths are categorized into three groups to utilize three designs of WP2.





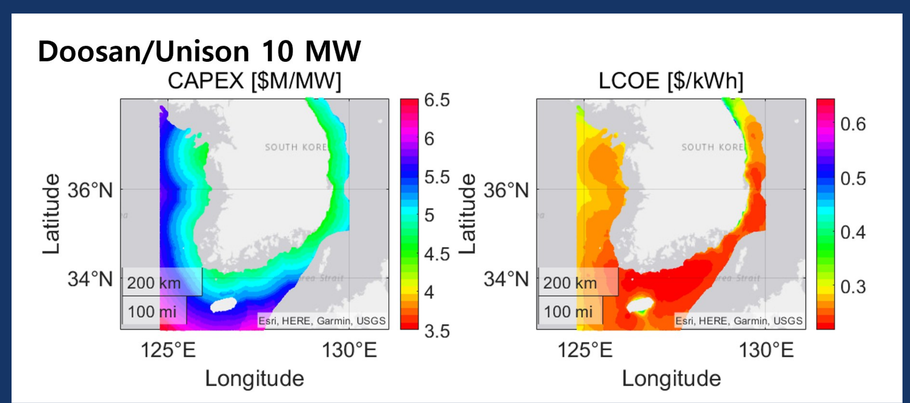


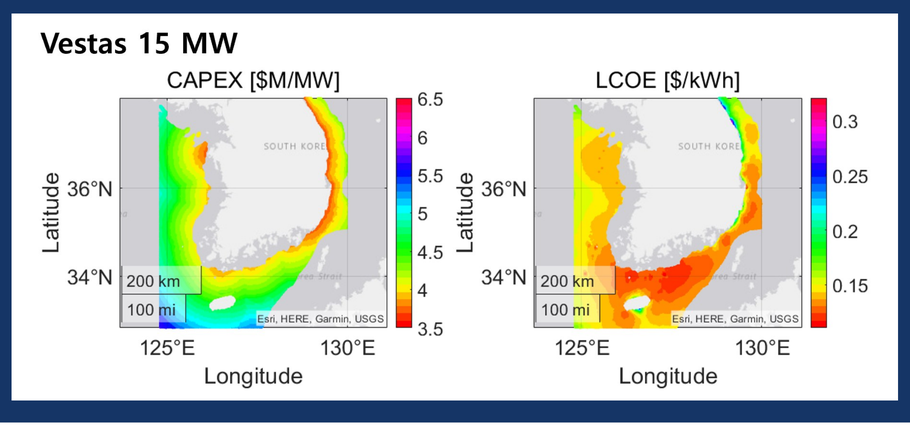


LCOE Map Results

OBJECTIVES: Reference FOWAs should a) represent the current state-of-the-art, b) be economic and c) achieve a good level of performance.

PARAMETERS: Focus on **array-level design** aspects and how different **elements are integrated** => incorporates existing designs for





Conclusion and Future Works

- The current preliminary LCOE map results based on simple formulations shows wind speed and scale of the system are most crucial.
- Detailed studies on optimal layouts, installation, O&M, and etc are required.
- Optimal layout studies will be carried out based on WISDEM, FLORIS, and other tools.
- Optimal installation and O&M cost estimation will be based on tools such as ORBIT and WOMBAT.
- As climate disasters rooming ever larger, rapid energy transitions based on Climate Resilient Development approach is utmost essential considering adaptation aspect equally.
- This is part of an ongoing work to build a one-stop map for offshore wind marine spatial map, which considers tens of constrains including fisheries and environmental concerns.

References

[1] C. Allen *et al.*, “Definition of the UMaine VolturnUS-S Reference Platform Developed for the IEA Wind 15-Megawatt Offshore Reference Wind Turbine,” National Renewable Energy Lab. (NREL), Golden, CO (United States), NREL/TP-5000-76773, Jul. 2020.

[2] M. Hall *et. al.,* “The IEA Wind Task 49 Reference Floating Wind Array Design Basis,” National Renewable Energy Lab. (NREL), Golden, CO (United States), NREL/TP-5000-89709 , June. 2024.

Acknowledgements

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