**Market potential and Technology assessment – Floating Offshore Wind**

**Project information**

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The Crown Estate

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**Indexing terms**

- Renewables
- Cleaner Energy
- Floating Wind Energy
- Offshore Wind Energy
**Introduction**

The Crown Estate gave DNV the task to perform an evaluation with the overarching goal to assess the commercialization potential of floating offshore wind energy.

DNV has conducted a high level evaluation on the current status and developments of the floating offshore wind industry, including assessments of the various technologies and markets. A global perspective has initially been taken prior to a more specific discussion on the UK potential and the on-going scoping for offshore wind demonstration sites.

In the study DNV has used public available information, utilized in-house expertise and approached technology developers.

**UK potential**

By utilizing existing capabilities, DNV believes that the UK has the potential to become one of the leading regions for offshore floating wind developments. ETI’s planned work on a floating offshore wind demonstrator is an important step for the industry as a whole, and for the UK in particular. Not only will this allow for important testing and evaluation of concepts, it could potentially also create a momentum for the industry and spur further investments. This is especially important from a European market perspective, considering the development activities taking place in Japan and the US.

Abundant offshore wind resources, governmental incentives and support frameworks combined with an extensive O&G, maritime and fixed offshore wind experience is advantageous and should allow for the UK to position themselves as a market leader also for floating wind solutions. With planned pilots and demonstration sites in Japan, Portugal and the US, the floating wind demonstrator project could be a way for the UK to initiate work on floating wind technologies and establish an even greater basis for a market in Europe.

**Technology Developments + Cost Reductions + Market Size = FLOATING OFFSHORE WIND**

### Floating concepts

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<tr>
<th>Semi-sub</th>
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<tr>
<td>A semi-submersible is a free-surface stabilized structure with relatively shallow draft. It is a versatile structure thanks to its relatively low draft and flexibility to site soil conditions. Generally, it is a heavy structure with a relatively high steel mass and manufacturing complexity due to the many welded connections.</td>
<td>The spar buoy is a weight-buoyancy stabilized structure with relatively large draft. The philosophy uses simple (few active components), well-proven technology with inherently stable design and few weaknesses. The spar will face challenges due to its large draft for the actual site, but primarily in terms of assembly sites and transportation routes, which could limit the deployment in parts of the world.</td>
<td>The Tension Leg Platform is a tension restrained structure with relatively shallow draft. The tension leg philosophy enables low structural weight of the substructure, and thus lower material costs. TLP’s could potentially have a higher operational risk, caused by the risk for a total loss of the structure in the event of a tendon failure, if not countered in the design. TLP designs also add requirements with regard to soil conditions at site.</td>
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### Development

![Graph showing technology levels](#)

- **Semi-sub**: Today
- **TLP**: Large array
- **Spar**: Small array
- **WindFloat**: Full scale demo
- **Hywind**: Today

The concept which has reached the highest technology readiness level today is the Hywind spar. Hywind has had a full scale prototype in operation since 2009. A small array of Hywind turbines is estimated to be deployed in 2015 and a large array and commercialisation in 2020.

WindFloat is the most developed semi-submersible concept. WindFloat has had a fullscale demo since 2011. A small array of WindFloat concept is estimated to be operational in late 2015 and a large array and commercialisation in 2021/2022.

No TLP has yet been deployed as a large scale prototype. However, PelaStar, the most developed TLP concept, being developed by Glosten Associates, has indicated a rapid future development. A full scale demo is planned in 2016 following by a small array in 2020 and a large array and commercialisation in the years thereafter.

### Cost reductions

Costs for both bottom fixed and floating structures are expected to flatten out and thereafter decrease in the coming years. The potential for cost reductions for floating structures is evident based on technical improvements taking place, learning effects and supply chain improvements.

Floating structures have a considerable advantage compared to fixed by not being as site dependent. This allows for a much more standardized design when not having to custom make every single foundation.

DNV expects the cost for floating wind farms to catch up with the cost for fixed farms over time. How long this will take and what the ultimate cost level will be remains uncertain as it is dependent on the volume built, which in turn is dependent on political support, market development and trends.

### A global market

The global market potential for offshore floating wind is significant. Vast wind resources offshore combined with large water depths makes floating wind solutions the only realistic option at many locations.

The industry emerged in Northern Europe, but today concept developments, research activities and governmental funded pilot projects are happening all over the world.

The US DOE supports a range of activities in order to reduce the cost of floating wind and in December 2012 it was announced that seven offshore wind projects, three of them floating, had been selected for funding to complete engineering, design and the permitting phase in order to support innovative solutions in the US. The government of Japan is currently involved in several large scale pilot projects and within the EU there are a number of programs supporting the development of floating offshore wind.

In the UK, ETI plans to invest £25m in a 5 to 7 MW demonstrator project in 60 – 100 m water depth.
The Crown Estate – UK Market Potential and Technology Assessment for floating offshore wind power

Activity 1 – Floating wind concepts

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</table>
Technical description

A welded structure that is constructed or assembled on-shore or in a dry dock. Transport to site is done by using conventional tugs. Fully equipped platforms can float with drafts lower than 10 meters during transport. Towing to field can typically be done in relatively high wave heights.

Because of the low draft and stability, transport can be done in shallow water. However, in order to pre-assemble when in shallow waters inshore, dry-dock or onshore assembly is required.

Application

Semi-submersibles have typically the lowest draft of the the philosophies and can be seen as a alternative to jacket structures in certain places. Transport can be done in 10 m draft allowing assembly and transport in shallow and sheltered areas.

Concepts and development

WindFloat, the most developed concept using the semi-submersible philosophy, has had a fullscale demo since 2011. A small array of semi-submersible structures is estimated to be operational in late 2015 and a large commercial array is estimated to be deployed in 2021/2022.

Operation and maintenance

Major maintenance can be done by towing the structure to shore. Most concepts can be reached from all columns in case of in-situ maintenance and service. Some concepts plan to build helidecks on the substructure. Regular inspection of welded connection, both above and below sea-level is necessary in order to identify and mitigate fatigue cracks, corrosion, etc.

Parameters

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<td>Monopile</td>
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<td>Jacket</td>
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Mooring, anchoring and seabed footprint

Mooring lines are typically taut or catenary. Anchors are chosen based on the soil conditions. Drag embedment anchors are versatile and often used, as is suction anchors. Large seabed footprint. Horizontal distance between anchor and fairlead is normally 4-6 times the waterdepth, but can potentially be considerably larger (10-20 times indicated).

Because of the low draft and stability, transport can be done in shallow water. However, in order to pre-assemble when is shallow waters inshore, dry-dock or onshore assembly is required.
Market potential and Technology assessment – Floating Offshore Wind

Floating wind concepts – Spar Buoy

**General description**

Traditionally a steel or concrete cylinder with low water plane area, ballasted with water and/or solid ballast to keep the centre of gravity below centre of buoyancy. Spars are stable in general, due to the large draft, which also minimises heave motions.

A spar is typically moored using catenary or taut spread mooring systems. The mooring line material is often anchor chain, steel cables or fibre ropes.

Due to large draft, the spar may require towing to a deep-water site in horizontal position, where it is up-ended, stabilized and the turbine is mounted by a crane barge. In case of deep water fabrication sites, the full assembly can be done in-shore, followed by tow-out using conventional tugs. Component replacement would typically be done offshore.

Constrained in areas with shallower water, both with regard to assembly site, installation site and transport phase.

**Technical description**

**Structural design**

Stable structure with high inertial resistance to pitch and roll motions. Relatively stiff in surge and sway, but more flexible in rotational modes.

**Mooring, anchoring and seabed footprint**

Mooring lines, typically taut or catenary. Large seabed footprint. Horizontal distance between anchor and fairlead is normally 4-6 times the waterdepth, but can potentially be considerably larger (10-20 times indicated).

**Fabrication and installation**

Due to large draft, the spar may require towing to a deep-water site in horizontal position, where it is up-ended, stabilized and the turbine is mounted by a crane barge. In case of deep water fabrication sites, the full assembly can be done in-shore, followed by tow-out using conventional tugs. Development of specialized vessels and/or customized turbines may enable horizontal towing. Concrete can be used instead of steel as manufacturing material.

**Operation and maintenance**

Component replacement would typically be done offshore. In case of deep water transport routes and maintenance site, hook-off and towing to shore could be possible.

**Application**

The spar concepts have usually the largest depth requirements. This limits the areas suitable for this concept.

**Concepts and development**

The spar concept which has reached the highest technology readiness level at today’s date is Hywind. Hywind has had a full scale prototype in operation since 2009. A small array of Hywind turbines is estimated to be deployed in 2015 and a large commercial array is estimated to be deployed 2020.

**Parameters**

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<td>TLP</td>
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<td>Jacket</td>
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**Strengths /Weaknesses**

- Inherently high stability structure
- Fatigue load in tower base might be higher for spar buoys than for TLP
- Relatively simple structure to manufacture, minimum amount of welds, and there is a possibility to use concrete instead of steel.
- The large draft may limit the possibility for in-shore assembly which would add several offshore operations.
- Relatively easy decommissioning is expected. Special purpose vessels may be used for transport to shore.
- Few active systems or complicated components
- The large draft may limit the possibility for tow-back to shore in case major maintenance is required.

**Market potential**

3) Hook up

Shallow waters inshore:

1) Transport of components
2) Offshore assembly & hook up

Deep waters inshore:

1) Inshore assembly
2) Towing turbine
3) Hook up

Deep water is required to upend the spar. If no sheltered deep water is found, typically along the UK coast, upending and assembly offshore might be required.
Market potential and Technology assessment – Floating Offshore Wind

Floating wind concepts – Tension Leg Platform (TLP)

### General description
TLPs normally have a large centre column, with number of submerged “arms” to which the tension legs are attached. TLPs have large buoyancy, and are held down by tension cables, tendon pipes or solid rods, which reduces the weight of the substructure as well as the overturning moment. The anchors could typically be of gravity based, suction or pile driven type.

A TLP can be assembled onshore or in a dry dock. It is considered as likely that special purpose vessels will be applied to provide the necessary stability during float-out to site, even though some developers indicate that concepts can be towed to site.

Component replacement would typically be done in- or onshore, as long as an easy hook-off system is in place. The hook-off procedure will have to deal with transitional phase of going from a TLP to a free-floating platform.

TLPs are quite flexible with regards to water depth, but have certain requirements when it comes to soil conditions.

### Technical description

**Mooring, anchoring and seabed footprint**
Vertical tendons connects the floating turbine to the anchors on the seabed. The anchors could typically be of gravity based, suction or pile driven type. The tendons are pre-tensioned and provides stability.

**Small seabed footprint.** Typically only directly below the floating structure.

**Schematic**

### Fabrication and installation
A TLP can be assembled onshore or in a dry dock. When the structure has been completed it can transported to site either with special purpose vessels, like for the PelaStar concept, or with more traditional solutions (towed to site) as has been indicated for the Gicon TLP. Various solutions are under development and remains to be proven in practice.

Because of the low draft and stability, transport can be done in shallow water. Some concepts might require additional stability support during transport and hook-up.

### Operation and maintenance
Component replacement would typically be done in- or onshore, as long as an easy hook-off system is in place. The hook-off procedure will have to deal with transitional phase of going from a TLP to a free-floating platform. This can be done by adding stability elements to the structure.

### Parameters

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<td>Semi-sub</td>
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<tr>
<td>Spar</td>
<td>100-125</td>
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<tr>
<td>TLP</td>
<td>125-150</td>
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</table>

### Strengths/Weaknesses

| Structural design | - Lower fatigue loads in tower and blades than semi-submersibles, and lower fatigue loads in the tower base than spar buoys
|                  | - Less technological experience from offshore wind application than for spars and semi-submersibles
| Fabrication & Installation | - Can be fully assembled in a dry-dock
|                  | - Tendon tensioning and transitioning from a free-floating phase to a TLP phase could be challenging
| Decommissioning | - Relatively easy decommissioning is expected. Special purpose vessels may be used for transport to shore.
| Operation & Maintenance | - Simple structure to inspect. Few active systems and components. Low amount of welds that will require inspection
|                  | - Can be challenging to disconnect for tow-to-shore in case of major repairs. Tendon termination points (and possibly active tensioning system) needs attention.

### Concepts and development

PelaStar is probably the TLP concept which is furthest in development and closest to deploying a large scale demonstration unit. A full scale demo is planned in 2015 following by a small array in 2020 and a large commercial array is estimated to be deployed in 2025.

### Application

TLP has low draft and can operate in depths down to 50 meters. The concept should be applicable also in sites with high tidal ranges based on the possibility to adjust the draft of the substructure. The draft of the PelaStar concept is 22m during operation.

### Diagrams

- **Today:**
  - Shallow waters inshore:
  - Deep waters inshore:

- **Structural design:**
  - TLPs are high stability platforms. Typically soft in surge and sway but stiff in the rotational modes

- **Operation & Maintenance:**
  - Simple structure to inspect. Few active systems and components. Low amount of welds that will require inspection.
  - Can be challenging to disconnect for tow-to-shore in case of major repairs. Tendon termination points (and possibly active tensioning system) needs attention.

- **Environmental conditions:**
  - Low draft and stability, transport can be done in shallow water. Some concepts might require additional stability support during transport and hook-up.
The Crown Estate – UK Market Potential and Technology Assessment for floating offshore wind power

Activity 2 – Floating wind markets

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Introduction

- The vast wind resources available in deep waters has led to an increased focus from the offshore wind industry on development of technologies that are feasible for these conditions.
- The development of deep water offshore floating systems has mainly been led by Northern Europe, but today a considerable amount of R&D, concept developments and testing of floating systems are performed also in US, Japan and within the EU.
- The US has significant deep water wind resources and a considerable potential to deploy floating wind technologies. In Japan the Fukushima nuclear accident of 2011 has led to major developments and incentives for floating wind technologies.
- An assessment by the European Wind Energy Association, EWEA, identified a project portfolio in European waters of 141 GW (online, under construction, consented or planned) of which close to 40 GW would be in the deeper waters of the Atlantic and Mediterranean sea. In Europe, the most interesting countries for floating wind power is Norway, Spain, Portugal and the UK.

Market size

Offshore wind power is expected to play an increasing role in future power generation. The exact numbers are however difficult to estimate, this is governed by many factors like political incentives, how far the costs for offshore wind can be brought down and also on how successful the commercialization process of floating wind technology becomes. Technical achievements, the availability of finance, a regulatory climate that incentivizes investments and social acceptance are parameters that will all have an impact on the market size for offshore wind and affect also the development of floating solutions.

The International Energy Agency, IEA, has presented a range of scenarios on the scale of offshore wind power that will be required in order to avoid global warming above 2 degrees celsius (as defined by UNFCCC), with estimates ranging from 100 GW to over 1000 GW by 2050:

- **Low scenario (32 GW by 2020, 119 GW by 2050)**
  Applicable if the world fails to remain on a path on 2 degrees celsius and/or few constraints on nuclear and CCS, and/or electricity demand is low, relatively.

- **Medium scenario (86 GW by 2020, 439 GW by 2050)**
  Applicable if the world keeps on a 2 degrees path and there are few constraints of nuclear and CCS.

- **High scenario (118 GW by 2020, 1142 GW by 2050)**
  Applicable if the world keeps on a 2 degrees path and there are strong constraints on nuclear and CCS.

IEA further reports that the global market turnover by 2050 could grow to £16 bn - £168 bn (£56bn in medium scenario). There are no specific numbers for floating wind technologies available, but considering the vast wind resources available in deep waters, the potential market turnover for such solutions could be significant.

Higher wind speeds at deeper waters – Market drivers for floating wind power

- Sites with high and regular wind speeds, with low/moderate wave heights, are essential conditions for floating wind solutions.

- New developments are taking place at increasing water depths and larger distances from shore. The average water depth of an installed offshore wind farm was 22.8 m in 2011, a 31% increase from the previous year. For projects under construction, the average depth is 25.3 m, another 11% increase compared to 2011.

- The 1st and 2nd market phases for offshore wind led to deployment in water depths below 40 m. Deployments in the German EEZ and UK round 3 has however moved the fixed market into deeper waters. Wind farms being consented and planned for today are also moving further and further away from shore. Figure 1 presents the average water depth and distance to shore for online, under construction and consented offshore wind farms, where the bubble size indicates the wind farms total capacity. As can be seen from the Figure, there is a clear indication that developers considers water depths of 50 m to be the limit for when an offshore wind farm is feasible, considering today’s cost levels. Only a few projects are planned in waters beyond 50 m water depth. It is therefore clear that there is a void for projects between 50 and 100 m water depth located no longer than 100 km from shore. The announced floating solutions have the potential to move the offshore wind market to even greater water depths.

Fig. 1: Average size, distance to shore and water depth. Source: EWEA 2012, key 2011 trends and statistics, January 2012.
Floating Offshore Wind Power

Floating wind power – Global market potential

- US ambition is to develop 54 GW of offshore wind generating capacity by 2030.
  - Over 60% of resources in deep water
  - The US Department of Energy has decided to fund development of up to seven offshore wind projects, including three floating.

- Offshore wind has the potential to deliver 50% of EU's electricity demand by 2050.
  - WindFloat demonstrator deployment outside Portugal and NER300 funding for a WindFloat farm consisting of five units with an overall capacity of 27 MW.
  - FP7 programme (HiPRWIND received M€ 11)

- ROC banding process vs. CFD FIT process is under negotiation.
  - Scottish government considers additional support for 'innovative offshore wind deployment in deep waters'.
  - ETI will fund 1 demonstration project in 60-100 m water depth.
  - Considerable deep water resources.

- Green certificates in joint programme with Sweden
  - Strong partners are taking an active part in the development and testing of full scale prototypes.
  - Considerable deep water resources
  - Hywind installed since 2009. Proven concept.

- Will finance up to 6 floating offshore wind demonstration projects
  - Vast majority of wind resources in deep waters
  - Floating wind has experienced a significant 'push' following the Fukushima nuclear accident.

Deeper waters: US, Japan, Norway, Spain/Portugal, parts of UK
Shallower waters (from 40 m): UK Round 3 & German Bight
Key reflections on US

- The opportunities for offshore wind are abundant with over 60% of the water available for energy production is in deep waters (>60m).
- An offshore wind industry is emerging through a range of incentives and enablers, the potential for floating wind deployment is significant.
- US Department of Energy (DOE) is actively funding research projects and are providing grants to promising floating wind concepts. The DOE wind program has selected (in December 2012) three floating projects to receive funding as part of a demonstration initiative for offshore wind energy.
- Production Tax Credit (PTC) for wind in order to support the operation of the producing facility during its first 10 years. The support has so far been minor (2.2 cents/kWh), and PTC alone is not expected to be a sufficient industry incentive.
- The US has the ability to start and scale up in the industry based on lessons learned from Europe, a significant experience in the O&G industry, ongoing research projects and active technology developers are key enablers. The US market is expected to respond quickly – once the technology become more cost-competitive.

Market size

- Analyses have shown that the technical offshore wind resource potential along the US coastline and the Great Lake waters is more than 4000 GW. 2400 GW of capacity (more than twice the size of US generating capacity from electric power plants) is available when considering restrictions based on competing uses and environmentally sensitive areas.
- As a majority of the US population lives along the coast, offshore wind could potentially provide cost-competitive electricity to highly populated areas, as the generation would then be relatively close to the load centers. A further motive for offshore wind energy development is the potential for local economic development benefits, advances in technology and the superior capacity factors experienced offshore.
- In 2008 DOE developed a scenario on how to achieve that 20% of the US electrical energy is produced by wind energy by 2030. It was then envisioned a total of 54 GW of offshore wind capacity. More recently, the US Department of Interior assessed the energy resources of the Outer Continental Shelf and concluded that almost the entire US electric energy needs could be met by deep water offshore wind solely. With over 60% of the wind resources in deep water, including all the offshore wind resources in Northern New England, the US West Coast and Hawaii (in water depths beyond 60 m) - floating offshore wind technologies is the only realistic and viable solution at many locations.

Governmental actions and incentives

The US Department of Energy (DOE) focuses on the development of a strategy to:

1) Reduce the cost of offshore wind energy to be cost-competitive with other electrical generation sources.
2) Reduce the uncertainties and timeline with US offshore wind developments.

- DOE is working on coordinating federal and state agencies, the industry, academia, the public and other stakeholder groups in order to establish collaborative actions, developments and demonstration activities. Table 2 provides an overview of activities, funding, the number of projects and the timeframe. Promising technology concepts have received funding from DOE to reduce the cost of energy (COE) through targeted technological advancement. In mid-December 2012 DOE decided that three floating projects would receive funding for deep-water demonstration site developments. (5 x 6MW WindFloat Semisubmersibles, 4x3MW Hywind Spar-Buoy and a 2x6MW development coordinated from the University of Maine).
- The DeepCwind consortium is a group consisting of 36 industrial, university and national laboratory partners, coordinated by the University of Maine through DOE funding. DeepCwind has a specific focus on floating offshore wind technologies and are involved in testing, deployment and design of pilot scale floating wind technologies.
Key reflections on Japan

- The vast majority of Japan’s wind resources are in deep waters
- The Fukushima nuclear accident in 2011 has led to a significant increased focus on the potential of the floating wind industry
- Through the shipbuilding industry Japan has significant floating steel construction competence
- Japan has a long experience in floating steel structures, mass production and lean manufacturing and strong maritime R&D
- Based on an energy industry in transformation, the ability to balance with natural gas and industrial capabilities in offshore structures, the floating wind industry is expected to expand at a fast pace in Japan.

Market size

- Deep waters, a steep seabed and limited land available for onshore wind has made Japan to consider and move forward with the development of floating offshore wind technologies in order to harness the abundant wind resources available offshore.
- Recent analyses performed by the Japanese Ministry of Environment has shown that the potential for floating wind power in Japan could be as high as 1270 GW.
- Japan is a country with very limited domestic fossil fuel resources. The Fukushima nuclear accident in 2011 therefore had a major impact on the power production. All of Japan’s 54 nuclear reactors closed down as a consequence of the disaster, 30% of the power production was lost and only 2 reactors have been restarted (July 2012). Today Japan spends a considerable amount of money on imported LNG in addition to what was spent before the Fukushima accident.
- Japan has a considerable experience in offshore floating structures through its ship building industry, a strong emphasis on maritime R&D and a culture and experience in mass production, enabling cost reductions and commercialization of technologies. The high technical capabilities of the Japanese ship building industry in conjunction with Japan having the world’s 6th largest Exclusive Economic Zone (EEZ), the energy crisis and high electricity prices makes floating offshore wind a highly realistic energy source for Japan and a catalyst to accelerate the developments of new offshore technology solutions.

Governmental actions and incentives

The Japanese government has decided to support the development of floating offshore wind power and are currently involved in several large national projects.

- Fukushima Floating Pilot Wind Farm: Four different floating wind structures are planned to be installed off the coast of Fukushima during 2013 and 2014. In the first stage a floating substation and a 2MW downwind floating turbine installed on a semi-submersible substructure will be installed. In stage 2 a 7MW turbine is planned to be installed on v-shaped semi-sub and an advanced spar solution respectively. The project is entirely funded by the Japanese government with the ambition to be able to commercialize one or more of the concepts. Participants are, among others, Mitsubishi, Mitsui and IHI Marine United.
- The Kabashima demonstration turbine: A consortium including the Ministry of the Environment, Sasebo and Fuji have installed a 100kW downwind turbine on a Spar solution in the sea outside Kabashima. A full scale solution with a 2MW turbine is planned for the summer of 2013 in this project funded by the Japanese government.
Market potential and Technology assessment – Floating Offshore Wind Power

Europe – Market Overview

Key reflections on Europe

- The work on deep water floating wind technologies was initiated by Norwegian companies based on the cost of installing bottom fixed solutions in Norwegian territorial waters.
- There are several full-scale and test pilots installed in European waters and new concepts and technologies are under constant development.
- EU is actively funding research and project activities in relation to floating wind technologies.
- Targets set for wind power production in Europe will require large scale deployment of floating wind technologies.
- The potential for floating wind technologies is considered as significant based on actual water depths, the wind resources available and the number of technologies being developed and tested.

Market size

- An assessment by the European Wind Energy Association, EWEA, identified a project portfolio in European waters of 141 GW (online, under construction, consented or planned) of which close to 40 GW would be in the deeper waters of the Atlantic and Mediterranean sea. With vast areas having waterdepth beyond 50m (see Figure 8), floating wind solutions are considered as a highly realistic solution to meet targets set for renewable energy production. Hotspots in Europe for floating wind developments are identified in:
  - The Western facing Atlantic coastline and off the coasts of Scotland, the UK, Ireland, Spain and Portugal
  - The Northern North Sea, off the coasts of Norway and the UK
- Past and projected offshore wind developments in Europe are indicated in Figure 9. The trend towards deeper waters is obvious in Europe.
- EWEA targets on installed capacity, electricity production and share of EU demand is presented in Figure 9. The aggressive targets set that 50% of the electricity demand in EU is covered by wind power in 2050.

<table>
<thead>
<tr>
<th>Year</th>
<th>Offshore wind (GW)</th>
<th>TWh offshore</th>
<th>EU-27 gross electricity consumption</th>
<th>Wind power’s share of electricity demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>40</td>
<td>148</td>
<td>3600</td>
<td>17.7%</td>
</tr>
<tr>
<td>2030</td>
<td>150</td>
<td>562</td>
<td>4051</td>
<td>28.5%</td>
</tr>
<tr>
<td>2050</td>
<td>460</td>
<td>1813</td>
<td>5000</td>
<td>50%</td>
</tr>
</tbody>
</table>

Table 3: Installed capacity, electricity production and share of EU demand; Source: Blue Growth, 2012

EU programs

Several EU member states have a strong interest in deep water applications and a number of EU funded research activities and projects are currently ongoing:

- The Seventh Framework Programme (FP7) has the objective to aid the creation and development of new technologies. FP7 has co-funded the HiPRWind project with 11M€ (2010-2015) which focuses on the development of a semi-submersible solution for deep waters. A full scale pilot is planned for 2013 and Spain is considered to be a likely alternative for a test site.
- The New Entrants Reserve (NER300) funding scheme will provide support for the WindFloat 27 MW wind farm that is intended to be operational by late 2015.
- Another FP7 program is the Inflow (Industrialization setup of a floating offshore wind turbine) program which has a long term goal to set-up an offshore wind farm with a total capacity of 26 MW, using vertical axis turbines. Test site is planned to be outside Marseille and EDF/Technip is heading the program.
The Crown Estate – UK Market Potential and Technology Assessment for floating offshore wind power

Activity 2 – Synergies (O&G)

Table of Contents
Page 15 Oil & Gas industry synergies
Page 16 Ongoing industry and research projects
Main reflections on synergies with the O&G industry – The knowledge and expertise is already out there

- The development of the wind energy industry has many similarities to the O&G industry. Both industries began as land-based industries that eventually took the step offshore. Advancing technology and new solutions have allowed the industries to move into deeper waters further from shore. Both industries are also subjected to many of the same challenges and concerns. The floating wind industry therefore has the opportunity to benefit from the many experiences and lessons learnt in the O&G industry. By making use of the existing knowledge, methodology and approaches used in the O&G industry, the development timeline to commercial scale deployment of floating wind turbines can most likely be reduced compared to its parallel analogue.

- The offshore energy industry, both O&G and renewable can share a large amount of technology and infrastructure. Knowledge on how to develop semi-submersibles, spar solutions and TLPs are already available and is being utilized in floating wind turbine developments.

- The model of Joint Industry Project is commonly used in the O&G industry in order to fund research projects and the development of the industry. Much of this research is of interest also for the floating wind industry, indicating that much research can be performed in conjunction, including participant from both the O&G and wind industry.

The O&G industries development with time can be seen in the presented figures:

- The offshore O&G industry started with steel platforms (Jackets) at relatively shallow water depths.

- The first Tension-Leg (TLP) platforms were deployed in the mid-eighties in the North Sea and a few years later in the Gulf of Mexico.

- Spar-buoy and Semi-submersible solutions emerged during the nineties.

- All the floating concepts of the O&G industry are today used at water depths larger than 2000 m.

Existing TLPs world wide

<table>
<thead>
<tr>
<th>Water depth and number of tendons and piles</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Legend:</strong></td>
</tr>
<tr>
<td>Single column:</td>
</tr>
<tr>
<td>Multicolumn:</td>
</tr>
<tr>
<td>Number of Tendons: 6, 8 ...</td>
</tr>
<tr>
<td>Piles: 6, 8 ...</td>
</tr>
</tbody>
</table>

![Fig. 10: Example of existing TLPs world wide (O&G installations), Source: DNV](image10.png)

Oil and gas production facilities – From onshore to deepwater

![Fig. 11: Source: Clauss et al., 2004](image11.png)

![Fig. 12: Offshore platforms and underwater completions; Source: Clauss et al., 2004](image12.png)
Market potential and Technology assessment – Floating Offshore Wind Power

Synergies – Ongoing industry and research projects

Collaborations in the form of Joint Industry Projects (JIPs) has for the Oil and Gas (O&G) industry been a successful way to take the next steps in technology development, carry out expensive research and a method to reach consensus and allow for the establishment of common standards and guidelines within the industry. Knowledge sharing, finding solutions to common problems and spreading the cost over a larger number of parties has incentivized this type of cooperative research activities.

Today, several JIPs and other research projects that are highly interesting also for the floating wind sector development are taking place. Participants in these projects vary from specialized, technology firms and developers to universities, utility companies, classification societies and major O&G companies. The work on a full-fledged standard for floating wind turbine structures is currently being finalized while other JIPs that may not have the same explicit focus on the floating wind sector at first sight, anyhow is expected to have major impacts on the industry’s development. Examples of recent and ongoing projects are related to for example cabling, transmission and mooring systems.

A standard for Floating wind turbine structures

Existing standards on offshore wind has a clear focus on bottom fixed structures where issues related to structural design of floating units, station keeping, dynamic cable design and floating stability are not covered. The industry has therefore shown a desire for the development of a standard applicable also for floating structures.

DNV initiated the work on a standard, that should be used in conjunction with DNV-OS-J101, to cover relevant aspects of floating wind turbine structure design. The objective of this Joint Industry Project (JIP) was to develop a standard for design of floating wind structures that provides principles, technical requirements and guidance for design, construction and in-service inspection of such structures.

10 participants, representing different stakeholder groups (turbine developers, utilities, technology developers, steel manufacturers) and geographical regions and markets (Europe, US, Japan and Korea) were part of the JIP.

The standard on Design of Floating Wind Turbine Structures, DNV-OS-J103, was released on the 22nd of June 2013.

Offshore HVDC (High Voltage Direct Current) – Enabling long distance transmission

Larger offshore wind farms installed longer distances from shore is expected to increase the demand for offshore HVDC transmission considerably in the coming years. Reliability, Availability and Maintainability are considered to be areas requiring specific focus based on the harsh environment these systems will operate in. The lacking operational experience is seen as a major challenge as well as the interoperability difficulties that may arise when deploying technology from multiple manufacturers. In order to mitigate these challenges and enhance the deployment of offshore HVDC transmission, DNV KEMA and STRI will together with a range of manufacturers, developers and operators develop a procedure for Technology Qualification of offshore HVDC technologies.

Mooring systems in deeper waters

With the O&G industry continuously going into deeper waters, requiring strong and lightweight technology, synthetic materials are being increasingly looked into. Permanently moored floating units at large water depths is made possible through the use of synthetic fibre ropes, systems that are of significant interest also for the floating wind industry in for example the mooring design for semi-submersibles and as tendon systems for TLPs.

Key industry members participate in several different research projects and JIPs with the aim to for example improve service life of fibre moorings and improve design practices.

Other guidelines for Floating wind under development

IEC: IEC is currently developing a Technical Specification (TS) for floating offshore wind turbines. The work is coordinated with the maintenance team supporting the existing IEC 61400-3 standard for bottom fixed offshore requirements to assure harmonized documents. This specification will define principles, technical requirements and assessment procedures for the design, installation and maintenance of floating offshore wind turbines.

ABS: The ABS Guideline #195 (ABS195) was issued in January 2013 and provides criteria for the design, construction, installation and survey of permanently sited floating offshore wind turbine installations.

Subsea Power Cables – ‘CableRisk’

Power cable manufacturers, cable installers and project developers are developing a guidance to decrease the risks associated with subsea power cabling, one of the main challenges that have been observed in relation to offshore wind farms. The project covers cabling between wind farms as well as the export cables connecting the farm to the onshore grid.

Dynamic cables are very high interest for floating structures in particular.

Dynamic cables – ‘Electrical power cables in offshore subsea applications’

Power cable manufacturers, installers and major oil & gas companies has developed a Recommended Practice for power cables being submerged in seawater at large water depths and/or being exposed to dynamic excitation. Dynamic cable issues are of very high interest for floating structures in particular.

Fig. 14: Schematic; Source: DNV KEMA

Fig. 13: HVDC Transmission; Source: DNV

Offshore substation

Riser cable

Submarine cable
The Crown Estate – UK Market Potential and Technology Assessment for floating offshore wind power

Activity 3 – Commercialization road map

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<th>Content</th>
</tr>
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<td>Cost &amp; Cost drivers</td>
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<tr>
<td>20</td>
<td>Cost Reduction</td>
</tr>
<tr>
<td>21</td>
<td>The UK case</td>
</tr>
</tbody>
</table>
Introduction/summary

There are certain development phases that are considered to be natural steps in the development process of a new technology. After successful proof of concept in laboratory, concept development and scale testing have to be undertaken. The technology readiness level (TRL) as applied by The Crown Estate is shown in Appendix A. In the TRL scale, the technology has now completed level 6. Entering level 7, a full scale demonstration technology is expected to demonstrate the technology in a realistic environment. The demonstration period is typically two years for an offshore wind turbine, corresponding to approximately 10% of its expected operational life time.

Even if the prototype demonstration is successful thus having reached TRL 8, it is not necessarily considered commercially ready. Therefore, many developers plan to develop pre-commercial projects comprising 3-5 units, making a small array. This is basically when the technology goes through the ninth and final level in the TRL scale. The aim of this final development step is to further refine the system and to finally demonstrate that it is technically proven. First when this phase has been demonstrated successful, the technology is considered ready for commercial deployment.

Completing all the nine steps in the TRL does not automatically mean that the technology can be deployed in large scale. There might still be restricting market factors such as cost of energy (also considering a supported market) hindering large scale project developments. This is however to a large extent outside the control of the developer. Below, the road-map to full commercialization for floating wind energy technology is presented by discussing the likely path for the three key philosophies.

Time to market – different concepts

It is foreseen to take several years until the floating wind energy market has become commercially ready. Today, there is a significant difference in level of development among the three technical philosophies. Considering the one concept within each of the three that has come furthest in development, gives the following picture:

Estimated time to commercialization for floating wind energy structures

<table>
<thead>
<tr>
<th>Year</th>
<th>Spars</th>
<th>Semi-subs</th>
<th>TLPs</th>
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<td>10</td>
<td></td>
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<td>25</td>
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</tbody>
</table>

The illustration above shows DNV’s assessment of the pathway to commercialization for the three key floating wind energy technologies. It should however be noted that the presented timeline to a large extent assumes that there are no major setbacks in the prototype testing and small array demonstration phases.

Spar

Statoil has completed a full scale prototype test of a 2.3 MW unit. The prototype was deployed in 2009 outside the west coast of Norway. The prototype is still operating.

Currently, Statoil is investigating and developing several different projects to find the most suitable ones for a small array park.

In December 2012 it was announced that Statoil’s Hywind was selected as one of the projects receiving DOE funding for the development of a 4x3MW wind farm in the Gulf of Maine. This development could possibly accelerate the deployment of other 3-5 WTG small arrays. Statoil has also expressed interest in developing projects in Scotland and Japan.

Semi

The first large scale semi-sub prototype, WindFloat by Principle Power, was deployed late 2011.

Drawing parallels to the Hywind development up to current date and the forward plans, it is likely that some 3-4 years will be required to implement all learnings from the prototype test, find a suitable project, make an investment decision and manufacture the structures.

Similar to Statoil, Principle Power’s WindFloat was selected for DOE funding in December 2012 for a 5x6MW wind farm to be deployed in deep water outside Oregon. EU’s NER300 funding will allow for the deployment of a WindFloat farm outside Portugal, consisting of five units with an overall capacity of 27 MW that is to be operational by late 2015.

TLP

No TLP has yet been deployed as a large scale prototype. PelaStar is currently the concept furthest in development and closest to deploying a large scale demonstration unit.

According to Glosten Associates (PelaStar’s developer), they are entering detailed engineering 2013, a phase which is aimed to be completed by the end of the same year.

About 1 to 2 years following the detailed engineering phase is estimated for procurement and construction of the full scale prototype, meaning that if everything progresses as anticipated we will see the first large scale TLP deployed 2015/2016. This time frame has also been indicated by one of the floating wind energy demonstration projects being planned for.
Is it plausible that the cost of energy for floating wind turbine structures when fully demonstrated and deployed at large scale can compete with other sources of energy?

It is a complex task to suggest when floating wind energy could achieve a cost of energy attractive enough to compete with conventional energy sources. It is however DNV’s belief that over time and as the market matures, floating wind energy could reduce its cost to a level equal to traditional offshore wind energy, thanks to some key cost reduction factors, inherent cost advantages and a potential for higher energy yield and thus revenue. These components all contribute to a more attractive cost of energy.

On the following pages, DNV’s view on the current cost, cost drivers and cost of energy for floating wind turbine structures are discussed and viewed in comparison to bottom-fixed turbines. Furthermore, likely cost reduction factors are being presented.

Cost of floating wind energy vs. bottom-fixed

An accurate investment cost for floating wind energy is difficult to estimate as the technology not yet has been deployed in any numbers, i.e. the amount of data is too limited. Furthermore, cost data from the only two prototype’s that are deployed would not be representative to use for comparison to bottom-fixed wind, as it would mean comparing prototype costs with commercial products. For bottom fixed, there is sufficient data as a few thousand turbines have been installed (3,987 MW by the end of 2011), but here the problem is that the project’s are difficult to compare fair and square. In the early days of offshore wind, projects close to shore in shallow waters with an overall low complexity was exploited first. Today, the low-hanging fruits are becoming more scarce, forcing the developers further offshore to deeper waters with more harsh weather. The operational costs (OPEX) is even more difficult to compare quantitatively. DNV has on the following slide made a qualitative comparison of cost elements differentiating the two technologies, including a discussion around OPEX costs.

The graph right shows four different recent estimates for bottom-fixed wind energy investment costs (blue bars), two estimates for floating wind energy based on data provided by technology developers based on two different studies (red bars), and two purple bars summarizing the estimates for the two technologies respectively. The purpose of doing this is to give a transparent illustration of the uncertainties in cost, together with an understanding of the approximate relationship between the current investment cost for floating wind turbines and bottom-fixed wind turbines. It is important to acknowledge that the estimate of the floaters is reflecting the cost that could be foreseen if the technology could deployed in a large scale today, not the cost of prototype structures nor accounting for learning effects or other cost reduction factors that can be foreseen by a gradually maturing market. See next page for more discussion on cost reduction effects.

Looking at the average graph for floating wind shows that the investment cost estimate is ranging from 3.2 to 4.55 M€/MW. By comparing the two purple graphs it can be seen that floating wind energy is estimated to be approximately 10-20 % more expensive than bottom-fixed wind energy. Comparing only DNV’s “low” estimate with the low average fixed cost, the floating wind structures are about 30 % more expensive.
Comparing Cost of Energy – Bottom-fixed vs. Floating Wind Energy

The cost of energy (CoE) is the most interesting key figure for any energy source, as it gives an idea about the actual production cost for one kilowatt hour. By considering the total investment cost, the operational costs and energy yield for both bottom-fixed and floating wind energy, it is possible to compare differences in CoE. DNV has done this comparison in a qualitative manner comparing some of the major investment cost drivers, operational cost drivers as well as the energy yield potential. The result is presented in the table right, where a green arrow indicates a potential upside for one of the technologies for a given cost of energy element.

- As floating wind turbine energy structures are not as bound to specific sites as fixed installations, the wind is the deciding factor and the technology can be deployed at sites with the highest or most optimal energy yield. As an example, Hywind achieved 50% capacity factor in 2011, a very impressive figure produced at a site where bottom-fixed wind energy would not have been feasible. This possibility to increase the energy yield will lead to higher revenue, thus driving the CoE down. Floating wind energy has a clear advantage in this respect.

- The transport and installation phase is perhaps the activity where floating wind energy has the largest advantage to its bottom-fixed peer. The full WTG assembly can often be done inshore or even in a dry dock and then the structure is towed to site using cheap and simple tugs – drastically reducing the exposure to weather delays and risky offshore operations. Bottom-fixed wind normally requires heavy lift jack-up/ floating installation vessels with day rates of approximately k€ 150+ to do offshore, weather exposed, assembly. The day rate for an advanced tug vessel used for more complicated installations of floating systems is estimated to be k€ 30. Lower costs are however expected when using less advanced installation vessels for floating systems.

- Floating wind energy structures are typically designed for being towed back to shore using cheap, standardized vessels when a major repair is called for. For bottom-fixed wind energy, a costly and weather sensitive jack-up vessel is needed for the major maintenance activities. Because of this, floating wind energy farms are likely to have relatively low operational costs thanks to lower equipment and material cost for service and maintenance work. It should however be noted that there are variations between the different concepts.

To conclude, as the table to the right shows, the qualitative cost of energy discussion indicates that there are more potential upsides with floating wind energy structures than it is for bottom-fixed structures. Based on this, DNV finds it likely that over time, when the two industries have matured and become truly commercial, a highly competitive cost of energy can be reached for floating wind farms and match that for traditional bottom fixed wind farms. In the next section, additional cost saving elements are discussed, that not only may be an advantage in relationship with bottom-fixed structures, but also could drive the absolute cost level down as the market matures.

Means for cost reductions

In order for floating wind energy to become truly competitive, it is not only important to achieve parity with traditional fixed offshore wind energy, but it will have to reach a level where it can compete also with other (renewable) energy sources, such as onshore wind energy and biomass. This has long been the reality for traditional offshore wind and the industry has paid high attention to the topic for several years, learning from experience, undertaking research et cetera. Even if the trend has been pointing upward the last years is it reasonable to believe that the overall cost level is likely to decrease both for bottom-fixed and floating wind energy.

Technical improvements, learning effects and supply chain improvements are expected to contribute the most to floating wind energy cost reduction. As the market matures and more and more systems are built, tested and deployed in a large scale, design and manufacturing process optimizations of the substructure and wind turbine will probably be the leading cost reduction factors. Also more radical inventions coming from research and development is foreseen to have a cost reduction effect, such as horizontal transport of WTGs, more lightweight materials et cetera. The possibility to use alternative material, e.g. concrete, in parts or for the entire substructure could also lower the cost as well as reducing the exposure to steel cost variations.

Site independency speaks in favour of floating wind turbine support structures: every structure is site independent, allowing for a much more standardized design. This is considered a significant advantage compared to bottom-fixed where every single foundation is custom-made for a specific location, as it enables optimization of the substructure manufacturing process, i.e. enabling true mass production, economics of scale and learning effects.

A positive scaling effect is expected: the substructure mass, and thus cost, will likely not scale linearly with an increase in WTG scale. Both EDP/Principle Power (WindFloat) and Statoil (Hywind) has indicated that they are expecting a positive scale effect. One should however bear in mind that many in the industry believes that the WTGs perhaps could reach 10 MW, but is hesitant that the upscaling will continue beyond that. Thus the scaling effect has a limit, but up to that point, it will contribute to a reduced cost of energy.

The most developed floating concepts are currently aiming for a substructure mass of 200 – 300 t/MW. Corresponding substructure mass for a jacket platform is approximately 100 t/MW.
Introduction/summary
The UK has the world leading position in offshore wind. Large zones with water depths feasible for fixed structures, vast wind resources, a long maritime history, a skilled workforce, offshore O&G experience and stable political frameworks have created the basis for the prosperous offshore wind industry.

As this report has shown, floating offshore wind technologies are receiving increased attention in many parts of the world. New technologies are under constant development to harness the abundant wind resources offshore and bathymetric conditions will only allow for such solutions at many locations. Further, costs are decreasing and are in the future expected to be at the same level as for fixed solutions or lower. The possibility for large scale production of floating solutions should be able to press cost considerably in a future, more established, industry.

DNV strongly believe that the UK can leverage on existing capabilities and become one of the market leaders also for floating offshore wind technologies. ETI’s work on a floating offshore wind demonstrator is an important step for the industry as a whole, and for the UK specifically. Not only will this allow for important testing and evaluation of concepts, it could potentially also create a momentum for the entire industry and facilitate a shorter timeline to commercialization than has earlier been expected.

Feasible concepts
As has been shown in Section 1 of this report, there are today three main floating wind concepts. For the UK, the Semi-submersible and TLP solutions are most likely to be used in the existing development areas due to their shallow draft. However, Statoil is currently looking into the development of siting a test farm with 3 to 5 turbines outside of Aberdeen or Lewis in Scotland for a Hywind demonstration. This indicate that there is a potential for deeper water deployment in UK waters also using Spar solutions.

Timeline to commercialization
There is an inherent uncertainty with regard to the commercialization timeline for the various floating concepts. DNV’s own assessment suggest the development as described by Figure 16 below. It is an approximated time difference of 5 years between the most and least developed concept in relation to small/large arrays. It should be noted that successful demonstration can assist in reducing this timeframe. It is in DNV’s opinion that commercialization of concepts are highly possible within a 10-year period, depending on the activities of the next few years.

Fixed and floating – Potentially competing markets
As is seen from Fig. 15 above, fixed jacket solutions and floating semi-sub/TLP solutions are both feasible in the depth range between approximately 50 – 60 m. The resources available for floating solutions are in the UK are however significantly larger than the ones available for fixed offshore wind installation, as shown in Tab. 4.

It is not unlikely that the two sub-structure options will compete for the same waters in the UK within a 10-15 year time period. Decreasing costs for floating wind, the environmental advantages from none/reduced piling activities and the vast potential in the 40-60m (and beyond) depth range of existing Round 3 zones are some of the key enablers for this development. Several important steps are required in order for this to happen, but the recent developments in the US, where the basis for floating wind demonstration sites are now being established, are of specific interest. This can potentially create a momentum for the entire industry and facilitate a shorter timeline to commercialization than has earlier been expected. A UK market where fixed and floating solutions co-exist and complement each other is by DNV considered as a realistic future scenario.

UK waters are feasible for floating solutions
Figure 17 below present an overview of the nine Round 3 zones and the percentage of water depth beyond 40 m and 60 m respectively. In eight out of nine zones, the majority of waters are beyond 40 m. For three of the zones 100% of the waters are more than 40 m in depth. For four of the zones there are considerable areas with waters beyond 60 m depth.

As is indicated by Figure 17, in current development areas there are sites suitable for floating wind solutions, but the majority of the areas will still be more feasible for fixed structure. Vast areas with larger water depths (beyond 60m) outside existing development zones however suggest the potential for floating wind farms in UK waters. Thus, it can be assumed that fixed and floating wind energy could be complimentary technologies in the UK market.

![Map of UK waters](image-url)
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The Crown Estate TRL definitions:

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<th>TRL</th>
<th>Technology status</th>
<th>Description</th>
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<td>Basic principles observed and reported</td>
<td>Scientific research begins to be translated into applied research and development.</td>
</tr>
<tr>
<td>2</td>
<td>Technology concept and/or application formulated</td>
<td>Practical applications of basic key principles can be &quot;invented&quot; or identified. The application is still speculative, there is no experimental proof or detailed analysis to support the proposal.</td>
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<td>3</td>
<td>Analytical and experimental critical function and/or characteristic proof of concept</td>
<td>Active research and development is initiated: analytical studies to set the technology into an appropriate context, and laboratory-based work to physically validate that the analytical predictions are correct. These should constitute &quot;proof-of-concept&quot; validation.</td>
</tr>
<tr>
<td>4</td>
<td>Technology / part of technology validation in a laboratory environment</td>
<td>Following successful &quot;proof-of-concept&quot; work, basic technological elements are integrated to establish that the &quot;pieces&quot; will work together to achieve concept-enabling levels of performance. The validation is relatively small scale compared to the eventual technology, it could be composed of ad hoc discrete components in a laboratory.</td>
</tr>
<tr>
<td>5</td>
<td>Technology / part of technology validation in working environment</td>
<td>At this level, the reliability / scale of the component being tested has to increase significantly. The basic technological elements must be integrated with reasonably realistic supporting elements so that the total applications can be tested in a &quot;simulated&quot; or somewhat realistic environment (which is almost always the working environment for energy technologies).</td>
</tr>
<tr>
<td>6</td>
<td>Technology model or prototype demonstration in a working environment</td>
<td>A major step in the reliability / scale of the technology demonstration follows the completion of TRL 5. At TRL 6, a prototype going well beyond ad hoc or discrete components is tested in a working environment.</td>
</tr>
<tr>
<td>7</td>
<td>Full-scale technology demonstration in working environment</td>
<td>TRL 7 is a significant step beyond TRL 6, requiring an actual system prototype demonstration in the working environment. The prototype should be near or at the scale of the planned operational system and the demonstration must take place in the working environment.</td>
</tr>
<tr>
<td>8</td>
<td>Technology completed and ready for deployment through test and demonstration</td>
<td>In almost all cases, this level is the end of true &quot;system development&quot; for most technology elements. This might include integration of new technology into an existing system. Represents the stage at which an example of the technology is tried and tested.</td>
</tr>
<tr>
<td>9</td>
<td>Technology deployed</td>
<td>In almost all cases, the end of last 'bug fixing' aspects of true 'system development' and represents the point at which the technology is proven, but not necessarily yet commercially viable in either a free or supported market. This might include integration of new technology into an existing system. This TRL does not include planned product improvement of ongoing or reusable systems.</td>
</tr>
</tbody>
</table>