

MegaCentre Planning Project

Marja-Leena Pykälä | Ville Lehtomäki | Minna
Kansola | Katri Valkokari | Hannele Holttinen |
Esa Peltola | Aslak Siljander

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VTT
PL 1000 (Tekniikantie 4 A, Espoo)
02044 VTT
Puh. 020 722 111, faksi 020 722 7001

VTT
PB 1000 (Teknikvägen 4 A, Esbo)
FI-02044 VTT
Tfn +358 20 722 111, telefax +358 20 722 7001

VTT Technical Research Centre of Finland
P.O. Box 1000 (Tekniikantie 4 A, Espoo)
FI-02044 VTT, Finland
Tel. +358 20 722 111, fax + 358 20 722 7001

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Abstract

MegaCentre Planning Project (MCP) is an initiation of the Finnish industry operating on the wind power area. The planning project was launched and managed by Moventas Wind Oy. The project aims at strengthening the technology position of the participating companies by founding a broadly-based experimental research platform supported by virtual modelling, which would combine the competences of both industry and research.

The goal of the MCP project was to design a globally leading research and development facility – MegaCentre – for the full-scale development and validation of next generation wind turbine technologies. Wind energy-related research program were investigated based on literature surveys and interviews. On the basis of the results obtained a strategy is provided on how and which research programs the MegaCentre could offer applied research services.

Keywords Wind Turbine, Gear box, Testing platform

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Tiivistelmä

MegaCentre on suomalaisen tuulivoima-alan teollisuuden aloite, jolla tavoitellaan yritysten teknologia-aseman vahvistamista perustamalla laajapohjainen sekä teollisuuden että tutkimuksen osaamista yhdistävä kokeellisen tutkimuksen ja koetoiminnan ympäristö, jota tukee myös virtuaalinen mallinnus. MegaCentre-hanke on suunniteltu Euroopan mittakaavaan. MegaCentren toteuttamiseksi on MoventasWind Oy:n aloitteesta ja johdolla käynnistetty suunnitteluhanke, jonka tuloksena tulee saada riittävät perusteet varsinaisen kokeellisen ympäristön toteuttamiseksi.

Projektissa tutkittiin kirjallisuuteen ja haastatteluihin perustuen tuulivoimaan liittyviä tutkimustarpeita ja alueen toimijoita. Saatujen tulosten pohjalta luotiin strategia, jota seuraten MegaCentre voisi tarjota tutkimuspalveluja.

Avainsanat Wind Turbine, Gear box, Testing platform

Preface

The project was financed by Tekes – the Finnish Funding Agency for Technology and Innovation, participating companies and research institutes mentioned below . The project consortium included the following partners:

Industry:

- Moventas (partial funding from Tekes)
- The Switch
- WinWinD
- ABB
- Vacon

Research:

- LUT Lappeenranta University of Technology (partial funding from Tekes)
- TUT Tampere University of Technology (partial funding from Tekes)
- VTT Technical Research Centre of Finland (partial funding from Tekes)

Special thanks are extended to the many individuals within the MCPP consortium for fruitful cooperation.

Espoo, 15 June 2012

Authors

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List of abbreviations

AERTO	Alliance of European Research Technology Organizations
CENER	Centro Nacional de Energías Renovables, National Renewable Energy Centre
DTU Riso	Danish Technical University, Riso
EARTO	European Alliance of Research Technology Organizations
ECN	Energy Research Centre of the Netherlands
EERA	European Energy Research Alliance
EHV	Extra High Voltage
EII Wind	European Industrial Initiative on Wind Technology
ENTSO-E	European Network of Transmission System Operators for Electricity
EUT	Equipment under Test
EWEA	European Wind Energy Association
EWI	European Wind Initiative
FRT	Fault Ride Through; LVRT Low Voltage Ride Through
HALT	Highly Accelerated Lifetime Testing
HV	High Voltage
HVDC	High Voltage Direct Current
IEA	International Energy Agency
IEA Wind	IEA implementing agreement on research, development and deployment of Wind Energy Systems
IEC	International Electrotechnical Commission
IGBT	Insulated Gate Bipolar Transistor
LORC	Lindoe Offshore Renewables Center
LV	Low Voltage

MC	MegaCentre
M CPP	MegaCentre Planning Project
MV	Medium Voltage
NaREC	National Renewable Energy Centre
PCC	Point of Common Coupling
PNI	Testing Laboratory for Grid Integration, Fraunhofer IWES
PMSG	Permanent Magnet Synchronous Generator
SET Plan	Strategic Energy Technologies Implementation Plan
SRA	Strategic Research Agenda
TEM	Topical expert meeting
TPWIND	Technology Platform Wind
TSO	Transmission System Operator

1. Introduction

1.1 Background

Finnish wind power manufacturers' current global market share of about 3% can be increased to 7% through leadership and technology development i.e. science-based innovations, Figure 1.

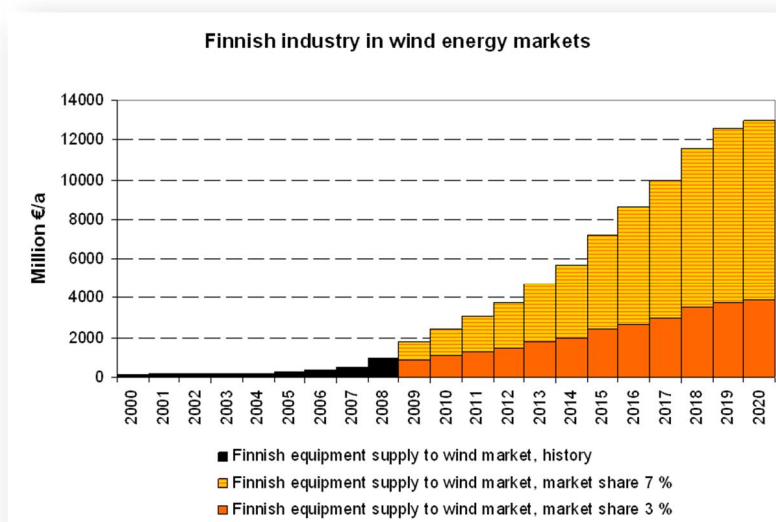


Figure 1. The development of the export value of Finnish Technology Industries into wind energy markets (Finnish Technology Industries, 2009)

Of particular importance regarding the future wind power business potential is to penetrate new markets e.g. wind farms in cold and icing conditions and off-shore with advanced solutions operating reliably in cold and other demanding climates like arctic conditions as well as offshore (Finnish Technology Industries, 2009).

In order to maintain and especially improve the position in the global wind technology market, access to a large scale experimental research facility of the main components and systems of a wind turbine is seen vital for the Finnish wind industry. This facility is called MegaCentre. The goal of the MegaCentre Planning Project (MCP) is to design a globally leading R&D facility – MegaCentre – for the full-scale development and validation of next generation wind turbine technologies.

In more details, the goals of the MCP project include the creation of:

- The best R&D facility for wind turbine and related technologies
- The business plan for it
- The operations structure including the mode of operation and the ownership structure
- Global R&D co-operation and networking aspects
- The implementation plan including budget and funding.

Once in operation and running, the MegaCentre:

- is an innovation centre between research and industrial organizations
- creates technology leadership brand(s) for Finnish wind power industry
- enables business growth and technology breakthroughs for global markets.

The durability and reliability aspects of the virtual design concepts for the next generation wind power solutions must be experimentally tested and verified (“proof-of-concept”) prior to their construction in e.g. remote harsh environmental conditions. Thus, the wide spectrum of scientific and engineering activities, e.g. virtual design, computational fluid dynamics, aerodynamics, machine dynamics and drive train dynamics, cover a significant part of the MegaCentre’s research agenda.

MegaCentre research and development facility was planned to be realized in three stages:

- wind power component and sub-system R&D and verification facility (stage 1)
- nacelle R&D and verification facility (stage 2)
- and wind tunnel and blade technology facility (stage 3).

The emphasis of arctic conditions is to be a special research subject for all three stages.

1.2 MegaCentre Planning project (MCP)

The MCP project contained four Work Packages (WPs) to reach the goals. This report documents work packages 1 through 3. The four (4) work packages are:

1. Concept design
2. Business and implementation plan
3. National and international networking and co-operation
4. MegaCentre implementation.

2. WP1: Concept design

The goals for WP1 according to the project plan were: “*Design parameter definition for each of the three stages, including:*

- *definition of the MegaCentre’s geographical locations*
- *definition of test system power & torque requirements*
- *evaluation of test system hardware alternatives*
- *definition of primary loads and displacements (peak-to-peak envelope, loads combinations and their phasing)*
- *definition of technology alternatives*
- *define simulations needed*
- *general design aspects*
- *layout design.*

2.1 Geographical location

Several meetings and visits (total of 6 different locations) concerning the possible geographical location for MegaCentre were conducted during 2011 and 3 alternatives were found to be most suitable:

- Hamina
- Kotka
- Vaasa.

These three locations were considered the best in terms of accessibility, existing infrastructure and strategic location. The rest of the goals listed in the project plan were more focused on assessing the technical specifications of MegaCentre and these goals are reviewed in the following chapters.

2.2 Consortium member interviews

In order to better understand the technical specifications and testing needs of all consortium companies regarding MegaCentre test equipment, 5 company interviews (excluding Wärtsilä interview due to their withdrawal from the project in April

2011) were conducted between February and March 2011. Here, only the technical specifications are considered, business related interview results are analysed in section WP2.

The goal of WP1 interviews were to find out company specific needs and eventually find MC specifications, that would suite all consortium members. The interview template and the summarized interview results can be seen in Appendix A.

2.3 Other large test facilities for wind energy applications

Large test facilities for wind energy applications (mainly nacelles and gearboxes) have had growing interest in the past 2 years. Several large nacelle test facilities are being planned in Europe, US and Asia. So far, largest efforts have been made in Europe and US.

In order to have some idea and benchmark existing or planned large test facilities to the MegaCentre's specifications, a short benchmark analysis was conducted and the summarized results are presented as pictures in Appendix B. In Europe, currently only one operational large drivetrain test facility exists in Spain, CENER (Appendix B, Figure 1) and some smaller or company-exclusive test rigs exist (Aachen University, Siemens, Voith, HUSUM WindEnergy, these are not presented in Appendix B because of limited data or due to insufficient technical specifications). Five large (≥ 5 MW nominal) testing facilities are in planning or constructions phase (NaREC, LORC, Fraunhofer, Sirris, Hansen, for more info, see Appendix B Figures 2–6).

Many of the test facilities presented in Appendix B are still in the planning phase and only minor efforts towards actual constructing these facilities have been made. Some facilities have partially confirmed budgets but the time schedules for facility opening ceremonies are seen as highly optimistic.

In the US, NREL has a functioning smaller test rig (Appendix B, Figure 7) but they are planning a larger one in the near future. Two test rigs in one facility are under construction with a confirmed budget at Clemson University, South Carolina (Appendix B, Figure 8).

2.4 MegaCentre technical specifications

According to the benchmark analysis of other large test facilities (Appendix B), consortium member interview results (Appendix A) and further developing the technical specifications within the MCPP consortium, the preliminary technical specifications and system layout are presented in Figure 2 and Figure 3.

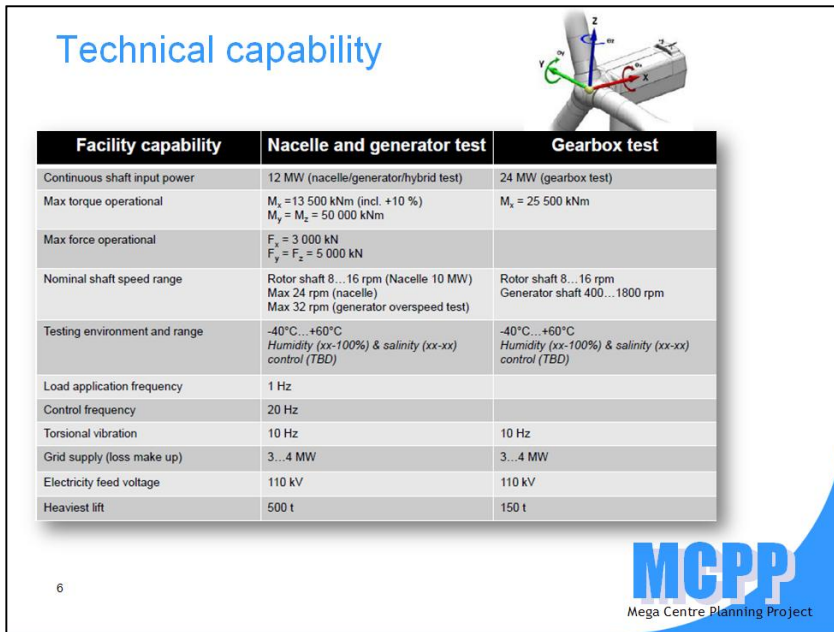


Figure 2. Preliminary MegaCentre technical specifications.

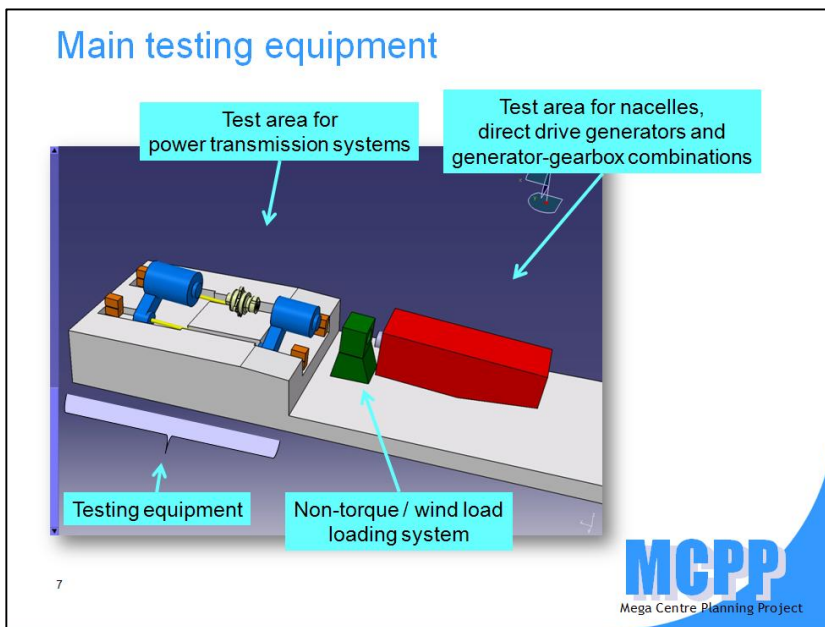


Figure 3. Preliminary MegaCentre test facility layout.

As can be seen from Figure 2, Figure 3 and Appendix A, MegaCentre technical specifications are close to other large testing facilities under planning. MegaCentre will have the capability to test “real life” conditions in controlled laboratory-like environment aiming at prototype testing for customer acceptance and/or classification. The MegaCentre test platform will be divided into two parts:

- Full nacelle and generator test rig and
- Gearbox test rig.

Prototype testing of mechanical transmission for customer acceptance and/or classification will include:

- Simulation of extreme loads
- Dynamic behaviour analysis
- Verification of theoretical simulation models
- Verification of noise and vibration characteristics
- Simulation of external load impacts
- Verification of functioning in extreme conditions (-40°C...+60°C)
- Highly Accelerated Lifetime Testing (HALT).

Prototype testing of generators or complete electrical drive train for customer acceptance and/or classification will include:

- Type certification of generators
- Measuring the quality of electricity
- Simulation of power transmission systems in various operational modes and circumstances (torsional vibrations, power, temperatures, voltages, currents, displacements, constructional stresses)
- FRT-capability.

Prototype testing of nacelle for customer acceptance and/or classification will comprise of in addition to the above mentioned:

- Verification of turbine control systems.

3. WP1: Electric testing opportunities in nacelle testing area

3.1 Principle of the MCPP testing facility

One option of the MegaCentre testing is the nacelle or generator testing system. Main circuit drafted by LUT, ABB and Moventas is shown in Figure 4.

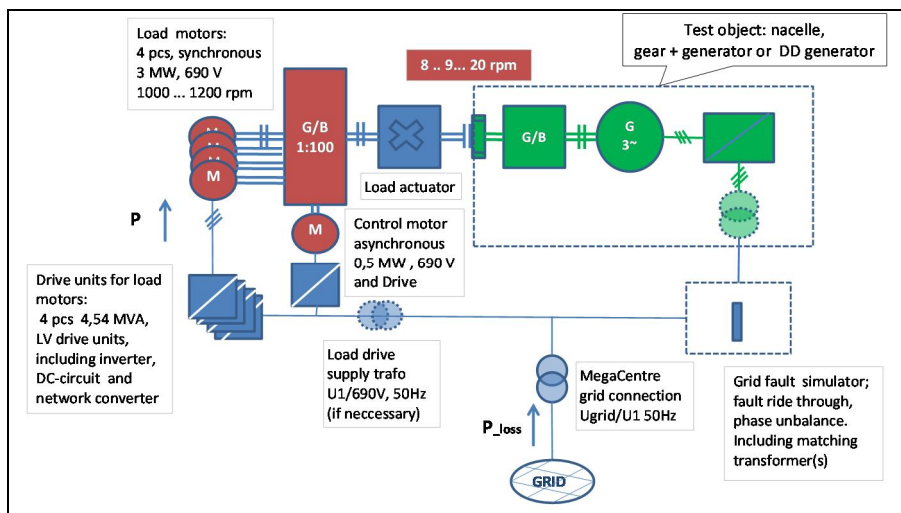


Figure 4. MCPP single line diagram, main circuit and drive train preliminary designed by Raimo Sakki/ABB, Jari Toikkanen and Olavi Rahkonen/Moventas.

The detailed specifications for the load motors and drives shall be determined during the implementation phase (WP4). Additionally, loss calculations of the system, operation profile, power network voltage level and protection needs the final planning as soon as the location and the power supply have been agreed. Design of the mechanical structures of the MegaCentre has to be done

parallel with the electric planning. The design values for the grid fault simulator and its integration to the MegaCentre network need a thorough planning and so does the integration of the test object to the MegaCentre instrumentation and automation system. The auxiliary power consumption and distribution for the building: lighting, air condition, cooling of the test facility etc. shall be designed after the location has been confirmed.

The supply voltage will be either 110 kV or 20 kV depending on the short-circuit power needed for the testing. The motors (4 pcs.) running the gear box test takes the power needed from the grid. While running the nacelle test the motors and the generator are connected in the back-to-back system. The voltage and frequency value may differ based on the manufacturer and the location where the system will be delivered.

In designing the nacelle loading circuit it is necessary to take into account the different dimensioning alternatives of the generator and converter system to be tested, such as generator type and rated values for power, voltage level and speed range

3.2 Testing possibilities

The MegaCentre test facility will be an ideal opportunity for testing in the laboratory conditions the characteristics of the nacelle or the generator-converter systems of a wind turbine. Tests can be performed either as design tests for prototypes or even as a part of type/conformity or commissioning tests.

Wind turbine tests and requirements are described in the IEC 61400-standard series. Power quality characteristics of wind turbines and requirements given for grid connection can well be preliminary tested in the MegaCentre test bench. In these cases especially the correct operation of the control system can be evaluated. Another important opportunity is to create measuring data to be used in the creation and validation the models for simulating the difficult phenomena related to grid faults and the way how wind turbine will respond to them.

The IEC 61400-25 series deals with communications for monitoring and control of wind power plants. The standard series is designed for a communication environment supported by a client-server model. One goal is to specify the information models related to condition monitoring for wind power plants and the information exchange of data values related to these models. Testing of monitoring and control suits well for the MegaCentre nacelle area.

VTT was asked to assess a fault ride through (FRT) testing methods planned for the MegaCentre. One alternative is so-called full converter based FRT-arrangement, which is capable to produce for instance voltage dips for FRT. The principle of the system is shown in Figure 5 (Pöllänen et al, 2011). The EUT, which is a full-power back-to-back converter connected to generator, is supplied by an identical full-power back-to-back converter. The grid side converter of the test bench controls the DC-link voltage to its reference and serves as a power supply to the grid emulator. Grid emulator converter operates as a controllable AC

voltage source and generates voltage dips and frequency by using an inbuilt voltage waveform generator. Both symmetrical and unsymmetrical voltage faults of various types can be emulated (Pöllänen, 2011). The LVRT test bench is designed for LV testing of wind turbine converters up to 2 MW.

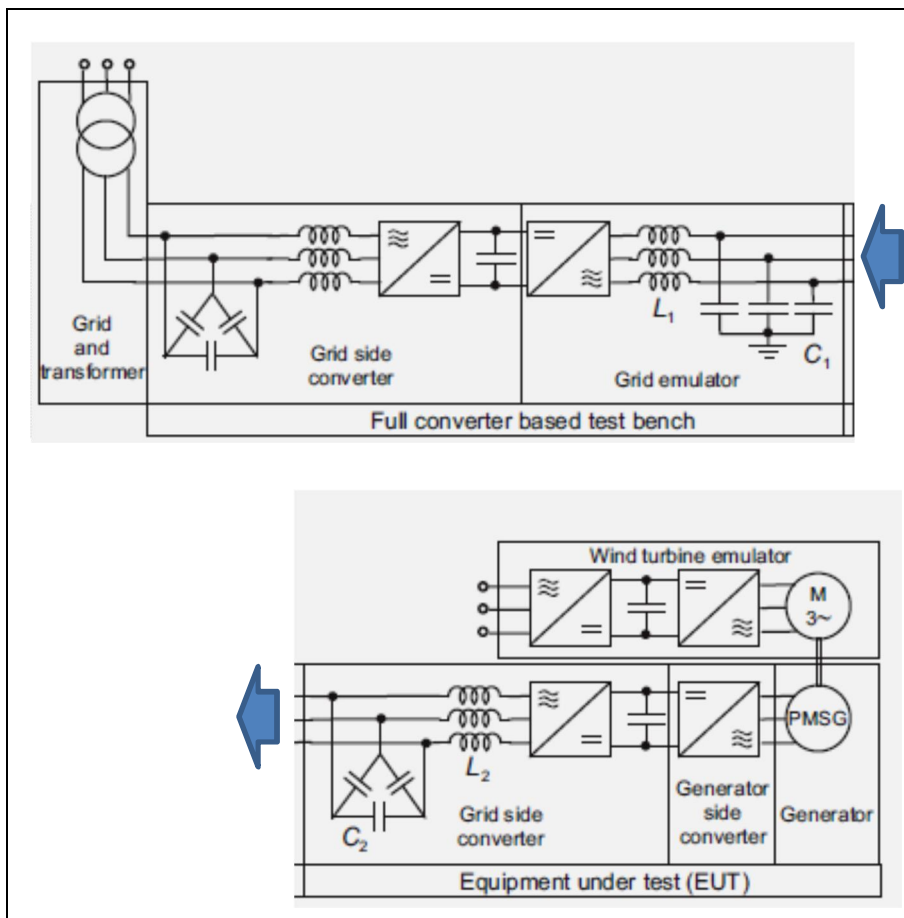


Figure 5. Overview of the full converter based LVRT test bench (Pöllänen, 2011).

Several other FRT-systems based on the standard (IEC 61400-21: 2008) have been built up at low or medium voltage levels. They are in this context called a conventional FRT-arrangement, see Figure 6. The principle is to use adjustable impedances (reactors), one for controlling the voltage dip shape and the other for limiting the stress of the dip in the supplying network. As an example a test facility made by ABB has the rated values 20 kV and 3 MW (ABB Press Release).

A test bench research project is the research programme TPWIND WG3. It will concentrate on wind power capabilities for system support and Virtual Power Plant operation, during 2013-2015.

Fraunhofer IWES has built the Testing Laboratory for Grid Integration (PNI) for research and testing services. The reference lab was created providing the possibility to realistically develop and test grid components and grid equipment in view of new system functions. Focus of the PNI is to investigate and test the grid interface of power generation plants and other appliances. The infrastructure permits investigations of low and medium voltage grids in the power range up to 6 MVA. The laboratory enables to proof the performance of devices and equipment at different grid conditions (Fraunhofer IWES, 2011).

Finally, the consortium for building the MegaCentre has to decide which type of the previously mentioned FRT-testing alternatives should be selected. The designed ratings for MegaCentre system are 10 MW at medium voltage level, either 10 or 20 kV. The following aspects have to be considered.

- a) The converter based LVRT test bench (Pöllänen, 2011) is designed for a low voltage and 2 MW. It is not yet known whether the upgrading of the system is possible.
- b) The grid connected FRT testing facility (a short circuit emulator) consists of impedances and a switch fulfilling the high current and voltage values of the MegaCentre.

Alternative a) would be more flexible in simulating the faults and the grid is isolated from the test area. The alternative b) is operating in the real grid conditions, which force the test specimen to be planned to cope with more severe circumstances, but the system may cause or may be caused by the interferences of the network.

The laboratory testing is expected to shorten the on-site testing time and costs. The final commissioning test has still to be done on site with the local network and a complete wind turbine. A voltage drop may cause a wind turbine to cut-off for many reasons, not only related to the electrical drive. Additionally, the switching event and the network conditions have an influence on the test result. It is therefore important to test the complete wind turbine finally on-site.

3.3 Wind turbines – Power quality measurements

Standard IEC 61400-21 specifies the quantities to be determined for characterizing the power quality of a grid connected wind turbines. The standard is briefly referred here keeping in mind the possible nacelle tests in MegaCentre facilities.

The power quality characteristics here include wind turbine specifications, voltage quality (emissions of flicker and harmonics), voltage drop response, power control (control of active and reactive power), grid protection and reconnection time, (IEC 61400-21: 2008).


3. WP1: Electric testing opportunities in nacelle testing area

The voltage fluctuations (flicker and voltage changes) shall be measured in the continuous operation and in switching operation like wind turbine start-up at cut-in speed or start-up at rated or higher wind speed. Detailed measuring procedure given in the standard.

The individual harmonic current components shall be specified for frequencies up to 50 times the fundamental grid frequency, and the total harmonic current distortion shall be stated as derived from these. The requirements and measuring methods are described in the standard series IEC 61000.

The system response test for the voltage drops described in Table 1 shall be determined at low output power values and close the maximum output of the wind turbine. The test is basically for verifying wind turbine response to voltage drops (due to grid faults) and providing a basis for wind turbine numerical simulation model validation (IEC 61400-21: 2008).

Table 1. Specification of voltage drops. The specified magnitudes, duration and shape are for the voltage drop occurring when the wind turbine under test is not connected (IEC 61400-21: 2008)

Case	Magnitude of voltage phase to phase (fraction of voltage immediately before the drop occurs)	Magnitude of positive sequence voltage (fraction of voltage immediately before the drop occurs)	Duration [s]
D1 – symmetrical 3-phase voltage drop	0,90 ± 0,05	0,90 ± 0,05	0,5 ± 0,02
VD2 – symmetrical 3-phase voltage drop	0,50 ± 0,05	0,50 ± 0,05	0,5 ± 0,02
D3 – symmetrical 3-phase voltage drop	0,20 ± 0,05	0,20 ± 0,05	0,2 ± 0,02
D4 – 2-phase voltage drop	0,90 ± 0,05	0,90 ± 0,05	0,5 ± 0,02
VD5 – 2-phase voltage drop	0,50 ± 0,05	0,75 ± 0,05	0,5 ± 0,02
VD6 – 2-phase voltage drop	0,20 ± 0,05	0,20 ± 0,05	0,2 ± 0,02
Shape in all cases			

NOTE 1 A voltage drop may cause a wind turbine to cut-off for many reasons, not only related to the electrical drive train. It is therefore important to test on-line the complete wind turbine.

NOTE 2 The purpose cases VD1 and VD4 is basically to test those wind turbines that have no capability toride through any deep voltage drops. These test serve as a basis for validation of the simulation models.

The response test to the temporary voltage drop of the wind turbines can be carried out a test set-up shown in Figure 6.

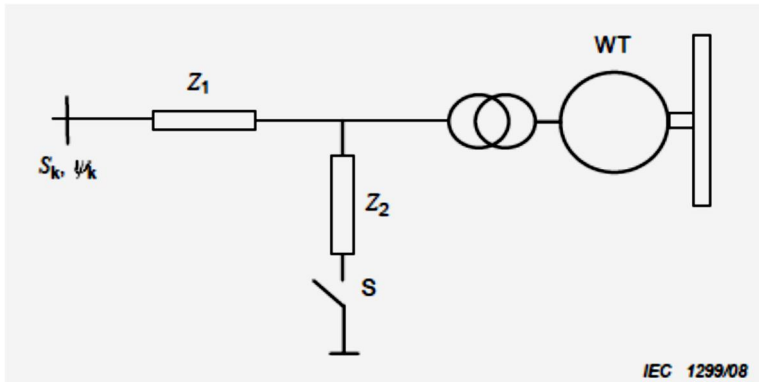


Figure 6. Short circuit emulator for testing wind turbine response to temporary voltage drop. In the figure WT is wind turbine; S_k, φ_k represents the is the short-circuit apparent power at the PCC and its phase angle; The impedances Z_1 and Z_2 are adjusted for voltage drop shape and limiting the effect of the short-circuit on the up-stream grid. (IEC 601400-21: 2008)

Active and reactive power measurements need the adjustment of turbine speed. The ability of the wind turbine to operate in active set-point control mode or in ramp rate limitation control mode shall be characterized by test results presented in a graph. The reactive power set-point control shall be described in a similar way as for the active power.

The protection levels and the disconnection times of the wind turbine shall be determined concerning over- and under-voltage and over- and under-frequency. The set-point protection levels and disconnection times of the controller shall also be specified.

The reconnection time after the wind turbine has been disconnected due to a grid failure shall be characterized. The reconnection time is the time from the instant when the grid is available on the wind turbine terminals to the instant when the wind turbine starts producing power.

3.4 Certification of wind turbines

Part 22 of the EC 61400-standard series defines rules and procedures for a certification system for wind turbines that comprises both type certification and certification of wind turbine projects installed on land or off-shore. This system specifies rules for procedures and management for carrying out conformity evaluation of wind turbines and wind farms, with respect to specific standards and other technical requirements, relating to safety, reliability, performance, testing and interaction with electrical power networks (IEC 61400-22: 2010). This kind of a certification may be needed.

3.5 Grid connection rules

The generator units to be tested in the MegaCentre nacelle testing area will be connected to medium or high voltage network. For the time being the grid connection rules in medium voltage network differ quite a lot from country to country. This means that the requirements and limits need to be checked case by case. Some general rules have been stated in (BDEW, 2008):

- stay connected during grid failures
- supply short circuit current
- supply reactive power under normal operation conditions
- reduce active power with over-frequency.

In the near future the grid codes within Europe will be harmonized by ENTSO-E organisation. In Finland the requirements of the Nordel Connection Code for wind turbines (Nordel 2006) are followed for high voltage (HV) systems.

Overvoltages on the overhead lines of the grid due to atmospheric phenomena are largely limited by the dielectric strength of the lines and the overvoltage protection of the transformer stations.

The limits values for harmonics at HV levels and those for low voltage (LV) and medium voltage (MV) differ between the countries. The European standard (EN 50160: 2010) describes the limits or values for the voltage characteristics and single rapid voltage changes. In general, the frequency and magnitude of rapid voltage changes are related to the load variation by the users and to the short-circuit power level of the network.

The standard series IEEE 1547 define interconnecting of the distributed resources. It is valid for the capacity of 10 MVA or less, interconnected at typical primary or secondary distribution voltages. The standard specifies the following specifications and requirements. Additionally, the standard provides the requirements for testing the interconnection system (IEEE 1547.1, 2005).

Figure 7 shows few examples of voltage dips required for FRT-testing (DER-lab, 2009). The European practises would be harmonised in the next ENTSO-E requirements.

Most of the different requirements are possible to fulfil in the MegaCentre test bench. As a conclusion of these test descriptions VTT will propose a careful reading of the requirement before each test taking into account the technical specifications of the wind turbine and the network. Finally, the requirements valid in the target country or target countries give the test program settings.

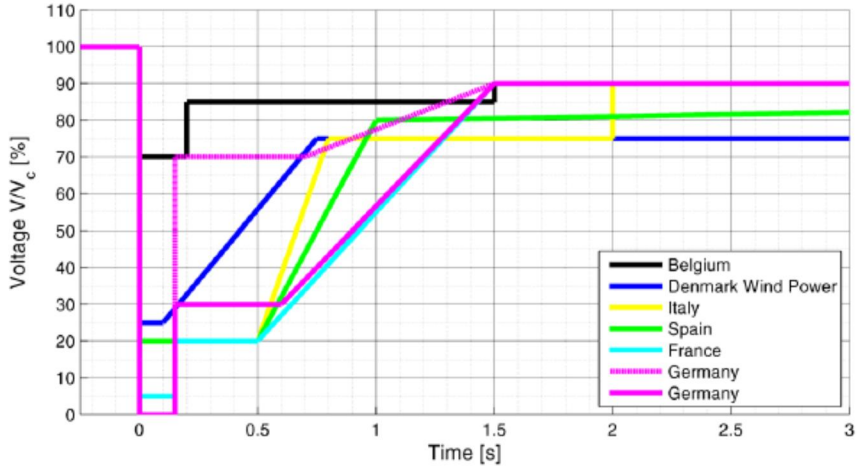


Figure 7. European Review on FRT Requirements. Voltage drop characteristics in different European countries (DERlab, 2009)

4. WP2: Business and implementation plan

Based on the project partner interviews, MegaCentre's business concept including the necessary elements (business idea, networks, offering, ownership, funding, customers, resources, skills, earning logic) has been created and refined into a business plan, Figure 8. The work in WP2 was executed in three interdependent tasks. The discussions with the consortium members were done at the same time with the designing phase of a business concept and financing and organizing phase of a business model. These discussions with the consortium members were conducted together with the technical discussions of WP1. The work in WP2 has been done without Tekes funding.

Especially when moving to the implementation phase of the business model, when the business model as a plan is translated into business structure, business processes and infrastructure, the consortium members need to be committed to the project. The commitment requires shared understanding about the targets and their alignment.

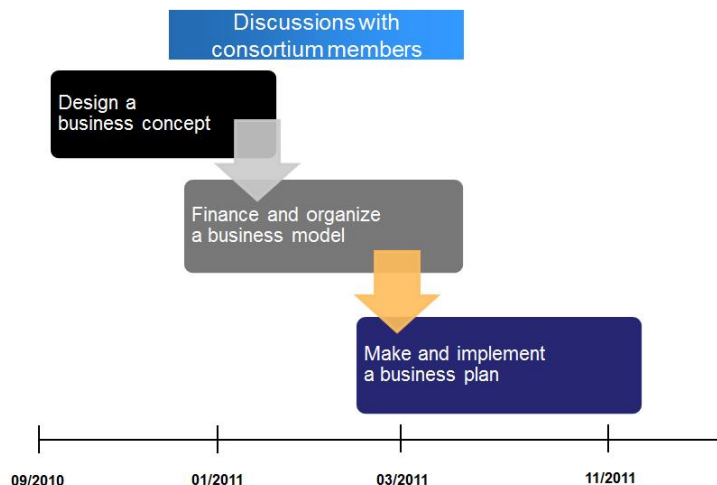


Figure 8. WP 2 (business model) execution.

4.1 Task 2.1: Business model and customers

Quoting the project plan: *“Business concept and market potential (key members, market summary, opportunities, competition, goals and objectives) focused on the needs of the MCPP consortium, will be designed and evaluated. The MegaCentre business must cover the operational expenses and the operations must be slightly profitable. MCPP consortium’s CEO level’s involvement in the Task 2.1 is essential. The outcome (deliverable) of the Task 2.1 is the MegaCentre business concept/plan and the strategy”.*

Business idea

The business idea (Figure 9) or vision is that the MegaCentre will be an independent world-class research and development facility addressing wind industry future needs. MegaCentre will enable the creation of international top know-how and its centralization in Finland.

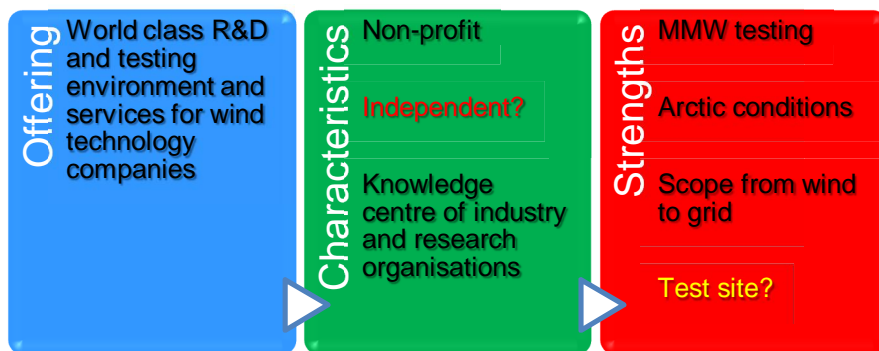


Figure 9. The business idea of the MegaCentre.

Demand

The main needs of the consortium companies were charted in interviews and taken into account in the offering of the facility. There will be two main testing stations (both “under the same roof”), one for gearboxes and the other for nacelles, generators and hybrids. The facility will be able to conduct cold climate tests to all the above mentioned tests and will have the ability to connect to testing equipment for studying of grid defects. Additionally the facility will be able to test power converters. The main driver for owners’ demand is the physical limitations of current testing equipment for the future applications. According to the interviews, the facility does not seem to have excess capacity.

Market environment

The wind industry is developing fast in terms of technology. The average sizes of new installations (wind mills) are increasing in all markets, the integration of the generator and the gearbox is creating new technological possibilities, the permanent magnet technology PMG is used to reduce the size of turbines and gearless turbines are gaining interest due to fewer parts. The off-shore technology is also developing and it is increasing in importance. The announced turbines under development are 5–7 MW. Their certification is as well getting more important. The grid codes are becoming more demanding, the gearboxes need to be certified already and the certification of generators could be a requirement or sales argument in the future.

There are already some existing and planned facilities in the market. They are shown in Figure 10.

Name	Num of test rigs (operational + planned)	Max Nacelle MW test (operational + planned)	Max Gearbox MW test (operational + planned)	Construction schedule	Info
NaREC/UK	0+(2)	0+(3MW+15MW)	0	3MW: 06/2012 15MW: 06/2013	ETI -funding 25 M€ (EU-funding?)
LORC/DK	0	0+(10MW)	0	Q4/2013	
NREL/US	1+(1)	2,5MW+(5MW)	0		National funding
Clemson/US	0	0+(15MW)	0+(7,5MW)	2013 (both)	DOE-aid 45 M\$ connected to public funding of 53 M\$ Weather room (10 m x 7m x 7m), lowest temperature -60 degrees Celsius. Suitability for heavy parts (up to 150 t). National funding. EU financing?
Sirris/BEL	0	0	0+(?)		
CENER/ESP	3				1. Large-capacity line test bench (only torque) 2. Generator test bench 3. Test bench for functional testing of nacelles, LVRT tests.

Figure 10. The existing and planned facilities in the market.

Offering

MegaCentre has both own resources and outsourced resources. The core offering consists of testing infrastructure for gearboxes, generators, power transformers and wind turbine nacelles. The core offering always includes the reporting of the test results, security of the premises and offices for customer's personnel. The secondary offering consists of assembly and warehousing of the tested equipment, preparation of test set ups, planning of the tests, analysis of the reports and connecting the customers to different subcontractors. The additional outsourced offer-

ing, that is optional for the customers and costs them extra, consists of logistics, subcontractors of added research, proof of concept verification and certification. The entire scope of offering is shown in Figure 11.

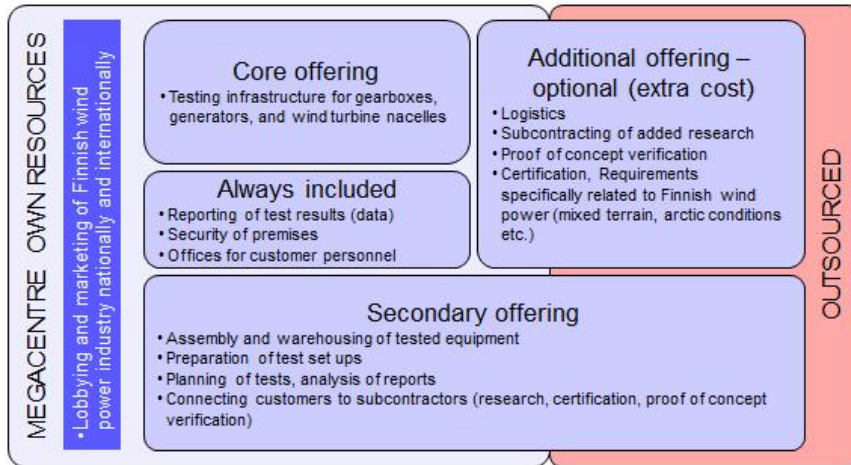


Figure 11. The scope of the MegaCentre's offering.

Operating model and resources

The operating model and organization of MegaCentre is shown in Figure 12. The operating model and resources are for the first operational year. The own employees of the MegaCentre are responsible for general management of the centre, as well as for the main testing operations. As another option it has been considered that VTT Expert Services (ES) could take main responsibilities for testing operations. This would require geographical proximity between VTT and the MegaCentre. Research operations, proof-of-concept verification as well as certification will be subcontracted from network partners. Also supporting operations like security, maintenance, IT, accounting etc. will be subcontracted.

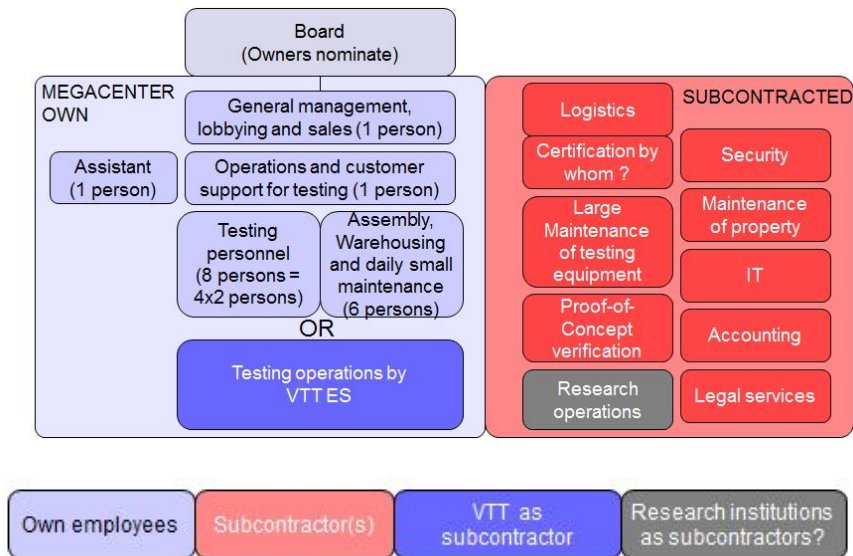


Figure 12. The MegaCentre’s operating model and organization, first operational year.

Customers

The main customers of the MegaCentre will be the consortium companies. Mega-Centre has also the capability to serve other wind technology companies and research organisations but the consortium companies are the priority customers. ***In order to ensure also public funding to the MegaCentre, openness and knowledge sharing between network actors (research institutes, consortium members and other customers) is needed.***

4.2 Task 2.2: Ownership and governance

Quoting the project plan: “*The most feasible business model, ownership structure, governance aspects and implementation plan will be designed. MCPP consortium’s CEO level’s involvement in the Task 2.2 is essential. The outcome (deliverable) of the Task 2.1 is the MegaCentre business organization structure*”.

Ownership and governance

WP 2 suggests that the MegaCentre’s owners will be the MCPP project consortium companies and research organizations, thus they will have the right to nominate a board member. The owners will cover the operational costs of MegaCentre and finance investments of the MegaCentre according to their ownership share. In exchange, the owners will be allocated time from the MegaCentre according to their ownership share.

The ownership of the consortium members is highly critical for MegaCentre. This is because, like stated earlier in task 2.1, the consortium companies are the main customers of MegaCentre. MegaCentre's future income also depends on the commitment of the consortium companies. The security to external funding can only be achieved through the commitment of the owners. ***Anyhow, it is important also to consider knowledge sharing practices and broader collaboration model(s) of the MegaCentre to gain the vision of competence centre and to ensure public funding.***

4.3 Task 2.3: Operational activities and earning logic

Quoting the project plan: *"The earning logic and the organizational activities harnessed for that purpose will be designed. The primary focus will be on the strategic and operational needs of the MCPP consortium member organizations. The secondary and subsequent focus will be on the associated research and development operations. Fixed and alternating costs for the three stages will be evaluated, from which the basis for the service pricing and earning logic aspects will be calculated. Finally, the preliminary operational budget will be defined. The outcome (deliverable) of the Task 2.3 is the MegaCentre operations plan. The outcome (deliverable) of the WP1 is a report describing the MegaCentre hardware concept, specification and layout"*.

Earning logic

The MegaCentre will operate on non-profit basis. The activities consisting of utilisation of testing equipment and related activities are charged from the customer according to the actual costs. This is how MegaCentre will create small operative income. The other customers than owners will be granted availability of facility only after owners and will be charged a market price.

Premises costs and testing equipment costs

The MegaCentre building consists of facility for testing and assembly and auxiliary facility for light substation, circulation lubrication etc. The premises costs and testing equipment costs are calculated for two cases; the high end case and the base case.

In the high end case the total facility area will be 4500 m². The facility for testing and assembly is 3600 m² (30 m*120 m), the auxiliary facility for light substation (110 kV/20 kV), circulation lubrication etc will be 400 m² and offices will be 500 m². In the base case the total facility area will be 3500 m². The facility for testing and assembly is 2700 m² (30 m*90 m), the auxiliary facility for light substation (110 kV/20 kV), circulation lubrication etc will be 300 m² and offices will be 500 m².

The testing equipment costs include load equipment, for both common mechanical infrastructure and common electrical infrastructure, gear-specific testing equipment, nacelle-specific testing equipment, heavy overhead cranes and also some miscellaneous. The mechanical test rig in both high end case and base case

4. WP2: Business and implementation plan

include gearboxes, shafts, coupling, circulation and lubrication. In both cases the costs of mechanical test rig is 6 M€. The electrical infrastructure in the high end case includes electrical drives, control, measuring system and Fault Ride Through (FRT) testing equipment. The costs of the electrical infrastructure are 6,1 M€. In the base case the electrical infrastructure includes electrical drives, control and measuring system. The costs of the electrical infrastructure in base case are 3,1 M€. The gear specific testing equipment includes among all shafts, couplings, lubrication and set-up equipment. The costs of the gear specific testing equipment in both high end case and base case are 1,1 M€. The nacelle specific testing equipment in the base case include shafts, couplings, equipment for fixing the nacelle onto the foundation and walkways. The costs of the nacelle specific testing equipment in the base case are 1 M€. The nacelle specific testing equipment in the high end case include all the same equipment than in the base case and a Wind Load Unit (WLU). The costs of the nacelle specific testing equipment in the high end case are 8 M€. The heavy overhead cranes in both high end case and base case include two cranes of 250 t and one crane of 50 t. The costs of the heavy overhead cranes in both cases are 2 M€. The miscellaneous in both high end case and base case include the same items and the same costs. The items are transporting equipment, storing equipment, auxiliary cranes, hand tools, fixtures, compressed air, furniture and equipment for office and ICT. The miscellaneous costs are 3,8 M€. The MegaCentre premises costs and testing equipment costs calculated according to these dimensions and divided into high end case and base case are shown in Figure 13.

Item	High end case	Base case
Building	13,0 M€ / 4500 m ²	11 M€ / 3500 m ²
Load equipment, common mechanical infrastructure	6,0 M€	6,0 M€
Load equipment, common electrical infrastructure	6,1 M€	3,1 M€
		(FRT -3,0 M€)
Gear specific testing equipment	1,1 M€	1,1 M€
Nacelle specific testing	8,0 M€	1,0 M€ (WLU -7,0 M€)
Heavy overhead cranes	2,0 M€	2,0 M€
Miscellaneous	3,8 M€	3,8 M€
Equipment total	27,0 M€	17,0 M€
GRAND TOTAL	40,0 M€	28,0 M€

Figure 13. Premises costs and equipment costs for high end case and base case.

Main uncertainties in cost estimates

The main uncertainties in cost estimates shown in Figure 13 come from the facts that the binding offers are not included in the numbers (as they are not available during the writing of this report), cost for building and unique structures are making regional development companies cautious and cranes and some other equipment

in buildings might be transferred in MegaCentre budget. Some uncertainties may also come from the cost of loading device for nacelle testing.

Cash cost elements for testing

The costs for testing consist of salaries, electricity, maintenance, rent and interests. The salaries consist of two management level persons and 15 employees. The electricity costs are based on the price of 100 €/MWh. The electricity is used 20% of total time with 2 MW input electricity. The maintenance costs are calculated to be 1% of investment cost per annum and the rent/leasing 9% of facility investment costs. The interest is based on 5% of investment per annum, the repayment period of 20 years and 50% of the capital being funded through loan. The costs shown in Figure 14 do not include capital cost (4,6 m€/a), depreciation or abbreviation.

Element	Cost (t€/a)
Salaries	636
Electricity	350
Maintenance	205
Other variable costs	135
Rent/leasing	1315
Interest	531
IN TOTAL	3172

Figure 14. Cash cost elements for testing without capital cost, depreciation or abbreviation.

First, the critical step toward implementation phase (WP4) is the commitment of consortium members, e.g. companies have to make the strategic decision whether to participate to MegaCentre funding, building, use and development together or not.

Secondly, the consortium members have to choose the business model of the MegaCentre. The main options for that are: 1) **the test facility model**, in which main customers are the consortium members and they utilise the premises for testing purposes independently and 2) **the competence centre model**, in which co-operation between network partners is more open and MegaCentre has also other customers than consortium members.

Thirdly, based on these decisions the more detailed operation model of MegaCentre can be described, analysed, accounted and agreed on

5. WP3: Wind technology r&d networks

5.1 National programmes and networks

A test facility could provide valuable measurements for research projects. Testing and measuring extreme condition behaviour can be used in model validation.

In Finland, there is ongoing research under FIMECC Finnish Metals and Engineering Competence Cluster (SHOK) that has related programmes and projects.

Tekes has changed the funding instruments so that the commonly used enterprise projects are no longer possible from large companies (personnel > 250). The new instruments still include projects in the category "Public research networked with companies" where enterprise projects and research projects are grouped together (research projects cannot exceed 50% of the whole budget of the group).

Wind energy r&d network would be a natural partnership to MegaCentre. However, there is no wind power research programme in Finland. The energy SHOK CLEEN started the work on wind energy programme preparation, but this WIPO programme was rejected by Tekes. It could be possible to prepare a joint programme with FIMECC and CLEEN for wind power research. This programme could have virtual prototyping as one research topic, that would be an excellent combination to MegaCentre tests and measurements. To start a research programme would need the wind industry in Finland to initiate the preparation of it and make a clear message to Tekes that this kind of work is needed. The SHOK programmes must have at least half of the work from the industry and maximum half made in the research institutes. The programmes are intended for long term research, so all results are commonly shared between the partners in the programme – this will push the work made towards longer goals as there may be competitors as partners in the programme.

5.2 International programmes and networks

5.2.1 Technology Platform Wind (TPWind)

European Technology Platform for Wind Energy is a forum to discuss future R&D and demonstration activities to be proposed to EU funding, and it has a close link with EWI the industrial initiative for Wind.

From MegaCentre point of view, TPWIND is important to follow as it prepares future European research agenda. Test facilities are listed in the activities to be funded.

TPWIND started with publishing a Strategic Research Agenda (SRA) in 2008. Then, SET Plan with Industrial Initiatives were formed and TPWIND secretariat has formulated a first draft of the EWI Wind Initiative, based on the SRA. Currently TPWIND is finalising texts for EWI Implementation plan 2013-15, listing important project topics and ways that they should be funded (FP7 calls, member state funding, etc), and starting working on updating the SRA document from 2008.

TPWIND was formed in 2007 and it has now started its second round for 2011–13. The members for 3 years are selected for 5 working groups, through an open "call for expression of interest". The members are from the wind industry and research sector, covering all member states. The wind energy association EWEA is coordinating the secretariat work with an EU funded project. The members come to the General Assembly meetings twice a year with their own funding.

The objective of TPWind is to identify areas for increased innovation, new and existing research and development tasks. These will then be prioritised on the basis of "must haves" versus "nice to haves," the primary objective being overall (social, environmental and technological) cost reductions. This will help to achieve EU objectives in terms of renewable electricity production. TPWind will also assess the overall funding available to carry out this work, from public and private sources. (<http://www.windplatform.eu/>)

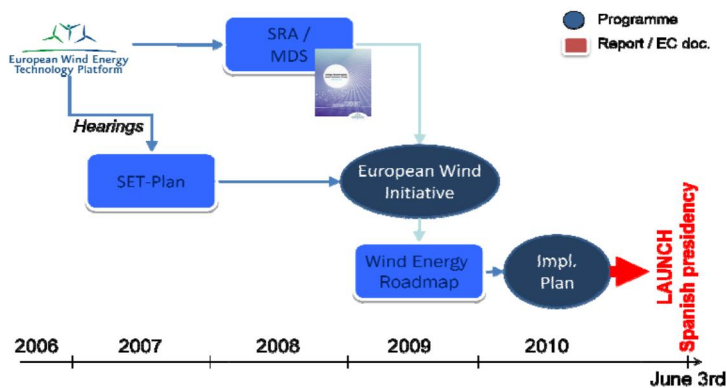


Figure 15. Links between Strategic Energy Technologies SET-Plan, European Wind Initiative (EWI) and Wind energy Technology Platform TPWind. Technology platform provides strategic research agenda as well as inputs to EWI Implementation Plan topics of future research.

5.2.2 European Wind Initiative (EWI)

The EWI is a long-term, large-scale Programme for funding wind power R&D and accelerate its development (NOTE funding through EU and national instruments).

From MegaCentre point of view, EWI is important as test facilities are listed in the activities to be funded – both in turbines and components and grid integrator. However, test facilities for components are not included in call texts but are proposed to be funded through EIB loan and equity. The test facility in grid integration strand is proposed to be funded by member states.

The EWI is one of the EU Industrial Initiatives of the 2007 Strategic Energy Technology Plan (SET-Plan). SET Plan is an EU blueprint for the development of low-carbon technologies published by the European Commission in 2009 in its Communication on “Investing in the Development of Low Carbon Technologies” (COM(2009) 519) and launched in 2010. It contains a short text for EWI, The Wind Energy Roadmap. The roadmap is set to become one of the most important instruments for the development of wind power in the 2010–2020 period and will play a key role in fighting climate change and in helping EU Member States to meet the 2020 targets identified by the new RES Directive (approved in December 2008), by achieving the following goals:

- A wind energy penetration level of 20% in 2020
- Onshore wind power fully competitive in 2020
- 250.000 new skilled jobs created in the EU by the wind energy sector in the 2010–2020 period.

The roadmap has a total budget of € 6 bn (private and public resources with estimated 50/50 split) for 2010–20, see Figure 19. Public resources will come from both Member States and EU Institutions, although European funds should cover the majority of costs, considering the EU added value and impact of the EWI. Public resources have been identified but still have to be secured: public authorities are already funding the EWI but have yet to commit to a specific, dedicated funding envelope. EWI is a long term programme for increasing and coordinating the funding of wind energy R&D, so as to ensure its quick development and deployment in the EU.

EWI strand	Total budget (€ m)	2010 – 2012 budget (€ m)	Budget intensity
1. New turbines and components	2,500	763	30%
2. Offshore technology	1,200	315	26%
3. Grid integration	2,100	337.33	16%
4. Resource assessment and spatial planning	200	36	18%
Total (including EEPR funds)	6,000	1,451.33	24%

Figure 16. EWI four strands and budget. (The Grid integration strand will be merged with EEGI Grid Initiative so the budget will be reduced in EWI side).

The roadmap focuses on the following key areas:

- New turbines and components
- Offshore technology
- Grid Integration
- Resource assessment and spatial planning.

The roadmap priorities for 2010–2012 period for these areas are highlighted in Figure 17.

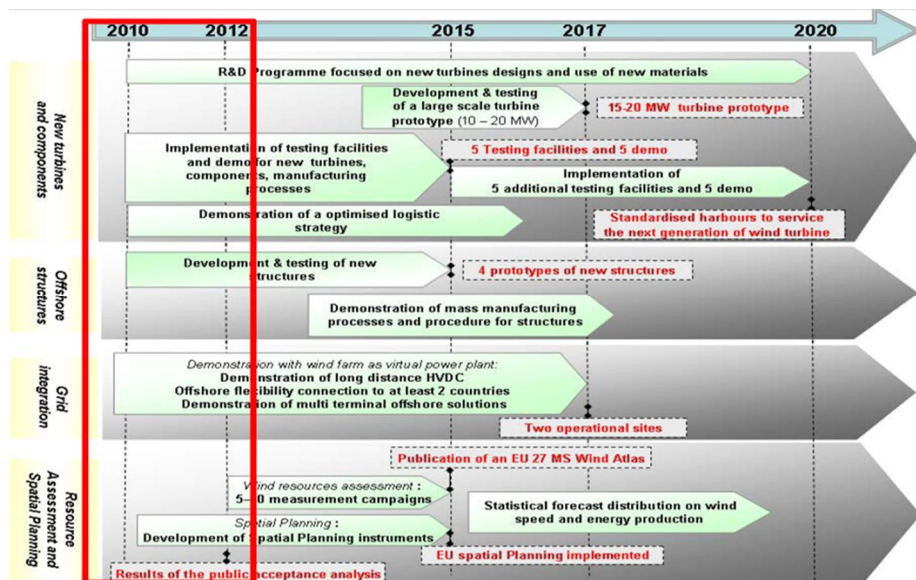


Figure 17. EWI main highlights.

The EWI was developed by TPWind in cooperation with the European Commission and Member States, the result of a transparent and shared process, in which all relevant stakeholders have been involved. Wind European Industrial Initiative Team (Wind EII Team) composed of EU, national and TPWind representatives translates the EWI into annual funding recommendations for EU and national authorities. This will follow the Implementation Plan documents (now 2013–15 document in finalising stage) and yearly work plans proposing project subjects for EU funding, for example.

The implementation of the EWI will:

- Speed up the development of wind power
- Help Europe to maintain its global technological leadership
- Contribute to the achievement of the EU 2020 binding targets
- Contribute to de-carbonize the EU economy and fight climate change
- Increase security of energy supply
- Create new jobs.

The objectives described by the European Commission’s Wind Energy Roadmap for New turbines and components are the following:

- To develop large scale turbines in the range of 10–20 MW especially for offshore applications

- To improve the reliability of the wind turbine components through the use of new materials, advanced rotor designs, control and monitoring systems
- To further automate and optimize manufacturing processes such as blade manufacturing through cross industrial cooperation with automotive, maritime and civil aerospace
- To develop innovative logistics including transport and erection techniques, in particular in remote, weather hostile sites.

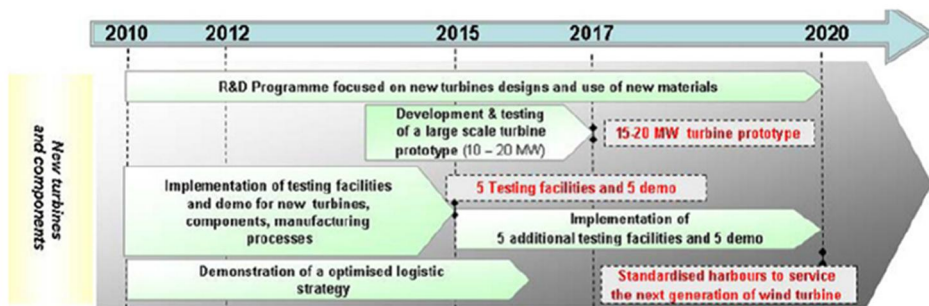


Figure 18. EWI strand turbines and components.

These objectives are supported by the following Actions:

- R&D programme focused on new turbine designs, materials and components addressing on- and offshore applications coupled with a demonstration programme dedicated to the development and testing of a large scale turbine prototype (10–20MW);
- A network of 5–10 European testing facilities to test and assess efficiency and reliability of wind turbine systems;
- An EU cross-industrial cooperation and demonstration programme drawing upon the know-how from other industrial sectors (e.g. offshore exploration) for mass production of wind systems focused on increased component and system reliability, advanced manufacturing techniques and offshore turbines. A set of 5–10 demonstration projects testing the production of the next generation of turbines and components will be carried out.

5.2.3 European Energy Research Alliance (EERA)

EERA is an alliance of leading organizations in the field of energy research. EERA aims to strengthen, expand and optimize EU energy research capabilities through the sharing of world-class national facilities in Europe and the joint realization of pan-European research programmes (EERA Joint Programmes).

From MegaCentre point of view, EERA can be a network that MegaCentre could join once it has been built. There is a subprogramme of Research facilities that VTT as a member of EERA JP WIND is currently following. MegaCentre company could join that network as an associate member of VTT.

The primary focus of EERA is to accelerate the development of energy technologies to the point where they can be embedded in industry-driven research. In order to achieve this goal, EERA streamlines and coordinates national and European energy R&D programmes. In order to contribute to achieving the SET-Plan objectives and strengthen the research base in the EU, the EERA aims to:

- Accelerate the development of new energy technologies by conceiving and implementing Joint Programmes of research in support of the SET-Plan priorities, pooling and integrating activities and resources, combining national and Community sources of funding and maximizing complementarities and synergies, including international partners.
- Work towards a long term, durable integration of excellent but dispersed research capacities across the EU, overcoming fragmentation, optimizing the use of resources, building additional research capacity and developing a comprehensive range of world class pan-European energy research infrastructures.
- Develop links and sustained partnerships with industry to strengthen the interplay between research outcomes and innovation

EERA Joint Programme Wind

The strategy and main activities of the JP Wind is described in the "Strategic Action Plan", which is updated annually. The programme vision is:


- to provide strategic leadership for the scientific–technical medium to long term research
- to support the European Wind Initiative and the Technology Roadmap's activities on wind energy, and on basis of this
- to initiate, coordinate and perform the necessary scientific research.

Joint Programme Wind has Sub-programmes

- Wind Conditions. Coordinated by Prof. Erik Lundtang Petersen, DTU Wind Energy (DK)
- Aerodynamics. Coordinated by Dr. Peter Eecen, ECN (NL)
- Offshore Wind Energy. Coordinated by Dr. John O. Tande, SINTEF (NO)
- Grid Integration. Coordinated by Dr. Kurt Rohrig, FhG IWES (DE)
- Research Facilities. Coordinated by Dr. Pablo Ayesa Pascual, CENER (ES).

- Structural design and materials. Coordinated by Dr. Denja Lekou, CRES (GR)

The present members in JP Wind are shown in Figure 19.



Participants

Full participants		Associated Participants	
Risø DTU	DK	University of Porto	PT
ECN	NL	NTNU	NO
CRES	GR	IFE	NO
CENER /CIEMAT	ES	Forwind/University of Bremen	DE
FhG IWES	DE	Forwind/University of Hannover	DE
LNEG/INETI	PT	DHI	DK
SINTEF	NO	University of Aalborg (AAU)	DK
VTT	FI		
University of Strachclyde	UK		
Forwind / University of Oldenburg	DE		

New applicants in progress
 CENERG (PO), UCD (IR), Tubitak (TU), WMC (NL), TUV (NL), CTC (ES), NAREC (UK), CNR (IT), ENEA (IT), SIRRIS (BE)

www.eera-set.eu

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Figure 19. EERA JP Wind members.

EERA Joint Programme membership

EERA accepts as members research institutions. There are three levels of membership: *Partners*, *Participants* and *Associates*. All three levels are *EERA members*.

Partners. VTT is partner and a founding member of EERA. Partners have a collective responsibility to ensure the overall good functioning of EERA. Partner CEOs form EERA Executive Committee (ExCo).

Participants. EERA Joint Programme Participants (Participants) have a collective responsibility to ensure the overall good functioning of an EERA Joint Programme. Associate Participants (see definition of Associates below) are linked to

a particular Participant and contribute¹ to the volume and scope of activities attributed to that Participant.

Participants contribute with at least 5 PPY² per year in a programme³ and member of the Joint Programme Steering Committee (JPSC is defined below).

Participants sign the Joint Programme Letter of Intent and EERA Declaration of Support.

A Participant is responsible for ensuring that its Associate Partners adhere to EERA principles and all other obligations resting with the Partner for its own activities. To EERA there should be no difference between participation of staff from the Partner itself and the Partners Associated Partners.

Participant also represents Associates at JPSC.

The JPSC decides on an appropriate contribution to be paid by Participants toward the costs of joint programme co-ordination.

Participants are invited to participate in EERA Annual Congress. No conference fee for 2 representatives from Participant. Further representatives from Participant may have to pay a standard Congress fee. (It is expected that the EC will cover the total cost for the EERA annual congress)

Associated participant is associated to one EERA Participant and contributes to a Joint Programme via a Joint Programme Participant. The annual fee of an associated participant is 10% of Participants contribution.

Associated participants are invited to participate in EERA Annual Congress. No conference fee for 1 representative from Associate Participant. Further representatives from Associate may have to pay a standard Congress fee.

Adding Participants and Associates to the Joint Programme

Additional Participants and Associates are foreseen in order for the Joint programme to extend and complement the range of research. The new Participants and Associates shall be approved by the JPSC after a submitted request from the Joint Programme Management Board (JPMB).

To become a member of the JPWE as an Associated Participant the institution needs to file an application and to be nominated by a Participant. The application of the nominated Associated Participant will be reviewed by a member of the JPMB based on the following criteria:

- The applicant belongs to a country, which is a member or associated member of the European Union

¹ This gives incentive for clustering and makes it possible for a number of smaller units to team up and form a single unit recognised by EERA as a Participant.

² PPY: Professional Person Year.

³ The EERA ExCo can for individual Joint Programmes decide to apply a different threshold. It may for instance be opportune for a limited period to lower the required participation to facilitate the initiation of a JP.

- The applicant is a recognised institution within its field
- The R&D competences and priorities
- The added value of the applicant's research to at least one sub-programmes of the JPWE
- The applicant will be willing to commit substantial human resources e.g. at least 3 person years per year.

The JPMB proposes new applicants to the JPSC. When an applicant has been accepted by the JPSC the Participant or Associated Participant shall sign the Joint Programme Letter of Intent (LoI) and the EERA Declaration of Support (DoS) to become a member of the JPWE.

5.3 IEA IA Wind

International Energy Agency (IEA) has Implementing Agreements (IAs) for different energy sectors. Implementing Agreement on Wind energy is an active forum, with 22 countries participating, meeting twice a year and presenting the current deployment and research activities in the countries. It also launches collaborative Tasks for different topics and organises Topical Expert Meetings four times a year for changing subjects.

IEA activities are funded by national research programmes and from Tekes funding for joining the Executive Committee (ExCo) work.

From MegaCentre point of view, IEA WIND activities can be followed especially regarding international collaboration possibilities. In addition to following the European networks like TPWIND and EERA, IEAWIND has a wider view as it has also participantce from outside Europe (US, Japan, China, South Korea, Mexico).

VTT is currently the Chair of the Executive committee (2011-12) and coordinating two research tasks Task 19 (Cold climates) and 25 (Wind integration). VTT is participating in Task 11 and is also joining Task 30 (Offshore code comparison). Motiva and wpdFinland joined Task 28 (Public acceptance) in 2008-11.

As long as Finland is through TEKES a contracting party of IEAWIND, Finnish companies, research institutes, universities and other stakeholders have right to participate the Topical Expert Meetings organized by IEAWIND Task 11. The invitations to these meetings are circulated in Finland through VTT.

5.4 IEC TC-88 Wind turbines

IEC TC88 stands for the Technical Committee 88 of International Electrotechnical Commission (IEC).

The scope IEC TC-88 is to prepare international standards for wind turbines that convert wind energy into electrical energy. These standards address design requirements, engineering integrity, measurement techniques and test proce-

dures. Their purpose is to provide a basis for design, quality assurance and certification.

The standards are concerned with all subsystems of wind turbines, such as mechanical and internal electrical systems, support structures and control and protection systems. They are intended to be used together with appropriate IEC/ISO standards.

From MEGACentre and their industrial stakeholders point of view IEC TC-88 is the forum where the new developments of the standards can be followed and influenced. Work of MegaCentre could provide both scientific and industrial basis and support for the standards or to the views important for the stakeholders.

Appendix B lists the IEC-standards for wind turbines. In Appendix C, the working groups that are active at the moment are shown.

5.5 ESFRI European Strategy Forum on Research Infrastructures

There is EU funding available for Research Infrastructures that are networked and open for researchers from other countries. The funding has mostly been for integrating activities, as well as design studies and preparatory phase of new infrastructures.

ESFRI created a specific working group to evaluate proposals for research infrastructures in the energy domain (report year 2010). They have listed 3 energy related infrastructures to be included in their roadmap, one of them wind related (Windscanner: European Centre for Wind Energy Research in Atmospheric Turbulent Flow). Research infrastructure needs listed include also Drive train test facilities and Other component test facilities for extreme environmental loading.

5.6 DER lab

European Distributed Energy Resources Laboratories (DERlab) e.V. is a network of leading research institutes working together for the grid integration of distributed power generation.

VTT is a member of DER laboratories. The technical expertise of VTT cover:

- Interconnection requirements of DER
- Grid-connected storage
- EMC requirements for DER
- Static converters in grids
- DER testing procedures
- Ancillary services
- Communication
- PV modules
- Power hardware-in-the-loop
- Network protection.

For MegaCentre the DERlab could offer testing and consulting services. There could be also common goals between MegaCentre and DERlab in relation to the grid integration, smart grid and communication issues of distributed generation, like wind. However, DERlab is probably more concentrating on smaller scale distributed generation whereas focus of the MegaCentre is in the large wind turbines and their components.

6. Road map for the MegaCentre

6.1 Concept design (WP1)

Based on the current MegaCentre's technical specifications and layout design, more efforts are needed in differentiating MegaCentre from other, large test facilities (see Appendix B). For MegaCentre to be globally competitive, it needs to be an attractive technical test facility and service provider for the major wind turbine manufacturers and component providers and simultaneously support the domestic wind energy sector. Global attractiveness can be achieved by differentiating the MegaCentre from similar, large test facilities.

Currently, three key specialization areas were identified

- Cold climate conditions (i.e. cold climate chamber)
- Offshore conditions (i.e. salt chamber)
- Grid fault simulations (FRT/LVRT).

According to the company interviews, the ambient cold climate test chamber (mainly temperature and humidity control) will be available only for the main nacelle components (e.g. gearbox and generator) and not for the entire nacelle. In addition for the component cold climate chamber, cold start-ups after a long grid loss period for the entire nacelle might be economically feasible to have as a test set-up. Also the component level cold climate chamber needs more detailed technical planning (insulation and electrical power requirements etc.).

Offshore ambient condition simulations (mainly humidity and saltness) are designed for main nacelle components but plans for the actual implementation on this offshore test chamber are still missing. As with the cold climate test chamber, the offshore test chamber needs more thorough technical planning.

Fault ride through (FRT) testing in the nacelle testing area of MegaCentre still needs a careful planning with technical and economic comparison between the alternatives called a converter based FRT and a conventional FRT method. The majority of other test types can well be performed in the MegaCentre.

In case some certification of the tested wind turbines are needed, the rules and procedures of the Part 22 of the EC 61400-standard series should be used.

6.2 Business and implementation plan (WP2)

First, the critical step toward implementation phase (WP4) is the commitment of consortium members, e.g. companies have to make **the strategic decision whether to participate to MegaCentre** funding, building, use and development together or not.

Secondly, the consortium members have to choose the business model of MegaCentre. The main options for that are: 1) **the test facility model**, in which main customers are the consortium members and they utilise the premises for testing purposes independently and 2) **the competence centre model**, in which co-operation between network partners is more open and MegaCentre has also other customers than consortium members. The public funding can be more easily applied based on the second operation model.

Thirdly, based on these decisions the more detailed **operation model of MegaCentre** can be described, analysed, accounted and agreed on.

6.3 Wind technology R&D networks (WP3)

Based on the information about national and international networks and opportunities with European (EU Framework programs) and national (Tekes & CLEEN) research programs, a roadmap (strategy) on how and which research programs the MegaCentre could offer applied research services is presented.

Financing the infrastructure of a research facility (when the MegaCentre has not yet been constructed):

- EU funding opportunities are limited to European Investment bank loan and equity. In EWI Implementation Plan it is proposed that test facilities for 10 +MW turbines and components to be funded through: EIB loan € 30m Individual Loan and EIB equity: € 10m Marguerite Fund
- EAKR regional EU funds can be applied for regions outside Helsinki and Tampere areas (Tekes, TEM).
- National funding opportunities: there is a subsidy for renewable energies at the Ministry of Employment and Economy (TEM). It is used for power plants and energy efficiency schemes so should be checked whether can be used directly for facility like MegaCentre. If not, then other options should be discussed with the ministry, also the EIB equity and loan options can be further discussed with them.

Offering applied research services (once the MegaCentre is “up and running”):

- **Seek funding from existing national research programmes.** Such opportunities include the following:
 - CLEEN SGEM (Smart Grids and Energy Markets) programme has work related with wind turbine capabilities for grid support (Switch, ABB), topics like fault-ride-through etc .
 - FIMECC SHOK programmes should be followed to look for opportunities to propose work that requires measurements in test facility, for code validation, extreme loads etc.
 - New large research collaboration: in their renewed financing schemes, TEKES requires networked public and private r&d. Project proposals including experimental and theoretical research in collaboration with MegaCentre can be submitted already when MegaCentre is in the building phase. These proposals could include planning of the experimental work and facilities needed for the specific needs.
- **Propose new national research programmes with national funding:**
 - A wind power research programme would have as one main topic virtual prototyping and validation measurements where the MegaCentre would have a bigger role. To advance this, the wind power industry in Finland needs to take a leading role in proposing this for TEKES. This could be realised as a SHOK programme (joint programme of machinery and energy related SHOKs FIMECC and CLEEN).
- **Propose new international (EU) research projects.**
 - EU project proposals – through EERA network – can be easier to get to a good consortium for a proposal. The MegaCentre can apply for an affiliate/associate membership of EERA JP WIND through VTT and this should be considered when the MegaCentre is (close to) operational. The EU project calls proposed to be opened in summer 2012, in a draft circulated in February are the following (the last in the list could be a new network interesting for MegaCentre):
 - Topic ENERGY.2013.7.2.2: Large-scale demonstration of innovative transmission system integration and operation solutions for (inter)connecting renewable electricity production.
 - Topic ENERGY.2013.10.1.2: ERA-NET Plus – European wind resources assessment (European wind atlas)
 - OCEAN 2013.4 Innovative transport and deployment systems for the offshore wind energy sector
 - Topic ENERGY.2013.10.1.5: Joint programme in the field of wind energy (aims at preparing the next wave of industrial demonstration and deployment of wind energy technologies, especially in the offshore environment. A key objective will be to address the research challenges of the SET-Plan European

Wind Industrial Initiative in a common and structured way at European level. The medium to long term research undertaken under the programme is expected to accelerate the development of efficient and cost-effective large offshore wind turbines, including their substructures and the large scale grid integration of wind energy).

7. Conclusions and recommendations

Finnish wind power manufacturers' current global market share of about 3% can be increased to 7% through leadership and technology development i.e. science-based innovations. To guarantee the reliability of the future designs (e.g. wind farms and off-shore applications with advanced automation operating reliably in cold and other demanding climates like arctic conditions as well as offshore), the industry needs a globally leading R&D facility – the MegaCentre – for the full-scale development and validation of next generation wind turbine technologies.

To understand better the future testing needs of all consortium companies and to guide the work, the MCPP project consortium members were interviewed for company-specific future needs, and parallel benchmark studies of other international existing or planned large test facilities were conducted.

Recommendations related to the concept design (WP1) were provided to come up with the technical specifications of the best R&D facility for wind turbine and related technologies. For the MegaCentre to be globally competitive, it needs to be an attractive technical test facility and service provider for the major wind turbine manufacturers and component providers and simultaneously support the domestic wind energy sector. Global attractiveness can be achieved by differentiating the MegaCentre from similar, large test facilities.

Identified key strategic choices for technical specifications and offered services are:

- Differentiating MegaCentre from other, similar test facilities by
 - Cold climate tests
 - Offshore tests
 - Grid fault tests.

Recommendations related to the business and implementation plan (WP2) were provided to come up with the business plan and the operations structure including the mode of operation and the ownership structure of the MegaCentre:

- companies make **the strategic decision whether to participate to MegaCentre**
- consortium members choose the business model of MegaCentre
- consortium members and network partners create detailed **operation model of MegaCentre** together.

Recommendations related to the national and global R&D co-operation and networking aspects (WP3) were provided to come up with financing opportunities of the research infrastructure (prior/during construction) as well as funding opportunities related to joint research programs (after construction i.e. when the MegaCentre is functional), see Chapter 6.3 for details:

- Seek European Investment bank loan and equity (prior/during construction)
- Seek regional EU funds (national EAKR) depending on the final geographical location of the MegaCentre (prior/during construction)
- Seek national funding for renewable energy via TEM (prior/during construction)
- Seek funding from existing national research programmes (after construction)
- Propose new national research programmes with national funding (during/after construction)
- Propose new international (EU) research projects (during/after construction).

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Appendix A: WP1 interview template

MCPP WP1 specification of company needs and requirements (template by Olavi Rahkonen/Moventas, 31Jan2011)

WP1 Interview summary

1. Definition of the products to be tested (systems, products, components):

- i) Wind turbine nacelles
- ii) Wind turbine gearbox
- iii) Permanent magnet generators and/or frequency converters
- iv) Direct drive generator & frequency converter, generator & gearbox & frequency converter, drivetrain in extreme hot/cold temperatures

2. Definition of testing dimensions (testing powers, torques, speeds, physical dimensions etc):

Nacelle: 10MW rated, gearbox overload testing: 24MW

7-9 rated, rpm, speed range=0-35 rpm

Emulated force/torque needs:

$F_{x,max}=4000$ kN

$F_y=F_z,max=10000$ kN

$M_{x,continuous}=13500$ kNm

$M_{y,max}\approx 4 \times M_{x}\approx 55000$ kNm

$M_{z,max}\approx M_{y,max}\approx 55000$ kNm

1 Hz load application frequency

3. Estimate of capacity need (h/a), estimate of required time per one test (average, time window), personnel need per test (24/7 or something less):

Total use: 40-68 weeks/yr (first operating years)

Majority: Facility use in 1-2 shifts. Only special, short occasions for 24/7 test needs.

4. Definition of the phenomena to be tested:

- i) Nacelle 6 degrees-of-freedom emulated wind loads
 - ii) Tower/nacelle main frame distortions
 - iii) Fully controllable grid behaviour: isolation from national grid, voltage dips etc.
 - iv) Generator and/or frequency converter testing: FRT, LVRT, Grid Code tests...
- General test types:
- i) Functional test
 - ii) Speeded lifetime fatigue tests
 - iii) Certification/type testing

Appendix A: WP1 interview template

5. Definition of testing environment:

- i) -40°C...+60°C (only for 1 component at a time, currently no need to cool/heat entire nacelle)
- ii) Humidity (up to 100%) & saltness control (also for 1 component at a time)

6. Does testing require any proprietary know-how:

- i) MC personel help for test assembly, dismantling
- ii) Smart test set-ups needed high level IPR control

7. Structural requirements on the testing environment

- **loads (e.g. requirements on the foundations):**
 - i) max component/assembly weight: 250-500tn
 - ii) minimum dimensions: 30m x 30m
 - iii) 6DOF foundation modal vibration
 - iv) FRT results in high torques/forces -> needs a solid foundation
- **effects of the testing (vibrations, noise and temperatures) to the environment and other test units and vice versa**
Electrical/mechanical isolation (e.g. isolating t=2mm sand bed to eliminate vibrations)
- **temperature and humidity control**
- **other**
Isolation from national grid (needs own power supply)
MC as a certification party?

8. Definition of loading techniques/mechanics:

Provided by external company

9. Definition of loading controls:

Realistic phasing of loads important, laboratory loads ≈ field loads

10. Requirements on power supply incl. control system:

- i) Nacelle 6DOF loading with frequency converter for accurate and realistic load phasing
- ii) Re-use of generated power, only 10% power from grid

11. Definition of measuring arrangement

In general measuring:

- i) structural loads (forces/torques), deflections, accelerations
- i) temperature (+ thermo-mechanical behaviour)
- ii) mechanical/electrical losses
- iii) voltage, current, frequency etc.
 - **quantities to be measured**
 - **measuring scales**

- **quality/accuracy of measuring results**
- **measuring techniques**

Strain gages for loads/deflections

- **measuring equipment**

Main/common measuring equipment should be MC property, only small equipment updates acc. to customer

12. Definition of auxiliary and peripheral device

- **lubrication systems**

20,000 ltr cooling oil tank

- **electrical systems**

Electrical back-to-back loop a must

- **lifting device: data handling infra (networks):**

i) 250-500tn

ii) internet connection

iii) Nacelle & outside network synchronizaton

- **ventilation and heating:**

Cooling outside air for inside use, $\approx 10\text{m}^3/\text{sec}$ (closed air circulation)

Generator water cooling $\approx 2\text{MW}$

13. Specification of other items than testing environment

Additional rooms mainly in common use

- **design of test set-ups:**

CAD-design of each test layout in advanced

- **manufacturing of test device:**

- **assembly facilities:**

Needed

- **light machining (for repair purposes): control rooms for testing personnel:**

Needed for small repairs and for test facility maintenance

- **warehousing needs (cold/warm, rotation or else, space requirement):**

Test area size warehouse for spare parts & test specimens.

Warehouse needs lift crane.

- logistical needs

- break rooms

Needed, 1-2

- locker rooms for personnel

Needed, at least 1 room with 10 lockers

- offices for researchers

Needed, for 3-5 researchers, 25-30m²

- offices for paying customers

Needed (common meeting rooms might be sufficient)

- meeting rooms and conference/training facilities

Needed, 2-3 rooms, one for 50 persons, two smaller

Appendix A: WP1 interview template

- show rooms
Option for 20m2
- **security of the premises (data, physical):**
High security class

Appendix B: Other large test facilities for wind energy applications

**Centro Nacional de Energias Renovables (CENER)
-Powertrain Test Laboratory-**

- Spain government funded
- Located in Sanqūesa Navarre Spain
- Designed for testing 5 MW wind turbines
- Total of 4 test benches:
 1. Powertrain test bench for Loads (only torque) and Life of gears and bearings
 2. Generator test bench for electrical equipment
 3. Nacelle test bench for nacelle functional tests, LVRT tests
 4. Nacelle Assembly Bench for nacelle assembly research
- Comment: no LSS/HSS multiaxial loading available.
- Wind Tunnel (2D-airfoil performance) →
- Supplier: MTS Energy Solutions



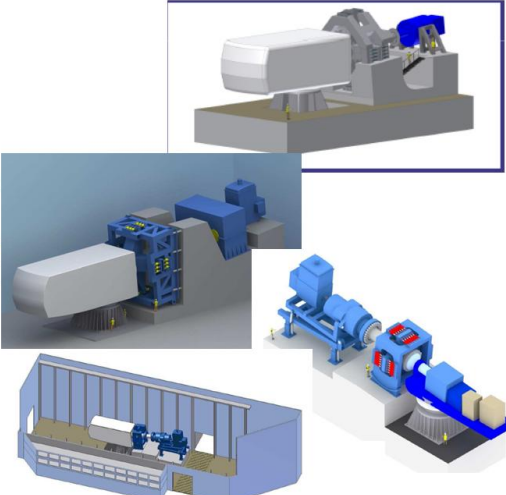
source: <http://www.cener.com/en/wind-energy/wind-turbine-test-laboratory.asp>

Figure 1. CENER test facility with 4 separate test benches (only operational facility in Europe)

Appendix B: Other large test facilities for wind energy applications

New and Renewable Energy Centre (NaREC)

- UK Government funded
- Blyth, Northumberland, UK
- Test facility design: 2 yrs of engineering development & indust. consultation*
- **Under construction**, estimated to be ready -> July 2011
- For offshore large wind turbines
- 15MW (for 10MW nacelles) and 3 MW test facilities (50m€+18m€)
- Supplier: MTS Energy Solutions




source: http://www.narec.co.uk/sectors/wind_energy/
http://www.suiparag-wind.org.uk/docs/presentations/2010-04-25_1020_EWEC2010_SideEvent_DriveTrain_StuartHerbert.pdf
* http://www.narec.co.uk/sectors/wind_energy/drive_train_test/

Figure 2. NaREC test facility overview

LORC, Lindoe Offshore Renewables Center, Denmark

- Founded by: Vestas, Siemens, Vattenfall, DONG Energy, Skykon, Odense Shipyard, University of Southern Denmark and Wave Star
- Lindoe Nacelle Testing (LNT), test rig capacity: 10MW rated nacelle power
- From Oceanwind article 3/2011: *"It will now be possible to make a 50 year simulation of wind loads and other extreme conditions (temperature, turbulence, moisture, etc.) that one would be very lucky to have at a test site... Grid simulator for Grid Code test (LVRT, TOV -> 50 vs 60 Hz...)"*

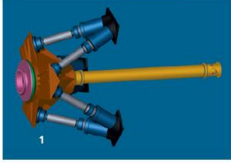
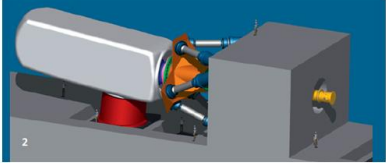


http://www.dk-export.dk/media/-300005/files/Profil_UK_LORC_Ewea_2011.pdf
<http://www.lorc.dk/lorc/subpage50.aspx>

Figure 3. LORC test facility summary

Fraunhofer Institute for Wind Energy Systems (Fh IWES)

- Germany Government funded
- Bremerhaven, Ger
- Ongoing research project: "Development of a drive train test machine"
- Special focus on gearless, direct drive technology*
- Test rig up to 8MW (or 10MW Direct Drive) nacelles*,***
- Sub-contractor: BPT Engineering for component specifications**
- Test rig opening in 2014***

1 Conceptual representation of a nacelle test stand
2 6 DOF force input allows authentic load testing -> or just 3DOF?***

Source:
* http://www.iwes.fraunhofer.de/en/images/2009_2010_IWES_annual%20report_tcm721-67170.pdf
** <http://www.baukollima.com/projects.htm>
*** VL contact in Fraunhofer IWES, 22.3.2011

Figure 4. Fraunhofer IWES drivetrain test facility overview

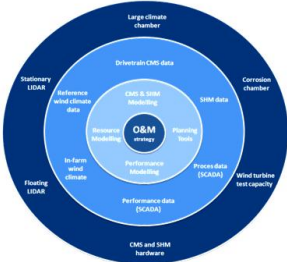
Sirris


Collective Centre of Belgium Technological Industry

- Focus: "...large climatic chamber for the validation process of large wind turbine drivetrain components (e.g. gearboxes, transformers, generators, yaw-systems ...). This project will provide capabilities to simulate corrosive and extreme cold conditions."*
- "The test infrastructure will be implemented and operated by Sirris."*
- Official opening of this test infrastructure is planned in the first half of 2012.
- Open for all European component suppliers.








Tech specs of climate chamber:

- -60°C to 60°C
- 10m x 8.5m x 9m [LxWxH]
- test heavy components up to 150 tons
- Integrated drive for gearbox testing and power supply for electrical components
- Infrastructure for unloading and transportation of heavy components





Project in partnership with:

Source:
* SIRRIS brochure from EWEA 2011

Figure 5. Sirris test facility overview

Appendix B: Other large test facilities for wind energy applications

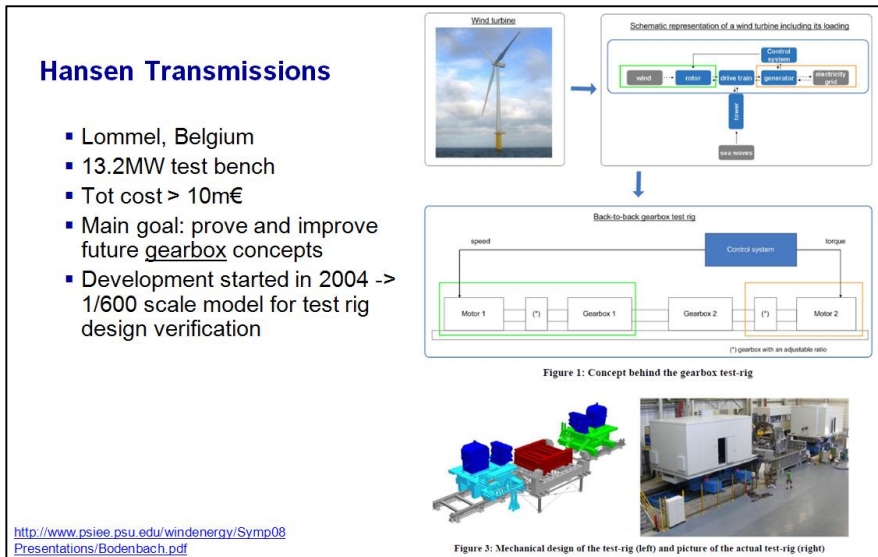


Figure 6. Hansen gearbox test rig overview

National Renewable Energy Laboratory (NREL)

- U.S. Government funded
- Golden/Boulder (Colorado), USA
- 2.5 MW rig, 1.8 MW max (5MW planned*)
- GE 1.5 MW turbine accepted to produce electricity to facilities -> used also for research
- Siemens 2.3MW prototype measurements
- Real-time online status available*
- Supplier: MTS Energy Solutions

source: <http://www.nrel.gov>
http://www.nrel.gov/features/20100517_wind.html
 * <http://wind.nrel.gov/Dyno/protected/dynowebsserver.jpg>

Figure 7. NREL facility overview

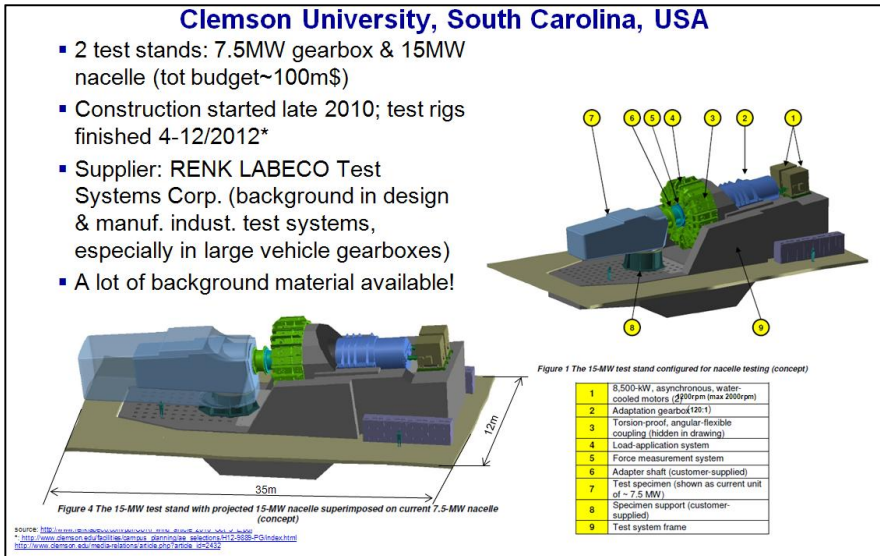


Figure 8. Clemson University's test facility overview

Appendix C: List of IEC-Standards for wind turbines

Published by International Electrotechnical Commission

- IEC 61400-1 (2005-08) Ed. 3.0 + Amandement 1 (2010): Design requirements
- IEC 61400-2 (2006-03) Ed. 2.0 Design requirements for small wind turbines
- IEC 61400-3 (2009-02) Ed. 1.0 Design requirements for offshore wind turbines
- IEC 61400-4 Ed. 1. Design requirements for wind turbine gearboxes, nykyinen
- ISO 81400-4 (2006-04) Ed. 1.0
- IEC 61400-5 Ed. 1.0 Rotor blades
- IEC 61400-11 (2002-12) Ed. 2.0 + Amandementi 1 (2006): Acoustic noise measurement techniques
- IEC 61400-12-1 (2005-12) Ed. 1.0 Power performance measurements of electricity producing wind turbines
- IEC 61400-12-2 Ed. 1.0 Power performance of electricity producing wind turbines based on nacelle anemometry
- IEC 61400-12-3 Ed. 1.0 Wind farm power performance testing
- IEC/TS 61400-13 (2001-06) Ed. 1.0: Measurement of mechanical loads
- IEC/TS 61400-14 (2005-03) Ed. 1.0 Declaration of apparent sound power level and tonality values
- IEC 61400-21 (2008-08) Ed. 2.0: Measurement and assessment of power quality characteristics of grid connected wind turbines
- IEC 61400-22 (2010-06) Ed. 1.0 Conformity testing and certification
- IEC/TS 61400-23 (2001-04) Ed. 1.0 Full-scale structural testing of rotor blades
- IEC 61400-25-5 (2006-12) Ed. 1. Communications for monitoring and control of wind power plants - Conformance testing
- IEC 61400-25-6 (2010-11) Ed. 1.0 Communications for monitoring and control of wind power plants - Logical node classes and data classes for condition monitoring
- IEC/TS 61400-26-1 Ed. 1.0 Time based availability for wind turbines and wind turbine plants
- IEC 61400-27 Ed. 1.0 Electrical simulation models for wind power generation

Appendix D: Work programme of IEC TC-88

Project Reference	Working Group	Project Leader (FIN contact)	MegaCentre relevance
IEC 61400-11 Ed. 3.0	MT 11	Mr. Bo Sondergard	MEDIUM
IEC 61400-12-1 Ed. 2.0	MT 12-1	T. F. Pedersen (P Antikainen)	HIGH if test site included
IEC 61400-12-2 Ed. 1.0	PT 61400-12-2	Mr. Frank Ormel (P Antikainen)	HIGH if test site included
IEC 61400-12-3 Ed. 1.0	PT 61400-12-3	Mr. Jens Carsten Hansen (P Antikainen)	HIGH if test site included
IEC 61400-13 Ed. 1.0	MT13	Richard Santos	HIGH
IEC 61400-2 Ed. 3.0	MT2	David Sharman	LOW
IEC 61400-21 Ed. 3.0	MT21	B Andresen	HIGH
IEC 61400-23 Ed. 1.0	MT 23	Mr. D.R.V. van Delft	LOW
IEC 61400-25-2 Ed. 2.0	MT 61400-25-2	A. Johnsson	MEDIUM
IEC 61400-25-3 Ed. 2.0	JWG25	A Johnsson	MEDIUM TO HIGH
IEC 61400-27-1 Ed. 1.0	27	Mr. Poul Sorensen	MEDIUM TO HIGH
IEC 61400-4 Ed. 1.0	JWG 1	Jens Demtröder (NN Moventas)	HIGH
IEC 61400-5 Ed. 1.0	PT 61400-5	Mr Wang Jianping	LOW
IEC/TS 61400-3-2 Ed. 1.0	PT 61400-3-2	Mr. Mann-Eung Kim	MEDIUM?
PNW 88-419 Ed. 1.0		J.D. Sorensen	MEDIUM
PNW/TS 88-427 Ed. 1.0	PT 61400-26	B. Sherwin	HIGH?

Title	MegaCentre Planning Project
Author(s)	Marja-Leena Pykälä, Ville Lehtomäki, Minna Kansola, Katri Valkokari, Hannele Holttinen, Esa Peltola, Aslak Siljander
Abstract	MegaCentre Planning Project (MCP) is an initiation of the Finnish industry operating on the wind power area. The planning project was launched and managed by Moventas Wind Oy. The project aims at strengthening the technology position of the participating companies by founding a broadly-based experimental research platform supported by virtual modelling, which would combine the competences of both industry and research. The goal of the MCP project was to design a globally leading research and development facility – MegaCentre – for the full-scale development and validation of next generation wind turbine technologies. Wind energy-related research programs were investigated based on literature surveys and interviews. On the basis of the results obtained a strategy is provided on how and which research programs the MegaCentre could offer applied research services
ISBN, ISSN	ISBN 978-951-38-7852.8 (URL: http://www.vtt.fi/publications/index.jsp) ISSN 2242-122X (URL: http://www.vtt.fi/publications/index.jsp)
Date	June 2012
Language	English
Pages	51 p. + app. 12 p.
Name of the project	MCP
Commissioned by	Tekes, VTT
Keywords	Wind turbine, Gear box, Testing platform
Publisher	VTT Technical Research Centre of Finland P.O. Box 1000, FI-02044 VTT, Finland, Tel. 020 722 111

Nimeke	MegaCentre Planning Project
Tekijä(t)	Marja-Leena Pykälä, Ville Lehtomäki, Minna Kansola, Katri Valkokari, Hannele Holttinen, Esa Peltola, Aslak Siljander
Tiivistelmä	<p>MegaCentre on suomalaisen tuulivoima-alan teollisuuden aloite, jolla tavoitellaan yri-tysten teknologia-aseman vahvistamista perustamalla laajapohjainen sekä teollisuuden että tutkimuksen osaamista yhdistävä kokeellisen tutkimuksen ja koetoiminnan ympäristö, jota tukee myös virtuaalinen mallinnus. MegaCentrehanke on suunniteltu Euroopan mittakaavaan. MegaCentren toteuttamiseksi on MoventasWind Oy:n aloitteesta ja johdolla käynnistetty suunnitteluhanke, jonka tuloksena tulee saada riittävät perusteet varsinaisen kokeellisen ympäristön toteuttamiseksi.</p> <p>Projektissa tutkittiin kirjallisuuteen ja haastatteluihin perustuen tuulivoimaan liittyviä tutkimustarpeita ja alueen toimijoita. Saatujen tulosten pohjalta luotiin strategia, jota seuraten MegaCentre voisi tarjota tutkimuspalveluja.</p>
ISBN, ISSN	ISBN 978-951-38-7852-8 (URL: http://www.vtt.fi/publications/index.jsp) ISSN 2242-122X (URL: http://www.vtt.fi/publications/index.jsp)
Julkaisu-aika	Toukokuu 2012
Kieli	Englanti
Sivumäärä	51 s. + liitt. 12 s.
Projektin nimi	MCCPP
Toimeksiantajat	Tekes, VTT
Avainsanat	Wind turbine, Gear box, Testing platform
Julkaisija	VTT PL 1000, 02044 VTT, Puh. 020 722 111

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