Annual Report 2024

Task 42

Photo: *Middelgrunden offshore wind farm, Denmark.* *(Photo credit: HOFOR.)*

Wind Turbine Lifetime Extension

Author: Asger Bech Abrahamsen, DTU Wind and Energy Systems, Technical University of Denmark; Jannie S. Nielsen, Department of the Built Environment, Aalborg University

The objective of Task 42 is to provide information about methods for estimating the accumulated fatigue damage of wind turbine components after operating the turbines for a certain number of years, which can be used for decisions of lifetime extension.

The activities of 2024 were focused on the following Work Packages (WPs):

WP1: Integrating economic reliability and risk, **WP2**: Data-driven life estimation, and **WP3**: Preparing for a sustainable future (2050).

A major activity of WP1 has been the mapping of barriers for performing lifetime extension of offshore wind farms, because the rules specifying how to apply for lifetime extension for offshore wind are limited.

In general, it has been found that the uncertainties of the rules were seen as the largest barrier for lifetime extension of many European-based stakeholders, where the oldest offshore wind farms are also placed. A review paper is being

written on the findings of the study, and a presentation was provided at the WESC2025 conference [1].

The focus of WP2 has been on identifying scientific papers illustrating different data-driven methods of estimating the consumed life of wind turbines and also estimating the remaining useful lifetime of wind turbines.

A review paper is being written on data-driven lifetime extension and is considered as a scientific input to the content of the newly published IEC 61400-28 Technical Specification "Wind energy generation systems - Part 28: Through-life management and life extension of wind power assets" [2].

Finally, WP3 has been focused on formulating scenarios of lifetime extension in beyond 2050, using a fleet description of the lifetime of the turbines as described in Abrahamsen et. al. [3]. By adding a future installation rate of a country or a region, it is possible to determine how large annual installations are needed after 2050 to keep a constant fleet capacity. This can then be used to estimate the amount of materials needed to expand the wind turbine fleet and to be recycled to maintain the fleet.

Introduction

In several regions of Europe, wind turbines are reaching their design lifetime as specified in the IEC 61400-1 and -3 standards and decisions if the turbines should be life extended are routinely being investigated for onshore wind turbines.

It is, however, not as clear how the process of applying for lifetime extension of offshore wind turbines should be handled. An interview study was therefore initiated by the task to identify the major barriers for lifetime extension of offshore wind.

The list of participants of the task is 14, representing seven countries and involving five companies in 2024 as shown in table 1.

COUNTRY/SPONSOR	INSTITUTIONS
Belgium	Vrije Universiteit Brussel (VUB)
China	Xinjiang Goldwind Science & Technology Co
Denmark	Department of the Built Environment, Aalborg University (AAU); DTU Wind and Energy Systems, Technical University of Denmark (DTU); EMD International; DNV
Germany	Institute for Steel Construction, Leibniz University Hannover (LUH); Technical University of Munich (TUM); Rambøll; EnBW
Ireland	University College Dublin (UCD)
Republic of Korea	Changwon National University (CWNU)
Sweden	Royal Institute of Technology (KTH); Chalmers University of Technology (Chalmers)

Table 1. *Countries Participating in Task 42*

Progress and Achievements

The interview study on the barriers of lifetime extension of offshore wind showed that several stakeholders considered the lack of clear rules outlining the procedure for applying for a lifetime extension as the largest challenge.

A second challenge is that the rules in the European countries are different and that lifetime extension of a wind farm might depend on a decision to lifetime extend the grid connection infrastructure, which might be owned by an independent or government body. The technical evaluation of the wind farm asset was not considered as a showstopper for lifetime extension and many stakeholders expressed that 10 years of lifetime extension was considered possible.

During the year several lifetime extension news have been observed with the release of the IEC 61400-28 TS [2], the release of the Danish guidelines on lifetime extension of offshore wind farms [4] and finally the granting of permission of lifetime extension of 10 year, 10 year and 25 years for the Danish offshore wind farms Samsø, Middelgrunden and Nysted as illustrated in Table 2 [5].

It is interesting that the Middelgrunden offshore wind farm has been granted 25-year lifetime extension after 25 years of initial operation. All of the lifetime extensions of Table 2 are conditional on limiting the bat collisions by either stopping or rotating slower after sunset when the wind speed is below 6 m/s in the period from 1 April and to 31 October.

Thus, the lifetime extension condition might have an impact on both the consumed life due to extra starts and stops as well as the economy of the wind farms due to lower annual energy production.

The work on data-driven lifetime extension methods has resulted in the creation of an overview of the sub-processes that must be performed as illustrated in Figure 1. These processes as specifying the data that is needed, methods of the load evaluation, different approaches to evaluate the damage accumulation and extrapolation of damage accumulation in space (between turbines in a wind farm) and time if only limited time series of condition monitoring data are available.

The task is working on a review paper linking scientific papers to the different topics outlined in Figure 1 and the intension is that the scientific papers can provide examples of the methods suggested in the IEC 61400-28 TS [2].

The work on lifetime extension scenarios in 2050 focused on creating a fleet model capable of describing how the wind turbine fleet of a country or region is expected to be decommissioned as specified by the observed decommissioning of Denmark [3] and Germany [6].

This was done by describing the decommissioning process of the fleet by a Weibull function, which for the onshore turbines of Denmark states that the age of the turbines when 50 % of an installation year is decommissioned is 29 years and the transition from 10 % to 90 % of the fleet being decommissioned is 9 years [3].

This decommissioning scenario is quite different from the simple assumption that all onshore wind turbines will be decommissioned just after passing the design lifetime of 20 years.

The model will be used to investigate the future fleet capacities in the case that the design lifetime of future wind turbines is increased, because a larger fleet is obtained with the same installation activity if the design lifetime is increased.

Investigations of the seabed lease period of several offshore wind farm tenders are indicating that the design lifetime of

Wind farm name	Capacity [MW]	Commissioning [Year]	Original Equipment Manufacturer	Operator / Owner*	Lifetime extension [Years]	Bat control[a]
Middelgrunden	40	2000/2001	BONUS B76/2MW Gravitation(4-8m)	HOFOR/Middelgrundens Vindmøllelaug	25	Yes
Horns Rev 1	160	2002	Vestas V80-2MW Monopile (6-14m)	Vattenfall/Ørsted	TBD	TBD
Rønland 1	8	2003	Vestas V80-2MW	Rønland Havvindmøllepark A/S	TBD	TBD
Samsø	21	2003	SWT82 - 2.3MW Monopile(~12 m)	Samsø Havvindmøllepark	10	Yes
Nysted	166	2003	Siemens 2.3MW Gravitation(6-10m)	Nysted Havvindmøllepark	10	Yes

Table 2. *Overview of the Danish offshore wind farms that have been granted lifetime extension by July 2025 and the farms still under review by the Danish Energy Agency [5].*

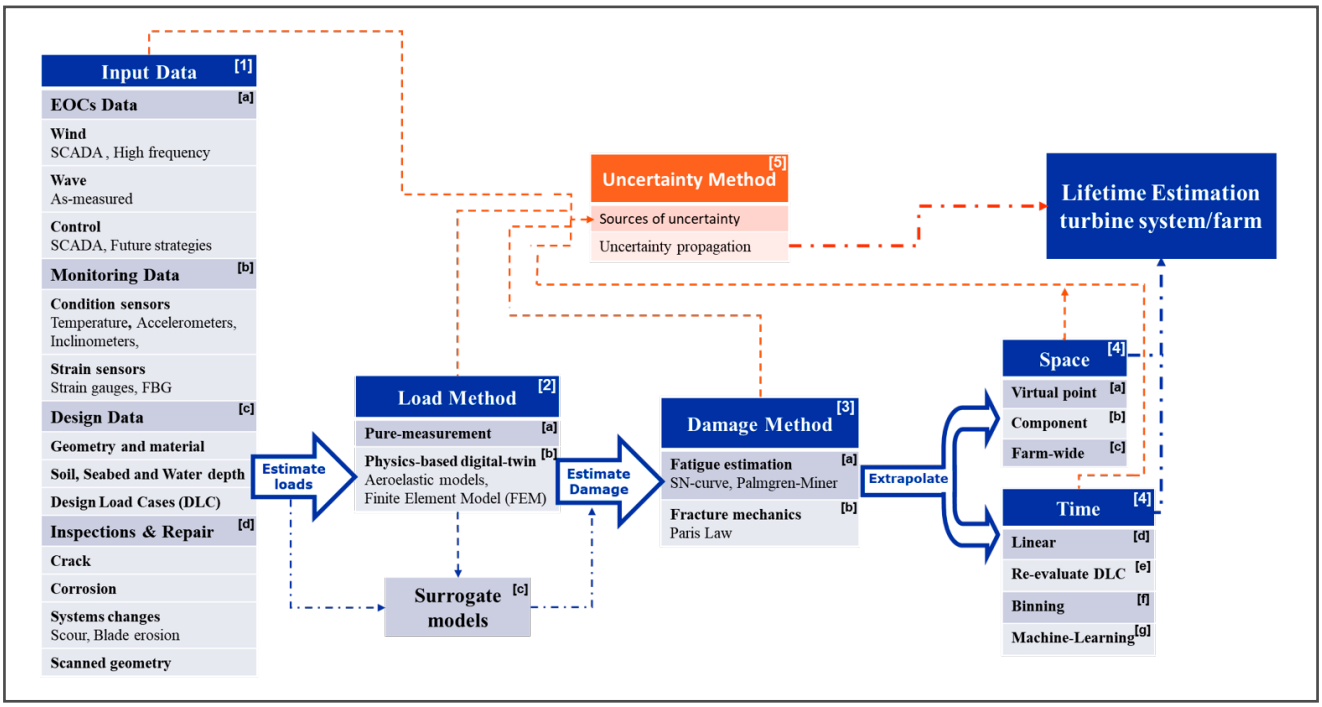

Figure 1. *Illustration of the data-driven lifetime extension evaluation methods. (Source: Bruno R. Faria et. al., IEA TCP Task 42 (ongoing).)*

current offshore wind turbines is probably in the range of 30-40 years. Secondly, it will be investigated if the fleet material usage can be obtained to discuss the needed material supply as well as the recycling flow once the fleet capacity is constant.

This information is useful for other IEA TCP Wind tasks investigating wind turbine blade recycling (Task 45) and Life Cycle Analysis (Task 60).

Highlights

- Interview study on barriers for lifetime extension of offshore wind has been performed [1]. Lack of clear rules is seen as the major challenge, but the granted lifetime extensions of 10 and 25 years to Danish offshore wind farms can be an inspiration for other countries [5].

- Data-driven lifetime extension methods have been investigated and a review paper to complement the IEC 61400-28 TS with scientific papers is in progress (see Figure 1).

- Scenarios of turbine fleet decommissioning in 2050 have been formulated using the observed decommissioning of Denmark [3] and Germany [6]. This can be used to investigate when a constant turbine fleet capacity is obtained after 2050 if the design lifetime of the turbines is increased. Extension with a fleet material usage model is in progress and can provide input to recycling and lifecycle analysis (LCA) studies.

Outcomes and Significance

The importance of wind farm lifetime extension has been stated well in the recent lifetime extension application of the Danish offshore wind farm Nysted, holding 80 turbines of 2 MW mounted in gravitational sub-structures and which was granted 10-year lifetime extension [7]:

- "20-25% expected improvement on climate change impact category (20-25% reduction of carbon footprint measured as kg C02/MWh)" [7].

- "Expected EROI (energy return of investment) increase with 30-35%" [7].

Next Steps

The second phase of Task 42 is working on completing a series of review papers covering the work of the work packages and the formulation of the final report of the task is in progress.

References

[1] M. Henkel, R. Harris and J.S. Nielsen, "Review of Current Lifetime Extension Practices for Offshore Wind Turbines", Session RS#05.1, ID 8733 presentation, Wind Energy Science Conference 2025, Nantes (2025).

[2] IEC Technical Specification 61400-28, IEC TS 61400-28:2025 "Wind energy generation systems - Part 28: Through-life management and life extension of wind power assets", International Electrotechnical Commission, Webshop; *webstore.iec.ch/en/publication/62236* (accessed June 2025).

[3] Bech Abrahamsen A, Beauson J, Wilhelm Lund K, Skov Madsen E, Philipp Rudolph D, Pagh Jensen J. Method for estimating the future annual mass of decommissioned wind turbine blade material in Denmark. Wind Energy. 2024; 27(2): 165-178. doi:10.1002/we.2882

[4] Danish Energy Agency, "Vejledning om ansøgnings- og tilladelsesprocessen for repowering og forlængelse af elproduktionstilladelse (levetidsforlængelse) af bestående elproduktionsanlæg på havet" (Guideline on application and permitting process for repowering and lifetime extension of electricity production facilities offshore); *ens.dk/energikilder/repowering-og-levetidsforlaengelse-af-eksisterende-havvindmoelleparker* (accessed July 2025).

[5] Danish Energy Agency, "Etablerede havvindmølleparker" (established offshore wind farms); *ens.dk/energikilder/etablerede-havvindmoelleparker* (accessed July 2025).

[6] Kathrin Julia Kramer, Asger Bech Abrahamsen, Justine Beauson, Ulrich Elmer Hansen, Niels-Erik Clausen, Anne P.M. Velenturf, Matthias Schmidt, "Quantifying circular economy pathways of decommissioned onshore wind turbines: The case of Denmark and Germany", Sustainable Production and Consumption, Volume 49, 2024, Pages 179-192, ISSN 2352-5509, https://doi.org/10.1016/j.spc.2024.06.022.

[7] Ørsted, "Nysted Offshore Windfarm - Application for Lifetime Extension and permit prolongation. Description and Environmental Assessment", August 2024. (Lookup Nysted under [5] and find document "Ansøgning om forlængelse af elproduktionstilladelsen (Nysted Havvindmøllepark)"). (Accessed July 2025).

Task Contact

Professor Athanasios Kolios
DTU Wind and Energy Systems
Technical University of Denmark
atko@dtu.dk

Websites
windenergy.dtu.dk/english
iea-wind.org/task42/