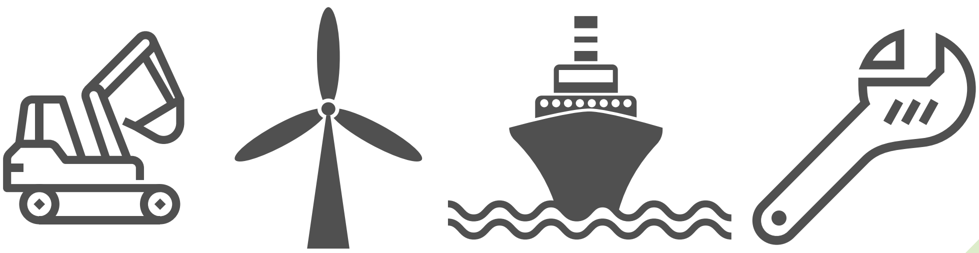
▶ Korea Offshore Wind Industry Classification(`23.03)

# 국내 해상풍력 공급망 세부 분류

## DETAILED CLASSIFICATION OF DOMESTIC OFFSHORE WIND POWER SUPPLY CHAIN



Korea Wind Energy Industry Association

<u>Abbreviation</u>

| Division | Meaning | Etc. |
|---|---|---|
| AEP | Annual Energy Production | 연간발전량 |
| AHT | Anchor Handling Tug | · |
| BoP | Balance of Plant | · |
| CTV | Crew Transfer Vessel | 12인승 내외의 유지보수 선박 |
| CMS | Condition Monitoring System | · |
| DEA | Drag Embedded Anchor | · |
| FEED | Front End Engineering Design | · |
| FID | Financial Investment Decision | · |
| HLV | Heavy Lift Vessel | · |
| ISP | Independent Service Provider | · |
| LCOE | Levelized Cost of Energy | 균등화 발전원가 |
| LTSA | Long Term Service Agreement | · |
| LIDAR | Light Detection Ranging | · |
| MWS | Marine Warranty Survey | · |
| OTM | Offshore Transformer Module | · |
| SOV | Service Operation Vessel | 40인승 내외의 유지보수 선박 |
| SPC | Special Purpose Corporation | 특수목적 법인 |
| TOC | Terminal Operating Company | 부두운영회사 |
| WTG | Wind Turbine Generator | · |

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## The author's words - Jone Oh / Blue Wind Engineering CEO/Ph. D. (KWEIA Industrial Sector Advisory Committee)

In 2021, the global offshore wind market witnessed 57.2GW, mainly contributed by Europe and China. While the worldwide market is mature, Korea’s installation remains 124.5MW based on three commercial offshore wind farms(including the land-sea complex). The Korean government plans to expand the capacity to 12GW by 2030, and it already has approved the over 12GW. Among them, the scales of the projects in Jeonnam and Ulsan are relatively large.

In the early days of business, Europe defined the offshore wind power industry as a government-driven industry as it requires the government’s active intervention and policies for forging a market, licensing, acceptance, and port hinterland. Furthermore, its capability to analyze the supply chain is significant. To this end, research on the current status of the supply chain is a prerequisite. However, Korea is lagging in this study.

Overseas studies on the capability of the supply chain have been systematically conducted. Referring to these studies, a classification for the domestic offshore wind power supply chain was prepared.

This paper summarized industrial characteristics, trends of overseas companies, domestic companies, domestic technology level by the supply chain. The comprehensive application of this research will be served as primary data for entry into new markets, training workforce, and direction of R&D.

However, it should be noted that this survey is an initial survey of industrial analysis, and complementary research and analysis should be continuously conducted in the future. Hopefully, This report will likely contribute to the direction of research on industrial ecosystem strategies to develop Korea's offshore wind industry.

## 1.1 Approaches

- Classification of offshore wind power supply chain is associated with the lifecycle of an offshore wind farm. It consists of four stages : Site development - Procurement & Manufacture - Installation & Construction - Operation. Decommission is included in the operation stage because Korea has not decommissioned. (Figure 5)
- Referring to foreign cases, though, this study classified detailed supply chains within four lifecycle stages.
- In some cases, wind turbines and Balance of Plant (BoP) are distinguished, but this research did not in the procurement & manufacture stage.
- In terms of licensing, it also did not analyze the government, local governments, government agencies, universities, and government-funded research institutes.
- Although the government manages the port hinterlands, they are included in the supply chain in consideration of their importance.
- Floating offshore wind power is still in the early stages of the industry and its supply chain is not formed, still it is included in the classification regarding its different industrial characteristics compared to the fixed type and the future industry.
- The substructure types of fixed offshore wind power are based on the monopile and jacket structures.

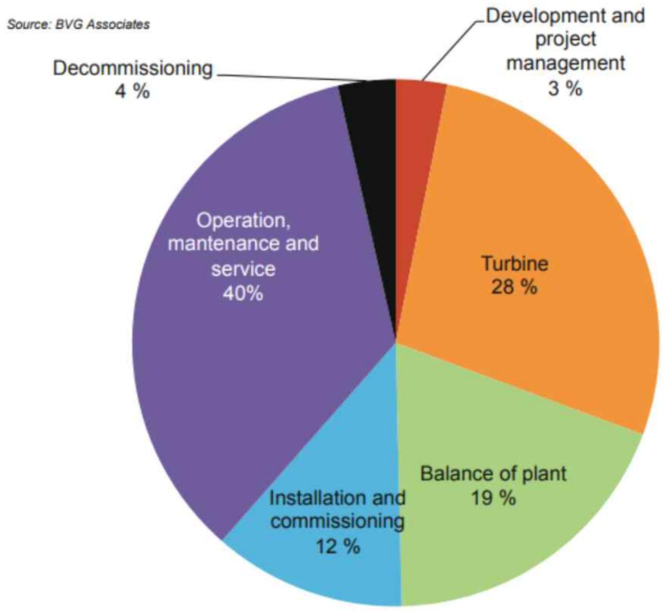
## 1.2 Economic Indicators

- LCOE is used for economic indicators for each stage.
- The quoted LCOE indicators were based on relatively recent European data.
- It is essential to note that there are slight differences between organizations.
- The recent data from the enormous prestigious agencies are included for comparison.
- Since the differences between fixed and floating offshore wind farms, Equinor's presentation slides are included as a reference, which operates a spar buoy floating platform in the commercial complex.

Figure 1. Period and proportion of LCOE by stage of offshore wind farm

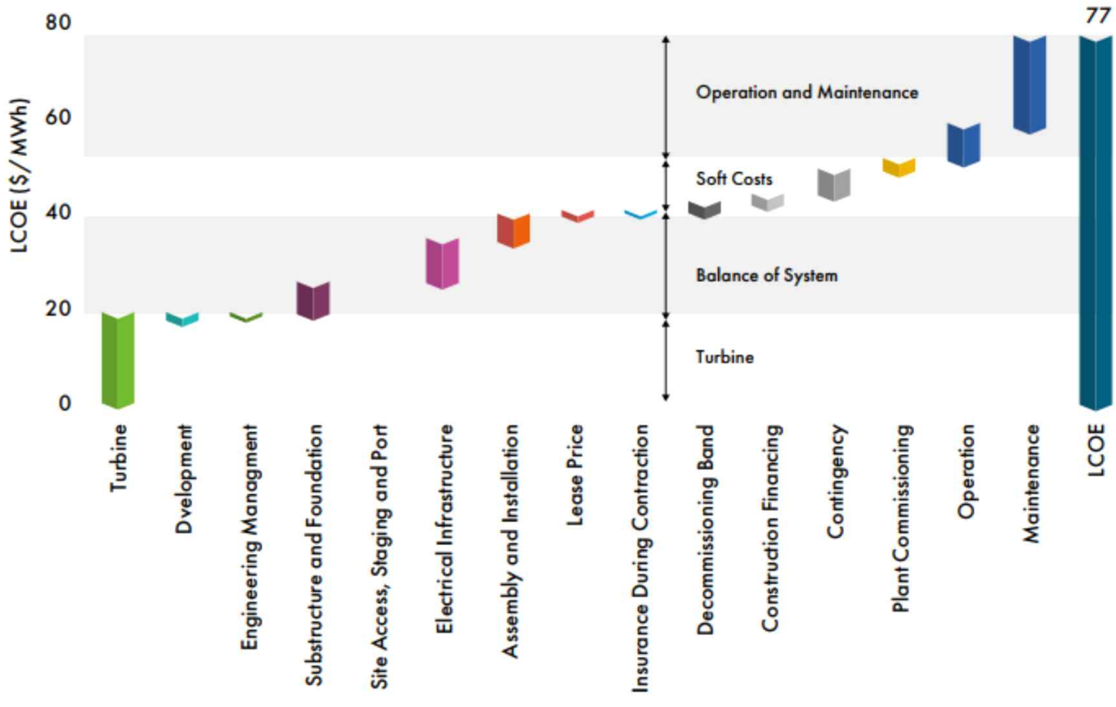

Source : ORE Catapult 외, Offshore wind industry prospectus, 2018

Figure 2. LCOE of fixed offshore wind power



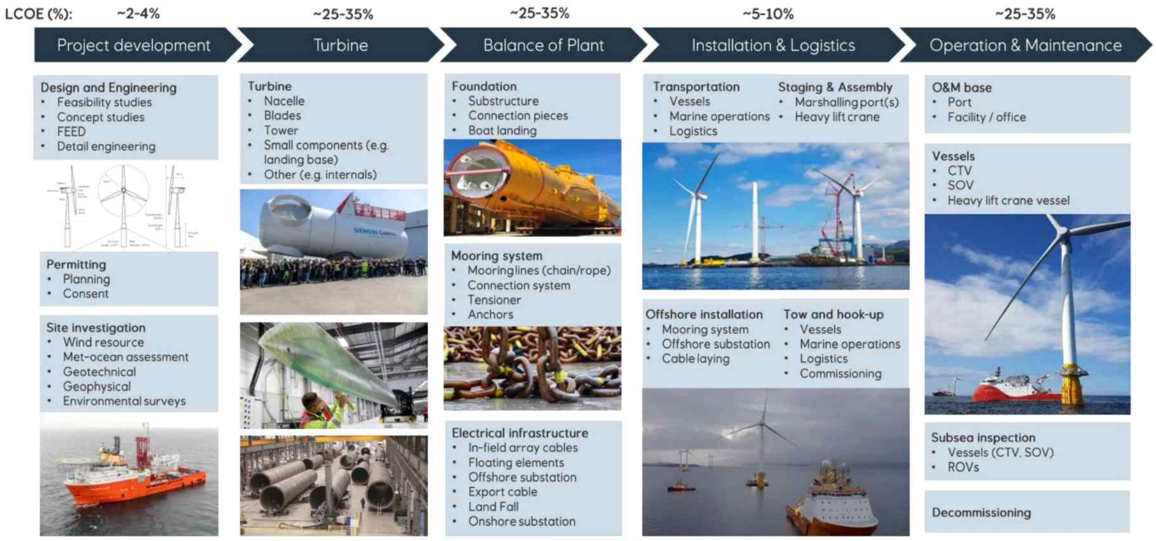

Source : BVG, Norwegian supply chain opportunities in offshore wind, 2017

Figure 3. LCOE of fixed offshore wind farm




Source : GWEC, Global wind report 2022, 2022

Figure 4. LCOE of floating offshore wind power

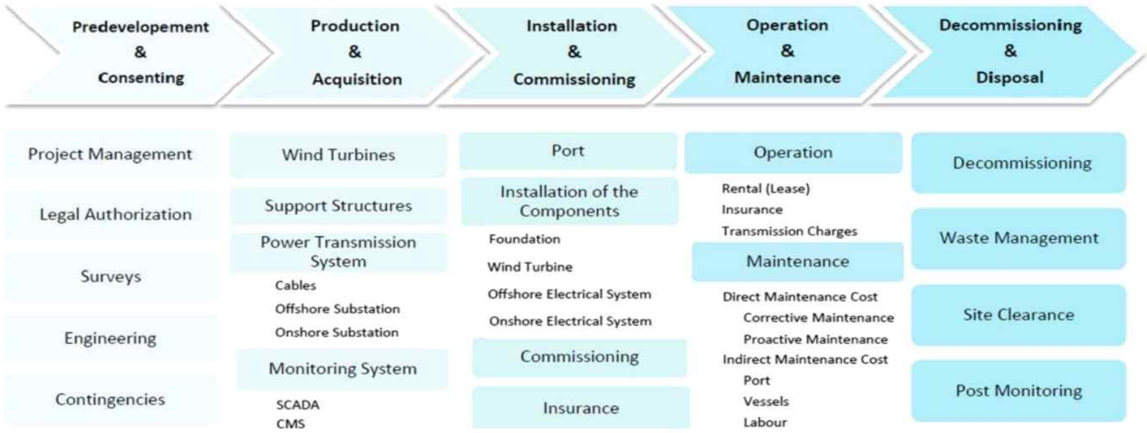



Source : Carbon Trust 외, UK Lesson: Global perspective on OSW supply chain opportunities for Maine, 2021

## 1.3 Lifecycle of Offshore Wind Farm

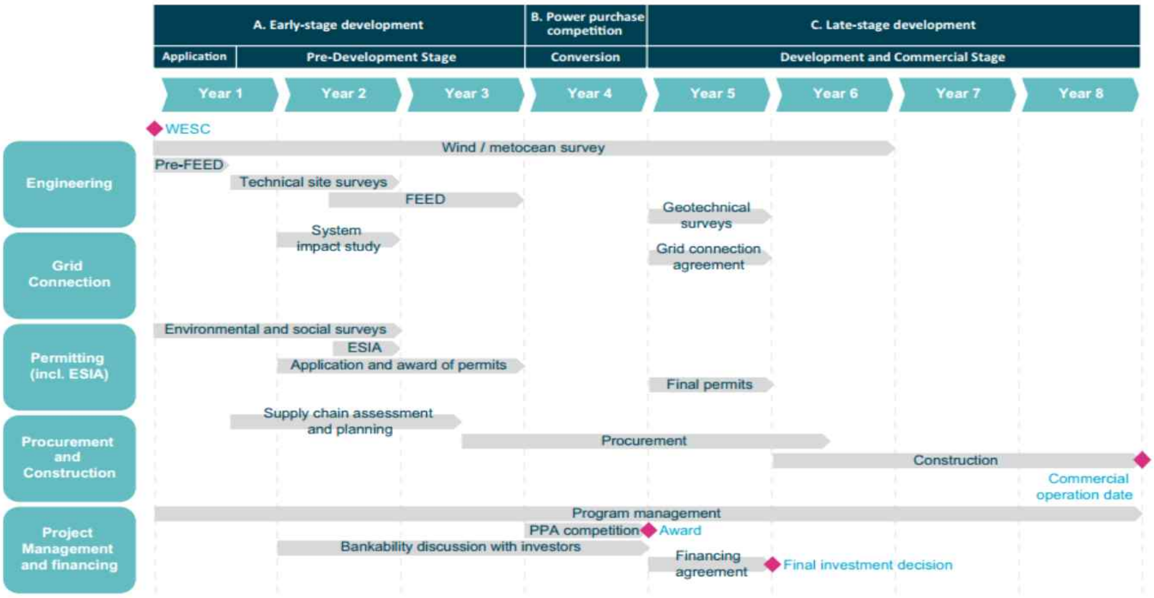
- The lifecycle is divided into Site Development, Procurement & Manufacture, Installation & Construction, and Operation.
- The second stage is divided into Procurement & Manufacture. This is because it can be a purchase stage from the perspective of a site developer. However, it also can be a manufacture stage from the perspective of an equipment manufacturer.
- In Europe, the completion of offshore wind power takes about eight years. (Figure 6)
- In Korea, the project takes two more years than in Europe to secure licensing and acceptance in the development stage.
- The operating period of the offshore wind farm is 20 to 25 years; if the development stage adds, the total project takes about 35 years.

Figure 5. Example of the lifecycle of offshore wind farm




Source : Mahmood Shafiee 외, Cranfield university, A parametric whole life cost model for offshore wind farms, 2016

Figure 6. Conventional lifecycle of offshore wind farm




Source : World Bank Group, Offshore wind program for the Philippines, 2021

Figure 7. Example of offshore wind farm supply chain

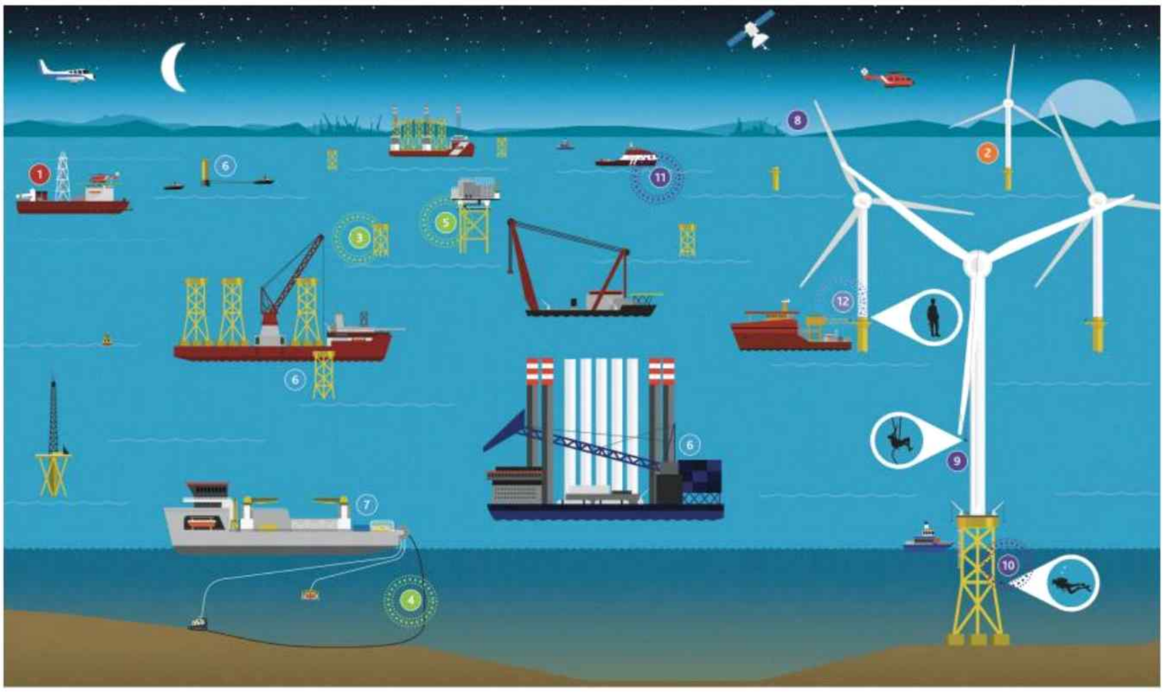


**Figure 1 Illustration of the offshore wind supply chain (greatest opportunities for Norwegian supply highlighted with concentric rays).**

| Development and project management | | Turbine supply | | Balance of plant | | Installation and commissioning | | Operation, maintenance and service | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Surveys, site investigations and development services | 2 | Turbine components manufacture and assembly | 3 | Foundation supply | 6 | Turbine and foundation installation | 8 | Wind farm operations |
| | | | | 4 | Cable supply | 7 | Cable installation | 9 | Turbine maintenance |
| | | | | 5 | Substation supply | | | 10 | Inspection and repair services |
| | | | | | | | | 11 | Offshore logistics |
| 12 Cross cutting activities | | | | | | | | | |

Source : BVG, Norwegian supply chain opportunities in offshore wind, 2017

Table 1. Comparison of Stages in Offshore Wind Farm

| Stage | Site Development | Procurement & Manufacture | Installation & Construction | Operation |
|---|---|---|---|---|
| Time | About 3~4 years | About 2 years | About 2 years | 20~25 years |
| LCOE | About 3~4% | About 45% | About 10% | About 35% |
| Scale of job creation | Small | Large | Large | Medium |
| Job creation period | short-mid term | short term | short term | long term |
| Job characteristics | Proportional to the size of newly built wind farm | Proportional to the size of newly built wind farm | Proportional to the size of newly built wind farm | Proportional to wind farm cumulative capacity |
| Major supply chain | • Site development<br>• Services<br>• Manufacturing and installing meteorological towers | • wind turbine<br>• Substructure<br>• Submarine Cable<br>• Offshore substation<br>• Floating body<br>• Mooring line | • installing turbine, substructure<br>• Laying cables<br>• Installing offshore substation<br>• Assembling floating body-turbine<br>• installing floating body<br>• Installation vessel<br>• Port hinterland | • Site operation<br>• Maintenance<br>• Decommissioning |

### 1.3.1 Site Development Stage

| | |
|---|---|
| Time | • About 3~4 years |
| Major tasks | • Site selection<br>• Founding SPC<br>• MET installation, atmospheric and oceanographic assessments<br>• Feasibility analyses (site layout, AEP calculation, WTG candidate selection, substructure type selection, system linkage, marine physics, marine drilling investigation, environmental impact assessment, military radio wave impact assessment, marine traffic safety diagnosis, etc.)<br>• FEED design (WTG selection, integrated load analysis and design of substructures)<br>• Business license (resident acceptance) |
| Stage characteristics | • Except for large foreign developers, it is impossible to carry out internally due to a large number of professional works.<br>• A lot of domestic and international professional services |
| Job creation | • About 10 people per development company operate the workforce.<br>• Foreign developers support specialized areas with the support of the headquarters.<br>• The size of job creation is small, but the ripple effect of job creation in site development and various value chains is significant. |
| LCOE | • About 2~3% |
| Etc. | • Stage with high uncertainty in the lifecycle of the project<br>• Uncertainty normally from ensuring acceptance from residents, and licensing |

### 1.3.2 Procurement & Manufacturing Stage

| | |
|---|---|
| Time | • About 2 years |
| Major tasks | • Procuring wind turbine, inter-array and export cable, offshore substation<br>• Installation company selection<br>• conducting in conjunction with FEED and detailed design in the development stage |
| Stage characteristics | • Intensive investment in construction costs<br>• The manufacturing lead time of wind turbines, inter-array and external cables, and offshore substations is about 2 years.<br>• If the procurement & manufacture lead time takes years or more, the FEED design phase requires collaboration. |
| Job creation | • Intensive job creation by manufacturers.<br>• The number of jobs generated by site developers is small because they are related to procurement.<br>• Procurement & manufacture jobs are proportional to newly installed capacity. |
| LCOE | • About 44~47%(fixed type)<br>• About 50~60%(floating type) |
| Etc. | • Job creation highly relied on product localization |

### 1.3.3 Installation & Construction Stage

| | |
|---|---|
| Time | • About 2 years |
| Major tasks | • Substructure installation<br>• Wind turbine installation<br>• Inter-array installation<br>• Export cable installation<br>• Offshore substation installation |
| Stage characteristics | • Intensive investment in construction costs<br>• In need of large installation vessels (to install substructure, wind turbine, inter-array and export cable, offshore substation) |

| | |
|---|---|
| | • The installation period depends significantly on the preparation of the port hinterland and the performance of the installation vessels. |
| Job creation | • Extremely high<br>• The number of workforces in the installation stage depends on the newly installed capacity. |
| LCOE | • About 12%(fixed type)<br>• About 5~10%(floating type) |
| Etc. | • Taking a relatively short time in the lifecycle of the project<br>• Intensive investment in construction costs<br>• Intensive job creation during installation<br>• Availability of installation vessels and port hinterland has a significant impact on the wind power project schedule |

### 1.3.4 Operation Stage

| | |
|---|---|
| Time | • About 20~25 years |
| Major tasks | • All-time maintenance<br>• Frequent use of small CTVs<br>• Temporary need for large vessels for unscheduled large-part repairs |
| Stage characteristics | • High proportion of daily maintenance typically for small CTVs<br>• Job creation by operators or maintenance services |
| Job creation | • Consistent job creation throughout the operation<br>• Number of maintenance jobs proportional to the cumulative capacity of offshore wind farm |
| LCOE | • About 35~40% |
| Etc. | • Most extended stage in the lifecycle of the project<br>• Stable job creation in the long-term period |

## 2.1 Site Development Stage Supply Chain

| 공급망 | 주요업무 |
|---|---|
| Site developer | • Wind farm area identification and development<br>• Wind farm planning licensing<br>• Securing acceptance<br>• Many of domestic and overseas companies |
| Services | • Providing commercial services related with site development: finance, accounting, legal, insurance<br>• Providing various engineering services for site feasibility<br>• Providing various exploration services for site design<br>• Many of domestic and overseas companies |
| MET tower manufacture and installation | • Manufacturing meteorological towers for weather observation<br>• Installing meteorological towers<br>• Dealing with major equipment for the towers<br>• Small number of manufacturers and equipment companies |

### 2.1.1 Site Developer

| | |
|---|---|
| Industry characteristics | • Working in the early stage of the lifecycle of offshore wind farm |
| Operating expenses | • 3 to 4% of LCOE<br>• Despite the low proportion of LCOE, but creating industry value and having a significant impact on business success |
| Foreign company trend | • Most of the major foreign developers have made inroads into Korea |
| Domestic company trend | • Active participation of government-run energy companies, large and medium-small companies<br>• Lots of site developers including SPCs |

| | |
|---|---|
| Current status of domestic technology | • Huge technical gap between domestic and foreign companies<br>• In terms of foreign developers, hundreds to thousands of professionals with experience in headquarters support their subsidiaries in Korea.<br>• Most of the domestic developers are carrying out development with about 10 workforces. |

## 2.1.2 Service Company - Commerce

| | |
|---|---|
| Industry characteristics | • Providing finance, accounting, insurance, and legal services related to investment in the early stage of development<br>• Providing common commercial services after financial investment decision. |
| Operating expenses | • Around 1 to 2 % of LCOE (excluding investment, construction and operational insurance costs) |
| Foreign company trend | • Different characteristics by each service sector<br>• Accounting services led by global companies<br>• Reinsurers led by global companies<br>• Domestic offshore wind power invested by a handful of global investors |
| Domestic company trend | • The impact of domestic local information on the service decides different characteristics.<br>• Highly competitive domestic companies for legal services |
| Current status of domestic technology | • As Korea's economy ranks 10th in the world, the level of commercial services follows global practices well.<br>• The absence of investment in an offshore wind farm with hundreds of MW would inevitably lead to confusion in the investment and insurance sectors. |

## 2.1.2 Service Company - Engineering

| | |
|---|---|
| Industry characteristics | • Requiring extensive engineering to design offshore wind farms<br>• Requiring various engineering in each stage, such as site selection, conceptual design, basic design, detailed design, etc. |
| Operating expenses | • About 1% of LCOE in offshore wind farms |

| | |
|---|---|
| Foreign company trend | • Except for a small number of large complex developers, most engineering services are outsourced to professional service companies.<br>• In spite of having internal experts, external services can be performed to secure objectivity.<br>• A small number of foreign engineering companies have established Korean subsidiaries to provide services, but their number has recently increased. |
| Domestic company trend | • Though relatively lacking experience in offshore wind power, all sizes of enterprises (large, mid-sized, and small and medium-sized) provide engineering services |
| Current status of domestic technology | • The engineering service technology gap between domestic and global companies is vast due to a lack of experience. |

### 2.1.3 Service Company - Exploration

| | |
|---|---|
| Industry characteristics | • Special exploration equipment is installed on the probe for marine physics and seabed investigation, providing important input data for the design of the wind farm.<br>• The results of the exploration are used for the basic design of the sub-structure, the path design of the external cable, and the burial depth design of the inter-array cable. |
| Operating expenses | • Billions of won in exploration costs |
| Foreign company trend | • A handful of global exploration service providers dominate the market<br>• Investment in probes and exploration equipment is required |
| Domestic company trend | • In Korea, no company has a probe requiring large-scale investment.<br>• Quality of service is proportional to investment in probes and exploration equipment. |

| | |
|---|---|
| Current status of domestic technology | • While relatively many geotechnical engineers are trained in Korea, they lack experience in applying their knowledge to offshore wind power, and there are insufficient probes with investment costs. |

### 2.1.4 Meteorological Tower Manufacturer & Installer

| | |
|---|---|
| Industry characteristics | • At least 1 year of wind source measurement is required for generation licensing.<br>• It is essential to install weather towers on land or at sea in the development complex and measure the weather elements.<br>• The measured wind source is utilized to calculate annual power generation. |
| Operating expenses | • The fixed marine weather tower requires an operating cost of about three billion won.<br>• Floating LiDAR in deep water requires about 1.5 billion won a year in rent. |
| Foreign company trend | • Rather than lattice, LiDAR is applied to the latest fixed meteorological towers.<br>• Floating LiDAR for deep water is certified with class 2 or class 3. |
| Domestic company trend | • The localization rate for the design and manufacture of recently installed fixed meteorological towers is 100%<br>• Sensors for weather observation and LiDAR are from overseas specialists. |
| Current status of domestic technology | • Based on rich experience, Korea is equipped with sufficient technical and competitiveness for the design and installation of fixed meteorological towers.<br>• Meteorological observation sensors and LiDAR equipment are imported from abroad and applied.<br>• Floating LiDAR is under development for localization by two domestic SMEs, but it is expected that it will take several years to secure class 2 certification. |

### 2.1.6 Safety Training Company

| | |
|---|---|
| Industry characteristics | • GWO(Global Wind Organization)'s safety training framework is well-established in the global offshore wind industry.<br>• In particular, foreign site developers operating in Korea require GWO certification for their workforces.<br>• As awareness of safety increases in Korea, GWO safety standards are expected to be established |
| Operating expenses | • Training costs about 1.5 million won per person and is paid by the companies. |
| Foreign company trend | • In Europe, a GWO safety license for the required personnel is essential in consideration of the work's characteristics. |
| Domestic company trend | • In the wake of safety accidents, awareness is on the rise in Korea.<br>• In particular, domestic companies cooperating with site developers from overseas must obtain GWO safety licenses.<br>• Currently, the Korea Energy Corporation is constructing an offshore wind safety training center in the city of Gunsan.<br>• Foreign companies are conducting a safety education recently. |
| Current status of domestic technology | • Growing awareness of safety importance in Korea<br>• GWO's safety standards are likely to be introduced in Korea |

## 2.2 Procurement & Manufacture Stage Supply Chain

| Supply chain | Major tasks (function) |
|---|---|
| Wind turbine company | • Converse wind energy into electrical energy<br>• Assemble supplied components from a number of wind turbine parts manufacturers<br>• Have high industrial ripple effects |
| Substructure manufacturer | • Steel structures supporting wind turbines<br>• High proportion of construction costs due to large structure with heavy weight |
| Offshore substation manufacturer | • Facilities for boosting electricity generated in wind farms and sending it to land through export cables |
| Submarine cable manufacturer | • Send electricity generated by wind turbines<br>• Small number of manufacturers and equipment vendors in the markets |
| Floating body manufacturer | • Usually, large iron structures supporting floating offshore wind turbine |
| Mooring system manufacturer | • Mooring system consisting of a mooring line and an anchor and allowing the floating body to be located in a targeted position<br>• Mooring line consisting of steel chain or fiber composite material |

### 2.2.1 Wind Turbine Generator Manufacturer

| | |
|---|---|
| Industry characteristics | • As a single product, the turbine takes up the highest proportion of offshore wind power projects.<br>• Enlarging turbines is being promoted to reduce LCOE.<br>• Top two makers dominate 92% of European market |
| Operating expenses | • 1.5 to 1.6 billion won per MW<br>• Wind turbines made in Korea are slightly more expensive than foreign ones. |

| | |
|---|---|
| Foreign company trend | • SiemensGamesa, Vestas 2 are two main players in European market.<br>• GE is emerging as the third as it succeeded in developing 12 MW wind turbines.<br>• Chinese companies' market share expands as China ranked first in offshore wind power in 2021<br>• Vestas carried out a 15 MW wind turbine type test. |
| Domestic company trend | • Doosan Heavy Industries & Construction carried out an 8MW wind turbine type test<br>(Southwest offshore wind farm, Tamra offshore wind farm with total 90 MW in domestic level)<br>• Unison is in the development process of 10 MW wind turbines |
| Current status of domestic technology | • The domestic track record is insufficient compared to European turbines due to the small domestic wind market.<br>• So far, impossible to realize economies of scale.<br>• insufficient technology and cost competitiveness of domestic wind turbines<br>• The size of the market must grow to secure technology and cost competitiveness |

### 2.2.2 Substructure Manufacturer

| | |
|---|---|
| Industry characteristics | • Second highest proportion of purchases following wind turbines<br>• In the case of large steel substructures that are installed in deep water, some of them are heavier than wind turbines<br>• Long time to design and build<br>• The substructure factory must be located on the coast for sea transportation.<br>• The types of substructures vary, and monopiles account for about 80% of the market so far in Europe.<br>• Jacket type has been selected due to the ground conditions of domestic offshore wind farms, but monopile and suction types have been applied to some farms. |

| | |
|---|---|
| Operating expenses | • Approximately 13% of LCOE<br>• Price depends on the type of substructure and water depth<br>• High proportion of material cost |
| Foreign company trend | • Many foreign companies are located in ports in each country<br>• To reduce transportation costs, a manufacturing plant should be located in a port near the offshore wind farm as much as possible.<br>• Jacket is divided into primary steel, and secondary steel ,such as a ladder, transition piece, and pin file.<br>• Depending on the company, the entire substructure is constructed or outsourced to a specialized company. |
| Domestic company trend | • Hyundai Steel Industries has a record of producing and installing 90MW of Tamra offshore wind farm and Southwest offshore wind farm.<br>• SK oceanplant has no domestic performance but has an experience in offshore wind power in Taiwan.<br>• As for the type of suction structure, Advact, a domestic company, has a performance of manufacture and installation (2 * 3 MW Doosan turbines)<br>• EEW, a German pin file manufacturer, is in business in Jeollanam-do. |
| Current status of domestic technology | • Outstanding domestic substructure production capacity<br>• Although production capacity was not high, production capacity was expanded to the global level by winning the Taiwan project contract. |

### 2.2.3 Offshore Substation Manufacturer

| | |
|---|---|
| Industry characteristics | • An offshore substation is a facility for boosting electricity generated in a wind farm and exporting it to land through external cables.<br>• Consists of substructure and top side<br>• In Europe, a substation generally transforms the voltage from 66 kV to 220 kV, but in Korea, it can vary depending on the size and the voltage of the substation to connect to the grid. |

| | |
|---|---|
| Operating expenses | • Approximately 120 million £ for a 1GW offshore wind farm |
| Foreign company trend | • Siemens and ABB lead the superstructure market<br>• Introducing Europe's Off-Shore Transformer Module (OTM) concept, significantly reducing construction costs |
| Domestic company trend | • Korea has the record of the first offshore substation in the Southwest offshore wind farm.<br>• Hyundai Electric manufactured the substation in the Southwest offshore wind farm.<br>• Hyundai Steel Industries performed the iron structures of lower and upper structures. |
| Current status of domestic technology | • Korea performed only one offshore substation, a considerable difference compared to Europe<br>• Korea's design and manufacturing abilities of land substations are excellent, so if domestic offshore wind performance is accumulated, the gap with Europe can be narrowed within a few years.<br>• The Korea Electricity Promotion Association is working on a national project to develop equipment for offshore substations. |

### 2.2.4 Submarine Cable Manufacturer

| | |
|---|---|
| Industry characteristics | • Submarine cables are divided into inter-array and external cables and transmit the generated power to substations on land.<br>• Submarine cables have international standards so international competition is fierce.<br>• Domestic voltage standards are different from those of other countries, so it is necessary to review them for future export.<br>• Europe's inter-array cable has been switching from 33kV to 66kV for two to three years, and the time to switch to 132kV is expected in the coming years.<br>• Dynamic cables for floating offshore wind power are expected to become a fierce market for development in the future. |

| | |
|---|---|
| Operating expenses | • The material cost of the inter-array and external cables is within 6-7% of the LCOE.<br>• If the length of the external cable is longer than 100 km, an HVDC cable review is required. |
| Foreign company trend | • Approximately 3 to 4 major cable companies occupy the offshore wind power market for inter-array and external cable respectively. |
| Domestic company trend | • LS Cable is the only company in Korea to export overseas.(Recently Ls Cable signed MOU with Orsted.)<br>• LS Cable's global market share is still low.<br>• Daehan Electric Wire Construction starts constructing of an offshore plant to enter the submarine cable market. |
| Current status of domestic technology | • 66kV cable for fixed offshore wind power has been localized by LS Cable and is being supplied to domestic and overseas markets.<br>• In the future, markets for 132kV fixed and dynamic cable could grow. |

### 2.2.5 Floating Body Manufacturer

| | |
|---|---|
| Industry characteristics | • Floating wind foundation types are divided into Spar Buoy, TLP, and semi-submersible, but semi-submersible is currently the most considered type in the market.<br>• The global floating wind power market is in the pilot-project stage, and the site's capacity is only less than 100 MW.<br>• No case of floating body production in Korea<br>• Steel structures are mainly applied, and some concrete is under review |
| Operating expenses | • Approximately 25 to 35% of floating offshore wind power LCOE<br>• May be higher than the proportion of construction cost of wind turbines |

| | |
|---|---|
| Foreign company trend | • The floating offshore wind farm is at the level of a pilot project with less than 100 MW, and there are no specialized companies yet.<br>• Due to the large size of the floating body, several companies made it and moved to the wind turbine-floating body assembly port to assemble it. |
| Domestic company trend | • Although there is no experience in manufacturing floating bodies in Korea, there is a high possibility of floating body manufacturing business by a sub-structure manufacturer with fixed offshore wind power. |
| Current status of domestic technology | • No design capability, but the manufacturing technology is likely to be sufficient.<br>• However, securing a sufficient area and quay wall for the manufacture of floating bodies is an issue. |

### 2.2.6 Mooring System Manufacturer

| | |
|---|---|
| Industry characteristics | • The mooring system consists of mooring lines and anchors.<br>• The types of mooring lines: catenary type for the semi-submersible platform and taut type for the TLP<br>• Depending on the ground conditions, the anchor will be selected among the DEA anchor, suction anchor, and driven file.<br>• The standard material of the mooring line is the steel chain and the sum fiber.<br>• In the Hywind project, steel chain mooring lines were applied, but hybrid mooring lines mixed with steel chain and sum fiber were adopted in the recent project.<br>• Although the proportion of construction costs of mooring lines is low, it is designed conservatively due to the risk of loss of suspended solids during fatigue fracture.<br>• Therefore, unlike the localization of steel chain mooring lines is easy, joint fiber mooring lines may not be accessible due to intellectual property rights.<br>• Anchor design is unlikely to be carried out in Korea, but production will likely be localized to reduce transportation costs. |

| | |
|---|---|
| Operating expenses | • The mooring system's LCOE is within 2 to 3% |
| Foreign company trend | • The DEA anchor market is monopolized by Vryhof.<br>• Dydeema has a high share of the synthetic fiber market. |
| Domestic company trend | • Steel chain is also applied to other industries and is localized<br>• If the floating offshore wind power market expands, the steel chain is expected to be localized. |
| Current status of domestic technology | • Steel chains applied to other industries are localized. |

## 2.3 Installation & Construction Stage Supply Chain

| Supply chain | Major tasks (function) |
|---|---|
| Substructure and wind turbine installers | • Transportation and installation of substructures<br>• Installation of wind turbine after installation of the substructure |
| Cable installer | • Installation of Inter-array cables between wind turbines, or between the wind turbines and offshore substations<br>• Installation of external cable between the offshore substation and landing point |
| Offshore substation installer | • Transportation and installation of offshore substations |
| Floating body-wind turbine assembly | • Assembly of floating bodies and wind turbine<br>• Transportation arrangements for floating bodies |
| Floating carrier | • Floating body transportation to the site<br>• Connecting floating bodies to mooring lines and dynamic cables |
| Installation vessel operator | • Operation of ships installing substructures and wind turbines<br>• Operation of cable-laying vessels |
| Port hinterland operator | • Provision of installation space for wind turbines, substructures, cables, floating bodies, etc.<br>• Need quay wall facilities for loading and unloading the installation target on the installation ship |

### 2.3.1 Substructure and Wind Turbine Installer

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|---|---|
| Industry characteristics | • Installation period has a significant impact on business feasibility<br>• To shorten the installation period, it is necessary to have a well-established installation plan, project management capability, excellent installation vessels, and installation vessel support.<br>• In the case of overseas, to shorten the installation period, installation vessels with excellent work capabilities work in two shifts.<br>• The readiness of the port hinterland may affect the shortening of the construction period. |
| Operating expenses | • Installation costs about 10 to 12% of LCOE.<br>• Installation is required to join the Maritime Inspection Service (MWS) to verify the risk of installation by a third party. |
| Foreign company trend | • Companies with large installation ships dominate the market. |
| Domestic company trend | • The consortium of Doosan Heavy Industries & Construction and Hyundai Engineering & Construction constructed the Southwest offshore wind farm.<br>• Doosan Heavy Industries & Construction constructed the Tamra offshore wind farm. |
| Current status of domestic technology | • There are no sizeable professional installation vessels in Korea, so it takes two years for the Southwest and Tamra offshore wind farm.<br>• Hyundai Steel is developing a Jackup vessel to install 8MW wind turbines as a national project.<br>• It is predicted that a number of large-scale specialized construction vessels will be needed to install 12GW by 2030. |

### 2.3.2 Cable Installer

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| Industry characteristics | • The installation period depends on the capabilities of professional cable laying vessels.<br>• A well-established installation plan, project management capabilities, and excellent installation vessels are required to shorten the installation period.<br>• In the case of overseas, in order to shorten the installation period, installation vessels with excellent work capabilities work in two shifts. |
| Operating expenses | • Cable installation costs within 7 to 8% of LCOE.<br>• Installation requires a surveyor from the Marine Warranty Survey (MWS) presence to validate third-party installation risks. |
| Foreign company trend | • The cable installation market has been dominated by professional cable installers, but cable manufacturers are increasingly inclined to install them in response to market demands to clarify cable installation risks. |
| Domestic company trend | • KT Submarine has an excellent fleet in Korea.<br>• Other than KT Submarine, relatively small companies are operating installation businesses. |
| Current status of domestic technology | • Cable installation process is likely to be a major obstacle in the future if the size of wind farms exceeds 200MW.<br>• It is predicted that a number of large-scale specialized construction ships will be needed to install 12GW of wind power by 2030. |

### 2.3.3 Offshore Substation Installer

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| Industry characteristics | • Install the superstructure after installing the substructure<br>• Offshore substations require a crane vessel with high lifting capability for heavy-weight installation.<br>• Compared to substructures or wind turbines, offshore substations can be installed in a shorter period due to a smaller number of installation quantities. |

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| Operating expenses | • Cable installation costs within 5 to 7% of LCOE<br>• Installation requires a surveyor from the Marine Warranty Survey (MWS) presence to validate third-party installation risks. |
| Foreign company trend | • Utilizing floating vessels with heavy-weight installation capability |
| Domestic company trend | • Korea has an installation record of a Southwest offshore wind farm.<br>• Construction by Hyundai Steel Industries |
| Current status of domestic technology | • The installation technology is secured thanks to the shipbuilding and marine industry. |

### 2.3.4 Floating Body-Wind Turbine Assembly Company

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|---|---|
| Industry characteristics | • If it is semi-submersible, floating body-wind turbine are assembled in the port hinterland<br>• Need a crane to lift wind turbines in the port hinterland |
| Operating expenses | • Floating body-wind turbine assembly costs less than 1% of LCOE<br>• Installation requires a surveyor from the Marine Warranty Survey (MWS) presence to validate third-party installation risk. |
| Foreign company trend | • They are in the early days of the floating offshore wind industry, there are no cases of floating body-wind turbine assembly on a large scale in one port. |
| Domestic company trend | • No domestic case of assembling floating body-wind turbine. |
| Current status of domestic technology | • Loading area and crane in the port hinterland are required for floating body-wind turbine assembly<br>• When Ulsan floating offshore wind farm is activated, it is highly likely that an assembly will be conducted by a company with floating body manufacturing capability. |

### 2.3.5 Floating Body Transport and Installation Company

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| Industry characteristics | • The installation of the floating body consists of a transport-mooring line connection-dynamic cable connection<br>• Transport of floats is carried to the site by approximately three knots using 2-3 towed vessels.<br>• Anchor of the mooring line before transporting the suspended body must be pre-installed using Anchor Handling Tug (AHT)<br>• After connecting the mooring wire, adjust the tension, and finally connect the dynamic cable. |
| Operating expenses | • Floating body transport and installation cost within 1-2% of LCOE<br>• Installation requires a surveyor from the Marine Warranty Survey (MWS) presence to validate third-party installation risk. |
| Foreign company trend | • In 2021, floating offshore wind saw 57 MW of new capacity installed, but according to GWEC, the average annual growth rate is expected to be more than 100% over the next few years. |
| Domestic company trend | • The capability of the supply chain is uncertain as there is no performance in the transport and installation of domestic floating offshore wind farm. |
| Current status of domestic technology | • The technology capability of the supply chain is uncertain as there is no record of transporting and installing floating offshore wind power in Korea. |

### 2.3.6 Installation Vessel Company

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|---|---|
| Industry characteristics | • Installation of equipment such as wind turbines, substructures, cables, etc. during the installation stage of offshore wind farms<br>• For fixed offshore wind power, an expensive professional installation vessels are required.<br>• For floating offshore wind power, except for cable installation, a different type of installation vessel than fixed offshore wind power is required.<br>• Selection of installation contractors requires a contract about 3 years prior to installation. |

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| Operating expenses | • Fixed offshore wind power installation costs within 10% of LCOE<br>• Floating offshore wind power does not need specialized installation vessels.<br>• Installation requires a surveyor from the Marine Warranty Survey (MWS) presence to validate third-party installation risk. |
| Foreign company trend | • Large installers with specialized installation vessels lead the market.<br>• Competition for developing installation vessel able to install large wind turbines in deep water |
| Domestic company trend | • There is only one domestic specialized installation company for substructures and wind turbines.<br>• The installation capacity of domestic cable laying vessels is insufficient compared to that of European ones.<br>• Anchor installation vessels for floating offshore wind power require investment to expand the floating offshore wind power industry. |
| Current status of domestic technology | • The number and capability of installation vessels fall short of achieving the domestic installation goal.<br>• Large investment in installation vessels is inevitable<br>• The supply chain's ability is uncertain due to the lack of domestic floating offshore wind transport performance in Korea. |

### 2.3.6 Port Hinterland

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| Industry characteristics | • Providing spaces to pile up turbines, substructures, cables, and floating bodies.<br>• In need of quay wall facilities to load and unload the installation target on the installation vessel. |
| Operating expenses | • Installation cost is proportional to installation period and space required for installation. |
| Foreign company trend | • Europe establishes a plan to analyze and utilize the capabilities of the port hinterland for the development of wind power at the national level. |

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| Domestic company trend | • Based on the trade port, 33 Terminal Operating Companies (TOC) are operating. |
| Current status of domestic technology | • In Korea, the analysis of the port hinterland for the development of the offshore wind industry is insufficient.<br>• If an offshore wind farm is simultaneously constructed in the same area, the availability of the port hinterland is likely to have a significant impact on the wind farm construction schedule. |

## 2.4 Operation Stage Supply Chain

| Supply chain | Major tasks (function) |
|---|---|
| Wind farm operator | • Operation and management of wind farms |
| Maintenance company | • Maintenance services using specialists in wind farm maintenance |
| Maintenance vessel operator | • Operating vessels for maintenance personnel and parts transportation |
| Decommissioning company | • Decommissioning of wind farms after designed life |

### 2.4.1 Wind Farm Operator

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| Industry characteristics | • Operation and management of wind farms during the design life<br>• The operator of the complex usually organizes and operates SPC.<br>• Largely divided into regular maintenance and corrective maintenance<br>• Reducing corrective maintenance is key to maintenance strategies and requires a Condition Monitoring System (CMS)-based strategy. |
| Operating expenses | • Total maintenance costs 35 to 40% of LCOE.<br>• Wind turbines account for a high proportion of maintenance costs. |
| Foreign company trend | • The operating period of the complex is increasing to more than 25 years.<br>• As SPC's maintenance experience and capabilities increase, companies tend to directly perform maintenance of wind turbines after the warranty period.<br>• With the establishment of asset management technology, the operation status of all complexes operated by Backoffice is systematically managed in conjunction with CMS.<br>• In the case of European offshore wind power, the proportion of independent maintenance companies (ISPs) is still low. |

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| Domestic company trend | • Domestic investors require Long Term Service Agreement (LTSA) during wind turbine life to reduce wind turbine maintenance risk.<br>• In the case of domestic offshore wind power maintenance, the operation period is still short, so it is within the warranty period, and the wind turbine company is directly under the maintenance contract period.<br>• Due to the lack of manpower, domestic wind turbine companies are outsourcing to ISPs. There are many wind turbine ISPs. |
| Current status of domestic technology | • Since domestic offshore wind farm started to operate for 2 to 3 years their operation experience is insufficient.<br>• Academic research on maintenance is also insufficient in Korea. |

### 2.4.2 Maintenance Service Company

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| Industry characteristics | • Maintenance service companies provide maintenance services to the complex operator.<br>• For wind turbines, provide service after the warranty period<br>• In the case of The Balance of Plant (BoP), professionals in the field provide maintenance services to the complex operator. |
| Operating expenses | • 30 to 35% of LCOE<br>• High proportion of maintenance vessel operating expenses<br>• Wind turbine maintenance costs have a high proportion among BoP (balance of plant), so wind turbine companies provide maintenance services within the warranty period. |
| Foreign company trend | • As the experience of offshore wind power accumulates in Europe, complex operators maintain wind turbines after the warranty period.<br>• However, BoP is maintained by professional maintenance companies.<br>• Long term supply contracts with CTV and SOV operators<br>• CMS specialized services |

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| Domestic company trend | • Domestic investors require Long Term Service Agreement (LTSA) during wind turbine life to reduce wind turbine maintenance risk.<br>• In the case of domestic offshore wind power maintenance, the operation period is still short, so it is within the warranty period, and the wind turbine company is directly under the maintenance contract period.<br>• Due to the lack of workforce, domestic wind turbine companies outsource to maintenance service companies.<br>• Many wind turbine maintenance service providers |
| Current status of domestic technology | • Since domestic offshore wind farms started to operate for 2 to 3 years, their operation experience is insufficient.<br>• Academic research on maintenance is also insufficient in Korea. |

### 2.4.3 Maintenance Vessel Company

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| Industry characteristics | • For the maintenance of offshore wind power, an operator servicing full-time and irregular vessels is required.<br>• Purpose of transporting personnel or equipment and parts<br>• CTV and SOV vessels are serviced for full-time maintenance.<br>• Vessels for irregular maintenance service are used for cable replacement, large wind turbine parts replacement, and excavation protection. |
| Operating expenses | • The proportion of ship operation costs among maintenance costs is high. |
| Foreign company trend | • Large support service providers for CTV and SOV are operating in Europe.<br>• CTV and SOV operators typically serve on long-term contracts |
| Domestic company trend | • Korea still has a small offshore wind power market, so there are no large maintenance vessel operators. |

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| Current status of domestic technology | • Overseas CTV and SOV operators install gangways in vessels to safely locate wind turbines or offshore substations.<br>• Only a few CTVs in Korea<br>• If the Ulsan floating offshore wind farm goes into operation, it is likely that the SOV market will be created because of the far distance between the complex and the coast. |

### 2.4.4 Decommissioning Company

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| Industry characteristics | • When the design life of the offshore wind farm is over, it is necessary to dismantle it to restore it to its original state. |
| Operating expenses | • 2% of LCOE |
| Foreign company trend | • The market for decommissioning has not yet been activated. |
| Domestic company trend | • In Korea, there are many cases of decommissioning the offshore meteorological tower, and usually the installer of the tower dismantled it.<br>• The domestic offshore wind power is in its infancy, and it takes more than 10 years for the decommissioning market to begin in earnest. |
| Current status of domestic technology | • When the offshore wind power installation market is activated, decommissioning facilities will be expanded. |

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