

DUWIND

TU DELFT WIND ENERGY INSTITUTE



# R&D PROGRAMME

*2015 – 2020*



# 1. Wind in sustainable power supply systems

- 1.1 System Integration
- 1.2 Social Responsible Innovation
- 1.3 Regulated Markets and Entrepreneurship



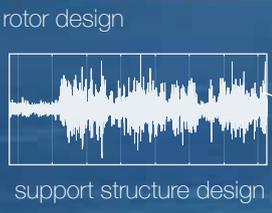
# 2. Wind power station

- 2.1 Wind Farm Design
- 2.2 Asset Management



# 3. Wind Energy Converters

- 3.1 Rotor Design
- 3.2 Generator Design
- 3.3 Support Structure Design
- 3.4. Vertical Axis Wind Turbines
- 3.5 Airbone Wind Energy



# DUWIND R&D programme

2015 – 2020

## Introduction

The TU Delft Wind Energy Institute (DUWIND) brings together engineering and science to meet the multidisciplinary character of wind energy research and education.

*Our ambition is to deliver pioneering interdisciplinary research and education on the design and operation of interrelated offshore wind energy technologies and - systems to meet the societal energy needs and expectations.*

This folder gives a summary of the DUWIND research programme for the years 2015-2020.

Traditionally research on Wind Energy strongly builds on mono-disciplinary approaches in engineering and applied science. It is only recently that especially offshore wind energy is expected to become an essential part of future sustainable energy systems. From this perspective it is not only necessary to consider technologically efficient, reliable and robust solutions of different components, but also reflect on interrelations of wind energy with other parts of energy systems as well as the regulation and management of this sector. Cross-disciplinary cooperation and research is essential to make further development possible.

Within TU-Delft wind energy research goes back to the late seventies. Currently DUWIND spans across six faculties of the TU Delft : Aerospace Engineering (AE), Electrical Engineering, Mathematics and Computer Sciences (EEMCS), Civil Engineering and Geosciences (CEG), Mechanical, Maritime and Material Engineering (3ME), Technology Policy and Management (TPM), and most recently Applied Sciences (AS). It involves 15 research groups. Over the years cross-disciplinary research extended, driven by the increasing scale of wind energy. Not only the fact that wind turbines are the largest rotating machines on earth, but also the steps from individual wind turbine to small onshore wind farms to large offshore wind power stations have made integration of all related disciplines one of the most important foci. Moreover the role of wind energy in society has changed dramatically: starting as a green, alternative, niche innovation, it is now one of the fastest growing sources of electricity provision in Europe and other continents.

This raises novel research challenges that we take up in our DUWIND research program by identifying three levels of analysis and design:

- **Wind in sustainable power supply systems : the interaction of large scale wind power with other energy sources and consumers in the electricity system is the central theme, as well as the interaction with society. This level of the Duwind research programme is new. The programme offers cooperation with research driven by the other sustainable energy sources, under the umbrella of the Delft Energy Initiative.**
- **Wind power station: here the main topics of designing and operating an offshore wind farm as power station are included. Integration of all design aspects for lowest cost of energy as well as advanced asset management are the two research lines.**
- **Wind energy converters: in this level the turbine itself, its components and required background knowledge, as well as alternative types on wind energy converters are addressed. Optimization of the design for lower cost of energy and longer life time are the drives of this research programme.**

The DUWIND R&D programme 2015-2020 is a strong and wide set of multidisciplinary ambitions which show the strength of the interaction of the different groups within TU Delft and the devotion to improving wind energy research and industry at large. Compared to the previous R&D programme it is clearly making a switch from only a hard engineering focus on the wind turbine, to more system integration and societal implication of wind energy engineering, accentuating the importance of research in offshore wind farms and wind in the overall sustainable energy system. For this reason, some parts of the programme are very realistic in numbers and predictions, while others have a more experimental character. The latter newcomers have clear ambitions and are eager to prove themselves in the years ahead.

*Prof. Dr. Ir. van Kuik, DUWIND Chairman*



The integration of large-scale wind energy in sustainable power supply systems requires a better understanding of the technical and socio-economic requirements of these systems. These requirements pose a great challenge as offshore and onshore energy systems need to be technically and institutionally integrated; markets and regulation have to be adapted to meet the needs of sustainable energy, and societal values and expectations need to be satisfied in order to safeguard social acceptability. This requires an energy system perspective and the application of an interdisciplinary approach that bridges engineering science and social science.

## 1.1 System Integration

Fundamental technical and institutional reconfigurations of the energy infrastructure are needed to enable large-scale offshore wind power production. For this engineering, economics, and politics need to be aligned. From an engineering perspective innovative networks need to be developed that include new AC and DC systems, power to gas options and energy storage systems. These networks will be instrumental to cope with the specific characteristics of wind power production. On top of this, market- and regulatory designs need to be reconsidered to facilitate innovative arrangements for scalable power storage, balancing, and demand side management. The policy perspective is needed as the physical interconnection of offshore networks across national boundaries requires an alignment of (inter)national energy policies.

### Objectives

**Providing an interdisciplinary and cross-sectorial system perspective on the development of offshore wind.**

**Integrated technological and socio-economic modeling and analysis of hybrid power systems.**

**Development of innovative concepts of energy networks, storage and demand side management in support of offshore wind.**

### Main lines

#### **Innovative network concepts.**

*Hybrid AC-DC power system modeling. Low inertia power system control. Low Frequency AC transmission. DC collection systems. Regulation and governance of innovative networks.*

4 PhD 

#### **Market design and policy alignment**

*Aligning national energy policies to optimize the offshore wind potential. Energy market designs in support of offshore wind. Modeling system integration between different infrastructures and industries.*

3 PhD 

#### **Energy storage and demand side management**

*Large-scale electricity storage in ammonia. Efficient long life energy storage in batteries. High energy density Li-S, Na-S and Mg-S batteries. Scalable power storage, balancing, and demand side management. Allocation of rights and responsibilities.*

3 PhD 

#### **Power-to-gas**

*Modeling power-to-gas for system optimization. System integration of power and gas.*

2 PhD 

### Cooperating expert groups

#### **Energy and Industry**

*Technology Policy and Management*

#### **Economics of Technology and Innovation**

*Technology Policy and Management*

#### **Policy, Organization Law and Gaming Mechanical**

*Technology Policy and Management*

#### **Intelligent Electrical Power Grids**

*Electrical Engineering, Mathematics and Computer Science*

#### **DC Systems & Storage**

*Electrical Engineering, Mathematics and Computer Science*

#### **Delft Institute for Applied Mathematics**

*Electrical Engineering, Mathematics and Computer Science*

#### **Materials for Energy Conversion & Storage**

*Applied Sciences*

## 1.2 Social Responsible Innovation

Societal acceptance for the development of large offshore energy systems is a significant challenge, sometimes even more than its technical realization. The lack of stakeholder acceptance is a current concern. Responsible innovation of offshore wind raises different challenges as compared to onshore wind. Decision-making processes are fundamentally different; various actors (e.g. fishery, tourism, naval transport, energy production, regulatory and policy making authorities,) are involved in different contexts and act according to different objectives, preferences and convictions. In this research program we go even further than ex post stakeholder analysis and argue that moral and social values must be considered in the design phase even before actually constructing these energy systems. A value sensitive design is needed to safeguard the long-term societal acceptability of offshore energy systems.

### Cooperating expert groups

#### **Ethics & Philosophy of Technology**

*Technology Policy and Management*

#### **Economics of Technology and Innovation**

*Technology Policy and Management*

#### **Energy & Industry**

*Technology Policy and Management*

#### **Policy, Organization Law and Gaming**

*Technology Policy and Management*

### Main lines

#### **Stakeholder acceptance.**

*Moral values and public concerns against offshore wind. Blocking and cooperative behavior of stakeholders. International collaboration and coordination. Successful governance towards societal acceptance.*

2 PhD 

#### **Value sensitive design**

*Identification of societal value conflicts and their resolution. Moral values as technical and institutional design parameters. Modeling and simulating value conflicts.*

2 PhD 

### Objectives

**Analyzing the specificities of stakeholders' acceptance for offshore wind, its technological and institutional consequences and possibilities for resolution.**

**Development of a value sensitive design for offshore energy systems.**



## 1.3 Regulated Markets and Entrepreneurship

The development of offshore wind is strongly driven by economic considerations and EU climate goals. Recently offshore wind is supported by various financial and regulatory arrangements in order to lower some initial economic hurdles. But ultimately offshore wind needs to become a competitive means of power production. Ultimately investments in offshore wind by private wind park developers and even public network operators need to have a positive business case. These business cases are strongly affected by the regulation of the electricity sector, the cost of fossil fuel supply, and also by the matching of increasingly intermittent supply and demand. The expected investments in transmission, storage and demand, varies under different regulatory regimes, economic incentives and different exogenous factors (such as fuel prices). This line investigates how the economic and technical performance of offshore wind is influenced by different national and international (European) regulatory regimes and various business strategies.

### Cooperating expert groups

#### **Economics of Technology and Innovation**

*Technology Policy and Management*

#### **Energy & Industry**

*Technology Policy and Management*

#### **Policy, Organization Law and Gaming**

*Technology Policy and Management*

#### **Delft Center for Entrepreneurship**

*Technology Policy and Management*

#### **Materials for Energy Conversion & Storage**

*Applied Sciences*

#### **Intelligent Electrical Power Grids**

*Electrical Engineering, Mathematics and Computer Science*

### Main lines

#### **Innovative market models for renewable energy.**

*Simulation and analysis of various market models. Regulation and investment risks.*

*Integration of offshore wind into energy markets beyond existing support schemes.*

2 PhD 

#### **Entrepreneurial strategies.**

*Business models for offshore wind. Dealing with specific market barriers. Convergence across infrastructures and even into other industrial sectors.*

2 PhD 

#### **Business cases for investments in offshore wind.**

*Meet investment needs for the ambitious offshore energy plans. Balancing long-term and short-term risks.*

2 PhD 

### Objectives

#### **Analysis of innovative regulatory and financial arrangements**

#### **Positioning offshore wind as a competitive means of power production**

#### **Development of entrepreneurial strategies and business models**



## 2.1 Wind Farm Design

The optimisation of an offshore wind farm brings together an extensive range of disciplines, for which choices have to be made under difficult conditions. The disciplines mutually influence what the best design choice is, by direct physical interaction or by affecting the weight of different contributions to the overall performance. Multiple sources of uncertainty play a role and have to be dealt with adequately. Choices have to be made in a cooperative process, where restrictions, decisions and the level of detail of available information continuously evolve.

### Cooperating expert groups

#### Wind Energy

*Aerospace Engineering*

#### Delft Center for Systems and Control

*Mechanical, Maritime and Materials Engineering*

#### DC Systems and Storage

*Electrical Engineering, Mathematics and Computer Science*

#### Structural Mechanics

*Civil Engineering and Geosciences*

### Objectives

**Understanding and dealing with the mutual influence of involved disciplines.**

**Understanding and dealing with uncertainty and a dynamic design framework.**

**Guidelines, methods and instruments for effective optimisation of wind farms.**

### Main lines

#### Disciplinary modules suitable for integration

*Modules for wake interaction, O&M, support structures, logistics, layout, electrical infrastructure, farm control etc., disciplinary uncertainty assessment, preparation of linking parameters.*

3 PhD 

#### Pairwise design integration

*Integration of 2 or 3 disciplines, e.g. layout and electrical infrastructure, layout and farm control, layout and support structures or support structures and farm control.*

2 PhD 

#### Framework for multidisciplinary wind farm design

*Conceptual and configuration design support, design problem formalisation, effective optimisation structures, dealing with linking aspects.*

1 PhD 

#### Uncertainty at the farm level

*Causality diagram, uncertainty propagation and traceability, mitigating measures, prioritising data and model improvements.*

1 PhD 

#### Dynamic framework for wind farm design

*Dealing with: gradual improvement of information accuracy, changing requirements, partial fixation of solutions and constraints, changes in available technology.*

1 PhD 



## 2.2 Next Generation Asset Management

The wind farm and wind turbine next generation asset management research program within DUWIND, aims at providing ways to maximize the remaining component life of its infrastructure. The only means of understanding the many degradation issues affecting wind energy industry is through a combined multi-physics and multi-disciplinary process, known as HoSIP (Holistic Structural Integrity Process). HoSIP is founded upon the primary idea that all failure mechanisms involved in the degradation of the structures are interconnected and should not be analyzed as merely the sum of individual mechanisms. DUWIND is developing new modelling tools that show the dependencies between the components in a more realistic way, developing a.o. in depth understanding of the loads supported by the structure, the initial structural conditions and material properties of the components composing the structure, and highly advanced numerical modelling techniques (such as agent based modelling, monte carlo simulations, artificial neural network data analyses, discrete numerical modelling, etc.). The research within this DUWIND programme allows for lessons on remaining component life and provide risk analysis, operational life cycle cost and deliver insights for the design and operation of new (offshore) wind farms with more optimal components for the given function.

### Cooperating expert groups

#### **Structural Integrity & Composites**

*Aerospace Engineering*

#### **Energy & Industry**

*Technology Policy and Management*

#### **Aerodynamics, Wind Energy & Propulsion**

*Aerospace Engineering*

#### **Design and Construction Process**

*Civil Engineering and Geosciences*

### Main lines

#### **Pre-requisites**

*Static and dynamic wind loads on wind turbine rotors and other components.*

2 PhD 

#### **Holistic Structural Integrity**

##### **Process for wind farms.**

2 PhD 

##### **O & M optimization of large-scale offshore wind farms with feedback into design with a focus on cost reduction.**

1 PhD 

##### **Insight into economic performance of wind farms and of its components in relation to costs, risks, (running) service contracts, downtime and revenue losses.**

1 PhD 

### Objectives

**Detailed integrated understanding of wind energy systems that takes into account information from the component level all the way up to the decisions taken in the control room**

**Optimize the life time of ageing assets**

**Optimal design life of wind farm components (support structures, blades,)**

**Long term cost saving through the implementation of condition based maintenance practice**



## 3.1 Rotor Design

The design of the rotor of a wind turbine rotor is a highly multidisciplinary effort. It involves engineering disciplines such as structures, materials, manufacturing, aerodynamics and control. The result of this multidisciplinary effort is a reduction in cost of energy. The goal of the rotor design research effort in the coming four years is to develop offshore and onshore multi-megawatt wind turbines beyond what exists today to achieve a lower cost of energy. Furthermore the risk and time of developing these wind turbines should be reduced to improve the number of designs that can be generated for wind farms with various requirements. Finally manufacturing methods for wind turbine blades should be improved for accuracy and throughput without increasing the cost of energy.

### Cooperating expert groups

**Wind Energy**

*Aerospace Engineering*

**Delft Center for Systems and Control**

*Mechanical, Maritime and Materials Engineering*

**Aerodynamics**

*Aerospace Engineering*

**Aerospace Structures and Materials**

*Aerospace Engineering*

**Precision and Microsystems Engineering**

*Mechanical, Maritime and Materials Engineering*

### Objectives

**Improve efficiency of multi-megawatt innovative wind turbines by more refined, faster, and integrated multidisciplinary design methodologies**

**Reduction of development next generation wind turbine rotor risk and time**

**Improve wind turbine blade manufacturing techniques**

### Main lines

**Improved certification loads calculation and testing process**

*Overview of current certification loads calculations and their reason/history; stochastic analysis of wind field measurements; development of shortened static and dynamic test programmes*

1 PhD

**Improved analysis and design methodologies**

*Design for manufacturing of wind turbines; loads, material and manufacturing uncertainty modelling; reduced order modelling of structurally nonlinear wind turbines; fluid-structure-control interaction and simultaneous optimisation*

2 PhD

**Improved understanding and modelling of the aerodynamics of wind turbine rotors**

*3D unsteady flows, including blade vortex interaction and wake rotor interaction; numerical modelling of wind turbine aerodynamics including multi-fidelity and hybrid models; simulation of mutual interactions between turbulent wind flows and blade motions/deformations; airfoil aerodynamics, including boundary layer control methods ranging from plasma actuators to suction*

2 PhD

**Noise abatement of onshore wind turbines**

*Investigation of serrations for the silent wind turbine; investigation and mitigation of noise sources like trailing edge flaps of smart wind turbines,*

1 PhD

**Manufacturing techniques with improved accuracy and throughput**

*Application of fibre placement technologies for large wind turbine blades; automated manufacturing of grid stiffened structures; investigation of additive manufacturing for wind turbine blade parts; development of out of autoclave production methods for improved manufacturing speed*

2 PhD



## 3.2 Drive Train and Electrical Conversion

Drive trains and electrical conversion systems in wind turbines may include different transmission systems, different generators, different power electronic converters and different controllers. The design of the drive train and the electrical conversion system plays an important role in the cost of energy, not only because of its cost, but mainly because of its efficiency, its availability, and the possibility of load reductions. This research focusses on choosing the proper components, optimizing these components, and making them more reliable.

### Cooperating expert groups

#### Electrical Power Processing

Electrical Engineering, Mathematics and Computer Sciences

#### DC Systems and Storage

Electrical Engineering, Mathematics and Computer Sciences

#### Delft Centre for Systems and Control

Mechanical, Maritime and Materials Engineering

#### Wind Energy

Aerospace Engineering

### Objectives

**Improved understanding of the operating principles of the drive train and their limitations**

**Improved understanding of the reliability issues in drive trains**

**Improved understanding of the control issues in drive trains and the consequences for the wind turbine design**

### Main lines

#### Design and optimization of better alternative transmission systems

*Some new transmission systems (hydraulic, magnetic, mechanical) have the potential to be significantly better than the currently used gearboxes.*

1 PhD 

#### Design and optimization of better alternative generators

*Some new generator types have the potential to be significantly better than the currently used generators. We focus on brushless doubly fed induction generators, and superconducting direct drive generators.*

4 PhD 

#### Design and optimization of better power electronics

*Modular, multilevel, fault tolerant converter design for better availability, and better integration of the wind turbine into the wind farm infrastructure.*

2 PhD 

#### Drive train and electrical conversions at system level

*Comparison and selection of drivetrains, design for reliability of generator systems, drive train control for load reduction during extreme loads and faults.*

2 PhD 



## 3.3 Support Structure Design

Accessing offshore compared to land-based turbines for maintenance is much more difficult and expensive, causing demands on the reliability (life-time) of components to be far more stringent. Due to the highly dynamic and uncertain nature of the loading offshore, determining the structural response and fatigue damage accurately remains a challenge. The main aim of the current research on support structure design at DUWIND is to increase our knowledge of the relation between dynamic loads and remaining fatigue life.

### Cooperating expert groups

**Offshore Engineering**

*Civil Engineering and Geosciences*

**Structures and Materials**

*Aerospace Engineering*

**Delft Centre for Systems and Control**

*Mechanical, Maritime and Materials Engineering*

### Objectives

**Detailed understanding of soil-structure interaction**

**Reduction of safety factors**

**Noise reduction during installation and in service**

**Development of novel support structure concepts**

**Integral modeling**

### Main lines

**Physics-based modelling of soil-structure interaction**

*3D pile in a poro-elastic medium. In situ geophysical (seismic) measurements for the identification of dynamic stiffness and damping parameters. Influence of non-linear effects. Validations with full-scale long term measurements.*

3 PhD 

**Monitoring & service-life**

*Robust structural health monitoring; integration into design process. Estimation of fatigue damage accumulation from operational vibrations. Sensor fault detection.*

2 PhD 

**Underwater noise pollution**

*Vibro-acoustic modelling of soil-fluid-structure interaction. Investigations into alternative installation techniques and mitigation measures. In situ noise measurement.*

1 PhD 

**Integral design**

*Simulation of coupled multidirectional dynamic response to misaligned nonlinear aerodynamic and hydrodynamic forcing. Balancing innovative control concepts and improved turbine designs with robust and cost-effective support structure solutions.*

1 PhD 

**Active/passive vibration control for fatigue reduction**

*Control measures in the substructure. Investigation into the influence of an increase in hydrodynamic drag on fatigue.*

1 PhD 

**Alternative support structures**

*Innovative concepts for deep waters.*

1 PhD 



# 3.4 Vertical Axis Wind Turbines

The Vertical Axis Wind Turbine concept may be the best solution to meet the challenges and opportunities of up-scaling and offshore wind energy, especially of floating offshore wind energy. The research on VAWTs at TU Delft builds upon our research in rotor design, and is carried out in close cooperation with several of our research and industrial partners. The research at TU Delft focuses on rotor and wind farm design, with a focus on aerodynamics and aeroelastic design, including optimisation for cost of energy. The objective of the research is develop knowledge, tools and technology to support the development of a 20 MW floating offshore rotor that would allow for a cost of energy below 100€/MWh. Current research shows that the more complex aerodynamics and structural design of the 3D actuator volume can actually allow for an easier up-scaling and more robust design, decreasing not only investment costs, but also O&M costs.

## Cooperating expert groups

### Wind Energy

*Aerospace Engineering*

### Aerodynamics

*Aerospace Engineering*

### Aerospace Structures and Materials

*Aerospace Engineering*

## Objectives

**Develop the knowledge, tools to design and model VAWT rotors up to 20 MW, with a focus on floating concepts**

**Develop models for simulation of VAWT wind farms, including optimisation of wind farm performance**

## Main lines

### **Aerodynamic models for VAWTs**

*Models for the aerodynamics of 3D unsteady actuators and rotors, including wake development.*

2 PhD 

### **Airfoil design for VAWTs**

*Airfoil optimisation including power and load control, blade-vortex interaction, dynamic stall and structural optimisation.*

2 PhD 

### **Aerodynamic, structural and aeroelastic optimisation of VAWT rotors**

2 PhD 

### **Rotor optimisation for minimum cost of energy, aeroelastic analysis including interaction with floating support structure**

2 PhD 



## 3.5 Airborne Wind Energy

Airborne wind energy technologies use tethered flying devices, such as wings or balloons, for harvesting wind energy. Key drivers for the developments are the substantial material reduction potential per installed kilowatt and the access to an unused energy resource, wind at higher altitudes, which is stronger and more persistent. For offshore deployment, the cost advantage can be major because a small floating platform is sufficient for anchoring the system. The economic viability of airborne wind energy technologies is strongly linked to advances in the fields of robust automatic flight control, including launching and landing of the flying devices and durable high-performance materials. The pioneering kite power research group of TU Delft has developed a pumping kite power system which uses the traction force of an inflatable membrane wing to drive a generator on the ground. The current 20 kW prototype is using a wing of 25 m<sup>2</sup> surface area

### Cooperating expert groups

#### Wind Energy

Aerospace Engineering

#### Control & Simulation

Aerospace Engineering

#### Precision and Microsystems Engineering

Mechanical, Maritime and Materials Engineering

#### Electrical Power Processing

Electrical Engineering, Mathematics and Computer Science

### Objectives

**Understanding and dealing with the mutual influence of involved disciplines**

**Improving the airworthiness, robustness and reliability of AWE technologies**

**Increasing the component life time of the critical airborne system components**

**Developing guidelines, methods and instruments for effective optimisation of AWE systems and AWE parks**

### Main lines

#### Tethered flexible wing aerodynamics and structural dynamics

*Tethered lightweight wings deform substantially under aerodynamic loading and due to changes in the bridle geometry resulting from steering and de-powering.*

*Developing high-fidelity models for numerical simulation of aeroelastic phenomena of inflatable and large rigid wings.*

5 PhD 

#### Development of large-scale pumping kite power system

*Continued development of the existing 20 kW pumping kite power system to achieve 24 h continuous automatic operation of a new 32 kW system in July 2015, followed by the commercial development phase targeting a 500 kW system. Automation of operation, including launching and landing, robotics, failure reduction.*

2 PhD 

#### System-level modelling, control and optimisation of AWE

*The prediction of the power generation potential of AWE systems and entire AWE parks requires advanced system-level models and optimisation strategies. This line spans from quasi-steady descriptions of pumping cycles without the need of flight control algorithms to flight dynamic models which capture the true flight path.*

3 PhD + 1 PostDoc  

#### Safety-critical and highly reliable software approach for AWE systems

*In the process of commercialisation of AWE applications, system safety and reliability are two main factors that must be considered. Software, hardware and their interaction take an important role in system safety and reliability. In designing embedded safety critical systems the hardware and the software are inseparable.*

1 PhD 



# Overview groups

DUWIND R&D 2015 – 2020

## TPM

### **Economics of Technology and Innovation**

*Rolf Künneke*

### **Energy and Industry**

*Paulien Herder*

### **Policy, Organization, Law and Gaming**

*Martijn Groenleer*

### **Delft Centre for Entrepreneurship**

*Roland Ortt*

### **Ethics & Philosophy of Technology**

*Ibo van de Poel*

## EEMCS

### **Intelligent Electrical Power Grids**

*Peter Palensky, Mart van der Meijden*

### **DC Systems & Storage**

*Pavol Bauer*

### **Delft Institute for Applied Mathematics**

*Kees Vuik*

### **Electric Power Processing**

*Henk Polinder*

## AS

### **Materials for Energy Conversion and Storage**

*Fokko Mulder*

## AE

### **Wind Energy**

*Gerard van Bussel, Gijs van Kuik, Roland Schmehl,  
Carlos Simao Ferreira, Michiel Zaaijer,  
Wim Bierbooms, Nando Timmer*

### **Aerodynamics**

*Alexander van Zuijlen*

### **Structural Integrity and Composites**

*Marcias Martinez, Dimitrios Zarouchas*

### **Control and Simulation**

*Max Mulder*

### **Aerospace Structures and Computational Mechanics**

*Roeland de Breuker*

## CE&G

### **Design and Construction Process**

*Rob Schoenmaker*

### **Offshore Engineering**

*Andrei Metrikine, Eliz-Mari Lourens*

## 3ME

### **Delft Center for Systems and Control**

*Jan Willem van Wingerden*



**This R&D programme describes the ambition of DUWIND research in terms of its applications. A more classical description of the research based on the scientific disciplines involved would provide another cross section through the same research subjects. Such a description will also be published, but awaits the results of the European Academy for Wind Energy (AEWE) discussion on the long term research challenges in wind energy. The publication of this research vision is due in 2015. TU-Delft experts coordinate this discussion and play an important active role in it. Once this EAWE-vision is ready, a DUWIND-vision connected to the R&D programme 2015-2020 will be issued.**

**Education in wind energy (related) topics at our university will be the focus of a third publication, due in 2015 as well.**

**The three documents together represent the core subjects in which DUWIND-members are involved.**

[www.duwind.tudelft.nl](http://www.duwind.tudelft.nl)



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