INTERNATIONAL ENERGY AGENCY

Implementing Agreement for Co-operation in the Research, Development and Deployment of Wind Turbine Systems
Task 11

Topical Expert Meeting #96 on

Wind Plant Decommissioning, Repowering and Recycling

IEA Wind Task 11

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GSE S.p.A., Rome, Italy

Source : DTU

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Executive Summary of TEM#96

Introduction

In the year 2000, many countries – such as the US, India, Denmark, Germany, Spain, the Netherlands, the UK and Italy – already had a considerable amount of installed wind power capacity. The average lifetime of an onshore wind turbine being 20 years (25 years for offshore), a significant number of these plants will reach their end-of-life within 5 years or less. There is therefore an urgent need to address the different options for turbine lifetime extension or end-of-life. Moreover, as the growth rate increased continuously and reached high levels in the last decade, tackling this issue now is also an important step for the future.

Additionally to lifetime extension, which is being tackled by the newly created Task 42, there exist two further options when reaching a wind plant end-of-life: decommissioning and repowering. Decommissioning consists of dismantling the whole wind power plant, while repowering means the complete replacement of old wind turbines. In order to ensure economic and environmental sustainability of either of these interventions, recycling of all turbine parts is a central issue, especially that of non-metallic components like wind turbine blades.

The objective of the International Energy Agency (IEA) topical expert meeting (TEM) number 96 was to identify near-term and future needs for wind plant decommissioning or repowering, as well as wind turbine blade recycling. Group discussion focused on the challenges and opportunities linked to these topics, highlighting the necessary steps to ensure a viable future.

Meeting Overview

TEM#96 on Wind Plant Decommissioning, Repowering and Recycling was hosted at the GSE facilities in Rome, Italy on November 14th and 15th, 2019. It was organized by Laura Serri and Davide Airoldi from RSE S.p.A. together with Luca Benedetti from GSE S.p.A..

A total of 35 participants with expertise in wind plant end-of-life and recycling and stemming from regional authorities, wind park and system operators, industry actors and research institutes were in attendance. Over 20 short presentations were given on the first day, aiming at:

- Introducing the topic and presenting the general framework
- Giving an overview of the different end-of-life options
- Identifying current and future needs and uncertainties
- Prioritizing the research areas

The second day was dedicated to breakout sessions to explore specific details of each of the three abovementioned topics in smaller groups, and to plenary discussion to identify priority areas of collaborative research. It resulted in a consensus to propose a new IEA Wind task on the recycling of wind turbine blades.

Main Results

The IEA TEM#96 gives a contribution to better understand the issues, the challenges and the opportunities related to the large amount of wind power capacity that is reaching its end-of-life. A community of experts from very different kind of organizations actively contributed to the discussion on the three sub-topics: decommissioning, repowering and recycling.

In the General Framework, Decommissioning and Repowering session, it was underlined that most of the wind plants at the end-of-life will probably benefit of a life-extension, but in a medium to long term scenario the amount of repowering interventions is going to grow significantly. The repowering interventions offer many benefits such as:

- Higher energy production in the same area
- Better support from new turbines to the power grid
- Environmental and visual impact: less turbines = less impacts
- Areas already used for wind energy: better social acceptance
- Reduction of national energy price
- Increase of (temporary) jobs in the sector

However, there are still many issues/challenges such as:

- No specific regulation for repowering
- Administrative matter: complex, unclear and long permitting
- Grid connection: lack of available grid capacity for repowered plants
- Transport to site of the new bigger wind turbines (especially in high complex terrain)
- (New) environmental and landscape contraints
- Difficult to allocate new incentives for RES and need of new mechanisms
- Difficult to develop wind plant at grid parity
- Dismantling and recycling of the components (turbine component - cables - foundations)

The most of the capacity facing today the end-of-life is based onshore, however in few years the number of offshore wind plants reaching the end-of-life is going to grow very fast according to the boom of offshore installations in the last decade. Some specific challenges, such as dismantling the offshore foundations, will have to be considered in this case.

Decommissioning and repowering of a great amount of wind power capacity means dealing with a high number of “waste” turbine components. The challenge of recycling these components, in particular the blades, has been discussed also in the vision of a circular economy. In particular, different recycling methods for composite materials have been presented underlining also the issue of the traceability in each step of the process.

The breakout sessions identified research gaps and needs for future collaboration for each subtopic. Concerning recycling, DTU gathered the interest of the recycling experts to prepare a proposal for a new collaborative research task inside IEA WIND TCP.

Concerning decommissioning, there is a challenging emerging issue about the offshore foundations. There is the suggestion to organize a Topical Expert Meeting on this topic inviting also experts from the Oil & Gas sector.

Concerning repowering there is the need of sharing information and best practices in the regulatory framework in order to develop guidelines for this kind of intervention. However, there is no one ready to take the lead of developing an IEA Wind task yet. This will be communicated to the IEA Wind Executive Committee to explore if it can be integrated in already active tasks such as Task 28 (Social Acceptance), Task 30 (Environmental Impacts) or Task 42 (Lifetime extension). Aspects related to repowering can be especially considered.

Summary of Presentations

Presentations from TEM 96 are available on the IEA website, on the TEM#96 community page. Information in this section provides an overview and selected highlights of each of the presentations.

Introduction and General Framework

Laura Serri from RSE S.p.A briefly presented the host GSE and the activities of the organiser RSE as well as its role within the IEA. She then gave an introduction into the triple topic of wind plant end-of-life (lifetime extension, decommissioning and repowering) and the underlying topic of recycling, before reminding the meeting agenda.

Nicolas El Hayek from Planair SA (Task 11 Operating Agent) provided an overview of the IEA Wind TCP and of Task 11. Background information and history of the IEA Wind was presented, as well as active tasks. The Task 11 operating agents and their activities were presented, covering Topical Expert Meetings, Recommended Practices and the community platform. In particular, the next TEMs and the recently approved Recommended Practice on Forecasting (Task 36) were advertised.

Matteo Giannì from GSE S.p.A. provided an overview of the recent trends of wind energy in Italy. At the end of 2018, 10.26 GW were installed and produced 17.7 TWh. The target capacity of wind energy in the NECP by 2030 is 19 GW (+ 9 GW and + 23 TWh with respect to now). An overview of the wind energy support scheme was done, pointing out that the majority of wind plants (85%) in Italy was still supported at the end of 2018. In the recent years, a large amount of small plants (20 kW<C<60 kW) were installed due to more favourable incentives. With regard to wind production, large plants have higher performances (full load hours greater than 2000), whereas small plants show lower performances with a very high variability. Investment and O&M cost were presented: in Italy the investment cost of large wind plants is now 1.4 € mln/MW compared to 4.8 € mln/MW of small ones. Wind turbine is the highest cost item, ranging between 50%-70%. The promotion of wind plant competitiveness in the auction mechanism was shown. In the past auctions (2012-2016) prices fell by 40% from 2012 to 2016 (66 €/MWh). The new incentive decree supporting the period 2019-2021 is technological neutral, the base tariff can be reduced by 70% and the support scheme is a sliding FIP. Consequently, PPA could be also a valuable option for future plants in place of participating in an auction. In the end, the percentage of wind plants approaching the end of incentives was shown: 1.4% by 2019 and 6.1% by 2028.

Alessandro Arienti from E2i Energie Speciali showed how repowering of wind farms could be a value for environment, community and economy. After an introduction about the company and its activity in the renewable energy sector in Italy (706 MW of installed wind capacity), the repowering (total reconstruction) projects conducted by E2i Energie Speciali were presented together with their technical details. The principles of the «Carta del Rinnovamento eolico sostenibile» (a guideline to a sustainable repowering of existing wind farms in the Italian country) signed by the main sector operators, the association of Italian Municipality and an important environmental association were explained. The critical issues (e.g. the long authorisation process and possible power grid constraints) and opportunities (e.g. the reduction of number of turbines) of repowering as well as a possible selection process of potentially suitable sites were presented. The next phases of the E2i repowering activity were explained.

Ivan Pineda from WindEurope presented a general view of the wind energy end-of-life strategies in Europe. After an introduction about the key role of wind energy in the decarbonisation process, the age repartition of the European onshore wind fleet was shown in a graphic (about 22 GW of the European capacity will approach the EoL in 2019-2023). The different actions of WindEurope in the three fields of the meeting were presented. Relevant issues in Decommissioning and Recycling were underlined. A detailed analysis of Repowering was presented. From some examples the pros of repowering were explained. The lack of regulatory framework was pointed out as well as the need of a clear definition of what repowering is. Some important points of the Clean Energy Package were shown. In the end, the WindEurope recommendations for all Member States in order to foster the achievement of the NECPs goals were presented (the risk of failure to reach them is high!).

Luca Di Carlo from ANEV (National Wind Energy Association) showed the results of the study conducted to estimate the potential that could come from the repowering of the existing Italian wind farms, assessing the opportunities and convenience for operators, in addition to the benefits for the country. 1.6 GW will reach its end-of-life by 2020 and 3.4 GW by 2030. Without a policy framework with the aim of promoting and supporting the repowering, the old wind plants will be decommissioned and the achievement of the NECP wind targets will be even more challenging.

Greg Bohan from IWEA (Irish Wind Energy Association) provided an overview and assessment of Ireland's potential considering the repowering of older wind farms and the policy framework. In Ireland, the wind capacity in 2019 is approaching 4 GW. The Climate Action Plan 2019 contains the ambitious objective of 70% of electricity from renewable sources for 2030. For this purpose, the installed onshore wind capacity is supposed to double and the repowering could play a key role. The age and location of Irish fleet from now to 2030 was shown: by 2030 more than 60% of the Irish fleet will be older than 15 years. The potential benefits of repowering were listed together with potential barriers (see IWEA Repowering Report). IWEA Recommendations for Repowering were reported. In IWEA, two additional groups are working on the decommissioning, with an eye to the possible recycling or reuse of wind turbines (Re-Wind project), and on the turbine lifetime extension.

Jørgen Kocbach Bølling from NVE (Norwegian Water Resources and Energy Directorate) presented an overview of the licencing process of which NVE is in charge and some issues related to the wind plant end-of-life in Norway. After showing the wind energy status, it was pointed out that about 146 MW has been already decommissioned. Most licenses in Norway state that at the end-of-life the wind power plant has to be removed and as far as possible the area to be returned to its natural state. A cost assessment of the whole decommissioning process and a specific guarantee are required for this purpose. The presentation ended with a video of a wind turbine decommissioning using the free-falling method.

Giancarlo Potenza from Enel Green Power presented the new approach to sustainability and innovation of its company, that is the world's largest private player in renewables (43 GW at the end of 2018). A crowdsourcing portal has been created for collecting innovative and sustainable solutions from anyone and in Enel's vision an important role will be played by circular economy, in term of circular design, optimal use and value recovery. In this vision wind turbine EoL could be seen as a business opportunity through reuse, remanufacturing and recycling. A big challenge for future will be the recycling and reuse of wind turbine blades.

Francesco Castellani from the University of Perugia presented innovative approaches for performance upgrade analysis and on-site early fault diagnosis. In the perspective of optimizing wind farm lifetime production two ways are available: to upgrade the turbine's

productivity/efficiency and to improve its availability through early fault diagnosis. Test cases (in collaboration with RENVICO) of wind turbine power curve improvements were shown. An overview of condition monitoring through on-site measurements was presented. The proposed approaches could represent a useful tool for supporting repowering or lifetime extension decision.

Decommissioning

Anand Natarajan from DTU (Task 42 Operating Agent) held a remote presentation on the project objectives, outcomes, structure – Work Packages – and deliverables of the new IEA Wind Task 42. He then focused on some research activities already started: remaining life prediction, combining physics-based models and data to give a picture of the load and power production of a given plant, definitions – for Life Time Extension, data and methods for Life Extension.

Jörg Gattermann from TU Braunschweig described in their presentation the challenges related to the decommissioning of offshore monopiles. After a description of the general framework with specific reference to the German regulation, they discussed the activities carried out in the project DeCoMP aimed at studying large-scale models for decommissioning of monopiles. The project started in December 2018, and it is still ongoing. They pointed out the need for sufficient complete decommissioning methods and for the development of possible alternative methods.

Repowering

Susan Waldron from the University of Glasgow presented via videoconference a project carried out by academic researchers, renewable industry, construction engineers, and regulators and aimed at investigating from a technical and environmental point of view the foundation reuse in the repowering onshore wind farms. The results of the project are available through a report that can be downloaded freely (DOI 10.17605/OSF.IO/SCZDE) and provide, among others, a best practise decision-based logic to approach repowering.

Davide Airoldi from RSE S.p.A. presented a tool developed in order to evaluate the repowering potential of Italian wind farms. Starting from RSE Italian Wind Atlas, planning constraints and the national WTG database and considering different parameters it is possible to calculate the composition of the total wind capacity (existing, repowered and new capacity) at a target year (2030 for National Energy and Climate Plan and 2050 for Long Term Strategy). After having collected new inputs on data and parameters from all the stakeholders, further experiments will be conducted to obtain different possible scenarios.

Annika Eberle from NREL presented two tools for assessing end-of-life options for wind plants. The first tool is a process-based balance-of-system (BOS) modelling for onshore wind plants and implications for end-of-life analysis (named LandBOSSE) that can be used to estimate all BOS costs associated with wind plant installation. The tool can be used to estimate how BOS costs might change for a variety of mid-fidelity applications and an open-source version is available on GitHub. The second tool is a prototype framework that will allow stakeholders to quantify and visualize potential regional advantages or disadvantages that could result from transitioning to a circular economy, through a set of complex metrics comprising both environmental and economic aspects.

Luca Bragoli from ERG, after a sketch of the Italian potential, described the effort of his company in repowering. He highlighted that repowering of existing wind farms is essential for reaching EU 2030 RES targets and his company is carrying out a repowering & reblading project that will increase the wind power capacity of 217 MW. ERG plans to extend this activity to 283 MW for repowering and 300 MW for reblading. Then he discussed some points that could be improved for promoting the repowering of wind plants, e.g. the lack of coordination between authorities in charge of environmental assessment ad of visual/landscape impact evaluation, the timing of the permitting processes, removing the national grid bottlenecks, and the need for stronger DSO-TSO coordination.

Ki-Yeoung Kweon from KETEP presented a project aimed at developing a repowering technology to improve the availability of old wind farms. Korea has an installed wind power capacity of near 1.3 GW, of which around 300 MW are already ten years or older. The first step of the project was establishing the repowering procedure; after that the partners developed the appropriate technology and implemented the procedure in a case study. The presentation ended with a description of another project for the development of chemical recycling technology for composite waste of wind power blades.

Massimo Bastiani from Ecoazioni presented the Win Wind Horizon 2020 EU project which is aimed at screening, analysing, discussing, replicating, testing and disseminating feasible solutions for increasing social acceptance and thereby the uptake of wind energy. After a discussion of the main acceptance barriers to wind power plants and an overview of the project activities, he described the transfer workshop methodology which is used in the project to transfer and share experiences from one region to the others. The workshops were organised using a “learning lab” approach and a specific implementation was described, specifically the transfer workshop organised in Mahon, Menorca. The presentation ended with a description of the activities carried out in the case study in the Abruzzo Region, in Italy, and the announcement of an International transfer seminar to be held in Rome on December 16, 2019.

Laura Antosa from the Abruzzo region was unfortunately unable to assist to the Thursday meeting. Her presentation is however available on the community page, and contains specific data about wind power development in Abruzzo and the experiences of repowering of four big wind power plants. The presentation ends with a description of the authorization requirements according to the present rules in force at the national and local scale.

Recycling

Justine Beauson from DTU provided an overview of wind turbine blade recycling in Denmark in 2019. Denmark has some of the oldest wind energy installations in Europe. Background information on the numbers of wind turbine installed and decommissioned were presented. The recycling solutions used currently were also presented.

Derek Berry from NREL started on presenting the research at NREL in particular concerning the challenges on wind turbine blades and the IACMI - the Institute for Advanced Composites Manufacturing Innovation. He then talked about circular economy of energy materials, and opportunities to address wind turbine composite material challenges. He continued describing different research projects dealing with the manufacturing and characterisation of thermoplastic wind turbine blades (9 and 13 m prototypes).

Markku Vilkki from Conenor revealed how the H2020[1] Ecobulk project deals with the process for recycling blade waste in reinforcing thermoplastic composites. He described how blade waste can be mechanically downsized and processed into thermoplastics becoming a circular material – which can be recycled again several times. He also showed products obtained from GFRP[2] waste, i.e. outdoor furniture and material for building and construction and described three demos in Finland, Portugal and UK. Then he talked about tests performed for the characterisation and comparison of these products. In his view, the technology and infrastructure exist, there is now only missing investment and engagement to create a sustainable blade recycling chain.

Nicoletta Picone from STIIMA-CNR presented the H2020 FiberEUse - Large scale demonstration of new circular economy value-chains based on the reuse of end-of-life fiber reinforced composites. In particular, she illustrated three FiberEUse cross-sectorial use-cases. Use case 1: GFRP parts mechanical recycling and re-use. Use case 2: CFRP-GFRP parts thermal recycling and re-use. Use case 3: CFRP parts remanufacturing. She showed also the cloud-based platform for value-chain integration under development. Lastly, she invited interested people to join the Stakeholder Advisory Board (SAB) of the project.

[1] H2020: Horizon 2020 is the biggest EU Research and Innovation programme

[2] GFRP: Glass Fiber Reinforced Polymer
CFRP: Carbon Fiber Reinforced Polymer

Breakout Session Notes

The breakout session of Friday morning saw the participants split into three groups to discuss the state-of-the-art, identify research gaps and needs for future collaboration in the areas of decommissioning, repowering and recycling. The outcomes of each group were presented to and discussed with the full group.

The following section provides a consolidated summary of the thoughts and notes from each of the focus groups. Raw notes from each of the three groups is provided in Appendix Four.

<u>Decommissioning and Dismantling (D&D)</u>

1. **Environmental impacts from different techniques for D&D:**
    - Compile different techniques available like, free-falling/tipping wind turbines, controlled dismantling using cranes, etc.
    - A better understanding of the environmental impacts of leaving components in place like foundations and cables.
    - Guidelines on how to include the environmental impacts from D&D in LCA?
    - Guidelines on how to mitigate impacts from the D&D operations (noise, habitat disturbance/potential loss).
    - The need to focus on research of offshore subsea elements D&D impacts

    → Outcome proposed: Best practices/guidelines

2. **Decision making process for D&D**
    - Development of a generic approach for decision making process (steps, criteria, indicators, documentation)
    - The need for a closer stakeholder involvement in D&D operations. What best practices and approaches can be applied from the construction phase?

    → Outcome proposed: Creation of a tool for D&D decision making with recommendations for practitioners and decision makers. Such tool could include a resource centre with a database from decommissioned projects (technique, equipment, contractor, lead-time for execution, elements remaining on site, elements disposed, reused, recycled, etc.).

3. **Mapping of regulation and standards**
    - List and comparison of current regulations for D&D, including their application hierarchy (International, European, national, regional, etc.)
    - Timeline of decommissioning administrative procedures (how long does it take to obtain the necessary permits/authorisations for works to commence)?

    → Outcome proposed: A list of aspects that could be standardized or harmonised in regulation

4. **Decommissioning of offshore subsea elements (foundations and subsea cables)**
    - List options and possible techniques with method statements for decommissioning
    - Identify challenges, possible solutions and risks associated

    → Outcome proposed: Best practices/guidelines

5. **Decommissioning of onshore foundations**
    - List options and possible techniques with method statements for decommissioning
    - Identify challenges, possible solutions and risks associated

    → Outcome proposed: Best practices/guidelines

6. **Risk assessments**
    - Compile a list of risks associated with different D&D techniques
    - Comparison of approaches for risk assessment
    - Evaluation (severity and probability) and detailed description

    → Outcome: A reference document for construction, H&S and authorities on risks associated with D&D and mitigation techniques.

Repowering

The participants to this session belonged to various types of associations such as Wind Energy Associations, Ministerial Institutes, Regional Authorities, Research Centers, and Wind Energy Operators. However, a consensus on the categorization and prioritization of the listed items was easily and quickly reached. Suggestion for activities to be carried out can be found in brackets after each subtopic.

1. **Regulatory Framework**.
    - **Definition** of "Repowering" (starting from existing definition, propose a comprehensive definition to be clearly applied in each field: policy, regulation, incentives, research, etc.).
    - **Permitting** (share best practices and experiences in order to speed up the alignment of the permitting timing in each country to an acceptable and effective one – i.e. 1 year set by European RED[3] II)
    - **Environmental issues** (identify actors and share best practices, differentiate environmental assessment for repowering and new field, share interpretations on environmental constraints such as Natura 2000 in Europe and other country specific constraints, share approaches to the landscape impact issue, define a common approach for traceability of used turbine components – blades, etc.)
    - **Social acceptance**: Task 28 could issue best practices applicable to repowering. Define and adopt effective communication strategies to the public authority and decision makers.

    → Outcome: Best practices/guidelines

2. **Economics** (develop models to assess the repowering market, establish savings of repowering interventions vs green field ones, gather data on existing turbines and develop strategies to rank the repowering interventions in a Region/Country,

[3] Renewable Energy Directive (RED II) - Directive (EU) 2018/2001 (recast) on the promotion of the use of energy from renewable sources.

modelling park – i.e. through digital twin approach, to assess the best time for repowering)

→ Outcome: methodologies and tools (possibly open access tools)

3. **Turbine technology** (define process to assess the best wind turbines for the repowering in a given site (where wind resource is well known), consider innovative technology in the repowering interventions, assess repowering in a long term scenario - 25 years - to be prepared for the next wave of repowering: reuse of foundations and turbine elements, new materials etc....)

   → Outcome: Best practices/guidelines

4. **Power grid** (identify barriers for the integration of the electricity production of repowered plants in the existing power grid – connection with Task 25 – and in the future smart grid – possible connection with IEA ISGAN TCP, find measures to support decisions for reinforcement of the grid at a national level according to the repowering strategy. This is a broader topic, not only concerning repowering, but also new capacity to be added to the grid.

   → Outcome: Best practices/guidelines

<u>Recycling</u>

1. **Technical topics**
   - **1.1. New materials:** New materials are for example novel thermoplastics based composite materials for use in blade design and manufacturing to enable recycling at end of life. With new materials, it is possible to promote a re-design approach to facilitate the waste treatment (label composition, tracking sensors presence of hazardous materials, …)
   - **1.2. Recycling methods:** Regarding the recycling methods, several subtopics were discussed. More efficient and viable recycling processes and methods (or decycle, reuse, etc.) both from technical and economic point of view for treatments of end of life GFRP / CFRP (carbon fibre reinforced polymer / glass fibre reinforced polymer) were discussed. Another point discussed was the need to research and find new products and volume applications for downsized wind turbine blade waste. Finally, the need to investigate scaling up of recycling methods (processes/demos/pilot) into industrial / commercial scale was also discussed.
   - **1.3. Reuse:** Reuse of wind turbine blades as they are or with few changes in railway sleepers and bridges for example was also mentioned as an interesting end of life solution. Reuse of end of life wind turbine blade materials in the production of the blades was also suggested.

2. **Analysis and value chain**
   - **2.1. Value chain evaluation:** Regarding the value chain, there is a need to integrate the relevant stakeholders in the analysis of the problem. This requires analyzing the overall process and identifying key partners in the value chain, such as waste providers, end users, recyclers, logistics operators. The potential markets for recovered materials need to be identified and a supply chain analysis needs to be performed in order to develop proper logistics for blade recycling. Circular business

models for innovative and advanced applications need to be developed. In the end, these will allow to exploit potential businesses and define economically feasible business models.

2.2. LCA, LCC: Recycling solutions for end of life wind turbine blades need to be assessed using life cycle analysis and life cycle impacts in order to ensure the feasibility of the solutions. KPI (key performance indicators) to assess the different recycling recovery methods were discussed. Life cycle costing was also mention as a tool to use.

2.3. Traceability: the question discussed here is how to trace end of life wind turbine blades. Wind turbine blades may be used and re-used in different locations. The implementation of a better collection/tracking system for end of life blade is needed. Another question related to traceability is the traceability of the wind turbine blade material once it is shredded and reused in new applications. How to track a shredded product from wind turbine blade through several lifecycles in new renewable product?

3. Legislation / standardization / certification

3.1. Legislation recommendations: Regarding legislations, it was discussed how important these were to initiate recycling practices in the countries and help promote material efficiency for circular economies. Incentives from the EU on governments would be very efficient. These legislations can be in the form of obligations, for example: extended responsibility of producers or banning on landfill.

3.2. International standard certifications: It was discussed that international standards could help formalizing the procedures and the processes at end of life, creating the need to have end of life solutions ready for wind turbine blades. Other standards regarding Building codes would be needed to standardize the use of new materials manufactured with waste. Finally, standards could also be used to promote best practices.

Conclusions & Next Steps

Participants expressed interest in collaborating on research on wind plant decommissioning, repowering and recycling. There was a substantial interest in focusing on wind turbine blade recycling, which is highly relevant for all three topics and will become an international priority in the near future. It will represent a necessity and not an option, since a large amount of existing wind parks throughout the world are reaching their end-of-life, with an estimated weight of composite material to be recycled in 2022 amounting to around 300'000 tons.

Development of an IEA Wind task focusing on wind turbine blade should be considered. One outcome of the meeting was that solutions for recycling thermoset blades exist and are being researched, along with new materials that are more easily recyclable, but there is a lack of an international regulatory framework for harmonizing the recycling process. The value chain should be well studied, and traceability of the blades is essential to include their end-of-life in the LCA. Outcomes of an IEA Wind task should provide the framework to support modifications or development of new standards. Recurring themes and key topics that should be considered for a task work plan include (non-exhaustive list):

- Recycling methods for existing (thermoset) blades, including re-use applications,
- Considerations for scale-up of processes (technical and economic)
- Research on new materials with guidelines for re-design and scale up
- LCA/LCI/LCC: guidelines for environmental assessment and feasibility of methods
- Value chain: understand logistics, stakeholders, circular business models
- Traceability: how to track materials to ensure complete recycling/end-of-life?
- Binding guidelines applicable internationally (for worldwide second-hand market also)
- Legislative framework: develop best policies internationally for circular economy

DTU will be leading the process for a new task proposal, and participants have expressed their strong support. The proposal along with the list of interested countries should be ready for the next ExCo spring meeting (date to be communicated).

Decommissioning and repowering should be the object of close attention by IEA Wind ExCo members, with consideration of integration into existing tasks or creation of future tasks if too little overlap. Task 28 on social acceptance of wind energy projects, Task 34 on resolving environmental effects of wind energy and Task 42 on wind turbine lifetime extension may be relevant both for decommissioning and repowering. Laura Serri, ExCo member for Italy, is to transfer the information to other ExCo members and operating agents of the tasks mentioned above during next ExCo meeting.

Participants pointed that a TEM on "Decommissioning of offshore wind plants" would bring a lot of value to the wind community, since it is not yet obvious to all stakeholders that it is bound to take tremendous importance in the future. Lessons learnt by the oil and gas industry could help anticipate problems linked to the decommissioning of subsea elements. WindEurope and Germany are to coordinate a TEM proposal for the next ExCo meeting.

APPENDIX ONE – TEM#96 Introductory Note

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BACKGROUND

Among the RES technologies, wind energy has nowadays reached a significant maturity level and a wide penetration. According to IEA WIND Annual Report 2017, at the end of 2017 the total net installed power capacity was 520.3 GW onland and 18.8 GW offshore respectively.

Many countries – i.e. United States, India, Germany, Denmark, Spain, The Netherlands, United Kingdom, Italy – had already installed a not-negligible amount of wind capacity within 2000. In the last decade the growth rate of the wind energy installation was very high.

Considering that nowadays the average life of an onland wind farm is twenty years and twenty-five offshore, a significant amount of wind plants is reaching the end-of-life very soon. Different options can be considered for the wind plants at the end-of-life: the life extension, the decommissioning and the repowering.

In the first case, exhaustively discussed in a previous TEM[4], the life of the plant is extended after a properly assessment and, if necessary, revamping interventions. The power plant goes on producing electricity.

In the second case the whole power plant is dismantled.
In the third case, the word "repowering" is intended as an intervention finalized to the complete replacement of the old wind turbines.

In order to increase the economic and environmental sustainability of the these interventions, the attention is more and more focused on recycling challenges and opportunities for wind turbine components. The biggest portion of wind turbine components are quite easy to recycle and reuse (i.e. metal parts), but the non-metallic portion of components, namely the blades, is less easy to be recycled.

OBJECTIVES

This topical expert meeting will put together experts and stakeholders to start a discussion on the main issues affecting this very hot topic such as:

- Which is the destiny of the dismantled turbines/components?
- Which are the recycling challenges and opportunities?
- Is there a second hand turbine market?
- Which are the relevant technical, economic and environmental aspects of the decommissioning/dismantling and repowering?
- Are there any dedicated support measures for dismantling or repowering projects that consider the recycle of components?
- Are there any relevant regulatory and authorization issues?
- Best practices?
- Lessons learnt?
- ……

[4] TEM93 “WT Lifetime Extension”, Roskilde, Denmark, December 2018, Community Page

Experts from very different fields will meet to discuss one of hottest issue for wind energy in the next future.

Participants will then explore the potential needs of collaboration in order to prepare a first outline of a new IEA Wind Task.

TENTATIVE PROGRAM

14TH November 2019

Registration till 9.30 am

1. Introduction
2. End of life capacity: what to do?
    a. Life extension (outcome from TEM 93)
    b. Regulatory aspects
    c. Onland and offshore similarity/differences
3. Repowering
   Challenges, opportunities, experiences, lesson learnt
4. Decommissioning
   Challenges, opportunities, experiences, lesson learnt
5. Recycling
   Challenges, opportunities, experiences, lesson learnt

15TH November 2019

1. Breakout sessions: discussion and identification of need of research activities and information exchange in the three main topics (decommissioning, recycling, repowering)
2. Summarizing the results of the breakout sessions
3. Discussion about the interest of a IEA Task on the topic of the meeting.
4. Conclusions and next steps

The meeting will end at 2 pm.

INTENDED PARTICIPATION

Participation is expected from academia, research institutes, regulatory bodies, policy makers, wind farm owners/operators and related associations, wind turbine manufacturers, waste and recycling industry etc.
All participants will be expected to make a presentation on the work that they have been involved in the above topic areas.

EXPECTED OUTCOMES

The outcome of this meeting will be a document including:

- Presentations from the participants
- Summary of the breakout sessions
- Framing potential proposal for a IEA Wind task

APPENDIX TWO - Meeting Agenda

IEA Wind Task 11 Topical Expert Meeting #96

WIND PLANT DECOMMISSIONING, REPOWERING, RECYCLING

ROME NOVEMBER, 14-15, 2019

Organiser: Laura Serri – Davide Airoldi – RSE S.p.A. Italy

Luca Benedetti – GSE Italy

The meeting will be hosted by GSE, Gestore Servizi Energetici
Viale Maresciallo Pilsudski, 92, 00197 Roma, Italy
https://www.gse.it/en/

AGENDA
Thursday 14th November 2019

Session: Introduction and General Framework

>09.00 Registration, collection of missing presentations

>09.30 Laura Serri, RSE, *Welcome and introduction to the topic*

>09.50 Recognition of Participants

>10.15 Nicolas El Hayek, Planair SA, *IEA Wind TCP and Task 11 activities*

>10.30 Matteo Gianni, GSE, *Wind energy in Italy*

>10.45 Alessandro Arienti, E2i Energie Speciali, *Repowering of the wind farm: a value for the environment, Community and economy*

●11.00 Coffee Break

>11.30 Ivan Pineda, WindEurope, *End of life strategies for wind energy in Europe*

>11.45 Luca Di Carlo, ANEV, *Wind repowering in Italy: an industrial opportunity and an environmental need*

>12.00 Greg Bohan, IWEA, *Repowering in Ireland: An Overview*

>12.15 Jorgen Kobach Bolling, NVE, *NVE - presentation from Norway*

>12.30 Giancarlo Potenza, ENEL, *Innovation & Sustainability: a new approach*

>12.45 Francesco Castellani, University of Perugia, *Innovative approaches for performance upgrades analysis and on-site early fault diagnosis*

●13.00 Lunch

Session: Decommissioning

>14.00 Anand Natarajan, DTU, *Lifetime extension Task 42 IEA Wind*

>14.15 Jörg Gattermann, Technical University of Braunschweig, *Offshore Monopile Decommissioning On A Scaled Basis*

Session: Repowering

>14.30 Susan Waldron, University of Glasgow, *Repowering onshore wind farms: a technical and environmental exploration of foundation reuse*

>14.45 Davide Airoldi, RSE, *Repowering of Italian Wind Farms: A tool to evaluate possible scenarios*

>15.00 Annika Eberle, NREL, *Process-based Balance-of-System Modeling for Land-Based Wind and Implications for End-of-Life Analysis*

●15.20 Coffee Break

>15.40 Luca Bragoli, Erg, *Erg and its wind projects repowering in Italy*

>15.55 Ki-Yeoung Kweon, KETEP, *Development of Repowering Total Technology to Improve Availability of Old Wind Farm*

>16.10 Massimo Bastiani, Ecoazioni, *Win Wind Horizon 2020 project: a repowering model transfer from Abruzzo to Balearic Islands*

>16.25 Iris Flacco, Abruzzo Region, *Abruzzo Region: policy instruments for Renewable energy*

Session: Recycling

>16.40 Justine Beauson, DTU, *Wind turbine blade recycling in Denmark*

>16.55 Derek Berry, NREL, *Wind turbine blade recycling*

>17.10 Markku Vilkki, Conenor, *Recycling blade waste in reinforcing thermoplastic composites (Project ECOBULK)*

>17.25 Nicoletta Picone, STIIMA-CNR, *FiberEUse: Large scale demonstration of new circular economy value-chains based on the reuse of end-of-life fiber reinforced composite*

>17.40 End of the Tuesday meeting

●18.00-20.00 “Aperitivo” on GSE Terrace

Friday 15th November 2019

>09.30 Stefano Maran, RSE, *First day wrap-up and programme on the day*

>09.40 Three parallel breakout sessions

Repowering: moderator Laura Serri, RSE

Decommissioning: moderator Ivan Pineda, WindEurope

Recycling: moderator Justine Beauson, DTU

●11.15 Coffee Break

>11.45 Breakout session outcomes and discussion, all

>12.30 Discussion on enabling recycling in the context of IEA WIND,
Justine Beauson, all

●12.45 Lunch

>13.45 Final remarks, Laura Serri, RSE

>14.00 End of the meeting

APPENDIX THREE - Meeting Participants

The meeting was attended by 35 participants from 12 countries. Following is the list of participants and their affiliations.

Name	Country	Company/Organization
Diederik Moerman	Belgium	Ministry of Economy
Anand Natarajan (remote)	Denmark	DTU
Justine Beauson	Denmark	DTU
Markku Vilkki	Finland	Conenor
Jörg Gattermann	Germany	TU Braunschweig
Nils Hinzmann	Germany	TU Braunschweig
Greg Bohan	Ireland	Irish Wind Energy Association
Laura Antosa	Italy	Abruzzo Region
Luca Di Carlo	Italy	ANEV
Luca Greco	Italy	CNR insean
Alessandro Arienti	Italy	E2i Energie Speciali
Massimo Bastiani	Italy	Ecoazioni
Virna Venerucci	Italy	Ecoazioni
Annalisa Sivieri	Italy	Enel
Giancarlo Potenza	Italy	Enel
Massimiliano Tarantino	Italy	Enel
Alessandro Lagostena	Italy	ERG
Luca Bragoli	Italy	ERG
Luca Benedetti	Italy	GSE S.p.A. - Host
Matteo Gianni	Italy	GSE S.p.A. - Host
Nicoletta Picone	Italy	ITIA-CNR
Ludovico Terzi	Italy	Renvico
Davide Airoldi	Italy	RSE S.p.A.
Laura Serri	Italy	RSE S.p.A.
Stefano Maran	Italy	RSE S.p.A.
Lorenzo Battisti	Italy	Università di Trento
Francesco Castellani	Italy	University of Perugia
Francesco Natili	Italy	University of Perugia
Ki-Yeoung Kweon	Korea	KETEP
Jørgen Kocbach Bølling	Norway	NVE
Nicolas El Hayek	Switzerland	Planair SA - Task 11 OA
Susan Waldron (remote)	United Kingdom	University of Glasgow
Annika Eberle	USA	NREL
Derek Berry	USA	NREL
Ivan Pineda	WindEurope	WindEurope

APPENDIX FOUR – TEM#96 Raw Breakout Session Notes

Decommissioning

1. Environmental impacts.

→ List | diff. techniques.
- free falling
- leaving things there

→ How to measure

→ How to mitigate.

- Noise | habitats
- Offshore | Subsea elements.

2. Decision making process

- Development of the approach
  - Identification of criteria
    - general area / indicator / measure
- Stakeholder engagement

Output → tool & recommendations.

- Data connection / resources sharing

3. Mapping of regulations & standards.

→ List / table w/ regulations

→ Comparison | · common elements
· Differences.
· Specific characteristics

→ Application hierarchy | · Local
· Federal
· National

→ ~~Specific tim~~ Decommission time (process)

→ Which aspects need standards

4. Decommissioning of offshore ~~foundations~~ sub-sea elem.

— foundations

— Subsea cables.

→ Options / techniques

→ Method statements | construction (avail. inf.)
+ Decom

→ Challenges associated to decom.

5. Decommissioning of onshore foundations.

6. Risk Assements.

⇒ List of potential risks. from decommissioning

→ Comparing risks btwn diff. techniques? (tool).

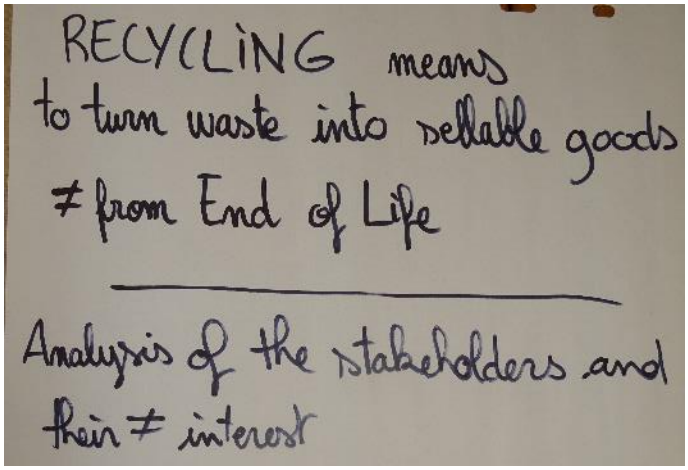
→ Evaluation of risks. | Severity

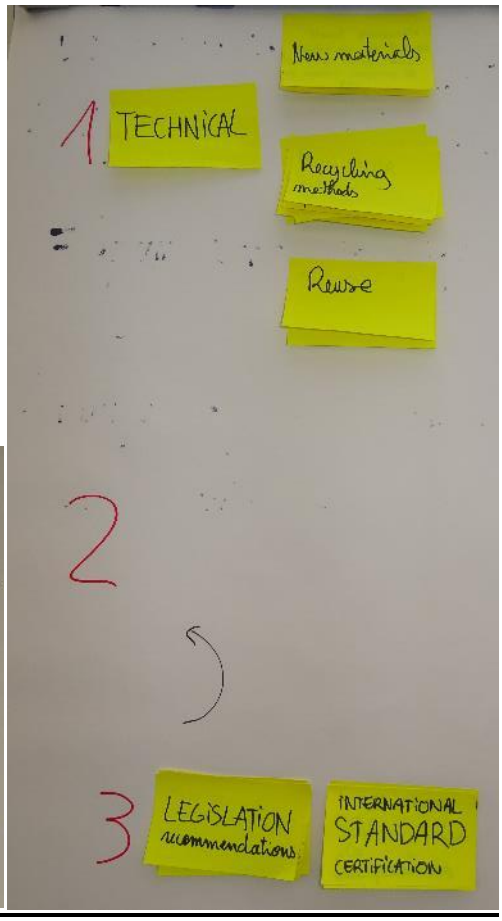
→ Description of the risks (detailed) | Probability

Repowering


REGULATOR FRAMEWORK
2 DEVELOP GUIDELINES
1.1
DEFINITION of REPOWERING
SHARE BEST PRACTICES for AUTHORISATION
1.2 PERMITTING
1.3 ENVIRONMENTAL ISSUES
1.4 SOCIAL ACCEPTANCE
BEST PRACTICES TO FOLLOW IN REPOWERING
* SEMPLIFICATION OF NORMATIVE
* INTEGRATION WITH
ESTABLISH A LEVEL PLAYING FIELD BE FOR REPOWERING & GREEN FIELD → IN ITALY, REMOVE THE "SPALMAINCENTIVI"
VALUE THE UPSIDE OF RPW ABOUT INCREASING OF PRODUCTION OF GREEN ELECTRICITY WITHOUT ANY FURTHER SOIL CONSUMPTION
• Permission process
• Regulation
• Certification
MAKE PERMITTING PROCEDURE COMPLIANT WITH REDII GUIDELINE (RPW MAX 1 YEAR, EXCEPT 4 DULY MOTIVATED CASES)
UPDATE OF THE EXCLUSION AREAS OR SUITABLE AREAS
ADDRESS THE ENVIRONMENTAL ASSESSMENT ON A DIFFERENTIAL BASIS FROM THE EXISTING SITUATION
COORDINATION BTW ENVIRONMENTAL & VISUAL/LANDSCAPE ASSESSMENT
COORDINATION AMONG STAKEHOLDERS (ALL THE ACTORS INVOLVED!)
* STUDY THE ENVIRONMENTAL AND LANDSCAPE CONTEXT
* Natura 2000
ENVIRONMENT
MORE-MORE ENVIRONMENTAL IMPACT STUDY OF WIN FARM
BLADE RECYCLING
2 STUDY ECONOMICS
• Market size (Global)
* Establish savings vs greenfield
DETAILED DATABASE OF WIND FARMS TO BE REPOWERED (RANKING?)
* Modelling when repowering is convenient
SOCIAL ACCEPTANCE
SHARE BEST PRACTICES FOR THE ACCEPTANCE
MORE INFORMATION TO PUBLIC AUTHORITY
* MORE INFORMATION AND COMUNICATION TO CITIZEN
3 TURBINE TECHNOLOGY
NEW MATERIALS
↳ RECYCLING
CHOOSING THE BEST WIND TURBINE IN THE REPOWERING SITE (KNOWLEDGE)
INNOVATIVE TURBINE TECHNOLOGY
4 POWERGRID TO ACCEPT REPOWER
SMART GRIDS
TIMING ALIGNMENT REPOWERING PROJECT COMMISSIONING & GRID CONNECTION
DEBOTTLENECKING
→ AUTHORIZATION & GRID EXPANSION PROGRAM

Recycling


RECYCLING means
to turn waste into sellable goods
≠ from End of Life
Analysis of the stakeholders and
their ≠ interest


1
TECHNICAL
New materials
Recycling methods
Reuse
2
3
LEGISLATION recommendations
INTERNATIONAL STANDARD CERTIFICATION

APPENDIX FIVE - IEA Agreement

International Energy Agency Agreement:

Implement Agreement for Co-operation in the Research, Development and Deployment of Wind Turbine Systems (IEA Wind)

The IEA international collaboration on energy technology and RD&D is organized under the legal structure of Implementing Agreements, in which Governments, or their delegated agents, participate as Contracting Parties and undertake Tasks identified in specific Annexes.

The IEA's Wind Implementing Agreement began in 1977 and is now called the Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems (IEA Wind). At present, 26 contracting parties from 22 countries, the European Commission, and Wind Europe, participate in IEA Wind. Austria, Belgium, Canada, Denmark, the European Commission, EWEA, France, Finland, Germany, Greece, Ireland, Italy (two contracting parties), Japan, Republic of China, Republic of Korea, Mexico, Netherlands, Norway (two contracting parties), Portugal, Spain, Sweden, Switzerland, United Kingdom and the United States are now members.

The development and maturing of wind energy technology over the past 30 years has been facilitated through vigorous national programs of research, development, demonstration, and financial incentives. In this process, IEA Wind has played a role by providing a flexible framework for cost-effective joint research projects and information exchange.

The mission of the IEA Wind Agreement continues to be to encourage and support the technological development and global deployment of wind energy technology. To do this, the contracting parties exchange information on their continuing and planned activities and participate in IEA Wind Tasks regarding cooperative research, development, and demonstration of wind systems.

Task 11 of the IEA Wind Agreement, Base Technology Information Exchange, has the objective to promote and disseminate knowledge through cooperative activities and information exchange on R&D topics of common interest to the Task members. These cooperative activities have been part of the Wind Implementing Agreement since 1978.

Task 11 is an important instrument of IEA Wind. It can react flexibly on new technical and scientific developments and information needs. It brings the latest knowledge to wind energy players in the member countries and collects information and recommendations for the work of the IEA Wind Agreement. Task 11 is also an important catalyst for starting new tasks within IEA Wind.

IEA Wind TASK 11: BASE TECHNOLOGY INFORMATION EXCHANGE

The objective of this Task is to promote disseminating knowledge through cooperative activities and information exchange on R&D topics of common interest. Four meetings on different topics are arranged every year, gathering active researchers and experts. These cooperative activities have been part of the Agreement since 1978.

Three Subtasks

The task includes three subtasks.

The objective of the first subtask is to develop recommended practices (RP) in collaboration with the other IEA Tasks.

The objective of the second subtask is to conduct Topical Expert Meetings (TEM) in research areas identified by the IEA R&D Wind Executive Committee. The Executive Committee designates topics in research areas of current interest, which requires an exchange of information. So far, TEMs are arranged four times a year. Additional TEM types that would allow shorter reaction times, broader audience and augmented visibility are currently being researched.

The objective of the third subtask is to provide room for exchanges within the wind energy expert community. This is done through the IEA Wind platform with online communities.

Documentation

Since these activities were initiated in 1978, more than 90 volumes of proceedings have been published. In the series of Recommended Practices, 20 documents were published and six of these have revised editions.

All documents produced under Task 11 and published by the Operating Agent are available to citizens of member countries participating in this Task. Some documents are publicly available one year after first publication.

Operating Agent

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COUNTRIES PRESENTLY PARTICIPATING IN TASK 11 (2019)	
COUNTRY	**INSTITUTION**
Belgium	Government of Belgium
Canada	Natural Resources Canada
Denmark	Danish Energy Authority
Finland	Business Finland
Germany	Federal Ministry for Economic Affairs and Energy (BMWi)
Ireland	Sustainable Energy Authority of Ireland (SEI)
Italy	Ricerca sul sistema energetico (RSE S.p.A.)
Japan	New Energy and Industrial Technology Development Organization (NEDO)
Mexico	Instituto de Investigaciones Electricas (IIE)
Netherlands	Ministry of Economic Affairs
Norway	The Norwegian Water Resources and Energy Directorate (NVE)
Republic of China	Chinese Wind Energy Association (CWEA)
Republic of Korea	Korea Institute of Energy Technology Evaluation and Planning (KETEP)
Spain	Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas (CIEMAT)
Sweden	Energimyndigheten - Swedish Energy Agency
Switzerland	Swiss Federal Office of Energy (SFOE)
United Kingdom	Offshore Renewable Energy CATAPULT
United States	The U.S Department of Energy (DOE)