CWTC Business Plan

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CWTC Business Plan

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Risø-R-1777(EN)
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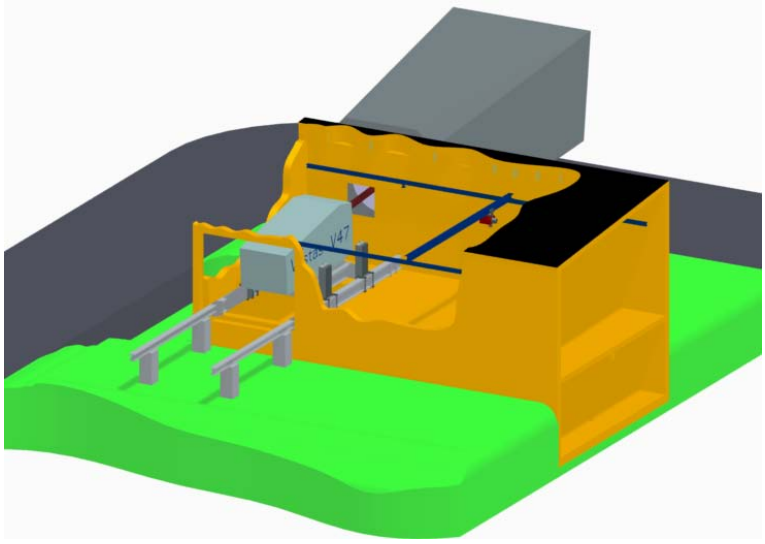

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Abstract (max. 2000 char.):
This report presents the Business Plan for the establishment of the Wind Turbine Component Centre (CWTC) to meet the objectives of performing theoretical research and experimental testing. The core idea of a CWTC is to support the Danish wind energy industry and research activities at the component level improving the competitive advantage of that industry.

The CWTC will in itself operate its activities, including access to test and experimental facilities, on a semi commercial basis. The business model for the CWTC presented is based on revenues coming from component manufacturers as well as research grants, and will include membership fees as well as hourly payment and larger projects where payment is a limited project sum.

The presented roadmap model clarifies the development path towards a fully developed CWTC, which will cover test of all important components along the drive-train as well as offering a comprehensive systematic understanding of the entire drive-train.

The CWTC will over time market and sell its products and services on a global scale, but first and foremost the CWTC is established to support and strengthen the Danish wind energy industry and specifically the Danish sub suppliers to the Danish wind turbine industry and also the Danish research establishments.

The presented organizational structure reflects that there are certain functions that are separated from the operations and it also reflects that scientific staffing are hired in on a project basis. Machine operators will be hired in on a permanent basis.

The breakdown of the cost for running the rig, both for R&D and commercial projects is presented. The income from the other activities is calculated based on the cost for the research staff, both for R&D activities and commercial. In the first year the income will be 100% from R&D activities, which is the cost for the staff to set-up the test-rig, the guidelines and test procedures, and partly for running the rig.

Within 3 years of operation the CWTC is expected to provide the full list of products and services, as described in the road-map, with around half of the activities being research based and the other half commercial. The first year of operation is expected to be pure research based, with the development of test cases, guidelines for testing, initial set-up and calibration of the test rig etc.

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Preface

CWTC is the acronym for Centre for Wind Turbine Components. A project supported by the Danish program EUDP J.nr. 63011-0064.

The CWCT project participants: Technical University of Denmark headed by Risø National Laboratory for sustainable energy. FORCE Technology, Teknologisk Institut, Aalborg Universitet, DONG Energy .

The objective is to establish a Wind Turbine Component Centre performing theoretical research and experimental testing within the area of wind turbine systems and components. Through these activities CWCT will contribute to the continued technical as well as commercial development and improvement of the component and the wind turbine industry, which is of outmost importance for sustaining Denmark's position within the wind energy industry.

CWCT will be part of a network of research and test facilities in Denmark, that support all aspects in the development process of next generations wind turbines from idea to product. Most important however is the direct and indirect (parallel) commercial effects which are expected to be seen in the value chain (component suppliers and wind turbine manufacturers) both in strengthening existing companies and opportunities for the establishment of new companies.

To facilitate these results CWCT will be engaged in a number of different activities, including knowledge and competence building at the highest international level, education and training, documentation and demonstration of wind turbine components and systems. Moreover, CWCT will through research, tests and consultancy establish a research environment, develop methods to design and test components to wind turbines, carry out tests to verify wind turbines and wind turbines systems. CWCT also intend to work with verification and compiling experiences from operation of wind turbines, including troubleshooting, analysis of wind turbine failures, reliability analysis and performance of components and wind turbines.

Finally CWCT will contribute to education and training of engineers in design and construction of wind turbines.

At present the physical frames and conditions for the CWCT are under establishment and construction works has taken place at DTU at the premises of Risø DTU. For CWCT itself and how the connected activities are to be in the future is envisaged in present business plan.

1 Core idea and perspective

1.1 The need for a Centre for Wind Turbine Components

One of the present major challenges for both wind turbine manufacturers and sub suppliers to the wind turbine manufacturers is the specification of the individual components in the wind turbine, the interaction between components in the system and the performance of these. Modern MW wind turbines and their sub-systems are highly complex designs, the specification of which is accomplished with the help of advanced calculation- and simulation tools.

A wind turbine is currently designed and dimensioned on the basis of the IEC 61400 standards, mainly the design requirements (Part 1), which result in a series of load calculations/simulations aimed at ensuring a turbine life time of 20 years. There are additionally different kinds of standardized tests for components such as gear, bearings and generators. However there are no standards for the experimental testing of components for the experimental verification of the component characteristics of wind turbine generator systems under conditions realistically simulating those experienced over the turbines 20 year lifetime. The final test is when components are implemented in wind turbines in operation. With the current situation, it is the case that many components have to be replaced before the 20-year expected lifetime: a gearbox for example is replaced on average on a wind turbine 2 to 3 times over the 20-year period. The implications of an insufficient understanding of the requirements for components developed for the use in wind turbines are many.

As demand for wind turbines seems to increase over the coming years many new competitors are entering the market, mainly in new economy countries like India and China. The entire value chain will be impacted and downstream new suppliers to wind turbines will evolve who will be – even more – limited than existing suppliers in their ability to develop components for the wind turbine industry. Transformation of market structures always includes a risk, and one of the dominant ones here is that the market will be flooded with components of varying quality which the manufacturers will only test during operation in the wind turbine. Seen from an industry point of view, component quality can therefore be one among a number of competitive parameters for the wind turbine manufacturers.

Thus, component suppliers and wind turbine manufacturers are in a situation where technical complexity is high and the market situation is subject to change with many new competitors who might differentiate heavily on price and quality. Furthermore the realization of really large structures like 20MW wind turbines might be difficult without a more dedicated focus on understanding both the individual components in the system and the system itself. Overall, there is a great need therefore to develop new knowledge, competences and test methods for design and verification of wind turbine components and systems and to increase collaboration in this area between component suppliers, wind turbine manufacturers and the research establishments.

Seen from a national Danish level it is a strong interest to support the Danish wind energy industry which is one the industrial locomotives in the Danish economy and help improving the competitive advantage of that industry. In other words, not only at the industrial level there is a need for a more subtle understanding of wind turbine components and their interplay in operation in the wind turbine. Also on a national level there must be a keen interest in strengthening the Danish wind turbine industry.

There is a clear need for a Centre for Wind Turbine Components (CWTC) established at the premises of Risø DTU, which already at initiation will have the necessary competencies and high level technical capabilities to develop superior understanding of wind turbines components and the interplay in the wind turbine. The CWTC will provide a strong link and communication path for the component suppliers and wind turbine manufacturers to develop a common language and understanding of the issues related to WTG component design and reliability. Furthermore it will provide a sharing and access to knowledge between the component suppliers, wind turbine manufacturers and the university research community in the field of experimental component testing, measurements and data analysing.

The core idea of a CWTC is to support the Danish wind energy industry and research activities at the component level. To further this aim, the CWTC is planned to form a relation with the test bench facility which is currently being planned at Lindø Offshore Renewable Centre (LORC) to support mainly the wind turbine manufacturers and wind turbine developers with test facilities of up to 10MW rated, 20MW peak power. As such the CWTC together with the LORC test facility will offer a comprehensive and complementary supply of testing opportunities thereby providing a strong support for component suppliers, wind turbine manufacturers and wind farm developers.

Expected benefits coming from the CWTC can be summarised as:

- Faster product development thereby increasing competitive positioning opportunities and ability to meet increasing demands from the wind industry;
- Better, more reliable components and WTGs;
- Improvement of internationalization prospects thereby increasing opportunities for market development and increase in turnover for both sub suppliers and WTGs;
- Better warranty conditions for WTG's due to more reliable turbines;
- Higher reliability of energy supply;
- Higher income for wind turbine operators due to decreased maintenance expenses and downtime costs.

As part of development of new knowledge, methods and experiment tools indirect effects which might appear in parallel with the above more direct effects – are expected to materialize in the form of:

- Development of new technologies, materials and conceptual tools directed towards use for component suppliers;
- A marked increase in research in this field;
- Development of new business areas, new markets and new (start-up) companies to commercialize on inventions resulting from the above activities.

1.2 Basis for operation and business model

The CWTC will in itself operate its activities, including access to test and experimental facilities, on a semi commercial basis. The business model for the CWTC is based on a combination of research grants and revenue coming from component manufacturers. The expected proportion of time for research activities versus commercial services is expected to be, in the long-run, about half.

The commercial operation and research activities of the CWTC will be based on the service and product portfolio offered to component suppliers to the wind energy industry, described in the Road-map model below. The portfolio of services will range from short term (here and now) advisory to long term testing of components. Component manufacturers will have to pay a yearly member fee to cover access to the portfolio of services. In that way the CWTC will operate an exclusive model where only members can use the CWTC and be accepted as customers. On top of the member fee customers will have to pay for services on a combination of a per hour base for which will be divided between lease of the test facility and needed man power to run the test and make necessary analysis following the test.

Manpower costs will be split between different categories of employees according to DTU's normal commercial rates for consulting services. The CWTC will not base its revenue on certification of components or entire systems for wind turbines, but will engage in the development of a strong technical foundation for testing and development of guidelines for experimental testing of WT components, with more research and development oriented activities focusing on understanding future load cases and anticipating component requirements accordingly.

Even though CWTC is not considered to be a high growth business case and the size of the market potential is not measured in billions of dollars, the potential impact is huge. CWTC will support the sub contractors in their endeavors to develop components for the wind turbine manufacturers who tap into a multimillion dollar market opportunity.

The central point here is that CWTC is an enabling tool that will help create value for predominantly Danish sub contractors and their customers, the wind turbine manufactures.

The global market for wind turbines can give an impression of the market opportunities that can be realized with the contribution from CWTC.
According to BTM World Market Update, the total market for wind turbines is expected to increase significantly over the coming years as can be seen from the forecast (Figure 1) below.

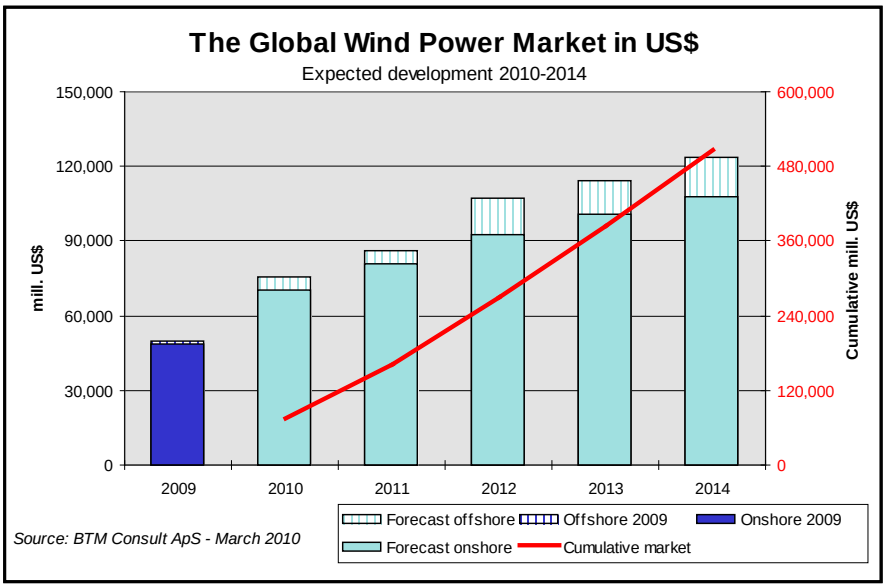

Figure 1 Global Wind Power Marked in USD

Vestas alone have a market share of around 12.5% (2009), currently worth more than USD 5 billion. As competition increasingly becomes fiercer the need for solutions (components) that will provide competitive advantages over competitors increases as well. Seen from that perspective the added value of CWTC can be realized in terms of sustained (or increased) market shares that for Vestas alone in 2014 add up to more than USD 7 billion.

Thus, to conclude, CWCT as an individual business case is probably not a new high growth/high value start up, but it is potentially a high impact construction that can contribute to realization of major increases in value for companies in the Danish wind industry.

1.3 Partners and CWTC

The initial project participants: Force, DTI, AAU, DONG Energy and DTU/Risø DTU in the CWTC establishment is composes by a number of Danish Universities, Research Centre and Approved Technological Service Institute as well as a large energy supplier with a common strong interest in the development of reliable wind power production.

The partnership adds a strong basic knowledge pool on testing of components and subsystems as well as the utilizing the common pooling access to a number of subtest facilities located at the partners premises respectively. This comprises e.g. highly specialised mechanical or chemical tests or targeted methods such as climate chamber testing, high pressure hydraulic tests, load and stress testing, mechanical root cause analysis after failures, testing of high tech welding methods etc.

1.4 CWTC and LORC

The CWTC will also engage in relations with complementary partners among which the primary one is the LORC drive-train test bench facility. The fundamental

rationale for cooperation between the CWTC and the LORC test bench facility is a division of activities and customer segments: the CWTC will mainly be focused on research into testing methods, guidelines development, component design, among others, and customers are mainly the component suppliers; the LORC test bench facility will mainly be focused on commercial drive-train testing and wind turbine manufacturers. CWET and LORC will also prepare and perform R&D activities together. Thus even though the CWTC will be built around a service portfolio described below, it is not expected to be a highly profitable business unit with a high growth commercial potential. The LORC test bench facility on the other hand is expected to realize early profits and to have better prospects for being a successful commercial operation.

The CWTC still serves an important role both in terms of supporting development of high quality components but equally as important in terms of enabling the commercial success of the LORC test bench facility. Specifically concerning the later, as the CWTC has already initiated operations, successful test projects will act as showcases of what can be realized at the LORC test bench facility. These demonstrator projects are also of a much less burdening cost structure due to the scale of the tests. That opens up for a more research based approach and over time a catalogue of successful testing methods and procedures, knowledge base and experimental methods can be adopted at the LORC test bench facility where the cost structure has stronger impact for the customers. Furthermore, the location of CWTC at the premises of Risø DTU allows for pooling of knowledge and skills from a highly specialized group of researchers in wind energy and wind turbine technology.

1.5 Summary

The core perspective on the establishment of the CWTC is that development of components for wind turbines is an increasingly complex process and that quality of components needs to be well validated and verified. Moreover, the demand for wind energy is expanding, impacting the entire value chain upstream as well as downstream. The CWTC will address the need for research and development of new components and quality verification of existing components through the development of the field of experimental testing procedures for wind turbine components. The CWTC will furthermore provide a strong link and communication path for the component suppliers and wind turbine manufacturers to develop a common language and understanding of the issues related to WT component design and reliability, as well as provide industry direct access to the research community in the field of experimental component testing. There is a strong relation between the CWTC and the LORC test bench facility, a clear division of activities between them and interdependence as the CWTC will help enable the success of the LORC test bench facility. The business model for the CWTC will be based on revenues coming from component manufacturers as well as research grants, and will include membership fees as well as hourly payment and larger projects where payment is a limited project sum.

2 Products and Services

The CWTC will offer a number of products and services targeted at sub suppliers to the wind turbine manufacturers and wind energy research establishments.

The roadmap below clarifies the development path towards a fully developed CWTC, which will cover test of all important components along the drive-train as well as offering a comprehensive systematic understanding of the entire drive-train. The service and product portfolio provided by the CWTC are described in the Road Map section as WTGs component design activities. The first successful sale of products and services is expected to happen within the first 12 months of operation and the CWTC will start offering additional complementary products and services according to the product road maps described below.

The development of the product and service portfolio will correspond to market demand, but being an innovative centre of excellence, the CWTC will also bring new products and services to market where CWTC anticipates future needs. In that way it is the intention of CWTC not to wait for industry players to acknowledge their needs for testing but to proactively help defining particular needs that will strengthen the competitive positioning opportunities for Danish sub suppliers of components for wind turbine manufacturers.

The products and services offered by CWTC will range from short term advisory / "hotline" services to high level testing services building on complex methodologies and a full understanding of the entire drive-train developed on top of many years of research at DTU/Risø DTU.

Over time CWTC will make sure to turn certain test and testing methodologies into guidelines after which sub suppliers must test their components. Over the long run CWTC will also be able to perform verification services according to developed guidelines and as such serve as an accrediting authority thereby creating demand for (some of) its own services.

2.1 Road-Map Model

The WTGs component design activities at the CWTC outlined below are a road-map in the support of component quality assurance and application specific component design. For each given research or commercial project all the specified activities may not necessarily need to be provided by the CWTC, or need to be completed at all, but this would need to be assessed on a project to project basis. The listed activities may thus be viewed as a description of the service and product portfolio provided by the CWTC, but also as a check list against which the projects will be described and evaluated. This road-map model will be updated and refined in the future with the knowledge and experience gained from the CWTC operation.

WTGS component design activities

Before the actual physical testing of a component in the test rig (activity 7), two key tasks need to have been completed.

- Firstly the **design envelope for the component** in the system i.e. the required tests needed, for the acceptance of the component against specified acceptance criteria, needs to be defined, both experimental tests and in simulation tests (activities 1, 2, and 3 below).
- Secondly the **specification and physical adaptation of the test rig** set-up, for the specific component, including instrumentation, needs to be defined (activities 4, 5, 6).

Once the defined tests on the test rig and in simulation have been successfully completed, the assessment of the component against the acceptance criteria and a component design review (activity 8) can be carried out.

Activity 1: System description (loads, dynamics, vibrations, temperature)

a. System modelling (full dynamic model/HAWC2, FEM, Multi body simulation)
b. Full calculation and simulation: all IEC 61400-1 load cases
c. Design envelope for component in system

Full aero-elastic models of the complete turbine will be implemented, as will a linearised model, to study the dynamic response of the full system, define the modes etc. The fatigue and ultimate loads will be calculated for the turbine, as described in 'IEC 61400-1: Wind Turbine – Part 1: Design requirements', from which the load cases for which are relevant to for the specific component can be identified.

Activity 2: Component in system

a. Definition of design driving load cases
b. Calculations and simulations
c. Design situations for component in system (Strength/lifetime/performance)

From the previous full turbine analysis the design envelope for the component will be further investigated to define the design driving load cases (fatigue and ultimate loads). Additional load cases not included in the IEC guidelines, that could be a design driver for the specific component, will be added. All these load cases will be run on more complex models of the component, including MBS and FEM. If relevant the additional load cases will also be implemented on the full aeroelastic model (step 1). The numerical studies (MBS and FEM) investigate the performance, strength and lifetime of the component and its response (instability/collapse and critical frequencies) and give insight into which tests need to be run to fully test the component.

Activity 3: Documentation of design basis for component

a. Required calculations for acceptance
b. Required tests for acceptance
c. Scale effects

From activity 1 and 2 above the required tests to be run on the test bench, and additional simulations that need to be run in order for the component to be fully approved, will be documented, as will the necessary test set-up requirements, including scaling of the tests.

Activity 4: Adaptation of the test rig set up for the specific component

a. Test rig modelling (full dynamic model)
b. Full calculation and simulation for component in test rig
c. Requirements to test rig to realistically represent the selected load cases for testing (for the purpose of achieving verifications)

The scaled test rig set-up, adapted for the specific component, will be modelled, including the complex model of the component from activity 2, together with the wind and load simulator as well as the sensors.

Based on the studies in 1 and 2, a description of the requirements for the test-bench-setup and methods for the calibration of the set-up, such that it best represent the conditions a wind turbine and its components are exposed to under different load configurations, will be developed. This would include guideline for the load generating system, drive train to electrical evacuation point, as well as the initial definition of system parameters (mass, stiffness, etc.), parameter variations, tolerances etc for the component tests. (These will be later validated step 8). The effect of scaling (down or up-scaling) the component to the test-rig will be fully investigated in simulation.

Selection and tuning of control algorithms that will be implemented on the test rig will be first done in simulation for the drive-train test setup. This will be based on a real-time (SIMULINK) interface, a set-up which will also be used on the real test-bench.

Activity 5: Test- and measurement procedures setup

a. Specification of the measurement campaign/test plan
b. Acceptance criteria

Specification of the required measurements and instrumentation needed to perform the tests documented in activity 3 above. Criteria for a successful measurement campaign will also need to be specified.

In the test and measurement programme setup for the specific tests (new) efficient measuring methods may need to be developed to e.g.:

- Measure/determine the stiffness properties of the support structure in the drive train (bed plate, bearing supports etc.).
- Filter out the global response of the test-setup. It is only possible to mimic the real stiffness properties to a certain extend in a test-bench-setup and therefore some tools/methods needs to be applied to filter out parts of the response to enable analyses on components and sub-systems.
- Apply vibration monitoring sensors for frequency analysis of the drive-train system with future applications in condition monitoring.

Activity 6: Specific component test rig modification

a. Test rig modification to the new component and calibration
b. Validation of test rig setup
c. SCADA and measurement system installation
d. Alarm and protection systems setup
e. Other labour safety issues

This is the physical construction phase of adapting the existing test rig to the component to be tested. The test-rig modifications, validation of these, and the physically setting up of instrumentation will be based on activities 4 and 5, which are both specification phases.

Activity 7: Experimental test in test rig and data acquisition.

a. Run planned tests
b. Data collection

The required tests specified in activity 3 to be run on the test bench, are completed and data collected in the process.

Activity 8: Data analysis, model verification, component acceptance

a. Post processing of data
   - Verification of component models and test-set-up using acceleration, velocity, displacement and strain measurements
   - Verification based on tests and measurements
   - Frequency analysis for condition monitoring
b. Design review: assessment against accept criteria
c. Reporting

The expected percentage of projects distributed between R&D and commercial products, in terms of % of time not turnover, for each of the above-defined activities is presented in Table 1. The turnover is given as a percentage of time for each of the eight defined activities.

Activity No	Activity Name	Turn over % per activity	R & D [%]	Commercial Products[%]
1	System description (loads, dynamics, vibrations, temperature)	10	30	70
2	Component in system	20	40	60
3	Documentation of design basis for component	5	45	65
4	Adaptation of the test rig set up for the specific component	5	70	30
5	Test- and measurement procedures setup	20	50	50
6	Specific component test rig modification	10	50	50
7	Experimental test in test rig and data acquisition	20	60	40
8	Data analysis, model verification and component acceptance	10	60	40

Table 1: Percentage of R&D and Commercial work per activity (in time, not turnover) and expected percentage of turnover from each activity.

2.2 Scope of component design activities

The below is a brief description of the expected research and commercial output of the projects at the CWTC centre.

R&D activity scope

The research activities within the CWTC will result in a strengthening of core knowledge in the field of experimental testing of components and sub-systems for wind turbines, component reliability improvement and development and establishment of test routines.

The specific R&D activities will lead to outcome such as:

- Development and definition of a methodology for the experimental testing of wind turbine components such as design envelope (load cases), acceptance criteria, test-rig set-up for e.g.:
  - Validation of components from new suppliers for possible substitution of existing components, new materials, etc.;
  - Retrofit testing;
  - Damage analysis;
- Description of test cases for experimental testing of components that can be accepted by industry, thus contributing to the development of international standards necessary for certification of drive-train components:
  - A description of load cases and conditions, which are relevant (and possible) to perform on an entire drive train in a test-bench-setup;
  - A description of the possibilities and limitations of experimental test performed on entire drive trains in a test-bench-setup;
  - Additional simulated load cases that need to be performed for the certification of the component;
- Guidelines for experimental testing of WT drive-train components leading to standards for experimental testing of WT components:
  - A description of how to reproduce the load case and conditions in a test-bench-setup;
  - Set-up of test benches: calibration, scaling effects etc;
  - Set-up of measurement campaign;
- Increased knowledge of the conditions the different components in the drive train are exposed to and their response to these conditions.
- Validation of WT and component models as well as system parameters currently used for design of wind turbine drive-train components;
  - Increased knowledge of the possibilities and limitations of the current aeroelastic simulations, when focusing on the modelling techniques of the drive train;
  - A description of specific tests for the validation of (drive-train models and) system parameters;
- Guideline descriptions of numerical modelling techniques regarding the drive train;
- Development of new methods and tools for the design and the dimensioning of components for wind turbine drive-trains;
- Improving conceptual designs of components;
- Methods for measuring, vibration monitoring and frequency analysis of drive-train system:

- Testing of sensors already used in the industry, or new sensors proposed by industry.

Commercial activity scope

The commercial activities will be mainly targeted to existing component and sub-system suppliers to the wind power industry, including wind turbine manufacturers, new entrants into the wind turbine component and sub-system supply chain, but also renewable energy producers. The focus would be on product development and design for the specific application of wind turbines.

The specific consultancy services within the commercial activities will be:

- Description of the specific conditions that the clients component is exposed to within a wind turbine, situated in a wind farm;
- Analysis of the dynamics of the component under these specific conditions in simulation and on the test bench:
  - Including wind loads and wake from other turbines;
  - Including controller feedback;
- Design-driving load case analysis;
- Failure analysis;
- Analysis of possible design changes of WT conditions (e.g. blades, controller) for improving component 'input-output' situation;
- Modelling of drive-train component or sub-system, including model of component within full aero-elastic model of wind turbine:
  - Model development;
  - Existing model validation;
  - Parameter validation;
  - Frequency domain description;
- Design review;
- Improvement of conceptual design;
- Set-up of measurement campaign for specific components.

An example of a research project

One of the primary activities in the Centre for Wind Turbine Components will be applied research projects where DTU, the CWCT partners and other research facilities join forces with industry to develop an improved design basis for wind turbines. Through this type of projects numerical and experimental methods and tools will be prepared supporting the industrial drive-train design and development, which will enhance the reliability and thereby minimize the total cost per kWh as a result of the increased lifetime of components and minimized maintenance cost.

In November 2010 the research project/centre REWIND received funding. REWIND is a Strategic research centre funded by Forsknings- og Innovationsstyrelsen, which contains 9 partners (DTU-MEK, Risø DTU, AAU, HelmHoltz-Zentrum für Materialen, Indian Institute of Technology (IIT), Dong Energy, Vatenfall, Vestas Wind Systems A/S, Magma GmbH). The Centre is headed by Professor Jesper Hattel from DTU Mechanical Engineering. It is the overall purpose of the centre to perform strategic research at the highest level in the field of materials-manufacturing-properties-performance of metallic components in the rotor and drive-train in large wind turbines, with the ultimate aim of enhancing the reliability, extending the lifetime

and arriving at an improved life expectancy prediction of such components. Moreover, it is also a specific purpose of the centre to provide the scientific foundation for the Danish strategic effort to build drive-train research facilities at the facilities at Risø DTU and LORC.

The work in the centre will be organized in seven work packages and it is expected that there will be a significant interaction between the WPs.

- WP0: Project management, headed by DTU Mekanik
- WP1: Materials engineering and failure analysis, headed by DTU Mekanik
- WP2: Mechanical properties and damage mechanics, headed by Risø DTU AFM
- WP3: Process modelling, headed by DTU Mekanik
- WP4: Fatigue and wear in rolling and sliding contacts DTU Mekanik
- WP5: System simulations and in-service loads, headed by Risø DTU VEA.
- WP6: Reliability, headed by AAU

It will mainly be the activities in WP5 which will utilize the possibilities for experimental testing of drive-trains in a controlled test-bench-setup. This WP will focus on the electro-mechanical interaction between the rotor and drive-train loads and the responses of different components of the drive-train, along with experimental testing to develop new conceptual designs of the drive-train with improved reliability. The models will include the effect of aerodynamics and controls along with the gearbox stages and respective bearings. A suitable electrical model of the generator completes the drive-train system. A gearbox unit will be tested under dynamic torsional load conditions to validate the software model. This will enable the prediction of the interactions between the different components and tailor the structural behaviour of each component for safe and reliable conceptual designs of the whole drive-train.

The main contributions to WP5 will come from Risø DTU (VEA) and Vestas Wind Systems A/S. Subtracts in WP5 includes:

WP5.1 Electromechanical drive-train simulation
The drive-train model from the main bearing to the generator is modelled as a flexible multibody system with appropriate generator controls based on a SIMULINK interface. Load cases with extreme drive-train events such as grid loss, emergency stops, as well as turbulent wind fatigue loads are studied under typical field conditions for a multi-MW machine. Optimization of the drive-train design for maximum fatigue life within extreme load design constraints is done in conjunction with the results from WP5.2.

WP5.2 Gearbox and bearings design
A number of bearings and gear failures have been reported in the field from all wind turbine manufacturers. The causes of these failures can be due to multiple reasons, but a significant dependency of the life of the gearbox is on the design type of bearings, gears, its configurations, lubrication and performance under speed variations. Different types of planetary gearbox and bearing designs will be assessed in this task in concurrence with the loads simulated in WP5.1 to substantiate the effect of the configuration design on the reliability of the drive-train. The work will use results from WP3 and WP4.

WP5.3 Experimental Validations

The drive-train test facility will be used to load a downscaled drive-train model with different ranges of torque settings under dynamic conditions. The effects of scaling will be considered and representative cases for the load cases in WP5.1 with the designs in WP5.2 will be tested. Wear predictions on the gear teeth face and mechanisms of wear will also be assessed in cooperation with WP4. The measured stress, strains at the gear tooth flank, the loads at the bearing points and shaft deflections will be used in WP5.1 to maximize the life of the drive-train.

The REWIND project will be running from mid 2011 to ultimo 2016 and is estimated to utilize the experimental facility for a total of 1000 hours over the project period, estimating an income of DKK 1,500,000 to CWTC.

An example of a commercial project

An example of a commercial project could be the testing of condition monitoring set-ups of the drive-train system. Application of condition monitoring on a turbine or rather the sub-systems thereof, can increase the reliability and availability of the turbines by applying predictive maintenance as, among others, better planning of servicing to components is achieved, and more importantly serious damage and breakdowns to these can be avoided. Potential customers are suppliers of condition monitoring systems, suppliers of measurement equipment and wind turbine manufacturers.

In a condition monitoring application, different physical signals can be measured to get a picture of the system as is, and changes to the state of the system using different analysis techniques can be detected: e.g. the expected frequency response of the system (drive-train) is compared to the actual frequency response of the system to detect changes in this, before any severe damage to the system is actually done. The testing (and development) of the measurement techniques and analysis tools for condition monitoring would be ideal in a lab set-up, in which the conditions and ‘failures’ can be defined by the user.

More specifically:

- An analysis of the (frequency) response of the drive-train, with a system ‘degradation’ emulated and under realistic operational conditions for a wind turbine in a wind farm, can be undertaken to investigate sensitivity of the applied method to identifying failures;
- An investigation into the sensors used and the placement of these to improve ‘degradation’ detection, both in models of the WT and on the test rig.

3 The Market

3.1 Background and expected market development

The CWTC will over time market and sell its products and services on a global scale, but first and foremost the CWTC is established to support and strengthen the Danish wind energy industry and specifically the Danish sub suppliers to the Danish wind turbine industry and also the Danish research establishments.

The Danish market consists currently of around 400 companies with varying competencies and specialties. The industrial structure is changing rapidly these years as the industry is consolidating. In the future there will therefore be fewer and more powerful sub suppliers. The development trend is partly a result of demand from the major wind turbine manufacturers like Vestas and Siemens Wind Power. Companies like these want to change their relationship with their sub suppliers from a traditional value chain understanding of the relationship towards a more partnership oriented model. The sub suppliers need to be able to team up with the wind turbine manufacturers and to meet the demand for quality, capacity (on time delivery), reliability and minimizing the failure rate. In other words a much increased focus on research and development will be the future for the sub suppliers. The sub suppliers also need to be able to follow wind turbine manufacturers to new markets and to establish production where the wind farms are placed. Internationalization is therefore also the key for the sub suppliers as well as financial strength is.

Since the market is currently in transition it is expected that the number of potential customers will decrease over time. Also, even though the Danish market is around 400 companies, it is expected that some of these will see themselves as candidates for acquisitions by larger players in the market and/or is currently facing serious financial problems and therefore will not be immediate customers in the CWTC. 40% of the Danish sub suppliers faced a negative result in 2009 but the situation might improve as the demand for wind turbines begins to increase again in the wake of the financial crisis.

Generally speaking the sub suppliers (not only Danish) can be divided into two main groups. The first one is the companies who have already established themselves in the important new emerging markets as in the Americas and Asia (US and China). The second one is the group of companies that have not been able to enter these markets, but are stuck in the European market. For the CWTC the initial focus will be directed towards the established sub suppliers to create a experienced group of core customers that will be able to create future demand for the products and services supplied by the CWTC.

Moreover, even though the absolute market size is expected to decrease (number of potential customers) the financial strength of the remaining potential customers will increase and their buying power – and even more importantly – their need for the products and services offered by CWTC will increase as they will need to meet requirements for quality and reliability in an increasingly competitive market.

Thus, to conclude, (Danish) demand for CWTC products and services will decrease in terms of number of customers, but the remaining customer base will probably be more in need for the products and services and more well financially suited to pay for these products and services. The financial crisis has put many sub suppliers under financial pressure, but as demand for wind turbines takes off again, sub suppliers will also experience positive demand side effects.

3.2 Market quantification

The size of the market is not easy to predict. Firstly, alternative testing organizations among which NREL is one of the most prominent, does exist, but their

offerings are not directly comparable to what the CWTC plan to offer and financial figures are not readily available for comparison purposes. Secondly, many Danish sub suppliers have not been buying testing products and services before, so in other words, there is no tradition for buying such services and no indicative budget set aside as well. Thus no real historic data are available for evaluation of demand figures. Thirdly, an idea could be to compare with average R&D expenditure in the sub supplier industry, but traditionally the R&D expenditure has been relatively low and as the need for component testing strongly increases as wind turbines grow in size, past R&D expenditures will not be indicative for future R&D activities and therefore for demand for CWTC products and services.

No matter how the market potential is calculated the result will only be an imprecise indication of a market size of which the CWTC will be able to gain a probably significant share due to the strategic nature of its products and services and the limited availability of such products and services in the market.

The real challenge for the CWTC is therefore most likely not a precise estimation of market size and attainable market shares, but a question of how to finance and organize the CWTC to be able to meet the demand for the most needed and important products and services. In other words the challenge is on the supply side, not the demand side.

The approach taken here is therefore to calculate the maximum expected number of products and services the CWTC will be able to supply, given its initial financing and expected incoming cash flow from operations.

The maximum offerings from the CWTC is a combined portfolio of products and services, previously presented, that is based on needs and priorities revealed in interviews[1] with some of the major sub suppliers to the wind turbine manufacturers.

3.3 Size of the market for CWTC services

Identification of the market size for CWTC services is challenged by the lack of reporting transparency. There are limited amount of financial data to rely on and the level of detail in annual reports is low as well. Moreover, for subcontractors which are owned by a parent company and are part of a larger conglomerate it is often difficult to identify detailed financial data since such data is often shown for the group and not for the individual business units.

That said some indicative parameters can be found that can be used as a basis for a rough estimation of the market size for the Danish market, which includes export and therefore also partly covers international markets.

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[1] *For further information about interview results, please refer to"Statusrapport for etablering af Videncenter for vindmøllekomponenter, Centre for Wind Turbine Components (CWTC)", September 2008, which is attached to this business plan.*

Firstly, total turnover for the 400 Danish subcontractors was around DKK 29 billion in 2008 and with a zero growth in 2009 the figure hasn't changed more than slightly even through 2010 turned out better than 2009. Still though, both manufacturers and subcontractors fought to bring down inventories in 2010 to a minimum so growth rates have been limited. In the latest industry statistics report (2011) from the Danish Wind Industry Association it is reported that the Danish wind industry is expecting 2-digit growth rates again from 2012-2015, indicating that the total turnover for the Danish subcontractor industry will probably increase from its base level of DKK 29 billion in 2008. As mentioned earlier, the Danish (and global) subcontractor industry is beginning to consolidate and already in 2011 the results in the form of mergers and acquisitions is expected to be realized. This movement will mean a strengthening of the individual sub contractors and some of them will be in a better position to gain market share, but also to put more focus on development, test and demonstration of new products.

Secondly, across the wind industry it seems that annual spending on R&D activities – where test, development and demonstration is expected to account for a significant share – can be estimated to around 2% of annual turnover. This figure will (probably) vary significantly between different types of sub contractors, but for the purpose here it will be used as an average measure. It should also be mentioned that this figure is an estimation based on information found in a limited number of annual reports, on the Internet and in various industry reports.
Thirdly, the total number of employees working with test, development and demonstration in the wind industry in Denmark is around 11%, which corresponds to approximately 2,700 employees (2010).

These parameters are not unambiguous and are all encumbered with some degree of uncertainty. However together they provide a basis for an estimation of the market size.

If it is assumed that the turnover basis is DKK 29 billion and the average spend on R&D activities is 2% then absolute spend on R&D is DKK 580 million per year. If it is further assumed that a significant part – i.e. 2/3 – of this spend is test, development and demonstration, spend on these activities is approximately DKK 390 million, which can be assumed to be an estimate of the market CWTC looks into.

Having reached that figure, a number of factors should be taken into account:
The turnover basis is the sum of turnover for all types of sub contractors. Some of these supply tower components, blades and other components that do not go into the drive train and will therefore not be relevant for CWTC.

The sub contractor industry is currently experiencing a structural change leading to consolidation. One result will probably be a stronger focus on R&D activities leading to increase in the need for services supplied by CWTC. On the other side, it will almost also invariably lead to fewer customers for CWTC and perhaps also to stronger R&D departments who will be able to in-source a larger portion of the R&D activities themselves leading to a decrease in market demand.

Subcontractors will differ in their spending on R&D but it is assumed here that CWTC's potential customers will represent the companies with the larger share of R&D spend.

Part of new product development will be kept inside the subcontractors. It is difficult to estimate the share, but is should contribute to a decrease in market size expectation.

CWTC will not be able to cover all kinds of drive train test demand – at least not in the first years of its lifetime – which should also contribute to a decrease in market size expectation.

The conclusion is that the base Danish market size can roughly be estimated to DKK 390 million, but this estimate should be corrected according to the factors mentioned above. A more realistic approach will probably be to assume a market size of DKK 75-100 million per year in the beginning. As the wind industry is expected to grow significantly again from 2012 more players will emerge and particularly the international market (which have not been included in the above considerations) for CWTC services will increase.

3.4 Risks

Seen from a risk point of view the CWTC only faces a few relevant competitors of which none is based in Denmark. Competitive pressure seems to a greater extent to come from structural industry changes among the different sub suppliers who currently experience mergers and acquisitions by larger sub suppliers and wind turbine manufacturers or by companies with ambitions to form conglomerate entities offering multiple sub supplier services. This movement is partly driven by the financial crisis, which has resulted in losses and negative results for more than 40% of the Danish sub suppliers, partly by the requirements to have management and financial strength to follow wind turbine manufacturers to important markets and to take a more system oriented approach to the sub supplier role.

To get a more detailed picture of the risk profile, the Five Forces model is applied:

Figure 2. Five Force

Competitive rivalry

Starting in the middle the competitive rivalry in the "industry" is dependent on the number of competitors and the degree to which the competitors are similar. To the extent that one or more of the players are significantly more powerful than the others, competition will be uneven. As mentioned above there are not many competitors in the particular industry the CWTC is part of and they are geographically dispersed, which indicates that each centre most likely will attract customers within its own region. Moreover, the CWTC enjoys a unique advantage being closely connected to DTU which is one of the most prominent wind energy research centres in world and drawing heavily on expert staff from DTU/Risø DTU and from the CWCT partnership. This distinct pool of competencies on which CWTC will base its operation does not make the CWTC a market leader from day one, but it ultimately creates the basis upon which such a position can be build. Seen from that point of view the CWTC does not suffer from severe competition.

Other measures of competitive rivalry are industry cost structures, exit barriers, degree of product differentiation and switching costs. Some of these are more relevant to CWTC than others. Specifically it should be mentioned here that CWTC aims at employing a strategy focusing on building a strong core customer base

consisting of some of the strongest and most advanced sub suppliers thereby setting the highest standards for its product and service portfolio but equally important to create product differentiation thus lowering the attractiveness of switching to alternative suppliers.

Threat of new entrants

Turning towards the threat of new entrants the focus is on the likelihood that new players will enter the industry creating increased competitive pressure. A number of parameters indicate whether the probability for new entrants is high, medium or low.

When evaluating the risks CWTC faces with respect to new entrants it is important to look at parameters like:

- Capital requirements;
- Access to distribution channels;
- Access to technology;
- Government regulations – access to subsidies.

Capital requirements are relatively high and survival in this industry requires either the ability to run as an (almost) not-for-profit organization or to be able to create products and services that are superior to what is already offered by the CWTC (or other savvy competitors). The ability to run as not for profit seems to available only to universities, national labs and other similar governmental institutions and presently only a very limited number of such organizations will have the ability to match the strong competencies of the CWTC. For that reason the other alternative – superior product differentiations – is not very likely too.

The CWTC has through the extensive and deeply rooted networks that have been built between DTU/Risø DTU and the wind energy industry access to a well developed distribution system for its products and services. Similar distribution channels will be difficult to develop for newcomers in the industry.

Access to technology is probably the key parameter, where the CWTC will be able to defend itself from competitors both existing and new entrants and the superior technology access enjoyable by the CWTC will be extremely difficult to match for new entrants.

Finally, government regulations and the access to subsidiaries from EUDP funding and other governmental grants have enabled the establishment of the CWTC. Such similar grants is also available in other European countries and has led to the projection of governmentally financed large nacelle test facilities in both Europe and US, including the LORC nacelle test facility in Denmark. However, it seems unlikely that a new entrant would enjoy the same governmental financial backing in Denmark.

Bargaining power of buyers

As mentioned earlier, many of the sub suppliers to the wind turbine manufacturers are currently under strong financial pressure due to the financial crisis. Many of them are also facing a pressure to either join forces with other sub suppliers or

finding other ways to consolidate. The majority of the group of buyers is therefore in a situation where they easily could be inclined to exert a pressure on price and complementary conditions or decide not to buy product or services from the CWTC. However, the offerings from CWTC is of a strategic and important nature and will over time develop in to “need to have” for the sub suppliers who want to survive in the future.

The most dominant risk concerning buyers, is that the financially, technically and managerially strongest companies might consider setting up test facilities themselves. This is a trend that has been seen among some of the large wind turbine manufacturers, and the strong the bonds between a wind turbine manufacturer the more likely it will probably be to see a sub supplier setting up its own test facility, in other words to backward integrate. The major drawback for those sub suppliers engaging in such activities will be that they will lack the strong competence base and experience rooted in DTU/Risø DTU’s organization on which the CWTC is built.

All in all the bargaining power of buyer does not seem to be real threat to the CWTC.

Bargaining power of suppliers and the threat of substitute products and services

The risks coming from suppler and substitute products and services are almost negligible to the CWTC. The major supplier to the CWTC is DTU/Risø DTU, who is also the parent organization of the CWTC, which is a 100% owned subsidiary of DTU/Risø DTU. There is therefore no real pressure to come from supplier side.

Also, as it has been argued earlier competition is limited, but substitute products and services do not exist. The only real alternative is to refrain from testing components, and this seems not to be a viable strategy for any sub supplier.

Summing up

To sum up, the CWTC seems to be in an attractive position to gain a significant share of the market for testing of components for wind turbine manufacturers. Competition seems to be minimal and the real challenge for the CWTC seems not to be on the demand side but on the supply side, i.e. to be able to meet demand for testing products and services.

4 Sale and Marketing

Sale, marketing and business development is organized in a separate staff function reporting to the centre manager who is overall responsible for these activities.

Sale and marketing activities has already begun when the first amount of capital was granted from the Danish Energy Agency.

The initial activities have been primarily network based and focused on creating awareness among sub suppliers about the establishment of the CWTC. This message has been given in broader forums like the EWEA (European Wind Energy

Association) yearly meeting, the HUSUM exhibition and other similar places. It has also been given to selected sub suppliers, who have been given the opportunity to contribute their inputs to the setup, profile and prioritized activities for the CWTC. Communication about the CWTC has been headed by deputy division manager of Risø DTU who is in charge of the CWTC during the establishment phase. The staff and partners have an extensive network both in academia and industry and have ensured that the message about the establishment of the CWTC has come across to a large number of the wind energy professionals in Denmark and Europe responsible for decisions about development and test of components.

The network activities will be maintained throughout the rest of the establishing phase to start building demand for the products and services offered by CWTC.

The CWCT partnership group (DONG Energy, AAU, DTI, Force and DTU/Risø DTU) are a strong pool of recourse and thus as important to involve in the marketing process as they can help create a pull effect for demand for the products and services offered by CWTC.

The partnership also adds a strong basic knowledge on testing of components and subsystems as well as the utilizing the common access to a number of subtest facilities located at the partners premises respectively. Thus compiling highly specialized mechanical or chemical tests or targeted methods such as climate chamber testing, high pressure hydraulic tests, load and stress testing, mechanical root cause analysis after failures, testing of high tech welding methods etc

However, as establishment progresses segmentation of target groups will be offered more attention and messages for each group will be developed accordingly. In the beginning the communication will be headed to two major roughly divided segments, namely the sub suppliers and the wind turbine manufacturers.

The wind turbine manufacturers will be targeted as one group and sales activities towards this group will be very limited. Wind turbine manufacturers will seldom have much advantage out of using the CWTC directly, but will instead use the test facility at LORC, that can handle up to 20MW peak. However, wind turbine manufacturers will be highly interested in working with sub suppliers who can document that their components have been tested at a qualified test centre. Wind turbine manufacturers are therefore important to involve in the marketing process as they can help create a pull effect for demand for the products and services offered by CWTC.

The sub suppliers will initially be targeted as one group as well, but in due time as establishment progresses towards commencement of activities, segmentation of sub suppliers will begin. Sub suppliers will be segmented and prioritized according to the planned roll out of products and services and massive sales campaigns will be directed to the particular sub suppliers. This will include direct mail campaigns, advertising in relevant magazines, visits to potential customers, and attendance at relevant exhibitions and conferences.

The renewable energy producers as the wind turbine owners and operators will in due time represent a significant target group with its need for reliable wind turbine and possible retrofits to be tested before implementation in large scale.

As a general sales and marketing tool a dedicated web site for CWTC will be developed which will be used to provide general information about CWTC but also as a knowledge sharing tool, where relevant technical information will be placed, including membership specific information only available through login. Through the website potential customers will also be able to find information about the products and services offered by CWTC, conditions for doing business, contractual agreements, testing availability etc. As a special feature potential customers will be able to see conditions, prices and availability for customized tests according to a number of predefined changeable parameters.

A marketing plan covering the activities, skills, and partners, will be carried through to market the CWTC. The marketing approach taken here aligns the target groups (wind turbine manufacturers, sub-suppliers, owners and operators) with the aims, objectives and strategy respectively.

Wind turbine manufacturers

The **aim** is: To get wind turbine manufacturers to create a pull effect for the products and services offered by CWTC.
The **objective** is: To inform and influence wind turbine manufacturers to understand how the CWTC can help create value for the wind turbine manufacturers in terms of enjoying increased competitive advantage relative to other wind turbine manufacturers.
The **strategy** is: The strategy entails several activities from creating awareness to build and gain understanding and acceptance of the CWTC with the right people which will be able to formulate and communicate testing requirements to specific sub suppliers.

To facilitate the actual transfer of recommendations and requirements from wind turbine manufacturers to sub suppliers, the CWTC will on an ongoing basis organize and host workshops about specific high impact topics, where representatives from both wind turbine manufacturers and sub suppliers will attend and work on implementation of new requirements into future components.

Sub suppliers

The **aim** is: To conclude contracts for membership of CWTC and delivery of testing products and services
The **objective** is: To inform and influence sub suppliers to understand how CWTC can enable them to develop components that will meet the requirements in future wind turbines.
The **strategy** is: The strategy entails several activities from creating awareness to build and gain understanding and acceptance of CWTC with the right people who will be able to build demand for testing of components internally within the sub suppliers' organizations and to decide about entering contracts about testing, development and membership of CWTC.

Owners and operators

The **aim** is: To conclude contracts for membership of CWTC and delivery of testing products and services improving reliable wind turbine operation.

The **objective** is: To inform and influence the wind turbines owners and operators to understand how CWTC can enable them to develop retrofit to subsystems or components that will meet the requirements in wind turbines.
The **strategy** is: The strategy will include development of test procedures, understanding and establishment of operational condition leading to failures of subsystems or components in order to facilitate development of retrofit solutions.

For creating awareness the following activities will be carried out:	Wind Turbine manu-factures	Sub Supp-liers	Owners and producers
Presentation of CWCT and the partnership behind through the Danish Wind Industry Association and the Danish Wind Turbine Owners' Association and their members.	x	X	x
Presentation at EWEA (European Wind Energy Association), including direct outreach contact (presentations and meetings) with wind turbine manufacturers present at the exhibition.	x	X	
Advertising in the EWEA 2012 Newspaper which is delivered daily in 5000 copies at the EWEA exhibition.	x	X	
Press releases to: International and Danish commercial newspapers like Børsen, Berlingske Business	x	X	
Newsletters and direct mails to Top 20 wind turbine manufacturers.	x		
½-yearly repeating of activities except EWEA.	x		
Advertising in the EWEA 2012 Newspaper which is delivered daily in 5000 copies at the EWEA.		X	
Development of dedicated newsletters (direct marketing campaign) to Top 100 Danish sub suppliers.		X	x
Direct phone calls to sub suppliers already known (personal networks) by CWTC to present information about CWTC.		X	
Development of professional marketing flyers and presentation material, including information on products and services, advantages, business model and contact info, which will be used at EWEA and in direct marketing campaigns.		X	
Establishment of a database of potential customers which will be maintained with specific CRM data on each individual sub supplier, which can be used to target further newsletters and information.		X	x

Table 2: Awareness activities by target group

For creating understanding and acceptance of CWTC the following activities will be carried out:	Wind Turbine manu-factures	Sub Supp liers	Owners and producers
Open Invitation to wind turbine manufacturers to a launch-event at the opening of the CWTC, where the vision, goals, strategy and planned activities will be explained in detail. It will also be presented how wind turbine manufacturers will benefit from CWTC and how CWTC will involve sub suppliers as well as wind turbine manufacturers to facilitate the highest level of understanding of the drive-train and the requirements to components in the future.	x	x	x
Invite key people from leading wind turbine industry to join sub groups working with e.g. guidelines development and similar industry generic topics.	x	x	x
Creating a database of wind turbine manufacturers to whom material about tests, activities, reports etc. can be disseminated based on expression of interest.	x		
Open Invitation to Danish sub suppliers to a launch-event at the opening of the CWTC, where the vision, goals, strategy and planned activities will be explained in detail. It will also be presented how sub suppliers can benefit from working with CWTC both for testing purposes but also to increase their understanding of future requirements and systematic understanding of the drive-train.		x	
2011: Visits to the 20-40 most important Danish sub suppliers (important here understood as most likely to buy products and services from CWTC immediately after commencement of activities) to explain about CWTC and clarify specific needs.		x	
2011: Field visits (1-2 days) to a selected few sub suppliers.		x	
Organization of workshops for sub suppliers about need for products and services.		x	
Organization of workshops for sub suppliers and wind turbine manufacturers about future component requirements for wind turbines.		x	
2012: Visits to next 100 Danish sub suppliers.		x	
2013: Visits according to need for generating demand for products and services.		x	
Invite key people from leading sub suppliers to join sub groups working with e.g. guidelines development and similar industry generic topics.		x	
Creating a database of sub suppliers to whom material about tests, activities, reports etc. can be disseminated based on expression of interest.		x	
Be prepared to iterate relevant elements that will help create understanding and acceptance.		x	x

Table 3: Understanding and acceptance activities by target group

5 Organization

The CWTC will be a 100% owned subsidiary of DTU/Risø DTU and will be organized as a centre that runs in close cooperation with its partners, which are: Aalborg University, Technological Institute, Force and Dong Energy.

The CWTC will be a virtual organization which will be part of the Wind Energy Department at Risø DTU and staffed with employees from that department as well. The employees working at the CWTC will retain their employment at DTU/Risø DTU or at the partners and will be allocated project by project to activities at the CWTC.

In that way the CWTC will be a project organization and during the first 6 months of operation the CWCT will be headed by the Deputy Manager for the Wind Energy Department, however anchored in the Research Program VIM (Wind Turbines).

After 6 months of operation a centre manager will be hired to run the CWTC. The centre manger will report directly to the head of the Wind Energy Division program and coordinate staffing with other program managers as necessary to allocate employees to the different projects according to the specific activities within each individual project.

Besides the centre manager the CWTC will also need to hire 1-2 full time machine operators to handle the practical testing of components at the CWTC. As the activity level progresses and some testing and controlling activities can run in parallel it will be necessary to hire 1-2 additional machine operators.

After 12 months operation the organization is expected to develop into the below structure:

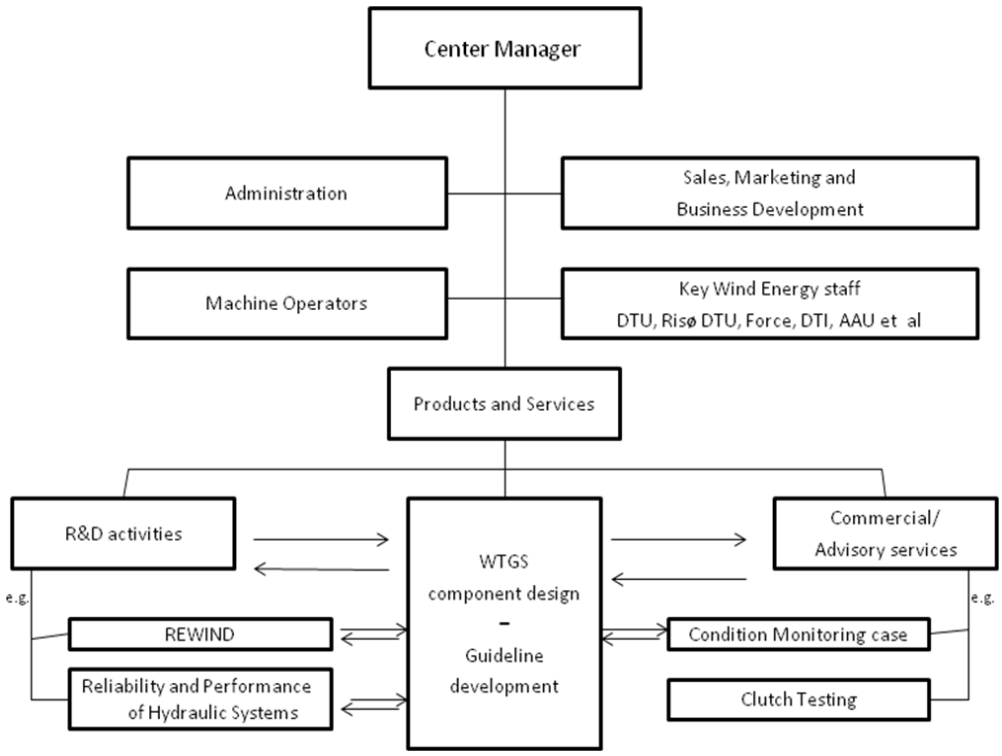

Figure 3. CWCT organization

The organizational structure reflects that there are certain functions that are separated from the operations (Sales & Marketing, Business Development and Administration) and it also reflects that scientific staffing are hired in on a project / consultant basis and does therefore not show un in the operations part of the organizational structure. Machine operators will be hired in on a permanent basis but they will be required to handle different tasks as well.

Turning to the operations part of the CWTC, it is worth mentioning that the more long term New Design Basis development is separated from the more short term test and component control and Advisory services, which is expected to generate revenues faster than products and services coming out of the New Design Basis activity. However, importantly the guidelines development activity, which is an important part of the CWTC is placed as a separate activity involving inputs from both the long term activities and inputs from the short term testing and control activities.

As mentioned above, the Centre Manager will report directly to the program manager for the VIM program in the Wind Energy department at Risø DTU, but the CWTC will also have an Advisory Board with no managerial power. The Advisory Board will consist of people representing the partners as well as other people from both industry and academia and will have as it sole purpose to advise the CWTC on its strategic development.

6 Development of CWTC

Within 3 years of operation the CWTC is expected to provide the full list of products and services, as described in the road-map, with around half of the activities being research based and the other half commercial. The first year of operation is expected to be pure research based, with the development of test cases, guidelines for testing, initial set-up and calibration of the test rig etc. The successful sale of products and services is expected to start within the first 12 months of operation. The development of the product and service portfolio will be according to market demand, but being an innovative centre of excellence, the CWTC will also bring new products and services to market where CWTC anticipates future needs,

Products and services
1 year: 100% R&D activities: mainly definition of test cases, guideline development for testing, initial set-up and calibration of the test rig.
3 year: Full product and service list offered, as defined in the Road-map model under Products and Services. Roughly 50% of activities are expected to be R&D and 50% commercial.

Expected turnover (see budget for more details):
1 year: DKK 897,860
3 year: DKK 1,695,937

7 Budgets

7.1 Investment Cost

The investment into the centre is from research grants, or self-financing from the partners, so this is not accounted for as a cost.

7.2 Operational budget

From Table 1, it is calculated that the activities at the centre will be 54% R&D activities and 46% commercial after the first 12 months of operation.

Several assumptions are made for the calculation of both the operational and income budget:

- The first year, 100% of the activities are expected to be research, for setting up design envelopes, guidelines for testing etc.
- After 2 years of operation, the actual running of the test rig (activity 7) is 20% of the overall activities in the CWTC. This will be reduced in the first and second year respectively, with only 6.5% and 14% of the time spent with the running of the test rig.

Based on this, the operational budget for running the test-rig (activity 7 only in the WTG component design activities) is estimated for the first 3 years of the test centre.

Operational cost, R&D activity	**year 1**	**year 2**	**year 3**
Power consumption	DKK 21,700	DKK 26,440	DKK 39,460
Manpower (one technicians)	DKK 57,240	DKK 72,220	DKK 111,510
General maintenance	DKK 24,750	DKK 30,150	DKK 45,000
Replacing or repairing one of the main components	DKK 41,250	DKK 50,250	DKK 75,000
Rent of buildings and other expenses	DKK 0	DKK 0	DKK 0
Total expenses for running (R&D activities) the test setup	DKK 144,940	DKK 179,060	DKK 270,970
Expenses per hour	DKK 1,489	DKK 1,510	DKK 1,531
Operational cost, Commercial activity	**year 1**	**year 2**	**year 3**
Power consumption	DKK 0	DKK 17,630	DKK 26,310
Manpower (one technicians)	DKK 0	DKK 90,920	DKK 138,650
General maintenance	DKK 0	DKK 20,100	DKK 45,000
Replacing or repairing one of the main components	DKK 0	DKK 13,400	DKK 50,000
Rent of buildings and other e expenses	DKK 0	DKK 0	DKK 0
Total expenses for running (commercial activities) the test setup	DKK 0.00	DKK 142,050	DKK 259,960
Expenses per hour		DKK 1,797	DKK 2,203

Table 4: Operational costs for running the test-rig

The operational budget in terms of manpower, assuming the average of the salary for one senior scientist and one scientist, for all the other listed WTG component design activities is:

Operational Cost for running test rig, R&D and Commercial	year 1 DKK 144,940	year 2 DKK 321,110	year 3 DKK 530,930
Manpower Cost, R&D and Commercial	year 1 DKK 752,910	year 2 DKK 1,147,420	year 3 DKK 1,164,990
Total Operational Cost, R&D and Commercial	**year 1 DKK 897,850**	**year 2 DKK 1,468,530**	**year 3 DKK 1,695,920**

Table 5: Total operational costs for CWTC

7.3 Income budget

From the percentage of time expected for each activity, broken down into R&D and commercial activities (Table 1), the income for the centre can be calculated. These are from year 3 and on. The first year, the activities are expected to be research

only, for setting up design envelopes, guidelines for testing etc. After 2 years of operation, the actual running of the test rig (activity 7) is 20% of the overall activities in the CWTC. This will be reduced in the first and second year respectively, with only 6.5% and 14% of the time spent with the running of the test rig.

The income from Activity 7 is the cost of running the rig per hour, including technical staff. The breakdown of the cost for running the rig, both for R&D and commercial projects is presented in Table 4, and this is directly the income for the centre. The income from the other activities is calculated based on the cost for the research staff, both for R&D activities and commercial (Table 6): the manpower for R&D and commercial work are staff members from DTU and Risø DTU wind energy groups and departments, considering the average cost of a scientist and senior scientist taken as the hourly rate. The cost of technical staff is only taken into account in the running of the rig.

Income description per hour	Year 1	Year 2	Year 3
Manpower for R&D *	DKK 638	DKK 660	DKK 677
Manpower for Commercial work	DKK 1,300	DKK 1,313	DKK 1,326
Running of test rig R&D**	DKK 1,488	DKK 1,510	DKK 1,530
Running of test rig Commercial**		DKK 1,823	DKK 2,117

Table 6: Income description per hour

		Income from activities		
No	**Activity description**	**year 1: 100% R&D**	**year 2**	**year 3**
1	System description (loads, dynamics, vibrations, temperature)	DKK 94,110	DKK 126,280	DKK 128,570
2	Component in system	DKK 188,230	DKK 310,320	DKK 314,590
3	Documentation of design basis for component	DKK 47,060	DKK 75,170	DKK 76,250
4	Adaptation of the test rig set up for the specific component	DKK 47,060	DKK 63,140	DKK 64,280
5	Test- and measurement procedures setup	DKK 188,230	DKK 291,070	DKK 295,440
6	Specific component test rig modification	DKK 94,110	DKK 145,530	DKK 147,720
7	Experimental test in test rig and data acquisition	DKK 144,940	DKK 321,110	DKK 530,930
8	Data analysis, model verification and component acceptance	DKK 94,110	DKK 135,910	DKK 138,140
	Total income per year:	**DKK 897,850**	**DKK 1,468,530**	**DKK 1,695,920**
	Manpower income	DKK 752,910	DKK 1,147,420	DKK1,164,990
	Running rig income	DKK 144,940	DKK 321,110	DKK 530,930

Table 7: Income per activity for the CWTC and total income.

In the first year the income will be 100% from R&D activities, which is the cost for the staff from the DTU/Risø-DTU wind energy department to set-up the test-rig, the guidelines and test procedures, and partly for running the rig (Table 7). This will

result from research grants (the REWIND project has already been accepted[2]), or funded by DTU/Risø-DTU if the grants are not secured for the first year of operation.

	R&D % of total: income	**Commercial % of total: income**
Year 1	100%	0%
Year 2	40%	60%
Year 3	40%	60%

Table 8: Percentage of income from R&D and from commercial activities

2 see section2.2: An example of a research project

Risø DTU is the National Laboratory for Sustainable Energy. Our research focuses on development of energy technologies and systems with minimal effect on climate, and contributes to innovation, education and policy. Risø DTU has large experimental facilities and interdisciplinary research environments, and includes the national centre for nuclear technologies.

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