Smarte Rotoren für kosteneffiziente Windenergieanlagen

DPG-Tagung (Arbeitskreis Energie)

Jan Teßmer, Münster, 28.03.2017

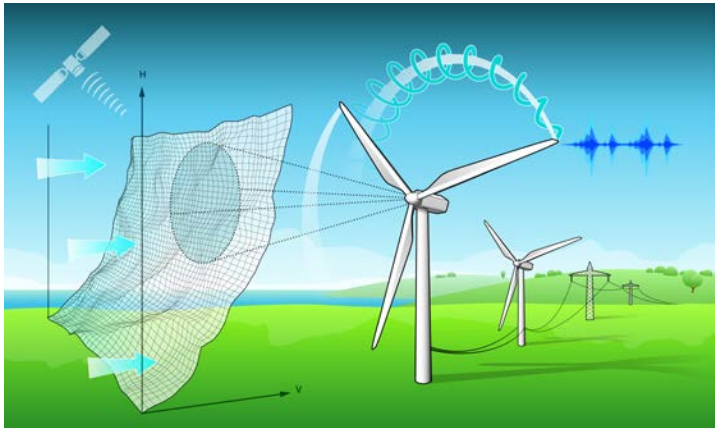
Forschungsverbund Windenergie

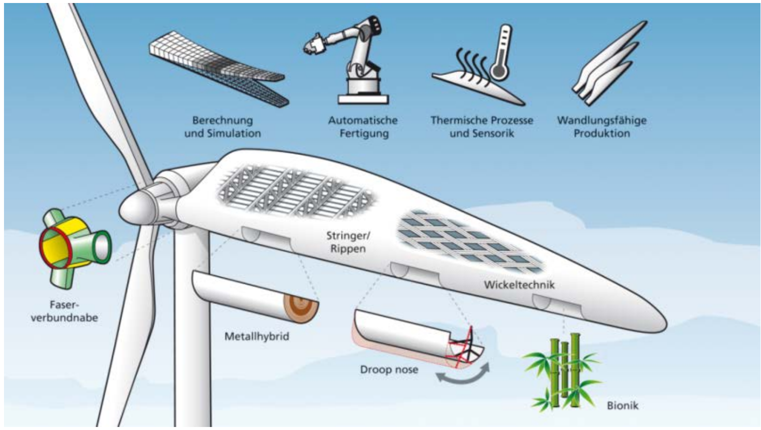
DLR

Smart Rotors for cost efficient Wind turbines

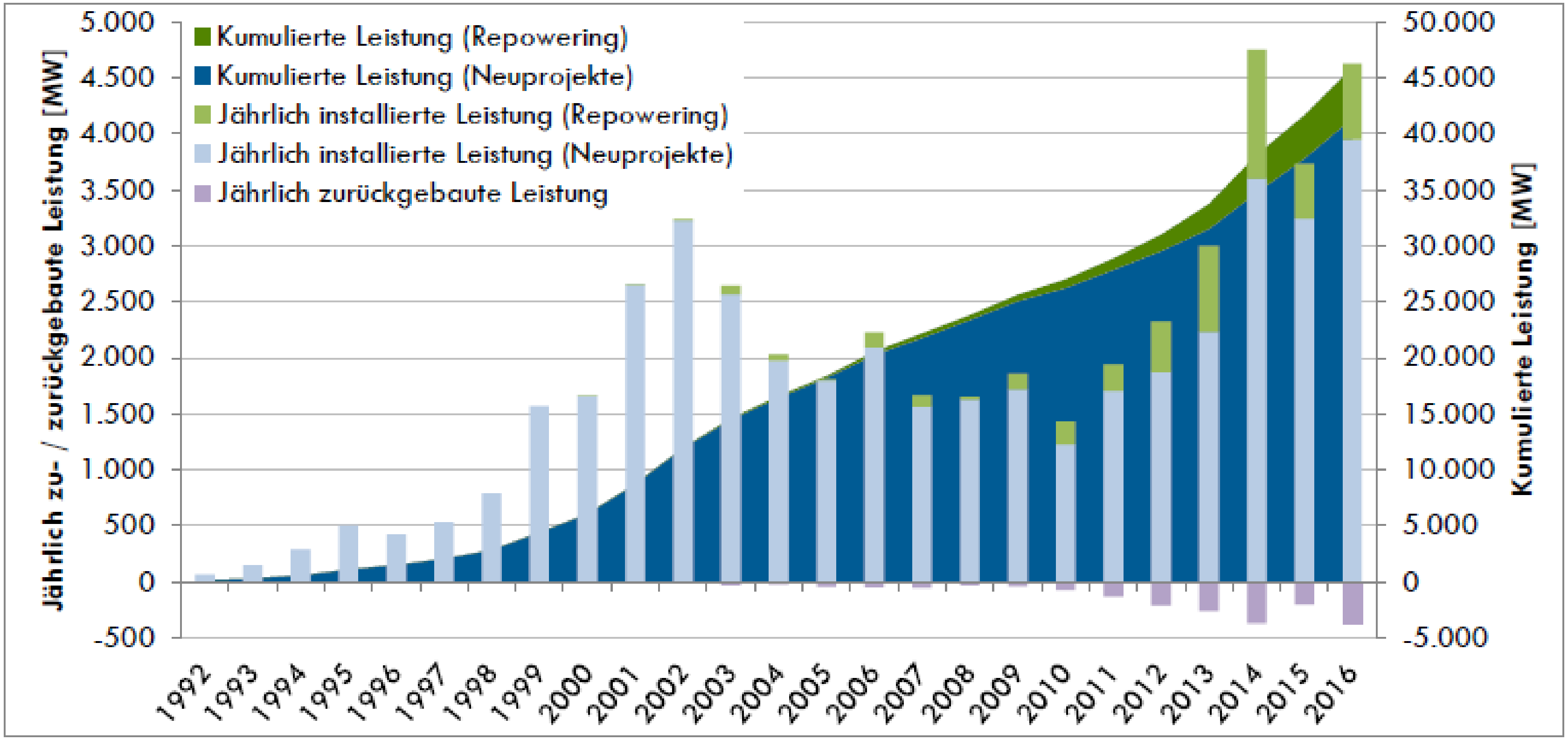
Agenda

- Some numbers
- Challenges for rotor & blades
- Experimental platform for wind energy research



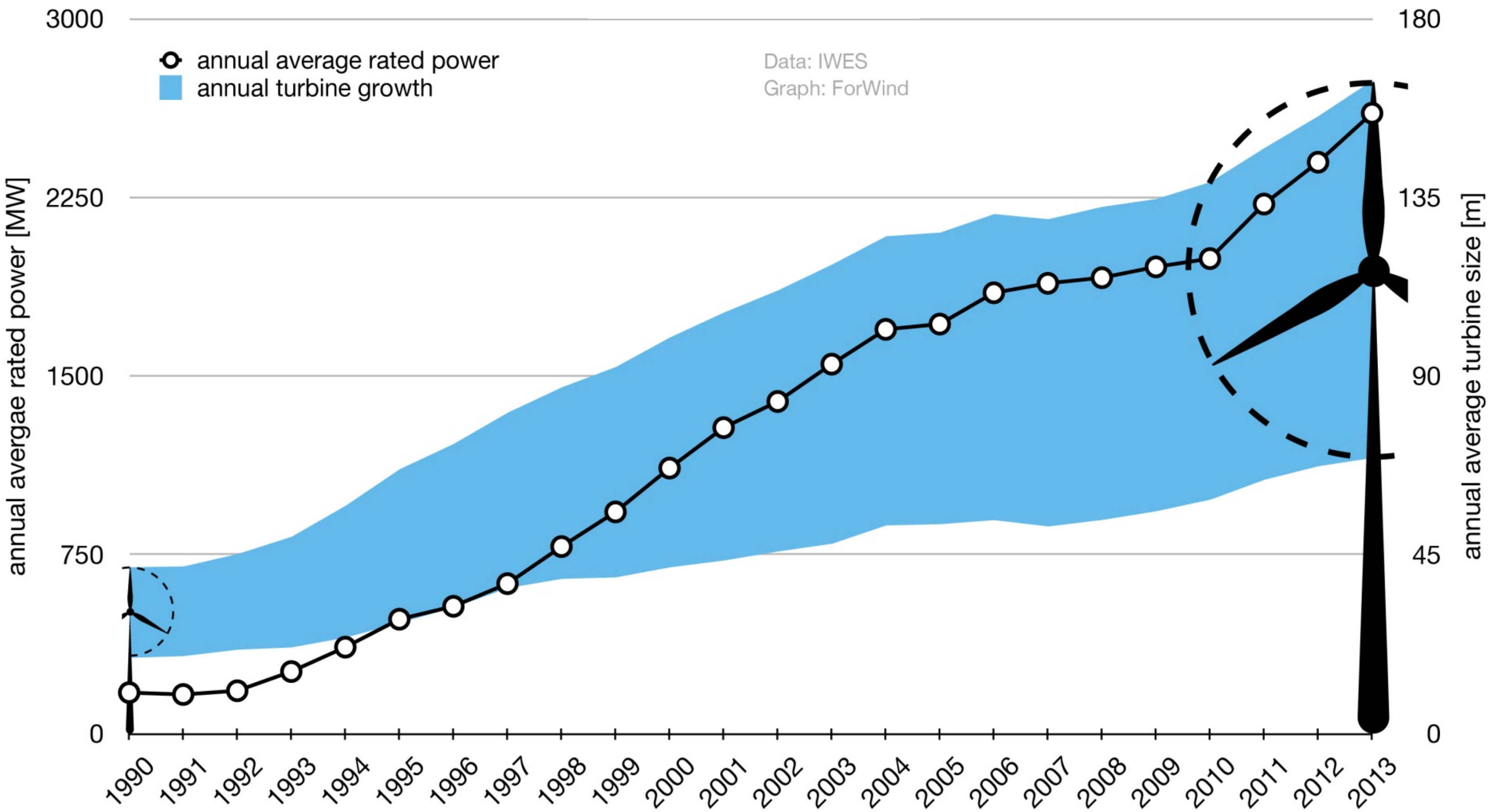


Wind energy Onshore in Germany



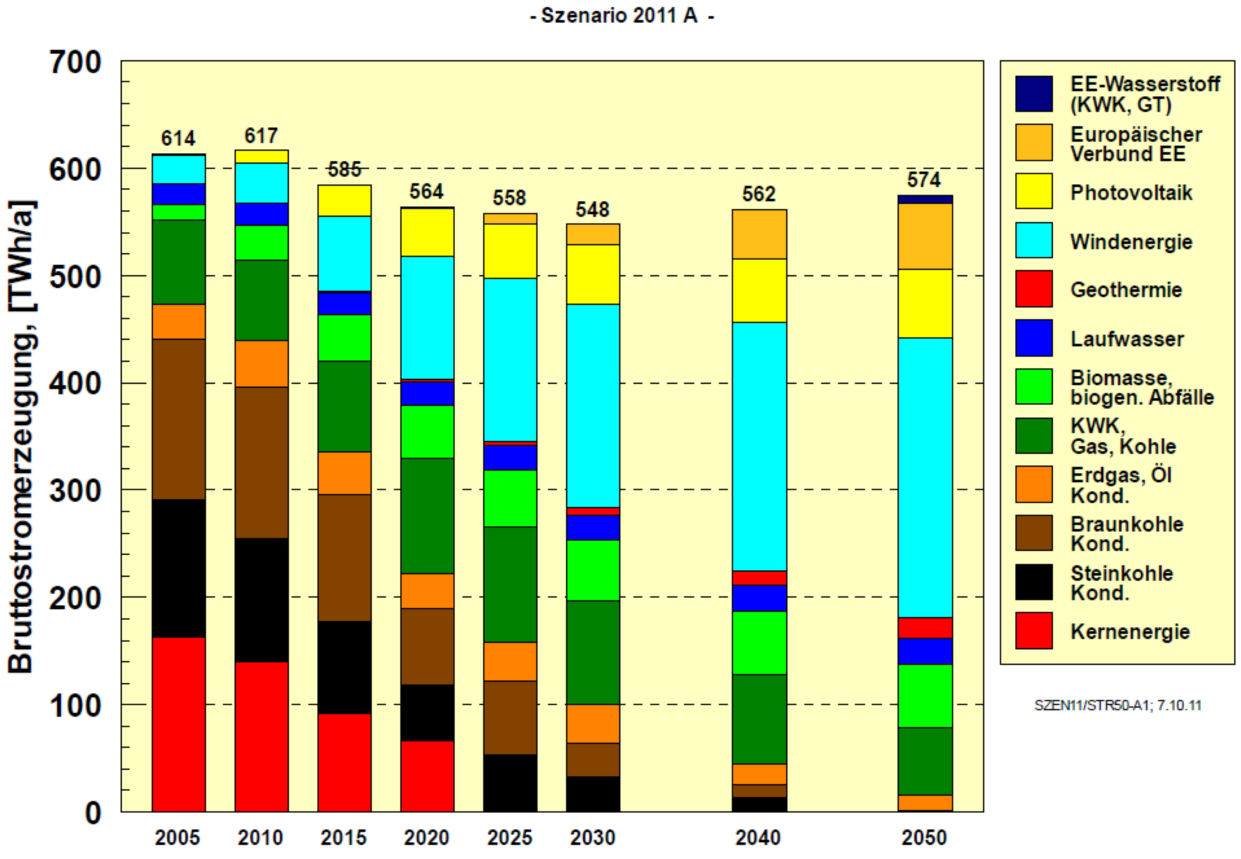
Quelle: DWG 2016, Status 31.12.2016

Growth of wind turbine size in Germany



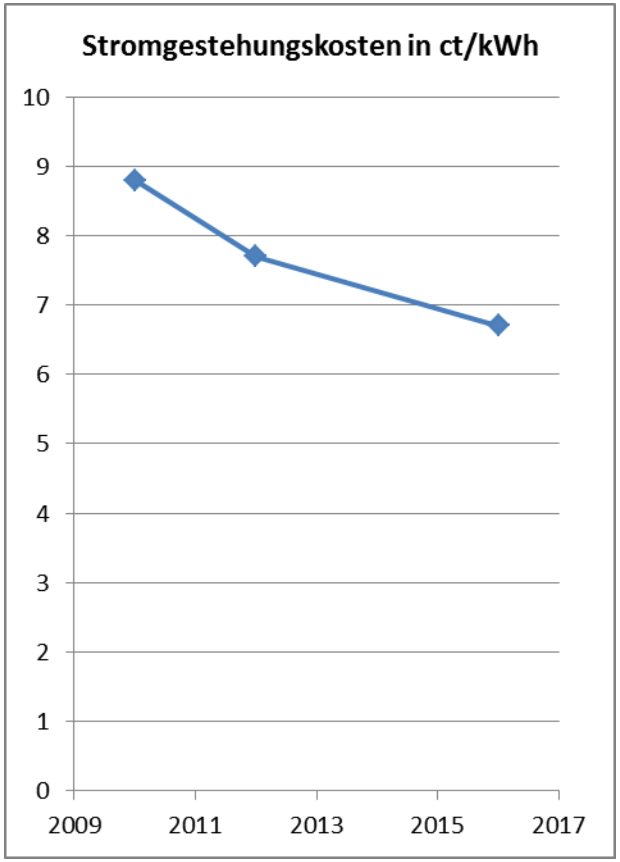
Quelle: ForWind 2014

Electrical Energy scenario for Germany



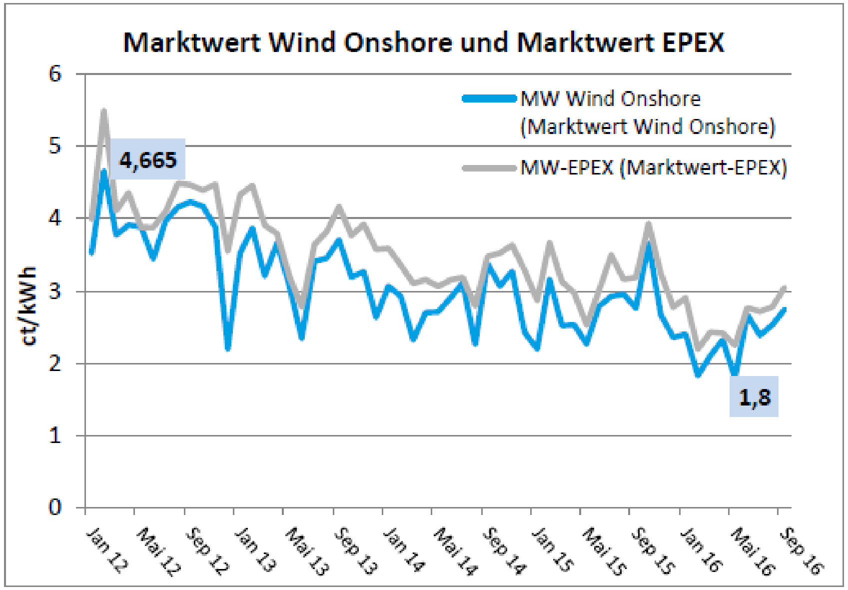
Quelle: DLR, IWES, IFBE 2011

Wind energy Onshore in Germany



Quelle: DWG 2011, 2013, 2015
(für 100% Referenzstandort)

Challenge: Costs!



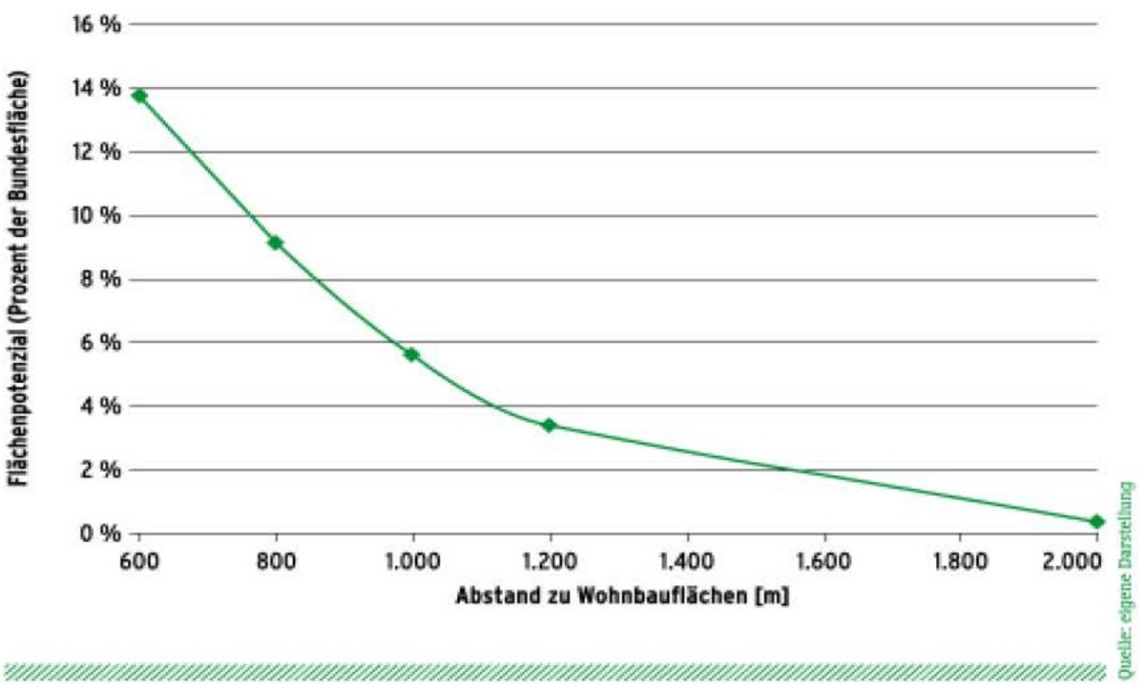
Quelle: DWG, ÜNB 2016

Wind energy Onshore in Germany

Challenge: Acceptance!

Potential und aktuelle Hemnisse

Abbildung 12: Einfluss des Abstands zu Wohnbauflächen auf die Höhe des ermittelten Flächenpotenzials



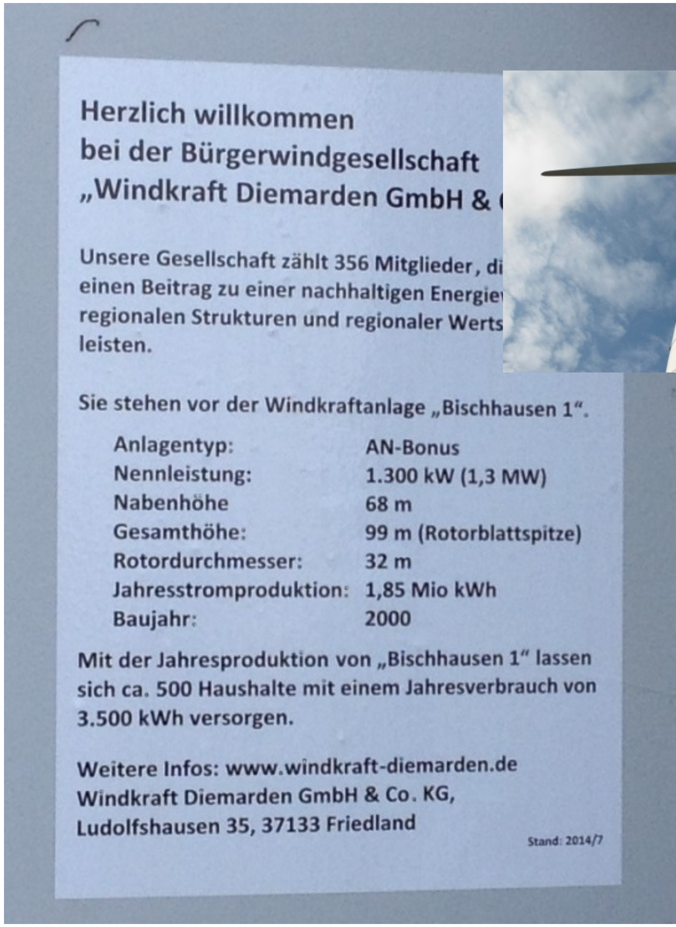
Quelle: Marktanalyse, BMWi 2015

Challenge costs - Power and Capacity at „same“ site -

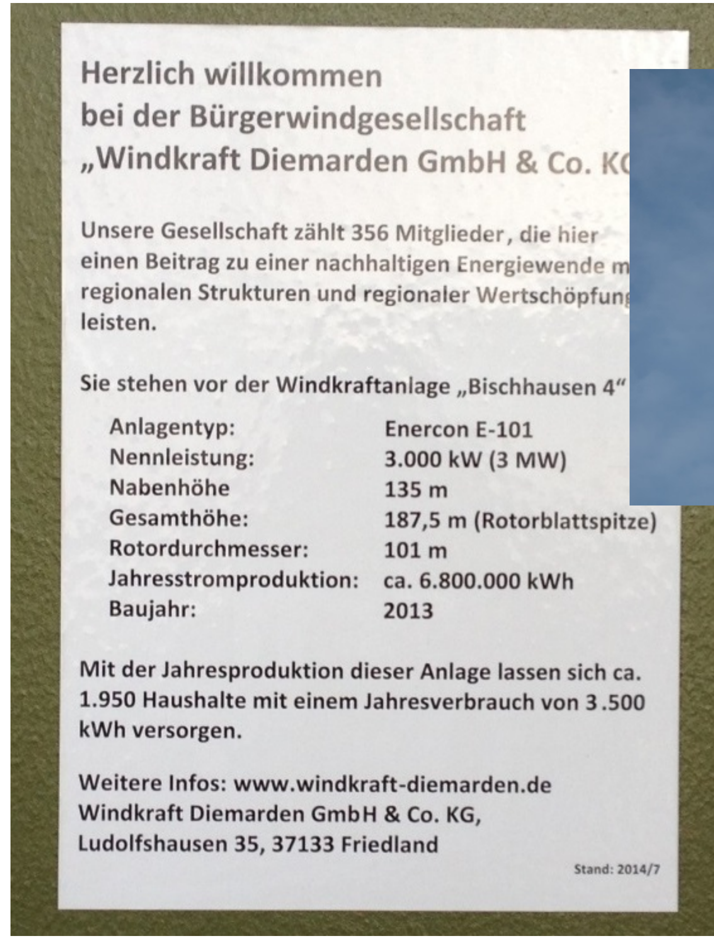
- Rated Power (MW)
- Capacity (MWh / year) ; 1 year = 8.760h

Challenge costs - Power and Capacity at „same“ site -

AN-Bonus



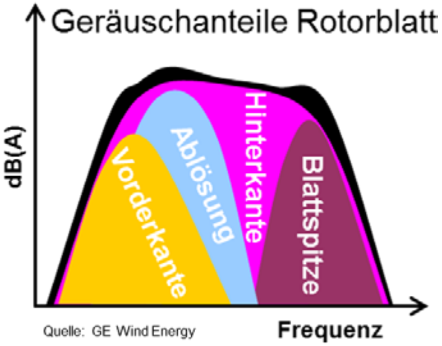
E-101



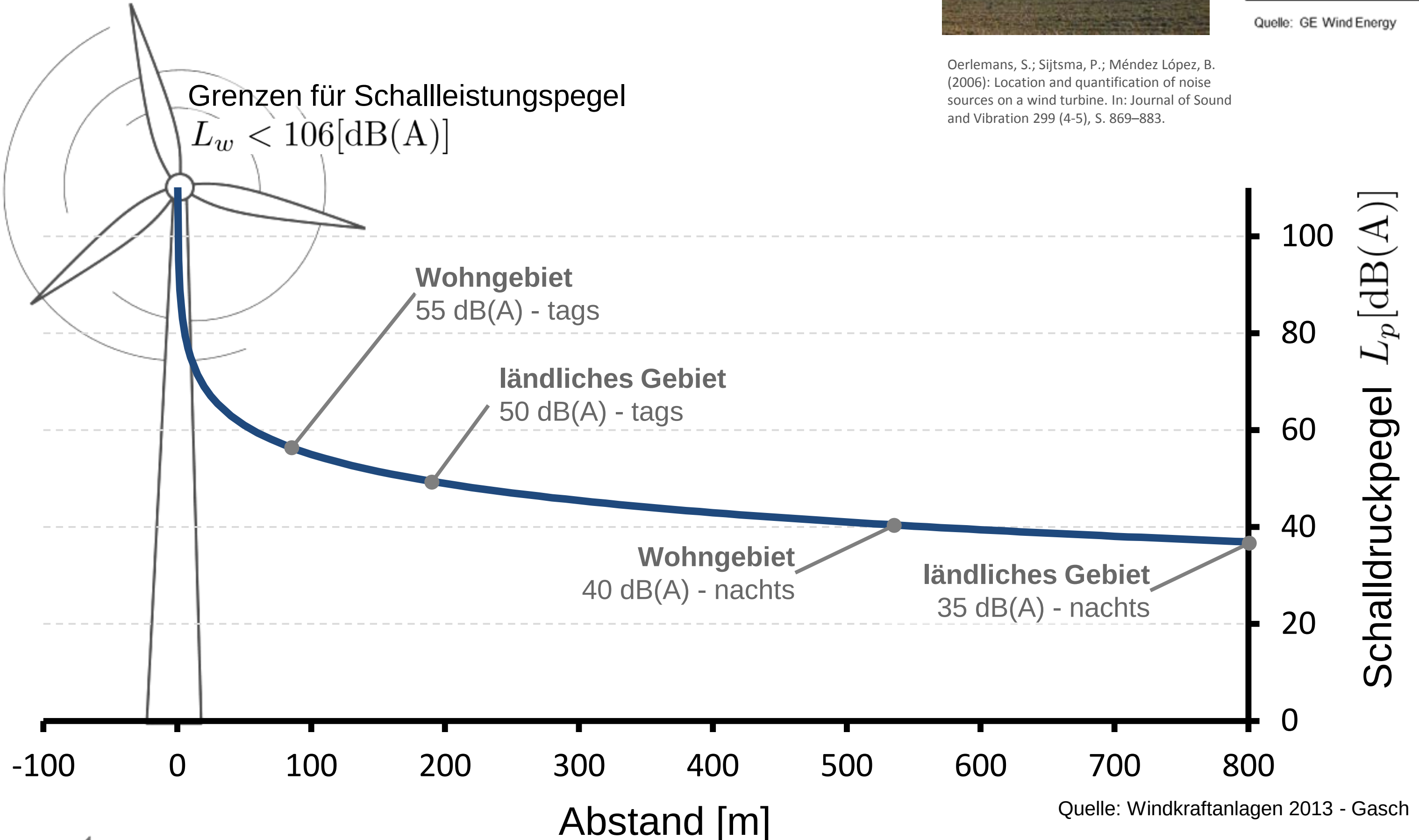
1.850 MWh / 1,3 MW = 1.420 h

6.800 MWh / 3,0 MW = 2.270 h

Challenge Acceptance - e.g. Noise -

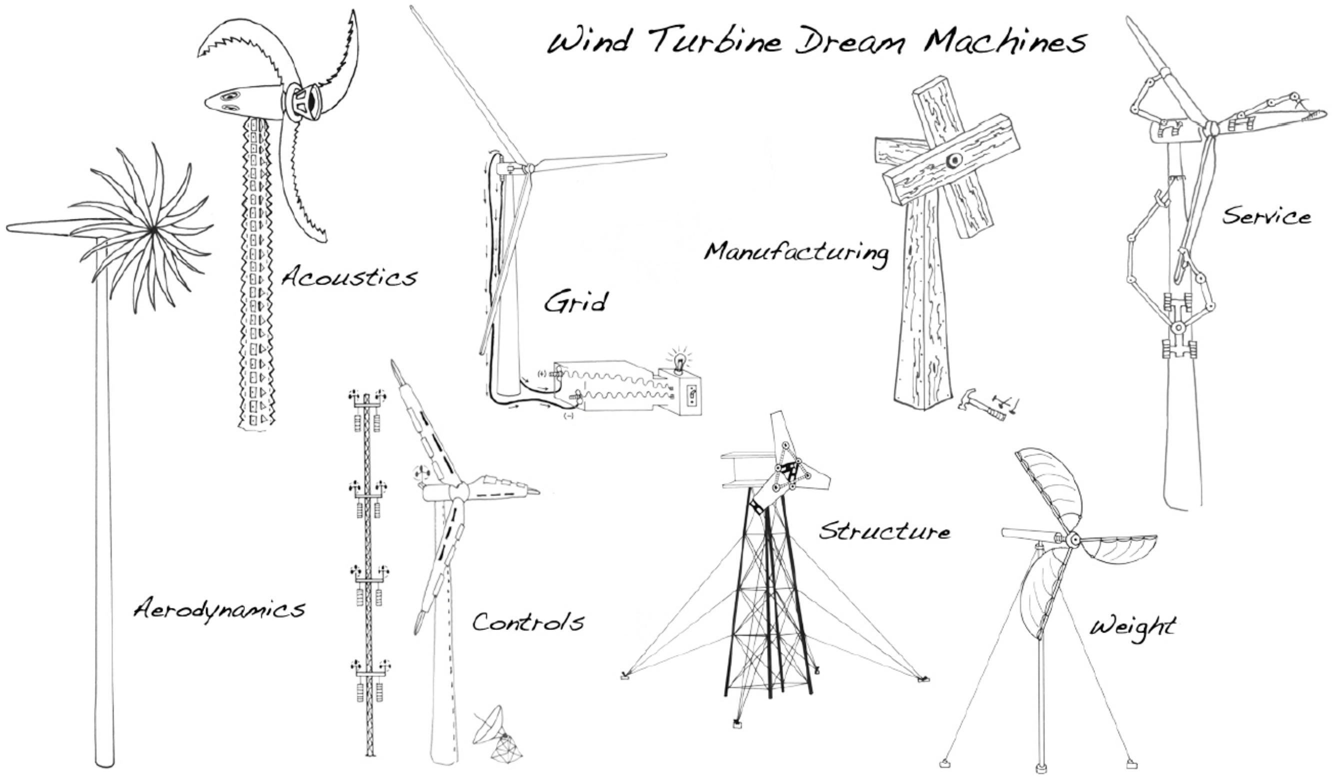


Oerlemans, S.; Sijtsma, P.; Méndez López, B. (2006): Location and quantification of noise sources on a wind turbine. In: Journal of Sound and Vibration 299 (4-5), S. 869–883.



Quelle: Windkraftanlagen 2013 - Gasch

Solutions …



Quelle: Dykes and R. Meadows: 'Applications of Systems Engineering to the Research, Design, and Development of Wind Energy Systems', Technical Report NREL, 2011

Large Rotor Blades - Noise Challenges -

Problem of „longer“ blades

→ Larger blade tip velocity u = f (L)

→ More Noise: N = f(u^5)

Measures

- Technologies for trailing edges with reduced noise emission
- RANS/CAA – based noise prediction for „Design2Noise“
- Validation measurment in acoustic wind tunnel (AWB)

→ Concepts investigated in BMWi Project BELARWEA

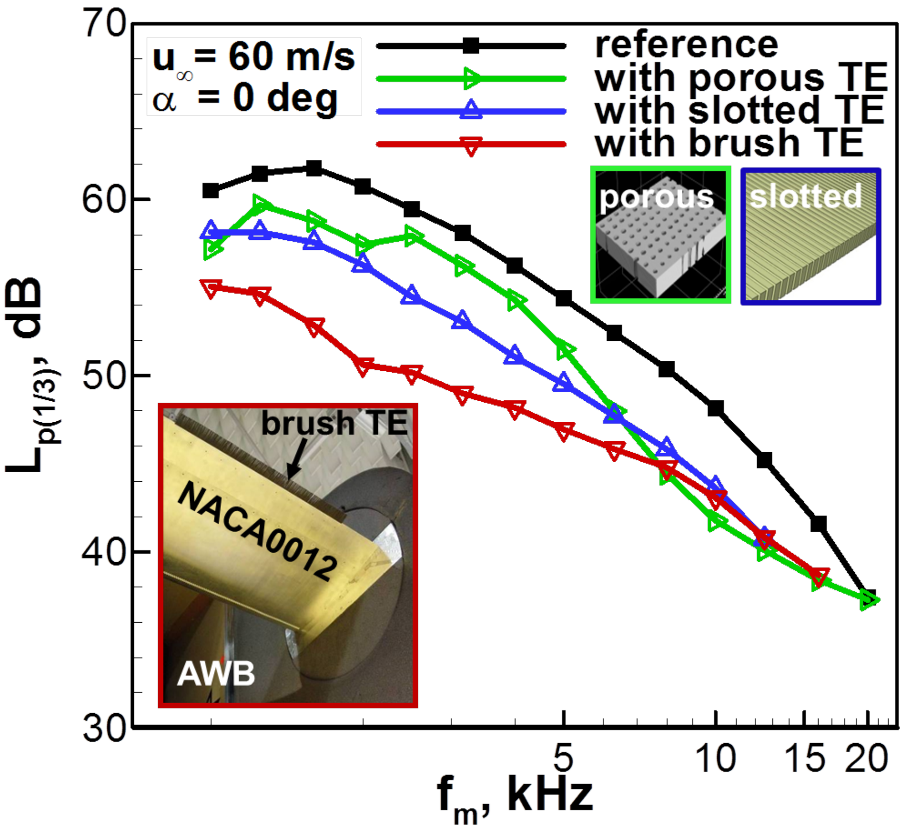
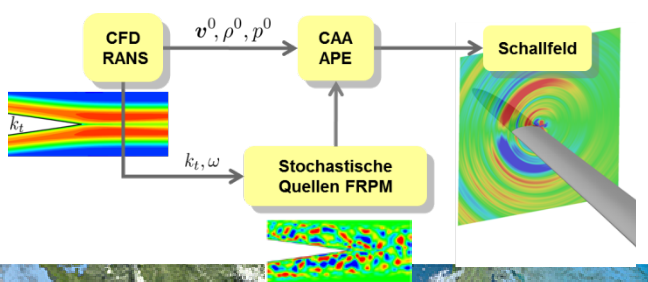


Bild: Herr (DLR)

Outlook

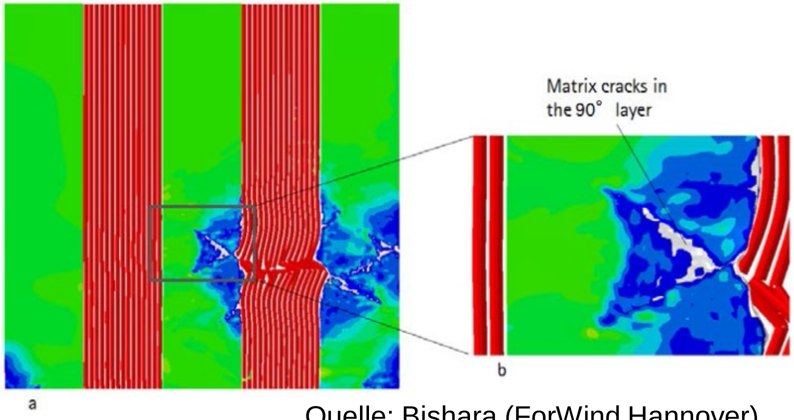
- Field test validation (→ DFWind)
- Multidisciplinary integration of structure-dynamic, aero-dynamic und acoustic computational methods within blade design



Large Rotor Blades - Cost Challenges -

Material

- Selection of performant and cost efficient material components
- Anisotropic material systems, suitable modelling and computational methods
- Test facilities & methods for validation and verification (V&V)



Quelle: Bishara (ForWind Hannover)

Production

- High placement rate and directional accuracy through Direct-Fiber-Placement technologies
- Automatic tolerance management, e.g. for monitoring of curing processes

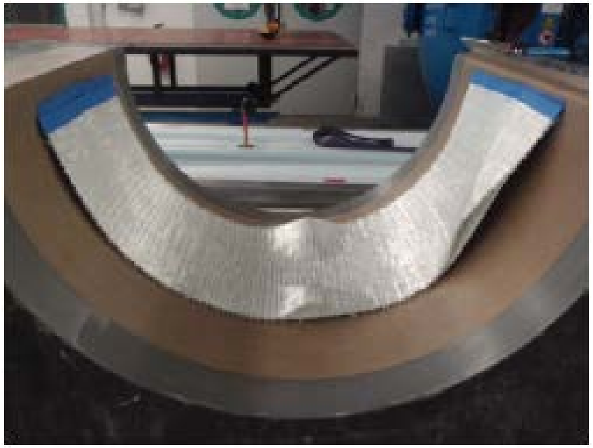


Bild: Wieland (DLR)

Operation and Maintenance

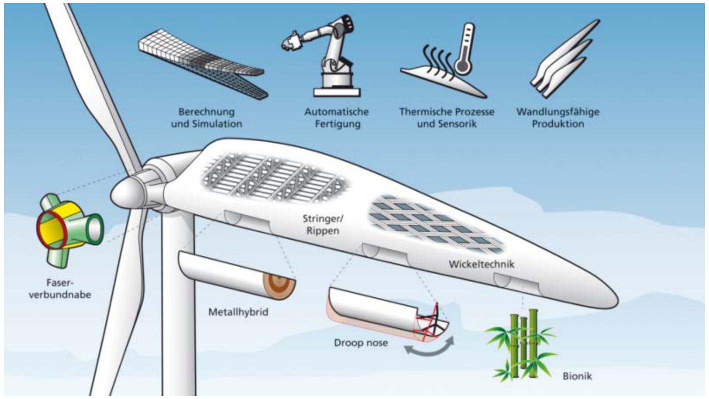
- Reliability analysis of wind turbines using smart blades

Forschungsverbund Windenergie

Large Rotor Blades - Load Challenges -

High loads & load changes, e.g. through
- Turbulent inflow conditions
- Maximization of rated load range
  - Large blades for high yield already at low wind velocities
  - Late cut-off at strong wind

Relief through intelligent rotor blades (Smart Blades)
- Passive technologies utilizing Bend-Twist-Coupling
- Active technologies utilizing quick mechanisms at leading and trailing edges
- Optimized controller methods



→ Concepts investigated in
BMWi Project SmartBlades / SmartBlades2

Gefördert durch:

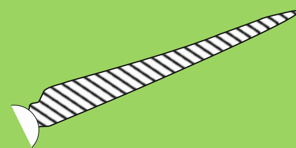
Bundesministerium für Wirtschaft und Technologie

aufgrund eines Beschlusses des Deutschen Bundestages

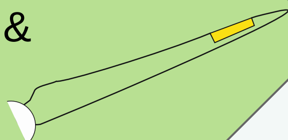
Smart Blades: Project structure and objectives

Cross technology topics

Technology 1: Bend - Twist - Coupled Blades



Technology 2: Moveables - Design & Control Strategies



Technology 3: Adaptive Slats

Strategic objectives

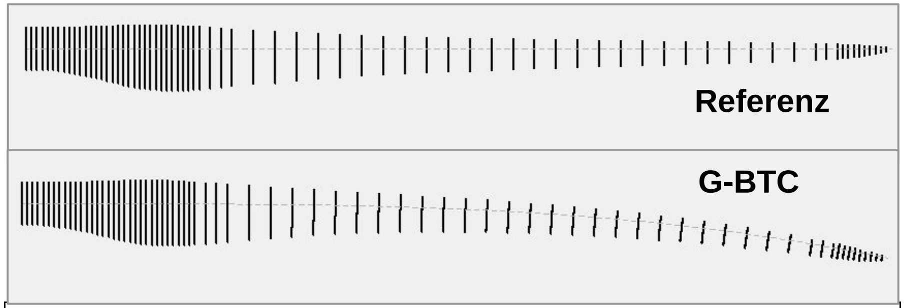
- Num. proof of load reduction with Smart Blades
- Decrease the CoE
- Test of demo blades on real turbine

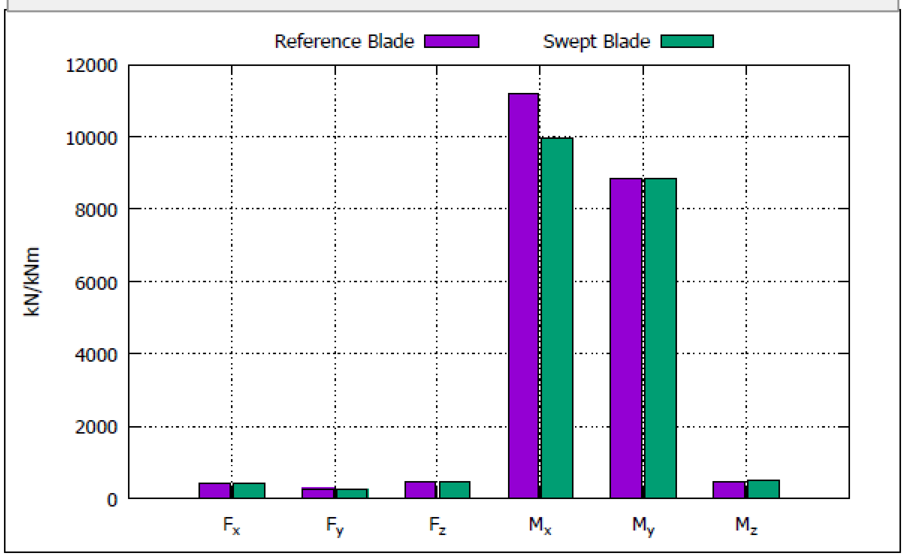
Timeline:

Concept → Num. simulation → Test in laboratory → Num. proof → Manufacturing documents → Part test in field → Manufacturing of demo blades → Blade test on turbine

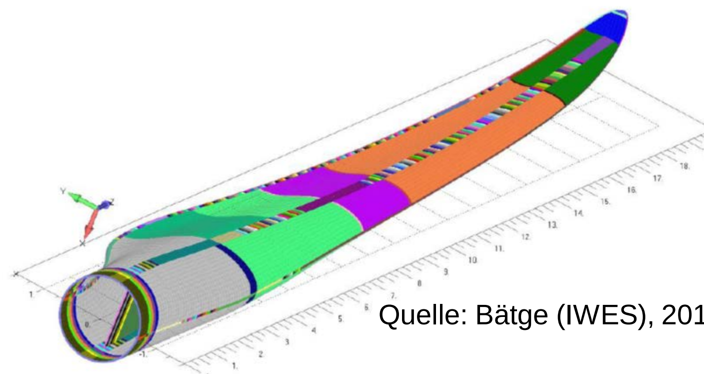
Smart Blades - Bend Twist Coupling (BTC) -

- Development of Geometric BTC blades and simulation on wind turbine
- Design of Demo Blade (20m) and manufacturing of the appropriate tooling





Fatigue DEL at blade root, Sevinc (IWES), 2016



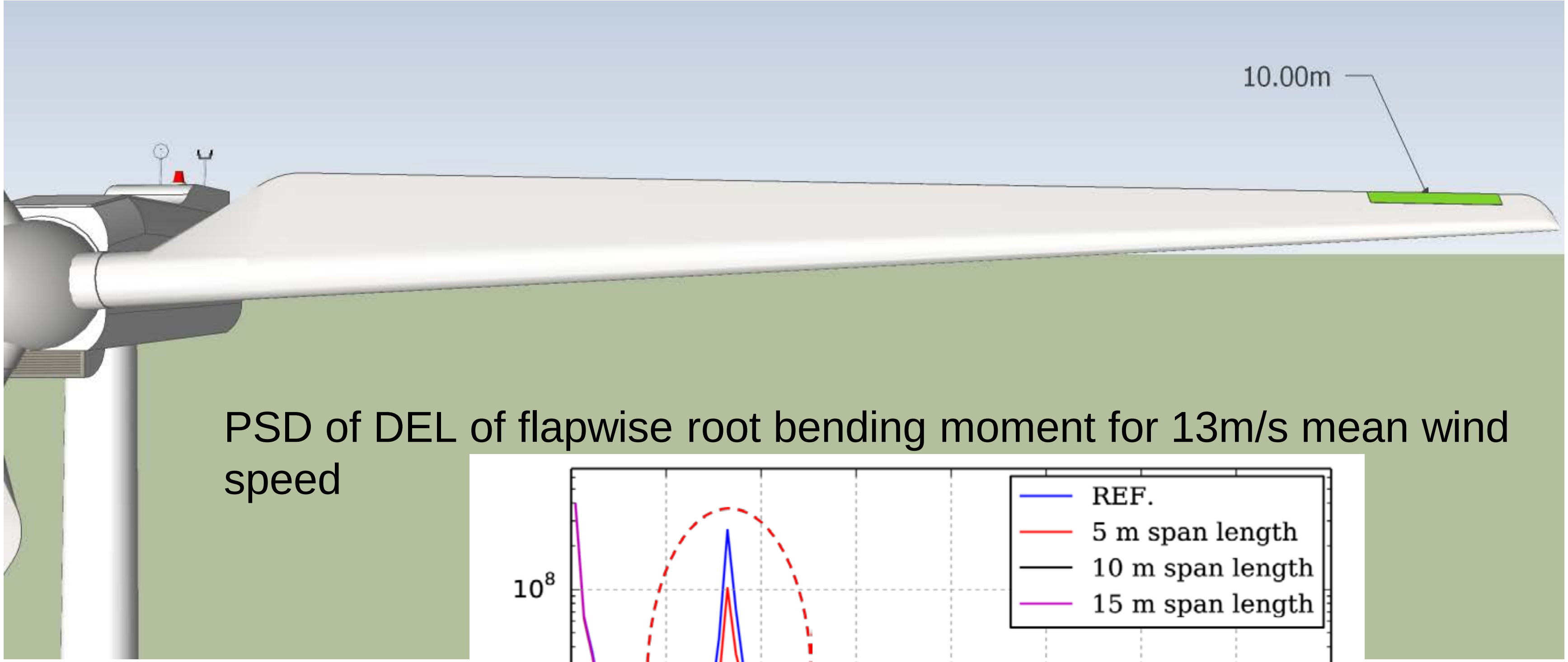
Quelle: Bätge (IWES), 2016

Quelle: DLR, 2016

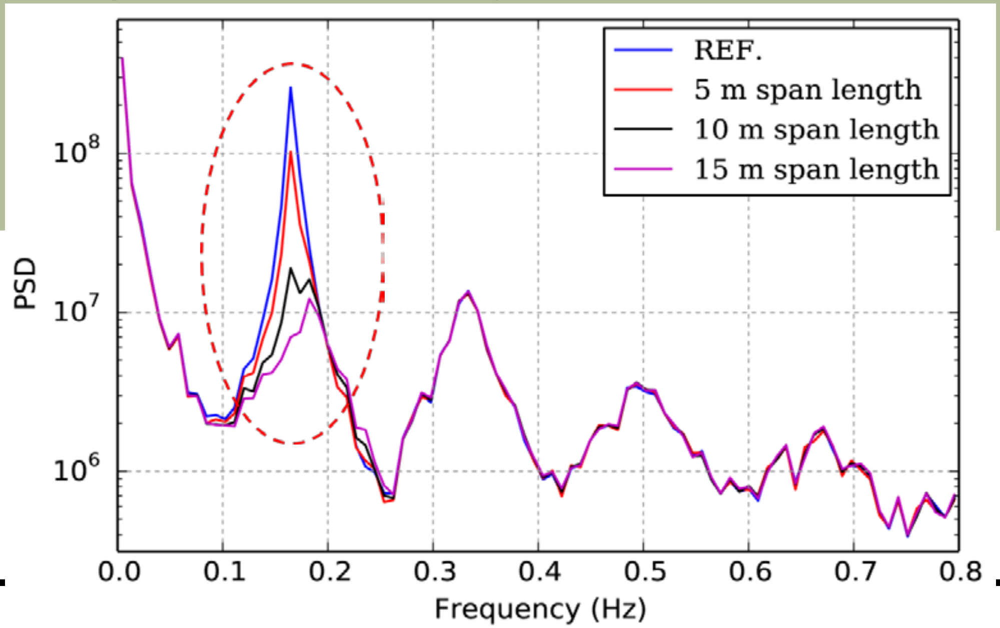
ForWind
Fraunhofer IWES
DLR Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft

Research Alliance Wind Energy

Smart Blades – Active trailing edge -



PSD of DEL of flapwise root bending moment for 13m/s mean wind speed



Quelle: N. Oltmann (DLR), R. Ungurán FW - OL)

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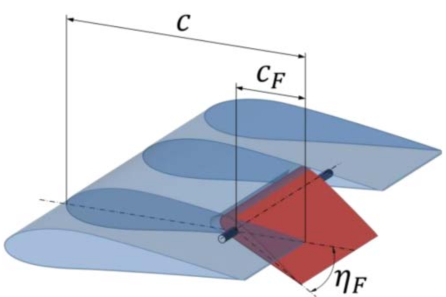
Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft
Forschungsverbund Windenergie

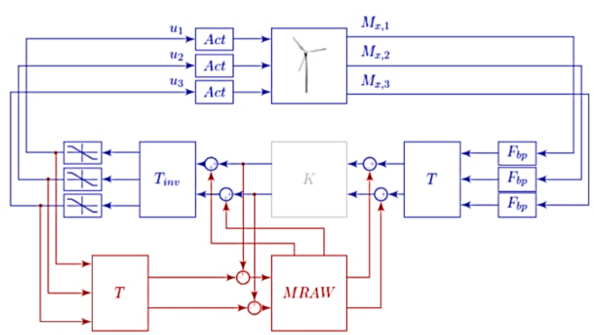
Smart Blades – Active trailing edge -

Moveables: Design & Control Strategies

- Concept and realization of a lightweight flexible trailing edge demonstrator for wind energy turbines
- A comparison of individual pitch and trailing edge flap control for structural load mitigation of a wind turbine
- Investigation on various configurations for Load Reduction of Wind Turbines



Quelle: Oltmann (DLR)

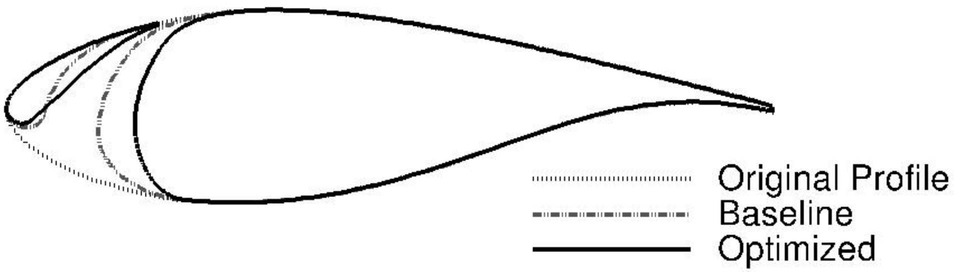


Quelle: Ungurán (FW - OL)

Quelle: Pohl(DLR)

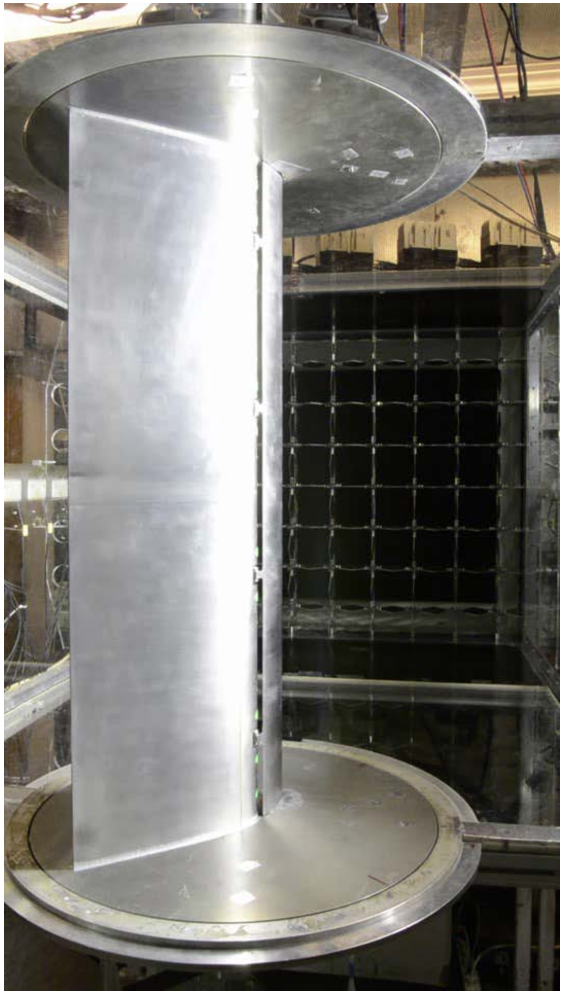
Smart Blades – Active leading edge -

Integrated Slat configuration



Quelle: Manso Jaume (DLR), 2015

- Design of an integrated leading edge slat
- Wind tunnel tests on airfoils with active slats
- Feasibility of adaptive slats concept is proofed



Quelle: T. Homeyer (FW-OL), Huxdorf (DLR), 2016

Smart Blades – Active leading edge -

Proof of concept

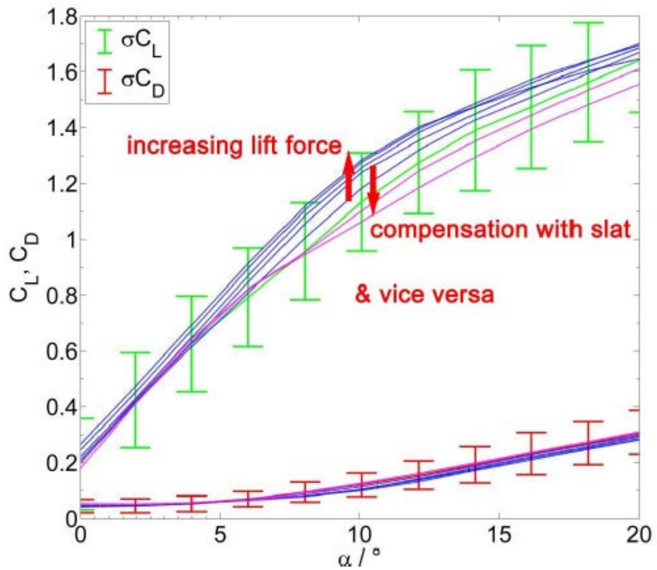
Wind tunnel measurments with fluctuating inflow (±6˚AoA at 5Hz) generated

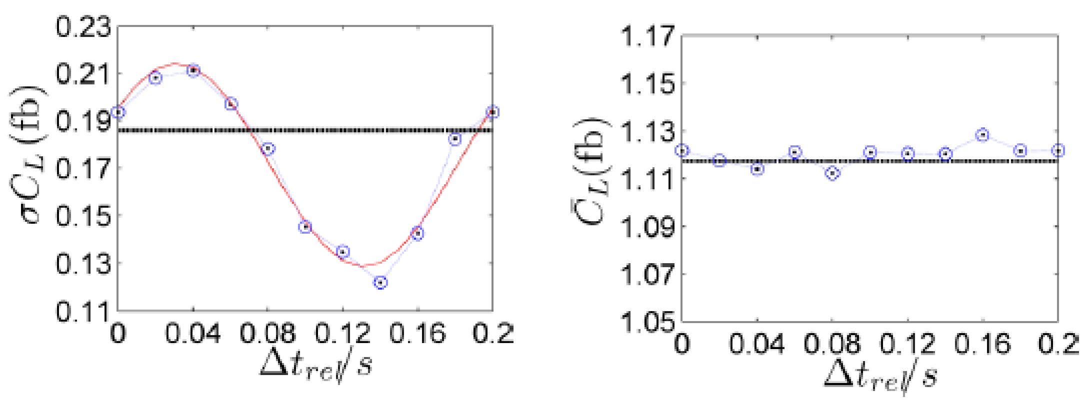
→ Proof of mechanism effectivity

- Load compensation through slat closing/opening

→ Proof of dynamic relevance

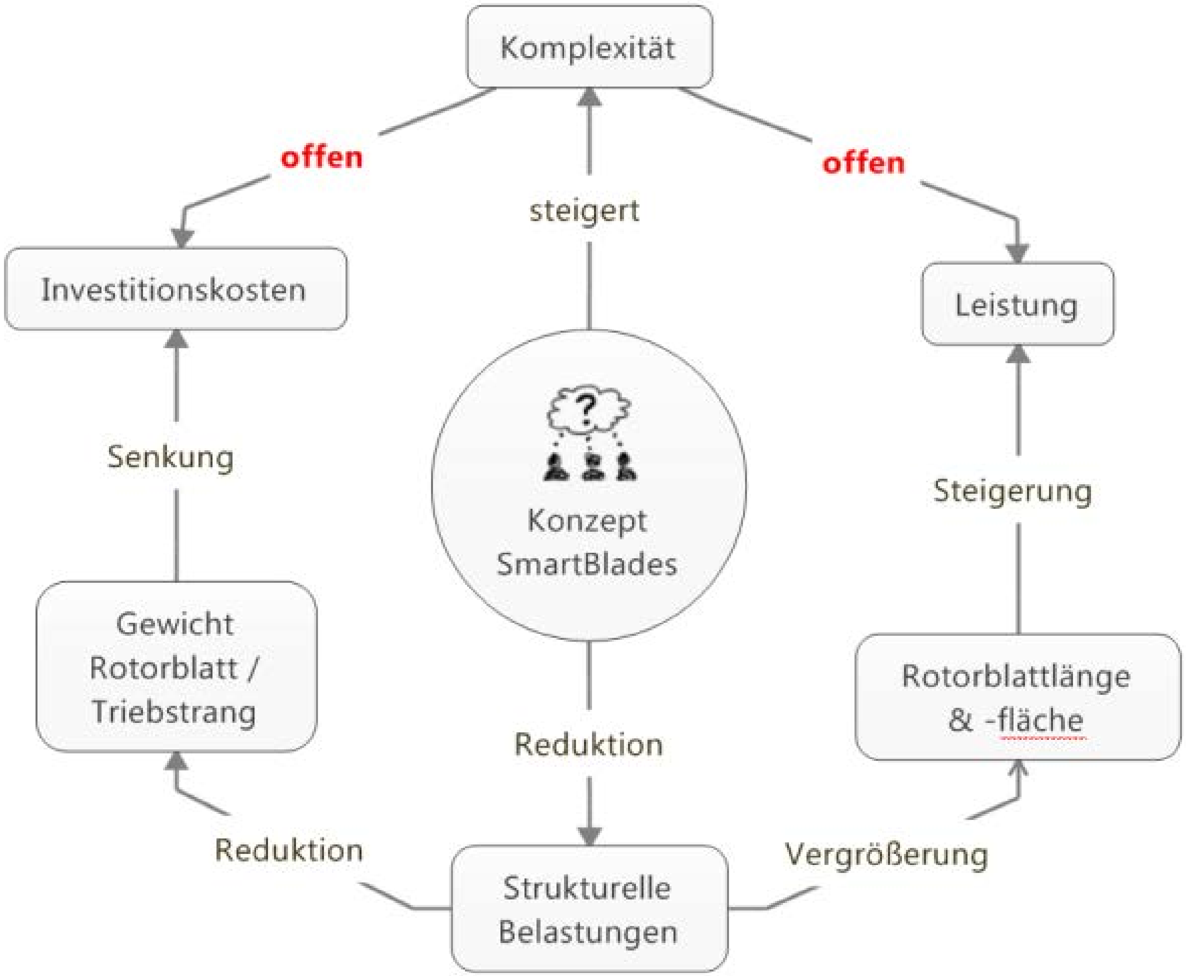
- turbulent loads (caused by σC_L) can be reduced at constant mean value ($\overline{C_L}$)





Quelle: T. Homeyer et al. (FW-OL), 2016

Smart Blades - Succesful? -

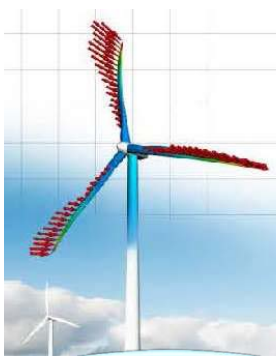


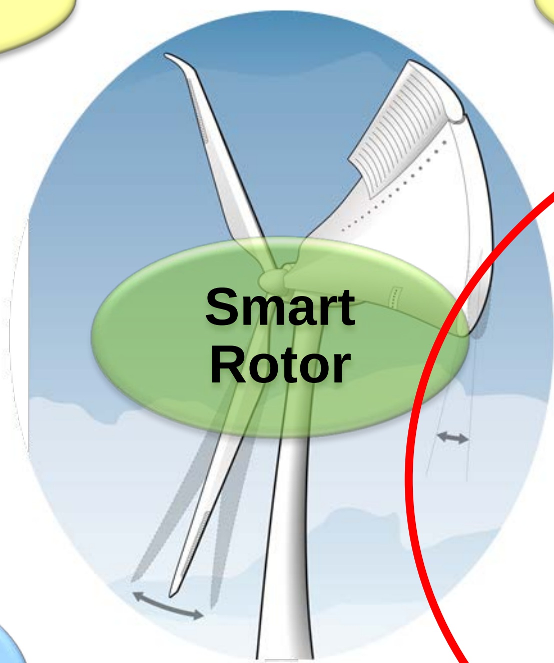
Methods and Technologies for Smart Rotors - Validation and Verification (V&V) -

Robust
Wind Resources,
Operation Strategies

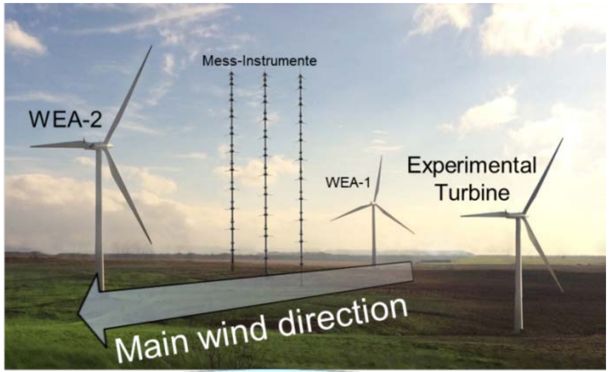
Efficient
Design, Analysis,
Production

Acceptance
Noise: Emission,
Transmission, Immission





Smart Rotor



Analyse & Simulation
Code-Development
- Multi-Disciplinary
- Multi-Fidelity

Loads, Sensitivities
Studies & Predictions

Experimental Research Platform
- Phenomena, Data
- Technologies: Testing & Qualification
- Methods: V&V

DLR

Platform for Wind Energy Research

Gefördert durch:

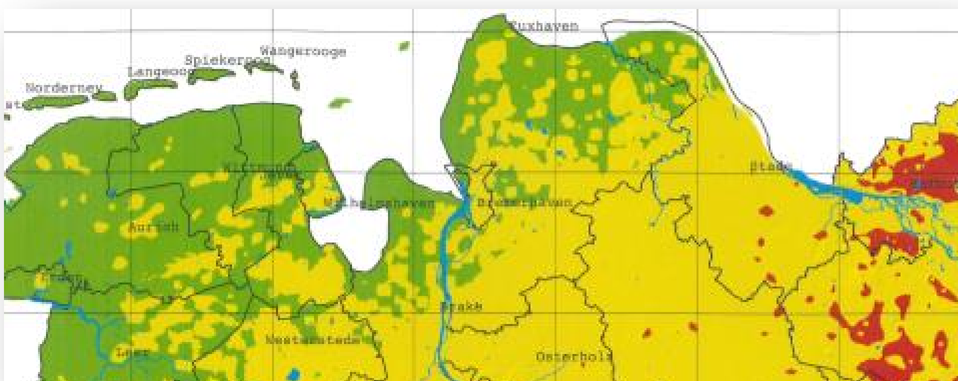
Bundesministerium
für Wirtschaft
und Energie

Niedersächsisches Ministerium
für Wissenschaft und Kultur

aufgrund eines Beschlusses
des Deutschen Bundestages

Project PROWind
- Implementation of Basic Research Infrastructure -

- Site selection, development and approval in Lower Saxony
- Planning and implementation of basic research infrastructure
- Erection of 2 WT (ca. 2,5 MW)

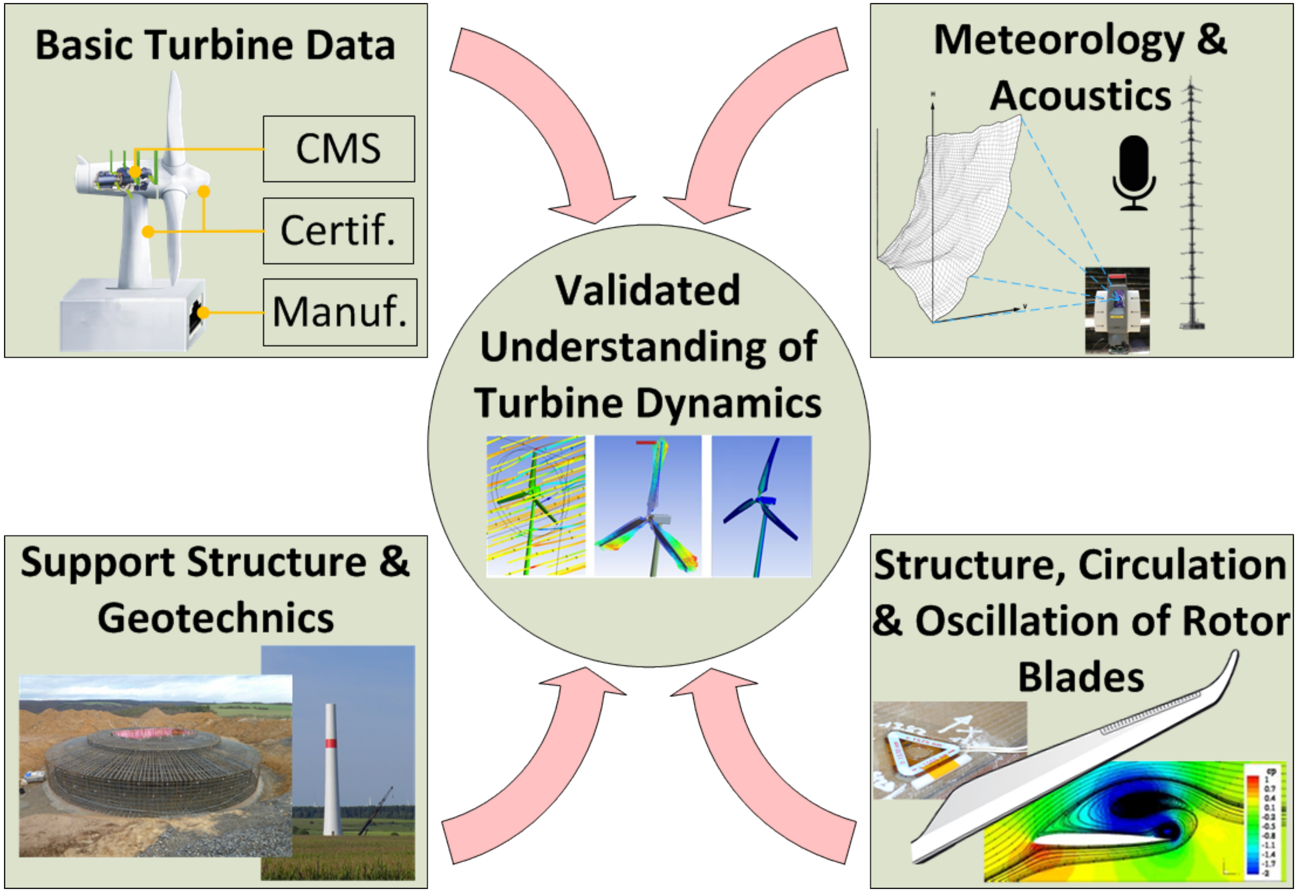


Gefördert durch:

Niedersächsisches Ministerium für Wissenschaft und Kultur

Forschungsverbund Windenergie

Project DFWind
- Research Enhancement (www.dfwind.de) -



Gefördert durch:

Bundesministerium für Wirtschaft und Energie

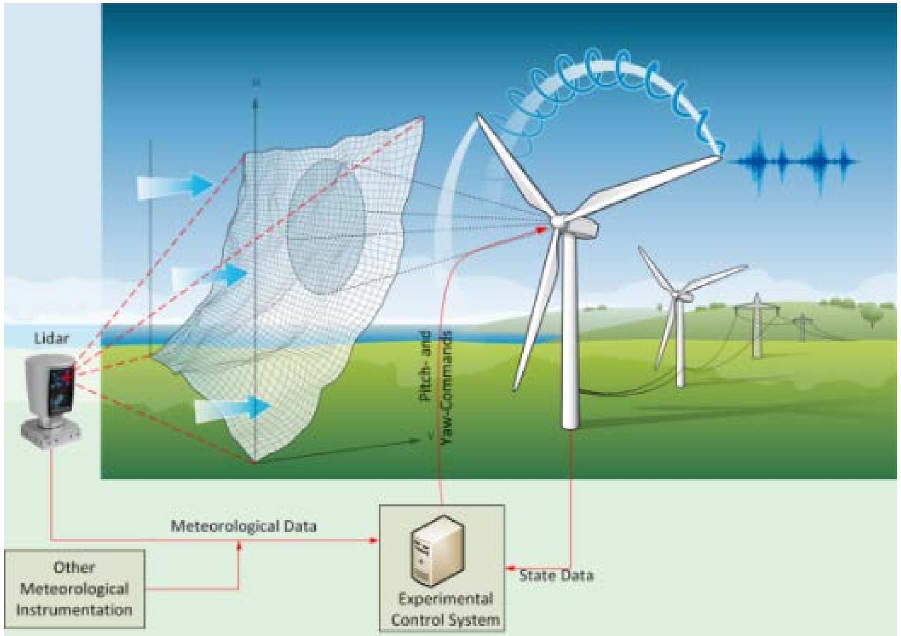
aufgrund eines Beschlusses des Deutschen Bundestages

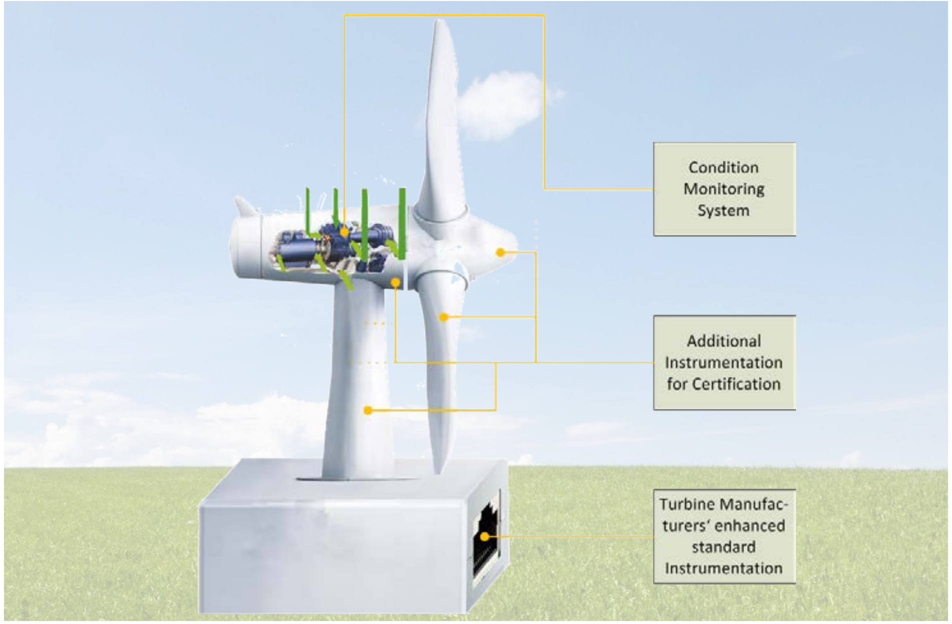
DLR Deutsches Zentrum für Luft- und Raumfahrt

ForWind Zentrum für Windenergieforschung

Fraunhofer IWES

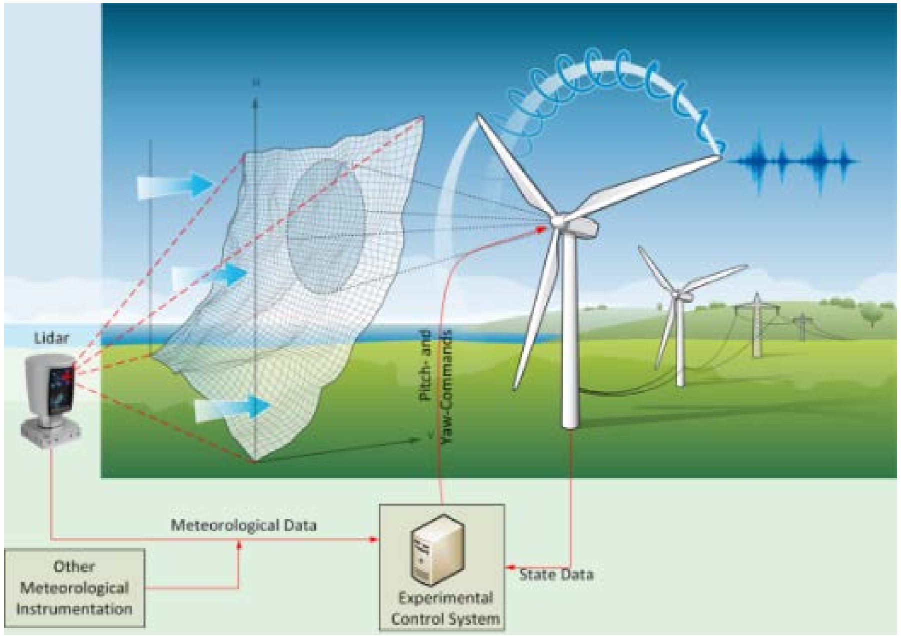
DFWind
- Turbine Instrumentation -

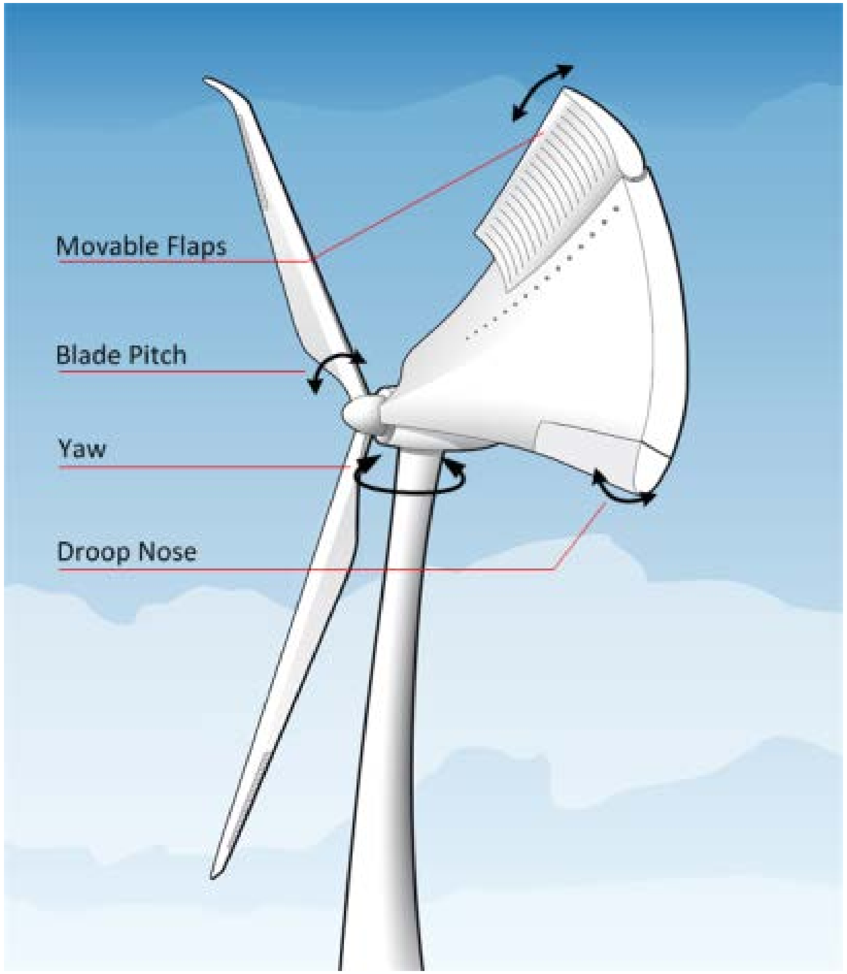




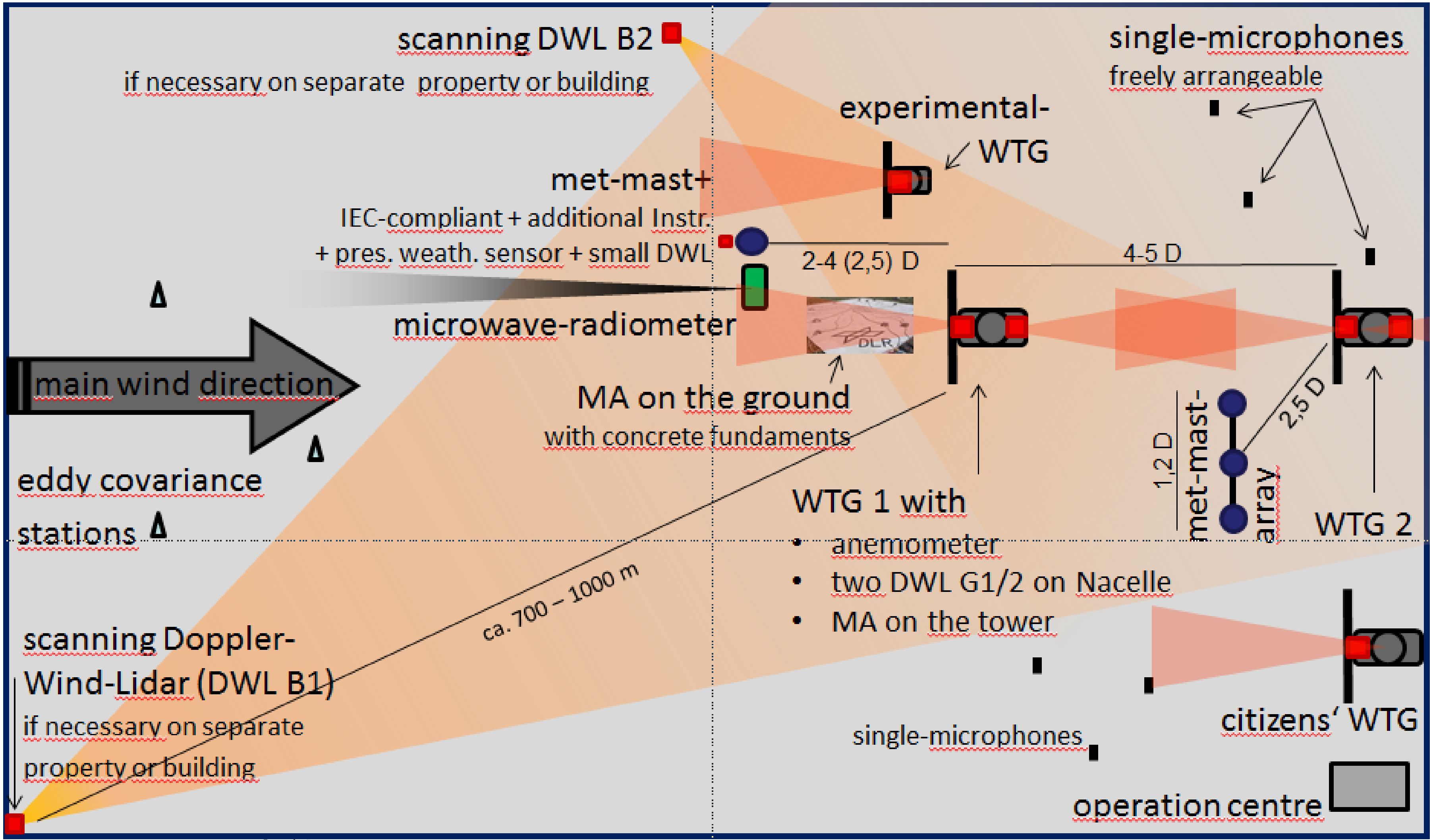
- Basic research instrumentation (acc. to IEC 61400)
- Electro-technics and EMC
- Nacelle - Condition Monitoring System

DFWind
- Experimental Turbine Control -





DFWind
- Instrumentation for Inflow, Meteorology, Acoustics -

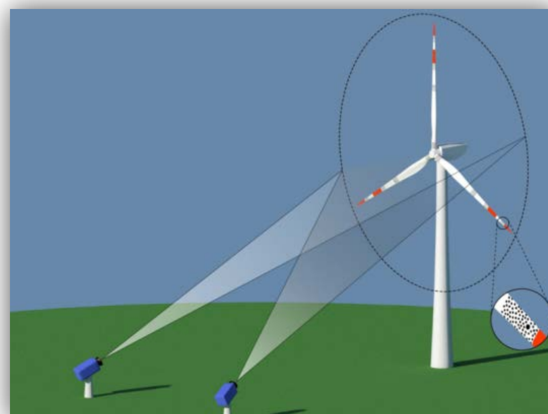


DFWind
- Rotor Blade Instrumentation -

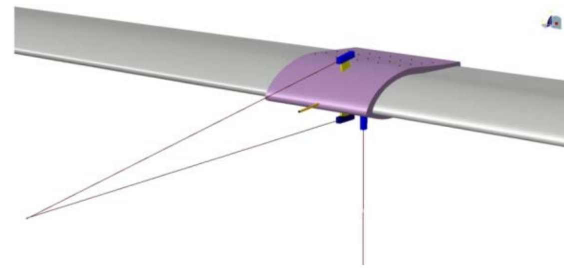
Production monitoring

Quelle: DLR

Deformations



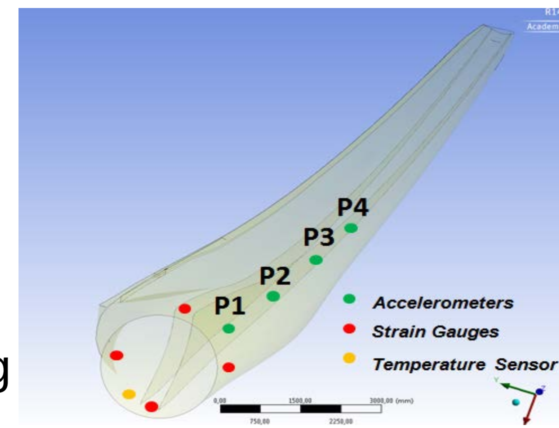
Aerodynamic properties



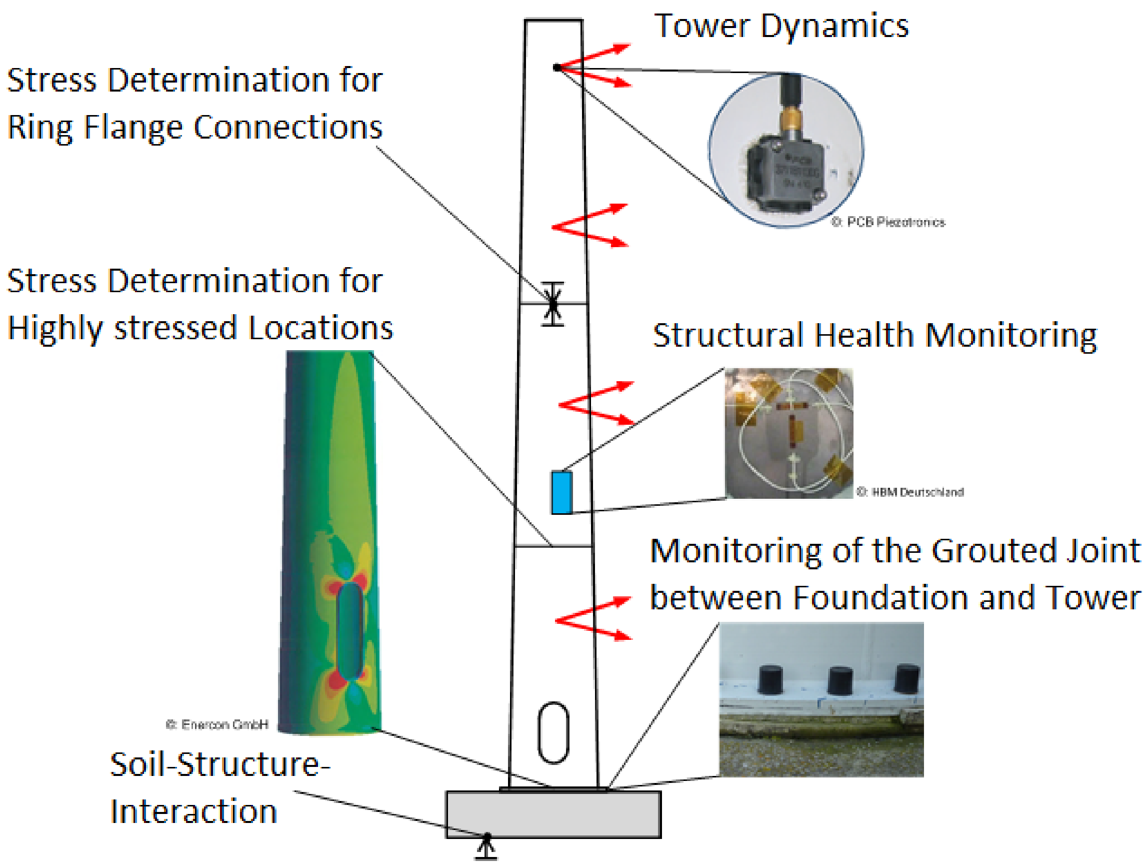
Aeroelastic identification

Quelle: Bishara, Garmabi, FW H

Structural Health Monitoring

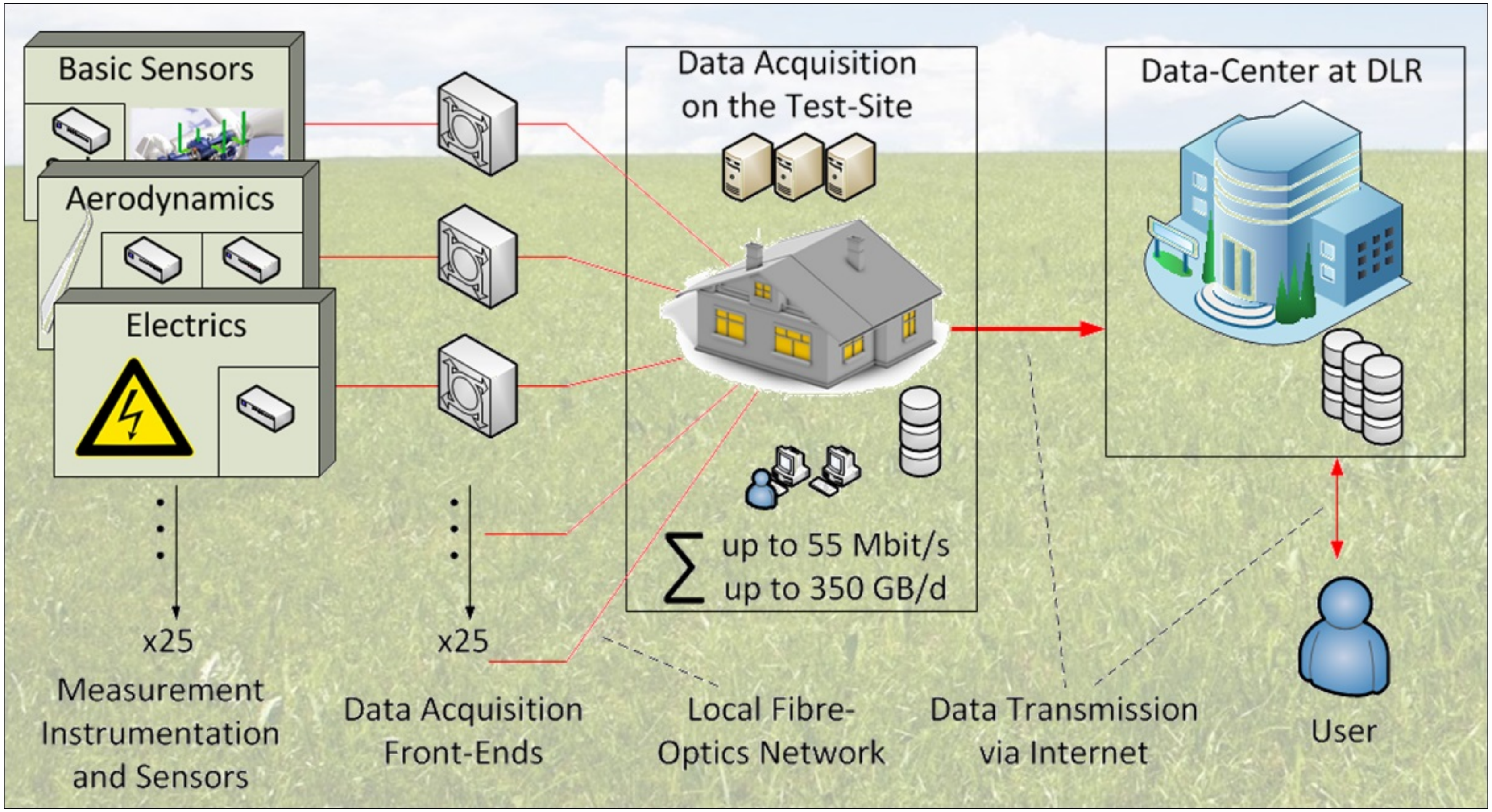


DFWind
- Support Structure and Geotechnics -

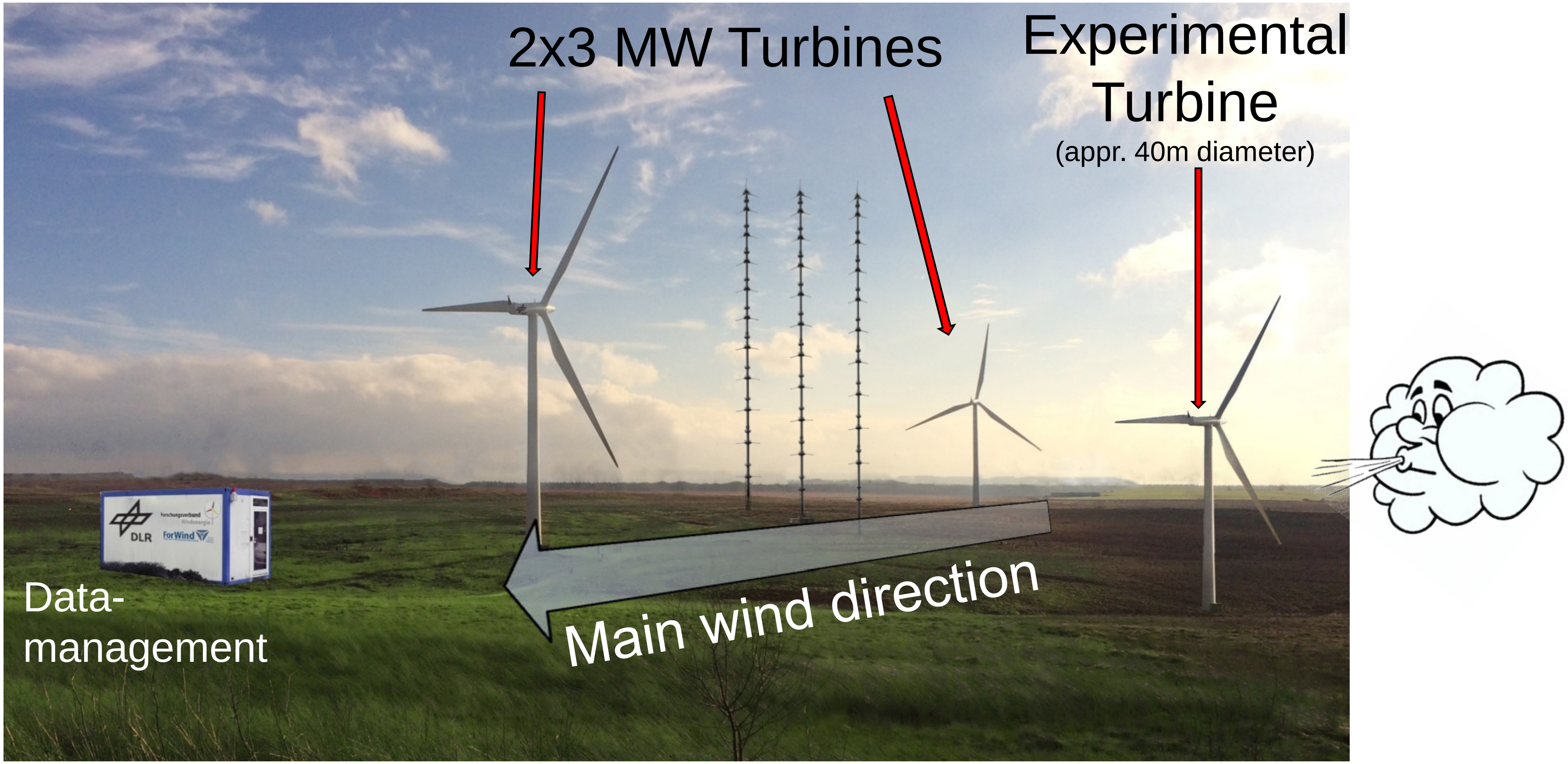


Tower / Foundation

DFWind
- Data Acquisition and Management -



Platform for Wind Energy Research
- Outlook -



! Open for corporate Research !

Smart Rotors for cost efficient Wind turbines

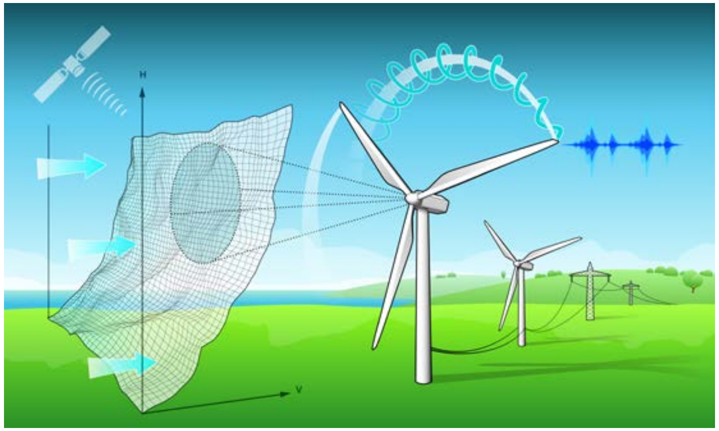
Summary

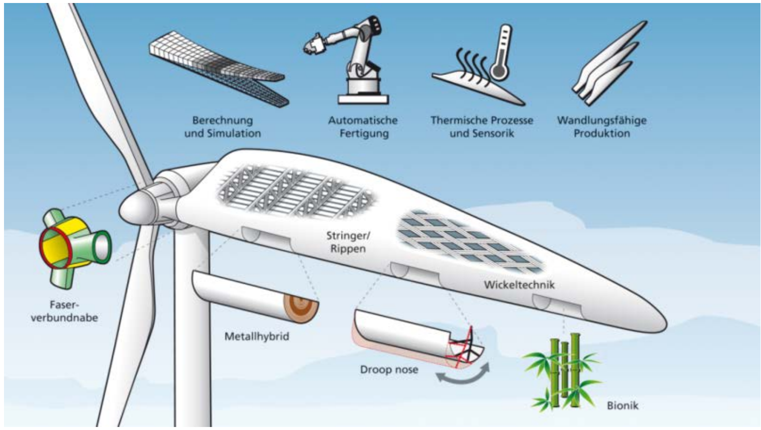
- Growth of wind turbines allowed for significant cost savings on LCOE (Levelized Cost of Energy

- Wind turbines are currently the largest rotating machines ever built

- Design → Production → Operation
  issues are extremely challenging and yield still large potential for savings

- Full scale Validation is of great importance to assure industrial implementation





References 1

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[Sevinc2 2015]: A. Sevinc, O. Bleich, C. Balzani, A. Reuter; Aerodynamic and Structural Aspects of Swept Blades in the Context of Wind turbine Load Reduction, EWEA 2015

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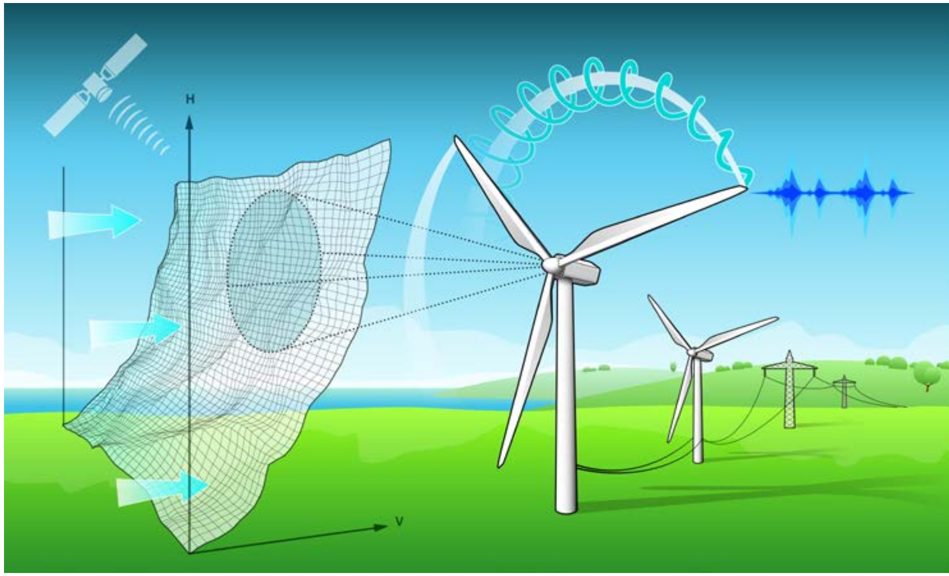

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