WIND POWER

ANNUAL RESEARCH AND INNOVATION AGENDA 2020

MEGAVIND

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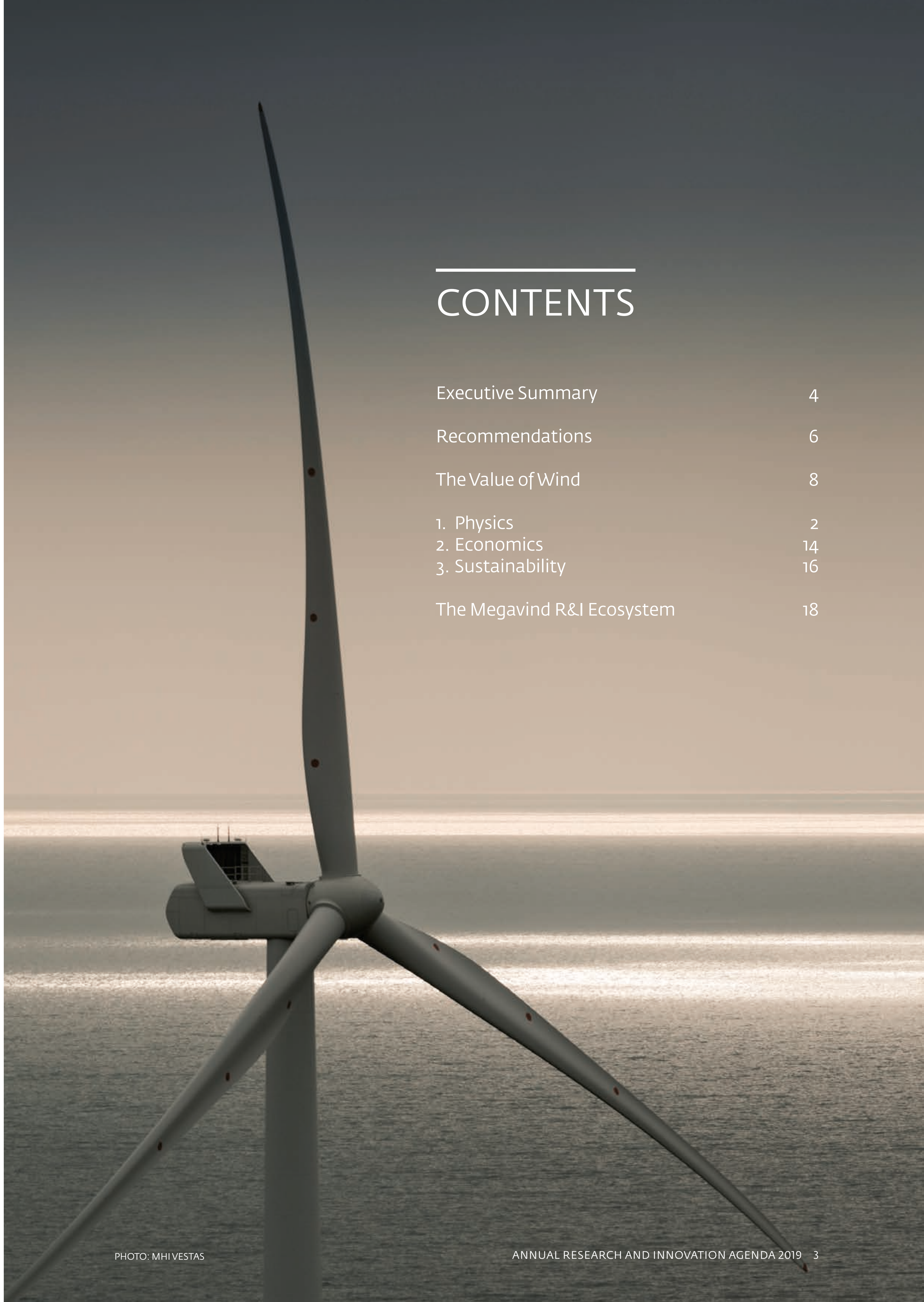

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PHOTO: MHI VESTAS

EXECUTIVE SUMMARY

Current energy research and innovation (R&I) policies are heavily focused on the development and contribution of power2x and sector coupling in driving the electrification of the energy system, and rightly so.

The wind energy sector, including Megavind, supports the efforts towards power2x and sector coupling.

However, in this fourth iteration of the Megavind Annual Research & Innovation Agenda, we look at the effects of the changing energy system on the technology and service development in wind energy.

The challenge in this year's annual agenda is this:

How can wind energy improve its bankability for society, its value on the market and increase its sustainability?

In short, we call it the *Value of Wind*. The recommendations presented here offer concrete measures to address this challenge.

The annual agenda is structured in five sections: an introduction to the value of wind, three sections addressing three areas of research and innovation affected by the changing markets and energy systems and a fifth section describing the R&I ecosystem for wind energy developed by Megavind. The three R&I areas are:

Physics – *managing uncertainty*. This section looks at how reducing uncertainty will reduce costs and improve the financing conditions for wind energy. Researching and developing new models improving the calculations of the physical operational conditions for current and future up-scaled wind farms will help to achieve this.

Economics – *capturing value in changing markets*. This section looks at how markets with a high penetration of wind power are challenging current business models and opening up new opportunities through market and technology innovation.

Sustainability – *innovating to reduce impacts throughout the wind turbine life cycle*. This section looks at how the wind power industry can take responsibility to reduce environmental impacts and CO_2 emissions throughout its supply chain and work with new partners to turn waste into new business opportunities.

Focus

The focus of this year's annual agenda is how the changing energy systems affect the technology and service development in wind energy

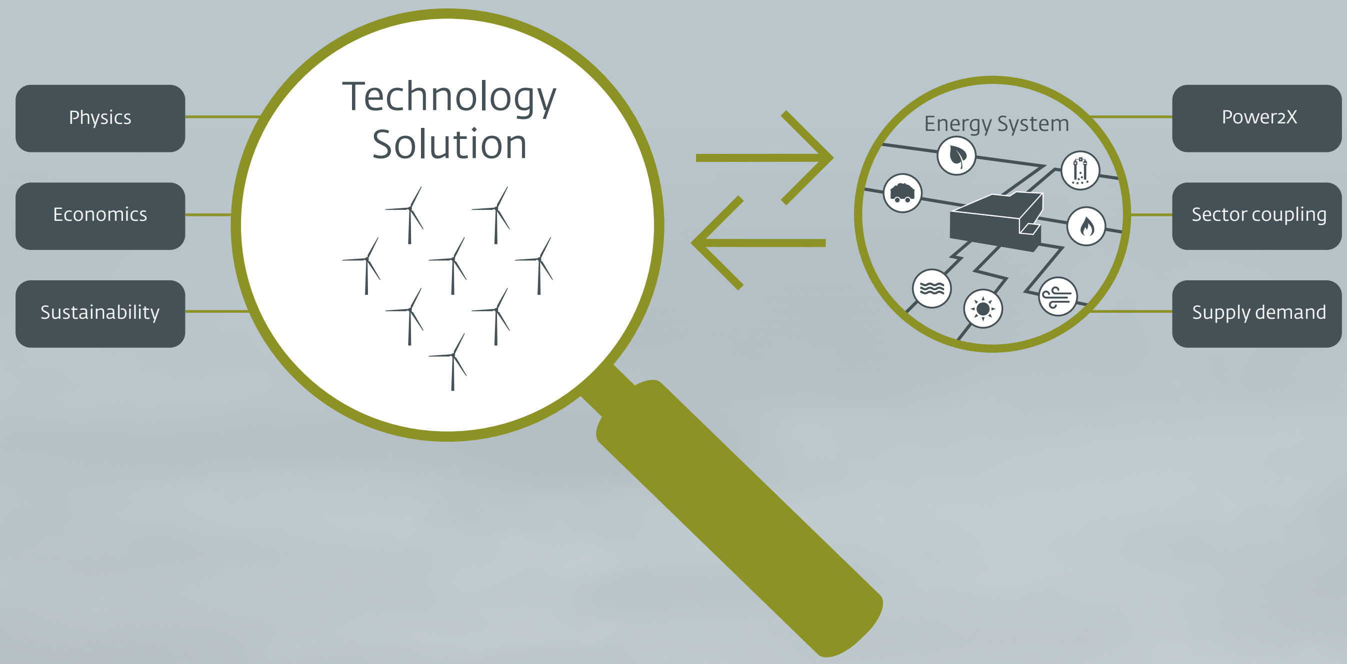


PHOTO: MHI VESTAS

RECOMMENDATIONS

– Megavind Annual Research and Innovation Agenda 2020

PHYSICS

The Danish public-private partnership in wind energy should join forces to establish next generation of up-scaled wind power systems on an improved understanding of the underlying physics [TRL 1-4]

- This means reducing financial and technical risks through basic long-term research on low TRL level enabling improved performance in upscaling of wind turbines and farms: e.g. better load-modeling advanced atmospheric flow modelling and full modeling complexes for floating offshore wind systems.

Translate better models and verification methods of physics into better technology solutions [TRL 4-8]

- Develop ways to shorten time to market for insights from new advanced models and verification methods into innovative marketable solutions including logistics and installation.

Denmark should increase collaboration towards industry standards based on recent understanding of the physics to increase competitiveness by reducing financial risks

- Research is required to translate new insights from R&D into appropriate formats for background documentation supporting new industry standards.
- The wind energy sector must take up the responsibility to accelerate the update and development of industry standards.

Improve background documentation to support standards for bankability of new technologies and system solutions

- Support for research organisations to research and bring forward back- ground material supporting the development of international standardisation.

ECONOMICS

R&D for new wind powered solutions to increase the value of wind in markets with high wind power production

- Public funding agencies should support low to medium TRL research projects adapting or developing technology solutions that target higher value of wind power production.

Push for industry standardisation and speed up efforts to optimize quality and reduce costs of more general components and systems

- CAPEX reduction is still a focus area in Megavind and industry standardization is one of the levers for this.
- Vertical and horizontal cooperation in the industry will enable a push for industry standardisation. To gain the benefits from industry standardisation (e.g. quality and cost) volume is needed for the components or systems in question.

Danish based companies should have access to special test zones to test energy management systems for 100 per cent renewably based systems

- By 2025 Denmark should have a minimum of two to three test areas to test integrated energy systems where complete or partial co-location of power or alternative energy carrier production (hybrid configurations) can be established. Such test areas should provide geographical or virtual connected hybrid and multi-energy carrier systems at different power levels as well as integration into country level energy infrastructure.

SUSTAINABILITY

R&D of circular approaches to composite materials and production methods, including barriers to recycling of waste

- Research and development of high-performance sustainable materials for wind turbine blades that are more easily recyclable.
- Development of a financial model for recycling of wind turbine blades.
- Analysis of life cycle impacts of new products made from recycled wind turbine materials.

R&D to build a supply chain to utilise waste from wind turbine components as a circular resource

- Demonstration of re-use of materials from recycled blades.
- Demonstration of industrialised recycling of wind turbine blades scalable to the coming volumes of end-of-life blades.

R&D to reduce CO_2 emissions from the use of steel in wind energy technology

- Optimised design and manufacturing of turbine and substructure steel components to reduce the amount of steel used.

R&I ECOSYSTEM

The Megavind research & innovation ecosystem

The research and innovation ecosystem developed by Megavind is guided by two strategic elements:

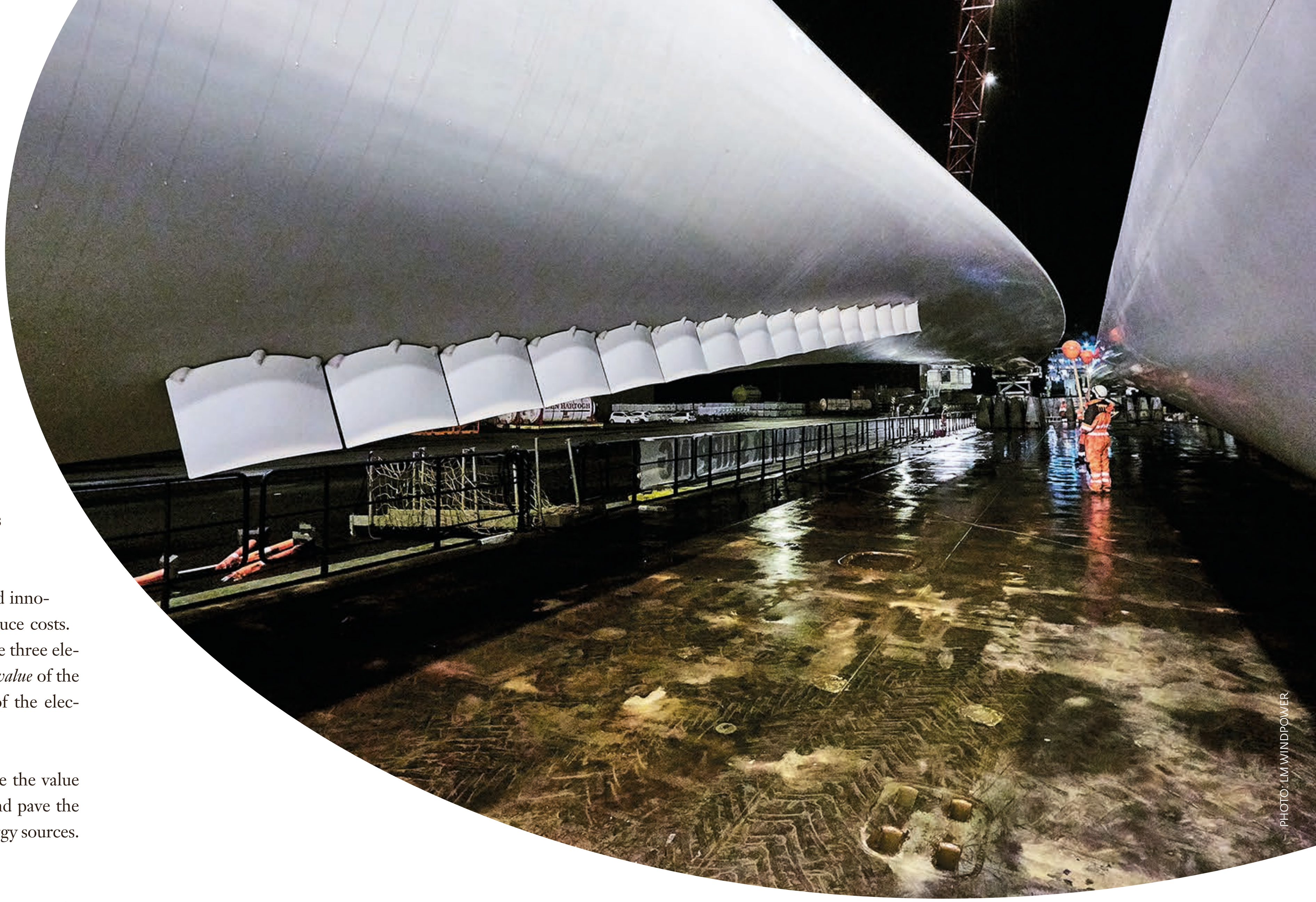
1. Six R&I themes for wind energy. These themes are based on the in-house roadmaps of the Megavind industrial members. Instead of listing a detailed range of topics, the R&I themes defines the main boundaries for relevant R&I.

2. Five innovation drivers that defines key parameters used to assess the impact of new R&I. The innovation drivers improve the assessment of the potential impact of new R&I compared to standard use of Levelised Cost of Energy.

Proposed R&I topics that falls within one of the six R&I themes and positively contributes to one or more innovation drivers are relevant for public or private investments.

PHOTO: WELCON

THE VALUE OF WIND



Wind energy will play a main role in achieving decarbonisation of the Danish economy through increased electrification as envisioned by a broad coalition of Danish political parties. Electrification requires further integration of the different sectors in the energy system. Sectors such as transportation, that currently runs primarily on fossil fuels, must convert to green electricity or green fuels produced from bioenergy or electricity.

Significant efforts are invested in developing and maturing the technologies and the physical and digital infrastructures needed to couple the different energy sectors. For example, without commercially viable power2x technologies to convert electricity into hydrogen and hydrogen into gas or liquid fuels, electrification will not happen.

Increased energy system integration does not only influence the choice of technologies enabling integration; it also influences the requirements to the renewable generation technologies such as wind energy technologies. This poses new questions for research and innovation to answer.

Cost, value and sustainability

For decades, the challenge for wind energy research and innovation was simple: reduce costs to make wind energy competitive with fossil fuels. This has now been achieved for onshore wind and for offshore wind in mature markets as witnessed by the zero-subsidy wind farm tenders in the North Sea over the past years.

Success has brought new challenges. During periods with high wind resources in markets with a significant share of wind power, the price of electricity will drop to the point where wind power is cannibalizing its own profitability. At the same time, larger wind turbines and changes in ownership of wind turbines and farms is increasing public resistance to wind energy. Combined with public concerns about the sustainability of wind turbines when they reach the end of lifetime, this calls for new solutions.

The challenge for wind energy research and innovation is therefore no longer simply to reduce costs. Today, research and innovation must balance three elements: the *cost* of generating electricity, the *value* of the electricity produced and the *sustainability* of the electricity production.

Balancing these three elements will increase the value of wind for society, citizens and industry and pave the way for a society powered by renewable energy sources.

Reducing cost

Reducing the cost of wind power is paramount to make green hydrogen from renewables competitive with hydrogen produced from oil and gas. Achieving cost reductions for wind can be done by improving our understanding of the physics governing the operation of wind farms.

Modern wind turbines are not only the largest rotating man made object on earth; they are also a complex machinery with more than a thousand embedded sensors. Put them together in an offshore wind farm and you have a sophisticated power plant constantly adapting its operation to changing impacts from the forces of wind and sea.

Advanced mathematical modeling, machine learning and smart use of the wealth of data coming from sensors are powerful tools to increase our understanding of the complex physical conditions, enabling us to optimize the design, operation and maintenance of wind farms.

Capturing value

Capturing the highest value from wind power depends on the how wind energy is integrated into the energy system in various geographical locations and markets. Different wind power technologies and services are economically attractive in different systems.

For example, although it may seem counter intuitive, onshore wind turbines designed to operate during periods with low wind speeds can be economically sound in markets with high shares of wind power since electricity prices are higher when wind production is lower. Here, the higher value of wind can offset the increased costs of having a turbine that only operates during certain periods. This requires radically new turbine designs, and in some cases also adopting new market mechanisms and policy regulations.

Sustainability

Sustainability is at the heart of wind power and major companies in the industry are committed to a sustainable development and achieving carbon neutrality. It only takes 4-6 months of operation to earn back the CO_2 emitted from manufacturing a wind turbine. More than 90% of materials from turbines are recirculated, but recirculating composite materials from wind turbine blades remains a challenge that requires research and innovation. The wind industry is working with other sectors to develop new solutions and build new value chains around the sustainable use of waste materials.

Sustainable wind power in an integrated energy system is an exciting development that affects all parts of the system. Research and innovation is needed to harness the full potential of wind power and realise the value of wind for society, citizens and industry as we move forward towards a sustainable world.

PHYSICS

– Managing uncertainty

The effect of uncertainty on cost and wind farm financing

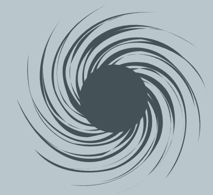
The upscaling of wind farms pushes the technology into new scales and operational conditions that current models for design, installation, operation and maintenance of wind farms cannot describe sufficiently well. This translates into increased uncertainties from the level of assessing the impact of weather systems and down to material properties at nano-scale. Uncertainties are managed by adding safety margins: thicker turbine blades, more frequent maintenance visits and lower annual energy production assessments. Safety margins add expenses. There is consequently a direct correlation between the level of uncertainty and the price of wind power.

Advanced modeling using the capacity of high performance computer systems combined with better data from wind farms and advancements in science and innovation could enable the development of high accuracy models reducing the uncertainty across the entire value chain for the benefit of companies, citizens and society.

The wind power industry continuously applies new knowledge and solutions as they are discovered and verified through research and innovation. However, translating the insights into effects on wind farm financing by investors requires solutions to be certified by trusted organisations. The wind power industry and international standards are therefore the key that unlocks the full potential.

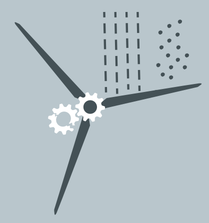
Standards are updated based on extensive procedures to verify and check that proposed solutions can be trusted to guide the design and operation of wind farms. As a consequence, there is a delay of up to 10 years from the time of new research discoveries until it can be certified according to standards. It is therefore essential that research results and operational experience are translated into the correct formats to speed up standardisation. This is a joint responsibility of the public and private sector.

Managing uncertainty



External Conditions

Uncertainty in external conditions affects safety margins of wind farms

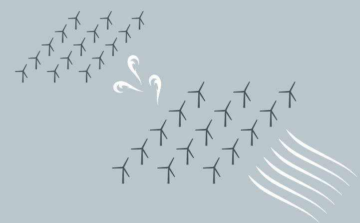


Operation & Maintenance

Wear and tear from different operational conditions affect the durability of wind farm components

Production Variability

Variable production due to operational conditions and grid requirements affect the revenue of a wind farm



Wind Farm Design

Uncertainty in wind farm yield influences the cost of financing wind farms

Recommendations

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ECONOMICS

– Capturing value in changing markets

Wind power in mature markets

Reducing the levelised cost of energy (LCOE) has been the main innovation driver for wind power research and development over the past 20 years. Lowering costs through standardisation and optimisation of the turbine and wind farm components have made wind power competitive with fossil fuels, but wind power is now starting to oversaturate mature markets. It is therefore time to find new ways of utilising wind energy in hours of high wind power production, as well as develop new business models and technology solutions to enable the delivery of wind energy in hours of lower wind power production.

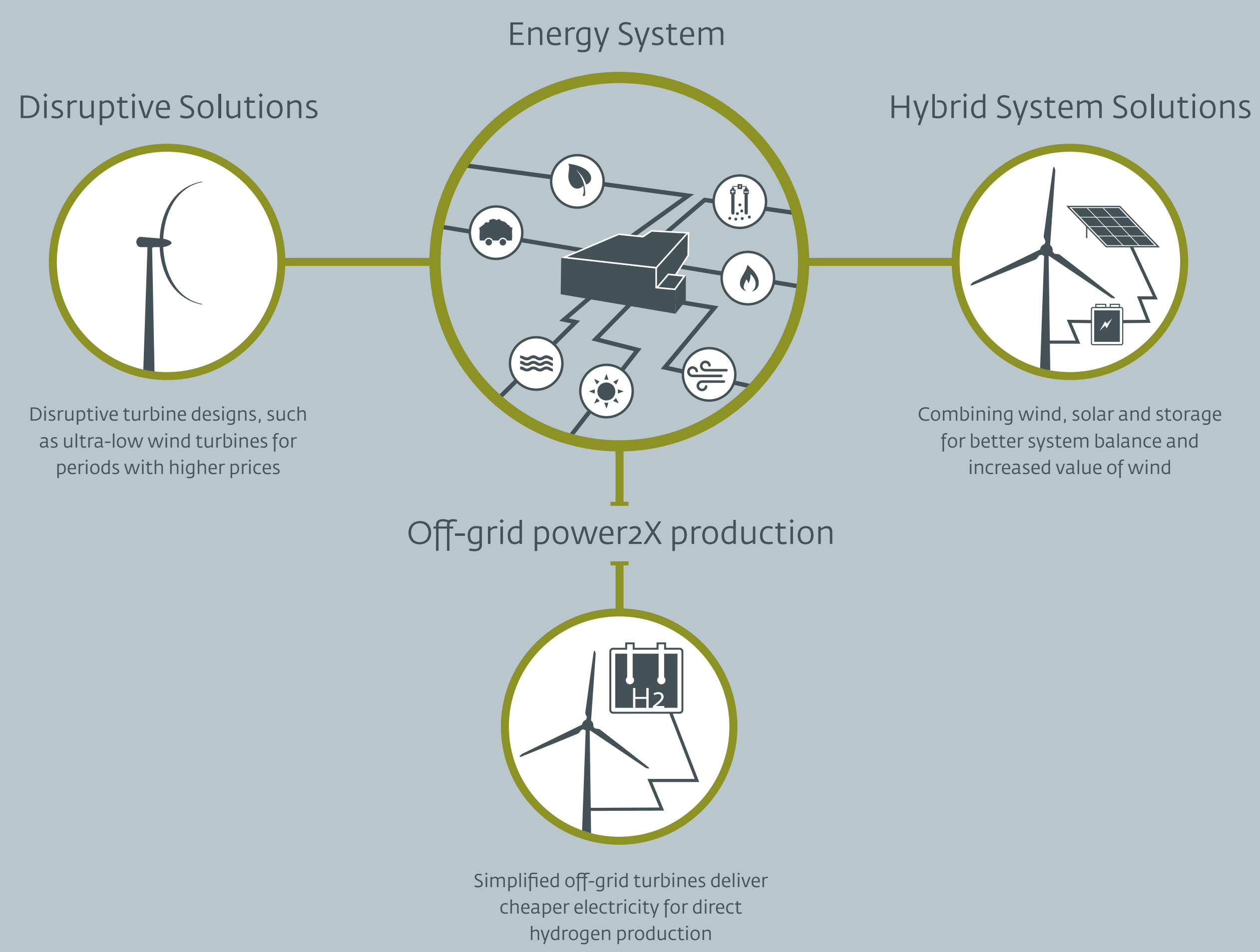
Innovation for sector coupling, business models and technology

The solution is three-fold. Firstly, increased electrification through sector coupling, including power2x and electrification of the transport and heating sector will increase and optimise the use of wind power for the benefit of society and the climate. Secondly, new business models deploying energy management and hybrid solutions will offer new opportunities to act more agilely on the market. Thirdly, academia and industry should explore new wind power technologies that target market segments where wind can capture a higher value.

Moving beyond LCOE

Companies and the research communities invest significant resources in developing superior cost and value models that describe how wind power can capture the highest price of electricity in a given energy market. In addition to levelised cost of energy, these models include environmental and social impact as well as the grid and market cost and value of wind power. Combined with R&D, new test facilities, new regulations and new partnerships this will support the development of solutions that can capture the best prices under changing economics and markets.

Capturing value in changing markets



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Push for industry standardisation and speed up efforts to optimise quality and reduce costs of more general components and systems

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SUSTAINABILITY

– Innovating to reduce impacts throughout the wind turbine life cycle

A circular value chain for wind power

Sustainability is key to the wind power industry's license to operate and companies have already set ambitious goals to reduce the environmental and social impacts throughout their supply chains. But sustainability is also an opportunity to innovate and create new business opportunities from recycling of waste. It is therefore essential to move towards a circular value chain for wind power, considering the life cycle impacts of both past and future wind turbines – from materials and design, to manufacturing, installation, operation and maintenance to decommissioning and beyond.

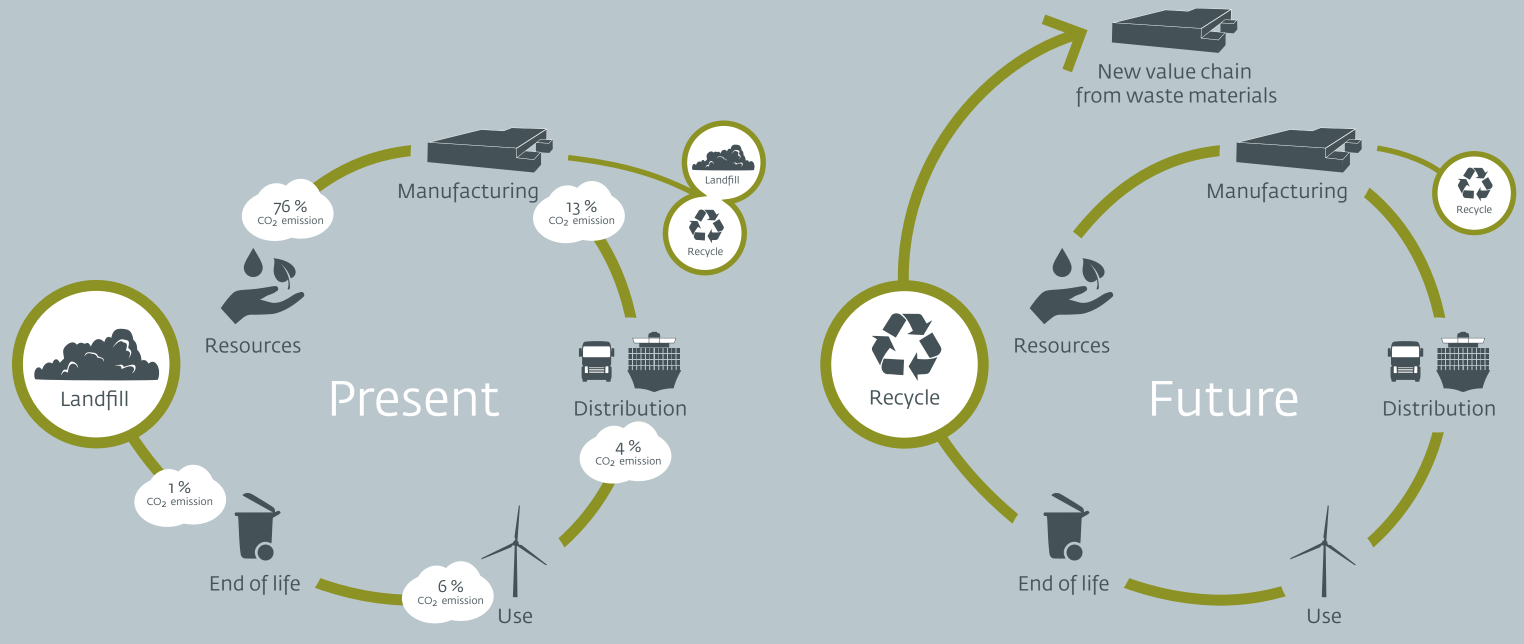
New partnerships to reduce CO_2 emissions

Moving toward a circular value chain requires building new partnerships within and beyond the wind power industry. A large portion of CO_2 emissions from the life cycle of a wind turbine occur long before the product takes shape - in the materials extraction and production stages. Research and collaboration with the wind turbine supply chain is an opportunity to develop more sustainable materials and to reduce the amount of materials that go directly to waste during the production process. Compared to the amount of materials used and CO_2 released during the materials extraction and production stages, a wind turbine at its end-of-life represents a much smaller fraction of the product's total CO_2 emissions.

From waste to value

Nevertheless, a truly circular value chain for wind power requires the wind power industry to work with waste processing companies to establish a value chain for recycled materials from wind turbine blades, as these composite structures are not yet cost-effective to recycle in most geographic areas. By accelerating development and demonstration of viable value chains for recycled composite materials from blades and other industries, the wind power industry has the opportunity to reduce the environmental footprint of its own products while also enabling other industries to replace virgin materials with recycled materials from wind turbines.

Innovation towards wind turbine blade circularity



Decommissioned wind turbine blades

66.000 tons

by 2025*

Full recycling of blade materials result in

-50 % CO_2 emissions

from wind turbine blades

Recommendations

R&D of circular approaches to composite materials and production methods, including barriers to recycling of waste

- Research and development of high-performance sustainable materials for wind turbine blades that are more easily recyclable.
- Development of a financial model for recycling of wind turbine blades.
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R&D to build a supply chain to utilise waste from wind turbine components as a circular resource

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R&D to reduce CO2 emissions from the use of steel in wind energy technology

- Optimised design and manufacturing of turbine and substructure steel components to reduce the amount of steel used.

*Accelerating Wind Turbine Blade Circularity, WindEurope 2020

THE MEGAVIND R&I ECOSYSTEM

As part of the 2018 Annual Agenda, Megavind developed its vision of a research and innovation ecosystem. The system is guided by two strategic elements:

1. Six R&I themes for wind energy. These themes are based on the in-house roadmaps of the Megavind industrial members. Instead of listing a detailed range of topics, the R&I themes define the main boundaries for relevant R&I.
2. Five innovation drivers that define key parameters used to assess the impact of new R&I. The innovation drivers are used to assess the potential impact of new R&I projects and offer a more nuanced set of metrics compared to the standard use of levelised cost of energy as a single metric.

The combination of R&I themes and innovation drivers provides a simple framework for funding agencies, industry and research organisations to assess the relevance of new R&I projects. Proposed R&I topics that fall within one of the six R&I themes and positively contribute to one or more innovation drivers are relevant for public or private investments.

Megatrends

Competitive, industrialised and global industry
Subsidy-free and technology neutral tenders
Integrated energy systems based on distributed generation sources
Digitalisation

Innovation drivers

Increase performance and efficiency
Decrease technical and financial risks
Increase the system value of wind power
Shorten the time to market
Address environmental and regulatory barriers to the market

Research, development and demonstration themes

Any research, development or demonstration project should fit in the matrix below

Research, development and demonstration themes	Onshore	Offshore	Floating
1. Wind, waves, soil and siting			
2. Wind turbine technology			
3. Foundations & substructures			
4. Electrical infrastructure & grid integration			
5. Environment & consenting			
6. Logistics & decommissioning			

An R&I project that falls within a R&I theme and scores high on one or more innovation drivers is a potenial high impact project.

Supported by human resources and test and demonstration facilities.

PHOTO: LM WINDPOWER

MEGAVIND PARTICIPANTS

wind denmark

DFFV

Liftra

Vestas

blaest BLADE TEST CENTRE

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RWE

Ørsted

ØGLÆND SYSTEM

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