International Energy Agency (IEA)
Implementing Agreement for Co-operation in the Research and Development of Wind Energy Systems (IEA Wind)

Task Proposal

IEA Wind Task 33 - Reliability Data
Standardization of data collection for wind turbine reliability and operation & maintenance analyses

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Content

1 Scope

The present proposal aims at the establishment of a new IEA Task under the IEA Wind implementing agreement dealing with standardized, well structured databases for optimizing reliability and maintenance procedures. The aim is to address the different developments of data collection and failure statistic to agree on standards and overall structures.
The purpose is to bring together the present actors in the industry and research community to create synergies and agreements in the many R&D activities already on-going in the field of statistical failure analysis.
The drivers for the proposal of a new IEA Task based on wind turbine reliability are:

- Extensive national research projects dedicated to reliability analyses on wind turbine failures have been performed during the last years, e. g. Denmark, Finland, Germany, United Kingdom, Netherlands, USA, Sweden. However, a consolidated multi-lateral and international exchange has to date just partially taken place.

- The increasing future demands on reliability and profitability of wind energy use especially offshore require the optimization of wind-turbine maintenance. For this in turn,an appropriate data management and sophisticated decision-support tools are prerequisites.

- Several working groups on appropriate standards for operation and maintenance of wind power plants have been launched on national levels for onshore wind energy application, e. g. joint activities on standardizing operation and maintenance measures, documentation and data structure.

The proposed activities build upon the discussions and work already performed in regards to failure statistics during the 65th IEA Topical Expert Meeting “International statistical analysis on wind turbine failures”, March 2011, Kassel, Germany. It was decided at the meeting to launch a new Task under the umbrella of the IEA Wind. [1]
The formation of Task 33 Reliability Data - Standardization of Data Collection for Wind Turbine Reliability and Maintenance Analyses under the wind implementing agreement was approved in principle by the IEA Wind Executive Committee 19 October 2011.

The new IEA Wind Task 33 is intended to have three Subtasks which have been selected as the most relevant at present. They reflect the experience of reliability analyses and failure statistics in the last decade not only in the wind industry, and the determination of data collection and analysis based on defined structures and standards.
This new Task will consequently address an intensive and effective investigation on common terminologies, preparing formats and guidelines for data collection (inventory, maintenance, failure and possibly condition data), setting up procedures for analysis and reporting.
The planned work involves a first activity of exchange for identification of common working fields and areas where specific research activities should be prioritized. Eventually there is a formulation of common detailed objectives and coordinated research activities in selected areas. In the following activities the working groups join efforts to exchange experience and results of individual or collective activities. The expected outcome is the formulation of guidelines towards data collection, data structure and data analyses for an overall wind turbine failure statistics.
The topics are also defined to be complimentary to the works being performed at present towards standardization of data management.

2 Introduction

High reliability guarantees a high degree of operating and personal safety, high system availability, low maintenance necessity Therefore, it is one of the overriding aims of development work in the area of wind energy technology.
Modern onshore wind turbines attain high technical availability of up to 98 %. Evaluation of maintenance work in previous projects shows, however, that high wind turbine availability requires additional maintenance work [2] [6]. However, there are also experiences of lower availabilities onshore and the upcoming commissioning of several offshore wind farms stimulates the demand for improved reliability and maintenance. Tough environmental factors resulting in higher requirements with regard to reliability, maintenance, and service management have to be adapted to the restricted accessibility and offshore conditions.

There is a considerable scope for optimizing the reliability and maintenance procedures. Statistical analyses of operation and maintenance data of turbines and their components can be used to identify weak points and to define maintenance services at an early stage.
Maintenance of wind turbines is currently being planned and carried out mainly to statutory requirements and rough guidelines from manufacturers. Unplanned maintenance measures due to sudden, not recognized malfunction of components can cause serious economic losses especially offshore. However, the current maintenance organization is still dominated by unplanned and corrective measures and should be shifted to more preventive measures in the near future. For this purpose it is necessary to make use of experience through acquiring a lot of information at different locations. This is possible only through a semi-automated and highly simplified data management. Also there is a need to gain more parameters, data and additional information compared with today, making electronically supported reporting by service teams necessary. The necessity of gathering more and especially more detailed data, while reducing maintenance effort should be the long-term goal. Necessary steps have to be introduced for operation and maintenance of wind turbines to bring available knowledge together and to use experience for improvements. At this point, information coming from databases, statistical methods as well as expertise is essential.

Existing work on wind turbine failure statistics include:

- Germany: One of the most renowned failure statistics has been established in the scientific measurement and evaluation programme “WMEP” (“Wissenschaftliches Mess- und Evaluierungsprogramm”), included in the German subsidy measure „250 MW Wind“ [2].The WMEP database contains a large quantity of operational and maintenance data and detailed information about both the reliability and availability of wind turbines, from about 1500 wind turbines from years 1989 to 2006. It provides the most comprehensive study of the long-term reliability behavior of wind turbines and the most trustworthy characteristic reliability parameters, Mean Time Between Failure (MTBF) and Mean Time To Repair (MTTR) published to date. A new initiative is Offshore~WMEP [4] that is currently starting. More statistics: Windstats Germany and Denmark, Landwirtschaftskammer Schleswig-Holstein (LWK) Germany.
- Sweden: Elforsk, data from 723 wind turbines from years 1997 to 2004 [10]
- Finland: VTT statistics, still on-going but limited amount of turbines even if covers nearly all installed in Finland. Available from yearly reports (captions in English) [9]
- US: Sandia CREW database [7].

It has been found that, despite their differences, there is agreement to a certain degree among the mentioned projects on wind turbine failure statistics. However, the loads on wind turbine components differ due to the technical concepts and site conditions, which lead to a dispersion of results.

The national initiatives aiming at collecting failure information for reliability analyses, e. g. Offshore~WMEP [4], Reliawind [5], EVW [6], Sandia CREW database [7] and OREDA database [8]. They all (except of [8]) intend to establish a database for wind turbine failure statistics and therefore they should somehow be coordinated to assure that the results may be combined in order to increase the statistical basis available. All initiatives share the following crucial issues:

1. Which data is to be collected?
2. What data are needed for the different analyses?
3. How to implement a system to collect information in an appropriate, structured, detailed and strongly automated way?

There are several challenges for the reliability databases:

- Turbine types have been evolving in fast pace in the 1990s this is one reason why getting long statistics has been difficult.
- Wind energy industry is still lacking in comprehensive cooperation of all parties: dialogue between operators, manufacturers, component suppliers, designers, service and research – which is common in other industries such as aerospace – does not take place. For this reason necessary steps have to be introduced for operation and maintenance of wind turbines to bring available knowledge together and to use experience for improvements.
- Common standards for the documentation of operation and maintenance measures as well as for a uniform structure of databases are missing. This would be needed for any systematic collection of data: uniform description of sub-assemblies and description of operating conditions, malfunctions and failures equally.
- Data collection for operators is difficult, labor intensive and limited, often as written reports from manufacturers or service companies briefly described, with encoded description, not detailed enough for failure analysis.

The uniform labeling of components, operating systems and the systematic storage of errors and data will initially enable the management a largely standardized and electronically supported logging. As a result, the data collection/reporting procedure and monitoring process can be simplified, the financial and technical reporting improved and cooperation with similarly oriented businesses enabled. This detailed documentation of all maintenance measures of a large population of plants and a purposeful structured database are necessary to extract sound conclusions out of the operational experience. This way of documenting and collecting data and information provides a number of possibilities for optimizing availability of wind turbines both in design and construction and in operation and maintenance, which result in higher turbine efficiency.
By using detailed, systematically recorded operation and maintenance data that has been processed with standardized and electronically aided protocols, validity can be achieved. However, only through a large amount of information, weak points can be identified clearly and statements on the failure probability of certain components get meaningful and only such a large database allows improving and optimizing maintenance strategies. For this reason, defined and standardized structures are an indispensable basis for comparing or merging different databases.

Analyses of captured information from collaborative databases provide resilient figures for detecting weak points and cost drivers as a basis for decision-making processes. As a result weak points can be identified, components can be qualified in cooperation with manufactures and suppliers and statements about the probability of failure behavior can be made.
For realizing standardized data collection and the comparison of different data sources with the overall aim to optimize reliability and availability of wind power plants, it has to be investigated how to possibly establish collaborations between the different initiatives with respect to sharing or grouping some data.

3 Objectives and Expected Results

The new IEA Task 33 will focus on common terminology, preparing the format and guidelines for data collection (inventory, maintenance, failure and possibly condition data), setting up procedures for analysis and reporting, and set up the basis of developing a central database that can be accessed by industrial and scientific parties, keeping in mind the confidentiality aspects. The objectives of the IEA Task are threefold:

1. Provide an international open platform for regular and continuous exchange of experience and progress from individual research activities and existing measurement projects on failure statistics on wind turbines.
2. Development of "Recommended Practices for Reliability Data" during the course of the Task.
3. Identify areas for further research and development as well as standardization needs.

The establishment of a data structure based on international standards will aim to:

- Establish an international forum for exchange of knowledge and information related to reliability data and failure statistics of wind turbines;
- Bring available knowledge together and to use experience for improvements;
- Develop and define internationally accepted, transparent set of data collection and structure that can be used by the IEA and other organizations;
- Start a broad dialogue on an international level between operators, manufacturers, service, component suppliers, designers and researchers;
- Simplify the monitoring process, to improve the financial and technical reporting and to cooperate with similarly oriented businesses;
- Provide a basis for sound conclusions out of operational experience in terms of reliability characteristics such as failure rates, repair times, etc.

The competences gained in the IEA Task 33 will be collected and summarized in an IEA "Recommended Practices for Reliability Data".

4 Approach and Methodologies

The activities of the new IEA Task 33 are divided into three Subtasks and coordinated as presented in Figure 1. It presents the scope and the topics each Subtask will concentrate on. Further optional aspects, which could come into consideration after agreement with the Participants at the initial workshop and after sufficient process on the main subjects, could be attended.
Next, the scope of each Subtask and the planned activities are elaborated.

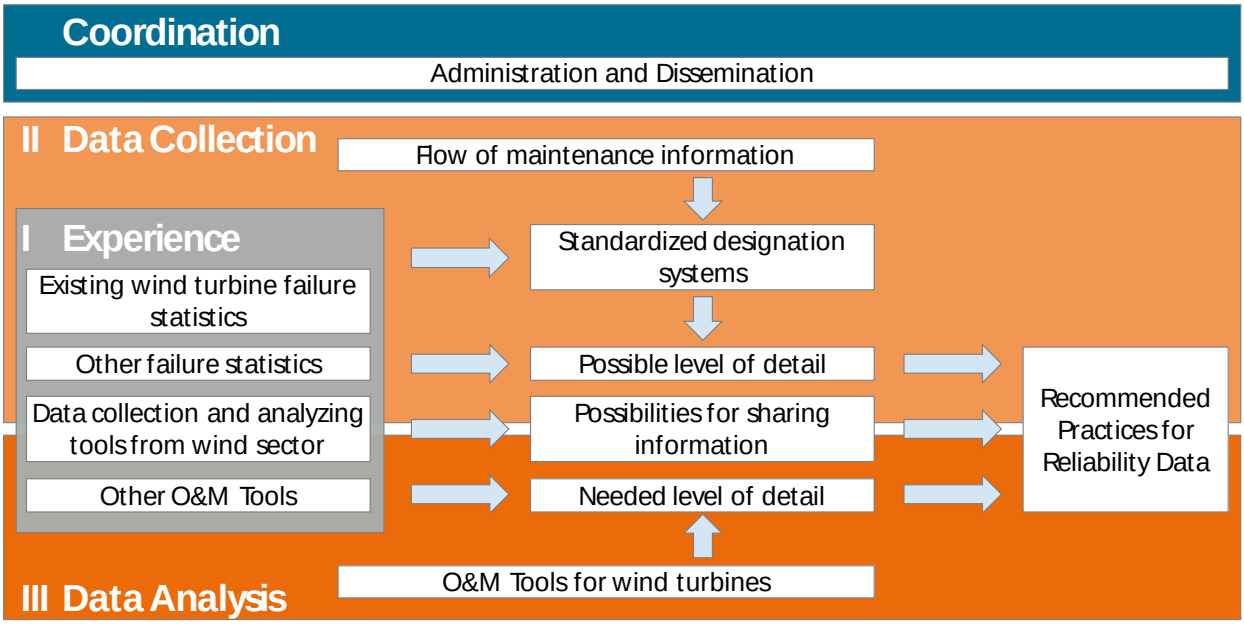


Figure 1: IEA Wind Task 33 - Scope and contents of the Subtasks

Subtask I: Experience
In terms of reliability the use of experience is indispensable. The Subtask I Experience is therefore a cross-section task and affects both Subtask II Data Collection and Subtask III Data Analyses. Comprehensive work and research have already been spent on gathering and comparing different failure statistics (IWES, Elforsk…) and approaches in various research activities. The experiences made with these failure statistics need to be taken into account for the future work. Experience from other industries like the oil and gas industry or the automotive sector has also to be considered (e. g. the OREDA-database). This task should process and present experience regarding data collection and analyzing tools from related as well as from the wind energy sector itself. Valuable findings will then be transferred and implemented in the overall structure of data collection and analyses.

Subtask II: Data Collection
This Subtask comprises different aspects of data collection. Basic requirements of the right set of reliability relevant data need to be defined. Therefore, an agreement on necessary data (e. g. core-, in-service-, event data) is required, whereby the flow of maintenance information needs to be considered and taken into account. The development and implementation of standardized designation systems is another main focus of this task. International standards like the adopted component designation system RDS-PP as well as national efforts of providing guidelines, e. g. the Technical Guideline “Maintenance of wind turbines” (Technische Richtlinie TR 7 “Instandhaltung von Windenergieanlagen”) from the Federation of German Wind Power FGW

(Fördergesellschaft Windenergie und andere Erneuerbare Energien), need to be developed further to a stage where they find application. Comprehensive efforts have recently been undertaken to agree on e. g. RDS-PP and the implementation as well as application of such designation systems (standards) have to take place globally.
Subtask II will therefore request all participating institutes to contribute the knowledge and recent activities/results in order to discover different development directions and to consolidate on a state of the art data collection for reliability analyses. Also contacts to operators/manufacturers/other industries will be formed to get a wide input and dialogue.
This task can benefit from the results of several projects such as Reliawind, Sandia CREW database, Offshore~WMEP, EVW, VTT statistics etc. as well as from different working groups for standardization such as VGB Powertech, RDS-PP Fast Track User Group, FGW etc.
Additionally this Subtask needs a strong trade-off with Task III (Data Analyses) for defining a necessary (for suitable analyses), but also possible (regarding the data collection efforts) level of detail of collected data.

Subtask III: Data Analyses
The main objective of this task is to identify the recent and most valuable O&M tools in the market. Beyond that, it is necessary to determine and commit oneself to a certain extent of analyzing detail. An agreement on type and scope of future O&M tools is considered, which includes the definition of possible and convertible reliability analyses. The interaction between the Subtasks II and II are important for the defined Data Collection or rather the level of detail, that are of great significance for a successful realization of preparing recommended practices. Because on the one hand demands and requirements of reliability data for O&M tools define to a certain point the level of detail for relevant data, on the other hand complexity of maintenance information from various locations will have an effect on the degree of analyzing opportunities.

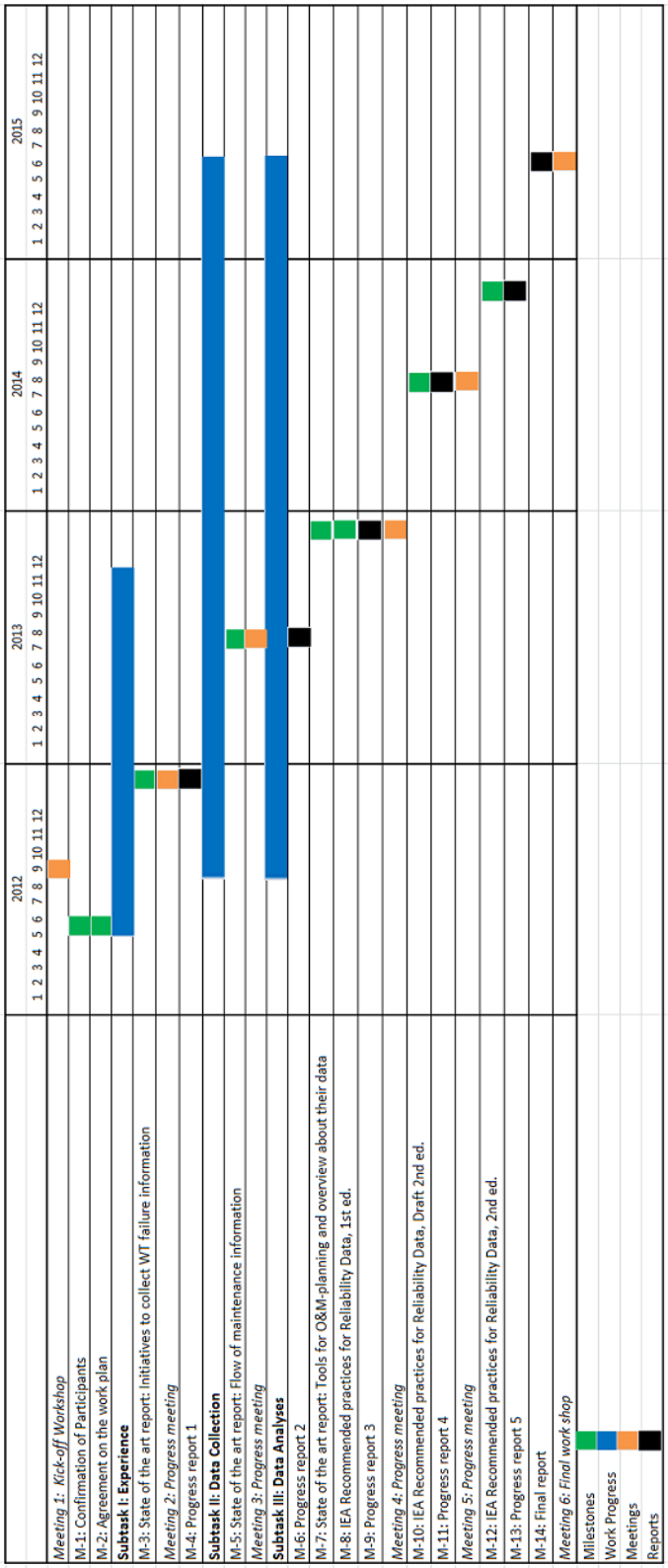
In the entire process and task duration, the possibilities of sharing information both in terms of data and analyses will be a topic and should be discussed. Only by means of more transparency and confidence the overall goal of defining a standardized data structure as a basis for sharing and merging information and receiving sound and purposeful analyses can be achieved.

5 Time Schedule with Key Dates

This IEA Task proposal was approved by the IEA Wind Executive Committee (ExCo) in October 2011. It will continue for a period of three years beginning in 2012 and ending beginning of 2015, or resumed at an earlier date, if the Agreement expires or is terminated.
At the conclusion of this three year period, two or more Participants, acting in the Executive Committee, have the option of extending the Task for a period to be determined at that time. Any extension shall apply only to the Participants who agree to the extension.
In the first months of the IEA Wind Task 33 an initial workshop will take place. During this meeting, Participants will share their experience in order to assess the state-of-the-art. Also, the activities concerning the Subtasks will be discussed and assigned. A draft work plan will be extended and will be approved by the Participants within two months (milestone M1).

Following the proposed time schedule is presented. Note that the Subtask descriptions are given in section 4. A description of the milestones and deliverables is given in the sections 6 and 7.

Table 1: Standardization of data collection for wind turbine reliability and operation & maintenance analyses



6 Reports, Deliverables, and Dissemination of Results

The IEA is intended to generate several editions of Reports and Deliverables for the research on reliability data, standardization of data collection and O&M tools, this will be also accompanied by further background and disseminations of further knowledge acquired. Besides the semi-annual progress reports to the ExCo, which reflect the current status of the task, some special reports will be written:

State of the art report: “Initiatives to collect wind turbine reliability information”, 2012

- Overview of different initiatives of failure statistics (past and present/other sectors)
- Comparison of approaches and methodologies for data collection
- Identifying possibilities of merging the experience gathered

State of the art report: “Flow of maintenance information”, 2012-2013

- Overview of maintenance organization in the wind energy sector
- Identifying necessary information locations
- Investigation of different systems and interfaces for data transfer

State of the art report: “Tools for O&M-plannings and overview of their data needs”, 2013

- Overview of different O&M-Tools (past and present/other sectors)
- Comparison of capabilities of different tools
- Investigation in trends and needs of future developments
- Identifying necessary data input

“IEA Recommended practices for Reliability Data”

- Standardized set of reliability relevant data
- Harmonized overall data structure
- Improved maintenance process with defined interfaces and data transfer
- Requirements for more sophisticated O&M-Tools
- Basis for sound reliability analyses and maintenance optimisation

Moreover a dedicated Task website will be developed for dissemination.

7 Methods of Review and Evaluation of the Work Progress

Every half-year, the Operating Agent will consult each project participant on the progress he/she made in comparison to the planning. More frequent consultations may take place in the start-up phase of the Task with the ”uncertain participants” in order to check their chance of participation.

The participant presentations and State-of-the-Art reports will form a basis for the semi-annual progress reports which will be submitted to the IEA Wind Executive Committee. If necessary the planning is refined.
Depending on the progress and the results achieved, a change in the work programme may be proposed.

Table 2: Key Milestones

No.	Milestone	Subtask	Month Due
M-1	Confirmation of Participants	-	2
M-2	Agreement on the work plan	all	2
M-3	State of the art report: Initiatives to collect wind turbine reliability information	I	6
M-4	Progress report 1	all	6
M-5	State of the art report: Flow of maintenance information	II	12
M-6	Progress report 2	all	12
M-7	State of the art report: Tools for O&M-planning and overview of their data needs	III	18
M-8	IEA Recommended practices for Standardization of Data Collection for Wind Turbine Reliability and Maintenance Analyses, 1st ed.	all	18
M-9	Progress report 3	all	18
M-10	IEA Recommended practices for Standardization of Data Collection for Wind Turbine Reliability and Maintenance Analyses, Draft 2nd ed.	all	24
M-11	Progress report 4	all	24
M-12	IEA Recommended practices for Standardization of Data Collection for Wind Turbine Reliability and Maintenance Analyses, 2nd ed.	all	30
M-13	Progress report 5	all	30
M-14	Final report	all	36

8 Obligations and Responsibilities

Operating Agent

It is noted that the main responsibilities of the Operating Agent are given in section ”7 Reports, Deliverables, and Dissemination of Results”. The main tasks of the Operating Agent are:

- To exchange information and to provide all relevant results to the Participants;
- To communicate with the Participants and to monitor the progress in order to achieve the Subtask deliverables and milestones;

- To compile status reports. The status reports will be included in the progress reports which are submitted to the IEA Wind Executive Committee;
- To present the progress reports at the meetings of the IEA Wind Executive Committee Meetings;
- To organise the technical/planning meetings;
- To write minutes of the plenary meetings;
- To compile the final report with the final evaluation of the results and the recommendations/descriptions for model improvement;
- To supervise the dissemination of results;
- To develop a Task website.

Participants
In addition to any obligations listed in the IEA Wind Agreement all of the Task Participants are responsible for:

- The progress of the work in correspondence with the work program in agreement with the time schedule;
- The reporting of progress to the Operating Agent on a semi-annual basis;
- The contributions to the final report.

9 Funding

The costs management will be performed similar to other IEA Tasks as combined Task and Cost shared task where the Participating countries share the costs from the coordination effort of the Operating Agent.
The funding principles are as follows:

- Each Participant shall bear their own costs for carrying out the scientific work, including reporting and travel expenses.
- The host country shall bear the costs of workshops and meetings convened in conjunction with this Task.
- The total costs of the Operating Agent shall be borne jointly and in equal shares by the Participating Countries.
- Each participant shall transfer to the Operating Agent their annual share of the costs in accordance with a time schedule to be determined by the Participants, acting in the ExCo.

The proposed Operating Agent is the Fraunhofer Institute for Wind Energy and Energy System Technology IWES of Germany. This is not the Contracting Party, but it accepts the rights and powers, and will carry out the obligations and functions of the Operating Agent as provided in the Agreement.

10 Budget Plan

Projected expense items of the Operating Agent for coordination, management and reporting are as follows (per year):

Table 3: Operating Agent Costs

		Euro/year
Person-months:	4	46,000
Travel:	3 meetings (plenary + ExCo)	6,000
Expenses:	publishing, mailing, etc.	1,500
	TOTAL	**53,500**

11 Management of Task

After the initial workshop, the Operating Agent will refine the planning and the contents of the activities and will redefine an action list and the milestones of the project. Intermediate workshops and meetings will be scheduled in order to discuss with the Participants the progress of the Subtasks (see time schedule in Section 5, Table 1).
The communication of intermediate results will take place through progress and technical reports that will be distributed to all Participants.

12 Information and Intellectual Property

(a) **Executive Committee's Powers**. The publication, distribution, handling, protection and ownership of information and intellectual property arising from activities conducted under this Annex, and rules and procedures related thereto shall be determined by the Executive Committee, acting by unanimity, in conformity with the Agreement.

(b) **Right to Publish.** Subject only to copyright restrictions, the Annex Participants shall have the right to publish all information provided to or arising from this Task except proprietary information.

(c) **Proprietary Information.** The Operating Agent and the Annex Participants shall take all necessary measures in accordance with this paragraph, the laws of their respective countries and international law to protect proprietary information provided to or arising from the Task. For the purposes of this Annex, proprietary information shall mean information of a confidential nature, such as trade secrets and know-how (for example computer programmes, design procedures and techniques, chemical composition of materials, or manufacturing methods, processes, or treatments) which is appropriately marked, provided such information:

(1) Is not generally known or publicly available from other sources;

(2) Has not previously been made available by the owner to others without obligation concerning its confidentiality; and

(3) Is not already in the possession of the recipient Participant without obligation concerning its confidentiality.

It shall be the responsibility of each Participant supplying proprietary information, and of the Operating Agent for arising proprietary information, to identify the information as such and to ensure that it is appropriately marked.

(d) **Use of Confidential Information.** If a Participant has access to confidential information which would be useful to the Operating Agent in conducting studies, assessments, analyses, or evaluations, such information may be communicated to the Operating Agent but shall not become part of reports or other documentation, nor be communicated to the other Participants except as may be agreed between the Operating Agent and the Participant which supplies such information.

(e) **Acquisition of Information for the Task.** Each Participant shall inform the other Participants and the Operating Agent of the existence of information that can be of value for the Task, but which is not freely available, and the Participant shall endeavour to make the information available to the Task under reasonable conditions.

(f) **Reports on Work Performed under the Task.** Each Participant and the Operating Agent shall provide reports on all work performed under the Task and the results thereof, including studies, assessments, analyses, evaluations and other documentation, but excluding proprietary information, to the other Participants. Reports summarizing the work performed and the results thereof shall be prepared by the Operating Agent and forwarded to the Executive Committee.

(g) **Arising Inventions.** Inventions made or conceived in the course of or under the Task (arising inventions) shall be identified promptly and reported to the Operating Agent. Information regarding inventions on which patent protection is to be obtained shall not be published or publicly disclosed by the Operating Agent or the Participants until a patent application has been filed in any of the countries of the Participants, provided, however, that this restriction on publication or disclosure shall not extend beyond six months from the date of reporting the invention. It shall be the responsibility of the Operating Agent to appropriately mark Task reports that disclose inventions that have not been appropriately protected by the filing of a patent application.

(h) **Licensing of Arising Patents.** Each Participant shall have the sole right to license its government and nationals of its country designated by it to use patents and patent applications arising from the Task in its country, and the Participants shall notify the other Participants of the terms of such licences. Royalties obtained by such licensing shall be the property of the Participant.

(i) **Copyright.** The Operating Agent may take appropriate measures necessary to protect copyrightable material generated under the Task. Copyrights obtained shall be held for the benefit of the Annex Participants, provided however, that the Annex Participants may reproduce and distribute such material, but shall not publish it with a view to profit, except as otherwise directed by the Executive Committee, acting by unanimity.

(j) **Inventors and Authors.** Each Annex Participant will, without prejudice to any rights of inventors or authors under its national laws, take necessary steps to provide the co-operation from its inventors and authors required to carry out the provisions of this paragraph. Each

Annex Participant will assume the responsibility to pay awards or compensation required to be paid to its employees according to the law of its country.

13 List of Participants

China, Finland, Germany, Norway, Sweden, USA already stated that they will participate in the Task.
The following countries and institutions have shown interest to participate in the Task.

Table 4: Participating Countries and Organisations and Potential Paticipants

Country	**Institution(s)**	**Contact(s)**
China	Chinese Wind Energy Association	Wang Siyong
Denmark	Risø National Laboratory for Sustainable Energy, Technical University of Denmark	Jøhn Dalsgaard Sorensen
Finland	Technical Research Centre of Finland – VTT	Ville Turkia
Germany	Fraunhofer Institute for Wind Energy and Energy System Technology IWES	Stefan Faulstich
Netherlands	Energy research Centre of Netherlands - ECN	Rene v.d. Pieterman
Norway	SINTEF Energy Research	Jörn Heggset
	Norwegian University of Science and Technology – NTNU	Jorn Vatn
Sweden	Chalmers University of Technology	Katharina Fischer
USA	Sandia National Laboratories	Alistair Ogilvie

14 References

[1] Felix Avia (Operating Agent, Task 11): IEA Wind Topical Expert Meeting TEM #65 "International Statistical Analysis on Wind Turbine Failures", (Proceedings), Kassel/Germany, March 2011

[2] WMEP - Wissenschaftliches Mess- und Evaluierungsprogramm/scientific measurement and evaluation program funded by the German Federal Ministry for the Environment, Nature Conversation and Nuclear Safety

[3] UpWind – Design limits and solutions for very large wind turbines; funded within the frame of the European Union's Sixth Framework Programme for RTD (FP6); www.upwind.eu

[4] Monitoring der Offshore-Windenergienutzung in Deutschland, Offshore~WMEP; funded by the German Federal Ministry for the Environment, Nature Conversation and Nuclear Safety; www.offshore-wmep.de

[5] Reliawind funded within the frame of the European Union's Seventh Framework Programme for RTD (FP7); www.reliawind.eu

[6] EVW - Erhöhung der Verfügbarkeit von Windenergieanlagen/improving availability of wind turbines funded by the German Federal Ministry for the Environment, Nature Conversation and Nuclear Safety; www.evw-wind.de

[7] Sandia CREW Database - Continuous Reliability Enhancement for Wind, Database and Analysis Program; www.sandia.gov

[8] OREDA – Offshore Reliability Data, Det Norske Veritas (DNV) Oslo, Norway; www.oreda.com

[9] VTT Technical Research Centre of Finland; http://www.vtt.fi/proj/windenergystatistics/?lang=en

[10] Elforsk: N. E. Carlstedt, C. Szadkowski, and C. Karlstr¨om Elforskrapporter. Driftuppfo¨ljning av Vindkraftverk, A° rsrapport (Performance of wind power plants, annual report); 1997–2004 98:4, 99:6, 00:11, 01:16, 02:20, 03:12, 04:19, 05:11. online; http://www.elforsk.se; January 2006