UpWind workshop, EWEC 2009

Marseille, March 18, 2009

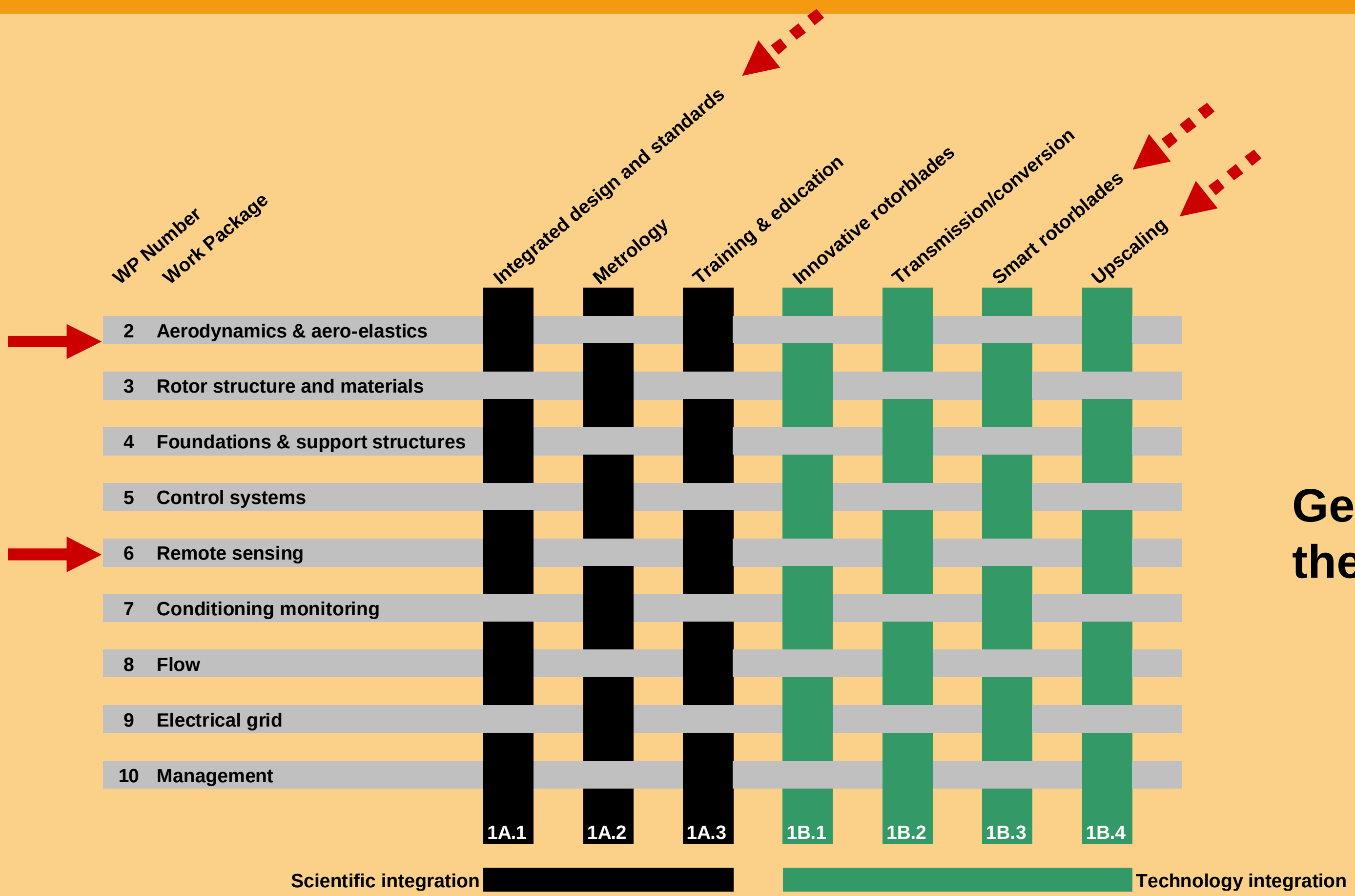
Remarkable results of the UpWind Project, Introduction and overview

Peter Hjuler Jensen & Jos Beurskens

SIXTH FRAMEWORK PROGRAMME

UpWind

This presentation



General remarks on the UpWind project

General remarks (1)

- Upwind has identified many priority topics which now are being adressed in the TPWind in the working groups WG ́s 1, 2, 3 and 4, however:
- This is not a duplication but emphasises the importance of the research topics.
- Overall progress is very satisfactory
- "Advanced "organisation works !
- Shows the sector has grown up and able to handle large complex challenges

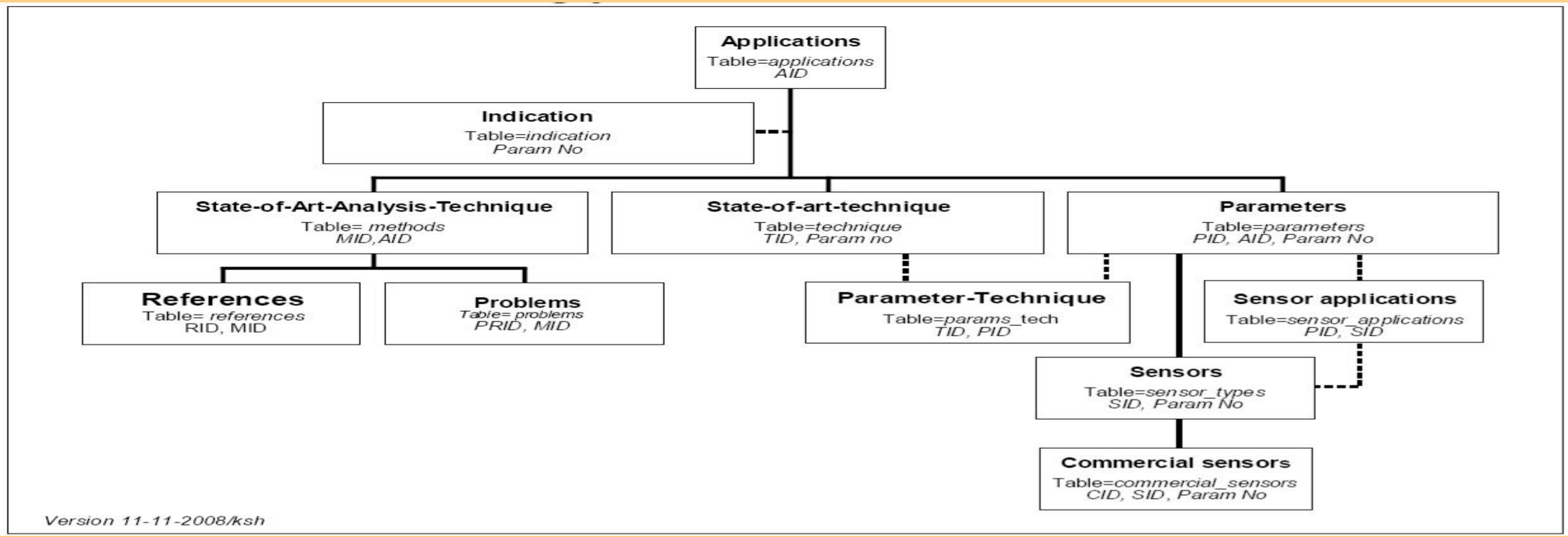
General remarks (2)

Upwind $ unique features:

- Integrates the scientific and technical disciplines to harvest synergies and to meet
- The sector $ needs for the entire development chain of wind turbine technology
- Integral design methodology
- Incorporation of Education aspects

WP 1A.2 Metrology

- Metrology Database of parameters has been defined
- Contents are being completed
- Before the summer a version is available within Upwind



WP 1A.2 Metrology

Contribution to IEC61400-12-1

- A new definition of wind speed when including the wind speed profile
- In close cooperation with WP6 (Remote sensing) 1A2 (Metrology) is investigating datasets for consequences of new definitions
- Existing datasets –in collaboration with WP6 –are investigated and the results are shared in the IEC61400-12-1 working group in May.

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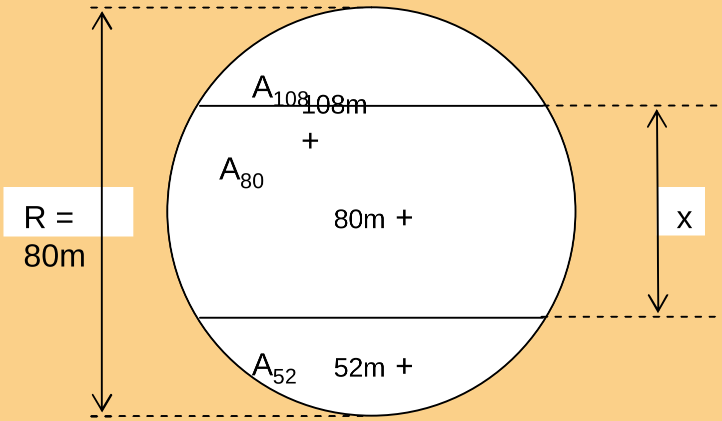
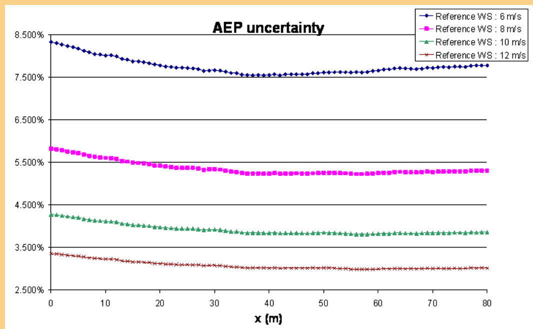
WP 1A.2 Metrology

Example shows

Do rotor-averaged wind speeds reduce uncertainty in power performance? Results at ECN test site (masts upto 108m) show no improvements.





$$Ws_{avg} = \frac{1}{A}(A_{52}Ws_{52} + A_{80}Ws_{80} + A_{108}Ws_{108})$$

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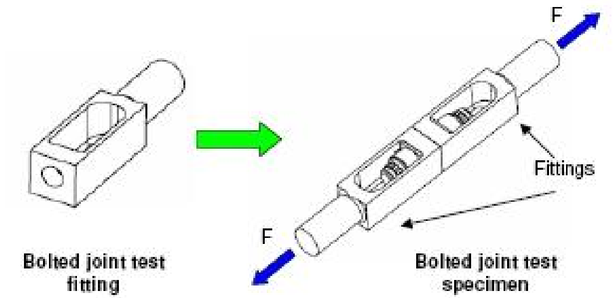
WP1B.1 Innovative rotor blades

Structure and Description of WP

Task ID	Task Name
WP1B1.1	Aerodynamic Design and Loads Calculation
WP1B1.2	Materials Selection, Structural Design and Structural Verification
WP1B1.3	Sensors and Monitoring Technologies
WP1B1.4	Blade Joints Design
WP1B1.5	Sub-component Testing
WP1B1.6	Manufacturing and Assembly Processes
WP1B1.7	Specimen Prototypes Manufacturing
WP1B1.8	Specimen Testing



WP 1.B.2 Transmission and conversion.

ü Mechanical Transmission

- Tools for detailed analysis of turbine & drive train loads

Generators

- Comparison of different generator configurations
- Electromagnetic optimization
- Optimization of the mechanical structure

ü Power Electronics

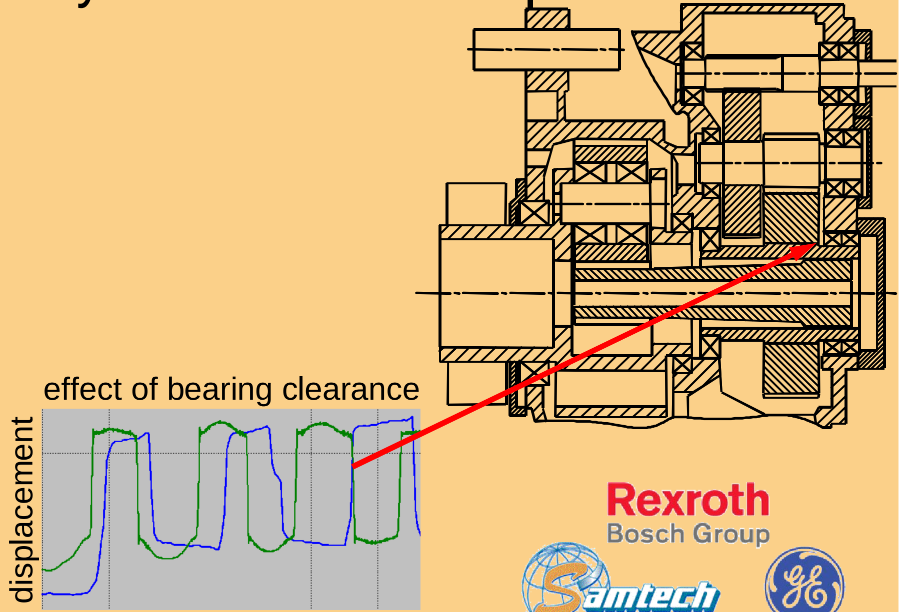
- Converter topologies

WP 1.B.2 Transmission and conversion.

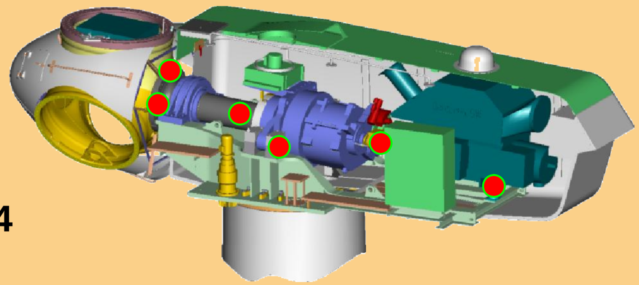
Short summary

- Development and validation of analysis tool with emphasis on Drive Train loads
  - **Detailed gear and bearing loads**
  - **Matches well with measurements**

- So far:
  - Ø Enhanced methods did not reveal hidden threads for gearboxes.
  - Ø State of the art methods seem not to underestimate loads – we are on the save side.
  - Ø But: safety margin is unclear, there is potential for cost reduction.



Rexroth
Bosch Group



- **See**: “**Matching experimental and Numerical Data of Dynamic Wind Turbine Loads by Modelling of Defects”. EWEC 2009 - Session CT2.4**
  (Andreas Heege, SAMTECH Iberica; Jan Hemmelmann, GE Global Research)

WP 1.B.2 Transmission and conversion.

Outlook

- Detailed dynamic loads are only the first step

- Enhanced bearing life calculation: 'a whole world to explore "
  - **example: how to deal with combined loads**
    - ? multi-dimensional load duration distributions (LDD)
    - ? statistical treatment
    - ? combining max loads as before
  - **example: which transient conditions are dangerous?**
    - ? how to identify critical dynamic conditions
    - ? methods to prove it under laboratory conditions
  - See: DEWEK 2008 'Advanced Drivetrain Simulation –Wind "
    (R. Hambrecht, Repower Systems AG; F.-D. Krull, Eickhoff Antriebstechnik GmbH)
- Component life prediction
  - right model fidelity: compromise between CPU time and details
  - identify representative (worst-case) load cases out of ~2000 available
- Certification: loads of new data, but what to do with it?

WP 1.B.2 Transmission and conversion.

Benefit of UpWind program

“WP Transmission & Conversion” hit an open nerve

- Drive train concepts are under investigation everywhere:
  - –no clear “winning technology” yet
  - –great potential in generator topologies
- The need for more precise dynamic loads is felt in whole industry:
  - –industry is taking initiative to develop methods and tools
  - –will become a standard method in future

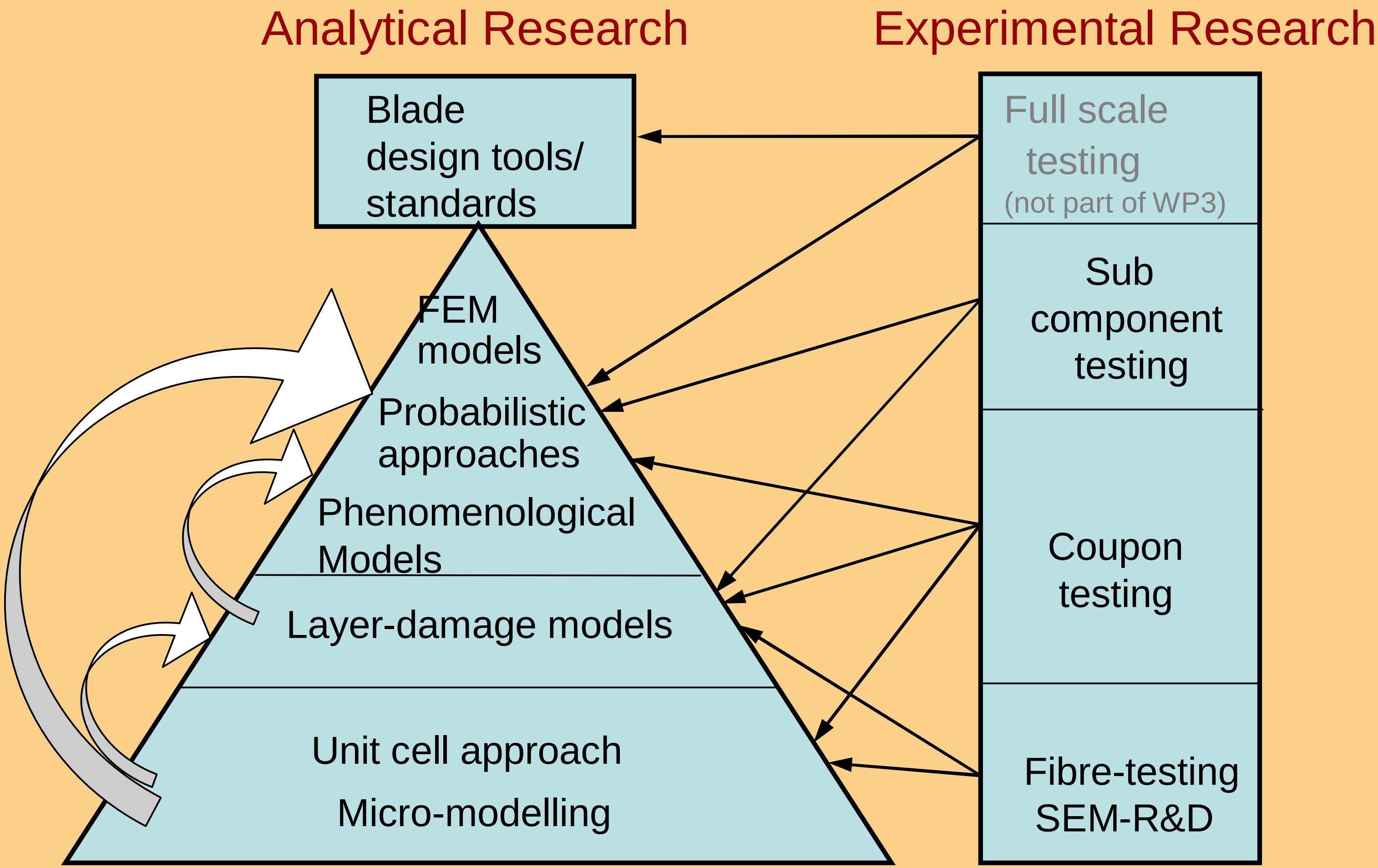
WP 3 Rotor Structure and Materials

WP 3 is subdivided into three Tasks:

- Task 3.1: Applied (phenomenological) material model (based on experiments)
- Task 3.2: Micro-mechanics based material model (RISØ) (based on fibre/ply modelling)
- Task 3.3: Damage tolerant design concept (Based on FEM with properties damaged materials)

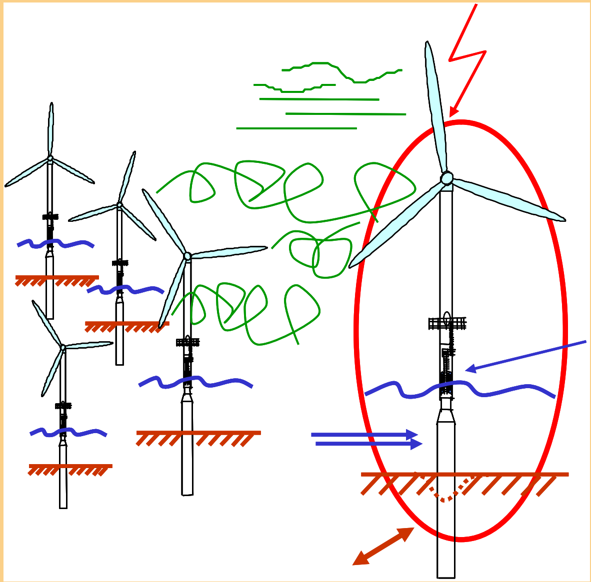
WP 3 Rotor Structure and Materials

Coherence of work within WP3

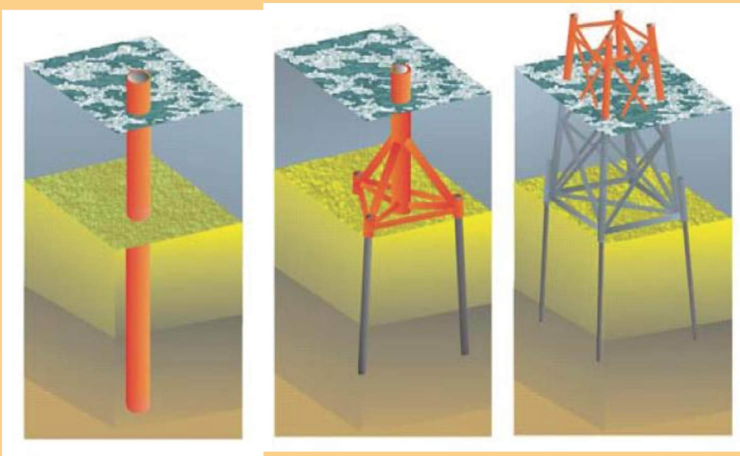


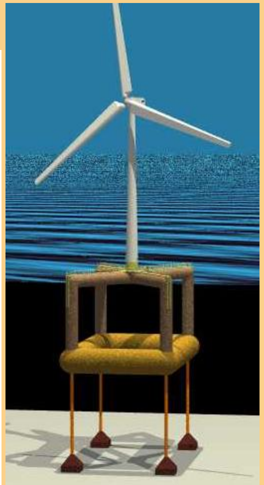
WP 4 Foundations and support structures

Cost reduction through
integrated design & design methods



Cost reduction through
weight reduction & standards





Cost reduction through
site-insensitivity & series production

WP 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

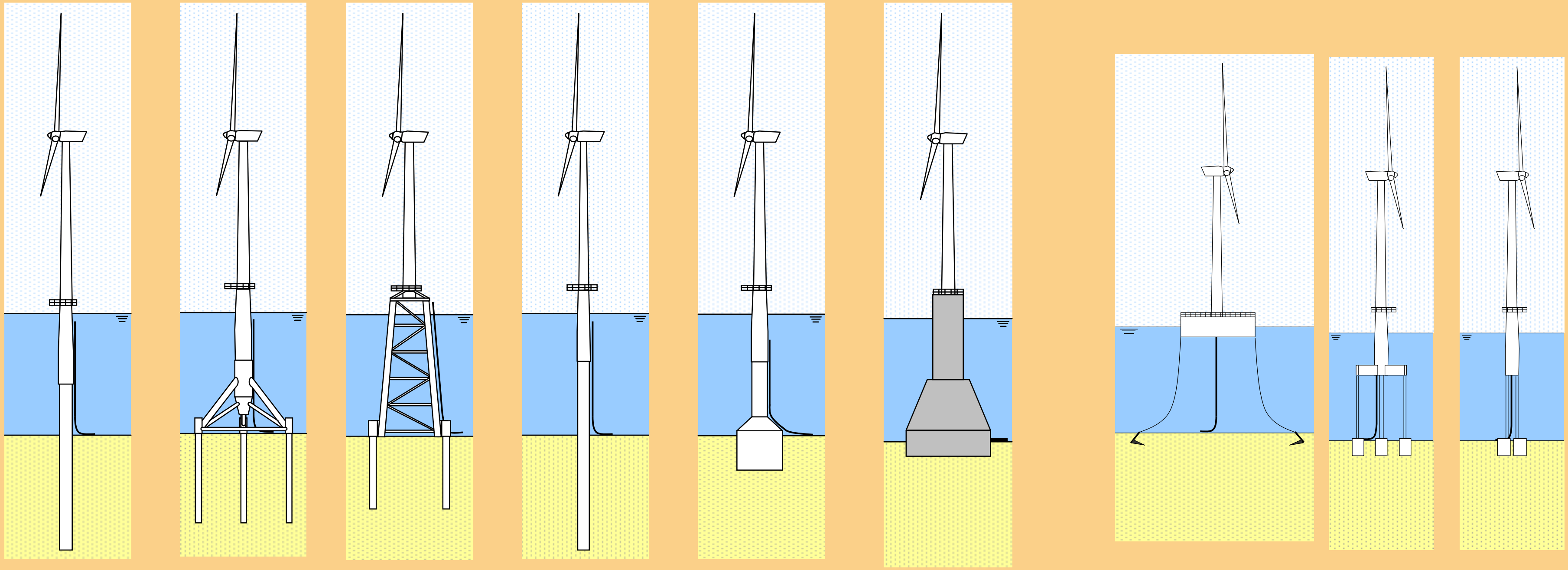
WP 4.2 **Concepts for deep water sites**

- 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

WP 4 Foundations and support structures



WP 4 Foundations and support structures

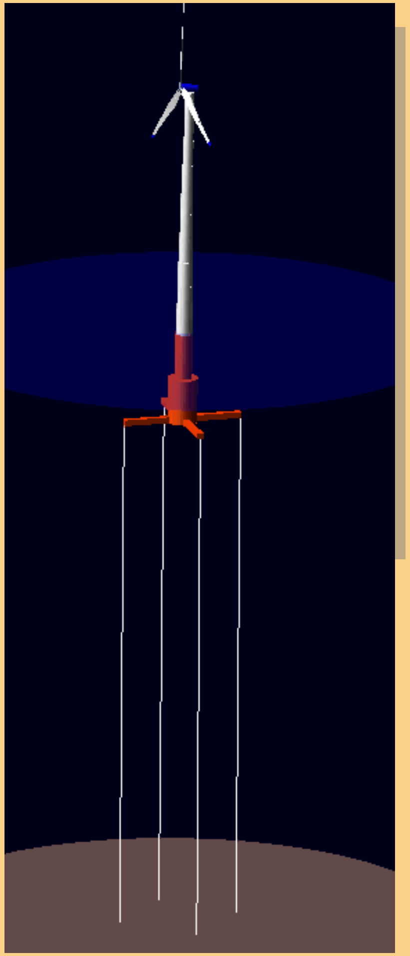
NREL

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

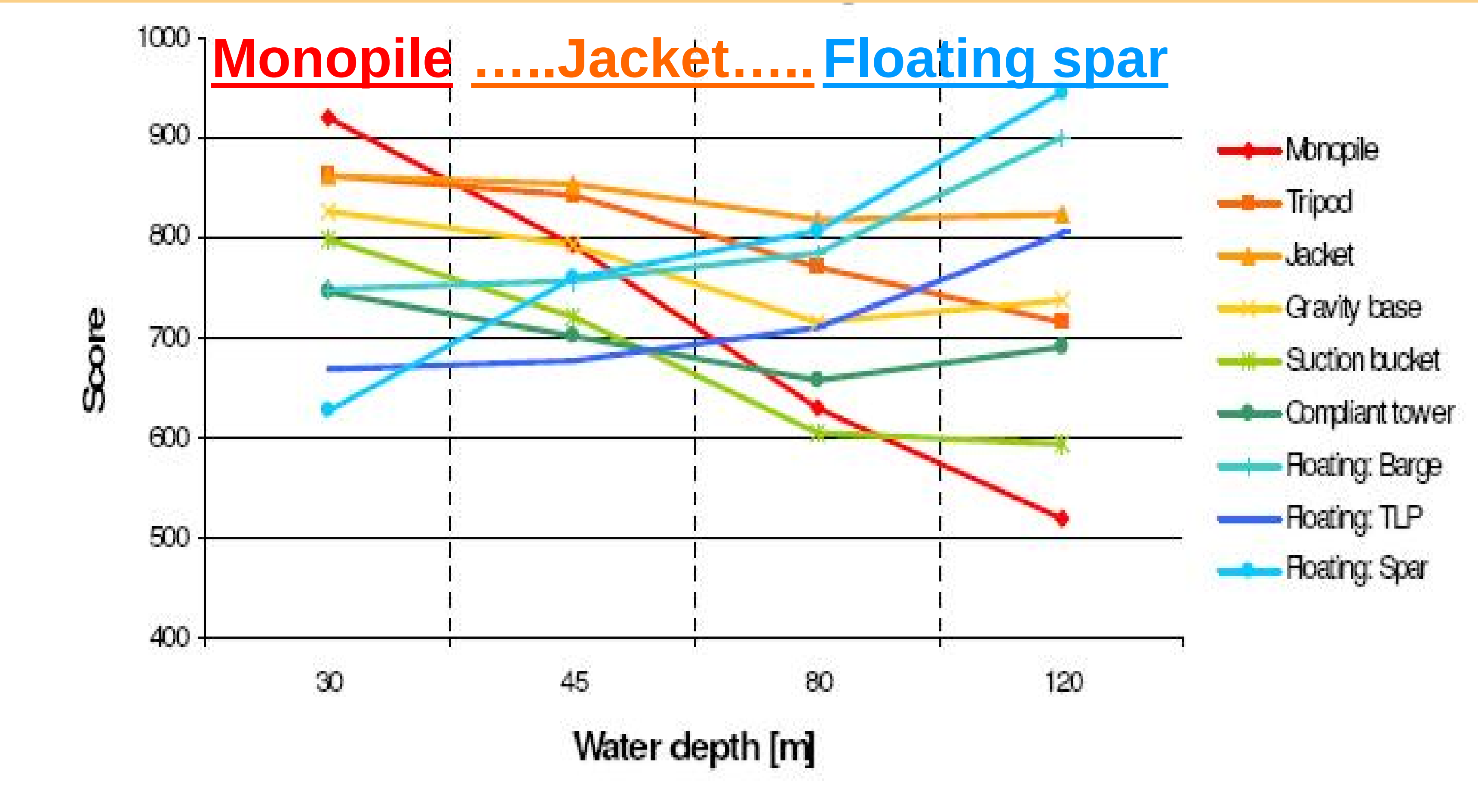
Centre for Wind Energy & Marine Technology (CWMT)

- 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



WP 4 Foundations and support structures



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WP 7 Condition monitoring

Subtasks:

7.1 Next Generation CMS for use in multi MW turbines

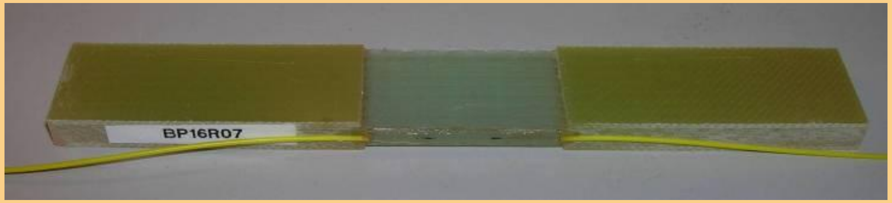
7.2 Flight Leader Turbine concept for cost optimised O&M on offshore wind farm WTs

7.3 Fault statistics to identify fault critical components of WTs

7.4 Integration of WP7 results into international standards and technical guidelines

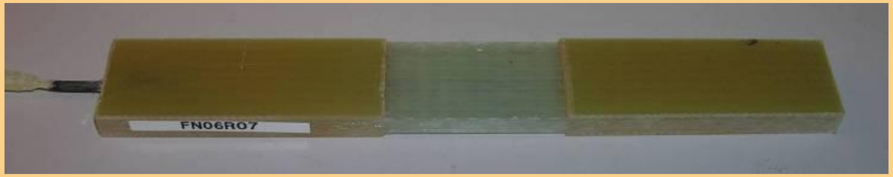
WP 7 Condition monitoring

WP7 Results Subtask WP7.1, Compression Fatigue Test Coupons



Before test

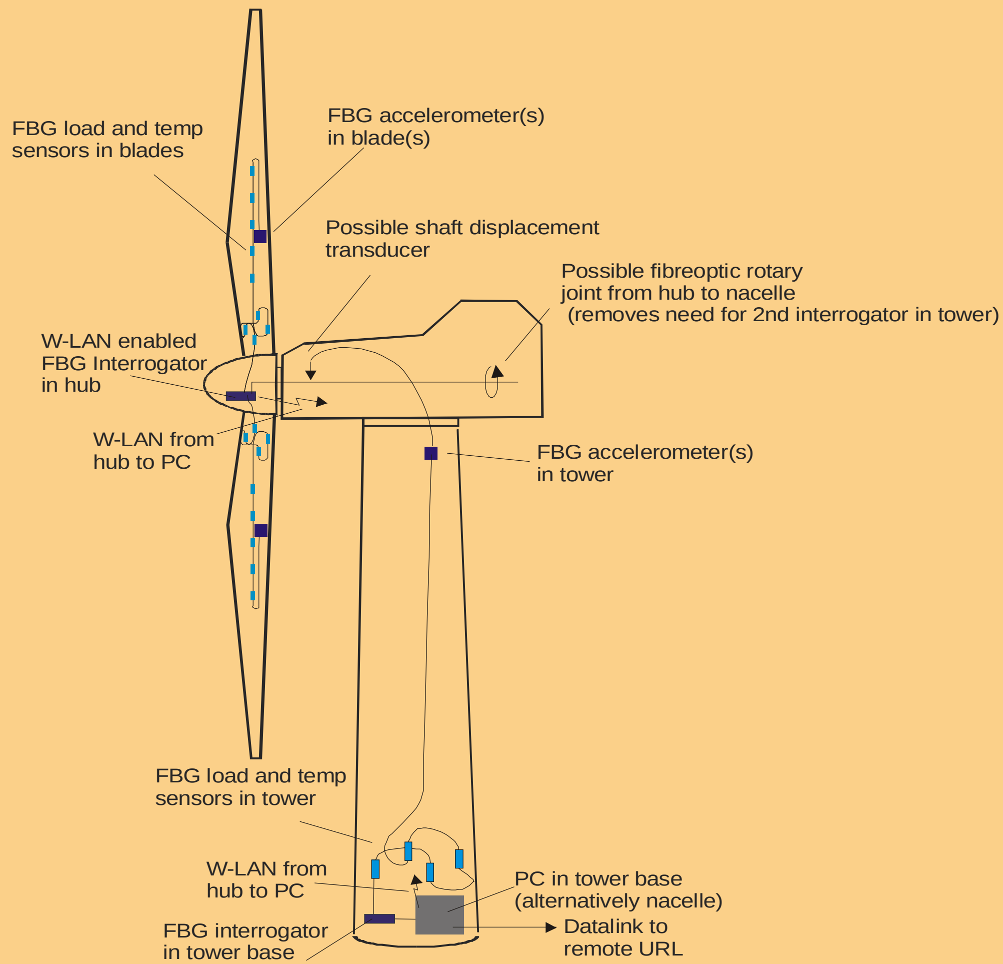
After test



Embedded sensor.

WP 7 Condition monitoring

FBG sensor
field test installation

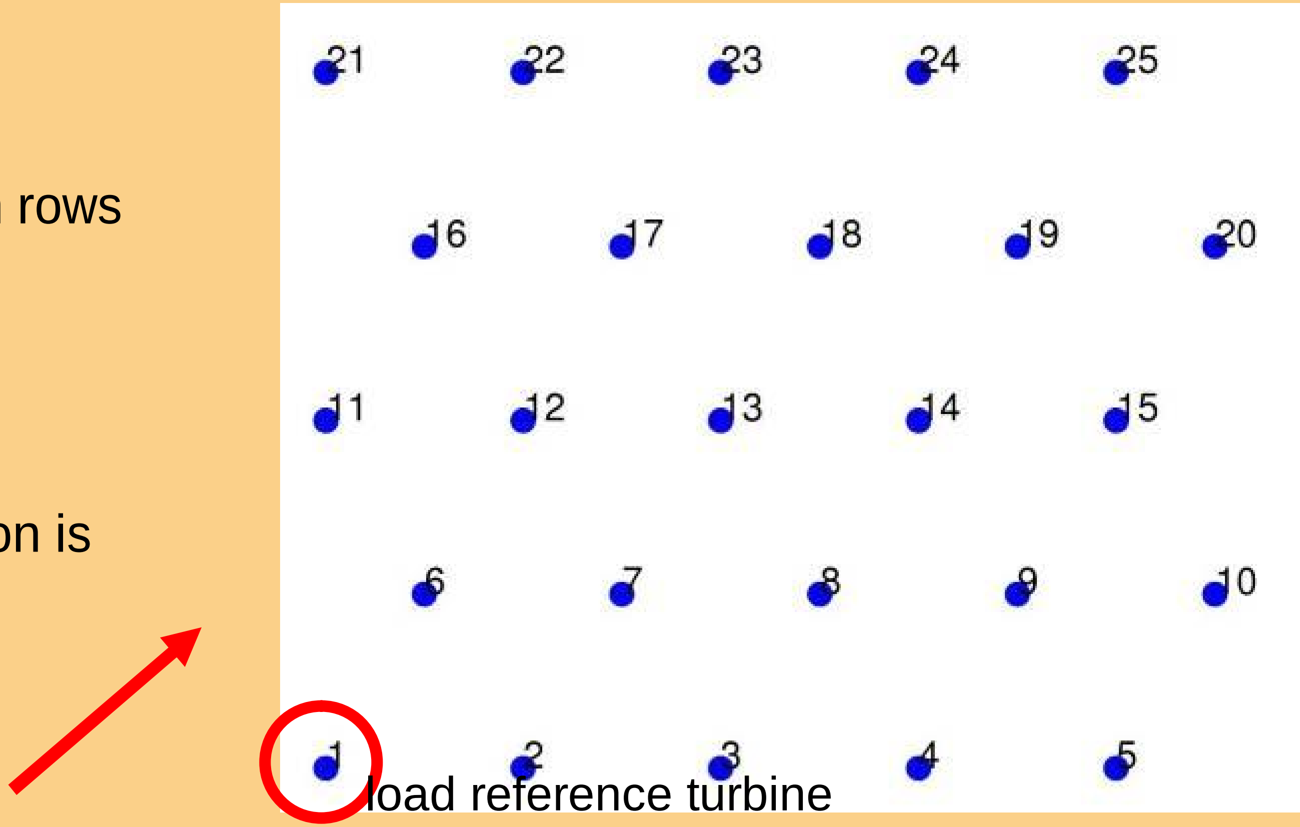


WP 7 Condition monitoring

Model Wind Farm Layout

Model wind farm:

- Distance between rows is 8.3 D_R
- Distance between turbines is 7 D_R
- Main wind direction is roughly SW

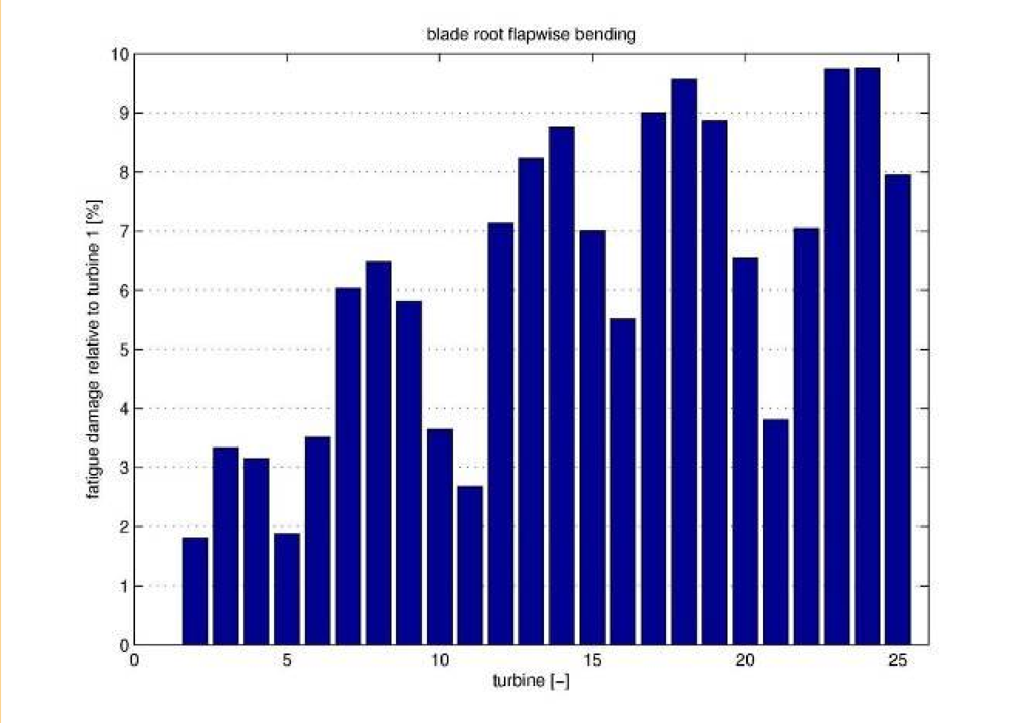


WP 7 Condition monitoring

Relative Loads in the wind farm

<u>Simulation results:</u>

- There is a significant difference in the load exposure to WTs in wind farms
- The more turbines have been passed before, the higher is the loading



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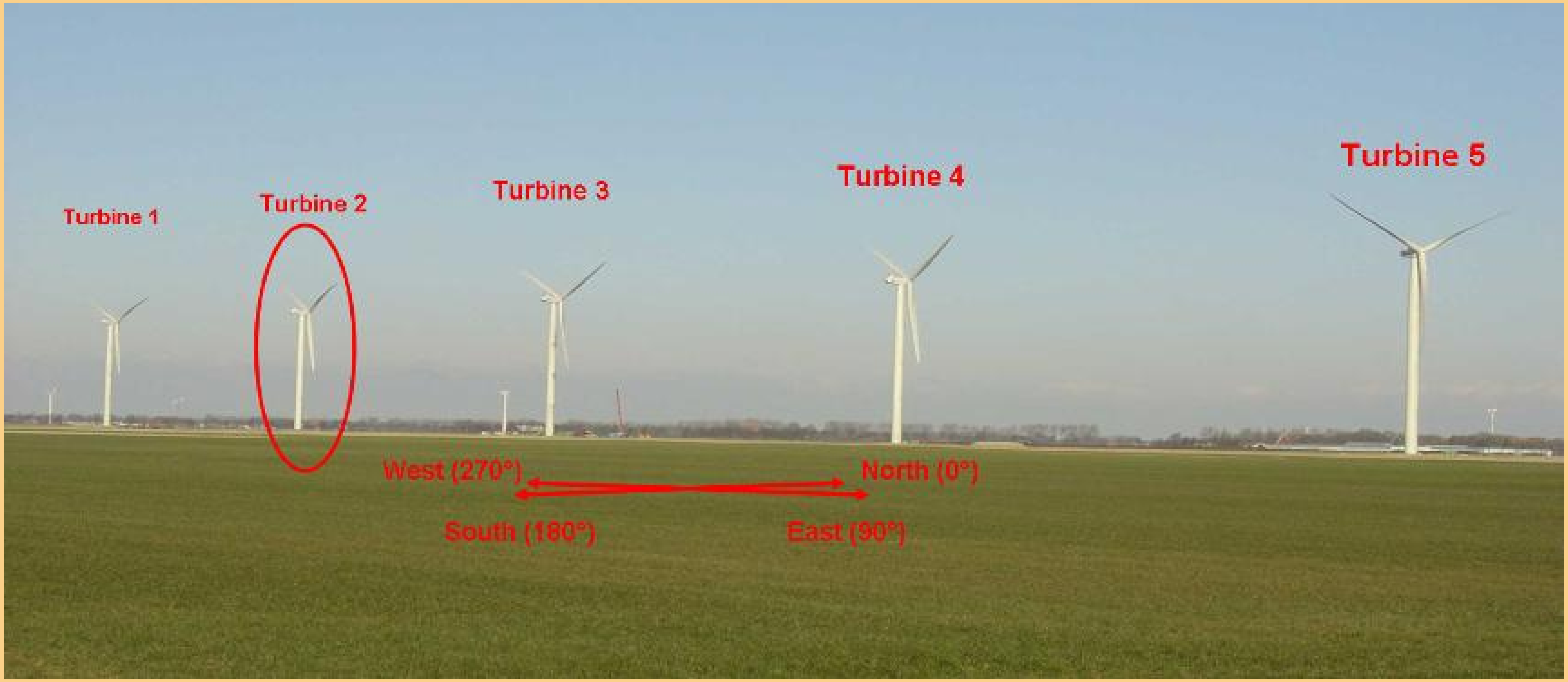
WP 7 Condition monitoring

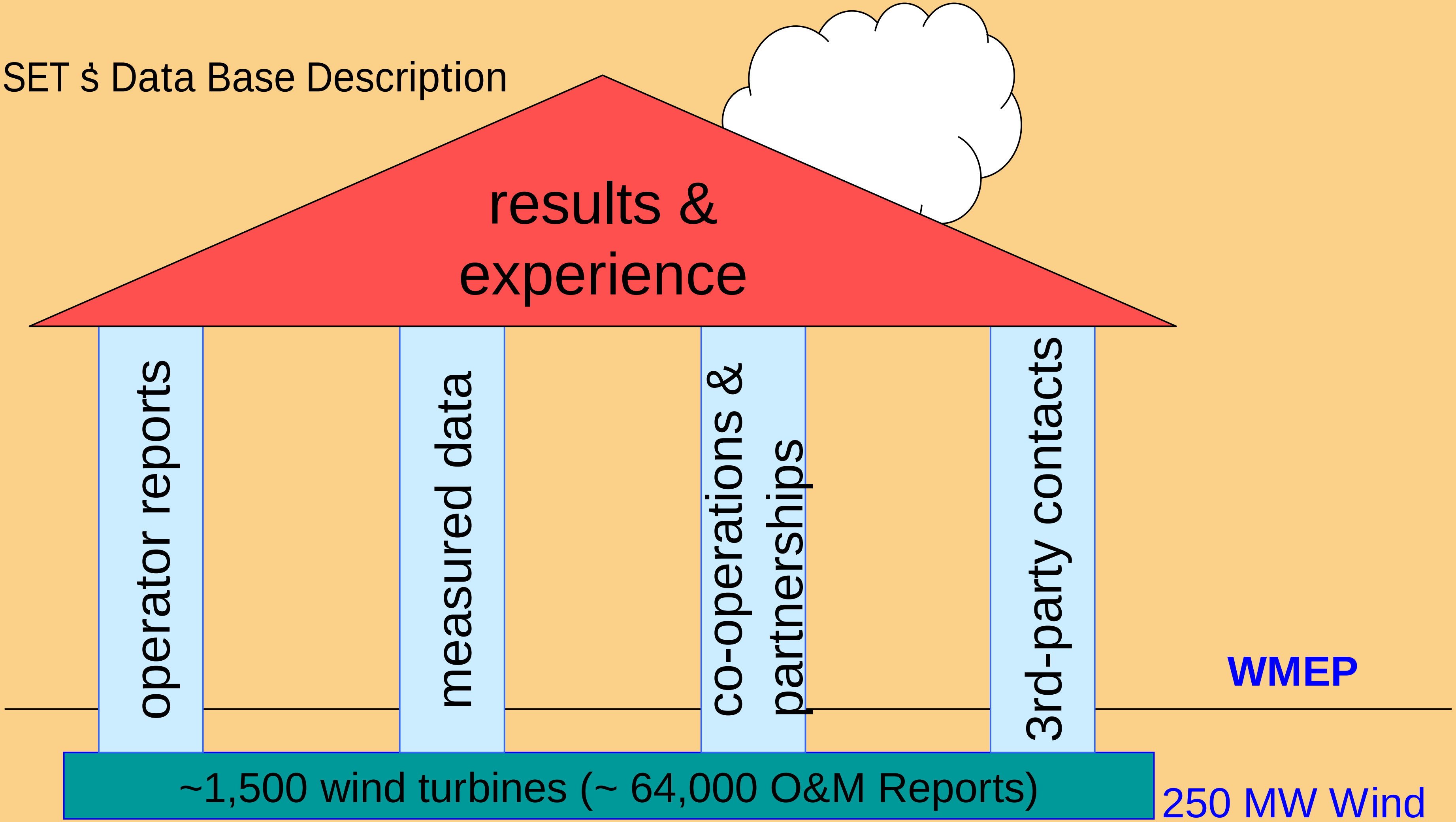
Flight Leader Turbine Field Tests



ECN ṡ test field in Wieringermeer, NL: 5 Nordex N-80 turbines with 2 MW each

WP 7 Condition monitoring

ISET ş Data Base Description



WP 8: Flow

Status

- Wind farms becoming large (multi-row). Wake losses predicted 5-8% but can be (much) larger
- In large offshore wind farms, models over-predicting power output i.e. under-predicting wakes. Not evaluated for large wind farms on land.
- In complex terrain, problem to predict both wind resource and wake losses
- Need new models/measurements to reduce uncertainty and provide accurate power output prediction
- Bridge gap between CFD and wind farm models

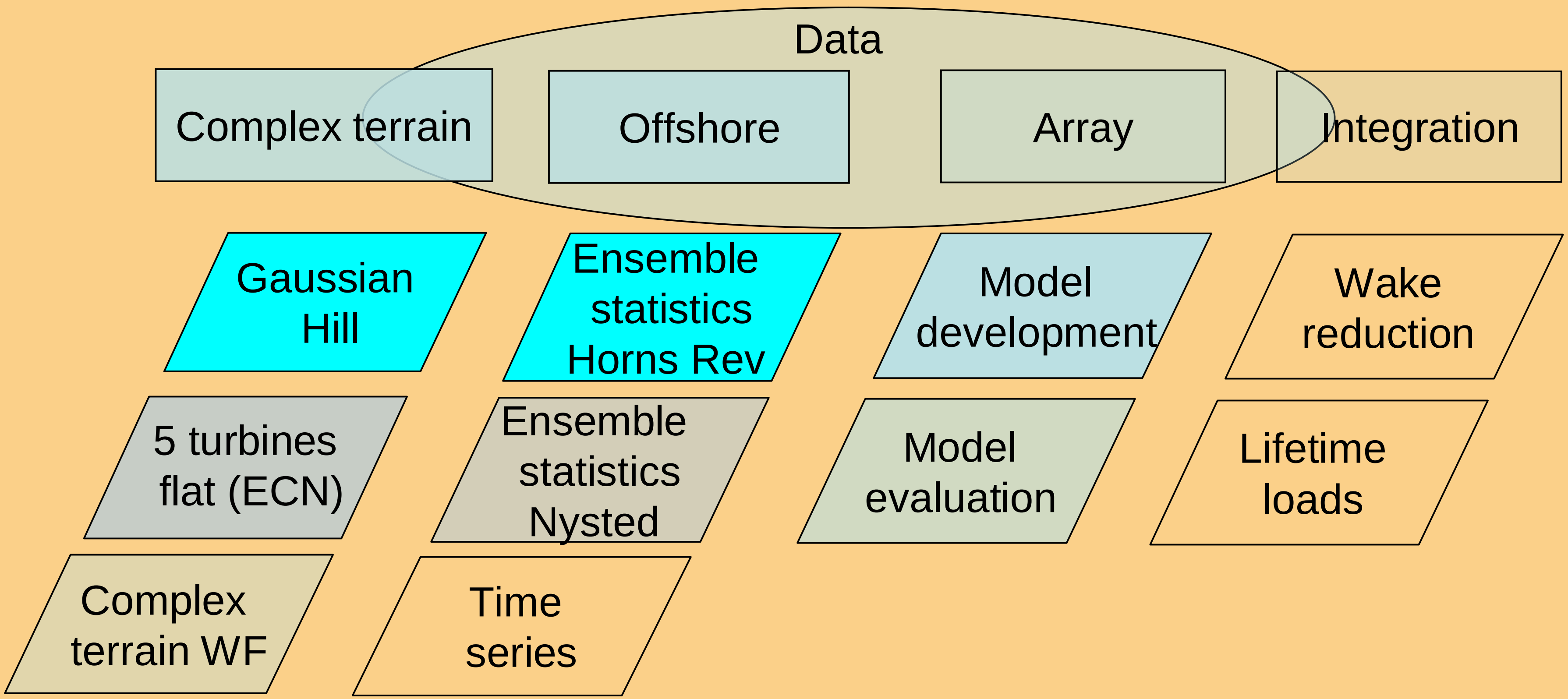
WP 8: Flow

Scientific issues

- **Current wind farm models appear to be missing a process which causes wake recovery to be slower in large wind farms than expected**
  - Feedback between turbines and boundary layer?
  - Multiple wake combinations?
  - Atmospheric stability?
  - Need more data and evaluation of model parameterisations and CFD
- **In complex terrain there is large uncertainty in resource and wake prediction**
  - CFD is seen as a way forward
  - Needs evaluation (a complicated task in itself)
  - Need more data sets
- **For multiple wind farms in close proximity (within 20 km) tools are needed to calculate downstream losses**
  - New models have been developed and need to be moved into the evaluation phase
- **Ultimately the wind industry expects to have a tool which combines wake impacts on power and loads so the optimal layouts can be determined**

WP 8: Flow

Structure of the EU funded UPwind project

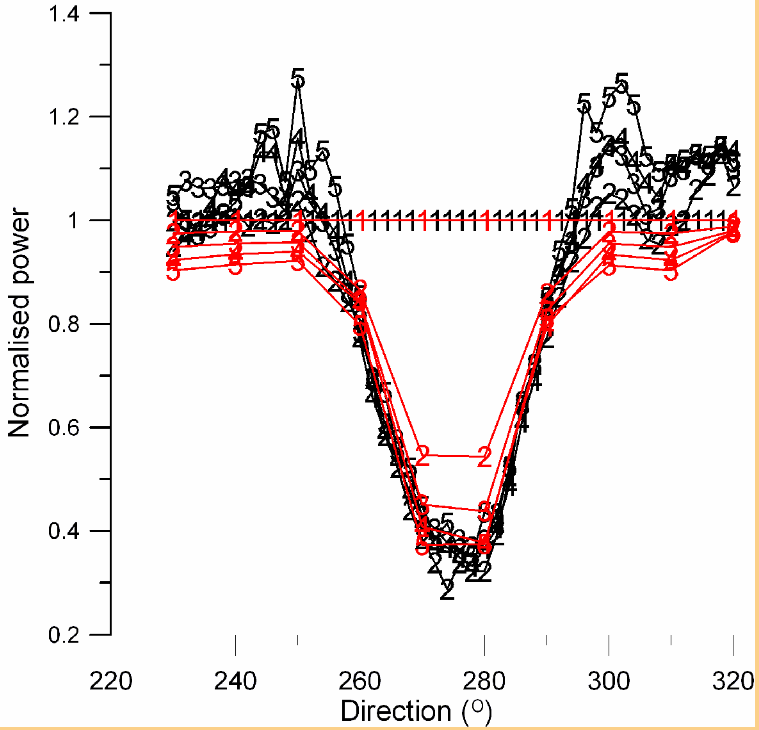


WP 8: Flow

Complex terrain - Research farm

Examining multiple wakes in complex terrain:

- Five **research** turbines (2.5 MW) with one 108m high meteorological mast (mm3)



Results courtesy ECN

WP 8: Flow

Complex Terrain –Wind farm data

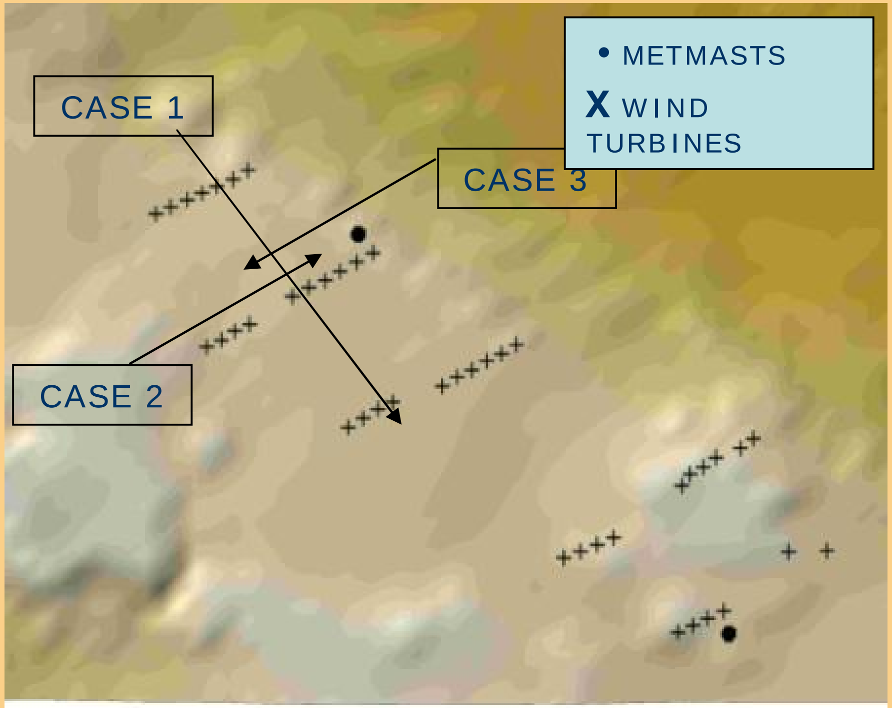
5 alignments NE-SW in moderate complex terrain

Wind farm data:

- 43 WTs x 700 kW
- Met masts WS & WD
- WT Nacelle Power
- WT Nacelle WS & WD

Three cases:

- Case 1: 325º±5º, 13D spacing
- Case 2: 247.5º±5º, 1.5D spacing
- Case 3: 67.5º±5º, 1.5D spacing



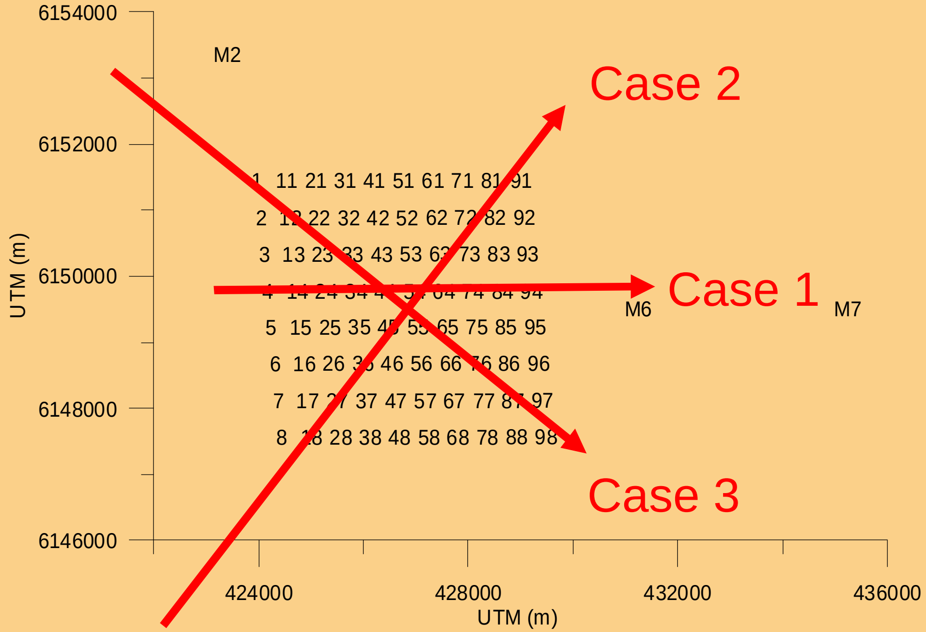
Data courtesy CENER

WP 8: Flow

Horns Rev - Ensemble statistics

Averages
- Identical conditions (ws,wd)
- Maximise number of observations
- Discrete in time
- Small wake widths=limited obs.

First set
- Direct down or across rows
- Different wake widths

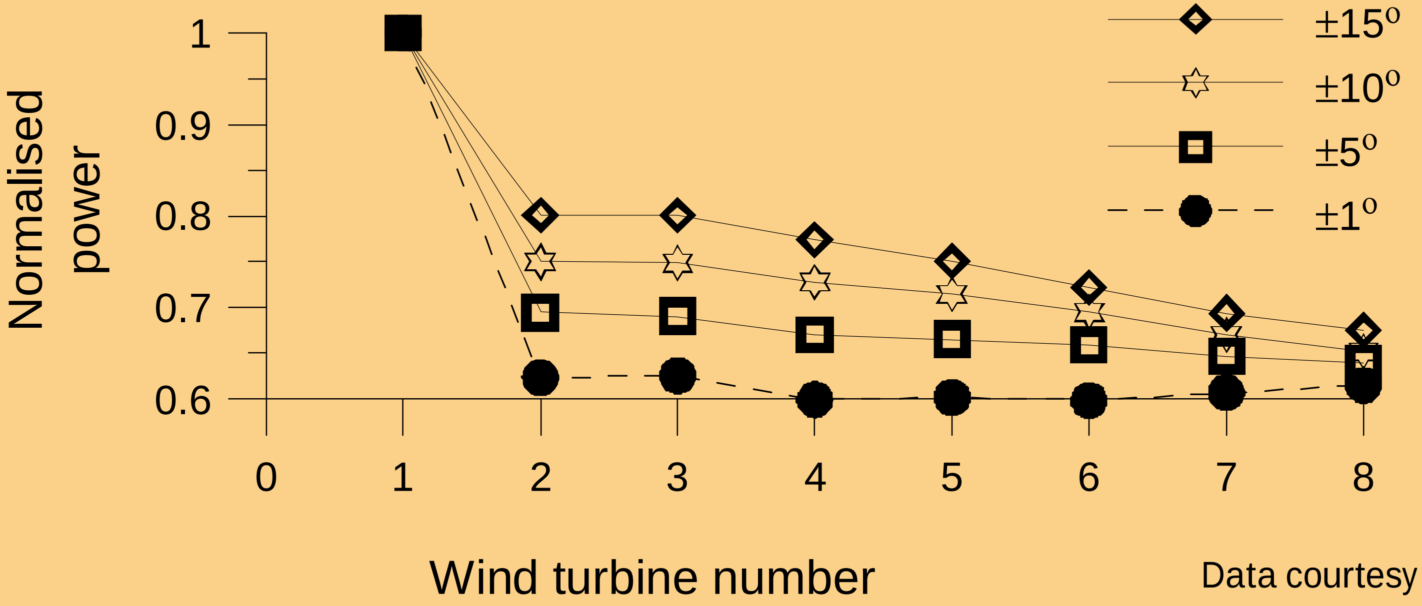


WP 8: Flow

Measurements at Horns Rev

Measurements directly down the row

- Case 1 (7D)
- Normalised power
- U at first turbine 8.0±0.5 m/s

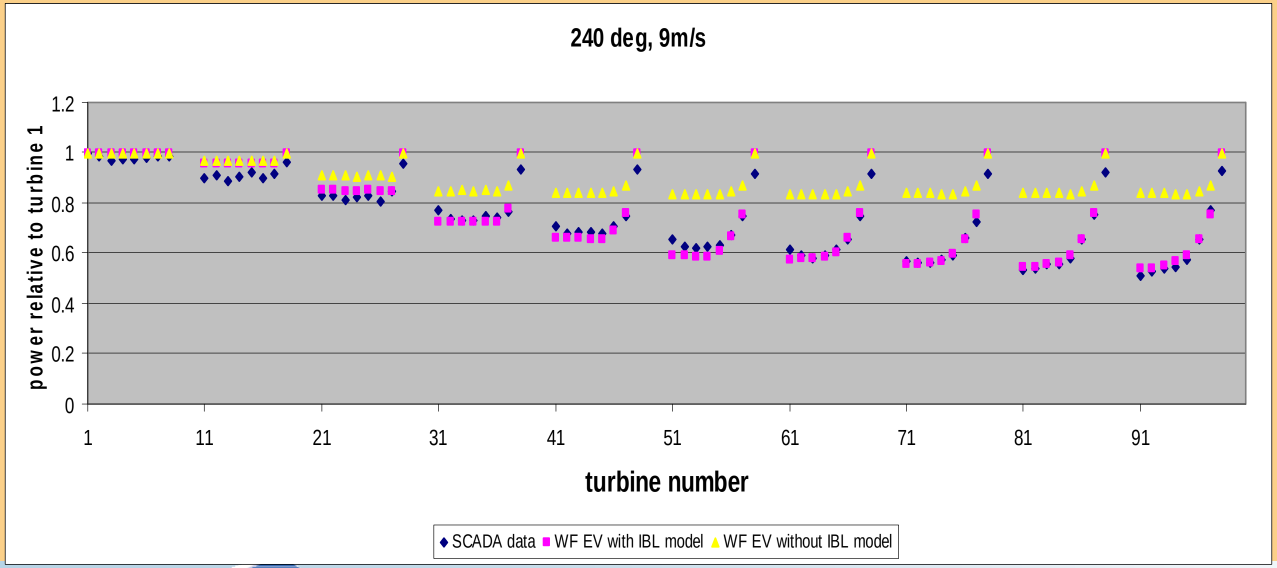


Data courtesy DTU

WP 8: Flow

Array effects - Results

- Tuning of TI (or via roughness) - good agreement with measurements
- Wind speed within the wind farm drops < 80% of freestream
- Recovery to ~ 90% occurs within ~5km of wind farm end
- Further recovery over ~20 km
- More: Frandsen et el. EWEA 2008/Risø-R-1615



W. Schlez,
Garrad Hassan & Partners

SIXTH FRAMEWORK PROGRAMME

UpWind

WP 8: Flow

Summary

- UpWind project
  - Provides platform for undertaking model evaluation
  - Provides platform for data sharing
  - Combined activity is most effective
- Progress made
  - Data sets collated and analysed
  - Model evaluation complete/underway
  - Areas for model development illustrated
  - 4 deliverables available at www.upwind.eu (made public)
- Future
  - Minimise power losses due to wakes
  - Integration of loads and power to give optimal layouts

WP 9 Electrical grid

Expected results

- Improved reliability assessment
- Better integration in power system
- Electrical design requirements for future wind turbines
- Cost analysis

WP 9 Electrical grid

Status of work

- Survey of wind farm reliability (completed)
- Reliability database (complete)
- Investigation on power system requirements for high wind penetration (completed)
- Study of wind farm design (nearly completed)
- Evaluation of extreme wind and control (pending)
- Work on cost function (just started)

WP 9 Electrical grid

Cost modelling; reference turbines and wind farms

Wind turbine electrical power:	5MW	20MW
Rotor diameter D	126m	252m
Tip speed	80 m/s	80 m/s
Hub height H	90m	153m

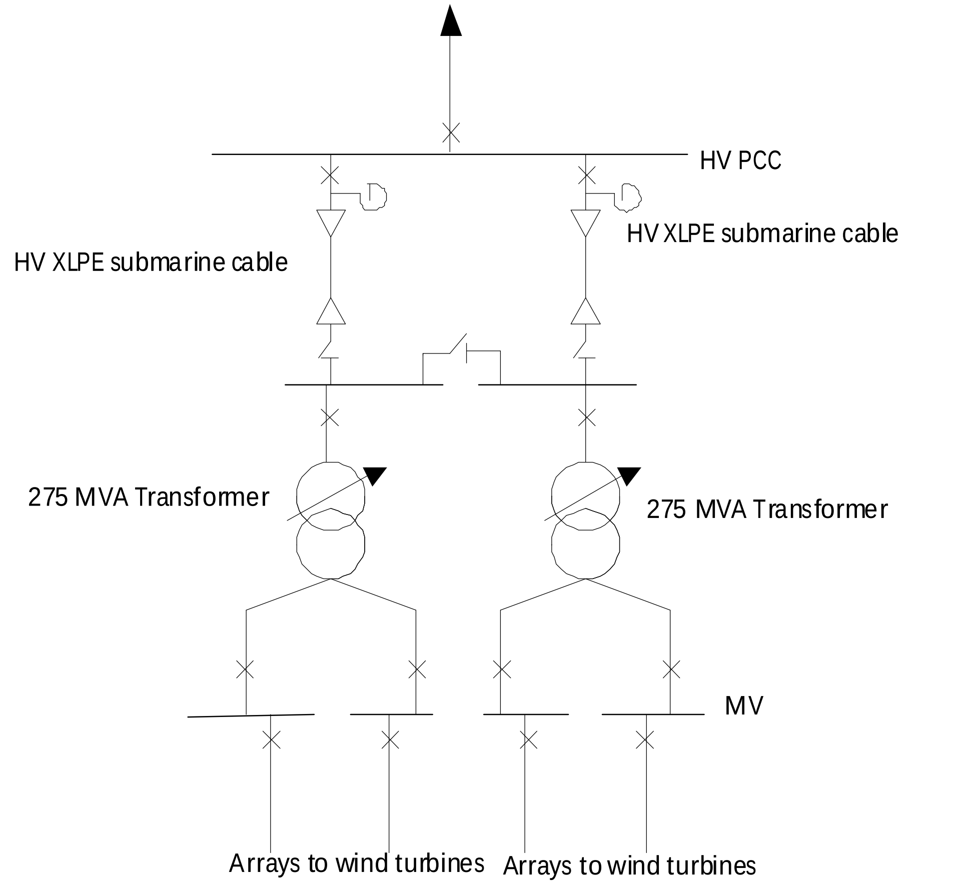
Reference wind farm	500 MW	1000 MW
Water depth	30 m	60 m
Distance to shore	25 km	100 km
Area	Square	Square / double square

WP 9 Electrical grid

Cost modelling; grid connection architecture

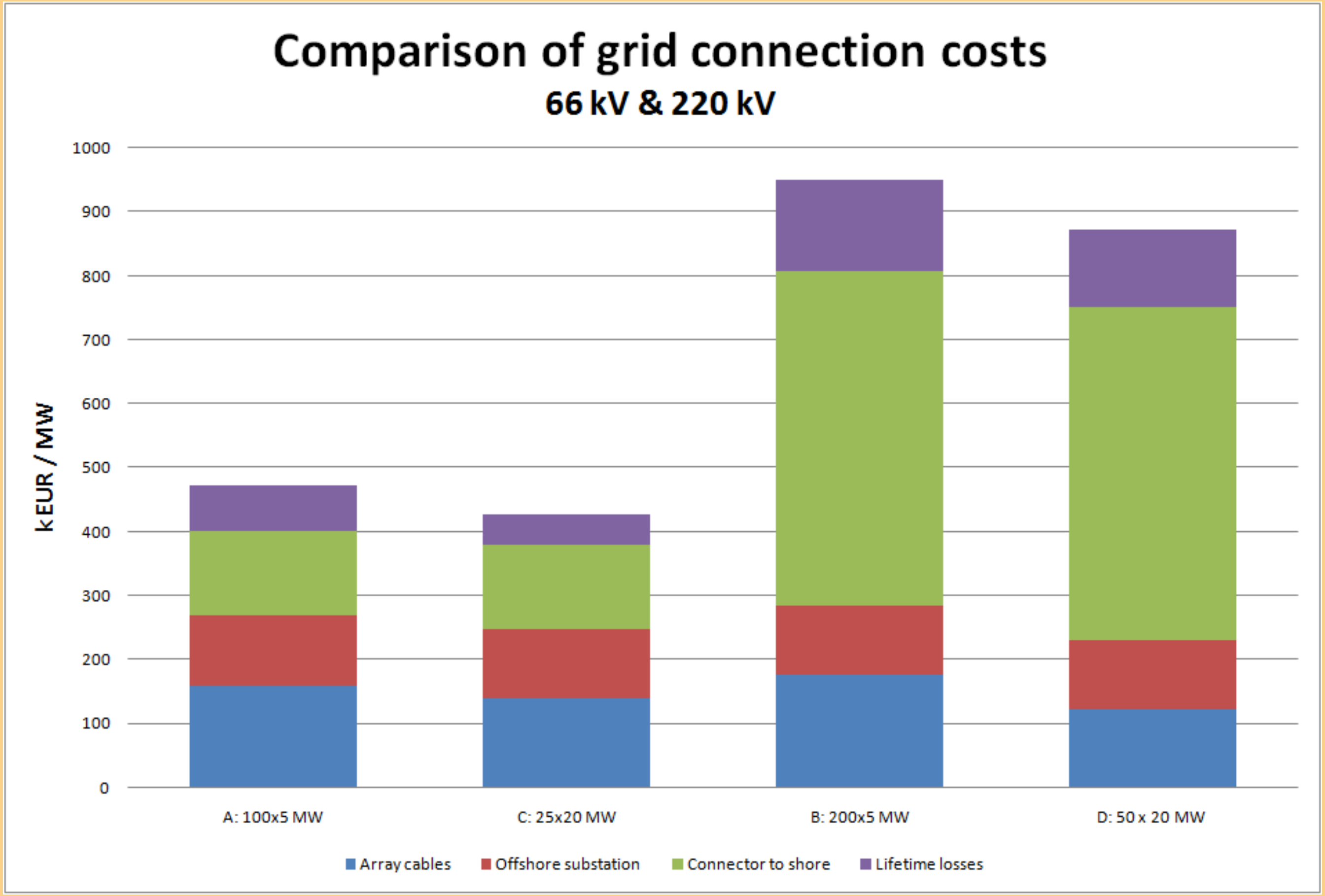
Simplifications:

- AC only
- Standard layout
- Present design principles



WP 9 Electrical grid

Cost modelling; comparison different configurations



WP 9 Electrical grid

Cost modelling; Conclusions

- Increase of voltage level of internal network is important
- Increase of voltage of connector to shore
  220 kV technical limit for AC. DC to be considered
- Costs mainly depending on distance to shore
- Costs are less depending on wind turbine size.

WP1A.3 Education and training

- Development of a number of training modules for international courses and the necessary supporting education/training material.
- To provide a modular framework for training

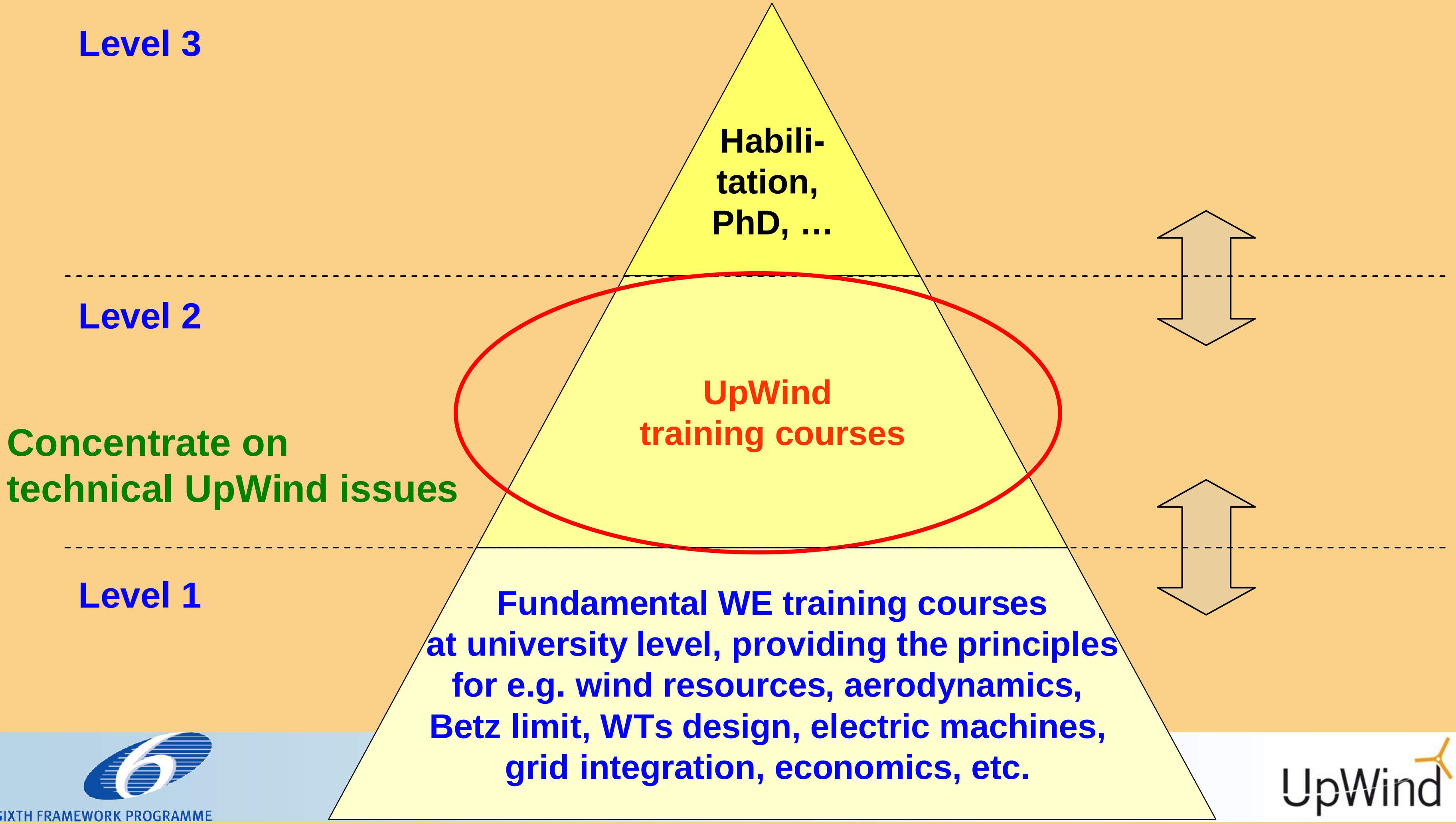
WP1A.3 Education and training

- researchers, post-graduate students → PhD level,
- industrial engineers (in particular those employed in SMEs), energy planners, project developers and consultants

- Training content: the state-of-the-art knowledge recently produced in particular results/outputs of the other WPs of the UpWind project.

WP1A.3 Education and training

Stages of wind energy training and education



WP1A.3 Education and training

Results

- It is **integrated** in the Renewable Energy Knowledge Transfer Network - **REnKnow.Net** (www.renknow.net)

WP 11 Dissemination of knowledge

EWEA

SIXTH FRAMEWORK PROGRAMME

UpWind

WP 11 Dissemination of knowledge

Challenge

Research activities

Results and expectations

Contact data

Participants of WG

THE RESEARCH ACTIVITIES

The main research activities for the integral design approach and standards' work package include:

- Defining and updating a reference wind turbine and a reference technical-economic cost model for benchmarking to be used for communication of the design parameters and design developments and the main economic and dynamic performance parameters for all UpWind project activities;
- Development, application and evaluation of an integral design approach methodology in offshore wind turbine design;
- Development of standards in general and for the application of the integral design approach, including definitions of interfaces between models, including data needs, specifications and protocols;
- Definitions and specifications of experimental data to be condensed into input design parameters for the design models or to verify critical design and performance issues.

In practical terms, the above research activities are sub-divided into 4 tasks.

SUBTASK A: REFERENCE WIND TURBINE AND COST MODEL

The subtask is dedicated at facilitating the integration of the different activities in all the horizontal (and vertical) work packages throughout the project. For this, a reference wind turbine will be defined to provide a basis for communication and comparisons. The design parameters and the main characteristics, including results of parameter sensitivity studies, will be defined and kept up to date. Input data will be provided from the other work packages. The data will be made easily accessible to all partners in the project.

SUBTASK B: INTEGRAL DESIGN APPROACH METHODOLOGY

Other technology sectors, such as air-transport, have experienced a development similar to wind energy with respect to increasing complexity and focus on specialists. For some of these technologies "Knowledge Based Engineering" (KBE) is investigated as a means to increase productivity of the design teams and to reduce the boundaries between disciplines. KBE tries to model not only properties of a product, but also the knowledge about the product that captures the engineering intent behind the design. KBE can be used in Design and Engineering Engines (DEE), to automate the multi-disciplinary processes. This automation is not intended to replace the design team, but rather to replace routine activities and to improve efficiency and consistency of information exchange. As a result, design teams will have more time for their creative contributions and thus can increase their productivity. Core element of the DEE is a (multi-) model generator in which the parametrical description of the product resides. It gets input from a concept generator and (re)generates the input for the analysis tools: the discipline silos. Typically, the discipline silos are commercial off-the-shelf analysis tools. The Knowledge Based Engineering tools reside in the concept generator.

Thus, the objective of this activity is to assess the feasibility of this approach for wind turbine design and to develop the knowledge needed to generate a DEE for this purpose. It is noted that the analysis tools in the discipline silos are external tools and are not part of the development undertaken in this activity. However, this activity will contribute to and make use of the common formats developed in this task, as these represent the interfaces between the model generator and the analysis tools. The reference turbine will be used as a case study.

Horizontally the scientific work packages are displayed and vertically the integration work packages.

SUBTASK C: DEVELOPMENT OF (PRE) STANDARDS FOR THE APPLICATION OF THE INTEGRAL DESIGN APPROACH

This subtask is dedicated to the development and formulation of standards in a broad sense, and for the application of the integral design approach of subtask B. Hence the subtask C aims at integrating the design models, experimental methods and concepts arising from the horizontal work packages.

SUBTASK D: INTEGRATION, REVIEW AND PLANNING WORKSHOPS

This subtask focuses on coordination and cross-cutting activities.

RESULTS AND EXPECTATIONS

So far cost functions for the components of the wind turbine, for which the input from parallel project activities is needed have been developed.

This WP works in close cooperation with the WP Upscaling (1B4).

The final results of the work package include:

- Guidelines for the integral design approach, including guidelines for design models, experimental methods and concepts arising from the scientific WP's;
- Recommendations and pre-standards to be submitted for IEC/ISO and CEN/CENELEC for the revision or development of international standards for design and tests of wind energy systems.

www.upwind.eu

Thank you for your attention !

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