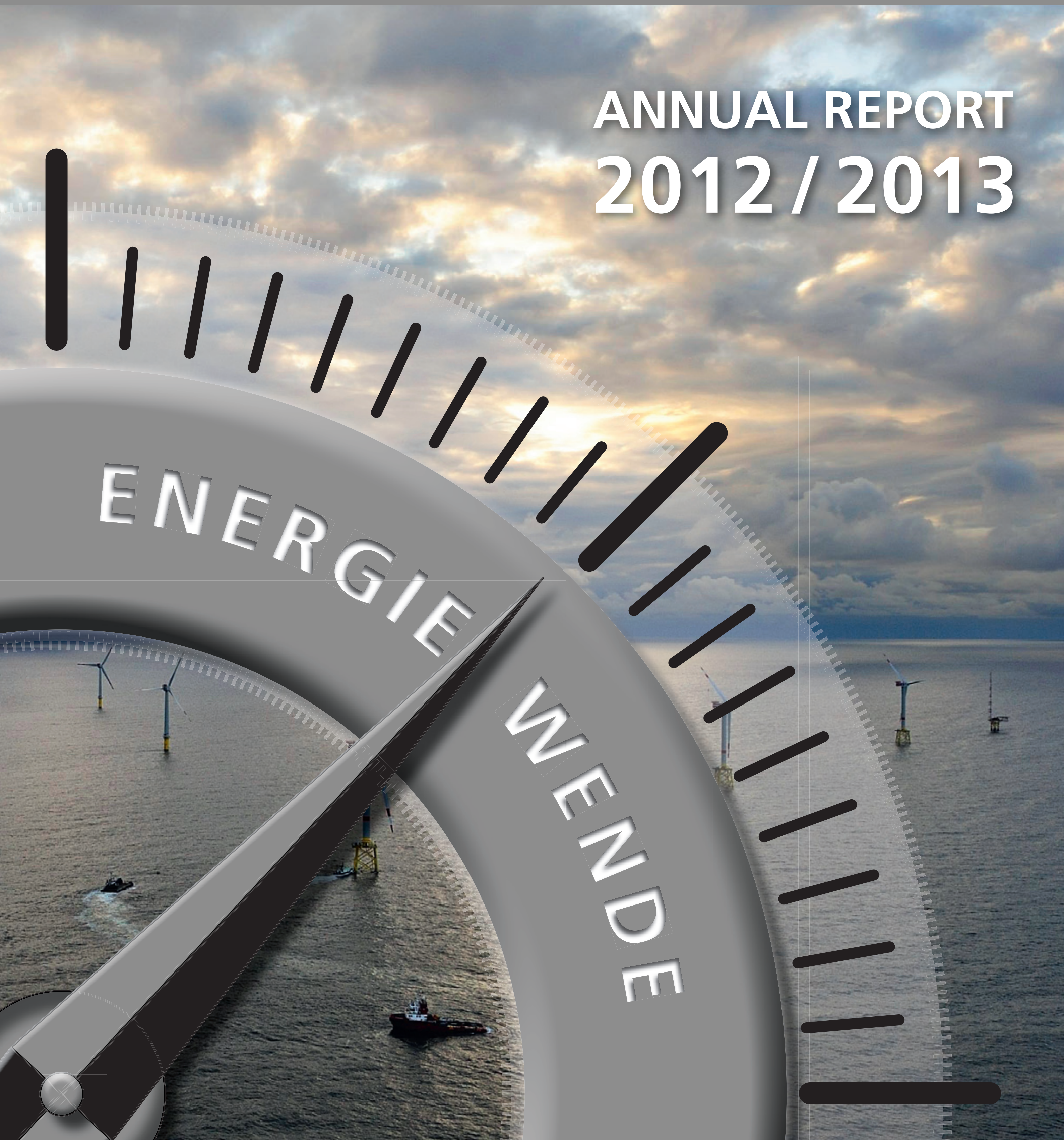
Fraunhofer IWES

FRAUNHOFER INSTITUTE FOR WIND ENERGY AND ENERGY SYSTEM TECHNOLOGY IWES

ANNUAL REPORT 2012 / 2013



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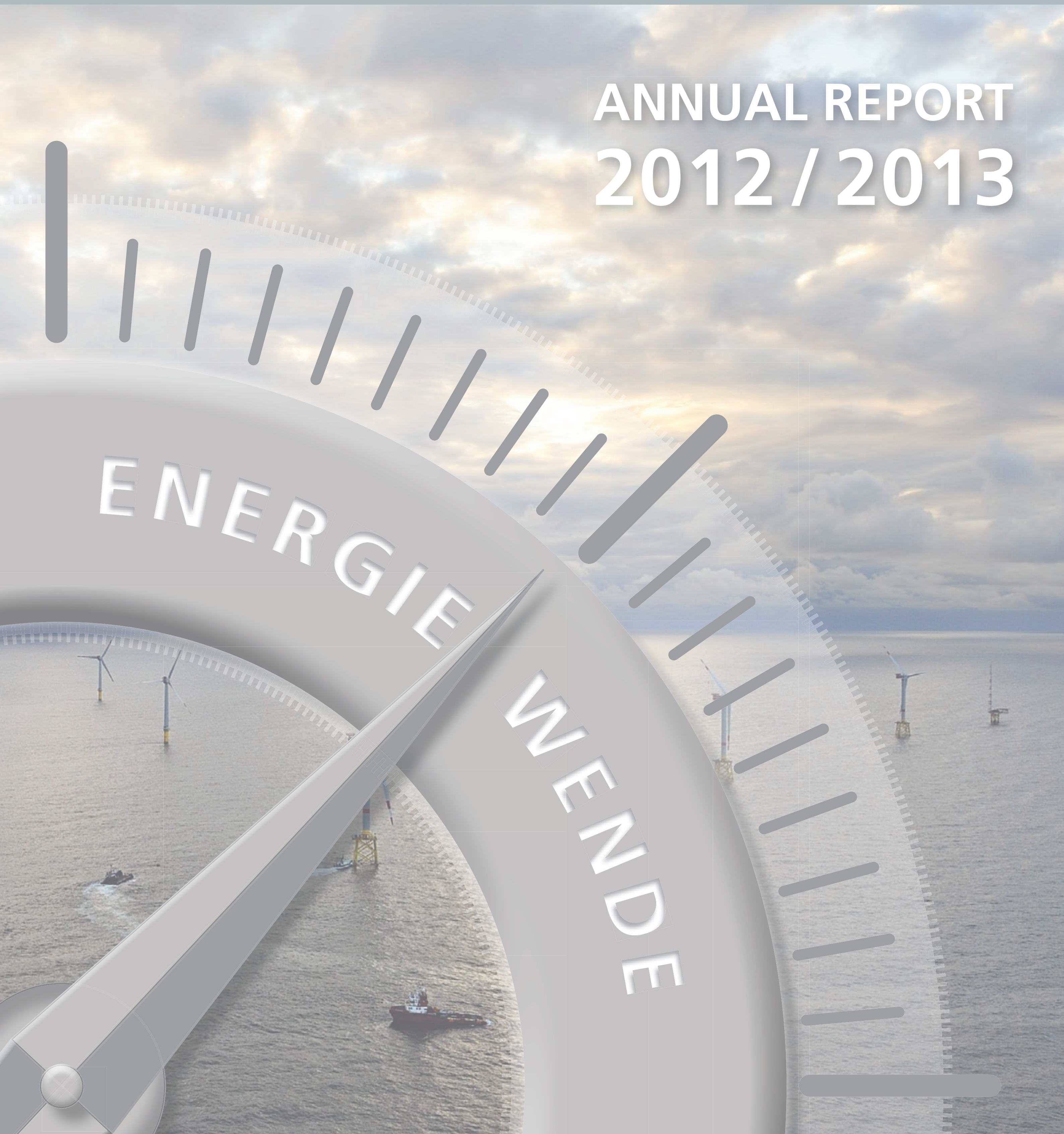

Fraunhofer Institute for Wind Energy and Energy System Technology IWES

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CONTENT

Preface

10 Percent of the "Energiewende" achieved!

This claim follows when comparing the final energy demands of consumers on the one hand with the production of renewable sources on the other. Once reaching 10 percent, the "Energiewende" now has to leave the shelter it has enjoyed during its initial stages of development and face much tougher competition. Further development is determined by infrastructural restraints and cash flow limitations. Such harsh winds are also being felt by both wind and solar plant producers. At present, there are significant overcapacities in both of these markets. This results in prices collapsing and producers getting into difficulties. Is the "Energiewende" in a crisis? Quite the contrary. Renewable energy power production becomes competitive rapidly due to the enormous pressures in the producer market.

Infrastructural questions must now be answered in order to increase renewable energy supplies from 10 to 80 percent or even to 100 percent. The age of the infrastructure has begun! This is where the real challenge lies. Tackling this herculean task requires a planned approach and forward-thinking planning is necessary in order to optimize the immense investment sums.

Fraunhofer IWES handles business model consulting, pre-production development as well as material and design validation for the technology areas of wind energy and energy systems technology.

What energy system technology actually is can be shown in this example: at present, what a sustainable concept for the future will look like is still very much in a state of flux. Is it a car powered solely by batteries, a vehicle by natural or synthetic gas, hydrogen in the fuel cell or methane in an internal combustion engine? Or is it a hybrid, a mixture of these different components? The answer can be found if one not only concentrates on the vehicle but rather on the complete system-technical chain, from the provision of the mobility service, the generation of the necessary energy, its transfer to the end consumers and along this chain, determining the availability, degree of efficiency, losses and costs.

Costs are further reduced by technicological development. In wind energy, larger rotors and greater hub-heights allow increased application inland. Here, exciting challenges for construction and regulation are to be found in the interaction between air current and the elastic structures of rotor blades with lengths of 80 to 100 meters.

Through connecting insights in the necessary infrastructures with economic issues, our institute has the required competence to provide support for decision-makers in companies and politics.

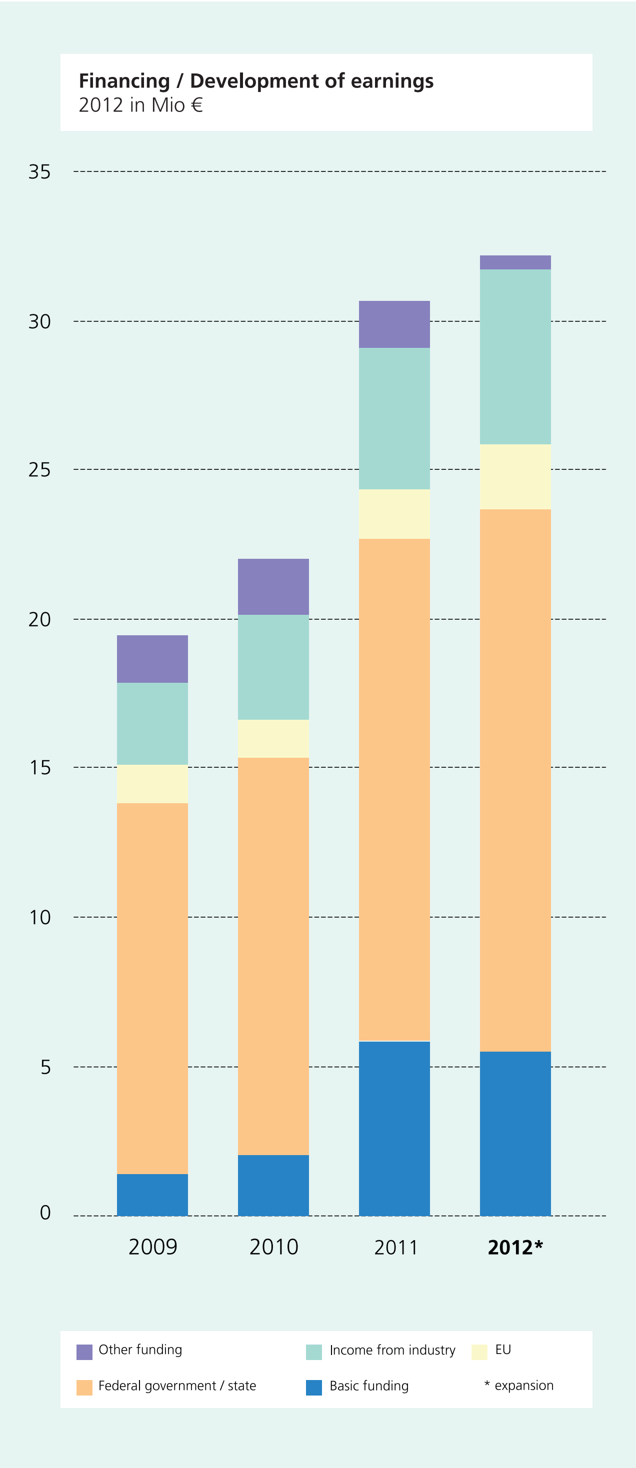
In order to cope with the tasks of the "Energiewende", Fraunhofer IWES has grown considerably in recent years. There were 200 staff members in 2009 compared with almost 500 in 2012. Further expansion is essential and planned. The necessary structures for this expansion will be created in business year 2013. An example of this is the formation, in the north-west, of a wind energy research association by DLR, ForWind and Fraunhofer IWES. Together with the authorities in the State of Hesse and the city of Kassel, planning is on-going for a new, large institute building in Kassel.

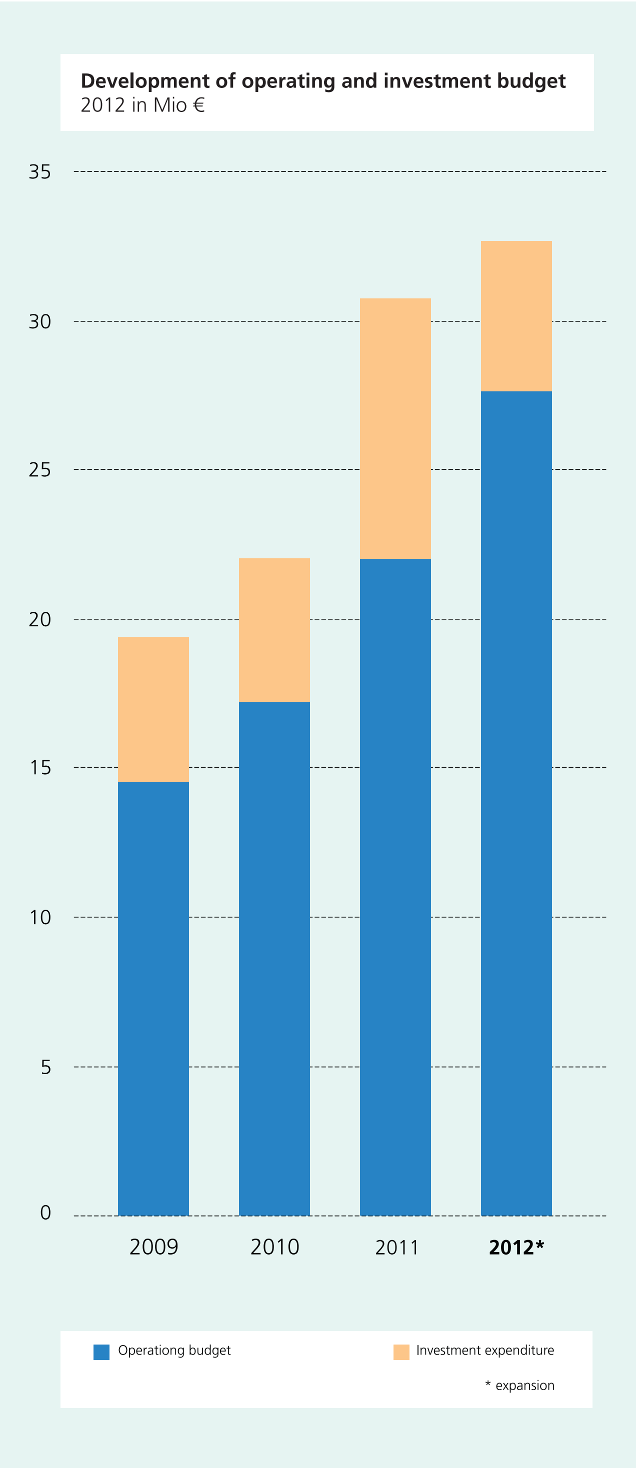
We look forward to cooperating with you!

Prof. Dr. Andreas Reuter
Director IWES North-West

Prof. Dr. Clemens Hoffmann
Director IWES Kassel

Fraunhofer IWES in Figures





Finance structure

The successful growth curve of the IWES was able to be continued in 2012. The overall budget rose in 2012 by a total of 1.8 million euros reaching 32.5 million euros altogether. An especially significant factor in this was the 25 percent increase of the operating budget in comparison with the previous year. Staff increase followed in accordance with the positive development of the operating budget.

Economic returns were also able to be increased significantly by a total of 1.1 million euros and overall economic returns for 2012 reached a new Institute's record of nearly 6 million euros. Equally gratifying was the development of EU receipts which rose by 500k euros and represented total earnings in 2012 of 2.1 million euros, that is to say 6 percent of the overall annual financial result. The special effects of the previous year in the field of public investment budget receipts, resultant from the completion of the Kassel test centres for new grids and biomass utilisation as also the completion in 2011 of the extension of the Bremerhaven rotor blade test halls, were no longer operant in report year 2012 and this led to a 43 percent reduction in the investment budget whereby overall public receipts in 2012 only showed a moderate rise of 8 percent in comparison with the precious year.

The investment budget value of 5 million euros now represents 15 percent share of the overall budget.

Personnel

as at 31.12.	2009	2010	2011	2012
scientists	110	138	192	232
technical staff	30	29	36	43
administration / internal services	25	31	48	53
assistants, trainees and students	29	27	100	151
total	**194**	**225**	**376**	**479**

Future Field Wind Energy

Wind energy

The benefits of research nowadays must be tangibly and quantifiably convincing: whether with shorter development times through realistic prototype testing, increased efficiency through aerodynamically optimized designs or a longer service life of the wind energy turbine through improved control and maintenance strategies, investments in research have to bring returns. In times of global one figure market growth however, the mode of "getting through the winter on a low flame" offers no new perspectives. The Fraunhofer IWES portfiolio with its highly developed technologies and unique infrastructure offers a "springboard" for the ambitioned company targets of wind branch players, enabling them to reach new heights.

In order to achieve this, it is necessary to perceive the wind energy turbine as a dynamically integrated system. The better the individual components are attuned and interact, the smoother the operation and the more full-load hours can be produced. Whosoever wishes to monitor turbine behaviour and as a next step optimize it, does not need extra spectacles but a wide field of vision. For this reason, the Fraunhofer IWES will be expanding strategically on its expertise in the coming years, using its own test fields, in order to be able to perform measurements and, at the customer's request, to support the complete turbine on a conceptional level.

Beyond controlling, the investment achieves an additional value in its own future viability, not expressed 1:1 in pure figures: user and cooperation partner satisfaction, attractiveness for employees, investor trust, discernability in the increasingly professionalized environment, image gain through technological leadership, and Germany's reputation as a technological base. And last but not least: the contribution towards a timely remodelling of the existing energy system which will have a decisive impact on the quality of our lives of and those of following generations. A task nobody can achieve alone.

Breathing space for further development

With a view to these key objectives, pre-competitive cooperative research seems to be a suitable remedy. The fundamentals can be developed in joint projects in order to allow all the parties to pursue their company targets. The IWES and the Deutschen Messe AG were able to give some initial impetus to the area of rotor blade and generator production technology during practical expert meetings in 2012. The event series served as a platform for a knowledge exchange between noted players and companies who had previously been active in other industrial branches such as, for example, automation or process technology, but now wish to serve the area of wind energy. A target oriented consolidation of various perspectives and know-how is important in order to stay on course in the ever changing wind energy market – the course in question being professionalization and large quantities for the time after recession. Delayed developments also embody the chance of using the time for increasing the technological toolbox and paving the way for improved competitiveness.

Industrialization and professionalization

In recent years, rising expectations concerning the reliability of turbines and new highly efficient generator concepts using permanent magnets have lead to the start of a change in trends: in particular, for the next generation of offshore turbines, the direct-drive concept with its competitive weights, dimensions and high reliability seems to have asserted itself on the market. This highly integrated approach requires though, a higher degree of automation in production processes; the current manufacturing level is not cost effective.

Power electronics is of key importance in all modern turbine concepts, regardless of the mechanical composition of the drive train. Inverter systems ensure line-frequency connection for variable-speed turbines. These components have higher demands on permissible environmental conditions and are often development derivatives from other branches of industry.

As a result, these components are increasingly at the top of breakdown statistics.

Within the framework of the ReliaWind-Project for variable-revolution turbines the most recently completed reliability study has shown that the share of gear-failure breakdowns only lies at five per cent, whereas around three times as many breakdowns and even 18 percent of downtime stems from the inverter system.

The causes for component failures are often only ascertained after great expense. A combination of extreme environmental conditions and wind-typical dynamic stress places high demands on inverters. More specifically, defined developments gained from true wind energy turbine operational conditions as also knowledge borrowed from extremely high reliability demand areas – e.g. the space industry – can be of great help in the future. A selective introduction of redundancy in the generator inverter system enables continuing operation of the dynamo, with reduced performance, in the event of fault. If wind speeds are low the turbine can even function completely without any notable loss of performance. This is a particularly important aspect for offshore turbine availability when turbine maintenance accessibility is greatly reduced in comparison with the onshore turbine.

The urgent need for action in the area of reliability in electronic performance systems in wind energy turbines has been recognized by the IWES: in 2012 a study carried out at Chalmers University of Technology, in close collaboration with partners such as Wattenfall, provided the first indications of breakdown causes and breakdown mechanisms in inverter systems. With the aim of contributing to the clarification of failure conditions and, based on this knowledge, to help develop reliable electronic performance for existing as also future turbines, the IWES is now expanding its activities in this field of research.

Production optimization: quality drive and cost reduction

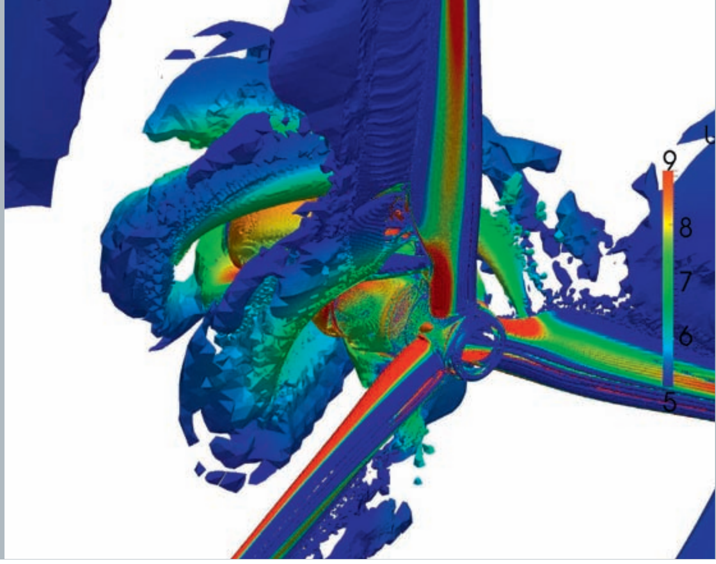
Potential for automated rotor blade production on an industrial scale is also highly rated. In the BladeMaker project, in collaboration with industrial and research partners, IWES scientists are studying the extent to which an upgraded automated production process can reduce the high cost pressure experienced by blade producers in the context of international competition. The complete assembly chain of rotor blade production is taken into consideration in order to achieve an overall production cost reduction well above ten per cent. The setting up of a demonstration centre should serve industry as a "shop window" to render own automisation potential accessible.

Intelligent rotor blade research

A further future issue aimed at the enhancement of wind exploitation is the so called Smart Blade. This issue is being addressed by the Wind Energy Research Group, the Fraunhofer IWES together with the Deutsche Zentrum für Luft und Raumfahrt (DLR), and the Wind Energy Research Centre formed by Oldenburg, Hanover and Bremen Universities (ForWind). The interfacing of over 600 scientists creates a network of competencies and is of great importance for further understanding of the system. With mutual collaboration, major, long-term and strategically important projects can be executed from ground research to implementation.

Relevant collaboration started in January with the BMU – funded project called "Smart Blades – Intelligent Rotor Blade Development and Construction". The project's target is to develop Smart Blade technology capable of reducing rotor blade fatigue loads.

On account of the increasing number of rotor blade formats pitch regulation is approaching its limits: in the meantime,



rotor blades of up to 85 meters in length cover per revolution an area equivalent to several football fields. Gusting characteristics lead to strongly varying wind conditions within this large area. A complete, relatively slow repositioning of the rotor blade can not compensate these changes in wind current with sufficient speed. Smart Blade systems provide remedial action: with trailing edges which form is changeable or flaps which can divert wind flow as necessary. Very large rotor blades equipped with such mechanisms can specifically compensate gusts and reduce performance variations and furthermore, indicate no reduction in long life. The challenge is not to allow such rotor blades equipped with active mechanisms to become more prone to faults nor to demand heavier and more intensive maintenance. All this must be attained without an increase in cost for the whole installation.

The researchers expect that the incurring load-reduction will enable an aerodynamically optimized and lightener design for wind energy turbines. The changes in design allow the reduction of material and logistics costs and increase the operating life of the turbine.

Validation of fibre composite materials

Investments in building up a testing infrastructure for fiber composite materials and whole rotor blades within the last years created a service spectrum that is a fundamentally contribution to Fraunhofer IWES´ portfolio. At present, our engineers are performing a fatigue test with the world´s longest rotor blade – 83.5 meters – and further "giants" will follow. Besides tests of whole rotor blades Fraunhofer IWES offers production and test of fibre composite test specimen and subcomponents. Therefore, the complete development chain is covered and uncertainties for the scale-up process to design stage can be reduced. In addition to mechanical stress tests, environmental loads can be applied on specimens in a climate chamber. The temperature, humidity, UV light, and salt content create a realistic and repeatable scenario.

By constructing tests stands for other important components of a wind energy turbine – like the nacelle or support structures – IWES is extending the successful concept. Industry leaders take an active part in defining the testing procedures in order to assure a use-oriented development due to the requirements of the wind energy sector.

Future Field Energy System Technology

Energy system technology

We are convinced that a future energy supply system can be built completely on renewable energy sources. In order to reach this goal, we have already developed different key technologies towards prototypical functional maturity. The cost of our "Energiewende" over a thirty year stretch amounts to about 1 percent of our German gross domestic product. By way of comparison: The Apollo project in the 1960s cost approx. 0.25 percent of the USA gross domestic product of that time over a period of ten years. Relatively speaking, it can be seen that our mission is four times larger and has to stay the course over a period which is three times longer. Meaning to say that the "Energiewende" as a project is a tremendous challenge but it is not astronomically greater than flying to the Moon.

The scientific and technological tasks for research and development lie for the most part in cost reduction and the further development of different conversion technologies as well as a new energy system technology with the aim to realize reliable and stable supply systems using 100 percent renewable energy under complex technological, economic and environmental boundary conditions. Energy system technology as a discipline focusses not so much on the individual components of generation and consumption but targets the optimal mixture of components necessary for a well functioning system as a whole. Deriving from considerations on the system level, new requirements for the design and control of the individual subsystems and components may emerge.

Main elements for a new holistic energy system technology include:

- the design of energy supply systems, i.e. the number, mixture and spatial distribution of different forms of generation
- the design of energy grids
- the design of control structures for generation, transmission and consumption for the system in operation
- Modeling of the environment, where the latter provides parametric input to the technical system
- Measurement technology for technical and environmental quantities
- Development of new actuators at the interfaces between the system components
- Energy storage
- Communication technology for transmission of measurement, control and economic quantities
- Micro- and macroeconomic assessment of the design for energy supply systems
- Design and analysis of market regulatory instruments used in transforming energy supply systems.

Examples of our research activities include:

Simulations and scenarios for the "Energiewende"

As part of studies and investigations, IWES generates a 15 minutes to hourly feed-in data of renewable energies. The computations are based on meteorological and hydrological conditions from different years which would happen in different scenarios. This results in very detailed time series for wind, solar, geothermal, biomass, and hydro power which can be used for assessing network expansion, the addition of storage systems, and the management of the energy economy. In addition conventional power generation scheduling and the balancing of fluctuations due to electrical transport, storage, and energy management are modelled. Therefore Fraunhofer IWES is providing a unique simulation platform on a powerful computer cluster with high time and spatial resolution. This is coupled with software tools for load flow calculations and planning and analysis tools. These simulations are being used to develop scenarios to expand the score of renewable energy, right up to a completely renewable energy supply, and for measures for the integration and harmonization of renewable and conventional electricity generation.

Increasing the wind energy use potential on land

The use of wind energy on land will play an important role as a pillar of future energy supply systems. Many German federal states are formulating new, and clearly more ambitious wind energy expansion targets reaching a total of around 60 GW by 2020. The technological development of wind turbines in recent years has lead to the availability today of especially high towers and large rotors. This has caused the potential of on-land wind energy use to increase significantly. This was confirmed in a Fraunhofer IWES study carried out on behalf of the Federal Association for Wind Energy (BWE). It was able to be shown that the proposed BWE target, 2 percent of German land to be developed for wind energy power production, is technically possible. This would be sufficient, using large, modern wind energy turbines with hub heights of up to 150 meters, to meet approximately 60 percent of present German electricity needs.Therefore exact knowledge of hilly or wooded inland region wind characteristics by high-resolution measurements and models is indispensable. Beside established measurement methods with wind measure masts IWES researchers are using LIDAR (laser-supported wind speed measuring) systems and developing methods for the deployment of the measurements in complex terrain. This new ground-based remote measuring technology should be capable, in the long term, of replacing wind measuring masts.

Characterization of offshore wind farm site conditions

It is compulsory to carry out geophysical measuring at the start of any offshore wind farm geological survey. The aim is to quickly and extensively determine the geological conditions of an area without having to carry out numerous time consuming sampling operations (geological drilling, cone penetration tests). This information is of utmost importance for the stability and serviceability of offshore wind energy turbines and the selection and dimensioning of foundations. The newly-developed and globally unique Fraunhofer IWES shallow-water measuring system is the missing link between established high-frequency single-channel seismics and low-frequency multi-channel seismics used in the field of hydro-carbon exploration. Its first use in the North Sea has shown that it is especially suitable for surveying construction site conditions in offshore shallow-water areas and that it is capable of increasing the quality of geophysical measurement data significantly.

Modern control systems for wind turbines

The growing height and rotor diameter of wind turbines exert an enormously increased structural load. Modern control systems limit and reduce both extreme loads and operating loads. Active load reduction through individual pitch control encompasses two different targets: the reduction of periodic excitations caused by dissymmetric air flow and the attenuation of natural oscillation through controlled generation of aerodynamic counterforces. The first target comprises pitch and yaw moment compensation at which these moments are measured and then compensated through individual pitch control. To do this a small individual offset to the collective pitch angle is predetermined for each rotor blade and varies cyclically with the rotor revolutions. The second target comprises active tower vibration damping whereby through individual pitch control periodic aerodynamic force components are generated in antiphase to the displacement speed at the head of the tower.

Grid integration of wind and solar energy

The Wind Power Management System (WPMS) of Fraunhofer IWES is a system that is used both nationally and internationally to forecast the wind energy supply in the short and medium term and is being continuously further developed. In the future renewable energies will frequently cover the overall energy demand. Conventional power stations will be used sparingly or shut down and renewable energy will provide system services to support stable grid operation. Fraunhofer IWES is developing tools such as online and forecasting models and

systems for managing power generation clusters to aid voltage and frequency control. Windfarm control systems coordinate the dynamic interplay of individual wind turbines taking into account the interactions caused by wake effects and observing numerous other criteria. This demands the use of highly developed optimization processes capable of handling multi-criteria target functions.

Expansion of photovoltaics and decentralized grid integration

The requirements for safe and reliable grid operation must also be achieved when a high number of PV systems are integrated into the grid. Fraunhofer IWES is evaluating measures for reducing local overvoltage in distribution networks and impermissibly high loads on equipment. This approach often allows capital-intensive grid expansion to be delayed or even avoided. Controllable PV systems can, for example, increase the capacity of distribution grids by making grid services available and so make an important contribution to reliable and safe grid operation. Work is therefore being carried out at Fraunhofer IWES to systematically investigate the control of photovoltaic systems and photovoltaic battery systems in grid operations. In consultation with manufacturers, grid operators, regulators, and testing institutes, new requirements for decentralized electricity generators are evaluated here.

Bioenergy on demand

Bioenergy, being a storable form of renewable energy, has a special role to play in future energy supply structures. For electricity grids in particular, it can be used as an as-needed form of energy to help balance supply and demand. Fraunhofer IWES has adopted a systemic approach and is making a key contribution to the integration of bioenergy into supply structures. This work covers all forms of bioenergy – from direct conversion into electricity via the combined production of heat to the production of natural gas substitutes and fuels. When designing technologies, sustainable concepts must be developed which allow bioenergy to be used with the highest possible efficiency, and utilizing its special properties. This is because biomass cannot fulfil all applications, nor as a single form of energy cover all needs. It is also essential that the technologies allow a seamless transition from the current fossil fuel dominated energy landscape via hybrid systems to eventually total renewable supply structures.

Long term storage: Connecting electricity and gas networks

For balancing over short periods, pumped-storage power stations are a good solution although their capacity in Germany is limited. They can only alleviate fluctuations over a short period. Fraunhofer IWES is researching with partners in the long term storage concept Power-to-Gas. At times when more renewable electricity is generated than can be used or transported across the network, this excess energy is used to split water into oxygen and hydrogen. Subsequently a methane-rich gas is produced in a Sabatier process from hydrogen and CO_2, and this gas is equivalent to natural gas. This can be fed into the natural gas network, which provides roughly 3,000 times more than the German pumped-storage power station capacity. If required, the stored gas can be fed back to gas power stations and so help to bridge shortages in renewable power generation for up to 2 months. The renewable gas also plays an important role in the de-carbonization of transport.

Renewable E-Mobility

Renewable energy sources and e-mobility are the future of individual transport. Fraunhofer IWES is working on advanced power supply concepts and their integration into future energy supply structures. It develops bi-directional power transfer systems for inductive charging, emulations of real batteries (virtual batteries) and strategies for efficient energy management.

Brief Portrait of Fraunhofer IWES

Objectives and main areas of work

The research activities of the Fraunhofer Institute for Wind Energy and Energy System Technology IWES cover all aspects of wind energy and the integration of renewable energies into energy supply structures.

The main areas of research are:

- Technology and operational management of wind turbines and wind farms
- Dynamics of wind turbines and components
- Component development for rotors, drive trains, and foundations
- Test and evaluation methods for wind turbines and components
- Environmental analyses of wind, sea, and seabed for utilization of wind energy and marine energy
- Control and system integration of decentralized energy converters and storage systems
- Energy management and grid operation
- Energy supply structures and system analysis

Development of Fraunhofer IWES

The growth of the institute was continued in 2012 and revenues were increased to approx. 32.5 million euros in total. Of this sum, 5 million euros were invested in infrastructural expansion. Income from industry grew from 4.8 to 6 million euros. The staff grew up from 370 employees in 2011 to 480 in 2012.

By agreement with the Fraunhofer-Gesellschaft, the institute directors also hold professorships at the universities in Hanover and Kassel. Fraunhofer IWES North-West is headed by Prof. Dr. Andreas Reuter who is professor of wind energy technology at the University of Hanover. Since October 2012 the new director of the Kassel site is Prof. Dr. Clemens Hoffmann who is also professor at the University of Kassel. He followed Prof. Dr. Jürgen Schmid who has been chairman of the former ISET executive board since 1998 and director of Fraunhofer IWES Kassel since 2009. For his "special services to the cultural and scientific life of the State of Hesse" Eva Kühne-Hörmann, the Hessian Minister for Science and the Arts presented the highest award of the ministry, the Goethe-Plakette to Jürgen Schmid. The Fraunhofer Executive Board honoured him with the Fraunhofer Medal, the highest award of the Fraunhofer-Gesellschaft.

Fraunhofer IWES was founded at the start of 2009 through the merger of the former Fraunhofer Center for Wind Energy and Maritime Engineering CWMT in Bremerhaven and the Institut für Solare Energieversorgungstechnik ISET e.V. in Kassel.

Collaboration

Fraunhofer IWES works very closely with the ForWind alliance universities of Hanover, Oldenburg, and Bremen. Both partners and the DLR form the new Wind Energy Research Alliance. Further intensive collaborative work is carried out with the University of Kassel. Moreover, amongst other colleagues, contact with the Bremerhaven Technical College has been strengthened.

The Hessian Biogas Research Center – HBFZ at the Landwirtschaftszentrum Eichhof in Bad Hersfeld is running jointly with the Landesbetrieb Landwirtschaft Hessen and Fraunhofer IWES. Within the Fraunhofer-Gesellschaft, use is made of the expertize and experience of partner institutes especially through the Fraunhofer Energy Alliance, and in Fraunhofer networks in the area of Wind Energy and Smart Grids. At a national and international level the institute successfully collaborates with many public and industrial research organizations. The application-oriented work of Fraunhofer IWES is highlighted by the large number of direct projects and contracts with industry. Our research results are the basis for the participation of many IWES scientists in national and international bodies such as DKE, CENELEC, and IEC and the use of those results for standardization and norms.

With its technical expertize, Fraunhofer IWES is thus able to shape political and commercial decision-making processes, for example the drawing up of the Renewable Energy Act (EEG), development of offshore wind energy utilization, development of future energy supply structures, and participation in the German Advisory Council for Global Environmental Change (WBGU).

Professorships with complementary departments at IWES

Prof. Dr.-Ing. Martin Braun	University of Kassel
Prof. Dr.-Ing. habil. Siegfried Heier	University of Kassel
Prof. Dr.-Ing. habil. Lutz Hofmann	Leibniz University Hanover
Prof. Dr.-Ing. Friedrich Klinger	Hochschule für Technik und Wirtschaft des Saarlandes
Prof. Dr.-Ing. Axel Mertens	Leibniz University Hanover
Prof. Dr. rer. nat. Joachim Peinke	Carl von Ossietzky University of Oldenburg
Prof. Dr.-Ing. Bernd Ponick	Leibniz University Hanover
Prof. Dr.-Ing. habil. Raimund Rolfes	Leibniz University Hanover
Prof. Dr.-Ing. Peter Schaumann	Leibniz University Hanover

1 *New institute building in Bremerhaven*

2 *Fraunhofer IWES in Kassel*

Test Centres and Laboratories

Support Structure Test Center

Starting in 2014, the Fraunhofer IWES in cooperation with the Leibniz Universität Hannover and the Center for Wind Energy Research ForWind will be offering a testing area for large-scale support structures, tailored to the needs of the industry. But even before the opening date, it is worthwhile to make contact: You can discuss test designs and possibilities early and make a reservation for your preferred period of time. We are looking forward to fathom with you the way to low-cost offshore wind power and thus to facilitate its future development. The Support Structure Test Center is suitable for all types of support structures and offers two large-scale test facilities: The foundation test pit enables exploration and evaluation of support and foundation structures and affiliated construction methods for their offshore installation in 1:10 scale and larger. On the span large-scale (1:9 to 1:5) support structures or large components can be clamped in with the aim of examining their fatigue behavior using multi-axial loading. In order to be able to fulfill preliminary tasks and accompanying examinations, the test center has special laboratories for steel, concrete, composites and geotechnical studies. Furthermore it is equipped with an autoclave, a resonance test machine and a salt water spray chamber with ocean climate.

↘ Dr.-Ing. Holger Huhn, holger.huhn@iwes.fraunhofer.de

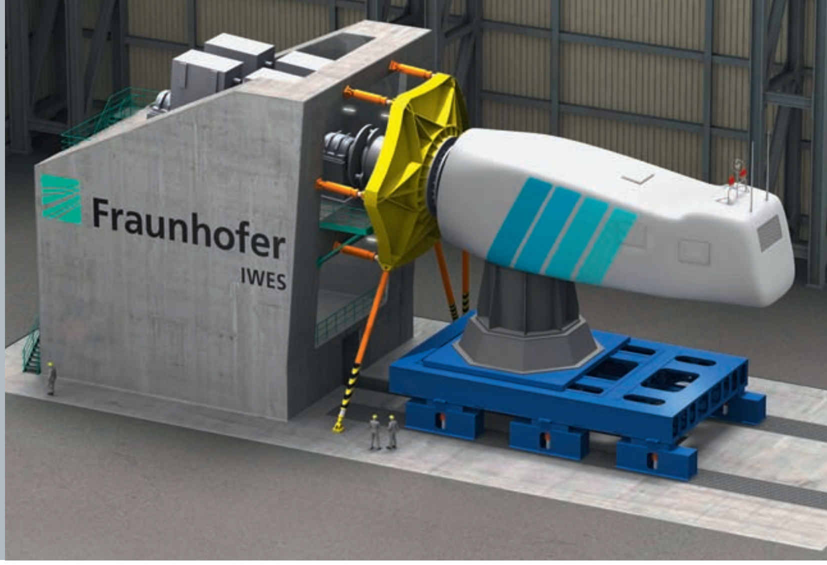
Offshore test locations and climate chamber

The cumulative loads at an offshore test site differ considerably from the loads on materials in laboratory tests. Materials are subjected to extreme conditions offshore: temperature fluctuations, increased UV radiation, exposure to seawater, biologically induced corrosion and mechanical loads. At four test locations – Wilhelmshaven, Sylt, Helgoland and at the mouth of the River Weser – materials and components are being tested under offshore conditions in order to acquire new knowledge about the long-term stability of sensor systems. The results are used for validation and improvement of current laboratory test methods. Laboratory material tests designed to mimic and increase the real loads are able to give meaningful statements in a short space of time. In turn, these results are used for developing general standard tests for offshore materials and components. New methods for material testing are also developed for specific tasks.

↘ Dipl.-Chem. Oliver Kranz, oliver.kranz@iwes.fraunhofer.de

Fraunhofer IWES has developed a special offshore test chamber; which for the first time simultaneously simulates the mechanical and environmental loads that offshore wind turbines are subjected to. Mechanical and electronic flaws and design errors can be discovered using HALT (Highly Accelerated Life Test) and HASS (Highly Accelerated Stress Screening) testing procedures.These procedures give feedback about the reliability of the systems under test and their service life. This test facility provides information about the mechanisms of material failure which are used to design near-reality tests under laboratory conditions. Laboratory tests that give reliable statements about material behavior are beneficial for customers, due to the accelerated testing and the reproducibility of the results.

↘ Dr.-Ing. Claus Kupferschmidt,
claus.kupferschmidt@iwes.fraunhofer.de



Rotor blade testing

Fraunhofer IWES offers static and fatigue tests on full-scale rotor blades and further develop its methods continuously. The objective is to predict the mechanical performance of a rotor blade, according to certification standards, over its 20 year life-span in just a few months with an inproved approximation of the complex operational loadings. This implies also new methods for non-destructive testing. During static loading, the force applied to the blade from each hydraulic cylinder is controlled using a loadcell placed between the blade and the loading cable. This setup enables Fraunhofer IWES to precisely control the loads and the corresponding bending moment distribution in the blade throughout testing.

↘ Dipl.-Ing Falko Bürkner, falko.buerkner@iwes.fraunhofer.de

Component testing

Component testing provides characteristic values for the evaluation and development of rotor blade substructures. Blade details like ply drops and bonded seams can be detected on structural beam specimens with realistic dimensions. For structural characterization, an adaptable test bench of 12 m x 3 m with versatile loading capabilities is utilized. The test specimens can be stressed with powerful hydraulics. For precise testing results, thermography, ultrasonic sound and acoustic emission can be applied in combination with structural and detail models. These methods reveal for example the development of the damage process in the trailing edge bond line.

↘ Dipl.-Ing Florian Sayer, florian.sayer@iwes.fraunhofer.de

Material testing

Material properties that are specified during coupon testing are the essence for designing whole rotor blades. Fatigue and the static material behavior are the elementary factors. Fraunhofer IWES continually improves existing testing methods and considers testing results for further refining.

↘ Dipl.-Ing Florian Sayer, florian.sayer@iwes.fraunhofer.de

DyNaLab: Dynamic Nacelle Laboratory

Within the scope of its publicly promoted research project DyNaLab, Fraunhofer IWES is working on a large-engineering test stand for complete nacelle of wind power plants. For the first time in Germany, beginning 2014, the DyNaLab will be a realistic test environment that is available to all wind power system manufacturers in the megawatt range so that they can carry out meaningful laboratory tests for assessing and streamlining existing and future turbine designs. The technical requirements for this test and experimental platform were defined in close cooperation with the wind power industry and research & development partners.

This pod test stand with a planned drive output of approximately 10 MW will have additional equipment for simulating various network states to replicate fault ride through scenarios and compatibility tests with various grid codes. On the one hand, the fact that it is designed for hardware-in-the-loop operation will make it possible to realistically simulate dynamic loads on the rotor shaft. On the other hand, this makes it possible to replicate the conditions at the network in-feed point. The setpoints for test stand regulation are calculated in real-time with the aid of turbine and wind simulation models. The goal of future work will be working together with business partners from industry and research to work out and validate interface definitions for drive train components and plant subsystems.

↘ Dipl.-Ing. Martin Pilas, martin.pilas@iwes.fraunhofer.de
↘ Dr.-Ing. Jan Wenske, jan.wenske@iwes.fraunhofer.de

Performance test areas for small wind turbine prototypes up to 50 kW

Fraunhofer IWES has installed two performance test areas for small wind turbines: in Bremerhaven, directly next door to the engineering building and the rotor blade test halls, and on the SysTec grounds very close to Kassel. Successful small wind turbine projects require robust, cost-effective design and best possible production management. The aim therefore is to optimize prototypes and commercial turbines in long-term tests in preparation for later certification. The test infrastructure enables the operation of small wind energy turbines with a performance of up to 50 kW and with a maximum height of 60 meters.

↘ Dr.-Ing. Jan Wenske, jan.wenske@iwes.fraunhofer.de
↘ Paul Kühn, paul.kuehn@iwes.fraunhofer.de

Laboratory for control systems for large wind turbines

A development platform for pitch control systems for rotor blades for large wind turbines is available in Kassel which enables load-reducing control systems to be developed. The test stand allows realistic testing of three interacting, controlled pitch drives for individual blade pitch control. Near-real counter-moments are produced via the real-time simulation of large wind turbines using synthesized inhomogeneous and turbulent wind fields. Additionally there is a test stand for antagonistically controlled pitch drives which permits very low-load blade pitch control.

↘ Martin Shan, martin.shan@iwes.fraunhofer.de

Wind measuring network and 200 meter measuring mast

Fraunhofer IWES has since 1990 operated a Germany-wide network of measuring masts. The network currently comprises 30 masts. All the measuring stations are close to wind farms and are fitted with MEASNET calibrated anemometers. Besides the standard 30 m masts (for wind measurement at heights of 10 m and 30 m), four 50 m masts have also been erected. These allow not only wind conditions but also other meteorological data to be recorded. The measurement data are recorded at a sampling rate of 1 Hz and are transferred hourly in 5 minute data sets to the data center in Kassel. In addition, Fraunhofer IWES operates three mobile LIDAR measuring units and these will be complemented this year by a 200 m measuring mast.

↘ Paul Kühn, paul.kuehn@iwes.fraunhofer.de

High performance computing cluster

A high performance computing cluster with 320 cores and 2.5 TB of memory is available for CPU-intensive tasks. It is able to simulate large scenarios for future energy supply structures in high temporally and regionally resolutions. A simulation environment is indicating the complete power supply (production, storage, grid and consumption). For producers of renewable energies in Europe dynamic simulations of expansions on basis of regionally high resolute aptitude and analysis of potentials are calculated as well as the simulation of temporally feed profiles with a resolution of a minimum of 15 minutes.

↘ Michael Scheibe, michael.scheibe@iwes.fraunhofer.de

IWES SysTec: Test Centre for Intelligent Networks and Electromobility

The new Fraunhofer test centre for intelligent networks and electromobility IWES SysTec was brought on line in 2011. The test centre comprises:

- PNI Grid Integration Research and Test Laboratory
- TPE Electromobility Test and Proving Centre
- Photovoltaic System Outdoor Test Areas

↘ Dr. rer. nat Thomas Degner, thomas.degner@iwes.fraunhofer.de

Outdoor testfields for photovoltaic systems

In outdoor test fields for photovoltaic systems, individual modules and complete systems are measured over a long period in accordance with European guidelines for different manufacturers. Kassel is a key reference site for standardized tests offered by DERlab e.V. Europe-wide.

↘ Peter Funtan, peter.funtan@iwes.fraunhofer.de

IWES PNI: Grid Integration Research and Test Laboratory

The new PNI is a reference laboratory, in which grid components and power supply operation equipment can be realistically developed and tested with regard to new system functions. The main focuses are grid storage interfaces, generators, combined heat and power plants, variable loads, electric vehicles, and adjustable transformers. The infrastructure enables investigation in low and medium voltage grids with a performance of up to 6 MVA. The laboratory can provide proof of behaviour of the devices and equipment under varying grid conditions especially in regard to the following aspects: static voltage support, voltage maintenance, dynamic voltage support, feed and load management, frequency support, co-ordinated control characteristics.

↘ Dr.-Ing. Gunter Arnold, gunter.arnold@iwes.fraunhofer.de

IWES TPE: Electromobility Test and Prove Centre

In the IWES TPE, IWES and partners from industry and the Kassel University research association for vehicle systems technology develop and test electric vehicles, batteries and charging systems as well as grid integration. On a dynamometer, vehicles and battery layouts in specific driving conditions can be tuned to compatibilty with the help of high-precision battery simulators (virtual batteries). Inductive loading is being further developed on electric vehicle charging stations and on a dedicated test circuit. Network simulators help develop the charging stations and the corresponding converter technology, and optimize them in response to new demands from so-called intelligent networks (smart grids).

↘ Markus Landau, markus.landau@iwes.fraunhofer.de

DERlab: European Distributed Energy Resources Laboratories

Under the direction of Fraunhofer IWES, the international non-profit association DERlab was founded at Fraunhofer IWES in Kassel. Over 20 leading research and test institutes are members of DERlab e.V., and carry out collaborative development of criteria for operation of decentralised energy generators on the grid. This development helps derive new test procedures and norms. The laboratory infrastructure is being built up in co-ordination with the partners whose work is therefore complementary. In the context of European research projects, DERlab offers the possibility of using its infrastructure for research purposes partly free of charge. The association's offer to carry out norm tests, such as grid integration tests, is also available to industry.

↘ www.der-lab.net

↘ Dr.-Ing. Philipp Strauß, philipp.strauss@iwes.fraunhofer.de

HBFZ: Hessian Biogas Research Center

The HBFZ came into being in August 2011. In cooperation with the Hessian state Laboratory (LHL) and the Hessian state Agricultural Institute (LLH) on the Training and Research Center Eichhof, Fraunhofer IWES operates an experimental center for bioenergy system technology in Bad Hersfeld (Hesse). The whole process chain from biomass production through to grid integration is covered here. A biogas test plant with a raw gas capacity of up to 50 m³/h is available for demonstration purposes and pilot plant trials. Up to 6 containers with test equipment can be provided. Experiments on biomass preparation, residue treatment, thermal biogas utilization, and gas upgrading and feed-in are possible. Laboratories are also available for investigating specific biological, chemical, and physical parameters.

Pilot plant station for bioenergy system technology

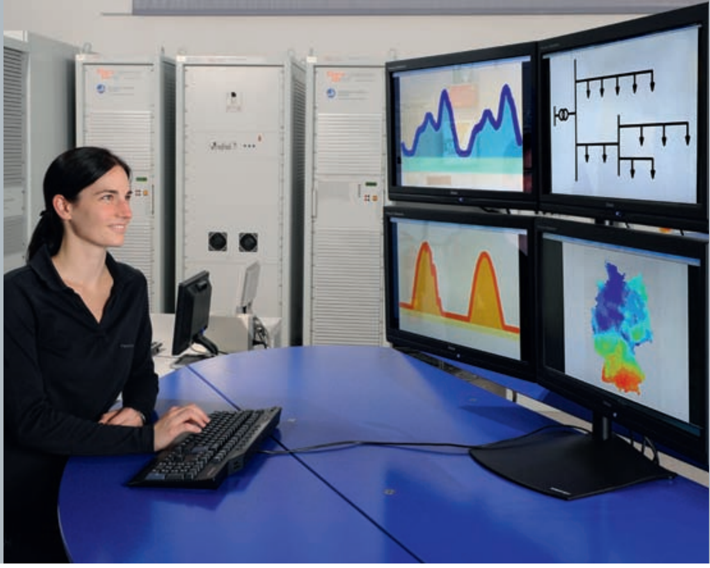
The IWES pilot plant station for bioenergy system technology offers a research infrastructure for projects dealing with the integration on bioenergy into energy supply systems. As it is embedded in the HBFZ, research projects concerning any parts of the whole agricultural bioenergy supply spectrum ranging from the farmer's field to the electrical socket can be dealt with. The technical equipment allows experiments with real gas in different degrees of size varying from the test tube to the mainframe plants.

↘ Dr.-Ing- Bernd Krautkremer,
↘ bernd.krautkremer@iwes.fraunhofer.de

Power-to-Gas Test Platform

Power-to-Gas is the generic term for a new technology which enables the sustainable, carbon-neutral storage and transport of regenerative energy in the form of hydrogen or methane. In this process, by means of water electrolysis, regeneratively-generated electricity is initially converted into hydrogen. This hydrogen can be either directly or, after the further step of methanation, fed into the natural gas grid as a synthetic natural gas or it can be intermediately stored. As preferentially CO_2 from a biogenic source is used for the methanation, there are thus synergies with biogas technology. This is the reason why the research platform was built at the Eichof in the Pilot Plant Station for Bioenergy System Technology, allowing research on this topic under real agricultural biogas plant conditions. The platform offers a technical infrastructure with raw gas conditioning, various desulfurization processes as well as different storage and utilization opportunities for the product gas, ensuring effective research under real conditions right through to technically relevant sizes in scale. A first project concerning the direct methanation of biogas has already been successfully completed.

↘ Frank Schünemeyer, frank.schuenemeyer@iwes.fraunhofer.de



DeMoTec: Design-Centre for Modular Supply Technology

The DeMoTec Center is jointly operated with the University of Kassel. Decentralized electricity generators, storage systems, loads, and novel energy management systems are developed and tested here. The network integration of converters and the design of hybrid systems and island grids have special roles. The control technology for decentralized grid services can be tested here on a real scale in combination with decentralized generators. In particular, systems for electrification in rural areas remote from the grid and on islands are optimized here and are used for training purposes. A reproducible hardware simulation of a 90 kVA grid connection and an adjustable direct current source allow accredited testing of grid converters and the evaluation of photovoltaic converters for example with regard to MPP tracking behavior.

↘ Markus Landau, markus.landau@iwes.fraunhofer.de

Accredited test laboratories for converters and electromagnetic compatability

Fraunhofer IWES, in its DIN EN ISO/IEC 17025 accredited laboratory, is investigating electromagnatic disturbance emissions and disturbance immunity as well as grid characteristics and efficiency factors of converters and decentralised power plants. The framework of accreditation covers, for instance BDEW tests, FGW-TR3 and DIN EN 50530, alongside the classic EMV testing norms. Development accompanying tests for the qualification of finished devices and components, especially converters, are also available.

↘ Jörg Kirchhof, joerg.kirchhof@iwes.fraunhofer.de

Development laboratories for converters

Fraunhofer IWES develops converters for wind turbines, battery systems and other decentralized electricity generators. Several laboratories are available for the development of electronic circuits. In the laboratory for microprocessor and device-oriented software technology, control circuits for converters can be developed using the hardware-in-the-loop and rapid-prototyping methods. The reliability of equipment can be tested in climate chambers and thermographically.

↘ Dr. Norbert Henze, norbert.henze@iwes.fraunhofer.de

Battery laboratories

The infrastructure for testing electrochemical systems comprises automated charging and discharging equipment, climate chambers, and the necessary measuring technology and safety technology. There is also a laboratory for testing fuel cell systems. These facilities are complemented by a development platform for virtual and multi-virtual electrochemical systems such as starter batteries and virtual lithium ion cells.

↘ Matthias Puchta, matthias.puchta@iwes.fraunhofer.de

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Drive train and system technology

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▸ Floating wind turbines ▸ Energy storage systems

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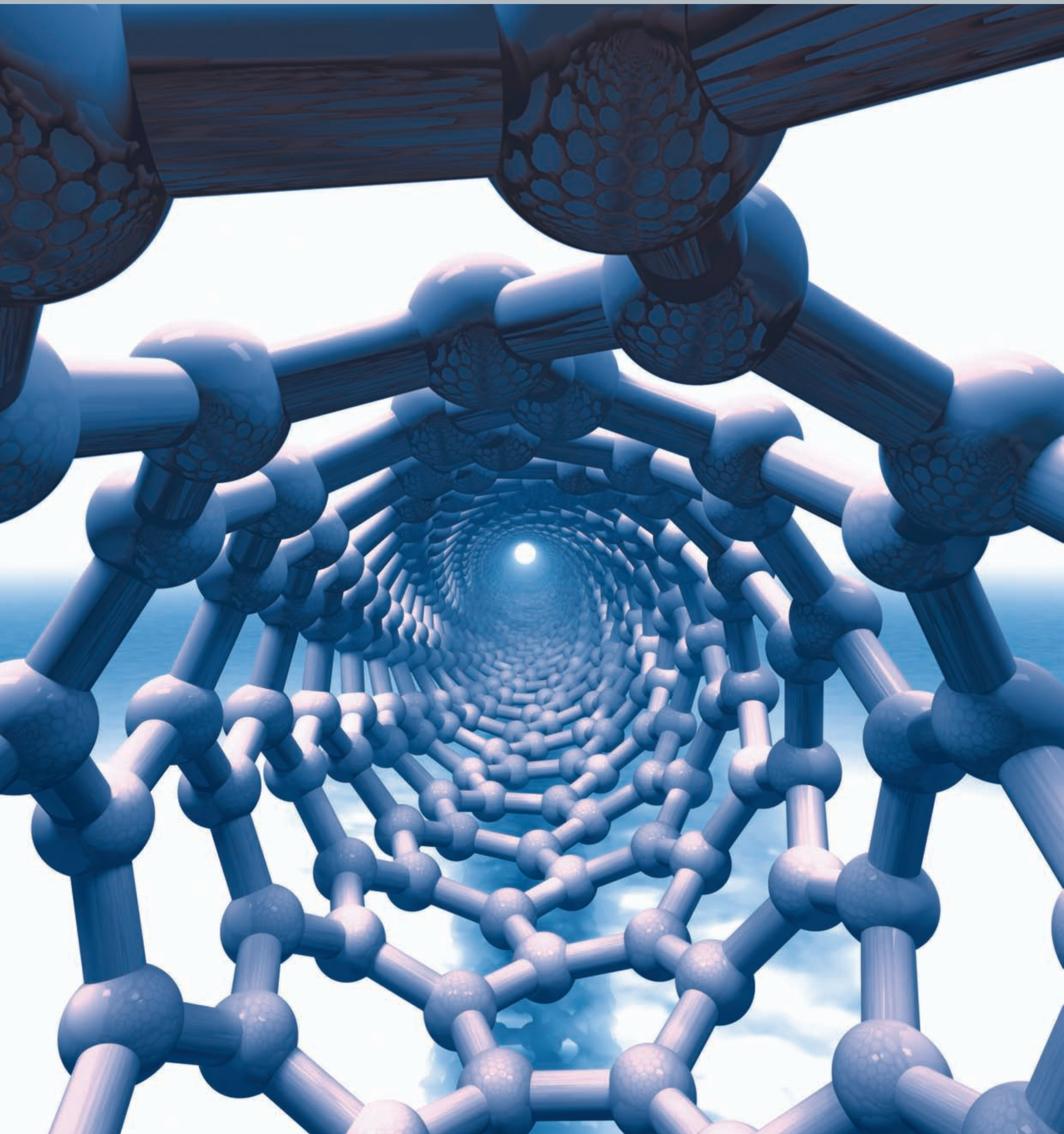

Research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesellschaft. Founded in 1949, the research organization undertakes applied research that drives economic development and serves the wider benefit of society. Its services are solicited by customers and contractual partners in industry, the service sector and public administration.

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www.fraunhofer.de

Carbon nanotubes are innovative materials of great promise. Nanotubes are being researched at Fraunhofer IWES for reinforcing rotor blades and improving the service life. www.inno-cnt.de

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2 Pod test stand with a planned drive output of approximately 10 MW

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2 200 meter measuring mast (photo: Uta Werner, Fraunhofer IWES)

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2 Chassis dynamometer for electric vehicle batteries
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2 Methanisation: 250 KW research plant of ZSW (photo: ZSW)

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