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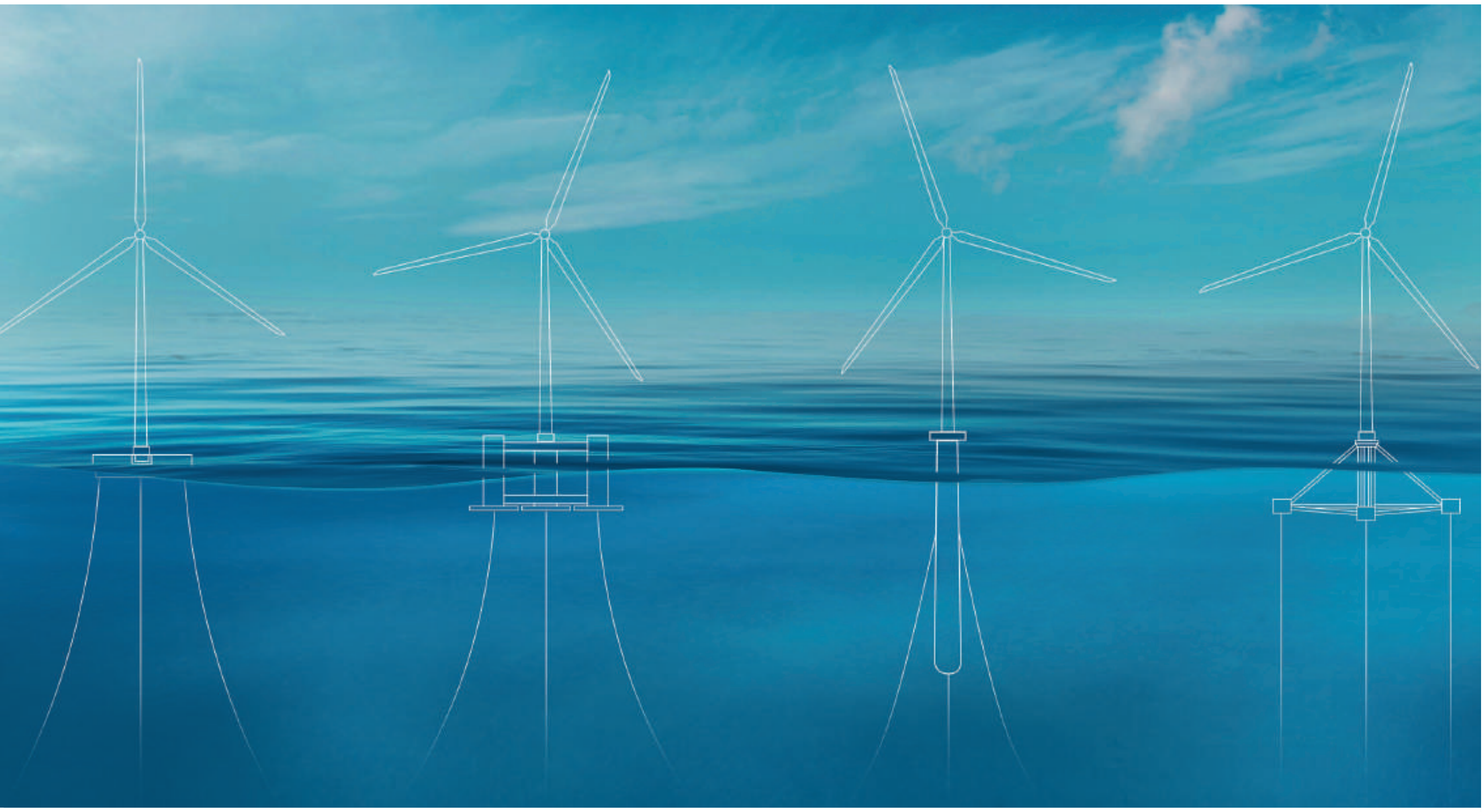

FLOATING WIND: THE POWER TO COMMERCIALIZE

Insights and reasons for confidence

SAFER, SMARTER, GREENER

FOREWORD

Floating wind is an emerging technology with an exciting future. It gives access to abundant wind resources over deep water – making it an important solution for coastal zones with large populations but with narrow continental shelves. These new wind resources will be an important addition to an energy mix that urgently needs to decarbonize.

Our projections are that floating wind will grow to reach a total capacity of 250 GW by 2050. That is almost 3,000 times the size of Equinor's Hywind Tampen floating wind power project in the Norwegian North Sea intended to provide electricity for the Snorre and Gullfaks fields from 2022.

We know that floating wind is technically feasible; the challenge now is to move rapidly to commercial deployments. There is a wealth of expertise to call on. The know-how from bottom fixed offshore wind, the competences of shipyards, and of oil and gas contractors all broadly align with the technical, logistical and operational challenges of floating wind. Pulling these resources together through joint industry projects to innovate new practices and standards is a major opportunity to bring step-change improvements to an emerging industry.

We at DNV GL offer our commitment to develop a cost-competitive and global floating offshore wind industry. In this report, we explore the potential to accelerate commercialization of floating wind by reflecting the opinions and experiences of our experts from numerous industries.

Remi Eriksen
Group President and CEO
DNV GL

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FLOATING WIND CAN BOOST THE ENERGY TRANSITION

The global energy system is transitioning fast – but not fast enough. The next phase demands the committed implementation of emerging technologies. Offshore wind is at the forefront of this evolution. And the emergence of floating wind makes affordable wind power a possibility in many more areas of the globe.

THE ENERGY TRANSITION PART 2

Globally, we are making progress towards decarbonizing energy and reducing emissions. There is massive ongoing electrification of the world's energy system. Electricity is less than 20% of the energy mix today, but this will double by 2050. Wind power will account for about 30% of this electricity, with solar delivering a similar share.

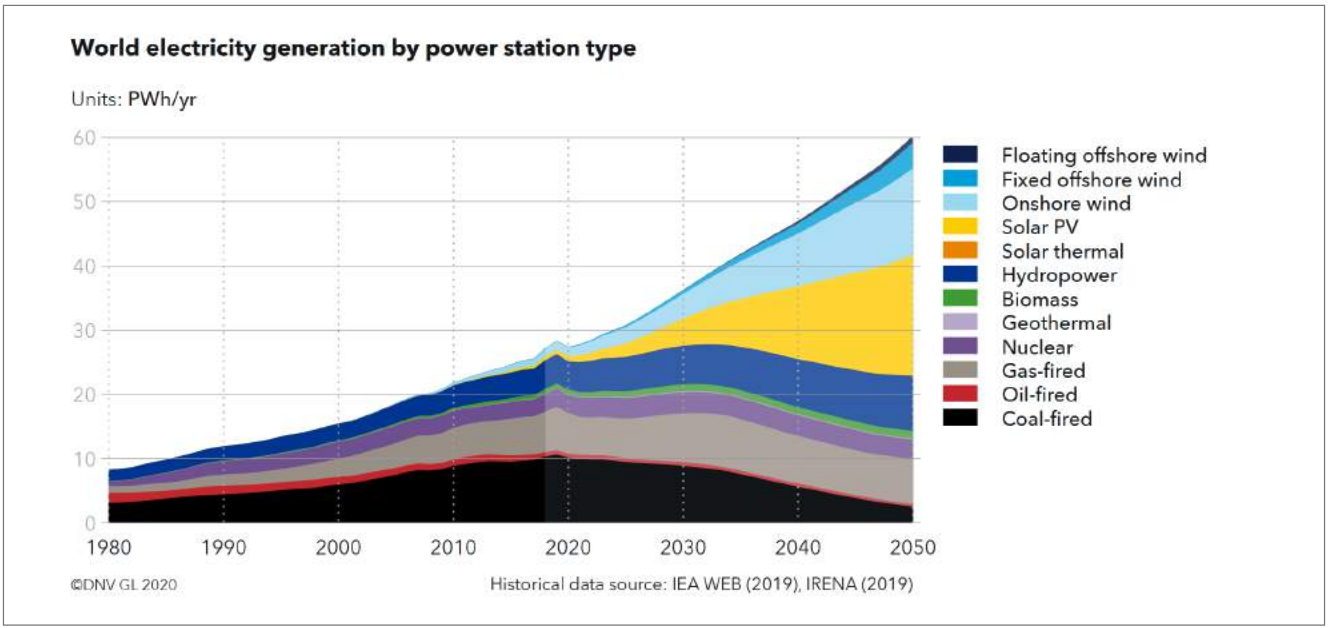
And yet, decarbonization is not happening fast enough. The world is likely to miss the Paris Agreement's climate goals. The good news is that we can meet the 1.5 °C ambition with existing technologies – including renewables, carbon capture and hydrogen – but the uptake of these technologies needs to be faster.

THE RISE OF FLOATING WIND

Global wind power capacity is expected to increase 10-fold in a little over a generation. The question arises: where are we going to put all these turbines?

Fixed offshore wind turbines need to be sited in relatively shallow water, and there is a limited range of suitable sites. But there are many more potential sites in deep water. Because floating wind can be deployed in any depth of water, it opens up these sites – bringing wind power in reach of much more of the world's population including the mega cities of Asia Pacific.

The two first pilot wind farms, Hywind Scotland and WindFloat Atlantic, and numerous prototypes have shown that floating wind is feasible. The 2020s will see the technology progress from these beginnings to commercial-scale deployments. And growth will continue from there. By 2050, the installed floating wind capacity will have grown from 100 MW today to over 250 GW – more than 20% of the offshore wind market and around 2% of the world's power supply.



Floating offshore wind (floating wind) will deliver 2% of the world's power by 2050

> “By 2050, the installed floating wind capacity will have grown from 100 MW today to over 250 GW - more than 20% of the offshore wind market

DRAMATIC COST REDUCTIONS

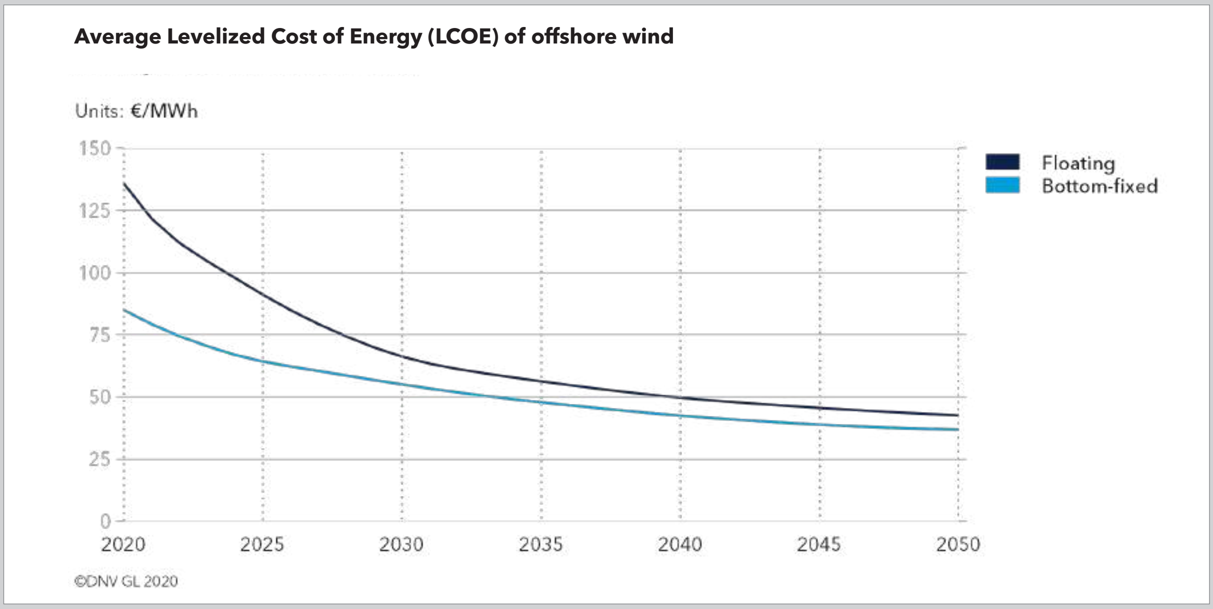
As more sites in deeper waters open up, floating wind will be a very competitive offshore solution in various locations worldwide. We do not expect floating wind to become cheaper than bottom-fixed wind, but the price difference will narrow as both fall.

According to our analysis[1], the cost of floating wind will go down almost 70% to a global average of 40 EUR per MWh in 2050. Key to these savings will be the introduction of larger turbines, larger wind farms, significant technology developments and the creation of a highly cost-competitive supply chain.

CHALLENGES AND OPPORTUNITIES

While driving down the costs, we also need to increase confidence in floating wind technology. Floating wind is opening up new markets that may not be familiar with offshore wind and other offshore industries. The industry needs to cope with new challenges like deeper waters, different soil structures and metocean conditions.
As floating wind goes global (much more quickly than bottom- fixed), geographic constraints and local content requirements will lead to new players entering the industry. All of this will have an impact on the costs and risks and could be a challenge.

But commercial floating wind also represents a huge opportunity for many players. Turbine manufacturers will have access to new markets for their products, oil and gas companies can repurpose their platform expertise for a more sustainable business as we pass peak oil, and shipyards around the world will be called on to manufacture floating structures by the dozen. Finally, floating wind looks a very attractive investment opportunity if risks can be mitigated (and we believe they can), bringing higher returns with less exposure to macro-economic cycles than commodities markets or traditional industry.

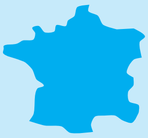


Cost-learning curve showing cost per unit of output over time. The steeper the curve, the quicker learning is driving down the levelized cost of energy. Competitiveness gains in bottom-fixed offshore wind have come from economies of scale due to larger wind turbines and mega-sized projects, and from co-locating projects for significantly lower grid-connection cost per megawatt. More efficient development and deployment processes, and an offshore supply chain dedicated more specifically to wind, have also reduced costs. Based on our 2020 Energy Transition Outlook, we predict LCOE reductions from floating wind through to 2050.

[1] *DNV GL Energy Transition Outlook 2020*

DEVELOPMENTS IN KEY MARKETS

FRANCE



France has taken bold steps in supporting the floating wind sector by tendering four pilot sites in 2015 and awarding these in 2016. The winning consortia will receive 240 EUR/MWh. Each project has chosen a different floater design which will support three 8 to 10 MW turbines per site. While all projects have progressed significantly, the planned completion dates will be pushed into 2023. Nevertheless, the strong involvement of French stakeholders to date and the prospect of three 250 MW tenders from 2021 to 2023 should drive developments forward.

NORWAY

Norway is very serious about realizing floating wind projects. On 1 January 2021, the Norwegian government is opening up for applications for offshore wind in two coastal areas: Utsira and Sørlige Nordsjø 2. The average water depth at Utsira is 267 m and only suitable for floating wind. Sørlige Norsjø 2 has an average water depth of 60 m with areas suitable for both floating and bottom-fixed wind. Norway is also home to the world's largest floating wind farm, the 88 MW Hywind Tampen which is currently under construction.

UNITED KINGDOM

The UK has two offshore floating wind farms, Hywind Scotland and Kincardine, both located off the eastern coast of Scotland. The development of new floating wind project is supported by the new seabed leasing programme – ScotWind Leasing - with the Crown Estate Scotland targeting multiple floating wind projects for development. The UK Government has committed to support innovation in floating wind, through the UK Offshore wind Sector Deal, including Investment in research and development to increase productivity and competitiveness of floating sub-structures.

UNITED STATES

There are significant floating wind resources to be harnessed in US waters. Currently, there are two primary markets that are being evaluated for floating wind: the Pacific Coast and the Gulf of Maine. The key driver in realizing development are aggressive state renewable energy targets. However, the federal leasing process through the Bureau of Ocean Energy Management has not opened up these ocean spaces for development yet. While there are call areas that have been identified, the auctions to lease these areas have not happened, though could happen as soon as late-2021 in California.

JAPAN

Deep waters and strong winds make Japan one of the most attractive countries for commercializing floating wind energy. In April 2019, the Ministry of Economy, Trade and Industry and the Ministry of Land, Infrastructure, Transport and Tourism jointly enacted the Offshore Wind Promotion Law which regulates an open tender process for offshore wind development in open seas through auctions. This is a big breakthrough for Japan. A floating wind site in the Goto Islands competed in the round 1 auctions. In addition, developers are looking at other potential areas to be taken up for public tender.

KOREA

Floating wind is a viable solution in South Korea, which currently has more than 40 offshore wind farm demonstration sites. Ulsan is the centre of the floating wind business with five major overseas companies - Green Investment Group (GIG), Copenhagen Infrastructure Partners (CIP), Shell/CoensHexicon, KF Wind Korea, and Equinor - who have signed a Memorandum of Understanding (MOU) with the city for 7 GW of expected capacity and more than 40 trillion Korean won (approx. 30 billion EUR) in investment.

RISK MANAGEMENT ENABLES HEALTHY INVESTMENT

Magnus Ebbesen, Business Lead Floating Wind

Floating wind is in a period of accelerated development and will grow rapidly in a number of markets. There is a lot of room for innovation and optimization, but also for brand new solutions. That brings some risk, but risks that can be managed and minimized. With an evolving technology, flexibility and forward thinking are imperative. Get it right, and floating wind presents a very attractive opportunity with healthy returns – for investors and the planet.

NEW MARKETS, NEW OPPORTUNITIES

With installed capacity expected to increase from 100 MW to 250 GW in the next 30 years, floating wind is a technology on the move. It opens up deep-water sites for electricity generation, allowing more countries to reap the benefits of offshore wind power. That makes it a very interesting option for local and international investors.

NEW TECHNOLOGIES, NEW RISKS

Floating wind draws on the oil and gas and (fixed) offshore wind industries. As such, investors and project developers can learn a lot from both sectors. But there are also significant differences. For example, compared to oil and gas platforms, floating wind has different loads, less redundancy and has to be produced in higher volumes at low cost.

The risk profile is more complex than for fixed offshore wind projects. Currently, we see more variation in project design and technologies deployed. And with each floating wind turbine comprising a floater, a turbine and a station-keeping / mooring system, there are more components that can go wrong, more interfaces and more suppliers involved, many of whom may have limited experience in the field. The possibility that the turbine moves more than intended, the advanced coupling between components, and dynamic cables all add further risk.

MANAGING RISK FOR STAKEHOLDER CONFIDENCE

As with any complex asset, the risks associated with floating wind projects will need appropriate management and mitigation measures to bring comfort for investors. Certification and classification will be essential in this (see pages 9-10 and 13-14). Developer and contractor experience, technology choice, contracting structure as well as considerations of the local condition will also be important.

FLEXIBILITY BRINGS LONG-TERM REWARDS

Stakeholders need to keep in mind the long timeframe between concept and installation for floating wind – typically 6-10 years. With this timespan and a rapidly evolving market, it is highly likely that the best design choices at the start of the project will no longer be the best available options at the time of construction.

> “ **Get it right, and floating wind presents a very attractive opportunity with healthy returns - for investors and the planet**

To handle this, projects will need to be smart in the way they are planned, using the best possible information available. Assumptions on e.g. turbine size will be critical as this drives loads which in turn impact the size of the structure and the mooring components that can be used to stress test the supply chain. But even with the best information and tools there is uncertainty, and it is therefore important to build in as much flexibility as possible.

For example, technical innovation and market evolution may mean that a specific project is better served by having, say, fewer platforms with larger individual outputs. But if permitting is too rigid to allow such a change, it could stop the project being competitive after a great deal of time and money has been invested. Flexible permitting that supports innovation and evolution is something that projects and regulators both need to think about.

LOOKING AHEAD ON COSTS

Like fixed wind, floating wind is on a breathtaking cost reduction path. Initially, components and supply chains for floating wind projects are likely to be adapted from other sectors, mainly fixed wind and oil and gas. But as the sector matures and we see dedicated products, approaches and suppliers, economies of scale will kick in giving a further boost to cost reduction efforts.

As with any emerging technology, investors and financiers committing at an early stage, will need to be more prepared for risks associated with an asset class with less track record. That said, with floating wind predicted to account for 2% of the world's power supply by 2050 and its levelized cost of energy expected to fall by more than two-thirds, it represent a massive global market with very attractive potential returns.

CERTIFICATION AND STANDARDS – DRIVING FLOATING WIND ENERGY TO NEW HEIGHTS

Kimon Argyriadis, Director Floating Wind Certification

Floating wind is a technology on the rise, with installed capacity increasing over 2,000-fold and costs plummeting. Standards are critical to the development of any emerging technology. But the variety of participants and concepts in floating wind make suitable standards and reliable assessment against them vital for the technology to reach its full potential.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CUTTING RISKS AND COSTS IN A NEW INDUSTRY

Following successful prototypes and demonstration projects, floating wind energy is taking the first steps towards commercialization. In this, it faces the same challenges as any emerging technology: confidence and cost.

Experience shows that certification against an agreed standard is the most trusted way to deliver stakeholder confidence. It indicates that risks have been understood and minimized, ensuring quality and reliability. And by minimizing risk, it helps the industry to reduce costs.

This is even truer for floating wind where new technologies are being deployed in new markets and locations with new conditions. Moreover, those technologies will be delivered by a new, wide-ranging supplier base comprising wind turbine manufacturers, oil and gas contractors and shipyards. What's more, many governments are specifying required levels of local content in the floating wind supply chain to maximize the wider economic benefit to their country. As a result, while each player may be an expert in their traditional field, many will initially have limited or no experience in this particular application.

An agreed certification process and standard lets project owners and investors assess the risks involved in each project. At the same time, it provides recipes for disparate and inexperienced suppliers, helping them understand the tolerances they have to work within to deliver a successful project. And it provides a common language for players from wind power, oil and gas and maritime industries to come together and create a thriving floating wind industry.


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DEFINING THE RIGHT STANDARDS

Developing floating wind standards is a challenge in itself. Experience and insight from both offshore wind and oil and gas platforms help, but floating wind platforms have unique features. These include different load regimes, novel station-keeping systems and dynamic free-hanging cables.

Moreover, floating wind platforms aren't simply a floating unit with a turbine on top. Changes to the turbine affect the floater's stability and changes to the floater impact the turbine's performance. Hence, they should be considered as an integrated whole. With turbine and platform manufacturers understandably wary of sharing sensitive information, project certification offers a way to verify the interfaces between suppliers and ensure changes during development don't negatively impact other components.

> “ Standards that consider new challenges and cover well-established manufacturing and installation processes will help to deliver big volumes while maintaining necessary quality levels

The scale of floating wind projects presents another challenge. Creating such large floating structures weighing more than 5,000 tonnes is not unusual for shipyards and the oil and gas industry. But producing and installing more than 20 such structures simultaneously is new. Standards that consider new challenges and cover well-established manufacturing and installation processes will help to deliver such volumes while maintaining the necessary quality levels.

EVOLUTION FOR COST REDUCTION

DNV GL has taken a leading position on developing requirements for floating wind turbine structures. Inspired by the first full-scale turbine, Hywind Demo, DNV GL issued its first guideline in 2009. This was later developed into a full standard in collaboration with ten partners that was issued in 2013. Building on experience from prototypes, research projects and the world's first floating wind farm, Hywind Scotland, a new update was issued in 2018 as the DNV GL-ST-0119 standard. Some of the key updates included optimized safety factors for fatigue, specific load cases related to loss of mooring lines and, shared anchoring, and the motion control. The standard fully aligns with the 2020 published class rules which help yards to achieve cost-effective floating wind construction.

In the next update, which will be published in spring 2021, DNV GL will look at factors that will enable a further round of cost reduction. Thanks to efforts such as these, the industry can be sure of standards that continue to support floating wind's growth as a major component of the world's energy mix.

DIGITAL INNOVATION – THE KEY TO RAPID, LOW-COST SCALING

Elling Rishoff, Senior Vice President and Director Software Ecosystems

Floating wind has huge potential, but for the technology to be scaled up rapidly and at low cost, the industry needs digital innovation. The combination of a floating support structure and wind turbine inherently introduces great complexity into modelling calculations. This requires numerous lengthy, expensive computations and large engineering effort for which conventional wind industry software design and analysis tools are not enough. To deliver optimal analysis, design, assessment and, subsequently, control and management, floating wind requires integrated digital solutions, standards and openness.

WHY FLOATING WIND IS A DIGITAL CHALLENGE

Software has been used to analyse and design ships and fixed offshore structures for the oil and gas industry since the late 1950s. Recently, tools have emerged for fixed offshore wind, which itself brought added complexity due to the time-dependent behaviour of the wind turbine. With the emergence of floating wind the engineering challenges have increased yet further because the floating support structure's motions must be taken into account along with wave loads, currents, wind flows and turbine states.

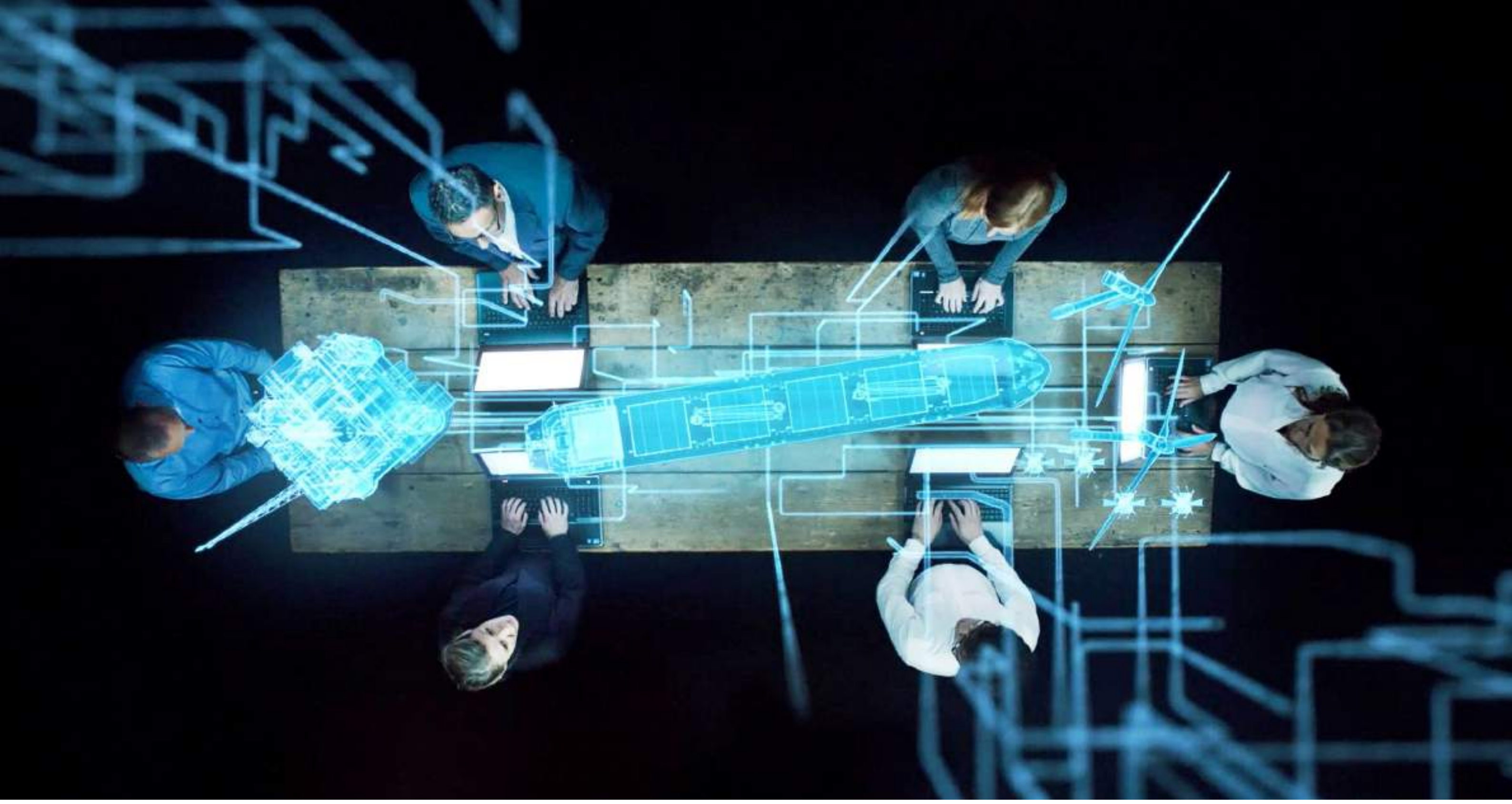
Analysing potential designs that combine all these variables requires far more computing power than fixed offshore wind. The software models typically contain many more finite elements. Plus, the simulations must be run over longer time periods (hours rather than minutes), alongside additional load cases and consideration of extreme loading event timings.

> "For the technology to be scaled up rapidly and at low cost, the industry needs digital innovation

STEP 1: CLOUD COMPUTING AND IMPROVED TOOLS

Cloud computing elasticity is part of the solution: it offers the processing power and capacity for massive quantities of data. However, the real gains will come from ensuring available computational resources are used efficiently, cutting costly investment in private High Performance Clusters (HPC computing) or cloud subscriptions, whilst reducing the time to obtain analysis results and allowing for further optimization.

This will require new methods to increase analysis efficiency and new engines for post-processing data into actionable information. With workflow automation and technologies such as machine learning, digital tools could quickly produce shortlists of optimized designs for engineers to consider, thereby reducing engineering hours and enabling deeper optimization of chosen designs, for instance, by minimizing steel use or improving the manufacturing process.



INTEGRATION, STANDARDS AND DATA SHARING

Above all, integration of tools will be key to scaling floating wind with reduced risk and lower costs. In a floating structure, the floater and the turbine must be analysed as a single entity. Yet current turbine and floating substructure engineering tools offer limited capabilities for modelling floating wind structures together in this way.

Partial solutions such as commercially available 'concept' turbine models that allow for an initial partial optimization of the foundation to the turbine exist. However, the real game-changer will be a fully integrated approach covering assessment and analysis of resources, loading, response, capacity and performance. For this, it is vital to develop industry standards for intellectual property (IP) protection and data exchange between collaborating organizations that make such a coupled solution both feasible and acceptable.

Open industry standards for modelling and exchange of information are essential to scaling and 'mass customization' in floating wind. With these in place, project clusters could rapidly create projects based on 'standard' structural elements, design methods, and floating wind-specific acceptance criteria that are incorporated in design tools.

LONGER TERM DEVELOPMENTS

Today, floating wind concepts are emerging from prototype stage and into early commercially viable systems. As floating wind expands, it will need to achieve the same levelized cost of energy (LCOE) reductions seen in onshore and offshore fixed wind. As this happens, digital tools will play a wider role. Modelling, digitalization and on-turbine sensors will support control and operational decision-making, and smart connection to grids. Throughout the whole lifecycle of a floating wind farm, innovative digital tools will be a crucial factor for successful commercialization.

STANDARDIZED SOLUTIONS HELP YARDS ACHIEVE COST-EFFECTIVE FLOATING WIND CONSTRUCTION

Erik Henriksen, Vice President Offshore Classification

Floating wind will create substantial opportunities for yards, vessel operators, offshore companies and many new players. Maximizing the returns on investment will require cost-effective, safe solutions for constructing, assembling, and commissioning units for installation offshore. Collaboration will be key from design basis and throughout the lifecycle plan.

To unlock floating wind's massive potential, ship yards in Korea, Japan, China and elsewhere require standardized solutions that support serial production and modularization for competitive, responsive project delivery. The term ‘constructability’ summarizes this need.

With some major floating wind projects likely to begin construction by 2023, the well known DNV GL class for ships and offshore structures rules can provide reassurance on cost and risk when making development choices. For example, our new class rules for floating offshore wind turbine installations (DNVGL-RU-OU-0512) combine offshore, energy, maritime and digital expertise into an integrated rule set. These rules complement DNV GL’s existing verification and certification services and standards for floating wind, thus providing well-tested rules and standardized processes for the new structures. In this way, both experienced and new players in the offshore project ecosystem can have a familiar framework to integrate new processes into existing production structures with confidence.

Owners, yards, original equipment manufacturers (OEMs) and others are used to working with our standards, are familiar with the process, and know the acceptance criteria. Studying the benefits of such familiarity in the oil and gas industry, we found that using a new standard instead of an existing one increased the uncertainties and cost of project phases in the yard.

> “ To unlock the potential of floating wind, yards in Korea, Japan, China and elsewhere require standardized solutions that support serial production

CHALLENGES FOR YARDS

The new rules are timely. Floating wind is moving up the agenda for governments worldwide as they set targets to decarbonize their energy systems and promote 'green' jobs growth for economy recovery.

As a part of these efforts, some yards might initially be looking to win as much work associated with floating wind as possible. However, they may be hesitant if this threatens to tie up their traditional ship and offshore capacity, as these wind projects will often be large-scale, intensive, multi-year projects. On the other hand, yards already have an excellent project and supply chain management track record and could use these skills to manage the needed capacity for floating wind projects.

Other yards might tender for more of the fabrication work, but could also potentially spread some of this work among subsidiary yards to maintain their capacity. Additionally, and depending on the OEMs, yards may also bid to integrate the floater with the tower and possibly also the wind turbine nacelle and blades, essentially undertaking the full commissioning of the unit at quayside before float-out.

Substantial quayside space and deep berths will be needed for marshalling and assembling structures with deep drafts. Large projects might support investment in yard infrastructure to create capacity and enable local content. Smaller projects may make yards think twice about the scope and scale of what they bid for.

THE BENEFITS OF CLASS

To support decision making, our new class rules cover all potential floater (hull) designs for floating wind: barge, semi-submersible, vertical floating columns (spar) and tension-leg platform.

Class rules also work with design and construction follow-up to verify that a unit was built according to design. Some owners now request class because it can also apply to operations follow-up, so that learnings from operations can be fed back through frequently updated rules.

Our new class rules are designed to scale as they consider not just the individual units but the entire floating wind field with data-based services and condition-based monitoring, and through linking with fatigue methodology sensor data.

For tow-out, floating wind will involve large-scale use of existing ships, such as tugs. However, some specialist mobile units will be needed for maintenance work offshore, and there may be a need for a new class of crane vessel with enormous reach for floating wind turbine installation.

HOW OIL AND GAS KNOW-HOW HELP BUILD CONFIDENCE AND DRIVE DOWN COSTS

Kristin Nergaard Berg, Principal Consultant Subsea & Asset Risk Management

International oil and gas companies, as well as energy businesses, power utilities and offshore contractors, are investing strategically in floating wind, expecting it to steadily become competitive in the lower-carbon energy mix.

Nearly two thirds of senior oil and gas professionals surveyed for our *2020 Industry Outlook* said their organizations would likely invest in offshore wind in 2020 as these companies seek to reduce the carbon footprints of their business portfolios. Floating wind appeals because 81% of total offshore wind electricity generation potential is estimated to be in waters deeper than 40 metres, where wind is more reliable and planning consent likely to be easier to obtain.[1] DNV GL's *2020 Energy Transition Outlook* predicts floating wind installed capacity of 250 GW in 2050 compared with 1,000 GW of bottom-fixed offshore wind.

Floating wind technology is currently too expensive to compete on a fully commercial basis with more established ways of generating power. However, investors have seen bottom-fixed offshore wind learn quickly as it scaled commercially. It has moved so far down the cost-learning curve (see page 5) that some European wind farms no longer need government subsidies. In the 2020s, floating wind will similarly move towards commercial-scale deployment, learning as it goes and acquiring existing knowledge from floating hydrocarbon production.

> **"Floating wind technology is currently too expensive to compete on a fully commercial basis with more established ways of generating power**

The oil and gas industry has strengthened its own focus on cost and quality amid lower oil prices than in 2014, and with the expectation that prices will remain under pressure in the energy transition. Oil is 35% cheaper to produce now than in 2014, with the 'clear cost savings winner' being new offshore deepwater developments, according to analysts Rystad Energy.[2]

Offshore wind deployment has moved down the cost-learning curve

[1] Bosch, J, Staffell, C, Hawkes, AD, (2018) *'Temporally explicit and spatially resolved global offshore wind energy potentials'*, Energy 163 (201) 766–781), https://bit.ly/36X1DXW
[2] *'Oil production costs reach new lows, making deepwater one of the cheapest sources of novel supply'*, 21 October 2020, https://bit.ly/3nLL0VO

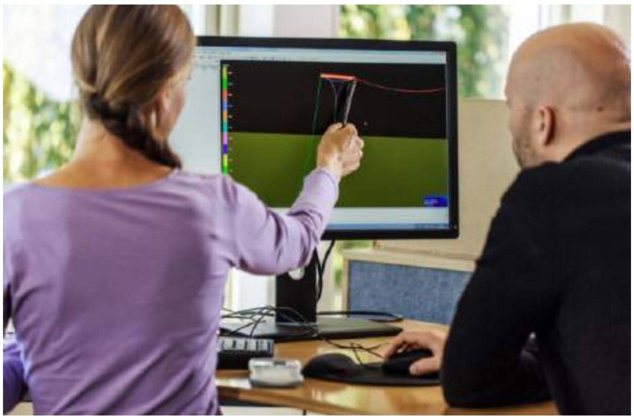
MANAGING MAJOR PROJECTS

For floating wind, the oil and gas industry offers decades of experience in managing major offshore development projects, global supply chains, contracting, purchasing and operations. The industry is also seasoned in qualifying suppliers for delivering to technically advanced new requirements in novel markets; regulatory compliance; and standardization for cost and quality benefits.

The oil and gas industry has designed and built floating structures for decades. Advanced software and digital tools have been developed to model the loads they experience, to predict behaviour and to dimension e.g. anchors and moorings for rough weather and seas. The industry understands how to safely handle, transport, and lift heavy equipment at sea. DNV GL sees significant demand to support offshore wind in this regard, for example Marine Warranty Surveys based on practices and knowledge from oil and gas.

The sector's experience can assist the evolution of new methods, materials or technologies to reduce floating wind mooring systems costs through fit-for-purpose design, easier and safer installation and/or reduced maintenance requirements. Oil and gas companies also design electrical power cables to remain reliable over their lifetimes in challenging subsea conditions and loads from waves and offshore handling.

Floating wind has its own health, safety and environment (HSE) risk profile. However, the oil and gas industry has practices to adjust HSE management requirements to different risk pictures through safety class philosophy, and to remove unnecessary conservatism by introducing science-based calibration of safety factors and structural reliability analysis.



New methods, materials or technologies that reduce the cost of mooring systems through easier and safe installation and/or reduced maintenance requirements can help to bring down the cost of floating wind power

COLLABORATING FOR THE FUTURE

Oil and gas industry competences align broadly with technical, logistical, and operational challenges that our floating wind customers face: for example, qualification of deepwater moorings and anchors, and optimization and qualification of high-voltage dynamic power export cables.

Mastering the competences and building on existing collaborative relationships between players in the supply chain and services, is a good start for developing and operating floating wind. The technical knowledge in the oil and gas industry and its long history in developing new technologies while managing the risk in operations can help the industry commercialize with confidence while driving down the cost.

FLOATING WIND AT A GLANCE

CUTTING-EDGE PROJECTS

Click to read more about projects where DNV GL's broad expertise facilitates floating wind.

Technology qualification services for aerodyn's new floating offshore wind design	Certification of Naval Energies' floater design basis for floating wind farm and design methods	Technical and market advice to Tokyo Gas on USD 22 million investment in Principle Power floating wind technology	Verification study for Equinor's Hywind Tampen floating wind farm
Technical due diligence for 25 MW Windfloat Atlantic floating wind project	Design standard and certification guideline for floating wind turbines	New class rules for floating offshore wind expands industry horizon	COWI improves efficiency with Sesam cloud solutions

THE BIG POTENTIAL

DNV GL's *Energy Transition Outlook Report 2020* predicts that, by 2050, floating wind will reach:

250 GW
installed capacity

€40/MWh
Levelized Cost of Energy

20%
of total offshore wind market

2%
of world's power supply

TODAY'S TECHNOLOGY

WHY FLOATING WIND?

Floating wind is attracting increasing investment and public policy support because it can access the estimated 81% of total offshore wind electricity generation potential that is in waters deeper than 40 metres.[1] There, wind is more consistent, but using bottom-fixed offshore wind support structures may be less feasible technically, logistically and economically, or just plain impossible.

WHAT TYPES OF STRUCTURES ARE INVOLVED?

Floaters aim to keep turbine assemblies afloat and in stable-enough positions to optimize power generation efficiency by countering complex ocean and wind motions. Four broad types are currently being used in floating wind pilot and demonstration projects made from steel or concrete. Three floater types – barge, semi-submersible and spar buoy – are moored to seabed anchors by chains, steel cables, or fibre ropes. The fourth type of floater, a tension leg platform (TLP), is vertically moored with teethers or tendons 'tension legs'. Very strong cables, pipes or rods link the legs to seabed anchoring. Different anchor types can be used depending on the type of mooring system, soil condition and expected environmental loads.

Four broad types of floaters are currently being used in floating wind pilot and demonstration projects

HOW ARE FLOATING WIND STRUCTURES MADE AND INSTALLED?

Floating wind turbines may be assembled onshore or in dry dock, then towed out by conventional tugs. Where fabrication sites with sufficient water depth are available, fitting towers and turbines can be done inshore prior to towing the full assemblies out to final location. With their large drafts, spars may need to lie horizontally for towing to site where they are then tilted to float vertically and ballasted prior to a crane barge mounting the turbine. TLPs can be assembled onshore and in dry dock. Some developers think TLPs could be towed to site, but special-purpose vessels may be needed.

[1] Bosch, J, Staffell, C, Hawkes, AD, (2018) *'Temporally explicit and spatially resolved global offshore wind energy potentials'*, Energy 163 (201) 766–781), https://bit.ly/36X1DXW

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About DNV GL
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