DeepWind Deliverable

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Investigation of other instruments

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The review has been carried out by DEB in accordance with MS19" Dissemination and exploitation planning decision. Risk assessment "

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Investigation of other instruments

From DeepWind DOW: D9.3) Investigation of other instruments: Collaboration with DTU (IPR). It is investigated how progress in public acceptance, promotion and for exploitation can be made and which scientific strategy can be set up to achieve this. The plan is discussed with the end-users and stakeholders in the advisory group. Task 9.3 will include: -internet and IPR searches - Surveys and exchanges with industrials and potential end-users [month 48]

Summary: The report contains a description of the instruments that can benefit the development of the DeepWind concept. Furthermore the international situation, as being surveyed on a web basis is briefly described and discussed on the applicability for DeepWind.

DTU corporate Office for Innovation & Sector Development (IPR) guides us to look to elements that can strengthen the project towards commercialization/exploitation with an overview of the planning tool shown in Figure 1 :

DRAFT INPUT to Exploitation planning - Deepwind project

1. Further research & demonstration

Phase/activity	Deepwind Project end	Search for: - Large industrial partner(s) - Research partner(s)	Funding: - Funds (applications) - Industrial partner	Pilot Demonstration Project
Comment	Concept not ready for commercialization	DTU Wind Energy will search for partners for next development stage	Funding will be sought from industrial partner(s) and through applications to e.g.: - EU - Højteknologifonden - Ministry of Science, Innovation and Higher Education	Development, construction and testing of 5-10pcs. 500KW wind turbines (e.g. in the North Sea) + further IPR development

2. Commercialization

Phase/activity	Pilot Demonstration Project end	Search for: - Large industrial partner(s) (Commercial partner(s))	Contracts and agreements	Production startup
Comment	Concept ready for commercialization Continued IPR process	DTU Wind Energy will search for industrial companies for commercialization	Involvement of Office for Law and Contracts (DTU)	

Figure 1 planning of steps for commercialization. Some of the funding schemes are national Danish instruments

The present situation tells us that there is no large industrial partner in the alliance-or may be? Nenuphar has just merged with AREVA(information is not found on the internet).

How to proceed?

For DeepWind we have applied for further funding within the premises of Horizon 2020 and under the EERA umbrella(www.eera-set.eu) to assist DeepWind as a promising technology with a low top head mass to cut 20-30% of existing costs compare with conventional offshore wind turbines. As one of the results from two independent cost analyses on the deepWind conceptual design, a LCOE of 0.07-0.09 €/kWh has been obtained, and with this result it fits well with the ambition of H2020 LEC2.

As part of the process towards commercialization the identification of industrial partners is important, as well as the attraction of potential investors.

As one of the initiatives to proceed, dissemination of the project results beyond the consortium- and the project lifetime, the consortium will produce papers and dissemination activities of public Deepwind results.

In general the business analysts will apply methods for understanding the process. A master project[1] describes the competition between HAWT and VAWT. In the thesis the roles of the science institutions and the industry is highlighted as one of the drivers in the development of commercialization. Many parameters obviously affect decisions an increasing return or decreasing returns, and industrial 'behavior'. To illustrate from the thesis some examples: being dependent on the surroundings(small versus large economy), industrial level of competences(steel-nation versus redefining commodities made from pre-manufactured components), education and how R&D is incorporated into industry affects the way to 'do' things as always but qualitatively better, contra innovative incitement to reduce costs (learning-by-doing *LBD*, learning by using *LBU*, learning by searching *LBS* and learning by interaction *LBI*) has an impact on the learning curve[23](how to change behavior patterns towards using clean renewable energy). The interactions are shown for the offshore wind industry in Figure 2.

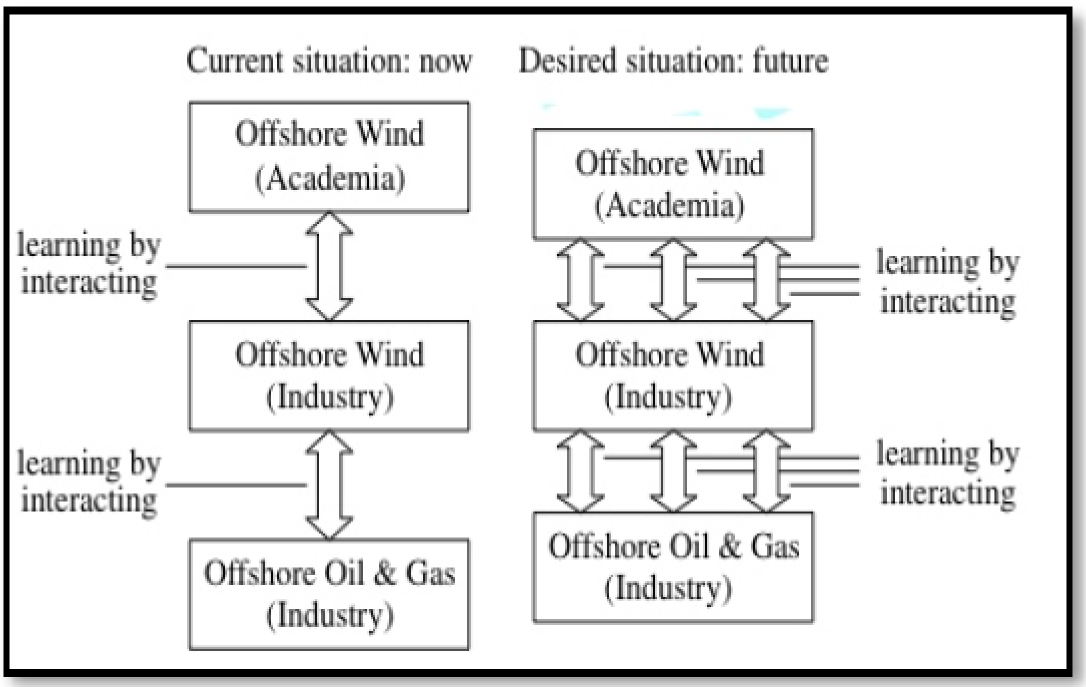

Figure 2 Learning-by -interacting in offshore wind industry

In our present case, the communication between academia and wind industry is important in developing new layers of competences.

The approach is to lower costs by increasing output, and in the industrial development relations between industry and surroundings are important. An interesting observation is the side effect how the industry interprets the value in the chain shown in Figure 2 .

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[1] Økonomisk vurdering af to vindmølletyper(Sachin Dhiman og Muqeet Ahmad Master thesis 2011)
[2] An analysis via the learning curve approach" (Kahouli-Brahmi, 2009).
[3] Technological Learning and Competitive Performance(Paulo N. Figueired 2001 p 23)

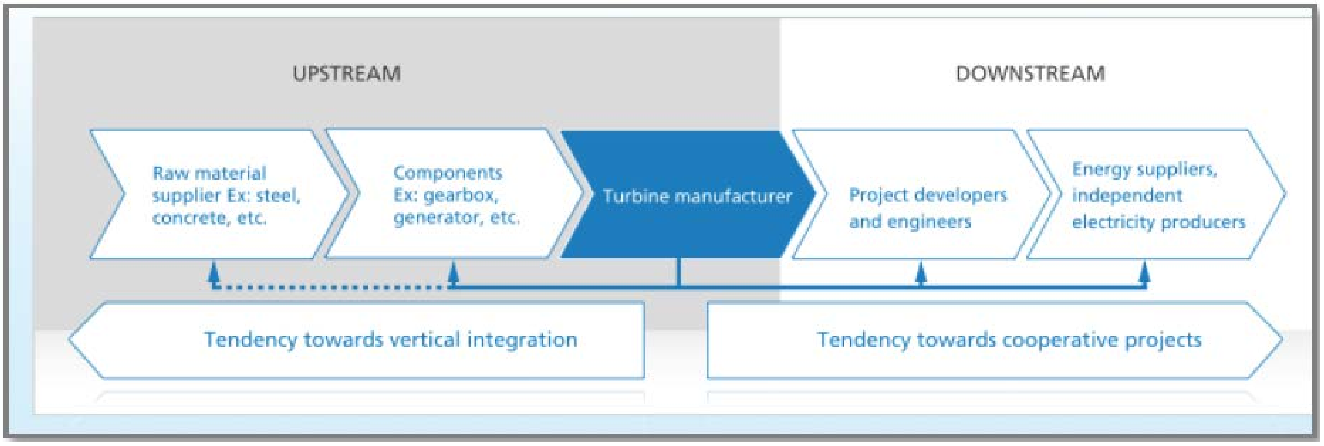


Figure 3 Value chain in the wind industry (Deutsches Cleantech Institur 2009)

Interaction between different actors are shown in Figure 4 .

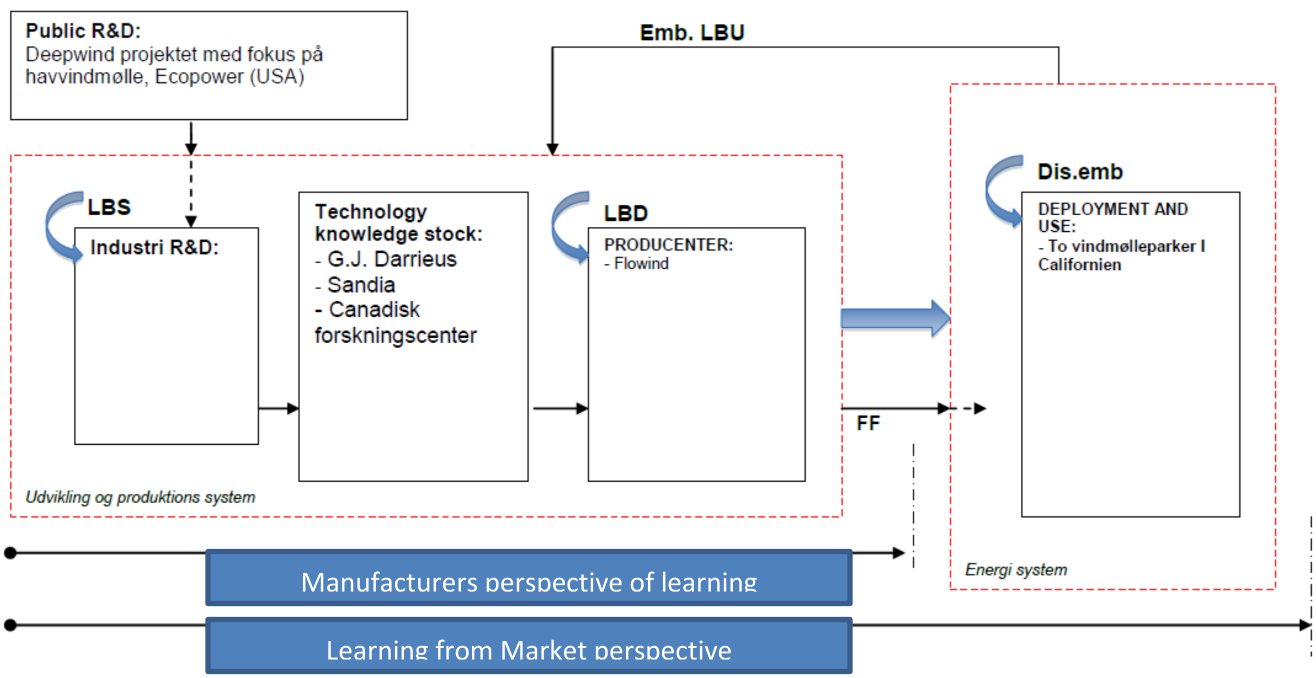


Figure 4 Relation between system boundaries and learning mechanism for VAWT reduction of costs[1]

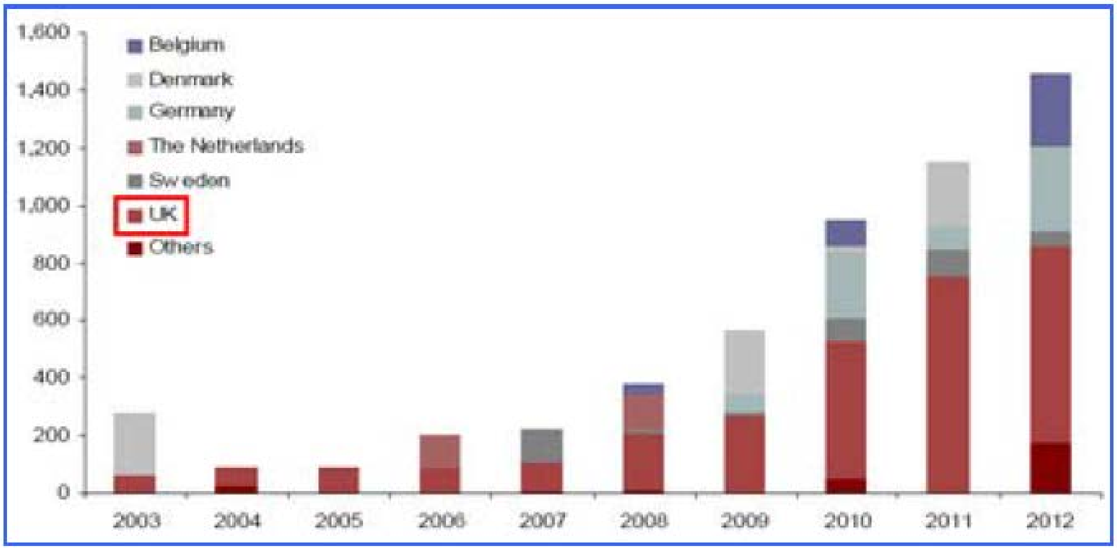
Global energy situation

The conditions are in favor for DeepWind in terms of offshore floating wind energy, with new markets for offshore wind energy(see Figure 2) and for floating power plants(see Figure 3). The offshore wind is often the most talked about part of the wind sector; it represents about 2% of global installed capacity. In 2012 1,296 MW of new offshore capacity was added, a 33% increase from 2011 market, bringing the total to 5,415 megawatts. The installed capacity for 2020 is forecasted to be 10% of global capacity[4] The majority of the wind marked is going on in the European sector, as seen on Figure 2, bottom, the rest is inter tidal and near shore projects in China(127MW), in one Korean project , and a floating offshore turbine near NAGASAKI (100 kW). As per 2013 the total capacity was planned to be 35 GW.

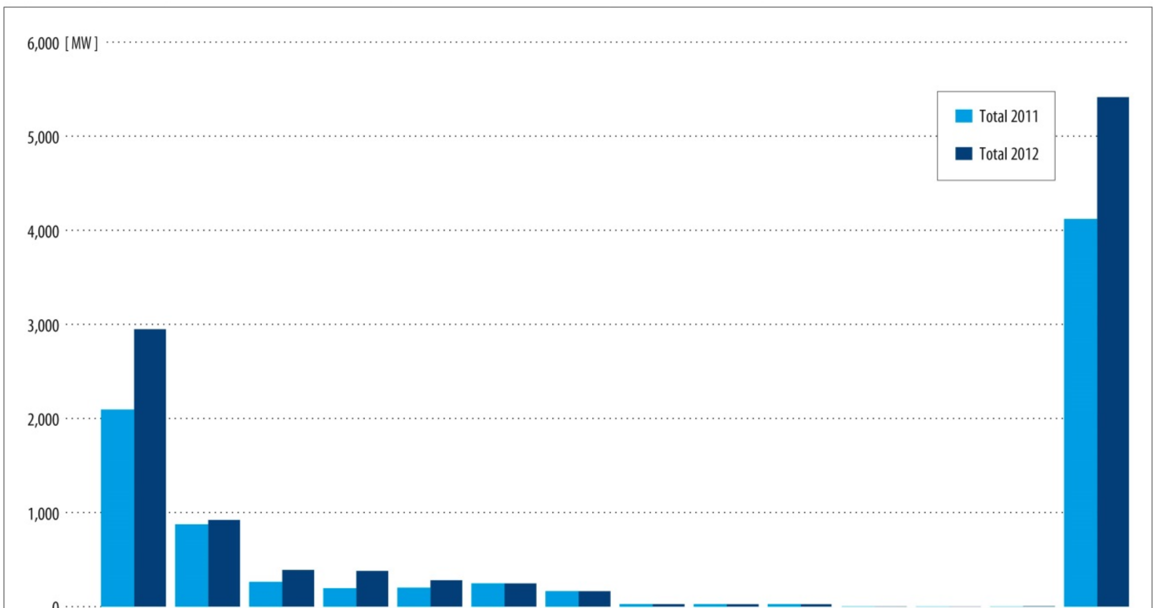
Particular the situation of the conditions in Japan has changed the offshore wind energy supply drastically with the Fukushima disaster, initiating with six 2-MW wind turbines. The initiatives from the Japanese Government to promote Mitsubishi and Kawasaki proves that offshore deep sea floating technologies are now have developed into demonstration projects, and the development and competition will probably be hard in the future because of the large capacity factor of these shipyards. Still DeepWind is a promising candidate, with respect to the R&D developed, and the results achieved. Shipyards like Hyundai, Samsung in Korea and likely other candidates will join the scene for floating offshore wind turbines[5](DeepWind mentioned).

Subsidies from governments(and institutions such as EC) are supported in EESI investigation[1] are supported in an investigation where people are promoting offshore wind energy.

[4] http://www.gwec.net/global-figures/global-offshore/
[5] http://en.wikipedia.org/wiki/Floating_wind_turbine (14-09-2014)



Global Cumulative Offshore Installed Capacity in 2012



	UK	Denmark	PR China	Belgium	Germany	Netherlands	Sweden	Finland	Ireland	Japan	Norway	Portugal	South Korea	TOTAL
Total 2011	2,093.6	874.3	262.6	195.0	200.3	246.8	163.7	26.3	25.2	25.2	2.3	2.0	2.0	**4,119.3**
New 2012	854.2	46.8	127.0	184.5	80.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	3.0	**1,295.6**
Total 2012	2,947.9	921.1	389.6	379.5	280.3	246.8	163.7	26.3	25.2	25.3	2.3	2.0	5.0	**5,415.0**

Source: GWEC

Figure 5 Top: Installed Offshore Installed Capacity EWEA report "Pure Power"2008. Below: Global Wind Energy Council on installed Capacity 2012

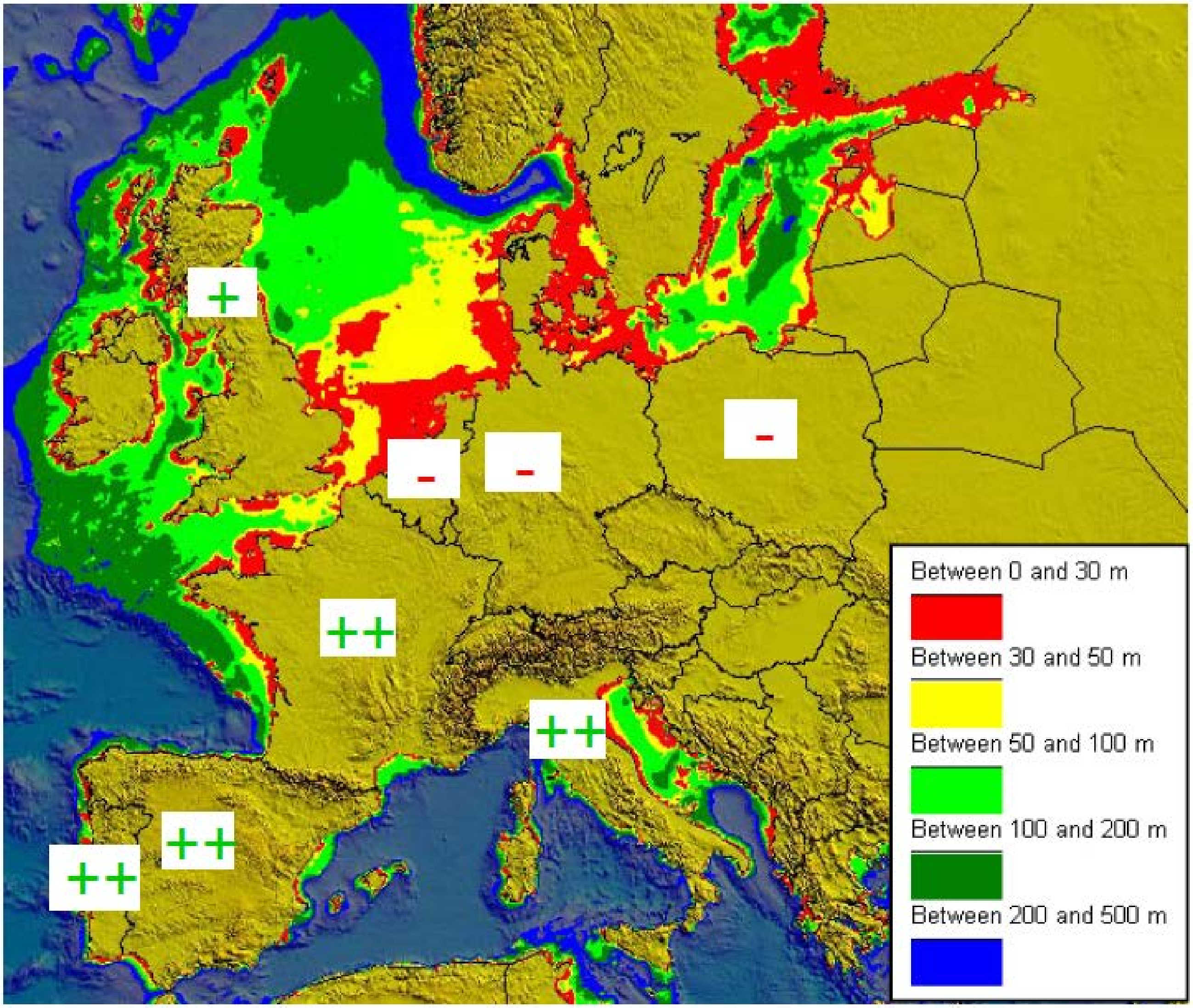


Figure 6 Offshore projects geographic locations – Ernst&Young2010 forecast (Source : Ernst&Young market analysis 2008).

Existing actors and near future actors

The following figure demonstrates well the tendency that certification bureaus and industry works side by side to accomplish cost savings with existing offshore wind energy technology and because of the demand of energy- market shares.

Hywind, an idea now being realized is one of the most investigated concepts, and will be exploited more on other markets than the Norwegian. Currently a Scottish initiative with the Statoil platform has been established as a demonstration project(seeFigure 4)

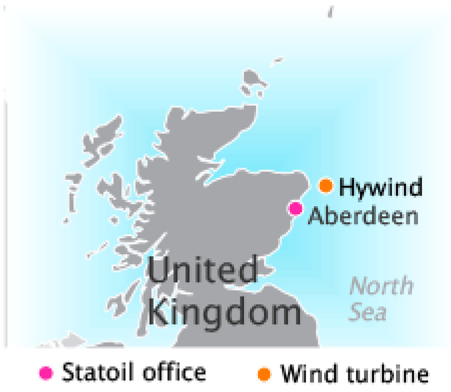


Figure 7 Hywind Scotland Pilot Park

Table 1 Statoil Scottish Hywind Park[6]

Area (sea level)	~4 km2
Water depth	95-120 m
Average wind speed (@100 m)	10.1. m/s
Mean waves, Hs	1.8 m
Installed capacity (5 WTG's)	30 MW
Offshore export cable length	ca 30 km
Onshore cable length	2-3 km
Transmission voltage	33 kV

No many radical technical solutions are presented on conferences, and symposia. One example is taken from an AWEA presentation by NREL, see Figure 4.

As a radical technology class, In the European sector Nenuphar has achieved much in the demonstration project INFLOW, where the wind turbine plat form is operating in a test configuration of the test rotor with 1/3 of full size rotor height[7]. Selsam(see Figure 9) has sold 20- 2 kW prototype on a commercial basis[8]

6 http://www.statoil.com/no/TechnologyInnovation/NewEnergy/RenewablePowerProduction/Offshore/HywindScotland/Pages/PilotPark.aspx

7 www.nenuphar-wind.com (14-09-2014)

8 Popular Science 2008 p 52

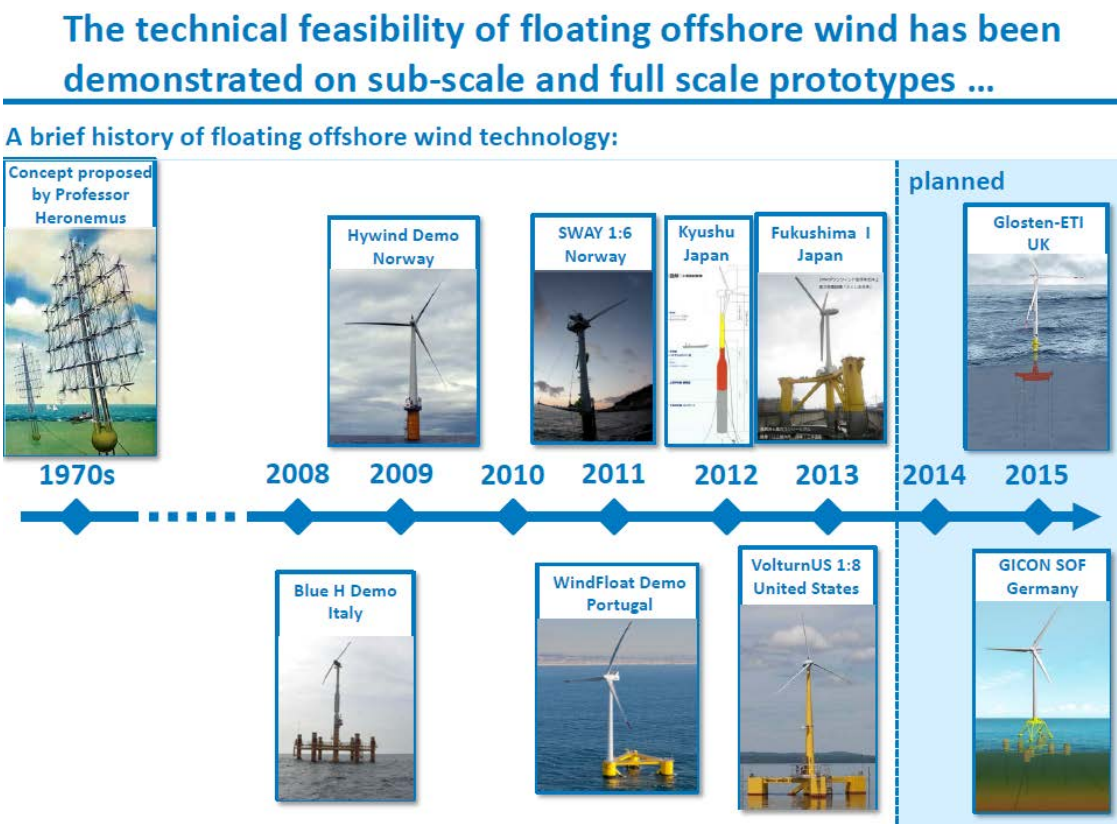


Figure 8 NREL's story of offshore wind turbines

The typical power plant to compare with is the OC3 NREL wind turbine.

In Table 2 the main features of the concept are drawn. In comparison with DeepWind, the technology is driven by a conventional design with potential risks: many components with high risk of failure (gearbox 1, blades 2, drivetrain 3.rotor hub 4, and electrical system 5)[9]. Out at the site off 25 km, costs on production loss are huge due to failure, repair and maintenance.

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[9] THE CORRELATION BETWEEN WIND TURBINE TURBULENCE AND PITCH FAILURE TavnerP. Paper 594_EWEA2011

Table 2 NREL OC3 specs

Category	Parameter
Wind Plant Rating (MW)	500
Number of Turbines	100
Turbine	NREL 5 MW Reference
Turbine Rating (MW)	5
Rotor Diameter (m)	126
Hub Height (m)	90
Drivetrain Type	Geared
System Design Life (years)	20
Distance to Port (km	25
Distance to Interconnect (km)	25
Electric Collection System (kV)	33
Electric Export System (kV)	132

Patents and IPR

The number of patents are increasing since 1995 and are a means to prevent others from business and protecting own foreground IPR. Patents are developed by highly specialized people within their field of competenses. For the DeepWind patents situation, currently no information has been conveyed to PM with regard to this point. In the pre-phase of the project a patent was applied for by DTU. Because a patent already existed (see Figure 2) and the invention (www.selsam.com), was close to the floating technology of DeepWind, we did not pursue patenting the DeepWind concept. With the tools developed for analyzing the concept, more and more details show up with potential character to be patented. In the development of the project, we have looked for industrial partners outside the consortium to assist the 5MW concept with parts made on an industrial scale. Two areas are important: the blades on the rotor and the generator (power generating module). For the blade manufacturing we have very few cases to compare with, and according to the recent paper presented at EWEA on the concept[10] two major constraints are identified:

- the pultrusion manufacture industry is lacking the capability of a pulling force of max 80 T capacity, that is to handle no longer than 3 m wide specimen.
- The generator industry supplies under water generator systems for tidal machines. Apart from submarine technology there is no commercial available deep sea underwater generator available. This is particularly true for a 20 MW power unit, operating at very slow speed compared to HAWT types.

If the pultrusion industry could be stimulated to build machines with satisfactory pulling force capacity, we can manufacture blades with material thickness of 60-80mm appropriate for a 20 MW concept.

[10] The 5 MW Deepwind Floating Offshore Vertical Wind Turbine Concept Design - Status And Perspective presented at the 2014EWEA conference in Barcelona, Spain(Paulsen, US)

For the generator module there are developments ongoing. From the tidal test site EMEC following information on client's description are available[11] . Alstom, Andriz Hydro Hammerfest, Atlantis Resources, Bluewater Energy services, Kawasaki Heavy industries, Open hydro, Scotrenewables Tidal Power LTD and Voith are under testing . To quote the description for Voith:".. Entering the marine renewables industry, **Voith Hydro Ocean Current Technologies** is a center of excellence for the development and manufacturing of tidal turbines. Its tidal current turbine has been designed to be simple, sturdy and low-maintenance, and a 1:3 scale prototype has been successfully tested in Jindo, Korea.

Voith's 1MW horizontal axis turbine HyTide 1000 has a rotor diameter of 13m and weighs 200 tonnes. Preparatory works commenced in summer 2011 with a 23m monopile installed in the seabed at EMEC's tidal test site at the Fall of Warness off the northern island of Eday. The turbine was installed at the end of 2013 and is currently undergoing extensive testing at EMEC."

A cornerstone in the tidal machines is the generator. Many are 1MW rated power under test (geared generator). Another actor (TheSwitch[12]) is supplying customers with PMG drive technology for offshore. We have approached a major European industry on their availability to provide a 6 MW generator which can be built according to a German patent DE 10 2009 034 158 A1 2011.02.03. It seems on paper to fit very well with the present 5MW conceptual design, with PM direct drive technology, few components and water lubrication.

The tidal renewables industry is developing technology where R&D needs to be focused to provide synergetic effects with DeepWind technology. The technology is in some areas less reliable because of gearbox, and eventually conventional bearings. Some of these use water lubricated bearings. A major concern is that these machines operate in shallow waters and likely suffer from deep see operation and maintenance issues.

Another issue for the DeepWind concept is the light rotor configuration, which consists of 3 sections with different airfoil sections. The different blade sections have to be connected with joints, which may create some considerations against the concept. A blade joint [10] exists on the market which is capable to integrate the blade parts, see Figure 2 .

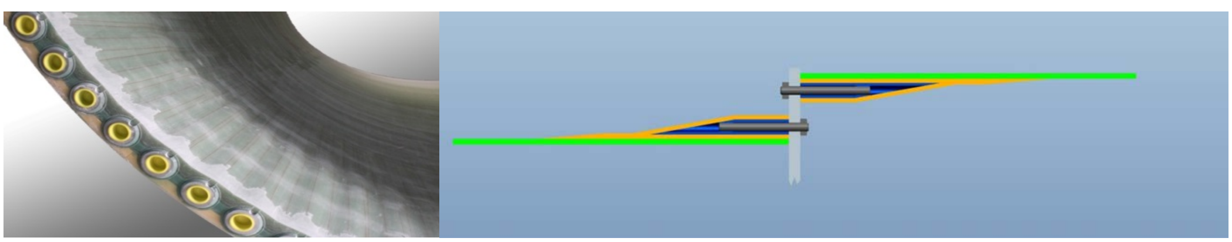

Figure 9 Blade joint connections (courtesy of SSP Technology. Right: Artistic view of a joint with two different sections (courtesy of DTU).

The above academic considerations are partly academic and partly business oriented views. Real interactions to be conducted are to approach management boards, and decision makers. An important instrument is to convince the politicians(e.g. political lobbyists in TP wind) that the concept is promising. This can be achieved by networking and dissemination(conferences, media writing). In the case of DeepWind the feeling from the

[11] http://www.emec.org.uk/about-us/our-tidal-clients/

[12] http://www.theswitch.com/wind-power/permanent-magnet-generators/

consortium is to have injected at least academic/scientific attraction towards the concept, but that the message still needs to be spread in the wind energy business.

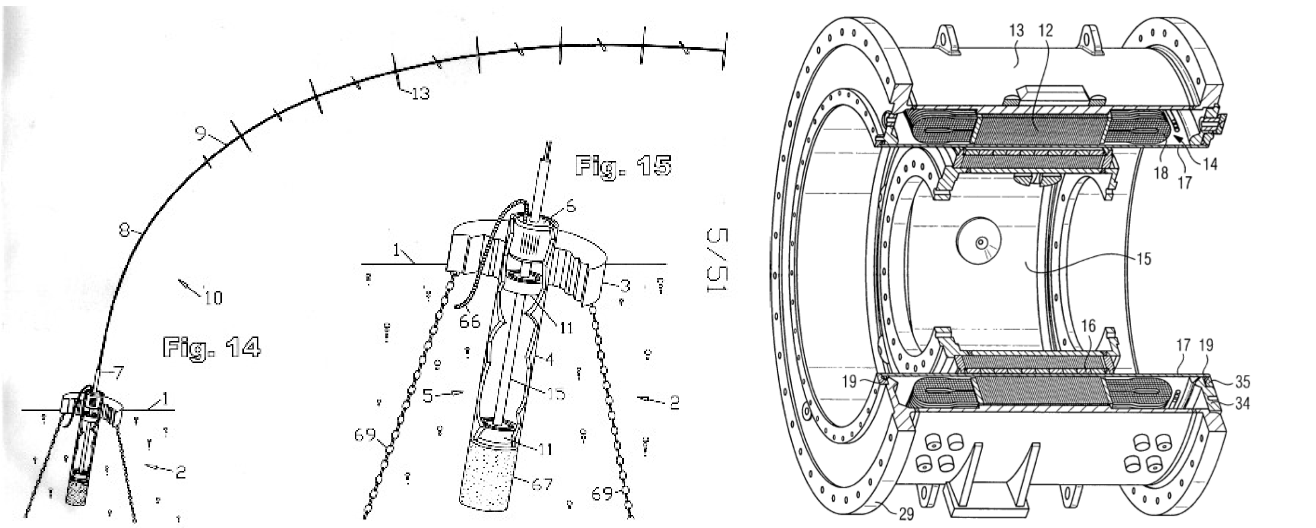

Figure 10 Left: the patent from Selsam.com. Right: Drawing of a new generator module for deep sea (from patent DE 10 2009 034 158 A1 2011.02.03)

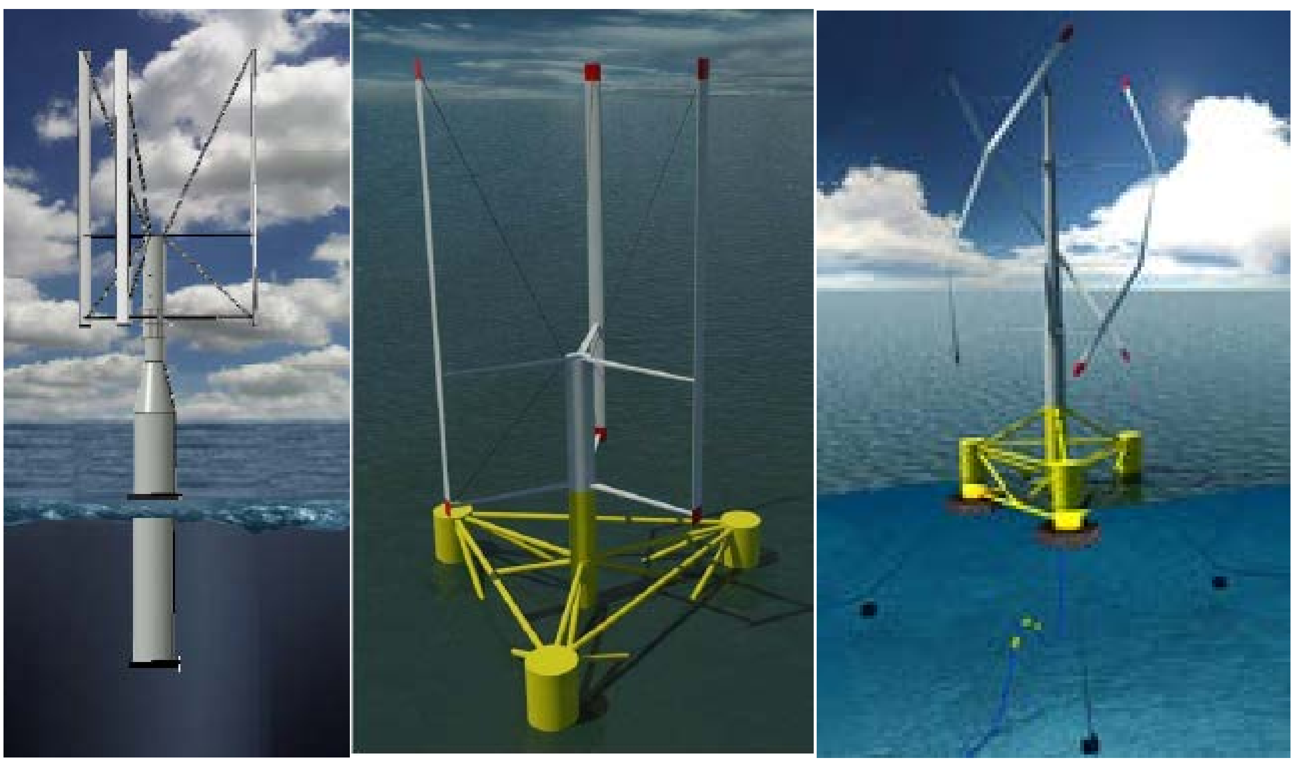

Figure 11 Left: Early Design(2008),Middle: intermediate(2012) and Right: present layout(2014)

Observations by trawling the internet

Some questions appear on the internet:" WHY AREN'T VERTICAL-AXIS WIND TURBINES MORE POPULAR?"[13] or from the same author[14] some points for discussion. The case is a good exercise showing that explanations have to reflect reality. One of the most powerful instruments is demonstration of a new technology, on a fair basis.

As a coordinating agent there are many results from DeepWind that are interesting and have a scientific impact in terms of arguments for design, loads, and costs. However along this projection we have assumptions incorporated, which needs proof-of-principle, and a demonstrations. We have investigated the 1 kW DeepWind rotor in the fjord, the ocean laboratory and in the wind tunnel. Results show that the technology is sound in though it needs further assistance for demonstration, and in this way proof to the community.

Other observations are promoting VAWT technology: *"…recent concepts are a great improvement on earlier vertical axis machines and justify a re-examination of VAWT potential. One of their arguments is that the technology has advanced considerably on what was available just a few years ago"*[15].

There are emerging new floating wind turbine concepts, majority based on HAWT technology and various types of tri-floaters(e.g. a variation of the windfloat concept). Based on this there is much momentum in the HAWT technology which is taken up by the inventors of new variants.

In the case of DeepWind the concept has to convince industry about that focused research and development/demonstration will break the perception of the above mentioned title question by proofing:

- DeepWind concept has at least as high as efficiency than existing HAWTs,
- the production of DeepWind blades is less costly and technically feasible
- DeepWind Improved installation, O&M cost structure over existing HAWTs
- Reliability higher for DeepWind concept than existing HAWTs
- The increased technology readiness level calls for industry interaction

Conclusion

DeepWind has to continue funding activities and dissemination with facts and results, that can lead to increase of LBD and LBU(e.g.demonstration), such as has been shown by Statoil and with this process to elevate to increased Technology knowledge stock. DeepWind needs as one of the other instruments to find an investor which is willing to put money into it(Statoil says 40 Mill € for the 1st prototype) and to attract news paths with industry by LDI.

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[13] http://barnardonwind.com/2013/02/23/why-arent-vertical-axis-wind-turbines-more-popular/

[14] ng/?utm_source=Cleantechnica+News&utm_medium=email&utm_campaign=649ffe57a1-RSS_EMAIL_CAMPAIGN&utm_term=0_b9b83ee7eb-649ffe57a1-331259845

[15] (Marsh & Peace, 2005, p. 42)