Spanish Wind Energy Technology Platform
6^{th} General Assembly
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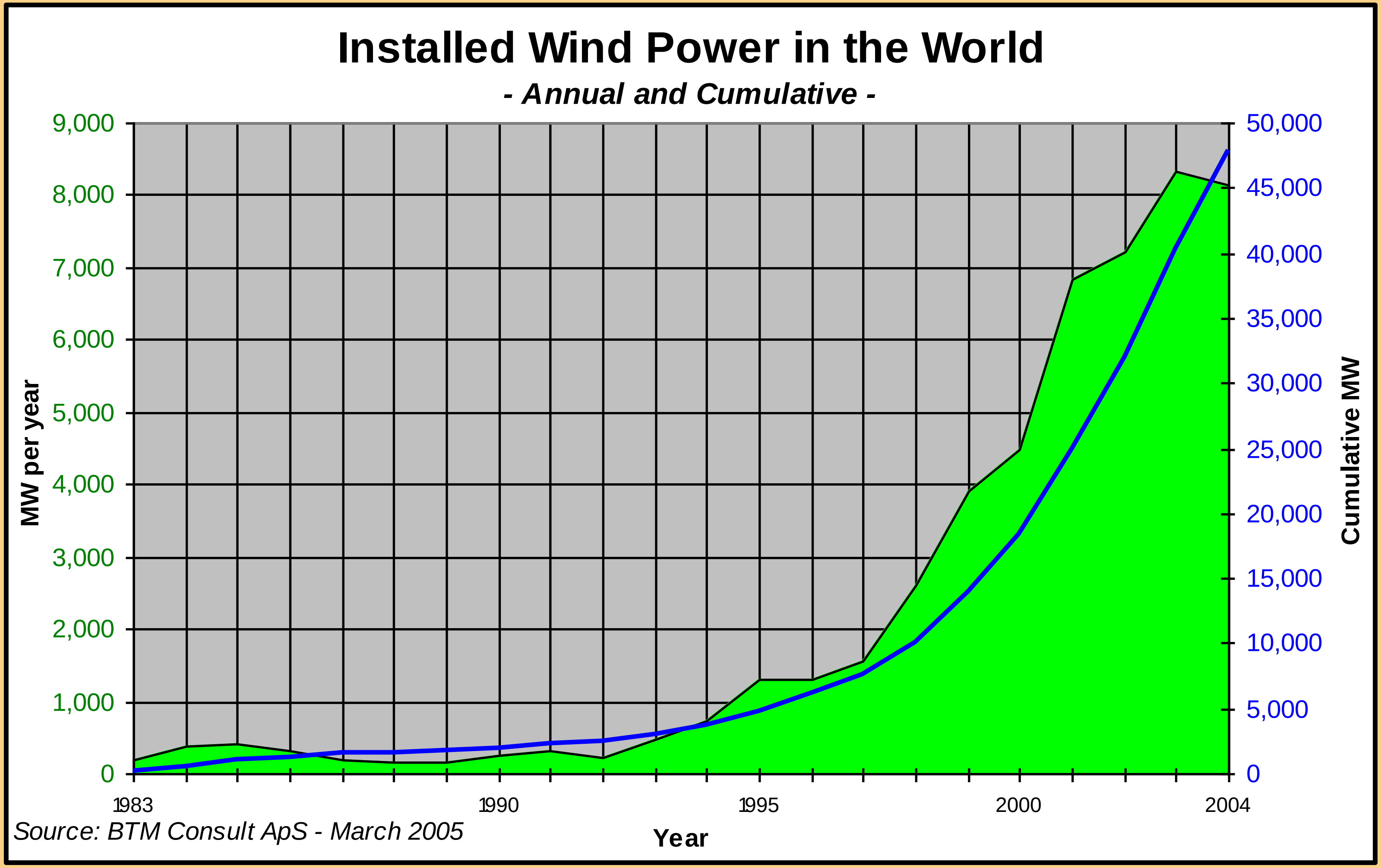
SIXTH FRAMEWORK PROGRAMME

UpWind

Outline

1. Background for UpWind
2. Presentation of the UpWind Project
3. General conclusions and results
4. Work and results in the 15 working groups
5. Today global status
6. Questions



World Market Update 2004 March 2005

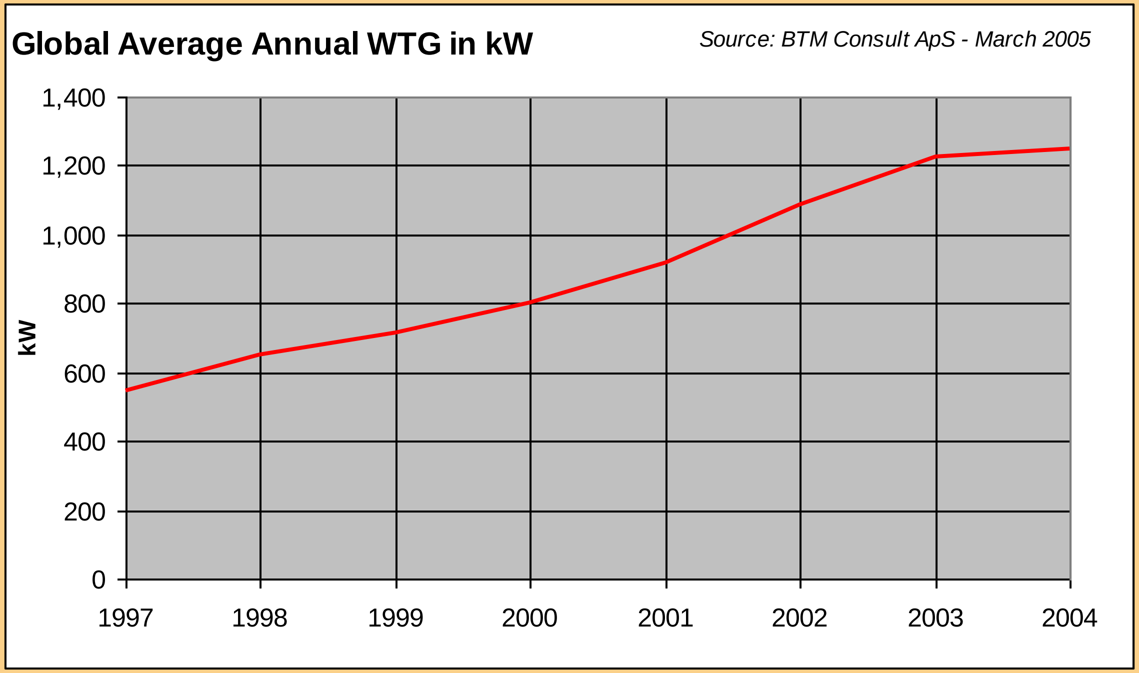
SIXTH FRAMEWORK PROGRAMME

UpWind

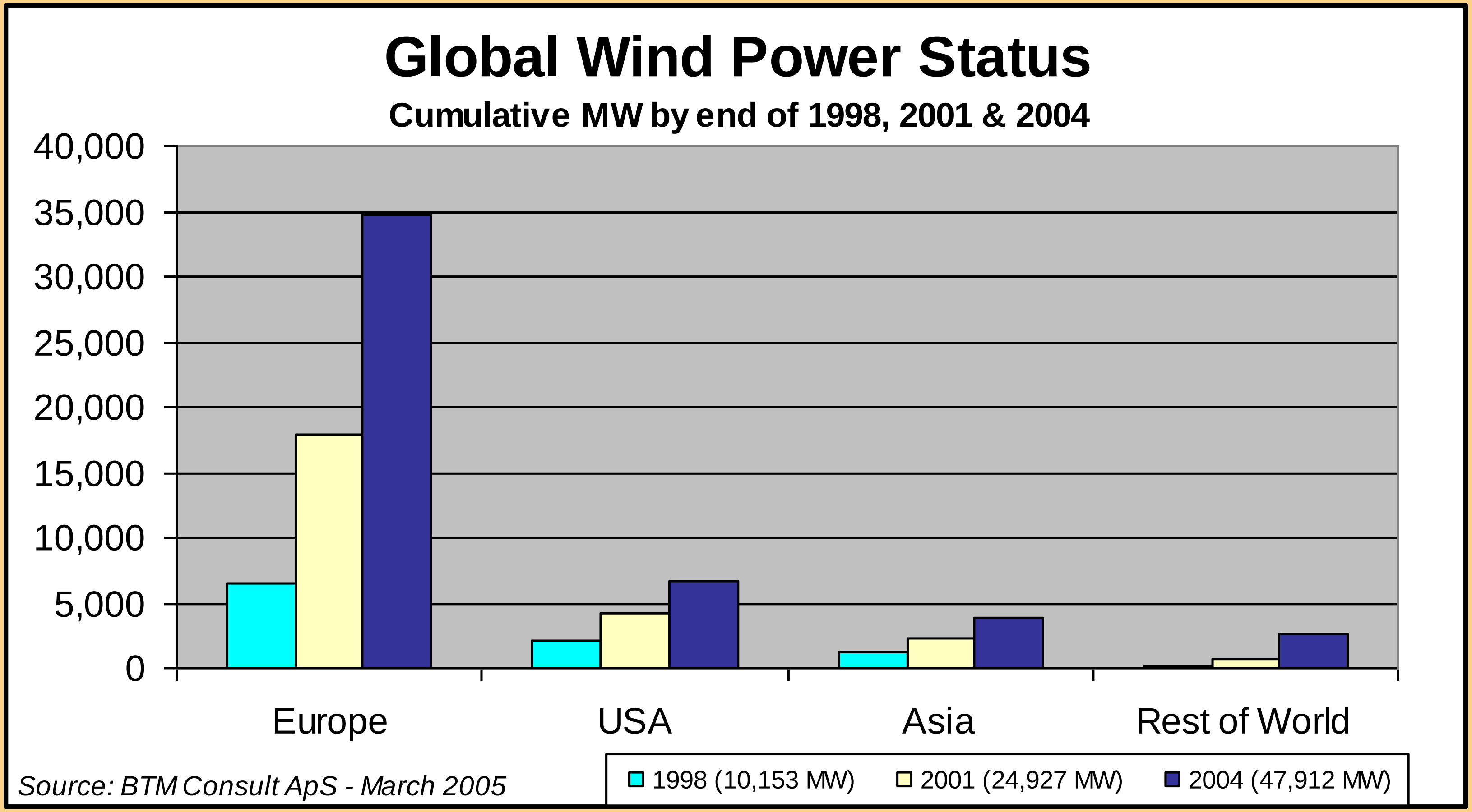
Year	China	Denmark	Germany	India	Spain	Sweden	UK	USA
2000	600	931	1,101	401	648	802	795	686
2001	681	850	1,281	441	721	1,000	941	908
2002	709	1,443	1,397	553	845	1,112	843	893
2003	726	1,988	1,650	729	872	876	1,773	1,374
2004	*771*	*2,225*	*1,715*	*767*	*1,123*	*1,336*	*1,695*	*1,309*

Source: BTM Consult ApS - March 2005

World Market Update 2004



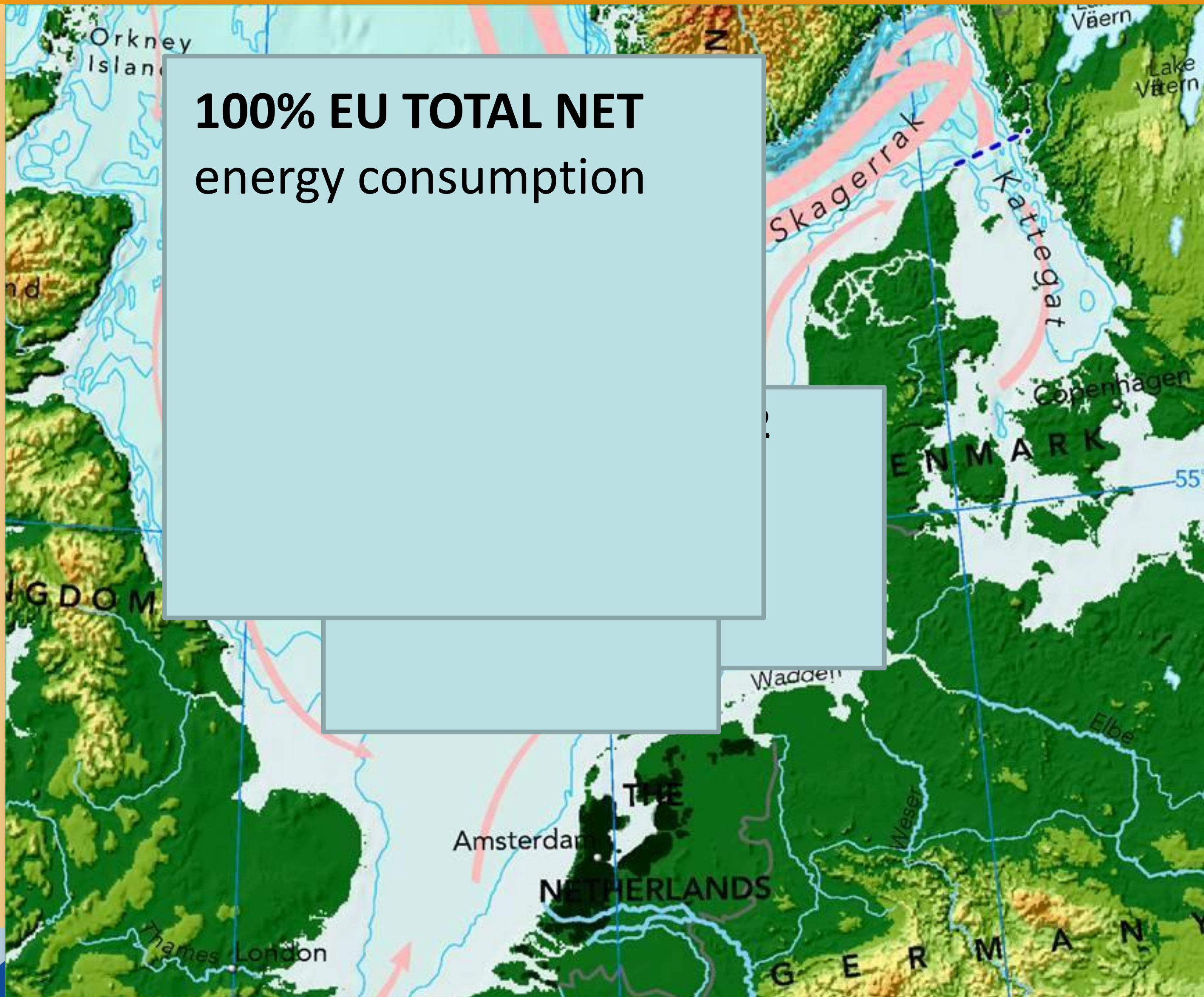
March 2005


Global Wind Power Status
Cumulative MW by end of 1998, 2001 & 2004
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Europe
USA
Asia
Rest of World
Source: BTM Consult ApS - March 2005
1998 (10,153 MW)
2001 (24,927 MW)
2004 (47,912 MW)

Technology development 1973 did start with competition between concepts

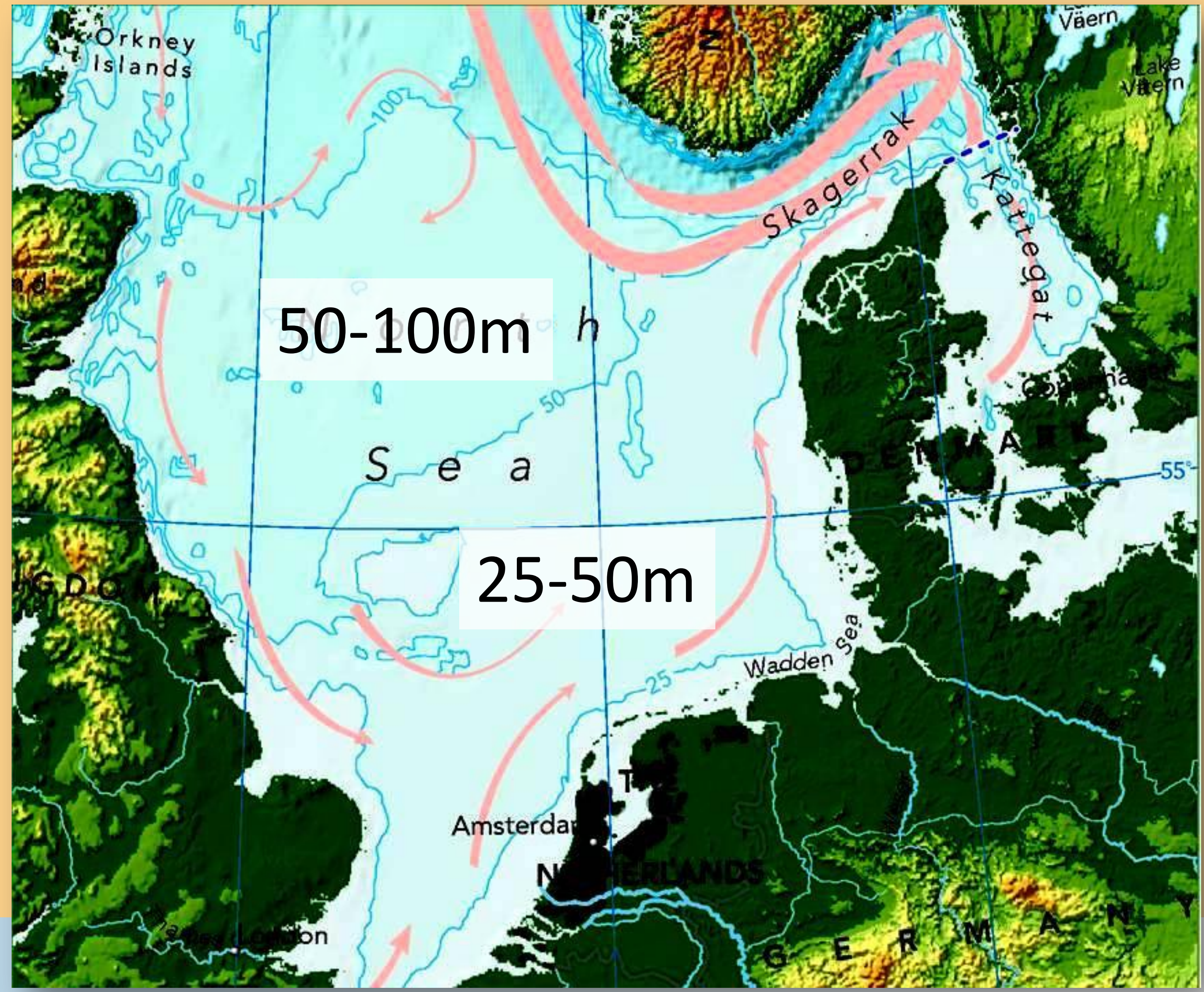
A temporary winner around 1990

100 % of EU total energy consumption EU2020



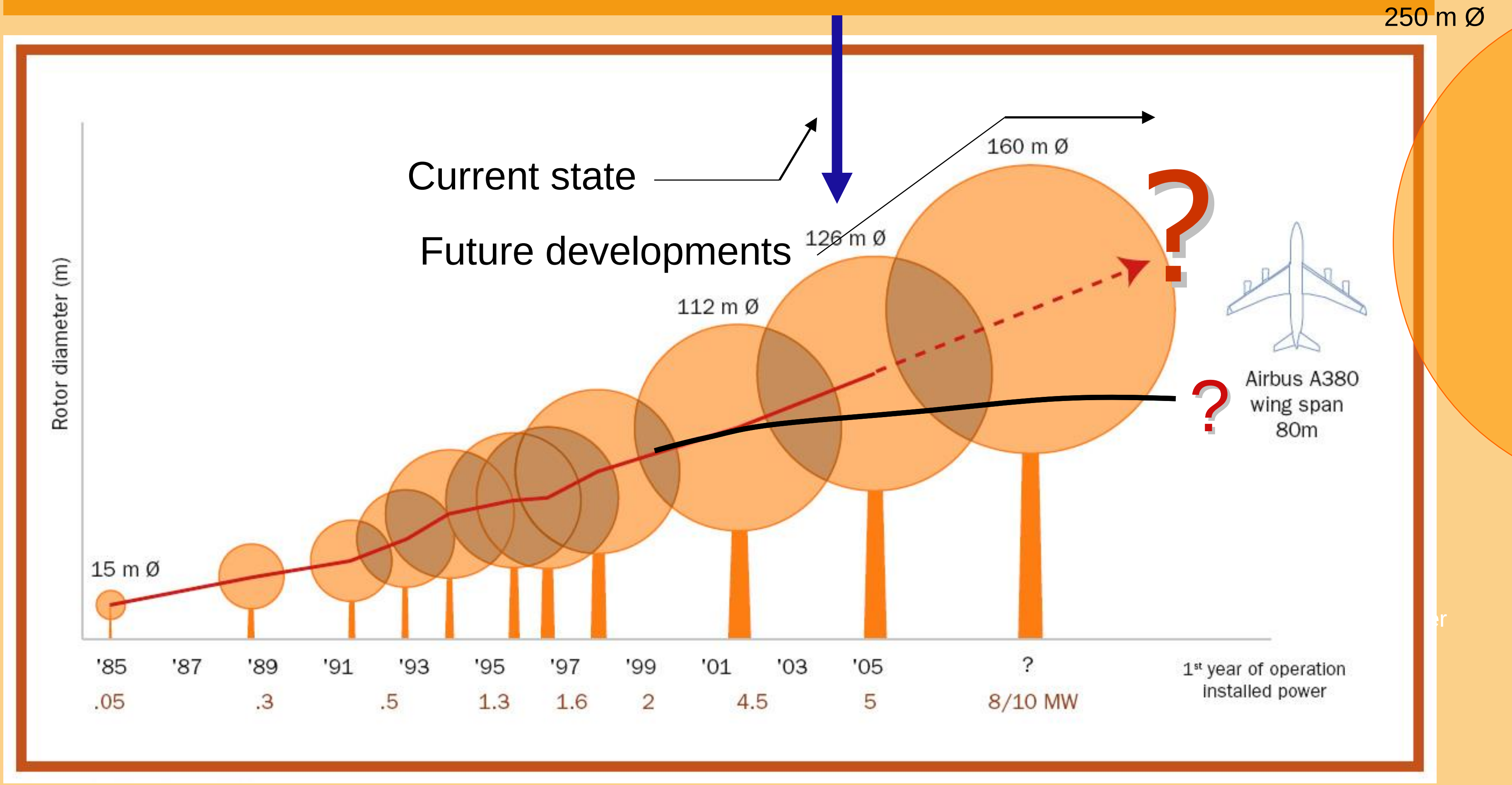
100% EU TOTAL NET
energy consumption

How deep is the NorthSee?



Super-grid in the North See

How Large can you make WTs?



The UpWind Project

- *FP6 Integrated project*
- UpWind got Wind Energy back in the EU 6 Framework Energy Research program (EWEA very weak as a lobby organization)
- ***Result of EWEA Thematic Network(EU-project):***
  1. EWEA Research Strategy
  2. UpWind
  3. EWEA Strategic Research Agenda
  4. Technology Platform
- **Behind UpWind application were EAWE, EWEA and the partners (December 08 2004)**
- **Last minute saving of Research Network in EU – one chance**
- **UpWind the glue/network and Lighthouse for EU R&D**

The UpWind Project

UpWind subtitle: Integrated Wind Turbine Design

- Start date: 1 March 2006
- Duration: 60 months
- Costs: 22,340,000 EUR
- EC funding: 14,288,000 EUR
- Coordinator Risø National Laboratory, The Technical University of Denmark DTU

Participants from Start

39 participants

- 11 EU countries
- 10 research institutes
- 11 universities
- 7 turbine & component manufacturers
- 6 consultants & suppliers
- 2 wind farm developers
- 2 standardization bureaus
- 1 branch organisation

The UpWind Project

- ***39 partners in UpWind Consortium from start***
- Cener added (+1)
- Risø and DTU merged to DTU and RisøDTU (-1)
- Elsam sold to Dong Energy and Wattenfall (+1)
- INCO call added 3 new partners (+3):
  - ISM: Institute for Superhard Materials of the Nat. Academy of Science, Ukraine
  - IITB: Department of Civil Engineering of the Indian Inst. of Technology Bombay
  - CUMTB: China University of Mining and Technology Beijing
- **43 partners in UpWind Consortium**
- **Informal partner: NREL USA**

Objective - 1

Develop and verify substantially improved design models and verification methods for traditional 3 bladed wind turbine components, industry needs for future design and manufacture of:

1 Very Large Wind Turbines

2 More Cost Efficient Wind Turbines

3 Offshore wind farms of several hundred MW

Objective - 2

- Consortium **integrates the disciplines and sectors needed** for the entire development chain of wind turbine technology
- 8 Scientific Work Packages – work programme
- 7 Integration Work Packages – work programme

Upscaling

- Today (2004): WT up to P = 5 MW and D = 120 m
- Future: WT upscaling: P = 10 MW and P = 20 MW
- Develop methods to overcome showstoppers/optimize

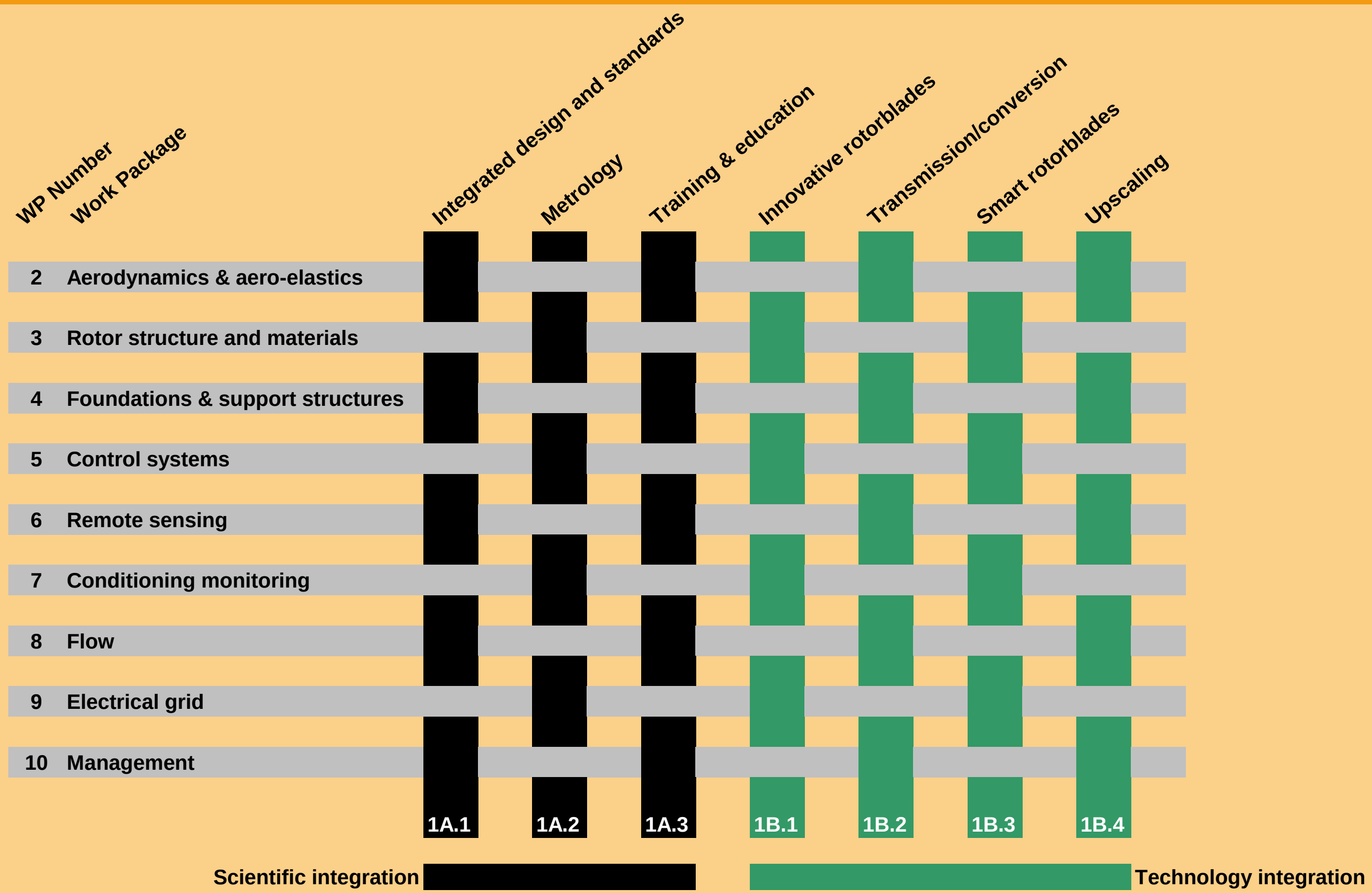
Overall results answering the fundamental question?

Is a 20 MW wind turbine possible to build and is it feasible?

UpWind develop cost functions for offshore wind turbines over project

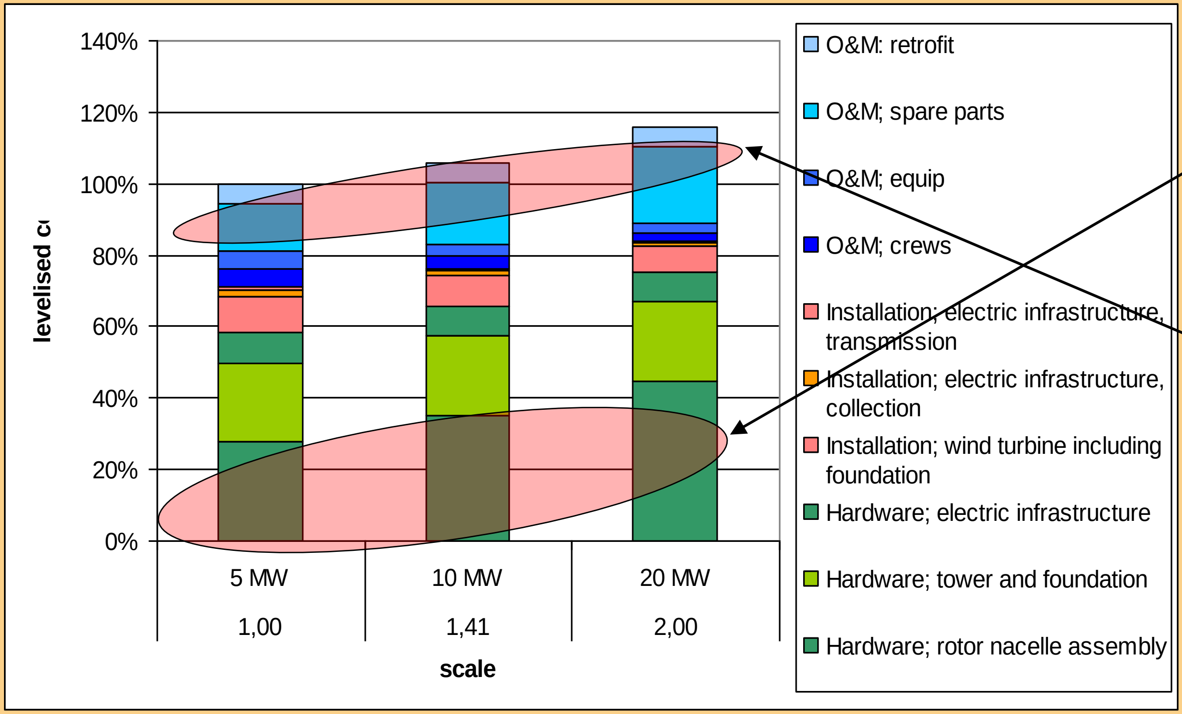
- Rotor (blades, hub)
- Drivetrain (main shaft, gear, generator, converter etc.)
- Nacelle (bed plate, yawing system etc.)
- Tower and foundation
- Grid connection system
- Control and sensor systems
- Condition monitoring system

Organisation
Classic and integrated research approach
Advanced Flexibel Modern Organisation



Overall result from cost functions

Up scaling – levelised cost



Levelised cost *increases* with scale

Reasons:

- Rotor and nacelle costs scale ~s^3 (?)
- Spare parts costs follow

Cost of energy over lifetime increase more than 20 % for increasing the Wind Turbine size from 5 to 20 MW so the power law for the rotor

Economical viability of 20MW W/Ts

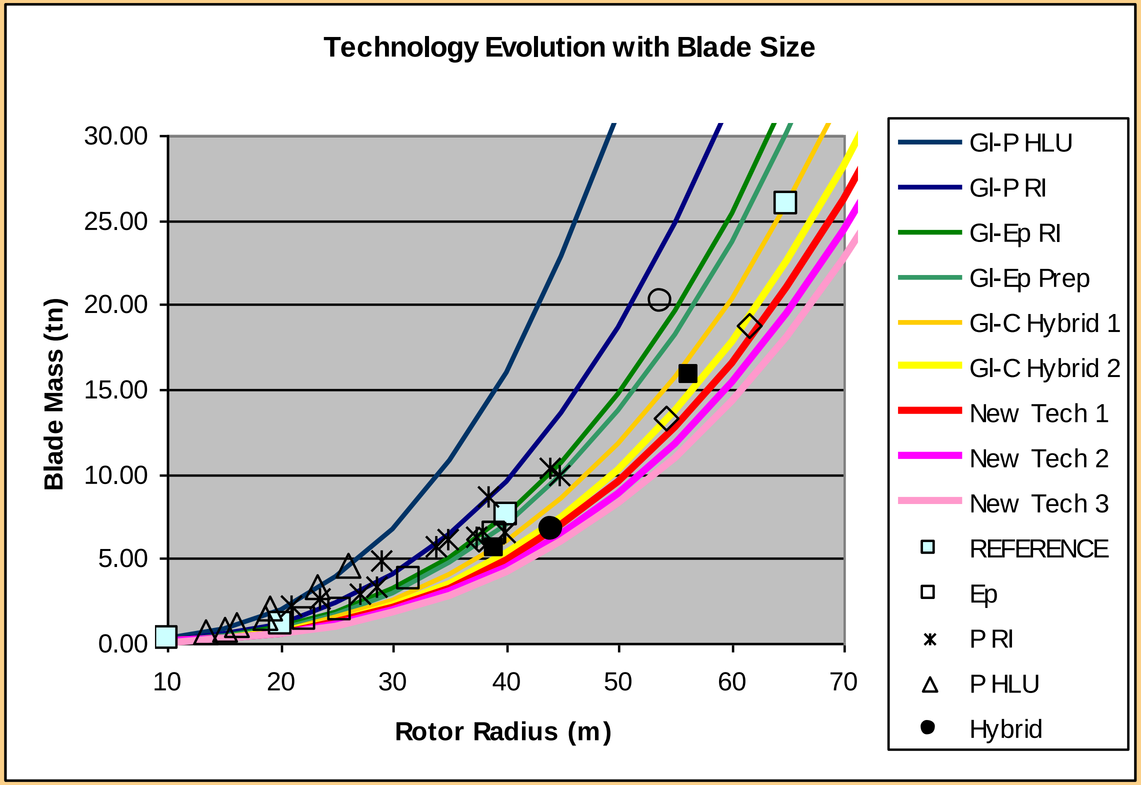
Case study: Blades

		PAST						FUTURE		
		GI-P HLU	GI-P RI	GI-Ep RI	GI-Ep Prep	GI-C Hybrid 1	GI-C Hybrid 2	New Tech 1	New Tech 2	New Tech 3
	Single Step r(t)/r(t-1)	1,00	0,59	0,79	0,93	0,86	0,87	0,93	0,93	0,93
	Cummulative r(t)	1,00	0,59	0,47	0,44	0,38	0,33	0,31	0,28	0,26
	Single Step a(t)/a(t-1)	1,00	1,08	1,08	1,10	1,10	1,00	1,03	1,03	1,03
	Cummulative a(t)/a(t0)	1,00	1,08	1,17	1,28	1,41	1,41	1,45	1,50	1,54
WT Power (MW)	Rotor Radius (m)	Mass (tn)	Mass (tn)	Mass (tn)	Mass (tn)	Mass (tn)	Mass (tn)	Mass (tn)	Mass (tn)	Mass (tn)
0,125	10	0,25	0,15	0,12	0,11	0,09	0,08	0,08	0,07	0,07
0,281	15	0,85	0,50	0,40	0,37	0,32	0,28	0,26	0,24	0,22
0,500	20	2,00	1,19	0,94	0,88	0,76	0,66	0,61	0,57	0,53
0,781	25	3,91	2,33	1,84	1,71	1,48	1,28	1,19	1,11	1,03
1,125	30	6,76	4,02	3,17	2,96	2,55	2,22	2,06	1,92	1,78
1,531	35	10,74	6,39	5,04	4,70	4,05	3,52	3,28	3,05	2,83
2,000	**40**	**16,02**	**9,53**	**7,52**	**7,01**	**6,04**	**5,26**	4,89	4,55	4,23
2,531	**45**	**22,82**	**13,57**	**10,71**	**9,99**	**8,60**	**7,49**	6,96	6,48	6,02
3,125	**50**	**31,30**	**18,62**	**14,70**	**13,70**	**11,80**	**10,27**	9,55	8,88	8,26
3,781	**55**	**41,66**	**24,78**	**19,56**	**18,23**	**15,71**	**13,67**	12,71	11,82	11,00
4,500	**60**	**54,08**	**32,17**	**25,40**	**23,67**	**20,39**	**17,75**	16,51	15,35	14,28
5,281	**65**	**68,76**	**40,90**	**32,29**	**30,09**	**25,93**	**22,57**	20,99	19,52	18,15
6,125	70		51,09	40,33	37,58	32,38	28,19	26,21	24,38	22,67
7,031	75		62,84	49,60	46,23	39,83	34,67	32,24	29,98	27,89
8,000	80		76,26	60,20	56,10	48,34	42,07	39,13	36,39	33,84
9,031	85			72,20	67,29	57,98	50,47	46,93	43,65	40,59
10,125	90				79,88	68,82	59,91	55,71	51,81	48,19
11,281	95				93,95	80,94	70,45	65,52	60,94	56,67
12,500	100					94,40	82,18	76,42	71,07	66,10
13,781	105					109,29	95,13	88,47	82,28	76,52
15,125	110					125,65	109,38	101,72	94,60	87,98
16,531	115						124,98	116,23	108,09	100,53
18,000	120						142,00	132,06	122,81	114,22
19,531	125						160,50	149,26	138,81	129,10
21,125	130						180,54	167,90	156,15	145,22

Overall results:

Case study: Blades – technology evolution with size

Innovations drive cost down in the past



Upscaling of offshore wind turbines

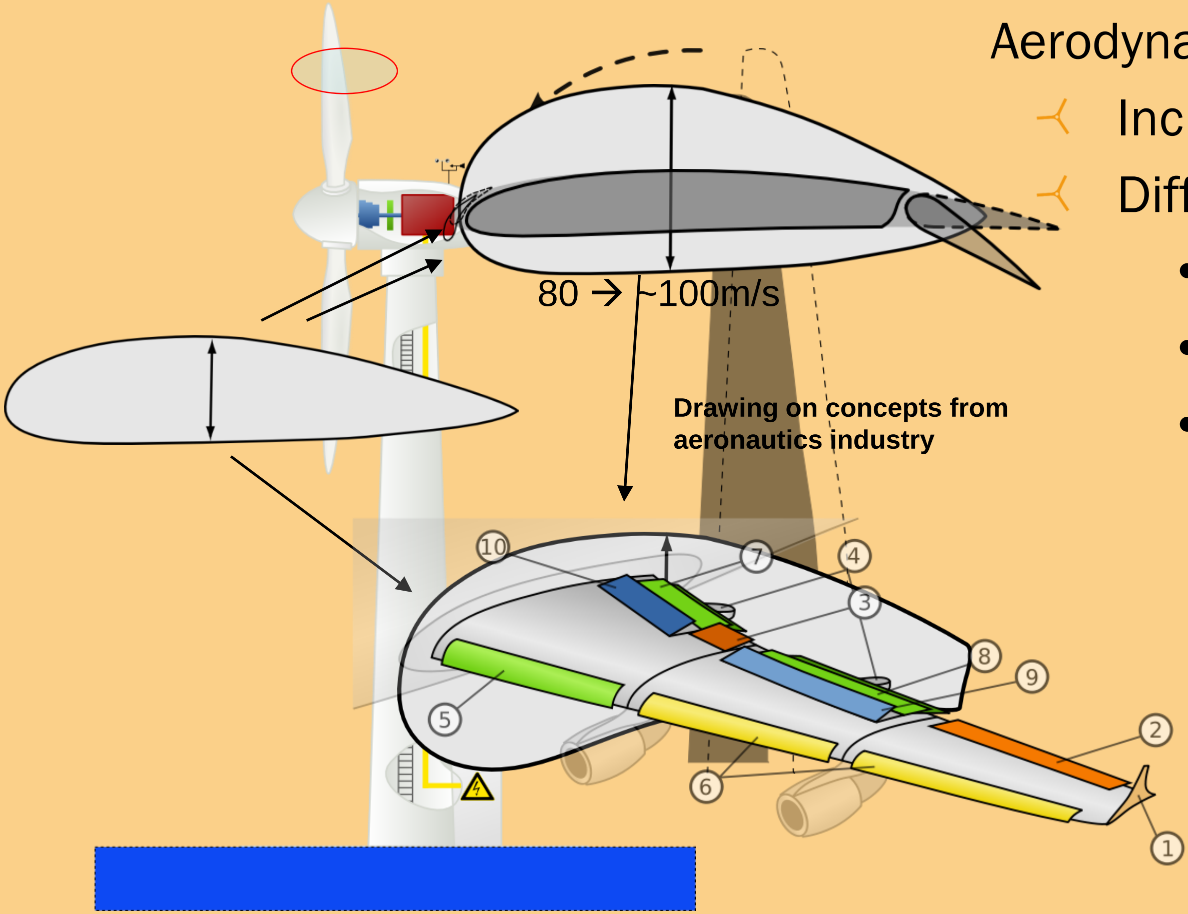
In the project there were focus on development of new innovations, new design methods and cost functions for main components:

- Blades
- Drivetrain
- Tower and foundation
- Grid connection system
- Control and sensor systems
- Condition monitoring system

Larger turbines can make new technologies feasible eg. Lidar measurents to be used in the control of turbines

Improvements in Wind Turbine Design

Rotor



Aerodynamic design

- Increased tip speed
- Different blade shapes
    - Thicker sections
    - Blunt TE sections
    - Multi-element airfoils

Large Wind Turbines in the future

- The details of the future design may be uncertain
- However it is obvious that…
  - Up scaling existing designs will *not* be enough
  - Integrated design for large scale should be pursued
  - New ideas and technological breakthroughs will be necessary to make very large wind turbines economically attractive
- It is certain therefore that **substantial R&D and industrial effort is still needed** to conquer all technical barriers!

Feasibility of 20MW wind turbines

The answers from available technical expertise and UPWIND project experience:

- Manufacturing *is* possible
- Transportation and installation *are* possible

BUT…

- …this does not mean that a 20MW version of a current state-of-the-art 5MW W/T will offer any cost/performance advantages

Presentation of some of the results from the working groups

Integration – and priorities

1.A.1 Integrated design and standards

- *Development of integral design approach methodology*
- *Development of (pre)standards for application of the integral design approach*
- *Coordinate and support pre-standardisation work*
- Develop cost models for application in other WP for comparisons and for demonstration of potentials and benefits of design developments
- Evaluate pros and cons of different design options by calculation of cost of energy
- Define the technological bottlenecks for successful up-scaling of wind turbines to **20MW**

1A2 Metrology

- The scale of UpWind made it possible to make a metrology work package covering very broad
- Identify the relevant measurands, the needed accuracies, influence parameters, traceability, accuracy and technically achievable accuracy (**D1A2.1**)
- For each identified problem in the list, different ways-out are proposed (**D1A2.2**)
- Successful measurement protocols for solution methods are described and demonstrated and will serve as recommended future testing methods. (**D1A2.3**)

1.A.3 Education and training

- Development of a number of **training modules** for international “new” courses in the field of WE and of the necessary supporting education/training materials.
- *(in other words)* Provision of the necessary infrastructure for the specialized training of:
- ✓ researchers, post-graduate students → PhD level,
- ✓ industrial engineers (working in SMEs), energy planners, project developers, consultants.. → CPD units,
- on the state-of-art knowledge and expertise produced lately in all Wind Power related topics,
- especially on the results/outputs of the other WPs of the UpWind project.

WP1B1 Innovative Rotor Blade: Segmented blade

- Task WP1B1.1 Aerodynamic Design and Loads Calculation
- Task WP1B1.2 Materials Selection, Structural Design and Structural Verification
- Task WP1B1.3 Sensors and Monitoring Technologies
- Task WP1B1.4 Blade Joints Design
- Task WP1B1.5 Sub-component Testing
- Task WP1B1.6 Manufacturing and Assembly Processes
- Task WP1B1.7 Specimen Prototypes Manufacturing
- Task WP1B1.8 Specimen Testing
- Elements to build the blade were developed and Gamesa has now a segmented blade

WP1B1 Innovative Rotor Blade: Work Package Task #4 (in progress)

TASK WP1B1.4 BLADE JOINTS DESIGN

PARTICIPANTS: GAMESA

DEFINITION OF MODULAR BLADE JOINTS DESIGN REQUIREMENTS:

1- Functional Requirements
- Loads
- Aerodynamic Requirements
- Structural Integrity
- Mass and Stiffness Distribution Limits
- Dynamic Requirements
- Weight

2- Material Requirements

3- Supportability Requirements
- Assembly on Site & Interchangeability
- Reliability
- Mainteinability
- Fail Safe

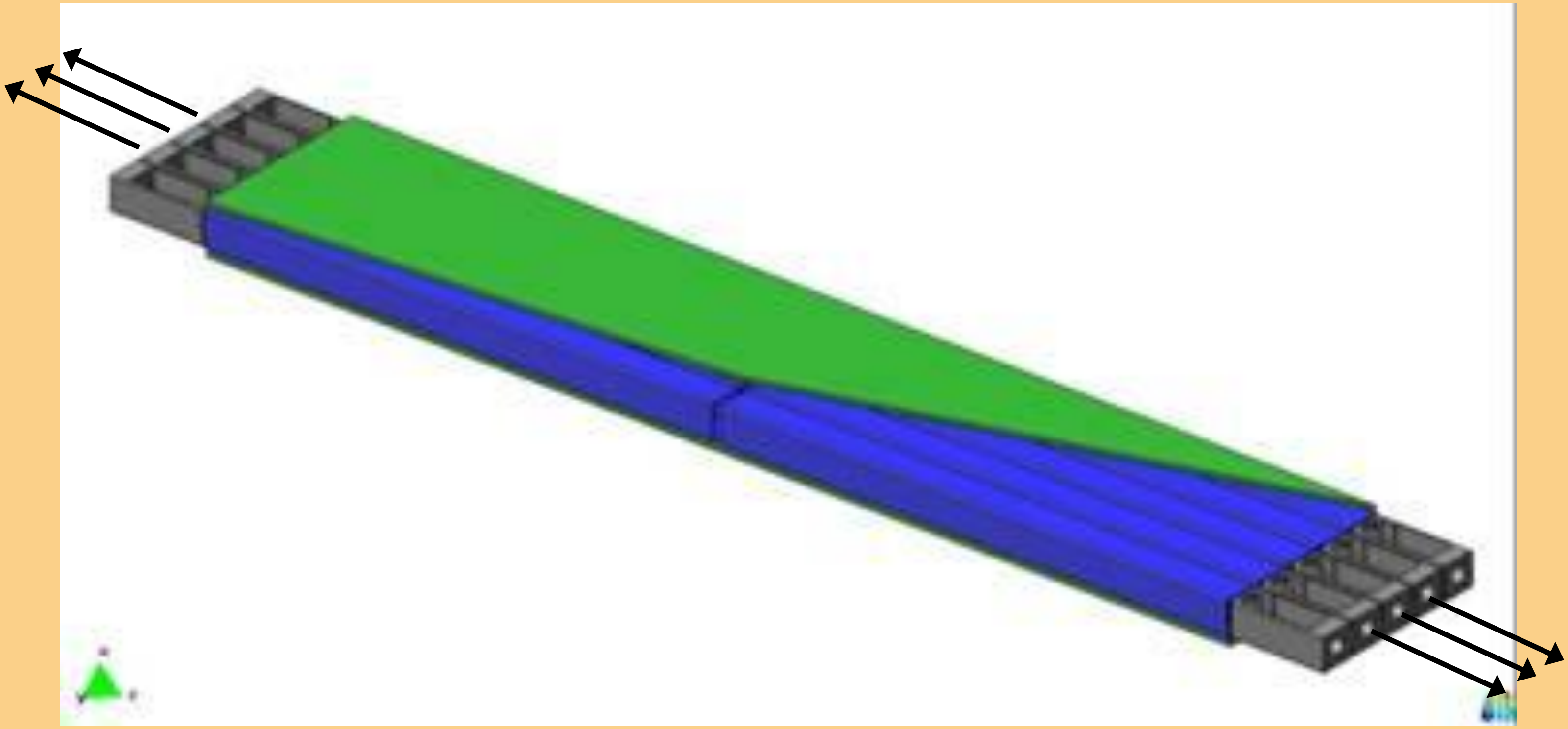
4- Validation and Certification

5- Secondary Systems
- Drainage System
- Lightning System

6- Manufacturing
- Assembly in Factory
- Tolerance
- Toolings
- Materials

Subcomponent Tests

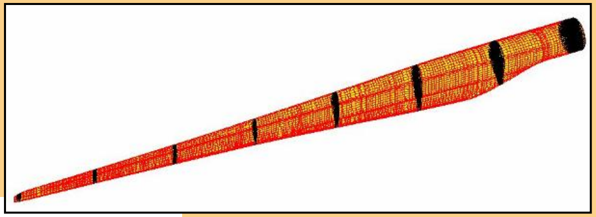
Test #3: Adhesive Joint Test at WMC

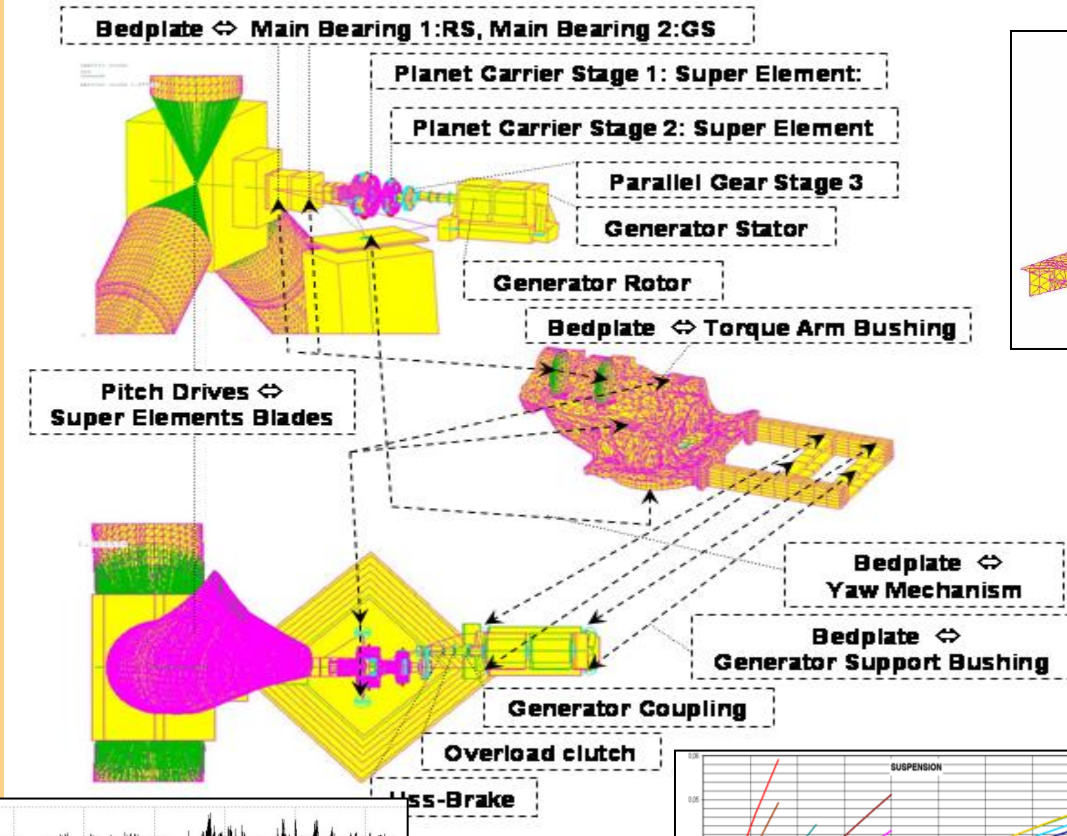


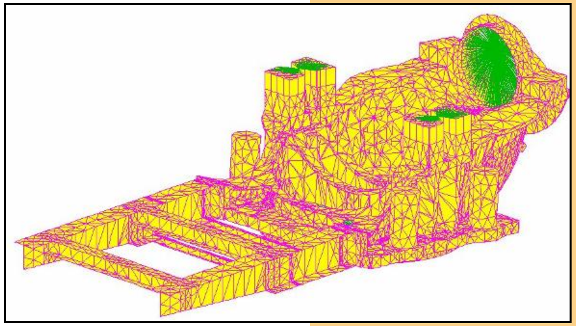
1B2 Transmission and conversion

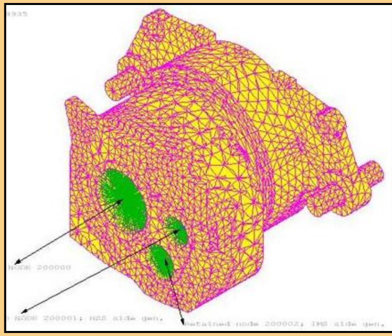
- WP 1B2.a – “**Mechanical Transmission**”
- WP 1B2.b – “**Generators**”
- WP 1B2.c – “**Power Electronics**”

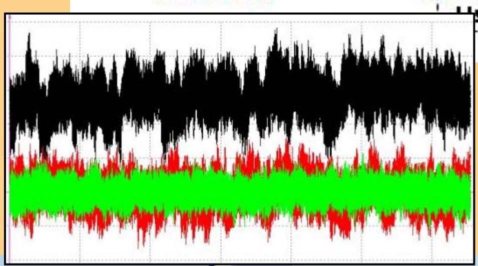
Mechanical Transmission Modeling example

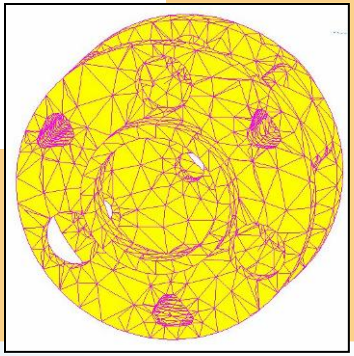


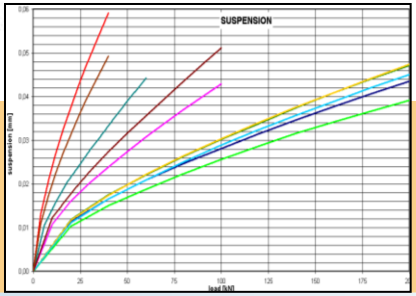












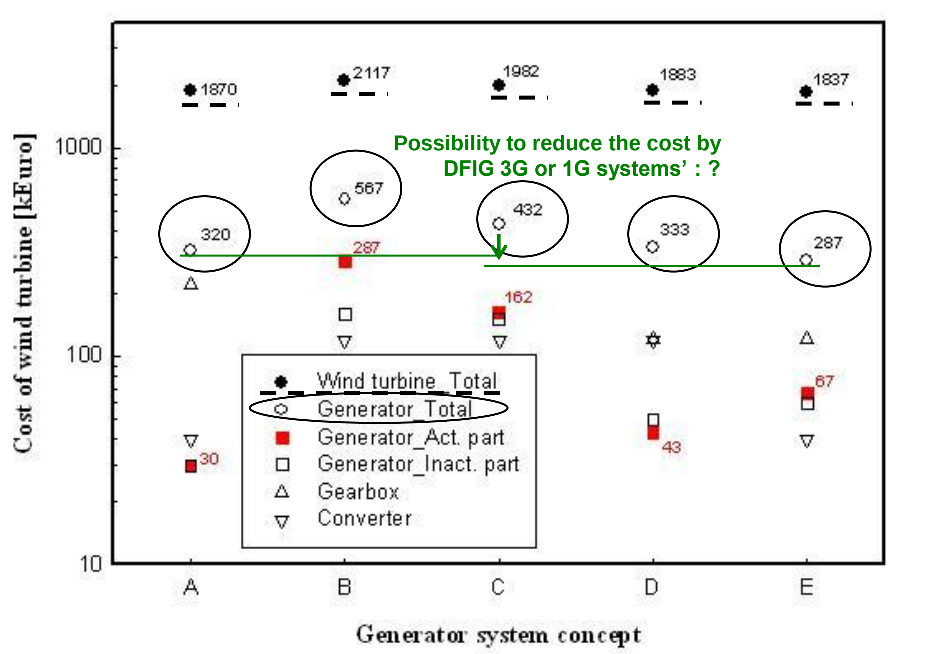
http://www.samcef.com

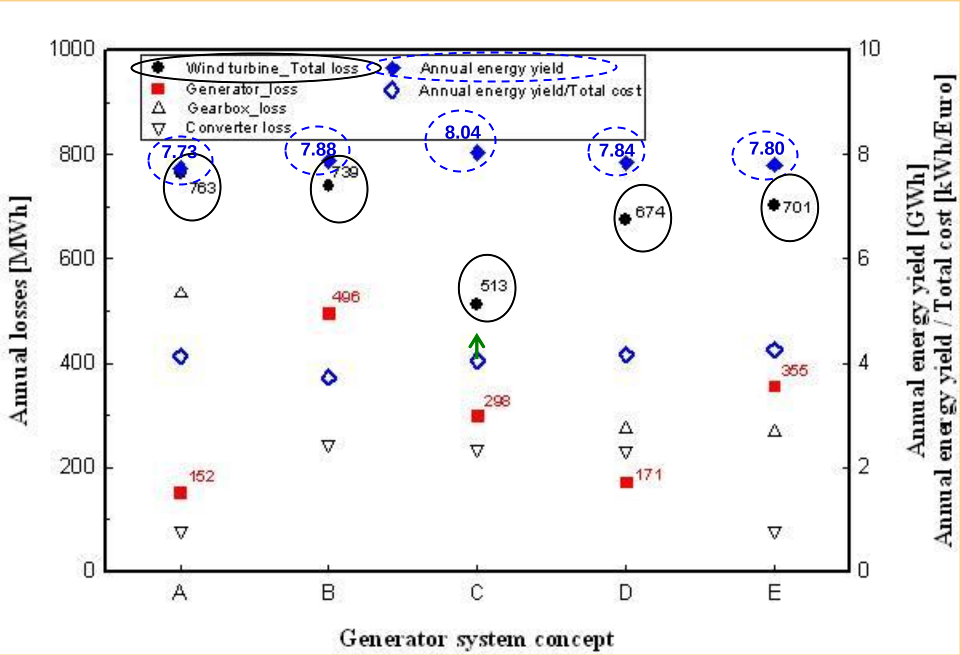
SIXTH FRAMEWORK PROGRAMME

UpWind

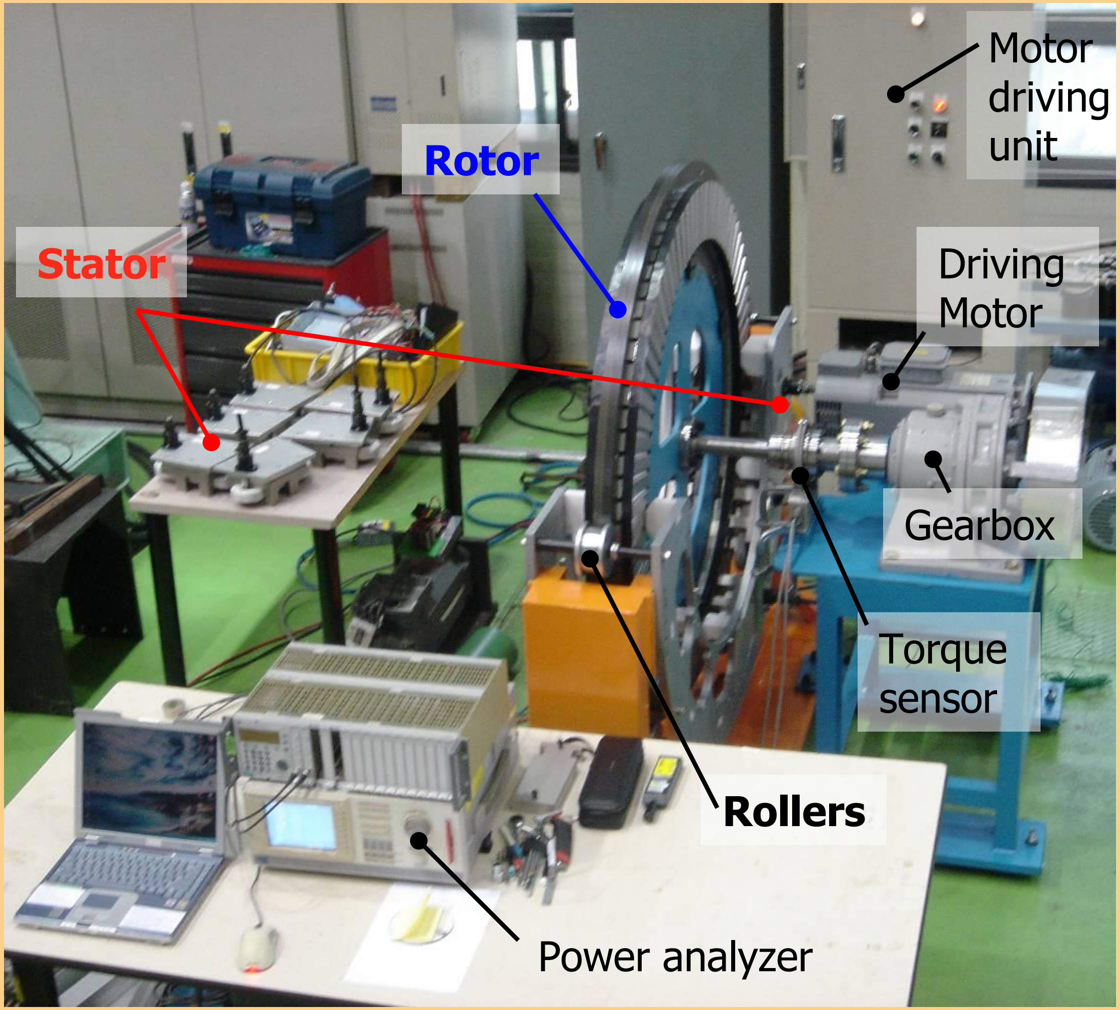
Comparison of different generator systems

- 3MW wind turbine with the direct-drive and geared-drive -





C. Experimental set-up



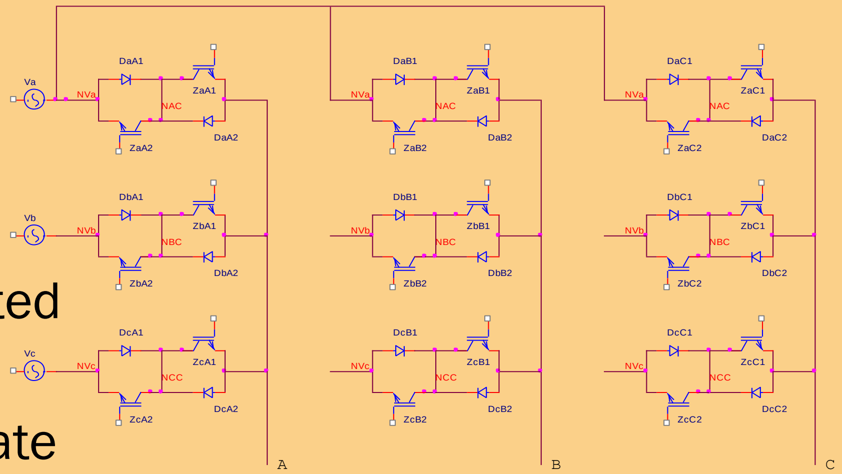
Driving motor	3ph AC machine - P_n: 14.3 kW - N_n: 2600 rpm - T_n: 52.7 Nm
Pulley & Belt	- D_{Pulley_1}=6 in - D_{Pulley_2}=12 in
Gearbox	43:1 gear ratio
Generator diameter	Do=1.3m, Di=1m
Air gap	4 mm (2 & 6 mm)

.

Task 1B.2.c_1: Benchmark and concept reports on devices and converters.

Analysis of Matrix Converters

- "**all silicon**" AC/AC converter
- **without DC-link**
- formed by n x m **bidirectional switches**
- **any** of the **outputs** can be connected to **any input** phase.
- bidirectional topology, it can operate in **four quadrants**

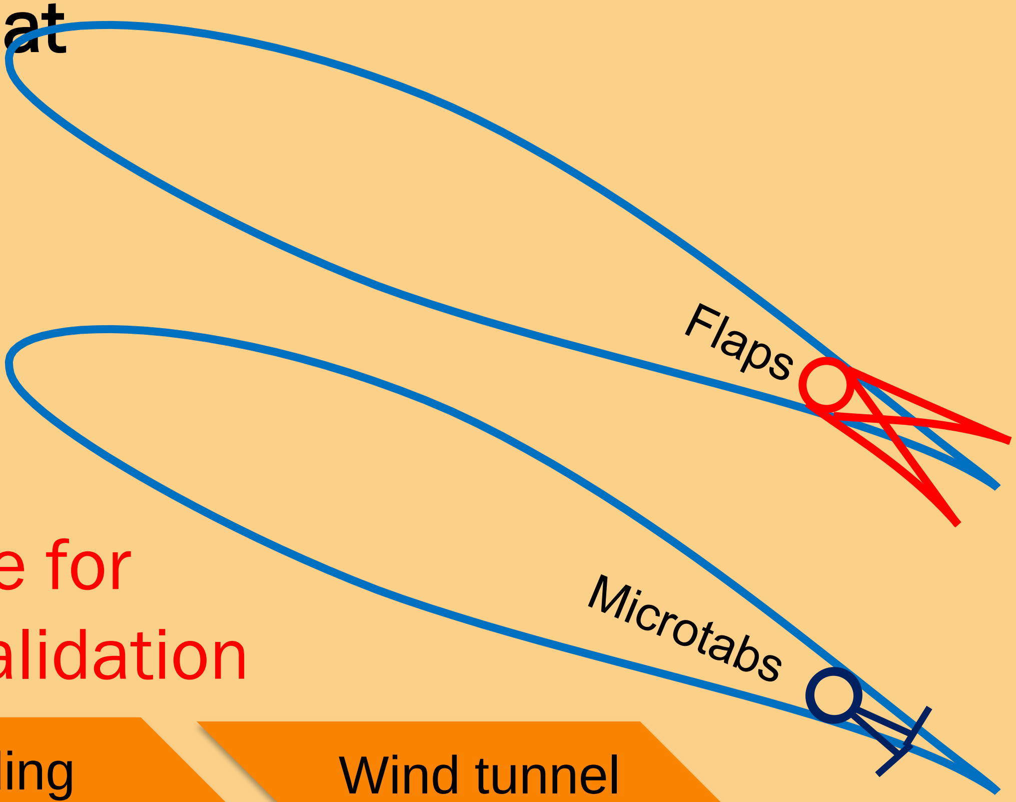


Structure of a three-phase matrix converter

1.B.3 Smart Rotor blades Aerodynamic devices

Test of several actuators at same flow conditions in LM wind tunnel:

- Model: DU-96W180
- Flap
- Microtabs
- Provide loads data base for aerodynamics model validation



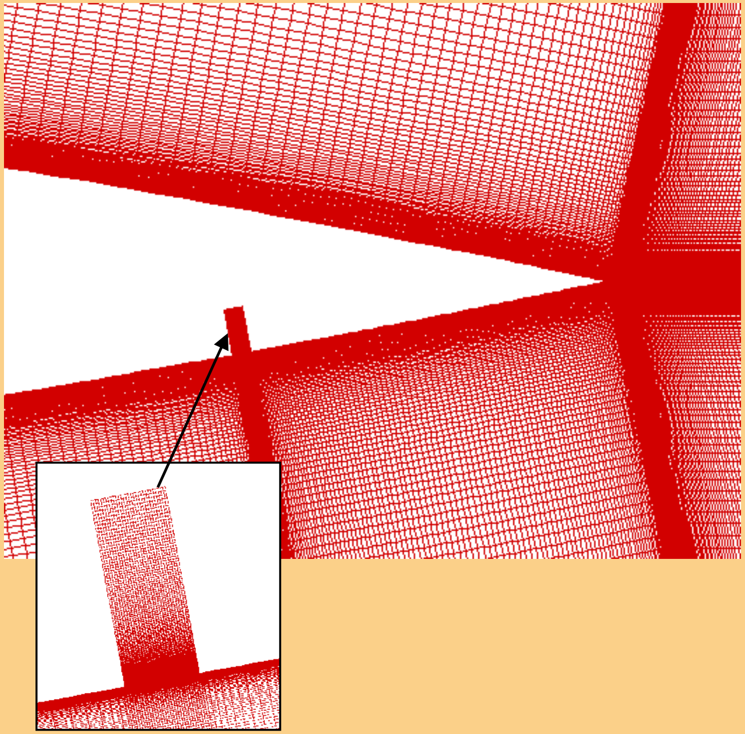
Setup definition (Apr 2010) → Building setup (Aug 2010) → Wind tunnel experiments (Oct 2010)

Aerodynamics of devices

Synthetic Jets: Numerical Method

Activities:

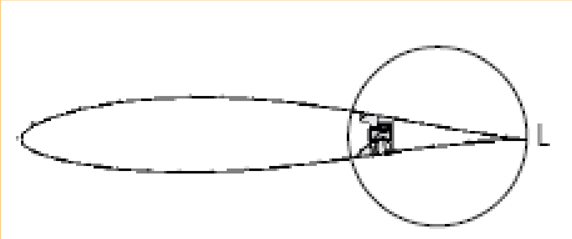
- Investigating best ways to simulate synthetic jet actuation.
- Incorporation of slot in combination with BC at bottom of slot allows jet to develop and gives better physical representation of flow near orifice compared to case without slot.
- Requires less computational time

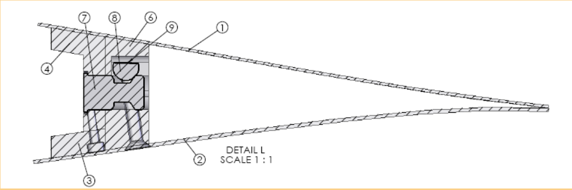


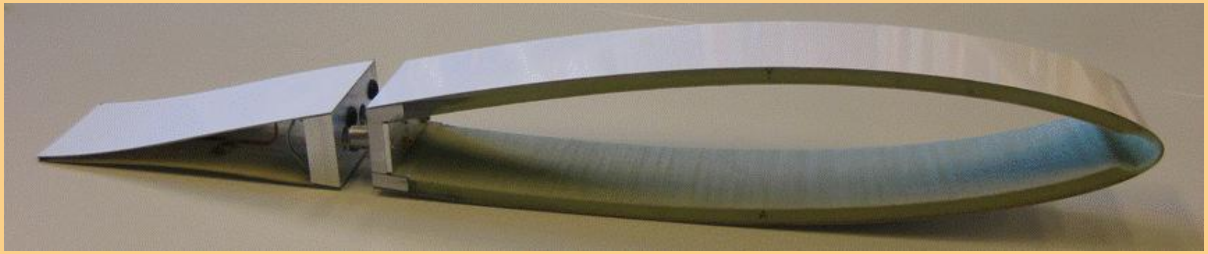
Actuator development

Modular, composite flap

1) Utilization of R-phase transformation
   - Small hysteresis
   - High forces
   - Fatigue resist
2) Self adaptive concepts based on super-elasticity
   - Passive solutions
   - Robust design







Summary

Wide range of activities:

- Topics: Aerodynamics, control, structures&materials
- Levels: Experimental, modelling, feasibility studies, design

Results:

Load control concepts:

- Proven ~50% reduction of signal standard deviation on a scaled rotor
- Cust load alleviation through 'smart' interfaces
- Bent-twist coupling: after the potential of coupling, now the potential of *achieving* coupling at different stages

WP 2 Aerodynamics and Aeroelastics,

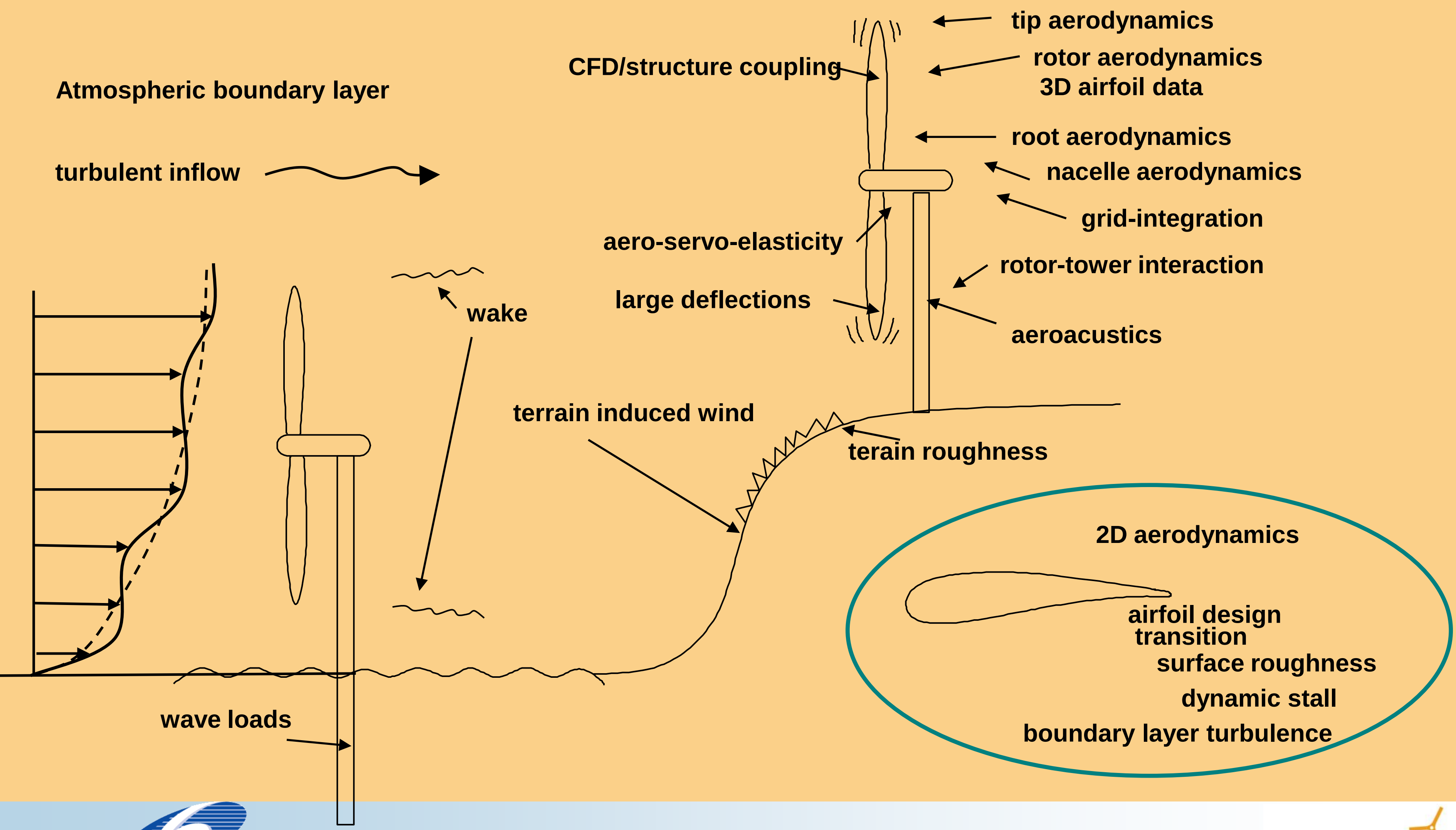
The overall objective is:

- to develop an aerodynamic and aeroelastic design basis for large multi MW turbines.
- to facilitate development and design of multi MW turbines, including possible new and innovative concepts.

WP2 Aero-dynamics and Aero-elastics OBJECTIVES (specific)

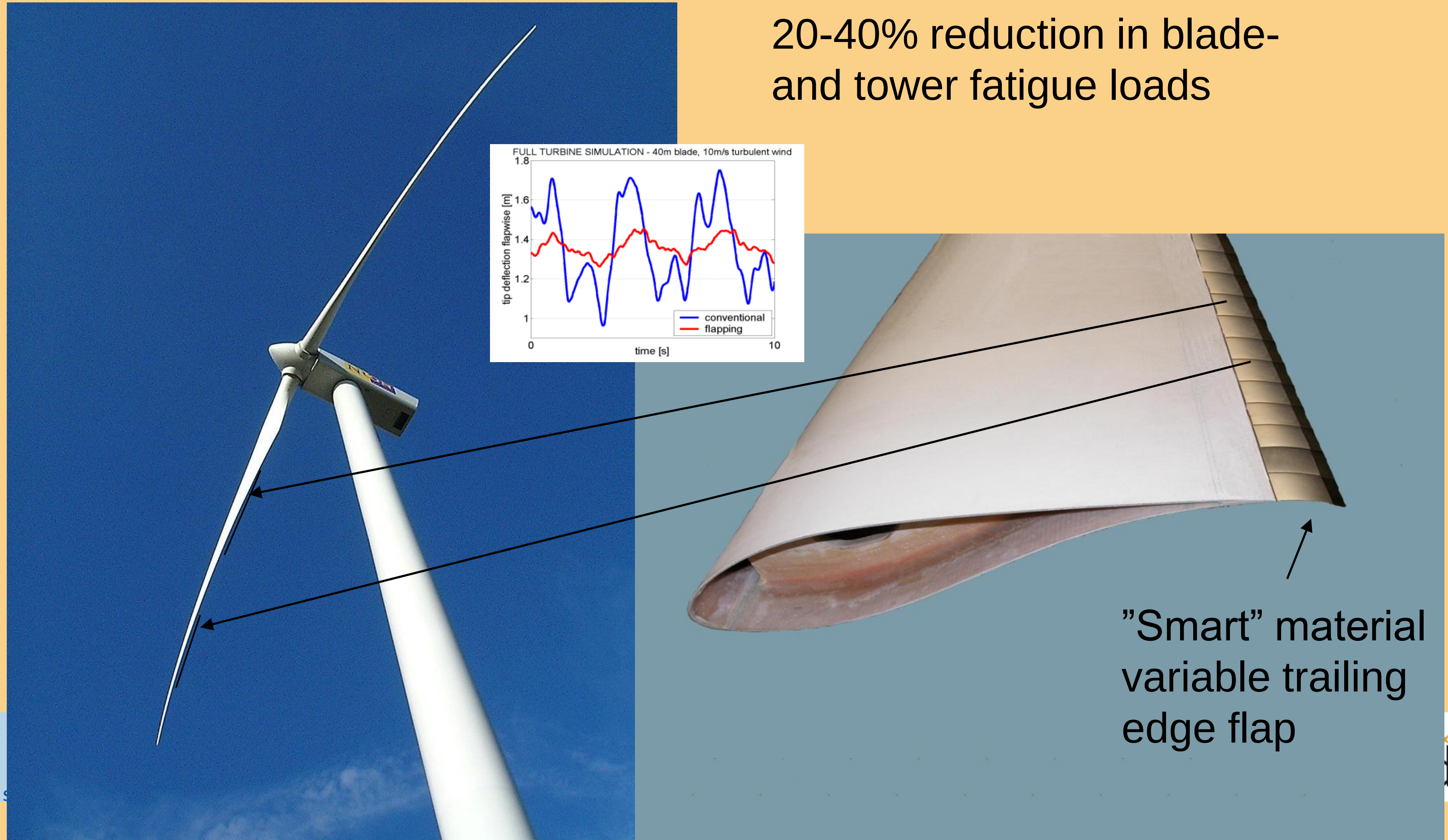
1. Development of **nonlinear structural dynamic** models (modeling on the micromechanical scale is input from WP3).
2. **Advanced aerodynamic models** covering full 3D CFD rotor models, free wake models and improved BEM type models. (The wake description is a prerequisite for the wake modeling in WP8).
3. Models for **aerodynamic control features and devices.** (This represents the theoretical background for the smart rotor blades development in WP 1.B.3)
4. Models for analysis of **aeroelastic stability** and total **damping** including **hydroelastic interaction**
5. Development of models for computation of **aerodynamic noise.**

Aeroelastic interaction

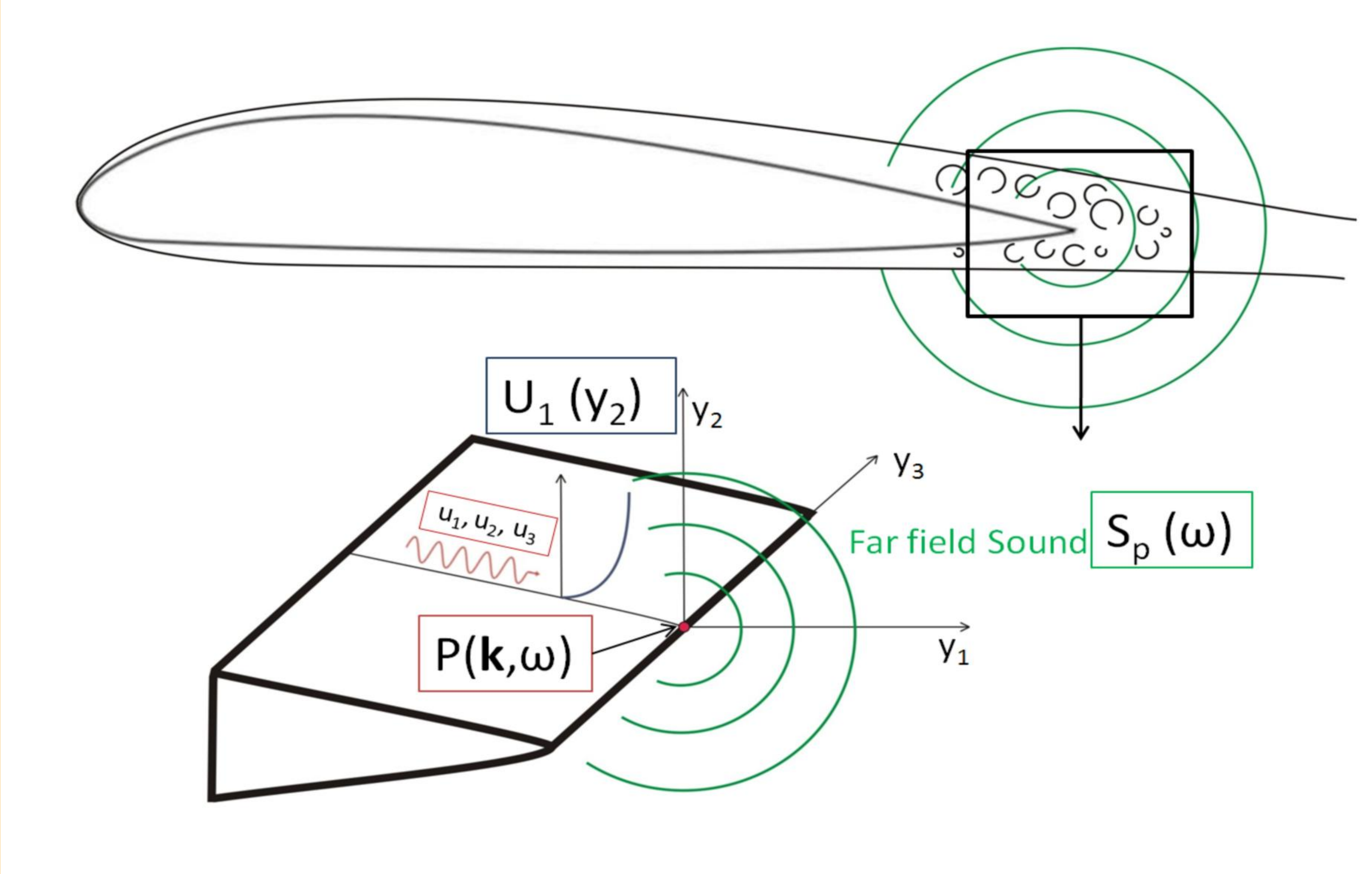


Task 3: Distributed aerodynamic control

20-40% reduction in blade- and tower fatigue loads



Trailing-edge Noise Mechanism



WP 3: Rotor Structure and Materials

WP 3 is subdivided into four Tasks:

- Task 3.1: Applied (phenomenological) material model (WMC) (based on experiments)
- Task 3.2: Micro-mechanics based material model (RISØ) (based on fibre modelling)
- Task 3.3: Damage tolerant design concept (UP) (Based on FEM with properties damaged materials)
- Task 3.4: Up-scaling and Cost Factors (CRES). (Based on question from WP 1A1 and 1B4)

Deliverables: Task 3.1

Del. [1] No.	Deliverable name and description	Recieving WP	Lead participant	Estimated indicative person month	Nature [2]	Disse-mination level [3]	Due Del date (proj. Month)	Realized del. Date
D3.1.1	Updated OPTIDAT material database, containing more material aspects and interactions as a basis for material models	WP1A.3 WP3	WMC (5)	4	O	RE	12	13
D3.1.2	General LCA material properties in OPTIDAT, coupled to design package for LCA of rotor blade	WP1A.3 WP3	WMC (5)	3	R	RE	18	18
D3.1.3	Updated design recommendations and procedures for qualification tests of materials	WP1A1, 1A3, 1B1, 1B3, 1B4	WMC (5)		R	RE	58 was 54	
D3.1.4	Guidelines for stress analysis of structural blade detail	WP1A1, 1A3, 1B1, 1B3, 1B4	WMC (5)		R	RE	58 was 54	
D3.1.5	Updated OPTIDAT material database, including alternative materials and subcomponent data	WP1A.3, WP3	WMC (5)	14	O	RE	30	30/36/ 42/48
D3.1.6	Report and experiments on performance of optical strain measurements	WP7, WP3	WMC (5)	6	O	RE	31	40
D3.1.7	Randomised NEW WISPER load sequence	WP1A.1, WP3	WMC (5)	5	O	RE	52 was 35	
D3.1.8	Experiments and modelling of influence and interaction of temperature and frequency on fatigue life	WP1A.1, WP3	WMC (5)	15	O	RE	49 was 39	

Deliverables: Task 3.2

D3.2.1	Demonstration and validation of theoretical damage model Report A	WP1A.3 WP3	RISØ (1)	11	R	RE	18	24
	Stiffness degradation model Report B	WP1A3, 1B1, 1B4, WP3	RISØ (1)	3	R	RE	20	24
D3.2.2	Implementation of damage models in existing design models, and comparison with respect to further development and applications for new materials and	WP1A1, 1A3, 1B1, 1B3, 1B4	RISØ (1)		R	RE	54 was 48	
D3.2.3	Validation of models with the results of SEM in situ experimental investigations of damage in composites	WP1A1, 1A3, 1B1, 1B3, 1B4	RISØ (1)		R	RE	58 was 54	
D3.2.4	Development and testing of compressive damage model of polymer FRP subject to cyclic loading, taking into account the random distribution of fibre misalignment in	WP1A.1 , WP3	RISØ (1)	15	R	RE	40	40

Deliverables due until month 42: Task 3.3 and 3.4

D3.3.1	Material model, incorporating loss of strength and stiffness during fatigue. Preliminary results from FE model implementation	WP1A.3 WP3	UP (9)	12	R	RE	18	18
D3.3.2	Verification and comparison of analytical models for probabilistic strength assessment of FRP laminates.	WP1A.3 WP3	CRES (7)	8	R	RE	18	18
D3.3.3	Replaced by D3.1.4							
D3.3.4	Verified material model incorporating progression of damage due to static loading and the effect of fatigue on residual strength and stiffness	WP1A1, 1A3, 1B1, 1B3, 1B4	UP (9)		R	RE	58 was 54	
D3.3.5	Probabilistic strength assessment of rotor blade	WP1A1, 1A3, 1B1, 1B3, 1B4	CRES (7)		R	RE	58 was 54	
D3.3.6	Test results from in-plane mechanical properties for complex stress states	WP1A.3, WP3	UP(9)	6	R	RE	42	
D3.4.1	Detailed plan of action with test plans etc. for the WP	WP10, WP3	ECN (4)	6	R	RE	6	8
D3.4.2	Annual report after 12 months (24,36,48,60)	WP 10, WP 3	ECN (4)	0,2	R	RE	12/24/ 36/48/60	12/24/36/ 48
D3.4.3	Report on scaling limits and costs regarding wind turbine blades	WP1B4	CRES (7)		R	RE		54

Deliverables
INCO part

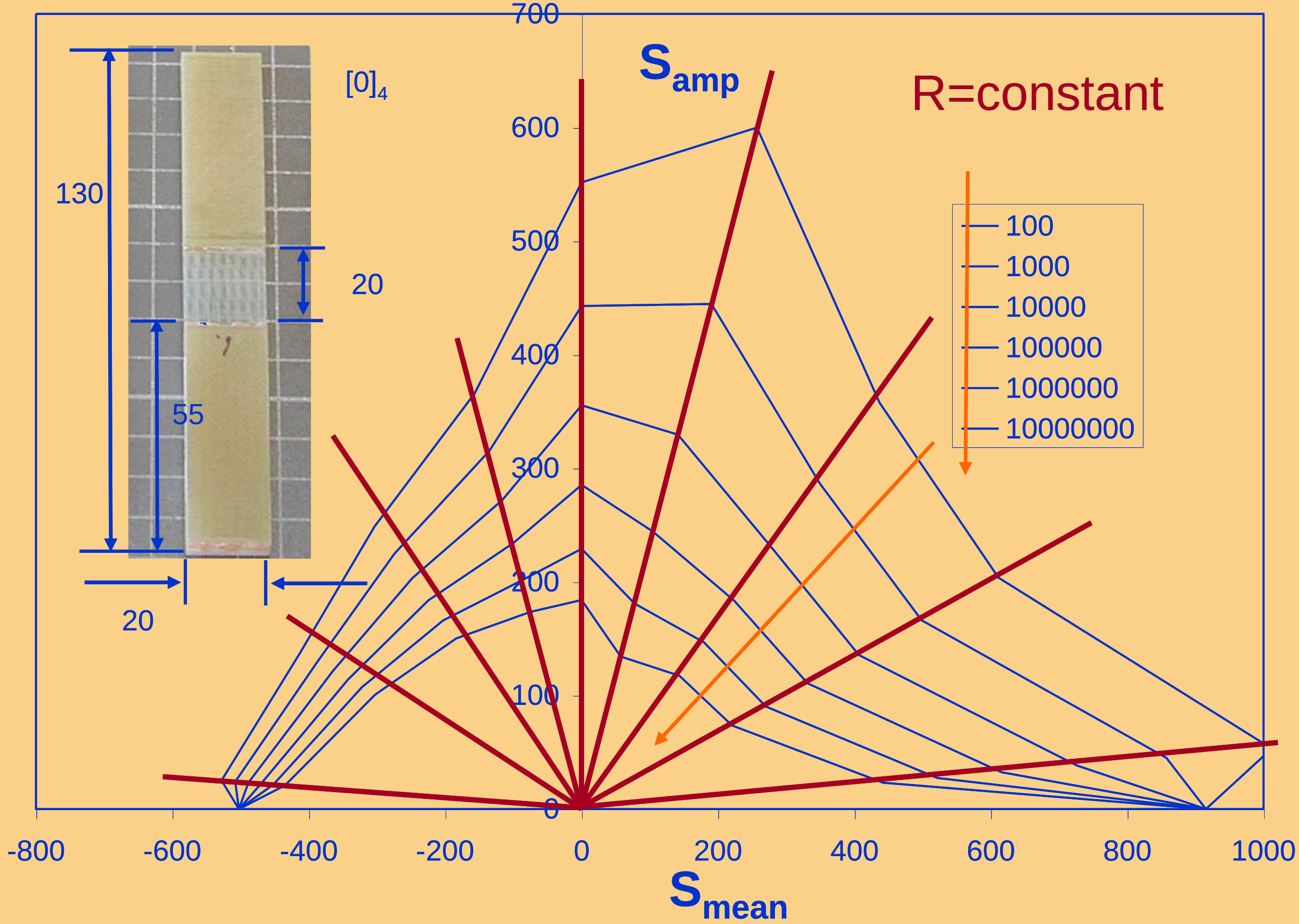
Deliverables (INCO-Part)

Del. [1] No.	Deliverable name and description	Recieving WP	Lead participant	Nature [2]	Disse-mination level [3]	Due Del.date (proj. Month)	Realized /new Del date
D3.2.1a	Background theory and ME technique-based code	WP3	ISM	R	RE	25	25
D3.2.1b	Model and numerical study of the micro damage induced anisotropy	WP3	ISM	R	RE	27	51
D3.2.1c	Model of fatigue micro damage in FR composite	WP3	ISM	R	RE	34	52
D3.2.1d	Model of progressive partial/complete matrix-fiber debonding	WP3	ISM	R	RE	36	47
D3.2.1e	Micromechanical fatigue strength theory of composite	WP3	ISM	R	RE	42	55
D3.2.2a	Report on SEM-in-situ experimental investigations of damage growth in composites under static loading	WP3	CUMTB	R	RE	18	18
D3.2.2b	Report of SEM in-situ experimental investigations of damage growth in the composites under fatigue loads	WP3	CUMTB	R	RE	30	30
D3.2.2c	Report on the experiments on degradation of composite materials under specific temperature, moisture and cyclic load	WP3	TIET	R	RE	31	not delivered
D3.2.2d	Report of Numerical simulation of interactions between matrix and fibre in the composites under uniaxial load and three-	WP3	CUMTB	R	RE	36	partially available
D-3.2.3a	State of the art report on the long term performance of fibre composite structures	WP3	TIET	R	RE	15	not delivered
D3.2.3b	Numerical procedure for coupled diffusion and mechanical analysis	WP3	TIET	R	RE	30	partially available
D3.2.3c	Model of fatigue damage in fiber reinforced composites	WP3	CUMTB	R	RE	30	52
D3.2.3d	Numerical procedure for bridging the micro and macro analysis	WP3	TIET	R	RE	31	not delivered
D3.2.3e	Combined hygro-thermal and fatigue analysis of fibre reinforced composites	WP3	TIET	R	RE	40	partially available
D3.2.3f	User element in ABAQUS for damage analysis with environmental and fatigue cycling effects	WP3	TIET	O	RE	40	not delivered

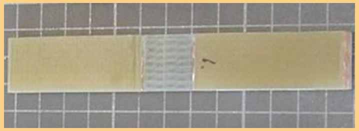
SIXTH FRAMEWORK PROGRAMME

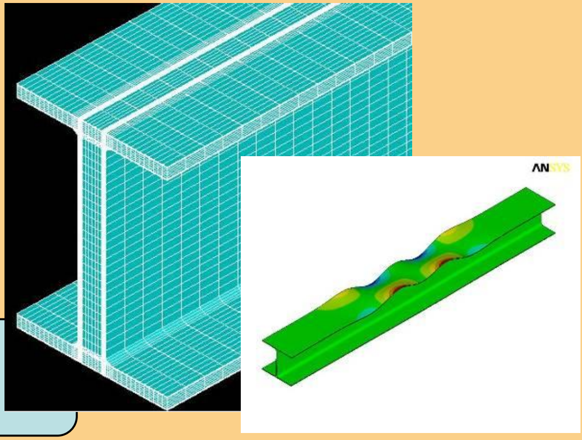
UpWind

Fatigue Behaviour of Reference Material



Subcomponents





Material data

Subcomponent

Test

Modelling

Repair

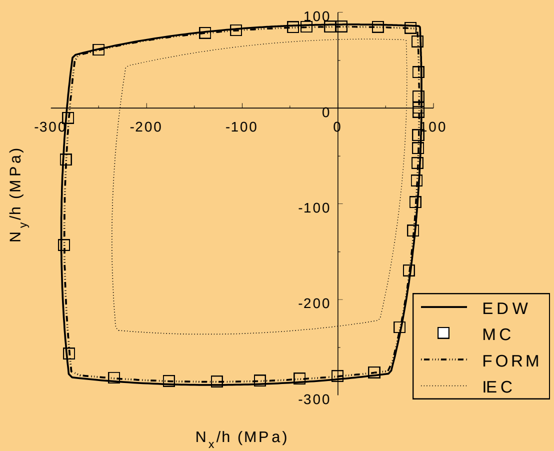
Design concept

Bondlines

Safety factors reduction

Possible on strength related factors

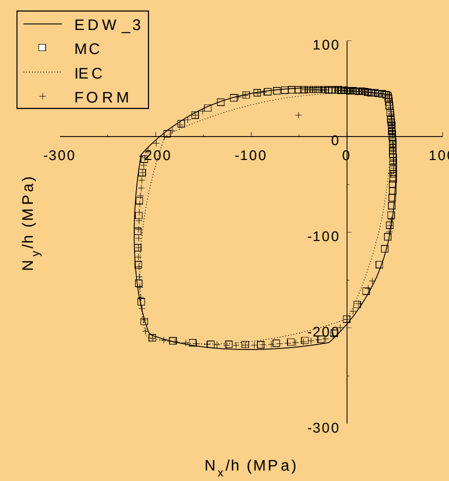
- Improving manufacturing control
  - Better quality should be rewarded with smaller safety factor
- Quantification as a result of WP3



$P_F=10^{-4}$

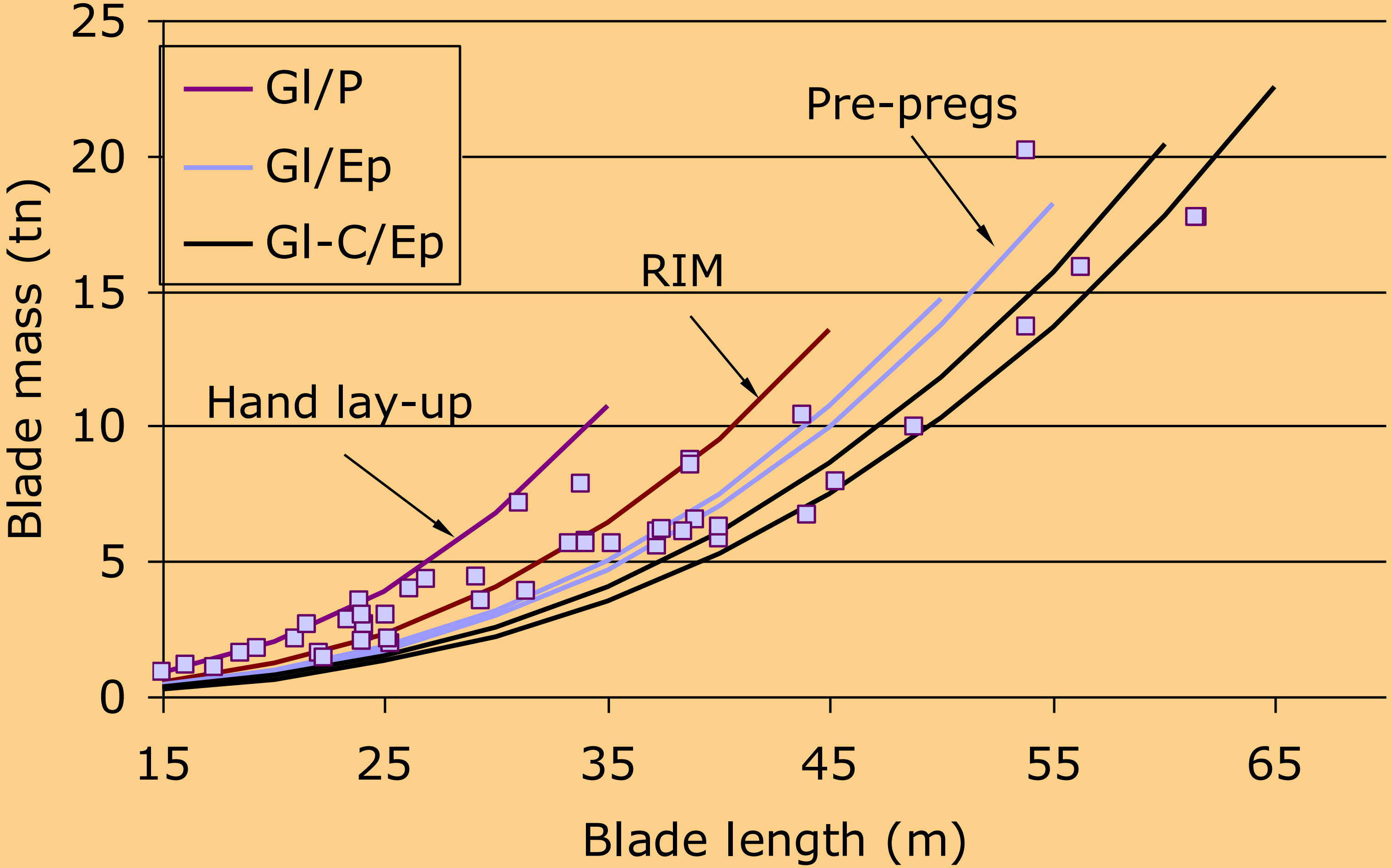
$[0/90]_S$

GI/EP



GI/P

Materials & Manufacturing

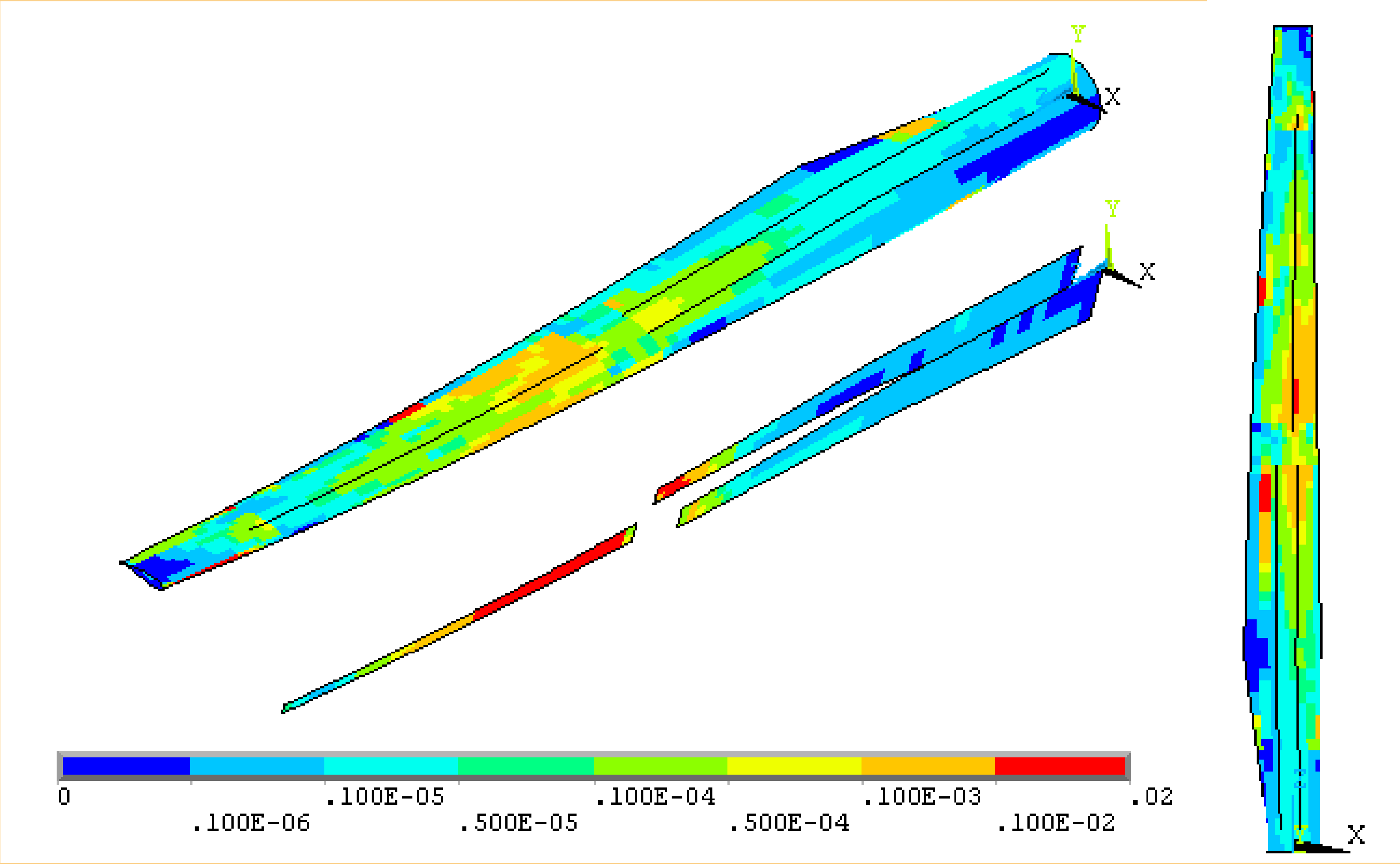


Probabilistic stress analysis

Specific objectives for the 4th year:

- Integration of the Response Surface Method (RSM/MC) in shell FE models of rotor blades and THIN-probabilistic
- Implementation of extreme load probabilistic analysis as per IEC 61400-1 ed.3 for determining structural reliability of a rotor blade in ultimate loading

RESULTS: Probability of failure



SIXTH FRAMEWORK PROGRAMME

UpWind

WG 4 Foundations and support structures

WG 4 Foundations and support structures

WP 4.1 Integration of support structure and turbine design

- Integrated design and WT control for mitigation of aerodynamic and hydrodynamic loading
- Compensation of site and structural variability

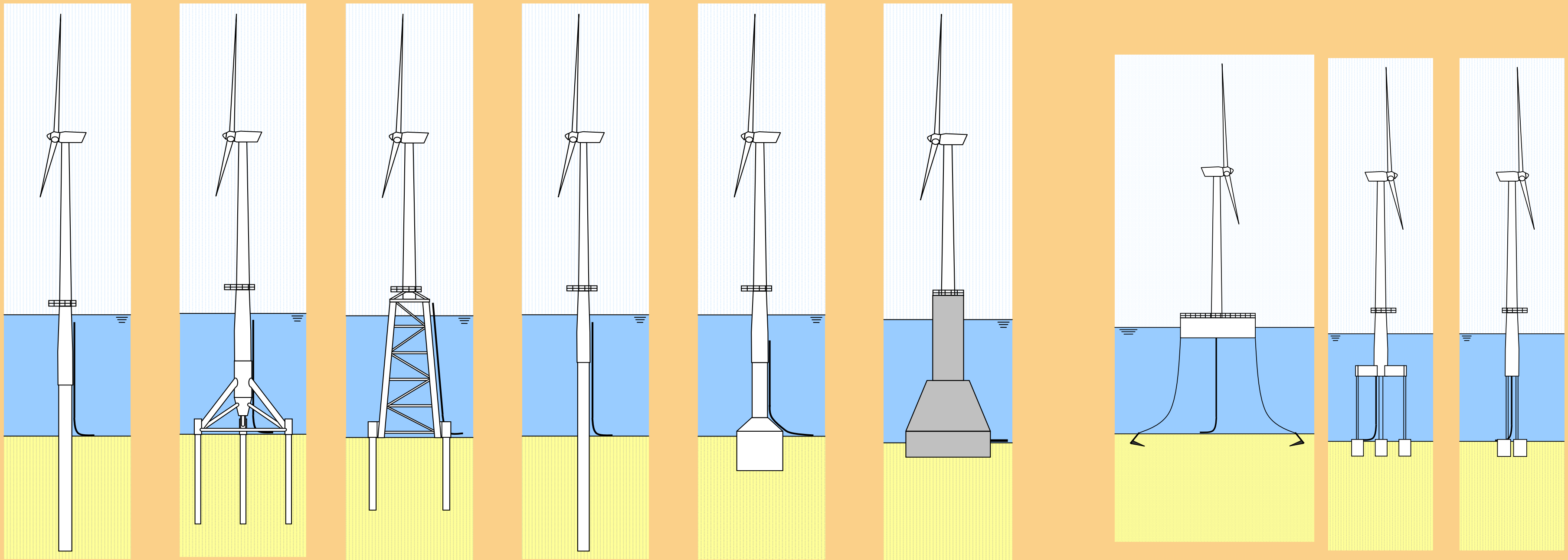
WP 4.2 Concepts for deep water sites

- Innovative bottom-mounted structures e.g. truss-type
- Very soft structures: monopile-type or braced-type
- Floating structures

WP 4.3 Enhancement of design methods and standards

- e.g. non-linear sea states, multi-member support structures, large number of similar designs, floating designs
- Support 1st revision of IEC 61400-3

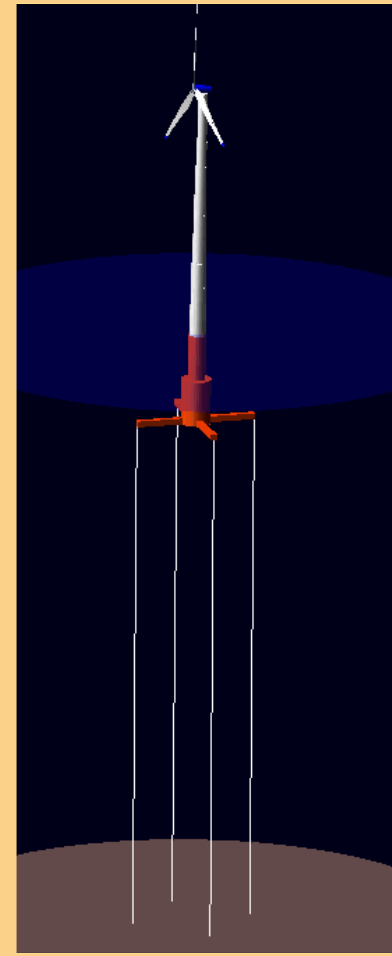
WG 4 Foundations and support structures



WG 4 Foundations and support structures

NREL

- Benchmark of design tools (IEA Wind Annex 23)
- Design tool for floating turbines (3rd & 4th year)
- Design of floating wind turbines (5th year)



Centre for Wind Energy & Marine Technology (CWMT)

- Sub-structuring of joints in braced support structures => UpWind reference design (4th year)
- Adaptive design of large number of support structures at varying site conditions (5th year)

Casted joint

CWMT
Fraunhofer Center Windenergie und Meerestechnik

NREL
National Renewable Energy Laboratory

Further Procedure – Design Integration

Concept Studies

→Different operational and dynamic control concept

Selected promising concepts

Design Study #1

- Mitigation of fatigue loads
- Focus on FA-Mode
- Using active control
  - Tower-feedback
  - Soft Cut-Out

(Paper at EOW 2009)

Design Study #2

- Mitigation of fatigue loads
  - Focus on SS-Mode
- Using active/pass. control
  - Drive-train damping
  - Indiv. pitch control

(Paper at Torque 2010)

Design Study #3

- Mitigation of fatigue loads
- Mitigation of extreme loads
- Using „passive“ control
  - Passive mass-damper
  - Active mass-damper

(Paper at ISOPE 2010)

til 02 / 2010 (D4.1.4)

Derive optimal overall concept into an overall controller

2nd Design Study

- Deep water site
- Jacket
- Structural optimization ???

Final Design Study

- Shallow water site
- Monopile
- Structural optimization

til 02 / 2011 (D4.1.5)

WP 5: Control

- **Controller design and évaluation**
  1. Algorithm development and evaluation
  2. Hardware testing and optimisation

- **Field testing and evaluation**

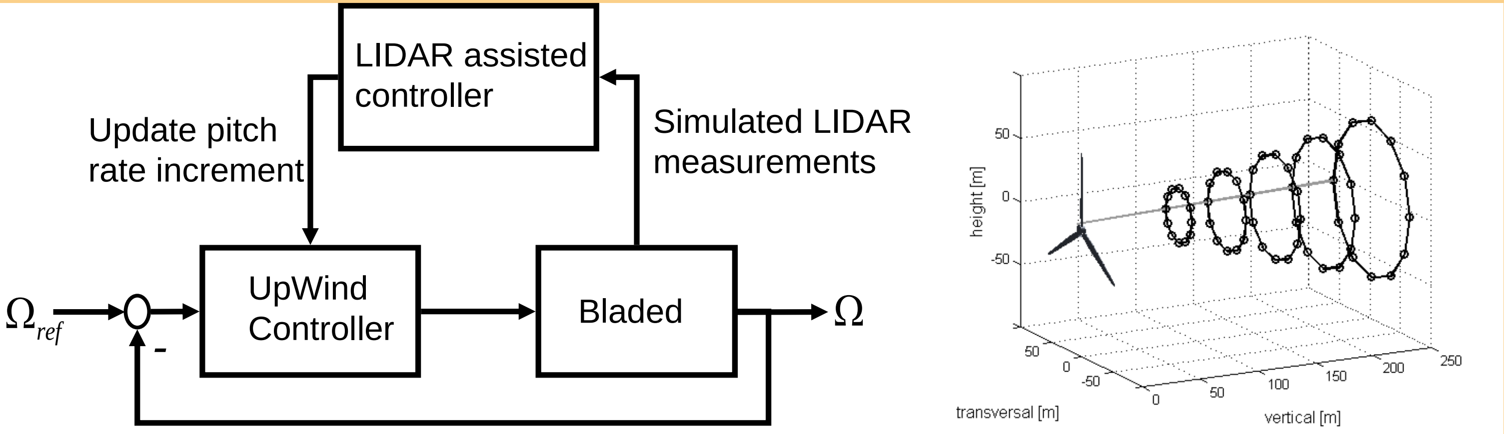
- **Grid and farm integration**
  1. Wind Farm optimization
  2. Electrical interaction in the network
- **Interaction with other work packages**

5 Control Deliverables

D5.1.1	Controller for 5MW reference turbine	GH	
D5.1.2	Load case and supervisory control implications of advanced control	GH	
D5.1.3	Use of Lidar in control	USTUTT	
D5.2	Promising Load Estimation Methodologies for Wind Turbine Components	ISET	
D5.3	Load estimation	ISET	
D5.4	Hardware test facility	ISET/GH	
D5.5.1	Cart2 field tests	GH	
D5.5.2	Cart3 field tests	GH	
D5.5.3	REpower field tests	REpower	
D5.7	Wind farm controller : replaced by new deliverable D5.1.3		
D5.8	Review of electrical drive train topologies	GH	
D5.9.1	Fast VAr control	GE	
D5.9.2	DFIG modelling and low voltage ride-through	Alstom	
D5.11	Closed loop system identification	CENER	
D5.10	WP5 Final report	GH	

Use of Lidars in control

- Scanning Lidar sensor model added to Bladed
- 5MW reference controller adapted for additional pitch rate input from Lidar algorithm
- Lidar algorithm implemented and tested with gusts and turbulent wind



SIXTH FRAMEWORK PROGRAMME

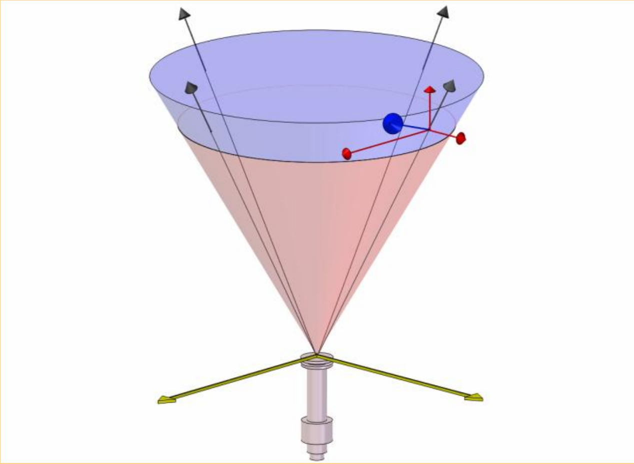
UpWind

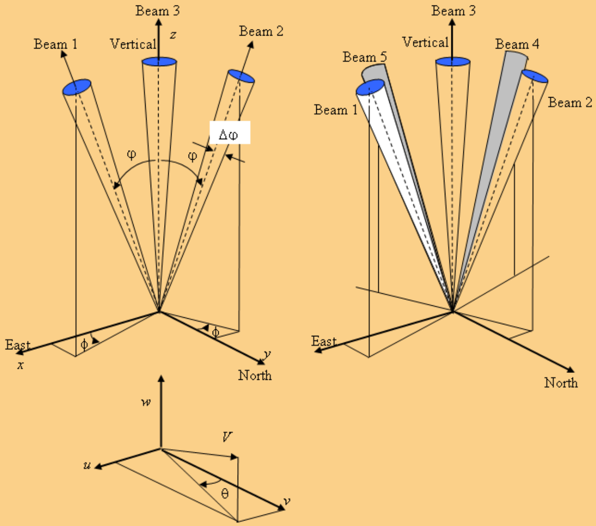
Field testing

- NREL CART2 IPC tests
  - Gearbox repair delayed testing until November 2009 ☹
  - Exceptionally poor winds over the winter ☹
  - First data at the very end of January 2010
  - Data collected in February/March, and most already analysed ☺
  - Excellent results right from the start ☺ ☺ ☺
  - More data hoped for if winds permit.
- NREL CART3 IPC tests
  - Controller designed and tested in simulations
  - Fully implemented on turbine and ready to start
  - Awaiting completion of turbine commissioning - ongoing
- REpower tower damping tests
  - Everything in place
  - Only a small amount of data has been collected so far due to very poor winds over the winter.

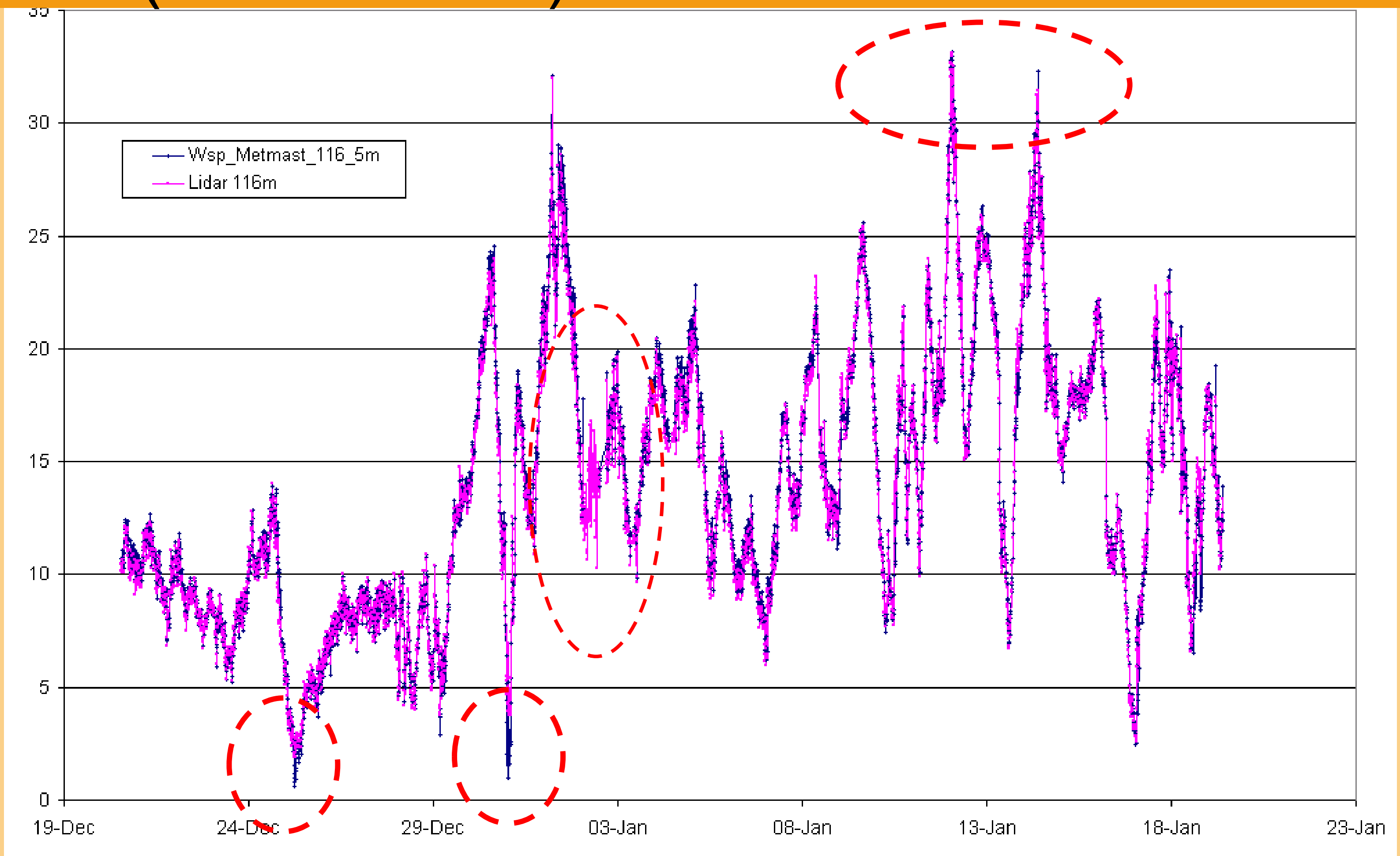
WG 6 Remote sensing

WP6. Remote sensing

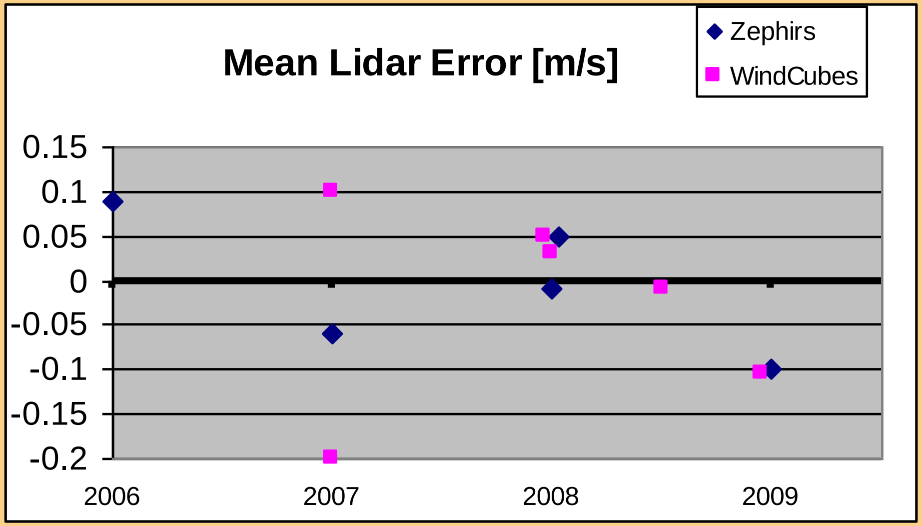


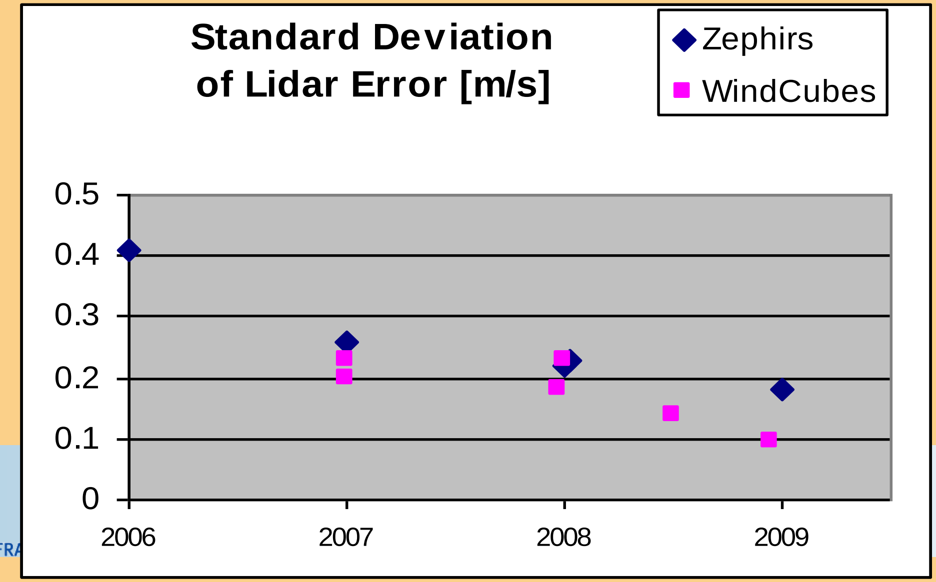


Lidar and cup at 116m vs time, all data (unfiltered)



WP 6 Development of Wind Sensing Lidars





2006: Zephir commercial model introduced. Hardware issues.

2007: Ceilometer installed, screening on clouds: positive bias and σ reduced, availability drops. Leosphere introduces Windcube.

2008: Cloud correction: availability increases. Cone angle accuracy: bias reduced.

2008.5: Cone angle accuracy Estimator improved: nonlinear problems reduced.

2009: Improved test conditions, lower RIN. Improved test conditions.

Vindicator and Galion commercial

Mean < ~±0.05 m/s σ ~0.20

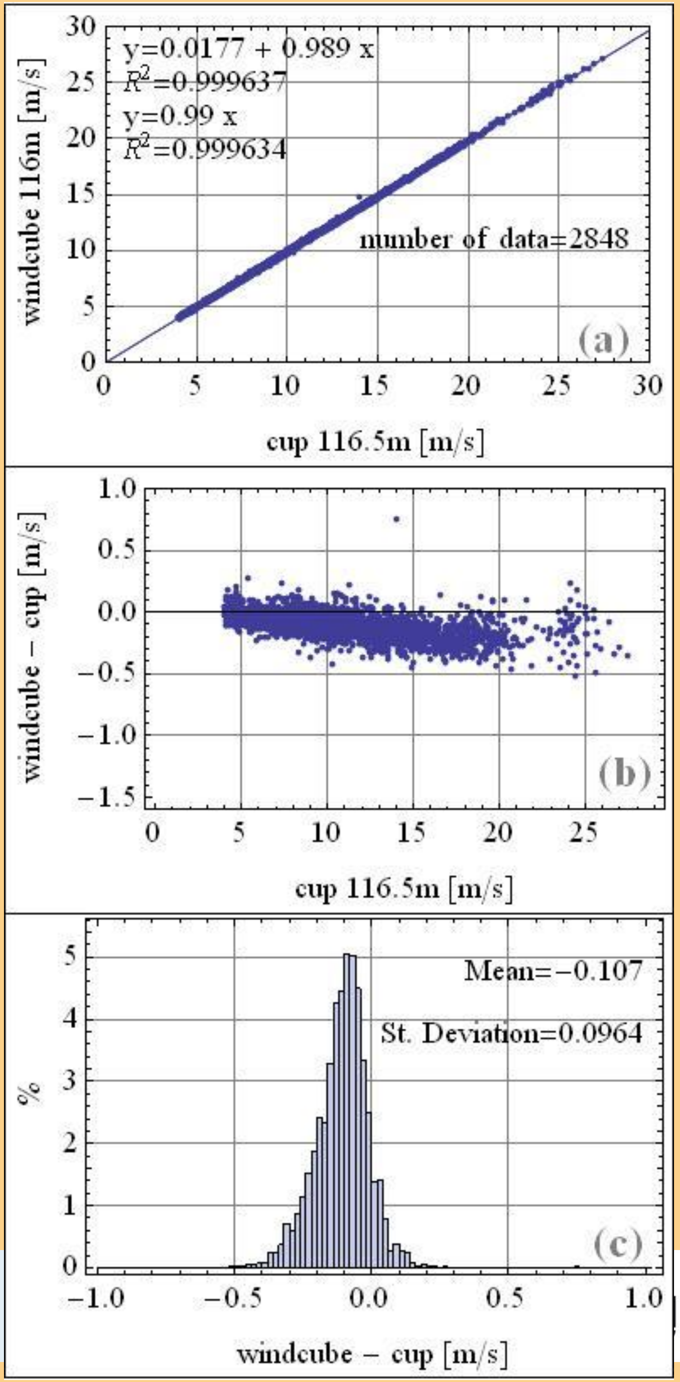
Mean < ~±0.05 m/s σ ~0.10

Good lidars are getting accurate in flat terrain!

Best lidars are within ±1.5% of traceable cup (for the heights we can test).

Very low noise

We are approaching the limit of what we can be verified with mast-mounted cup anemometers.



WP7 Condition monitoring

7.1 Next Generation CMS for use in multi MW turbines

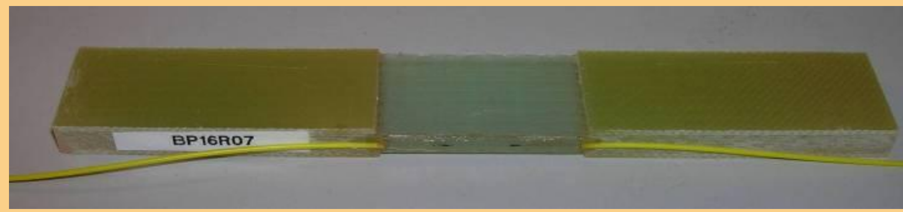
7.2 Flight Leader Turbine concept for cost optimised O&M on offshore wind farm WTs

7.3 Fault statistics to identify fault critical components of WTs

7.4 Integration of WP7 results into international standards and technical guidelines

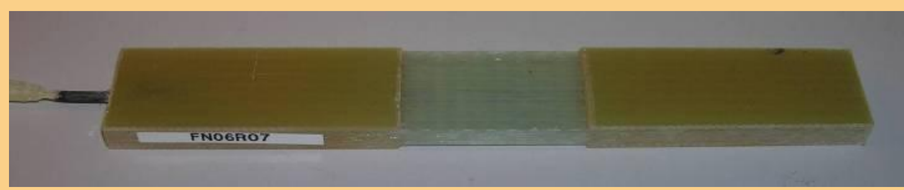
WG 7 Condition monitoring

CMS for use in multi MW turbines; material properties



Before test

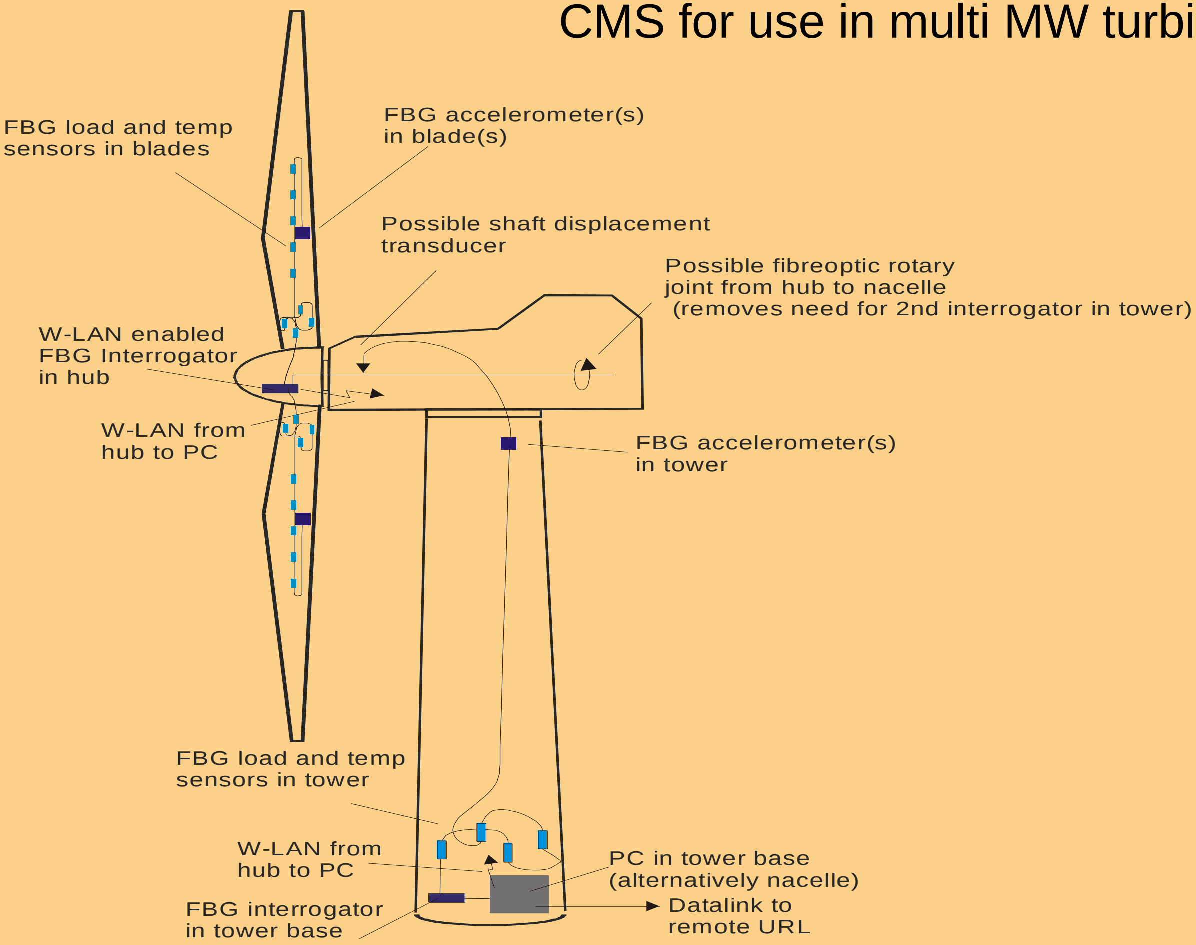
After test



Embedded sensor.

WG 7 Condition monitoring

CMS for use in multi MW turbines; operational verification



SIXTH FRAMEWORK PROGRAMME

UpWind

WP 8 Flow

- Data collection from Wind Farms - Wakes
- Comparison with existing flow models
- Participate in international standardization (IEC)

Flow

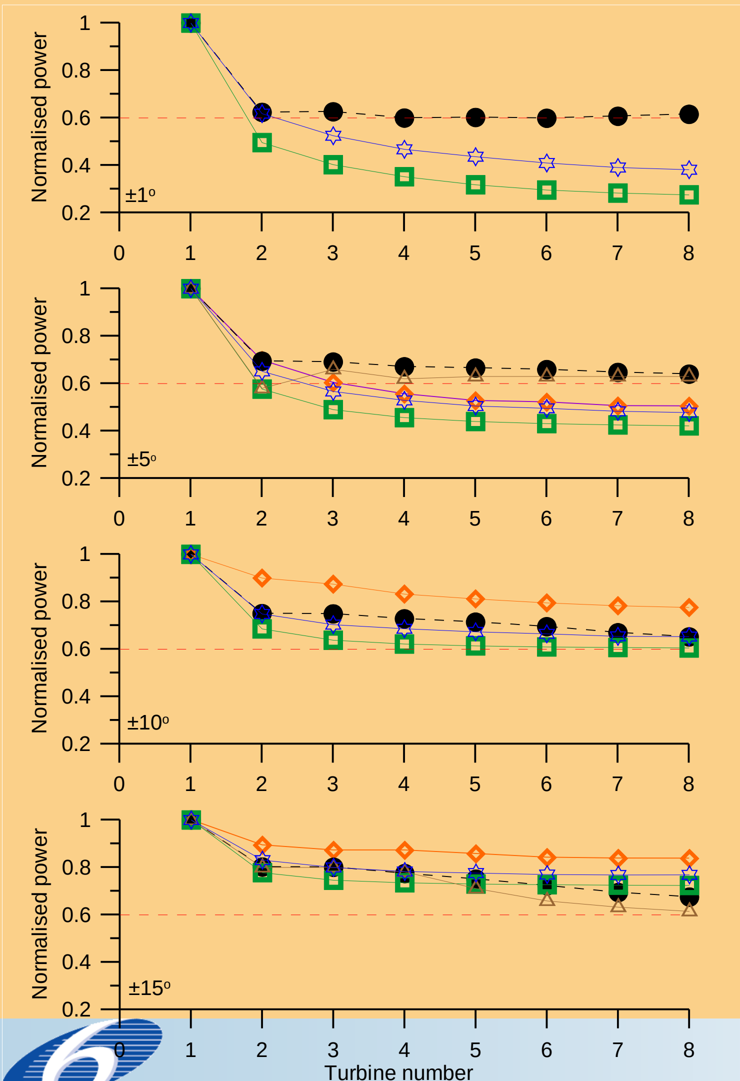
Structure of WP 8 Flow

UpWind Wp8

Data

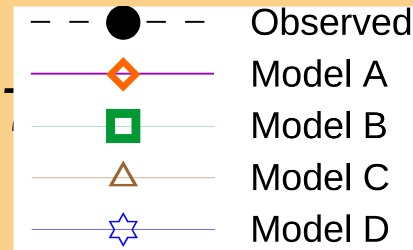
- Complex terrain
  - Gaussian Hill
  - 5 turbines flat
  - Complex terrain WF
- Offshore
  - Ensemble statistics Horns Rev
  - Ensemble statistics Nysted
  - Time series
- Array
  - Model development
  - Model evaluation
- Integration
  - Wake reduction
  - Lifetime loads

Horns Rev case studies - 7D spacing



8±0.5 m/s

- Direct down the row wake losses are the largest esp. at low wind speeds
- Defining narrow rows and wind sectors gives few values
- Not representative for all wind speeds and directions
- Case 1 270°,
spacing

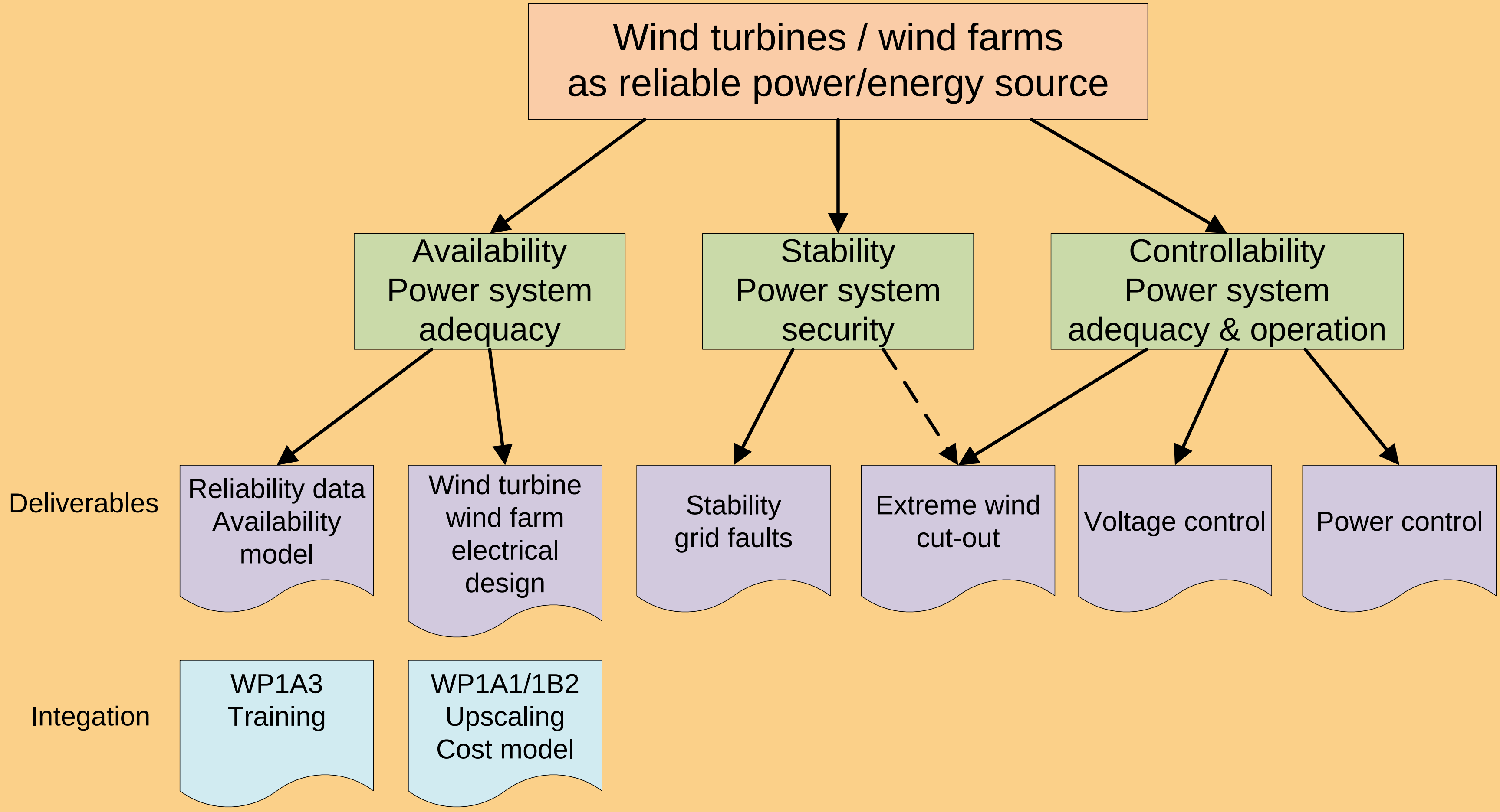


WP 9 Grid

- Emphasis on grid reliability and design conditions for WT coming from grid conditions

- Participate in international standardization (IEC)

WP9 Electrical Grid



Cost model - Main design parameters

Power	**5 MW**	10 MW	15 MW	**20 MW**
Rotor diameter	**126 m**	178 m	218 m	**252 m**
Tip speed	**80 m/s**	80 m/s	80 m/s	**80 m/s**
Hub height	**90 m**	116 m	136 m	**153 m**

- Wind turbine type: reference WT (based on NREL 5 MW)

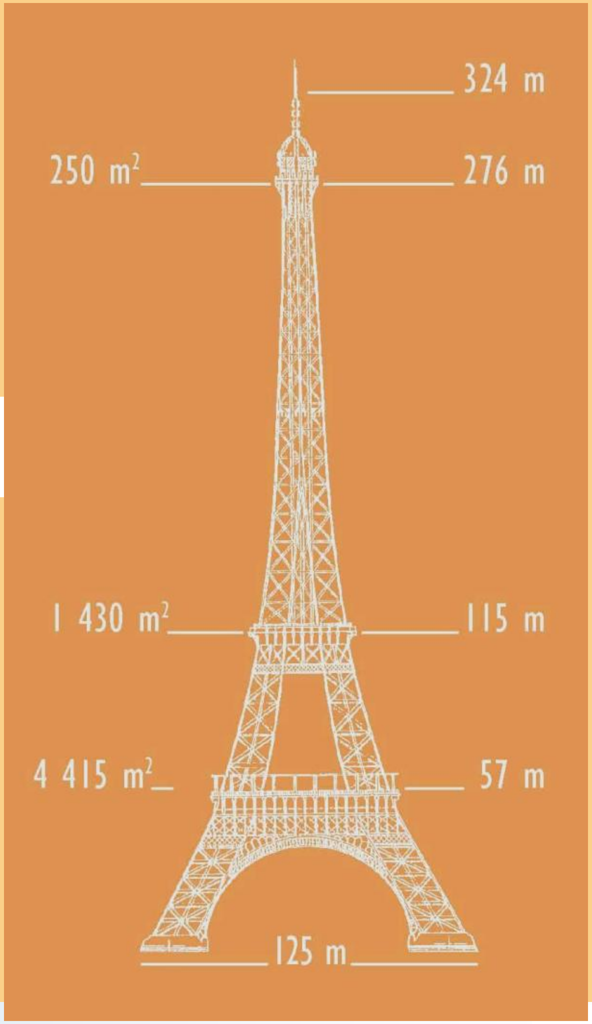
- 500 MW (1000 MW) offshore wind farm
- North Sea wind and wave conditions
- Water depth: 30m and 60m
- Distance to shore: 25 km and 100 km

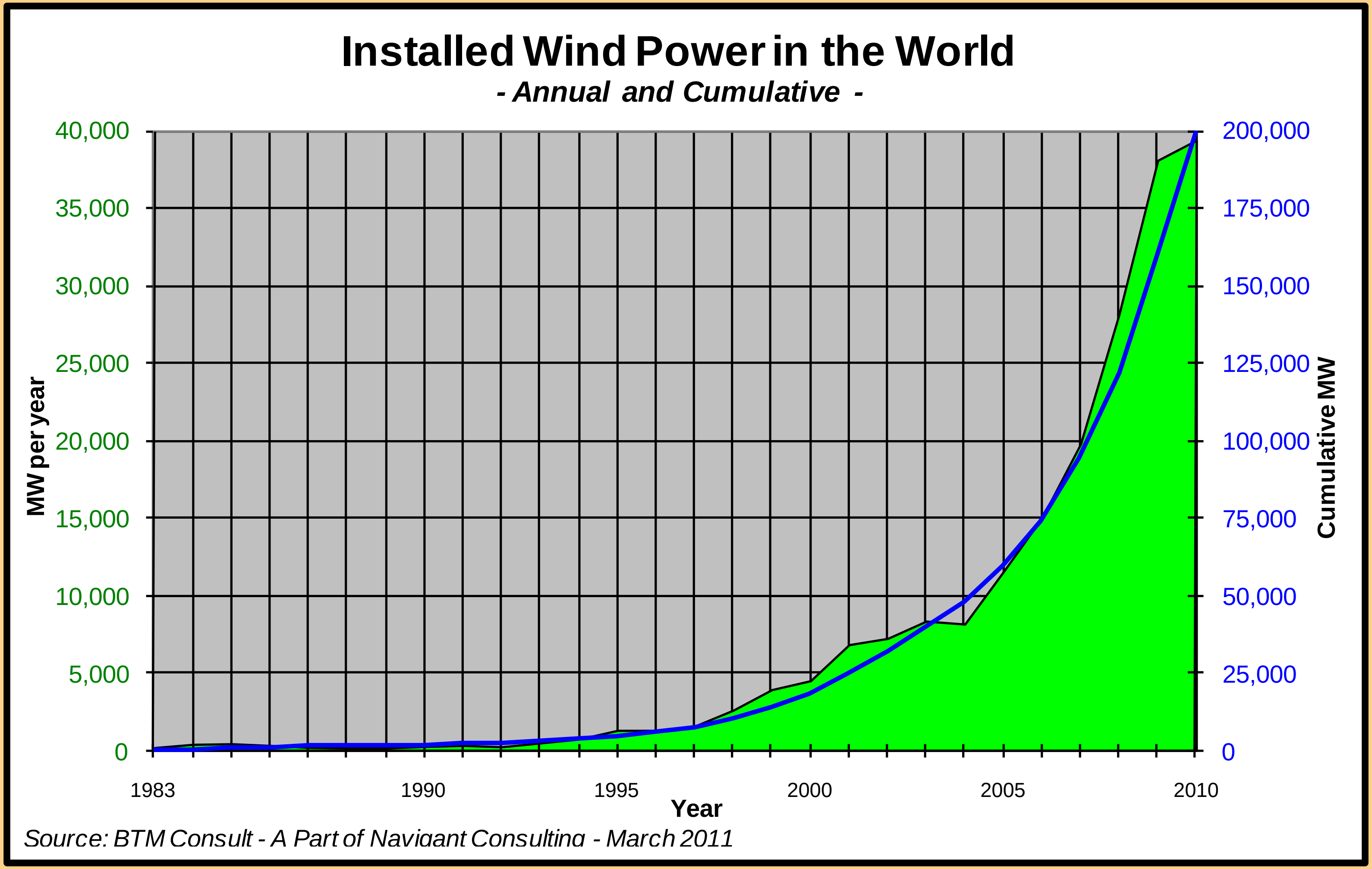
WP 11 Information and dissemination

1. External web site
2. Work shop on EWEC every year with presenations
3. Worksob

20MW møllen og Eiffel tårnet

$\approx 300m$





World Market Update 2010

March 2011

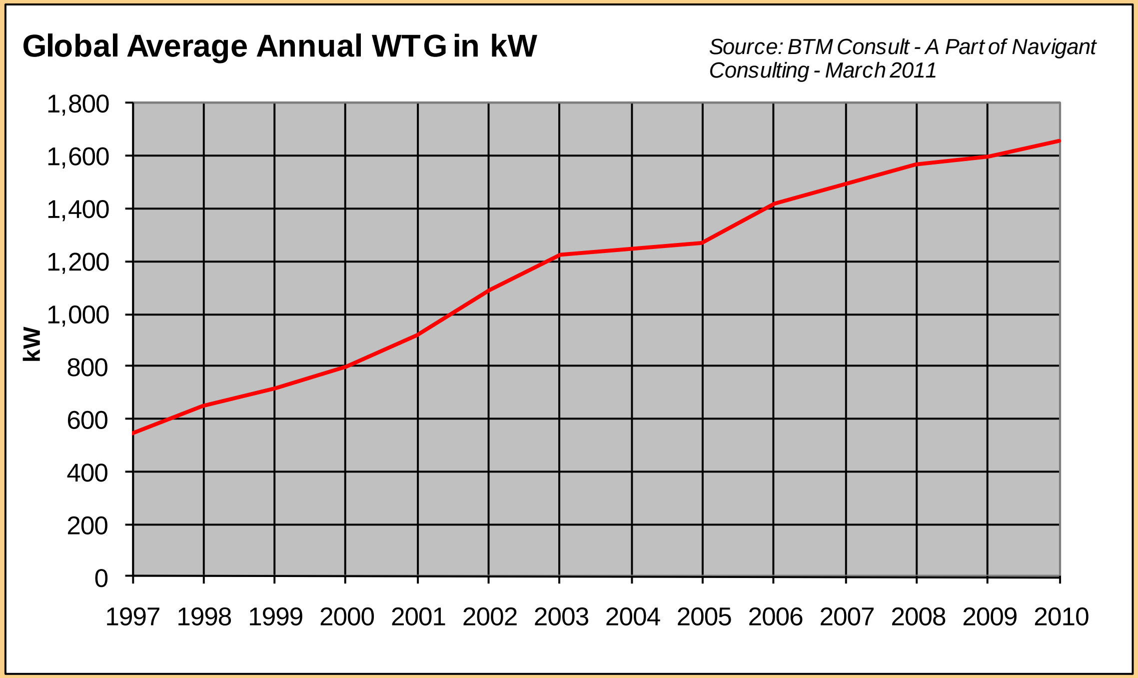
SIXTH FRAMEWORK PROGRAMME

UpWind

Average size WTG (kW) installed each year

Year	China	Denmark	Germany	India	Spain	Sweden	UK	USA
2005	897	1381	1634	780	1105	1126	2172	1466
2006	931	1875	1848	926	1469	1138	1953	1667
2007	1079	850	1879	986	1648	1670	2049	1669
2008	1220	2277	1916	999	1837	1738	2256	1677
2009	1360	2368	1976	1117	1904	1974	2241	1731
2010	*1,469*	*2,514*	*2,047*	*1,293*	*1,929*	*1,995*	*2,568*	*1,875*

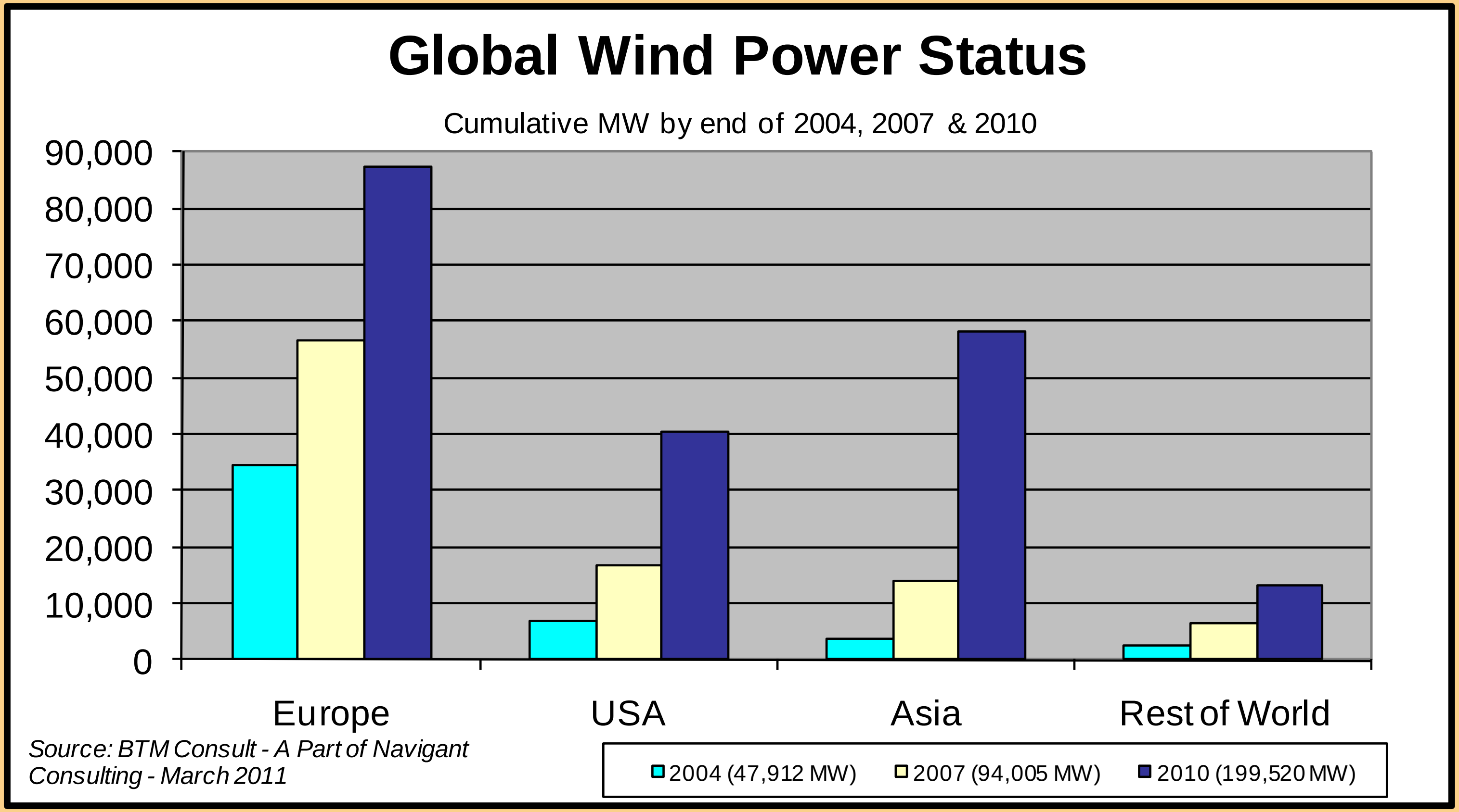
Source: BTM Consult - A Part of Navigant Consulting - March 2011



World Market Update 2010 March 2011

SIXTH FRAMEWORK PROGRAMME

UpWind



World Market Update 2010 March 2011

SIXTH FRAMEWORK PROGRAMME

UpWind

Highlights of wind power development in 2010

- ***Record installation of 39.4 GW.***
- ***Strong presence of four Chinese wind turbine suppliers in the Top 10 list.***
- ***China became the No. 1 market in the world, with 18.9 GW of new capacity.***
- ***Offshore on track for increased contribution to wind power in Europe.***
- ***Market value will grow from EUR66.8 billion in 2011 to EUR111.7 billion in 2015***
- ***Technology: direct drive turbines now account for 17.6% of the world's supply of wind power capacity.***
- ***Wind power will deliver 1.92% of the world's electricity in 2011.***
- ***This year's forecast and prediction up to 2020 indicate that wind power can meet 9.1% of the world's consumption of electricity by 2020, ten years away.***

Questions?