Technology Collaboration Programme
by iea

IEA Wind TCP

IEA Wind Task 46 Annual Progress Reports for IEA Wind TCP ExCo Meeting 94

Task 46: Erosion of wind turbine blades

Date: 7 May 2024

Operating Agent, Charlotte Hasager, DTU

Please note, the change of Operating Agent 1 June 2023 (from before Raul Prieto, VTT).

1 Background and Goals

Task Description: Erosion of wind turbine blades, Commencement data was 15 March 2021 and completion date is 14 March 2025.

Task Description:

The purpose of the IEA Wind Task 46 Erosion of wind turbine blades is to improve understanding of the erosion driving factors, develop datasets and model tools to enhance prediction of leading edge erosion likelihood, identify damage at the earliest possible stage, and advance potential solutions.

The task scope is aligned with two of the research priorities established by IEA TCP, namely:

- **Resource and site characterization**: Improving the practices in resource characterization regarding susceptibility to erosion at wind farm sites.
- **Advanced technology**: erosion damage models, material properties, characterization of erosion resistance, characterization and improvement of wind turbine operation with erosion.

The scope of work is divided into four technical work packages:

·**WP2 Climatic conditions driving blade erosion:** The science goals are to (i) provide a priori assessments of wind sites regarding the potential for excess LEE and (ii) inform wind farm operation to optimize blade lifetimes. The long-term objective is to characterize erosion-relevant properties geospatially / temporally and generate GIS layers (with quality index/uncertainty) for inclusion, like the Global Wind Atlas (https://globalwindatlas.info/). Sara Pryor coordinates this WP from Cornell University.

·**WP3 Wind turbine operations with erosion:** This work package has three key overarching objectives: (i) Promote collaborative research to mitigate erosion using wind turbine control, assessing the viability of erosion-safe mode. (ii) Improve the understanding of droplet impingement in the context of erosion. (iii) Improve the understanding of wind turbine performance in the context of erosion, especially the effect of LEE surface roughness on aerodynamics. David Maniaci coordinates this WP from Sandia National Laboratories.

·**WP4 Laboratory testing of erosion:** The objective of this work package is to facilitate the convergence of laboratory erosion testing practices to achieve a high-fidelity test setup representative of the erosion phenomena observed in the field and reduced uncertainty associated with the preparation of the samples and the testing process and the data analysis. Nicolai Frost-Jensen Johansen coordinates this WP from DTU.

·**WP5 Erosion mechanics & material properties:** The aim is (i) to understand the influence of the material parameters used for leading-edge protection on the performance and (ii) to understand the damage mechanisms and to identify appropriate damage models for accumulative droplet impact erosion attending operational conditions (droplet impact velocity, droplet size, number of impacts per unit surface, etc); and failure modes (surface wear, interface debonding, cracking of underlying layers etc). Fernando Sanchez Lopez coordinates this work from Universidad Cardenal Herrera CEU.

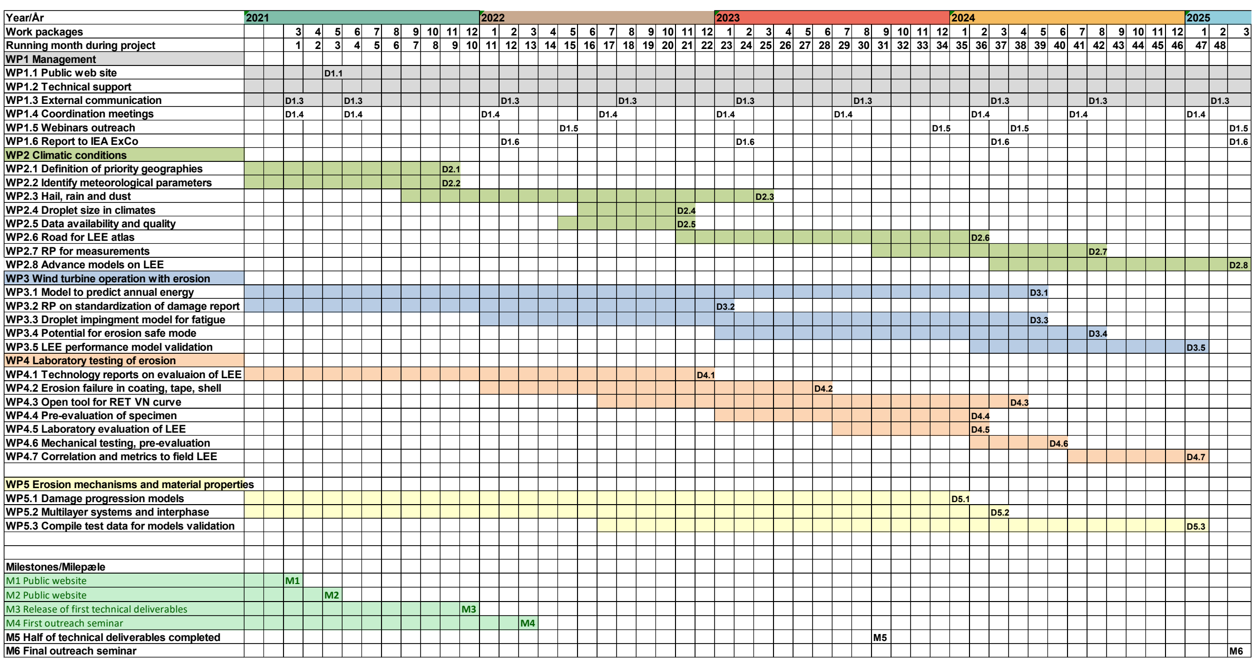
Task Time Plan and Milestones

Table 1. Milestone Table: Work Plan Milestones, Contributors, and Due Dates (in red deliverables changed from year #3 to year #4).

No.	Deliverable	Lead organization	Month Due	Status
D1.1	Public website	DTU	3	Delivered
D1.3, D1.4	External communications, coordination meetings	OA	1,4,11,12,17,18,23,24,29,30,36,37,41,42,47,48	Delivered/On track
D1.5	Webinars	OA	15,31,38,48	Delivered/On track
D1.6	ExCo Report	OA	12,24,37,48	Delivered/On track
D2.1+D2.2	Pryor et al. Technical Report: Atmospheric drivers of wind turbine blade leading edge erosion: Hydrometeors.	Cornell University	9	Delivered
D2.3	Pryor et al. Technical report: Atmospheric drivers of wind turbine blade leading edge erosion: co-stressors	Cornell University	25	Delivered
D2.4+D2.5	Pryor et al. "Atmospheric Drivers of Wind Turbine Blade Leading Edge Erosion: Review and Recommendations for Future Research" Energies 2022, 15(22), 8553.	Cornell University	21	Delivered
D2.6	Roadmap for LEE atlas	Cornell University	30	planned year #3
D2.7	Recommended practice for measurement of LEE drivers	Cornell University	40	planned year #4
D2.8	Methods to perform V&V on LEE drivers	Cornell University	47	planned year #4
D3.1	Model to predict annual energy production loss on blade erosion class	Sandia National Laboratories	30	planned year #3
D3.2	Maniaci, D.C., MacDonald, H., Paquette, J., Clarke, R. Leading Edge Erosion Classification System	Sandia National Laboratories	23	Delivered
D3.3	Droplet impingement model for use in fatigue analysis	Sandia National Laboratories	33	planned year #3
D3.4	Potential for erosion safe-mode operation	Sandia National Laboratories	37	planned year #4
D3.5	Accuracy of LEE performance loss model based on field observations (validation).	Sandia National Laboratories	47	planned year #4
D4.1	Finnegan W., Bech J.I., (Eds.) Technical report: Review on available technologies for laboratory erosion testing	NUI Galway, DTU	22	Delivered
D4.2	Johansen, N. F.-J. Erosion failure modes in leading edge systems	DTU	28	Delivered
D4.3	Evaluation of specimen from RET beyond VH-curves ~~Normalization of test~~	DTU	34	planned year #3

	~~substrates~~ (software recommended practice)			
D4.4	Pre-evaluation of test specimens (recommended practice)	DTU	31	planned year #3
D4.5	Test data analysis, damage accumulation and VN curves (recommended practice)	DTU	35	planned year #3
D4.6	Simple mechanical test for screening of key parameters (report)	TU Delft, DTU	40	planned year #4
D4.7	Correlation between RET data and expected field service life (report and model)	DTU	47	planned year #4
~~D4.8~~	~~Aging – unloaded and during testing (literature review and RP)~~	~~DTU~~	~~47~~	~~planned year~~ #4
D5.1	Damage models based on fundamental material properties (report)	Universidad Cardenal Herrera	26	pending
D5.2	Multilayer systems (report)	Universidad Cardenal Herrera	37	planned year #4
D5.3	Microstructure and macroscopic material properties (Report)	Universidad Cardenal Herrera	47	planned year #4

Figure 1: Schedule: Work Packages, Deliverables, Dates



Deliverables for past 6 months:

The deliverables D2.1, D2.2, D2.3, D2.4, D2.5, D3.2, D4.1 and D4.2 are completed.

The deliverables D2.6, D3.1, D3.3, D4.3, D4.4 and D4.5 are in progress but delayed from year 3 to year 4. Deliverable D5.1 is pending since year 2.

Milestones for past 6 months:

Milestones: M1, M2, M3, and M4 are completed on time.
M5 is delayed from year 3 to year 4.

Three peer-reviewed articles have been published open-access. The first two articles are based on WP2 and relating to D2.6 (not yet completed). The third article is based on collaboration between WP2 and WP5 combined relating research from D5.1 (not yet completed) and D2.6 (not yet completed):

- Pryor et al. 2023 in *Energies* https://doi.org/10.3390/en15228553
- Hannesdóttir et al. 2024 in *Results in Engineering* https://doi.org/10.1016/j.rineng.2024.102010
- Letson and Pryor 2023 in *Energies* https://doi.org/10.3390/en16093906

The Task 46 has been presented in the 5th Erosion Symposium (Feb/2024) at DTU Risø, by the OA and WP leaders (David Maniaci, Fernando Sanchez) which communicated the task work and outcomes.

The Task 46 presented by WP2 leader (Sara Pryor) organized a mini-symposium at WESC May 2023 Glasgow on blade erosion.

A Task workshop (face to face) was held in Roskilde on the 9th of February, with 28 participants who contributed to plan the incoming deliverables.

A second outreach webinar on 4 December 2023, where progress was presented by the work package leaders and operating agent. The webinar was followed online by 40 attendees.

2 Progress Toward Goals

The Task continues advancing according to plan though with some delay. Key results in 2023 include one main deliverable (technical report) and three peer-reviewed journals, as well as dissemination in a second outreach webinar and the 5th Erosion Symposium and at a mini-symposium at WESC. The material is available in the Task website https://iea-wind.org/task46/.

3 List of Participants

The 41 participating organizations from 12 countries represent the key wind energy actors relevant to the erosion challenge: owners, wind turbine manufacturers, leading edge protection suppliers, and the research community. The composition is the following:

- 1 certification body
- 8 wind farm owners
- 2 consultancy
- 4 wind turbine manufacturers
- 7 coating manufacturers
- 19 academic/R&D organizations

Table 2. Participants Table.

	Country/Sponsor	**Participant Organisation**	**Expert Participant**	WP2	WP3	WP4	WP5
1	**Belgium**	**Engie**	**Nicolas Quiévy**	1	1	1	
2	**Canada**	**WEICan**	**Marianne Rodgers**	1	1		
3			Jessica Ma	1	1		
4	**Denmark**	**DTU**	**Charlotte Hasager**	1	1	1	1
5			Jakob Ilsted Bech			1	1
6			Ásta Hannesdóttir	1			
7			Leon Mishnaevsky				1
8			Nicolai Frost-Jensen Johansen			1	
9			Ebba Dellwik	1			
10			Christian Bak		1		
11			Ole Bang			1	
12			Anders Smærup Olsen		1		
13			Jamie Engelhardt Simon			1	
14			Coraline Lepre			1	
15			Alexander Meyer Forsting		1		
16			Christian Rosenberg Petersen			1	
17		**Hempel**	**Pablo Bernad**			1	1
18			Maral Rahimi			1	1
19		**Ørsted A/S**	Jacob Kronborg Andersen	1			
20			Birger Carstensen	1			
21		**Power Curve**	**Nicholas Gaudern**		1		
22			Niels Bruhn Brønnum		1		
23	**Finland**	**VTT**	**Teijo Arponen**	1	1		
24			**Jennifer Spencer**	1	1		
25	**Germany**	**Fraunhofer IWES**	**Cate Lester**				1
26			**Johannes Theron**		1		
27			Stefan Krause			1	
28			Steffen Czichon				1
29		**Covestro**	**Pantea Nazaran**			1	1
30			Hung Banh			1	1
31			Laura Woods			1	1
32		**Emil Frei (Freilacke)**	**Frank Berger**			1	1
33			Sandra Nille			1	1
34			**Benjamin Mark**			1	1
35			Heiko Blattert			1	1
36		**Nordex Energy SE**	Steffen Heinz	1	**1**	**1**	
37		**DNV**	**Amilcar Zambrano**		1		
38			Margarita Ahne		1		
39			Christopher Harrison				
40		**Mankiewicz**	**Philipp Costa**			1	**1**
41			Alexander Weinhold			1	
42		**Henkel**	**Larissa Spilke**			1	

43			Inigo Roca			1	
44			Pradiba Kannan			1	
45			Olaf Hartmann			1	
46			Luis Quiroga			1	
47		**RWE**	**Sandro di Noi**	1			
48			Johannes Witten	1			
49			Guillermo Lozano	1			
50	**Ireland**	**South East Technological University**	**Edmon Tobin**			1	
51		**University of Galway**	**William Finnegan**			1	1
52		**University of Limerick**	**Trevor Young**			1	1
53			Mohammad Ansari			1	1
54	**Japan**	**AIST**	**Motofumi Tanaka**	1	1	1	1
55			Aya Aihara		1	1	
56			Hirokazu Kawabata		1		
57		**Osaka University**	**Tomoo Ushio**	1		1	
58		**TOKYO GAS Co.**	**Yoko Nishida**			1	1
59		**Asahi Rubber Inc.**	**Nobuyoshi Watanabe**			1	1
60			Kiyoshi Minegishi			1	1
61	**Netherlands**	**TU Delft**	**Julie Teuwen**			1	1
62			Dominic von Terzi		1		
63		**TNO**	**Harald van der Mijle Meijer**	1	1		
64			Gerard Schepers		1		
65			Kishore Vimalakanthan		1		
66			Marco Caboin		1		
67			Iratxe Gonzalez Aparicio	1			
68			Henk Slot				1
69	**Norway**	**Equinor**	**Helene Konstantia Vrålstad**				1
70			Gunnar Hognestad				1
71		**University of Bergen**	**Joachim Reuder**	1			
72			Bodil Holst				1
73			Stephan Kral	1			
74		**Statkraft**	**Birgit Junker**	1			
75	**Spain**	**Aerox**	**Asta Šakalytė**		1		1
76		**Cener**	**Beatriz Méndez**		1		
77		**Nordex Energy Spain**	**Elena Llorente**		1		
78			Rubén Gutierrez		1		
79			Sergio Diaz			1	1
80		**Siemens Gamesa Renewable Energy**	**Busra Akay**		1		
81			Jairo Escudero		1		
82			Dimitris Siorikis		1		

83		**Universidad Cardenal Herrera - CEU**	**Fernando Sánchez**			1	1
84			Luis Doménech				1
85		**DNV Iberica**	**Amilcar Zambrano**	1	1	1	
86			Jorge García	1	1	1	
87	**UK**	**ORE Catapult**	**Kirsten Dyer**	1	1	1	1
88			Peter Kinsley	1		1	
89			Stephen Jones				
90		**Univ Bristol**	**Terence Macquart**		1	1	
91			Ian Hamerton			1	
92			Matt Bone				
93		**Lancaster University**	**Sergio Campobasso**		1		
94			Alessio Castorrini	1	1		
95		**Imperial College**	**Hao Hao**				1
96			Alex Taylor				1
97			Maria Charalambides				1
98			Yannis Hardalupas				1
99			Antonis Sergis				1
100		**Vestas UK**	**Tomas Vronsky**				
101			Francesco Grasso		1		
102		**Ilosta**	**James Nash**	1	1		1
103			Lukasz Zapotoczny		1		
104			Saber Khayatzadeh		1		
105			Tony Hamill		1		
106			Miguel Ubago Torres				
107	**US**	**Cornell University**	**Sara C Pryor**	1			
108			Rebecca J Barthelmie	1			
109		**Sandia National Laboratories**	**Josh Paquette**		1		
110			David C Maniaci		1		
111			Lawrence Cheung		1		
112			Kenneth Brown		1		
113	**US**	**3M**	**Benton Free**				1

4 Statement of Accounts and Value of Contributions

Status of accounts and cost of participating:

- Task Annual Budget: 52 995 EUR
- Participation Fee (2024) 3 041 EUR (12 countries). Total fee for year 4 is **36,492** €, which accounts for unused budget from years #1, #2 and #3 (16.503 EUR) moved to year #4.

Fee per country is 3 041 € (12 countries).

Annual Operating Agent Costs (year #4)

Cost item	Annual use (Person-months)	EUR/Unit DTU	EUR/year
Technical support, website & data platform	**0.2**	**€ 29,500**	**€ 5,900**
Internal coordination teleconferences	**0.4**	**€ 29,500**	**€ 11,800**
Outreach webinars	**0.2**	**€ 29,500**	**€ 5,900**
Reporting	**0.2**	**€ 29,500**	**€ 5,900**
Travel costs	**3 meetings (2 Task meetings + 1 ExCo)**	**€ 1,500**	**€ 5,492**
Other	**website, yearly meeting venue**	**€ 2,450**	**€ 1,500**
TOTAL			**€ 36,492**

Total fee (accounts for funds transferred from years #1, #2 and #3).	**€ 36,492**

Value of in-kind activities.

The Task has allowed the wind energy community to work together on the complex and multidisciplinary topic of blade erosion. The forum formed by the 113 persons from 41 organizations produces not only the deliverables, but also technical discussions in the periodic meetings of the topical work packages, and in the plenary sessions.

The two key outcomes of the task are:

- a deeper knowledge about the erosion topic by the participants, which feeds to the wider energy sector thru the deliverables and the dissemination sessions.

  a strong and well aligned research portfolio in the topic of erosion, thanks to the communication between 41 organizations involved, which helps focus the efforts to solve the challenge.

5 New Developments Since Last Report

WP2: Climatic conditions

Recent progress has been made in improving our understanding of the performance of different hydrometeorological measurement systems and data processing approaches. The quantification of co-stressors that may amplify damage initiated during extreme hydroclimate events is considered (Pryor S.C., Barthelmie R.J., Dellwik E., Hasager C., Kral S.T., Prieto R., Reuder J., Rodgers M., Veraart M. (2023): Atmospheric drivers of wind turbine blade leading edge erosion: Ancillary Variables. Technical report from IEA Wind Task 46 Erosion of wind turbine blades. 20 pp. IEA Wind TCP ExCo). Data sets and meta-data have been generated and made publicly available via ZENODO (e.g., https://zenodo.org/records/7734765 and https://zenodo.org/records/5648211). Figure 2 shows disdrometer data of droplet size distribution and relation to rain rates. As the scatterplot shows, there is a large spread in droplet diameter and rain rates. Further details on the analysis are presented in Pryor S.C., Barthelmie R.J., Candence J., Dellwik, E., Hasager C.B., Kral S.T., Reuder J., Rodgers M., and Veraat M. (2022): Atmospheric Drivers of Wind Turbine Blade Leading Edge Erosion: Review and Recommendations for Future Research. *Energies* 2022, 15(22), 8553; https://doi.org/10.3390/en15228553.

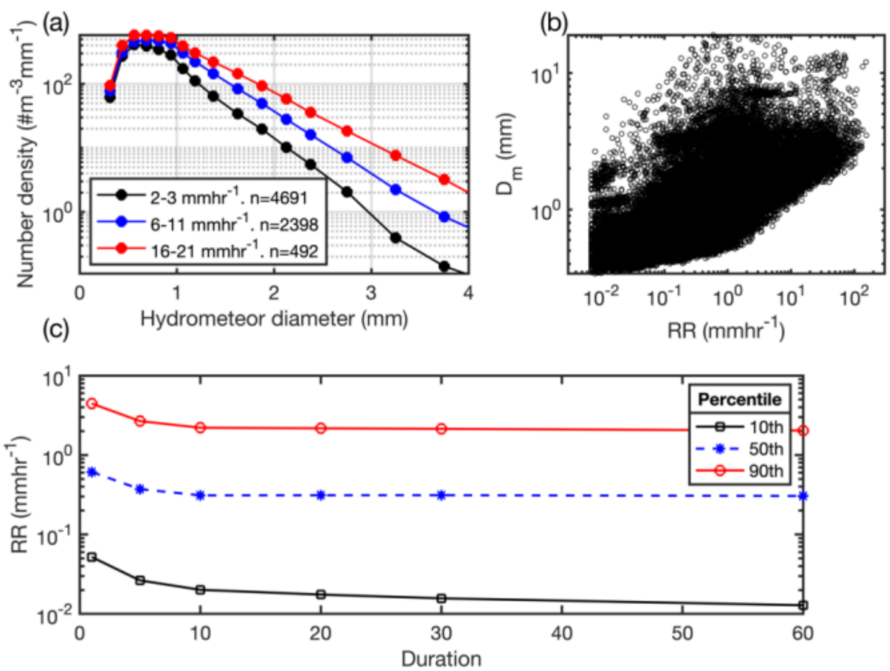


Figure 2. (a) Mean droplet size distributions for different rainfall rate classes (RR); 2–3 $mmhr^{-1}$, 6–11 $mmhr^{-1}$ and 16–21 $mmhr^{-1}$. The legend shows the number of 1 min periods (n) in each class. (b) Scatterplot of 1 min RR versus the mass-weighted droplet mean diameter (Dm). (c) 10th, 50th and 90th percentile rainfall rate (RR, in mmhr–1) as a function of averaging period. All analyses based on 1-minute data collected with an OTT Parsivel2 disdrometer at the US SGP site conditionally sampled for liquid only precipitation (Figure adapted from two figures presented in (Pryor et al. 2022)). From Pryor et al. 2023 (D2.4+D2.5).

Another important step towards the roadmap for erosion risk is how the precipitation and damage modeling interplay. In collaboration with WP5 on damage modeling, the results are presented in Letson F. and Pryor S.C. (2023): From Hydrometeor Size Distribution Measurements to Projections of Wind Turbine Blade Leading Edge Erosion. *Energies* 16 3906 https://doi.org/10.3390/en16093906). This work is based on disdrometer data.

The roadmap for erosion risk also deals with how numerical modeling can contribute to this. The first results of this work have been investigated and published Hannesdóttir, Á., Kral, S. T., Reuder, J., Hasager, C.B. (2024) Rain erosion atlas for wind turbine blades based on ERA5 and NORA3 for Scandinavia, *Results in Engineering*, Volume 22, 2024, https://doi.org/10.1016/j.rineng.2024.102010. The software used for producing the atlas is pen-access software code at GitLab, https://gitlab.windenergy.dtu.dk/astah/era5_erosion_atlas, Ásta Hannesdóttir (2024). Figure 3 shows the study area of Scandinavia covered by the NORA3 hindcast model and ERA5 reanalysis. The two models provide wind speed and precipitation. Only rain (not snow and hail) is used in the subsequent analysis of damage. Figure 4 shows the accumulated rain impingement on the blades yearly for a hypothetical installation and operation of a 15 MW IEA wind turbine in every grid cell (ignoring wake effects). It is seen that the west coast of Norway receives vast amounts of impinged rain and has short on-set times of erosion. Furthermore, NORA3 resolves the complex terrain with much greater detail than ERA5.

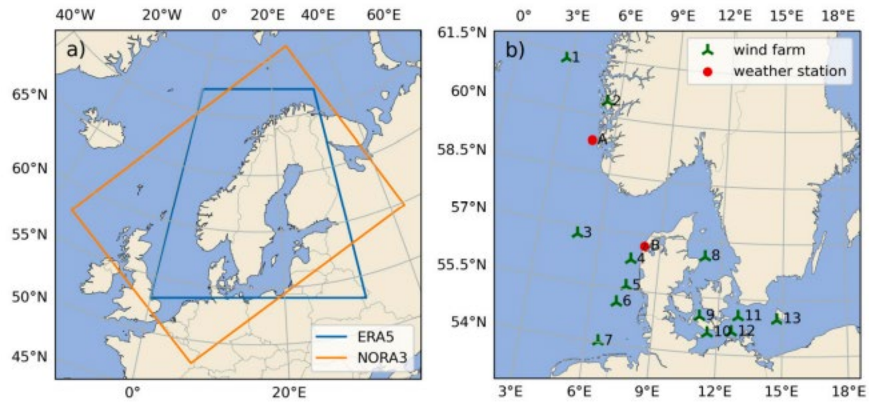


Figure 3. a) A map of the selected domains of ERA5 data and NORA3 data. b) Locations of weather stations (red) and wind farms (green). From Hannesdóttir et al. 2024.

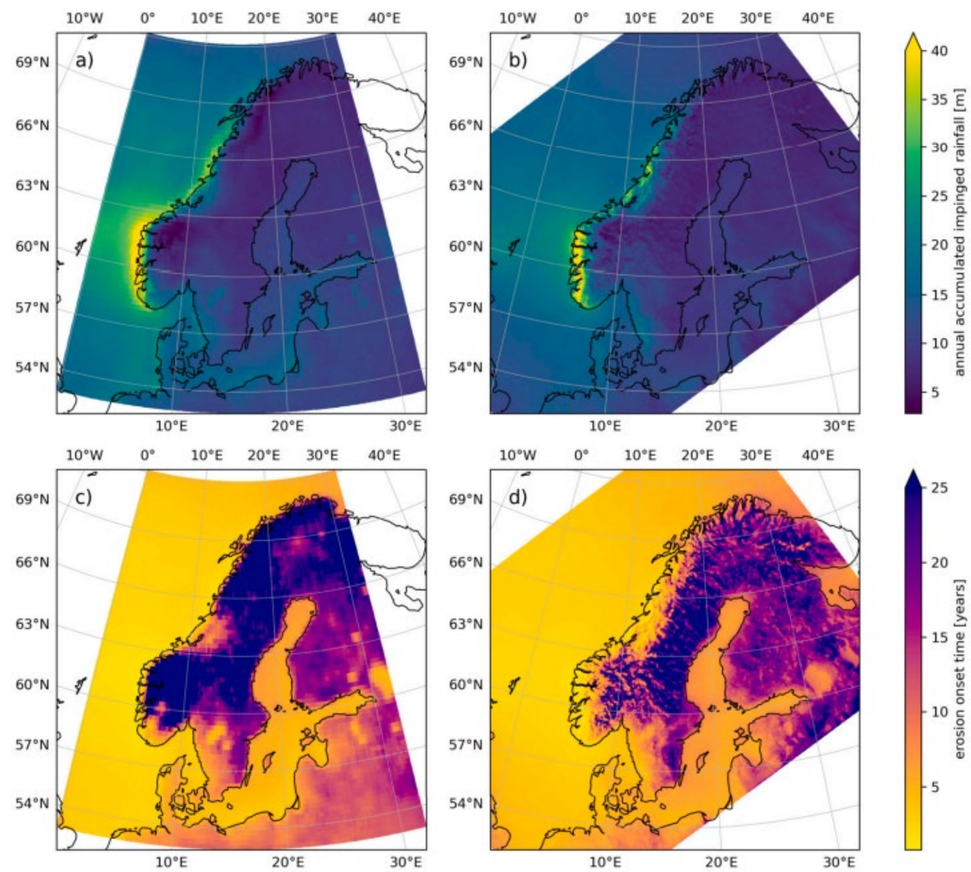


Figure 4.The annual accumulated impinged rainfall for a) ERA5, b) NORA3 and the onset time of erosion for c) ERA5 and d) NORA3. The layers are calculated for the IEA 15 MW wind turbine (all panels) and a commercial blade material (lower panels). From Hannesdóttir et al. 2024.

The impingement of rain on a blade is roughly ten times larger than the water hitting the ground due to the rotation of blades; see the schematic in Figure 5 (from previous work). It is shown here to emphasize the need to accurately assess rain climatology from measurements or with robust numerical modeling. This is part of the ongoing next steps.

Figure 5. Illustration of annual rain amount hitting 1 cm2 on the tip of a blade, the closing velocity between the blade and the falling rain droplet being 324 km/h (bucket A), versus rain on the ground hitting 1 cm2 with a closing velocity of 22 km/h between the land surface and the falling rain droplet (bucket B). From Hasager et al. 2021.

One of the following step results is the analytic methods for disdrometer droplet size distribution data. This work will be presented orally at the Torque conference in Florence, Italy (May 2024) and published in the forthcoming article Hannesdóttir, Á., Dellwik, E., Hasager, C.B.: Prediction of Rain Erosion Damage Progression Using Disdrometer Rain Data: The Importance of Liquid Water Content, in the IOP Journal of Physics (accepted). This work also supports the next steps towards roadmap for erosion risk atlas (D2.6).

WP3. Wind turbine operation with erosion

Two activities take place in parallel. One is about how the rough, eroded blades impact annual energy production. This work relies much on data collected in the wind tunnel at DTU in the Danish-funded LerCAT project. This work on estimating aerodynamic loss for different erosion classes has resulted in software shared via open access: Christian Bak and Meyer Forsting, A. R. (2023). SALT - Simplified Aerodynamic Loss Tool (1.0.0 - beta). DTU Wind, Technical University of Denmark. https://doi.org/10.5281/zenodo.7906333. This work strongly supports the activities in WP3. The other activity is a benchmark based on data from several participants on the aerodynamic properties of rough blades. Both works were presented at the 5th International Symposium on Erosion of Wind Turbine Blades and will soon be published in the deliverables, D3.1 and D3.3.

WP4: Laboratory testing of erosion

Recent progress is on different failure modes and how to characterize these from visual inspection, presented in Johansen, N. F.-J. (2023) IEA Wind task 46 Technical Report: Erosion failure modes in leading-edge systems. 28 pp. https://iea-wind.org/wp-content/uploads/2023/06/IEA-WT46-WP4.2-Erosion-failure-modes-in-leading-edge-systems.pdf. The most recent work is a report on normalization of test substrates: VN curves fitting for

Recommended Practise. This will be supplemented with software (currently in beta version) for testing data belonging to partners.

The damage characterization was studied based on input from several partners of images showing different types and levels of damage. An anonymous survey was then conducted.

To explain the characterization, the layers were numbered from the base and outwards. Figure 6 shows the simplified damage at a specimen. Figure 7 shows the n-layer characterization for the different damage classes. This classification scheme is inspired by the work by Maniaci et al. (2022) from WP3. Maniaci, D.C., MacDonald, H., Paquette, J., Clarke, R. (2023) IEA Wind task 46 Technical Report: Leading Edge Erosion Classification System. 52 pp. https://iea-wind.org/wp-content/uploads/2023/02/IEA-Wind-Task-46-Erosion-Classification-System-report.pdf

The survey results for damage classification showed that the participants agreed well with the most minor and most severe damage classes. However, the assessment had a large spread for the intermediate levels. Figure 8 shows the 'classical' point erosion damage used in the testing for coating durability.

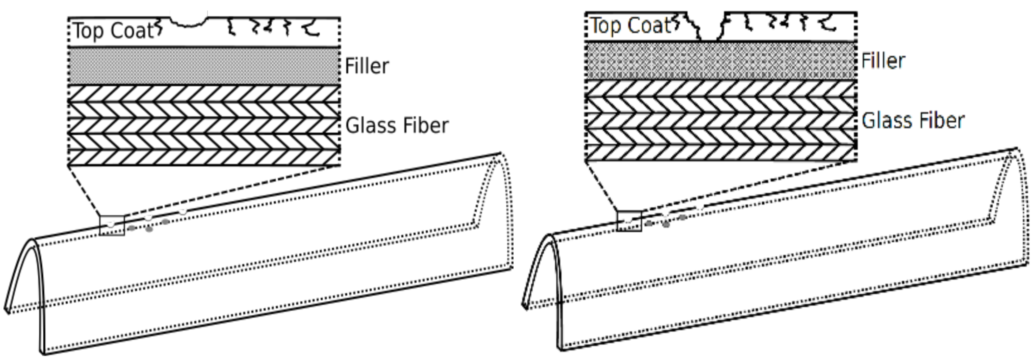


Figure 6. Sketches of rain erosion test specimen with damage. From Johansen (2023) (D4.2)

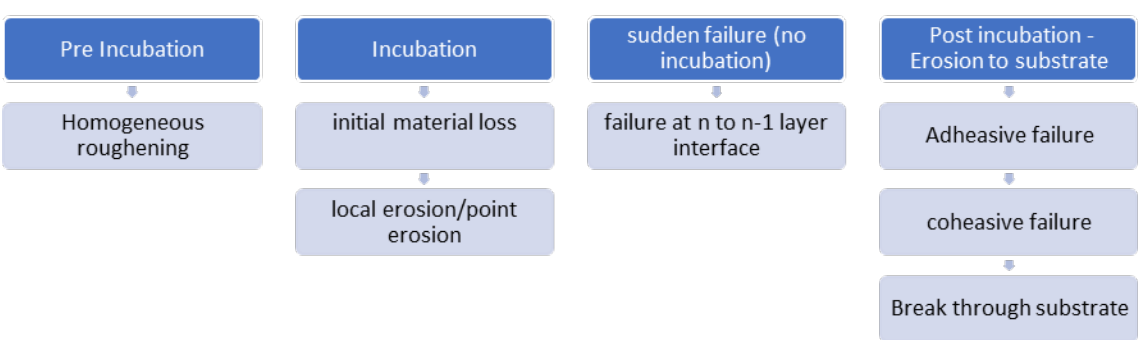


Figure 7. Overview of damage classes. From Johansen (2023) (D4.2).

Description	Defect Appearance
The defect is characterized by local material loss exposing an underlying layer. This is usually the starting point of erosion development. The damage is within a confined area without connecting to preexisting erosion. Within this area, the defect can propagate to the underlying area.	Defect size is equal to coating thickness squared or larger. The damage has removed part of the n layer exposing the n-1 layer. Typically, underlying layers have different colors to the top coating. This makes this type of damage, relatively easy to identify. And

Affecting layers

Example of coating specific layer name	LEP	Coating	Filler	Surface laminate	Laminate
Layer number	n	n-1	n-2	0	-1
Affecting layers	x	x	(x)		

Interchangeable defects

1 Initial material removal

2 Homogeneous roughening

Approximate IEA erosion severity Level:

0:	1:29%	2:14%	3:14%	4:29%	5: 14%

Example images

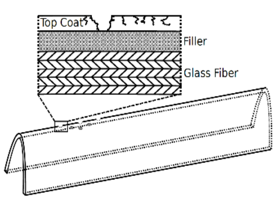
Illustration	1	2
		

Figure 8. Damage images for incubation, point erosion. From Johansen (2023) (D4.2).

WP5: Erosion mechanics & material properties

Joint activities between WP5 and WP4 on the failure modes have been performed (see reference in WP4 Johansen, 2023). Joint activities between WP5 and WP2 have been on the Springer model for the prediction of damage (see reference in WP2 Letson and Pryor, 2023). WP5 has been closely integrated/overlapping with the other WPs.

6 Future Milestones

Plans and Deliverables for the Coming Year

The work for the coming year involves completion of deliverables delayed from year #3, and those planned in year #4. It is very ambitious. It is anticipated that most will be successful.

Table 3. Deliverables Table.

No.	Deliverable	Lead organization	Month Due	Status
D1.3, D1.4	External communications, coordination meetings	OA	1,4,11,12,17,18,23,24,29,30,36,37,41,42,47,48	Delivered/On track
D1.5	Webinars	OA	15,31,38,48	Delivered/On track
D1.6	ExCo Report	OA	12,24,37,48	Delivered/On track
D2.6	Roadmap for LEE atlas	Cornell University	30	planned year #3
D2.7	Recommended practice for measurement of LEE drivers	Cornell University	40	planned year #4
D2.8	Methods to perform V&V on LEE drivers	Cornell University	47	planned year #4
D3.1	Model to predict annual energy production loss on blade erosion class	Sandia National Laboratories	30	planned year #3
D3.3	Droplet impingement model for use in fatigue analysis	Sandia National Laboratories	33	planned year #3
D3.4	Potential for erosion safe-mode operation	Sandia National Laboratories	37	planned year #4
D3.5	Accuracy of LEE performance loss model based on field observations (validation).	Sandia National Laboratories	47	planned year #4
D4.3	Evaluation of specimen from RET beyond VH-curves (RP)	DTU	34	planned year #3
D4.4	Pre-evaluation of test specimens (recommended practice)	DTU	31	planned year #3
D4.5	Test data analysis, damage accumulation and VN curves (recommended practice)	DTU	35	planned year #3
D4.6	Simple mechanical test for screening of key parameters (report)	TU Delft, DTU	40	planned year #4
D4.7	Correlation between RET data and expected field service life (report and model)	DTU	47	planned year #4
D5.1	Damage models based on fundamental material properties (report)	Universidad Cardenal Herrera	26	pending
D5.2	Multilayer systems (report)	Universidad Cardenal Herrera	37	planned year #4
D5.3	Microstructure and macroscopic material properties (Report)	Universidad Cardenal Herrera	47	planned year #4

The two remaining milestones will be completed in year #4. These are:

- Milestone 5 Half of the technical deliverables completed.

- Milestone 6 Final outreach seminar.

7 Detailed work plan for coming year

The planned activities are to continue the work in the four technical work packages. This work included the development of a roadmap to create a methodology to make an atlas for erosion risk. Furthermore, the work will provide input to recommended practice on rain-erosion test data analysis to better assess the expected lifetime of blade coatings. An activity will assess the erosion-safe mode operation of turbines to limit erosion during control. Finally, understanding damage processes from experiments and modeling will be continued.

The next plenary meeting will be held in Albuquerque, NM, US, hosted by Sandia National Laboratory. It will be back-to-back to the Blade workshop (held every second year) and will form the basis for face-to-face outreach.

8 Publications, presentations, dissemination

Publications are described above in sections 1 and 5.

Participation in the Task meetings

Task 46 held a second outreach webinar on 4th December 2023, where progress was presented by the work package leaders and operating agents. The webinar was followed online by 40 attendees.

Task 46 has had bi-annual plenary meetings. In spring online and in autumn face-to-face. The autumn plenary meeting was hosted by Univ. Cardenal Herrera CEU in Valencia. There were 28 task participants participating on site, and many others joined remotely. Figure 9 show the meeting attendees.

Figure 9. Photo: Task 46 plenary meeting in Valencia hosted by Univ. Cardenal Herrera CEU.

Industry participation

The industry participation is strong. There are 22 companies among the task participants. This is just over 50%. The interest is high and four companies entered into the task during year #3. These are Ilosta, Henkel, PowerCurve and Statkraft.