Recommendations towards a climate-neutral energy system

Annual Research
& Innovation Agenda

2024

Danish Alliance
For Renewables

Megavind changes name and broadens scope

Per Hessellund Lauritsen,
Offshore Research Manager
at Siemens Gamesa Renewable Energy and Chairman
for Danish Alliance for Renewables (DAFRE)

Building on Megavind's success, Danish Alliance for Renewables will continue to deliver strategic guidance and expertise on research, development, demonstration and education for the benefit of all in the energy industry.

Research, innovation, demonstration and education lie at the heart of the development of a climate-neutral society over the next twenty years. Danish Alliance for Renewables (DAFRE) is fully committed to supporting and expanding their vital role in this development.

The Alliance builds on the experience and expertise forged by Megavind over recent decades. Our scope has broadened, so from previously concentrating primarily on wind energy we now embrace the entire renewable energy sector responsible for the green transition in Denmark, Europe and globally.

We believe that for Denmark to meet the 2030 climate goals and beyond to 2045, and avail of Denmark's leading global position, particularly in the area of renewable energy, a holistic approach stressing sectoral integration and all-encompassing energy solutions is essential.

One of DAFRE's primary tasks is to provide expert research and development advice and professional strategic guidance to policy makers to ensure optimal benefit for public research funds.

'Triple helix' at its best

The evolution of global markets requires that we in Denmark continue to focus on our strength within key technologies and the unique connections that exist between knowledge institutions, industry and authorities .

Denmark is capable of the exceptional: Coordinating strategic guidance across the industry in collabo-

ration with knowledge institutions and working closely with the authorities. 'Triple helix' at its best!

This has resulted in the world's most advanced prototype test centre for wind turbines, in Østerild, which affords the industry a unique competitive edge and enables production to remain in Denmark at a time when global competition is intensifying.

Significant levels of R&D are crucial

In this publication we present our perspective on how to create a climate-neutral society as quickly as possible. 'Capacity expansion', 'sustainability' and 'system optimization' are three key concepts.

Currently, DAFRE is expanding our network of expert partnerships, so that working closely with Green Power Denmark we can inspire the continued development of key technologies and competences.

DAFRE believes it is crucial that Denmark maintains an exceptional level of research and development funding, (at a minimum, 1% of GDP, without offsetting EU funds), so already well-functioning collaborative initiatives continue to place Denmark in a technological pole position.

We believe it is vital that Denmark can make tough decisions, including when to opt out. There are already numerous R&D funding initiatives, thus the task ahead is not to add more initiatives but to strengthen the ones that create value. Government must pave the way and ensure continued progress. There is neither the time nor money to develop multiple competing technologies concurrently: Reaching our climate goals for 2030 and 2045 is the imperative.

For the energy sector, it is important that public funding is allocated to technological development relatively close to the market. This include development- and demonstration projects at a high 'technological readiness level (TRL)' or projects that contribute to further streamlining and scaling up of existing technologies. EUDP's funding programmes are central to this end and bring added value for society, as evidenced from continuous evaluation.

'Denmark is capable of the exceptional: Coordinating strategic guidance across the industry in collaboration with knowledge institutions and working closely with the authorities.'

Danish Alliance for Renewables believes it is crucial that the Danish business support system is designed to stimulate knowledge, skills and technological development.

A positive division of labour

Competition between nations gives rise to the need for strong national systems and we should encourage the successful results achieved in Denmark to date: A positive division of labour between Innovation Fund Denmark and EUDP, that encompasses both lower and high TRL levels, ELFORSK and not least Energy Cluster Denmark, which as a cluster organization facilitates and enables a significant proportion of the innovation projects supported by Danish and European R&D funds.

The clock is ticking and we must make the right decisions in light of global megatrends and the opportunities offered by both proven and evolving technologies. We look forward to working with you.

Megatrends on the path to a gigawatt world

Wind and solar energy are established technologies, but continual research, development and demonstration are still essential to keep pace with global trends.

- Energy systems are evolving towards climate neutrality/zero carbon economy. Wind and solar energy will increasingly become system supporting technologies.
- Wind and solar projects are increasing in size and becoming industrialized – both standalone and in combination with other technologies (e.g. hydrogen/power-to-X and batteries).
- Markets and companies are globalizing. Competition will intensify.
- The state, society and companies are developing models that can share both risks and economic gains.
- Social sustainability (e.g. labour rights and community engagement) and environmental sustainability (e.g. biodiversity and nature) will gain increased focus.
- Continued geopolitical instability will result in challenges to supply chains and necessitate industrial policy initiatives.

Source: Danish Alliance for Renewables

‘All the technologies are available, but not at the necessary scale. We need to move from megawatt to gigawatt and this requires optimization of all current and coming stages’

John K. Pedersen, Pro-dean, Aalborg University

Green gigawatts require innovation at every stage

Research, development and demonstration will determine whether the Danish and European energy industry succeeds in scaling up wind and solar energy, as well as power-to-X and infrastructure for electrons and molecules.

With a planned capacity of 1 GW, the Thor offshore wind farm currently under construction in the Danish North Sea will be Denmark's largest renewable energy power plant to date.

Thor is an example of one of the building blocks essential for fostering a climate-neutral society, where heating, transport and industry will rely on a significant degree of electrification.

To reach the EU's 2030 targets for renewable energy, there is a need for the equivalent of 30 x 1 GW or even 20 x 1.5 GW offshore wind farms.

In addition to robust and rapid implementation, the green transition also requires a massive commitment to research and innovation:

"Research, development and demonstration of components and systems are an essential element of our journey towards hundreds of green GW power plants, both in Europe and globally. Innovation will enable the scaling up of green power generation technologies while reducing the infrastructural costs of transporting electrons and molecules," says Senior Executive Officer Mattias Andersson from DTU, based on conversations in Danish Alliance for Renewables.

The Alliance sees the transformation and scaling up of the combined energy system as two of the megatrends that companies must keep abreast of, to ensure hitting the EU's climate target of 55% greenhouse gas emissions reduction by 2030. Scaling up will include the development of larger renewable energy farms, but not necessarily larger turbines.

Full throttle towards 2030… and 2040

While the industry is sharply focused on reaching the 2030 target, policymakers across Europe are debating whether the 2040 target should be approximately 90% towards achieving climate neutrality by 2050.

Approaching 2030 and 2040, a growing number of electricity generating plants on energy islands in the North Sea and the Baltic, as well as onshore parks in GW size will be established, which raises questions around energy systems, infrastructures, security, and dialogue with the surroundings:

"Denmark has highly developed research competencies and cutting-edge companies working across these areas, but the Danish public research and funding authorities have been somewhat unable to support collaboration. At Danish Alliance for Renewables we want to encourage all stakeholders to participate in an open dialogue on how we can change things for the better, together," says Mattias Andersson.

Power-to-X scaling/ optimization

One challenge going forward is the pairing of very large wind and solar power plants with different types of power-to-X plants for the production of fuels for long haul shipping and aircraft, for example.

Achieving climate-neutrality in shipping and aviation through electrolysis (indirect electrification via hydrogen) requires supplying enormous amounts of green electricity to, the end users, such as Maersk and SAS.

According to Danish Alliance for Renewables, sector integration and energy-use consolidation calls for continuous innovation:

"All the technologies are available but not at the necessary scale. We have to move from megawatt to gigawatt and this requires optimization of all current and coming stages," says Pro-dean John K.

From 5 MW to 1 GW in 35 years

Vindeby Offshore Wind Farm (1991–2017) was the world's first offshore wind farm. The 11 turbines of 450 kW had a total capacity of approximately 5 MW. The Thor offshore wind farm, which will be fully operational in a few years, will consist of 72 turbines of 15 MW with a total capacity of more than 1,000 MW (1 GW).

Pedersen from Aalborg University, on the pursuit of increased energy efficiency combined with lower costs.

Power-to-X is a good example: The EU has set ambitious GW targets for electrolysis, which is an integral part of power-to-X. The European Commission's target is the production of ten million tonnes of renewable hydrogen in the EU by 2030.

The means to produce hydrogen through electrolysis have been known for over 100 years, but currently energy power plants are 'only' MW sized. In total, the EU currently has a production capacity of less than 1 GW: The target is over 100 GWs sustainable hydrogen production by 2030.

"The electrolysis plants must be optimized, scaled up and integrated into optimally functioning overall concepts. They must be stable and highly efficient," points out John K. Pedersen who advocates for turbocharged innovation of all the links in the many, complicated chains (electricity/grid, hydrogen, water, CO2, heat from waste, etc.).

'Design for X'

The Gigawatt society requires strong collaboration between industry, research institutions and national agencies in Denmark and the EU. Danish Alliance for Renewables recommends that both the industry and society continue to focus on

- ensuring a competitive European industry
- promoting system and sectoral integration
- withstanding climate change and cyber/physical attacks
- developing circularity and sustainability
- contributing to innovation of attractive financial and regulatory frameworks

By concentrating on these key areas, the energy industry can continue the transition that has been underway for several decades: 40 years ago, the Danish electricity system consisted of approximately 15 large power plants fired solely by fossil fuels. In recent years, a decentralized system primarily based on wind and solar energy production has been created: renewable technologies now feature ever-increasing system supporting properties.

'Research, development and demonstration of components and systems are an essential element of our journey towards hundreds of green GW power plants, both in Europe and globally'
Mattias Andersson,
Senior Executive Officer, DTU

"We now have both centralized and decentralized renewable energy, but we really need significantly more. The innovative solutions must be economically sustainable and rapidly implemented. All the elements involved must be seen in the round and this requires research and innovation," says Mattias Andersson.

"At DTU, for example, we work with the concept 'Design for X' for wind turbines, where we design turbines specifically to suit different markets, be it for sustainability, power-to-X or different production conditions in regional energy systems," he continues.

Wind turbine technology contains untapped potential, which can be harvested by including 'everything' in an initial comprehensive design phase. Danish Alliance for Renewables believes there is an urgent need for further development of relevant design premises and tools.

Abundant wind and solar

The EU has adopted a target where renewable energy accounts for 42.5% (and preferably 45%) of energy consumption by 2030. To achieve this goal, the construction of a substantial number of wind and solar energy power plants in the coming years is essential. Denmark has initiated two international agreements:

- The Esbjerg Declaration (four countries): 65 GW offshore wind in the North Sea by 2030 and at least 150 GW by 2050.
- The Marienborg Declaration (eight countries): 19.6 GW offshore wind in the Baltic Sea by 2030.

With the Ostend Declaration, France, Great Britain, Ireland, Norway and Luxembourg are also on board. Target: Minimum 300 GW offshore wind by 2050.


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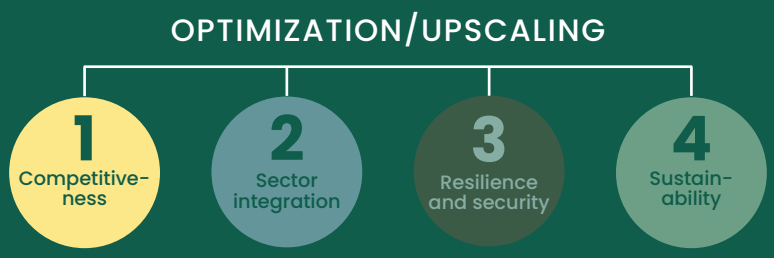


Smart and intelligent design must drive Europe's wind turbine industry

'Cheaper and bigger' has been the primary driver of wind energy development to date. To compete with Chinese manufacturers in particular, wind energy must in the future be considered in expanded system contexts – e.g. with solar energy and power-to-X.

We have to be 'smarter'. If one word sums up how Danish and European wind turbine and components manufacturers must tackle the global competitive situation, it is 'smarter'.

"The world is facing a massive expansion of wind and solar energy. Even marginal improvements of turbines and related components can have a considerable impact, so continued innovation is absolutely crucial," says Kenneth Thomsen, Head of Wind Turbine Design at DTU.

China now dominates the production of almost every solar cell-related element and is making strong inroads into wind energy. According to the Global Wind Report 2023, China is home to 60% of global blade production, 65% of generators and 75% of gearboxes.

Quality and integration

Chinese manufacturers have a protected domestic market at a volume that is difficult to match: Danish Alliance for Renewables believes the European industry must compete by continually improving product quality and integration with other energy technologies.

"We need to continue optimizing the cost of individual wind turbines and enhance the performance of wind farms. In addition, we must become better at designing wind and solar energy power plants to suit specific applications including power-to-X. By becoming more proficient in the 'integrated-design' of the various components in an energy system, we can generate a substantial competitive advantage," says Kenneth Thomsen, on the basis of discussions in the Alliance.

Being 'smarter' requires a determined commitment from the indus-

Recommendation 1. Industrial competitiveness

Research and innovation are a cornerstone of the European energy industry's global competitiveness. Components and systems, hardware and software, technology and services and competencies are all areas where close cooperation between knowledge institutions and the industry is vital.

The planned expansion coupled with increased system complexity requires *a new generation of design methods and models* to deliver superior products and services with commercialization firmly to the fore. This includes the introduction of enhanced testing and validation methods, which help reduce development time and boost quality. At the same time, there must be a continued emphasis on research and innovation throughout *the system's life cycle and a special focus on operation and maintenance.*

The European industry must deliver the lowest 'cost of ownership', not just the lowest-priced products on the market. We need to create innovative solutions to ensure superior quality on non-price criteria such as sustainability.

The industry must develop products and solutions that deliver the most competitive and value-creating difference in the green transition, both in the short and long term. Cost-competitive products and solutions, when and in what form the energy is delivered, sustainability, social responsibility, and nature/biodiversity must all be part of the package.

Source: Danish Alliance for Renewables

'The world is facing a massive expansion of wind and solar energy. Even marginal improvements of turbines and related components can have a considerable impact, so continued innovation is absolutely crucial'

Kenneth Thomsen, Head of Wind Turbine Design, DTU

try itself, firmly supported by Danish R&D programmes such as Innovation Fund Denmark and EUDP as well as EU funds e.g. from Horizon Europe. Innovation can also be encouraged by setting alternative criteria rather than merely 'the lowest possible price' when formulating tenders for offshore wind, for example. Novel products and price reductions remain important, but they must be accompanied by the development of energy production facilities with reduced risk profile, greater modulation and consistent industrialization, the Alliance believes.

Testing: Experimentation is vital

Denmark has a strong global position, with testing facilities located at some of the world's largest manufacturers and under the auspices of DTU. Part of the 'smarter' package involves developing new testing methods and models and continuing to support state-of-the-art facilities such as the National Test Centre Østerild, currently undergoing plans for expansion.

Østerild's windswept landscape is a testing bed for wind turbines of up to 15 MW. In addition to producing more kilowatt hours than their smaller counterparts, the new turbines currently being brought to market incorporate a number of novel technical solutions, including improved control systems.

"Larger turbines can give rise to unforeseen issues that we need to understand and manage. Experimentation is vital: we need to be able to model and validate products. We are constantly approaching the limit of our expertise and experience, and that's healthy and necessary," states Kenneth Thomsen, pointing out that after all it is better that something breaks during testing than during commercial operation.

"Replacing components on a 1 GW offshore wind farm is prohibitively expensive," he continues.

Competitiveness can also be enhanced through improved technical risk management expertise in relation to combined projects, whether smaller scale or 1, 1.5 or 2 GW:

"Technical risk management will be a key competitive parameter. It's vital that developers can understand, quantify and solve technical challenges. In order to strengthen this competence, we need commitment to both model development and experimental validation," says Kenneth Thomsen.

Designing to the limit

While components such as transformers, generators, gearboxes, hubs, control systems and blades are designed to perform at the utmost of their abilities, individual turbines and wind farms must also be developed to complement an increasing number of related tasks. As a system supporting technology, wind energy must provide downregulation and frequency control, as well as solar energy, storage/batteries and hydrogen production compatibility.

"Turbines will play a different role than in the past," says Kenneth Thomsen.

With 15 MW turbines placed offshore, there will be increased focus on operation and maintenance, which today accounts for approximately a third of total wind farm costs.

If the turbines can be designed so that they require less service or are easier to maintain, expenses can be cut and billions of dkk can be saved. To optimize the chosen designs, more accurate models must be developed to calculate life span and optimal operation in relation to local weather conditions, load and control.

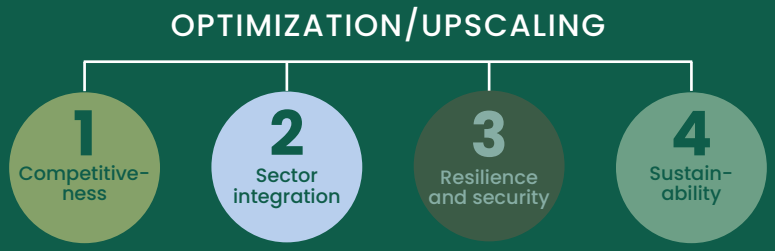
"Anything we can do to increase large-scale production and even more dedicated service will have tremendous impact and value. Here, too, we need to be much smarter," says Kenneth Thomsen.

Competition on price, time, design, sustainability, social responsibility, and environment

European industry must focus on products and solutions that deliver the most competitive and value-creating difference in the green transition, both in the short and long term, says the Danish Alliance for Renewables.

"Competitiveness is about more than just having the cheapest products or low-cost energy production solutions. It's increasingly about when, and in what form that energy is delivered," says Thomas Hjort, Director of Innovation, Offshore Wind, Vattenfall.

"Given the increasing share of renewable energy production, the requirements for future solutions will change, both in relation to traditional parameters, but also on non-price criteria such as sustainability, social responsibility and the environment," he adds.



Smart grids and renewable power generation must enrich each other

Modelling and solutions design will strengthen Denmark's new green trinity: The electricity grid, wind and solar energy production and more flexible electricity consumption will ensure an economical green transition and create competitive advantages in global markets.

By 2030, EU countries will invest €584 billion in power grid supports to assist the transition to renewable energy (RE) and alleviate rapidly increasing consumption. In Denmark, the level of investment for the distribution grid alone will total approximately DKK 50 billion by 2030. In addition, billions of kroner of investments in the transmission grid are also required.

"The power grid is the cornerstone of the green transition. To keep investments and expansion at a sustainable level, we need to learn more about future capability demands, and how to push the grid closer to the limit of what is technically possible," says Technology Director Jørgen S. Christensen from Green Power Denmark, who is now an active participant in Danish Alliance for Renewables on behalf of the grid companies.

Wind and solar provide more than 60% of Denmark's electricity annually. These two weather-dependent technologies set a preliminary coverage record on July 3 2023, when they delivered 146% of consumption. A massive expansion of renewable energy has occurred, with the electricity system maintaining a stunning delivery stability of 99.9%.

System supporting technologies

Jørgen S. Christensen points out that wind and solar energy are now system supporting technologies, and that there are ever-increasing amounts of renewable electricity on the way, as we move towards climate neutrality in Denmark and Europe. Thus, the technologies must also provide services that ensure a stable electricity system. Continued research, development, and demonstration on the interplay between renewable energy and power grids and other types of infrastructure is essential.

"We need to recognize that our high renewable energy share in Denmark is a technology competitive advantage. We have an enviable position that we can consolidate through systematic innovation. I'm convinced it will give our industry a competitive advantage in export markets," says Jørgen S. Christensen.

The increasing production from renewable energy will go to electrification of transport (batteries) as well as heating and industry (heat pumps), so that these sectors can

Recommendation 2.
Sector integration and electrification

Sector integration and increased electrification of other sectors such as transport and heating require the development of new generations of hardware and software to fully exploit their potential. This applies at both the system modelling and component level.

Solar and wind energy must be designed for power-to-X and the provision of system services. Electrolysis and power-to-X must be optimized both in relation to efficiency and dynamic effect, including heating system compatibility.

Intelligent expansion of energy infrastructure both on land and at sea is crucial, if we are to integrate gigawatts of renewable energy while keeping investments and growth at a sustainable level. This requires *the development of new technical concepts and sector-integrating legislation.*

Source: Danish Alliance for Renewables

'The power grid is the cornerstone of the green transition. To keep investments and expansion at a sustainable level, we need to learn more about future capability demands and how to push the grid closer to the limit of what is technically possible'

Jørgen S. Christensen, Technology Director, Green Power Denmark

reduce their fossil fuel dependency. Wind and solar production fluctuate in relation to weather and times of the day, and as striking a balance between production and consumption in an electricity system is important, the consumption side must also prove flexible.

"With up to 1.5 million electric cars forecast on the roads by 2030, there will be greater electricity demand, but we will also have an increased storage capacity of up to 1.5 million batteries. At the same time, there will also be power-to-X plants producing and storing hydrogen flexibly. Danish R&D must demonstrate how we can make a world of sector integration work, together," says Jørgen S. Christensen.

Exceptional electricity quality is crucial

Electrification forces coal, oil, and fossil gas out of the energy system, thus reducing the climate impact. During this transformation, it is crucial that grid providers maintain a high level of supply stability and exceptional electricity quality, as voltage quality is an important parameter for many industrial companies.

We have, so far, managed to maintain this high level of quality during the transition to increased production from wind and solar energy, which have different technical characteristics than traditional power plants, and are under pressure from ever-expanding consumption patterns fuelled by power electronics found in many contemporary products, from baby monitors to computers.

"The power system is moving from classic synchronous generators to power electronics on both sides.

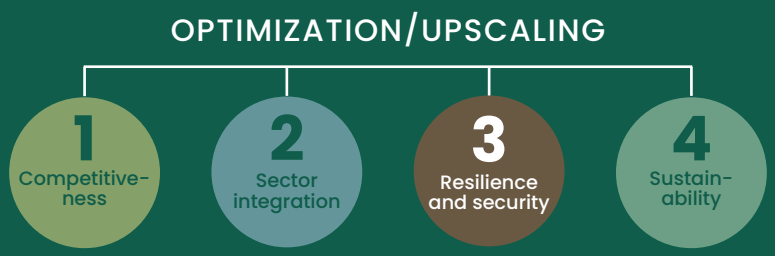
This presents challenges and opportunities, so research at both component and system level is essential," says Jørgen S. Christensen.

The balance in the weather-dependent Danish electricity system is ensured by controllable CHP plants, international connections, and flexible consumption – all tied together by the interplay between several markets. In the future, interaction with a hydrogen infrastructure will also be a strong element in the overall energy system.

The grid in brief

The Danish power grid consists of 160,000 kilometres of cables and overhead lines linked together by thousands of large and small transformer stations. The collective power grid is divided into two parts: the transmission grid, which is owned and operated by state-owned Energinet, and the distribution grid, which is owned and operated by local and regional grid companies.

The transmission grid (132/150 and 400 kV) is often described as the power grid's superhighway and transports power from production to distribution grid, and to-and-from neighbouring countries. The distribution grid (0.4- 50/60 kV) is the local grid connecting electricity consumers to the transmission grid and supplying electricity to consumers.



Wind and solar energy are system supporting technologies – and this brings responsibilities

Climate-friendly electricity must be secure energy. Innovation must improve renewable energy power plants' resilience to climate change, to (cyber)attacks from hostile powers and reduce vulnerability in challenged supply chains.

Wind and solar energy now supply more than 60% of Danish electricity consumption. In 2023, wind turbines produced 19.4 TWh and solar cells 3.4 TWh – a total of 22.8 TWh out of a consumption of 36.1 TWh. In 2023, CO2 emissions from an average kWh in a Danish socket were below 100 grams for the first time.

"Wind and solar energy are system supporting technologies, and with that comes a responsibility to safeguard critical infrastructure. The energy system must be secure; we must protect our facilities from natural and man-made events," says John Korsgaard, Executive Manager, LM Wind Power.

Increasing amounts of wind and solar energy are on the way in Denmark and the EU, with an overall renewable energy goal of 42.5% (and preferably 45%) by 2030. Germany, Poland, Netherlands, Belgium... everyone must have increased quantities of renewable electricity as part of the electrification of a Europe on its way to climate neutrality.

Security in an uncertain world

"In recent years, cyber security has become an integral part of the contractual obligations wind energy must comply with to operate in the United States. Considering the energy crisis following Russia's attack on Ukraine, these requirements have now come to Europe. We need to protect our energy system and be mindful that no chain is stronger than its weakest link," says John Korsgaard, who working under the auspices of Danish Alliance for Renewables, is helping to formulate recommendations for relevant research and development.

These include the design, testing and integration of robust technologies in relation to climate change and attacks by foreign powers and criminal organizations. Through its NIS2 directive, currently being implemented by the 27 member states, the EU is boosting its level of cybersecurity, and this will place additional demands on the energy industry.

Physical protection of energy installations

In addition, there is an increased focus on the physical protection of power plants, whether in the form of cables, transformer stations,

Recommendation 3. Resilience and security

Renewable energy has become a critical part of the energy system. This creates a responsibility to safeguard infrastructure and systems and ensure constant consumer access to stable electricity supply. Hardware and software integrity is essential.

Robust safety procedures and resilient energy systems must be capable of delivering energy when parts of the system are subject to interruptions, attacks, or other extreme natural events. This requires research and innovation in *new control and regulatory systems*.

The goal is a high degree of security, both physical and cybersecurity.

Source: Danish Alliance for Renewables

‘In a world of geopolitical tensions and trade barriers, security is also about access to raw materials and resources’
John Korsgaard, Executive Manager, LM Wind Power

offshore wind farms or other elements within the energy system.

“In a world of geopolitical tensions and trade barriers, security is also about access to raw materials and resources,” John Korsgaard points out, addressing a theme that Danish and European innovation into the robustness of supply chains may be needed in sted of sourcing rare earth elements primarily mined in China.

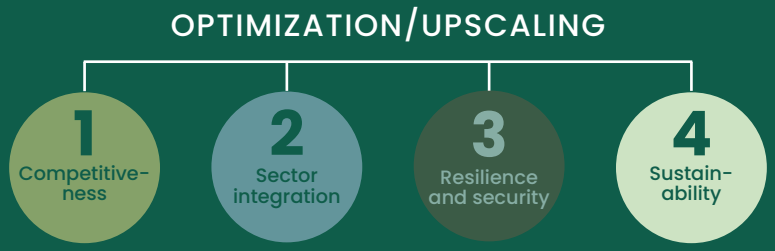
The EU aims to address these issues through its Critical Raw Materials Act, allowing for increased mining/processing, and the recycling and design of components and products on the basis of other materials.

“Substitution is about looking at life cycles and availability from material to material. Overall, we must constantly improve all facets of production, from turbine blades and other components to fully assembled wind turbines. Quality will be paramount at all stages so that we can produce electricity for 25–30 years with minimal service,” says John Korsgaard, who also stresses the importance of the interplay between the grid and the overall energy system.

Important research themes for the green transition

- How do we increase production and efficiency in renewable energy power plants?
- How do we ensure a stronger interaction between renewable energy power plants and the energy system/ the outside world?
- How do we reduce technical and financial risks?
- How do we create greater system value from wind and solar energy?
- How do we ensure a reduced interval from concept to market?
- How do we address environmental, social, and regulatory barriers?

Source: Danish Alliance for Renewables



The Green Industry's universal theme is sustainability

Wind and solar energy are system supporting technologies, and this requires commitment from all involved: Sustainability must be an integral part of existing and new production in the supply chain, and in the interaction with local communities and ecosystems regarding the location of renewable energy power plants.

In just a few years, wind and solar energy will account for the equivalent of more than 100% of Danish electricity consumption. System supporting technologies demand commitment that must be met through innovation. Providing climate-friendly electricity is itself an achievement, but it cannot stand alone.

"Sustainability must remain high on the industry's agenda. We've already made considerable headway, and regulators are also pushing the boundaries of sustainability, for example through offshore wind auctions, where other parameters than price can come into play," notes Allan Korsgaard Poulsen, Head of Materials and Sustainable Scaling, New Concepts and Power-to-X, at Vestas Wind Systems.

Creating a more precise definition of 'sustainability' is a topic Danish Alliance for Renewables recommends companies and researchers examine, together with policymakers and stakeholders.

The need for a common language

Nature is another focal point. Consideration for birds, bats, dolphins and other living creatures is similarly a topic that crops up in connection with the establishment of renewable energy power plants. There may be a threat to endangered species and thus objections become part of a larger biodiversity conversation, which like climate change is one of humanity's global challenges. Questions on CO2-footprint calculation can also arise.

"Renewable energy power plants must be established in harmony with local communities and ecosystems, but we lack a common language, standards, and sustainability measurement methods.

Life cycle analyses differ across the industry. None of these methods are inherently wrong, but they can lead to different choices of technologies," Allan Korsgaard Poulsen points out.

Recommendation 4. Circularity and sustainability

To limit the need for extraction of new materials and the associated environmental impact, increased recycling of used components and materials must be ensured. This requires the development of sustainable recycling methods for existing materials as well as the production of new circular materials that are easier to recycle.

In the wind industry, the development and demonstration of novel glass and carbon fibre materials for wind turbine blades with increased recyclability and reduced CO2 footprint is a particularly important area, as well as the development of alternatives to permanent magnets, reducing the amounts of rare earth elements.

For electrical and grid components, alternative materials for valves, conductors and transformers must be researched and produced. Lead and other critical substances must be replaced by new materials and alternatives to SF6 gas-insulated switchgear must also be developed.

A robust and sustainable energy system also requires a strong and stable supply chain with access to multiple markets and raw materials, as well as the ability to quickly scale up deliveries of raw materials.

Source: Danish Alliance for Renewables

'Sustainability must remain high on the industry's agenda. We've already made considerable progress, and regulators are also pushing the boundaries of sustainability e.g. in offshore wind auctions, where other parameters than price can come into play'

Allan Korsgaard Poulsen, Head of Materials and Sustainable Scaling, New Concepts and Power-to-X, Vestas Wind Systems

A need for more interdisciplinary cooperation

Allan Korsgaard Poulsen and Danish Alliance for Renewables invite anthropologists, biologists, and other professional groups to collaborate with engineers and other technicians on taking the next steps towards the smooth establishment of renewable energy power plants.

"We encounter slightly new and different objections to every new turbine or wind farm. Many of the challenges are difficult to gather into a comprehensive whole from case to case, but perhaps there are some similar contexts and common denominators at play," says Allan Korsgaard Poulsen, mentioning as a positive example, research's debunking of the myth of wind turbines as bird killers. Wind energy is not a threat to bird populations: Traffic, hunting, windows, and cats are to a much greater extent responsible for bird deaths.

"Research should have a strategic focus on biodiversity and moving from NIMBY to YIMBY," says Allan Korsgaard Poulsen, based on conversations in Danish Alliance for Renewables, on changing attitudes from 'Not In My Back Yard' to 'Yes In My Back Yard'.

Critical raw materials from China

Raw materials and resources are another focal point of the sustainability debate. Wind turbines consist of foundations, towers, nacelle, and blades, each containing components constructed from various materials.

Behind a turbine's construction lies a number of design choices, and sustainability is also about reducing rare materials that are often mined and refined in China. China has a de facto monopoly on some of the materials needed for the green transition.

The EU has passed a Critical Raw Materials Act to encourage less dependency by member states on imports from, among others, China. The EU countries must extract and process more raw materials themselves, just as new import agreements with specific countries can help alleviate the overall dependence. A recent agreement with Chile is one example: The European Commission establishing an office in Greenland another.

"We must also innovate our way out of our dependency by, for example, devising generators and sensors that can function with greatly reduced amounts of critical raw materials. If we can't avoid using these materials, we should at least use less," says Allan Korsgaard Poulsen, who also mentions longer turbine lifecycles and extensive recycling as another means for fostering a better material economy.

Recycling blades

Somewhere between 85% and 95% of a wind turbine can be recycled. Wind turbine blades have, however, long been a source of contention. Solutions to reduce the blades' sturdy materials into new raw materials are now available, which is necessary considering society's calls for increased sustainability.

A viable decommissioning and recycling program has been created by the project consortium Decom-Blades involving innovation and input from several leading companies.

"Given the increasing share of green production, the requirements demanded of future solutions will change, both in relation to traditional parameters but also on non-price criteria such as sustainability, social responsibility, and the environment"

Thomas Hjort, Director of Innovation, Offshore Wind, Vattenfall

Wind and solar in the fast lane

A projection shows that close to 3,700 GW of new renewable energy capacity will be connected to global energy systems from 2023-2028. Solar and wind energy will account for 95% of the expansion.

2024

In 2024, wind and solar PV together generate more electricity than hydropower.

2025

In 2025, renewables surpass coal to become the largest source of electricity generation.

2025–26

Wind and solar PV each surpass nuclear electricity generation in 2025 and 2026, respectively.

2028

In 2028, renewable energy sources account for over 42% of global electricity generation, with the share of wind and solar PV doubling to 25%.

Source: The International Energy Agency (IEA)

Visit Energiforskning.dk

Energiforskning.dk is a joint web portal for Innovation Fund Denmark, EUDP and ELFORSK. Here you can find information and links to all Danish-funded energy research, development, and demonstration projects. You can also find a number of EU-supported projects.

56 GW ↓ 2023

56 GW solar energy in 2023

As of 2023, 56 GW of solar energy has been installed across Europe, which is a new record with growth rates of over 40% for a third year in a row.

SolarPower Europe expects slightly lower growth (11%) in 2024, with a projected installation of 62 GW.

As of 2023, Germany has established 14.1 GW, Spain 8.2 GW, Italy 4.8 GW, Poland 4.6 GW, and the Netherlands 4.1 GW.

Source: European Market Outlook for Solar Power 2023-2027, SolarPower Europe.

Top 6 in Europe

Wind energy delivers an increasing share of the electricity mix in several European countries. Here's a rundown from 13 March 2024:

Denmark
57%

United Kingdom
41,7%

Ireland
37,5%

Netherlands
33,5%

Portugal
24,2%

Belgium
24,2%

Source: WindEurope

Research & Innovation 2024:
Recommendations towards
a climate-neutral energy system

Publisher:
Danish Alliance for Renewables
(April 2024)

Website:
www.dafre.dk

Editor:
Jesper Tornbjerg,
Green Power Denmark

Editorial Committee:
Mattias Andersson,
Per Hessellund Lauritsen,
and Maj Held Sallingboe-West

Photo:
Green Power Denmark, Vestas,
Siemens Gamesa, LORC,
Vattenfall, and Unsplash

Layout:
Lisbeth Neigaard, vinkdesign.dk

Edition (online)
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Danish Alliance
For Renewables