Introduction to the 1.2 GW Floating Offshore Wind Farm Project in the East Sea, Ulsan, Korea

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Trondheim, Norway
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Convenor
IEC TC88 MT3-2 (for Revision of IEC 61400-3-2)

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University of Ulsan, KOREA

Outline

0. Introduction to the University of Ulsan, Ulsan, Korea

Ulsan, KOREA

Wikipedia

Source : Explore Korea through Statistics 2018

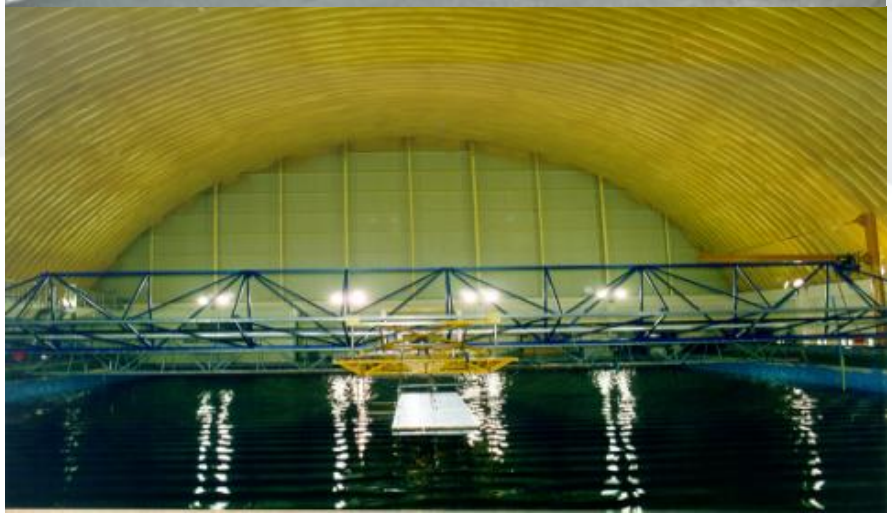
Kim Yuna,
Figure skating Queen
Gold medalist,
at the Vancouver 2010 Winter Olympics
Silver medalist,
at the Sochi 2014 Winter Olympics

0. Introduction to the University of Ulsan, Ulsan, Korea

Floating Airport Model Test

Ocean Engineering Wide Tank, UOU, Korea

LxBxDxDw=30x20x3x2.5 m

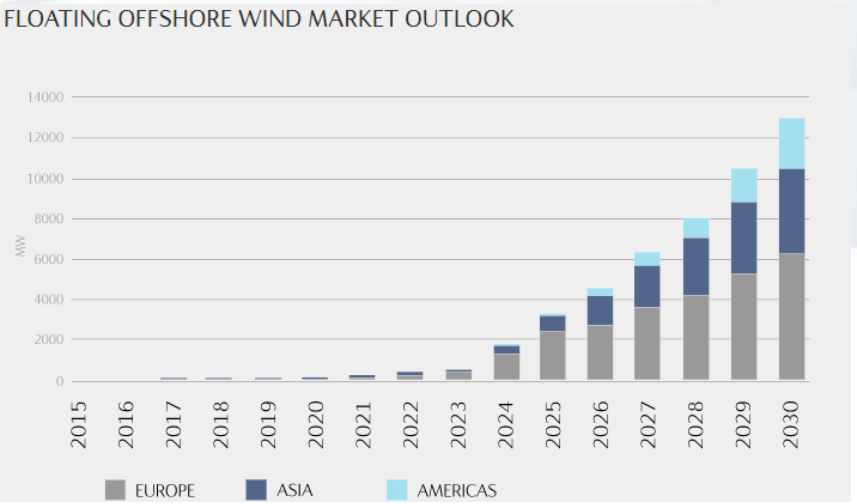


1. Why Offshore Wind ? Why FOWTs ?

Industry	Compound annual growth rate for GVA between 2010 and 2030	Total change in GVA between 2010 and 2030	Total change in employment between 2010 and 2030
Industrial marine aquaculture	5.69%	303%	152%
Industrial capture fisheries	4.10%	223%	94%
Industrial fish processing	6.26%	337%	206%
Maritime and coastal tourism	3.51%	199%	122%
Offshore oil and gas	1.17%	126%	126%
Offshore wind	24.52%	8 037%	1 257%
Port activities	4.58%	245%	245%
Shipbuilding and repair	2.93%	178%	124%
Maritime equipment	2.93%	178%	124%
Shipping	1.80%	143%	130%
Average of total ocean-based industries	**3.45%**	**197%**	**130%**
Global economy between 2010 and 2030	**3.64%**	**204%**	**120%[1]**

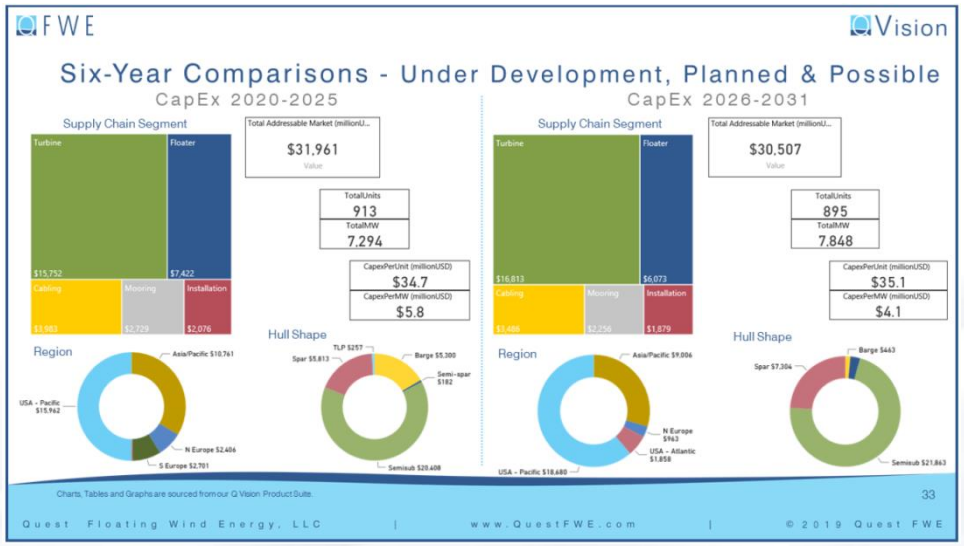
1. Based on projections of the global workforce, extrapolated with the UN medium fertility rate.

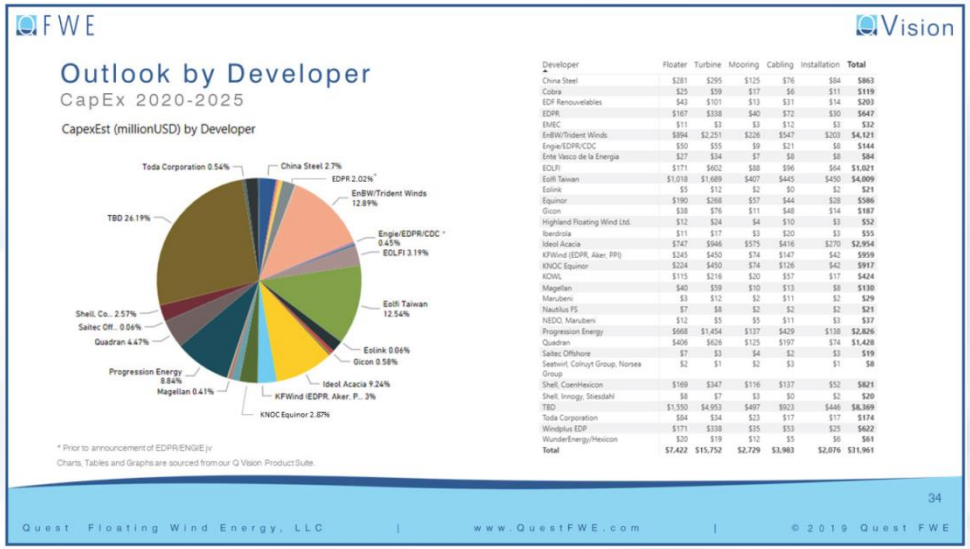
Source: Authors' calculations based on OECD STAN, UNIDO INDSTAT, UNSD; Lloyd's Register Group (2014; 2013); World Bank (2013); IEA (2014); FAO (2015).

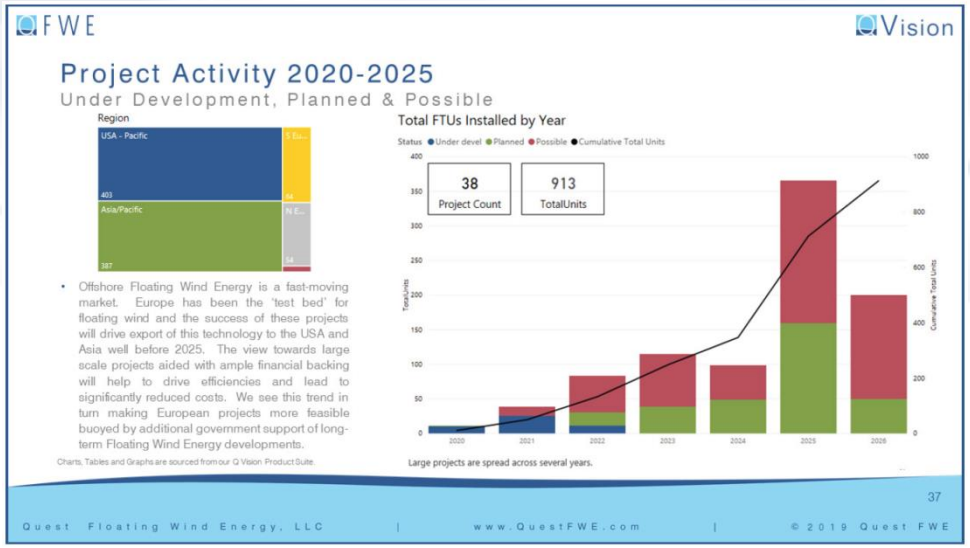


https://www.statoil.com/en/what-we-do/hywind-where-the-wind-takes-us.html

1. Why Offshore Wind ? Why FOWTs ?







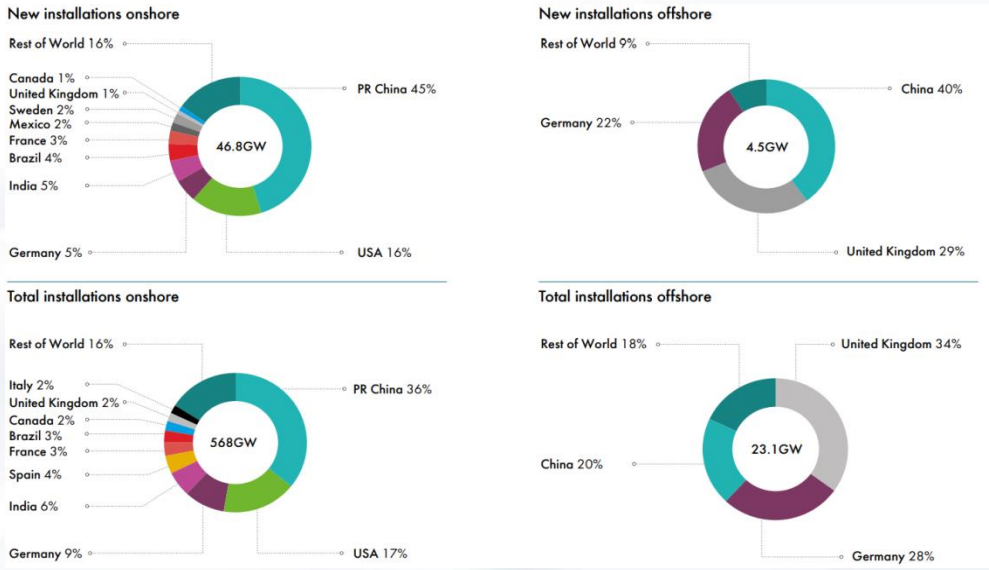
Global Floating Wind Energy Market & Forecast 2019~2031
(Source : Quest Floating Wind Energy 2019)

1. Why Offshore Wind ? Why FOWTs ?

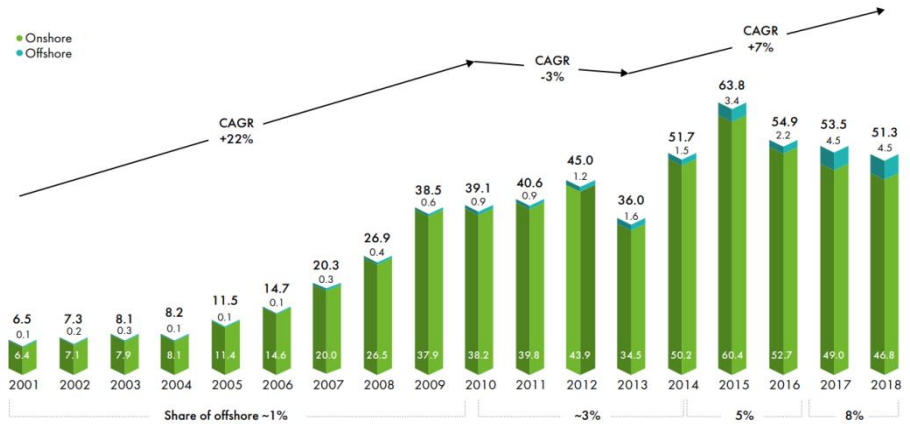
Historic development of total installations, MW (GWEC, Global Wind port 2018, 2019.04)

MW, onshore	New installations 2017	Total installations 2017	New installations 2018	Total installations 2018
Total onshore	48,996	521,774	46,820	568,409
Americas	**10,572**	**123,091**	**11,940**	**135,041**
USA	7,017	89,047	7,588	96,635
Canada	341	12,240	566	12,816
Brazil	2,027	12,769	1,939	14,707
Mexico	478	4,006	929	4,935
Argentina	24	228	494	722
Chile	269	1,418	204	1,621
Other Americas	416	3,383	220	3,605
Africa, Middle East	**632**	**4,758**	**962**	**5,720**
Egypt	0	810	380	1,190
Kenya	0	26	310	336
South Africa	618	2,085	0	2,085
Other Africa	14	1,837	272	2,109
Asia-Pacific	**23,927**	**231,419**	**24,902**	**256,320**
China	18,499	185,604	21,200	206,804
India	4,148	32,938	2,191	35,129
Australia	501	4,813	549	5,362
Pakistan	199	789	400	1,189
Japan	170	3,399	262	3,661
South Korea	103	1,102	127	1,229
Vietnam	38	197	32	228
Philippines	0	427	0	427
Thailand	218	648	0	648
Other Asia	51	1,502	141	1,643
Europe	**13,865**	**162,506**	**9,016**	**171,328**
Germany	5,334	50,779	2,402	53,180
France	1,692	13,757	1,563	15,307
Sweden	197	6,499	717	7,216
United Kingdom	2,641	12,412	589	13,001
Turkey	766	6,872	497	7,370
Other Europe	3,235	72,187	3,248	75,435

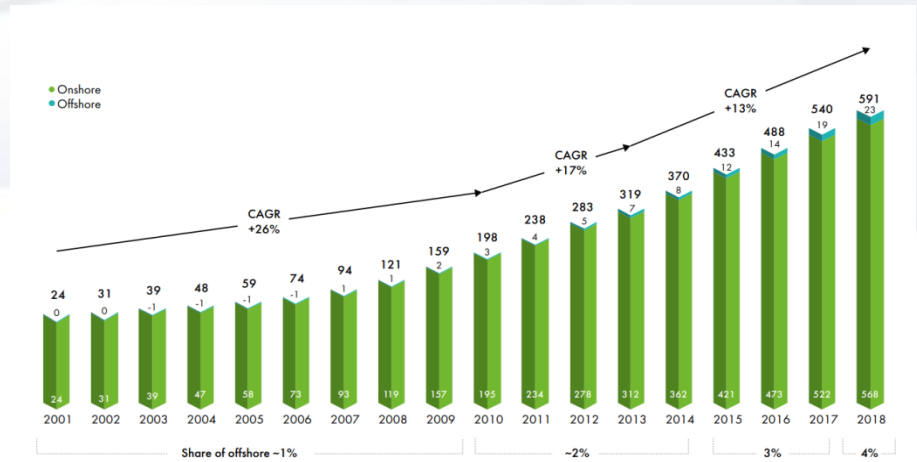
MW, offshore	New installations 2017	Total installations 2017	New installations 2018	Total installations 2018
Total offshore	4,472	18,658	4,496	23,140
Europe	**3,196**	**15,630**	**2,661**	**18,278**
United Kingdom	1,715	6,651	1,312	7,963
Germany	1,253	5,411	969	6,380
Belgium	165	877	309	1,186
Denmark	0	1,268	61	1,329
Netherlands	0	1,118	0	1,118
Other Europe	63	305	0	302
Asia-Pacific	**1,276**	**2,998**	**1,835**	**4,832**
China	1,161	2,788	1,800	4,588
South Korea	3	38	35	73
Other Asia	112	172	0	171
Americas	**0**	**30**	**0**	**30**
USA	0	30	0	30



Market Status 2018 (GWEC, Global Wind Report 2018, 2019.04)



Historic Development of New Installations, GW (GWEC, Global Wind report 2018, 2019.04)



Historic Development of Total Installations, GW (GWEC, Global Wind report 2018, 2019.04)

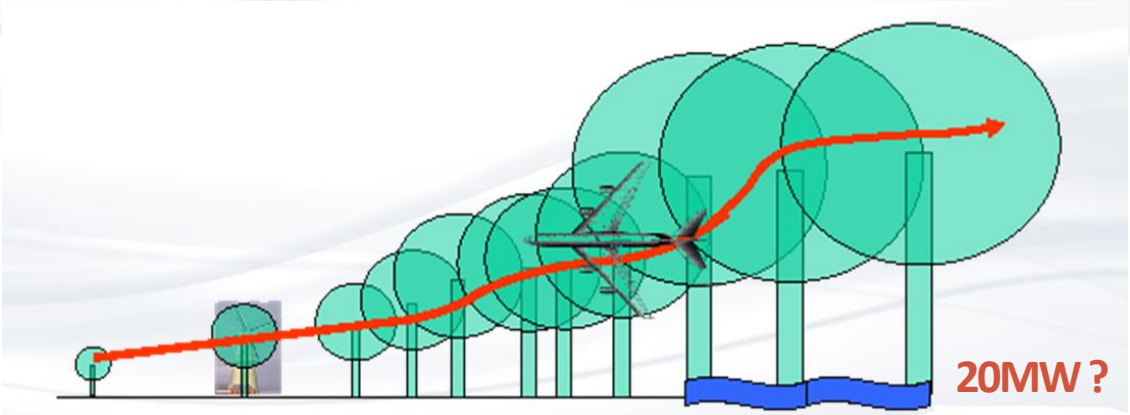
2. Critical needs for FOWTS in Korea

Why FOWT?

- **Quantum Jump for Korea Wind Industry**

  (System & Supply Chain: ~~HHI, SHI, DSME, STX,~~ Doosan, Hyo sung, UNISON, Hanjin, etc.)

- **Jobs & the 4th Industrial Revolution**
- **LCOE (6cent/kWh)**
- **Energy Poverty in North Korea**

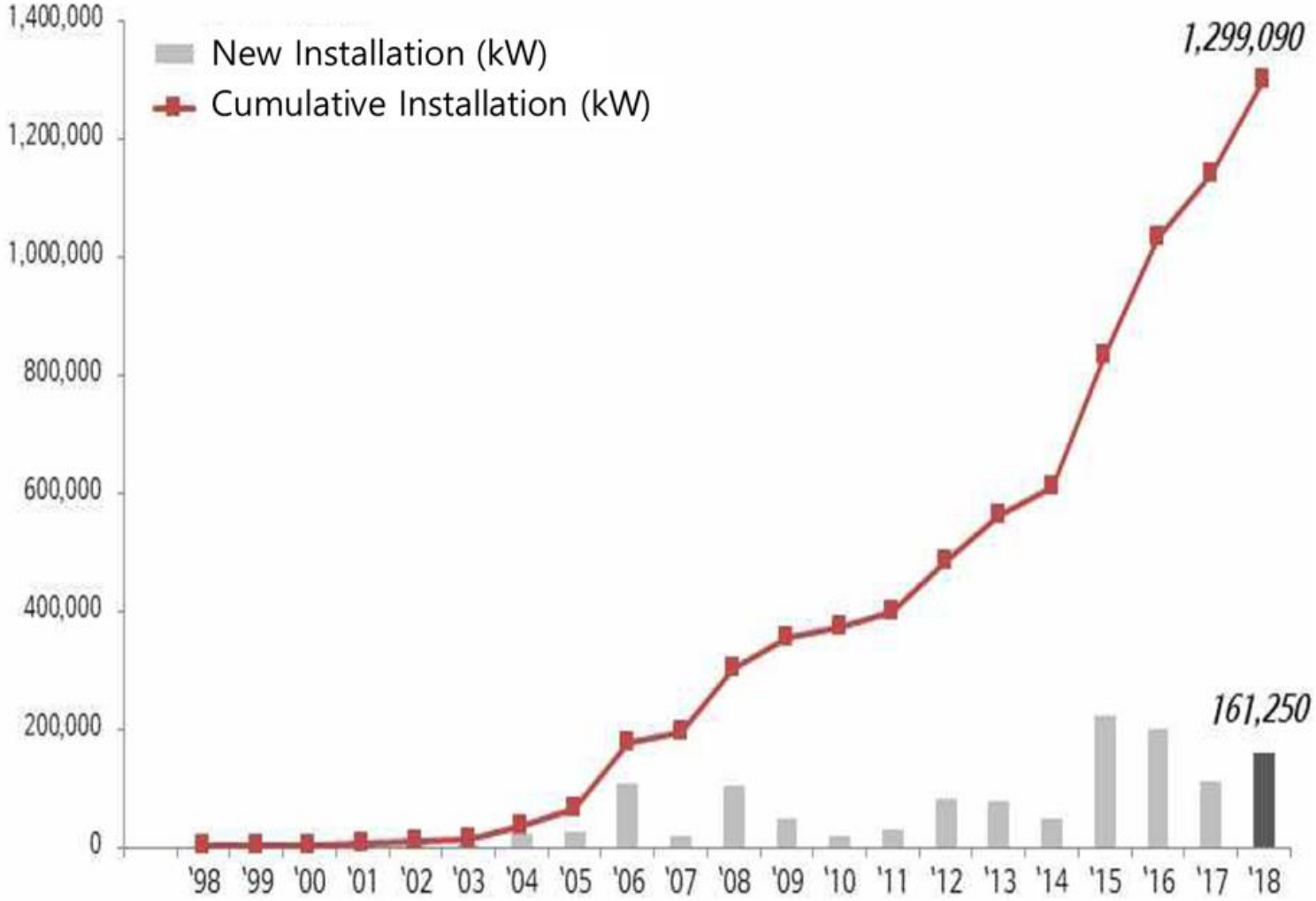


2. Critical needs for FOWTS in Korea

Light through Darkness (NASA, Feb. 2014)

3. Floating Offshore Wind Farm Projects Planned in the East Sea, Korea

Annual new and cumulative installation capacity, Korea



※ '11: 2,835 kW, '13: 1,410 kW, '15: 750 kW, '16: 4,640 kW, '17: 2,760 kW, '18: 2,070 kW

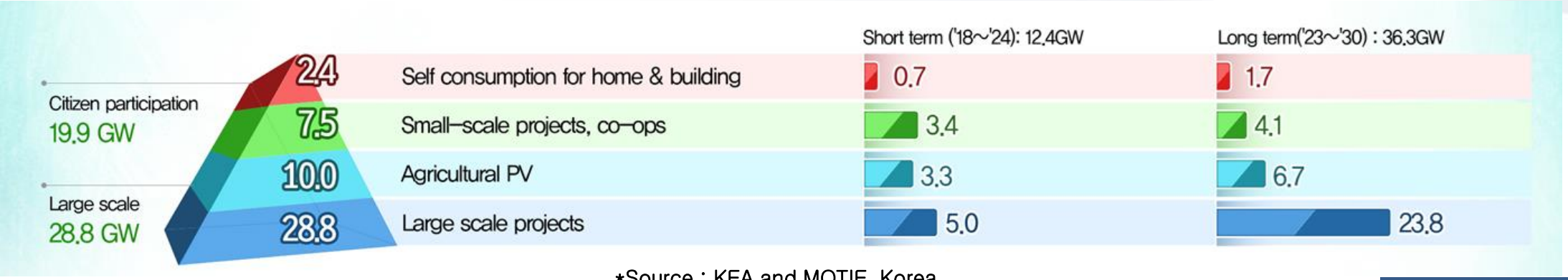
(Source : 2018 Annual Report on Wind Energy Industry in Korea, Korea Wind Energy Industry Association)

3. 1 Korea's RE 3020

Renewable Energy Target : 20% of power generation by 2030

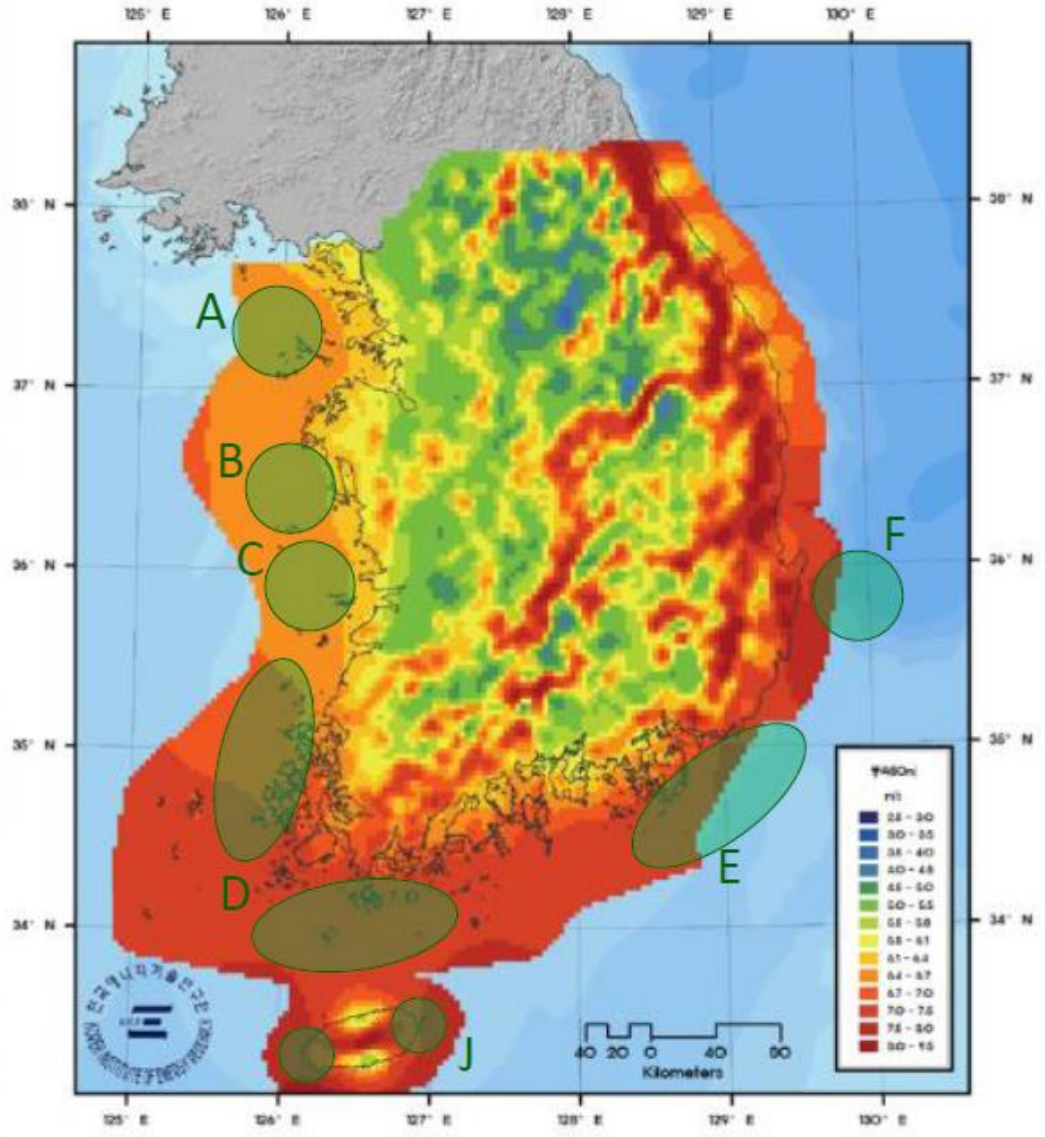
- More than 95% of new capacity is PV and Wind
- Offshore wind is 14 GW and Land-based Wind is 3.7 GW

Method : Citizen participation and large-scale projects



*Source : KEA and MOTIE, Korea

3. 1 Korea's RE 3020
Offshore Wind Potential, Korea



Region A : Incheon
- Planned : Choji

Region B : Chungnam
- Planned : Tae-ahn

Region C : Jeonbuk (100MW + α)
- Process : Saemangeum (100MW)
- Planned : Gogunsan

Region D : Jeonnam (1,045MW + α)
- Process : Duwuri(99MW), Jeonnam-Sinahn(300MW), Jeonnam (96MW), Yeonggwang-Yawol(50MW), Yeonggwang-Changwoo(150MW), Wando(150), Wando-Geumil(200MW)
- Planned : SoughWest Ph.2, Yeonggwang-nakwol, Sinahn-Ui, Anma

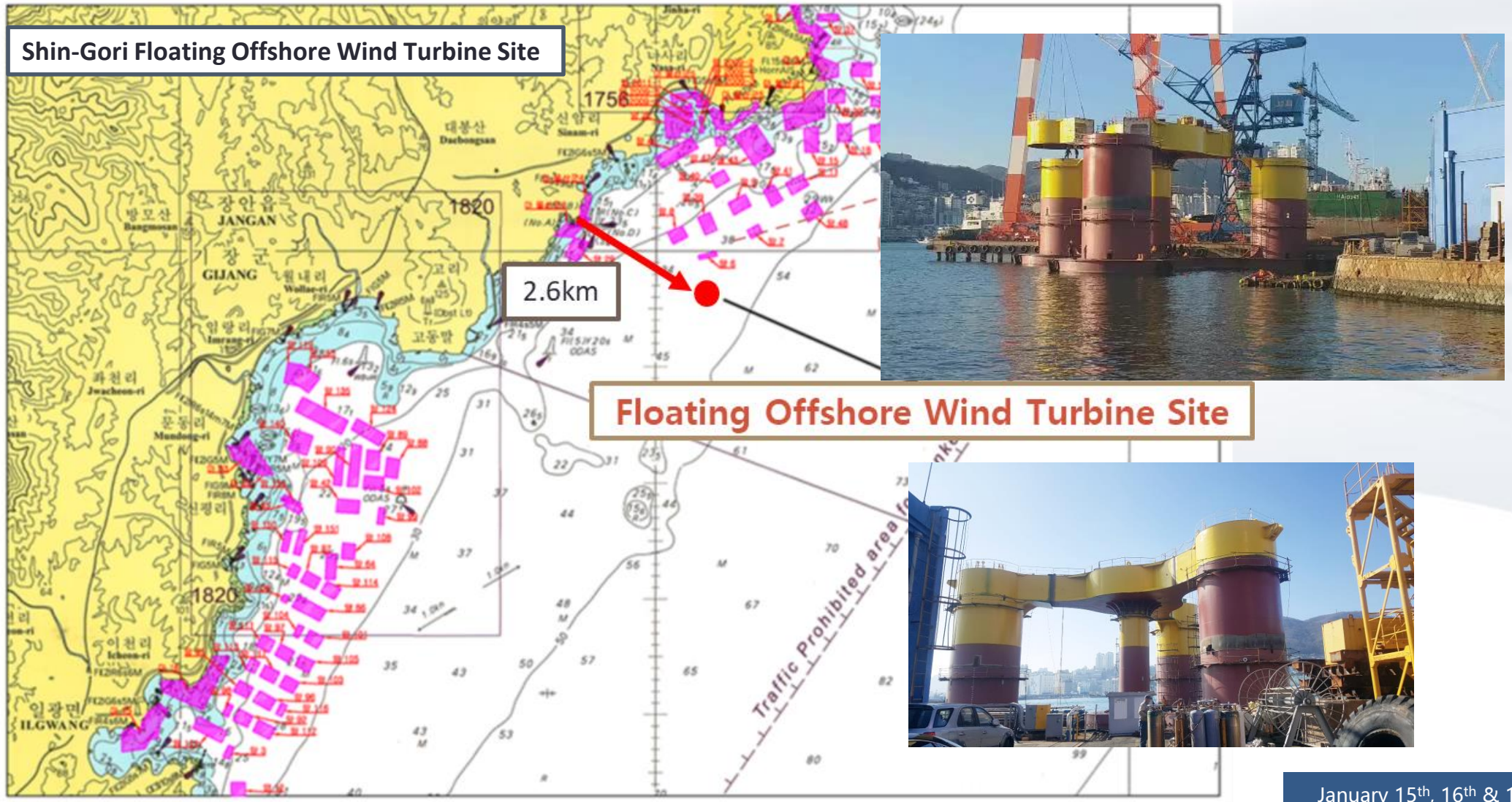
Region E : Busan/Gyeongnam (40MW + α)
- Process : Cheongsa(40MW)
- Planned : Yokji, Haegi

Region F : Ulsan/Gyeongbuk (136MW + α)
- Process : Southeast-shore(136MW)
- Planned : Floating Offshore

Region J : Jeju Island (565 MW)
- Process : Hallim(100MW), Daejeong(100MW), Handong(105MW)
- Planned : Hangwon(125MW), Pyoseon(135)

***Source : FOWF 2019, Ulsan, Korea**

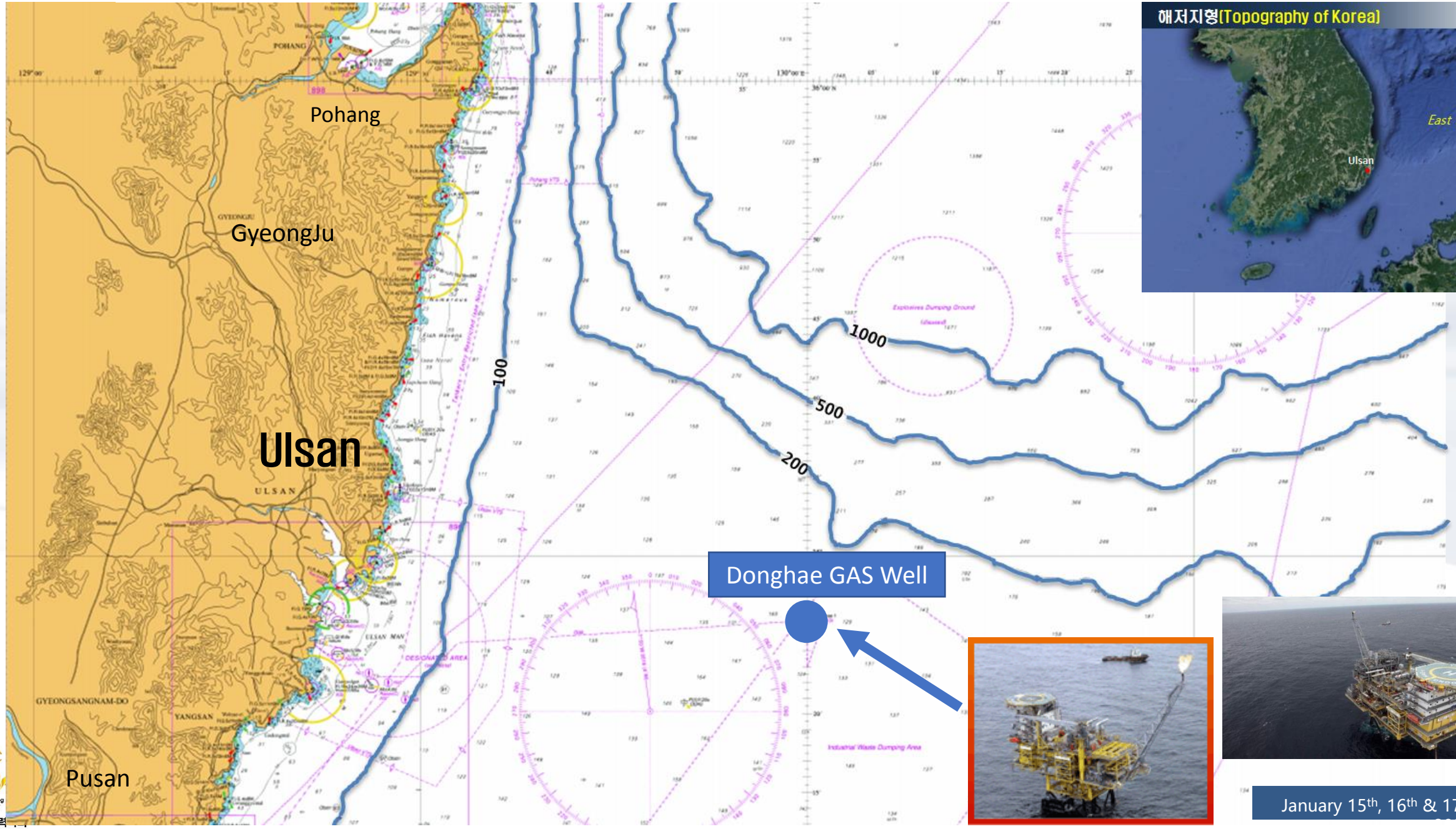
3.2 Ulsan Shin-Gori 750kW FOWT Pilot Project



3.2 Ulsan Shin-Gori 750kW FOWT Pilot Project

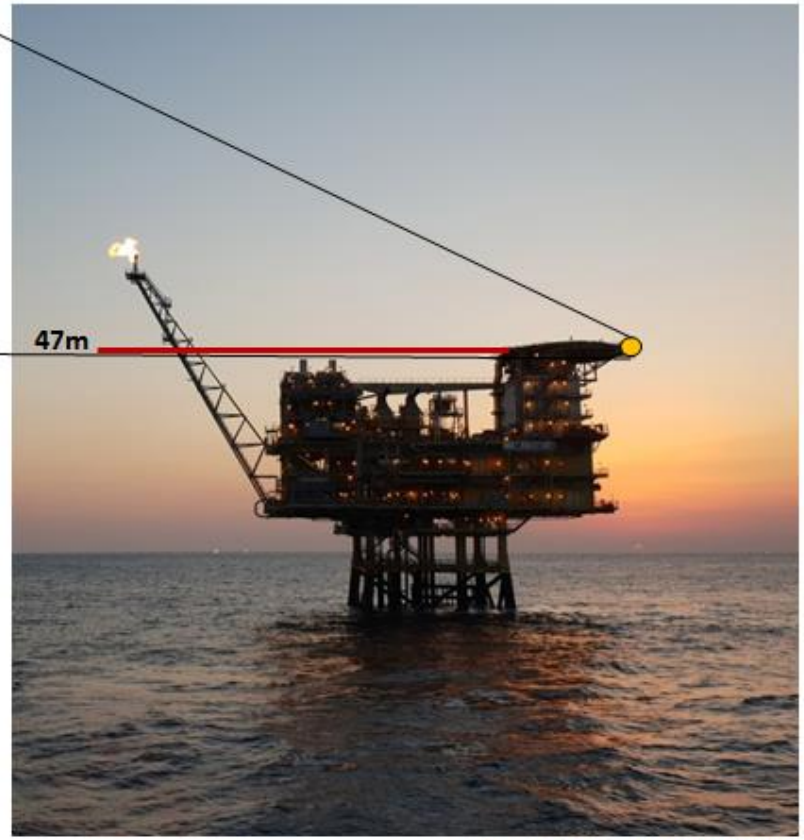
- Demonstration Project of a Pilot (750kW) Floating Offshore Wind Turbine in 50m deep

3.3 Plan of Floating Offshore Wind Farms in Ulsan



3.3 Plan of Floating Offshore Wind Farms in Ulsan

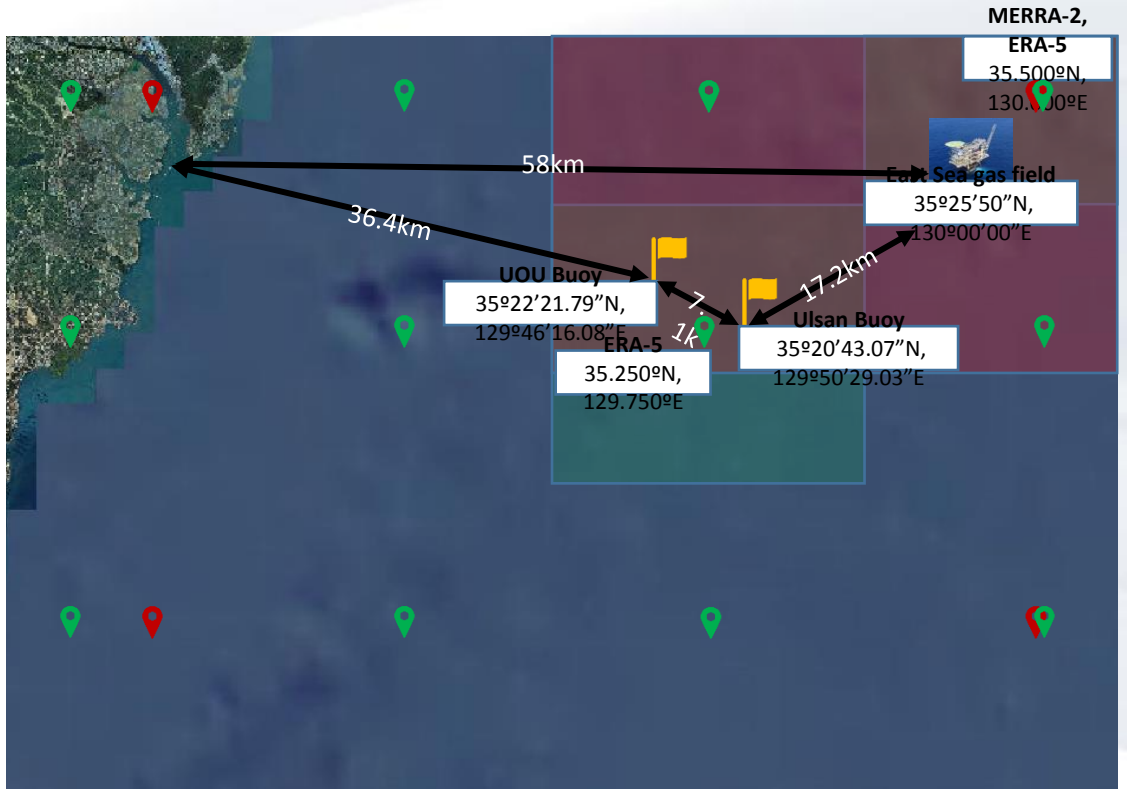
LIDAR Measured height



Specifications	
Range	40m to 200m
Data sampling rate	1s
Number of height	12
Speed accuracy	0.1m/s
Speed range	0 to 60m/s
Direction accuracy	2°

*source: WINDCUBE v2 / NRG systems

*Image: East Sea gas field / KNOC



Correct the wind data measured height

40m to 200m -> 87m to 247m (Increase 47m)

3.4 Green Energy Programs of Ulsan Metropolitan City (2018 ~)

- Project Progress
- Supporting Technology, Research & Development
- Building Floating Offshore Wind Farm Roadmap
- Resolving Issue of Navy's Operation Area Overlapping
- Arbitrating between Developers and Fishermen
- Cooperating with Ministries to Amend Irrational or Excessive Regulations

- Plan and schedule
- Site selection, LIDAR deployment, Wind Turbine Conceptual Design (Jul 2018~2020)
- SPC Establishment, licenses acquisition, Financing, etc. (2021~2022)
- EPC of Floating Offshore Farm (2023~2024)
- Demonstration and Operation (2025~)
- Supporting Technology, Research & Development

3.4 Green Energy Programs of Ulsan Metropolitan City (2018 ~)

EEZ off the coast, Ulsan, Korea is the best offshore for floating offshore farms

- Environmental conditions for Floating offshore wind farms
- Well-developed shipbuilding and offshore industry
- Grid accessibility
- Possible utilization of Donghae gas field infrastructure
- Public acceptance (EEZ)
- Lots of ports

o MOTIE(KETEP) , Ulsan Metropolitan City, Ulsan TechnoPark and UOU consortium : 200 MW
o KNOC consortium : 200 MW
o Five international consortiums

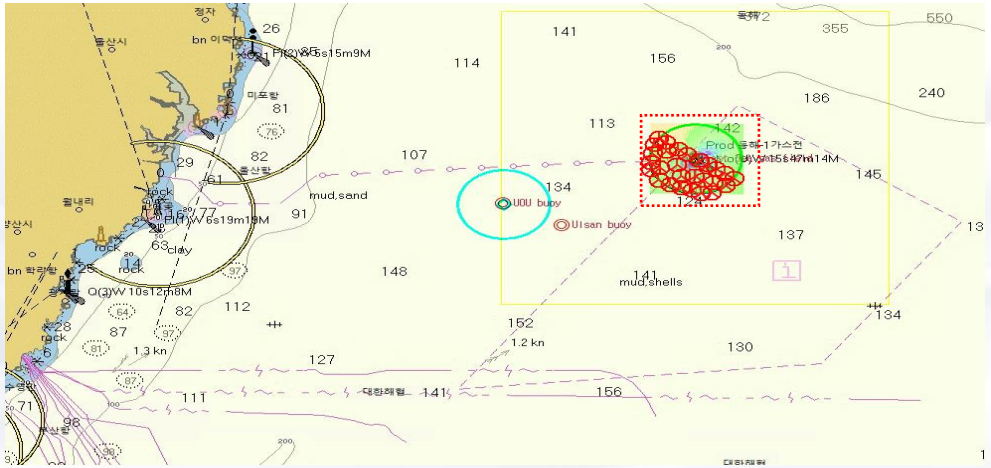
- CIP : 200 MW, Ulsan White Heron Project
- GIG : 200 MW, Project Gray Whale
- Shell : 200 MW, Donghae TwinWind Project
- EDPR, PPI, Aker : 200 MW, KFWind Project
- Equinor : 200 MW, Donghae 1 project
- NAVAL Energies : 200MW (?)

3.4 Green Energy Programs of Ulsan Metropolitan City (2018 ~)

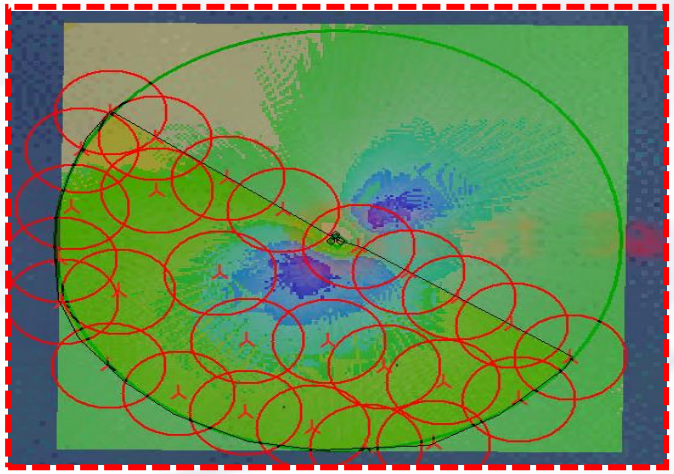
MOTIE(KETEP) , Ulsan Metropolitan City, Ulsan TechnoPark & UOU consortiums : Planned FOWT Farm (1)

Expectation of Annual Energy Production - East Sea gas field location

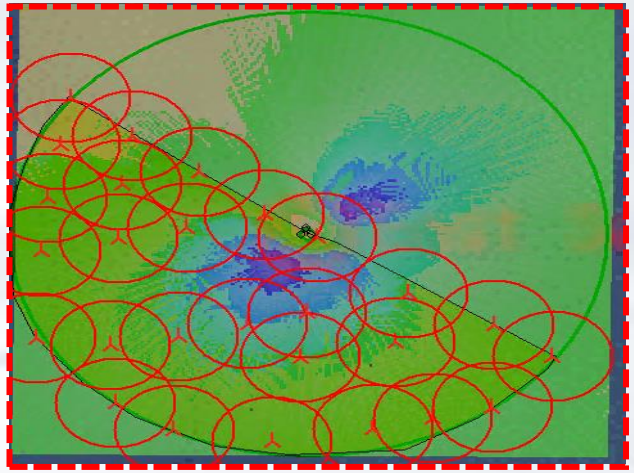
200MW Floating Offshore Wind Farm



Minimum AEP



Maximum AEP



Specification of wind generator : ENERCON 7.5MW x 27 / Rotor diameter = 127 m
Distance between turbines : 1,000 m

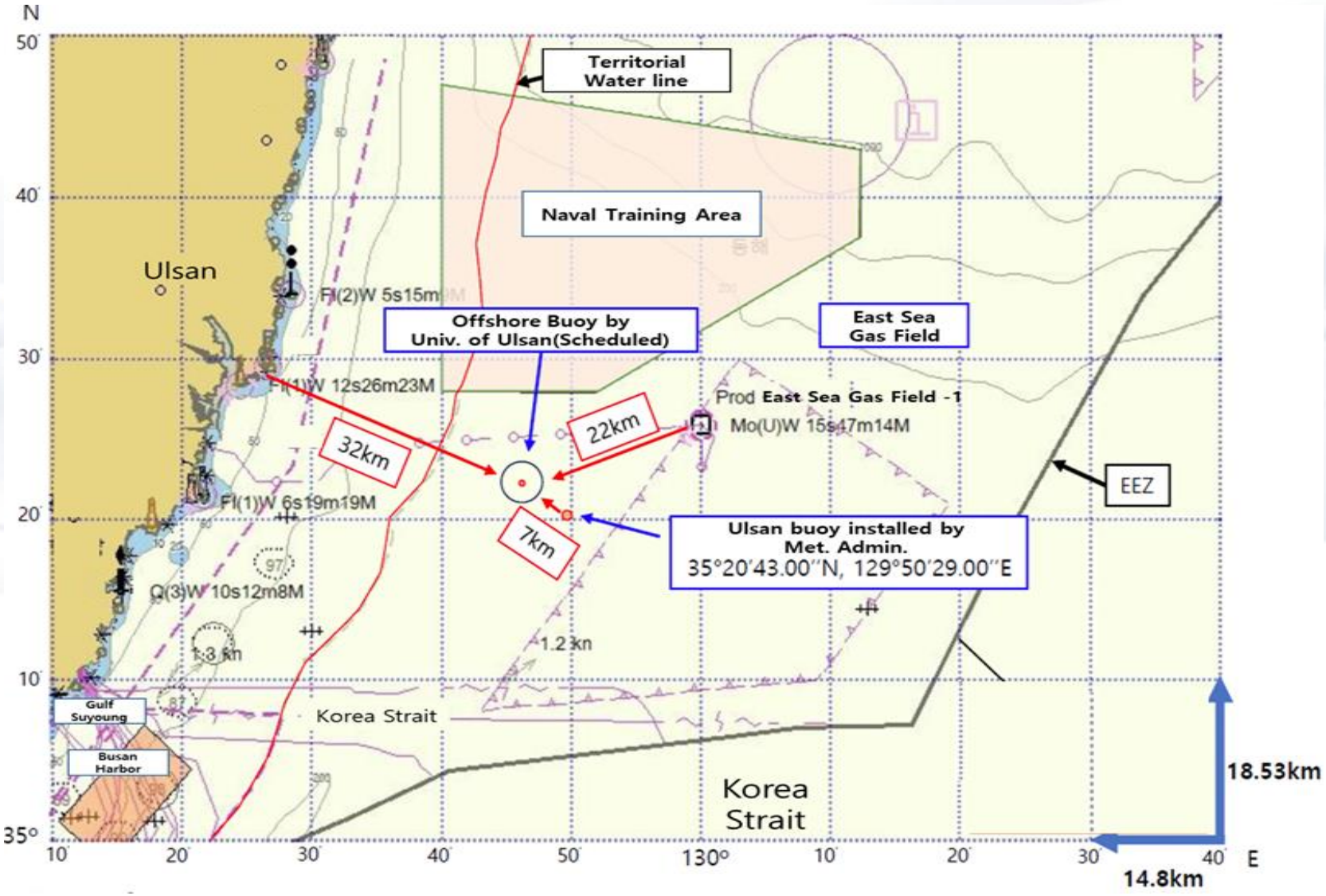
Items	Minimum AEP	Maximum AEP
MWh/y	465,081	681,593
REC Weight =3.44	1,599,878	2,344,680
SMP	KRW39,848,140,080	KRW58,398,888,240
REC	KRW67,287,668,924	KRW98,612,551,440
SMP+REC	KRW107,135,809,004(U$91,887,533.00)	KRW157,011,439,680 (U$134,664,535.00)

- SMP: KRW85,680/MWh (2020.01.03)
- REC : KRW42,058/MWh (2020.01.03)
- REC Weight =3.44

3.4 Green Energy Programs of Ulsan Metropolitan City (2018 ~)

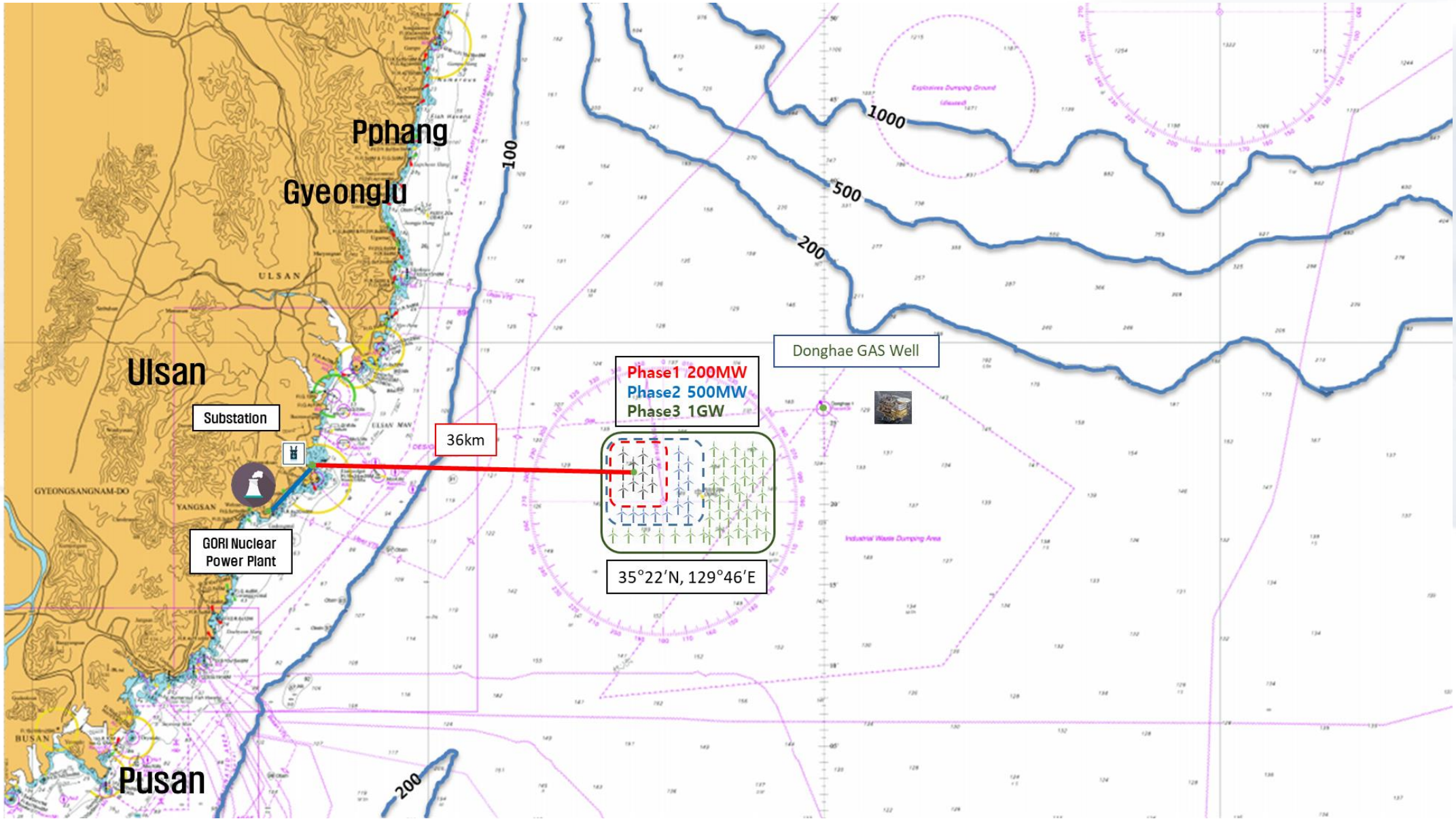
MOTIE(KETEP) , Ulsan Metropolitan City, Ulsan TechnoPark & UOU consortiums : Planned FOWT Farm (2)

Location of ocean data buoy of University of Ulsan and 200 MW / 1GW floating offshore wind farm site (planned)



3.4 Green Energy Programs of Ulsan Metropolitan City (2018 ~)

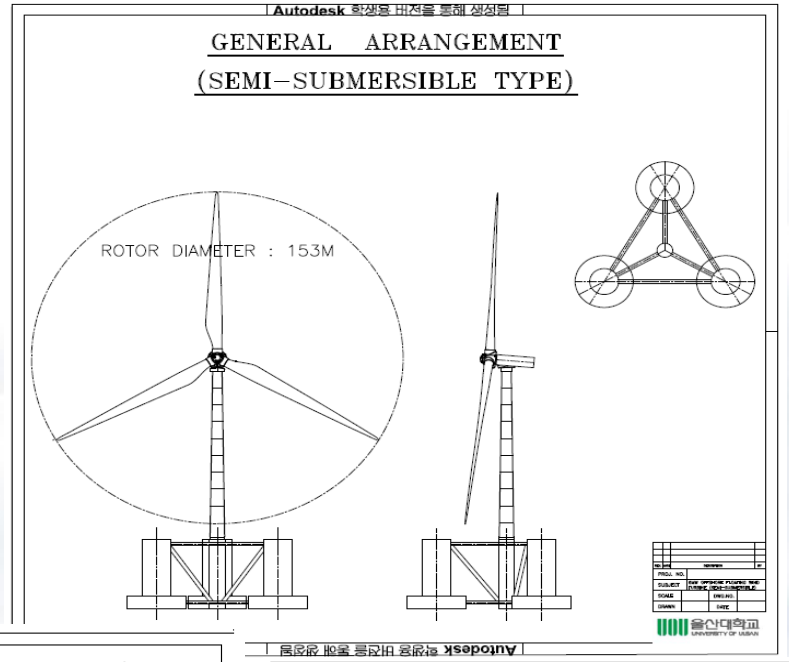
MOTIE(KETEP) , Ulsan Metropolitan City, Ulsan TechnoPark & UOU consortiums : Planned FOWT Farm (2)

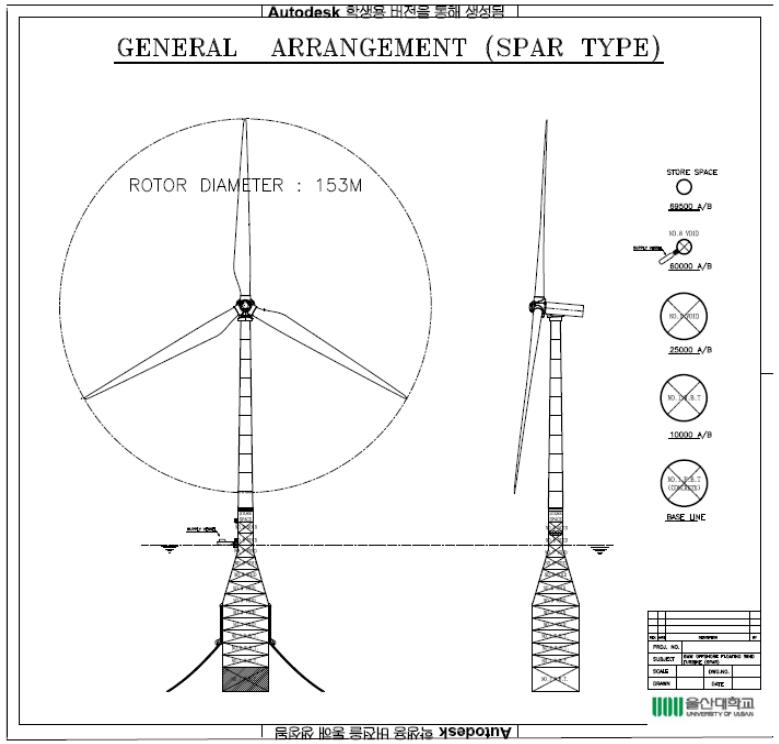


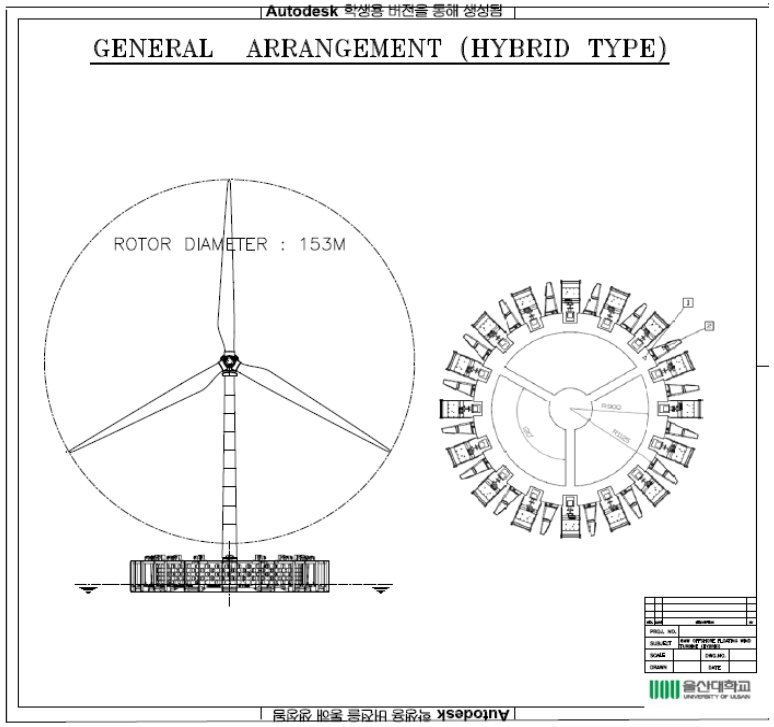
Department of Floating Offshore Wind Energy Generation Systems
부유식해상풍력학과

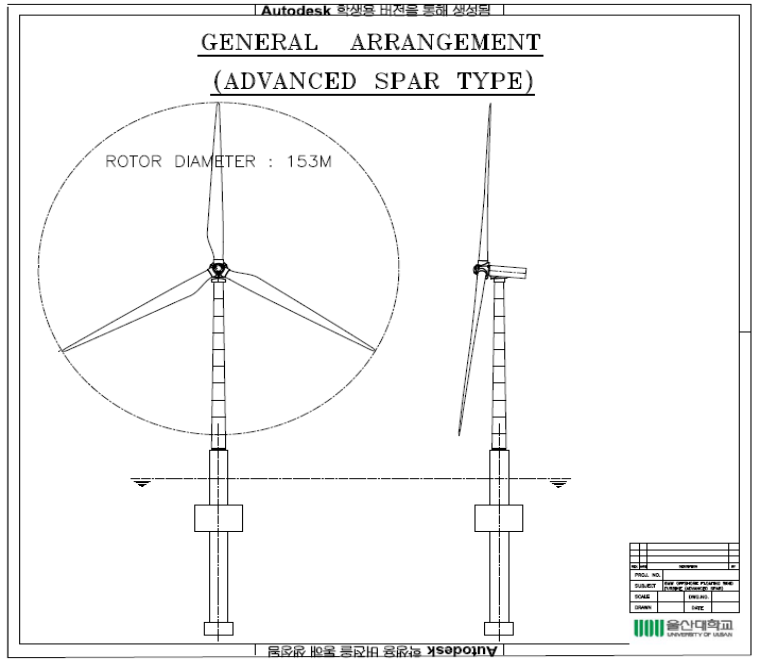
Unit : kg

	UOU_Spar	UOU_Semi	UOU_Hybrid	UOU_Advanced Spar
Turbine	710,151	710,151	710,151	710,151
Floater	2,600,000	4,393,420	4,600,000	2,428,000
ballast	10,913,200	8,969,147	10,150,000	3,539,000
Total	14,223,351	14,072,718	15,460,151	6,677,151









Four different types for 6 MW floating offshore wind turbine (UOU_Spar, UOU_Semi, UOU_Hybrid, UOU_Advanced Spar)

3.4 Green Energy Programs of Ulsan Metropolitan City (2018 ~)

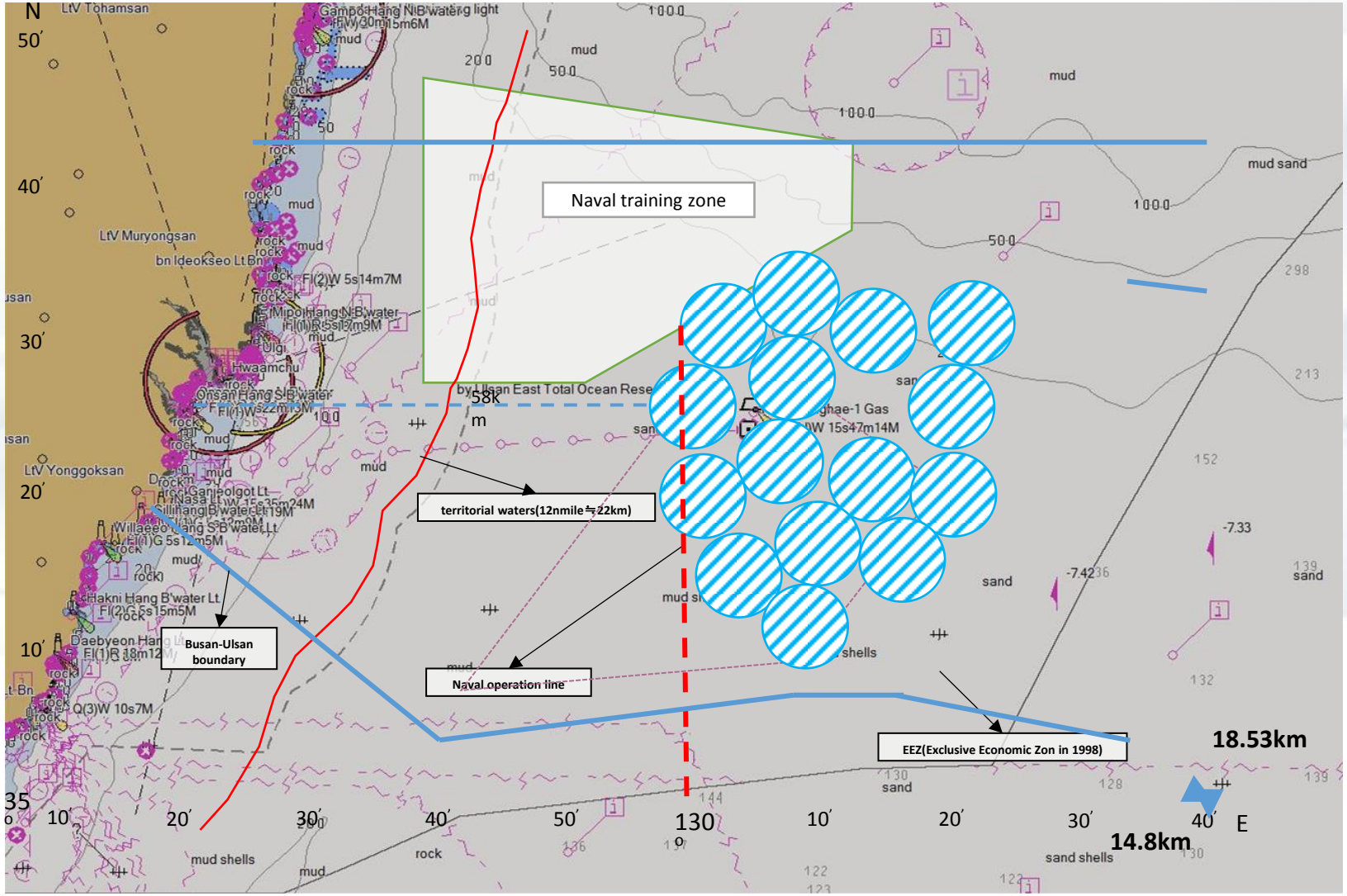
Five international consortiums

- Five international consortiums (CIP, Shell, GIG, EDP, Equinor) will take part in the project to build floating wind farms through cooperation with the city of Ulsan, South Korea.
- The city has been involved in green energy programs with government support.

*Source : Ulsan Metropolitan Government, Korea

3.4 Green Energy Programs of Ulsan Metropolitan City (2018 ~)

5 international consortiums : Planned FOWT Farm



3.4 Green Energy Programs of Ulsan Metropolitan City (2018 ~)

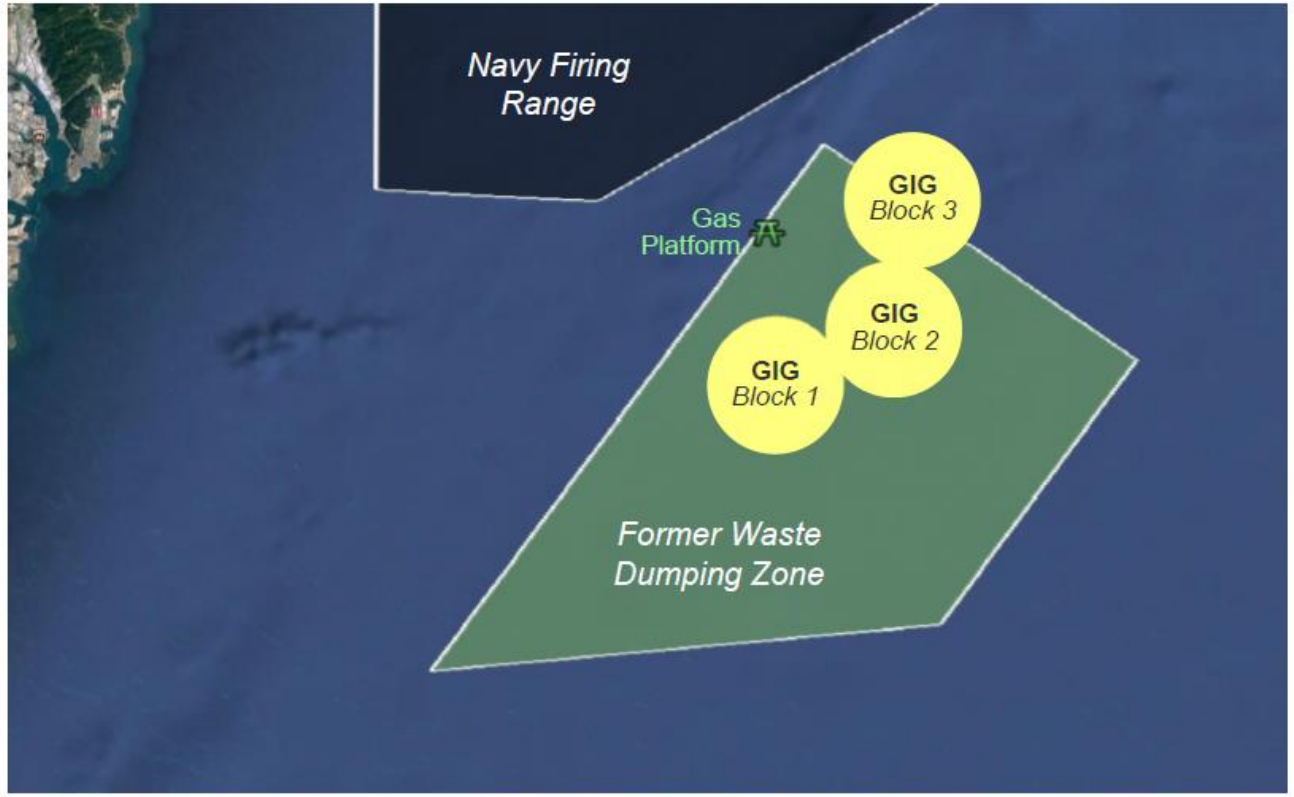
Project Gray Whale

Project overview

MACQUARIE | Green Investment Group

Project Gray Whale is a greenfield 1.5GW floating OSW farm development across 3 blocks off the east of Ulsan coastline

Project Gray Whale



Strategic locations

1. Robust wind condition
2. Sufficient distance from Navy firing range
3. 150m-deep flat seabed allowing for any types of buoy
4. Former waste dump into green energy park

*Source : FOWF 2019, Ulsan, Korea

3.4 Green Energy Programs of Ulsan Metropolitan City (2018 ~)

Project Gray Whale
Development timeline

Feasibility study — Mar 2018

MOU with Ulsan City — Jan 2019

Deployment of the 1st floating LiDAR in Korea — Jun 2019

In discussion with fishermen to install additional LiDARs — Present

Electricity Business License — 2020

Environmental Impact Assessment — 2022

Phase 1 Construction Start — 1H 2023

Phase 1 Construction End — 2H 2025

*Source : FOWF 2019, Ulsan, Korea

3.4 Green Energy Programs of Ulsan Metropolitan City (2018 ~)

Project Overview

Ulsan White Heron Project

Key facts

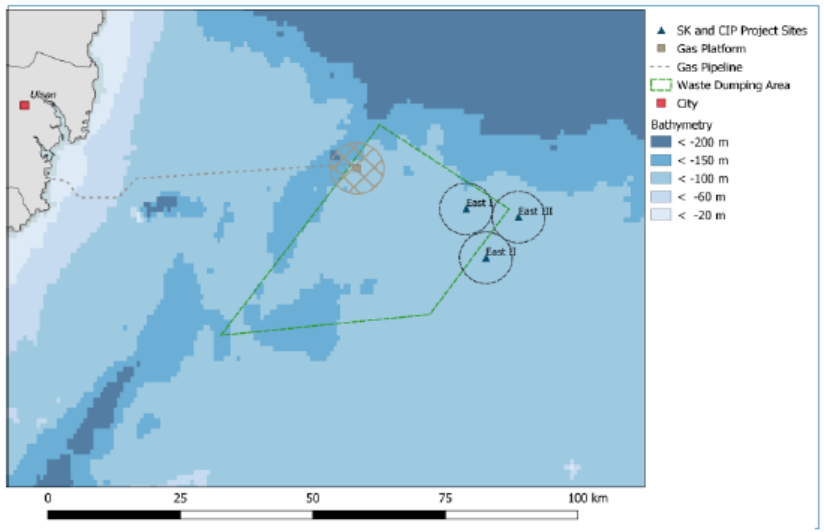
Proposal	▪ CIP proposes to construct **up to 1.2 GW offshore wind** in Ulsan. ▪ In order to secure a sustainable job creation in the area, it is proposed to split the construction in several phases. ▪ The **following three phases** could be developed as **3 x 400 MW large-scale** floating wind projects.

Local Content	▪ Local production of all major steel components, including:
	  ▪ Floating foundations, transition pieces and mooring lines
	  ▪ Turbine towers
	▪ Use of local harbours and onshore civil contractors

Site	▪ Expected wind speeds of ~8.5 m/s ▪ Floating foundation site water depths between 100-200m ▪ Potential suitable harbour (Ports in Ulsan)
Technology	▪ Leading WTG supplier with proven offshore manufacturing experience will be chosen ▪ Use the TetraSpar floating foundation developed by wind energy pioneer Henrik Stiesdal.

Timeline	▪ Steady flow of construction projects **until 2027**
	  ▪ COD Phase 1 Site: 2025
	  ▪ COD Phase 2 Site: 2026
	  ▪ COD Phase 3 Site: 2027
	▪ Steady flow of O&M **until 2047**

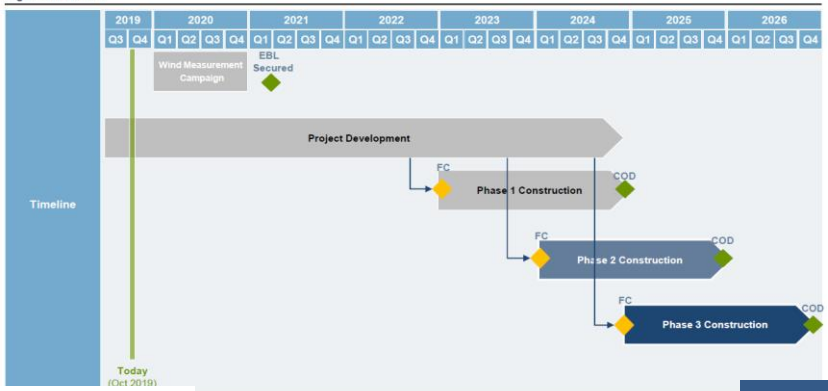
Site location



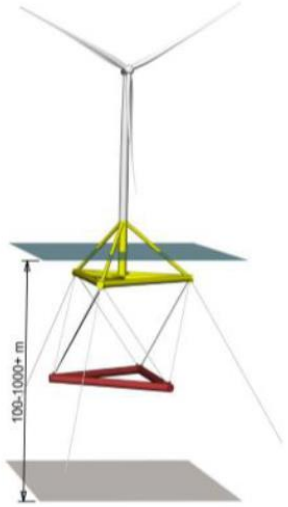
Project overview

Phase	Sites	Capacity	COD	Depth	Wind
1	Ulsan Floating Site Phase 1 (East I)	400MW	2025	134m	~8.3 m/s
2	Ulsan Floating Site Phase 2 (East II)	400MW	2026	143m	~8.3 m/s
3	Ulsan Floating Site Phase 3 (East III)	400MW	2027	146m	~8.5 m/s

High-level timeline



Stiesdal



TetraSpar

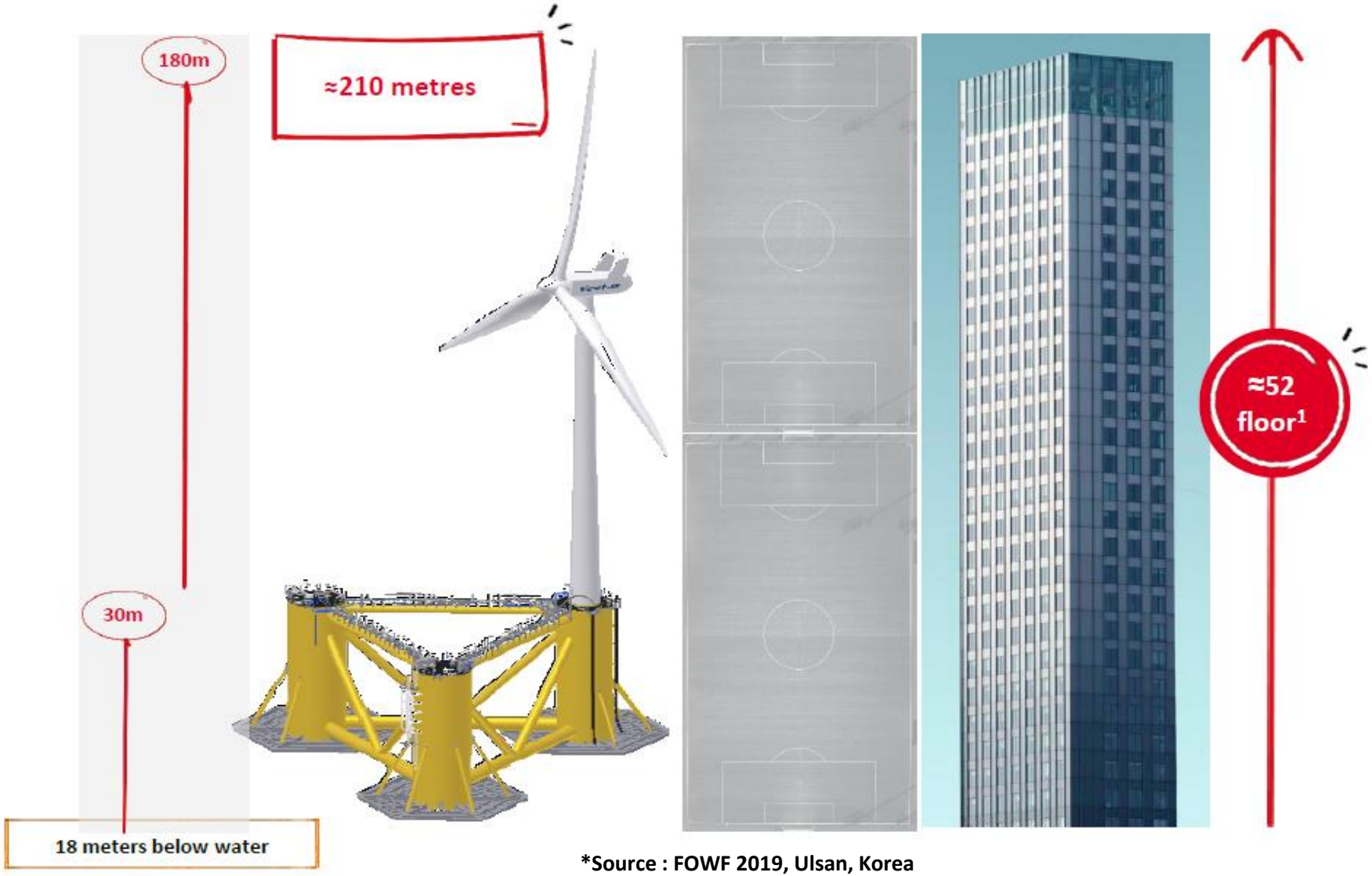
*Source : FOWF 2019, Ulsan, Korea

3.4 Green Energy Programs of Ulsan Metropolitan City (2018 ~)

KFWind Project

edp renováveis AkerSolutions WPK

...and WindFloat Atlantic

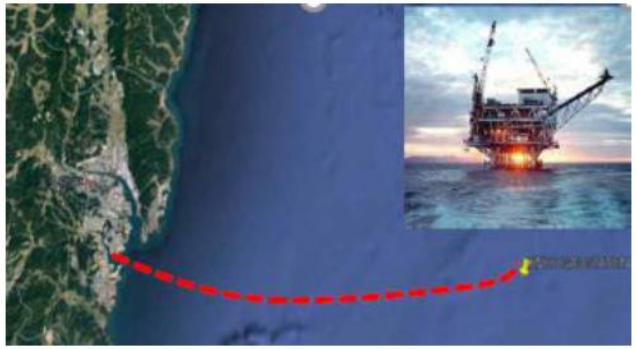


*Source : FOWF 2019, Ulsan, Korea

3.4 Green Energy Programs of Ulsan Metropolitan City (2018 ~)

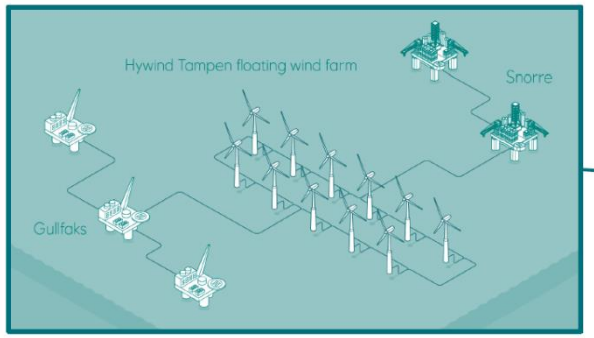
Donghae 1 Project

- 200 MW Donghae 1 Project
- 58 km to shore
- Water depth ~ 145 m
- MoU and consortium agreement signed between KNOC/Equinor/EWP
- Wind measurements and feasibility studies ongoing
- FID/COD 2022/2024



Firefly Project

- Development size 800MW
- 60-70 km to shore
- Water depth ~ 230 m
- Wind Speed 8.0-8.2 m/s
- Feasibility study 2020 / Concept selection 2021/ FEED 2022/2023
- FID/COD 2023/ 2025-2026



11 wind turbines between Snorre and Gullfaks

Combined capacity of 88MW

Concrete substructures and shared anchors

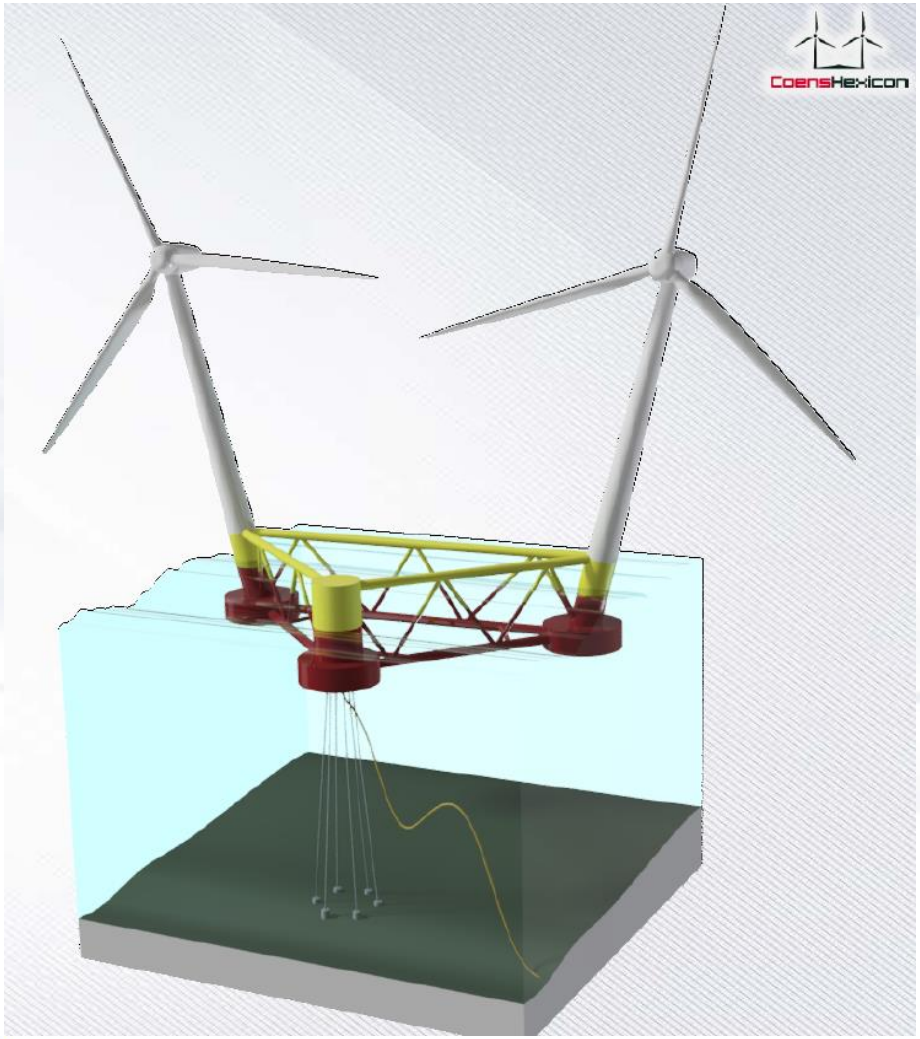
Considerable CO2 emission reductions

*Source : FOWF 2019, Ulsan, Korea

Hywind Tampen-Offshore Wind Farm connecte

3.4 Green Energy Programs of Ulsan Metropolitan City (2018 ~)

Donghae TwinWind Project



Support services and solutions provider to the oil & gas industry, spanning across fabrication yards and engineering offices.

coens

hexicon

Technology and project developer with a unique and patented floating foundation technology

IP rights for Hexicon's technology in Korea

CoensHexicon

Joint Development Agreement

Donghae TwinWind Project

*Source : FOWF 2019, Ulsan, Korea

OUR OFFSHORE WIND OFFERING FOR SOUTH KOREA

NAVAL ENERGIES

- ***Local conditions in Ulsan are very favourable for floating offshore wind:***
  - Constant wind around 8m/s
  - Suitable water depth
  - Advanced shipbuilding industry
  - Good grid conditions and availability
  - Strong political support

- ***Naval Energies*** has already conducted ***feasibility studies in the East Sea*** as well as a ***screening of industrial means*** in South Korea

*Source : FOWF 2019, Ulsan, Korea

3.4 Green Energy Programs of Ulsan Metropolitan City (2018 ~)

From (345 kV Substation)		Substation Candidate (154 kV Substation)	To (Load & Other 154kV Substation)		Remarks
(Name/Bus#)	Transformer (Spare/Total capacity-MVA)		(Name/Bus#)	T/L (Spare/Total capacity-MVA)	
Shin Onsan 3 (9300)	1st Trans. 265/500 2nd Trans. 265/500 3rd Trans. 260/500 4th Trans. 260/500	**Shin Onsan 1 (9310)**	OnSan(9311) YongAm(9335) DangWeol (9340)	734/1040 813/894 330/472	Total trans. spare capacity: 1,050 MVA Load spare capacity: 1,877 MVA Close to the Gori NP1 (Nuclear power plant)
DongUlsan 3 (9850)	1st Trans. 350/500 2nd Trans. 350/500 3rd Trans. 350/500	**Dong Ulsan 1 (9860)**	MaeGok(9885) SanHa(9920) HyoMoon(9980)	706/894 796/904 712/828	Total trans. spare capacity: 1,050 MVA Load spare capacity: 2,214 MVA Close to the WeolSung NP3 (Nuclear power plant)

3.5 Comparison with Measured Data and Reanalysis Data in East sea

Annual Energy Production

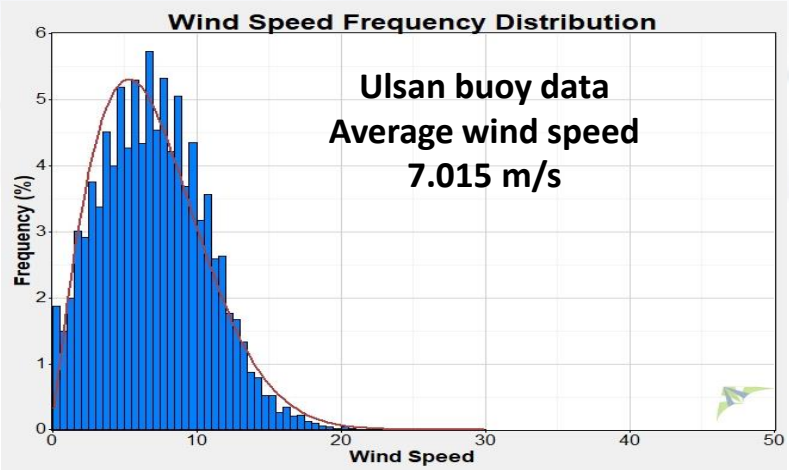
Minimum AEP

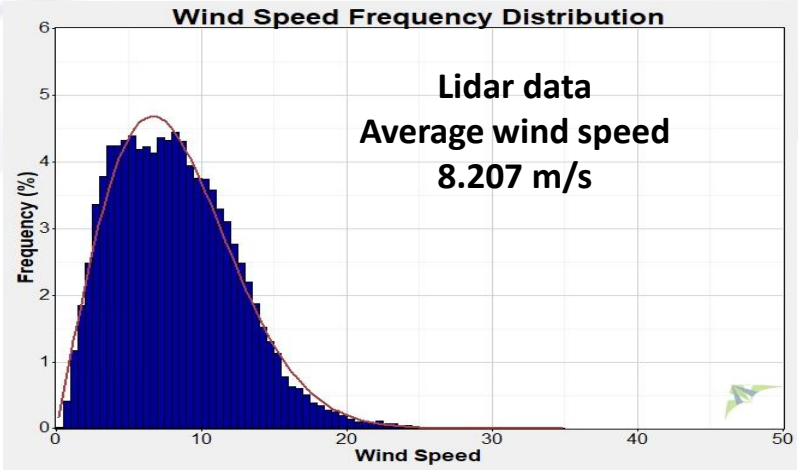
Meta Information	
Data	Ulsan buoy
Interval	1-hour
Measure height	4.3m
Power law exponent	-
Coordinate	35.35ºN, 129.84ºE
Measure period	2016.01.01 00:00 ~ 2020.01.01 00:00
Management	Meteorological Agency

VS

Maximum AEP

Meta Information	
Data	East Sea gas field Lidar
Interval	10-min
Measure height	87m – 247m
Power law exponent	0.0321
Coordinate	35.43ºN, 130.00ºE
Measure period	2018.11.01 00:00 ~ 2019.11.01 00:00
Management	KNOC





*Wind data analyzed at 100m height (Power law exponent = 0.0321)

3.5 Comparison with Measured Data and Reanalysis Data

Ulsan 6m-NOMAD Weather buoy
Average Wind Speed (Weibull)
11.11m/s

ERA-5(ECMWF)
Average Wind Speed (Weibull)
8.72m/s

MERRA-2(NASA)
Average Wind Speed (Weibull)
8.73m/s

Table 5. 10-minutes average Extreme wind speed at hub height (90m)

Ulsan 6m-NOMAD Weather buoy	
Scale=1.802, Mode=19.798	
Period [yr]	Max Wind Speed [m/s]
5	33.09
10	35.08
15	36.21
20	36.99
30	38.09
50	39.46
100	41.31
200	43.16
500	45.59
1000	47.43

Source : Ulsan 6m-NOMAD Weather buoy
Location : N35.345 E129.841
Measure period: 3 years
(2016-01-01 ~ 2018-12-31)

ERA-5	
Scale=3.540, Mode=25.259	
Period [yr]	Max Wind Speed [m/s]
5	31.81
10	34.57
15	36.13
20	37.22
30	38.75
50	40.65
100	43.23
200	45.79
500	49.17
1000	51.72

Source : ERA-5 (ECMWF)
Location : N35.250 E129.750
Analysis period: 8 years
(2010-01-01 ~ 2017-12-31)

MERRA-2	
Scale=3.511, Mode=22.528	
Period [yr]	Max Wind Speed [m/s]
5	31.21
10	34.17
15	35.84
20	37.01
30	38.64
50	40.68
100	43.43
200	46.18
500	49.80
1000	52.53

Source : MERRA-2 (NASA)
Location : N35.500 E130.000
Analysis period: 39 years
(1980-01-01 ~ 2018-12-31)

THANK YOU.

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