SUPPORT
FACILITY FOR THE
IMPLEMENTATION
OF EU-JAPAN
STRATEGIC
PARTNERSHIP
AGREEMENT (SPA)

Study on Best practices in Floating Offshore Wind Energy Technical Regulations in the EU and Member States

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1. Background and rationale

The development and growth of offshore wind energy worldwide over the last years has been very relevant. Annual growth rates in many countries are clearly increasing and Europe is currently leading the global offshore energy market. Offshore wind power is a high political priority in the EU in line with the European Wind Charter[1].

The Floating Offshore Wind energy (FOW) is a step forward in the offshore wind energy sector as, despite being a major technological challenge, it represents a potential improvement in available space and performance with respect to the fixed-support option. Many of the EU Member countries have made significant progress during recent years in the development of floating wind projects and test plants together with the associated technological and regulatory improvements.

In the case of Japan, FOW sector represents a promising and fast-growing sector. Japan has made ambitious commitments regarding carbon neutrality and increasing the share of renewables in the energy mix. One of the key new sectors in reaching these targets is offshore wind power. Japan's objectives are ambitious not just when it comes to increasing the FOW capacity but also in creating a local supply chain.

The present "Study on Best practices in Floating Offshore Wind Energy Technical Regulations in the EU and the Member States (hereinafter referred to as the "Study") is carried out within the framework of the Strategic Partnership Agreement (SPA).

As FOW is a sub-sector of offshore wind energy sector, with largely common regulatory frameworks, this Study is in some ways a continuation of the 2022 study focusing mainly on fixed-support offshore wind energy.

1.2. Objectives and scope

The objective of the Study is to compile technological and regulatory information on FOW in the EU and the Member States (MS) with a view to carrying out a benchmarking analysis on the best practices for clarifying possible application in Japan, which could further be used in relevant bilateral fora with the Japanese authorities as benchmarks for the development of the regulatory framework related to FOW.

The Study is limited to FOW technical regulation and standards existing both online and in competent institutions and companies. Compilation of other local regulations such as environmental impact assessment, maritime spatial planning, fishing rights, etc. are out of the scope of the analysis.

A comprehensive search for information on comparative experiences in relation to FOW has been organised around the EU, its Member States and Japan. The starting point focuses on the situation in Japan regarding FOW and, on this basis, best practices and experiences in EU member states are explored for possible application in Japan. Therefore, the two analyses for EU and Japan were organised in parallel to make a comparative analysis on Standards, Certification and Conformity Assessment at a later stage.

Concerning the EU member states, in order to conduct an in-depth analysis and enable comparative references in the Study, Germany, France, Spain, and Italy have been selected due to their level of project implementation and forecasts, technological capacity and relevant policy and regulatory development.

Before starting the analysis of the technical regulation in Japan and the EU, a section on the technological challenges that condition the expansion of floating offshore wind farms is included in order to highlight key topics that will help to outline the main contents of the Study.

The analysis of the compiled information on FOW is organised around three parts:

1) Technical Regulation and Standards
2) Accreditation Procedures and Certification Systems for Conformity Assessment.
3) Best practices, benchmarking, and conclusions

The first two sections follow the same approach: an analysis of the situation in Japan, followed by a similar analysis of the situation in the EU and a comparison of the two cases. Finally, some indicators are selected to proceed with a final benchmarking in order to identify the Best Practices for their possible application in Japan.

[1] The European Wind Charter, signed in Brussels on 19 December 2023, is the EU's Great Wind Commitment to implement the actions set out in the EU Wind Power Package.

1.3. Technological challenges in the expansion of FOW

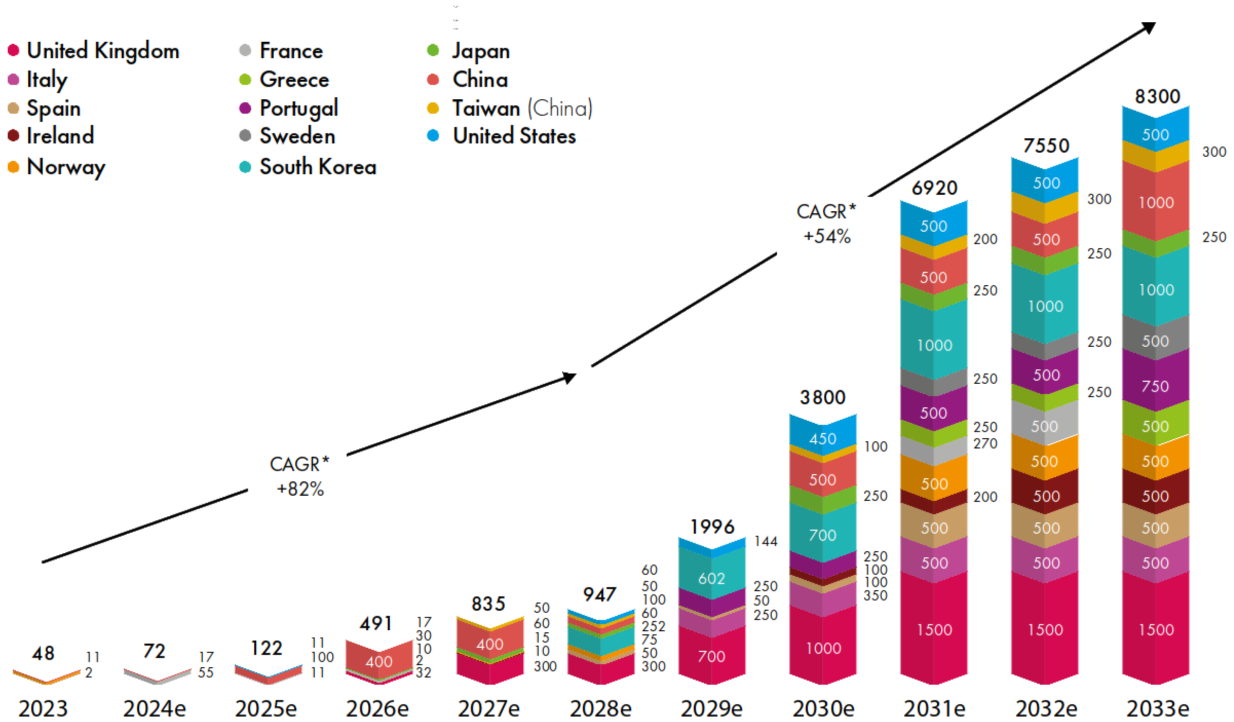
1.3.1. Europe leading the floating wind energy market

As a symbol of the current dynamic of the floating offshore wind sector, the GWEC (Global Wind Energy Council), has revised its long-term outlook and predicts 8,5 GW to be built globally by 2030.

According to the GWEC Market Intelligence prediction [2], floating wind will become fully commercialized towards the end of this decade and multi-GW levels of new installation will be achieved post 2029/2030 as can be seen in the following Figure. Only 8% (2,5 GW) of the total projected additions (31GW) will be installed in the first half of the forecast period.

As for regional distribution, the GWEC analysis confirms that Europe remains the global leader in floating offshore wind and is expected to be the larger contributor to the FOW increase, with 60% of the total installations added followed by APAC (33%) and North America (7%) in the forecast 10-years period 2024-2033. The 31 GW of floating wind likely to be installed worldwide by the end of 2033, will bring its contribution to total offshore wind installations from today's 0,3 to 6%.

Figure 1 New floating wind installations Global (MW)**



Source: GWEC Market Intelligence, June 2024.
Note**: this floating wind outlook is already included in GWEC´s global offshore wind forecast.

[2] Global Offshore Wind Report 2024 (Published on 17 June 2024): Floating Offshore Market Outlook to 2033

1.3.2. FOW support structures

Most of the components of floating wind turbines are the same as those for fixed-bottom wind turbines, including the nacelle, most of the electrical system, the blade and tower. But the foundation's components are different. The floating foundation of offshore wind turbines normally includes two main parts: a floating structure and the pre-installed mooring and anchoring system that keeps the floater in place.

There are many different floating design concepts linked to the pilot projects that have been developed around the world, but globally like considered in IEC 61400-3-2 standard, the most widespread designs can be summarised in four basic prototypes as shown in the following figure:

- **Spar platform**: a vertical buoyant cylinder ballasted at the bottom with a deep draft that is connected to the seabed with long mooring lines.
- **Tension leg platforms/buoys (TLP/TLB)**: consist of floating hulls made of buoyant columns and pontoons. The hull is holding below its natural flotation level via vertical tendons, usually steel pipes, anchored to the sea floor.
- **Ship-shaped structures and barges**: characterized by their flat and elongated ship-like shape, which provides buoyancy and stability. The simplicity of their design makes them easier and often less expensive to construct, but less stable in rough water conditions.
- **Semi-submersible platforms**: consist of three or four columns connected at a distance from each other. These platforms are also anchored to the seabed via mooring cables.

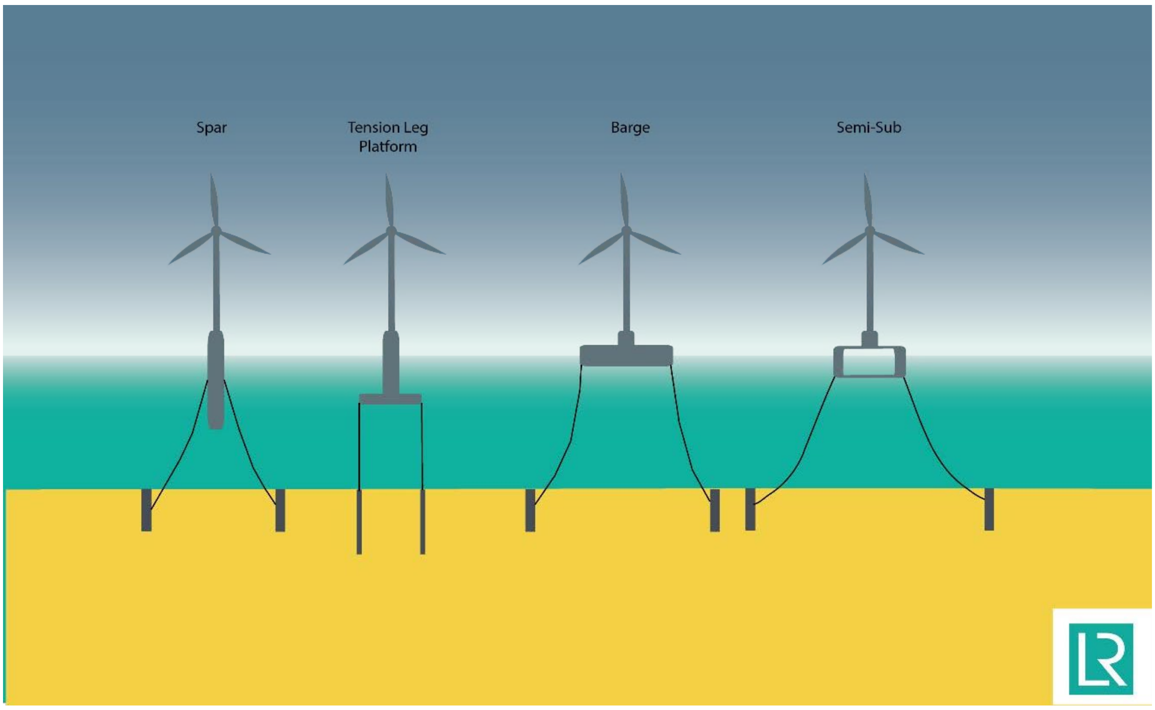
Mooring system differs for different floaters, for example semi-submersibles and spar floaters, use longer but simpler mooring system, while TLPs are secured with more complex anchoring systems and vertically loaded mooring lines.

Each type of floating platform has its own set of advantages and disadvantages, and the choice depends on factors such as water depth, seabed conditions, wind conditions, and project budget.

Some advantages of the **spar platforms** include good performance in rough sea conditions due to deep draft and mooring with taut mooring lines, providing stability. But they normally offer limited space for heavy equipment and maintenance crews and tend to have higher motions in waves compared to other designs. Typically, easier and less expensive to manufacture compared to other designs.

The **Tension Leg Platforms** provide good stability in both calm and rough seas and minimal motion in waves due to tensioned vertical tethers. They can support large turbines and heavy equipment. However, they often require complex mooring system involving tensioned tethers attached to the seabed and limited flexibility in deployment locations due to water depth requirements. Construction and installation costs are normally higher compared to other designs.

Figure 2 The main types of FOWT support structure



Source: Recommended Practice for Floating Offshore Wind Turbine Support Structures (LR-RP-003)

In the case of **Ship-shaped structures and barges**, they have a relatively shallow draft, which makes them suitable for areas with water depth variations and easier to tow to the site and install. They are less stable in rough water conditions compared to other designs, limiting their suitability for very deep waters. For intermediate water depths, they can be more cost-effective due to their simpler design and construction.

The **Semi-Submersible Platforms** provide greater stability in rough seas due to multiple pontoons, can accommodate larger turbines and heavier equipment and have more deck space for maintenance and operations. The mooring systems required for stability are more complex and they normally have higher construction and installation costs compared to spar-buoy designs.

Concerning **materials** used in construction of platforms, steel is commonly used in the construction of floating platforms for wind turbines in Europe. It is used for the structural components of the platform such as the hull, columns, and braces due to its high strength-to-weight ratio and durability in marine environments.

Concrete is another key material used in the construction of floating platforms, particularly in spar-buoy designs. Concrete provides stability and buoyancy to the platform, and it is often used for the submerged portion of the structure. Additionally, concrete can be reinforced with steel to enhance its strength and durability.

The **anchoring and mooring** systems are critical components of floating offshore wind turbines, playing essential roles in the stability, positioning, and overall performance of these structures.

The **mooring** system in FOW turbines (FOWTs) connect the floating structure to the anchors on the seabed. It typically consists of chains, wires, or synthetic ropes, and its primary function is to maintain the floating structure in a predefined area, allowing for controlled movement while minimizing the impact of environmental forces. The mooring system is designed to absorb energy and reduce the motion of the floating structure, ensuring operational stability and safety. It must be both strong and flexible, capable of adapting to changes in water depth, seabed conditions, and environmental loads.

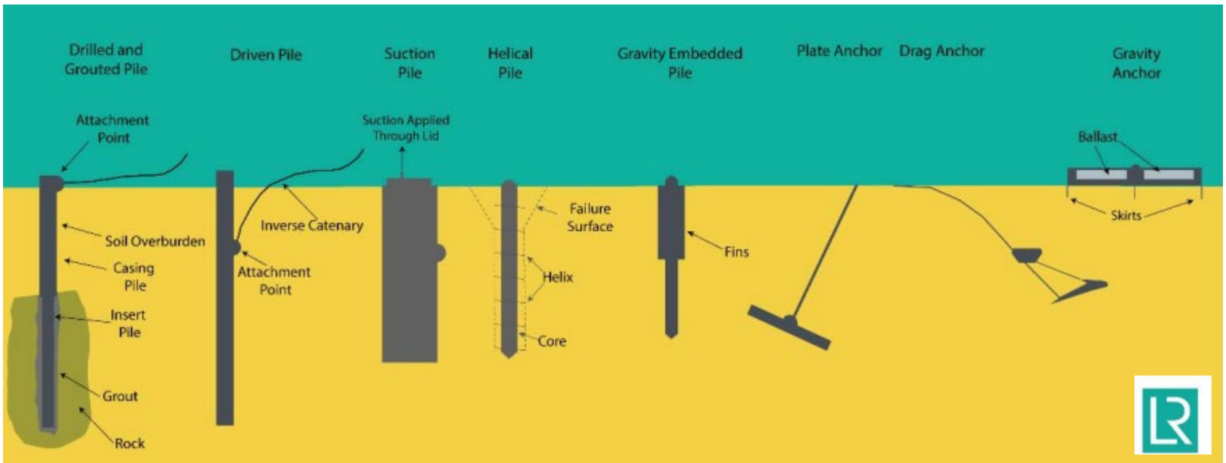
The purpose of the **anchoring** system in FOWTs is to securely fix the structure to the seabed, ensuring that the floating turbine remains in its designated location despite the forces acting upon it. The anchoring system must withstand various dynamic loads, including those from waves, wind, currents, and the operational movements of the turbine itself. These systems must be robust and durable, capable of resisting pull-out and sliding forces over the lifetime of the project, which can span decades.

The relationship between the anchoring and mooring systems in FOWTs is inherently interdependent. In summary, while the anchoring system secures the turbine to the seabed and the mooring system connects the turbine to these fixed points, allowing for controlled movement, both systems must be meticulously designed and integrated to ensure the operational efficiency, safety, and longevity of floating offshore wind turbines.

Designing the mooring and anchoring systems is quite a complex process, but overall, the technology has reached certain maturity given the many years of experience and knowledge acquired by adjacent sectors such as offshore oil and gas and knowledge from these sectors is transferrable to the floating wind market.

Concerning anchors, the main types normally considered are the following ones showed in the figure below:

Figure 3 The main types of anchor



Source: Recommended Practice for Floating Offshore Wind Turbine Support Structures (LR-RP-003)

The following is a brief description of the anchoring types in the figure used for securing floating offshore wind turbines to the seabed.

- **Driven Pile:** A long, slender column, often made of steel, which is hammered or vibrated into the seabed to a desired depth. Driven piles offer high strength and are suitable for various soil types, including sand, clay, and rock.
- **Suction (Installed) Pile:** Consists of a large, hollow, open-bottomed cylinder that is placed on the seabed and then embedded into the sea floor by evacuating the water inside the cylinder, creating a pressure differential. Particularly useful in soft sediments and can be used in various water depths.
- **Helical Pile**: Features one or several helix-shaped blades attached to a central shaft. When the pile is rotated, the helices drive it into the ground in a screw-like manner. Known for their ease of installation and minimal environmental impact.
- **Gravity Embedded Anchor (e.g., Torpedo Pile):** This type of anchor relies on its weight and shape to penetrate the seabed upon impact. It is a cost-effective solution for deep-water applications where traditional pile driving is not feasible.
- **Plate Anchor:** A flat, wide plate attached to a shank, buried beneath the seabed. The anchor is installed by dragging it into position and then pulling it deeper into the seabed. It distributes loads across a wide area, making it effective for soft seabed conditions.
- **Drag Anchor**: Similar to traditional ship anchors, drag anchors are designed to dig into the seabed as they are dragged along by the attached structure. They are particularly valued for their adjustability and ease of relocation.
- **Gravity Anchor:** Relies purely on its weight to maintain position on the seabed. Made from concrete or steel, gravity anchors are often used in combination with chains or cables to secure floating structures. They require significant weight to be effective, more suitable in shallow waters or areas with less dynamic environmental conditions.
- **Drilled and Grouted Pile**: Involves drilling a hole into the seabed, placing the pile, and then filling the gap between the pile and the borehole with grout. Particularly useful in rocky seabed or where there is a need for deep penetration to reach stable ground.

Each of these anchoring methods has unique characteristics that make them suitable for specific conditions and requirements in offshore wind turbine installations.

1.4. FOW and the expansion of the offshore wind energy

Fixed-bottom wind turbines have been dominant in the offshore wind power sector, and they will continue to grow at a steady pace for many years. However, this development will eventually slow down as the installation of fixed-bottom foundations are limited to water depth of less than 60 meters, at least with the technology and technical solutions available today. Floating wind turbines are technically feasible options for developing wind power potential in waters above this depth level.

Since the installation of the first offshore wind turbine in 1990, the size of the turbines, their distance from coasts and the water depth in which the foundations are installed have been continuously substantially increased. The average water depth has risen more than six times between 2000 and 2022, and the forecasted average trend line indicates that the upward trend will continue to about 44-meter water depth by 2035[3].

Thanks to stronger and more frequent wind speeds further offshore, floating wind turbines could have a higher capacity factor than wind turbines located closer to shore, thus generating more energy throughout the year. Offshore wind farms are therefore considered more efficient than onshore wind farms mainly due to their access to stronger and more consistent wind speeds and their almost complete lack of interfering physical objects. Moreover, floating wind turbines create less visual pollution, leading to less NIMBY effects than near-shore fixed-bottoms, as most floating wind turbines will be located far from the coast.

But while floating wind technology has undoubted potential for development, it presents significant technological challenges that need to be addressed.

For example, the size, weight, and type of material of the floating platform are critical variables in efficiency and cost reduction. A smaller platform size can lead to mass production without compromising the stability of the platform. The use of concrete instead of steel as a construction element can also contribute to cost reduction, although it implies a longer construction time for the platform. And the power of the wind turbine also plays a critical role in the final size of the floating platform.

Another important aspect that requires proper optimisation is the installation process of the floating platform. Knowledge of available metocean windows, the development of optimised offshore operation strategies with tugs and barges, monitoring of the metocean climate and the availability of a nearby port with adequate loading

[3] Source Bloomberg NEF Rabobank 2023

and assembly infrastructures will be key factors in the development of this type of technology.

Operation and maintenance strategies can also make an important contribution to the cost savings associated with the floating platform. The development of new methodologies for which operations can be performed in-situ and which require port access considering all the processes involved (undocking of the platform from its mooring system and electrical cables, towing to port, maintenance and commissioning and reconnection times) are of vital importance to demonstrate the technical feasibility of this technology.

Floating wind farms in operation will have many components that will need to be monitored and inspected regularly to ensure their integrity. The mooring system of a wind turbine platform is a critical component in the survival of the floating installation. This is the element that requires the most optimisation, not only to reduce the cost but also to reduce the risk of breakage.

In large wind farms, floating electrical substations and dynamic high-voltage cables are specially designed for flexibility, allowing them to accommodate platform movement caused by waves, tides, and wind forces. These elements are critical and must be precisely engineered to handle increasing voltage requirements.

Integrated modelling of a floating wind platform is a key tool for the development of this technology. The coupled design of all dynamic loads on the floating platform (the aerodynamics from the wind turbine, the hydrodynamics of the floating platform and the model of the mooring system) allows optimisation of the conceptual designs and evaluation of wave and turbulence effects on the energy production of the wind farm in order to optimise the configuration of the wind farm. The development of this type of models requires their validation through experimental scale tests carried out in wave tanks because they allow eliminating uncertainties in the design and having a first approximation of the real behaviour of the floating platform.

The conventional control system of a wind turbine to cope with loads and accelerations in the nacelle will need to be modified when on a floating platform. Close collaboration between designers and manufacturers is required to achieve efficient solutions that maximise the turbine's energy output, reduce turbulence and platform movements, and optimise the size of the platform.

The viability of a floating wind farm in each region depends largely on its social and environmental impact. The development of this type of project requires mitigating possible conflicts with other uses of the sea and assessing the impact on different environmental aspects such as the impact that may be produced on the seabed using anchors and moorings or the impact that may be generated on birds by collisions with the turbine rotor.

Floating wind turbines will be crucial for the future expansion of offshore wind energy when the low hanging fruits of shallow water sites are filled up with fixed-bottom wind turbines. For countries with limited shallow waters, such as Japan, France, Italy and Spain, floating wind turbines could be a key technology to harness great wind resources.

In this scenario, some barriers and challenges must be overcome to effectively promote floating wind technology into the power supply mainstream. These include insufficient port infrastructure, incipient research and development and high levelized costs of energy (LCOE).

2. INTERNATIONAL STANDARDS ORGANISATION

There are many standardization bodies and organizations that produce codes and standards relevant for the bottom fixed and floating offshore wind industry. All of them are international in character, and their main task is the development and promotion of standards in the field of technology, scientific testing, safety, durability, working conditions, social implications, etc. The main ones are as follows:

- International Organization for Standardization (ISO)
- International Electrotechnical Commission (IEC)
- Institute of Electrical and Electronics Engineers (IEEE)
- European Committee for Standardization (CEN)
- European Standards (EN)
- British Standards Institute (BSI)
- American Petroleum Institute (API)
- Deutsches Institut für Normung (DIN)
- Det Norske Veritas (DNV)

These organizations share the collective goal of harmonizing technical specifications and quality criteria across countries, collaborating to develop and implement standards that transcend national borders and promote interoperability. They work to ensure that products, services, and processes are safe, efficient, and environmentally friendly, thereby facilitating global commerce and innovation.

The content of the standards developed by these organizations covers a wide array of subjects, including but not limited to, quality management, environmental management, information security, energy management, and social responsibility. They address the needs of various sectors such as manufacturing, technology, healthcare, agriculture, and energy, ensuring that products and services meet stringent criteria of quality, safety, and efficiency.

ISO (International Organization for Standardization) is a worldwide federation composed of representatives from more than 160 national standards organizations. ISO standards cover almost all industries and sectors, including manufacturing, technology, healthcare, energy, agriculture, food safety and environmental management.

IEC (International Electrotechnical Commission) is an international standards organization focusing on standards for electrical, electronic, and related technologies. They develop and publish international standards for all electrical, electronic, and related technologies to ensure safety, reliability, and interoperability. IEC covers a wide range of industries, including renewable energy, power generation, transmission, distribution, electronics and telecommunications. IEC works closely together with ISO. Standards that the ISO and IEC jointly develop are identified by the prefix ISO/IEC.

The Institute of Electrical and Electronics Engineers (IEEE), focuses on electrical, electronics, computer engineering, and related technologies through the development and dissemination of standards, publications, and educational activities. IEEE standards cover a wide range of areas, including electrical and electronic devices, telecommunications, power and energy, information technology, aerospace, and healthcare.

The European Committee for Standardization (CEN) is a regional standards organization responsible for developing European standards (EN) across various sectors. CEN standards cover a.o. construction, engineering, materials, consumer products, environmental management, and healthcare. EN standards are developed and published by CEN and the European Committee for Electrotechnical Standardization (CENELEC).

British Standards Institute (BSI) is the UK's national standards body and a founding member of ISO. BSI standards cover various sectors, including manufacturing, healthcare, construction, information technology, and business management.

The American Petroleum Institute (API) is the largest trade association for the oil and natural gas industry in the United States. API standards cover exploration, production, refining, transportation, and distribution of oil and natural gas, as well as related industries such as petrochemicals and renewable energy.

Deutsches Institut für Normung (DIN) is the German national standards organization responsible for developing and publishing standards in various fields. DIN standards cover a wide range of sectors, including manufacturing, engineering, construction, materials, environmental management, and healthcare.

Det Norske Veritas (DNV) is a Norwegian classification society with extensive experience in the maritime industry. DNV has evolved into a global provider of classification, certification, verification, and advisory services to industries such as maritime, oil and gas, renewable energy, and healthcare to ensure safety, reliability, and sustainability.

In the energy sector, international standards organizations cover standards for renewable energy technologies, energy efficiency, and the development of smart grid technologies. These standards facilitate the integration of renewable energy sources into existing grids, improve energy efficiency in industrial processes, and ensure the safety and reliability of energy production.

Moreover, in the realm of emerging technologies such as wind, solar, and bioenergy, international standards provide a foundation for innovation and growth, ensuring that new technologies can be seamlessly integrated into the global market. This not only accelerates the adoption of renewable energy sources but also contributes to the resilience and sustainability of energy systems worldwide.

The increased loads from floating offshore wind turbines may exceed what the turbines is certified for in bottom-fixed foundations. This means that for floating wind, a more site and floater specific assessment must be done.

Most of these standardization bodies and organizations produce codes and standards relevant for the bottom fixed and floating offshore wind industry. The level of is diverse, but all of them have at least some standards that can be implemented to floating offshore wind even if it does not have that specific purpose alone.

At European level the international standards organizations play an important role in shaping the global marketplace, enhancing technological advancements, and promoting sustainability across various industries. These entities, encompassing a broad spectrum from ISO to IEC, IEEE and various European standards bodies such as CEN, collaborate to develop and implement standards that transcend national borders, fostering international trade, safety, reliability, and efficiency.

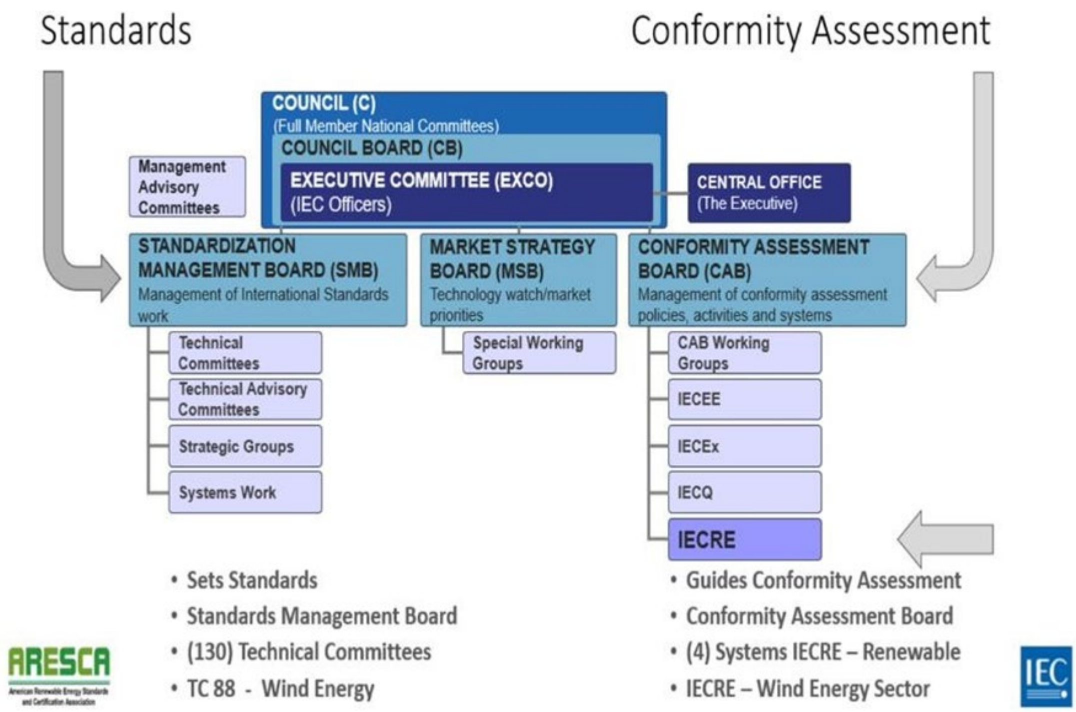
IEC standards describe in offshore wind energy sector, the design requirements of wind turbines and wind farms as well as measurable requirements, tests, and methods. They are grouped in the IEC 61400 series covering from design, construction, testing, inspection, performance, and operations to maintenance monitoring, etc. Taken together, they aim to ensure that the wind farm is as safe, reliable and performs as expected.

ISO/IEC do not undertake conformity assessments or issue certificates on any particular product or project themselves, but they are defining the rules and procedures of such activities. For this, IEC has a Committee on Conformity Assessment that works on standards related to the certification process.

The establishment of the IEC conformity assessment framework for renewable energy (IECRE) and its Operational Documents (ODs) in 2014 provided transparency and consistency for the assessment and IEC 61400-22 has been withdrawn with effect from 1st of September 2018. However. IECRE wind certification schemes OD-501 and OD-502 still need to be properly implemented internationally, and many regulations still refer to IEC 61400-22.

The figure below shows the organisation in IEC including the relation between standards and conformity assessment.

Figure 4 IEC Standards structure and IECRE Conformity assessment organization



Source: American Renewable Energy Standards and Certification Association

2.1. IEC Standards relevant to FOW projects

The establishment of an international standard for conformity assessment / certification processes under the IECRE enabled multilateral recognitions agreements. It is frequently used, especially on type and component certification.

Countries participate in ISO/IEC work via National Standards Bodies (NSBs), as well as through input received from liaison organisations. National positions on ISO/IEC work are developed by the NSBs on an ongoing basis. Most NSBs establish a National Mirror Committees (NMCs) in order to reflect the work of international or regional standardization organizations.

Relevant Technical Committees in the ISO/IEC structure are the IEC TC88 Wind Energy Generation Systems, the ISO TC60 Gear and the IEC TC14 Power Transformers.

Here is a first approach to specific references to standards and guidelines from the International Electrotechnical Commission (IEC) Standards:

Table 1 IEC Standards

Relevant IEC standards handled within the TC88 Wind Energy Generation Systems:	
• IEC 61400-1: Design requirements • IEC 61400-2: Small wind turbines • IEC 61400-3-**1:** Design requirements for fixed offshore wind turbines • IEC TS 61400- 3-2: Design requirements for FOWT (Technical Specification) • IEC 61400-4: Design requirements for wind turbines gearboxes • IEC 61400-5: Wind Turbine Blades • IEC 61400-11: Acoustic noise measurement techniques • IEC 61400-12-1: Power performance measurements of electricity producing wind turbines	• IEC 61400-13: Measurement of mechanical loads • IEC 61400-14: Declaration of sound power level and tonality values • IEC 61400-21: Measurement of power quality characteristics • IEC 61400-22: Conformity Testing and Certification of wind turbines (withdrawn) • IEC 61400-23 TR: Full scale structural blade testing • IEC 61400-24 TR: Lightning protection • IEC 61400-25-(1-6): Communication • IEC 61400-26 TS: Availability • IEC 61400-27: Electrical simulation models for wind power generation
IEC standards recently published or in progress are as below:	
• IEC 61400-3-2: Design requirements for floating offshore wind turbines (publishing schedule 2024-11) • IEC61400-50: Wind measurements (published 2022-08-30) • IEC61400-50-1: Wind measurements application of meteorological mast, nacelle and spinner mounted instruments (published 2022-11-16) • IEC61400-50-2: Wind Measurement - Application of Ground Mounted Remote Sensing Technology (published 2022-08-30) • IEC61400-50-4: Use of floating lidars for wind measurements (publishing schedule 2024-12)	

3. OWP/FOW TECHNICAL REGULATIONS AND STANDARDS IN JAPAN

3.1. Laws and Regulations

Among the laws and regulations related to offshore wind power in Japan, the main ones concerning technical standards are presented in the subsections below. Offshore wind farms are required to comply with the technical regulations set by each act.

Many parts are common to the bottom-fixed OWP, the details of which are discussed in the Study report of 2022[4].

3.1.1. Electricity Business Act

Offshore wind power generation facilities fall under the category of Electric Facilities for Business Use under the Electricity Business Act (Article 38, Paragraph 2 of the Act). Electric Facilities for Business Use shall conform to the technical standards established by Ordinances of the Ministry of Economy, Trade, and Industry (METI) (Article 39). Specifically, there is the "Ministerial Ordinance Establishing Technical Standards for Electrical Facilities " that establishes standards for general electrical safety, and the "Ministerial Ordinance Establishing Technical Standards for Wind Power Generation Facilities" that establishes standards for the safety performance of wind turbines and supporting structures.

3.1.2. Port and Harbour Act

The support structures for offshore wind power generation facilities are mooring facilities where vessels for maintenance come ashore, and therefore must conform to the technical regulations for port facilities under the Port and Harbour Act and the related ministerial ordinance established by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) (Article 56-2-2).

3.1.3. Ship Safety Act

Floating offshore wind facilities are classified as "special vessels" under Article 1, Paragraph 4 of the Ordinance for Enforcement of the Ship Safety Act and are subject to safety regulations based on the Act [5].

Floating offshore wind turbines are treated as ships, and therefore the Building Standard Act does not apply to them. However, there are parts of the technical standards that are referred to this Act (e.g., snow loads).

Meanwhile, under the Ship Act, floating offshore wind turbines are not considered as ships, and it does not apply to them[6].

3.1.4. Act on Promoting the Utilization of Sea Areas for the Development of Marine Renewable Energy Power Generation Facilities

When offshore wind power generation facilities are installed in the Promotion Zones for the Development of Marine Renewable Energy Power Generation Facilities (hereinafter, the Promotion Zone) under the Act on Promoting the Utilization of Sea Areas for the Development of Marine Renewable Energy Power Generation Facilities (hereinafter, the Renewable Energy Sea Area Utilization Act), the project details are described in the Exclusive Occupancy and Use Plan over Public Bidding (hereinafter, the Exclusive Occupancy and Use Plan). The offshore wind power generation facilities and maintenance methods described in the Exclusive Occupancy and Use Plan must conform to the technical regulations specified by the ordinances of METI and MLIT (Article 15, Paragraph 1, Item 3 of the Renewable Energy Sea Area Utilization Act). Article 5 of the Ordinance for enforcement of this act specifically defines the regulatory standards, and the MLIT's Notification defines the performance

[4] Sectoral Study: Standards, technical regulation and conformity assessment in the Japanese and European offshore wind power market: current implementation and best practices, July 2022.
https://www.eeas.europa.eu/sites/default/files/documents/OWP%20Study%20-%20DTU-REI_publication_EN.pdf

[5] The material of Maritime Bureau, MLIT, Study Group on Issues under International Law Concerning the Implementation of Offshore Wind Power Generation in the Exclusive Economic Zone (EEZ), 2nd meeting held on November 8, 2022, material 1.
https://www8.cao.go.jp/ocean/policies/energy/pdf/shiryou21.pdf

[6] The Ship Act does not provide a specific definition of a "ship". However, the Act treats a ship as having the three elements of "buoyancy", "carrying capacity" and "mobility". Since floating offshore wind turbines are fixed to the seabed by mooring cables and lack "mobility", they do not meet the criteria to be classified as "ships" under the Act" and are therefore not subject to the Act.

requirements, basics of performance verification and settings, among others[7].

To expand potential development areas, an amendment of the Act is being prepared to establish a domestic legislation for the development of offshore wind in the exclusive economic zone (EEZ). The bill is under discussion in the Diet.

3.1.5. Environmental Impact Assessment Act

In 2012, the Environmental Impact Assessment Act made it mandatory for wind power installations of 10 MW or more. In 2021, the size requirement of wind power plants in the Act was revised to 50 MW or more.

In 2020, the reference items for environmental impact assessment were reviewed[8] to speed up the implementation of wind power facilities. The 'Technical Guide for Environmental Impact Assessment Methodology for Offshore Wind Power Plants'[9] and 'Reference Materials'[10] for offshore wind power became effective in December 2023. Although the guidelines are based on fixed-bottom wind turbines, it is assumed that the same will apply to FOW.

In August 2023, a study group report on the "New Environmental Assessment System for Offshore Wind Energy"[11] was published, which covers developments in areas defined in the Renewable Energy Sea Area Utilization Act as well as in the EEZ. This report serves as a basis for further examination of the early implementation of a new scheme, including consideration of the necessary legal framework. The Ministry of the Environment (MOE) organized a dedicated council and the Council published a recommendation report to revise the legal system for environmental impact assessment procedures for offshore wind power. According to the Council's report, MOE will collect a wide range of information and knowledge from interested parties and local communities at an early stage before selecting a project developer. The Ministry conducts field surveys after determining the method of environmental assessment in advance, and appropriately reflect the survey results in studies such as zone selection based on the Renewable Energy Sea Area Utilization Act and in project plans drawn up by the selected project developer. This reform is included in the bill of the amendment to the Renewable Energy Sea Area Utilization Act, which is under discussion in the Diet.

3.1.6. Civil Aeronautics Act

In order for aircrafts to take off and land safely, certain areas around airports must be kept free of obstructions. No structures, plants, or other objects are allowed to be installed, planted, or left at a height above the approach surface, transitional surface or horizontal surface (the extended approach surface, conical surface, or outer horizontal surface for certain large airports), as indicated in the public notice of MLIT (Obstacle Limitation Surfaces, Articles 49 and 56-3). The Obstacle Limitation Surfaces are defined for each airport[12].

In addition, notification and consultation with the Civil Aviation Bureau is required when wind turbines are to be constructed near VHF Omnidirectional Radio Range (VOR) and Distance Measuring Equipment (DME) stations, which provide both azimuth and distance information to aircraft operating within their effective communication range.

3.1.7. Meteorological Service Act

If a wind turbine is installed in close proximity to a weather radar, notification and consultation are required under Article 37, depending on the size of the turbine, its altitude, and its distance from the radar[13]. This is because the turbine has the potential to block radio signals or generate false echoes, which could significantly impact observations. The distance between the radar and the wind turbine is

[7] MLIT, "Public Notice of Necessary Matters Concerning Standards for Offshore Renewable Energy Power Generation Facilities or Methods of Maintenance and Management Thereof"

[8] Electricity Safety Division, Industry Safety Group, METI, "Review of Reference Items for Environmental Impact Assessment of Wind Power Plants" (February 5, 2020) https://www.meti.go.jp/shingikai/sankoshin/hoan_shohi/denryoku_anzen/newenergy_hatsuden_wg/pdf/021_01_01.pdf

[9] Environmental Impact Assessment Division, Minister's Secretariat, Ministry of the Environment (MOE), Electricity Safety Division, Industrial Safety Group, METI, "Technical Guide for Environmental Impact Assessment Methodology for Offshore Wind Farms" (December 2023) https://www.env.go.jp/content/000184694.pdf

[10] Environmental Impact Assessment Division, Minister's Secretariat, Ministry of the Environment (MOE), Electricity Safety Division, Industrial Safety Group, METI, "Technical Guide for Environmental Impact Assessment Methodology for Offshore Wind Farms Reference Materials" (December 2023) https://www.env.go.jp/content/000184695.pdf

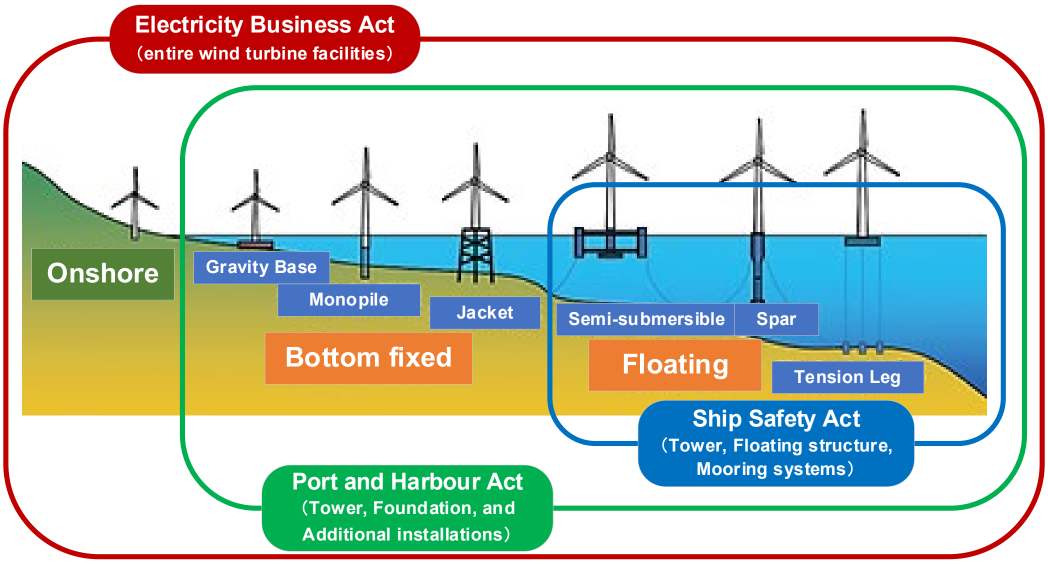
[11] Study Group on the Optimal Environmental Impact Assessment System for Offshore Wind Power Generation, "NewEnvironmental Assessment System for Offshore Wind Power Generation" (August 2023) http://assess.env.go.jp/files/0_db/seika/1055_03/report.pdf

[12] East Japan Civil Aviation Bureau, MLIT website "Restrictions on the installation of buildings and other structures in the vicinity of airports (Obstacle Limitation Surfaces)" https://www.cab.mlit.go.jp/tcab/restriction/02.html

[13] Japan Meteorological Agency, MLIT, "For coexistence of wind power facilities and weather radar" (January 25, 2022) https://www.enecho.meti.go.jp/category/saving_and_new/saiene/yojo_furyoku/dl/kyougi/akita_oga/01_docs06.pdf

determined according to the World Meteorological Organizations guidance statement on weather radar/wind turbine siting (The CIMO Guide, 2021), Additionally, the Ministry of Defense mandates that operators consult during the early stages of project planning to minimize the impact on radar.

Figure 5 Scope of the Electricity Business Act, Port and Harbour Act, and Ship Safety Act



Source: created by REI based on ClassNK, "Wind Turbine Certification and Related Services" p.27 [14]

3.2. Standards

3.2.1. ISO/IEC and JIS

Japanese Industrial Standards (JIS) are established in accordance with ISO and IEC standards. ISO and IEC are applied in Japan as they are, but to facilitate their application in the country, the major ones that are expected to be used widely are incorporated into JIS standards. Specifically, the Japanese Industrial Standards Committee (JISC) deliberates on JIS drafts proposed by related organizations, and the competent minister establishes or revises them. However, JIS standards are established or updated several years after the publication and revision of ISO/IEC standards due to translation into Japanese and the addition of supplementary explanations[15]. Supplementary explanations include explanations of terms that are not in common use in Japan and addition of references to the national standards (e.g., earthquakes) where the standards indicate to do so.

For wind energy generation systems, the Japan Electrical Manufacturers Association (JEMA) has established a technical committee on wind energy generation systems as a domestic deliberative body for IEC/TC88 (Technical committees 88), which deliberates, proposes, and votes on approval of draft international standards, and prepares draft JIS for the domestic market.

Based on a proposal from Japan, in IEC61400-1 ED4.0 (Design requirements), in addition to the existing wind turbine classes (I, II, III, and S), Class T (Tropical) was added as a requirement for Japan and Southeast Asia, where typhoon attacks and turbulent flow intensity are significant. In IEC61400-24 ED2.0 (Lightning protection), in addition to the existing requirements of 150 and 300 coulombs, a new requirement of 600 coulombs has been added for regions with high lightning energy.

IEC and JIS publication status is shown in Annex II.

[14] https://www.classnk.or.jp/hp/pdf/authentication/renewableenergy/ja/RD2101_202108_Jpn.pdf

[15] To speed up the information dissemination after the ISO/IEC publishment, somean operational reforms are under discussion, including publishingreform was introduced in August 2023. It allows Technical Specification/specification (TS) ,Technical Reports (TR) and Preliminary Draft for JIS (PD) to be published earlier than the enactment of JIS standards. METI, Japanese Industrial Standards Committee, The Basic Policy Committee, "Draft Interim of JISC recommends to use machine translation for prompt preparation of PD. First Committee on Standards and Second Committee on Standards, JISC, "Implementation Guidelines for TS, TR and PD publication" (Revised in August 7, 2023) https://www.jisc.go.jp/jis-act/pdf/tstr-youryou.pdf, Basich Policy Committee, JISC, "Summary Report" (May 30, 2022 - Japanese Model for Accelerating Establishment of Standards- "(June 2023) https://www.meti.go.jp/policy/economy/hyojun-kijun/jisho/pdf/20230620tori.pdf

3.2.2. Transition to IECRE and Japan's response

The IEC standard on conformity testing and certification for wind turbines (IEC 61400-22 Ed. 1.0) was discontinued at the end of August 2018 under the policy of separating technical and certification standards and was replaced by IECRE [16], a certification system for renewable energy equipment including not only wind power systems but also other renewable such as photovoltaic systems. Regarding wind power, 14 countries [17] including Japan participate in its activities. It aims to promote international trade in equipment and services used in the renewable energy sector. The IECRE OD-501 Edition 3.0 2022-10-23 is used for type and component certification, while the IECRE OD-502 Edition 1.0 2018-10-11 is used for project certification [18]. The following eleven certification bodies[19] are registered by IECRE.

Table 2 IECRE Certification Bodies in the Wind Energy Sector

Country/Location	RE Certification Body Name
China	China General Certification Center (CGC)
China	China Quality Certification Centre
China	China Classification Society Certification Co., Ltd. (CCSC)
France	Bureau Veritas Certification France
Germany	UL Solutions
Germany	WindGuard Certification GmbH
Germany	TÜV SÜD Industrie Service GmbH
Germany	TÜV NORD CERT GmbH
Germany	DNV Renewables Certification GmbH
Germany	TÜV Rheinland Industrie Service GmbH
United Kingdom	Lloyd's Register Marine Limited

Source: IECRE

In Japan, however, JIS C 1400-22:2014, which is equivalent to IEC61400-22:2010 Ed.1.0, remains valid and applies to wind power system, although IECRE is used as a reference. It could be a transitional measure, but the competent authority has not announced yet when IECRE would be officially applied in the country.

Before IECRE system would be applied, wind turbines that obtained type certification under IECRE in other countries, would be utilized in Japan under the mutual recognition if the equivalence to IEC61400-22 is confirmed.

3.3. Official Explanation, Technical Standards and Safety Guidelines

3.3.1. Official Explanation of Technical Standards for Offshore Wind Power Generation Facilities

Offshore wind farms are required to comply with the technical regulations stipulated by the relevant laws. To reduce the burden on operators and streamline the examination procedures, it is necessary to avoid duplication of procedures and complications due to differences in regulations. From this perspective, the "Official Explanation of Technical Standards for Offshore Wind Power Facilities (March 2020 Edition)" (hereinafter referred to as the "Official Explanation") was published as "an explanation of the unified approach of each law regarding the technical regulations to which offshore wind power facilities must conform based on the Electricity Business Act, the Port and Harbour Act, and the Renewable Energy Sea Area Utilization Act"[20].

The contents of the Official Explanation apply to the examination of the structure of offshore wind power generation facilities, based on the Electricity Business Act, the Port and Harbour Act, and the Renewable Energy Sea Area Utilization Act (p.14)[21]. Many parts of the contents applied to FOW are common to the bottom-fixed offshore wind, the details of which have been discussed in the 2022

[16] IECRE - IEC System for Certification to Standards Relating to Equipment for Use in Renewable Energy Applications https://www.iecre.org
[17] Member bodies IECRE
[18] Rules, operational documents & guides
[19] Certification Bodies (RECBs) | IECRE
[20] The contents of the document were discussed by the "Offshore Wind Power Facility Study Committee," a council of METI and MLIT. Official Explanation of Technical Standards for Offshore Wind Power Facilities https://www.mlit.go.jp/common/001339422.pdf Appendix https://www.mlit.go.jp/common/001336262.pdf
[21] Although the main subject of this document is suport structures for offshore wind power generation facilities among offshore wind power generation facilities, it is said that offshore wind power generation facilities can be read as offshore transition facilities and observation towers and applied to them respectively. In the design of submarine transmission lines and communication cables, the design methods for support structures covered in this commentary may not be directly applicable, and in such cases, international and national standards and certification standards may be referred to

Sectoral Study report. The part of the Official Explanation that relates to support structures applies mainly to the bottom-fixed, while the Safety Guidelines for Technical Standards for Floating Offshore Wind Power Facilities, which are detailed in the next section, apply to the FOW.

3.3.2. Technical Standards for Floating Offshore Wind Power Generation Facilities

MLIT has established the "Technical Standards for Floating Offshore Wind Power Generation Facilities" [22] . This standard applies to floating facilities and towers, which are support structures for FOW facilities. After its publication in April 2012, this standard was revised in March 2020 to refer to IEC 61400-3-1 and IEC TS 61400-3-2. The main contents are as follows:

A) Part 2 Technical Standards – Chapter 1 External Conditions

This chapter describes the technical standards regarding 1. General conditions, 2. Wind conditions, 3. Sea conditions, and 4. Other environmental conditions, including 4-1. Earthquakes, 4-2. Seabed deformation and Scour, and 4-3. Snow loads.

*The content of "**4-1. Earthquakes**" is described as below (1) to (4). The seismic motions in the horizontal and vertical directions need to be considered in the case of the fixed-bottom type, whereas the consideration for the FOW is mainly for vertical seismic motions, due to a buffer effect of seawater. The methods for evaluating the impact of earthquakes and tsunamis on floaters are indicated in Appendix 1 of the Safety Guidelines for Technical Standards for Floating Offshore Wind Power Facilities, described later.*

(1) Appropriate consideration shall be given to the effects of earthquakes. Earthquakes shall be considered to be the maximum level that has occurred in the past in the vicinity of the installation area.

(2) Tsunami effects shall be appropriately considered. The largest tsunami that has ever occurred in the vicinity of the installation area shall be considered. However, if the water depth is deep enough, tsunami effects may be considered as tidal fluctuations and ocean currents.

(3) When considering earthquakes and tsunamis, environmental loads such as wind and waves may be assumed under normal conditions.

(4) Liquefaction of the ground in the event of an earthquake must be considered.

B) Part 2 *Technical Standards – Chapter 2 Rules for Structures* - Section 1 *Materials*

"1. Materials used"

(1) For materials used in the main structural parts of floating offshore wind power generation facilities and drainage facilities, etc., materials specified in the Ship Structure Regulations (Ministry of Transport Ordinance No. 16 of 1998) shall be used.

(2) If materials other than those specified in (1) above are to be used, an inquiry shall be made to the Director, Inspection and Survey Division, Maritime Bureau, MLIT, together with the necessary data.

C) Part 2 *Technical Standards – Chapter 2 Rules for Structures* – Section 2 *Loads*

This Section stipulates the rules for 1. General matters, 2. Loads, and 3. Design conditions and load cases.

In "*1. General matters*", it is indicated that "*coupled analysis in the time domain* (coupled analysis using time-series historical data and repeating the calculation with tine time increments) *must be performed for floating facilities and towers. In the analysis, sufficient simulation time shall be allowed to accurately determine the loads. Meanwhile, model tests may be used to calculate the loads if deemed appropriate by the competent marine authority*". "2. *Loads*" further specifies gravity and inertia loads, aerodynamic loads, operating loads, hydraulic loads, sea ice loads, and other loads. In" *3. Design conditions and load cases*", 29 cases are specified for power generation from DLC (Design Load Case) 1.1 to DLC 8.4, and 8 cases for sea ice from DLC D1 to D8.

D)* Part 2 *Technical Standards* – *Chapter 3 Position Holding Systems

In this chapter, the following items are specified: *1. General matters*, *2. Mooring system*, *3. Mooring analysis*, *4. Design of mooring lines, etc.*, and *5. Mooring equipment*.

"1. General Matters" specifies that "*floating facilities shall be equipped with a position holding system that satisfies the items specified in this chapter or the standard in ISO 19901-7*".

"3. Mooring analysis" specifies a total of nine items, including the following:

(1) The mooring analysis shall be based on the external conditions specified in Chapter 1. The analysis shall include an evaluation of the drifting

[22] Safety Policy Division, Maritime Bureau, MLIT, "Technical Standards for Floating Offshore Wind Power Generation Facilities" (March 2020) https://www.mlit.go.jp/common/001331375.pdf

forces and the response of the floating facilities resulting from these external conditions and the corresponding line tensions.

(2) The mooring system shall be subjected to mooring analysis deemed appropriate by the competent marine authority for all possible mooring conditions. In this case, the effect of changes in the draft of the floating facility shall also be taken into account. In the case of mooring to separate CALM buoys or other mooring facilities independent from the floating facilities, the mooring analysis shall be performed for the entire system including these mooring facilities.

From (3) to (8) omitted

(9) The calculation of tension in mooring lines shall take into account at least the items listed below. This analytical method is referred to as quasi-static analysis, and this quasi-static analysis method shall be the standard method for calculating the tension acting on mooring lines. The maximum tension in the mooring line calculated by the quasi-static analysis method shall, in principle, have the safety factor listed in the following table for the specified cutting load of the mooring line.

(i) Static tension in the mooring line due to the dead weight and buoyancy of the mooring line

(ii) Steady tension in the mooring line due to steady horizontal displacement of the floating facility caused by wind, waves and currents

(iii) quasi-static variable tension in the mooring line due to the motion of the floating facility caused by waves.

Table 3 Mooring Line Safety Ratios [23] [24]

Condition	Safety Factor	
	Chains and wire ropes	Synthetic fiber rope
at non-damage		
For dynamic analysis	1.67	**2.50**
For quasi-dynamic analysis	2.00	**3.00**
Single cable rupture state (equilibrium state after rupture)		
For dynamic analysis	1.25	**1.88**
For quasi-dynamic analysis	1.43	**2.15**
Transient state at single cable breakage		
For dynamic analysis	1.05	**1.58**
For quasi-dynamic analysis	1.18	**1.77**

In "*5. Mooring equipment*", it contains the item *"(2) Chains, Wires, etc."*, which specifies as follows:

(a) Chains, wire or synthetic fiber ropes, intermediate sinkers, intermediate buoys, anchors serving as submarine mooring points, sinkers, piles, etc., used in mooring systems shall be those deemed suitable by the competent marine authority.

3.3.3. Safety Guidelines for Technical Standards for Floating Offshore Wind Power Facilities [25]

The Guidelines systematically provide technical solutions that can be practically applied by actual designers in order to promote rational and efficient safety design of floating facilities and towers, which are the support structures of floating offshore wind power facilities. It was published by the Maritime Bureau of MLIT in May 2023. It is a commentary on the Technical Standards for Floating Offshore Wind Power Generation Facilities, and introduces calculation methods based on the Building Standard Act and a database of meteorological and marine conditions as reference. The main contents are as follows.

A) **Part 2 *Technical Standards* – Chapter 1 *External Conditions***

"4-1. Earthquake, (1)"

...The design earthquake ground motion is determined by multiplying the basic maximum acceleration by the seismic topography coefficient. The basic maximum acceleration is 160gal and 320gal, which correspond to the expected values for 50 and 500 years, and the seismic topography coefficient (0.7 to 1.0) is determined for each region.

The methods for evaluating the impact of earthquakes and tsunamis on floating

[23] It is not specified whether the synthetic fiber rope is nylon, high modulus polyethylene (HMPE), or aramid.
[24] UK-based Marine Power Systems is the first company in the world to apply Norway-based FibreMax mooring cables made from Japanese aramid fibers to its TLP floats. https://www.marinepowersystems.co.uk/mps-joins-forces-with-the-worlds-strongest-cable-manufacturer-fibremax/
[25] Safety Guidelines for Floating Offshore Wind Power Facilities Technical Standards (Revised March 31, 2023) https://www.mlit.go.jp/common/001331376.pdf

structures are presented in Appendix 1 of the Guidelines, as follows:[26]

"1.1 Horizontal earthquake motion"

Since horizontal seismic motions are hardly transmitted to the floating facilities via the ground, anchors, and mooring cables (chains), the effects on each component of the wind power generation facility can be omitted and should be evaluated in terms of tension fluctuations in the mooring cables.

"1.2 Vertical earthquake motion"

Vertical seismic motions are transmitted to the floating facilities via the ground, anchors (sinkers), and mooring cables (chains). Vertical seismic motions should be evaluated from the following perspectives:

1) Effect on floating facilities

2) Effect on sinkers

B) Part 2 *Technical Standards – Chapter 2 Regulations Concerning Structure – Section 1 Materials*

1. Rolled steel plate

"Materials that conform to the requirements specified in the Notification of MLIT ("Notification establishing requirements for materials for hull and drainage systems") are those shown in Table 2-1-1-1(Table 4 in this report as below). The requirements specified in the Notification mean that, depending on the location of use, mild steel as specified in Appendix Table 4 of the Notification shall be used when mild steel is used, and high tensile steel as specified in Appendix Table 5 of the Notification shall be used when high tensile strength steel is used. For details, the Ship Structure Rules（船舶構造規則） should be referred to.

In the case of Class NK's Part P (Offshore Structures and Work Vessels) of the Rules for the Survey and Construction of Steel Ships（鋼船規則 P 編）, Chapter 2 of Part P of the Rules shall be applied. In this case, rolled steel materials used for hull structure and outfitting, etc. shall conform to the provisions of Part K (Materials) of the Rules for the Survey and Construction of Steel Ships. For details, Part K of the Rules should be referred to."

Table 4 Classification of rolled steel used for hulls (by the Ship Structure Rules)

Mild steel	*High tensile strength steel*
MA steel MB steel MD steel ME steel	*HA32 steel HD32 steel HE32 steel HA36 steel HD36 steel HE36 steel*

Table 5 Types of rolled steel for hulls (by the NK Rules for the Survey and Construction of Steel Ships, Part K)

Materials used	*Symbols defined in Part K*
Mild steel	*KA KB KD KE*
High tensile strength steel	*KA32, KA36, KA40 KD32, KD36, KD40 KE32, KE36, KE40, KF32, KF36, KF40*
Structural tempering High Strength Rolled Steel	*KA420, KA460, KA500 KA550, KA620, KA690 KD420, KD460, KD500 KD550, KD620, KD690 KE420, KE460, KE500 KE550, KE620, KE690 KF420, KF460, KF500 KF550, KF620 KF420, KE460, KE500, KE550, KE620, KE690*

2. Concrete

"Concrete materials (including cement and other binding materials, crushed stone aggregate, sand, slag aggregate, rebar, etc.) must be suitable for the purpose for which they are to be used and where they will be used.

Concrete is classified into cement concrete, asphalt concrete, and resin concrete, depending on the composition of the materials mixed.

Composites with steel are classified as reinforced concrete, prestressed concrete, and others.

In floating offshore wind power generation facilities, it may be applied as a fixed ballast for floating facilities and as a composite material with steel for the foundations for fixing floating facilities, towers and mooring equipment at the seabed.

When concrete is used as a structural strength member for floating facilities, towers, etc., it must be confirmed that it is sufficiently safe through appropriate strength evaluations. Due to the material properties of concrete, particular attention should be paid when it is used as a member subject to bending moments and tensile loads."

Details are described in Section 3, of the Supplement of the "Guidelines for Design and Construction of Concrete Floating Offshore Wind Power Facilities".

[26] Appendix 1 of Safety Guidelines for Technical Standards for Floating Offshore Wind Power Facilities (Revised March 3, 2020) https://www.mlit.go.jp/common/001331294.pdf

C) Part 2 *Technical Standards Chapter 2 Rules for Structures Section 2 Loads*

"(2) Coupled analysis"

...When conducting an integrated coupled analysis, a well-validated program should be used, or the accuracy of the analysis results should be verified by comparing them with model test results. Particular attention should be paid to the modelling of the analysis target.

In analysis, coupled time series analysis is the standard, but frequency domain analysis is also used in some cases. Frequency-domain analysis refers to solving the equations of motion assuming harmonic oscillation by using these coefficients to solve the equations of motion for a phenomenon that combines many frequency components by breaking them down into their individual frequencies.

D) Part 2 *Technical Standards Chapter 3 Position Holding Systems*

"1. General matters"

ISO 19901-7:2013 Petroleum and natural gas industries - Specific requirements for offshore structures - Part 7: Station keeping systems for floating offshore structures and mobile offshore units specifies the requirements for station keeping systems for floating facilities for oil and gas development. The major difference between offshore wind power facilities and floating facilities for oil and natural gas development is that the environmental external forces can vary significantly depending on the operating conditions, such as power generation and standby.

Therefore, this technical standard combines the "design load case (DLC)" concept established by the IEC with the analytical methods set forth in ISO 19901-7, the leading standard for position-retention systems for floating facilities.

"5. Mooring equipment"

(2) Chains, wires, etc.

Chains, wire or synthetic fiber ropes, intermediate sinkers, intermediate buoys, anchors that serve as mooring points on the seabed, sinkers, piles, etc., used in mooring systems must comply with international standards and be approved by the controlling marine authority.

3.3.4. (Supplement) Design and Construction Guidelines for Concrete Floating Offshore Wind Power Facilities [27]

This guideline was issued by the Maritime Bureau of the MLIT in May 2023, aiming to provide technical solutions that actual designers can refer to in practice to promote rational and efficient safety design of concrete floating structures, which are the support structures of floating offshore wind power generation facilities. Items common to steel floating offshore wind power generation facilities refer to the "Safety Guidelines for Technical Standards for Floating Offshore Wind Power Generation Facilities, March 2020". The main contents are as follows.

A) Part I General Provisions

"The characteristics of steel and concrete floating facilities in offshore wind power facilities are shown in the table below".

Table 6 Characteristics of steel and concrete floating facilities

Item		***Steel structure***	***Concrete structure***	***Relevant sections of the Guidelines***
Material	*Material Composition*	*Single material (steel)*	*Composite materials (cement, mixing water, aggregates, admixtures, admixtures, reinforcing bars, structural steel, PC steel, reinforcing fibers, etc.)*	*Part 2, Chapter 2, 1-1-3 Concrete Materials*
	Material Performance	*Select materials as needed*	*Formulation should be designed according to the intended use.*	*Volume 2, Chapter 2, 1-2. Compounding Design*
	Material Properties	*・Corrosion protection is necessary due to its corrosive nature.*	*・Composite structure in which the concrete bears the*	*Part 2, Chapter 2 3-2. Design Objectives and*

[27] Maritime Bureau, MLIT, "(Supplement Appendix) Guidelines for the Design and Construction of Concrete Floating Offshore Wind Power Generation Facilities" March 2023) https://www1.mlit.go.jp/maritime/content/001598467.pdf

Item		*Steel structure*	*Concrete structure*	*Relevant sections of the Guidelines*
		・In general, the slenderness ratio of members is large, and buckling verification and buckling prevention measures are required	*compression and the steel bars bear the tension. ・Where water tightness is required, measures (prestressing, etc.) should be taken to prevent or control cracking of the concrete. ・Measures to prevent rebar corrosion are needed."*	*Design Conditions 3-6. Verification of Durability 3-6-2 Verification of Crack Width*
Construction	*construction method*	*・There are two methods of construction: factory-built and factory-manufactured steel members joined together on site. ・Factory manufacturing is not affected by weather (except for those requiring outdoor work)."*	*・There are two methods of building structures: concrete is poured into forms on site, and precast concrete manufactured in a factory is joined on site. ・Construction methods and controls must be such that they are not affected by weather conditions (except for those that can be factory-manufactured)*	*Reference 1 Construction of concrete floating facilities*
	construction process	*・No curing time is required.*	*・Since it takes time for concrete to develop strength, this affects the process when concrete is placed on-site to build structures.*	*Reference 1 Construction of concrete floating facilities (2) (c) Curing*
Examination		*・Hydraulic testing and water tightness testing, etc. ・Defects in structural members and welds (visual or non destructive) for flaws, cracks, etc.) ・Paint Inspection."*	*・Inspection of rebar coverage (non-destructive testing) ・Inspection of crack width ・Inspection of concrete joints ・Inspection of precast member joints . water pressure tests and water tightness tests"*	*Reference 2 Inspections on Floating Facilities*

Source: (Supplement) Design and Construction Guidelines for Concrete Floating Offshore Wind Power Facilities, Explanation Table 1-1 Characteristics of steel and concrete floating facilities, translated in English by REI

B) *Part 2 Technical Standards – Chapter 2 1. Materials and Compounding Design 1-1.*

"1-1-1. General"

For materials to be used for concrete floating facilities, it refers to the Japan Society of Civil Engineering (JSCE) Standard Specifications for Concrete, namely, [Construction: Construction Standard, Chapter 3 Materials] and [Construction: Special Concrete, Chapter 7 Marine Concrete]. In this chapter of the Guidelines, only special considerations are given for materials used for concrete floating facilities.

"1-1-2. Concrete Type"

(1) For concrete used for concrete floating facilities, it refers refer to the JSCE Standard Specifications for Concrete [Construction: Construction Standard, Chapter 3, Materials] and [Construction: Special Concrete, Chapter 7, Marine Concrete].

(2) The characteristic value of compressive strength (design basis strength) of concrete used for the main structural members of concrete floating facilities shall be 30 N/mm2 or more as standard.

(3) In addition to standard concrete (AE concrete with a design basis strength of less than 50 N/mm2 and a minimum slump of 16 cm or less for placing), "fluidized concrete," "high flow concrete," "high strength concrete," "expanded concrete," "short fiber reinforced concrete," "pre-stressed concrete," "precast concrete," "plant products," and "lightweight aggregate concrete" alone or in combination. In addition, the use of concrete with new features with proven quality, such as "Ultra High Strength Fiber Reinforced Concrete" (UFC), should also be considered.

"1-1-3. Concrete Materials"

It refers to the JSCE Standard Specification for Concrete [Construction: Construction Standard, Chapter 3 Materials], [Construction: Special Concrete, Chapter 7 Marine Concrete] and [Design: Main Part, Chapter 5 Materials].

C) Part 2 Technical Standards Chapter 2 3. Design of Concrete Floating Structures

"3-1. General"

It refers to the MLIT Guidelines [Volume 2, Chapter 2, 3.1 General Matters].

The design of concrete floating facilities shall take into account material deterioration, cracking, permeability, and corrosion of reinforcing bars and other materials inherent in concrete to ensure adequate durability and to satisfy safety and usability requirements.

3.3.5. Official Explanation of Operation and Maintenance for Offshore Wind Power Generation Facilities

Conformity of offshore wind power facilities to regulations is required by law to be verified in the operation and maintenance phase as well. As with the design and construction phase, the operation and maintenance of offshore wind power facilities are subject to multiple laws and regulations (Electricity Business Act, Port and Harbour Act, and Renewable Energy Sea Area Utilization Act). In order to reduce the burden on operators and streamline the review process, the "Official Explanation of Operation and Maintenance for Offshore Wind Power Generation Facilities (March 2020 edition)"[28] and "Reference Material"[29] was published. In addition to operation and maintenance, this Official Explanation covers matters related to decommissioning (removal).

Many parts of the contents are common to the bottom-fixed offshore wind, the details of which have been discussed in the 2022 Sectoral Study report.

3.3.6. The role of standards in the technical regulations

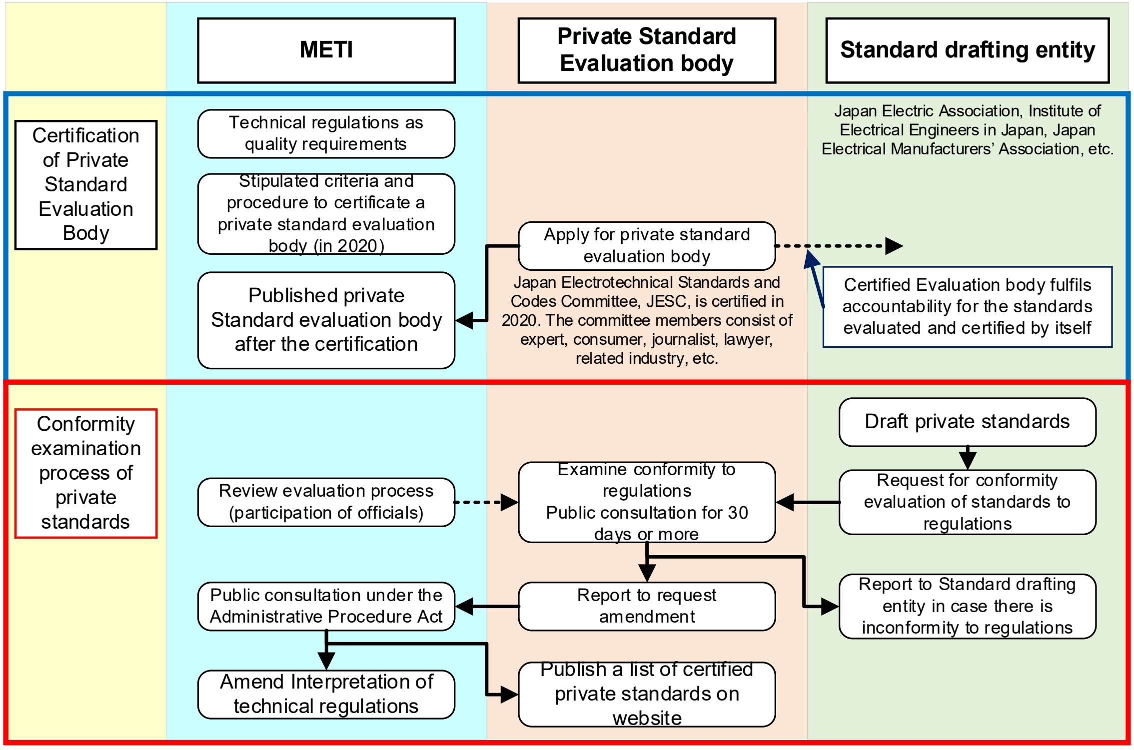
As mentioned earlier, METI and MLIT publish respectively various documents including "Official Explanation" and "Safety Guidelines" in order to show specific methods for conformity assessment to each regulatory requirement. The International standards and JIS standards are the referenced information for this objective alongside of the Guidelines published by JSCE, among others.

Due to the speed of technical innovation, it is important for the regulation to follow the latest technology development flexibly. In this sense, METI started a new scheme to incorporate standards developed at the initiative of the private sector into technical regulations since 2020. Under the scheme, METI accredits a Private Standard Evaluation body, which receives a draft standard from a Standard Drafting entity (industrial institution or academia). The Private Standard Evaluation body examines the conformity of the draft to technical regulations, conducts public consultation and publishes as the standards. The ministry controls the accredited body by participating in its meetings and periodic checks. When receiving a report from the accredited body, METI amends the interpretation of the technical regulations, after public consultation based on the Administrative Procedure Act.

[28] Offshore Wind Power Facility Study Committee, "Official Explanation on Operation and Maintenance for Offshore Wind Power Generation Facilities" (Version of March 2020) https://www.mlit.go.jp/common/001335973.pdf

[29] "Reference Material of Official Explanation on maintenance and management for Offshore Wind Power Facilities" (Version of March 2020) https://www.mlit.go.jp/common/001335974.pdf

Figure 6 Adoption of technical standards at the initiative of private sector



Source, created by REI based on METI, Industrial Structure Council, Subcommittee on Safety and Consumer Product Safety, "Immediate reform and important issues for the future in the field of industrial safety" (December 21, 2021), Figure 64, p.65

3.4. Examinations on technical regulations and third-party certification procedures

Examination procedures for conformity to related technical regulations have been changing with the introduction and spread of third-party certification. Duplication of certification procedures and regulatory reviews, reworking, and prolonged procedures have become issues. In light of these circumstances, some institutional and operational reforms have been made and discussed, and currently in a transitional period of change.

3.4.1. Examination under the Electricity Business Act

A) Planning Phase

When installing an offshore wind power generation facility, a business operator shall notify METI of the Construction plan (Article 48, Paragraph 1 of the Electricity Business Act). METI shall examine whether the Construction plan conforms to the technical regulations established in the Electricity Business Act, and if it finds that the Construction plan does not conform to the technical regulations, it may order the revision or discontinuation of the Construction plan within 30 days (Article 48, Paragraph 4 of the said Act; the period may be extended, Article 48, Paragraph 5).

In the past, the process took a long time due to the requirement to obtain Japan's own "Wind Farm Certification [30]" when submitting a construction plan, and the overlap between the certification process and METI's internal procedures.

In June 2022, the Electricity Business Act was amended to introduce a pre-verification system by a conformity verification body, replacing METI's examination procedures (including those by the Ministry's expert committee), which came into force on 20 March 2023. This system eliminates the need for METI to conduct a

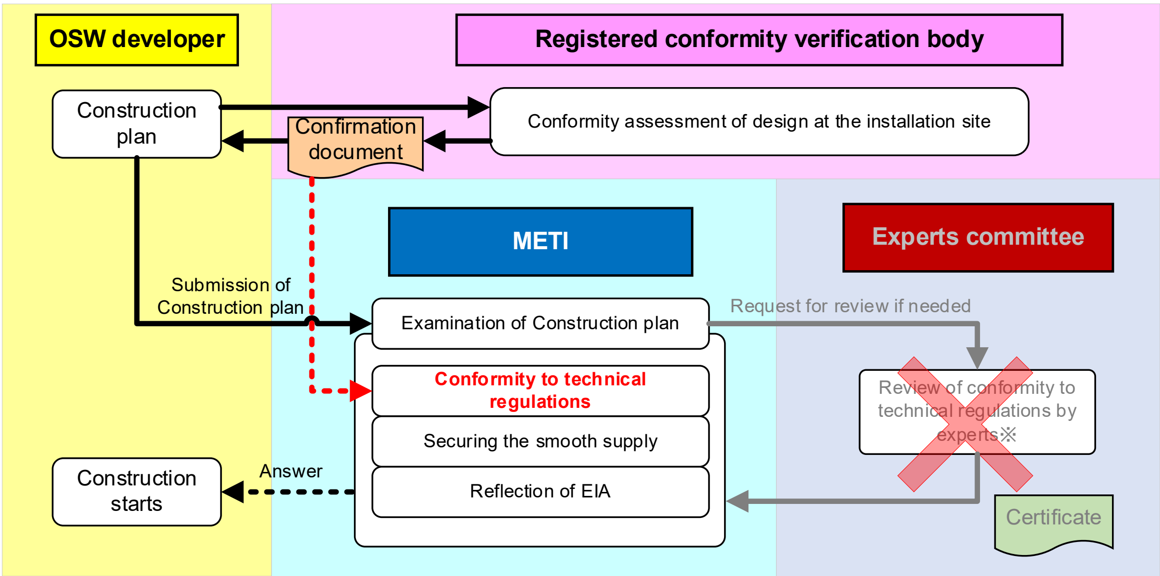
[30] According to ClassNK, one of the certification bodies in Japan, the "Wind Farm Certification" is "unique to Japan" (see below for details), which "evaluates the environmental conditions of the site where the wind farm is constructed, and confirms that the strength and safety of the wind turbines and supporting structures are guaranteed in terms of design based on those environmental conditions" and is "considered for use in the examination of construction plan notification under the Electricity Business Act". Compared to a full project certification, it is equivalent to a site suitability evaluation (project design certification in IECRE OD-502 Edition 1.0).

review when prior confirmation has been obtained from a registered conformity verification body.

At present, this system is limited to wind power generation facilities. Conformity verification bodies evaluate the conformity of wind power generation facilities (such as nacelles, supports, and foundations) with the technical standards and if the equipment meets the standards, a confirmation document is issued. METI is responsible for registering entities that meet all the registration criteria (Article 69).

There are currently two conformity verification bodies, ClassNK and Bureau Veritas. ClassNK is a conformity verification body registered under Article 48-2 of the Electricity Business Act as of 31 March 2023. Its scope of work encompasses onshore wind, bottom-fixed offshore wind and floating offshore wind power plants. Bureau Veritas is registered as of 31 March 2023 and its scope of work includes onshore and fixed-bottom offshore wind power plants.

Figure 7 New review process for conformity assessment in construction plans for OSW



Source: Created by REI, based on the material of 27th Meeting of the Industrial Structure Council, Industrial Structure Council, Industrial Safety and Consumer Product Safety Committee, Subcommittee on Electric Power Safety, Document 1

B) Pre-commercial operation phase

Before starting to use an offshore wind power generation facility, the operator shall conduct a Pre-use Safety Management Inspection (Article 51 of the Electricity Business Act). Specifically, before the start of use, the operator shall conduct a self-inspection of the relevant Electric Facilities for Business Use, record the results of the inspection, and preserve them. The self-inspection shall confirm that the construction work has been performed in accordance with the Construction plan and that the work conforms to the technical regulations[31]. Additionally, the operator shall submit the system for conducting a pre-use self-inspection to undergo examination by METI.

C) Operation and maintenance phase

The operators must maintain offshore wind power generation facilities to ensure that they comply with technical regulations (Electricity Business Act, Article 39, Paragraph 1), and offshore wind power generation facilities are subject to periodic inspections (Electricity Business Act, Article 55, Paragraph 1, Item 2; Ordinance for Enforcement of the Electricity Business Act, Article 94, Item 10). The inspection frequency is six months or one year,

[31] Interpretation of Pre-use Self-inspection and Pre-use Self-confirmation Methodshttps://www.meti.go.jp/policy/safety_security/industrial_safety/sangyo/electric/files/230310shiyoumaenaiki.pdf

depending on the part of the wind turbine[32 33 34].

Meanwhile, project certification is not widespread in Japan. The reasons for this are: the technical regulations conformity assessment based on the Electricity Business Act focuses on safety; METI, rather than a third- party certification body, has been conducting site suitability assessments for the climatic, geological, and seismic conditions of the construction site for wind turbines with type certification. Pre-use Safety Management Inspections and periodic inspections are legally required. Insurance companies and financial institutions have not made obtaining project certification a condition for contracting or financing, although marine warranty survey (MWS) is one of the conditions for contracting or financing. In addition, the cost of obtaining project certification has been pointed out as a factor.

Recently, a new inspection scheme, so-called "Advanced Safety Implementation Operator system" using smart technologies was introduced by the amendment of Electricity Business Act and was enacted in December 2023[35]. A business operator certified by METI shall conduct self-inspection using advanced technologies and will be exempted from undergoing examinations by METI. This new system will be expected to reduce administrative burdens and to facilitate for the capable business operator to undertake the O&M by using their own know-how.

3.4.2. Examination under the Port and Harbour Act

A) Planning Phase

For safety inspections based on the Port and Harbour Act, the Coastal Development Institute of Technology (CDIT)[36], a verification agency registered by MLIT, conducts the conformity verification inspections. CDIT is responsible for confirming conformity with technical regulations with respect to port facilities as below, and mooring facilities equipped with offshore wind power generation facilities are subject to the review (the Ordinance for Enactment of Port and Harbour Act, Article 28-2).

***1**

- Mooring facilities with a water depth of 7.5 m or more
- Mooring facilities for mooring vessels carrying dangerous goods, passenger ships or car carriers
- Mooring facilities with seismic resistance to level 2 earthquake motion
- Mooring facilities equipped with offshore renewable energy power generation facilities, etc.

***2**

- Only those facilities that are specified as large-scale earthquake-resistant facilities in the port plan for the port in question.

Target Facilities

- Outer facilities
- Mooring facilities *1
- Roads and bridges
- Fixed and track-type cargo handling equipment *2
- Waste landfill revetments
- Beaches
- Green space and open space *2

In order to avoid duplication of procedures, a joint assessment has been initiated by a METI-registered conformity verification body (Nippon Kaiji Kyokai, ClassNK) and a MLIT-registered verification body (CDIT). A bilateral agreement with CDIT would enable other METI-registered conformity verification bodies to apply this concept.

[32] Official Explanation of Operation and Maintenance for Offshore Wind Power Generation Facilities, p. 73. Note that Article 94-2, Paragraph 1, Item 5 of the Ordinance for Enforcement of the Electricity Business Act stipulates that the inspection frequency is within a period not exceeding three years, but the details are determined by the Interpretation of this ordinance

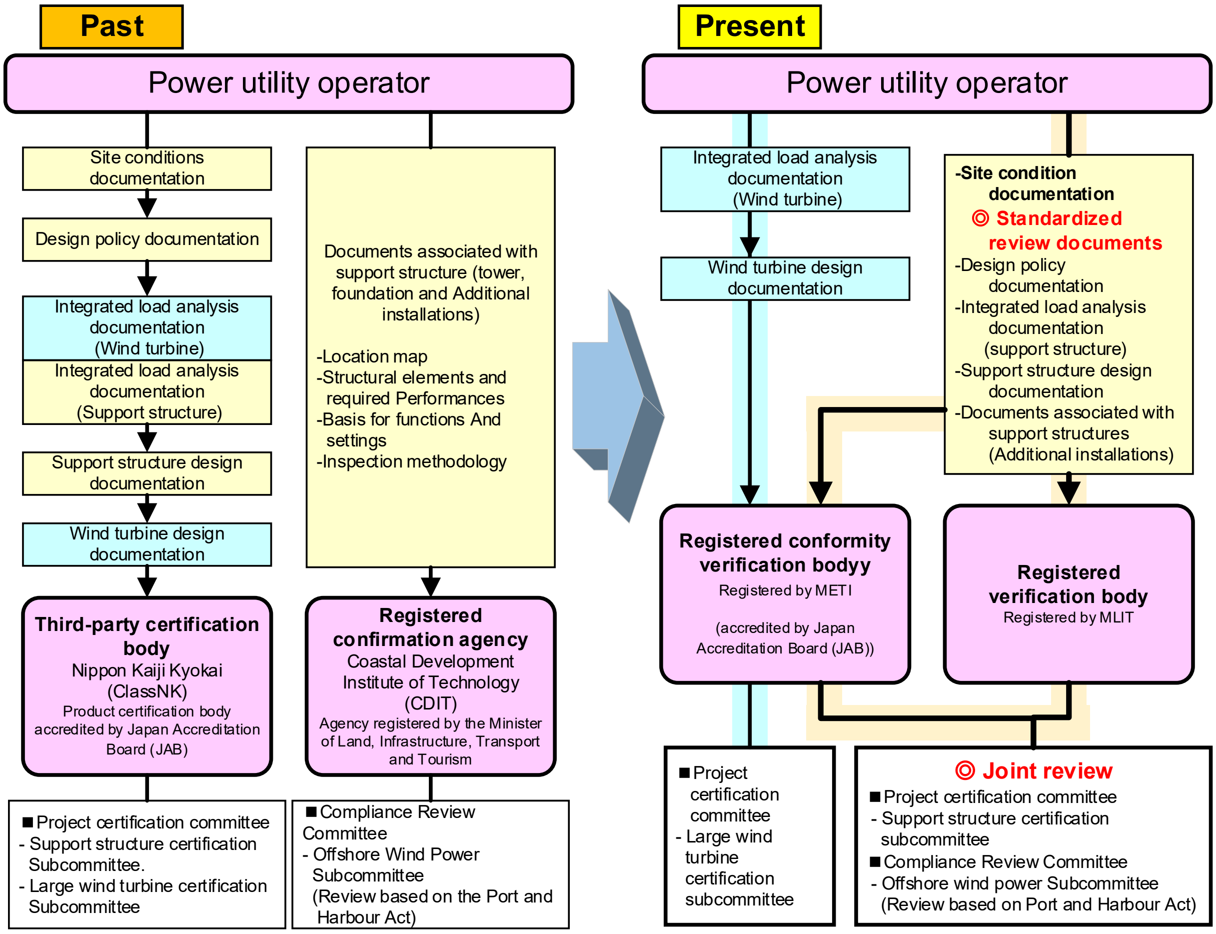
[33] There are also provisions for periodic inspections under the Renewable Energy Sea Area Utilization Act and the Port and Harbour Act.

[34] Interpretation of the periodic inspection method by the operator prescribed in Article 94-3, Paragraph 1, Items 1 and 2 of the Ordinance for Enforcement of the Electricity Business Act (p. 11) https://www.meti.go.jp/policy/safety_security/industrial_safety/law/files/20210414teiken-kaisyaku.pdf

[35] Electricity Safety Division, Industrial Safety Group, METI, " Certified Advanced Safety Implementation Operator system" (December 2023) https://www.meti.go.jp/policy/safety_security/industrial_safety/sangyo/electric/files/ninteigaiyou.pdf

[36] Coastal Development Institute of Technology https://www.cdit.or.jp/

Figure 8 Unification of the procedure of conformity verification under the Port and Harbour Act and a third-party certification for wind power generation facilities [37]



Source: Created by REI, based on ClassNK, "ClassNK Wind Turbine Certification and Related Services" (August 2021) p.29

B) Pre-commercial operation phase

The Initial inspection and diagnosis is conducted by an operator at the completion stage immediately after construction or improvement, or at the stage of formulating an operation and maintenance plan for an existing facility, in order to grasp the initial state of operation and maintenance not only for the facility as a whole, but also for each component and ancillary equipment ("Guidelines of the Inspection and Diagnosis for Port Facilities" revised March 2021, MLIT, Ports and Harbors Bureau).

The contents of the Initial inspection and diagnosis are the same as those of the Periodic inspection and diagnosis. The Initial inspection and diagnosis for new construction should preferably be conducted within two years of completion of construction, but the initial condition may be ascertained based on the results of quality and form inspections at the time of completion of construction.

C) Operation and Maintenance Phase

The operator must maintain mooring facilities to ensure that they comply with technical regulations (Article 56-2-2 of the Port and Harbour Act), and offshore wind power generation facilities are subject to periodic inspections. The Port and Harbour Act applies to underwater sections of offshore wind power facilities, and the frequency of inspection ranges from one year to ten years, depending on the section.[38]

[37] 6th Meeting of Electrical Safety System Working Group, Electricity Safety Subcommittee, Subcommittee on Safety and Consumer Product Safety, Industrial Structure Council Document 3: Review of Construction Plan Examination to Promote the Introduction of Offshore Wind Power Generation Facilities METI June 2021 https://www.meti.go.jp/shingikai/sankoshin/hoan_shohi/denryoku_anzen/hoan_seido/pdf/006_03_00.pdf
[38] Official Explanation of Operation and Maintenance for Offshore Wind Power Generation Facilities, p. 73 and following.

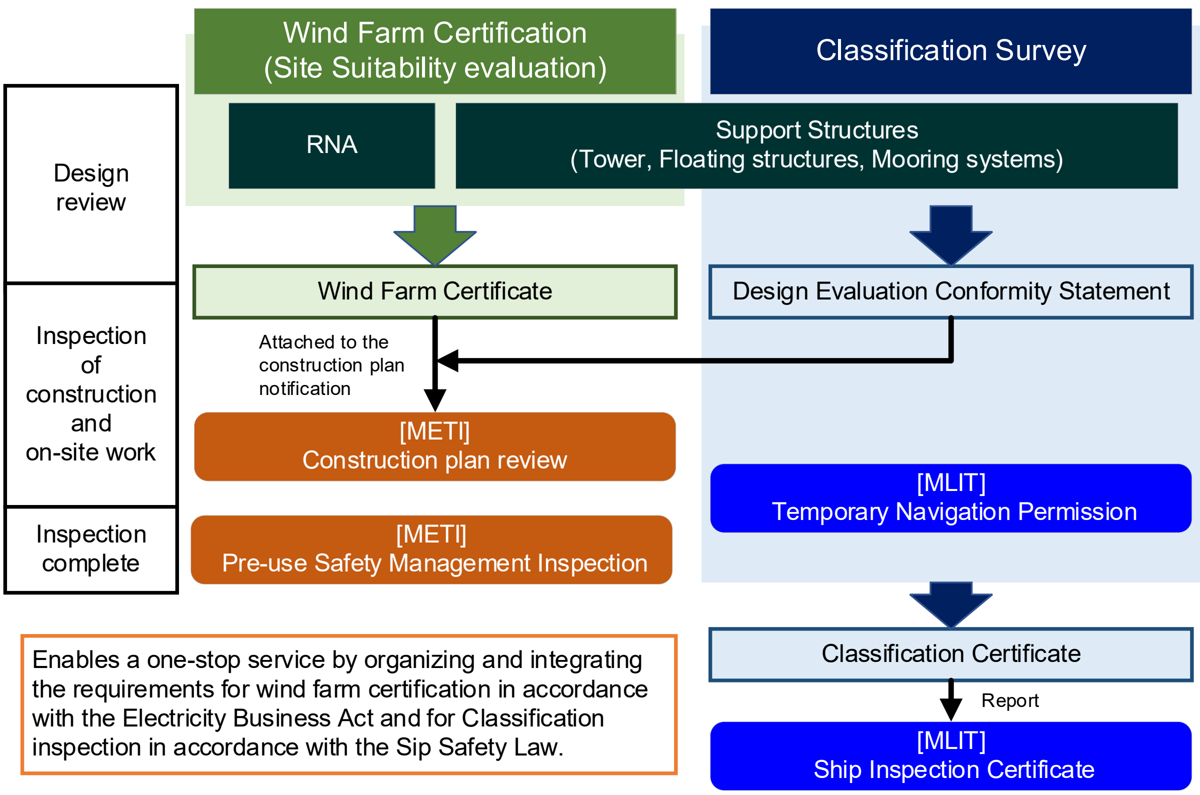
3.4.3. Examination under the Ship Safety Act and Classification survey

A) Planning Phase

Under the Ship Safety Act, floating offshore wind power generation facilities fall under the category of special vessels (Article 1, Paragraph 4 of the Ordinance for Enforcement of the Ship Safety Act, and the public notice stipulating vessels with special structures or facilities in Article 1, Paragraph 4 of the Ordinance for Enforcement of the Ship Safety Act). Survey details regarding the floating facilities and tower as support structures follow the technical regulations for floating offshore wind power generation facilities. The survey is conducted by the District Transport Bureau. However, floating offshore wind power generation facilities that have undergone a classification survey by a classification society registered by MLIT as stipulated in Article 8 of the Ship Safety Act, are deemed to have undergone and passed a survey by the District Transport Bureau[39].

ClassNK has experiences of classification survey for FOW project in Japan (in Kyushu and Fukushima) and issued the guidelines for classification survey for FOW back in 2012. Namely, ClassNK defines offshore wind power generation facilities as offshore wind power generation vessels in Part P of the Rules for the Survey and Construction of Steel Ships. The "Guidelines for Floating Offshore Wind Turbines – Classification Survey – " (December 2021) is the revised version based on the latest regulations and standards such as Technical Standards for Floating Offshore Wind Power Generation (Safety Policy Division, Maritime Bureau, MLIT, March 2020), IEC TS 61400-3-2 (2019), and other parts of the Rules for the Survey and Construction of Steel Ships.

Figure 9 Procedure of classification survey and site suitability evaluation



Source: Created by REI, based on ClassNK, "ClassNK Wind Turbine Certification and Related Services [Public website version], August 2021, p.33[40]

Inspection and Diagnostic Guidelines for Port Facilities, July 2014 (partially modified in June 2008), Ports and Harbors Bureau, MLIT.

[39] A "Classification Society" in the Act is equivalent to a Recognized Organization, acting on behalf of the flag administration for inspections and surveys.

[40] https://www.classnk.or.jp/hp/pdf/authentication/renewableenergy/en/RD2101_202108_Eng.pdf

Ship inspections based on the Ship Safety Act are shown in the figure above, while Class NK's classification inspections are divided into two main categories: registration inspections and periodic inspections.

Table 7 Ship inspections based on the Ship Safety Act

Type of inspection	Contents
Manufacturing inspection	Inspection that manufacturers undergo when manufacturing vessels 30 meters or more in length
Periodic inspection	A detailed inspection to be carried out when the ship is put into service for the first time or when the ship's inspection certificate expires.
Interim inspection	Simple inspection taken between periodic inspections. It is subdivided into three types: Type 1 Interim Inspection, Type 2 Interim Inspection, and Type 3 Interim Inspection, and the type of vessel determines which inspection the vessel is subject to.
Temporary inspection	Inspection to be performed when alterations, repairs, or new equipment are made.
Temporary navigational inspection	Inspection to be made when a vessel is temporarily put into service without a vessel inspection certificate
Preliminary inspection	Inspection of equipment, etc. listed in Paragraph 1, Article 2 of the Ship Safety Law, when the ship to be installed is not specified (If the equipment, etc. passes the inspection, the above inspection is omitted).

Source : MLIT webpage, "Proper implementation of vessel inspections (Overview) [41]

In the planning stage, the same inspections as those for ordinary vessels are conducted, including structural, hydraulic, and watertightness tests as registration inspections, and inspections are also conducted during tower fabrication and assembly.

B) Pre-commercial operation phase

After the construction of the floating structure is completed, a stability test will be conducted. Since it is difficult to conduct a stability test in the sea area where the floating structure will be installed, it is acceptable to conduct a stability test before the wind turbine is installed and add the effect of the wind turbine to the results of the test. In the installation site, a tension test of the mooring line of the floating facility, a check of the control system of the wind turbine, and a check of the operational status of the equipment are conducted. The tower will also be inspected when it is mounted on the floating facility.

C) Operation and Maintenance phase

There are three types of periodic inspections: annual inspections, interim inspections every two to three years, and periodic inspections every five years.

Annual inspections are in principle document checks. For interim and periodic inspections, an inspection plan and inspection procedures are prepared in advance, and the inspections are conducted based on the plan and procedures after obtaining approval from ClassNK. In the interim inspection, the visible area is inspected, while in the periodic inspection, the inside of the floating structure and underwater structures are also inspected.

[41] MLIT webpage, "Proper implementation of vessel inspections (inspection overview)" https://www.mlit.go.jp/maritime/maritime_fr8_000018.html

4. FOW TECHNICAL REGULATION AND STANDARDS IN THE EU

4.1. Overview of EU Technical Regulation and Standards

Floating offshore wind energy within the European Union (EU) is backed by a strong framework of standards and technical regulations. The adherence to international standards, specific EU norms, certification system and accreditation procedures are critical for the safety, reliability, and global recognition, ensuring conformity assessments and contributing to the success and sustainability of projects.

European standards can be adopted by the European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC) or the European Telecommunications Standards Institute (ETSI). They must be transposed into national standards in all EU Member States and, in case of conflict, the European Standards (EN – German name *Europaische Norm*) supersede any national standard. EN standards may be adopted by direct reference to ISO (by CEN) and IEC (by CENELEC), in which case they are prefixed with "EN ISO" or "EN IEC".

When an EN standard is adopted as national standard, the name is prefixed by the country-specific abbreviation, e.g. “DIN[42] EN ISO”. In the area of electrical and electronic standards, close to 80% of European standards are in fact IEC International Standards (IEC, 2022). International standards may also be adopted with amendments.

In addition to the international and European standardization bodies and organizations such as ISO, IEC, CEN, or CENELEC that produce codes and standards relevant for the bottom fixed and floating offshore wind industry, each EU country has its own national regulator.

National positions on ISO/IEC work are developed by the National Standardisation Bodies (NSBs) and most of them establish National mirror committees (NMCs) to mirror at national level the work of international or regional standardization organizations.

These committees allow for the participation of national experts in the development and adoption of international standards, ensuring that national interests and specificities are taken into account. Mirror committees typically review, comment on, and adopt international standards for use within their respective countries.

The mirror committees function in such a way to reflect at national level the system of committees and working groups organised at the ISO/IEC level on the one hand, and the CEN/CENELEC on the other (in Europe).

In the application of codes and standards to FOW turbines, IEC standards reference the ISO 19900 series of standards for specific aspects of design for offshore wind turbines. Satisfying the requirements of IEC standards normally require additional codes for the design of FOW turbines support structures, using ISO 19900 standards and other technical documents.

Project development and execution stages normally include design basis, concept selection, basic engineering, detailed design, manufacturing, transport, and installation, commissioning, O&M and end of life including decommissioning and recycling or disposal.

IEC 61400-3-1 and IEC 61400-3-2 are the main international standard documents for FOW turbines support structures and CIGRE TB 862 is one of the main publications that addresses submarine dynamic cables.

Globally, a FOW farm development is subject to various regulations and requirements. A typical hierarchy of requirements is provided below, and this may be adapted to the needs of a specific project:

- International, national, and local laws
- Regulatory requirements
- Standards for offshore wind turbine design including IEC 61400-3-1 and IEC 61400-3-2, considering requirements of any certification scheme such as IECRE OD-501 or IECRE OD-502
- Other industry design standards (for example, ISO 19900 to 19906)
- Project developer’s requirements
- Industry papers and guidance documents

The following is a draft list of relevant standards and guidelines of possible application to floating offshore wind turbines, including those from IEC as well as from ISO, IEC, CEN, and other from certification and classification societies as DNV, API, CIGRE and ABS

[42] DIN: refers to the German Institute of Standardisation (Deutsches Institut fur Normung)

Table 8 Relevant standards and guidelines of possible application to floating offshore wind turbines

Relevant standards and guidelines of possible application to floating offshore wind turbines 43		
Design and general requirements[44]	- ISO 19901-2: Seismic Design Procedures and Criteria - ISO 19901-7: Stationkeeping Systems for Floating Offshore Structures and Mobile Offshore Units - ISO 19904-1: Floating offshore structures; Ship-shaped, semi-submersible, spar and shallow-draught cylindrical structures - IEC 61400-1: Wind turbines design requirements - IEC 61400-2: Small wind turbines - IEC 61400-3-1: Design requirements for offshore wind turbines - IEC 61400-3-2: Design requirements for FOWT - IEC 61400-5 Wind Turbine Rotor Blades - IEC 61400-11, Acoustic noise measurement techniques - IEC 61400-12-1 Power performance measurements - IEC 61400-13 Measurement of mechanical loads - IEC 61400-14 Declaration of sound power level and tonality - IEC 61400-21 Measurement of power quality characteristics - IEC 61400-22 Conformity Testing and Certification of WT (Withdrawn 2018/08/31) - IEC 61400-23 Full scale structural blade testing - IEC 61400-24 Lightning protection	- IEC 61400-25-(1-6) Communication - IEC 61400-26-1 Availability for wind energy generation systems - IEC 61400-27-(1-2) Electrical simulation models - IEC 61400-50: Wind measurements - IEC 61400-50-1: Wind measurements application of meteorological mast, nacelle and spinner mounted instruments - IEC 61400-50-2: Wind Measurement - Application of Ground Mounted Remote Sensing Technology - IEC 61400-50-4: Use of floating lidars for wind measurements (in progress) - CEN/TS 17083: Design, construction, and installation of FOWT - DNVGL-ST-0119: for design, certification, and assessment of FOWT - DNVGL-RU-OU-0512: for installation of FOWT installations - DNVGL-RU-OU-0571: for floating infrastructure installations - IECRE OD-501: Type and Component Certification Scheme - IECRE OD-502: Project Certification Scheme - IECRE OD-502-1: Conformity assessment and certification of Site Assessment by RECB - API RP 2F and API RP 2SK: Planning, designing and construction of FO systems - API RP 2RD: Recommendations for design of floating production systems - CIGRE TB 490 and CIGRE TB 863: for testing of submarine cables - ABS Guide for Building and Classing Floating Offshore Wind Turbines (January 2024)
Concrete Structures	- EN 1992: Concrete structure requirements - EN 1992-1: Design of concrete structures	
Steel Structures	- EN 10025: Hot rolled products of structural steel - EN 1993-1 Design of steel structures - EN 1993-1-10: Design of steel structures. Material toughness and through-thickness properties. - EN 13173: Cathodic protection for steel offshore floating structures	
Mooring and foundations[45]	- DNVGL-ST-0054: Transportation and installation of offshore wind turbines - DNVGL-ST-0126: Support structures for wind turbines - DNVGL-ST-0437: Load and site conditions for wind turbines - API RP 2T: Recommended Practice for Planning, Designing, and Construction Tension Legs Platform	

[43] This list of relevant standards is indicative, not exhaustive
[44] DNVGL to be renamed by DNV
[45] DNVGL to be renamed by DNV

The list of standards and technical codes applicable can be much longer when considering all regulations and technical documentation applicable to wind turbine types, components, and projects. There are many standards, codes, and technical recommendations of possible implementation in floating offshore wind turbines to assess general aspects of installations or specific components.

The following sections describe the certification processes, key technical assessments and the implementation of specific standards which together with the above and other relevant documents and recommendations, are compiled in Annex I.

4.2. Adoption and implementation of standards

4.2.1. Adoption of standards

The International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) have established a comprehensive process for the development and adoption of international standards. This process is designed to ensure that all standards are universally relevant and applicable, benefiting from the input of experts from various countries. It follows a six phases process in the development of standards:

1. **Proposal Phase**: The process begins with a new work item proposal (NWIP) by a body member. The proposing member must justify the need for a new or revised standard. The proposal is then submitted for voting by the relevant committee or subcommittee. If approved, the project is added to the work program.
2. **Preparatory Phase**: A working group or expert group is established to draft the standard. This group compiles the initial draft based on contributions from various stakeholders. The draft undergoes several rounds of revision based on feedback from working group members until a working draft (WD) or committee draft (CD) is stabilized.
3. **Committee Phase**: The committee draft is shared with all committee members for comment and voting. This stage aims to reach consensus on the technical content. Based on feedback, the draft is revised. Multiple committee drafts may be circulated until consensus is achieved.
4. **Enquiry Stage**: The CD, once approved, becomes a draft international standard (DIS) and is circulated to all ISO or IEC body members for voting and comment. Comments received during the voting are taken into account, and the draft may be modified accordingly.
5. **Approval Stage**: The revised draft is circulated as a Final Draft International Standard (FDIS). All body members vote on the FDIS. If approved, the document proceeds to publication. If not, it goes back for further work.
6. **Publication**: Once approved, the standard is published and made available to the public as an International Standard. Standards are periodically reviewed and may be revised or withdrawn.

The ISO/IEC Directives allow for parallel voting, which means that the draft international standard (DIS) and FDIS stages are voted on simultaneously by both ISO and IEC members if the project is under the jurisdiction of a Joint Technical Committee (JTC).

Voting rules state that only participating members of the relevant committee are obliged to vote, while observer members can choose to vote. Abstentions do not count towards the total votes but are recorded. Members may abstain if they believe the standard is not relevant to their country or if they do not have sufficient expertise to cast an informed vote.

This structured process ensures that ISO/IEC standards are developed reflecting the needs and concerns of all stakeholders involved.

4.2.2. Implementation of standards

While the ISO/IEC system provides a framework for the development and adoption of standards, the actual implementation into a member country's context can vary significantly based on local laws, industry practices, and economic considerations. However, there are common principles and phases in the implementation process.

First, once a standard is adopted, the national standards body (NSB) or equivalent authority notifies relevant stakeholders, including industry associations, regulatory agencies, and the public, about the new standard and its implications. Information about the standard, including its content, benefits, and implementation guidelines, is widely disseminated through various channels such as workshops, seminars, publications, and online platforms.

Then organizations assess their current operations against the requirements of the new standard to identify gaps that need to be addressed. Based on the gap analysis, a detailed plan is developed, outlining the steps needed to comply with the standard, including timelines, responsibilities, and resources required.

All changes to processes, systems, and procedures are documented according to the requirements of the standard. This documentation is critical for audits and certification. Organizations conduct internal audits to assess compliance with the standard and to identify areas for improvement. The results of internal audits and compliance assessments are reviewed by management to ensure ongoing alignment with the standard and to address any issues.

Many organizations choose to seek certification from an accredited body to demonstrate compliance with the standard. Continuous monitoring of compliance with the standard is essential to maintain its benefits. As standards are periodically reviewed and updated, organizations must also update their practices to remain in compliance with the latest version.

While some standards become mandatory through regulation, the principle of voluntary adoption is central to the ISO/IEC system. Effective implementation requires the involvement of all relevant stakeholders to ensure that the standard is applied in a manner that meets the needs of the industry and society.

A summary of main FOW Technical Regulation and Standards in EU relevant countries is included in the following Table 9. It summarises in a first comparative approach at EU level and among the four member countries analysed, the main parameters defined by the regulatory bodies and the most relevant standards adopted and applied in the evaluation and certification process.

In addition to the main legislative, authorisation, licensing and standardisation bodies, the table shows that the most relevant applicable standards (ISO, EN and IEC) coincide in the four countries, as these are European-wide regulations.

Member Countries participate in ISO/IEC work via national standardization bodies (NSBs). National positions on ISO/IEC work are developed by the NSBs on an ongoing basis and most NSBs establish the National mirror committees (NMCs) bodies to reflect the work of international standardization organizations.

Site investigation standards involve comprehensive assessments of seabed conditions, water depth, and meteorological conditions. EN ISO 19901-4 provides guidance on geotechnical and metocean site assessments.

Table 9 - Summary of main FOW turbine Technical Regulations and Standards in EU relevant countries

	EU	GERMANY	FRANCE	SPAIN	ITALY
Legislation Authorization and Licensing	-RED-EU Maritime Spatial Planning	-Renew Energy Act Federal Maritime -Spatial Planning Act -Federal Maritime and Hydrographic Agency (BSH)	-Energy Transition Green Growth Act -Maritime Planning Law -French Agency for Biodiversity (AFB) -DAM Directorate of Maritime Affairs	-Law on Climate Change and Energy Transition -Maritime Terrestrial Public Domain Law	-National Energy Strategy -Environmental Impact Assessment legislation
Standardization Bodies	IEC, CEN	IEC, CEN, DIN	CEN, CENELEC AFNOR IEC	CEN, CENELEC; ETSI UNE	IEC ENEA
Adoption of international Standards	IEC 61400 series ISO/IEC 17025 EN 1090-2	IEC 61400 series ISO/IEC 17025 EN 1090-2	IEC 61400 series ISO/IEC 17025	IEC 61400 series ISO/IEC 17025	IEC 61400 series ISO/IEC 17025
Specific Standards	EN 61400-3 IEC 61400-3-2 EN 1992-1 EN 1993-1	EN 61400-3 IEC 61400-3-2 EN 1993-1	EN 61400-3 IEC 61400-3-2 EN 1992-1 EN 1993-1	EN 61400-3 IEC 61400-3-2 EN 1992-1 EN 1993-1	EN 61400-3 IEC 61400-3-2 EN 1992-1 EN 1993-1
Site investigation	EN ISO 19901-4	EN ISO 19901-4	EN ISO 19901-4 As required by French regulations for offshore struct.	EN ISO 19901-4 As required by Spanish regulations for offshore struct.	EN ISO 19901-4 Committee for Safety of Offshore Operations
Assessment of loads	ISO 2394 EN 61400-3-2 DNV; BV; …	ISO 2394 EN 61400-3-2	ISO 2394 EN 61400-3-2	ISO 2394 EN 61400-3-2	ISO 2394 EN 61400-3-2
Steel Standards	EN 10025 series	DIN EN 10025 series	EN 10025 series	EN 10025 series	EN 10025 series
Concrete Standards	EN 1992-1 ISO 19904-1	EN 1992-1 ISO 19904-1	EN 1992-1 ISO 19904-1	EN 1992-1 ISO 19904-1	EN 1992-1 ISO 19904-1

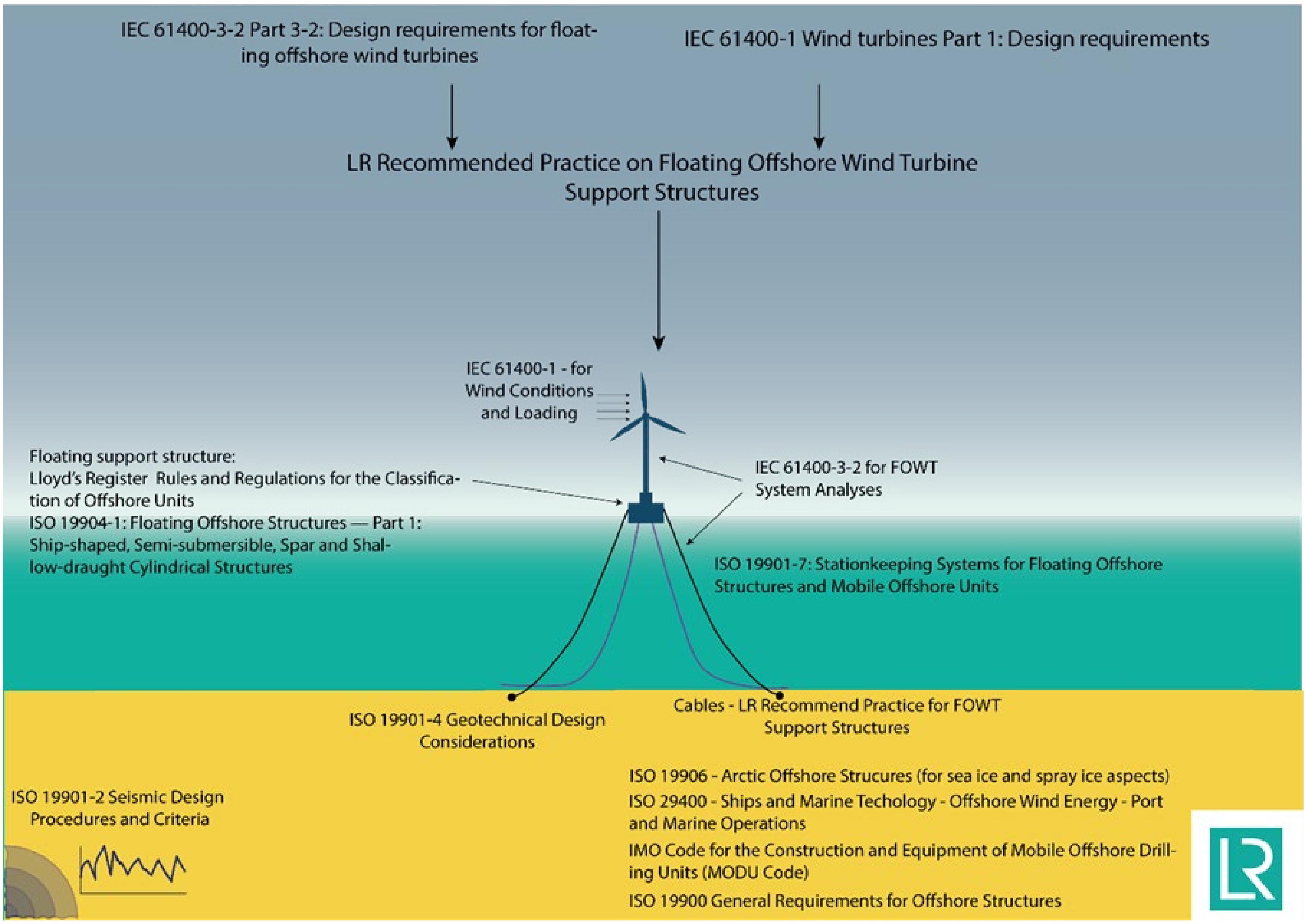
Load assessments consider specific site conditions. EN 61400-3-2 provides guidelines for assessing loads on floating offshore wind turbines, considering factors like wind, waves, and currents.

Steel standards, such as EN 10025 series, ensure the quality and durability of steel components used in floating offshore wind structures and concrete standards, and the main references for concrete structures correspond to the ISO 19904-1 and EN 1992-1 standards.

For the implementation of standards, IEC standards reference the ISO 19900 series of standards for specific aspects of design for offshore wind turbines. To further approach FOW structures, ISO 19900 standards, as well as DNV, LR, CIGRE and other similar relevant documents and guides can be used, as showed throughout the study.

The following figure—shows as an example the interface of IEC/IECRE standards and ISO 19900 standards recommended by Lloyds Register for FOW turbine structures.

Figure 10 Overview of IEC standards and ISO standards applied to FOW turbine support structure design



Source: Recommended Practice for Floating Offshore Wind Turbine Support Structures (LR-RP-003)

4.3. Certification process and requirements

The certification process can start with classification. Classification may be a requirement of project stakeholders such as the developer, regulators, financiers, or insurers. The wind turbine, Rotor-Nacelle Assembly (RNA), tower and dynamic cable would be covered under certification and not via classification. Where appropriate, the influence of the wind turbine, dynamic cable and tower on the floating substructure and mooring would be considered for classification.

Classification results in issuing a **classification certificate** attesting the level of compliance of the Floating Offshore Wind Turbine with the classification rules of the Society [46]. The units complying with the requirements of the Class Notation [47] are eligible for the assignment of the Service Notation [48] FOW turbine as defined in Offshore Rules.

The **certification** results in issuing **certificates attesting the compliance** of FOW turbine and/or its components **with rules or standards**. The certification process of a FOWT consists of review of plans and calculations, surveys, checks, and tests intended to demonstrate that standards/national regulations are met.[49]

Concerning certification of FOW turbine in compliance with specific national regulations, it can be delivered by the Society only when it is authorized to do so by the competent national authority.

FOW turbine operating in national waters are to comply with the administration rules in addition to the Society rules. In case of disagreement between rules, the administration rules will prevail on the Society rules, except when the latter provide a higher safety level. In this case, decision will be taken in agreement between the Society and the owner of the FOW turbine, on a case-by-case basis. In case of application of statutory requirements, attention is drawn upon the necessary agreement of the flag and/or coastal authorities.

The certification process of a FOW turbine is usually based on a goal-based approach, which integrates three closely related elements to set the objectives to be achieved and how they should be achieved:

- **Objectives:** Provide a floating wind structure that ensures production throughout its life cycle, safety of personnel and safety of the surrounding environment.
- **Criteria:** Satisfy the requirements of IEC 61400-3, IEC 61400-3-1 e IEC TS 61400-3-2 and other IEC standards, to protect against damage from all hazards during the planned lifetime. A key output from the design process, and any project certification, should be an accurate understanding of what may lead to property damage or business interruption and what possibilities are available to mitigate potential losses, in terms of repair or maintenance.
- **Methodology:** Design methodology is usually provided by IEC standards together with other recognised standards as ISO 19900 to 19906 for offshore structures. Where necessary, standards and codes may also be supplemented by other industry practice and technology qualification.

The assets covered include the integrated floating wind turbines (floating substructure, tower with associated Rotor-Nacelle Assembly (RNA), loads and station-keeping systems (including mooring lines and anchors)). The dynamic portion of cables is also considered, given the relationship with floating turbine motions.

All project stages are normally considered, including site condition assessment, design basis, concept selection and concept design, FEED [50], detailed design, and subsequent stages including manufacturing, transport and installation, commissioning, and in-service management.

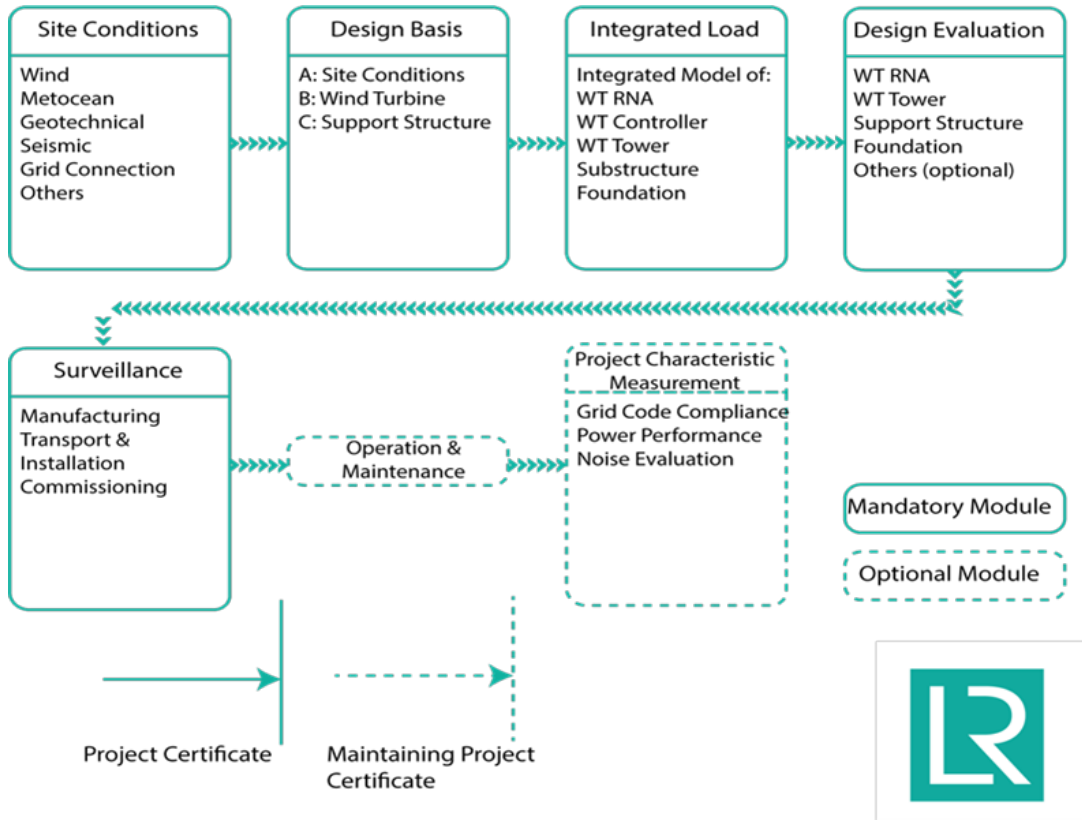
Project certification according to IEC 61400-22 (withdrawn but still referenced) and IECRE-OD-502 consists of completing a series of modules.

Within the project certification framework there are mandatory modules and optional modules, with the outline of the modules shown in figure *"Wind Certification Modules according to IEC* 61400-22 and IECRE-OD-502" recommended by Lloyds Register.

The investigations of the site conditions for the installation of floating offshore wind turbines involve comprehensive assessments of various factors including wind conditions, seabed conditions, metocean and geotechnical characteristics, environmental impacts, grid connection and infrastructure requirements.

[46] Society: The independent certification (or classification) body, the third-party certification society
[47] Class Notation indicates the compliance of the FOW turbine with the specific rule requirements of the society
[48] The Service Notation is a formal recognition or label indicating that FOW turbine has met the rules set forth by the classification society
[49] Some differences between classification and certification are described, for example, in Section 5.1 of PN000405-RPT-002-D1-FOW-Standards-Certification-and-Classification-Mapping-Report_Formatted.pdf (catapult.org.uk).
[50] FEED: Front-End Engineering Design

Figure 11 Wind Certification Modules according to IEC 61400-22 and IECRE-OD-502



Source: Recommended Practice for Floating Offshore Wind Turbine Support Structures (LR-RP-003)

The basic design should cover the generic design documentation for the subsequent detailed design, which includes the site-specific design approval of the integrated structural system and the verification of load calculations.

For the load analysis, an integrated model including wind turbine RNA, controller, tower, substructure, and foundation, is recommended.

The final module includes the necessary monitoring and surveillance task during manufacturing, transport, and installation prior to commissioning of the wind turbine.

Certification requirements for floating offshore wind projects in EU member states are regulated, primarily by the national authorities. Three main certification areas for floating offshore wind are to be considered, including references to specific standards for floating offshore wind turbines.

The certification process encompasses type, component, and project certification, each adhering to specific standards set by various organizations. The standards ensure the safety, reliability, and environmental sustainability of offshore wind installations:

- **Type Certification**: aimed at design bases evaluation, design evaluation, type testing, manufacturing evaluation, and final evaluation of a wind turbine according to specific standards and technical requirements relating to safety, reliability, performance, testing, and interaction with electrical power networks. Some optional phases such as foundation design and manufacturing evaluation may apply. Some examples of type certification compliance with international standards are:
  - IEC 61400 series: includes IEC 61400-3-1, IEC 61400 3-2 for design requirements
  - DIN EN: relevant standards include DIN EN 61400-1 for general design requirement.
  - DNV(GL)-ST-0126: DNV standard for certification of wind turbines, addressing design verification, type testing, and documentation requirements.
  - IECRE standards: International Electrotechnical Commission for Renewable Energy standards for project certification.
  - IECRE OD-501: this certification scheme covers the wind turbine type generator systems, including floating offshore wind turbines.

- **Component Certification**: similar to type certifications applied to major components (blades, gearbox) according to the same specific standards and technical requirements as type certification. Compliance with relevant international standards and industry-specific standards for component certification may include:

- IEC 61400 series: Includes IEC 61400-1 for design requirements.
- DIN EN standards: relevant standards include DIN EN 61400-1 for general design requirement.
- DNV(GL)-ST-0376: DNV standard for certification of floating wind turbines, addressing design requirements and testing procedures for components. Some optional phases such as foundation design and manufacturing evaluation may apply.
- IECRE OD-501 also covers wind turbine components certification.

- **Project Certification**: consists in the verification of wind farm design and whether it meets site-specific conditions. It includes a soil investigation, a review of measuring campaigns [51], an evaluation of energy yield reports, an assessment of marine conditions, a verification of load-case definitions. Compliance with international standards such as:

- ISO 9001: ensures adherence to quality management systems throughout the project lifecycle.
- DNV(GL)-ST-0378: DNV standard for certification of offshore wind farms, covering design verification, construction supervision, and documentation requirements.
- IECRE OD-502: covers the certification of offshore wind farms, including floating offshore wind projects.

A full project certification is formally not required in every EU offshore wind market. Wherever it is required, it usually refers to national rules and may only be an indirect requirement to fulfil finance, insurance or developer requirements[52]. Component certification is expected to facilitate the integration into type and project certification.

Certification requirements for floating offshore wind projects in the EU are regulated and primarily overseen by the national authorities. For example, in Germany, by the Federal Maritime and Hydrographic Agency (BSH).

4.4. Site investigations

Site investigations for the installation of floating offshore wind turbines in the EU involve comprehensive assessments of various factors including seabed conditions, metocean characteristics, environmental impacts, and infrastructure requirements. These investigations are crucial for determining the feasibility and optimal design of offshore wind projects.

The external site conditions shall be assessed according to IEC 61400-1, IEC 61400-3-1 and additional requirements given in 61400-3-2. A site conditions report shall be developed to document the detailed methodology used to determine long-term wind and oceanographic conditions.

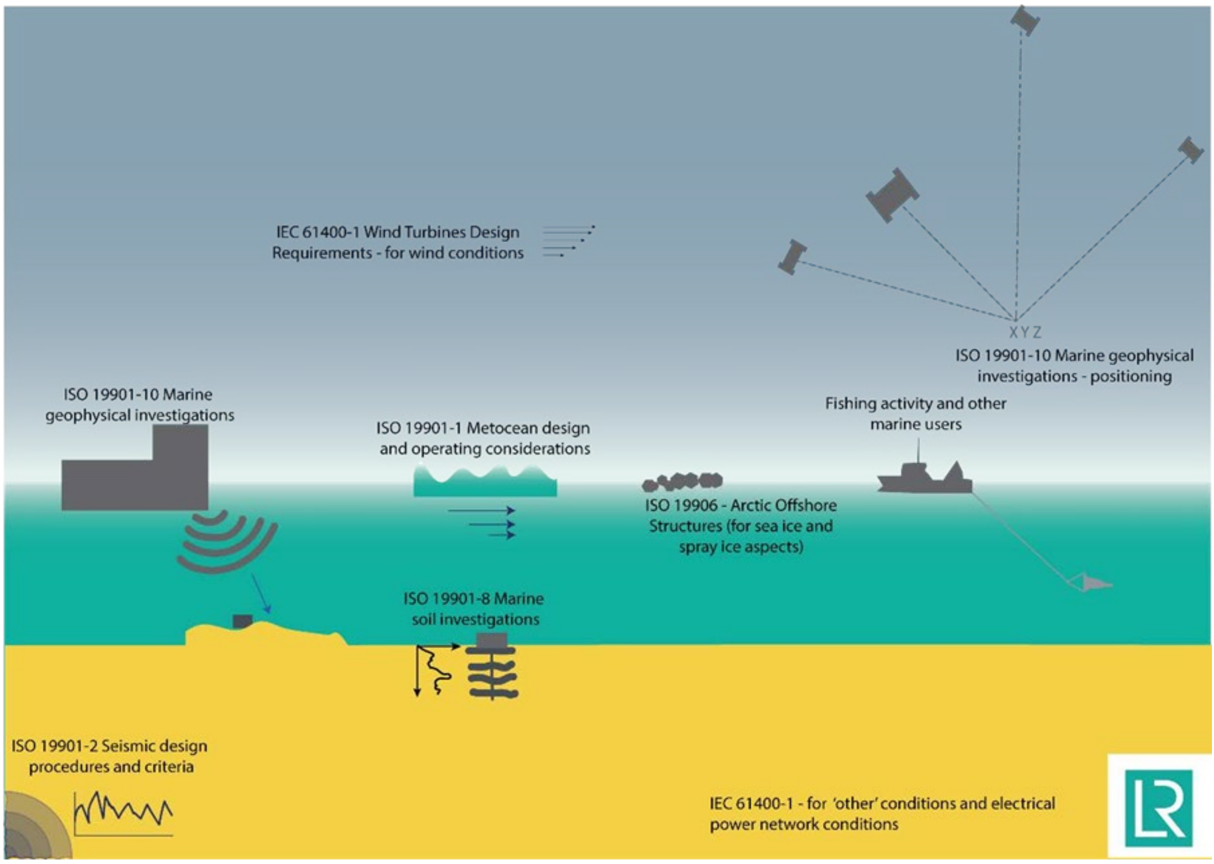
An example of external site conditions requiring assessment is included in the following Figure, showing site conditions and associated codes and standards recommended by Lloyd´s Register. The aim is to ensure that sufficient information is available for design and construction of the assets and to meet other requirements for all stages within the development life.

In a seismically active area, the effect of seismic conditions on FOWT support structure design shall also be considered on a project-specific basis. Where seismic hazard is confirmed to be low, as defined by an assessment such as that defined in ISO 19901-2, it may be acceptable to ignore seismic aspects within the design.

[51] All measuring and testing procedures related to the structural, production and safety evaluation included in the project certification

[52] Reference taken from “Risk Management from Prototypes to commercial projects”; 3rd Annual Floating Wind Europe Conference; Kimon Argyriadis, DNV.

Figure 12 Overview of site conditions and associated codes and standards



Source: Recommended Practice for Floating Offshore Wind Turbine Support Structures (LR-RP-003)

The impact may be a function of ground motions on the anchors or by associated sudden wave loading (Tsunamis). For tension moorings, taut moorings or compliant towers, seismic conditions may lead to loading being transmitted through the station-keeping system or dynamic cable into the floating substructure and subsequently to the tower and wind turbine RNA. A seismic event may also lead to liquefaction of the seabed, which can cause loss of support or geotechnical capacity of dynamic cables, mooring lines and anchors.

Ice loading can be a relevant load case depending on the icing climate of the location. It shall be determined whether icing of the turbine may be significant and therefore require further consideration through the design and operation of FOWTs. Where ice loading may be significant, turbine performance shall be evaluated due to mass imbalance caused by ice accretion on the blades and the change in aerodynamic performance of the blades. Ice fall and ice throw from the wind turbine may also pose a hazard to the FOWT itself, to the surroundings of a FOWT or to any equipment or personnel on board or near the turbine. Ice throw and ice fall shall be considered where necessary.

For the electrical power network conditions, several grid requirements should be included as part of the site condition report as required by IEC 61400-3-1, including the grid's normal connection point voltage range, the transitory effects of any transformer auto-tap changing equipment, the normal frequency range and rate of change and the estimated spare-rated capacity in kVA at maximum and minimum power factors.

Relevant guidelines and standards for site investigations in the EU vary depending on the country and may include the following:

- **Seabed and Geotechnical Surveys:** Assessing the seabed conditions is crucial to determine the feasibility of installing floating wind turbines. The surveys assess the seabed conditions to ensure the stability and suitability for anchoring floating wind turbines. Standards such as ISO 19901-8 provide guidelines for geotechnical investigations for offshore structures.
- **Metocean Studies:** Understanding metocean conditions, including wind speeds, wave heights, currents, and water depths, is essential for designing and operating floating wind turbines. Metocean studies analyse meteorological and oceanographic conditions at the project site, wave heights, currents, scour and water depths. Relevant standards include ISO 19901-1 for

environmental conditions and ISO 19901-3 for metocean criteria.

- **Navigation and Safety Assessments:** Ensuring the safety of maritime navigation and minimizing risks to other marine users, such as shipping and fishing activities, is also essential. Site investigations should include assessments of navigational hazards, vessel traffic patterns, collision risks, seismic conditions, and safety buffer zones around wind turbine installations.

Advanced numerical modelling tools and implementing long-term monitoring programs are also relevant practices to assess the dynamic behaviour of FOW turbines under various metocean conditions.

Floating offshore wind turbines can cause significant radar interference, which presents challenges for radar systems essential for navigation, weather forecasting, and national defense. This interference primarily arises from the large physical structure of the turbines and their spinning blades, which produce radar clutter and Doppler-shifted returns that can mimic or obscure other objects. The rotating blades particularly affect the radar's ability to distinguish between different moving targets due to their size and movement, which introduces ambiguous returns on radar screens.

In response to these interferences, EU member states have implemented mitigation strategies to ensure that radar systems can continue to operate effectively near wind farm sites. Various measures have been considered, including the use of radar-absorbing materials on turbines, improvements in radar technology, and specialized radar systems that can better discriminate between wind turbines and other objects.

4.5. Assessment of loads

The purpose of an integrated load analysis of a floating offshore wind turbine is to confirm that the site-specific loads on the integrated WT structure, including the RNA, the floating substructure and supporting soils (where applicable), have been derived in conformity with the design basis. The requirement shall ensure that the calculated loads are within those assumed for the WT type certificate and for the floater designed according to a wind turbine class (IEC 61400-1).

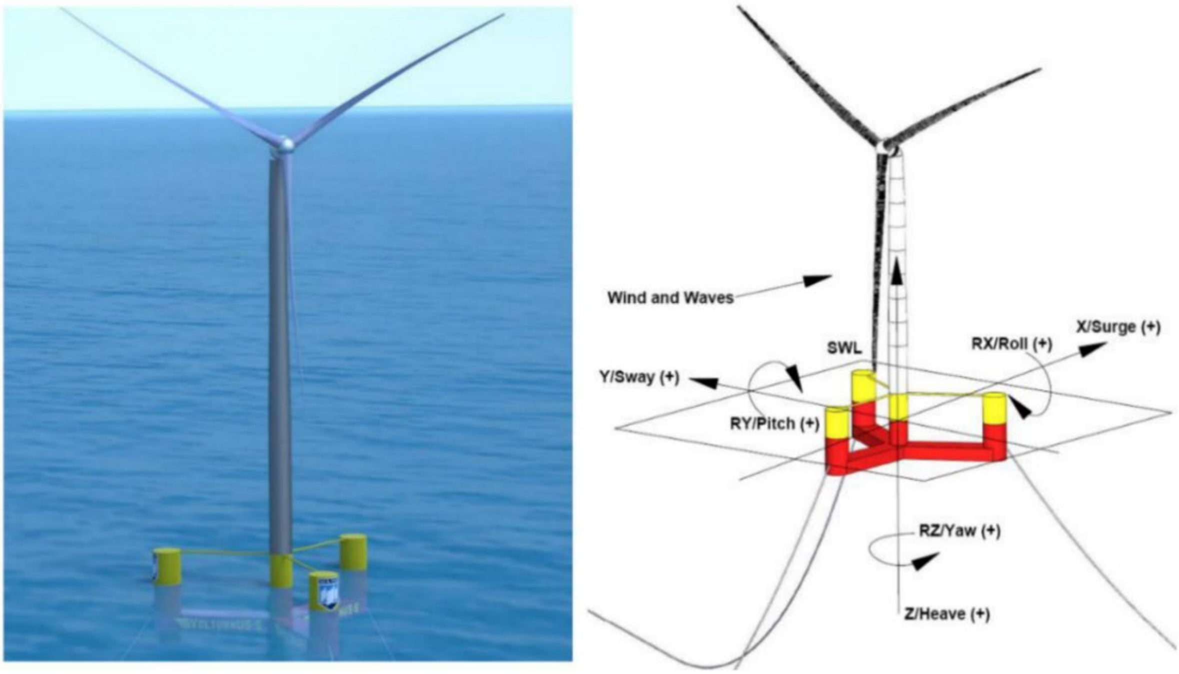
In the load response characteristics of floating wind turbine [53], the wind force on floating structures presents a greater challenge than that on bottom-fixed structures, because the wind will impose global motions which in turn will contribute significantly to the stresses in various structural members.

Determination of floater motions is vital for design because the floating structure will be subject to significant dynamic responses from aerodynamic and hydrodynamic loading, including wind excitation, wave excitation, added mass, aerodynamic damping, wave damping, structural damping, mooring tensions, and the hydrostatic stiffness and the geometry of the floater, as well as the control strategy of the WT.

Concerning motion responses and their natural periods, the compliant six degrees of freedom or modes of motion (i.e. surge, sway, heave, roll, pitch, and yaw) of the floating unit shall require a more thorough assessment of load responses due to wind and wave/current misalignment than is typically required for bottom-fixed turbine structures. Particularly the misalignment of mean wind direction with the direction of swells. In this regard, floating substructure design symmetry and mooring system symmetry could help to reduce the relevant misalignment cases.

[53] Load response characteristics of floating substructures: Recommended Practice for Floating Offshore Wind Turbine Support Structures (LR-RP-003), January 2024

Figure 13 15 MW floating offshore wind turbine system and reference coordinate system.



Source: Load Evaluation for Tower Design of Large Floating Offshore Wind Turbine System According to Wave Conditions; Energies 2023, 16(4), 1862; https://doi.org/10.3390/en16041862

For the RNA, loads resulting from floater motions (e.g. yaw loads resulting from a tilted rotor during pitch motions of the floater) shall be assessed. These loads are not typically covered by the WT type certificate. Therefore, the aero-hydro-servo-elastic software to be used in the design shall be validated with scaled model tank testing, other numeric software and/or available measurements of FOWT with similar characteristics.[54]

The design shall in general avoid coupled vibration forms when heave periods are too close to roll and pitch periods. The coupling effects between all six degrees of freedom motions may be important, because of the combined effect of rotor loads and the control algorithms.

Environmental loads include all loads caused by external site conditions, which may vary with time in terms of magnitude and direction, including aerodynamic loads due to wind action, hydrodynamic loads due to wave and current, and loads due to change of water levels, marine growth, snow and ice, and earthquake.

Metocean return periods of interest will be identified using the IEC-61400-3-2 floating offshore wind turbine standard, which includes the applicable Design Load Cases (DLCs) indicated for each design situation by their associated metocean conditions and operational behavior.

The evaluation of environmental loads shall also consider the natural periods of the floater motions in order to adequately capture the non-linearities, second order effects (e.g. slow drift hydrodynamic effects) and slowly varying responses of the loads. Depending on the load case in question, the simulation period may need to be increased from the typical duration of 10 minutes to three hours as a minimum, and up to six hours in some cases.

In order to assess the effect of low and high frequency excitations on the FOWT motion and load response, a coupled analysis of the floater and turbine in time domain in operational phases of the turbine shall be carried out.

Frequency domain methods can be applied for the early stages of concept engineering or design. Time domain analysis is typically required for floating offshore wind turbines on the basis that it better captures non-linearities in the aerodynamics, structural dynamics and control system.

For fatigue load analysis, stress ranges caused by wind and wave loading during fault conditions shall be established by time domain analysis under due consideration of the motion characteristics of the floater and its interaction with the control system.

[54] More information on model testing in Annex k of IEC 61400-3-2

Accidental (or abnormal) loads are foreseen to be loads related to accidental events, abnormal operations or technical failures.

The guidance on load analysis requirement of a wind farm starts with the effect of upstream wake conditions, which should be considered when they can be reasonably foreseen. Examples of when upstream wake conditions could influence a wind farm include:

- Wind farms which are being developed as a series of zones, and
- Wind farms which may be influenced by other upwind wind farms

Assessment of wake conditions within the wind farm should be made, and consideration as to how the primary conditions of wind speed and turbulence intensity vary within the wind farm array should be provided at a selection of WT locations for load analysis. The impact of potential movement of the floater units should be included in the assessment.

Existing EU-based standards may not adequately address the long-term performance of floating wind turbines under extreme environmental loads like typhoons, earthquake and lightning strikes. More data and experience are needed to inform standards that ensure these structures can withstand these events over their operational lifetime.

4.6. Relevant materials

The most common structural materials used in the manufacture of floating offshore wind turbines include steel, concrete, composites, polymers and aluminium.

Steel is predominantly used in the construction of turbine towers, floating platforms, and substructures due to its strength, durability, and resistance to harsh marine environments. Steel is often used in different forms, including carbon steel for structural components and stainless steel for corrosion-resistant parts.

Concrete is utilized in floating platforms for its buoyancy, durability, and low maintenance requirements. Concrete platforms can be more cost-effective for certain designs and environments, offering stability and weight that can be advantageous for floating structures.

Composites, mainly in the form of fiberglass and carbon fiber, are used in the blades and nacelles of wind turbines. These materials are chosen for their high strength-to-weight ratios, corrosion resistance, and ability to be moulded into aerodynamic shapes that optimize efficiency.

Synthetic fiber ropes, such as those made from polyester, nylon, or HMPE, are increasingly used due to their lightweight and high strength, especially suitable for deep water applications where traditional chain moorings become impractical. Plastics and polymers are used in various non-structural components and insulation within the turbine itself. These materials can offer durability, resistance to weathering, and flexibility in application.

Sometimes aluminium is used in secondary structures and components of the turbine and platform due to its light weight and resistance to corrosion. It is less commonly used for primary structural elements due to its cost and lower strength compared to steel.

The selection of materials for any part of the floating offshore wind turbine system depends on a variety of factors, including cost, environmental conditions, design requirements, and specific performance characteristics needed for the application. The following is a more detailed overview of steel and concrete as the most relevant materials.

4.6.1. Steel and concrete

Steel and concrete are both renowned for their strength and durability, making them ideal materials for constructing floating platforms capable of withstanding harsh offshore conditions. Concrete provides excellent buoyancy, helping the platform stay afloat, while steel structures can be designed to provide stability against waves and wind loads.

Steel and concrete offer adaptability and can be shaped and designed to fit various designs and configurations, allowing for flexibility in the construction of floating platforms tailored to specific offshore locations.

While initial construction costs may be higher compared to other materials, the long-term durability and low maintenance requirements of steel and concrete structures can lead to cost savings over the lifecycle of the wind turbine. In addition, steel and concrete structures can be scaled up to support larger turbines and accommodate future advancements in wind turbine technology, allowing for the development of more efficient and powerful offshore wind farms.

Overall, the use of steel and concrete in floating offshore wind turbine construction offers a reliable and effective solution for harnessing wind energy in deeper waters.

Steel standards are based on Eurocodes and EU Machinery DIR and mainly grouped within EN 10025 and CE marking on structural steelwork is the regulatory requirement under the European Union's Construction Products Regulation CPR (see 5.1). If a

Classification Society (CS) is issuing a Class certificate, its own Rules seem likely to be used[55]

In floating offshore wind turbines, steel is predominantly used in several key components. The transition piece connects the turbine tower to the substructure. It is typically made of steel and serves as a transition between the floating platform and the tower structure. It is also commonly used in the construction of the substructure, which includes the main support structure beneath the water surface. This steel substructure provides the necessary buoyancy and stability to support the turbine tower and rotor assembly.

Steel cables or chains are often employed as part of the mooring system to anchor the floating platform to the seabed. These mooring lines are essential for maintaining the position and stability of the turbine in varying weather conditions.

For wire ropes and chains, a common safety factor used in mooring design is 1.67 for intact conditions and may go down to 1.25 when considering damaged states. This is in line with general industry standards for mooring safety, which apply across different mooring patterns and materials[56].

When it comes to floating offshore wind turbines, concrete is also of particular interest in several key parts, and it is commonly used as the primary material for the floating platform itself. These platforms can be either monolithic structures or consist of modular units. Concrete provides excellent buoyancy and stability, making it well-suited for supporting the weight of the wind turbine tower and rotor assembly.

Concrete can also be used as ballast within the floating platform to ensure stability and counteract the forces of wind and waves. By adjusting the amount of ballast, engineers can optimize the platform's draft and center of gravity to enhance its performance in varying sea conditions.

Concrete blocks or anchors are often employed as part of the mooring system to secure the floating platform in place. These concrete mooring elements provide reliable anchoring solutions and can withstand the harsh marine environment.

When designing and testing steel and concrete structures for floating offshore wind turbines in Europe, several standards and technical codes are commonly used to ensure compliance with safety, performance, and quality requirements. Here's a selection of the most relevant steel standards:

- EN 10025-1: Part 1: General Technical Delivery Conditions (TDC)
- EN 10025-2: Part 2: TDC for non-alloy structural steels
- EN 10025-3: Part 3: TDC for normalized/normalized rolled weldable fine grain structural steels
- EN 10025-4: Part 4: TDC for thermomechanical rolled weldable fine grain structural steels
- EN 10025-5: Part 5: TDC for structural steels with improved atmospheric corrosion resistance
- EN 10025-6: Part 6: TDC for flat products of high yield strength structural steels in the quenched and tempered condition
- EN 1993-1 Design of steel structures (related to EN 1993 Eurocode 3)
- EN 1993-1-10: Design of steel structures. Material toughness and through-thickness properties.
- EN 13173: Cathodic protection for steel offshore floating structures
- BS EN 1090: Steel structures and aluminium structures relevant to FOWT
- ISO 19902: Fixed Steel Offshore Structures (Petroleum and natural gas industries)
- DNV-OS-B101: Metallic Materials
- LR Rules for Manufacture, Testing and Certification of Materials

For concrete structures, EN, ISO and DNV standards specify requirements and provide guidelines for the design of concrete offshore structures applicable to floating offshore wind turbines:

- EN 1992 Eurocode 2: Design rules for concrete structures, including offshore structures. It covers various aspects of structural design, including material properties, structural analysis, and design criteria for different types of loading conditions.
- EN 206-1: Specification requirements for concrete, including materials, production, and performance criteria. It covers aspects such as cement types, aggregate properties, mix design, and testing procedures for assessing the quality and durability of concrete used in offshore structures.
- ISO 19901-7: Station keeping systems for floating offshore structures and mobile offshore units
- DNV(GL)-ST-0119: Guidelines for the design of FOW structures. It covers structural design principles, load conditions, material properties, fabrication requirements, and testing procedures.

Relevant practices in EU as regards to steel and concrete for FOW structures include selection of materials suitable for offshore environments, for

[55] While in Japan ClassNK Rules are applied, in the EU if the CS is issuing a Class certificate, then CS own Rules for materials seem likely to be used. Normally Classification is conditional upon compliance with the CS own requirements for materials, and compliance to different rules can only be accepted to the discretion of the CS.
[56] GuidetoFloatingOffshoreWind)

example corrosion resistant steels or use of high-performance concrete mixes which incorporate additives to enhance durability, resistance to seawater corrosion and mechanical properties.

4.7. Mooring and anchoring

Although there are many proposals for mooring systems inherited from other industries such as oil and gas, the criteria used in these industries do not necessarily have to match those required in offshore wind. Generally, floating platforms in the oil and gas industry are located in much deeper waters than offshore wind turbines, so it is necessary to design customised mooring systems at shallower depths, taking into account additional factors such as the type of seabed and the bathymetry of the seabed.

Most of the components of floating wind turbines are the same as those for fixed-bottom wind turbines, including the nacelle, most of the electrical system, the blade and tower. But the foundation's components are different. The floating foundation of offshore wind turbines normally includes two main parts: a floating structure and the pre-installed mooring and anchoring system that keeps the floater in place.

The anchoring system secures the turbine to the seabed and the mooring system connects the turbine to these fixed points, allowing for controlled movement. The mooring system is designed to absorb energy and reduce the motion of the floating structure, ensuring operational stability and safety. It must be both strong and flexible, capable of adapting to changes in water depth, seabed conditions, and environmental loads. It is the element that requires the most optimisation, not only to reduce the cost but also to reduce the risk of breakage.

For the floating substructure and mooring, in the UE there are no specific complete standards or standard suites enforced by law beyond the IEC 61400-3-2 impacting the design and system analysis. The code ISO 19901-7 "Petroleum and natural gas industries - Specific requirements for offshore structures- Part 7: Stationkeeping systems for floating offshore structures and mobile offshore units." is the recommended guide for offshore mooring in the EU.

The following codes can be also considered in mooring system analysis of a FOWT:

- DNV(GL)-RP-C203: Recommended practice for Fatigue Design of offshore steel structures
- DNV(GL)-OS-C101: Design of steel structures (LRFD method)[57]
- DNV-RP-C202 Buckling Strength of Shells
- DNV-OS-E301: Design and installation of fluke anchors
- API RP 2T: Recommended Practice for Planning, Designing, and Construction Tension Legs Platform

Over the last few years, the experience associated with FOWT projects and test installations has led to relevant progress in the techniques and procedures for the installation of mooring and anchoring systems that are largely shared among countries.

Traditional anchoring systems used in oil & gas platforms may not be optimal for FOW. Newer mooring technologies like suction anchors are being explored for their efficiency and reduced seabed disturbance. However, standards may not fully address the design, installation, and long-term performance of these novel anchoring systems. Floating foundations need further maturity and standardisation is still under development, making it difficult to develop safe and affordable designs.

Other relevant mooring technological development in the EU focus on real-time monitoring systems, which incorporates strain gauges, motion sensors, and underwater cameras to provide live data feeds to onshore facilities for immediate response. Very relevant as well is the continuous development and testing of composite lines, made from high-strength synthetic and corrosion-resistant fibers that reduce operational costs and extend the lifespan of the system.

The American Bureau of Shipping (ABS) have some specific standards related to mooring systems as ABS PMS Guide for Position Mooring Systems, ABS Fiber Notes on the Application of Fiber Rope for Offshore Mooring, and ABS Chain Guide for Certification of Offshore Mooring Chain.

4.8. Safety requirements

Regarding the safety requirements of a floating wind farm, it is necessary to address various risks such as navigation hazards, vessel traffic patterns and collision risks. But in a marine environment such as Japan's, the potential risks from earthquakes and tsunamis require specific and detailed analysis.

The effect of seismic conditions on the design of FOWT support structure shall be considered on a project-specific basis in a seismically active area. Impact can be a function of ground motions on the anchors or by associated sudden wave loading as in tsunamis.

In the EU, earthquakes or seismic events shall be considered based upon a typical return period for the limit state being considered. According to IEC

[57] Load and Resistant Factor Design method, for weld strength checks

61400-1, a seismic event with a return period of 475 years shall be assessed.

The site condition assessment shall define the seismic conditions for the site and the seismic design criteria for each asset. This shall include the likelihood and magnitude of seismic events that may affect the wind farm site, the ground response to such events, and the impact they may have on the assets.

In general, it is expected that seismic conditions shall be assessed in accordance with ISO 19901-2, or equivalent. Where seismic hazard is confirmed to be low, as defined by an assessment such as that defined in ISO 19901-24, it may be acceptable to ignore seismic aspects within the design.

In a seismically active area, the effect of seismic conditions on FOWT support structure design shall also be considered on a project-specific basis. The impact may be a function of ground motions on the anchors or by associated sudden wave loading (Tsunamis).

For tension moorings, taut moorings or compliant towers, seismic conditions may lead to loading being transmitted through the station-keeping system or dynamic cable into the floating substructure and subsequently to the tower and WT RNA. A seismic event may also lead to liquefaction of the seabed, which can cause loss of support or geotechnical capacity of dynamic cables, mooring lines and anchors.

The presence of active fault lines within the mooring footprint or cable corridor should also be assessed. The relevant geological authority in a country is generally aware of which faults are deemed to remain active, and it may be consulted. Active faults within the footprint of a FOWT station-keeping system can lead to seabed level changes, including differential changes between anchor locations, if a seismic event occurs.

A screening assessment shall be performed to determine whether the soil is liquefiable. If soils are liquefiable, then a full assessment of liquefaction shall be performed to determine the nature and duration of any impact of liquefaction on the assets. Aside from liquefaction, for certain mooring configurations, a detailed Probabilistic Seismic Hazard Assessment (PSHA) is likely to be required to fully assess seismic conditions.

4.9. Projects and test sites

Herewith are some examples of relevant projects and test sites whose development and operation have shown innovative techniques or procedures related to site investigation, load analysis, use of relevant materials and foundations (mooring and anchoring), for the installation of floating offshore wind turbines in European countries.

1. WindFloat Atlantic Project (Viana do Castelo, Portugal). Entry into operation (EO): July 2020; Power installed (P): 25,2 MW (3T x 25,2MW). First semi-submersible floating offshore wind farm in Europe, using innovative mooring technology for deep waters over 100 m. It is a pioneering example of integrated site characterization for floating offshore wind. The project utilizes advanced survey techniques, including multibeam echo sounders and seabed coring systems, to assess seabed conditions and geotechnical properties at the project site. Long-term metocean monitoring is conducted to collect data on wind speeds, wave heights, and currents,
2. The Hywind Tampen Project (North Sea, Norway). EO: Nov 2022; P: 94,6 MW (11T x 8,6 MW). World's first floating wind farm to supply power to offshore oil and gas installations, located 140 km off the coast in water depths between 260-300 m. The project employs computational fluid dynamics (CFD) simulations to simulate wind and wave interactions with the floating structures. By accurately predicting loads and responses under extreme weather conditions, it can ensure the structural integrity and reliability of the wind turbines, enhancing safety and reducing operational risks.
3. Kincardine Floating Offshore Wind Farm (Aberdeenshire, Scotland). EO: Sept 2021; P: 50MW (5T x 9,5 MW + 1T x 2 MW). With turbines installed on WindFloat semi-submersible platforms, this project showcases the application of risk-based approaches to site investigations and project development. The project site undergoes thorough risk assessments to identify and mitigate potential hazards associated with seabed conditions, metocean phenomena, and operational challenges.
4. Floatgen Project (Coast of Le Croisic, France). EO: Sept 2018; P: 2 MW (1T). First floating offshore wind turbine in France, it features a semi-taut mooring system with synthetic fiber (nylon) lines and showcases the viability of concrete structures for floating offshore wind applications, particularly in areas with deeper waters. It also incorporates habitat mapping, species monitoring, and environmental impact assessments to assess potential ecological impacts and ensure compliance with regulatory requirements.
5. ELISA Project (Gran Canaria, Spain). EO: March 2019; P: 5 MW (1T). This project involves the

deployment of the ELISA (Enabling Future Arrays in Tidal) floating platform, which incorporates steel components in its structure. The use of steel in the ELISA platform has demonstrated success in providing stability and structural integrity for floating offshore wind turbines in coastal environments.

6. Poseidon Project (Tyrrhenian Sea, Italy). Construction expected to begin in 2025, planned EO: 2029; P: 1,008 MW (72T x 14 MW). The project features the Poseidon floating platform, which utilizes steel components in its substructure. The Poseidon platform has been recognized for its innovative design and use of steel materials to provide a stable and reliable foundation for offshore wind turbines in the Mediterranean Sea.
7. DolWin3 Project (German North Sea). EO: 2020; P: 900 MW (several wind farms). The project utilizes a unique concrete jacket foundation design for its offshore wind turbines. The concrete jacket foundations provide stability and support for the wind turbines in challenging marine conditions. This project has demonstrated the effectiveness of concrete structures in offshore wind energy applications.
8. 7SeasMed Project (Marsala Coast, Sicily). EO: 2028-2030; P: 250 MW. This project recently received its EIA approval. The foreseen wind farm will use innovative floating platform technology anchored to the seabed, allowing for deployment of floating offshore wind turbines in deeper waters. It is expected to provide around 5% of Sicily´s total electricity consumption.
9. EMEC European Marine Energy Centre (Orkney, Scotland). EO: 2021. EMEC has planned a new 100 MW floating offshore wind test and demonstration site further out to sea from its existing wave energy test facility at Billia Croo on the west coast of Orkney. AFLOAT, CLEANWINDTUR and BLOW are some examples of floating offshore wind energy projects in which the centre is involved.
10. METCentre, Marine Energy Test Centre (Norway). Founded in 2009, this centre provides opportunities to test and validate floater technologies in full scale. The centre offers infrastructure and services required for testing technologies both in shallow and deep waters (over 200 meters) under varying testing conditions.
11. PLOCAN Test Site (Gran Canaria. Spain). EO: 2020; P: 5 MW (1T). X1 Wind has installed its Pivot Buoy floating offshore wind turbine prototype. The prototype, fitted with a Vestas V29 turbine, is installed at a 50-metre water depth in a downwind configuration, creating a passive 'weathervaning' effect that could eliminate the need for an active yaw system. Researchers and industry partners have conducted tests and trials to assess the feasibility and reliability of concrete foundations and floating platforms in the Spanish marine environment.
12. AMETS Atlantic Marine Energy Test Site (County Moyo, Ireland). This project is being developed by Sustainable Energy Authority of Ireland (SEAI) to facilitate testing of full-scale wave energy converters and floating offshore wind technologies in harsh open ocean conditions. It offers two test areas with water depths of approximately 50m and 100m, making it suitable for a wide range of device testing. Test site is not yet in operation for developers.
13. Green Volt Floating Offshore Wind Farm (Scotland). Planned EO: 2029. Europe's first commercial-scale floating wind farm and is part of Crown Estate Scotland's Innovation and Targeted Oil and Gas (INTOG) leasing round. The project will replace natural gas and diesel power on offshore oil and gas platforms and deploy new floating technology on a large scale.
14. Corewind Project (EU). Research and development EU funded project (2019-2023). Its key innovations focus on reducing costs and improving the performance of floating wind turbines by optimizing mooring systems, anchoring systems, and dynamic cables. The project uses virtual simulations to test different floating wind technologies like semi-submersible and spar designs, to achieve cost reductions and scalability. This is particularly crucial for future deployments in deeper waters.

5. BENCHMARKING BETWEEN JAPAN AND EU STANDARDS AND TECHNICAL REGULATION

5.1. Comparison between Japanese and European practices

To facilitate benchmarking on standards and technical regulation, the table below summarises for each indicator (vertical column on the left) the key statements tackled in chapter 3 for Japan and in chapter 4 for the EU, highlighting differences in red and similarities in blue. The extensive analysis comparing the situation in Japan and the EU is to be found further down, after the recapitulative table.

Table 10 Comparison EU-Japan on adoption and development of FOW Technical Regulation and Standards

IND	The EU	Japan
Adoption and development of standards	• IEC standards integrated in EN, ISO and IECRE standard (see 4.1) • ISO/IEC 6 phases for development and adoption of standards (see 4.2) • Most countries without national FOW standards but participate in ISO/IEC and IECRE (see 4.1) • National positions in ISO/IEC through NSBs. Most NSBs establish National Mirror Committees (NMCs) (see 4.2) • Key standards IEC 61400-3-1 and IEC 61400-3-2; IEC 61400, ISO 19900 and 19901 series (see 4.3) • Increasing supply of standards from independent third-party classification and certification societies (see 5.1) • Germany provides OW standards BSH 7004 and BSH 7005 (see 5.1) • Other countries preparing “Offshore Wind Expert Groups” to enhance technical regulation (see 5.1) • General collaborative approach among participating nations (see 5.2.1)	• ISO and IEC are applied in Japan. The main standards are also published in JIS. (See 3.2.1) • Participation in ISO/IEC/IECRE activities. (see 3.2.1) • Conditions specific to the Asian region proposed by Japan are reflected in the IEC standards. (see 3.2.1) • In addition to IEC standards, METI/MLIT publishes standards and guidelines. (See 3.1.4, 3.3.2 and 3.3.3) • Interpretations of several standards are summarised in “Official Explanation of Technical Standards for OWT” (See 3.3.1) • METI/MLIT hold committees of experts and publish detailed explanations of technical standards. (See 3.3.2)

IND	The EU	Japan
Certification and Permitting	• Certification and permitting required to ensure compliance of standards. • Certification schemes as IECRE-OD-502 (see 4.3) • Type, component, and project certification adhering to specific standards (see 4.3) • Full project certification not formally required, usually referring to national rules (e.g. BSH) to fulfil finance requirements, insurance, etc. (see 4.3) • Permitting often based on certificates issued by accredited third-party bodies • Germany certification from third-parties (DNV, BV...) and permits from BSH (see 4.2 Table) • France: Certification through BV Certification through BV and other recognized and accredited bodies (see 4.3) • Certification can start with classification inspections conducted by recognized classification societies CS issuing a Class certificate (see 4.6.1).	• OW standards require technical review under the Electricity Business Act, Port and Harbour Act and Ship Safety Act (See 3.1.1,3.1.2 and 3.1.3) • Japan refers to IECRE, but JIS C 1400-22:2014 corresponding to the obsolete IEC 61400-22:2010 Ed.1.0 remains valid. (See 3.2.2) • Conformity verification by a registered verification body of METI is equivalent to a project design certification as specified in IECRE OD502 6.3 (See3.4.1) • The project certification system is not used. (See 3.4.1) • Conformity assessment of mooring facilities by registered verification body of MLIT (See 3.4.2) • Classification inspections by a recognized classification society of MLIT (See 3.4.3) • The guidelines for FOW of ClassNK, a registered verification body and a recognized classification society are based on IEC 614003-1 and IEC TS 614003-2 (See 3.4.3)
Site Investigations	• Relevant assessments: Seabed conditions, metocean studies, environmental impact assessment and infrastructure and grid connection (see 4.4) • Site conditions according to IEC 61400-3-1 and additional requirements given in 61400-3-2 (see 4.4) • EN ISO 19901-4 provides guidance on geotechnical and metocean site assessments (see 4.4) • Advanced practices in survey techniques, geophysical and geotechnical integration, numerical modelling and long-term monitoring programs (see 4.4) • Radar interference caused by FOWT shall be assessed (see 4.4)	• The government specifies the external conditions that must be considered when designing FOW turbine installations and requires the following studies: general matters, 2. wind conditions, 3. sea conditions and 4. other (See 3.1.4 A and 3.3.2 A) • Environmental impact assessment (See 3.1.6) • Impacts on radar and mitigation measures (See 3.1.8)

IND	The EU	Japan
Integrated load analysis	• Evaluation of environmental loads shall follow the Design Load Cases (DLCs) of IEC 61400-3-2. (see 4.5) • Integrated Load Analysis based on selected load cases for fatigue and extreme loads • Assessment of DLCs related to fatigue strength may be used based on environmental data series (see 4.5) • Coupled analysis of the floater and turbine in operational phases of the turbine shall be carried (see 4.5) • Stress ranges caused by wind and wave during fault conditions shall be established by time domain (see 4.5) • Software to be used shall be validated with scaled model tank testing, (see 4.5) • Loads related to accidental events, abnormal operations or technical failures should be considered (see 4.5)	• Design conditions and load cases are specified for 29 cases of power generation from DLC 1.1 to DLC 8.4 and 8 cases of sea ice from D1 to D8 (See 3.1.4 C and 3.3.2 C) • For floating facilities and towers, a coupled analysis in the time domain shall be performed (See 3.1.4 C) • If integral coupled analysis is performed, a well-validated programme shall be used, or the analysis results shall be validated by comparison with model test results (See 3.3.2 C).
Steel and concrete	• In the EU FOW standards are typically regulated under maritime or offshore laws rather than building regulations. • Only in Norway and UK the classification of FOW standards falls under building category. • Relevant practices on materials selection, design optimization, and construction techniques (see 4.6.1) <Steel> • Steel standards based on Eurocodes and EU Machinery DIR mainly grouped within EN 10025. If a CS is issuing a Class certificate, its own Rules are expected to be used (see 4.6.1) • CE marking on structural steelwork (see 4.6.1 and 5.1) <Concrete>. • EN, ISO and DNV standards provide guidelines for concrete offshore structures (see 4.6.1)	• FOW are classified as "special vessels" under the Ship Safety Act (See 3.1.3) • Materials specified in the Ship Structure Regulations (Ministry of Transport Ordinance No. 16 of 1998) must be used. (See 3.3.2 B) • If materials not specified in the Ship Structure Regulations, the MLIT must be approached with the necessary documentation. (See 3.1.4 B) <Steel> • Chapter 2, Part P of the NK Steel Ship Rules applies. In this case, the rolled steel used shall comply with the provisions of Part K of the NK Steel Ships Rules (see 3.3.2 B) <Concrete>. • Apply the materials listed in the Guidelines for the Design and Construction of Concrete Floating Offshore Wind Power Facilities. (See 3.3.2 B and 3.3.3 B)

IND	The EU	Japan
Mooring and anchoring	• Four basic prototypes of floating structure and mooring-anchoring system as considered in IEC TS 61400-3-2 standard (see 1.3.2). • IEC TS 61400-3-2 for design, ISO 19901-7 for offshore mooring and DNV, API and ABS standards for fatigue analysis can be considered (see 4.7) • Qualification procedures by certification bodies to be applied for new materials, e.g. currently undergoing nylon ropes for permanent mooring systems (see 4.6) • Technological development on Real-Time Monitoring Systems, Mooring Lines, Anchoring Solutions and Weather adaptation (see 4.7)	• Chains, wire or synthetic fiber ropes, anchors, etc. used in the mooring system must be approved as appropriate by the competent maritime authority (See 3.1.4 D) • Components and materials used in mooring systems must comply with international standards and be appropriately approved by the competent maritime authority. (See 3.3.2 D) • A safety factor of about 1.5 times is specified for synthetic fibers compared to chains for mooring lines. (See 3.1.4 D) • It is not specified whether the synthetic fibers mentioned above are Nylon, High Modulus Polyethylene or Aramid. (See footnote 3.1.4 D)
Earthquakes and tsunamis	• According to IEC 61400-1, seismic event with a return period of 475 years shall be assessed (see 4.8) • Seismic conditions shall be assessed in accordance with ISO 19901-24 (see 4.8) • Impact can be a function of ground motions on the anchors or by associated sudden wave loading (Tsunamis) (see 4.8) • Full assessment of liquefaction of seabed shall be performed (see 4.8) • Probabilistic Seismic Hazard Assessment (PSHA) is likely to be required for certain mooring configurations (see 4.8) • Other safety problems include navigational hazards, vessel traffic patterns, collision risks, and safety buffer zones around wind turbine installations (see 4.4).	<Earthquakes> • Earthquakes should be considered at the maximum level that has previously occurred in the vicinity of the installation (See 3.1.4A) • Horizontal and vertical seismic motions need to be taken into account, although the FOW mainly considers vertical seismic motions due to the buffering effect of seawater. (See 3.3.2 A) • Design earthquake ground motions are to be determined by multiplying the basic maximum acceleration by the seismic topography coefficient. (See 3.3.2 A) < Tsunamis > • Tsunamis shall be taken into account at the largest one that have occurred in the past in the vicinity of the installation area. (See 3.1.4A) • If the water depth is sufficiently deep, the effects of the tsunami may be regarded as tidal fluctuations and ocean currents. (See 3.1.4A)

Adoption and development of standards

European countries generally adopt IEC standards integrated in EN, ISO and IECRE standards. Independent certification societies such as DNV, BV or LR also develop international standards covering key FOW technology issues. In addition, the floating nature of FOWT opens the potential for the application of a range of technical regulations aimed at the maritime and navigation sector, specifically, vessel classification and certification.

The general principle of voluntary adoption is central to the ISO/IEC system, although some standards become mandatory through regulation. Effective implementation requires the involvement of all relevant stakeholders to ensure that the standard is applied in a manner that meets the needs of the industry and society.

Standards are developed through the participation of countries in ISO/IEC work via national standardization bodies (NSBs). National positions on ISO/IEC work are developed on an ongoing basis and most NSBs establish national mirror committees (NMCs) to reflect the work of international standardization organizations.

Some countries rely on FOWT Expert Groups to enhance offshore wind technical regulation. Only Germany so far has a specific “Technical Expert Committee” through which it has launched two Offshore Wind national standards.

The participation of Japan in ISO and IEC activities is well established. Japan was not a founding member of these organisations but joined relatively early in the history of these organisations, more than 50 years ago.

ISO and IEC are applied in Japan as they are and conditions specific to the Asian region proposed by Japan are reflected in the IEC standards. However, in order to facilitate their application in the country, the standards that are expected to be used widely, are incorporated into JIS. The adaptability and flexibility provided by EN, ISO and IECRE allow for the integration of the requirements of FOW installations.

The response to IEC is almost the same in Japan as for EU countries. The government provides detailed explanations and guidelines regarding technical regulations, in which standards are also referred to, and it is mandatory to conform to them. The standards are established based on the discussion of the expert group organized by the government. NSB's activities are almost the same, while translation in Japanese and incorporation in JIS standards take time.

Japan refers to IECRE, however JIS C 1400-22:2014 corresponding to the obsolete IEC 61400-22:2010 Ed.1.0 remains valid. Japan should urgently move towards the application of IECRE OD501 and OD502. Unfortunately, no timeline indication regarding its transition to the IECRE standards has been provided by Japan. Maintenance Team IEC TC88 needs to be launched for the publication of IEC 61400-3-2 ED2.

In addition to IEC standards, METI/MLIT convene expert committees and publish standards and guidelines:

- Technical Standards for Floating Offshore Wind Power Generation
- Safety Guidelines for Technical Standards for Floating Offshore Wind Power Facilities
- Design and Construction Guidelines for Concrete Floating Offshore Wind Power Facilities

Certification and permitting

In the EU, certification results in the issuance of certificates attesting the compliance of FOW and/or its components with rules or standards. The certification process consists of review of plans and calculations, surveys, checks, and tests intended to demonstrate that standards/national regulations are met. Full project certification is normally undertaken.

The conformity assessment procedure for a FOW project involves a series of evaluations and verifications to ensure that the design, construction, and operation of the wind turbines meet specific standards and regulations. This detailed evaluation process also helps mitigate risks and enhances the project's acceptability to stakeholders, including investors, regulatory bodies, and the public. Conformity assessment is normally based on IEC 61400 series, IECRE OD 501 (type and component) and 502 (project) certification schemes and no government entity is normally involved. Full project certification is formally not required in every EU country.

The permitting process usually requires submitting detailed project plans and documentation to government or regulatory bodies. The primary outcome of obtaining permits is legal authorization to proceed with the project. There is normally only one national authority responsible for all offshore wind permitting and at best, permitting processes are merged to ensure that there is only one entry point towards authorities. This procedure avoids double-tasks regarding conformity assessment procedures.

In EU countries, permitting procedures for projects like floating offshore wind turbines often can be streamlined or facilitated based on certificates issued by accredited third-party bodies. This approach leverages the concept of "mutual recognition" where a certification provided by an accredited body in one EU member state is recognized across other member states, reducing redundancy in assessments and speeding up the permitting process.

Classification societies are key in providing third-party technical assessment and certification, ensuring that floating offshore wind projects not only meet local regulatory requirements but also adhere to international safety and quality standards. Classification inspections are conducted by recognized classification societies in several countries.

The certification bodies operate under international standards that are widely recognized and accepted in the global maritime and offshore energy sectors. For instance, DNV's standards for the design, construction, and operation of floating wind turbines are based on comprehensive research, industry knowledge, and best practices that have been developed in collaboration with global stakeholders.

Other example is Bureau Veritas, which states in this regard that "Recognized Classification Societies have the competencies and capacities to develop and maintain technical standards (Class Rules) tailored made to floating units, mooring systems and power cables"~~,~~

In Japan, ClassNK, is a registered verification body and a recognized classification society based on IEC 614003-1 and IEC TS 61400 3-2, that needs to apply for registration with IECRE as certification body to accelerate international recognition.

Japan requires technical review under the Electricity Business Act, Port and Harbour Act and Ship Safety Act. Concerning the Electricity Business Act, conformity verification by a registered verification body of METI is equivalent to a site conformity assessment as specified in IECRE OD502 6.3 and project certification system is not used.

The Port and Harbour Act establishes conformity assessment of mooring facilities by registered verification body of MLIT. The Ship Safety Act stipulates classification inspections by a recognized classification society of MLIT.

This policy includes a shift to examination by third-party organizations, for example the establishment of "Official Explanation" series and "Safety Guidelines for FOW", as well as the above-mentioned introduction of conformity verification body under the Electricity Business Act, which attempts for unified/parallel review initiated by ClassNK.

Site investigations

In EU countries, the site investigations for the installation of floating offshore wind turbines involve assessments of various factors including seabed conditions, geotechnical formations and metocean characteristics.

The external site conditions shall be assessed according to IEC 61400-3-1 and additional requirements given in 61400-3-2. Other specific standards and guidelines for site investigations vary depending on the country. Given their potential relevance, some good practices of research and studies in the EU are discussed below.

Challenges may arise from varying seabed compositions, such as hard rock, soft sediments, or complex geological formations, which can impact the stability and anchoring of floating structures. Specific surveys assess the seabed conditions to ensure the stability and suitability for anchoring floating wind turbines. Standards such as ISO 19901-8 provide guidelines for geotechnical investigations for offshore structures.

In response to possible radar interferences, EU countries have implemented mitigation strategies to ensure that radar systems can continue to operate effectively near wind farm sites. These measures include the use of radar-absorbing materials on turbines, improvements in radar technology, and specialized radar systems that can better discriminate between wind turbines and other objects.

In Japan, the government specifies the external conditions that must be taken into account when designing FOW turbine installations and requires the following studies general matters: wind conditions, sea conditions and other, including Earthquakes, Seabed deformation and Scour, and Snow loads. Floating offshore wind farms encounter specific environmental conditions in Japan depending on location.

If a wind turbine is installed in close proximity to a weather radar, notification and consultation are required under Article 37 of the Meteorological Service Act, depending on the size of the turbine, its altitude, and its distance from the radar. The Ministry of Defense mandates that operators consult during the early stages of project planning to minimize the impact on radar.

In Japan, the technological development of seabed geological survey methods at great depths is one of the target areas of research and development subsidized by the government. Regarding the radar interference challenge, the only response in Japan is not allowing construction in the affected area.

Integrated load analysis

The EU-Japan comparison in relation to standards and technical regulation concerning load analysis shows no appreciable differences.

The modes of motion of the floating unit shall require a more thorough assessment of load responses due to wind and wave/current misalignment than is typically required for bottom-fixed turbine structures. Coupled analysis of the floater and turbine in operational phases of the turbine shall be carried.

The Integrated Load Analysis of a floating wind platform is a key tool for the development of this technology. For the RNA, loads resulting from floater motions (e.g. yaw loads resulting from a tilted rotor during pitch motions of the floater) shall be assessed. These loads are not typically covered by the wind turbine type certificate.

The evaluation of environmental loads shall follow the Design Load Cases (DLCs) specified in TS IEC 61400-3-2, including ice loads, if relevant, based on environmental data representative of the target region and relevant for the operation in question, taking into account the type, size and shape of the floating substructure as well as its response characteristics.

For design conditions and load cases 29 cases are specified, for power generation from DLC 1.1 to DLC 8.4, and 8 cases for sea ice from D1 to D8. Japan has been tackling the same issues and coupled analysis is one of the areas targeted for technological development through government subsidies.

When the environmental data time series, such as long-term measurement or hindcast data with a sufficient length are available, the data may be used for the assessment of the DLCs related to fatigue strength.

For fatigue load analysis, stress ranges caused by wind and wave loading during fault conditions shall be established by time domain analysis under due consideration of the motion characteristics of the floater and its interaction with the control system.

The development of this type of models requires their validation through experimental scale tests carried out in wave tanks because they allow eliminating uncertainties in the design and having a first approximation of the real behaviour of the floating platform.

In Japan, the regulations stipulate the rules for General matters, Loads, and Design conditions and load cases. Within General matters, coupled analysis in the time domain must be performed for floating facilities and towers.

Steel and concrete

There are important differences in the regulatory approach to FOW structures between the EU and Japan.

In EU member states, FOW structures are normally regulated under maritime or offshore laws, while in Japan they are classified as "special vessels" under the Ship Safety Act. In Japan it is necessary to apply the materials listed in the Guidelines for the Design and Construction of Concrete Floating Offshore Wind Power Facilities.

Materials used in Japan for FOW structures are specified in the Ship Structure Regulations (MLIT) If materials not listed in these MLIT regulations are to be used, MLIT must be approached with the necessary documentation. For offshore structures and work vessels, rolled steel materials used for hull structure and outfitting shall conform to the provisions of Part K (Materials) of the Rules for the Survey and Construction of Steel Ship.

Japan has separate regulations regarding the materials that can be used. In addition to meeting JIS materials and standards set by the JSCE, materials must be certified by the government as usable each time. Regarding floaters, when ClassNK conducts a classification inspection, it is necessary to use NK materials certified by ClassNK.

Steel standards in EU MS are based on Eurocodes and EU Machinery DIR mainly grouped within EN 10025, which specify the technical delivery conditions for hot rolled products of structural steel. . CE marking on structural steelwork is a regulatory requirement under the European Union’s Construction Products Regulation (EU CPR). This marking indicates that a product, such as structural steelwork, meets the necessary EU safety, health, and environmental requirements. If a classification society is issuing a class certificate, its own Rules are normally used.

For concrete structures, EN, ISO and DNV standards specify requirements and provide guidelines for the design of concrete offshore structures applicable to floating offshore wind.

Mooring and anchoring

For the installation of FOW mooring and anchoring systems, there are no specific and complete standards or standard suites enforced by law beyond the IEC TS 61400-3-2. The four basic prototypes of floating structure and mooring-anchoring system and the design requirements as stipulated in this standard can be considered in all countries, as well as ISO 19901-7 for offshore mooring and DNV, API and ABS standards for fatigue analysis.

Qualification procedures are currently being applied in the EU for new materials as Nylon ropes for permanent mooring systems.

In Japan, chains, wire or synthetic fiber ropes, intermediate sinkers, intermediate buoys, anchors that serve as mooring points on the seabed, sinkers, piles, etc., used in mooring systems must comply with international standards and be approved by the controlling marine authority. It is not specified whether the synthetic fibers are Nylon, High Modulus Polyethylene or Aramid. According to the Safety Guidelines, the requirements set to combine the analysis method specified in ISO 19901-7 with the concept of the "Design Load Case (DLC)" specified by IEC.A safety factor of about 1.5 times is established in Japan for synthetic fibers compared to chains for mooring lines. This safety factor is set high as there have been few examples of application, nevertheless it would be desirable to set safety rates corresponding to each material.

Earthquakes and tsunamis

In EU member states, earthquakes or seismic events shall be considered based upon a typical return period for the limit state being considered. According to IEC 61400-1, a seismic event with a return period of 475 years shall be assessed in accordance with ISO 19901-2 or equivalent. Impact can be a function of ground motions on the anchors or by associated sudden wave loading (Tsunamis)

For tension moorings, taut moorings or compliant towers, seismic conditions may lead to loading being transmitted through the station-keeping system or dynamic cable into the floating substructure and subsequently to the tower and wind turbine RNA. A seismic event may also lead to liquefaction of the seabed, which can cause loss of support or geotechnical capacity of dynamic cables, mooring lines and anchors.

A screening assessment shall be performed to determine whether the soil is liquefiable. If soils are liquefiable, then a full assessment of liquefaction shall be performed to determine the nature and duration of any impact of liquefaction on the assets.

Aside from liquefaction, for certain mooring configurations, a detailed Probabilistic Seismic Hazard Assessment (PSHA) is likely to be required to fully assess seismic conditions.

In Japan, the earthquakes should be considered at the maximum level that has previously occurred in the vicinity of the installation.

Horizontal and vertical seismic motions need to be taken into account, although the FOW mainly considers vertical seismic motions due to the buffering effect of seawater. Design earthquake ground motions are to be determined by multiplying the basic maximum acceleration by the seismic topography coefficient.

Tsunamis shall be taken into account at the largest one that have occurred in the past in the vicinity of the installation area. If the water depth is sufficiently deep, the effects of the tsunami may be regarded as tidal fluctuations and ocean currents.

In Japan, the effects of the largest earthquake and tsunami ever to occur, as well as ground liquefaction, must be appropriately considered. At the same time, it is said that floating structures are generally considered to be less susceptible to earthquakes and tsunamis (except TLP type are sensitive to vertical earthquake motion), which is shown in Appendix 1 of the “Safety Guidelines” with the evaluation model and calculation results.

Regarding liquefaction, the Safety Guidelines set requirement to take samples during a ground survey in the installation sea area and determine the position of the mooring anchor based on the survey data.

5.2. Best Practices

Best practices in FOW standards and technical regulations are identified based on the above comparison between the EU and Japan, calling for possible application in Japan.

5.2.1. Global Standardisation and Regulation

- ✓ **Multifaced regulatory framework**: The floating nature of FOW introduces unique challenges that need a multifaceted approach drawing from the maritime and navigation sectors. The adaptability and flexibility of the regulatory frameworks provided by EN, ISO, and IECRE prove invaluable, allowing for the integration of technical regulation tailored to the specific requirements of offshore wind installations.
- ✓ **Compliance with the design requirements of IEC 61400-3-2 ED1**: scheduled for publication in November 2024, this standard requires updating the standards and guidelines of each country and each certification body from the currently applicable technical specification IEC TS 61400-3-2:2019
- ✓ **IEC TC88 MT needs to be launched for the publication of IEC 61400-3-2 ED2**: As some areas are still in the technological development stage, IEC TC88 MT addresses the application of new technologies and materials, based on the achievements of prototypes and commercial installations.
- ✓ **Japan must make JIS C 1400-22:2014 obsolete**: Japan, which is also an IECRE member, needs to move to applying IECRE OD501 and OD502 to update their respective standards and guidelines.
- ✓ **In Japan ClassNK needs to apply for registration with IECRE as a certification body**: **this will accelerate the application of international mutual recognition.** Certification can start with classification societies, and the guidelines for FOW of ClassNK are based on IEC 61400-3-1 and IEC TS 61400-3-2.
- ✓ **Permitting provides the legal authorisation to proceed with the project, which usually simplifies tasks in relation to conformity assessment procedures.** The permitting process normally requires submitting detailed project plans and documentation to government or regulatory bodies.
- ✓ **Third-party certification societies bring research capacity, industry knowledge, and best practices developed in close collaboration with global stakeholders**. The involvement of these independent entities underscores the global reach and credibility of the regulatory bodies. Their contributions ensure that standards remain at the forefront of technological advancements and industry innovations. Japan can leverage the expertise of third-party certification societies, drawing upon their independent research capacity, industry knowledge, and best practices to ensure the quality and safety of FOW installations. For example, DNV and BV include standards, references and recommended practices to relevant standards.
- ✓ **Informing other certification bodies on materials certified by national certification bodies registered with IECRE or accredited as third-party is desirable**. This will facilitate their application in other countries through an international mutual recognition system.

5.2.2. Robust Technical Assessments

5.2.2.1. Assessment of external site conditions

- ✓ **Use of surveying technologies, such as multibeam echo sounders, side-scan sonar, and seabed coring systems**: enabling more accurate and detailed assessments of seabed conditions. These techniques provide valuable data on sediment types, bedrock formations, and geotechnical properties, enhancing the understanding of seabed stability and suitability for anchoring floating structures.
- ✓ **Integrating geophysical and geotechnical survey data**: allowing a comprehensive characterization of the seabed, combining information on bathymetry, seabed morphology, and soil properties. This integrated approach facilitates better site selection, foundation design, and risk assessment for floating wind projects.
- ✓ **Application of advanced numerical modelling tools**: advanced tools such as finite element analysis (FEA) and computational fluid dynamics (CFD), are increasingly utilised to simulate the dynamic behaviour of floating wind turbines under various metocean conditions. These models help optimise design parameters, assess structural loads, and predict performance in real-world operating environments.
- ✓ **Implementing long-term monitoring programs at project sites**: enabling continuous data collection on metocean conditions, environmental parameters, and structural performance. This real-time monitoring allows for the validation of design assumptions, identification of trends, and early detection of potential issues, enhancing operational efficiency and safety.
- ✓ **Adopting risk-based approaches to site investigations**: which involves assessing and managing uncertainties associated with seabed conditions and metocean characteristics. By quantifying risks and uncertainties through probabilistic analyses, developers can optimise design margins, prioritise risk mitigation measures, and improve decision-making throughout the project lifecycle.

5.2.2.2. Mitigating radar interference

- ✓ **Radar Absorbent Material (RAM)**: Applying materials that absorb radar waves to the turbine structures can reduce their radar cross-section, thereby minimising the radar signature of the turbines.
- ✓ **Radar blanking and filtering**: Radar systems can be configured to ignore signals coming from the locations of wind turbines. This technique involves either blanking out the area where the turbines are located or applying sophisticated filters to distinguish between turbine blades and other objects.
- ✓ **Installing radar transponders on turbines**: These devices receive radar signals and send back a clear response identifying them as non-threat objects, thus reducing confusion and clutter on radar screens.
- ✓ **Upgrading radar software to better discriminate between turbine interference and genuine aircraft or weather phenomena:** Enhanced signal processing algorithms can help in distinguishing between different types of objects.

5.2.2.3. Integrated Load Analysis

- ✓ **A coupled analysis of the floater and turbine in time domain in operational phases of the turbine shall be carried.** The stress ranges caused by wind and wave loading during fault conditions shall be established by time domain methods for fatigue load analysis.
- ✓ **The aero-hydro-servo-elastic software to be used in the floater design shall be validated with scaled model tank testing**, other numeric software and/or available measurements of FOWT with similar characteristics. Further information on model testing is provided in Annex K of IEC TS 61400- 3-2.
- ✓ **Calculation methods and formulae to be internationally standardised in the development of technical regulation is recommended**. This would facilitate that the assessment can be conducted by differing in the numerical values to be entered.

5.2.2.4. Steel and concrete

- ✓ **Selecting high-quality steel materials suitable for offshore environments is key to the design of FOW.** This includes utilizing corrosion-resistant steels to ensure long-term durability and performance.
- ✓ **Regular maintenance and inspection of steel components are essential to ensure the continued safe and reliable operation of floating offshore wind turbines**. European best practices emphasize the importance of implementing comprehensive inspection programs and employing advanced monitoring technologies to detect potential issues early and prevent costly downtime.
- ✓ **Use of high-performance concrete mixes tailored to the specific requirements of floating offshore applications**. These mixes often incorporate additives and reinforcements to enhance durability, resistance to seawater corrosion, and mechanical properties.
- ✓ **Information on the application of materials and new materials certified by national certification bodies registered with IECRE or**

accredited as third party should be notified to other certification bodies. This facilitates application in other countries through an international mutual recognition system.
- ✓ **Sustainability and circularity models, in which products can be reused, remanufactured, recycled or recovered,** are gaining importance for technical design and assessments.

5.2.3. Mooring and Safety Expertise

5.2.3.1. *Mooring and anchoring*

- ✓ **Real-Time Monitoring Systems**: This technology incorporates strain gauges, motion sensors, and underwater cameras to provide live data feeds to onshore facilities for immediate response. The Floatgen project developed by Ideol and located in France employs real-time monitoring technology to optimize maintenance schedules and prevent failures.
- ✓ **Composite Mooring Lines**: These lines are made from high-strength synthetic fibers that are corrosion-resistant, reducing operational costs and extending the lifespan of the system. Projects like WindFloat Atlantic have started testing composite lines to evaluate their performance under real-world conditions.
- ✓ **Anchoring Solutions**: Drag Embedment Anchors are widely used for their effective holding capacity in sandy and muddy seabed, while Pile Anchors are referred in rocky seabed where drag embedment anchors would be less effective. Suction Anchors Favoured for rapid deployment and strong holding force in suitable seabed types.

The installation procedures involve the deployment of anchors using GPS and DP (Dynamic Positioning) systems on vessels, followed by the laying of mooring lines using winches and guide sheaves. Maintenance includes periodic ROV inspections and the use of acoustic monitoring to detect line tension and potential wear or damage.

- ✓ **Weather adaptation and Environmental Sensitivity**: The Beatrice wind farm off the coast of Scotland has provided insights into designing mooring systems that can withstand severe North Atlantic storms.

Early projects like those in the North Sea highlighted the impact of mooring systems on benthic ecosystems. Newer projects now include comprehensive environmental impact assessments pre-deployment.

- ✓ **In Japan, synthetic fiber ropes are being applied with new materials and a safety factor of 1.5 times compared to chains for mooring lines is specified**. It would be desirable to set safety rates corresponding to each material.

5.2.3.2. *Safety Requirements*

- ✓ **Earthquakes and tsunamis need to be considered at the maximum levels that have occurred in the past in each country.** The impact of earthquakes, tsunamis and tropical storms such as hurricanes and typhoons, needs to be adapted to the actual conditions of each country.
- ✓ **It is recommended that calculation methods and formulae for the assessment of seismic events to be internationally standardised**. So that each country can handle its differences by using different input values to the calculation formulae.
- ✓ **Given Japan's geographical and environmental conditions, including seismic activity, its regulatory frameworks for FOW must be adaptable and resilient**. Considering technical regulations from the maritime and navigation sectors, as demonstrated by European and North American standards bodies, can help address these challenges effectively while ensuring the safety and reliability of offshore wind installations.

6. ACCREDITATION FOR CONFORMITY ASSESSMENT BODIES AND REGISTRATION FOR CONFORMITY VERIFICATION BODIES IN JAPAN

In this Chapter, the accreditation and registration system for bodies that examine conformity to technical standards will be discussed. Details of the examination regarding technical standards and third-party certification procedures have been discussed in Chapter 3.4.

6.1. Accreditation of conformity assessment bodies

A third-party certification body is accredited by the Japan Accreditation Board (JAB) based on ISO/IEC17065 (JIS Q 17065). JAB is a member of the International Laboratory Accreditation Cooperation (ILAC), an international organization of accreditation bodies for testing and inspection laboratories and has agreed to the ILAC Arrangement.

JAB has established "Sectoral Guidelines on 'Criteria for Accreditation' - Wind Power Generation Systems: Wind Farms, Projects" [58] as guidelines applicable to product certification bodies accredited under JIS Q 17065:2012 (ISO/IEC 17065IDT) for the certification of wind power generation systems. According to this guideline, the evaluation method is based on JIS C 1400-22:2014, which is equivalent to IEC 61400-22:2010 Ed. 1.0, and the method specified by the "Site Conformity Assessment Methodology for Wind Power Generation" of the Japan Electrical Manufacturers' Association (JEMA). This is because IEC 61400-22 has withdrawn and been replaced by IECRE but the JIS standard has not been abolished. In addition to JIS and international standards, laws and ministerial ordinances, their interpretations, and the JSCE guidelines are listed as criteria for assessing conformity. Currently, two organizations are accredited as third-party certification bodies as below:

- Nippon Kaiji Kyokai (Class NK)
- Bureau Veritas Japan K.K.

6.2. Conformity verification body under the Electricity Business Act

Previously, after obtaining Wind farm certification from a third-party certification body, METI conducted an examination by an expert meeting for conformity to technical standards. From March 2023, the examination has been carried out by a conformity verification body, scrapping the examination by an expert meeting.

In March 2023, METI published "Guidelines for verification of applications and notifications for registered conformity verification bodies" [59], and reviewed requirements including operational structure, citation standards, confirmation methods, and standard processing periods before registering.

Currently, the following two organizations are registered by METI.

- Nippon Kaiji Kyokai (Class NK)
- Bureau Veritas Japan K.K.

6.3. Verification body under the Port and Harbour Act

Based on Article 56-2-3 of the Ports and Harbors Act and Article 28-4 of the Ordinance for Enforcement of the Ports and Harbors Act, MLIT registers a verification body after examining the requirements.

Currently, the Coastal Development Institute of Technology (CDIT) is the only registered verification body that conducts verification process for offshore wind in practice.

6.4. Classification society under the Ship Safety Act

Classification societies under the Ship Safety Act are registered by MLIT after its examining the requirements of Article 25-47 of the Act. Based on the Ship Safety Act and the Act on the Prevention of Marine Pollution and Maritime Disasters, MLIT receives an application for registration as a ship inspection organization and approval of inspection business regulations, conducts a document review, on-site inspection, etc., and registers the organization.

Currently, Class NK is the only classification society that conducts classification survey of FOW in Japan.

[58] Japan Accreditation Board, "Sector-specific guidelines on "Criteria for Certification -Wind Power Systems: Wind Farms, Projects- JAB PD366:2024" '(Revised on January 19, 2024) https://www.jab.or.jp/cms/uploads/PD3662024V3_6c57bfbb0b.pdf
[59] Director-General for Technical Supervision and Security, Minister's Secretariat, METI, "Confirmation Procedure for Application, Notification, etc. for Registration of Registered Conformity Verification Bodies" (March 20, 2023) https://www.meti.go.jp/policy/safety_security/industrial_safety/law/files/tekigouseikikann_kakuninyouryou.pdf

7. ACCREDITATION PROCEDURES AND CERTIFICATION SYSTEM FOR CONFORMITY IN THE EU

7.1. Certification system and accreditation in the EU

Conformity assessment bodies seeking accreditation in the EU undergo evaluations aligning with EA-1/17, which contains rules and procedures related to accreditation within the European cooperation for Accreditation (EA) framework. Accreditation procedures align with EA-1/17, and certification systems like IECRE are recognized.

The Accreditation procedure for Conformity Assessment includes:

- IECRE (International Electrotechnical Commission System for Certification to Standards Relating to Equipment for Use in Renewable Energy Applications): EU conformity assessment bodies may participate in the IECRE certification system, enhancing global acceptance.
- National Accreditation Bodies (NABs): Each EU member state operates a National Accreditation Body, adhering to EU standards. NABs assess and accredit conformity assessment bodies to ensure competence in evaluating adherence to standards.

Under IECRE system, a certification body that is accredited to ISO/IEC standards operates within a structured framework that ensures they meet the global criteria for conformity assessment. The summary of the process includes the following steps:

1) **Accreditation Standards**: The primary standards for certification bodies include ISO/IEC 17011 for management systems certification, ISO/IEC 17024 for certification of persons, and ISO/IEC 17065 for product certification.
2) **Accreditation Process**: A certification body undergoes a rigorous assessment by an accreditation body to ensure compliance with the relevant ISO/IEC standards
3) **Ongoing Surveillance**: Accredited certification bodies are subject to regular surveillance audits by their accreditation body to ensure ongoing compliance and to address any potential issues.
4) **Mutual Recognition**: Through arrangements like the International Accreditation Forum (IAF) Multilateral Recognition Arrangement (MLA), accreditations granted in one country are recognized in others.
5) **Compliance and Integrity**: Accredited certification bodies must adhere to ethical guidelines and operate in a manner that maintains trust in the certification process. Overall, the IECRE system ensures that certified products, personnel, or management systems meet international standards and are consistent, reliable, and recognized globally.

In addition, ISO/IEC 17011 standard specifies requirements for the competence and impartiality of accreditation bodies that assess and accredit conformity assessment bodies. It covers the overall process of accreditation including handling of complaints and appeals.

EC Regulation 765/2008 [60] mandates that each EU Member State must appoint a single national accreditation body that operates in a non-profit manner, is financially stable, and capable of carrying out its responsibilities effectively. The aim is to ensure that products marketed within the EU meet applicable standards and thus can be traded freely across the EU.

Each EU member country operates therefore a National Accreditation Body, adhering to EU standards. NABs assess and accredit conformity assessment bodies to ensure competence in evaluating adherence to standards. Key accreditation bodies in the EU include Deutsche Akkreditierungsstelle (DAkkS) in Germany, COFRAC in France, ENAC in Spain and ACCREDIA in Italy.

7.1.1. Certification bodies in the EU

The Accreditation Procedures for Conformity Assessment through EA ensures the mutual recognition of accreditation activities across Europe. EA offers certification schemes for conformity assessment bodies. Certification under EA schemes signify adherence to recognized European standards.

System for Conformity Assessment in the EU involves assessing products, processes, and services against relevant standards. Accredited conformity assessment bodies play a crucial role in this process.

The German Accreditation Body (DAkkS) provides accreditation services for conformity assessment

[60] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32008R0765

bodies involved in testing and certification related to floating offshore wind turbines. It ensures that these bodies meet internationally recognized standards for competence and impartiality.

The Germanischer Lloyd (GL) Certification GmbH is a prominent certification body in Germany specializing in renewable energy projects, including offshore wind. It offers certification services for floating offshore wind turbines to verify compliance with technical requirements and safety standards.

In France, the French Accreditation Committee (COFRAC) oversees the accreditation of conformity assessment bodies. Accredited bodies adhere to rigorous criteria to ensure the reliability and integrity of their services. In Spain, ENAC is the Spanish Accreditation Body and ACCREDIA in Italy.

Third-party certification entities such as Bureau Veritas, a global leader in testing, inspection, and certification services, offer certification for floating offshore wind projects in France. They assess compliance with technical specifications, safety standards, and environmental regulations. Bureau Veritas is also present in Spain and Italy. Other recognised third-party societies working in Europe are DNV, Lloyds and TUV.

In Italy RINA, a global provider of testing, inspection, and certification services headquartered in Italy, offer certification for floating offshore wind projects. RINA recently issued a new guide for the certification of floating offshore wind turbine installations, emphasizing the latest technological advancements in the field and supporting the sustainable development of offshore wind power.

The certification standards and guidelines provided by DNV and Bureau Veritas are internationally recognized and applied in various countries. DNV(GL)-ST-0119 and DNV(GL)-SE-0422 standards provide a framework for designing and certifying floating wind turbine structures and are applicable to complete wind farms, individual turbines, and their components.

DNV updates its standard for floating wind turbine structures to allow for cost reduction and optimization. The main change in the recent update includes a completely revised section on floating stability, allowing the industry to further optimize floating wind turbine structures while maintaining a sufficient level of safety.

Bureau Veritas' NI572 standard addresses the classification and certification of floating platforms for offshore wind turbines, aiming to ensure the structural integrity and operational efficiency of floating wind projects[61].

The certification standards and guidelines provided by DNV and Bureau Veritas are internationally recognized and applied in various countries, The international recognition of these independent bodies facilitate the global exchange of technology and promotes the adoption of best practices in the floating wind energy sector.

7.1.2. Certification practices for conformity assessment

Conformity assessment in the EU member states involves thorough inspection and evaluation of floating offshore wind turbines at various stages of the project lifecycle to verify compliance with regulatory requirements and industry standards. This assessment covers design verification, manufacturing processes, installation procedures, and ongoing operation and maintenance practices.

For offshore wind energy projects within the EU, certification bodies specifically tailor conformity assessments to meet the sector's unique demands and regulatory requirements. The four main areas of conformity assessment as developed by certification bodies in the EU are as follows:

- **Calibration**: This involves ensuring that all measurement instruments used throughout the project—from wind speed sensors to electrical output gauges—are calibrated accurately against recognized standards.
- **Testing**: Includes a range of tests to verify the structural integrity and functional performance of turbine components, from blades to nacelles, under various operational and environmental conditions.
- **Certification of Equipment**: Equipment certification is paramount, particularly for turbines, substations, and support structures.
- **Project Certification**: Encompasses a comprehensive assessment of the entire project lifecycle, from design and manufacture to installation and operation. International recognition

7.1.3. International recognition

International recognition of conformity assessment bodies facilitates global trade and cooperation in the renewable energy sector, including offshore wind energy projects. One of the key mechanisms for achieving this recognition is through **Mutual Recognition Agreements (MRAs)**.

MRAs between countries or regions allow for the recognition of conformity assessment results (such as testing, certification, and inspection) performed by bodies in one country by the regulatory authorities in another. This mutual recognition helps streamline the process of bringing products and

[61] BV NI572 mostly refers to other BV standards including IEC, ISO, EN, IMO, API, AISC, AWS, ASTM and NORSOK standards.

services to new markets and ensures compliance with local standards and regulations.

In general terms, the most important elements that can be facilitated by international recognition of conformity assessment bodies are: 1) Trade, 2) Standardization and Harmonization, 3) Enhancement of Cooperation and 4) Economic Efficiency.

Regarding the current state of MRAs between the EU and Japan, [62] it covers various sectors, potentially including aspects relevant to offshore wind energy, such as electrical products and electronic equipment which can relate indirectly to components used within offshore wind projects.

The EU-Japan MRA covers telecommunications equipment, electrical products, and good manufacturing practices (GMP) for pharmaceuticals.

While not specifically tailored to offshore wind projects, the principles and framework set by this MRA can facilitate the acceptance of conformity assessments for components that are part of such projects.

For components used in offshore wind projects that fall under the categories covered by the EU-Japan MRA, manufacturers could benefit from reduced certification times and easier market access in both regions. This could be particularly relevant for advanced electronic and electrical components used in wind turbines and monitoring systems.

The MRA between the EU and Japan also encourages ongoing regulatory cooperation and dialogue, which can help adapt and update the agreement as new technologies and standards emerge, particularly those relevant to renewable energy sectors.

[62] EU-Japan mutual recognition agreement (MRA):Council 20017747/EC, last update 17/07/2018

8. BENCHMARKING EU-JAPAN ON ACCREDITATION AND CONFORMITY PROCEDURES

8.1. Comparison between Japanese and European practices

In order to facilitate comparison between the EU and Japan, the table below summarizes for each indicator (vertical column on the left) the key statements tackled in Chapter 6 and Chapter 7, highlighting differences in red and similarities in blue.

A more extensive analysis comparing the situation in Japan and the EU is to be found further down, after the recapitulative table.

Table 11 Comparison on FOW accreditation procedures, certification system and conformity assessment

Indicator	The EU	Japan
Certification System and Accreditation	• Conformity assessment according to EA-1/17 and IECRE certification system (see 7.1) • IECRE system ensures that certified products meet international standards, are consistent, reliable, and recognized globally (IAF and MLA) (see 7.1) • EC Regulation 765/2008 mandates each EU Member State to operate a National Accreditation Body (NABs) adhering to EU standards (see 7.1) • NABs ensure competence of conformity assessment bodies involved in FOW certification (see 7.1) • Certification body undergoes a rigorous assessment to ensure compliance with the relevant ISO/IEC standards ISO/IEC 17011 and ISO/IEC 17065 (see 7.1)	• Requires technical review under the Electricity Business Act, Port and Harbour Act and Ship Safety Act (See 3.1.1,3.1.2 and 3.1.3) • Third-party certification bodies are accredited by the Japan Accreditation Board (JAB) (See 6.1) • Site conformity assessments under the Electricity Business Act are carried out by a registered conformity verification body, registered by METI (See 6.2) • The assessment of mooring facilities under the Port and Harbour Act are carried out by a registered verification body, registered by MLIT (See 6.3) • Classification inspections under the Ship Safety Act are carried out by a registered classification society, registered by MLIT (See 6.4)
Certification bodies and International Recognition	• Third-party independent entities (GL, BV, DNV) issue conformity certificates indicating the project meets all required standards and regulations (see 7.1.1) • MRAs between countries or regions allow recognition of conformity assessment results performed by bodies in one country by the regulatory authorities in another (see 7.1.3). • Under certain categories covered by the EU-Japan MRA, manufacturers can benefit from reduced certification times and easier market access (see 7.1.3).	• ClassNK is a third-party certification body, a registered conformity verification body, registered classification society and members of IACS. (See 6.1,6.2, and 6.4) • ClassNK has track records in Japan but is not registered with IECRE (See 3.2.2)
Accreditation Procedures for Conformity Assessment	• ISO/IEC 17011 accreditation for conformity assessment (see 7.1) • FOWT Conformity assessment is carried out by third-party bodies (CABs) accredited by NABs (see 8.1) • Accreditation by these bodies is crucial as it represents the last level of control in the conformity assessment chain, providing competence recognized by government (see 8.1)	• Requires technical review under the Electricity Business Act, Port and Harbour Act and Ship Safety Act (See 3.1.1,3.1.2 and 3.1.3) • Regarding certification, Japan refers to IECRE, but JIS C 1400-22:2014 corresponding to the withdrawn IEC61400-22:2010 remains valid. (See 3.2.2 and 6.1)

Certification system and accreditation

In EU member states, the FOW accreditation procedure aligns with EA-1/17 and with rules under the European Cooperation for Accreditation (EA) framework. It is based on IECRE system, a certification body accredited to ISO/IEC standards ensuring that certified products are subject to regular surveillance audits, granted in one country and recognized in others through mutual recognition.

EC Regulation 765/2008 mandates each member state to appoint a single accreditation body NAB adhering to EU standards, operating in a non-profit manner and ensuring competence of conformity assessment bodies in certification. IECRE system ensures that the certification procedures, i.e. guidelines to reach Project Certification or Project Classification, comply with the global criteria for conformity assessment including accreditation standards and process, ongoing surveillance, and mutual recognition. The process is well explained in proven IECRE 0D502 and/or Classification Rules.

IEC has developed IEC 61400 series, which covers the entire floating wind turbines and is largely used by the industry, On-site evaluations include a comprehensive review of assessment procedures, staff competencies, and quality management systems to assess the conformity with ISO/IEC 17011 standards.

Nevertheless, the standards applicable to floating foundations & mooring have not reached full maturity. FOW is a field under development, the technology of which is not yet fully established and international standardisation needs to be accelerated. Recognised Classification and Certification societies demonstrate in this regard agility for integrating the regulatory requirements and continuous feedback from the industry into their rules.

In Japan, IECRE is not applied and JIS C standards based on the obsolete IEC61400-22:2010 is still used. In addition, they are required to evaluate the conformity of the technical regulations as stipulated by laws.

Accreditation and certification require in Japan technical review under the Electricity Business Act, Port and Harbour Act and Ship Safety Act. The site conformity assessments under the Electricity Business Act are carried out by a conformity verification body registered by METI. The assessment of mooring facilities under the Port and Harbour Act are carried out by a verification body also registered by MLIT.

In Japan, third-party certification bodies accredited by a Japan Accreditation Board (JAB) are actively involved in the certification system. JAB has established "Sectoral Guidelines on Criteria for Accreditation Wind Power Generation Systems: Wind Farms Projects" as guidelines applicable to product certification bodies for the certification of wind power generation systems, but the obsolete JIS C1400-22, instead of IECRE, is referenced.

Applying IECRE certification system could help to improve FOW accreditation and certification procedures in Japan and is therefore recommended. This is because international mutual recognition will be accelerated if third-party certification bodies accredited by JAB are also registered with IECRE.

Certification bodies and international recognition

Most coastal EU member states have certification bodies specializing in renewable energy projects, including offshore wind, offering certification services to verify compliance with technical requirements and safety standards. They cover the main areas for conformity assessment including calibration, testing, certification of equipment and project certification.

Third-party certification societies offer certification for floating offshore wind projects. They assess compliance with technical specifications, safety standards, and environmental regulations. These independent accredited entities with proven experience in offshore wind projects guarantee objectivity and the highest standards of assessment.

In Japan, ClassNK, a third-party independent body, conducts technical standards conformity assessment of FOW. It is accredited by JAB and is under mutual recognition system. The classification inspections under the Ship Safety Act are carried out by ClassNK, which also acts as a classification society (Recognized Organization) registered by MLIT. However, it is not registered as an IECRE certification body.

Both the European and Japanese experiences demonstrate that bilateral or multilateral mutual recognition agreements with other countries allow for the acceptance of conformity statements from international partners, reducing redundancy and fostering global cooperation.

Some components used in FOW projects, like telecommunications terminal and radio equipment or electrical products, can fall under categories covered by the existing EU-Japan Mutual Recognition Agreement (MRA) which may be relevant to streamline the certification process.

It would be desirable registering ClassNK as an IECRE certification body. The registration of third-party certification bodies accredited by JAB with IECRE would accelerate international mutual recognition. These third-party certification bodies will then become globally recognized certification bodies.

Concerning international recognition, mutual recognition should be common worldwide, but the MRA with EU ahead of others has especial interest for FOW development, in particular concerning materials and construction methods.

Accreditation procedures for Conformity assessment

In the EU, the accreditation process is managed by independent bodies that are separate from technical regulation and standardisation authorities. This confers impartiality and credibility to the bodies responsible for carrying out conformity assessment. National Accreditation Bodies (NABs) assess and accredit Conformity Assessment Bodies (CABs) to ensure competence in evaluating adherence to standards. Accreditation by NABs is crucial as it represents the last level of control in the conformity assessment chain.

Accreditation aims to ensure that the organizations performing conformity assessment are competent and reliable. Conformity assessment is according to EA-1/17 and IECRE certification system.

In Japan, CABs accredited by the JAB are involved in technical standards conformity assessment. At the same time, there is a framework under which an organization registered by the government verifies conformity to technical standards and CABs conduct the assessment as a government-registered body.

Japan refers to IECRE but is currently applying for certification JIS C 1400-22:2014 corresponding to the withdrawn IEC61400-22:2010 which remains valid. The system should be common worldwide and JIS C 1400-22:2014 should be abolished.

It seems also clear from both the European and Japanese experience that when conformity assessment is conducted by independent accredited bodies with proven experience in offshore wind projects, this helps to ensure objectivity and high standards of assessment.

8.2. Best practices identified that may be relevant for Japan

8.2.1. Quality Accreditation

- ✓ **Independent Bodies**: Ensure that accreditation is conducted by independent bodies that are not involved in technical regulation or standardization. This independence is crucial for maintaining objectivity and credibility.
- ✓ **On-Site Evaluations**: Implement rigorous on-site evaluations to assess the conformity of organizations with ISO/IEC 17011 standards. These evaluations should include a comprehensive review of assessment procedures, staff competencies, and quality management systems.
- ✓ **International Peer Reviews**: Regularly engage in international peer reviews to benchmark practices against global standards and incorporate best practices from other regions. This helps maintain high levels of trust and credibility in the accreditation process.
- ✓ **Continuous Improvement**: Foster a culture of continuous improvement within accreditation bodies and the organizations they accredit. Regular training, updates to procedures, and adoption of new technologies are essential for staying current with industry advancements.
- ✓ **Transparency and Documentation**: Maintain transparent and well-documented accreditation processes. Clear records of assessment procedures, findings, and decisions should be readily available to demonstrate compliance and accountability.

8.2.2. Independent Assessment and Mutual Recognition

- ✓ **Independent Accredited Bodies**: Ensure that conformity assessments are conducted by independent accredited societies with proven experience in offshore wind projects. This guarantees objectivity and the highest standards of assessment.
- ✓ **Mutual Recognition Agreements**: Establish bilateral or multilateral mutual recognition agreements with other countries that have IECRE accredited certification bodies. This will allow for the acceptance of conformity statements from international partners, reducing redundancy and fostering global cooperation.
- ✓ **Capacity Building and Training**: Invest in capacity building and training for local certification bodies to ensure they meet international standards. This includes ongoing professional development and exchange programs with EU counterparts to stay updated on best practices and technological advancements.

9. CONCLUSIONS AND RECOMMENDATIONS

FOW is a developing field where construction plans are being drawn up in various countries since it is currently one of the most promising alternatives in the field of electricity production with renewable energies.

Thanks to stronger and more frequent wind speeds further offshore, floating wind turbines could have a higher capacity factor than wind turbines located closer to shore, thus generating more energy production.

Europe is currently leading the global floating wind energy market with 208 MW of operational capacity and according to the GWEC, is expected to be the larger contributor to the FOW increase over the next 10 years.

However, the technology is not fully established, and international standardization efforts need to accelerate.

In both the EU and internationally, FOW standardization should be actively promoted, with robust involvement from Japan, which would benefit all stakeholders. There is no single, universally accepted set of standards specific to floating wind turbines. EU countries generally adopt IEC and standards integrated in EN, ISO and IECRE standards. IEC 61400-3-1, IEC 61400-3-2 and IECRE OD501 - OD502 are the main international standards and certification schemes for FOW turbine structures.

In Japan, the response to IEC is almost the same as for the EU. The government provides detailed explanations and guidelines regarding technical regulations, in which standards are also referred to, and it is mandatory to conform to them.

The standards are established based on the discussion of expert groups. NSB's activities are also similar, while translation in Japanese and incorporation in JIS standards take time.

For Japan, the experience exemplified by the European standardisation and regulation bodies together with industry technology expertise and best practices, could offer valuable insights and potential pathways for advancing its own regulatory frameworks and industry standards.There are currently numerous standards, codes and technical recommendations of possible application in FOW turbines to evaluate general aspects of the installations or specific components.

Throughout the present study, some of the most relevant ones for the main application areas have been discussed and finally included in an extended, but still indicative and non-exhaustive, list in **Annex I**. A detailed list of the major IEC wind power generation standards is also included in **Annex II**.

Japan´s offshore wind power potential, calculated for those sea areas for which both wind speeds and water depth data are available, is shown in **Annex III**.

The present Study has been developed in accordance with above statements, and the most relevant recommendations are set out below:

1. **The external site conditions should be assessed according to IEC 61400-3-1 and additional requirements given in 61400-3-2.**

Specific standards and guidelines for site investigations vary depending on the country. EU best practices include survey techniques, geophysical and geotechnical integration, and advanced numerical modelling.

Advanced technologies such as multibeam echo sounders, side-scan sonar, seabed coring systems, integrating geophysical and geotechnical data and numerical modelling, facilitate assessing seabed and metocean characteristics for the installation of floating offshore wind turbines.

Radar interference caused by FOW turbines shall be assessed for site investigations. Mitigation techniques involve several technologies including Radar Absorbent Material (RAM) and radar blanking and filtering.

2. **Load analysis for FOW should incorporate validated aero-hydro-servo-elastic software and time-domain coupled analysis.**

The aero-hydro-servo-elastic software to be used in the floater design should be validated with scaled model tank testing, other numeric software and/or available measurements of FOW turbine with similar characteristics.

A coupled analysis of the floater and turbine in time domain in operational phases of the turbine should be carried out. The stress ranges caused by wind and wave loading during fault conditions should be established by time domain methods for fatigue load analysis.

3. **The foundation system for FOW platforms needs further development and standardization.**

Most of the components of floating wind turbines are the same as those for fixed-bottom wind turbines, but the foundation's components are different, including the pre-installed mooring and anchoring system that keeps the floater in place. The foundation system of floating installations needs further maturity and design standardisation is still lacking, making it difficult to develop safe and affordable designs It is the element that requires the most optimisation, not only to reduce the cost but also to reduce the risk of breakage.

Four basic prototypes of floating structure and mooring-anchoring system as considered in IEC TS 61400-3-2 for design standard, ISO 19901-7 for offshore mooring and DNV, API and ABS standards for fatigue analysis can be considered.

Best practices for mooring and anchoring include Real-Time Monitoring Systems, Mooring Lines, Anchoring Solutions and Weather adaptation. Synthetic fiber ropes are being applied with new materials both in EU and Japan, and in Japan a safety factor of 1.5 times compared to chains for mooring lines is specified. It would be desirable to set safety rates corresponding to each material.

4. **Material standards should be considered essential for FOW installations, emphasizing steel and concrete.**

Steel standards are based on Eurocodes and EU Machinery DIR mainly grouped within EN 10025 while EN, ISO and DNV standards provide guidelines for concrete offshore structures.

Selecting high-quality steel materials suitable for offshore environment is key. This includes corrosion-resistant steels to ensure long-term durability and performance. Regular maintenance and inspection of steel components are also essential.

European experience suggests the use of high-performance concrete mixes tailored to the specific requirements of floating offshore applications. These mixes often incorporate additives and reinforcements to enhance durability, resistance to seawater corrosion, and mechanical properties.

Synthetic fiber ropes are increasingly used due to their lightweight and high strength, especially suitable for deep water applications.

In Japan, for materials linked to power generation facilities, the Ship Structure Regulations should be considered, and materials listed in the Guidelines for Design and Construction of Concrete FOWP Facilities need to be applied.

It is advisable to inform other certification bodies on materials certified by national IECRE certification bodies or accredited as third-party. This will facilitate their application in other countries through mutual recognition system.

5. **The effect of seismic conditions on FOW support structure design should be considered on a project-specific basis in a seismically active area.**

Impact can be a function of ground motions on the anchors or by associated sudden wave loading as in tsunamis. They need to be considered at the maximum levels that have occurred in the past in each country.

A seismic event may also lead to liquefaction of the seabed, then a full assessment of liquefaction shall be performed. According to IEC 61400-1, a seismic event with a return period of 475 years should be assessed.

Japan´s environmental and seismic conditions make it advisable for its regulatory frameworks for FOW to be adaptable and resilient.

Consideration of technical regulations from the maritime and navigation sectors, as demonstrated by European and North American standards bodies, can help address these challenges effectively while ensuring the safety and reliability of offshore wind installations.

6. **Quality accreditation for conformity assessment in FOW energy projects should be applied to ensure reliability, safety, and performance of these innovative energy systems.**

EU Regulation 765/2008 set out requirements for accreditation in the EU while ISO/IEC 17011, provides a structured framework for evaluating and accrediting organizations that assess compliance with established standards.

The accreditation process is managed by independent bodies that are separate from technical regulation and standardisation authorities. On-site evaluations, international peer reviews and Mutual Recognition Agreements are also key components for maintaining high standards in accreditation practices.

7. **The complexity, site-specificity and evolving technology of the floating systems need to be addressed.**

Floating wind turbines involve complex interactions between the turbine structure, mooring systems, and the floating platform. Floating offshore wind farms encounter unique environmental conditions depending on location, more evident in Japan´s case.

Accreditation, Certification and Conformity (ACC) assessment procedures need to address these complexities and variations ensuring all components are assessed thoroughly and the project is suitable for the specific site.

ACC procedures need also to be adaptable to keep pace with rapid advancements in design, materials, construction and installation and O&M methods of the floating systems.

8. **The involvement of third-party certification bodies underscores the global reach and credibility of the regulatory bodies.**

These independent entities bring research capacity, industry knowledge, and best practices developed in close collaboration with global stakeholders. Their contributions ensure that standards remain at the forefront of technological advancements and industry innovations.

Japan can leverage the expertise of third-party certification bodies, drawing upon their independent research capacity, industry knowledge, and best practices to ensure the quality and safety of FOW installations. Collaborating with global certification bodies such as DNV, TÜV, BV, LR, ABS and others can enhance the reliability of Japan's regulatory frameworks, instilling confidence among investors and stakeholders.

9. **EU and Japan should prioritise the following Research and Development areas for FOW project success:**

Standardisation and regulation: Establishing clear frameworks to streamline project development and ensure safety.

Performance improvements: Technological maturity of foundations, advanced mooring systems, improved floating platform stability and wind resource characterisation in deeper waters.

Grid integration: Developing advanced grid integration solutions to handle the variable nature of wind power and ensure efficient transmission.

Cost reduction: Economical turbine and platform designs, availability of a nearby port with adequate loading and assembly infrastructures and establishing a robust domestic supply chain for critical components of FOW projects.

Environmental considerations: Environmental impact assessment and decommissioning strategies regarding end-of-life process.

10. **The experience exemplified by the EU and Member States on standardisation and regulation, industry technology and best practices, can provide valuable insights for further progress of FOW in Japan**

In Japan, adequate FOW development requires specific legislative and regulatory activity, technological and industrial capacity, and availability of potential development areas.

The participation of Japan in IEC, IECRE and ISO is well established, but it should be consolidated by applying IECRE certification system. Specific areas of high potential for FOW development have been identified (EEZ) and ambitious national targets have been set, both in terms of capacity and supply chain.

In this favourable context for the development of FOW in Japan, the extensive experience linked to the European activity on standardisation and regulation procedures, robust technical assessments, industry technology expertise and best practices, can be of great value in strengthening this development. This would justify close cooperation in this field between the EU and Japan in the coming years.

ANNEX I: FOW RELEVANT STANDARDS AND CODES IN EU

	Relevant standards and guidelines of possible application to floating offshore wind turbines (*)
Design and general requirements	- ISO 19901-2: Seismic Design Procedures and Criteria - ISO 19901-7: Stationkeeping Systems for Floating Offshore Structures and Mobile Offshore Units - ISO 19904-1: Floating offshore structures; Ship-shaped, semi-submersible, spar and shallow-draught cylindrical structures - IEC 61400-1: Design requirements for wind turbines - IEC 61400-3-1: Design requirements for fixed offshore wind turbines - IEC TS 61400-3-2: Design requirements for floating offshore wind turbines (Technical Specification) - IEC 61400-4: Design requirements for wind turbine gearboxes - IEC 61400-5: Wind Turbine Blades - IEC 61400-6: Tower and foundation design requirements. - IEC 61400-11-2: Acoustic noise measurement techniques - IEC 61400-12-1: Power performance measurements of electricity producing wind turbines - IEC 61400-13: Measurement of mechanical loads on wind turbines - IEC 61400-14: Declaration of sound power level and tonality values - IEC 61400-21-2: Measurement and assessment of electrical characteristics - IEC 61400-22: Conformity Testing and Certification (Withdrawn) - IEC 61400-23: Full scale structural testing of rotor blades - IEC 61400-24: Lightning protection - IEC 61400-25-(1-6) Communication - IEC 61400-26-1: Availability for wind energy generation systems - IEC 61400-27-(1-2): Electrical simulation models - IEC 61400-50: Wind measurement - IEC 61400-50-1: Wind measurements application of meteorological mast, nacelle & spinner mounted instruments - IEC 61400-50-2: Wind Measurement - Application of Ground Mounted Remote Sensing Technolo - IEC TS 61400-50-4: Use of floating lidars for wind measurements (in progress) - IEC 60183: Guidance for the selection of high-voltage A.C. cable systems - IEC 60502: Test methods and Requirements; power cables from 1 kV - IEC 60840: Test methods and Requirements; p. cables above 30 kV - IEC 62067: Test methods and Requirements; power cables above 150 kV - IEC 63026: Test methods and Requirements; submarine power cables - CEN/TS 17083: Design, construction, and installation of FOWT - DNV(GL)-ST-0119: for design, certification, and assessment of FOWT - DNV(GL)RU-OU-0512: for installation of FOWT installations - DNV(GL)-RU-OU-0571: for floating infrastructure installations - IECRE OD-501: Type and Component Certification Scheme - IECRE OD-502: Project Certification Scheme - IECRE OD-502-1: Conformity assessment and certification of Site Assessment by RECB - API RP 2F and API RP 2SK: Planning, designing and construction of FO systems - API RP 2RD: Recommendations for design of floating production systems - CIGRE TB 490 and CIGRE TB 863: for testing of submarine cables - LR: Guidance Notes for Offshore Wind Farm Project Certification - LR: Recommended Practices for Floating Offshore Wind Turbine Support Structures - LR: Rules for Manufacture, Testing and Certification of Materials - BV NI572: Classification & Certification of FOWT, mostly refers to other BV standards including IEC, ISO, EN, IMO, API, AISC, AWS, ASTM and NORSOK standards) - ABS Guide for Building and Classing Floating Offshore Wind Turbines (January 2024)
Concrete Structures	- EN 1992: Concrete structure requirements - EN 1992-1: Design of concrete structures - DNV(GL)-ST-C502: Offshore concrete structures - DNV(GL)-ST-0119: Guidelines for the design of floating concrete structures for offshore WT - EN 206-1: Specification requirements for concrete
Steel Structures	- EN 10025: Hot rolled products of structural steel - EN 1993-1 Design of steel structures - EN 1993-1-10: Design of steel structures. Material toughness and through-thickness properties. - EN 13173: Cathodic protection for steel offshore floating structures - BS EN 1090: Steel structures and aluminium structures relevant to FOWT - DNV-OS-B101: Metalic materials

Relevant standards and guidelines of possible application to floating offshore wind turbines (*)	
Mooring and foundations	- DNV(GL)-ST-0054: Transportation and installation of offshore wind turbines - DNV(GL)-ST-0126: Support structures for wind turbines - DNV(GL)-ST-0437: Load and site conditions for wind turbines - DNV(GL)-RP-C203: Recommended practice for Fatigue Design of offshore steel structures - DNV-OS-C101: Design of offshore steel structures (LRFD method) - DNV-RP-C202: Buckling Strength of Plated Structures - DNV-OS-E301: Design and Installation of Fluke Anchors - API RP 2T: Recommended Practice for Planning, Designing, and Construction Tension Legs Platform - ABS PMS Guide for Position Mooring Systems, - ABS Fiber Notes on the Application of Fiber Rope for Offshore Mooring, - ABS Chain Guide for Certification of Offshore Mooring Chain
Corrosion Control	- NACE SP0108: Corrosion Control of Offshore Structures by Protective Coatings - NACE SP0176: Corrosion Control of Submerged Offshore Structures - NACE SP0387: Cast Galvanic Anodes for Offshore Applications - DIN 50929-3: Corrosion metallic materials. Buried, underwater pipelines, structural comp.
Power Cables	- IEC 60183: Guidance for the selection of high-voltage A.C. cable systems - IEC 60502: Test methods and requirements of power cables (1-30 kV) - IEC 60840: Test methods and requirements of power cables (30-150 kV) - IEC 62067: Test methods and requirements of power cables (150-500 kV) - IEC 63026: Test methods and requirements of submarine power cables (6-60 kV)
Other ISO Standards (Petroleum and natural gas industries)	- ISO 19900: General requirements applicable for offshore floaters - ISO 19901: Specific requirements applicable for offshore floaters - ISO 19901-1: Specific requirements for Metocean design for offshore structures - ISO 10901-3: Specific requirements for offshore structures; Topside structures - ISO10902-4: Specific requirements for offshore structures; Geotechnical and foundation design - ISO 10902-6: Specific requirements for offshore structures; marine operations - ISO 10902-7: Specific requirements for offshore structures; Stationkeeping systems for floating offshore structures and mobile offshore units - ISO 10902-8: Specific requirements for offshore structures; Marine soil investigations - ISO 19902: Fixed steel offshore structures - ISO 19903: Fixed concrete offshore structures - ISO 19904: Floating offshore structures; Requirements and guidance for the structural design and/or assessment of floating offshore platform - ISO 2394: General principles on reliability for structures; Principles of structural assessment - ISO 12473: General principles of cathodic protection in seawater - ISO 12696: Cathodic protection of steel in concrete - ISO 12944: Corrosion protection of steel structures by protective paint systems

(*): -This list of relevant standards is indicative, not exhaustive or complete.

- DNVGL to be renamed by DNV.

ANNEX II: MAJOR INTERNATIONAL AND DOMESTIC STANDARDS FOR WIND POWER GENERATION SYSTEMS

- **IS: International Standards 国際規格**
- **TS: Technical Specification**
- **TR: Technical Report**
- **AMD: Amendment**
- **CSV: Consolidated version**
- **COR: Corrigendum**

IEC				JIS		
Reference	Edition	Publication date	Title	規格番号	発行 年月日	名称
-----	-----	-----	-----	JIS C 1400-0:2023	2023-09-20	風力発電用語 Glossary of terms for wind energy generation systems
IEC 61400-1:2005 /AMD1:2010	Edition 3.0	Withdrawn 2019/2/8	Design requirements	JIS C 1400-1:2017	2017-01-20	設計要件
IEC 61400-1:2019	Edition 4.0	2019-02-08	Design requirements			
IEC 61400-1:2019 /COR1:2019	Edition 4.0	2019-09-16	Corrigendum 1 : Design requirements	JIS C 1400-1:20XX	予定 2024/10	設計要件
IEC 61400-1 /AMD1 ED4	Edition 4.0	Frcst Pub 2025/09	Design requirements			
IEC 61400-2:2013	Edition 3.0	2013-12-12	Small wind turbines	JIS C 1400-2:2020	2020-02-20	小形風車の設計要件
IEC 61400-2:2013 /COR1:2019	Edition 3.0	2019-10-10	Corrigendum 1 Small wind turbines			
IEC 61400-3:2009	Edition 1.0	Withdrawn 2019/4/5	Design requirements for offshore wind turbines	JIS C 1400-3:2014	2014-08-20	洋上風車の設計要件
IEC 61400-3-1:2019	Edition 1.0	2019-04-05	Design requirements for fixed offshore wind turbines	JIS C 1400-3-1:20XX	予定 2025/03	着床式洋上風車の 設計要件
IEC TS 61400-3-2:2019	Edition 1.0	2019-04-05	Design requirements for floating offshore wind turbines			
IEC 61400-3-2	Edition 1.0	Frcst Pub 2024/11	Design requirements for floating offshore wind turbines	JIS C1400-3-2:20XX	予定 20XX	浮体式洋上風車の 設計要件
IEC 61400-4:2012	Edition 1.0	2012-12-04	Design requirements for wind turbine gearboxes			
IEC61400-4	Edition 2.0	Frcst Pub 2024/11	Design requirements for wind turbine gearboxes			
IEC 61400-5:2020	Edition 1.0	2020-06-16	Wind turbine blades			
IEC 61400-6:2020	Edition 1.0	2020-04-21	Tower and foundation design requirements	JIS C 1400-6:20XX	予定 2025/03	風車のタワー及び 基礎の設計要件
IEC 61400-6:2020 /COR1:2020	Edition 1.0	2020-11-24	Corrigendum 1 Tower and foundation design requirements			
IEC 61400-11:2012	Edition 3.0	2012-11-07	Acoustic noise measurement techniques	JIS C 1400-11:2017	2017-01-20	騒音測定方法
IEC 61400-11:2012 /AMD1:2018/COR1:2019	Edition 3.0	2019-10-10	Corrigendum 1 - Amendment 1 - Acoustic noise measurement techniques			
IEC 61400-12:2022	Edition 1.0	2022-09-05	Power performance measurements of electricity producing wind turbines - Overview			

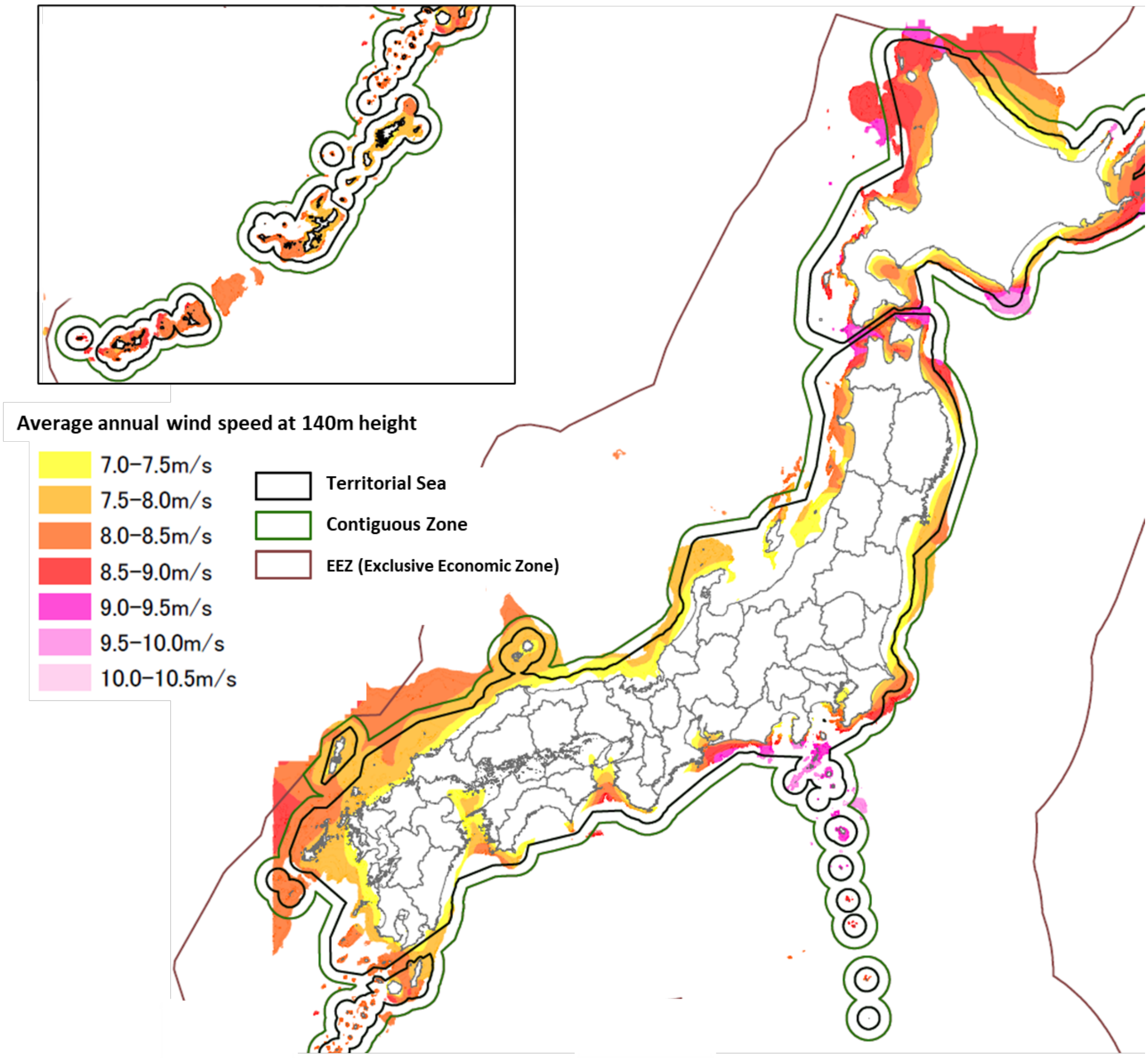
IEC				JIS		
Reference	Edition	Publication date	Title	規格番号	発行 年月日	名称
IEC 61400-12-1:2005	Edition 1.0	Withdrawn 2017/3/3	Power performance measurements of electricity producing wind turbines	JIS C 1400-12-1:2010	2010-06-21	発電用風車の性能試験方法
IEC 61400-12-1:2022	Edition 3.0	2022-09-05	Power performance measurements of electricity producing wind turbines	JIS C 1400-12-1:20XX	予定 2025/03	発電用風車の性能試験方法
IEC 61400-12-2:2022	Edition 2.0	2022-09-05	Power performance of electricity-producing wind turbines based on nacelle anemometry	JIS C 1400-12-2:20XX	予定 2026/03	ナセル風速計による発電用風車の性能計測方法
IEC 61400-12-3:2022	Edition 1.0	2022-08-29	Power performance - Measurement based site calibration			
IEC TR 61400-12-4:2020	Edition 1.0	2020-09-22	Numerical site calibration for power performance testing of wind turbines			
IEC 61400-12-5:2022	Edition 1.0	2022-08-30	Power performance - Assessment of obstacles and terrain			
IEC 61400-12-6:2022	Edition 1.0	2022-08-30	Measurement based nacelle transfer function of electricity producing wind turbines			
IEC 61400-13:2015 +AMD1:2021 CSV	Edition 1.1	2021-12-03	Measurement of mechanical loads			
IEC TS 61400-14:2005	Edition 1.0	2005-03-22	Declaration of apparent sound power level and tonality values			
IEC 61400-21:2001	Edition 1.0	Withdrawn 2008/8/13	Measurement and assessment of power quality characteristics of grid connected wind turbines	JIS C 1400-21:2005	2005-11-20	系統連系風車の電力品質特性の測定及び評価
IEC 61400-21-1:2019	Edition 1.0	2019-05-20	Measurement and assessment of electrical characteristics - Wind turbines			
IEC 61400-21-2:2023	Edition 1.0	2023-03-29	Measurement and assessment of electrical characteristics - Wind power plants			
IEC TR 61400-21-3:2019	Edition 1.0	2019-09-13	Measurement and assessment of electrical characteristics - Wind turbine harmonic model and its application			
IEC 61400-22:2010	Edition 1.0	Withdrawn 2018/08/31	Conformity testing and certification The withdrawal of IEC 61400-22:2010 has become possible with the creation of the IECRE Conformity Assessment (CA) System and the deliverables for the wind sector contained therein.	JIS C 1400-22:2014	2014-08-20	風車の適合性試験及び認証
IEC 61400-23:2014	Edition 1.0	2014-04-08	Full-scale structural testing of rotor blades			
IEC 61400-24:2019	Edition 2.0	2019-07-03	Lightning protection	JIS C 1400-24:2023	2023-01-20	雷保護
IEC61400-24	Edition 3.0	Frcst Pub 2026/09	Lightning protection			
IEC 61400-25-1:2017	Edition 2.0	2017-07-20	Communications for monitoring and control of wind power plants - Overall description of principles and models			

IEC				JIS		
Reference	Edition	Publication date	Title	規格番号	発行 年月日	名称
IEC 61400-25-2:2015	Edition 2.0	2015-06-30	Communications for monitoring and control of wind power plants - Information models			
IEC 61400-25-3:2015	Edition 2.0	2015-06-30	Communications for monitoring and control of wind power plants - Information exchange models			
IEC 61400-25-4:2016	Edition 2.0	2016-11-30	Communications for monitoring and control of wind power plants - Mapping to communication profile			
IEC 61400-25-5:2017	Edition 2.0	2017-09-20	Communications for monitoring and control of wind power plants - Compliance testing			
IEC 61400-25-6:2016	Edition 2.0	2016-12-16	Communications for monitoring and control of wind power plants - Logical node classes and data classes for condition monitoring			
IEC TS 61400-25-71 :2019	Edition 1.0	2019-09-13	Communications for monitoring and control of wind power plants - Configuration description language			
IEC 61400-26-1:2019	Edition 1.0	2019-05-29	Availability for wind energy generation systems			
IEC 61400-27-1:2020	Edition 2.0	2020-07-30	Electrical simulation models - Generic models			
IEC 61400-27-2:2020	Edition 1.0	2020-07-14	Electrical simulation models - Model validation			
IEC TS 61400-29:2023	Edition 1.0	2023-02-07	Marking and lighting of wind turbines			
IEC TS 61400-30:2023	Edition 1.0	2023-09-15	Safety of wind turbine generators - General principles for design			
IEC TS 61400-31:2023	Edition 1.0	2023-11-15	Siting risk assessment			
IEC 61400-50:2022	Edition 1.0	2022-08-30	Wind measurement - Overview			
IEC 61400-50-1:2022	Edition 1.0	2022-11-16	Wind measurement - Application of meteorological mast, nacelle and spinner mounted instruments			
IEC 61400-50-2:2022	Edition 1.0	2022-08-30	Wind measurement - Application of ground-mounted remote sensing technology			
IEC 61400-50-3:2022	Edition 1.0	2022-01-07	Use of nacelle-mounted lidars for wind measurements			
IEC TS 61400-50-4	Edition 1.0	Frcst Pub 2024/12	Use of floating lidars for wind measurements			
IEC TS 61400-50-5	Edition 1.0	Frcst Pub 2026/08	Use of scanning doppler lidars for wind measurements			

ANNEX III: Japan's Offshore Wind Power Potential

This potential is calculated from wind speed and water depth conditions only for those sea areas for which both wind speed and water depth data are available.

- Not a potential for the entire Exclusive Economic Zone (EEZ).
- Sea areas with feasibility difficulty, such as areas with water depths over 1,000m on the marine cable laying route are excluded.



Unit: GW	Fixed-bottom Water depth: less than 50m			Floating - 1 Water depth: 50m or more, less than 100m			Floating - 2 Water depth: 50m or more, less than 200m			Floating -3 Water depth: 50m or more, less than 300m		
	Territorial Sea	Territorial Sea + Contiguous Zone	Territorial Sea + EEZ	Territorial Sea	Territorial Sea + Contiguous Zone	Territorial Sea + EEZ	Territorial Sea	Territorial Sea + Contiguous Zone	Territorial Sea + EEZ	Territorial Sea	Territorial Sea + Contiguous Zone	Territorial Sea + EEZ
Annual average wind speed 7.5m/s or higher	**176**	180	180	351	377	381	747	1,066	1,281	897	1,321	1,621
Annual average wind speed 8.0m/s or higher	81	85	85	165	180	184	381	**542**	733	470	690	**952**
Annual average wind speed 8.5m/s or higher	24	26	26	50	58	61	127	178	229	160	236	300

Source: https://www.renewable-ei.org/en/activities/reports/20231219.php

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