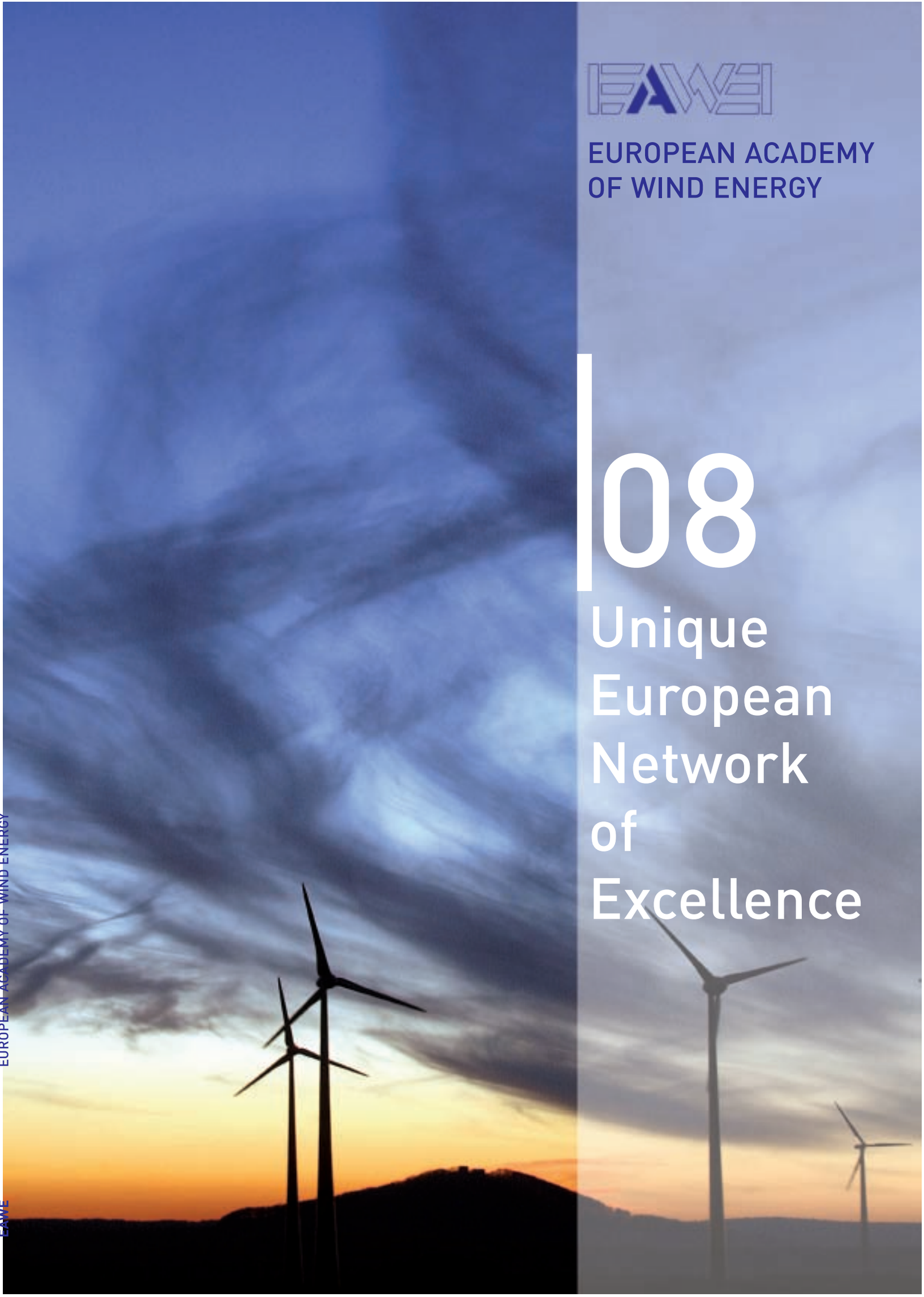

EUROPEAN ACADEMY
OF WIND ENERGY

08

Unique European Network of Excellence

EUROPEAN ACADEMY OF WIND ENERGY
EAWE

IMPRINT

The brochure has been prepared in co-operation with the EAWE-members

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CONTENT

PREFACE

The European Academy of Wind Energy (EAWE) was initiated by the leading European research institutes and universities in the field of Wind energy. The aim of this initiative is to arrive at a critical mass in an internationally oriented and globalised world and to form a unique European Network of Excellence.

The systematic co-operation between research centres and universities allows not only for long-term and high level research but at the same time for international and intercultural education, especially at PhD level.

The Academy is open for joint research with European industry, for co-operation projects within the European Research Area (ERA) and for European PhD education.
EAWE is open for new members, provided they offer research or education in wind energy at the highest level.

Prof. Dr.-Ing. Jürgen Schmid President

Prof. Dr.Ir. G.A.M. van Kuik Vice President

Unique European Network of Excellence

The European Academy of Wind Energy aims at integrating the activities of the highest level academic and research institutes in Europe working on Wind Energy. Particular attention will be paid in spreading excellence through joint education and training activities.
The benefits of past R&D in the wind energy sector have been clearly demonstrated by the increasing sizes of turbines and the lower production cost per installed capacity of electricity. Production costs of wind turbines have been reduced drastically. Today, wind energy is close to being cost competitive with other forms of electrical generation at locations with a good windresource.
At present, Europe is leading in the wind energy field, both with respect to industry, installations and research.
This is a unique position in a rapidly growing international market characterised by major development in technology, size and application.
To maintain the position and fully exploit the growth perspectives requires both continued technology development and education and training of a highly qualified workforce in Europe.
Continued R&D in long-term aspects is essential to provide further reductions in cost and uncertainty, strengthen acceptability and reliability and increase the overall value of wind power in order to realise the anticipated level of deployment.
The nature of the long-term research needed is highly multidisciplinary in the technological sense and trans-disciplinary in the implementation sense (different wind-climates, offshore-flat terrain-complex terrain, large scale integration - isolated island grids etc). It is the kind of research particularly well suited to be performed by a network of excellence at the European level.
If further R&D is one necessary component for the future success of Wind Energy, qualified human resource at all levels (technical and non-technical) is a second. High level education and training is a key issue for developing the human resource needed to support the anticipated wind energy market boom. Moreover, high level education and training are hallmarks of a living research network.

The Partnership

The members of the European Academy of Wind Energy include at present 27 entities, representing 7 EU countries and more than 80% of the long-term research activity in the field of Wind Energy. During the years, the group members have established strong links through a systematic collaboration under the European Framework Programmes and through common participation in human networks, including European and International Standardization and Certification bodies.
All partners have an outstanding position in their national Wind Energy research activities

The network will advance knowledge in the area of wind energy, by pooling a critical mass of competence and skills.
The group is structured with national nodes, represented by major wind energy research institutes with associated partners from universities or other research institutes.

INTEGRATION ACTIVITIES

PhD-Exchange

In training better young European scientists, the Network of Excellence will contribute to bridging the gap it has with the Unites States and Japan in terms of density of researchers per inhabitant thus allowing businesses to hire personnel trained in high and new technologies.

Exchange of scientists

Short term exchange of scientists among the network's participants in order to promote the integration of R&D contributes to the education of PhDs and the preparation of dissemination activities.

Exploitation of existing research infrastructures

WT test-stations, blade-testing rigs, wind tunnel facilities, atmospheric and sea-state field measurement systems etc. are made available for all academy members and its students.

Long-term research activity

The following thematic areas and topics are identified as first priority long-term R&D issues for EAWE's joint programme of activities:

Long-term Wind forecast	• Wind resources, • Micro-sitting in complex terrain, • Annual energy yield, • Design wind conditions (turbulence, shear, gusts, extreme winds) offshore, onshore and in complex terrain
Wind Turbine External Conditions	• Characteristics of wind regime and waves • Atmospheric flow and turbulence • Interaction of boundary layer and large wind farms • Prediction of exceptional events
Wind Turbine Technology	• Aerodynamics, aeroelasticity and aeroacoustics, • Electrical generators, power electronics and control • Loads, safety and reliability • Materials and composite structures, fracture mechanisms • Material characterization and life cycle analysis • New wind turbine concepts
System Integration	• Grid connection and power quality issues • Short-term power prediction • Wind farm and cluster management and control • Condition monitoring, maintenance on demand • New storage, transmission and power compensation systems
Integration into Energy Economy	• Integration of wind power into power plant scheduling and electricity trading • Profile-based power output, virtual power plants • Translational and transcontinental supply structures • Control of distributed energy systems

ACTIVITIES OF SPREADING THE EXCELLENCE

Development
of international training courses to provide a suitable vehicle for the training of researchers, students, engineers and industrial executives (in particular for SMEs), and of other potential users of the knowledge produced within the network. Such clearly identified training activities should contribute to the professional development of the persons concerned and incorporate a mobility aspect. The member institutes will create and perform joint courses of different levels and durations. Practical training will be included. These courses will be offered to European and extra-European customers.

Dissemination of knowledge
- Web site: public access to R&D outputs
- Intranet work communication and partner meetings
- International seminars
- Summer schools for graduate and PhD-students

Services in support of technological innovation in SMEs
- Training courses for industry technical staff
- Development of computer software for technology development
- Targeted R&D news service

Standardisation
Specific R&D for the preparation of proposals, evaluation and participation in CENELEC and IEC technical committees and working groups in the R&D fields of the network.

The Technical University of Denmark, DTU

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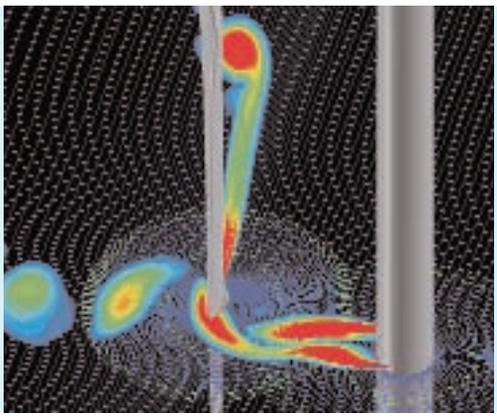

Short Presentation

In 2007, the former Risø National Laboratory became part of the Technical University of Denmark, DTU, under the Danish Ministry of Science, Technology and Innovation.
The research of the present Risø DTU covers a variety of scientific disciplines and technologies, but is mainly concerned with the development of economic and environmentally viable procedures and technologies for energy supply and consumption, and the development of health-related technology. Risø DTU employs a total of 750 staff, and the wind energy field occupies some 185 staff throughout the entire DTU, including PhD students.

The major part of DTU's wind energy activities are concentrated in Risø DTU's Department of Wind Energy and supplemented by a number of other departments. The Department of Wind Energy at Risø currently employs a staff of 110 people, 2/3 of whom are scientists and engineers. The department is organised in research units with attached technical and commercial services. Approximately 90 per cent of the department's activities are directly concerned with wind energy. Other fields of interest are atmospheric research, particularly into boundary layers and the atmospheric dispersion of matter.
We seek to meet the needs for scientifically based knowledge, methods and procedures from government, the scientific community and the wind turbine industry.

Our research and development activities range from boundary layer meteorology, fluid dynamics and the mechanic as well as the dynamic quality of structures, to power and control engineering, risk analysis, materials and wind turbine loading and safety. They also include research into atmospheric physics and environmental issues related to the atmosphere.

Our assistance to the wind turbine manufacturers serves to pave the way for technological development and thus further the exploitation of wind energy worldwide. The means to this end are research, innovation, education, testing and consultancy services as well as development of procedures for operation and maintenance.

A significant proportion of our activities are on a commercial basis: Wind energy mapping, technology development, consultancy on wind energy projects and capacity building. Other commercial activities are software development, measurement systems development and accredited testing of wind turbines.

Research groups involved

Altogether, some 185 staff are working with a wide range of wind energy projects as well as teaching at master and post doc level within the DTU wind forum.

At Risø DTU, wind energy activities are concentrated in the Department of Wind Energy, but the departments of Materials Research and Systems Analysis also contribute in this interdisciplinary work forum. In Systems Analysis the focus lies within economics, energy market life cycle analysis and wind turbine reliability (risk analysis), whereas the Department for Materials Research is engaged in the development, analysis and testing of materials for wind turbines and blades.
The Department of Wind Energy currently employs a staff of 110 people, 2/3 of whom are scientists and engineers.
The department is organised in research units with attached technical and commercial services.
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The Department of Wind Energy has the following research programmes:

Meteorology

Experimental and theoretical boundary layer meteorology applied for:
Models for real-time estimation of dispersion from point sources, modelling and measurement of surface exchange.
Wind power meteorological methods for the estimation of wind resources, short-term wind prediction, wind characteristics and wind loads.

Aero-elastic Design

Research, development and application of aero-servo-elastic programs, computational fluid dynamics code and software design tools for aerofoils, blades and wind turbines. Aero-elastic methods for the estimation of:
Interaction between aerodynamics and the structure's elastic deformation and application in the design of conventional and new concepts for wind turbines, onshore as well as offshore.

Wind Turbines

Methods for wind turbine design basis and application studies:
Probabilistic and empirical estimation of loads and safety, structural design and testing of components, assessment of performance, risks and feasibility, wind turbine certification.

Wind Energy Systems

Methods for estimation, optimisation and design in relation to:
Control, adjustment and function monitoring, integration of wind power in supply systems and interaction with the power supply system, electric machines, hybrid systems, international consultancy.

Test and Measurements

Experimental methods for the estimation of wind resources and the characteristics of the wind and wind turbine response:
Metrology, remote sensing, efficiency, loads, structural dynamics, stability, aerodynamics, acoustic emission.

Wind Turbine Testing

Research-based and internationally certified testing of wind turbines in relation to:
Type approval, documentation and support to industrial development.

DTU Mechanical Engineering, Lyngby

Efficient exploitation of renewable energy sources; aerodynamics, aero-elasticity, aero-acoustics, computational and experimental fluid mechanics, offshore engineering, structural dynamics.

DTU Civil Engineering, Lyngby

Development of new materials for wind turbines and turbine blades.

DTU Informatics, Lyngby

Models and methods for the prediction of wind power, ensemble forecasts of wind power production, advanced model-based predictive controllers, combined forecasting and use of multiple meteorological forecasts, extreme value modelling and wind energy.

DTU Electrical Engineering, Lyngby

Power electronics, grid connection, supply systems and electric power apparatus.
The section Electric Power Apparatus deals with knowledge and research related to components and apparatus in the electric power grid. This research area comprises the technical/scientific basis for the development, construction and surveillance of electric power plants and parts thereof. It covers all components of the grid and includes high voltage engineering, testing and measuring techniques, materials science and the associated theoretic and experimental tools. Components design and condition evaluation are keywords, and there is a close collaboration with users, manufacturers and international partners, thus ensuring dynamic research that will match future requirements for plants and the surrounding grid, as well as the interaction between electrical discharges and material for wind turbine blades – particularly in relation to lightning protection.

The establishment of CET – Centre for Electric Technology – in a collaboration between DTU and the utility companies, is aimed at the development of technology for the management of less centralised power systems.
The knowledge and state-of-the-art tools available from this cooperation are also used for providing consultancy and technical advice for international projects regarding the development and application of wind power technology.

The Megavind partnership was initiated by the Danish government in 2007 in order to promote wind power as the leading energy form in Denmark. DTU plays a key role in this partnership which includes research institutions and the entire Danish Wind turbine industry.

The Danish Wind Energy Research Consortium is a collaboration between the Technical University of Denmark – DTU, Aalborg University and DHI Water & Environment. The purpose of this forum is to enhance research and development in the field of wind energy utilisation.

Facilities & Advanced Research Tools

Høvsøre Test Station	HTS is a test facility for large wind turbines, located at the west coast of Jutland. A total of five test stands with a capacity of up to 5 MW each
SysLab	Risø DTU's new laboratory for intelligent, active and distributed power systems, used for a wide range of investigations, such as how the operation of markets for power and ancillary services may be integrated by a decentralised approach to systems control.
Experimental Blade Research	A new facility for research-based experimental blade testing is established at Risø DTU. The test facility includes a multi-channel strain gauge and deformation sensor measurement system as well as a 3D digital optical deformation measuring system (ARAMIS) and will be used for investigations of the structural properties of turbine blades for up to 1.5 MW wind turbines. The first tests will commence in the spring 2008.
Power system Bornholm	The Danish island of Bornholm, just south of Sweden, has made its power distribution system available to experimental use as part of the PowerLab DK set-up. The system has approx. 28,000 customers, and the overall purpose of this project is to develop an improved electric power system with reduced carbon emission. The system will manage an increased share of renewable energy and distributed generation, enable an open market and secure the reliability of supply. The Bornholm system presently includes 30 MW wind power.
Risø Test Stands	A number of small research wind turbines at the Department of Wind Energy, Risø DTU, used for conceptual testing and student projects. Six turbine stands with a capacity of up to 500 kW each.
	WAsP code for the determination of wind resources WAsP Engineering determines design wind conditions A suite of modern meso-scale meteorological models Aero-elastic code HawC A series of aero-elastic and aero-acoustic codes Advanced wind speed measurements Advanced remote sensing methods (LIDAR and SODAR) Advanced wind turbine test methods Advanced wind farm simulation models Advanced electrical simulation models Advanced models simulation integrated energy system Advanced blade test methods Advanced material models
Electric Lab and High Voltage Lab	3000 m2 general purpose laboratory for research in wind power components and systems. Include equipment for high voltage and current AC/DC, lightning test, power quality etc.

R&D Strategy

The key areas of scientific expertise are boundary layer meteorology, aerodynamics, aero-acoustics, fluid and structural mechanics, electrical design and control as well as machine and construction technology. The scientific expertise is advanced through field experiments tests, laboratory tests and numerical modelling.

	TERM short	medium	long
Meteorology (wind resources, observational and numerical wind atlas, design wind conditions, forecasting)	◉	◉	◉
Aerodynamics and aerofoil design (Numerical wind tunnel)	◉	◉	◉
Aero-elasticity (aero-elastic modelling and verification)	◉	◉	◉
Structural dynamics	◉	◉	◉
Structural design (structural modelling and verification)	◉	◉	◉
Load and safety (for land and offshore)	◉	◉	◉
Electrical design and power quality assessment	◉	◉	◉
Wind power integration in the electrical power system	◉	◉	◉
Hybrid systems and high wind energy penetration	◉	◉	◉
Experimental methods (meteorology, wind turbine testing, remote sensing, blade performance analysis, power quality, safety)	◉	◉	◉

Education and training activities

The Master of Engineering degree may also be obtained within the field of wind energy. Since 2002, DTU has offered a dedicated MSc in wind power with a choice of two specialisations: electrical engineering and mechanical engineering.

Further educational activities aim to support PhD, Master and Bachelor degrees within areas of relevance for wind power production, so that

- personnel who are qualified within the relevant areas of expertise may continue to be available to the wind energy industry.
- departmental research activities may be supported by Bachelor, Master and PhD student projects.

The Department of Wind Energy at Risø DTU currently participates in several national and international academies and networks, involving the exchange of and schools for PhD students and young researchers. We also carry out short-term educational activities in line with the department's expertise.

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Short Presentation

DHI is an independent, self-governing international research and consultancy organisation, established in 1964. DHI has been authorised as an Approved Technological Institute by the Danish Minister of Science, Technology and Innovation. DHI's objectives are to build competence and promote technological development in areas relevant to water, environment and health in the fields of ecology and environmental chemistry, water resources, hydraulic engineering and hydrodynamics as well as other related fields.
DHI's competencies include numerical modelling, CFD, environmental laboratories and physical modelling test facilities, field surveys and monitoring programmes, and institutional capacity building and training. The Institute has a total staff of more than 750 worldwide. The majority are professional engineers and scientists with post-graduate qualifications – 35% have a PhD – and several years of consultancy and R&D experience.
Furthermore, DHI has subsidiaries and branch offices and project offices in 20 countries including Sweden, Germany, Australia and the USA.

Research groups involved

The following groups are involved in research activities relevant to offshore wind turbines and farms:

Ports & Offshore Technology

(Physical and numerical modelling of waves, operational and design data, hydrodynamic load and response of vessels and foundations, scour and scour protection).

Coastal and Estuarine Dynamics

(Wave-current-sediment transport modelling, morphological modelling, water quality modelling).

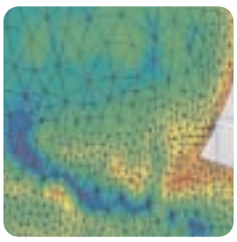
Ecology and Environment

(Modelling of water quality, physical, biological and chemical aspects).

DHI Software Products

(Development of software model for waves, currents, water levels, transport of sediment etc).

DHI collaborates with the universities in and outside Denmark. In particular through, the Danish Research Consortium for Wind Power, which is a collaboration between Risoe National Laboratory, Technical University of Denmark, University of Aalborg and DHI.



Facilities & Advanced Research Tools

Test facilities	Wave and current basin, 25 m by 35 m, 0.8 m deep Wave basin 32 m by 30 m, 0.45 m deep Wave basin 30 m by 30 m, 0.75 m deep Wave and current basin 30 m by 20 m, 3 m deep Wave flume 28 m by 0.74 m, 1.2 m high Wave and current flume 35 m by 5.5 m, 0.8 m deep Facilities are used for the determination of loads and response of installation vessels, foundations (fixed or floating), and for scour and scour protection. All facilities are equipped with sensors and data acquisition and analysis hard ware and software.
Field survey	A wide range of field survey instrumentation is available at DHI for measurement of the hydrodynamics (waves, currents) and the physical, biological and chemical environment. Instruments include ADCPs, current meters, wave riders, echo sounders, sensors for temperature, salinity, turbidity etc.
Laboratory facilities	Microbiological, biological, solid waste, chemical, C-14, water and waste water treatment laboratories.
Numerical models	MIKE 21: water levels and currents (operational and design). Modules include water quality and sediment transport MIKE 21 SW, BW, EMS, PMS: wave models for operational criteria, design parameters and loads MIKE 3: three-dimensional current model LICPACK: integrated modelling package for simulation of sediment transport and morphology NS3: CFD code for fluid-structure interaction

R&D Strategy

TERM	short	medium	long
Development of state-of-the-art wave and hydrodynamics models	◉	◉	◉
Wave models for kinematics and loads in shallow and deeper waters	◉	◉	◉
Development of refined flow models for local flow, loads and erosion at foundation units		◉	◉
Design of scour protection	◉	◉	
Models for fatigue damage due to wave/current/wind (ice) action		◉	◉
Operational aspects and collision risk analysis for installation and service vessels		◉	◉
Models for sediment transport and long-term morphological changes	◉	◉	◉
Measurements and modelling of the environment including biological and chemical aspects		◉	◉
Methods to assess impact on migrating birds	◉	◉	◉
Methods to assess impact on cetaceans and fish	◉	◉	◉

Education and training activities

DHI cooperates with the universities and assists in both lecturing, training and tutoring of students on MSc and PhD levels.

Aalborg University

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Short Presentation

Wind energy research at Aalborg University (AAU) is organized in WEST, which is a virtual centre for Wind Energy Structures and Technologies with participants from several departments at the university. WEST was established in 2001, but wind energy research was previously organized individually at the different departments.

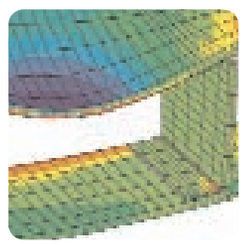
The activities of WEST are to coordinate research and teaching within the fields of wind energy at the Faculty of Engineering, Science and Medicine at Aalborg University, to strengthen the collaboration between wind energy research at the different research environments at the university, to increase the visibility - internally and externally - of the university's research and teaching on wind energy, to initiate research and development activities and to coordinate activities related to the test wind turbines.

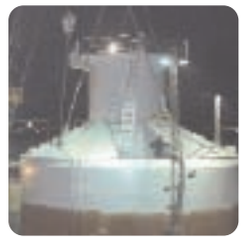
The research is focused on wind energy and wind turbines in the following areas: energy planning, power electronics, generators, electrical drives and power systems, power quality control, analysis and design of composite structures, aerodynamics, structural dynamics and analysis, foundation engineering as well as loads and safety.

Research groups involved

Aalborg University has more than 40 researchers working with wind energy including 20 Ph.D. students.The activities are organized in research groups from the following departments at the Faculty of Engineering, Science and Medicine:

Department of Development and Planning:	Energy planning
Department of Energy Technology:	Power Electronics, Generators, Electrical Drives and Power Systems
Institute for Electronic Systems:	Control
Department of Mechanical Engineering:	Analysis and design of composite structures – blades
Department of Civil Engineering:	Aerodynamics, Structural Dynamics, Loads and Safety, Offshore technology and Geotechnics





Facilities & Advanced Research Tools

Offshore wind turbine in Aalborg:	2.75 MW offshore wind turbine placed at Aalborg harbour used for research and education. A meteorology mast is placed close to the wind turbine.
Offshore wind turbine in Frederikshavn:	3 MW wind turbine with bucket foundation placed in Frederikshavn. The bucket foundation is 12 m in depth and 12 m in diameter and is instrumented.
Power electronic and converter laboratory:	Facilities with generator-set, power device test bench, power converters and grid simulator, DSPACE, AC drive systems, inverter-systems for fuel cell and photovoltaic
High Voltage and Power System Lab:	Equipment for insulation test, high voltage AC and DC, Power Quality, Dynamic Voltage Restorer, Lightning
Green Power Lab Wave-Current Lab	New laboratory focusing on the topic of renewable energy systems (photovoltaic, wind, fuel-cells, etc.) with grid connection. 2 Wave basins and 2 wave flumes with possibilities of reproducing wave-current conditions in scale 1:20 to 1:40
Software	In house developed simulation platform: Wind Turbine Blockset (a beta version for Matlab) Power Factory (DigSilent) is a dedicated electrical power system simulation tool used for assessment of power quality and analysis of the wind turbine interaction with the grid. It has focus on the power system and not on the wind turbine itself. Matlab/Simulink is used as a general model developing tool and also for validation of the models. After validation of the models they are implemented in other simulation tools for instance Power Factory. Computer models for the analysis of integration of wind power into energy systems and computer models for the assessment of wind resources

R&D Strategy

	TERM short	medium	long
Components in wind power systems New power converter topologies for the next generation wind turbines. That includes different multilevel topologies as well as new generator concept.		◉	
Control and monitoring for wind power systems Develop methods to identify failures or potential failure in gearbox and high-voltage transformer. Develop advanced control methods for power electronic systems for wind turbines/farms.		◉	◉
Simulation and design tools for wind power conversion systems Extend the Matlab/Simulink toolbox with new models to cover as many possible configurations as possible. Complement the Matlab/Simulink toolbox with corresponding PSCAD/EMTDC models Models for simulating HVDC power transmission for wind farms.	◉	◉ ◉	
Planning, design and optimisation of the electrical systems for large scale wind farms Develop model setup for being able to optimise a wind farm in respect of cost and reliability. Run optimisations with practical applications.	◉ ◉		
Interconnection of the wind turbines/farms into power networks Develop technologies for existing wind turbines/farms to address the requirements from utilities, Investigate the impacts of large scale grid integration of wind power on power systems and develop advanced methods to improve power grid performance with the integration of wind turbines/farms.		◉ ◉	◉
Integration of wind power into regional and national energy systems	◉	◉	◉
Probabilistic design of wind turbines	◉	◉	
Risk based Operation and maintenance planning		◉	◉
Effects of Waves and Currents on Offshore Wind Turbines -Run-up on towers supported by different types of foundations -Slamming Forces on Entrance Platforms -Scour Development under Varying Wave and Current Conditions	◉ ◉ ◉		
Analysis and Design of Composite Structures - Analysis and design of lightweight composite and sandwich structures		◉	◉
Structural Dynamics - Multi-body dynamics of wind turbines - Non-linear rotor dynamics		◉	◉
Aerodynamics: - Aerodynamics and CFD		◉	◉

Education and training activities

Aalborg University has three faculties with more than 13,000 students enrolled. The faculties of Engineering, Sciences and Medicine has about 4,000 students and offer more than 25 international M.Sc. programmes. The most relevant Master Programmes related to wind energy are Sustainable Energy Planning and Management, Wind Power Systems, Power Electronics and Drives; Electrical Power Systems and High Voltage Technology; Structural and Civil Engineering.

Furthermore WEST is offering from 2008 the continuing education programme 'Master in Wind Energy' which is a two-year master programme on part time. The study programme has an electrical and a mechanical specialization, see http://www.windmaster.aau.dk/ .

About 25 Ph.D. students are working with wind energy related topics at Aalborg University and they are also related to the graduate school Danish Academy of Wind Energy (DAWE).

The university offers training courses on-site related to wind energy like simulation of wind turbines, advanced control of electrical drives, materials, foundation and optimization.

Institut für Solare Energieversorgungs-technik e.V. (ISET)

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Short Presentation

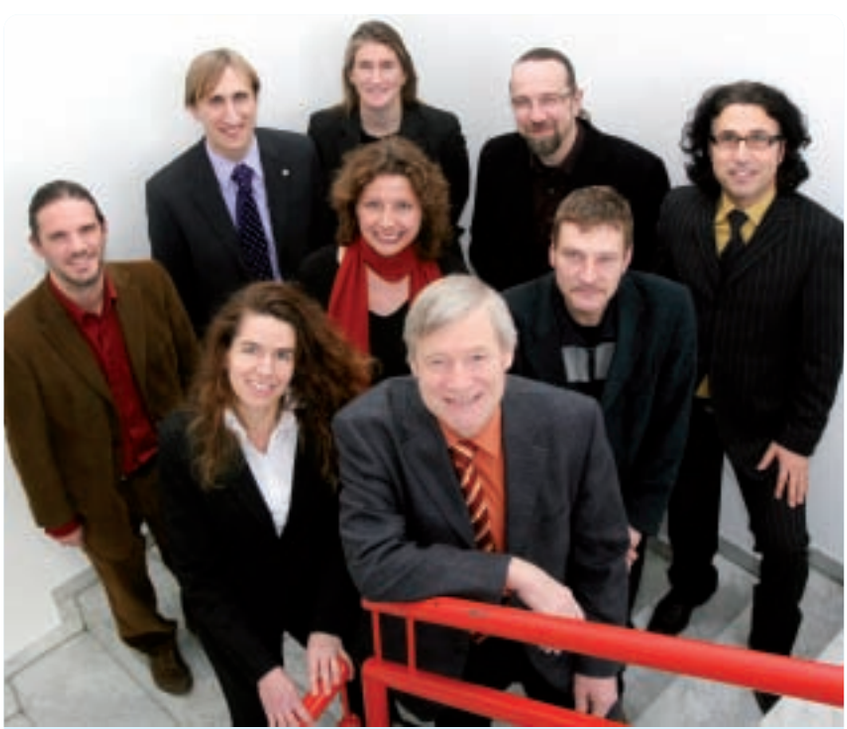
The "Institut für Solare Energieversorgungstechnik e.V." (ISET) was founded in 1988 as a non-profit making research institute, associated with Kassel University. In order to realize a strong link to industry needs in the strategic R&D programme, about 50% of the scientific advisory board are representatives from the industry. At the moment the institute employs some 150 people, corresponding to a capacity of 110 full-time positions, of which about 85 are regularly employed.

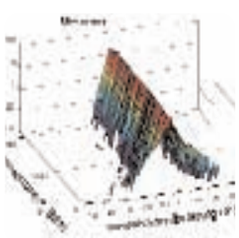
ISET's activities in the field of wind energy range from theoretical investigations via experimental research and the execution of field tests and measurement programmes to the development of control, inverter and information systems. The main focus is on the electrical and systems engineering aspects of wind power applications which arise both at component and grid integration level.

Research groups involved

The R&D programme area Information and Energy Economy deals with the technical an economic issues of and increased use of renewable energies and the changing power supply structures which are more and more characterised by competition and trade as well as by an increasing penetration with fluctuating energy sources. The major fields of occupation focus on the use of wind energy, power supply structures with a high share of renewable energies, information and communication technologies for an improved integration of renewable energies into power supply systems as well as carrying out education and training programmes.

The field of work of the R&D division for energy conversion and control engineering covers the optimal usage of renewable energies as well as the rational use of limited energy resources. Besides the technical and economic investigation of subsystems of different energy supply technologies, such as wind power, the division improves the design and layout of complete systems. In addition to technological and constructive progress, this requires in particular the application of a modern methods of control and systems engineering. In particular this division has been involved in the development of advanced control systems for megawatt wind energy converters and commercially available modern fault prediction or condition monitoring units.





ISET

Facilities & Advanced Research Tools

Wind energy remote measurement network	data acquisition for on-line monitoring of wind energy converters, wind measuring network with 80 selected sites in Germany
Laboratories for software development	specific dynamic simulation, controller design and plant rating, hardware-in-the-loop system, PLC development environment
Generator / inverter laboratory	hardware and software simulation environment for wind turbine drive trains and control concepts
Power electronic and converter laboratories	set up and measurment of electronic circuits and converters, circuit layout system
EMC laboratory	accredited in accordance with IEC 17025, CE certifications, equipment for investigations of electromagnetic compatibility, EMC measurement chamber
Battery laboratories	dynamic battery testing field up to 2000 A and 400 V, climatic cabinets, HO2 analyzers for hybrid applications
Fuel cell laboratory	HO2 gas supply system, fuel cell measuring fields up to 10 kW, PEM experimental system with 2 x 1.5 kW electrical power
Water pump laboratory	water pumps laboratory for specific supply tasks, e.g. powered by wind turbines

R&D programme

ISET's short-to-medium-term wind power R&D programme covers the following subjects:

- technical and economic studies and systems analysis for the further development of wind power technology and application,
- development of new models and tools for the dynamic simulation of wind energy converters and systems
- development of new control concepts for reduced load impact and improved reliability,
- development of information and energy management systems for the improved integration of large scale wind power into electrical networks,
- development of short-term prediction systems for wind power forecasting
- condition monitoring and fault prediction in wind turbines as a basic for wind farm supervision and maintenance / repair scheduling
- development of new microprocessor technology in control and inverter systems,
- development of small wind turbines for application in hybrid systems,
- design and execution of measurement programmes, operation and further development of remote measurement networks,
- planning, supervision and execution of development and pilot projects,
- trainee courses and further education measures.

Education and training activities

ISET offers training courses "Wind Energy Utilization – Potentials, Technology, Economics, Planning, Operation", which are tailored to the special demands of industry, utilities and organisations for international capacity building.
The Training activities vary from 1-day seminars to 4-month programmes in-house and abroad.
In cooperation with the Kassel university groups "Electrical Energy Supply Systems", "Efficient Energy Conversion" and ISET, a special topic of study concerning Renewable Energies and Efficient Energy Conversion was established at the University of Kassel:

- Providing support for course work and diploma theses, as well as for trainees and graduate assistants
- Qualification of staff through limited, multi-year work at ISET and through the opportunity to write a doctoral thesis

Furthermore the Renewable Energies Knowledge Transfer Network www.REnKnow. Net has been developed and is operated by ISET.

Leibniz Universität Hannover

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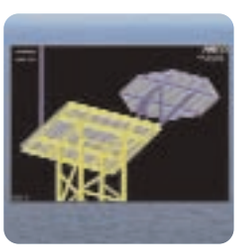
Short Presentation

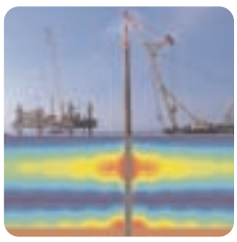
The heart of Leibniz Universität Hannover beats in the idyllic Welfenschloss, the Guelph Palace. In 1879 the Higher Vocational School, originally founded in 1831, moved into the palace. Later, this school became the Königliche Technische Hochschule, the Royal College of Technology. With more than 60 interdisciplinary and practice-orientated courses of study, Leibniz Universität Hannover provides degree and further education courses which are orientated both towards demand and quality.
ForWind, the Center for Wind Energy Research of the Universities Oldenburg and Hannover was founded in 2003.
Research and development represent the core of ForWind`s activities.
Since its foundation it has been continuously supported by the state of Niedersachsen. Furthermore ForWind provides scientific expertise for industry and special off-the-job training for employees of wind energy businesses.
ForWind cooperates with national and international institutions.

Research groups involved

At LUH about 40 highly qualified scientific co-workers focus their activities on wind energy research topics. Four faculties, including civil engineering (7 institutes), mechanical engineering (4 institutes), electrical engineering (2 institutes) and the faculty of architecture and environmental planning (1 institute) all contribute to interdisciplinary research and development in four fields of competence.
The first field –wind energy integration- is concerned with issues arising from electricity network connection and the integration and control of wind energy systems.

The second competence field -machine and rotor- performs essential tasks such as determining plant-specific drive train load spectrums, lifetime analyses of rolling bearings as well as condition monitoring and efficient production. Moreover, the development of material models for composite rotor blades is aimed at, as well as the investigation of aeroelastic problems.
Within the third field –offshore and operation- all questions concerning the support structure, maintenance and reliability of wind energy plants are typical research topics. Within this context, system and load identification, structural health monitoring with methods of early damage detection and damage localisation are important issues.
Activities in the forth competence field –environment- focus on the environmental impacts of offshore technology.
The reduction of hydro noise during the building of a plant is of great relevance here, as well as fauna protection.





Institute for Steel Construction

ISD

ForWind

Leibniz Universität Hannover

Facilities & Advanced Research Tools

Large Wave Channel	Worldwide largest wave channel for the simulation of waves and wave breaking
Further wave testing facilities	Simulation of waves, currents and fluids in Basins and open channels
Underwater Technology Center (UWTH)	Sub-aqueous and atmospheric cutting, welding and material removal methods
Structural testing laboratories	Large 10 MN test stand; different testing facilities (resonance; fatigue), servo-hydraulic test stand, large hydraulic test frame
In situ and field measuring equipment (for dynamically loaded structures)	Mobile exciter facilities (harmonic, stochastic and sweep); complete equipment for acoustic and hydraulic measurement
Measuring equipment	Complete optical, acoustic and electrical equipment
Large rolling bearing test stand (start in summer 2008)	Testing of wind power typical large bearings with bore diameters up to 500 mm
Different test bed facilities for bearings	Investigation of average life span, friction and operating performance
Software	In-house integral SHM-system for beam-like structures requiring minimal number of sensors; tools like Waveload, Poseidon, HanOff or HanRiWa for the simulation of wind turbines.

R&D Strategy

	TERM short	medium	long
Wind energy integration:			
1) Operation of wind turbines on an undisturbed / disturbed grid	◉	◉	
2) Grid connection of large scale wind farms			◉
3) Power system simulation with deterministic and probabilistic methods		◉	◉
4) Analysis of power quality		◉	◉
Machine and rotor:			
1) Life span of large rolling bearings	◉	◉	
2) Operating conditions and identification of plant-specific load spectrum and short-time excessive loads		◉	◉
3) Improved analysis and design fundamentals for composite rotor blades (material model, failure criteria, fatigue, influence of manufacturing imperfections)		◉	◉
Offshore and operation:			
1) Fast and cost efficient holistic design concept for offshore wind turbine support structures		◉	◉
2) Integrated global SHM-system for foundation, tower and blades (new algorithms, new sensors, validation onshore and offshore)		◉	◉
3) Holistic safety concept based on probabilistic methods		◉	◉
Environment:			
1) New procedures for measurement, prediction and reduction of hydro noise and for fauna protection	◉	◉	

Education and training activities

Within the faculties strong emphasis is put on all matters concerned with primary structures of wind turbines. Many graduates from Hannover are working for the wind industry. In cooperation with several institutes the faculty offers advanced training on 'Load-carrying structures for wind turbines I and II' (two courses starting in sequential semesters)'. Further important courses are 'Stability Problems of Steel Structures' and 'Fibre Composite Lightweight Structures' to prepare students for typical issues in their career. Thus knowledge in the field of modelling, loading and design of wind turbines can be transferred directly to engineers in industry. The courses offer training for graduating students as well as for employed engineers.

IEE Institut für Elektrische Energietechnik

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Short Presentation

For about 30 years, the Institut für Elektrische Energietechnik (IEE) at the University of Kassel has been working in the field of electrical power supply and wind energy research. The institute has ca. 20 employees.
The research fields of the institute include power conditioning, PV hybrid systems and wind energy technology. The main topics in these fields are; electrical grid formation, the control and supervision of feed-in and storage systems, the grid integration of wind energy turbines, photovoltaic systems, diesel aggregates, phase shifters and battery units and the accompanying inverter technology. In addition to the research activities the institute introduces regular and advanced lectures in the field of renewable energy, which include wind energy converters, control and integration of wind turbines, solar energy.

Research groups involved

The institute of energy supply technology (EVS) at the University of Kassel has worked in the wind energy research and teaching fields for 30 years. Its staff is organised in two research and development (R&D) divisions:
The first R&D division of 'supply systems, communication and power electronic' concentrates its work on the control and management of power supply systems and components and communication technology. Therefore, safety, functionality, lifetime and cost-effectiveness are the basic aspects that are considered. Further point of interest of this division is the development of power electronic units such as converters and inverters.
The second R&D division 'wind energy technology, grid Integration and grid calculation' works not only with wind turbines but also with component development, grid quality investigation and the design of wind farms. Furthermore, in cooperation with software companies, simulation programmes are developed for investigating the positive characteristics of the wind energy converters and analysing different power supply systems. Also, these programmes are used to study the control, tracking and stability of grids.

UNIKASSEL
VERSITÄT

Facilities & Advanced Research Tools

Laboratory	Power converter laboratory for prototype production incl. test field Photovoltaic laboratory incl. PV-experimentation platform Battery laboratory incl. inspection station for long-term and short-term tests Two machinery test facilities, specially qualified for variable rotation speed in the power range of 50 kVA and 400 kVA Laboratory for modular system technology incl. hybrid plant for the power supply of island grids
Development	Development environment for simulation and processor systems Development of components for system configurations and system simulations in conjunction with autonomous power supply units (test facility for pumps)
Demonstration	Demonstration and test Centre DeMoTec (together with ISET)

R&D Strategy

The R&D programme of the institute includes several points of interest for the next half decade. Such R&D activities are:	TERM short	medium	long
Power electronics (power converter technology) as the connection between power supply components and systems: Development of decentralised power electronic components and devices, accompanying analysis concerning the electromagnetic compatibility (EMC) during the development of power electronic components and devices	◉	◉	◉
Structuring of complex systems: Microcomputer (micro controller, digital signal processors) and its application for controlling and managing electronic supply systems Conversion and utilisation of decentralised and regenerative energies: Dynamic and quasi	◉		
Steady-state modelling and simulation of components and systems, controlling and grid integration of components and systems (virtual power plant / distributed generation), grid quality, development and technical realisation		◉	◉
Study of grids and grid branches: Simulation and power flow calculations, design, measurements	◉	◉	
Modular systems (hybrid technology): Design, communication interfaces for modular systems, control and energy management, modelling and simulation		◉	

Education and training activities

The University of Kassel hosts 18000 students and the IEE department focuses on Renewable Energies. The institute offers advanced lectures in the field of renewable energy, especially in wind and solar energy, as follows: "Use of Wind Energy", "Control and Grid Integration of Wind Energy Converters", "Photovoltaic System Technology", "Solar Energy and Electrochemical Storage" and "Energy Economy". Postgraduate studies (Master of Science (MSc.) and doctor of Philosophy (PhD) in engineering) in the field of renewable energy are further regular qualifications the institute offers by means of limited work contracts during which the PhD thesis can be completed. Moreover, in co-operation with ISET, a special topic of study concerning Renewable Energies and Efficient Energy Conversion was established at the University of Kassel.

The Otto-von-Guericke-University Magdeburg

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Short Presentation

The Otto-von-Guericke-University (OvGU) Magdeburg was founded in 1993. It evolved from the former Otto-von-Guericke-University of Technology, the Teachers Training College and the Medical Academy. Due to this fusion the University has an interesting profile which covers different fields, beginning with electrical engineering, mathematics and computer sciences, through the natural sciences, humanities and social sciences up to medicine and economics. Currently, more than 13,000 students are studying at 9 faculties.

- Faculty of Engineering,
- Faculty for Process and Systems Engineering,
- Faculty of Electrical Engineering and Information Technology,
- Faculty of Computer Science,
- Faculty of Mathematics,
- Faculty for Natural Science,
- Medical Faculty,
- Faculty for the Humanities, Social Sciences and Education,
- Faculty of Economics and Management.

Although the university is very young, its development has reached a very high level. The Otto-von-Guericke-University is initiator and member of ZERE e.V. (Center of Renewable Energies Saxony-Anhalt) which was founded 2006 by the Minister of Trade of Saxony-Anhalt.

Research groups involved

Research in the field of wind energy is mainly being conducted by two groups at the OvGU: the Chair for Electric Power Networks and Renewable Energy Sources from the Faculty of Electrical Engineering and Information Technology, and in the Department of Psychology, the Research Group "Environmental Psychology", which belongs to the Faculty for Humanities, Social Sciences and Education.

The first group is headed by Prof. Dr. Zbigniew. A. Styczynski and deals generally with the technical aspects of wind energy. Here the research is focused on the modelling of wind turbines and the dynamic simulation of their influence on the power system operation. The analysis of bottleneck development in the power system due to the intermittent character of wind generation as well as the analysis of the application of the network security management system is the focus. Moreover, the application of virtual reality systems and 3D visualization methods in the field of wind energy is being researched. The research activities of this group are significantly enhanced by the cooperation with the Center of Excellence for Electrical Networks and Renewable Energies of the Fraunhofer IFF in Magdeburg.

The second group is headed by Prof. Dr. Petra Schweizer-Ries. This group investigates and works with people in their (social) environments, investigating their perceptions, feelings and behavioural decisions concerning different socio-technical systems and environmental protection. Man-technology-environment transactions are of interest on various levels: individuals, collectives and those responsible for structures and the conditions of behaviour towards the environment. Here the main focus is the acceptance of wind turbines: – what are the influencing factors and which planning strategies should be used in order to support further wind projects?

Facilities & Advanced Research Tools

Laboratory for wind turbine simulation	Modelling and dynamic simulation of wind turbines and wind farms with PSSTMNETOMAC. Analysis of possibilities to support system operation by wind turbines.
Laboratory for network planning and simulation	Tools for multi-criteria network planning with regard to wind generation using game theoretical approaches.
Laboratory for power quality	Joint lab with Fraunhofer IFF. Measurement and evaluation systems for power quality analysis with special consideration of non-linearities in the grid.
Laboratory for protection systems	Tools for analysis and configuration of protection units.
Laboratory for wide area monitoring	Analysis of application possibilities of the synchronized phasor measurements (PMU) for wide area monitoring systems.
Laboratory for 3D visualization	Joint lab with Fraunhofer IFF. Platform for 3D visualization of system elements and creation of virtual reality based applications.
Public acceptance analysis questionnaire	Standardised measurement instrument for measuring public acceptance.
Laboratory for environmental simulation	Multimedia-system for environmental visualization to analyse perceptual preferences.

R&D Strategy

	TERM short	medium	long
Analysis of the impact of network security management systems NSM on the network operation with a high penetration of DGs, especially wind generation.		◉	
Development of an approach for reduced representation of wind farms in the dynamic simulations of the power system.	◉		
Dimensioning a hybrid system with energy storage to balance the power from the large-scale wind farms.			◉
Analysis of the impact of wind farms on the grid operation and support of the system services.		◉	
Development and analysis of virtual power plant systems.			◉
Development of an application for 3D visualisation of wind farms and its integration into the wind farm calculation tool.	◉		
Development and actualisation of an e-learning platform for supporting wind energy lectures.		◉	
Basic research of the social aspects of wind energy with the objective of developing a model for explaining and predicting acceptance of wind energy.		◉	
Development of a holistic strategy and outlining of recommendations concerning further planning and implementation strategies.			◉

Education and training activities

The Faculty of Electrical Engineering and Information Technology at OvGU offers a special block of lectures about wind energy for its students. These lectures include a broad introduction to the issue. Moreover, a series of practical exercises supplements the aforementioned lectures. The wind energy education is supported by the e-learning based platforms and 3D visualization tools. Since 2008 a master course of study in renewable energies will be proposed for the students.

Environmental Psychology is another part of the academic training offered in Magdeburg. The teaching contents span from basic Environmental Psychology topics up to Social, Differential, Educational and Organisational Psychological issues. Moreover, in integrated seminars psychology and engineering students are taught together with a focus on human-technology-environment interaction in an interdisciplinary way. Regular visits to a local wind turbine producer are also part of the seminars.

Oldenburg University

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Short Presentation

Oldenburg University is one of the leading German universities in energy research. The university itself has put energy research at the top of its own research agenda. In 2003, wind energy research was concentrated in the new Center for Wind Energy Research, ForWind, an institution established in cooperation with Hannover University having its headquarter in Oldenburg. 2008 saw the start of the new EWE Research Center for Energy Technology which is an industry-funded institute mainly concentrating on photovoltaics, fuel cells and storage technologies.

The wind energy research mainly concentrates on the beginning of the wind energy conversion chain with emphasis on meteorological aspects of wind energy conversion, turbulence characteristics and their impact on turbine behaviour and advanced wind measurement techniques. System-oriented aspects and grid integration studies complete the research spectrum. In these fields, Oldenburg University has participated in numerous national and international wind energy related research projects.

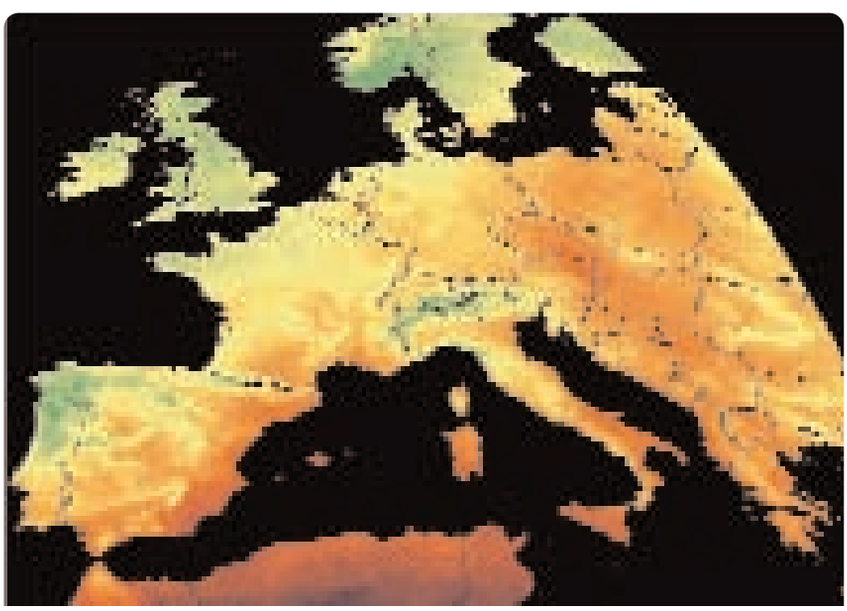
Oldenburg University has a strong background in renewable energy education and is currently increasing its efforts in this direction. From Oldenburg University, several spin-off companies in several domains of wind power applications have been established within the last decade.

Research groups involved

Wind energy research at Oldenburg University is concentrated in the Institute of Physics.
The hydrodynamics research group with its scientific basis in experimental fluid dynamics and turbulence research focuses on characterisations of the small scale turbulent flow both experimentally and by stochastic modelling of wind data.
The work aims at providing relevant data for optimized turbine design. The group consists of approximately 15 scientists related to wind power research.

The Energy Meteorology Unit investigates the influence of atmospheric processes on the availability of wind power and on the performance of wind turbines depending on atmospheric conditions. Main activities are related to wind power forecasting, numerical flow modelling and boundary layer characteristics, wind farm modelling. The group consists of approximately 15 scientists.

These two groups form Oldenburg University's contribution to ForWind, the Center for Wind Energy Research.
In addition to physical research in wind power conversion the university's computer science department and its OFFIS institute work on information management aspects of grid integration of wind power and decentralised energy systems. Minor activities in flow modelling and environmental aspects with respect to offshore wind power utilisation are carries out within the Institute of Marine Chemistry and Biology (ICBM).



Facilities & Advanced Research Tools

Power curve estimator	Method to determine wind turbine power curves by stochastic data analysis procedure reflecting the turbine dynamics; reduction of measurement time to a few days; alternative to IEC 61400-12-1
Wind tunnel	1.0mx0.8m cross-section, 3m test section length, max. wind speed 50 m/s, turbulence intensity below 0.2%, profile measurements at Reynolds numbers up to 7x105; measurement techniques: Laser Doppler and hot-wire anemometry
Sphere Anemometer	optical sensing of the deflection of a rod on top of which a sphere is mounted; measurement of wind speed and direction; no moving parts; high temporal resolution
Wind Power Forecasting	Operational regional and single site forecasts incl. specification of uncertainties; different forecast models as research tools;
Numerical Flow Modelling	High resolution numerical simulation of turbulent flows; time resolving DNS/LES simulations for turbulence analysis; simulation under non-laminar boundary conditions
Extreme Wind Calculation	Modelling of extreme wind situations for use in turbine design; gust statistics
Mesoscale Atmospheric Model	Regional wind resource calculation for offshore and complex domains; high resolution
Wind farm flow modelling	modelling of wake effects within onshore and offshore wind farms; wake effects of complete offshore wind farms

R&D Strategy

	TERM short	medium	long
High resolution flow modelling		◉	
Contribution to improved standardization procedures for power curve estimation	◉		
Contribution to improved standardization procedures for meteorological conditions (for example, extreme winds)	◉		
Improving understanding of the structure of the marine atmospheric boundary layer		◉	◉
Introduction of new optical wind measurement systems with high temporal resolution		◉	◉

Education and training activities

Oldenburg University has long experience in educational activities in both general Renewable Energies and special Wind Energy related topics. More than 50 Diploma and MSc degrees and more than ten PhD degrees have graduated at the Institute of Physics in wind energy research. Most of the former students are now in relevant industrial positions, several of them found own enterprises as spin-offs.

The Postgraduate Program Renewable Energy (PPRE) was established in 1987 as a M.Sc. course of 16 months (3 terms) designed for scientists and engineers mainly from non-industrialised countries intending to prepare for a professional career in the field of renewable energy. Up to now more than 300 students have successfully completed the courses and many of them have graduated in wind energy research.

As a new activity, the part-time postgraduate program „Wind Energy Technology and Management" addresses applicants already active in industry. The course is organised in close cooperation with industry and is held in the German language.

On a European level, Oldenburg University contributes as a core provider to the Renewable Energy Master course of the European Renewable Energy Center's (EUREC) Agency.

Within the European projects WindEng and POW'WOW, Oldenburg University strongly supports the exchange of PhD students working on topics in wind energy meteorology

Universität Stuttgart

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Short Presentation

The University of Stuttgart boasts a long tradition in wind energy research. Prof. U. Hütter did pioneering work on wind turbine design and composite structures as early as the 1950s. As director of the Institute of Aircraft Design he developed the StGW-34, the predecessor of many modern wind turbines. At the Institute of Aerodynamics and Gas Dynamics (IAG), Prof. F.X. Wortmann in the 1970s designed and tested airfoil sections specially suited for wind turbine applications. Thus, the basis for the rapid wind turbine industrial development during the 1990s was established.
Today, the Endowed Chair of Wind Energy (SWE), the IAG and some other groups jointly conduct wind energy research. The number of staff currently working on wind energy topics within these institutes is approx. 20, with the number steadily increasing.

Research groups involved

Endowed Chair of Wind Energy (SWE)
The SWE was endowed in January 2004 by a private-public partnership of Karl Schlecht, the founder and chairman of the supervisory board of Putzmeister AG, a well-known manufacturer of mobile concrete pumps. The SWE is the one and only German wind energy chair.
The SWE's research activities focus on structural dynamics and control, especially for offshore applications, load monitoring and the operation of wind turbines, as well as on composite structures.

Institute of Aerodynamics and Gas Dynamics (IAG)
The IAG concentrates on numerical and experimental aerodynamics, aeroacoustics and aeroelasticity of wind turbines.

Universität Stuttgart
Germany

Facilities & Advanced Research Tools

Laminar Wind Tunnel	Open return wind tunnel with a closed test section of 0.73 x 2.73m², flow velocity up to 90m/s, extraordinary low turbulence level of less than 2x10-4 in a range from 20 - 5000Hz, PSI-pressure scanning systems, hot-wire and traversing systems, high resolution infrared camera, stereo PIV system, acoustical in-flow microphone array and CPV-system
Gust Wind Tunnel	Test section with ø 6.3m, flow velocity up to 17m/s, slotted bypass chamber for reduced blockage effects, integral balance measurements, flow visualization
Wind Turbine Field Testing	Test site for small experimental wind turbines Equipment for power performance and load validation of large commercial wind turbines (incl. 100m metmast and lidar)
Wind metmast	A 102m high metmast with measurements at different heights is located near Bremerhaven in the north of Germany
LIDAR	A pulsed LIDAR for measurement of vertical wind profiles
Textile Composite Laboratory	2D and 3D-Preforming with CNC and Robot-assisted stitching. Advanced braiding machine and curing of the matrix in fiber reinforced materials with microwave heating Analytical laboratory for composites analysis
Composite Structure Laboratory	Manufacturing and static and/or dynamic test of composite components
Static, dynamic and life-cycle testing	2 static testing machines multi-axial loading. Climate chambers for high temperature testing Hydraulic actuators for dynamic tensile/compression and torsion testing in a range of 16 - 250kN and 4kNm, climatic chambers
Software	In-house developed and commercial windfarm software e.g. FLaP, WindPRO. Additionally, codes for aeroelastic turbine simulation, design of offshore support structures, analysis of measurement data e.g. SIM-PACK, Flex5, Bladed, FOCUS, FAST. CFD codes ranging from boundary element methods to Reynolds-Averaged Navier-Stokes solvers, program system ARLIS for the linear dynamic and aeroelastic analysis of wind turbines, in-house CAA codes, the CFD-based numerical optimisation environment POEM, airfoil de-sign, optimisation & analysis methods.

R&D Strategy

	TERM short	medium	long
Development of load monitoring and control techniques for large wind turbines through simulation, lab and field testing		◉	◉
Advanced tools and methods for the optimisation of space-frame offshore support structures	◉	◉	
Online load monitoring and performance evaluation using standard wind turbine signals		◉	
Development of aeroelastic simulation tools of wind turbine loading in wind farms		◉	
Development of wind turbine aeroelastic simulation tools using multi body approach		◉	◉
Development of LIDAR technologies for support of wind turbine performance measurement and control strategies	◉	◉	◉
Investigation of new structural concepts and semi-automated assistance in the manufacture of rotor blades		◉	◉
Multi-disciplinary research on wind turbine design through establishment of inner-faculty and inter-faculty collaboration		◉	◉
New measurement techniques for basic boundary layer experiments under controlled disturbance conditions. The main goal is the improvement of transition prediction tools, which enables drag reduction by passive means, i.e. transition control by specially prescribed boundary layer development.			◉
Novel aeroacoustic sensor technologies for application in noisy, aerodynamic wind tunnels, which could replace the classical hot-wires by nano-tubes. The expected gain in signal-to-noise ratio will lead to a significant step with respect to the necessary measurement time and the quality of the data.			◉
Use of synergy effects of aircraft, rotorcraft and wind turbines with respect to coupled unsteady CFD and aeroelastic FE simulations			◉

Education and training activities

The University of Stuttgart, hosting 19,700 students, has a major focus on energy technologies including renewables such as wind, solar, biomass and hydro in research and teaching at five of its 10 faculties. Since 1971, more than 1,000 students have attended a lecture on wind turbines at the Faculty of Aerospace Engineering and Geodesy.
The SWE offers five courses on wind energy applications, wind turbine design, and measurement techniques. These courses can be extended by lectures on renewables, on the history of wind energy as well as a basic course on machine elements for aerospace applications. Teaching at the IAG includes aerodynamics, aeroacoustics, aeroelastics and airfoil design. New approaches to teaching are utilized, examples of which include project-based teaching, experiments (e.g. in the wind tunnel) integrated into lectures as well as excursions to wind turbines and the wind energy industry. Various projects at undergraduate and postgraduate (master, PhD) level are being carried out.

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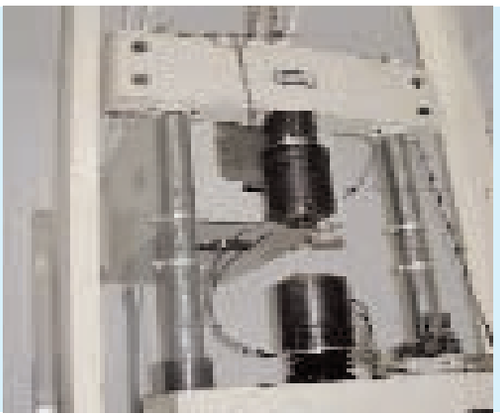


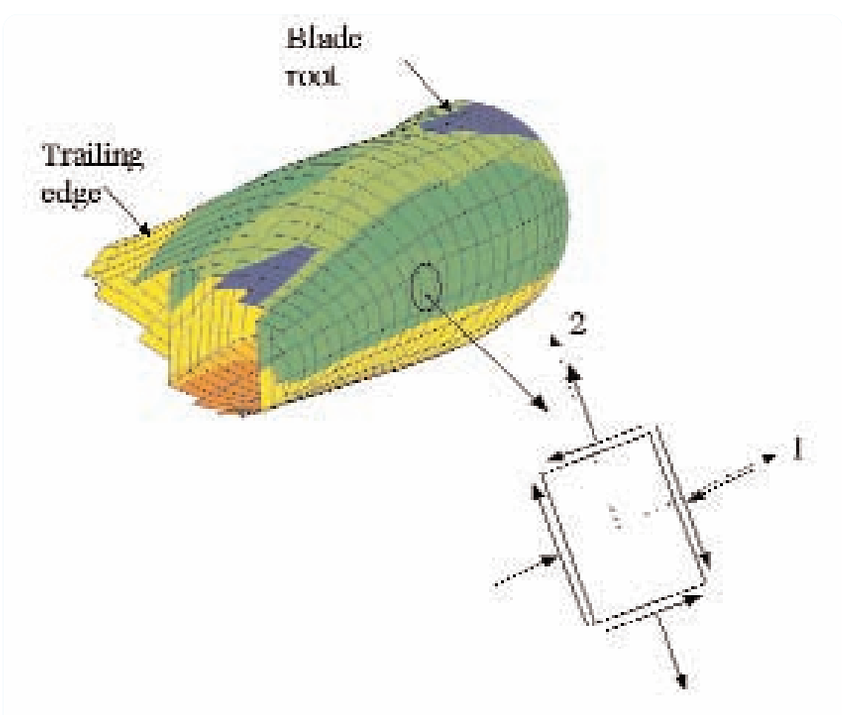
Short Presentation

Applied Mechanics Laboratory, Dept. Mechanical Engineering and Aeronautics of the University of Patras (AML/UP) is in operation since 1980 and deals mainly with the general field of materials & structures, giving emphasis in the science, technology and the applications of composite materials. Since 1990 AML/UP has systematically accumulated experience in wind energy technologies related to design, manufacturing, testing and certification of rotor blades. AML is associated with industry through consultancies, by participating in the technical committees of several corporations and in numerous national and EC-funded research projects.
After 1990, AML has been involved in private, national or EU R&D projects involving Greek industries and public organizations, aiming at the design and manufacturing of composite rotor blades or assessment of their structural integrity. AML/UP as a part of an educational institute provides courses about mechanics of composites, non-destructive testing techniques, structural mechanics, finite element and boundary element methods, structural dynamics, boundary elements in graduate and postgraduate level.

Research groups involved

Applied Mechanics Laboratory/UP consists of four University Professors, three Postdoctoral fellows and 20 PhD students. Their activities cover the following major research areas:

- Structural analysis of composite structures, Mechanics of composites, Smart materials/structures
- Development of novel analytical and numerical tools for design of composites (FEM, BEM, etc)
- Condition monitoring, NDT, Adaptive structures.
- Nanomaterials and Nanocomposites



Research Focus

Application focus of the AML/UP expands in the following areas:

- Structural Analysis & Finite Element Methods for Composites and Structures
- Damped structural dynamics models of large wind-turbine blades including material and structural damping
- Structural Damping (Passive & Active Vibration Control). Development of Specialty Composite Finite Elements with Damping Capabilities
- Smart Materials and Structures. Mechanics for Composite Materials & Structures with Embedded Actuators and Sensors. Active Shape Control.
- Anisotropic Material Property Characterization
- Structural Design, Optimisation and Dynamics of Composite Wind-Turbine Rotor Blades of current designs
- SHM and NDE Self-Detecting Smart Structures
- Fatigue Failure Prediction of Multidirectional Laminates under Combined Stress State and Variable Amplitude Loading
- Probabilistic Methods in the Design of Composite Structures
- Fatigue Characterization of Composite Materials using Conventional and Non-Destructive Testing
- Development of Numerical Tools (FEM and BEM)
- Vibration Testing

Facilities & Characteristics

Mechanical testing of materials	Hydraulic Universal Testing Machine Instron 8872 (25 kN) for tensile, compression and fatigue testing Hydraulic Universal Denison-Mayes Testing Machines (100 kN) for tensile, compression and fatigue testing, equipped with oven for working from sub-ambient temperature to 5000 C Hydraulic Universal Testing Machine Instron (250 kN) for tensile, compression and fatigue testing equipped with video-extensometer 2 Quasi-Static Universal Testing Frames 25 kN 2 Electromechanical Universal Testing Machines Scheunk, (Maximum capacity 100kN and 25 kN), equipped with an induction heating oven for high temperature testing in air. Both may perform low cycle fatigue tests Dynamic and Thermal Analysis DuPont 2000 Equipment with 9900 Programmer Low velocity impact machine. Ballistic-Impact testing equipment Impact Pendulum (Sharpy & Izold Impact)
Data acquisition systems	Various multi-channel High-Speed Data Acquisition Devices Multi-channel high-speed dynamic data acquisition and spectral analyser Dynamic acceleration, strain, force and temperature measurements
Non-destructive testing	Equipment and system for in-situ SHM-NDE using active piezoelectric sensors NDT Equipment (pulse generator, resonant and broadband piezoelectric transducers, angle beam sensors, pre-amplifiers) USIP 11 Krautkraemer pulse generator and C-scan peripherals with bath size 1200x1000 mm for Ultrasonic Testing Ultrasonic System dedicated to the characterization of the stiffness matrix of anisotropic materials and the anisotropic damage developed under thermo-mechanical fatigue conditions. The necessary software (developed in-house) is included 6-channel SPARTAN 2000 (PAC) for Acoustic Emission 4-channel MISTRAS (PAC) for Transient Acoustic Emission Analysis 2-channel MISTRAS custom boards (PAC) for High-Frequency AE Analysis
Fabrication	RTM unit (1- and 2-component resins) Torrus Mill for dispersion of nanoparticles in polymer resins Laboratory platens press 300x300mm, hydraulic force 300 kN, Max. temperature 4000 0C Hand Lay-up and Spray-up systems with vacuum bagging for the manufacturing of composite components Vacuum casting device for the manufacturing of working prototype components. Vacuum forming system Access to autoclave system for the manufacturing of composite components Full access to a Rapid Prototyping set-up consisting of SLA, LOM and Z-Print systems
Fractographic analysis	Nikon Thermo-camera system Nikon-Optiphot 66 Microscope equipped with CCD and video recorder
Conditioning chambers	Conditioning chamber for humidity and temperature control Conditioning chamber for bellow zero temperatures
Software	Nastran/Patran, ANSYS, ALGOR and LS-DYNA3D Finite Element codes Franc 2-D and 3-D for Fracture Analysis Several in house developed codes for advanced FEM, BEM and Statistical Pattern Recognition.

R&D Programme

The research group of AML/UP dealing with rotor blade structures has a long-term research plan on different aspects of composite materials applications for wind energy industry, aiming to achieve the following in the next 4 years period:

- Damped structural dynamics models for large wind-turbine composite blades. Inclusion of nonlinear structural effects.
- Optimized design procedures using advanced FE modeling techniques to improve rotor reliability. This includes the efficient 3D anisotropic material strength & stiffness experimental characterization, the introduction of structural damping tensor as a design parameter and the development of 3D fatigue life and residual strength computational procedures
- Detailed 3D stress analyses (analytical & numerical) of structural joints such as T-bolts for very thick (→30 mm) composites and development of efficient life prediction procedures, including stochastic modeling of material property and loading
- Development of damage tolerant design techniques for composites used in the wind-turbine industry introducing the use of NDI methodologies for assessment of blade structural integrity and composite repair efficiency in specific life intervals
- Development of real-time data processing methodologies and NDT monitoring procedures including in-situ piezoelectric actuators and sensors for active damping control and assessment of blade dynamic response.

Advanced research techniques

AML/UP, produces advanced techniques that concern mechanics of composite materials, design with composites and smart materials.

- Composite Damping Mechanics, which include integrated damping models (micromechanics, ply, laminate) for polymer matrix composite laminates and layerwise models for laminates with constrained damping layers and sandwiched foam cores. Multi-Damped Composite Laminates with Shunted Piezoelectrics.
- Detecting Damage in Composite Laminates Using in-situ Piezo-Actuators & Sensors. Combined analytical and experimental work aims to study the effects of damage on the vibrational response and guided wave propagation in composite laminates with embedded piezoelectric sensors and actuators. The ultimate objective is the development of novel smart material and structural systems with damage self-detecting and self-monitoring capabilities.
- Composite Damping Characterization & Measurement of Damping Coefficients. A unique testing system is available for measuring Damping Coefficients and Elastic Constants of a composite material. There is also capability for characterizing the dependence of damping and elastic coefficients on frequency and temperature.
- In-house developed and commercial computational tools for advanced 3D stress analyses of thick composite structures (FEM, BEM), stochastic and reliability analyses
- In-house developed pattern recognition codes based on either conventional algorithms or neural networks for classification problems of data emanating from NDT measurements
- 3D experimental characterization of damage accumulation in thick composite samples using through-transmission ultrasonic testing and dedicated, in-house developed, S/W
- Acousto-Ultrasonic and AE NDT methods to assess structural integrity of new or repaired blade structures
- Characterization of composite damping properties and measurement of structural damping, Passive & Active vibration control

Centre for Renewable Energy Sources, CRES

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Short Presentation

CRES was founded in 1987 and since 1994 is the Greek national coordination centre for Renewable Energy Sources and Energy Saving. CRES is supervised by the Ministry of Development, enjoying, however, financial and administrative independence. The Wind Energy Department of CRES has accumulated a notable experience through its participation in numerous wind energy related national and international projects, covering all aspects of wind energy, including wind energy potential assessment, wind turbine and wind turbine components design, testing and assessment, wind powered desalination and integration in autonomous power systems.
CRES in cooperation with other authorities is developing the National Wind Turbine Certification System, participates in relevant activities in the European and International level (CENELEC, IEC) and is a founding member of the MEASNET network. Moreover, within the Wind Energy Department the Laboratory for Wind Turbine Testing provides high quality measurement services, accredited according to ISO 17025, covering the whole aspects of wind turbine systems and their components, as well as wind potential measurements and analysis.

Research groups involved

The wind energy department of CRES has a scientific staff of 20 highly experienced and specialized scientists, engineers and technicians. Their activities can be divided in following major research groups:
The technical support group, which is responsible for equipment issues (purchase, maintenance, calibration), design and development of measuring systems, preparation, testing and installation of complete measuring systems for testing purposes.
The group of the laboratory for wind turbine testing, which is responsible for execution of tests within the services provided by the wind energy department of CRES.
The quality assurance group, which is responsible for the execution of projects under the quality specification required by the accreditation scope of the laboratory for wind turbine testing.
The numerical tools development group, which is responsible for the implementation of the theoretical findings in the design and analysis software used for wind energy applications.
The standardization and certification group, which deals with the relevant issues as part of the national development of standardization code, as well as the harmonization of the different wind turbine certification systems used in the EU.

Facilities & Advanced Research Tools

Laboratory for wind turbine testing	Services include Wind Turbine Power curve & Power quality measurements, Load & Noise measurements, Wind Resource Assessment
W/T Blade testing Laboratory	Full scale modal, multi-axial static and fatigue testing of wind turbine blades up to 20m with suitable servohydraulic equipment.
NDT for Wind Turbine Blades	Non Destructive Testing of composite materials including Acoustic Emission and Ultrasonic applications and blade geometry quality control
Mechanical Testing of materials	Static and fatigue experiments of blade materials and components with a servohydraulic MTS 250kN testing machine
Wind Tunnel	Anemometer calibration in the wind speed range 4m/s to 16m/s with calibration uncertainty better than 0.5% in a measuring section of 0.8x0.8m2
Test site & Demonstration wind farm	Complex terrain test site for R&D and certification of Wind Turbine systems. Demonstration wind farm comprising 5 medium sized wind turbines
Hybrid Wind-Diesel Laboratory System	Simulation of small autonomous grid operation. System is equipped with a 45kW diesel generator, a 30kW wind turbine simulator, control and monitoring systems.
Measuring equipment	Hardware and software for measuring mechanical loads and vibrations, noise, power quality and wind characteristics. Mobile equipment for data acquisition and communication
Software	In-house developed software ranging from CFD modelling to remote monitoring and control of wind turbine operation
Accreditation	Laboratory for wind turbine testing and W/T blade testing facility accredited according to ISO 17025. MEASNET member

R&D Strategy

	TERM short	medium	long
Characterization of the main features of complex or mountainous sites, affecting both the power performance and the loading of different types of wind turbines operating at such environments	◉	◉	
Development of wind turbines for installation in hostile environments of limited infrastructure		◉	◉
Improvement of damping characteristics and thereof aerodynamic stability of wind turbine blades	◉	◉	◉
Development of new techniques for power quality measurement and assessment	◉	◉	
Contributing know-how to Wind Turbine standardization procedures	◉	◉	
Developing blade-testing techniques including non destructive testing		◉	◉
Understanding generic aeroelastic performance of WT blades through CFD techniques	◉	◉	◉
Developing cost-effective micro-siting techniques for complex terrain topographies	◉	◉	◉
Developing new techniques for wind speed and direction measurements	◉	◉	◉
Improving characterization of composite material 3D fatigue life and residual strength through experiments for enhancing reliability of wind turbine blades	◉	◉	◉

Education and training activities

The Wind Energy department of CRES in support of academic research has created strong links with universities on a national basis. CRES researchers are taking part in consulting committees during PhD preparations with subjects relative to wind energy. Moreover professional training is taking place in the laboratory for wind turbine testing for students of National Technological Institutes. On a European level CRES supports programs like SOKRATES/ERASMUS, while CRES researchers are invited speakers for courses such as EUREC master course program.

CRES also provides its testing facilities for academic research in support of PhD or master thesis preparations, as well as for hands-on trainings during master courses on subjects relevant to wind turbine and wind turbine component design, testing and construction. In general CRES is very supportive of educational activities covering the needs from the elementary school, allowing for example educational visits to its premises, to the higher academic level, amongst others offering a 3-year scholarship on PhD candidates with relevant subjects.

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Short Presentation

NTUA is the oldest engineering HE Institution in Greece. The total number of students is about 10000, 8500 undergraduate and 1500 graduate ones. NTUA is divided in 9 faculties, each further subdivided in departments/laboratories covering all engineering disciplines. In parallel to education NTUA is also very active in research. Over the last ten years the mean contribution of the research activities to the total budget of NTUA was 70% originating from both the public and private sector.
Mainly two of NTUA's faculties have been involved in Wind Energy research and education: the faculty of Electrical and Computer Engineering and the faculty of Mechanical Engineering. Activities have been directed on a wide range of topics both with respect to the analysis and design of wind turbines as well as the implementation and integration of wind energy.

Research groups involved

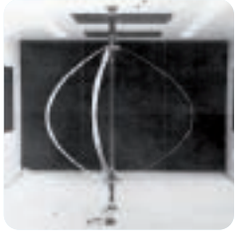
Electric Power Division, School of Electrical and Computer Engineering

The main lines of research concern integration of wind power and design of components. The integration line concerns the analysis of technical constraints from the integration of wind power into electrical grids, the management and control of island power systems with increased wind power penetration and power quality issues. The design line concerns lightning protection of wind turbines and wind parks and the design of electrical components for variable speed machines, including permanent magnet synchronous generators, power electronic converters and their controls.

Fluids Section, School of Mechanical Engineering

The focus is on the aeromechanical aspects of wind turbines and includes modelling and design with respect to performance (aerodynamics), safety & reliability (aeroelasticity) and noise. Another line of activity concerns wind parks and includes: the analysis and design of wind parks in particular as regards terrain and wake effects.

There is close collaboration between the two groups especially on the integrated modelling of the complete wind turbine system. Both groups are in close collaboration with CRES basically regarding the joint development of software and the sharing of testing facilities.



Facilities & Advanced Research Tools

Wind Tunnel	Closed circuit wind tunnel test facility supported with hot-wire anemometry, LDA and PIV suitable for: aerodynamic measurements up to Re=106 at a test section 1.8m x 1.4m and scaled site mean flow measurements 3.5m x 2.5m
RTDS	The Real Time Digital Simulator (RTDS) is capable of modelling power networks and test external devices and control circuits via digital and analogue inputs. Particularly useful for studying Wind Turbine effects on power quality
Computing Facility	20 proc Cluster for MPI computations, 10 Workstations
Software	Optimal design of wind turbine rotors Full aeroelastic simulation of wind turbine configurations Aeracoustic modelling of wind turbines Noise propagation models in the atmosphere Drive train electo-mechanical analysis and design Power quality analysis for constant and variable speed operation Wind energy integration modelling Operation and management analysis of isolated power systems with increased wind power penetration Lightning protection and grounding system analysis CFD for aerodynamic analysis and site evaluation Wind farm modelling and design

R&D Strategy

TERM	short	medium	long
Optimal aerodynamic design of airfoils	◉		
Optimal aeroelastic design of blades		◉	
Detailed CFD analysis of wind turbine rotor systems			◉
Aeroelastic modelling of full wind turbines configurations with emphasis on stability	◉		
Aeroacoustic analysis of wind turbine rotors		◉	
Design and testing of control systems for wind turbines		◉	
Investigation of generic aeromechanical systems for performance improvement and load alleviation (solid and air-jet vortex generators, moving flaps, active structural control)			◉
Investigation of new concepts (flexible rotors, floating wind turbines)		◉	
Grounding and lightning protection of wind generators		◉	
Design and analysis of wind farms including integration and power quality issues		◉	
Investigation of new concepts (flexible rotors, floating wind turbines)			◉
Operation and management of micro-grids and distributed generation including wind		◉	
Investigation of new concepts (flexible rotors, floating wind turbines)			◉

Education and training activities

Education and training activities on Wind Energy at NTUA covers all education levels. There are undergraduate courses offered by the two main faculties. At the Electrical and Computer Engineering faculty there is a dedicated course that focuses on integration issues while the material concerning the analysis and design of generators and control is covered by specific courses. At the Mechanical Engineering faculty, there is a general course on renewable energy sources which also contains an introduction to wind energy as well as a special course dedicated to wind energy. Topics such as Aeroelasticity, Aeracoustics, Machine design and Manufacturing are covered by specific courses which make reference to wind turbines as application cases. At post-graduate level, there is a course entitled: "Energy generation and management" having two options, one of which is on Renewable Energy Sources and Rational use of Energy including courses on Wind Energy.
The students follow a two semester training course followed by a project of nominal duration of 4-6 months. In addition NTUA is participating in the EUREC Master Course program, by organizing the Wind Energy Specialty Option covering the fall semester.
Other education and training possibilities include enrolment on a 4 year project leading to a PhD as well as shorter training courses. These two options are open also to non-greek speaking students coming to NTUA either through EU training programs such as SOKRATES/ERASMUS or through bilateral agreements with other Universities.

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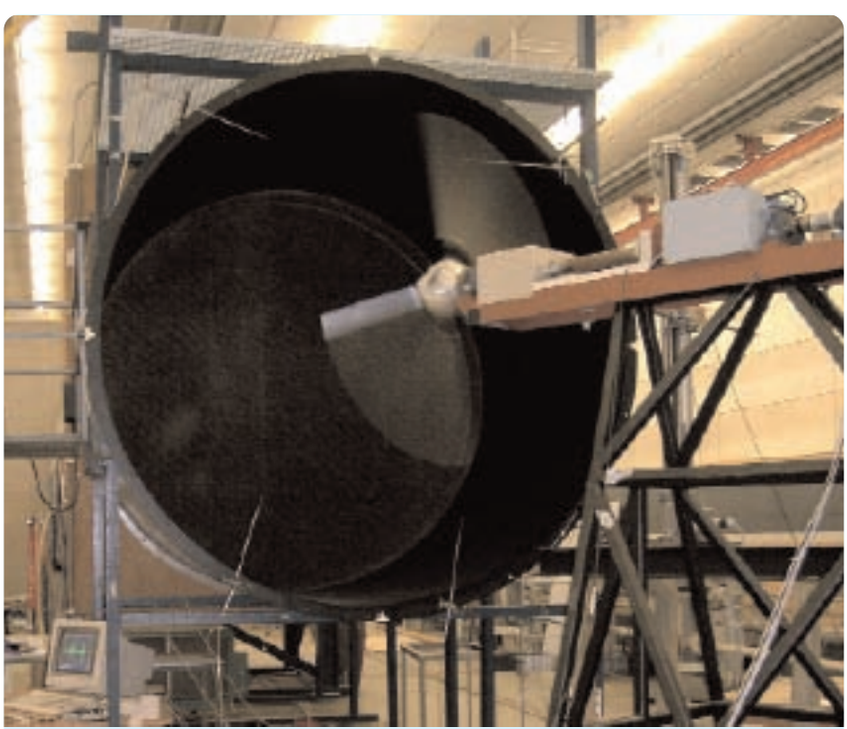
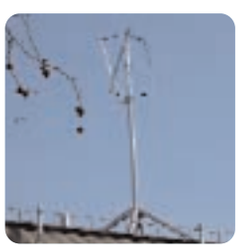
Short Presentation

Research on wind energy at the Delft University began 30 years ago, starting with an aerodynamic project at Aerospace Engineering. Nowadays the research programme (later program) covers almost all aspects of modern wind turbine technology, and is undertaken across 5 faculties, see below. Each of the research groups at these faculties has its own specific expertise, but an increasing number of research problems require a multi-disciplinary approach. Duwind is the wind energy organisation at the Delft University of Technology. The focus of Duwind is on long term, pioneering research, which implies that PhD research, is the core of Duwind. Duwind comprises approximately 45 (full time equivalent) researchers, of which about 30 PhD candidates. The focus of Duwind's program is on the development of turbine and wind power station technology, ranging from fundamental aerodynamic research to development of design methodologies, and anything in between. Duwind offers a MSc curriculum in wind energy, and provides courses for professionals in the wind energy industry.

Research groups involved

Duwind encompasses 10 research sections. The Wind Energy Section at Aerospace Engineering is the only one fully dedicated to wind energy, all others use wind energy as a challenging application of their expertise. Key-words of the research are:
Faculty of Aerospace Engineering
Aerofoil and blade design, rotor aerodynamics (experimental, analysis, CFD), fluid-structure-interaction, rotor dynamics, aeroelastic stability, design of turbines and of offshore wind power stations, design methodology, wind field description, structural reliability, composite materials, component testing, production techniques, smart structures, urban wind turbines
Faculty of Civil Engineering and Geosciences
Offshore design tools, support structure, access systems, offshore availability and reliability.
Faculty of Electrical Engineering, Mathematics and Computer Science
Electric conversion systems, direct drive generators, configuration of offshore wind parks
Wind as part of renewable energy systems, integration of renewable energy in the grid, stand-alone systems.
Faculty of Mechanical, Maritime and Materials Engineering
Fault-tolerant control. Nonlinear analysis, control and identification. System identification, design and testing of turbine control systems, analysis of turbine dynamics, reliability based design methods.
Faculty of Technology, Policy and Management
Introduction of new infrastructures in society, scenario development for large scale Dutch offshore windpower.





TU Delft

Facilities & Advanced Research Tools

Facilities	
Low speed, low turbulence tunnel	High quality closed loop wind tunnel, up to 120 m/s wind, turbulence ranges from 0.015% at 20 m/s to 0.07% at 75 m/s. The 10 interchangeable octagonal test sections are 1.80 m wide, 1.25 m high and 2.60 meters long.
Open Jet Facility	The OJF is an open jet tunnel specifically for wind energy. The test section is 3m Ø, max windspeed is 30 m/s. The tunnel will be operational early 2008.
Several small wind tunnels	Ideal for small scale test, as preparation for experiments in the large tunnels.
Structures and Material Laboratory	Laboratory for composite material development and coupon testing, testing of structures, development of manufacturing processes.
Wave basin, towing tank	The towing tank has a length of 145 m, width of 4.22m, equipped with a wave generator. The wave basin is 25*25m, with wave generators in three directions
Many other university laboratories	
Advanced Research tools	
Aerofoils	A series of DU aerofoils have been designed, tested and used by industry. The aerofoils are in the public domain
WimSim	In-house developed Matlab based turbine design tool, for quick and easy preliminary design and load calculations
Contofax	In-house developed tool for O&M simulation of offshore wind farms
Aerofoil and blade design tools	In-house developed codes, can be transferred to users after in-house training
Design tools and design support for	controllers support structures direct drive generators blade material and manufacturing processes

R&D Strategy

Duwind cooperates closely with ECN, the Dutch Energy Research Institute. The research program and expertises are adapted to each other, keeping the character of each institution in mind: Duwind focuses on long-term, fundamental R&D while ECN focuses on applied R&D, with enough overlap to cooperate and compete. Duwind and ECN share a common international Advisory Board.

The research programme of DUWind is driven by the following three objectives:

- To maximise the reliability of wind turbine and wind farm operation
- To minimise the loads on the structures (on both the rotors and support structure)
- To optimise the entire energy supply chain (wind, wind turbines, grid layout and onshore connection, integration into the main grid).

The Duwind research program is divided into 5 program lines. These five major areas are:

- unsteady aerodynamic loads
- smart dynamic control (smart structures)
- offshore design aspects
- design methodology
- electric conversion and large scale electricity supply

The majority of the research is done by PhD researchers (in the Netherlands a PhD takes 4 years full-time research). The first objective is knowledge and understanding, with design tools and guidelines at the second place. This implies that almost all work is considered to be long-term research. However, whenever possible, knowledge is transferred to the market either by direct contact and training of industry, or by design projects together with ECN.

Education and training

Duwind offers a specialization on wind energy in many Delft MSc degrees, supported by dedicated MSc student courses on wind turbine design, rotor aerodynamics, wind and site conditions, offshore wind farm design, blade materials and construction. Students choosing to specialize in e.g. control of wind turbines follow the control MSc track at the faculty of Mechanical Engineering, and include some of the mentioned courses in their portfolio. Students preferring to specialize in rotor aerodynamics do the same at Aerospace Engineering. The overall turbine design and systems engineering approach is offered at Aerospace Engineering. Duwind welcomes international students to do a MSc at Delft, or a traineeship. The same holds for the PhD research: Duwind stimulates PhD students to work for some time at another university of institute, and welcomes other PhD's to come to Delft.
Duwind also takes care of the wind energy education at the other Dutch Technical Universities in the framework of the joint MSc in Sustainable energy Technology, and contributes to the EUREC MSc.
On request Duwind offers post-academic courses for industry, and courses on advanced topics.

The Energy research Centre of the Netherlands (ECN)

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Short Presentation

The unit ECN Wind Energy is part of the Energy research Centre of the Netherlands (ECN); an independent market oriented knowledge centre for energy research and development. The strategic position between universities and industry has been a successful basis for many developments and innovations since the start of ECN's wind energy activities in 1975. With 40 employees ECN is covering all relevant wind energy disciplines. ECN's research varies from long term and more fundamental research to high level consultancy for industry. Core activities include aerodynamic and structural design and analysis of wind turbines, design of control algorithms, resource assessment, wind farm design and monitoring of wind farm operation through power performance and mechanical load measurements.
ECN Wind Energy is committed to bring wind energy down the learning curve: our mission is to increase the value and reduce the costs of wind energy. That is the drive for our research activities. That is the reason we are using our expertise for turbine manufacturers and their suppliers, project developers and investors, contractors and wind farm operators.

Research groups involved

Within the Unit ECN Wind Energy there are three research groups, focusing on different research lines, and a group specialized in conducting measurements and experiments:

The group Design & Control covers the priority areas:

- Wind Turbine Control
- Aero Elastics - the structural dynamic part

The group Aerodynamics covers the priority areas:

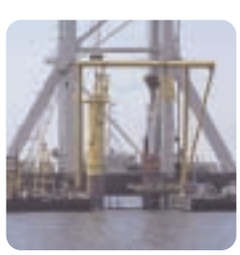
- Aero Elastics - the rotor aerodynamic part
- Wind Farm Aerodynamics

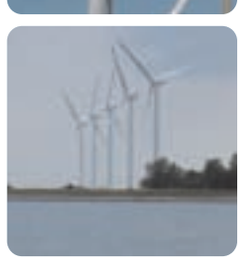
The group Wind Farm Operation & Condition Monitoring focuses on two priority areas:

- Condition Monitoring and Measurement Techniques
- Operation and Maintenance

The group Experiments & Measurements provides the experimental services for the different R&D projects in all research areas and is accredited according to ISO 17025 for:

- Power Performance Measurements
- Noise Measurements
- Load Measurements





Facilities and Advanced Research tools

Wind farm for R&D purposes (EWTW)	ECN owns a research wind farm, consisting of five 2.5 MW wind turbines for experimental purposes.
Scaled farm	ECN operates a scaled wind farm, consisting of 10 wind turbines with a rotor diameter of 7 meters and 16 measurement masts for experiments in the field of wake and farm aerodynamics and farm control strategies.
Test site for proto type turbines (EWTW)	The ECN test site offers a well-balanced infrastructure for prototype testing of offshore wind turbines up to 6 MW, including three measurement masts of 108 m height.
Test site for smaller turbines	ECN offers a smaller test site for prototype testing of wind turbines up to 250 kW.
Measurement equipment	ECN developed a distributed data acquisition system, called Dante, including software for data analysis. ECN also offers a system to register bird collisions (WT-Bird) and a system and software for blade monitoring with optical strain gauges.
Blade test facility (WMC)	Together with TU Delft, ECN founded WMC, a new testing facility for wind turbine blades up to 70 meters.
Facility for destructive and non-destructive material research (WMC)	At WMC different testing infrastructure is available for destructive and non-destructive testing of composite materials.
Software	ECN provides a wide range of design software for industrial use, including software for blade design, structural design, controller design and software for optimizing operation and maintenance of wind farms
Accreditation	ECN is ISO 17025 accredited for power performance measurements, mechanical load measurements and noise measurements, and is a full member of MEASNET.
Wind tunnels	Wind tunnel facilities exist near to ECN at the German Dutch Wind tunnel DNW (the largest wind tunnel in Europe), at TNO and at TU Delft.

R&D Strategy

	TERM short	medium	long
Supporting turbine and blade manufacturers in specific R&D issues	◉		
Developing integral design tools (and sub-models) for designing heavy-duty low-maintenance large turbines in extreme conditions - rotor aerodynamics and structural dynamics	◉	◉	◉
Research into improved availability and reliability of offshore turbines and the development of cost-effective measuring systems and software for optimal Operation & Maintenance strategies	◉	◉	◉
Developing tools for designing multi-parameter control algorithms and strategies		◉	◉
Developing knowledge and models of flow in and between wind farms and control strategies for optimum wind farm operation - wake and farm aerodynamics	◉	◉	◉
Modelling wind turbines, wind farms and grid models and conducting studies on grid integration of large quantities of offshore wind energy in the electricity grid	◉	◉	◉

Education and training activities

The Wind Energy department of ECN has strong links with universities throughout Europe. Staff members of ECN participate in advisory boards of different universities and scientific committees.
On a regular base, staff members of ECN are invited guest lecturers at universities. ECN offers dedicated courses related to the design software and the different research topics. PhD candidates are frequently working at ECN for shorter and longer time periods.

SINTEF, IFE and NTNU - Centre for Renewable Energy (SFFE)

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Short Presentation

The SINTEF Group, IFE (Institute for Energy Technology) and NTNU (Norwegian University of Science and Technology) cooperate on wind energy R&D through Centre for Renewable Energy (SFFE). The Centre is virtual and has a coordinative and consultative function for the education and research groups within renewable energy, including small scale hydropower, wind, solar, wave, and bio-energy as well as the social dimensions of energy use.

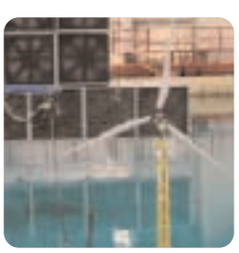
Wind energy is a major area of the SFFE-network at NTNU, SINTEF and IFE involving some +30 scientific staff including about 10 professors and 10 PhD students. The activities are multi-disciplinary involving highly qualified scientific staff from various specialist research groups within the network. These research groups are not only working with wind energy, but are specialized on a specific scientific subject, e.g. materials or electrical engineering. All aspects of wind energy are covered, though main focus and strength areas are on grid integration and offshore technology.

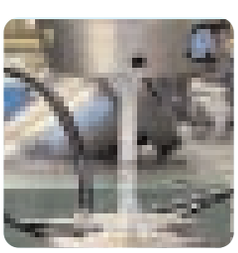
Laboratory facilities include a test station for wind turbines, a wind power electro-technical lab with generators, power electronics and loads, a wind tunnel (11x3x2 m) and an ocean basin lab (80x50x10 m). In total NTNU, SINTEF and IFE operates well over 100 laboratories within a large range of fields, e.g. testing and characterizing of materials, corrosion etc.

Research groups involved

The wind activity at NTNU, SINTEF and IFE involves some +30 scientific staff including about 10 professors and 10 PhD students. All aspects of wind energy are covered, though main focus and strength areas are on grid integration and offshore technology. The research units being involved in wind energy are listed below.

Research unit	
SINTEF Energy Research	- Coordinator of wind activity within SFFE - Grid integration and market operation - Power quality measurements - Asset management / O&M strategies - Electric components incl. sub-sea - Assessment and design of control systems
MARINTEK	- Offshore hydrodynamics - Offshore structures - Marine operations (installation / access) - Logistics and O&M strategies
SINTEF Materials and Chemistry	- Corrosion protection (cathodic / coating) - Metallurgy / Cast-iron components





Research unit	
SINTEF Information and Communication Technology (ICT)	- Modelling and simulation of ice and wind conditions over complex terrain and offshore
IFE	- Rotor aerodynamics - Aero-elastics (Onshore & Offshore turbines) - Wind turbine optimization - Simulation of wind in complex terrain / offshore
NTNU	- Cover all aspects of wind energy - Responsible for MSc and PhD students - Focus on grid integration and offshore - PhD students works include generator technology, power electronics, control systems, offshore structures, materials, hydro and aero-dynamics, wind assessment and social science

The main activity of the institutes within the SINTEF Group and IFE is contract research, whereas the main activity of NTNU is education of MSc and PhD students.

Facilities & Advanced Research Tools

Test station for wind turbines	Test station at Valsneset at the west-coast some 2 hours drive from Trondheim with good wind exposure (annual average 8.4 m/s at 50 m agl). Installations include met mast and measurement equipment, a service house, one 225 kW wind turbine (currently rebuild for testing a novel hydraulic drive-train), one 900 kW wind turbine (to be installed) and one 2.3 MW wind turbine. New sites / offshore are currently being investigated.
Wind power electro-technical lab	Lab for testing, research, development and demonstration of novel generators, power electronics and control solutions. Strong, weak or isolated grid operation is facilitated with equipment (generators etc) up to 50 kW.
Wind tunnel	Wind speed up to 30 m/s. Test section: 11 x 3 x 2 meters (L/W/H). 6-component balance for measurements of the 3 forces and 3 moments. Equipment for measuring Temperature, Pressure and Velocity.
Ocean basin lab	A total environmental simulation including wind, waves and current offers unique testing conditions for models of all types of fixed and floating structures. A water depth of 10 metres offers excellent testing possibilities for deep water structures intended for the offshore industry in future. Length: 80 m - Width: 50 m - Depth: 0-10 m
Laboratories (general)	In total NTNU, SINTEF and IFE operates over 100 laboratories within a range of fields, e.g. testing and characterizing of materials, corrosion etc.
Measurement equipment	A broad range of advanced measurement equipment, both in labs and portable for use in the field.
Software	A broad range of advanced software tools including both in-house and commercial packages.

R&D Strategy

	TERM short	medium	long
Progress of design tools (analytics, numerical methods and experiments) for the (structural, control, concurrent engineering) design of (deep-sea) offshore wind energy concepts	◉	◉	◉
Assessment, test and development of wind turbine design solutions adapted for offshore / deep-sea conditions, e.g. mono-pile, jackets, floaters, up-wind/down-wind, 2 or 3 blades etc.		◉	◉
Test and development of new materials and coatings for offshore wind turbines (e.g. lightweight hub, corrosion protection, etc)	◉		◉
Test and development of new robust and light-weight wind turbine drive-train solutions (PM generators, power electronics, hydraulics)		◉	◉
Development of solutions for cost effective grid connection of large wind farms, incl. deep-sea novel concepts and components (sub-sea connectors, dynamic cable, etc.)		◉	◉
Assessment of an offshore "super-grid" structure, including development of a methodology for optimizing such a grid	◉		◉
Facilitate efficient power system operation with large amounts of wind energy (meeting the challenges of EU2020 and beyond), including understanding wind variations and methods to balance these (wind farm control, aggregation, storage, market, DSM, etc)		◉	◉
Development of offshore logistics and access technology		◉	
Development of procedures and techniques for efficient asset management, operation and maintenance	◉	◉	
Contributing know-how to wind turbine standardization works	◉		
Measurement and modelling of power quality characteristics of wind turbines, including fault-ride through capabilities	◉		
Development of methods (numerical/measurements) for cost effective assessment and on-line prediction of wind conditions and icing over complex terrain and for offshore also waves	◉	◉	
Assessment of (offshore) wind impact on society, environment, policy and industry value creation	◉	◉	

Education and training activities

Education and training activities constitute a significant part of the wind energy activity within the SFFE-network of NTNU, SINTEF and IFE. NTNU has the main responsibility for the educational activities, graduating MSc and PhD students. The MSc students are graduated within the classical fields of science and technology, whereas PhD students may specialize within specific fields of wind energy. The cooperation between NTNU, SINTEF and IFE largely enhances the quality of both education and research.

The Spanish National Renewable Energy Centre (CENER)

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Short Presentation

The Spanish National Renewable Energy Centre (CENER) is a national technological centre dedicated to research, development and promotion of renewable energies in Spain. It was founded in 2002 and it operates in six main areas: wind power, solar thermal, photovoltaic, biomass, bioclimatic architecture and power electronics.
CENER participates in key areas of R&D, offers the very latest technological services, and is involved in training schemes and in standardization committees.
The CENER wind energy department was set up to support the industrial sector and to act as a technological referent both at national and international level. The department is clearly positioned as an independent body at the service of the major agents in the sector, including developers, manufacturers, certification authorities, financial institutions, users, associations and administrative bodies. The department is engaged in providing the services required by the different agents and in developing new technologies aimed at promoting and improving the competitiveness of the wind sector. With this two-fold objective, work is being carried out on different research projects, both internally and in cooperation with technological centers, institutions and companies. Intensive work is being carried out on standardization, with active participation in national and international regulation development work groups.

Research groups involved

The CENER wind energy department has a scientific staff of 80 specialized scientist, engineers and technicians. The department is organized in three groups: Wind test laboratory and Certification, providing services for Wind Power Curve, Power Quality, Loads and Noise measurements according with the IEC standards.
In March 2004 CENER signed a collaboration agreement with Det Norske Veritas (DNV) for the standard certification of wind turbines in Spain, in agreement with the outlines of IEC-61400-WT01.

Wind test laboratory and Certification, providing services for:
Wind Power Curve, Power Quality, Loads and Noise measurements according with the IEC standards
Blade structural testing
Drive train testing
Materials testing and blade manufacturing process technology
Wind tunnel testing

In March 2004 CENER signed a collaboration agreement with Det Norske Veritas (DNV) for the standard certification of wind turbines in Spain, in agreement with the outlines of IEC-61400-WT01.

Wind analysis and design of Wind Turbines. The group is currently comprised of 20 people, grouped into the following knowledge areas:

- Aerodynamics
- Structural mechanics
- Control
- Composite materials and blade manufacturing processes

Assessment and prediction of wind resources. The wind resources assessment group offers the following services:

- Preparation of wind energy resource maps
- Energy assessment of wind farm locations.
- Prediction of energy production for wind farms
- Project audits

CENER is already involved in several projects aiming at the development of new technologies in the wind energy field that require performingfull scale test of wind turbines and components.

Facilities & Advanced Research tools

Wind Turbine Test Laboratory	To perform on site different field tests: Power curve, Energy quality, Acoustic noise, and Mechanical loads
Blade Test Laboratory	To perform tests in agreement with standard 61400-23 (Full-scale structural testing of rotor blades). Possibility to test simultaneously 2 blades of up to 75 m. Static and dynamic test and characterisation of physical properties, as well as pitch bearing tests. Two 30 T cranes. 8 static actuators with capacity ranging from 100 to 400 kN. Hydraulic actuators for resonance fatigue testing. Hydraulic equipment for blade assembly. Test rigs designed for 100,000 kNm (static) and 50,000 kNm (dynamic).
Drive train test bench	To perform mechanical tests on the drive train (including gear box) of wind turbines up to 5 MW, with hydraulic actuators to apply loads on WTG components to simulate efforts coming from rotor and wind. Static and dynamic tests. Mainly oriented to fatigue test. One Indoor 100 T crane. Specific instrumentation: Two data acquisition systems and electric measurement equipment. Remote control of the test benches with visual access to benches to improve safety in operation
Electrical Test Bench	To perform tests on generator and power electronic equipment of wind turbines up to 5 MW. It also allows performing complete nacelle functional tests when adding mechanical reducer already available on bench.
Nacelle assembly test bench	Outdoor WTG assembly bench to perform tests on tooling and to train personnel for assembly and maintenance activities.
Composite Materials Laboratory	Composite materials characterization laboratory. Workshop for development and testing of blade manufacturing processes
Experimental Wind Farm (at planning stage)	Large wind turbines testing in complex terrain, on prototypes up to 5 MW rated power wind turbine. Average wind speed: 8 m/s. 6 positions up to 5 MW WT. Electrical Infrastructure: Medium Voltage (20kV). Substation: 20kV/66kV. Instrumentation: Calibrated Sites. Meteo towers.
Wind Tunnel (at planning stage)	For characterization of aerodynamic airfoil characteristics, optimised for the following kind of tests: Static 2D profile testing, Dynamic 2D profile testing (Pitching and Plunging), Aero-acoustic measurement and Flow visualisations.
Measurement Equipment	Hardware and software for measuring mechanical loads and vibration, noise, power quality and wind characteristics (including LIDAR systems). Mobile equipment for data acquisition and communication.
Software	Standard software for WT design (Bladed, Fast, ..) and Wind Flow simulation (Fluent, Wasp, ...), EEM (MSC.Nastran, Marc), MBS (MSC.Adams), CAE (Unigraphics, Fibersim, Autocad) In-house developed software: Wind generator modelling tool, aimed at the design of controllers (in Matlab-Simulink). Wind generator dynamic analysis tool, aimed at pre-dimensioning the entire system and obtaining loads in wind generators. Wind generator design specific CFD code (collaboration with Glasgow University).
Accreditation	Wind Turbine Test Laboratory ENAC accreditation as a test laboratory (Dossier No. 355/LE803). MEASNET member

R&D Strategy

	TERM short	medium	long
CFD model for simulation of the wind field and wakes	◉	◉	◉
Coupling of mesoscale-CFD and turbine load models		◉	◉
Mesoscale and statistical models for characterisation of extreme winds	◉	◉	
New measurement techniques (LIDAR)	◉	◉	
New meteorological models for the wind prediction		◉	◉
Advanced statistical models to detect and eliminate systematic prediction errors	◉		
Mesoscale models for wind mapping	◉	◉	
New concepts for Wind turbines and components	◉	◉	
New wind turbines design tools		◉	◉
New materials and manufacturing process for large WT		◉	◉
Offshore Wind Resource assessment	◉	◉	
Wind Turbine design for offshore wind power plants		◉	◉
Support Structure design for offshore wind power plants		◉	◉
Electrical lay-out of offshore wind power plants and grid connection		◉	◉

Education and Training Activities

CENER is involved in several courses for training technical personal in different fields of the wind energy sector, and is collaborating with universities and others centers in different undergraduate and post-graduate training programs.

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Short Presentation

CREST was established in 1993 with the remit to advance renewable energy technology so as to provide substantial and benign energy options for present and future generations. Specifically,

CREST:

- contributes to the development and implementation of renewable energy systems through high quality research and demonstration,
- works with research institutions, industry and related organisations at home and abroad to promote renewable energy, and
- provides training and education in both theoretical and practical aspects of renewable energy systems technology.

CREST's research is principally focused on the technologies for generating electricity with renewable energy, and the integration of these technologies into electricity supply systems. The Department of Electronic and Electrical Engineering, of which CREST is part, provides an ideal environment for such research.

The Wind and Water research team at CREST has built up significant expertise through domestic and international research projects, including wind resource assessment on and offshore, condition monitoring, small wind turbine modelling and design and wind power integration.

Research groups involved

Wind power research at CREST is carried out within the Wind and Water team which consists of one academic, two post-doctoral researchers and four PhD students.
Research within this team covers:

- Wind forecasting and integration of wind energy
- Energy storage technology
- Wind resource modelling
- Condition monitoring of wind turbines
- Control and system integration of wind turbines
- Structural dynamics of wind turbines
- Wind turbine aerodynamics and design
- Building mounted wind turbines

CREST is looking at the benefits of remote condition monitoring which will become increasingly important as offshore wind power is developed, and an EU project is assessing advanced techniques for the monitoring of offshore wind farms. CREST is also part of a nine-partner SUPERGEN programme in order to extend work in this very important research field.

There is increasing pressure to develop wind power offshore, in areas of complex terrain onshore and within the built environment. CREST is in the forefront of this research using computational models to asses wind speeds in these areas. As wind turbines become ever larger, active control systems become more important. Research within CREST is ongoing on the development of an active drive-train damper control system for a large wind turbine to relieve structural forces.

Facilities and Advanced Research Tools

Desalination rig	Rig for developing optimum control system for wind-powered desalination.
Roof-top testing	Performance testing of small building-mounted wind turbines; assessment of wind resource in the urban environment.
Wind turbine	2.2kW experimental wind turbine.
Wind tunnel	Active section 1.8m × 1.3m (within the Department of Aeronautical and Automotive Engineering).
Software	CFD software for wind resource estimation, software for modelling turbine performance.

R&D Strategy

	TERM short	medium	long
Wind resource estimation in the built environment	◉		
Wind profile characterisation offshore		◉	
Wind resource methodologies for offshore and near forests		◉	◉
Availability assessment for wind turbines	◉		
Techniques for effective condition monitoring of wind turbines		◉	
Small wind turbine design		◉	◉
Energy storage development and modelling			◉
Wind power integration	◉	◉	◉
Wind turbine control		◉	

Education and training activities

Since 1994, CREST has delivered the now world-renowned MSc in Renewable Energy Systems Technology. This provides a technical, theoretical and practical overview of all of renewable energy generation technologies including wind power and has provided many graduates to the renewable energy industry. CREST is also a core provider to the EUREC European Masters in Renewable Energy. In addition, the Department of Electronic and Electrical Engineering teaches an undergraduate MEng in Electrical and Renewable Energy Systems. For industrial training, CREST provides a yearly summer school in Wind Energy. In terms of postgraduate research, CREST supports a number of PhD students to underwrite the Centre's research programme. Some of these are funded through research grants and some through departmental scholarships. European cooperation is facilitated through the Erasmus-Socrates programme and CREST takes an active part with strong links with the University of Malta and the University of Zaragoza in Spain.

Durham University

Contact

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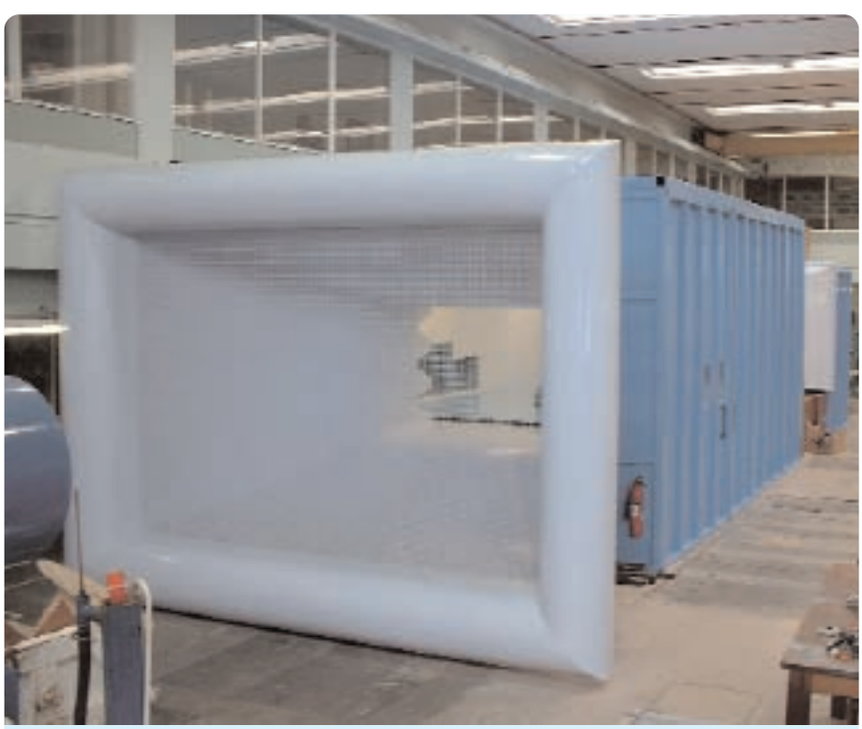
Short Presentation

The New & Renewable Energy is part of the Energy Research Group of the School of Engineering, given a Grade 5 rating in the 2001 Research Assessment Exercise. Research focuses on the conversion of energy from new or renewable sources and integration into energy networks with industrial and national & international academic partners. The group is part of the Durham Centre for Renewable Energy, party to setting up the New & Renewable Energy Centre (NaREC) at Blyth, Northumberland, with large scale laboratory facilities. The Group's will deploy renewable energy demonstrators at NaREC, beyond the scope of our own laboratories.

Group research has been funded by EPSRC, EU Frameworks 5 & 6, DTI and industries. Current funds are about £1M. Research aligns with UK government policy to meet energy targets set out in the 2003 Energy White Paper. The Group participates in two EPSRC Supergen projects, on wind and photovoltaic, with Durham as a Financial Hub. The Group has formed one "spin-off" company, Evolving Generation, which developed a generator for large, direct drive, wind turbines.

Facilities & Advanced Research Tools

Laboratories	Wind tunnel facilities up to and including 2 m2 cross section air jet with computer controlled force balance, pressure and flow measurements and particle velocimetry measurement. Integrated power laboratories for energy conversion measurements up to 50 kW. Distributed generation laboratory. Thermal power facilities with Domestic CHP, solar thermal and PV
Measuring equipment	Data monitoring equipment for power conversion from renewable sources
Software	FLUENT, MATLAB Simulink, LabVIEW, Flex, ABAQUS, STRAND



Durham University

Research Strategy

The Group's strategy is to conduct first class research and to contribute to technology transfer and teaching through current research objectives:

- The design of electrical machines of novel topology for use at low or high speed in renewable applications, particularly for wind, wave and marine current energy converters.
- The application of these electrical machines to hybrid Engine/Generator configurations for electric vehicles, embedded generation and other renewable applications.
- The application of Stirling engines to hybrid configurations for renewable applications.
- The application of renewable technologies such as solar power to water pumping for developing countries.
- The development of power electronics for the control and recovery of electrical energy from renewable energy schemes.
- The simulation and modelling of renewable energy components and systems, including electric and hybrid electric vehicle energy studies.
- The integration and control of distributed generation in electrical networks.
- The modelling of electromagnetic devices, particularly electrical machines of novel topology.

Education and training activities

The Group teaches on our acclaimed 4 year MEng in New & Renewable Energy and we run a one year MSc in New & Renewable Energy. Design and research project form an integral part of our courses.

Imperial College London

Contact

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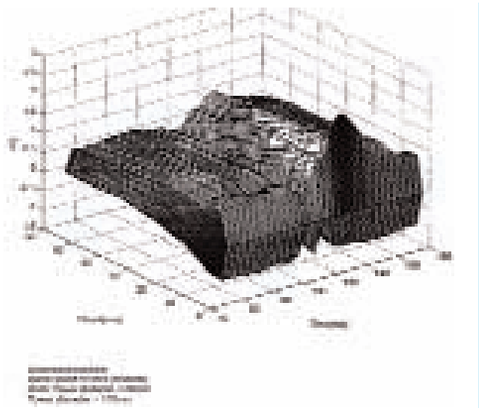


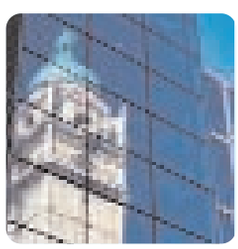
Short Presentation

Imperial College was founded from three constituent colleges (Royal College of Science, Royal School of Mines and The City and Guilds College (Engineering)) in 1907. A medical school and a business school were added in the 1990s. The College became an independent university (retaining the name Imperial College) in 2007, its centenary year. Aeronautics was first established in the College in 1920 as part of the Royal College of Science. It moved to Engineering as the Department of Aeronautics in 1932. The Department consists of 22 staff divided into an Aerodynamics section, an Aeronautical Structures section and a new research group specialising in Control. Research work in the Department covers both fundamental studies and a wide range of applications. It includes Computational Fluid Dynamics with a strong emphasis on RANS and DNS simulations, experimental aerodynamics from low subsonic up to hypersonic, turbulence research, aircraft configuration research, structural analysis with an emphasis on composite structures and modelling, bio-fluidmechanics, road vehicle aerodynamics, marine technology, wind engineering and wind energy research.

Research groups involved

Research in wind energy has been carried out for about 20 years within the Aerodynamics section in a small group working with Prof. Mike Graham. The main area of research has been horizontal axis rotor aerodynamics, including studies of stalling, stall delay (3-dimensional effects), effects of yaw, incident turbulence and wakes and interactions between rotor blades and the tower or other adjacent structures. The group coordinated the EC Joule project ROTOW which studied Rotor-Tower interaction and carried out all the aerodynamics for the EC Joule project WEB (Wind Energy in the Built environment). Work has also been undertaken relating to Wave Energy (Investigation of the fluid mechanics of the Wells turbine which is used in oscillatory flows generated by waves) and currently the hydrodynamics of tidal stream turbines (studies of blockage effects and added mass in unsteady incident flows) and blade load control in turbulence are being researched. The research techniques used have ranged from measurements of blade pressure distributions on a 17m diameter rotor in the natural wind to smaller scale laboratory measurements in wind tunnels and water channels. In parallel with the experimental work there has been a considerable programme of numerical flow simulation.
The Aerodynamics section has a large programme of work on Marine Technology some of which overlaps with offshore wind energy interests including research into wave and current loads on offshore wind-turbine towers.
The Aeronautical Structures section carries out a large programme of work in structural analysis, including structural dynamics. This work is mainly focused on composite materials, particularly CFRP and is concerned with crack propagation, impact damage and fatigue prediction. Application is general and not particularly directed to wind turbine structures.

Imperial College London



Research Facilities

Laboratory	Low Speed (up to 40m/s) Wind Tunnels, working sections up to 3m x 1.5m x 10m. High quality water flume (up to 1m/s), working section 0.6m x 0.8m x 7m with computer controlled towing carriage to +/-3m/s. Structural testing equipment, fatigue testing and impact testing equipment.
Measuring equipment	Pressure measuring equipment including multiple pressure blocks with rapid electronic scanning, hot wire, LDA and PIV equipment.
ABL tests	The 3m x 1.5m x 10m wind tunnel has provision to model the atmospheric boundary layer of the natural wind including a range of mean shear and turbulence profiles typically at 1:200 scale. The group has also used the 17m 3-bladed horizontal axis wind turbine at the Rutherford-Appleton test site.
Noise and vibration.	The Department has standard equipment for acoustic and vibration measurements.
Computing Resource	Multi-(64) processor machine, and a computing cluster within the Department, access to larger machines within the College.

R&D Strategy

	TERM short	medium	long
Rotor blade aerodynamics, particularly unsteady flow resulting from aerodynamic interactions with structures, wakes and incident turbulence.		◉	
Aerodynamic control techniques to reduce unsteady loading and increase fatigue life.		◉	
Applications of wind turbines in the urban environment.	◉		
Tidal stream turbines, free surface interaction effects including waves. Application of reversible turbines to wave energy.		◉	

Education and training activities

The Aeronautics Department offers two 1 year taught masters degree courses, one on Composite Materials and one on Advanced Computational Methods for Aeronautics, Flow Management and Fluid Structure Interaction. Neither course is specifically aimed at wind energy problems but both cover techniques which are relevant.

Manchester Metropolitan University

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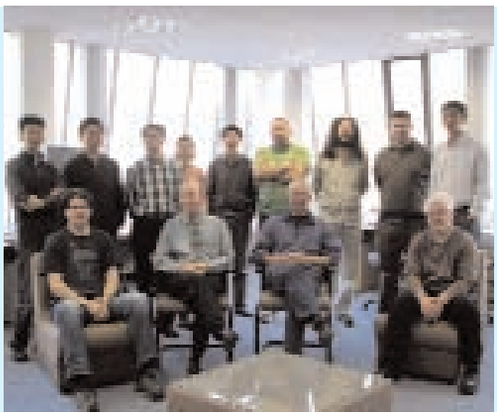

Short Presentation

Manchester Metropolitan University is a forward-looking university.

At MMU we are proud of the exceptional breadth of choice we can offer our students and of the University's links with business, industry, the professions and local communities that contribute to the learning experience.

The University has a varied population, attracting students from a broad range of backgrounds and countries, which contributes to its lively and dynamic atmosphere.

We are based at seven campuses, five in the Manchester area and two at Alsager and Crewe - MMU Cheshire. The central Manchester campuses form part of the largest higher education campus in the UK and one of the most extensive education centres in Europe.

Centre for Mathematical Modelling and Flow Analysis

The Centre for Mathematical Modelling and Flow Analysis (CMMFA) was formed in 1993 and is based in the Department of Computing and Mathematics at Manchester Metropolitan University (MMU). The CMMFA undertakes research in the area of computational fluid dynamics (CFD) and specialises in the development and application of computational hydraulics. Current projects include simulation of scour at the base of offshore wind turbine mounts and simulation of novel wave energy devices in extreme waves. The centre currently has 4 staff, 6 post doctoral research fellows and 5 PhD students.

STFC Rutherford Appleton Laboratory

Contact

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Technology
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Short Presentation

The Science and Technology Facilities Council (STFC) is one of Europe's largest multidisciplinary research organisations supporting scientists and engineers world-wide. It was founded in 2007 from the merging of two former UK research councils, PPARC and CCLRC. The Council operates world-class, large scale research facilities and provides strategic advice to the UK government on their development. It also manages international research projects in support of a broad cross-section of the UK research community. The Council's Rutherford Appleton Laboratory (RAL) is situated 10 miles south of Oxford and has a multi-skilled workforce of professional scientists and engineers. RAL's facilities include the pulsed neutron and muon source ISIS, a Central Laser Facility, space science test facilities, and a renewable energy test site operated by the Energy Research Unit (ERU).

Research groups involved

The main wind energy research effort at RAL is carried out within the Energy Research Unit, but several other groups in the laboratory do relevant work.
The Energy Research Unit (ERU) currently employs 5 scientists and engineers working on a diverse range of sustainable energy topics, including solar & wind energy, energy storage (flywheels and batteries), and hydrogen energy systems.
ERU has a long track record of R&D in non-destructive testing techniques applied to wind turbine blades within national and EC-funded programmes, including studies utilising infra red thermography, thermoelasticity, and acoustic emission.
ERU is currently leading the Structures and Materials theme of The Supergen Wind Energy Technologies consortium (Supergen Wind for short) within which it is developing state of the art finite element (FE) models of future large wind turbine blades. The integration of these models with the dynamics of the rest of the machine will result in valuable insight into design constraints for future large wind turbines.
ERU has additional expertise in wind resource assessment and wind power forecasting. The group has written and marketed its own in-house wind power forecasting software under the name PowerPredict.
The Cryogenics and Superconductivity Group primarily works on cryogenic systems design for space and telescope applications, but their cryogenics technology is relevant to the development of high efficiency superconducting generators for offshore wind turbines.
The Radio Communications Research Unit has studied the impact of land based wind farms on radio links for the UK radio regulator and is interested to extend its work on the influence of wind turbines on radar signatures.

Facilities & Advanced Research Tools

Open air test site	Open air test site for testing and operation of small to medium size wind turbines
Hybrid wind diesel test facility	Demonstration wind-diesel-flywheel system with 30 kW wind turbine and 45 kW diesel genset.
NDT for wind turbine blades	Infra red thermography and thermoelastic stress analysis applied to wind turbine blades during laboratory certification testing. Acoustic emission (AE) monitoring system for blade condition monitoring.
Wind energy in buildings test platform	Rotatable "model" building with space for small wind turbine to be mounted in the centre for testing building-integrated turbine operation.
Generic, modular blade finite element model (ABAQUS)	Finite element blade model for comparing different blade geometries, varying material type and lay-up distribution, and "smart" blade control features.
Mechanical testing of materials	100 kN servo-hydraulic test machine for static and fatigue testing of samples of blade materials

R&D Strategy

	TERM short	medium	long
Develop generic wind turbine blade finite element model	◉		
Study aeroelastic blade (and turbine) response and use to develop "smart" blade concepts		◉	
Study design principles for future large scale wind turbine blades	◉	◉	◉
Develop wind turbine blade condition monitoring system(s)	◉	◉	◉
Real time wind power forecasting	◉	◉	
Aeroelastic behaviour of wind turbines		◉	◉

Education and training activities

A key part of the STFC mission is to ensure that its investment in major facilities in the UK and overseas and peer reviewed funding within UK universities, has a positive impact on the UK's economy through innovation.
To meet this challenge the STFC will ensure that knowledge generated from its facilities, research and technology programmes and interactions with universities and academic partners will be transferred to the wider economy for enhanced productivity and economic growth.

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Short Presentation

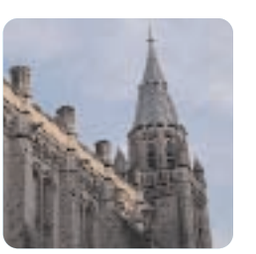
Manchester is a technological university with a strong emphasis on collaboration with industry, encompassing sponsored research and commercial application of results. In October 2004 the new University of Manchester was formed by merging UMIST with the Victoria University of Manchester. The School of Electrical and Electronic Engineering, is currently 58 academics and is one of the largest in the UK with an exceptionally high proportion of postgraduate activity.

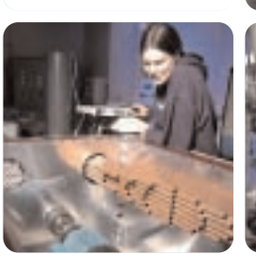
The University has long been active in the field of power engineering particularly electrical machines and power systems engineering. Within the School, the Manchester Centre for Electrical Energy (MCEE) comprises 16 academic staff plus 3 Visiting Professors and approximately 20 post-doctoral research associates and 60 PhD students.

Radar, communications and related microwave research currently comprises 12 full time academics and includes the £1.9m JIF Funded Electromagnetics Design Centre. Research is currently being conducted on a wide range of radar and communications systems and components. The group is part of a BAESystems led consortium looking at impact studies of existing designs of wind turbines on radar performance.

Research groups involved

The School is principally involved in two areas of activity relating to wind turbine technologies: condition monitoring of the electrical systems in wind turbines - 'Reliability, Availability and Operation', and radar and lightning protection - 'Design Influence of External Factors'.





The School has a long-standing and international reputation in the field of power engineering, particularly electrical machinery and power systems engineering. The Electrical Energy and Power Systems Group at The University is one of foremost power engineering groups in the world and includes the new £1.5M National Grid Transco High Voltage Research Centre housing, amongst other high voltage equipment, a 2MV impulse generator for lightning simulation. The Power Conversion Group have recently refurbished their machines, drives and power electronics laboratories to accommodate the Rolls-Royce University Technology Centre and includes state-of-the-art test facilities for work on doubly-fed induction generators (DFIG) and other novel generators for wind turbines. Projects include: Supergen V - Wind Energy Technologies - condition monitoring of wind turbine generators; HVDC Electrostatic Generators for Wind Turbine Applications; Wind-farm Conversion Systems and Grid Interfaces; and Lightning protection of wind turbines.

The school has recently combined its activities in the areas of Microwave Engineering and Communication Engineering into one research group namely Microwave and Communication Systems (MACS). This research group considers a wide range of advanced topics applicable to communications and radar; from highly mobile wireless networks, propagation, microwave and milli-metric components, through to digital signal processing, coding and signal analysis. The research group operates at radio frequencies from HF to 200GHz and allows a wide range of cross disciplinary issues to be studied whist retaining a strong focus on communications and microwave component research. Projects include: Supergen V - Wind Energy Technologies - Lightning Protection and Radar Impact; and Stealth Technology for Wind Turbines.

The aims of the research group are to model and optimise microwave and millimetre-wave components and circuits for communication and radar systems, to design instrumentation for industrial applications, and to understand and control electromagnetic radiation and its effect on electronic equipment (EMC).

Facilities & Advanced Research Tools

Facilities & Advanced Research Tools	The motor and drives laboratories include Wind generator test facility for condition monitoring and control A calorimeter for high precision measurement of machine losses. A microgrid test rig based around a 20MJ energy storage flywheel. Cryogenic rigs for superconducting & low temperature power electronics research. A test chamber for fuel cell characterisation. A re-configurable multi-phase induction motor rig. An electric vehicle power train including supercapacitor energy storage. National Grid High Voltage Research Centre contains the following equipment: 2MV impulse generator 800kV AC test set 600kV DC test set 20kVA high current source (configurable to maximum current of 10kA) Salt fog and environmental test chambers Modern digital measurement equipment Material processing and characterisation equipment The Electromagnetics Centre includes: Agilent Microwave & MM-Wave Laboratory Microwave Sensing Laboratory Electromagnetic Computation Laboratory
Instrumentation	All of the laboratories offer a modern & comfortable working environment, & we are well equipped with network, impedance & power analysers, oscilloscopes & current probes.
Software	Power System Analysis Packages: IPSA (Interactive Power Systems Analysis) and Powerworld are two commercial packages that we use. We also have a number of specific packages developed to perform studies relating to power system optimisation and power system dynamics. Output from the CDEGS software showing earth potential plots-CDEGS: This powerful pakkage is used to peform investigations relating to earthing, stray voltages / currents and electromagnetic coupling PSCAD: This power system transient simulator can be used in a wide range of studies ranging from insulation coordination to the simulation of power electronic controllers used within modern power systems FEA Simulation: Vector Fields 'OPERA' is used to perform both 2D and 3D finite element analysis, typically using an electrostatic based code. Flux2D/3D software for electromagnetic machine design Large-scale optimisation: Xpress-MP is used to solve complex mixed-integer power system optimisation problems.

R&D Strategy

	TERM short	medium	long
Reliability, Availability and Operation of Large Wind Turbines		◉	
Wind system drive system characterisation - Electrical System Characterisation	◉	◉	
Condition Monitoring – Integrated System Model and Test Rig	◉	◉	◉
Generator design, modelling and control	◉	◉	
Radar cross section and Lightning Protection -		◉	◉

Education and training activities

The School offers a wide variety of postgraduate opportunities including one-year taught Masters programmes to one or three-year MPhil and PhD research degrees. The School also offers a Masters by Research which combines taught and research elements of study. Current relevant taught MSc programmes are: Electrical Energy Conversion Systems; Communication Engineering; and Electrical Power Systems Engineering.

The ICC at the University of Strathclyde

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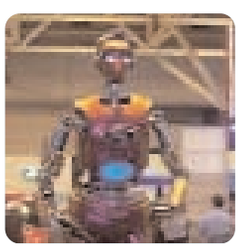
Short Presentation

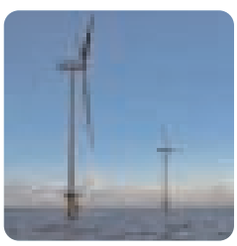
The ICC at the University of Strathclyde was established two decades ago and is an internationally known centre of excellence for control theory and application research. The ICC strives to maintain a 50:50 balance of innovative research together with a portfolio of real industrial application projects. It works across many industrial sectors including: Metals and Manufacturing, Automotive and Marine, Energy, Environment and Power, Chemical and Petrochemical, Aerospace and Defence. During the last two decades, the ICC has established strong links with many national and international companies and universities resulting in successful control system design and industrial implementation projects. The ICC is an autonomous research group within the Institute of Energy and the Environment (InstEE) at the University of Strathclyde, The InstEE is widely recognised for its internationally leading research and is the largest academic group in the UK concerned with electrical power systems and electric power generation. Wind energy is a major activity at the ICC, which is well known for its work on wind turbine control, and the InstEE.

Research groups involved

The wind energy team in the ICC consists of 2 academic staff and 4 researchers. Its interests include the dynamic analysis, modelling and simulation of wind turbines together with ther control system design. Over 20 years controllers have been designed and implemented on a wide variety of commercial wind turbines including both constant speed and variable speed machines ranging in size from 300kw to 5MW. A focus of current research is active regulation of wind turbine structural loads on large multi-MW offshore wind turbines. In addition, the implication of advanced control systems on the design of wind turbines is also being investigated. ICC staff has wide experience of using industry standard simulation packaged such as BLADED and FLEX. Other collaborating teams within the InstEE are those in Renewable Energy, Plant Monitoring, Energy Conversion and Power Systems. Both the Renewable Energy and Plant-Monitoring teams' actively research condition monitoring for offshore wind turbines including the application of intelligent system techniques to implement fault diagnosis, prognosis and machine learning within these systems. Wind energy research activity of these 4 teams also includes active load management, offshore resource assessment, advanced power electronic converters for improved reliability and stabilisation of local connection, power systems technical architectures and protection techniques for wind farms. The ICC chairs the EPSRC Wind Energy Research Consortium.



University of Strathclyde



Facilities & Advanced Research Tools

Software	Advanced wind turbine control system analysis and design toolset.
Software	Access to industry standard simulation packages such as BLADED and FLEX
Machine monitoring	A commercial wind turbine has been fully instrumented and a monitoring programme is underway

R&D Strategy

	TERM short	medium	long
Integration of on-line identification of aerodynamics and integration into wind turbine controllers.	◉	◉	
Improved active load regulation of offshore multi-MW wind turbines and the its impact on machine design.	◉	◉	◉
Integrated design platforms for wind turbine control system analysis and design.		◉	◉
Stability and dynamic issues related to integration of very large amounts of wind generation.	◉	◉	
Improved matching of supply and demand through active load management.	◉	◉	◉

Education and training activities

The ICC is committed to undergraduate and postgraduate teaching in the Department of Electronic and Electrical Engineering and strongly engages in technology transfer to industry through various training schemes. Its cosmopolitan environment attracts research engineers and students from around the world. The ICC closely collaborates with well known international control engineering Centres around the world and encourages academic exchange and visiting scholarships for closer collaboration. Every two years, at least one international conference and several workshops are hosted, where both the academic researchers and industrial engineers can exchange and discuss their work and research results.

University of Surrey

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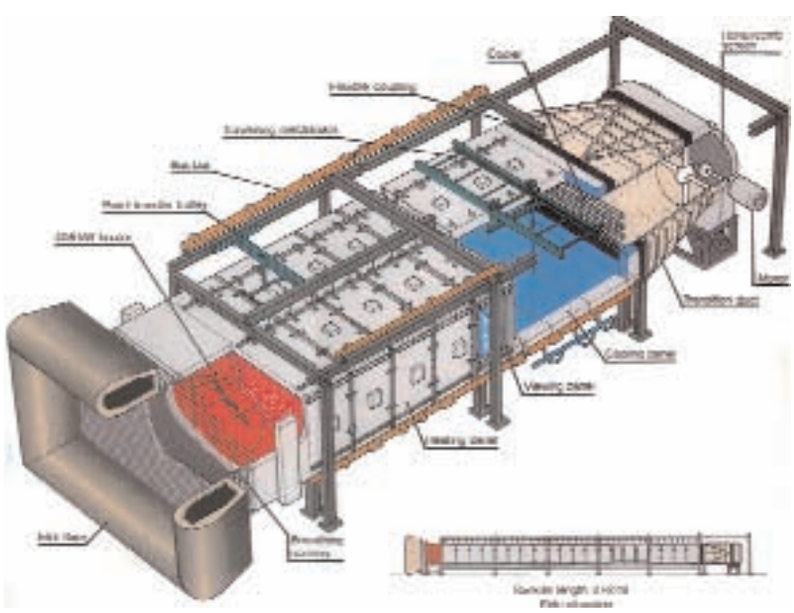
Short Presentation

The EFRC, Enflo Laboratory is part of the Fluid Research Centre (FRC) in the Faculty of Engineering and Physical Sciences. The FRC brings together academic staff from all engineering disciplines, typically thirty researchers and several visiting and associate staff. The Centre is engaged in typically thirty research projects, with funding from a wide range of sources including major industrial, European and UK national grants. The research income supports major programmes of experimental research and numerical simulation. Research areas include aerodynamics, turbomachinery, vehicle aerodynamics, turbulence, wind engineering, environmental flows, chemical and bio-reactor hydrodynamics, multi-phase flows, non-newtonian fluids, osmosis. The turbomachinery work is done within the Rolls-Royce-funded University Technology Centre for Thermal and Fluid Systems. EnFlo, the Environmental Flow Research Centre, was established in 1993 as a focus for UK research activities based on laboratory scale simulation of atmospheric flow and pollutant dispersion. It is a NERC-NCAS Centre for Atmospheric Sciences and a member of the UWERN and APRIL research networks. EnFlo was established by the donation of two major facilities, a wind tunnel and a towing tank, by National Power plc to the University. Both can be operated in a density stratified mode, which gives the laboratory a unique experimental capability and also permits a very wide range of environmental conditions to be modelled. The wind tunnel has a 20m long working section, 3.5x1.5m in cross section, and is stratified by differential heating of the incoming air, together with heating and cooling of the tunnel walls. The 12m long towing tank has a 1x1m cross-section and is stratified by mixing fresh water and brine during its filling. The FRC has five other wind tunnels.

Research groups involved

The wind power work takes place within the EnFlo laboratory part of the FRC. The current main activity is on wakes of large (5MW) wind turbines and their interactions together and on downwind machines, in both offshore and on-shore atmospheric conditions, including the effects of stratification. The work, which is primarily experimental, is being done as a partner of the (UK) EPSRC research consortium SUPERGEN-V, Wind Energy Technologies programme. The Surrey work is also being done in conjunction with Imperial College, Dept of Aeronautics, where the attention is on the loading on the rotor blades.



Facilities & Advanced Research Tools

Laboratory	Stratified environmental flow wind tunnel, and five other wind tunnels.
Measuring equipment	Laser Dopper anemometry, particle image velocimetry, hot-wire anemometry, pulsed-wire anemometry, flame-ionisation concentration.
Instrumentation Software	Labview-based software for fully automatic data control and acquisition.
Software	Fluent, LES codes, ADMS.

R&D Strategy (Wind-flow related)

	TERM short	medium	long
Dispersion studies in urban and industrial-plant environments	◉	◉	◉
Wind flow over topography, momentum and scalar transport, complex terrain		◉	◉
Wind power aerodynamics		◉	◉
Industrial aerodynamics		◉	◉

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