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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IEC TC88 MT3-2 (for Revision of IEC 61400-3-2)

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Outline

0. Introduction to the University of Ulsan, Ulsan, Korea
1. Why Offshore Wind? Why FOWTs?
2. Critical Needs for FOWTs in Korea
3. Floating Offshore Wind Farm Projects Planned in the East Sea, Korea
   3.1 Korea’s RE 3020
   3.2 Ulsan Shin-Gori 750kW FOWT Pilot Project
   3.3 Plan of Floating Offshore Wind Farms in Ulsan
   3.4 Green Energy Programs of Ulsan Metropolitan City (2018 ~)
   3.5 Comparison with Measured Data and Reanalysis Data
0. Introduction to the University of Ulsan, Ulsan, Korea

Ulsan, KOREA

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

Source: Explore Korea through Statistics 2018
0. Introduction to the University of Ulsan, Ulsan, Korea

Floating Airport Model Test
Ocean Engineering Wide Tank, UOU, Korea

LxBxDw=30x20x3x2.5 m
1. Why Offshore Wind? Why FOWTs?

<table>
<thead>
<tr>
<th>Industry</th>
<th>Compound annual growth rate for GVA between 2010 and 2030</th>
<th>Total change in GVA between 2010 and 2030</th>
<th>Total change in employment between 2010 and 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial marine aquaculture</td>
<td>5.69%</td>
<td>303%</td>
<td>152%</td>
</tr>
<tr>
<td>Industrial capture fisheries</td>
<td>4.10%</td>
<td>223%</td>
<td>94%</td>
</tr>
<tr>
<td>Industrial fish processing</td>
<td>6.26%</td>
<td>337%</td>
<td>206%</td>
</tr>
<tr>
<td>Maritime and coastal tourism</td>
<td>3.51%</td>
<td>199%</td>
<td>122%</td>
</tr>
<tr>
<td>Offshore oil and gas</td>
<td>1.17%</td>
<td>125%</td>
<td>126%</td>
</tr>
<tr>
<td>Offshore wind</td>
<td><strong>24.52%</strong></td>
<td><strong>8.037%</strong></td>
<td><strong>1257%</strong></td>
</tr>
<tr>
<td>Port activities</td>
<td>4.58%</td>
<td>245%</td>
<td>245%</td>
</tr>
<tr>
<td>Shipbuilding and repair</td>
<td>2.93%</td>
<td>178%</td>
<td>124%</td>
</tr>
<tr>
<td>Maritime equipment</td>
<td>2.93%</td>
<td>178%</td>
<td>124%</td>
</tr>
<tr>
<td>Shipping</td>
<td>1.80%</td>
<td>143%</td>
<td>130%</td>
</tr>
<tr>
<td>Average of total ocean-based industries</td>
<td><strong>3.45%</strong></td>
<td><strong>197%</strong></td>
<td><strong>130%</strong></td>
</tr>
<tr>
<td>Global economy between 2010 and 2030</td>
<td><strong>3.64%</strong></td>
<td><strong>204%</strong></td>
<td><strong>120%</strong></td>
</tr>
</tbody>
</table>

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).

1. Why Offshore Wind? Why FOWTs?

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


1. Why Offshore Wind? Why FOWTs?
2. Critical needs for FOWTS in Korea

- Quantum Jump for Korea Wind Industry
  (System & Supply Chain: HHI, SHI, DSME, STX, Doosan, Hyosung, 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

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

January 15th, 16th & 17th
3.3 Plan of Floating Offshore Wind Farms in Ulsan
3.3 Plan of Floating Offshore Wind Farms in Ulsan

**LIDAR Measured height**

<table>
<thead>
<tr>
<th>Specifications</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Range</strong></td>
<td>40m to 200m</td>
</tr>
<tr>
<td><strong>Data sampling rate</strong></td>
<td>15</td>
</tr>
<tr>
<td><strong>Number of height</strong></td>
<td>12</td>
</tr>
<tr>
<td><strong>Speed accuracy</strong></td>
<td>0.1m/s</td>
</tr>
<tr>
<td><strong>Speed range</strong></td>
<td>0 to 60m/s</td>
</tr>
<tr>
<td><strong>Direction accuracy</strong></td>
<td>±2°</td>
</tr>
</tbody>
</table>

*Source: WINDCUBE V2 / KNRG systems

*Image: East Seagas 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

- MOTIE(KETEP), Ulsan Metropolitan City, Ulsan TechnoPark and UOU consortium: 200 MW
- KNOC consortium: 200 MW
- 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

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

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

- 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)
<table>
<thead>
<tr>
<th></th>
<th>UOU_Spar</th>
<th>UOU_Semi</th>
<th>UOU_Hybrid</th>
<th>UOU_Advanced Spar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbine</td>
<td>710,151</td>
<td>710,151</td>
<td>710,151</td>
<td>710,151</td>
</tr>
<tr>
<td>Floater</td>
<td>2,600,000</td>
<td>4,393,420</td>
<td>4,600,000</td>
<td>2,428,000</td>
</tr>
<tr>
<td>ballast</td>
<td>10,913,200</td>
<td>8,969,147</td>
<td>10,150,000</td>
<td>3,539,000</td>
</tr>
<tr>
<td>Total</td>
<td>14,223,351</td>
<td>14,072,718</td>
<td>15,460,151</td>
<td>6,677,151</td>
</tr>
</tbody>
</table>

Unit: kg

**GENERAL ARRANGEMENT**

- **SPAR TYPE**
- **HYBRID TYPE**
- **ADVANCED SPAR TYPE**

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

Naval training zone

Territorial waters (12 mile = 18.53 km)

Busan-Ulsan boundary

Naval operation line

EEZ (Exclusive Economic Zone in 1998)
Project Gray Whale

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

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
MOU with Ulsan City
Deployment of the 1st floating LiDAR in Korea
In discussion with fishermen to install additional LiDARs

- Feasibility study: Mar 2018
- MOU with Ulsan City: Jan 2019
- Deployment of the 1st floating LiDAR in Korea: Jun 2019
- In discussion with fishermen: Present

Electricity Business License
Environmental Impact Assessment
Phase 1 Construction Start
Phase 1 Construction End

- 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 ~ )

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

*Source: FOWF 2019, Ulsan, Korea*
3.4 Green Energy Programs of Ulsan Metropolitan City (2018 ~ )

KFWind Project

...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

*Source : FOWF 2019, Ulsan, Korea*
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.

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

IP rights for Hexicon’s technology in Korea

Joint Development Agreement

Donghae TwinWind Project

*Source : FOWF 2019, Ulsan, Korea
3.4 Green Energy Programs of Ulsan Metropolitan City (2018 ~ )

OUR OFFSHORE WIND OFFERING FOR SOUTH KOREA

- **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 ~ )

<table>
<thead>
<tr>
<th>From (345 kV Substation)</th>
<th>Substation Candidate (154 kV Substation)</th>
<th>To (Load &amp; Other 154kV Substation)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Name/Bus#)</td>
<td></td>
<td>(Name/Bus#)</td>
<td></td>
</tr>
<tr>
<td>Shin Onsan 3 (9300)</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; Trans. 265/500 2&lt;sup&gt;nd&lt;/sup&gt; Trans. 265/500 3&lt;sup&gt;rd&lt;/sup&gt; Trans. 260/500 4&lt;sup&gt;th&lt;/sup&gt; Trans. 260/500</td>
<td>Shin Onsan 1 (9310) OnSan(9311) YongAm(9335) DangWeol (9340)</td>
<td>734/1040 813/894 330/472</td>
</tr>
<tr>
<td>DongUlsan 3 (9850)</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; Trans. 350/500 2&lt;sup&gt;nd&lt;/sup&gt; Trans. 350/500 3&lt;sup&gt;rd&lt;/sup&gt; Trans. 350/500</td>
<td>Dong Ulsan 1 (9860) MaeGok(9885) SanHa(9920) HyoMoon(9980)</td>
<td>706/894 796/904 712/828</td>
</tr>
</tbody>
</table>

- **Remarks:**
  - Total trans. spare capacity: 1,050 MVA
  - Load spare capacity: 1,877 MVA
  - Close to the Gori NP1 (Nuclear power plant)

- **Remarks:**
  - 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

<table>
<thead>
<tr>
<th>Minimum AEP</th>
<th>Maximum AEP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Meta Information</strong></td>
<td><strong>Meta Information</strong></td>
</tr>
<tr>
<td>Data</td>
<td>Ulsan buoy</td>
</tr>
<tr>
<td>Interval</td>
<td>1-hour</td>
</tr>
<tr>
<td>Measure height</td>
<td>4.3m</td>
</tr>
<tr>
<td>Power law exponent</td>
<td>-</td>
</tr>
<tr>
<td>Coordinate</td>
<td>35.35°N, 129.84°E</td>
</tr>
<tr>
<td>Measure period</td>
<td>2016.01.01 00:00 ~ 2020.01.01 00:00</td>
</tr>
<tr>
<td>Management</td>
<td>Meteorological Agency</td>
</tr>
</tbody>
</table>

#### Wind Speed Frequency Distribution

**Ulsan buoy data**

- Average wind speed: 7.015 m/s

**Lidar data**

- Average wind speed: 8.207 m/s

*Wind data analyzed at 100m height (Power law exponent = 0.0321)*
3.5 Comparison with Measured Data and Reanalysis Data

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

<table>
<thead>
<tr>
<th>Period [yr]</th>
<th>Max Wind Speed [m/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>33.09</td>
</tr>
<tr>
<td>10</td>
<td>35.08</td>
</tr>
<tr>
<td>15</td>
<td>36.21</td>
</tr>
<tr>
<td>20</td>
<td>36.99</td>
</tr>
<tr>
<td>30</td>
<td>38.09</td>
</tr>
<tr>
<td>50</td>
<td>39.46</td>
</tr>
<tr>
<td>100</td>
<td>41.31</td>
</tr>
<tr>
<td>200</td>
<td>43.16</td>
</tr>
<tr>
<td>500</td>
<td>45.59</td>
</tr>
<tr>
<td>1000</td>
<td>47.43</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Period [yr]</th>
<th>Max Wind Speed [m/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>31.81</td>
</tr>
<tr>
<td>10</td>
<td>34.57</td>
</tr>
<tr>
<td>15</td>
<td>36.13</td>
</tr>
<tr>
<td>20</td>
<td>37.22</td>
</tr>
<tr>
<td>30</td>
<td>38.75</td>
</tr>
<tr>
<td>50</td>
<td>40.65</td>
</tr>
<tr>
<td>100</td>
<td>43.23</td>
</tr>
<tr>
<td>200</td>
<td>45.79</td>
</tr>
<tr>
<td>500</td>
<td>49.17</td>
</tr>
<tr>
<td>1000</td>
<td>51.72</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Period [yr]</th>
<th>Max Wind Speed [m/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>31.21</td>
</tr>
<tr>
<td>10</td>
<td>34.17</td>
</tr>
<tr>
<td>15</td>
<td>35.84</td>
</tr>
<tr>
<td>20</td>
<td>37.01</td>
</tr>
<tr>
<td>30</td>
<td>38.64</td>
</tr>
<tr>
<td>50</td>
<td>40.68</td>
</tr>
<tr>
<td>100</td>
<td>43.43</td>
</tr>
<tr>
<td>200</td>
<td>46.18</td>
</tr>
<tr>
<td>500</td>
<td>49.80</td>
</tr>
<tr>
<td>1000</td>
<td>52.53</td>
</tr>
</tbody>
</table>

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

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

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

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

Scale = 1.802, Mode = 19.798

ERA-5 (ECMWF)
Scale = 3.540, Mode = 25.259

MERRA-2 (NASA)
Scale = 3.511, Mode = 22.528

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

This project is being supported by the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea government (MOTIE) and by the Ulsan Metropolitan Government, Korea. Also we deliver many thanks to the international developers and wind industries: Shell, CIP, GIG, EDPR, PPI, Aker, Equinor, KNOC, SK enc, Coens, HEXICON, Stiesdal, Ulsan Technopark, etc.