International Renewable Energy Agency

NURTURING OFFSHORE WIND MARKETS

GOOD PRACTICES FOR INTERNATIONAL STANDARDISATION

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Acronyms

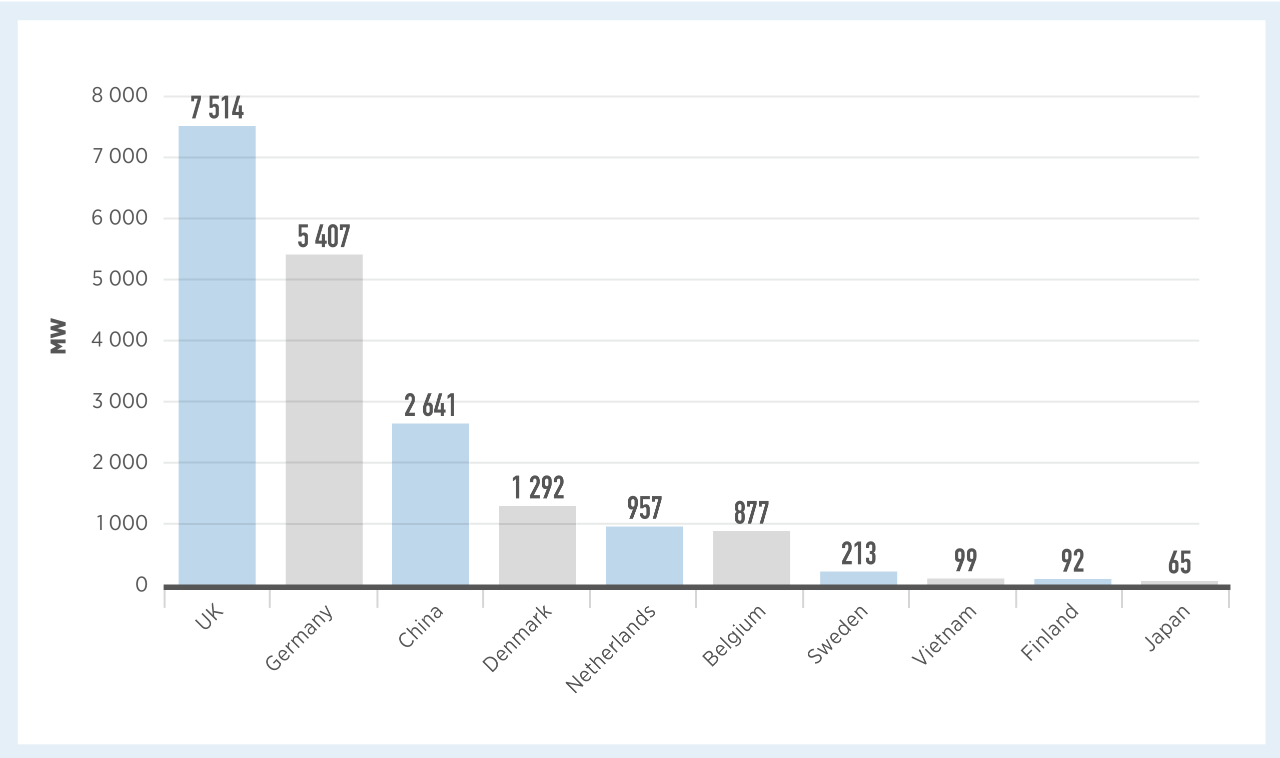
ABS	American Bureau of Shipping
API	American Petroleum Institute
AWEA	American Wind Energy Association
BSH	German Federal Maritime and Hydrographic Agency (Bundesamt für Seeschifffahrt und Hydrographie)
BV	Bureau Veritas
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CREEI	Chinese Renewable Energy Engineering Institute
DEA	Danish Energy Agency
DIN	German Institute for Standardisation (Deutsches Institut für Normung)
DKE	German Commission for Electrical, Electronic & Information Technologies (Elektrotechnische Normen und VDE-Vorschriften)
DMA	Danish Maritime Authority
DNV	Det Norske Veritas
DNV GL	Det Norske Veritas Germanischer Lloyd
EEZ	Exclusive Economic Zone
GL	Germanischer Lloyd
GW	Gigawatt
IEC	International Electrotechnical Commission
IECRE	International Electrotechnical Commission System for Certification to Standards Relating to Equipment for Use in Renewable Energy Applications
INSPIRE	International Standards and Patents in Renewable Energy
IRENA	International Renewable Energy Agency
ISO	International Organization for Standardization
MW	Megawatt
NSMT	DIN Shipbuilding and Marine Technology Standards Committee (Normenstelle Schiffs- und Meerestechnik)
QI	Quality Infrastructure
R&D	Research and Development
TC	Technical Committee
UK	United Kingdom
US	United States of America

Summary for
POLICY MAKERS

The fast pace of offshore wind development has resulted in remarkable growth, from less than 1 gigawatt of total installed capacity in 2006 to more than 19 gigawatts (GW) in 2017, and the pace is expected to accelerate.

Over the past 25 years offshore wind technology has developed rapidly, with the first commercial plant beginning operation in Denmark in the early 2000s. By 2017 the United Kingdom (UK), Germany, China, Denmark and the Netherlands had the largest offshore wind markets, both in the number of wind farms and in total installed capacity (see Figure 1) (IRENA, 2018a). As such, these European countries, and recently China, have the most relevant experience to share with emerging offshore wind markets. Other non-European offshore wind markets – such as Japan and the United States (US) – are also growing but at a slower pace. According to projections from the International Renewable Energy Agency (IRENA), growth in offshore wind energy will accelerate in the coming years, with installed capacity rising from 19.2 GW in 2017 to 521 GW in 2050 (IRENA, 2018b).

Figure 1: Installed capacity of offshore wind by country in 2017



Standardisation in offshore wind emerged mainly from the offshore oil and gas industry and is happening almost exclusively at the international level.

As offshore wind technology moves from the demonstration stage towards wider commercialisation, there is a need to deploy instruments to foster its global scale-up. An important instrument for the globalisation of offshore wind markets is the development and implementation of internationally harmonised standards, documenting good practices and lessons learned to enable a rapid diffusion of this technology.

A standard is a repeatable, harmonised, agreed and documented way of doing something. Standards contain technical specifications or other precise criteria designed to be used consistently, as a rule, guideline or definition. Standards result from collective work by experts in a field and are an instrument to reduce costs, mitigate technical risks, attract investment, gain public acceptance and set expectations by all stakeholders.

International standardisation is crucial to harmonise requirements and enable global scale-up of offshore wind technology

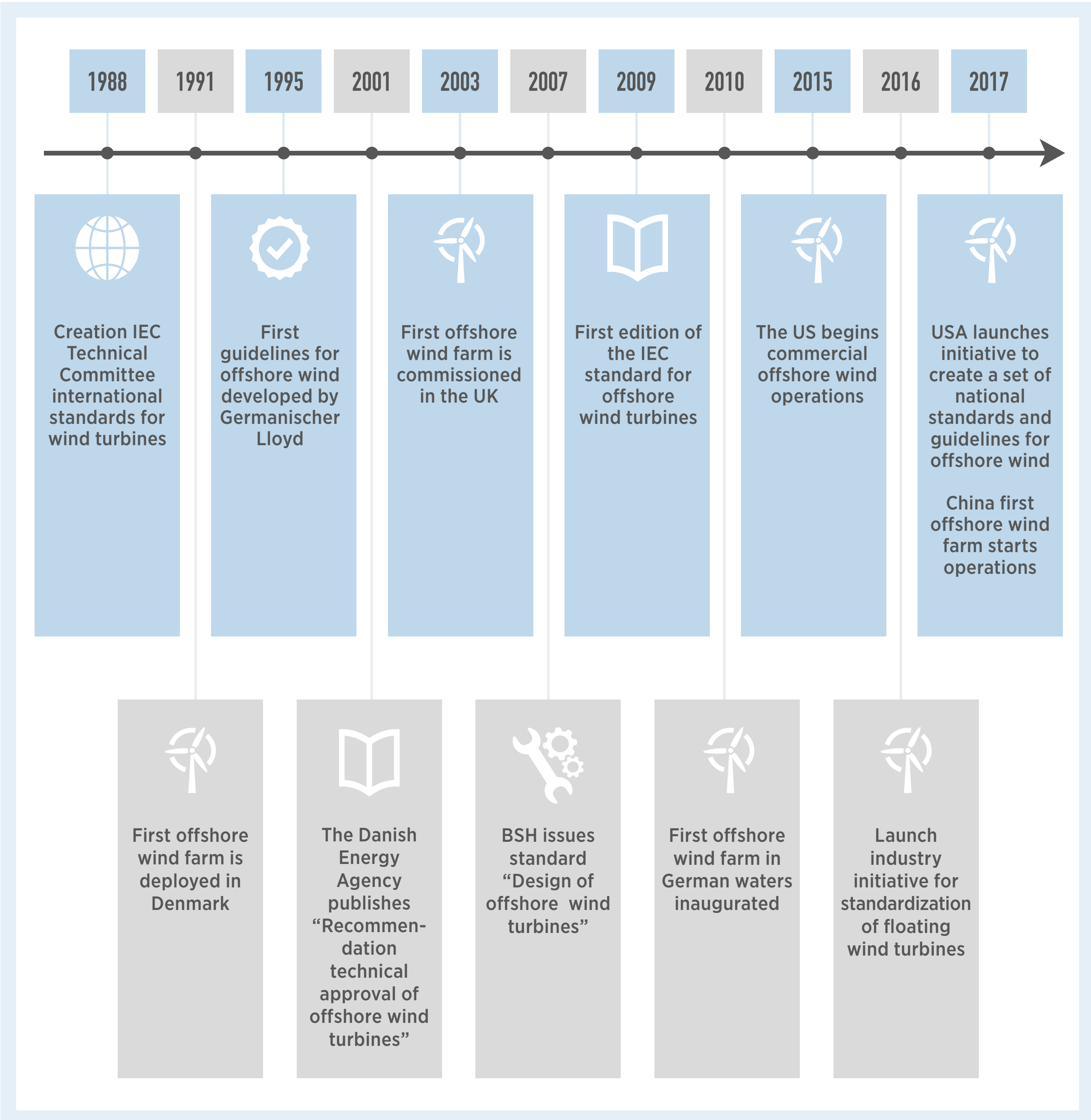
Several countries with existing offshore wind markets have developed their own customised national standards for this technology. However, the industry is currently striving for stronger international co-ordination and thus harmonised standards, as developed under the International Electrotechnical Commission (IEC) and its technical committee IEC TC 88 on wind energy generation systems.

Standardisation for offshore wind technology has been influenced by two main industry sectors: offshore oil and gas, and onshore wind. These two markets have provided the basis for developing offshore wind standards, and international efforts from the offshore wind industry have resulted in a number of standards already available. Despite remarkable progress in offshore wind, however, the sector needs to continue to reduce costs, to ease its integration with onshore electricity grid systems and to expand its reach into new markets, while also addressing environmental, health and safety aspects. The development of international standards and their adoption at the national level is essential in this regard. Efforts must continue and be strengthened to keep up with the state of the art of the technology, to accommodate technological innovation and to ensure the international harmonisation of technical requirements for a globalised scale-up of offshore wind.

Markets in China, Denmark, Germany and the UK have adapted offshore wind standards to meet local needs, customising their legislation, certification requirements and regulatory measures. However, while technical requirements in standards should consider local market conditions, the industry would benefit from having these conditions reflected in international standards, avoiding the need to meet different requirements for each market, enabling economies of scale and reducing transaction costs. This calls for close engagement of both mature and emerging offshore wind markets in an international standardisation process to ensure that these local contexts are well incorporated in international standards.

Most of the historical experience in offshore wind standardisation comes from countries that have more mature markets, such as Denmark, Germany and the UK (see Figure 2 for a summary of milestones). This report provides a deeper analysis of these three markets, based on multiple expert interviews and showcasing both historical developments and current practices. The report also details cross-cutting initiatives led by other countries and regions that are now advancing important activity in offshore wind standardisation.

Figure 2: Timeline of standardisation for offshore wind



Nuances exist in national implementation of standards for offshore wind. For example, in Denmark and Germany standards are used in certification requirements for projects to receive approval from the respective government authorities. In the UK certification is not a legal requirement but generally is needed for projects to secure financing, as funding institutions regard certification based on guidelines and standards as a means to mitigate technical risks.

Denmark's offshore wind market was influenced by the country's long-term experience in the onshore wind industry and has focused largely on standards for turbines, foundations and structures. In Germany emphasis has been placed on clear responsibilities and co-ordination of various standards committees relevant to the offshore wind sector. Close co-ordination among the committees dealing with turbines and power-producing components is important for port operations and support vessels; for example: interaction is needed between the respective committees handling the maritime sector and wind turbine foundations. Work on standardisation in the UK has concentrated mainly on health and safety aspects similar to those being addressed in the country's offshore oil and gas industry. Figure 3 shows a summary of the good practices in these three national markets.

Figure 3: Good practices for standardisation in national markets

Denmark

- Majority of standards taken from the onshore wind industry, benchmarked on lessons learned from Danish experience
- Emphasis on standards for turbines, foundations and structures
- Very comprehensive certification scheme

Germany

- Strong co-ordination among various standards committees
- Developed own step-wise certification and approval scheme for offshore projects within the Exclusive Economic Zone
- The approval authority supervises the project progress by approving individual phases on the basis of evaluation of the listed certification bodies.

United Kingdom

- Based on experiences from offshore oil and gas
- Focus on standardisation of health and safety aspects
- National standards on health and safety fostered by the government
- Picking up on the topic of standardisation for floating offshore wind

With regard to health and safety, all three markets largely follow their national standards and regulations, and harmonisation in this area has begun slowly

Standardisation in offshore wind has been shaped predominantly by market conditions in Europe; however, new standards today also must consider the needs of international offshore wind markets.

The expansion of offshore wind markets is moving beyond front runners such as Denmark, Germany and the UK. Because turbine manufacturers and other industry stakeholders operate transnationally, the industry is a major promotor of harmonising and developing international standards that will cover local conditions in new and future markets.

Countries such as Australia, Canada, China, Turkey and the US have ambitious plans to develop their offshore wind markets over the next few years. This market expansion comes with new requirements that must be rapidly incorporated into international standards. For example, because the first offshore wind markets emerged in Europe – a region with relatively shallow waters (particularly in Denmark and Germany) – the focus was on fixed structures, and floating offshore wind turbines have emerged only recently. The standards for floating offshore wind are now being developed for markets with deeper waters (depths greater than 50 metres), such as Japan and the US.

Around 85% of the world's installed capacity for offshore wind is currently in Europe

Moreover, the climatic and natural conditions in Europe do not reflect the extreme conditions found in other parts of the world, leading to the need to adjust standards to address, for example, typhoons, cyclones, earthquakes and icing. In the case of China, the offshore wind industry started by applying components and equipment used in other industries. As such, the industrial supply chain for offshore wind power is focusing on technology development of specialised installation equipment (e.g., vessels) and methods tailored for national conditions.

The international standardisation bodies – the International Electrotechnical Commission (IEC) and the International Organization for Standardization (ISO) – are key actors for the offshore wind industry. These organisations need to be supported to be able to respond at the speed needed by the rapidly growing offshore wind market. Private actors as well as classification societies are active in setting organisations' standards and guidelines, which serve the industry as international standardisation work evolves. Private actors also provide input to international standardisation bodies through the technical committees of these bodies. Figure 4 presents a, non-exhaustive, summary of the commonly used standards and technical guidelines in the offshore wind industry.

Figure 4: Standards and technical guidelines applicable to the offshore wind value chain

INTERNATIONAL AND COUNTRY STANDARDS AND GUIDELINES

Turbine and system design

International
- IEC 61400-1 Design requirements for wind turbines
- IEC 61400-3 Design requirements for offshore wind turbines

European Standard
- EN 50308:2004 Wind turbines. Positive Measures. Requirements for design, operation and maintainence

Classification Society
- DNV-OS-J101 Design of offshore wind turbine structures

Germany
- BSH Standard design of offshore wind turbines

Equipment selection

International
- IEC 61400-6 Tower and foundation design requirements

China
- NB/T 31094-2016 Offshore specific environmental conditions and
- technical requirements for wind power generation equipment.
- GB/T 33630-2017 Offshore wind turbine generator systems: specifications for corrosion protection
- NB/T 31006-2011 Technical code for anticorrosion of offshore wind farm steel structures
- NB/T 31041-2012 Converter of offshore doubly fed wind turbine generators.

Installation and commissioning

International
- ISO 19900 General requirements for offshore structures

China
- GB/T 50571-2010 Code for construction of offshore wind power projects
- NB/T 31031-2012 Code for preparation of offshore wind power projects pre-feasibility study report
- NB/T 31032-2012 Code for preparation of offshore wind power projects feasibility study report
- NB/T 31033-2012 Code for construction planning of offshore wind power projects
- NB/T 31029-2012 Specification of wind energy resource measurement and marine hydrographic observation for offshore wind power projects
- NB/T 31030-2012 Specifications for engineering geological investigation of wind power projects

Germany
- BSH Minimum requirements concerning the constructive design of offshore structures within the Exclusive Economic Zone (EEZ)
- BSH Ground investigation for offshore wind energy

Classification Society
- DNVGL-ST-0054 Transport and installation of wind power plants
- DNV-OS-J201 Offshore substations for wind farms

Performance, operation and Maintenance

International
- IEC 61400-22 Conformity testing and certification for wind turbines

European Standard
- EN 50308:2004 Wind turbines. Protective measures. Requirements for design, operation and maintenance

China
- GB/T 31519-2015 Wind turbine generator system under typhoon conditions

End of life

Decommissioning and waste management of offshore wind still need to be properly addressed in international standards.

Note: This list comprises the standards discussed in this report; it is not exhaustive. For more details, refer to the standard-making body of a specific country or to the international standardisation bodies.

Standardisation in offshore wind will be crucial to spur widespread deployment of this technology in the future.

Key messages in this study arise from the work developed by the front runners in offshore wind markets. The points below provide a summary of the state of international good practices in standardisation and outline the opportunities for the future trajectory of standardisation in offshore wind.

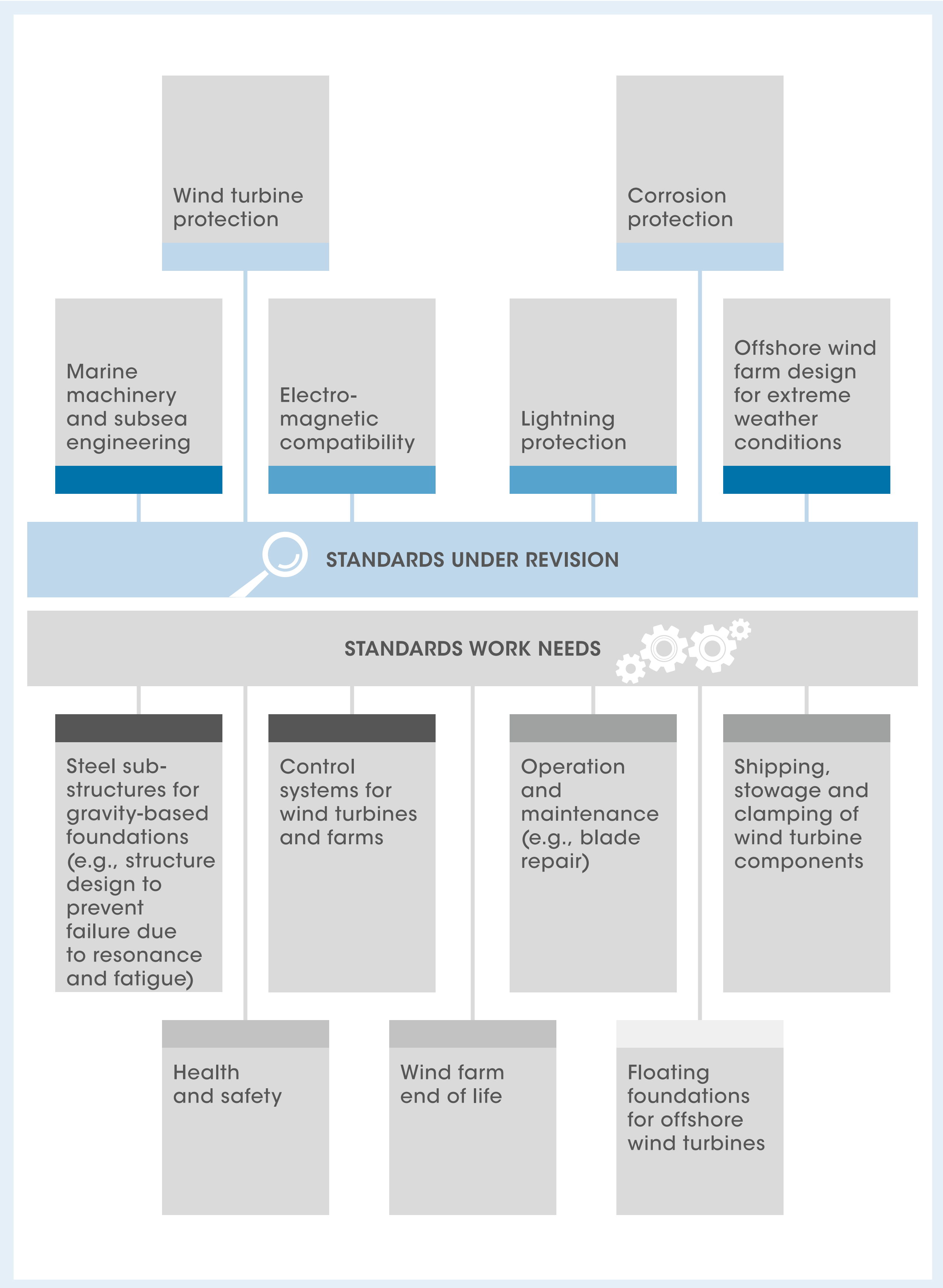
- **Standards developed through an engaging and consensus-based approach can facilitate innovation in the sector.** New offshore wind technologies can better compete in globalised markets if requirements are harmonised and if safety and performance are quality assured. Furthermore, some standards developers and certification bodies have developed concepts of certifying innovative components by using risk-based certification of innovative designs.

- **Quality infrastructure has to be in place to operationalise standards.** In order to implement and verify that requirements in standards are met, there is a need for quality infrastructure (QI). QI includes metrology, testing, certification and accreditation services that support industry, regulations and end-users.

- **Lessons learned from the offshore oil and gas sectors offer opportunities, but they cannot be applied one-to-one to develop offshore wind standards.**

- **To keep up with the market pace and with technology developments,** a number of standards are already being updated. Also, further work is needed for offshore wind standards focused on components and equipment tailored to industry needs. Figure 5 depicts the standards under update and areas where additional work is needed for the offshore wind industry.

Figure 5: Standards work



- **Health and safety standards and regulations are expected to accelerate standardisation and innovation in other areas as well.** Health and safety requirements lead to the development of new installation vessels, infrastructure in quays and automated production processes. Some national markets adopted health and safety standards from other offshore sectors, such as oil and natural gas, early on, but it became obvious that there was a need for advanced health and safety regulations beyond what had been developed. These efforts have been fruitful, although work is still required to create harmonised international health and safety standards for offshore wind.

- **International offshore wind standards need to incorporate weather and natural conditions of new markets.** Aspects such as earthquakes, severe storms and icing on lakes need to be taken into account in international standards. This is understandable, as the majority of existing standards were initially developed for European conditions, which can differ from those elsewhere.

Standardisation efforts must be supported and strengthened to keep up with state-of-the-art technology

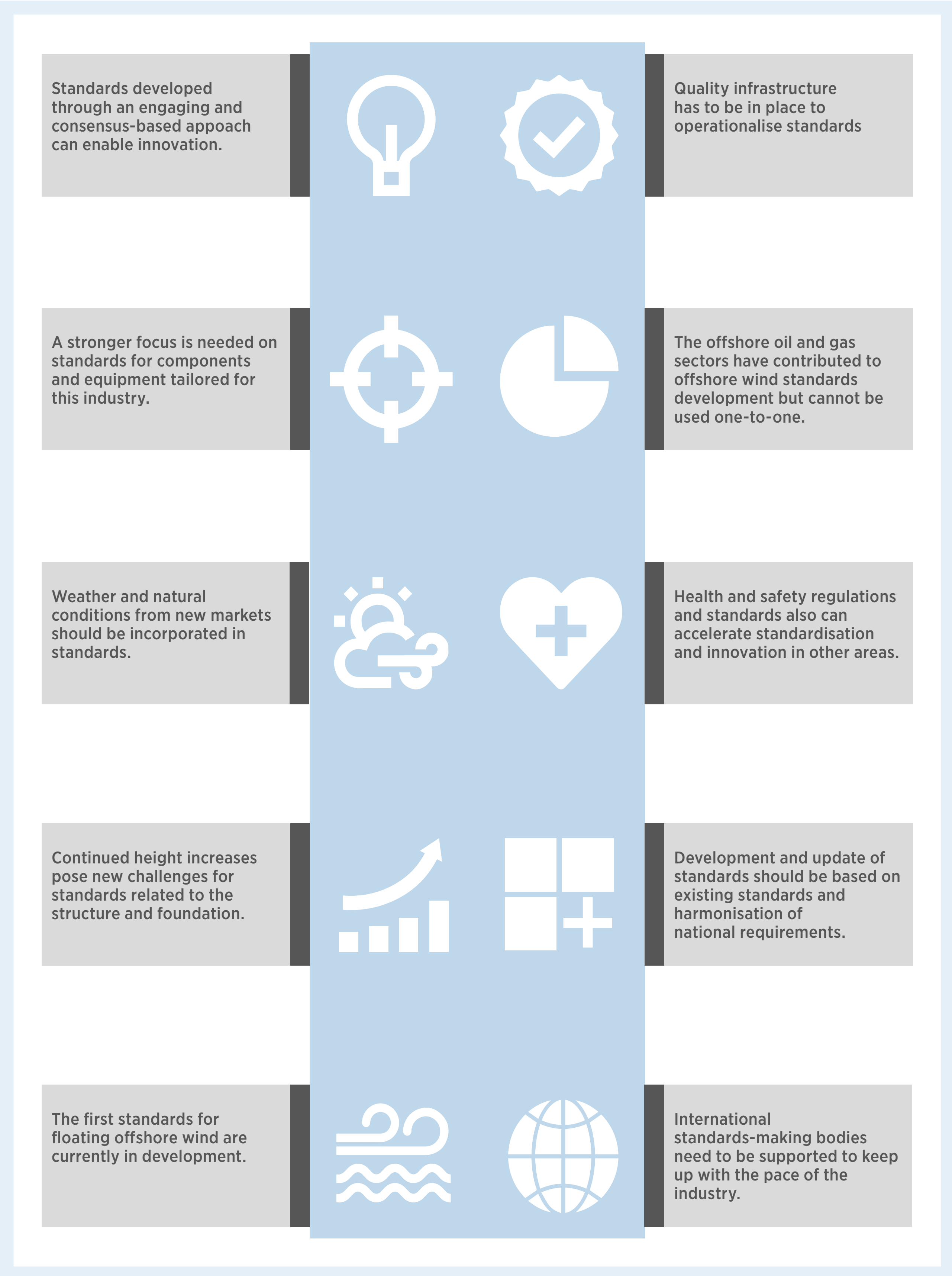
- **New developments in standards should take as their base existing standards and harmonisation of national requirements,** balancing between market needs and not adding specifications that may limit the potential of developers to innovate or optimise their projects. Harmonising requirements and reflecting this in international standards and certifications is key. An example provided by interviewed experts is to harmonise the national requirements for turbine certification, easing the deployment of cross-border projects.

- **As the height of structures such as monopiles continues to increase, this poses new challenges for structure- and foundation-related standardisation.** Standards-making bodies and classification societies are starting to develop new standards to provide solutions in the context of tilt tolerances and stability. Floating foundations can be an alternative solution, as they rely on mooring adjustments.

- **Standards for floating offshore wind** are needed for markets with deep waters and are currently in development. In the IEC, the sub-committee TC 88/PT 61400-3-2 is working on standards for the 'Design requirements for floating offshore wind turbines'. The aim of the work is to minimise the technical risks for this technology, facilitating its scale-up. The sub-committee is at present led by the USA and Korea. It includes experts from European countries, like Germany, Denmark, Netherlands, United Kingdom, Spain, France and Norway, as well as from other countries with a potential market for this technology, such as Japan, China, Korea and South Africa.

- **International standards-making bodies need to be supported to keep up with the pace of the industry.** International standards are developed under a transparent and inclusive process. These bodies require support from countries, for example by sending experts to technical committees and by ensuring that their local conditions are reflected in international standards.

Figure 6: Nurturing offshore wind markets



Standardisation for

OFFSHORE WIND

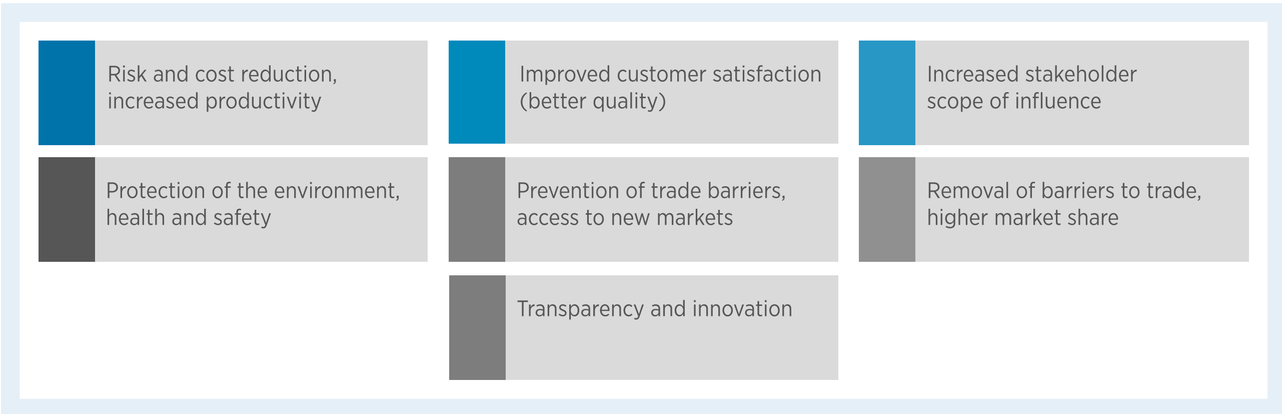
1

1. STANDARDISATION FOR OFFSHORE WIND

A standard is defined as a repeatable, harmonised, agreed and documented way of doing something (IRENA, 2013). It is established by consensus and approved by a recognised body, aimed at achieving the optimum degree of order in a given context. Figure 7 summarizes some of the main advantages of standardisation, this includes the cost savings due to optimised working procedures, increased influence and participation of various stakeholders, increased customer confidence in product quality, and improved market access through the removal of unnecessary barriers to trade.

Standards contain technical specifications or other criteria that are designed to be used consistently – as a rule, guideline or definition

Figure 7: Benefits of standardisation



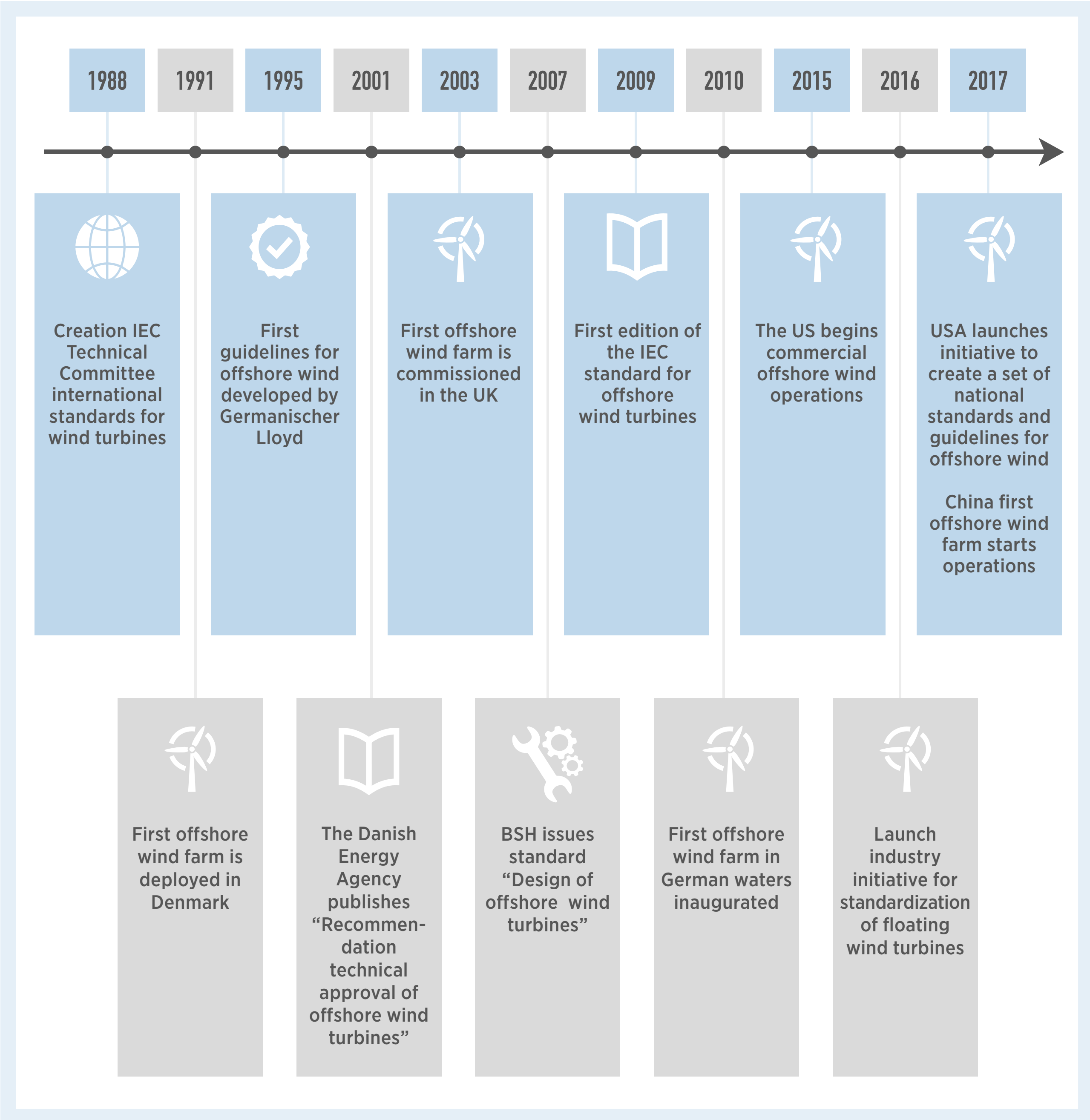
1.1. Evolution of offshore wind standards

Standards adopted from the onshore wind industry relate mainly to the top-side structure (the tower, rotor and nacelle), while several standards imported from the offshore oil and gas industry are commonly applicable to the support transition piece (the tower, substructure and foundation or floating hull, mooring, anchors and piles). Design improvements through the standardisation of wind turbines, specifically adapted to offshore wind conditions, have contributed to significant cost reductions. Standardised offshore wind installation vessels and improvements in electrical interconnection equipment also have contributed to optimised operations (IRENA, 2016).

This report analyses three forerunner markets in offshore wind – Denmark, Germany and the UK – as well as initiatives occurring in emerging markets such as China and the US. To better understand this context, relevant aspects of the history of offshore wind standardisation related to these markets is explained chronologically below and summarized in Figure 8:

- **1988:** Technical Committee 88 of the IEC begins ongoing efforts to compile international standards for wind turbines, with a number of working groups and project and maintenance teams developing and regularly revising standards, technical reports and specifications.
- **1991:** The first offshore wind farm is deployed in Denmark's waters.
- **1995:** The first guidelines are developed by Germanischer Lloyd (GL) and Garrad Hassan, addressing regulation for certification of the offshore wind energy. The final guidelines are released as a GL document, combining technical knowledge from the wind power and offshore oil and gas industries.
- **2001:** The Danish Energy Agency (DEA) publishes its "Recommendation for technical approval of offshore wind turbines", a guideline that is still valid today (DEA, 2001).
- **2003:** The first offshore wind farm is commissioned in the UK.
- **2007:** At a local level, the German Federal Maritime and Hydrographic Agency (BSH) issues the standard "Design of offshore wind turbines".
- **2009:** The IEC launches its first standard for offshore wind turbines.
- **2010:** Germany's first offshore wind farm starts operations.
- **2015:** The US begins commercial offshore wind operations.
- **2016:** Thirteen global partners launch the Joint Industry Project, an industry initiative that aims to standardise floating wind turbines (Energy Business Review, 2016).
- **2017:** The US launches an initiative with major key stakeholders to create a set of national standards and guidelines for offshore wind that is recognised by the American National Standards Institute and the US Bureau of Offshore Energy Management (Offshore Wind, 2017).
- **2017:** China's first offshore wind farm starts operations.

Figure 8: Timeline of standardisation for offshore wind



1.2. Key aspects shaping offshore wind standardisation

The history and experience in standardisation of the offshore wind industry should be seen and assessed by considering the following:

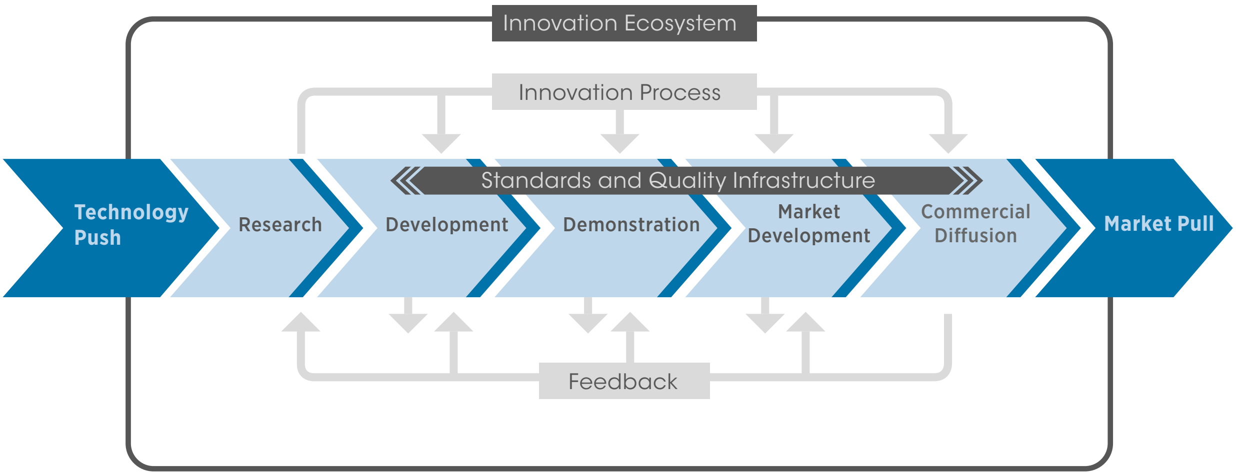
1. **Debates about standardisation now occur almost exclusively at the international level.** In the early years of offshore wind, national debates about standardisation emerged in individual countries as the market was small enough to allow the development of national standards adapted to each country's industry. In the late 1980s and early 1990s standardisation work began at an international level within committees of the IEC and ISO.

2. **In several countries two main sectors – onshore wind and offshore oil and gas – greatly influenced offshore wind standardisation.** The onshore wind sector served as a role model for turbines, while the offshore oil and gas industry has been very influential for structures. The influence of these two sectors brought gains as well as shortcomings. Minor adjustments or direct reference to existing standards in these sectors brought cost reductions and experience with implementation; however, in certain cases the conditions for offshore wind technologies were very different, and at times this resulted in a need for revision of the standards or for the development of completely new standards. Some of the interviewed experts raised concerns about the differences between manned platforms (in offshore oil and gas) and unmanned platforms (in offshore wind), which require different standards in areas such as health and safety. The standards for turbines are mostly the same for offshore and onshore wind, with the exception of site-specific loads.

3. **Floating offshore wind technology is rapidly attracting interest in some countries.** Certain European countries, such as Denmark and Germany, have access to shallow waters suitable for fixed structures for offshore wind farms. Therefore the development of floating wind turbines was not an early priority for the industry in Europe, which has had limited activity in standardisation for floating foundations. This situation is changing, however, as more cost-competitive technologies for floating offshore wind expand to geographies with deeper waters. In the IEC, the sub-committee TC 88/PT 61400-3-2 is working on standards for the 'Design requirements for floating offshore wind turbines'. The aim of the work is to minimise the technical risks for this technology, facilitating its scale-up. The sub-committee is at present led by the USA and Korea. It includes experts from European countries, like Germany, Denmark, Netherlands, United Kingdom, Spain, France and Norway, as well as from other countries with a potential market for this technology, such as Japan, China, Korea and South Africa.

4. **A false dichotomy exists between standardisation and innovation.** There is a misconception that, in certain cases, innovation might be held back by standardisation in certain cases. This may happen if the use and implementation of standards is done in a poor and unstructured manner. Therefore, sound standardisation processes and quality assurance should be present throughout the entire innovation ecosystem, from research and development (R&D) to commercialisation and diffusion (see Figure 9). Standardisation can support innovation by documenting and disseminating information on state-of-the-art technologies, levelling the playing field for innovative products, allowing focused R&D efforts built upon best technology practices, and facilitating the transition from R&D to commercialisation. In the offshore wind industry, for example, the IEC offshore wind turbine standards are performance-based standards that specify the environmental and operating conditions that must be addressed, rather than limiting the developer to strict configurations. These standards give the developer greater liberty in turbine design methods.

Figure 9: Innovation ecosystem, from technology push to market pull



1.3 Operationalising standards

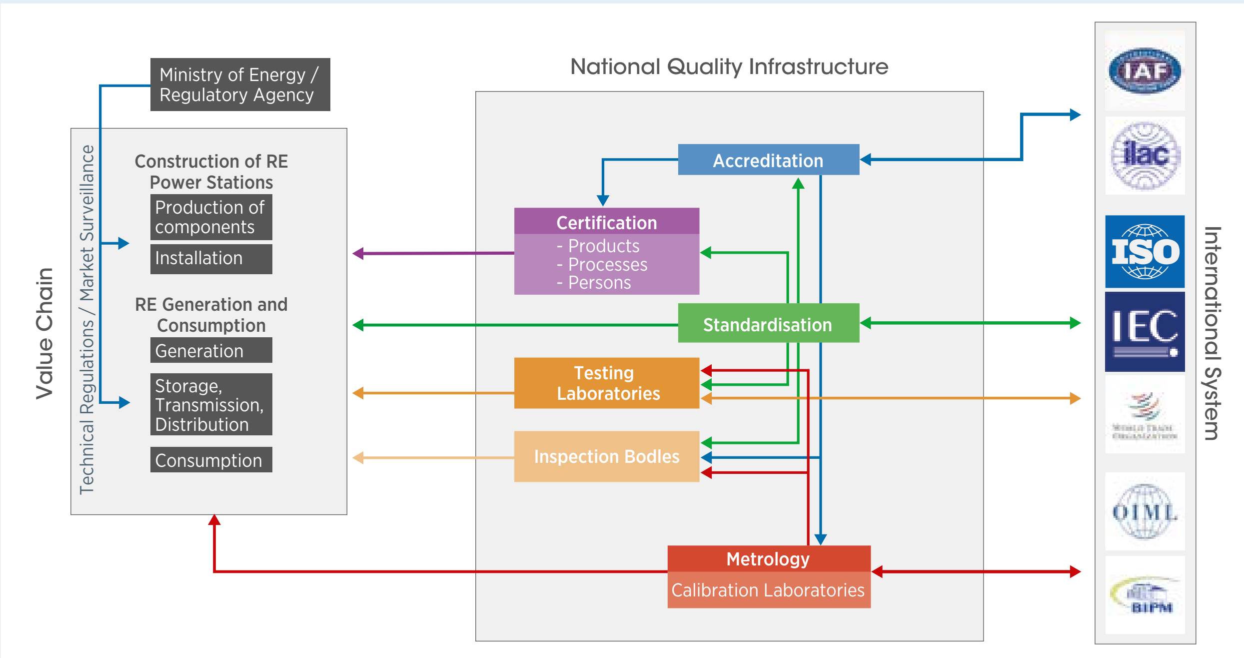
Ensuring high-quality technologies requires first establishing an institutional infrastructure that utilises standards, testing, metrology and certification, among other elements – better known as quality infrastructure (QI). Figure 10 shows the close interrelations among these elements and how they apply across the value chain of renewable energy technologies. Standards are defined and supervised by international organisations, such as the IEC, ISO and the World Trade Organization, which use a stakeholder's inclusive and consensus-based approach.

Operationalising international technical standards via testing and certification can address this risk and at the same time spur technological improvements. QI development mechanisms depend on each country's context and market maturity. At a mature stage, QI enables the implementation of internationally harmonised standards, contributing to the global transfer and trade of renewable energy technologies.

CERTIFICATION

Standardisation can be used to carry out both type certification and project certification. The purpose of the certification is to assess whether wind turbines, single components, and support and foundation structures, among others, are in line with external conditions, applicable assembly procedures and electrical installation regulations, as well as other site-specific requirements (Hpcert, n.d). It is common practice to conduct type certification for wind turbines, and project certification for the complete wind farm.

Figure 10: Elements of quality infrastructure



Source: Based on The National Metrology Institute of Germany (Physikalisch-Technische Bundesanstalt), 2010

Country experiences in

STANDARDISATION AND REGULATION


2

2. COUNTRY EXPERIENCES IN STANDARDISATION AND REGULATION

Denmark, Germany and the UK are important markets for offshore wind, and their varying experiences provide useful case studies on how stakeholders have shaped the agenda of standardisation in the field and which topics have been of particular interest for each country.

> Standardisation provides a common language and understanding of the potential of renewable energy technologies.

2.1 Denmark

The development of Denmark's offshore wind industry was influenced strongly by the small machinery manufacturers that created and developed the wind turbine industry. However, during the period of industry consolidation in the 1990s, the sector became increasingly dominated by large, often internationally owned companies. During this period the process of standards development in Denmark included strong public involvement, with early development of quality assurance documents in comparison to other countries. In 2001 the Danish Energy Agency published its "Recommendation for technical approval of offshore wind turbines (DEA, 2001).

Denmark's early standards for the offshore wind industry were taken from the onshore wind industry. The Danish committee dealing with standards for wind turbines, Dansk Standard DS 588, was very influential in shaping the regulatory framework in this area. However, since 1988 when the first IEC TC 88 meeting took place, Dansk Standard gradually lost its influence and the IEC 61400 series was introduced in Denmark. Today the Danish Standards Association mirrors developments that occur at the international level. The Danish offshore wind market is considered relatively small (smaller than the German and UK markets) to implement national standards.

The DEA is the sole authority that issues licences to project developers active in the offshore wind sector. The Agency permits project development either by a tender or through an open-door procedure; in either case, three licenses are required:

1. Licence to carry out preliminary investigation
2. Licence to establish the offshore wind turbine (provided if preliminary investigations show that the project is compatible with the relevant interests at sea)
3. Licence to exploit wind power for a certain number of years and approval for electricity production in compliance with electricity legislation (DEA, 2018).

Before the submission of tenders, an environmental impact assessment should be carried out. Other licences are required for the approval of new grid connections (DEA, 2015).

Installing wind turbines in Danish waters requires the application of a technical approval scheme of the DEA for wind turbines and foundations. The approval scheme, based on adherence to relevant technical specifications, has been in place since the early 1980s and requires compliance with safety, energy and quality requirements before project approval. It was followed by the first certification system, in effect from 1981 to 1989, and in 1990 the first legislation related to the certification scheme was issued. At that time, certification was based fully on Danish standards. Thus, the scheme was important in the initial development of standards for the sector (DEA, 2015). In 2004 the Danish certification scheme was replaced in Danish legislation with the certification scheme associated with IEC 61400-22.

Wind turbines and foundations in Denmark must be certified according to the requirements of the Danish certification scheme. The DEA Executive Order on a technical certification scheme for wind turbines (No. 73 of 25 January 2013) and the relevant guideline describe the rules and procedures (Ea Energy Analysis, 2017). The scheme is managed by the DEA's Secretariat for Danish Wind Turbine Certification.

The DEA is the competent authority for Danish offshore wind power projects. It regulates offshore wind farm installation sites in co-operation with two other agencies: the Danish Maritime Authority (DMA) and the Danish Working Environment Authority (DMA, 2015).

Marine access to offshore wind farm development and enforcement of regulations is divided into three main areas:

- Port facility: Danish Coastal Authority
- Vessel transfer from shore to offshore wind farm site, including access to installation (DMA)
- Offshore wind farm site (DEA and wind farm operator) (DMA, 2015).

An area with great potential for standardisation in the near future is foundation structures. Interviewed experts highlighted that the results of testing in foundation structures may be incorporated in already existing standards or through the development of new standards. Denmark is not fully engaged in floating offshore wind as its waters are relatively shallow, but the country observes global progress in this area.

Interviewed experts from Denmark described opportunities to improve standardisation of towers and foundations, with such improvements to be given effect through the introduction of the international standard IEC 61400-6. For standards that are applicable to site-specific loads and load cases, Denmark does not differentiate between offshore and onshore wind.

Denmark has very comprehensive legislation regulating most activities related to the deployment and operation of wind power plants. Offshore wind turbines are regulated primarily by the Promotion of Renewable Energy Act ("Renewable Energy Act"). However, the Renewable Energy Act does not regulate special issues relating to occupational health and safety. This area is covered only by general Danish Law (in stark contrast to the Danish offshore oil and gas industry, where such legislation exists). In the absence of specific safety and health regulations for offshore wind, the provisions in the Working Environment Act apply. The Renewable Energy Act also does not apply to offshore wind plants beyond the limit of 12 nautical miles from shore (but that are located in Denmark's Exclusive Economic Zone (EEZ) – for instance, the Horns Rev II facility).

Some offshore wind projects in Denmark are supported by public funds, as there is rising interest among the population in offshore wind energy. Experts interviewed for this study stated that the level of standardisation for these projects could be stricter in the country, with a more stringent risk mitigation process.

LESSON LEARNED FROM DENMARK

Denmark has one of the most comprehensive legislative systems for offshore wind. The country uses a large number of international standards for offshore wind, providing stakeholders with trust, reliability and comparative advantages when accessing project funding. This legislation also is recognised for its comprehensive certification scheme, which is commonly used by the local industry.

2.2 Germany

Historically, standardisation efforts for offshore wind in Germany have focused on offshore logistics and marine operations since, according to interviewed experts, Germany had no significant offshore energy industry prior to offshore wind. The German Institute for Standardization (DIN) has developed standards and set them at the international level. The work of ISO is handled at the national level by DIN, while the work of the IEC is handled by the German Commission for Electrical, Electronic & Information Technologies (DKE).

German standardisation efforts for offshore wind are divided into three main areas:

1. A DIN working group on all issues related to the maritime segment, such as vessels, port operations, safety procedures, etc.
2. A DIN working group dealing with foundations; this group also deals with foundations for various structures and buildings.
3. A DKE working group that oversees power production from offshore wind technology. Furthermore, it co-ordinates the harmonisation with other sectors. For instance, DIN's Shipbuilding and Marine Technology Standards Committee (NSMT) not only monitors the work of marine operations in offshore wind, but also co-ordinates with other committees and working groups such as inland waterway vessels and small marine vessels to harmonise standards. Similar arrangements exist with the committees working on foundations and turbines.

In Germany, the approval and application procedure for new offshore wind technology projects covers:

– Certification as a legal requirement (BSH regulations apply here)
– Regulatory procedures for offshore wind farms, depending on the site of construction. For the German coastal sovereign territory (within 12 nautical miles of the coast) admission and administrative processes are the responsibility of the states. However, most offshore wind plants are located in the EEZ, which stretches from 12 nautical miles up to 200 nautical miles. For wind farms in the EEZ, the BSH issues permits and has oversight.

With regard to standardisation, Germany's authority for approving new offshore wind projects has issued its own standards. These instructions, aimed at improving legal and investment security, have been developed in co-operation with groups of experts, specifying detailed minimum requirements for mandatory geological, geophysical and geotechnical site investigations at planned wind farm sites. A further standard has been elaborated, it specifies the requirements for offshore wind turbine construction and ensures that all installations and structural components are certified (BSH, 2017).

The regulatory process for offshore wind is managed by BSH. Only in Germany's territorial waters are the federal states the authoritative body. However, since nearly all offshore wind power projects in Germany are located farther from shore, in the EEZ, the federal states exercise only minor influence in this sector. The project approval process includes an examination of whether the installations and structural components were certified according to the BSH standard for the design of offshore wind turbines, first issued in 2007. The standard covers the development, design, implementation, operation and decommissioning of offshore wind farms and regulates various structural components of the farms (BSEE, 2018). It also makes reference to other BSH standards for foundations and environmental impact assessment.

The BSH standards (effectively technical regulations) are developed by a team of experts – a steering group – comprising members from different classification societies. The project approval process follows a defined scheme with consecutive certification steps, and the certification body must be selected from a list that also includes classification societies. However, different certification bodies may cover different phases of the project, such as design certification, manufacturing, transport, etc.

BSH needs to approve the five project phases of development, design, implementation, operation and decommissioning. In approving these five phases, BSH often is supported by external experts, for example a geotechnical expert for the development phase or a wind turbine expert for the design phase. Some interviewed experts mentioned that the market may benefit from a simplified and more rapid approval process by BSH.

For the design – which covers site conditions and serves as the basis for subsequent phases – the project developers/owners must demonstrate that a feasible and compliant catalogue of applicable standards and methods has been prepared and that site conditions are clarified. Furthermore, the design must be compliant with the state of the art. Standards will be determined to specify, for example, the support structure or wind turbine. Surveillance of the processes is required during manufacturing, transport and installation, and follow-up evaluation and regular inspection are demanded during plant operation.

LESSON LEARNED FROM GERMANY

The German system of standardisation in offshore wind can be characterised by accurately defined responsibilities of work on standardisation. Germany has an elaborated system related to co-ordination of standardisation in this field. As a consequence, standards can be harmonised at a very early stage of development, and the risks of duplication of effort or overlap can be reduced.

Germany also has developed its own standards for certification of offshore wind farms. These standards are used as technical regulations, since they must be followed in order for a project to be approved. These BSH standards also reference international standards, and project developers must propose standards for every phase of project implementation. In addition, developed projects require certification prior to their deployment, where several certification bodies can evaluate different stages of the project. Under these circumstances, BSH has played a key role in regulating and approving all phases of a project to ensure consistency and secure implementation.

2.3 United Kingdom

The UK's target for installed offshore wind capacity is approximately 10 GW by 2020. This positive outlook has been reinforced by a decline in costs stimulated by auctions using Contracts for Difference, permitting projects to gather revenues from balancing and ancillary services (UtilityWeek, 2018). Likewise, standardisation could contribute to further cost-competitiveness and help to ensure continuous progress in offshore wind deployment. Offshore wind is "leased" in rounds, which enables organised project planning over the next few years. Round 1 projects and most Round 2 projects are now operational, and Round 3 projects are in various stages of development, with the first one commissioned in 2018. Licensing of offshore wind projects is co-ordinated by The Crown Estate (RenewableUK, 2016).

The UK has many years of experience with offshore oil and gas, and best practices in this industry have served as a benchmark for offshore wind structures and foundations. When considering standardisation for these support structures, the country adopted related standards from international standards-making bodies such as the IEC and ISO (BSI, 2014). These standards were developed mainly by experts from the public and private sectors to define codes and procedures for structural design and construction. UK regulations do not require certification of the project or of single components according to specific standards. However, to reduce risks, financing institutions often require projects to undertake certification prior to securing finance. Stakeholders such as the government, wind plant operators and design offices are influential in the area of health and safety, especially for operation of the project.

As early consideration was given to safety and health standards in the UK, the focus has now shifted to improving and optimising individual standards. The emphasis is not on developing new standards, with the exception of a few cases. Areas identified for future standards development include:

- control systems for wind turbines and offshore plants
- blade repair
- in-service maintenance and repair
- shipping, stowage and clamping of wind turbine components
- data exchange
- lightning protection
- environmental impact assessment
- offshore renewable energy statutory stakeholder criteria (BSI, 2014).

One matter that the UK has brought forward to the international level is lightning protection, which is considered a topic of high impact and relatively easy implementation. The long tradition in this topic at IEC TC 88 is expected to further ease the process.

Interest in standardisation for floating offshore wind will continue to increase in the UK. Scotland, which has access to deep sea waters, is promoting the technology and engaging in related standardisation work.

LESSONS LEARNED FROM THE UNITED KINGDOM

During the initial development of its offshore wind sector, the UK had the significant advantage of being able to draw from experience in its mature oil and gas sector, especially in the area of health and safety. Although some of the standards in this area could not be applied directly to offshore wind, the oil and gas experience contributed to early development in this sector in the UK. Health and safety guidelines and standards still need to be improved on the international level, and the UK can be seen as a forerunner in this field.

2.4 Comparison of national markets

Table 1 provides a summary comparison of the offshore wind markets in Germany, Denmark and the UK.

Technical regulations and legislative frameworks are different for each of the three countries examined. All countries apply national legislation in their respective EEZs, which stretch from 12 to 200 nautical miles from the coast, adjusted by the median line as the boundary between two neighbouring states. Territorial waters stretching 12 nautical miles from the coast are handled differently by each country.

Current technical regulations in the field are often based on international standards, developed by the IEC, and historically a set of rules was based on the IEC WT 01 (IEC system for conformity testing and certification of wind turbines), establishing a context for reciprocal international recognition of approval and type tests (DEA, 2015). With regard to installation, standardisation of wind towers is often dealt with in the civil engineering codes of each country.

Table 1 Comparison of national markets[1]

	Denmark	Germany	United Kingdom
Standards development	First national offshore specific standards replaced by international standards very early in the development of offshore wind technology. Almost all standards taken over from onshore wind industry.	Less focus on national standards. Several committees working on standards related to structure/foundation, marine issues (e.g., vessels, port procedures) and turbines (power-producing unit). German national standards developed for technical and environmental regulation (BSH standards).	Standardisation shaped by experiences from the offshore oil and gas sector. Early focus on health, safety and environmental guidelines and related standards development. In the area of structures and foundations, international standards were taken over. BSI has promoted standards on design requirements for offshore wind turbines.
	General tendency to improve rather than develop new standards.		
Focus standardisation efforts	Turbines and lessons learned from Danish onshore wind experience.	Offshore logistics, clear separation but co-ordination among various standardisation working groups.	Health and safety, structures and foundations, lessons learned from offshore oil and gas.
National standards	Almost no significance.	Significant role for technical regulation and certification of wind farm project development.	Minor significance, related mainly to specific gaps in international standardisation, i.e., health and safety.
	For some countries it can be too costly for the industry to follow national standards and to adjust products to each individual market. Thus, the industry has played an important role in harmonising and developing international standards.		
Legislation and certification requirements	First system certification during the 1980s. Has a unique and comprehensive legislation, applicable to all power plants. All projects are developed at sites with planning consent and grid connection provided. A comprehensive certification scheme, based on IEC 61400-22, must be followed to receive project approval from DEA.	Similar to Denmark. Germany also has developed technical regulations by BSH as a basis for the certification process. BSH standards reference IEC standards.	No certification is required by approving authorities, but banks and funding institutions often demand certification for risk mitigation.
Regulatory measures	Regulation takes a more prescriptive approach, regulating in particular the design, construction and operation of offshore wind turbines to reach acceptable levels of safety, reliability and performance.		Flexible approach, relatively market-driven.
Actors and stakeholders	Public and private actors are equally involved, and both have pushed standardisation processes in the sector. The industry has issued relatively few complaints, due likely to functioning certification requirements. Interviewed experts highlighted that standardisation can be more strict.		Initially government, then industry and commercial interests. Public sector is very engaged in health and safety, and environmental protection. Some disagreement between the finance sector and the industry about risk mitigation and sufficient means to avoid risk.
Responsible bodies for offshore wind power project approval, and competent authority	Danish Energy Agency (DEA)	Federal Maritime and Hydrographic Agency (BSH), within the EEZ	The Crown Estate
Floating offshore wind	At the international level only. Committee member from Denmark seconded to respective Working Group at the IEC.	At the international level only. Committee member from Germany seconded to respective Working Group at the IEC.	Of national interest. The UK is pushing the topic at the national and international levels, led by Scotland.

1 Based on literature research (refer to bibliography section) and country expert interviews.

2.5 An emerging market: China

In only a one-year period, China increased its installed offshore wind capacity by 62%, going from 1.6 GW in 2016 to 2.6 GW in 2017, according to the Chinese Wind Energy Association. Development trends suggest that China is a clear model of an emerging market and that the industry is on track to achieve the government's offshore wind targets of 5 GW of installed capacity and 10 GW under construction by 2020 (NEA, 2016). The progress in technical standards development has contributed to this rapid growth. At present, the following technical standards have been developed for offshore wind power in China:

AMBIENT MEASUREMENT AND CONDITIONS FOR OFFSHORE WIND POWER

The energy industry standard NB/T 31029-2012, entitled "Specification of wind energy resource measurement and marine hydrographic observation for offshore wind power projects", stipulates the scope, procedures and requirements for conducting resource assessment and marine hydrology measurements for offshore wind farm development. The standard not only provides crucial inputs to designing offshore wind turbines but has been required as an integral component of the preparations for offshore wind farm development. NB/T 31030-2012, entitled "Specifications for engineering geological investigation of wind power projects", also serves as a reference point for resource assessment.

TURBINE DESIGN

The standard NB/T 31094-2016, entitled "Offshore specific environmental conditions and technical requirements for wind power generation equipment", provides reference parameters and guidelines for offshore wind turbine design, transport and operation.

Given that Chinese south-eastern coastal areas have experienced typhoons with wind speeds of up to 50 metres per second, China has since 2010 studied the impact of typhoons on offshore wind turbines and farms, and has begun developing technical standards in this area. In 2014 China General Certification issued the "Technical guideline for simulation and design of anti-typhoon wind turbines". A year later, the Chinese government issued the national technical standards for anti-typhoon wind turbines known as GB/T 31519-2015, entitled "Wind turbine generator system under typhoon conditions".

POWER GENERATION EQUIPMENT

The design of offshore wind power generation units requires compliance with two national technical standards: GB/T 18451.1-2012 "Wind turbine generator systems" (equivalent to IEC 61400-1:2005), and GB/T 31517-2015 "Design requirements for offshore wind turbines" (equivalent to IEC 61400-3:2009). Special focus is given to anti-corrosion.

In 2011 an energy industry standard, i.e. the NB/T 31006—2011 "Technical code for anticorrosion of offshore wind farm steel structures" was issued, stipulating anti-corrosion methods such as surface pre-treatment, coating, and other relevant technical requirements for steel structures of the power generation units and substations in the design, construction, commissioning, as well as maintenance and operation. A recent issued national standards GB/T 33630—2017 "Offshore wind turbine generator systems: specification for corrosion protection" is focused on the control of corrosive environments, anti-corrosion methods and relevant technical requirements for the system, including power generation units, electronic components, steel structures and parts, and composite materials.

In addition, a series of energy industry standards were issued that focused on the control system, on electric motors and on inverters, including NB/T 31041-2012 "Converter of offshore doubly fed wind turbine generators", NB/T 31042-2012 specifically for the inverters for permanent magnet synchronous generators, NB/T 31043-2012 "Technical specification for main control system of offshore wind turbine generator systems", NB/T 31063-2014 "Permanent magnetic synchronous generator for offshore wind turbine" and NB/T 31064-2014 "Technical specifications for offshore type doubly fed wind generator".

PROJECT DEVELOPMENT

In early 2008 the Chinese Renewable Energy Engineering Institute (CREEI) issued a technical guideline FD 005-2008 "Preparation rules of offshore wind power projects planning report", followed by FD 006-2008 "Preparation rules of offshore wind power projects pre-feasibility study report" and FD 007-2008 "Preparation rules of offshore wind power projects feasibility study report". Three years later CREEI developed and issued the technical guidelines for offshore wind project construction. Building on these efforts, three energy industry standards related to pre-feasibility study, feasibility study and project construction, respectively, were issued in 2012, known as NB/T 31031-2012 "Code for preparation of offshore wind power projects pre-feasibility study report", NB/T 31032-2012 "Code for preparation of offshore wind power projects feasibility study report" and NBT 31033-2012 "Code for construction planning of offshore wind power projects".

In 2010 a national standard GB/T 50571-2010 "The code for construction of offshore wind power projects" was issued, providing technical requirements for the preparations related to project construction, transport, infrastructure need, installation of generation equipment and project management, among others.

Along with the growing number of offshore wind installations, new technical standards are being developed. With the support of the World Bank, three technical standards are under development to provide technical guidance on support structures for offshore wind turbines, substations and power cables, respectively (DNV GL, 2017). For grid integration of offshore wind generation facilities, no energy industry technical standards or national standards exist. The "technical rule for connecting offshore wind farm into the power grid" or Q/GDW 11410-2015, developed by the State Grid Corporation of China and issued in 2016, lays the foundation for developing the corresponding energy industry and/or national technical standards.

International standards adjusted to climatic conditions in China

At times, using international standards can be accompanied by a lack of confidence in offshore wind technology due to risks not specified in the standards. The probability and severity of earthquakes is higher in Asian waters in comparison to European waters. Another environmental condition is that large stretches of China's coasts and waters are characterised by seabed deposits washed out by large rivers, posing the threat of soil liquefaction. New and existing standards should take into account the danger of earthquakes, soft soil and other harsh environmental conditions in each location, as these are critical in the development of foundations and supporting structures.

In the case of China, internationally recognised standards are adapted to the national context. Chinese certification and advisory agencies could exercise a major role in this regard. Similar to Europe, these service providers may possess considerable market influence in the future and offer classification, certification and consulting for the industry. However, at present, their influence is still limited and is not yet comparable to the European market.

International

STANDARDISATION EXPERIENCE


3

3. INTERNATIONAL STANDARDISATION EXPERIENCE

Throughout the history of offshore wind, standardisation has come in the form of international and national standards. In the late 1980s IEC efforts towards wind energy standardisation commenced and established international standards for onshore wind projects. Two leading motivating factors spurred the development of international standards:

1. Existing national standards for onshore wind had to adjust to the extended lifetime of wind turbines and to related new and different quality issues. Excessive downtimes, caused chiefly by breakdowns of gearboxes and blades (some after just 10 years) were endangering the industry.

2. The industry was especially interested in harmonisation of standards in order to extend market outreach.

3.1 International standardisation bodies

INTERNATIONAL ELECTROTECHNICAL COMMISSION[2]

At the international level, most of the work in standardisation in the field of wind energy generation systems is implemented by Technical Committee 88 of the IEC, which has responsibility for wind energy generation systems including wind turbines, wind power plants and connection to the electrical system. The secretariat, provided by Denmark (IEC, 2017b), addresses various issues through IEC standards, such as site suitability and resource assessment, design requirements, engineering integrity, modelling requirements, measurement techniques, test procedures, and operation and maintenance (IEC, 2016).

IEC TC 88 serves as one of the main platforms for experts to discuss technology developments in the offshore wind industry and implement good practices in international standards. Historically, the wind industry has greatly benefited from the TC 88 work, which was established to develop harmonised international standards for wind turbines. Relevant IEC standards in the offshore wind sector include IEC 61400-1 (Design requirements for wind turbines), 61400-3 (Design requirements for offshore wind turbines) and IEC 61400-22 (Wind turbines – Part 22: Conformity testing and certification) for the process of type certification.

The standard IEC 61400-1 defines design classes, design load case, fault conditions, environmental conditions for each design class, procedures for assessing static and dynamic loads, electrical requirements, and methods for assessing the site-specific suitability of the turbine. One of the most important parts is the detailed definition of turbulent wind environments.

The first standard issued specifically for offshore wind, IEC 61400-3, was published in 2009. The standard provides an overall framework to design an offshore wind turbine structure, including the blades, nacelle, support structure and foundation. As a comprehensive standard, it places strong emphasis on wind turbine requirements and complements the offshore support structures by referencing other standards from the American Petroleum Institute (API), ISO, DNV and GL.

The standard for certification of wind turbines, IEC 61400-22, describes and defines methods for type certification, project certification and component certification. It includes requirements from IEC 61400-1 and 61400-3 but also is seen as having limited adjustability for offshore wind turbines (the standard excludes specific offshore conditions). This has led to demands for revision of the standard. Currently GL-IV standards/guidelines are another option for certification.

2 The titles and descriptions of IEC standards are extracted primarily from https://webstore.iec.ch/?ref=menu.

IEC standards, if necessary, are evaluated and revised to be in line with the needs and constantly changing environment of the industry. An advantage of the IEC standards is that they are used as a starting point for any new standards being developed by public or private entities.

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

Many of the ISO standards relevant to the offshore wind industry were based on standards developed for offshore oil and gas. Most of the relevant standards deal with the design and reliability of structures. In particular, the ISO 19900 standard is used in offshore wind. The ISO work for platforms and structures is based largely on API standards. Apart from structures and foundations, ISO also deals with standards in the areas of ships and the marine operations relevant for offshore wind (ISO/TC 8) (ISO, 2018).

CEN/CENELEC

Each document developed by IEC/ISO is also forwarded to the respective regional standardisation committees. In Europe, these are the European Committee for Electrotechnical Standardization (CENELEC) and the Committee for Standardization (CEN) for parallel harmonisation. Documents that obtain the status of a European standard are also published as national standards, for example as DIN EN, BS EN, etc.

Standardisation in the area of health and safety traditionally has been a topic of late action. The standard EN 50308 (Wind turbines – safety requirements for design, operation and maintenance) was an important step in closing a gap in this field.

For CEN/CENELEC a prospective role in the future will be the co-ordination and harmonisation of standards related to grid connection, once plants move farther from the immediate near-shore zone. After 2020 very few applications are expected to be submitted for wind farms located near shorelines due to restrictions concerning the environment, shipping routes or aesthetics.

3.2 Classification societies and other organisations developing technical guidelines

Private companies and non-governmental organisations have developed their own technical rules and guidelines, in particular in the areas of design, construction, offshore structures and vessel operations. Most of them have extensive experience in the field and are known commonly as classification societies. The classification societies Det Norske Veritas Germanischer Lloyd (DNV GL) and the American Bureau of Shipping (ABS) have drafted industry guidelines for the offshore wind sector. In some cases, the guidelines are shaped by European influence and do not, for example, touch on harsh environmental conditions present in America or Asia.

Several classification societies are active in the field of standardisation for offshore wind. Guidelines produced by classification societies such as the ABS, Bureau Veritas (BV) or DNV GL are typically used in the field; these guidelines are not consensus-based standards.

AMERICAN BUREAU OF SHIPPING

The ABS has been a front runner in the offshore oil and gas industry and has extensive experience in fixed and floating offshore structures. One important document, the Guide for Building and Classing, Offshore Wind Turbine Installation (ABS, 2010), was drafted by merging experiences from the oil and gas sector with the requirements stated in the IEC 61400 series. The ABS also provides a document for electric service platforms, the ABS Rules for Building and Classing Offshore Installations, which is used worldwide in the verification of bottom founded structures.

AMERICAN PETROLEUM INSTITUTE

API standards are used in the oil and gas industry. Although these standards are not specifically designed for the offshore wind industry, they often have served as a source for developing ISO standards covering the field of offshore wind structures. In particular, API Recommended Practice 2A (Planning, designing and constructing fixed offshore platforms) has been influential in directing the work of the relevant ISO 19900 series (API, 2014).

BUREAU VERITAS

Bureau Veritas is a global company offering testing, inspection and certification services. In 2011 BV issued guidelines for the classification and certification of floating offshore wind turbines. Particular focus is given to environmental conditions under which floating offshore wind turbines may serve, structural design, load cases for platform and mooring systems, stability and the design of the structure (TRB, 2011).

DNV GL

DNV GL is an international classification society and certification body. It was created as a merger of Det Norske Veritas, Germanischer Lloyd and other organisations in 2013. DNV GL is one of the main actors in research on offshore oil and gas design requirements and also has developed several standards for offshore wind, being a contributor to IEC standards. As a certification body acting at the international level as well, DNV GL has harmonised and customised national standards to serve its own practices.

DNV's first offshore wind guideline, DNV-OS-J101 (Design of offshore wind turbine structures), was issued in 2004 and has been revised frequently since. This guideline covers design, construction, installation and inspection. The guideline applies to all components of the structure beneath the nacelle, including the foundation. Particular focus is given to construction and constant/regular observation of the support structure. Essential requirements are provided for steel and concrete structures, cast fittings, protection of corrosion, loads, transport and installation. The initial guideline covered support structures and foundations for offshore wind turbines, and drew in large part from API Recommended Practice 2A. Further guidelines were issued in the following years covering blades, design and certification issues.

GL was a pioneer in developing guidelines for wind turbine design. GL grew in light of the emerging wind industry in Germany and the requirement of project approval prior to developing projects in the sector. The guideline for the certification of offshore wind turbines has been updated regularly and covers structures, systems and components of offshore wind turbines as well as support structures and foundations. In particular, according to interviewed experts, the guideline could include more details related to offshore electric service platforms and floating support structures.

GL has been very active in updating its certification guideline to reflect the latest developments. Interviewed experts stated that this guideline is very comprehensive in terms of offshore (and onshore) wind turbine requirements. This certification scheme for type and component certification of wind turbines (DNV GL-SE-0441) was updated to incorporate experiences from previous certification projects and standards, especially type and component certification.

DNV GL standards are related to structures and conformity assessment, such as certifications. The most frequently used standards[3] are:

- DNV-OS-J101 Design of offshore wind turbine structures
- DNV-OS-J201 Offshore substations for wind farms
- DNV-RP-H103 Ship transit accelerations
- GL-IV-1 Guideline for the certification of wind turbines
- DNV OS-H205_2014-04 Lifting operations
- DNVGL-ST-0054 Transport and installation of wind power plants (DNV GL, 2018).

LLOYD'S REGISTER

In the UK, Lloyd's Register is a classification society that has partnered with the wind industry to encourage a new technical specification to provide verification of wind farm maintenance strategies throughout their full life-cycle. This specification, IEC 61400-28 (Through life-management and life extension of wind power assets), will give companies sufficient wind system information to fully assess the inspection and maintenance requirements for an asset, helping to have structured information when making decisions related to life extension, repowering or decommissioning (New Energy Update, 2018).

THE FINDINGS OF CLASSIFICATION SOCIETIES AND OTHER ORGANISATIONS

A large quantity of standards relevant to the offshore wind industry are available. The offshore wind actors interviewed for this study indicated that new developments in standards need to be based on existing standards, be updated with the latest technology and market developments, and be aimed at harmonised international requirements. A number of standards are already being updated to keep up with the market pace and with technology developments. The topics are:

– Marine machinery and subsea engineering
– Wind turbine design and lightning protection
– Electromagnetic compatibility and wind turbine protective measures
– Corrosion protection.

3 The titles and descriptions of IEC standards are extracted primarily from https://www.dnvgl.com/rules-standards/index.html.

The IEC is currently revising certain standards related to the abovementioned topics, such as 61400-1 (Design standards), 61400-3 (Design for offshore wind turbines) and 61400-3-2 (Design requirements for floating offshore wind turbines). Further progress has been made in lightning protection, with the IEC TC 88 reviewing the standard IEC 61400-24 on this topic.

Other important standards are being designed as well. The IEC started a project to elaborate a standard in electromagnetic compatibility, and the standard 61400-6 (Tower and foundation design) is expected to resolve problems with standardisation of the structure and foundation.

To avoid corrosion of structures, standards developed by classification societies elaborate options for implementing appropriate measures. However, the interviewed experts evaluated the measures as inadequately dealing with the challenge and therefore are in need of updates and revision. The experts stated that the commonly used standards are not completely in line with actual experiences related to the typical corrosion challenges that occur at the structures.

Further work in standardisation is needed in the following areas:

- Control systems for wind turbines and farms
- Blade repair (no repair standards for offshore blades)
- Operation and maintenance
- Shipping, stowage and clamping of wind turbine components
- Wind farm end of life
- Floating foundations for offshore wind turbines
- Health and safety.

In this relatively young industry, health and safety standards and guidelines have not been harmonised and are based mainly on individual projects or on the industry itself. Manufacturers, developers and operators must commonly find and implement their own approach for each country or project. In the last few years several deaths and injuries have highlighted the importance of regulations and standards in this area. Working conditions, such as using heavy lift cranes, working at heights and undertaking maritime operations in relatively harsher weather and with larger turbines, are among the challenges related to health and safety conditions.

3.3 Compilation of standards and technical guidelines for offshore wind

The international standardisation bodies and classification societies active in setting organisations' standards and guidelines, which serve the industry as international standardisation work evolves. Figure 11 presents a, non-exhaustive, summary of the commonly used standards and technical guidelines used in the offshore wind industry.

Figure 11: Standards and technical guidelines applicable to the offshore wind value chain

INTERNATIONAL AND COUNTRY STANDARDS AND GUIDELINES

Turbine and system design

International
- IEC 61400-1 Design requirements for wind turbines
- IEC 61400-3 Design requirements for offshore wind turbines

European Standard
- EN 50308:2004 Wind turbines. Positive Measures. Requirements for design, operation and maintainence

Classification Society
- DNV-OS-J101 Design of offshore wind turbine structures

Germany
- BSH Standard design of offshore wind turbines

Equipment selection

International
- IEC 61400-6 Tower and foundation design requirements

China
- NB/T 31094-2016 Offshore specific environmental conditions and
- technical requirements for wind power generation equipment.
- GB/T 33630-2017 Offshore wind turbine generator systems: specifications for corrosion protection
- NB/T 31006-2011 Technical code for anticorrosion of offshore wind farm steel structures
- NB/T 31041-2012 Converter of offshore doubly fed wind turbine generators.

Installation and commissioning

International
- ISO 19900 General requirements for offshore structures

China
- GB/T 50571-2010 Code for construction of offshore wind power projects
- NB/T 31031-2012 Code for preparation of offshore wind power projects pre-feasibility study report
- NB/T 31032-2012 Code for preparation of offshore wind power projects feasibility study report
- NB/T 31033-2012 Code for construction planning of offshore wind power projects
- NB/T 31029-2012 Specification of wind energy resource measurement and marine hydrographic observation for offshore wind power projects
- NB/T 31030-2012 Specifications for engineering geological investigation of wind power projects

Germany
- BSH Minimum requirements concerning the constructive design of offshore structures within the Exclusive Economic Zone (EEZ)
- BSH Ground investigation for offshore wind energy

Classification Society
- DNVGL-ST-0054 Transport and installation of wind power plants
- DNV-OS-J201 Offshore substations for wind farms

Performance, operation and Maintenance

International
- IEC 61400-22 Conformity testing and certification for wind turbines

European Standard
- EN 50308:2004 Wind turbines. Protective measures. Requirements for design, operation and maintenance

China
- GB/T 31519-2015 Wind turbine generator system under typhoon conditions

End of life

Decommissioning and waste management of offshore wind still need to be properly addressed in international standards.

3.4 International certification for wind technology – IECRE

The IEC System for Certification to Standards Relating to Equipment for Use in Renewable Energy Applications (IECRE) is a conformity assessment system based on international standards prepared by the IEC (IECRE, 2018a). IECRE aims to provide a global framework for independent assessment and certification of equipment and services associated with renewable energy applications. This international certification system recognises and harmonises certification across all the major international markets.

IECRE is well aware of the international standardisation and testing setting; it provides an open and transparent system that introduces peer assessment and mutual recognition for certification bodies at a global level. This means that all certification bodies throughout the world, which operate within IECRE, accept the IECRE Test Reports and Certificates that are issued by an accepted IECRE Testing Laboratory or associated Certification Body, if applicable. These test reports and certificates can be used in national certifications, without the need to repeat the tests themselves. This is a key benefit of IECRE, greatly easing the certification process through its mutual recognition framework (the certification body is accepted in many countries worldwide) (IECRE, 2018b). Also, this approach provides a clear set of rules for new certification bodies entering the offshore wind market.

3.5 Cross-cutting work and other standardisation initiatives

At a minimum, two major groups of stakeholders need to collaborate in standardisation for offshore wind. One is the maritime technology sector, which has long-term experience in construction and is often referred to in the guidelines of classification societies. The other is the actors that have experience in onshore wind farms, such as turbine and foundation suppliers, developers and operators of wind farms, national and regional trade associations, and transmission system operators who have increasingly become responsible for offshore grid connection.

A relevant example of cross-cutting work was proposed by Germany's NMST, ISO and the Lübeck University of Applied Sciences, to work on a zone model relating to individual zones. The model identifies objects relevant to the offshore wind farm. The final version was designed as a matrix, incorporating spatial location of objects (air, land, water, underwater), dynamic property of the objects (temporary, movable, stationary/permanent) and function (production of energy, transformation of energy, transport of energy, maintenance or construction) (ISO, n.d.).

In 2012 the American Wind Energy Association (AWEA), noticing the rising activity in the US offshore wind market, elaborated practices for the design, deployment and operation of offshore wind turbines in the US. These recommendations are based on consensus among offshore wind energy and offshore industry experts and are adjusted to the unique conditions present at US wind facilities (AWEA, 2012). In September 2017 the US launched an initiative for multiple stakeholders to jointly develop standards for offshore wind. This project involves the Department of Energy, the National Renewable Energy Laboratory, the Bureau of Ocean Energy Management, the Bureau of Safety and Environmental Enforcement, the Business Network for Offshore Wind and the AWEA. The initiative also contemplates industry stakeholders to guide the work in technical sub-groups, covering topics such as floating offshore turbines, geotechnical data, meteorology and oceanography requirements for US waters (Wind Power, 2017).

Another cross-cutting approach is the North Seas Energy Cooperation. In 2016, ten countries in the North Sea region signed a political declaration on energy co-operation among the North Sea countries to reaffirm their commitment to the development and cost-effective deployment of offshore renewable energy, in particular wind (EC, 2018). Four areas were selected for collaboration among the countries, one of which focuses specifically on standards, technical rules and regulations in the offshore wind sector.

Their work covers harmonisation of:
- health and safety requirements,
- certification standards for components
- crane operations
- best practices exchange regarding park layout
- crew and vessel requirements
- waste management
- lightning and painting of turbines (EC, 2018).

A wide variety of stakeholders participates with the aim of assuring a secure and reliable offshore wind energy supply and promoting interconnection among the different North Sea markets.

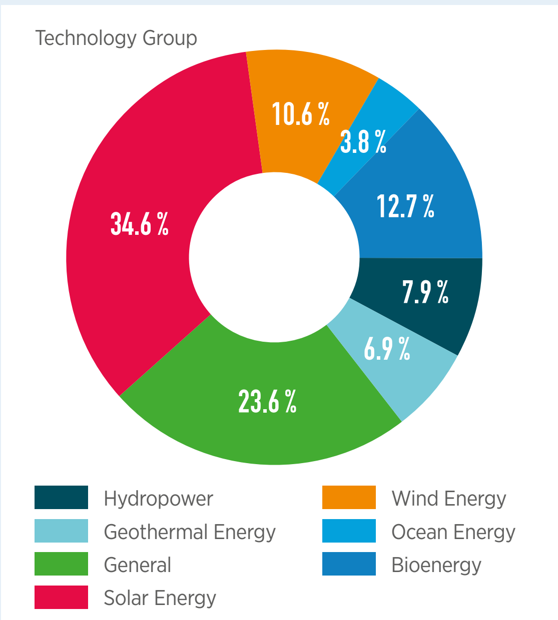
Stakeholders have acknowledged the health and safety challenges associated with offshore wind and are working on a more unified approach by sharing data and developing standards for safety training. One example is the Global Wind Organisation, an association of wind turbine owners and manufacturers that aims to support an injury-free work environment in the wind industry. The association has developed the Basic Safety Training Standard identifying best practices for health and safety as a way to reduce risks for personnel working on-site and for the environment (GWO, 2017).

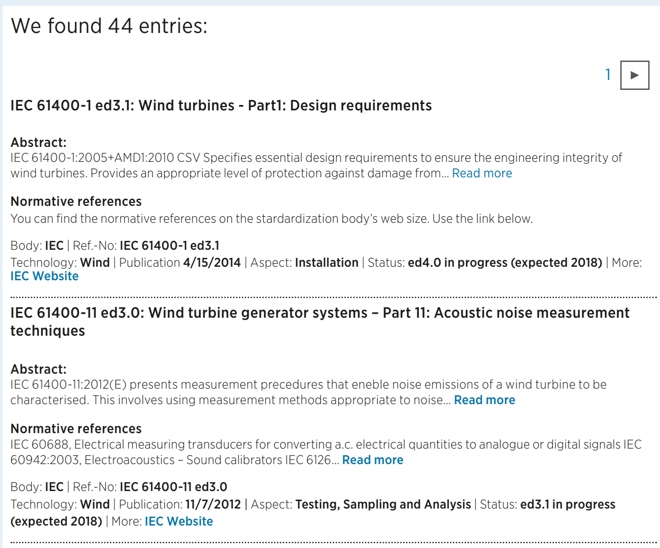
Japan offers a good example of standardisation in policy making. The country had plans to submit a law in 2018 that makes reference to standardisation of offshore wind power. The government of Japan aims to set standards for the installation of wind turbines and the number of years of permitted operation. With this initiative, the national government intends to promote safe installations, diminish risks for operators and encourage new entries of companies in Japan by instituting the occupancy permissions for offshore wind farms (Nikkei Asian Review, 2017).

INSPIRE – International Standards and Patents in Renewable Energy

INSPIRE is an online tool developed by IRENA to perform analysis on patents and technical standards in renewable energy. The platform helps users search through, locate and analyse more than 2 million patents and around 400 international standards for renewable energy technology. INSPIRE offers three key elements: search engines, learning sections and a networking space that reflects the key organisations and Technical Committees involved in the development of standards.

Access INSPIRE at: ***www.irena.org/inspire***




We found 44 entries:

1

IEC 61400-1 ed3.1: Wind turbines - Part1: Design requirements

Abstract:
IEC 61400-1:2005+AMD1:2010 CSV Specifies essential design requirements to ensure the engineering integrity of wind turbines. Provides an appropriate level of protection against damage from... Read more

Normative references
You can find the normative references on the stardardization body's web size. Use the link below.

Body: **IEC** | Ref.-No: **IEC 61400-1 ed3.1**
Technology: **Wind** | Publication **4/15/2014** | Aspect: **Installation** | Status: **ed4.0 in progress (expected 2018)** | More: **IEC Website**

IEC 61400-11 ed3.0: Wind turbine generator systems – Part 11: Acoustic noise measurement techniques

Abstract:
IEC 61400-11:2012(E) presents measurement precedures that eneble noise emissions of a wind turbine to be characterised. This involves using measurement methods appropriate to noise... Read more

Normative references
IEC 60688, Electrical measuring transducers for converting a.c. electrical quantities to analogue or digital signals IEC 60942:2003, Electroacoustics – Sound calibrators IEC 6126... Read more

Body: **IEC** | Ref.-No: **IEC 61400-11 ed3.0**
Technology: **Wind** | Publication: **11/7/2012** | Aspect: **Testing, Sampling and Analysis** | Status: **ed3.1 in progress (expected 2018)** | More: **IEC Website**

Lessons learned and prospective areas for FUTURE WORK

4

4. LESSONS LEARNED AND PROSPECTIVE AREAS FOR FUTURE WORK

As the offshore wind sector spreads across countries, standardisation can serve as a key instrument to overcome market barriers and spur the deployment of offshore wind technologies. Investigating and promoting the development of standards results in competitive and inclusive trade, robust co-operation mechanisms with international organisations and increased confidence from consumers regarding foreign products.

Standardisation in offshore wind is still in an early stage; however, the initial efforts have unlocked more rapid deployment rates in countries such as China, Denmark, Germany, the UK and the US. Ongoing revision and optimisation of existing standards is taking place globally. However, because of the importance of including numerous stakeholders and taking into account occasionally diverging opinions, this is a time-consuming process that needs to happen more quickly to match the fast-changing needs of the industry.

Standardisation plays an important role in reducing costs and improving safety. A good example of this is the co-ordination of marine standards. Standardisation in this area has meant fewer vessel journeys and faster delivery of services, which is critical in the rough environments of seas and oceans and thus reduces cost.

Standardisation has been said to be threatening innovation in the sector, but this is not the case. Some standards developers and certification bodies have developed concepts centred on risk-based certification of innovative designs. In such a case the certification bodies must work closely with the designer and owner of the innovative structure or component.

Lessons learned from the offshore oil and gas sector offer benefits and opportunities for improvement. Opportunities are provided in adjusting standards and even in adapting them without much additional effort. However, the risks of failing to adjust the standards to specific offshore wind conditions should not be neglected. For instance, gravity-based substructures are frequently used in offshore wind but are poorly documented with regard to standards in steel substructures, among the most commonly used by the offshore oil and gas industry. However, the design of shallow-water steel structures for oil and gas is concerned mainly with preventing plastic collapse, while the design of offshore wind turbines is more concerned with preventing failure due to resonance and fatigue (TRB, 2011). Thus, there is a need to draft more appropriate standards for the offshore wind industry, in particular for foundation structures, substations and floating platforms. Furthermore, oil and gas standards tend to be fairly conservative because of the need to protect personnel and the value of the assets; in contrast, offshore wind stations are generally unmanned (BSI, 2014).

Standardisation in health and safety, especially for regulatory purposes, will continue to be improved and updated. At the early stages of the industry, the already existing shore-based safety, health and environmental requirements in terms of quality and standards were adopted or adjusted slightly to serve the needs of the offshore wind industry. Large numbers of accidents occurred in the past during construction, installation and maintenance. These accidents were preventable, as they tended to arise from hazards when working at heights, dropped objects and crush injuries. It became apparent that those standards do not always integrate well with marine standards and legislation, opening an opportunity to work further in advanced health and safety regulations beyond what had been developed for offshore oil and gas. The health and safety regulations and standards are expected to accelerate standardisation and innovation in other areas, such as installation vessels, infrastructure in quays and automated production processes, the main sources of accidents and injuries.

All three of the leading markets for offshore wind – Denmark, Germany and the UK – follow in large part their own national standards and regulations related to health and safety requirements. It is not surprising that individual countries are going this way, as health and safety requirements are often of national concern and are translated into regulatory conditions. Harmonisation in this area has begun only slowly.

Offshore wind markets outside of Europe could get more involved in the development of international standards, contributing to the creation of standards suitable for all regions. Currently offshore wind standardisation is influenced mainly by European countries, as Europe is a leading market for this type of energy. International offshore wind guidelines and standards can be improved further by considering the conditions of offshore wind projects outside Europe.

So far certification requirements have managed to guarantee the safety and reliability of the technology to a large extent. However, type certification of wind turbines needs to better encompass extreme climates, such as hurricanes in non-European waters. The IEC is working on this, advising that design standards require a type certification according to the wind conditions at the site. This certification can be coupled with an extreme weather assessment, a suitable approach when working in regions outside of Europe.

The continued increase in the height of structures such as monopiles poses new challenges for standardisation related to structures and foundations. New standards from DNV and the IEC (61400-6) are expected to address this problem. IEC 61400-6 (Tower and foundation design) is expected to provide solutions for many problems related to tilt tolerances and stability. The expected increase of turbine size will probably cause similar challenges.

Multiple countries have on their radar standardisation in floating offshore wind. Floating wind power is an emerging and potential key area of development in countries such as China, France, Japan, Portugal, the UK (in particular Scotland) and the US. The first standards are currently in development but rely heavily on further progress in standardisation related specifically to the design of offshore wind turbines.

Classification societies are key for supporting international standardisation in the field. For one, they possess experience and knowledge. Moreover, they have not only commercial interests but also participate in the ongoing work of most standardisation bodies and thus have considerable influence on the scene.

International standardisation bodies, such as the IEC, require bold support from governments to be able to respond quickly to the needs of an industry that is developing faster than expectations, as is the case with offshore wind. Countries can sponsor experts to engage in technical committees, learning from and sharing good practices while ensuring that national local conditions are incorporated into international standards.

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