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Fraunhofer Institute
for Wind Energy Systems IWES

STRATEGY REPORT 2020–2025

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Fraunhofer Institute for Wind Energy Systems IWES
Am Seedeich 45, 27572 Bremerhaven, Germany
Phone: +49 471 14290-100
www.iwes.fraunhofer.de

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Fraunhofer-Gesellschaft
zur Förderung der angewandten Forschung e.V.
Hansastraße 27 c, 80686 München, Germany
Phone: +49 89 1205-0, Fax: +49 89 1205-7531
www.fraunhofer.de

Editorial team
Inna Eck (coordination), Lisa Bösch, Julia Kiefer

Authors
Christian Broer, Mariel Busch, Dr. Steffen Czichon, Nora Denecke, Torben Jersch, Jenny Kuball, Hans Kyling, Dr. Bernhard Lange, Dr. Benedict Preu, Prof. Andreas Reuter, Dirk Sandhop, Dr. Alexander Schenk, Dr. Bernhard Stoevesandt, Prof. Jan Wenske, Dr. Arnoldus van Wingerde

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1. INTRODUCTION AND STATUS REPORT

The last systematic strategy process at the Fraunhofer Institute for Wind Energy Systems IWES was completed in 2016 and included a development perspective for the Institute up to 2020.

On the basis of this, a follow-up process was initiated in the fall of 2019 with the aim of evaluating the results up to that point and also defining new goals and recommendations for action for the Fraunhofer IWES through to 2025. In contrast to the first strategy process, a bottom-up approach was integrated this time, i.e., all the Institute's heads of department participated in an intensive and continuous exchange process with the Institute's management and worked together to develop the results presented here. All those involved at the Institute were guided in particular by the common goal of promoting innovative strength and impact despite the COVID-19 pandemic.

- Significant changes in the dynamic wind energy sector demand, first and foremost, an analysis of the market and research landscape, which can be found in this chapter.
- The Institute's performance capacity is evaluated in the subsequent chapter.
- Based on the previous strategy report, the most important strategic goals for the next five years will then be established, followed by the thematic priorities for this time period.
- The fifth chapter comprises an evaluation of the Institute's financial situation and growth plans through to 2025.
- The sixth chapter summarizes the most important strategic action fields as so-called "stepping stones" and illustrates the goals for the coming years in a condensed format.

The Institute would like to take this opportunity to thank all those involved both internally and externally for the constructive and positive cooperation aimed at rendering the Fraunhofer IWES both future-oriented and sustainable.

Prof. Andreas Reuter
Managing Director

1.1 STATUS OF WIND ENERGY

The wind energy sector has faced increasing market internationalization right from the beginning of the last decade. This trend has gained pace most recently and will certainly continue to shape the market in the coming years. The periods of double-digit growth on the global market of ten years ago have been replaced by stagnation at a moderately high level, with deviations in terms of the relevance of individual regional markets. According to the prognoses from the Global Wind Energy Council (GWEC), no major changes in this sector are expected over the next few years.

The causes of this stagnation are manifold and, for the most part, country specific. It can often be put down to a combination of market saturation due to a lack of sites or acceptance and technical challenges such as delays with regard to the requisite grid expansion.

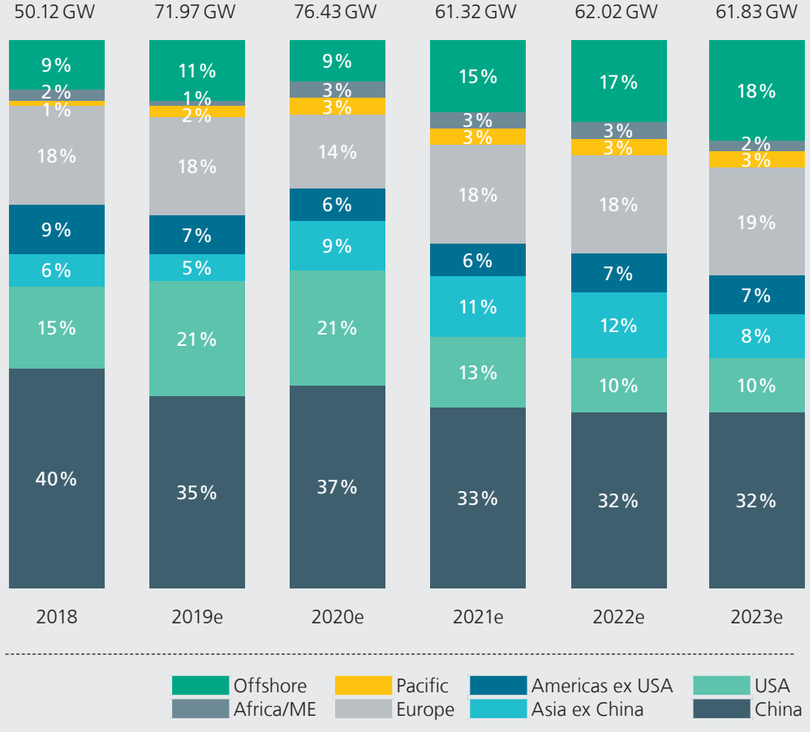
The offshore business in Europe in particular has developed into an independent market with demanding yet relatively stable boundary conditions. The prognoses here are considerably more optimistic; significant growth is anticipated up to 2030.

The challenging boundary conditions have left their mark in the form of accelerated consolidation along the entire value-added chain in this industry. The Fraunhofer IWES was especially affected by the buyout or merger of Adwen/Gamesa with Siemens and the bankruptcy of Senvion. Alongside the direct financial losses, the waning number of possible cooperation partners and, in turn, the greater reliance on the remaining players pose a problem for the Institute.

In stagnating markets, the relevance of differentiation based on technology in order to acquire additional market shares is growing. This trend is also clearly evident in the wind sector.

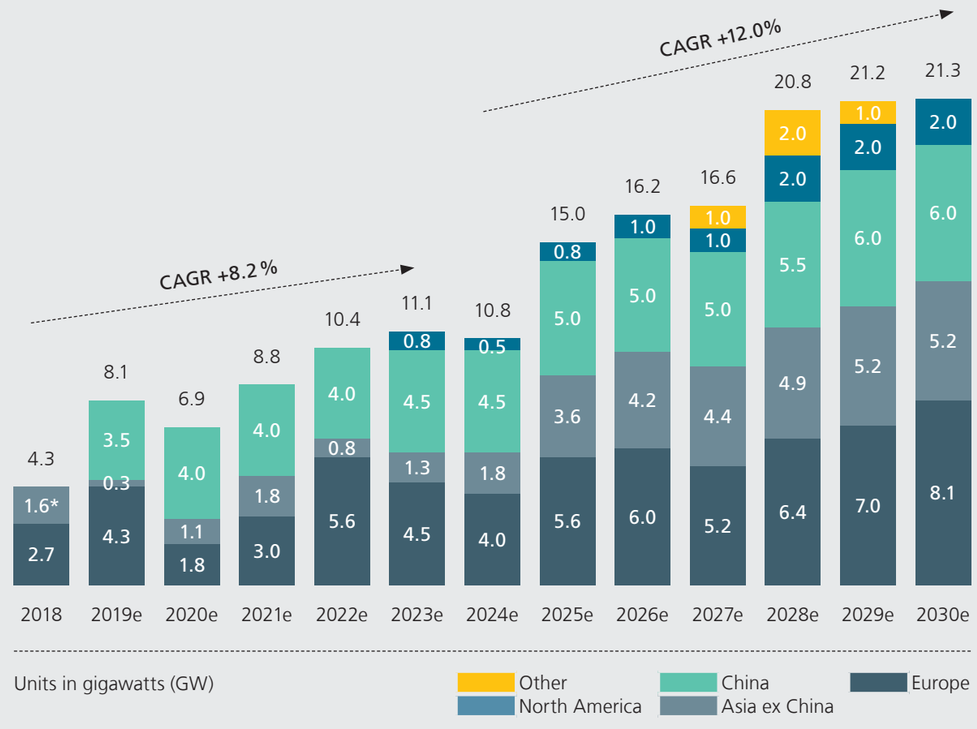
The rotor sizes and nominal ratings of turbines, particularly offshore, are increasing rapidly at present. The principle aim of all developments is to reduce power generation costs. In the interim, it has proved possible to undercut all conventional energy sources and wind energy is now engaged in a neck-and-neck race with solar power. This development is set to accelerate further in most markets given the successive switchover from the grant scheme to tendering models. However, these lower costs are unable to compensate for the limiting factors of lack of acceptance and grid problems as outlined above.

Development and prognosis of the global wind energy market 2018–2023



Source: GWEC 2019

Development and prognosis of the global offshore wind energy market 2018–2030



* Installation in China for 2018 adjusted to 1.6 GW new installations, source: CWEA
**CAGR = CAGR = Annual Growth Rate (Source: GWEC Market Intelligence)

Source: GWEC 2019

The issue of climate change was at the fore in 2019 ("Greta effect"/Fridays for future). This discussion in Germany has politicized the issue of wind energy and the previous, almost cross-party consensus as regards the future expansion of this sector is now being intensively questioned by conservative groups. Paradoxically, this essential examination of climate change has led indirectly to an almost complete collapse of the local market and has even impacted on energy research. However, at the same time, "green hydrogen" as a means of achieving the necessary decarbonization of industry and transport has enjoyed considerable funding. Even if the business applications are still not clear, this presents a new developmental opportunity for the wind sector as a whole and for the Fraunhofer IWES in particular.

1.2 TECHNOLOGICAL DEVELOPMENT

Over the past few years the wind energy sector has been characterized by a strong focus on developments in turbine efficiency and, in turn, the reduced levelized cost of energy (LCOE). Those manufacturers (OEMs) remaining on the market have faced extreme cost and competitive pressures and have increasingly developed their own research and development skills. The onshore sector in particular has seen fewer fundamental, yet more rapid development cycles based primarily on the idea of turbine platforms with a portfolio of different rotor diameters and nominal ratings in order to be able to adapt to the site. To this end, the manufacturers have remained true to their existing technical turbine concepts. For example, the rotor bearing and transmission concepts of the product lines in the 2–3 megawatt (MW) range have been adopted and their performance capacity virtually doubled using systematic technological detail optimizations. In the offshore sector, there has been a jump from the now established 6–7 MW class with rotor diameters of between 150 m and 170 m to the first turbines which are approaching the double-digit performance range of 9–10 MW. Here, too, there has not been a fundamental change in the technological concepts, but rather the focus has been on intelligent detail developments and improvements. Optimized offshore logistics and assembly processes (pallet systems, decentralized production with optimized delivery chains, feeder systems, semi-automatic individual setup steps, etc.) have played a pivotal role in the significant drop in power generation costs in recent years. In terms of the technologies used, up to now the offshore turbine class has been dominated by direct drive and monopile foundation structures. Nevertheless, there are also alternative concepts with a lower but still stable market share available.

In 2019/2020, all renowned manufacturers of onshore turbines have 5 x MW platforms with rotor diameters of between 140 m and 160 m in their portfolios or these are in the advanced field trial stage. Interestingly, this increase in performance has been achieved with virtually unchanged tower head masses, i.e., it has been possible to reduce the specific power/weight ratio effectively. Compared with earlier development phases for onshore turbines, this is a truly remarkable change. On the one hand, it underscores the greater efficiency potential of these new turbine generations and, on the other hand, the fundamentally enhanced development expertise of OEMs in terms of calculation and simulation, material utilization and operational stability, automation and control technology, which rendered the requisite improvements possible in the first place.

The dominant onshore wind turbine concept in 2020 is that of a "classic" transmission system (3-phase) with intelligent 3-point bearing and a doubly-fed asynchronous machine. In the onshore sector, direct drive technologies are assuming a more niche role. The maximum tower heights for inland sites would appear to be stagnating at 160 m due to the regulatory requirements and limitations. In the offshore sector, 10–12 MW turbines with rotor diameters of between 193 m and 212 m are poised to be launched by various manufacturers and are planned for wind farm projects in the coming two years. The direct drive technology continues to shape the market here.

According to a current trend, the remaining manufacturers are continuing to evolve from providers of wind turbines and services into expert system providers. Proven expertise in the field of system integration (grid integration) is increasingly being seen as a deciding factor on the cost-driven wind energy market. In contrast, a systematic development of knowledge is also being observed in an operator landscape which has undergone many changes in the last years. Newly aligned energy supply companies are dominating the major wind energy projects. Furthermore, in addition to classic financial and technical operational management, they aim to expand their in-house expertise in the field of turbine technology greatly, especially in the areas of site assessment, control technology, and electrical wind turbine systems. Seemingly in the classic energy sector, too, alongside the economically motivated goal, there is interest in retaining a large percentage of the added value internally over the entire service life of the turbine. As such, it can be said that the system relevance of wind energy in future electrical power supplies has finally been fully appreciated. In the Fraunhofer IWES' view, this rapidly developing equilibrium in expertise on the market is having a thoroughly positive impact on both system integration and supply security as well as serving to strengthen cross-sector approaches. This is demonstrated by the large number of corresponding projects (real labs, hydrogen strategies, e-mobility and e-fuels) in the research and commercial sector as well as intensified standardization activities in terms of grid integration and certification of the electrical properties of inverter-coupled equipment.

Looking ahead to future developments (up to 2025), the Fraunhofer IWES anticipates decelerated growth in turbine performance and rotor sizes for the onshore and offshore segments. The reliability and availability of the very high levels achieved here to date must be confirmed in series production over the coming years. Even without any fundamental technological changes or other disruptive innovations (e.g., superconduction, rotor hybrid materials, SiC for power electronics), there is potential for up to 15 MW and rotor diameters well in excess of 200 m. The official announcement from Siemens Gamesa Renewable Energy (SGRE) of their intention to launch a SG 14-222 DD (14 MW nominal power, 222 m rotor diameter) onto the market in 2024 can certainly be regarded as confirmation of this internal assessment.

From the Fraunhofer IWES' perspective, the greatest potential for further increases in efficiency and reliability lies in the medium term in the systematic use of digitalization technologies. The fields of prognosis, in-situ farm optimization, field-based service optimization, online performance evaluation, and adaptive, self-optimizing turbine and farm controls appear particularly promising.

In the offshore sector in particular, floating systems for greater water depths could mark a breakthrough as there is an ever greater need for future regenerative energy production in many coastal regions. East Asia, where many states boast shipbuilding expertise, could establish itself as a world leader from a technology and realization perspective. In the export nation of Germany, it is felt that the opportunities here are limited, since there is hardly any national research funding and barely any research projects or demonstrators in this area.

For the development of offshore wind energy in Germany, the Renewable Energy Act of 2017 (EEG 2017) and the Offshore Wind Energy Act (WindSeeG) marked a system change from the feed-in tariffs to a tendering procedure. The Federal Maritime and Hydrographic Agency of Germany (BSH) is responsible for offshore wind development and, specifically, for the spatial planning of suitable areas and their pre-examination. The results of pre-examinations are made available to the tendering participants, who use them as the basis for their bids. Comprising the determination of wind conditions and examination of the ground, the pre-examination covers two areas in which the Fraunhofer IWES is a pioneer as regards the development of innovative measurement methods.

Given the size and concentration of wind farms, shadowing effects are more relevant offshore than onshore. With large offshore farms and wind farm clusters, the interaction of the farms with the entire atmospheric boundary layer must be taken into account, as this leads to so-called cluster wake effects and blockade effects. According to the market leader, Ørsted, this has not been taken into consideration sufficiently by the wind industry to date and the energy yields have thus been overestimated.

The planned major expansion of offshore wind energy in the North and Baltic Seas demands the international networking of power connections and offshore grids to make optimal use of the energy produced. Research is currently focused on issues relating to high-voltage direct current transmission grids and energy islands, etc.

As state funding is reduced or even cut completely, the integration of the wind industry into the power markets will take on an ever more important role. In the future, the profits achieved by wind farm operators will depend largely or even exclusively on the power market. Alongside the sale of the power produced on the spot market, long-term supply contracts and the provision of system services are set to become increasingly important. This also has an impact on the operational management of wind farms, for example in terms of the operating and maintenance (O&M) concept.

1.3 RESEARCH DEVELOPMENT

Research Institutions
Further research institutions have been founded throughout Europe (ORE Catapult, SINTEF), which, together with the established players (DTU Wind, TNO/ECN, CENER), represent the Fraunhofer IWES' main competitors in terms of industrial projects and European funding. The Institute engages in regular exchanges with these players in order to coordinate research activities. However, the interests of the individual institutions are frequently shaped by specific national boundary conditions, which complicates systematic cooperation.

The European Energy Research Alliance (EERA JPWIND) represents an important platform for European research which can exert considerable influence on the contentual framework of projects within Horizon Europe. The core themes at German and European level are congruent to a great extent. One exception to this are floating wind turbines, which are only considered to be important outside of Germany.

Research efforts are also being expanded upon outside of Europe in the USA and China. These countries mainly serve local markets, but do so at a high technological level.

In Germany, the RWTH Aachen University with the Center for Wind Power Drives (CWD) remains one of the Fraunhofer IWES' main competitors, but its limited testing bench sizes are unable to accommodate the dynamic growth in the size of wind turbines and the testing options are currently more restricted than at the Fraunhofer IWES.

Industrial Research
As the OEMs continue to consolidate, the research and development capacity of the remaining large companies is growing considerably (e.g., development costs of one billion euros for a new offshore wind turbine type at GE Wind Energy). Significant efforts to develop systematic expertise internally are also evident among wind farm developers and operators.

Since the major players in the wind industry are now operating globally, it can be assumed that they will only be interested in engaging in research cooperations with internationally leading research institutions in the medium term.

Other University Research
Interest in dedicated wind energy research is generally in decline at German universities as, for example, the focus topic "Excellence" attaches less importance to application-oriented topics. The increasing maturity of the technologies is shifting the research topics to more fundamental issues in materials science, electrical engineering, and IT. There, they represent only one of many possible fields of application – and are therefore less visible.

There has also been a drop in the number of students pursuing degrees focusing on wind energy in Germany (University of Hanover, University of Oldenburg, etc.), whereas the corresponding range of degrees offered in other European countries (Denmark, United Kingdom) as well as in the USA and Asia has grown.

2. SITUATIONAL ASSESSMENT

This section briefly outlines the positioning of the Fraunhofer IWES, taking both internal and external assessments into account. This is then taken as the basis for describing the Institute's action fields and goals for the next five years in the subsequent chapters.

2.1 TECHNICAL STATUS

The Fraunhofer IWES unites wind energy system technologies on all scales – from nanometers (material development) to kilometers (site investigations and wind field simulations) – under a single roof.

Thanks to comprehensive investment in the testing infrastructure and targeted academic further development, the Institute has been able to secure itself a leading position in a series of research fields since its foundation.

Lifespan | Fatigue | Accelerated Testing
The Fraunhofer IWES works intensively in the fields of large bearing testing, large-scale components of the drive train, and supporting structures in order to optimize testing strategies and infrastructures. The combination of various specializations (tribology, control technology, automation technology, mechanical engineering, civil engineering), has allowed the design and realization of highly complex and unique test systems which are able to simulate a complete service life of more than 20 years in just a few months with realistic damage effects.

System Testing | System Expertise
Today, with the Dynamic Nacelle Testing Laboratory (DyNaLab), the Fraunhofer IWES is a global leader with an impressive track record when it comes to the mechanical and electrical system testing of wind turbine nacelles. A broad spectrum of different test scenarios has been realized both for customer orders and in a range of research projects, impressively demonstrating the flexibility and capacity of the testing infrastructure.

Simulation | Validation of Production Chains
When it comes to rotor blades, the Fraunhofer IWES is able to simulate the entire production chain involved in the manufacture of a blade: from the production steps on a laboratory scale through to the final product (BladeFactory). This also includes the accompanying validation tests – from material-science tests on fiber composite materials through combined rain erosion/ice build-up tests to biaxial complete blade testing with elliptical stimulation. The Fraunhofer IWES' expertise in production and testing technology results in intensive synergies which can be utilized for the mutual optimization of processes and technologies.

Wind Farm Development
As regards wind farm development, the Fraunhofer IWES focuses on those areas where research and development are able to make relevant progress for the industry. The partners and customers are essentially the planners and operators of offshore wind farms as well as their service providers and suppliers.

The Institute has developed a wind LiDAR buoy to measure the wind conditions at potential offshore sites: a robust measurement system for flexible determination of offshore wind conditions at heights of up to 300 m. To date, the Fraunhofer IWES has built seven buoys, and these are now in use around the world. Furthermore, the buoy is produced under license by the company Titan in China for the Chinese market.

A 3D offshore site investigation technique based on multi-channel seismology, the only one of its kind in the world, was developed in collaboration with the University of Bremen for the investigation of sites for offshore wind farms. It is used by various farm developers and the BSH to create soil profiles and detect boulders.

One of the Fraunhofer IWES' main focuses is the simulation of offshore wind conditions and, indeed, it has assumed a leading international position in this field. It is the only institute to boast comprehensive expertise in determining wind conditions in and around offshore wind farms based on various size scales. This makes it possible to analyze in detail wake effects within wind farms and on a larger scale and describe turbulence properties.

2.2 SWOT ANALYSIS

The SWOT analysis considers the strengths and weaknesses as well as the relevance of trends and prognoses. SWOT stands for: Strengths, Weaknesses, Opportunities, and Threats. The following analysis applies to the entire Institute, taking account of all internal and external services, and thus does not go into the details of the individual technology areas or market segments. The strategic goals, measures, and action fields derived from this SWOT analysis are dealt with in detail in the subsequent chapters.

Strengths

- Established as a sector expert right along the value-added chain
- Core issues established on stable pillars, well diversified over a range of selected topics
- The Fraunhofer IWES functions as an innovation engine thanks to its practical experience and methodological expertise
- Sound financial situation and infrastructure
- Attractive employer: long-term staff loyalty, good cooperation opportunities
- Decentralized structure at attractive sites
- The Fraunhofer IWES: "we" are a team
- Attracting of cross-sector orders based on interdepartmental, interdisciplinary cooperation
- New topics can be implemented effectively and quickly in-house

Weaknesses

- Dependency on public funding from the Federal Ministry for Economic Affairs and Energy (BMWi)
- Lots of young employees with limited industrial experience
- Inefficient administration processes (procurement, IT, customer-relevant interfaces such as contracts)
- High surcharges make the Fraunhofer IWES' services expensive
- Industry orders are essentially focused on test bench services
- In the case of the key test benches, it is not possible to compensate for the loss of major orders

Opportunities

- The offshore market boasts considerable technological development potential and offers a stable market environment in Europe
- Use of committee work to position the Fraunhofer IWES as a pioneer
- New customer group: potential from serving operators' needs
- Development of scalable products
- Positive funding conditions on the part of the BMWi
- Greater exploitation of internal programs within the framework of the Fraunhofer group/alliance

Risks

- The difficult market environment is resulting in consolidation by manufacturers and, in turn, a decline in the number of new product evelopments
- Increasing political polarization resulting from the energy transition
- Major increase in international competition in terms of R&D
- Increase in industrial in-house research
- Globalization of customers and competition
- There is no domestic market for the future issue of floating

3. STRATEGIC GOALS – ACTION FIELDS AND MEASURES

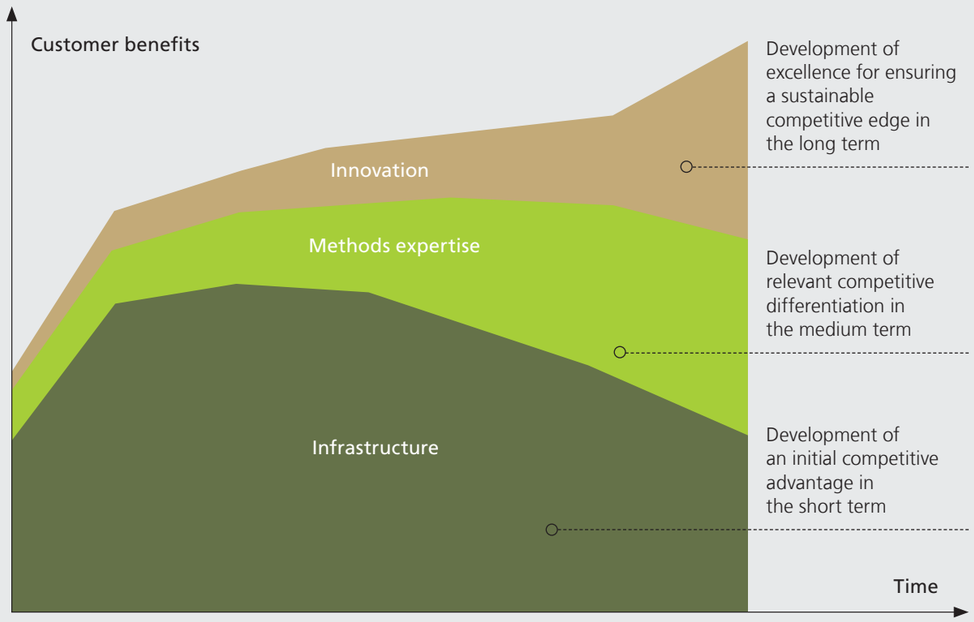
This chapter firstly outlines the strategic starting point for further observations and is followed by a summary of the challenges to be faced over the coming years as seen by the Institute's management. This chapter is rounded off by a description of the current action fields through to 2025.

3.1 REFERENCE TO 2015 STRATEGY

The strategic process upon which this report is based is a review, realignment, and continuation of the activities commenced in 2015 and 2016. Back then, the fundamental orientation of the Fraunhofer IWES was defined for the first time and the results were evaluated within the scope of a review by external experts and found to be good. The key results of the last report are summarized in brief below.

Development of Methods Expertise
As a still relatively young institute in a demanding and dynamic sector, a realistic scenario for presenting qualified customer benefits had to be defined. Over the course of discussions, the issue of methods expertise based on the competitive infrastructure already in existence to some extent emerged as a means of ensuring success. The continuous improvement of the staff's specialist skills became the focus of the development perspective. Building upon this, innovative concepts were to be derived in a subsequent phase.

Concept for developing the methods expertise based on infrastructure



Focus on Validation
The Fraunhofer IWES' contentual orientation should focus on the issue of risk minimization and the securing of innovative wind energy technology while taking realistic growth scenarios into account. This was summarized by the term "Focus on Validation", with technologies from the field of project development and the supplier industry also being explicitly included.

Focus on Industry Relevance / Rho-Wi 50+
Another major central aspect of the last strategy process was the clear commitment to prioritizing industry-relevant activities, with academic excellence being not classed as contradictory to but rather in support of this. This goal was brought within reach by specifying a relevant goal for industrial income: at least half of the operating budget should come from direct industrial income ("Rho-Wi* 50+").

3.2 FRAUNHOFER IWES 2025 – STRATEGIC PERSPECTIVE OF THE INSTITUTE'S MANAGEMENT

The Fraunhofer IWES can look back on five very successful years even though not all the strategic goals were achieved. The methods employed to date therefore need to be tested so as to realign and tailor processes in order to accommodate the latest developments. The key questions and current challenges are outlined below:

Positioning of the Institute in Dynamic Times
The wind energy industry is (once again) undergoing a very clear process of transformation. It is currently impossible to say how the various players will be positioned in the long term, nor can it be stated with any certainty what future business models will look like against the backdrop of the energy transition. Nevertheless, the Fraunhofer IWES must be able to make strategic investment decisions in order to position itself competitively in the wind energy research sector over longer implementation periods (up to 2025). To this end, decisions are made on the basis of joint estimates, these will be regularly reviewed using verifiable criteria, and, if necessary, corrected.

Continuation of Successful Concepts for Cooperation in the Wind Sector
The accelerated consolidation of the industry is increasingly impacting upon players from all areas of the value-added chain, i.e., in addition to wind turbine manufacturers also project developers, operators, and suppliers. The Fraunhofer IWES' task is to embrace this development and to intensify cooperation with the likely winners of this consolidation process.

Risk Minimization with Respect to the Institute's Public Financing
It has not yet been possible to minimize the risk identified back in 2015 resulting from dependency on the Federal Ministry for Economic Affairs and Energy (BMWi) as the authority which awards almost 95% of all public funds – largely due the good success rate when applying for funds from this source. The intensified political discussion on issues relating to the energy transition and initial budget problems in the BMWi mean that this problem is back on the agenda once again. For the period up to 2025, further growth must go hand in hand with a diversification of the origin of public funds and the largest possible increase in revenue from industry above the current level. This means a two-fold increase in revenue from industry from €10 million at present to €20 million by 2025.

* Rho-Wi refers to the percentage of the operating budget made up by industrial income.

Growth Phases of the Institute Transition from a Start-Up to an Established and Networked Institute
The Fraunhofer IWES can already look back on more than ten years of history, with the first years being characterized in particular by the development of the infrastructure and positioning in the national and international research landscape. In the pending phase, there will be a stronger focus on issues such as professionalization and the optimization of workflows. Further networking within the Fraunhofer-Gesellschaft and exploitation of the resulting opportunities will also become increasingly important.

Further Internationalization and Covering of the Value-Added Chain vs. Focusing and Excellence
On the one hand, greater efforts must be made in the highly dynamic and complex wind energy sector to minimize the economic risk faced by the Fraunhofer IWES. It could prove expedient here to expand the range of research services offered for additional parts of the value-added chain or to intensify internationalization. On the other hand, in order to maintain the existing customer relationships, efforts must be continuously invested in ensuring the excellence of the offerings, something which is only possible by means of further focusing. Sustainable paths for developing the Institute must be identified between these conflicting requirements.

Some solutions to these challenges are presented below. These are the result of a structured strategy process, which was driven in essence by the Institute's entire management team.

Photo left:
Prof.Dr.-Ing. Jan Wenske,
Deputy Director, Technical Director

Photo right:
Prof. Dr.-Ing. Andreas Reuter,
Managing Director

3.3 FURTHER DEVELOPMENT OF METHODS EXPERTISE

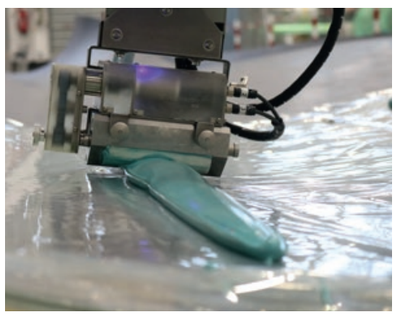
An increasing trend towards consolidation is evident within the wind energy industry. This, in turn, means the competitive situation for the Fraunhofer IWES as a provider of research and development services is intensified: on the one hand, the number of possible customers for research services is falling and, on the other hand, given their growing size, more and more companies are carrying out their own R&D work in-house and are only cooperating with the leading research facilities in their fields. The Institute will position itself among these facilities both nationally and internationally to secure and build on markets shares in the long term.

The following measures are necessary for this: initially, the Fraunhofer IWES will identify and define the fields in which it aims to expand its expertise and experience over the coming years, establishing itself as a leading international expert. This requires an ongoing focus on the activities under the motto "Focus on Validation" together with an expansion of the culture of cooperation at the Institute so as to make optimal use of the resources available. The envisaged fields are:

- Testing & validation,
- Digitalization,
- Measurement methodology,
- Life cycle and
- Sector coupling focusing on hydrogen.

The Fraunhofer IWES is developing these issues through the development of knowledge carriers in interdisciplinary project teams with the aim of promoting the exchange of knowledge and exploiting synergies. The focus remains on the continuous further development of staff and the recruitment of additional personnel with suitable professional experience. Nevertheless, the use of internal resources to ensure the targeted growth of expertise and international networking with external specialists are still important.

The Fraunhofer IWES communicates these skills in the relevant fields through tailored Public Relations activities such as participation in selected academic conferences with a high range and excellent signal effect, strategic public relations work with a new focus on the important channels (press releases, website, blogs, etc.), and active involvement in relevant industrial and academic international committees.



3.4 FOCUS ON WIND FARM OPERATORS

The Fraunhofer IWES would like to appeal more to the operators of wind farms as potential customers. Based on the existing expertise and infrastructure, the Institute is determining the research requirements of this market segment, expanding its service portfolio, and developing innovative and customized solutions for this group of customers.

Motivation

Against the backdrop of the wind industry landscape, wind farm operators are growing in importance as partners for the Fraunhofer IWES. While technical design and realization of wind farm projects were originally carried out by a large number of subcontractors, wind farm operators are now more likely to coordinate and manage all the technical aspects of the upstream sector. This applies in particular to operators of large offshore wind farms, who, in addition to a high level of technical knowledge, also offer major research and development programs aimed at exploring and optimizing new technologies. Cooperation with operators is a logical step for both parties. Adaptation and expansion of the Fraunhofer IWES portfolio is thus not only expedient but, in fact, imperative.

Action Fields and Measures

In order to be considered by wind farm operators as the preferred research partner, the research portfolio needs to be continuously aligned to the needs of these operators, starting with the existing knowledge base and current services. This strategy comprises both a strategic and thorough analysis of needs, a portfolio analysis based on this, and a continuous process to adapt services.

Acquisition and public relations work should concentrate more closely on those areas which facilitate direct contact with wind farm operators. In this way, contracts and research jobs can be acquired successively and long-term partnerships established.

Specific Measures

- To enable the technical challenges faced by wind farm operators to be clearly identified and to establish initial contact, the Fraunhofer IWES is to be introduced to identified key wind farm operators, e.g., Equinor, Shell, Innogy, Vattenfall, and Ørsted, by a delegation. This could also provide important feedback on the strengths and weaknesses of the performance portfolio.

- Equally, the dialog with wind farm operator committees needs to be actively sought, e.g., with the Bundesverband der Windparkbetreiber Offshore e.V. for German offshore operators (BWO), the Bundesverband Windenergie e. V. (BWE) for onshore operators, and the Offshore Wind Accelerator for British offshore operators.

- An appropriate means of presentation must firstly be identified so as to visualize the Fraunhofer IWES' portfolio simply and intuitively (e.g., the presentation of services based on the life cycle of the wind farm – planning, operation, and decommissioning).

- All heads of department are regularly informed about subject areas via an internal exchange and are thus able to function as Institute-wide disseminators vis-à-vis wind farm operators. An acquisition plan is being developed jointly which includes all departments and activities; this will be regularly reviewed to ensure it is still effective and adapted if necessary.

- Further operators are to be invited to join the Fraunhofer IWES' advisory board. This strengthens the ties with operators and enables regular feedback to be given on the Institute's portfolio.

3.5 DIVERSIFICATION OF PUBLIC FUNDING

The Institute's financing remains greatly dependent on funding from the BMWi within the scope of the energy research program. Funding from the BMWi made up 56% of the total budget in 2019. The Institute therefore depends heavily on a financial source which, itself, is influenced by political decisions. Given that the potential amount of industrial income is limited for a research institute, future risk minimization efforts should concentrate on the diversification of public funding and take greater account of internal Fraunhofer programs. The following points have been identified as key obstacles here:

- Concentration of application-oriented wind energy research is politically endorsed by the BMWi.
- As the home to the headquarters, the state of Bremen has access to very limited resources.
- The subjects worked on at the Fraunhofer IWES are only adaptable to a very limited extent outside of the BMWi.
- The Fraunhofer IWES business model as an industry institute has only few points of reference with other Fraunhofer institutes, which impedes the cooperation required for internal programs.

Action Fields and Measures
Since the Fraunhofer IWES is unable to influence the political boundary conditions, the content-related challenges faced by the Institute must be dealt with primarily.

Specific First Steps

- Identification of more basic research-oriented fields which promise industrial marketability and, for example, which match the typical funding lines of the Federal Ministry of Education and Research (BMBF) (e.g., material development focusing on operational stability).
- The development of issues which facilitate support from other federal ministries, e.g., the issue of hydrogen, which is supported by the Federal Ministry of Transport and Digital Infrastructure (BMVI).
- Development of new topics which offer enhanced potential for cooperation within Fraunhofer, e.g., hydrogen and the circular economy.
- Strengthened and with other Fraunhofer institutes agreed personnel recruitment for network formation and to align the various working cultures.
- Further development of activities in Hamburg in order to exploit the funding opportunities there.

3.6 STRENGTHENING OF THE CULTURE OF COOPERATION

The Fraunhofer IWES is shaped by a trust-based culture of cooperation which promotes collaboration across departments and sites. The Institute has a total of nine sites in three federal states. Specialists from ten interdisciplinary departments work together with colleagues from internal service departments on scientific and economic success. An Institute culture which promotes strong internal and overarching cooperation has a central role to play here. The Fraunhofer IWES regards open and direct communication, tolerance, a transparent error culture, and joint goal attainment as the basis for an Institute-wide cooperation culture.

Various mechanisms are required in everyday working life in order to realize this goal:

- Time and space must be provided to agree upon and coordinate content. This not only includes regular subject-specific networking among managers, but also exchange at specialist level. For this reason, subject-related workshops and the expansion of digital platforms are to be encouraged to allow staff at the various sites to engage in exchange.
- The Institute prefers project ideas which involve at least two departments in the draft phase.
- In order to help staff identify ideas and to channel creative ideas, managers should clearly prioritize cross-specialization subjects and ideas which are of strategic importance to the Institute. This automatically enhances exchange at an operational level.
- Values and the Institute culture must be embraced by management.
- The intradepartmental drafting of codes of conduct and rules for cooperation can help to manage conflicts and failures, improve general communication between staff members, and also facilitate more conscious interaction.
- The Fraunhofer IWES regards mistakes as an opportunity to grow and improve, which is why it fosters a transparent error culture and the sharing of experiences.

In light of the internationalization of the wind energy and labor market, language training of current and future employees forms an imperative platform for the use of these mechanisms. Greater investment in staff bilingualism is planned.

3.7 IMPROVED POSITIONING ON THE LABOR MARKET

Since the start of 2017, the Fraunhofer IWES has invested efforts into its positioning as an employer within the scope of its strategy process. This involved implementation of an Institute-wide process aimed at developing the employer identify and an Institute-specific "employer brand". This includes, among other things, modernization of the recruitment process, optimization of the career website, and implementation of a professional onboarding process.

The success and growth curve of the Fraunhofer IWES is flanked by the challenge of remaining attractive to the right personnel. In addition, the Institute is also becoming more interdisciplinary in its structure and, as such, the spectrum of specialist skills required by new staff is growing. Alongside the classic fields of machine engineering, physics, and wind energy technology, electrical engineering, IT, geotechnics, or chemical engineering are also gaining ground.

The transition from an employer to an applicant market, together with the changing wind energy situation in Germany, requires the Institute to further optimize its personnel marketing and recruiting activities, but also to ensure an external communication consistent with internal processes and content, e.g. positive attributes which are also lived throughout the Institute.

Strategic Recruitment at the Fraunhofer IWES up to 2025

Diversity is generally recognized as a key factor behind the future viability of any organization – as such, in line with the Fraunhofer-Gesellschaft's policy, increasing the percentage of women working as research associates at the Institute has been accorded top priority. In particular, the number of women in managerial positions is also to be increased.

In order to remain successful, staff are needed who generally share the same or similar values as the Fraunhofer IWES. It has therefore been shown that the advantages of the Institute, namely scope to shape how one works, the assumption of responsibility early on, and tailored development opportunities are highly valued by academic staff with professional experience.

Accordingly, the specific strategic recruitment goals at the Fraunhofer IWES are as follows:

1. The number of female scientists and academics recruited is to be increased significantly. By 2025, the proportion of women at the Institute is to increase from the current 22% to the Fraunhofer-wide target of 30%.

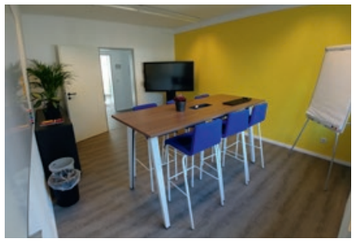
2. When filling new positions, priority should be given to independent, highly qualified, and experienced candidates with industrial and/or academic experience.

3. Graduates are to be recruited primarily from the internal pool of students.

Development Opportunities as a Factor for Success – The Fraunhofer IWES as an Attractive Employer

Achievement of the goals set out above requires an employer marketing strategy which clearly highlights the Institute's decisive attractive features at an early stage. Today, the important key factors which define attractive employers are personal development opportunities and an appreciative working atmosphere. Personal development opportunities and a modern Institute culture are already a matter of course and a practiced reality at the Fraunhofer IWES. That's why the focus of personnel recruitment measures will be on these decisive advantages. A transparent presentation of the broad range of further training opportunities, the possibility to take on additional responsibility, and scope to shape one's career as well as specialist and managerial career paths, for example on the career website and directly in job postings, will all serve to enhance the Institute's competitive advantages. Further accompanying measures include:

- The use of staff contacts to raise interest for the Fraunhofer IWES among potential candidates from their personal spheres.
- Increase in awareness of the Institute and the communication of its successes: greater presence on various channels – Fraunhofer IWES blog, social media, (specialist) press, trade fairs, conferences, and lectureships at universities.
- Establishment of regular recruitment events.



3.8 OPTIMIZING INTERNAL PROCESSES

The world of work is growing in complexity. In light of the working structures in place at the Fraunhofer IWES, such as the co-working space in Bremen, multiple sites, and various test benches, the traditional notion of a location-based workplace is becoming increasingly outdated. This transition means greater organizational complexity and also places high demands on administrative mechanisms. To support the Institute's administration, the strategic goal is to reduce the pressure on academics through efficient, effective, and targeted processes. The time spent on administrative tasks by scientists is to be reduced to a minimum and non-technical risks are to be rendered transparent at an early stage.

Action Fields and Measures

1. With the introduction of SAP, it will be possible to digitalize all administrative processes completely. The digital workflow will mean that procurement staff can place orders regardless of where they are, releases can be issued, and the status of orders can be queried. This will boost both flexibility and transparency.

2. More meetings are to be scheduled between administration and the departments at the various sites as a way of facilitating communication. Intensive exchanges equate to an improved understanding of processes. Workflows and tasks can be discussed and adapted. A process of continuous improvement offers the framework for precisely this. The already initiated workshops focusing on quality, work, and environmental protection management within the scope of certification are to be expanded to include more departments.

3. Administration is to be integrated more closely into scientific work and controllers are to be made responsible for ensuring correct figures and bookings. This, in turn, will lead to an improved mutual understanding and allow the specialist departments to be supported more effectively, e.g., with gap analyses.

4. A uniform reporting system is to be set up to enable heads of department to assess economic development both reliably and efficiently. Furthermore, fixed deadlines for reporting are to be defined.

5. Additional Institute-wide documents and tools will be developed and made available to simplify workflows, e.g., templates for the project initiation and drafting phases and contract specifications. Further support is to be afforded to the specialist departments through joint evaluation of the lessons learned and with error analyses for example. Workshops on project management, taking the SAP requirements into consideration, will also get underway in spring 2021.

3.9 CONTINUOUS SITE DEVELOPMENT

At present, the Fraunhofer IWES is spread over five sites in three federal states (Bremen, Hamburg, Lower Saxony) and housed in nine buildings. This distribution is, in part, for historical reasons; back in 2009, the Institute began operating with subsidiaries in Bremerhaven, Hanover, and Oldenburg. The additional sites came about due to specialist requirements and an urgent need for space. 2018 marked the start of a discussion on further site development taking the home states into account – a discussion which was very open to the idea of consolidating the situation if deemed possible and expedient. However, it was concluded that all of the current sites are required for the Institute's work and a merger would result in key fields and development opportunities being relinquished. As such, it was decided to view the complexity of the site situation not just as a challenge but also as an opportunity. The following two aspects should therefore be emphasized:

New Work and Digital Working
The Fraunhofer IWES takes advantage of the diverse activities which are normally summarized under the term "new work" as an approach to site development. Modern, digital working methods will enable staff to participate in Institute projects regardless of their location. This also opens up the door to flexible recruitment since vacancies can be offered at all sites and the pool of suitable applicants is larger. Furthermore, digitalization of the working environment also offers opportunities in terms of a better work-life balance since, for example, mobile working is facilitated. A co-working space established at the University of Bremen campus has proved itself as an alternative to the option of working from home and, at the same time, is a popular venue for internal and external meetings.

Decentralized Staggered Development
Against the backdrop of the opportunities presented by new work, the potential of all sites was analyzed and expansion plans were drawn up, which will enable the Institute to grow over the coming years. The details of this are outlined below:

In Bremerhaven, the acquisition of the Windhaus is currently under discussion in the committees and the building can be taken over by the Institute in the near future. Following investments to modernize the offices, around 20 additional workplaces are now available. Offices at the airfield have also been set up for eight employees; the construction of LiDAR buoys and, in future, the hydrogen project will be managed from there. The office situation at the DyNaLab is also being optimized at present and a further five workplaces have been created by boosting flexibility and via consolidation. Here, too, the testing hall capacity is subject to continuous expansion to create space for the already approved investments and to develop a longer-term new construction concept to establish further office workspaces on site.

In 2019, the Fraunhofer IWES opened its first co-working space on the campus of the University of Bremen. This space is home to flexible workstations and meeting rooms with various configurations for all staff. The Site Evaluation department works permanently from this site. Next year, there is the prospect of taking over the current premises of the Fraunhofer MEVIS with its 65 workplaces. This building is located in the close vicinity and this would significantly boost development potential at this site.

In Hanover, the Institute is housed at two sites relatively far apart: in the city center with an office close to the central station and at the Marienwerder research campus with the Test Center Support Structures (TTH). An additional office story is to be created here over the course of this year. This will offer space for another 15 members of staff.

At present, the Hamburg site is enjoying dynamic development as the test laboratory for large bearings based there has been very well received by the industry sector. Moreover, the new activities in the hydrogen field together with the North German Real Laboratory mean that additional office workspaces are required. In response to this, the city of Hamburg is planning a new research building in cooperation with the Hamburg University of Applied Sciences. If everything goes to plan, this project will be completed in 2022 and is expected to offer a further 25 workspaces.

In total, around 90 new office workplaces are either being realized or are in planning and, as such, the envisaged growth of the Institute in this area will also be achieved.

Perspective
The Bremen site and the intensified links to its university are at the heart of short- and medium-term formative planning at the Institute. The two planned cooperation professorships and another electrical technology laboratory for joint use create a substantial basis at a working level to this end.

The envisaged takeover of the MEVIS building and the development of further Institute functions on site will help to relieve the pressure on premises in Bremerhaven and also create a new gravitation center, which, given its central location both in terms of the university campus in Bremen and with relation to the other IWES sites, will potentially stimulate many other positive developments.

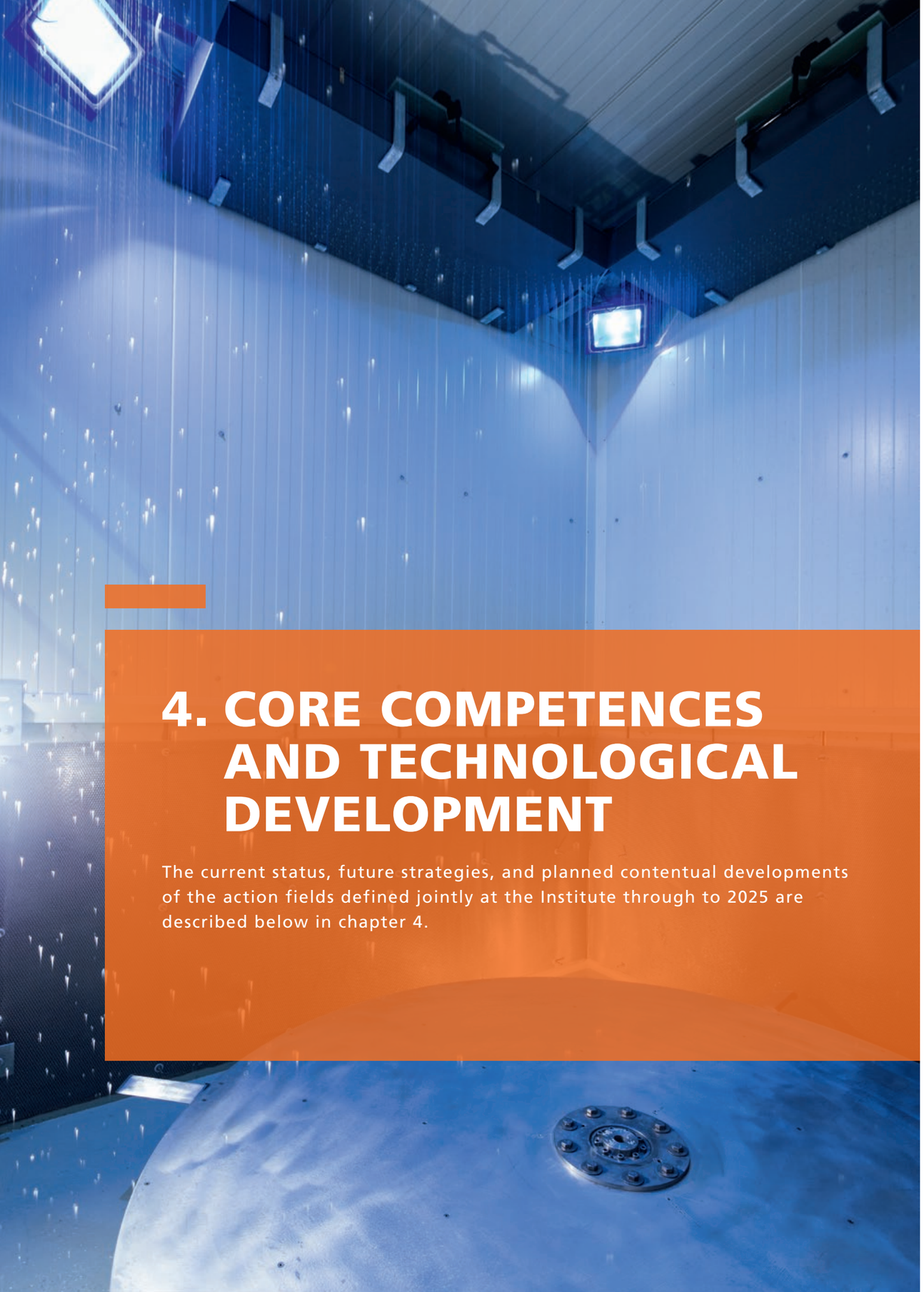
3.10 INTERNATIONAL POSITIONING VIA SCIENTIFIC COMMUNICATION

It is essential that the Fraunhofer IWES clearly positions itself as an industry Institute in the wind energy sector. Successes and progress achieved within the framework of the strategic objective can be transported authentically and convincingly via different channels to the relevant target groups using marketing and communication instruments. The Institute's target groups are many and varied: industry customers from the wind energy sector whose operations are becoming ever more global and who communicate professionally via all media channels; the focus area of scientific research and development with its highly demanding content; the general public faced with the conflicts associated with renewable energies and climate protection; media representatives, sponsors, the Fraunhofer-wide internal stakeholders and staff as the Institute's ambassadors.

Motivation
With the aim of becoming more visible on the international stage and to be viewed by the relevant target groups as a successful global research institute, the Fraunhofer IWES sets great store by honing its external communication and developing this further in the relevant fields. The goal here is to establish the Institute as an expert international partner in all business fields and for all target groups.

Action Fields and Measures
Alongside increased content-based networking with other institutes and research facilities, it is also vital to use the communication channels systematically to spread the Fraunhofer IWES' messages and content and also to tap into new formats. The associated goal here is to aid customer acquisition through specific public relations work. The following measures are optimized and adapted within the scope of regular internal exchanges: support of networking (contributions to alliances), assistance through specific media work (PR articles, press releases, etc.), establishing of a blog, expansion of social media activities (e.g., Xing, LinkedIn), website optimization, testing of new digital formats.

The success of the measures taken will be evaluated quantitatively and qualitatively. Quantitative performance checks will be done by means of access figures, links, and media monitoring, the qualitative evaluation via customer and staff surveys.



4. CORE COMPETENCES AND TECHNOLOGICAL DEVELOPMENT

The current status, future strategies, and planned contentual developments of the action fields defined jointly at the Institute through to 2025 are described below in chapter 4.

The Fraunhofer IWES will focus on the systematic further development of its core competences (testing and validation, measurement methods) and also develop forward-looking and technologically suitable activities in order to achieve the strategic goals in the action fields described in chapter 3. The focus here is firmly on the action fields of sector coupling by means of hydrogen, digitalization, and life cycle. With respect to new strategic activities and action fields at the Fraunhofer IWES, a great deal of energy must be invested into linking the Institute's existing unique features and evident strengths (see SWOT analysis) with promising market trends in an expedient and goal-oriented manner.

The Fraunhofer IWES remains fully committed to its over-riding goal of pursuing industry- and application-oriented research. This makes it even more important not to lose sight of the ongoing academic development of the Institute and its staff. This forms the necessary basis for sustainable expansion of the requisite technical expertise and the academic reputation of the Fraunhofer IWES. Our understanding that industry-oriented research and scientificality can not only co-exist but actually depend on each other must be promoted. Accordingly, a subpoint of this chapter is dedicated to the strategically important scientific further development of the Institute.

A road map graphic visualizes the timing of measures and activities within the respective strategic action fields as well as the planned specific milestones of the developments derived from this through to 2025.

4.1 TESTING AND VALIDATION

Over the past ten years, the Fraunhofer IWES has developed into an internationally recognized testing institute for wind turbines. Large test benches such as the DyNaLab, the TTH, and the test benches for blade bearings (Large Bearing Laboratory) and rotor blades are in great demand among international manufacturers and are essentially operating at full capacity.

Among other factors, two main trends in the wind energy sector appear to be determining the Institute's future development. On the one hand, the growth of turbines is continuing relentlessly and turbines in the 15 MW class will be launched on the market in the near future, yet there is a lack of corresponding testing and inspection infrastructure. On the other hand, there is now a sharper focus on the operating phase of turbine life cycles since the optimal use of components is growing in importance due to the high cost pressure. These components should not only last the calculated service lifetime of the turbines, but must also ensure maximum turbine availability and minimum operating risks. While this premise held true in the past, it is now more valid than ever before.

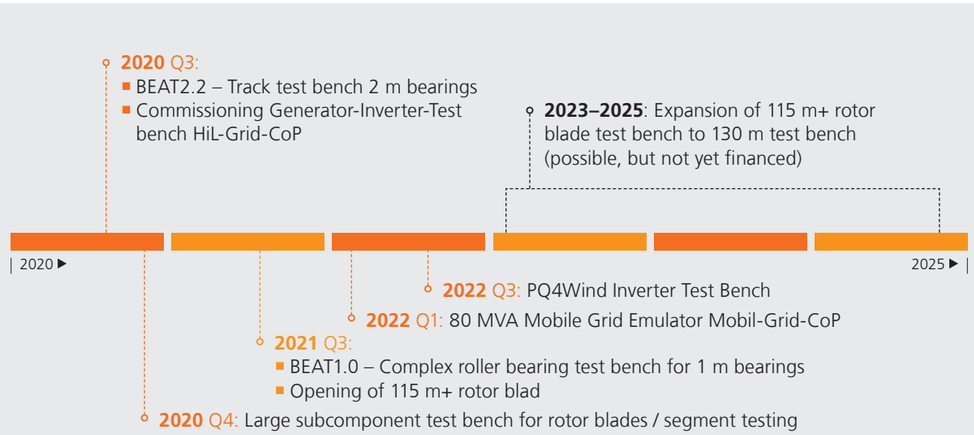
Infrastructure Development

The Fraunhofer IWES has already expanded its testing infrastructure significantly to accommodate these trends and is fully committed to further expansion as one of its fundamental strategic goals. For example, test methods for measuring wind, wind wake, model validation, and structural mechanics validation on an industrial scale can be developed and trialed on the AD8/180 research platform. A test block for rotor blades measuring in excess of 115 m in length with the option of modular expansion, a mobile 80 MVA medium voltage grid emulator to perform grid compliance testing for

wind energy systems up to 20 MW, a generator/inverter test bench for onshore wind turbine systems with a drive power of 9 MW, and a fully electronic inverter test bench without rotating machine set are all planned for 2021.

In this environment, testing on system level (e.g., nacelle testing) is increasingly revealing the exponential growth in costs for new, larger test benches. At the same time, the number of manufacturers venturing into the 15–20 MW class looks set to remain negligible. This makes the construction of ever larger test benches fraught with risk, and the public funding thereof is questionable from a funding policy perspective.

Methods Development and Component Testing
Consequently, when developing new test benches at the Fraunhofer IWES, suitable test methods are systematically used in order to carry out more testing at component level and, in turn, validate properties at system level. Accordingly, the Institute has set up a test bench for performing highly dynamic testing to validate electrical component models. This component certification strategy enables a considerably increased testing depth and a high level of reproducibility at low cost compared to the corresponding system tests. Such approaches are also being pursued at the Fraunhofer IWES, including with new test benches and methods for the component and section testing of rotor blades.



Timeline Test and Validation 2020–2025: Projects and infrastructure

4.2 DIGITALIZATION

One focal point of strategic development in the information age seeks to answer the question: "what added value can the Fraunhofer IWES generate for customers and society through digitalization methods?"

Since around 2013, the term digitalization in the German media has been used almost exclusively to describe the far-reaching mega trends of digital transformation and penetration of all areas of the economy, state, society, and daily life. Generally speaking, this refers to "the targeted identification and systematic exploitation of potential arising from digital technologies".*

The Fraunhofer IWES' digital strategy pursues defined activities in the areas of digital twin/shadow, digitalization of the development, planning, and operating phase as well as

* Source: https://de.wikipedia.org/wiki/Digitalisierung#cite_note-8

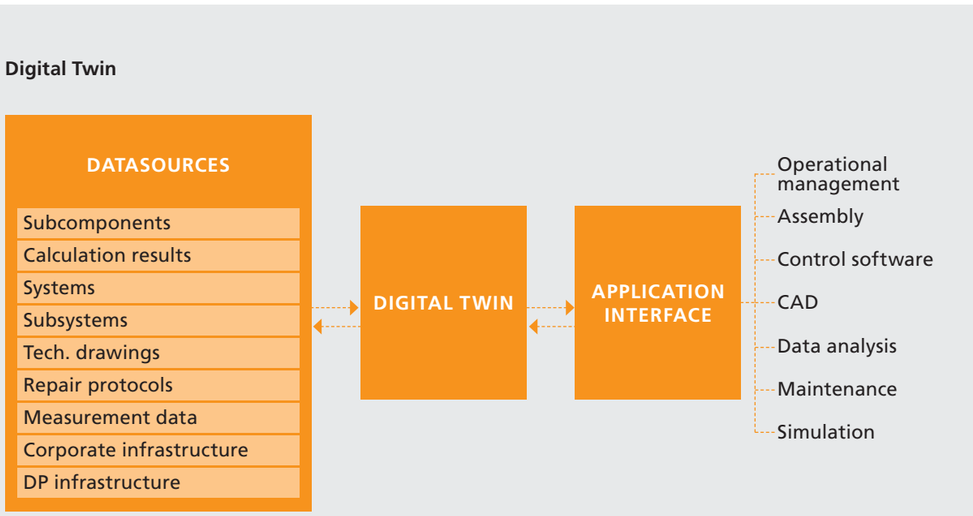
digitalization of environmental measurements and site conditions. The methodology of virtual testing as a digital basic technology is one of the developmental focal issues at the Institute. This methodology is shaped in particular by so-called virtual test benches as digital reproductions of the actual large test benches and measurement facilities. They are used in test planning, scaling, and model validation.

The digitalization activities within the lifetime cycle of wind turbines and farms comprise measurement and simulation data flows, the circular economy, reliability, and maintenance as well as the control of wind turbines, farms, and supply grids. With respect to environmental measurements and site characterization, in addition to the digital processing and evaluation of measurement data, the integration of measurements and modeling results are also at the heart of activities.

The digital twin can be characterized by the following properties:

- Forms a digital replica of a product (e.g., test bench, wind turbine, component) together with the relevant information,
- Comprises the complete product life cycle (beginning of life -> middle of life -> end of life),
- Supplies model descriptions, a data pool, metadata structures, and ontologies, which allow data/information to be connected and thus create added value through complex knowledge representations,
- Manages information and serves various users and issues,
- Provides structured information on various applications via a uniform interface,
- Serves various users, e.g., fitters, works managers, designers, logistics experts, engineers,
- Takes advantage of diverse data sources, e.g., corporate structure, production, manufacturing and material data of digitalized products, physical systems, embedded systems, sensors, product data sheets, technical drawings, measurement data, repair logs, calculation results, etc.

The following graphic illustrates the term digital twin.
In simple terms, the so-called digital shadow can be defined as a subset of a digital twin. It answers specific questions and, accordingly, only has a reduced relevant data pool with corresponding structures.



Huge amounts of data are accrued in the operating phase of wind turbines and wind farms in particular. The use of data science methods to evaluate this data helps to optimize operation and service, e.g., with regard to early error detection, failure cause analysis, and yield optimization.

Digitalization also plays a central role for a multitude of reasons when it comes to site characterization. It facilitates the development of new measurement methods (e.g., remote exploration such as seismics, LiDAR, and radar), complex data analysis procedures (e.g., calculation of synthetic CPT), and the integration of measurement data and modeled data (e.g., digital buoy, completion of data series, error corrections).

Fraunhofer IWES Activities
The ongoing and planned activities at the Fraunhofer IWES under the umbrella term "digitalization" can be assigned to one of the previously defined fields. The list below provides an initial overview to this end.

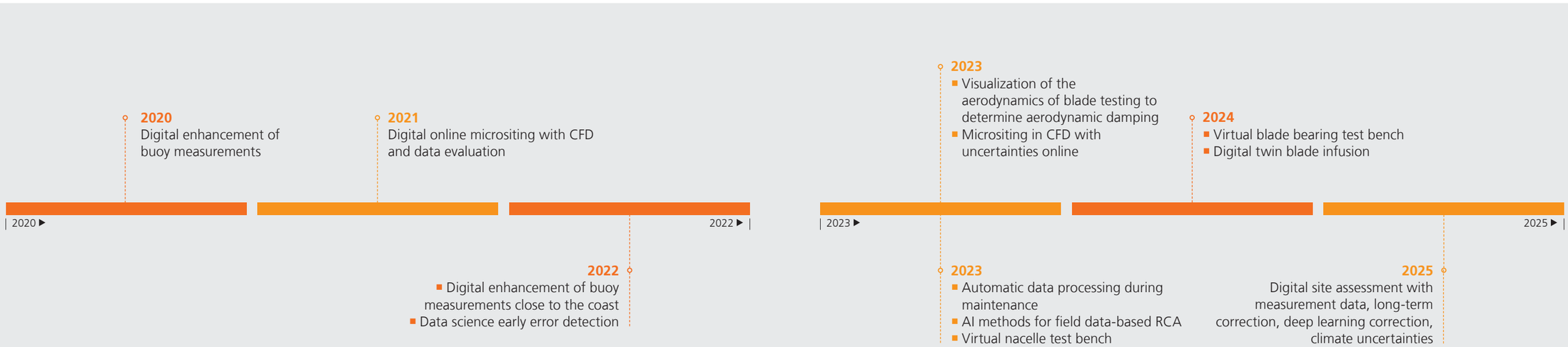
Virtual test benches/measurement facilities:
- Virtual buoy: Integrated measurement and modeling,
- Virtual blade bearing test bench: Simulation of the testing environment and numerical test design,
- Digital testing files: Recording of all test results in the whole blade test,
- Digital component files: Recording of production and load history,
- Rotor blade, issues relating to the binational joint research project "ReliaBlade",
- Multimodal reliability models for controlling and maintenance,
- Virtual nacelle test bench: Mechanical model validation and certification of electrical properties,
- Virtual support structure: Experimentally proven software models of support structures and their ground/structure interactions to validate customers' engineering models, design assumptions, and structures.

Summary of the shared goals of virtual test benches:
- Virtual preparation of testing orders,
- Development of complementary products for testing orders,
- Virtual test performance,
- Digital post-processing of testing orders, digital validation.

Digitalization of the operating phase:
- Statistical analysis of various data flows in the field as well as measurement data as the basis and input for online evaluations during operation,
- Use of machine learning methods for advanced evaluations of wind turbine operation for early error detection and failure cause analyses (data science).

Digitalization of environmental measurements:
- Establishment of synthetic CPT measurements as a product for the geotechnical exploration of wind farms,
- Development of an integrated, geostatistical overall model of the subsoil,
- Probabilistic modeling of uncertainties in the subsoil model.

With its various departments, the Fraunhofer IWES already boasts a wealth of expertise in the application of digital methods. In the medium-term, these are to be pooled in a matrix structure to form agile teams in order to generate digital solutions and corresponding added value across the Institute. The Institute continues to focus essentially on specific applications and questions in relation to the wind industry and coupled sectors. There are no plans for the internal development of specialist structures within the organizational units (OU) in the field of digital technology (e.g., AI, high-performance computing, cyber safety). The Fraunhofer IWES sets great store by cooperative partnerships with the relevant specialist institutes within the Fraunhofer-Gesellschaft (e.g., SCAI, ITWM, IAIS, FIT, IZB).



Timeline Digitalization 2020–2025: Projects and infrastructure

4.3 MEASUREMENT METHODS

The Fraunhofer IWES has set itself the task of tailoring, developing, and applying innovative and relevant measurement methods for the benefit of the wind industry. The Institute sees itself as providing a bridging function: with regard to basic research and subsequent measurement technique development, it is identifying new methods of interest for use in the wind industry, developing these in line with the needs of the sector and putting them into practice.

Over the past few years, the development of measurement methods for environmental conditions has been shaped by two major trends: remote sensing technologies on the device side and algorithms for data processing and evaluation. As a result, new technological possibilities for measurement technology have been created which have fundamentally improved the measurement of environmental conditions for wind farm development, particularly offshore. When it comes to important core topics, the Institute has shown itself to be a driver of innovation for the wind industry and has made key contributions to the establishment of new measurement methods. Particular mention must be made here of wind potential determination with the Fraunhofer IWES LiDAR buoy and boulder detection based on 3D multichannel seismics since these are unique selling points of the Institute in the global market.

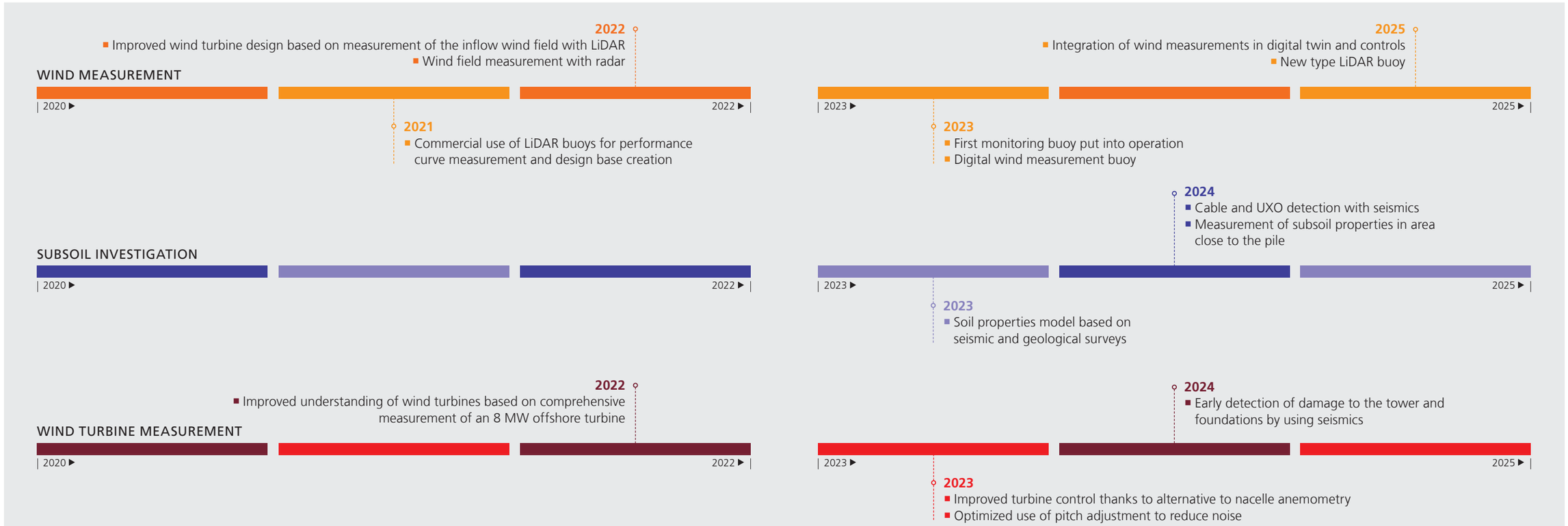
When it comes to wind turbine measurement, the Fraunhofer IWES is an institute accredited to ISO 17025 for the measurement of load conditions and the power curves of wind turbines. Expertise in wind measurement, the installation and handling of measurement technology, and the interpretation of the recorded field measurement data have been merged here.

Ongoing digitalization remains the most important factor for the strategic development of this topic at the Fraunhofer IWES; innovations here are not only in the form of improved processing and evaluation of measurement data but are also extending increasingly to the integration of modeling results and the fusion of measurements and modeling. Good examples of this are:

- The coupling of in situ wind measurements with weather model driven simulation results,
- The integration of in situ measurements in digital twins and
- The integration of measurements and real-time simulations in turbine and wind farm control.

The technological development of remote sensing methods is also being driven forward and offers new possibilities for the wind industry. Examples of this include the measurement of 4D wind fields up to the scale of wind farm clusters by means of dual Doppler radar and the detailed characterization of turbulent input wind fields to ensure optimized turbine design and operation of large farms.

The Fraunhofer IWES also focuses on enabling the wind industry to get the maximum possible benefits from the developed measurement methods and to improve and qualify these for new applications. Take, for example, the seismic methods developed for the efficient documentation of the subsoil characteristics of offshore wind farms. These shall also be used to obtain a complete 3D seismic measurement of wind farm areas with integrated geotechnical characterization and for novel seismic UXO and cable detection methods. The Fraunhofer IWES LiDAR buoy is currently being qualified for further applications, e.g., power curve measurements and the determination of the design basis.



Timeline Measurement methods 2020–2025: Projects and infrastructure

With respect to turbine measurement, the Institute is aiming to develop special and innovative sensors which are perfectly tailored to the needs of the wind energy industry. An impressive level of expertise has been built up in the measurement of pressure ratios, acceleration measurements, and thermography as well as general mechanical load measurement. This is to be increasingly utilised over the next few years in interdepartmental research projects.

The Fraunhofer IWES can benefit two-fold from the development of sensors for use in wind turbines: depending on the intended application, the innovative sensors are put through their paces on test benches such as the DyNaLab, the large bearings test bench, the TTH, and the blade test bench. The new measurement methodology can then be used both in the field and directly on the test benches.

4.4 LIFE CYCLE

Considering the growing number of wind turbines, value creation in the wind energy sector is moving away from the production and setup of turbines and farms toward a more comprehensive take comprising the entire turbine life cycle. This not only includes the planning processes for wind farms, development, and construction together with the setting up of turbines but also operation, the monitoring of turbines, repair processes, and, ultimately, decisions on service life through to dismantling and recycling of the machines. The Fraunhofer IWES has already contributed to this life cycle approach in many areas with its work. This core theme is to be further expanded upon to allow the Institute to meet its goal of becoming the leading wind energy research facility.

The life cycle management approaches cover very different subject areas. What they have in common, however, is the changed target group: operators and their business fields are being addressed first and foremost. This also means that a closed and targeted approach is required for the product development of life cycle management.

The following areas are set to become central development fields over the coming years:

Circular Economy/Production of Rotor Blades from Sustainable Materials

Assuming it is not caused by singular events such as a lightning strike, structural damage on rotor blades can be divided into two categories: production- and design-related damage. The Fraunhofer IWES intends to grow its testing expertise in order to support wind farm operators optimally with repair solutions in the future. This can be done via a full-scale test or a 1:1 component test. The methods already developed in the project “Future Concept” for section and component testing are therefore particularly well suited for certifying repair solutions.

New production methods are being developed and trialed in the BladeMaker Demo Center. This knowledge will be used in the future to better assess the suitability of materials for production which have the goal of making it easier to recycle rotor blades. The infusion tests, the development of infusion strategies for thermoplastics, and the use of renewable resources are all focal issues here.

This should go hand in hand with the development of a recycling center for rotor blades. The Fraunhofer IWES is striving to become a central institution for rotor blade recycling and, in doing so, to anchor expertise in rotor blades over their entire life cycle at the Institute.

Monitoring Concepts

Thanks to the operation of test benches, the Fraunhofer IWES can avail itself of numerous options for testing a great variety of monitoring systems. Efforts in the future will be concentrated on carving out this area of work.

The manufacturers of SHM and CM systems for rotor blades can validate these systems in the full blade test. Above and beyond this, together with a partner, the Institute is developing cost-effective acoustic emission sensors for structural monitoring. The Fraunhofer IWES is also assisting the developers of SHM systems with the validation of hard- and software in connection with support structures, i.e., towers, jackets, and various foundation systems. The Institute is able to simulate realistic loading conditions in support structures with large-scale mechanical testing facilities and a foundation test pit.

When it comes to early error detection based on operating data (monitoring), the aim is to ensure improved forecasting and detection of component failure by using existing data flows. This forecasting allows for more efficient and cost-effective maintenance planning and shifts the operator’s attention to turbine errors ahead. Both operators and control room software manufacturers benefit from this.

The ratio between overall yield and total costs is relevant for the operators of wind farms. However, whether the yield achieved was the optimal value possible can only be determined using complex post-construction analyses with the inclusion of wind conditions in the calculations. The Fraunhofer IWES is expanding its existing skills from the offshore sector to the onshore sector and, among other things, is pursuing the goal of further digitalizing (automated tool chains) and standardizing this expertise.

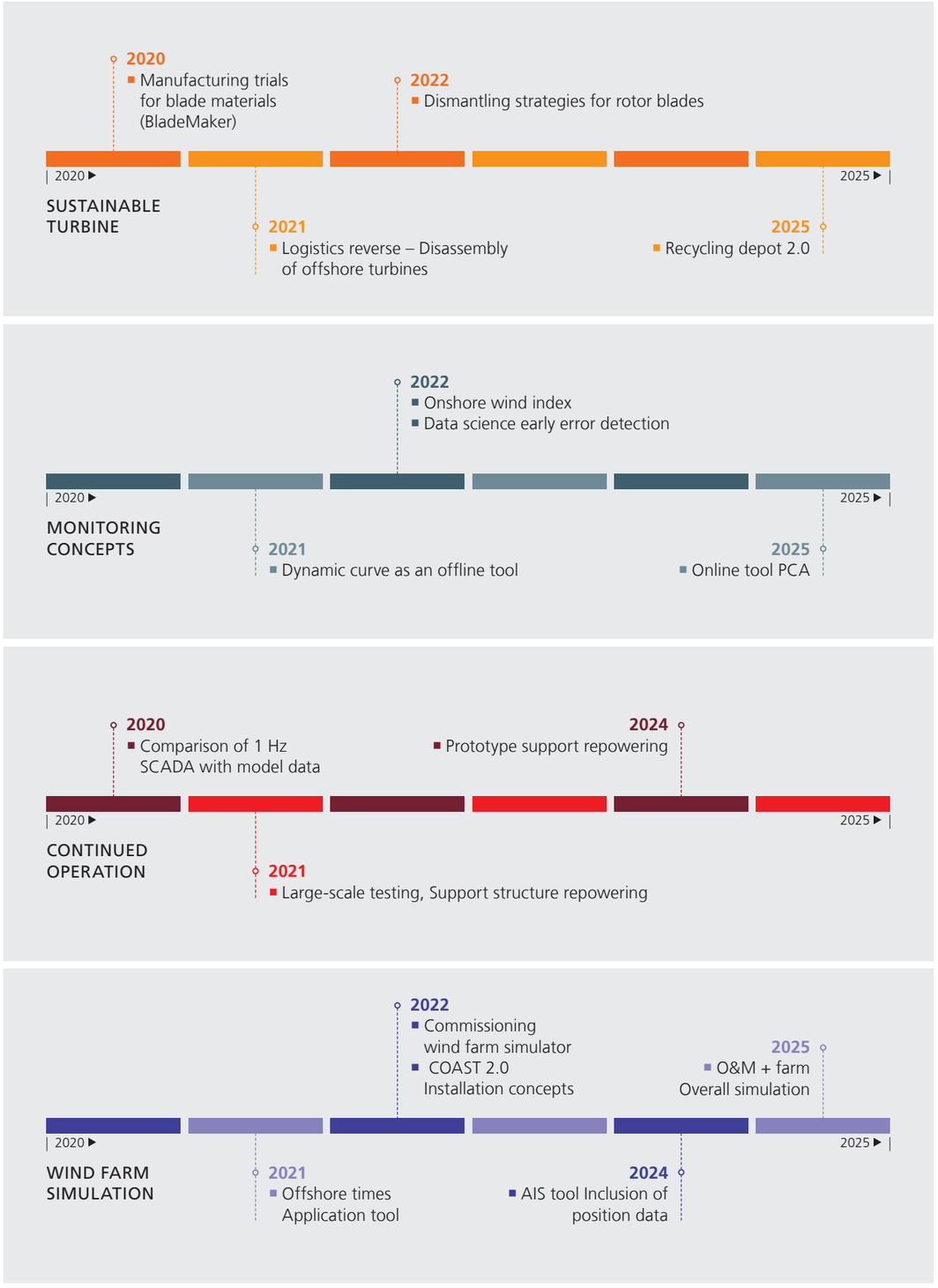
Continued Operation

In 2021, wind energy turbines with a total output of around 4,000 MW in Germany will cease to be funded. Up to 2025, on average up to 2,400 MW annually and a total of around 16,000 MW will follow (source: BWE e.V.). Repowering, however, is being slowed down by approval processes. The continued operation of turbines is of great interest to turbine operators for monetary reasons and also from an environmental policy perspective. In order to extend the service life of turbines, their technical condition must be evaluated as precisely as possible at the end of the designated operating life time so as to be able to predict the remaining service life. For this estimate, the fatigue loads of the affected turbines are generally determined using generic simulation models and compared against the originally calculated design loads. However, the information on the remaining service life is frequently subject to considerable time differences and uncertainties, as the generic models used are error-prone due to model simplifications or difficult-to-reconstruct wind conditions, for example. The Fraunhofer IWES is developing new and improved methods for the market here both with regard to load calculation and in terms of support structure design. In connection with offshore repowering in particular, the Institute is already working intensively with innovative systems to improve the condition of offshore pile foundations so as to extend lifetimes and thus repowering, i.e., the strengthening of support structures to withstand larger turbines.

Wind Farm Simulation

To date, operating wind farms have been analyzed based exclusively on their measured state. In other fields, on the other hand, co-simulations of industrial processes are being performed which can determine what is currently happening on and in a machine. Using its existing knowledge, the Fraunhofer IWES is striving to make this possible not only in wind farms but also in whole wind farm clusters. To this end, a real-time wind farm simulator is being developed which can simulate the events in the wind farm, taking account of the wind conditions, and thus represent all processes virtually. This results in a digital twin, which enables the service lives of the turbines and their components to be estimated and which also allows error analyses based on deviations between actual operation and the simulation. A simulator of this kind can also serve to optimize layout in the planning phase and subsequently operating modes or to evaluate special operational scenarios in order to ensure grid stability for example.

In the future, the real-time simulator platform should be combined with existing Fraunhofer IWES simulation tools for transport and installation (T&I) as well as the operation and maintenance (O&M) of offshore wind farms. These can virtually depict the entire installation and operating phase of 20–25 years on an hourly basis. In doing so, the statistical reliability simulation, maintenance processes, weather data, operational limits, and resources (personnel, ships, spare parts, locations) are taken into account. Moreover, the income development is determined while allowing for the electricity market models and costs. The O&M simulation programs are thus virtual test centers for logistical concepts for the construction and operation of offshore wind farms and help to optimize offshore processes right along the value-added chain. The software can also be used to assess innovations, e.g., in research projects. With the help of ship and helicopter positioning data, among other things, the actual state of seaside wind farm logistics is to be recorded and optimized online using simulations in the future.



Timeline Lifecycle 2020–2025: Projects and infrastructure

4.5 HYDROGEN ACTIVITIES

A future focal point of research for the Fraunhofer IWES will be sector coupling and the conversion of green electricity into other energy storage media such as hydrogen. Cross-sector solutions will be essential in the future in order to meet Germany's and the EU's CO2 savings goals and to push ahead with the energy transition. Fluctuations in regenerative feed-in can be smoothed out by converting electricity into other storage media, resulting in security of supply and grid stability. This will make it possible to avoid the curtailment and switching off of wind turbines due to temporary surplus production and capacity bottlenecks in the transmission grid. At the same time, the annual energy production from wind energy can be used more effectively. These secondary effects of sector coupling, especially with the help of hydrogen, serve to cut costs at the energy system level.

In the offshore sector in particular, the conversion of the electrical energy generated in the wind farms into hydrogen directly on site is being considered. Yet, comprehensive testing of the interaction of the various technologies and subsystems used is necessary before this technology can be used on a large scale offshore. The test site in Bremerhaven is ideal to this end as not only are the wind and general environmental conditions (e.g., salinity of the air) similar to an offshore site given the close proximity to the River Weser and the North Sea but the technical test infrastructure is already either in place (wind turbines, grid emulator, etc.) or is being developed.

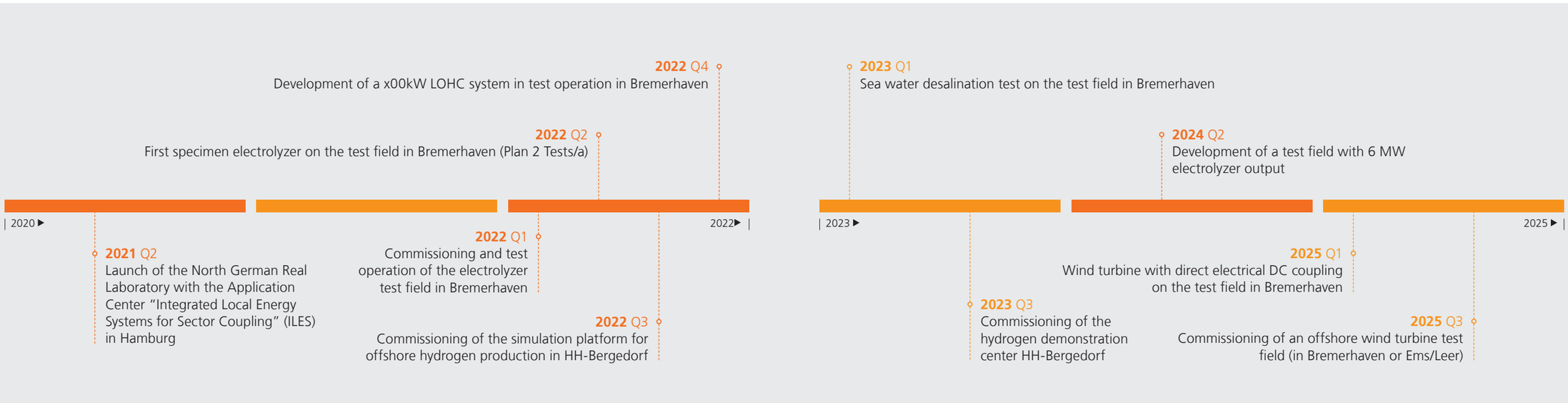
As part of the "Green Hydrogen for Bremerhaven" project funded by the European Regional Development Fund (ERDF), the Fraunhofer IWES will set up a multi-MW electrolyzer test site on the former airfield in Bremerhaven, here green wind energy will be converted directly into hydrogen (off-grid concept). The Institute's research interests include the measurement of the electrical properties of electrolyzers and fuel cells as well as the further development of special hydrogen storage options (for example, LOHC – liquid organic hydrogen carrier), which have been attributed a central role in the future of maritime technologies and shipping.

Furthermore, the switchover of the energy supply of the LiDAR buoy, which has been used more and more to determine the available wind resources offshore in past years, from diesel emergency operation to hydrogen-based operation, is to be examined and implemented within the scope of the project.

For the Fraunhofer IWES, the development of skills in this sector represents an opportunity to establish a hydrogen hub for sector coupling and hydrogen in the Bremen/Bremerhaven region in cooperation with other local institutes such as the Bremerhaven University of Applied Sciences and the ttz Bremerhaven – a step which is all the more important in light of the development of the Green Economy Region in the nearby Lune Delta.

The Fraunhofer IWES is also a partner of the North German Real Laboratory (NDRL). As part of these activities, research results from the project in Bremerhaven are being actively shared with those partners involved in the NDRL.

Together with the Competence Center for Renewable Energies and Energy Efficiency (CC4E) at the Hamburg University of Applied Sciences, the Fraunhofer IWES is systemically studying aspects of green hydrogen production by means of electrolysis. The emphasis here is on the system level focusing on technical reliability, the improvement of system efficiency, and the analysis of system time constants and coupled cost models. The database for these analyses is generated by measurements on MW electrolyzers and at tests fields in Hamburg-Bergedorf, Bremerhaven, and in the NDRL as well as including data from ongoing projects and industrial partners. The goals include the development of a data pool for hydrogen generator technologies and the development of test methods for further component certification in the field of hydrogen generation and reconversion.



Timeline hydrogen activities 2020–2025: projects and infrastructure

4.6 SCIENTIFIC DEVELOPMENT

Scientific excellence is of central importance to the Fraunhofer IWES in order to be considered by politicians and funding bodies as an outstanding player in the German scientific landscape, to acquire and retain customers as an attractive cooperation partner, and to be successful in the fight for the best minds.

The Fraunhofer IWES has undergone dynamic development in the years since its foundation. While the focus in the first years was essentially on developing the Institute and achieving the Rho-Wi goals, there has been a shift towards ensuring scientific excellence in more recent years. In a first step, the role of Senior Scientist was defined, and cooperation was established with several universities in order to support the Institute's scientific development.

In 2017, the Senior Scientist team prepared a catalog of measures based on four pillars to ensure the scientific quality of the Institute:

1. Organization of targeted training sessions for staff,
2. Development of a scientific strategy at OU level,
3. Greater emphasis on scientific work and its exploitation in project planning,
4. Determination and tracking of OU-specific research indicators.

Moreover, an additional budget has been made available in order to award an annual prize for the best publication from the Institute and to offer support for doctoral students in the last phase of their PhD. This has resulted in a considerable increase in the scientific output of this relatively young institute. This is demonstrated, among other things, by the Fraunhofer research indicators, which are used within the Fraunhofer-Gesellschaft to assess the institutes scientific output. In the most recently evaluated year, 2018, the Fraunhofer IWES ranked among the top 30 of 71 evaluated Fraunhofer institutes for the first time, with an overall result of 12.2 points. It should be noted, however, that, accounting for around a third of the points, a not insignificant and recently increased share of contributions can be attributed to Fraunhofer IWES-associated professors.

Goal Setting

The Fraunhofer IWES aims to position itself as an internationally leading research facility in selected fields in order to remain an attractive cooperation partner for global players in the long term (see chapter 4 "Core Competences and Technological Development"). To achieve this, it is vital that the Institute increases its scientific excellence in precisely these fields. This goal is to be pursued by means of the subgoals and specific measures outlined below. The Fraunhofer-Gesellschaft's research indicators should continue to be used to track these measures and quantify the results. The goal here is to ensure that the Fraunhofer IWES consistently ranks in the top third of the research indicator table of Fraunhofer institutes.

Subgoal 1 – Cooperation with Universities

Strengthening cooperation in the core fields with internationally leading universities is one of the Fraunhofer IWES' central strategic goals. This will optimize the dovetailing of basic and applied research and ensure that scientific work is supported properly in the long term. Approaches in this regard include the use of personnel overlaps through the creation of shared positions and, in particular, of cooperation professorships, the joint supervision of PhD projects, and involvement in national and international initiatives with a strong academic focus (e.g., the European Wind Energy Academy EAWE).

Subgoal 2 – Strengthening of Cooperation within Fraunhofer

Especially in times of reduced public funding, internal Fraunhofer funding programs enable joint initial research with other Fraunhofer institutes, e.g., within the framework of lead and PREPARE projects (also see the section "Diversification of Public Funding"). They not only offer a chance to improve networking and the visibility of the Institute within the Fraunhofer-Gesellschaft but are also an ideal way to identify expert partners for future projects. With the exception of an innovation cluster, the Institute has barely addressed internal Fraunhofer funding programs in the past. Following on from the successful acquisition of the first Fraunhofer IWES-led PREPARE project at the start of 2020, greater efforts will be invested here in future. The medium-term goal is to apply for at least one internal Fraunhofer cooperation project annually by 2025. The experiences gained from the application process and the implementation of these projects will be compiled and assessed to tailor the future course of action.

Subgoal 3 – International Cooperation

The scientific work and the industry activities in the wind energy sector take place against an international backdrop. To allow the Institute to build upon its leading position abroad in the future, international networking and cooperation with international partners will be higher up on the agenda over the coming years. This demands that the working environment at the Fraunhofer IWES also becomes more international, especially when it comes to competing for the best international minds. A bilingual working culture in which instructions (e.g., in e-mails, Confluence, and Quentic) and meetings at the Institute are in English should ensure that non-German-speaking colleagues feel comfortable at the Institute and are able to produce first-class results and contribute to the success of the Institute.

To intensify this international cooperation, e.g., at conferences and project meetings, attention should be shifted to the Fraunhofer IWES so as to acquire new staff and customers. The following measures are particularly well suited for this:

- International cooperation projects within the scope of Horizon Europe and multinational projects such as ReliaBlade,
- International cooperation within, for example, EERA Wind,
- Participation in international workshops and conferences as a means of establishing further cooperations,
- Committee work/work on standards within IEA Wind, IEC, etc.,
- Cooperation with international universities which are pioneers in their fields.

Subgoal 4 – Optimizing the Use of Research Data and Results/Open Science

A wide range of research data in various scientific fields is gathered through research and development activities (R&D). The efficient use of this data in subsequent projects can have a long-term positive impact on the development of new methods at the Institute. To this end, an effective infrastructure must be created, e.g., with an easy-to-access database for a variety of test data and an efficient structure for software development. In addition, new scientific approaches need to be identified which will serve to complement the work at the Institute. Tapping into AI methods and machine learning which can be applied to a wide range of fields would appear to make good sense here. Digitalization should not just be applied to individual fields but is of fundamental importance for the Institute as a whole and all its departments (also see section 4.2. "Digitalization"). The diversity of the work carried out at the Institute poses a challenge in terms of identifying new areas and skills which should be focused upon. For this reason, research activities must be planned and potential synergies derived from the expertise represented by the Fraunhofer IWES must be identified based on large-scale cooperation between the OUs (also see chapter 3.6. "Strengthening of the Culture of Cooperation").

In the future, research work at the Fraunhofer IWES is to be supported by using the data gathered, while ensuring compliance with data rights and the transparency of research projects by means of the following measures:

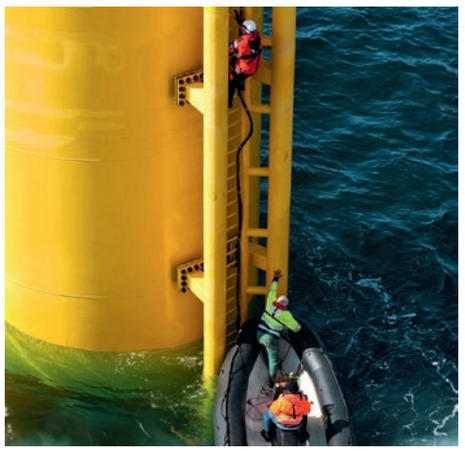
- Development of clear guidelines on the use of data (taking both the requirements of public research and the safeguarding of industry partners' interests into account) by the Senior Scientists,
- Use of the existing open science tools,
- Use of open science to hone the scientific profile and to render the Institute more appealing as an employer.

In many cases, open science is not in contradiction to the industry focus but rather offers the possibility to professionalize the Institute with respect to transparent and reproducible processes.

Conclusion

Since the introduction of the Senior Scientist position and the five-person Senior Scientist team in 2012, the number of research associates and breadth of subject fields at the Institute have grown considerably. In order to carry out the above tasks with the same level of excellence and, in particular, to provide sound scientific support to all subject fields, alongside a sixth position filled by a geophysicist at the start of 2020, the addition of two further Senior Scientists to the team is also regarded as important: a mechanical engineer with a PhD to provide scientific and academic support, in particular to the System Validation of Mechanical Drive Trains department in the DyNaLab and the Large Bearings group in the Large Bearing Laboratory, and an electrical engineering scientist specializing in power electronics to support and develop this rapidly growing area in the DyNaLab.

The regular introductory trainings to scientific work should also be expanded as a further means of establishing a firmly anchored scientific culture at the Fraunhofer IWES. Formal as well as content-related subjects which form part of scientific methodology – literature research, quotation standards, selection of suitable methods, statistical relevance when performing tests, evaluations, and the presentation of results – are seen as expedient components of this kind of training. To this end, guidelines are now being drafted which will define the expected scientific output according to staff category as well as the associated time frame.



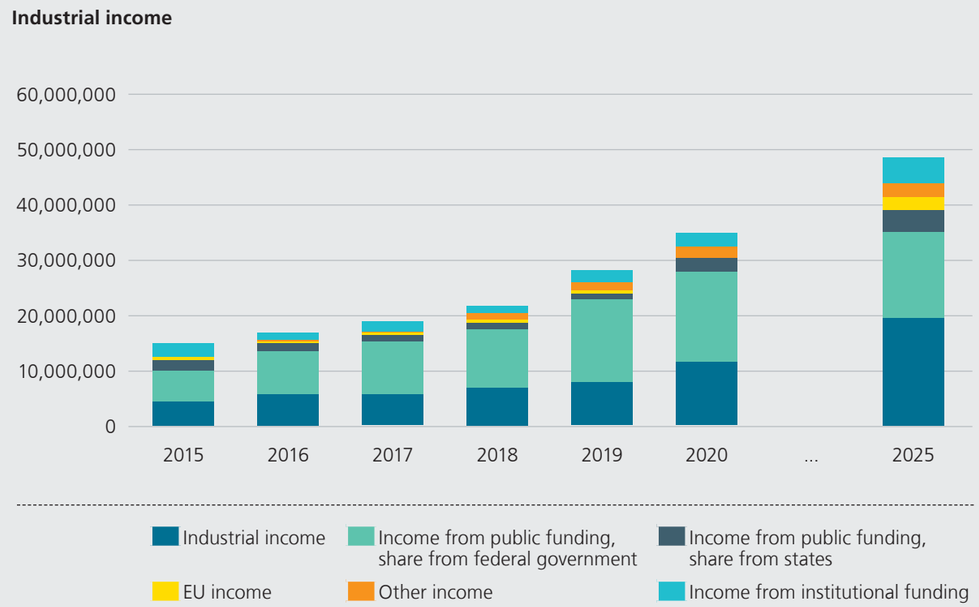
5. FINANCE AND INVESTMENT PLANNING

Growth in the Operating Budget

Over the past years, the Fraunhofer IWES has been able to achieve considerable growth on the revenue side in the operating budget together with a consistently high investment volume.

This growth was reported by all areas. For example, the public funding secured at national and state level rose from €7.5 million in 2015 to €16.2 million in 2019.

On closer observation, it can be seen that the share of state funding vis-à-vis the total funding volume is, however, falling. In 2015, state funding still represented 12% of the financing of the operating budget, yet by 2019 this figure had dropped to just 3%. This change can be put down to a variety of reasons, including a change in priorities in terms of wind energy research in the home states, the end of start-up financing and the complexity of the EFRD financing often used in the federal states. The share of state funding on the other hand rose to 56% over the same period.

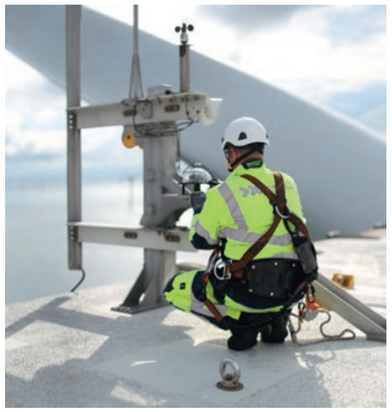


Growing Investment in Infrastructure
In the past, investments were largely financed using funds from the BMWi.

In the last five years, €9 million were invested annually on average. With a total sum of €45 million, the target of €25 million as set out in the last strategy report has been far exceeded*.

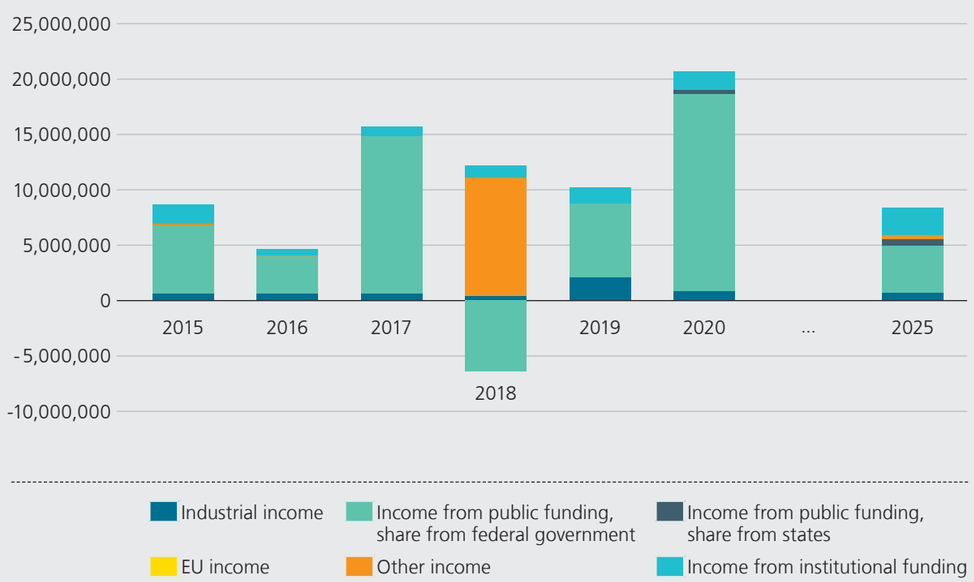
The substantial development of infrastructure is also planned for the coming years; the focus here will be on developing and expanding the existing test benches.

In addition, in order to boost the potential customer portfolio, considerable investments are planned up to 2021 to further establish hydrogen expertise with associated infrastructure. Funds to the tune of €11 million have already been approved for this purpose. These investments are being funded by the federal state of Bremen within the framework of ERDF support.

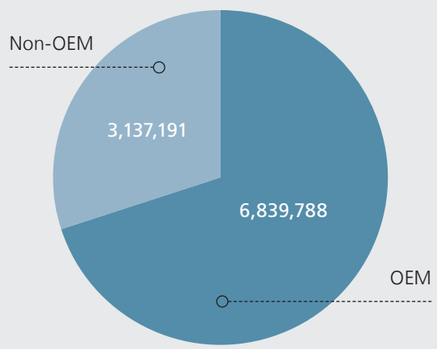


* In 2018, the purchase of a wind turbine was converted into a rental model in a major federal project. For this reason, the public revenue (federal government) is shown as negative.

Income in the investment budget

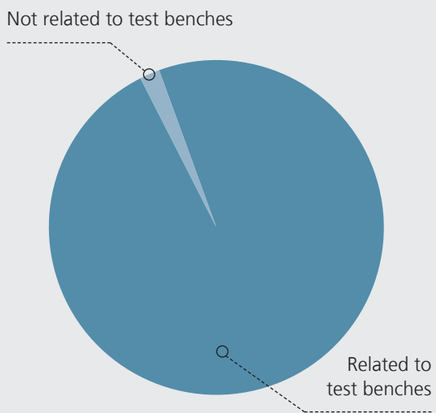


GRAPHIC 1: Growth in industrial revenues – Analysis of industrial customers (2019)



in Euro

GRAPHIC 2: Growth in industrial revenues – Analysis of industrial projects (2019)



Growth of Industry Revenue
The analysis of the composition and origin of industry revenue is of particular importance in order to better estimate the growth potential of this sector. Within the context of strategy development, the aspect of customer acquisition must also be considered against the backdrop of the falling number of OEMs.

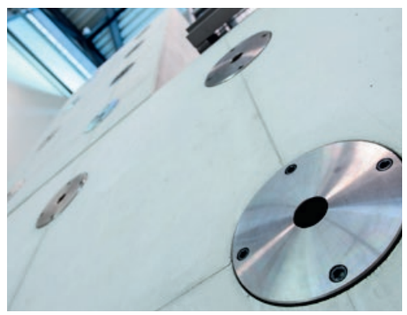
In 2019, the distribution between OEMs and other customers in the value-added chain was as follows: see graphic 1.

Although a large amount of revenue is still generated by the classic Fraunhofer IWES customer group, the share generated by project planners and suppliers has increased to pprox. 30%.

The previous Fraunhofer IWES business model is closely linked to the development of test bench and measurement infrastructure capacities; this close link is the result of the analysis of the content of industrial projects in 2019: see graphic 2.

Around 98% of all industrial projects are related to the Fraunhofer IWES' infrastructure. It would thus seem very difficult to acquire projects exclusively through staff expertise.

This problem has already been addressed with activities related to the digital twin and other digitalization initiatives, which will increasingly decouple the portfolio from the direct test bench hardware. Nevertheless, this is still a limiting factor for the growth of the Institute.



Financing Challenges over the Coming Years – from Rho-Wi 50+ to the Group Average
For more than ten years now, wind energy research has concentrated on funding from a ministry – initially under the control of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and now the Federal Ministry for Economic Affairs and Energy. Consequently, and unlike other Fraunhofer institutes, this has given rise to an unfavorable dependency on one ministry and the risks this entails.

To counter this problem, risk minimization was already decided upon during the last strategy discussion by expanding the industrial income to a share of 50%. This, however, was not achieved (maximum 38%). Paradoxically, the easy availability of this money was the main reason behind the failure to achieve this goal, as it always seemed more expedient to invest in the development of the Institute than to satisfy financial indicators.

It has also become evident in the recent past that almost all relevant industry income is more or less directly linked to the availability of large infrastructure and, as such, this limits the size of the projects which can be realized here.

In light of this analysis and in order to define a credible finance goal, the Rho-Wi aim for the period up to 2025 has been lowered to 35%, which corresponds to the average value of the Fraunhofer institutes in the Materials group. Nevertheless, given that this figure is extremely important (calculation of basic financing, visibility on the Fraunhofer stage), this new goal must be pursued with absolute dedication and, unlike the 50+ target, is a minimum value which must not be undercut under any circumstances. This results in corresponding requirements for the budgeting and controlling process and, of course, for the operational approach of all managers.

Furthermore, public funding in terms of industrial relevance and subsequent implementation in industrial projects must be used more efficiently. The first figures to be evaluated with this in mind show a broad range within the Institute and these can be used increasingly for strategic decisions.

In addition to the efficiency of the use of public funds as defined by the generation of industry income, greater attention must be paid to the composition and origin of this funding. Despite the lowered goal for industrial income, the Institute must work towards securing the broadest possible range of public sponsors.

	2015–2019 Industry in Euro	2015–2019 Public in Euro	Ratio
Support structures	1,026,806	6,236,216	16.47%
Rotor blades	9,158,236	17,573,609	52.11%
Drive train	16,250,933	39,797,098	40.83%
Aerodynamics	709,711	4,097,827	17.32%
Wind farm development	7,552,831	9,827,292	76.86%

Efficiency of how funds are used: ratio of public revenue to industrial income

Budget Planning 2020–2025
On the basis of departmental planning for the period up to 2025, the consolidated and department-specific development of the Institute is described below:

In summary, it can be assumed that the planned growth in public projects is in harmony with the corresponding growth in industrial revenue and, accordingly, the pursued target corridor for the Rho-Wi can be met.

Institute as a whole	2021	2022	2023	2024	2025
KoWiKap*	227	239	251	263	271
Industry revenues	12,857,470	13,765,011	16,622,770	18,270,842	20,282,245
Operating budget	36,719,728	37,408,251	41,650,308	45,768,252	48,798,521
Rho-Wi**	35%	37%	40%	40%	42%

* KoWiKap= Cost-effective capacity
** Rho-Wi= Percentage of the operating budget made up by industrial income

Industrial revenues and operating budget: in Euro

6. SUMMARY AND PRIORITIZATION OF STRATEGIC GOALS

By 2025, the Fraunhofer IWES will have secured a reputation as an internationally renowned Institute for the cost- and time-efficient validation of wind turbines and wind farms. The Institute will achieve this by providing qualified support to project developers, OEMs, suppliers, and operators along the entire value-added chain of the global wind industry. This, in turn, will enable them to safeguard their investments thanks to its unique combination of highly specialized measuring and test infrastructure and leading methods expertise.

STEPPING STONES 2025

Financial Perspective	We will double industry revenues to €20 million by 2025.	We will generate 5% of industrial income in the hydrogen business field by 2025.	We will use cooperations and internal programs to accelerate the development of our methods expertise.	Our growth is based on a sustainably well-balanced budget.	We will reduce the financing of personnel from industry and BMWi funds to 60%. We will finance 40% by the EU, internal programs, the states, the Federal Ministry of Education and Research, the Federal Ministry of Transport and Digital Infrastructure, etc.
Customer and Market Perspective	By 2025 we will have at least five each of the most globally relevant OEMs, suppliers, developers, project developers, and operators as customers.	We will work on portfolio management that develops our core competences in line with customer and market requirements.	We will develop business models through to their international marketing by honing our methods expertise.	We will identify relevant fields of excellence from our core activities and develop these into an engine for innovation.	We will develop the target group- and market-specific presentation of our portfolio and core activities.
Technology and Digitalization Perspective	We will develop leading methods to accelerate life cycle simulation on real and virtual test benches.	We will structure the development of infrastructure, core activities, and skills based on detailed road maps.	We will promote structured Group- (Fraunhofer-Gesellschaft) and institute-wide (IWES) digitalization projects in the field of sector coupling (shared platforms).	We will professionalize our work in the field of QM and optimize our processes (SAP, digitalization).	We will further enhance our organizational structure and QM processes so as to implement our strategy.
Expertise and Development Perspective	We will use our expertise and infrastructure to develop the hydrogen business area.	We will strengthen our cooperations within the Fraunhofer-Gesellschaft in order to develop cross-sector skills and new business areas more efficiently.	We will promote an institute culture of transparency, appreciation, and cooperation which is focused on the joint achievement of goals.	We will develop the leadership skills of our managers based on our guiding principles.	We will create a decentralized structure at the Fraunhofer IWES and support this development through the introduction of alternative (digital) working methods (“new work”).

7. CONCLUSION AND FORECAST

As part of the broad and systematic review of the Fraunhofer IWES' strategic alignment, most of the paths pursued over the past five years have been shown to be expedient and these will be continued along through to 2025. The Institute remains committed to its "Focus on Validation".

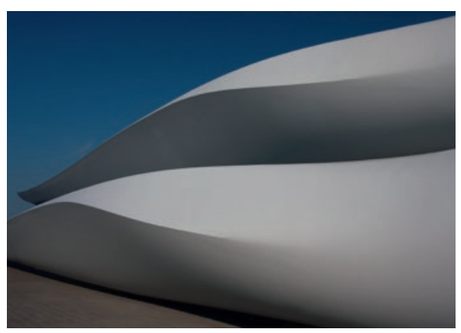
Some of the already recognized issues such as the digitalization of processes have proved to be as complex as originally assumed. The progress made here demands that we double down on our efforts in order to have marketable products in this field by 2025.

The issue of the diversification of the origin of public funds could not be realized as originally hoped. This, however, is also due to the pleasing fact that cooperation with the BMWi has been very positive and almost all the key projects could be implemented. As such, the responsible and reliable implementation of these activities took priority over the securing of new sources of income.

Major changes in the industry and the greater possibilities due to the development of expertise at the Fraunhofer IWES over recent years both demand and indeed enable additional content-based stimuli. The most important steps are the enhancement of the Institute's service portfolio for wind farm developers and operators as well as the creation of a new business area for hydrogen technology. This will be done in close cooperation with regional initiatives such as the North German Real Laboratory and coordinated with other institutes of the Fraunhofer-Gesellschaft which are also working on this technology.

Not least, the Institute will have to look closely at new forms of working and changes in the way staff work and interact in the near future. The term "new work" is used to describe a multitude of activities and offerings which will result in a completely new working culture. At the same time, the increase in the number of female employees, especially in managerial positions, as well as the internationalization of recruitment activities need to become top priorities.

The Fraunhofer IWES has every reason to anticipate continued success in the future based on the achievements to date. Ongoing contentual development, the professionalization of processes, and a willingness to embrace change are all necessary. The very best Fraunhofer IWES team of all time is ready to accept these challenges and make a major contribution to realigning the energy supply of the future.



CERTIFICATION AND ACCREDITATION

Quality, Occupational Safety and Environmental Management System
The Fraunhofer IWES' quality, occupational safety, and environmental management system is certified in accordance with DIN EN ISO 9001, DIN ISO 45001 and DIN EN ISO 14001.

The rotor blade, material laboratory and field measurement laboratory areas oft the Institute are accredited in accordance with DIN EN ISO/IEC 17025. Fraunhofer IWES offers accredited testing for the following fields in these laboratory areas: experimental structural testing of rotor blades, testing to determine the physical properties of fiber-reinforced plastics and fiber composites by means of mechanical-technological and thermal tests and also tests on the mechanical loading of wind turbines and measurement of wind turbine performance.

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The Fraunhofer IWES accredited laboratory has been approved for the testing of rotor blades as per IEC 61400-23 by the IECRE committee. The IECRE System (IEC System for Certification to Standards Relating to Equipment for Use in Renewable Energy Applications) offers an internationally valid certification system for products and services in the renewable energy sector. With this, we also satisfy the very highest safety requirements at the same time.

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