WIND POWER: INVESTING IN SUSTAINABLE OPERATIONS

Strategies for identifying wind turbine efficiencies and advancing sustainability goals

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EXECUTIVE SUMMARY

The energy transition is underway. As a result, we are witnessing a significant shift in how energy is generated, shared and used, at both a supranational and domestic level, as we collectively work towards a cleaner future.

Wind power has the potential to play a big part in this equation. But while operators have an opportunity to maximise growth in a flourishing market environment, they must do so sustainably, by integrating economic, environmental and social considerations. Sustainable growth will help ensure operations remain as competitive as possible in the here and now, as well as viable and resilient over the long term.

This paper will provide wind business owners and operators with strategies to achieve this, particularly when it comes to the controllable operational elements such as turbine maintenance.

We will look at the current state of play in the market as well as projected sector growth, before delving into the unique challenges the wind industry faces. We will also discuss the strategies, such as effective lubrication management, that can be put in place to help: optimise operations; boost competitiveness; and drive sustainability efforts.

We would like to thank DNV for its insights and contributions that helped to build this report; a great example of how collaboration in expertise can help to drive the industry forward.

FOREWORD

Wind power is taking on an increasingly central role in Europe's energy transition. A role that has undoubtedly been accelerated by the COVID-19 pandemic, but one that was already taking shape in the years prior.

The sector's growth is driven by several interconnected issues, from expanding digital capabilities and decreasing operational costs to bigger picture considerations like the need for a clearer – and swifter – roadmap towards a substantial renewable energy framework.

And behind these considerations are the various stakeholder groups that continue to shape Europe's future energy mix: the industry's investors, regulators and customers, and of course, the owners and operators of each current and planned wind farm across the continent.

While investors may fund wind's growth, regulators govern it, and customers inform its direction. It is this last group, however – the owners and operators – that bear the onus of wind power's ongoing success.

After all, it is their choices – regarding everything from project development and turbine measurement to support services and maintenance approaches – that will decide whether wind farms can live up to their label as a clean, efficient and productive form of energy generation. And it is their actions – to collaborate with others, integrate new technologies and optimise current operations – that will help the industry to fulfil its potential.

Keir Harman, Renewables Operations Director, DNV

RENEWABLE ENERGY: TURNING AMBITIONS INTO ACTIONS

The 2015 Paris Agreement on tackling climate change committed the world's nations to taking action to mitigate the impact of global warming. An ambition was set to hold the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels.

More recently, the European Commission has adopted a package of proposals – including the Renewable Energy Directive and the Energy Efficiency Directive – to ensure that the European Union's policies are aligned with its desire to be climate neutral, including:

At least a 55% cut in greenhouse gas emissions by 2030, from 1990 levels[1]

A 40% share of energy from renewable sources by 2030[1]

At least a 39% improvement in reducing primary energy consumption by 2030[2]

Clearly, cleaner, renewable sources of power will be indispensable to meeting the targets set by the Paris Agreement. Wind energy, already a pillar of the energy transition, is expected to assume a greater responsibility as a result. According to analysis by WindEurope, the European Union will need 451GW of wind power capacity by 2030, up from 180GW today, to meet its renewable energy target from 32% to 40% by 2030.[3]

And so, the time is now for operators to maximise on growth potential to become key players in the future energy mix.

THE ENERGY TRANSITION IS ALREADY UPON US

These targets build on already significant achievements from the renewables industry, of which wind energy is a key component. In 2020, renewables overtook coal and gas to become the main source of electricity in Europe for the first time, generating 38% of Europe's electricity for the year.[4] Wind and solar alone generated a fifth of Europe's electricity in 2020.[4]

According to research by analysts at DNV, solar and wind will represent 69% of grid-connected power generation by 2050 – with 33% of grid-connected electricity supply being wind-based.[5] Meanwhile, cost reductions for fixed and floating offshore wind will be 44% and 80% respectively from 2020 to 2050 with operating and maintenance efficiencies driving cost savings.[5]

As Keir Harman, Renewables Operations Director from DNV, comments: "We're approaching a golden age for renewable energy demand, which is being driven by ambitious green targets. Electricity generation from wind is expected to skyrocket from 1,420 TWh/yr in 2019 to 17,840 TWh/yr in 2050, with the sector clearly benefitting from financially supportive policies and growing awareness of the impact of conventional energy sources on the environment and the climate."[5]

And this optimism is reflected in the growth of the sector, specifically in Europe, where the International Energy Agency (IEA) predicts that additions to Europe's renewable power market are set to break the record for the first time since 2011 – becoming the second-largest market after China.[6]

While this progress means there are evidently huge opportunities for wind businesses, wind power's future success cannot be taken for granted. To secure its place in the future energy mix, wind must demonstrate both its reliability and its ability to maximise output, while reducing costs and driving sustainability within operations.

In this paper, we look at which steps the wind power industry can take to maximise its success, today and in the future.

REGIONAL FOCUS: EUROPE

DNV's Harman offers an insight into what we can expect from the wind sector in Europe: "There's no doubt that Europe is a frontrunner in the wind energy sector, with the energy source an indispensable part of Europe's energy transition.

While 2020 was bumpy for the renewables sector due to: supply chain disruptions; lockdown measures; social distancing guidelines; and emerging financing challenges caused by the pandemic, wind energy still contributed a signification portion of Europe's electricity.[7]

Yet, wind energy still contributed a significant portion of Europe's electricity during the pandemic, with wind playing an integral role in the United Kingdom and the European Union's drive toward net zero.[8] As a result, we anticipate that wind's contribution to Europe's energy demand will only increase – with onshore and offshore providing up to nearly 50% by 2050".[5]

Meanwhile, we are also seeing increasing innovation within the European wind sector. Floating offshore wind is one such area, with 43 GW of new capacity expected to be installed by 2050.[5]

ENERGY FOCUS: WIND'S ROLE IN HYDROGEN PRODUCTION

But wind also has an indispensable role in producing clean, alternative fuels such as renewable hydrogen. This is because wind energy is the raw material for producing green hydrogen, which is generated through the electrolysis of water powered by zero-carbon electricity.

What's more, the European Union has acknowledged that hydrogen will play a key role in future energy systems, and in delivering on the aim set out in the European Green Deal of achieving carbon neutrality in the EU by 2050.[5]

According to DNV's recent Energy Transition Outlook, by 2050, hydrogen will meet 12% (4.5 EJ) of Europe's final energy demand, representing 20% of the world's hydrogen energy use.[5] While, in its Hydrogen Strategy, the European Commission has pledged to ramp up electrolyser capacities for renewable hydrogen to 6GW by 2024 and 40GW by 2030.[9]

Furthermore, DNV suggests that the future production of hydrogen for energy purposes will indeed be dominated by electrolysis using dedicated off-grid renewables, such as solar and wind farms; this is because electrolysis powered by grid electricity is disadvantaged by the limited number of hours of low-priced electricity available.[5] Ultimately, DNV believes that by 2050, only 18% of hydrogen will be grid-based, while 43% will come from dedicated capacity comprising solar PV (16%), onshore wind (16%) and fixed offshore wind (9%).[5]

HARNESSING THE POWER OF NATURE

SIZE AND SCALE

The tallest wind turbine in the world is

246.5m[10]

The world's longest turbine blade is

107m

long, equal to 1.4 times the length of a Boeing 747[14]

A single SG 14-222 DD turbine can deliver power for approximately

18,000

average European households every year[16]

The Gansu Wind Farm in China is the largest onshore wind farm in the world with

7,000

turbines in the Gobi Desert[17]

WEATHER AND LOCATION

Wind turbines can endure temperatures as low as

–30°C[11]

Global Tech 1 wind farm in Germany lies

110km

from shore[15]

Some wind turbines can withstand typhoon-strength speeds of up to nearly

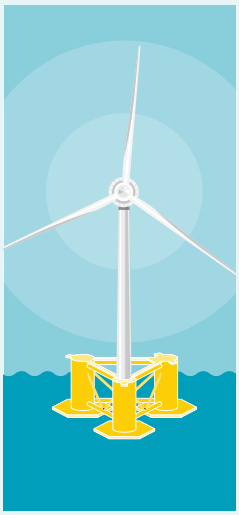
80m/s[18]

FLOATING FARMS

Europe has a total of

34

floating wind farm concepts in comparison to the rest of the world's **16**[12]



Floating wind can potentially power

12m

homes in Europe by 2030[13]

Floating offshore wind opens up **80%** of the world's offshore wind resources, which are located in waters deeper than

50m[12]

MAINTENANCE

Global onshore wind operations and maintenance costs reached nearly $15 billion in 2019 with

$8.5 BILLION SPENT ON UNPLANNED REPAIRS

and correctives caused by component failures[19]

Offshore wind projects can have maintenance and servicing costs amounting to nearly **19%** of the total annual budget[20]

Each year there are approximately **1,200 gearbox failures** – which can be costly. The gearbox accounts for **13%** of the overall cost of the turbine[21]

Operations and maintenance costs typically account for **20% to 25% of the total levelized cost of electricity** (LCOE) of current wind power systems[22]

SUSTAINABLE SOLUTIONS

Shell offers a variety of **carbon neutral lubricants for the wind sector**, including gear oils, greases, and hydraulic oils with full transparency on certificates

Shell uses **nature-based solutions** to offset the entire product lifecycle carbon footprint of its selected lubricants portfolio

OPTIMISING OPERATIONS: KEY CHALLENGES

With some types of power generation, jobs can be run to the tightest schedule with almost every variable controlled. This is possible because engineers work in stable and predictable environments. However, wind farm maintenance engineers do not have this luxury. Wind farms are often sited in remote and extremely challenging areas, whether it be offshore sites with limited access or onshore equipment that is exposed to the elements.

In fact, a significant opportunity to exploit the potential of offshore wind power exists in deep waters of 60+ metres and beyond, where an estimated potential capacity of 4000GW could be installed thanks to using cutting-edge technology such as floating offshore wind.[23]

And with wind turbines increasingly located in these challenging environments, alongside the demand for lower levelized cost of energy, it is important for owners and operators to have solutions that can be relied upon to safeguard performance over longer periods of time.

This may be an effective lubricant that can reduce the need for frequent oil changes or a grease that can ensure the consistent protection of bearings.

Either way, overcoming these challenges requires a fresh approach, since any inefficiencies stemming from manual legacy processes in the wind farm operations will inevitability impact the energy produced from the assets. But, the question top of mind for many wind farm operators is how to tackle these inefficiencies without incurring additional costs.

The first step is to shift from traditional reactive maintenance to predictive maintenance, underpinned by: Industry 4.0 digital technologies; effective data utilisation; and a digitally savvy workforce. This shift will enable operators to proactively manage the performance of their wind turbines and therefore maximise annual energy production while minimising operational costs and lengthy downtime.

There is no doubt that modern-day wind farms offer considerable amounts of data with the potential to have an immediate impact on wind farm productivity. But, are owners and operators making the most of this data by using it to generate insights that can boost revenues and minimise downtime? These data insights – combined with the skills and expertise of operations and maintenance professionals – can have an immediate impact on extending the lifespan of the wind turbine and maximising its potential.

However, to do so requires skilled staff. Therefore, it is vital that wind farm operators upskill their staff so that they can make the most of the cutting-edge digital solutions and data. With 76% of energy, utilities and resource sector CEOs citing the availability of digital skills among their list of growing concerns, the failure to upskill staff could see wind farm operators miss out on untapped opportunities to boost operational efficiencies.[24]

A DOUBLE HIT ON MAINTENANCE

The challenges of operating in remote and hostile environments fall into two main categories: access and equipment strain.

ACCESS:

With turbines on remote hillsides, offshore, and in cold climate locations, it can be difficult to get the right equipment and personnel onsite quickly if an unexpected problem occurs. This can consequently lead to increased downtime and a loss of profits. According to one study, logistics alone accounts for up to 17% of the annual operational budget of offshore wind farms.[25] This underlines the importance of preventative maintenance in addressing problems before they occur.

EQUIPMENT STRAIN:

Equipment in these environments is under constantly – and often rapidly – changing, or generally increased, loads. For example, cold climate sites provide high energy yield but cause increased structural loading levels. This makes effective and consistent operation challenging as it increases stress on key turbine components, which can lead to unplanned downtime if unmanaged.

A study by the Fraunhofer Institute for Wind Energy found that the mean downtime on the sites studied was up to eight days for the drive-train system and six days for the transmission system.[26] The financial impact of this can be huge and shows the importance of not only implementing predictive maintenance measures, but also having the right experts onsite when needed.

THE TRUE IMPACT OF EFFECTIVE LUBRICATION

In the face of tough external conditions, a crucial factor in determining how much downtime a site suffers, is its lubrication regime. A Shell Lubricant Solutions survey of power operators found that nearly one in five (19%) had experienced equipment breakdowns because of ineffective lubrication.[27]

But 21% say that lubrication is not an organisational priority.[27] This is a missed opportunity when you consider that simply choosing an effective synthetic lubricant for your specific equipment and location can help to reduce costs significantly – and that's even before you consider optimising other aspects of lubrication management.[27]

As the size, power and operational time (capacity factor) of turbines increases, the impact these factors have on maintenance costs, reliability and return on investment, will grow. This makes getting maintenance right – and doing so now, in preparation for the expansion of wind capacity – more important than ever.

WHY FAILURE TO OPTIMISE IS NOT AN OPTION

The wind power industry is highly complex, meaning operators are faced with a wide range of challenges and opportunities. These range from the increased complexity (and effectiveness) of big-data analytics to the need to reassure investors that subsidy-free operating models do not over-expose them to energy price fluctuations.

With so many issues competing for their attention, power operators are often not aware of how significant an impact optimisation through maintenance can have on their bottom line.

THE FINANCIAL RISKS OF SUBOPTIMAL OPERATIONS

According to a recent report, globally, wind farm operators spend more than $8 billion on maintenance.[28] For offshore wind projects, maintenance and servicing costs make up about 25% to 30% of the total budget.[29]

Without data-based optimisation, these costs will continue to rise. This is not sustainable and, left unchecked, will prevent the industry from scaling up. It is, however, unlikely that the whole industry will fail to come to grips with the issue.

More probably, the approach will be variable and those companies that do not optimise will find it harder and more expensive to attract the investment they need to expand, particularly as the sector moves to a subsidy-free model. Ultimately, this will prevent them from taking advantage of the opportunities offered by the energy transition, giving their competitors a business edge.

For offshore wind projects, maintenance and servicing costs make up about 25 to 30% of the total budget.[29]

A COMPETITIVE OPPORTUNITY FOR FIRST MOVERS

The continued prioritisation of other issues above the need to optimise operational and maintenance costs has created an odd industry dynamic. While power generation companies know that operational optimisation is an issue that will have a significant impact on their bottom line and long term sustainability, in many cases, these companies are not yet acting on that knowledge.

GAINING AN EDGE THROUGH A TOTAL COST OF OWNERSHIP (TCO) APPROACH

By taking a TCO approach to operations, companies can significantly reduce their running costs.[27] Looking at the full picture when purchasing or maintaining equipment and/or operations allows decisions to be made based on cost-efficient output, rather than short-sighted, up-front costs.

A study by Accenture found that operators which streamlined their operation and maintenance practices with the introduction of third-party experts, reduced their overall running costs by 30%.[30] Operators who increasingly favour a holistic approach to maintenance will therefore be well placed to gain a competitive edge over their rivals. This will help not only with the immediate bottom line but also by ensuring they are strategically placed for securing future investment.

LUBRICATION: AN UNREALISED EFFICIENCY OPPORTUNITY

Research by Shell Lubricant Solutions found that 83% of decision-makers recognised that effective equipment maintenance can generate savings and have a significant impact on the bottom line.[27] Lubrication is a key pillar of wind turbine maintenance but despite this, there appears to be a gap between intention and action, with more than one in five (21%) saying that lubrication is rarely a priority.[27] And as a result, 19% say their companies still experience regular breakdowns because of ineffective lubrication.[27]

A key reason for this appears to be a lack of training and understanding around the benefits that effective lubrication can bring to equipment, with 83% thinking maintenance staff would benefit from additional training in the theory and practice of effective lubrication.[27]

But the right knowledge and training can be invaluable. High quality lubricants and greases, when effectively managed, could help improve equipment productivity and reduce unplanned downtime. They protect the heart of the wind turbine – the gearbox – and the strong thermal stability of synthetic lubricants allows them to optimally protect equipment in the extreme temperatures faced. By minimising deposit wear and ultimately friction, wind turbines can run smoothly, contributing to extended equipment life.

The oil life of lubricants varies from product to product and can also play a big part in effective

equipment maintenance. For example, the 10-year oil life of Shell Omala S5 Wind reduces the number of oil changes for operators by 33% over a 20-year lifespan, when compared to a conventional synthetic wind turbine gear lubricant.[31] Choosing a lubricant that offers oil life benefits such as this supports a reduction in equipment downtime and the costs associated with oil change.

And then there are the environmental considerations that are increasingly taking centre stage for wind farm owners and operators. After all, behind wind turbine performance lies an ongoing need to balance increased operational output with reduced environmental impact. And lubrication can help here too: Shell has launched an extended range of carbon neutral lubricants that can benefit customers' operational and sustainability goals, thanks to Shell's global portfolio of nature-based solutions.[32]

THE POWER OF PARTNERSHIPS

Collaboration will be key to unlocking success in the wind industry. Only the combined experience and eagerness from stakeholders will be sufficient to suitably drive down the cost of ownership and levelized cost of energy in order to deliver Europe's green energy revolution.

Third-party experts can help to identify the right technical and organisational approach to challenges, while specialist OEMs, parts and consumables developers and industry bodies can provide wind turbine operators with industry-leading tools, research and expertise that it may not be cost-effective to develop in-house.

Through knowledge sharing, consultancy and close collaboration, operators can draw on this expertise to achieve: measurable efficiencies; cost-savings; and improved return on investment for their equipment, their consumables and their specialist personnel.

For example, the Industry 4.0 revolution has seen an influx of new digital technologies such as Artificial Intelligence (AI) and blockchain. However, as research commissioned by DNV shows, wind sector staff require digital skills training to capitalise on these advancements; 91% of participants regard it as critical for their organisation to invest in digital skills training, while 71% consider it important for immediate investment.[33]

Barriers exist, however, with 41% of wind industry professionals stating that their main obstacle for digitalisation is internal priorities.[33] Therefore, there is still work to do if organisations are to enjoy the short- and long-term benefits of digitalisation.

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INDUSTRY 4.0

The industry 4.0 revolution is blowing its way through the wind sector in response to the demands for lower energy costs and increased output on tight margins. Wind power, therefore, needs to present itself to the grid like a conventional power plant – using the same language, protocols and willingness to engage with cutting-edge digital solutions that can save costs and boost output.

According to DNV's Keir Harman, the wind sector must reap the digital dividend: "The wind industry was born 'digital'. Since the first, modern-day wind turbines, detailed operational data has been at the sector's disposal. Now, the sector is beginning to take advantage of its data to move from a reactive to predictive environment to anticipate faults, undertake maintenance and ensure uptime.

"Industry 4.0 technologies can have a profound impact in boosting revenues and extending the lifespan of a turbine. These cutting-edge technologies can be a means to extend asset lifetimes beyond warranty in a bid to boost revenues and save costs on expensive retrofits.

"To remain competitive and meet the demand for a lower cost of energy, wind farm owners and operators must boost investment in Industry 4.0 digital technologies to ensure operational innovation continues.

"For instance, a diagnostic maintenance strategy, including the logistical challenges of routinely transporting engineers and technicians to remote sites, can be very expensive if repeated.

"By preventing system losses and protecting system revenue against operation and maintenance costs, Industry 4.0 is enabling a risk-based, prognostic approach that will work to further optimise wind operations throughout the life of the asset."

HOW TO GET THE MOST OUT OF YOUR WIND FARM

Wind farm operators are under pressure to offer lower energy costs while balancing tight profit margins. And as the demand for energy increases, wind turbines are expected to work longer and harder to meet this demand. DNV's Keir Harman sheds light on a range of digital solutions that are having an immediate impact on the wind sector.

DIGITAL TWIN

WHAT IS IT?

A digital twin is a virtual representation that serves as the real-time digital counterpart of a physical object or process.

HOW CAN IT UNLOCK EFFICIENCIES?

Digital twin technology combines real-world turbine operating data with numerical modelling to improve understanding and enable a risk-based approach to maintenance activities. In doing so it can: reduce unplanned activities; improve health and safety; lower costs; and rectify underperformance in turbines such as blade cracks and gearbox inefficiencies.[34]

WHOLE WIND FARM CONTROL

WHAT IS IT?

A wind farm is not a series of autonomous turbines. It is a highly complex array of turbines and should be perceived as a wind power station. Whole wind farm control is one way that wind farm operators can optimise turbines to get the best of them.

HOW CAN IT UNLOCK EFFICIENCIES?

Whole wind farm control can manage wind energy loss effects and maximise the overall energy capture of your farm while ensuring a long service lifetime. It can provide a significant increase in the annual energy yield of new or existing assets, while reducing fatigue loading by 1% to 10% and boosting energy capture by 3%.[35]

PREDICTIVE ANALYTICS

WHAT IS IT?

Predictive data analytics encompasses statistical techniques from data mining, predictive modelling, and machine learning to make predictions on future events.

HOW CAN IT UNLOCK EFFICIENCIES?

Predictive data analytics can enable wind farms to: enjoy a strong competitive edge; cut their operational costs; and reduce the levelized cost of energy. In particular, predictive analytics enables wind farms to use their real-time data to predict when a part may potentially fail.[36]

LiDAR ASSISTED CONTROL

WHAT IS IT?

LiDAR, which stands for "Light Detection and Ranging", is a technique where a laser source is used to sense the incoming wind field in front of a wind turbine rotor, from up to several hundred meters ahead of it. Strategies that use LiDAR are called LiDAR-assisted control.[37]

HOW CAN IT UNLOCK EFFICIENCIES?

LiDAR-assisted control technology has the potential to decrease a wind turbine's load level by up to 20% on selected components,[38] while improving operational stability and even increasing a wind turbine's annual energy production.

CONCLUSION

This is a time of tremendous opportunity for the wind industry. Sentiment among policy makers and the public has shifted considerably, while growth opportunities are aplenty, producing an industry environment that is conducive to meaningful change.

But, along with opportunity, these changing fundamentals will bring with them competing priorities – most noticeably, a need to ensure competitiveness is achieved through sustainable growth. And to compete with other power sources, the sector must maximise efficiency, cost effectiveness and uptime, while staying true to its label as a vehicle for clean energy. Individual operators must do the same if they hope to be successful in bidding for new locations and contracts as these become available, delivering performance with lower emissions, fewer natural resources and less waste.

Maintenance is key to this quest for greater efficiency. Through the application of Industry 4.0 technologies, wind farm operators can move to a regime of data-driven, predictive and ongoing maintenance methods to improve uptime while limiting cost. Innovation, however, cannot achieve this alone.

To make effective use of new technology, the quality of lubrication will be vital in ensuring that equipment is working to maximum operational efficiency with minimal environmental impact, and is therefore a crucial element of the new maintenance regime employed by wind farm operators.

As wind power becomes a bigger player in the future energy mix in the face of tougher emissions targets, industry collaboration and knowledge sharing will be critical to its sustained success.

SHELL LUBRICANT SOLUTIONS

The term "Shell Lubricant Solutions" collectively refers to Shell Group companies engaged in the lubricants business. Shell sells a wide variety of lubricants to meet customer needs across a range of applications. These include heavy-duty transport, construction, mining, power, agriculture and general manufacturing. Shell's portfolio of lubricant brands includes Shell Rimula, Shell Argina, Shell Gadinia, Shell Corena, Shell Diala, Shell Morlina, Shell Mysella, Shell Naturelle, Shell Omala, Shell Spirax, Shell Tellus, Shell Tonna, Shell Gadus, Shell Risella X and Shell Turbo. We are active across the full lubricant supply chain. We are active across the full lubricant supply chain. We manufacture base oils in four plants; blend base oils with additives to make lubricants in 29 plants; distribute, market and sell lubricants in more than 100 countries. We also provide technical and business support to customers. We offer lubricant-related services in addition to our product range. These include: Shell LubeMatch – the market leading product on-line recommendation tool available in more than 100 countries in 26 languages, Shell LubeAdvisor - helps customers to select the right lubricant through highly trained Shell technical staff as well as online tools, and Shell LubeAnalyst - an early warning system that enables customers to monitor the condition of their equipment and lubricant, helping to save money on maintenance and avoid potential lost business through equipment failure. Shell's world-class technology works to deliver value to our customers. Innovation, product application and technical collaboration are at the heart of Shell lubricants. We have leading lubricants research centres in USA, China, Germany, and India. We invest significantly in technology and work closely with our customers to develop innovative lubricants.

We have a patent portfolio with more than 150 patent series for lubricants, base oils and greases; more than 200 scientists and lubricants engineers dedicated to lubricants research and development. Customer benefits include lower maintenance costs, longer equipment life and reduced energy consumption. These technical partnerships enable us to expand our knowledge of lubrication science and transfer cutting-edge technology from the racetrack to our commercial products. Contact us to hear more about how our products, services, and expertise can unlock improved performance and better efficiency with lower emissions, using fewer natural resources and less waste.

DNV

DNV is an independent assurance and risk management provider, operating in more than 100 countries, with the purpose of safeguarding life, property, and the environment. As a trusted voice for many of the world's most successful organizations, we help seize opportunities and tackle the risks arising from global transformations. We use our broad experience and deep expertise to advance safety and sustainable performance, set industry standards, and inspire and invent solutions.

We provide assurance to the entire energy value chain through our advisory, monitoring, verification, and certification services. As the world's leading resource of independent energy experts and technical advisors, we help industries and governments to navigate the many complex, interrelated transitions taking place globally and regionally, in the energy industry. We are committed to realizing the goals of the Paris Agreement, and support our customers to transition faster to a deeply decarbonized energy system.

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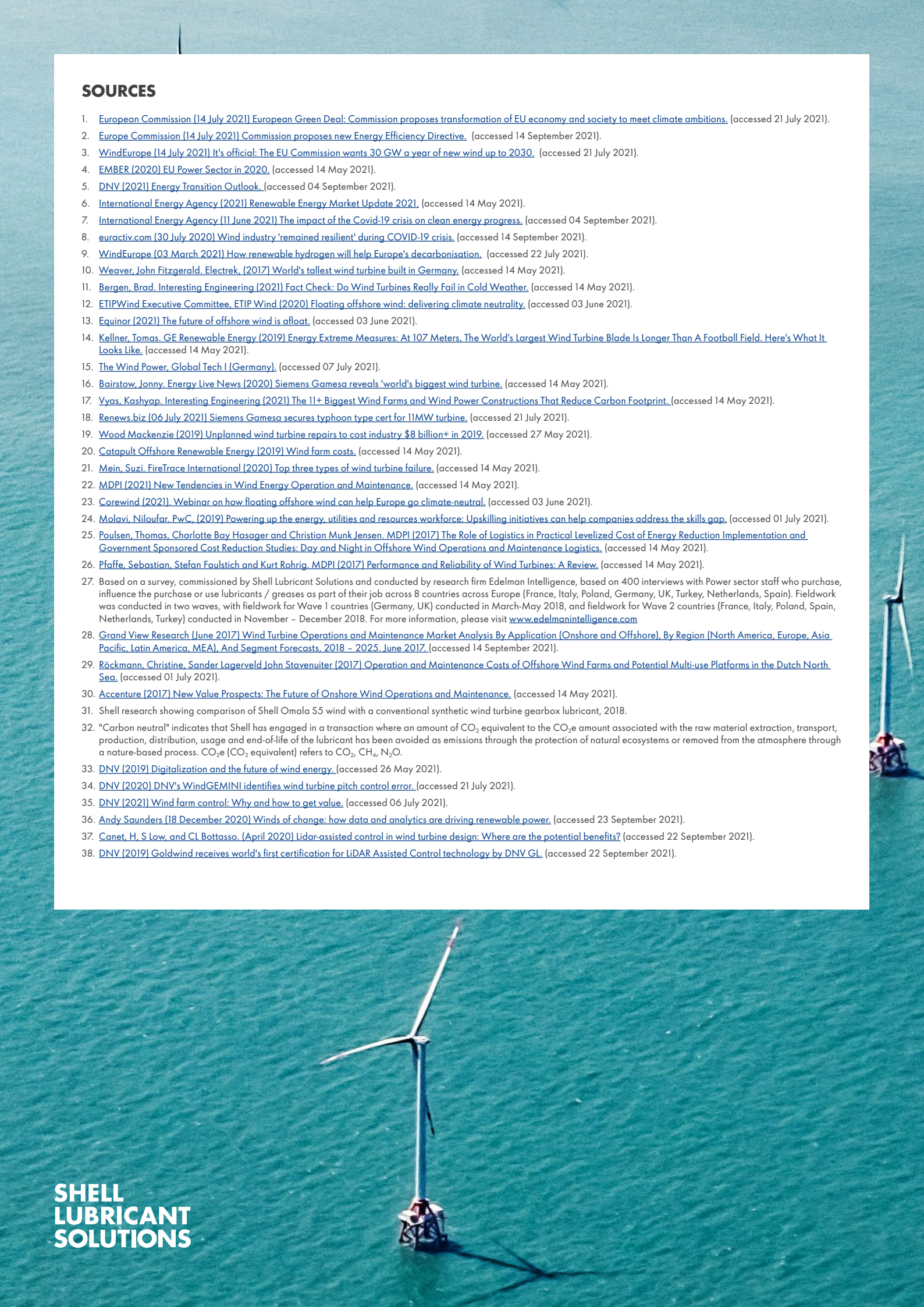

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