



ANALYSIS OF LEADING EDGE EROSION IMPACT ON THE DESIGN AND PERFORMANCE OF WIND FARM FLOW CONTROL

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- 02 METHODOLOGY
- 03 CASE STUDY
- 04 CONCLUSIONS



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01

INTRODUCTION



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INTRODUCTION

- Leading edge erosion (LEE) → Impact on wind turbines operation and maintenance cost
- Offshore sites are more sensitive to LEE occurrence:
 - Higher average wind speeds
 - More rainy conditions
- LEE causes a loss of aerodynamic efficiency at below rated wind speeds
- This loss also affects the flow interaction with the rest of wind turbines in the wind farm (thrust coefficient) [1]
- It could also have an impact on wind farm flow control (WFFC) strategies
- **Objective: analyse the impact of LEE on WFFC strategies (wake steering in this case)**



Image from Vattenfall (<https://group.vattenfall.com/>)
Photographer: Christian Steiness

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METHODOLOGY



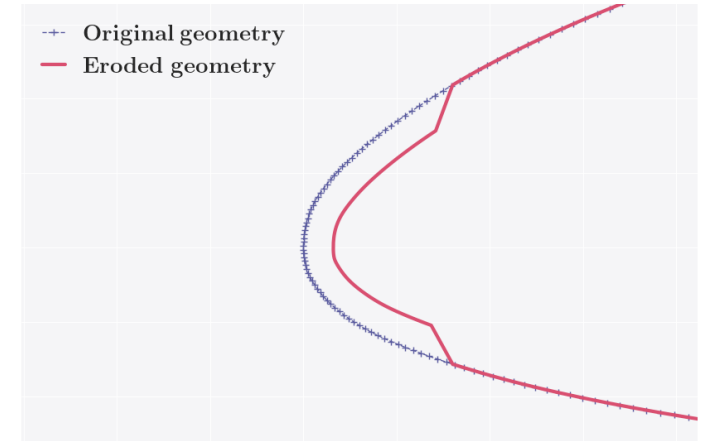
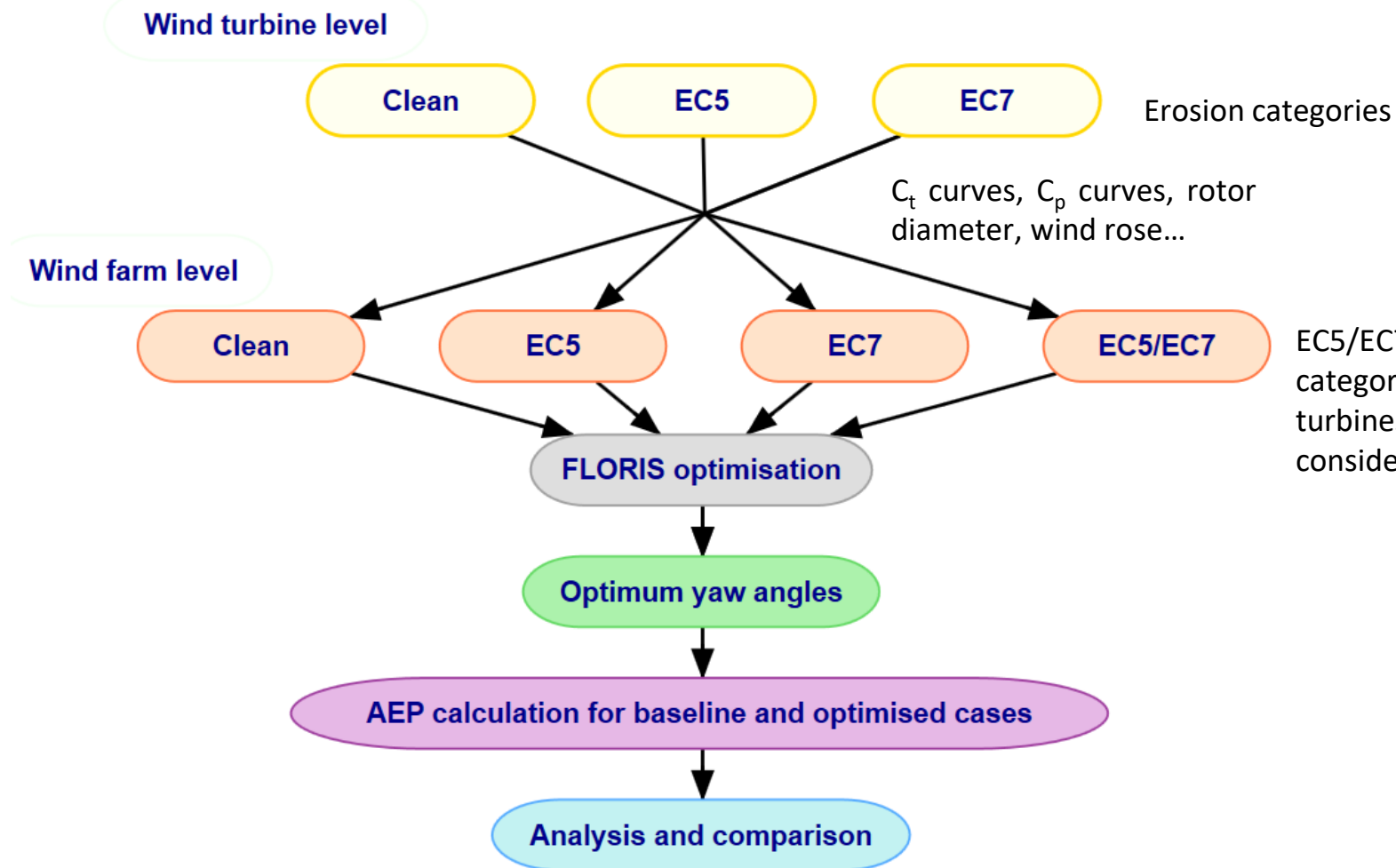
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METHODOLOGY



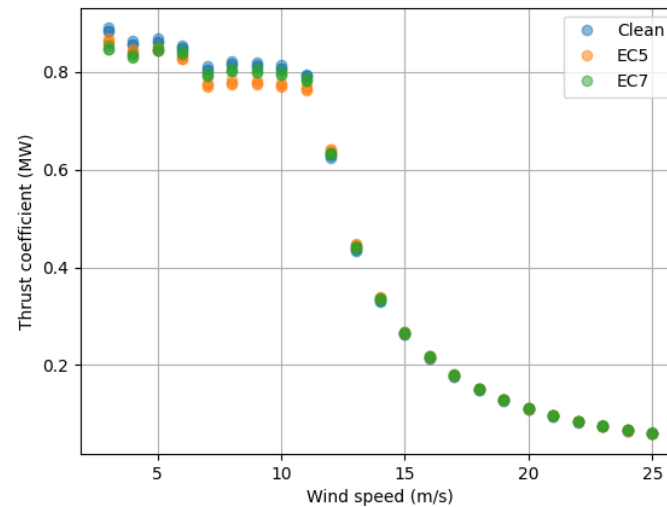
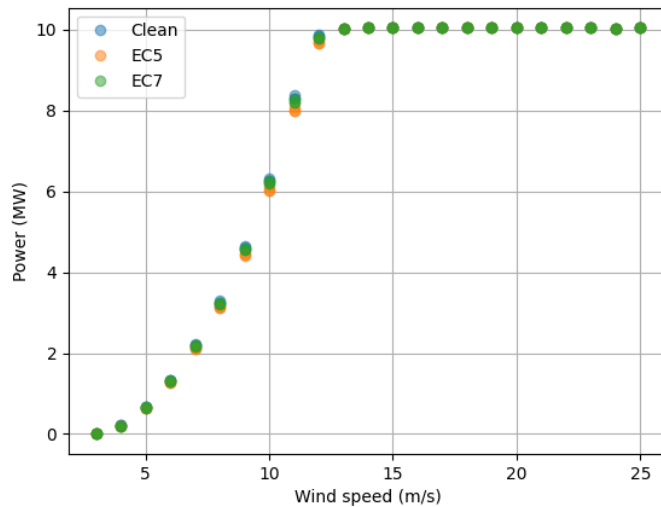
EC5/EC7: Combination of different erosion categories at the same wind farm. Unwaked wind turbines (in most probable wind directions) considered to be more eroded (EC5)

METHODOLOGY

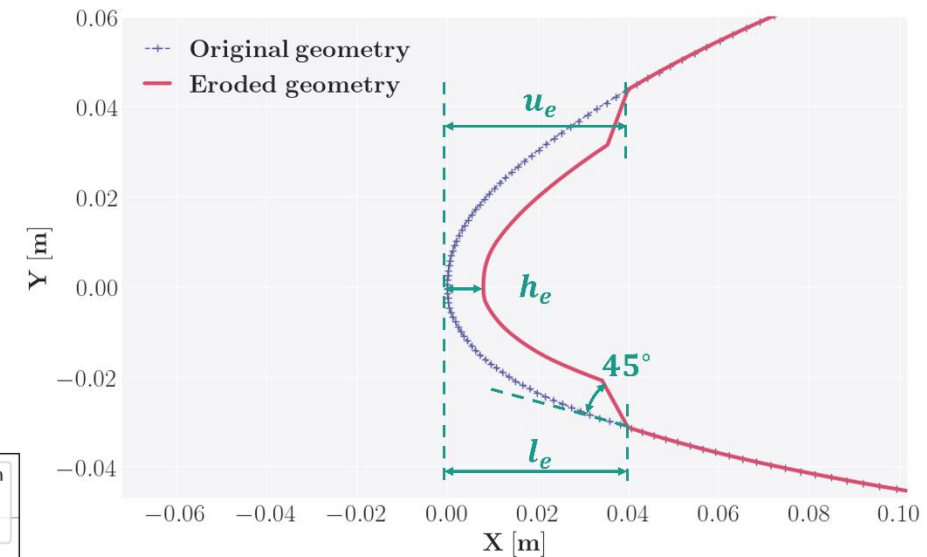
➤ Erosion categories used (loss of material):

- Last 30% of the blade with erosion [2, 3]
- Constant erosion with blade length

➤ Power and C_t curves for the selected erosions (inputs for FLORIS):



Erosion category	h_e [%c]	u_e [%c]	l_e [%c]	Max. efficiency loss [%]	$\frac{C_L}{C_D}$
5 (higher)	0.12	8	8	38.72	
7 (lower)	0.12	5	5	22.47	



Polars obtained with OpenFOAM (CFD)

← Polars used in OpenFAST

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CASE STUDY



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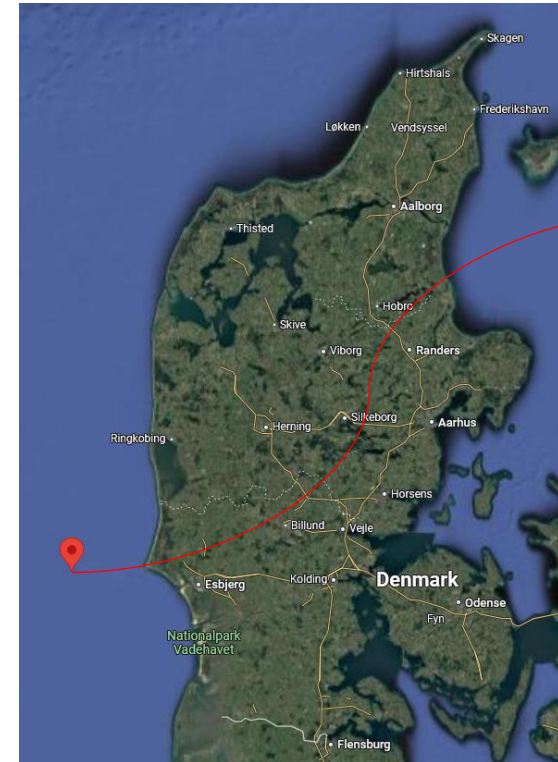
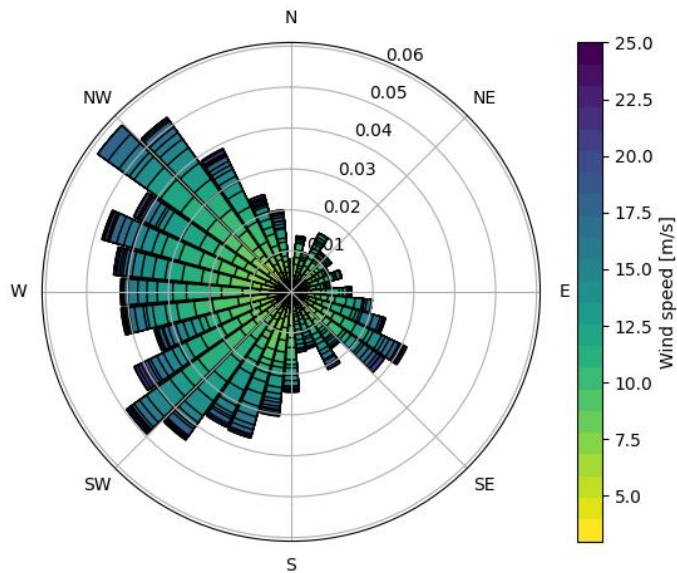


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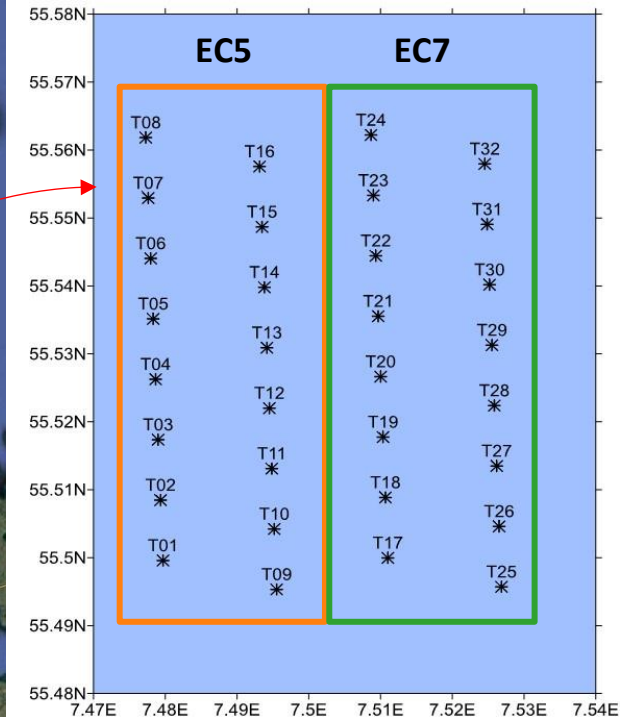


CASE STUDY

- Virtual wind farm: TotalControl Reference Wind Power Plant (32 wind turbines) [4]
- Wind turbine: DTU 10MW Reference Wind Turbine [5]
- Resource data extracted from [6, 7, 8]
- Eroded blade profile: FFAW3241
- Wind turbine modelling tool: OpenFAST [9]
- Wind farm modelling and optimisation software: FLORIS [10]

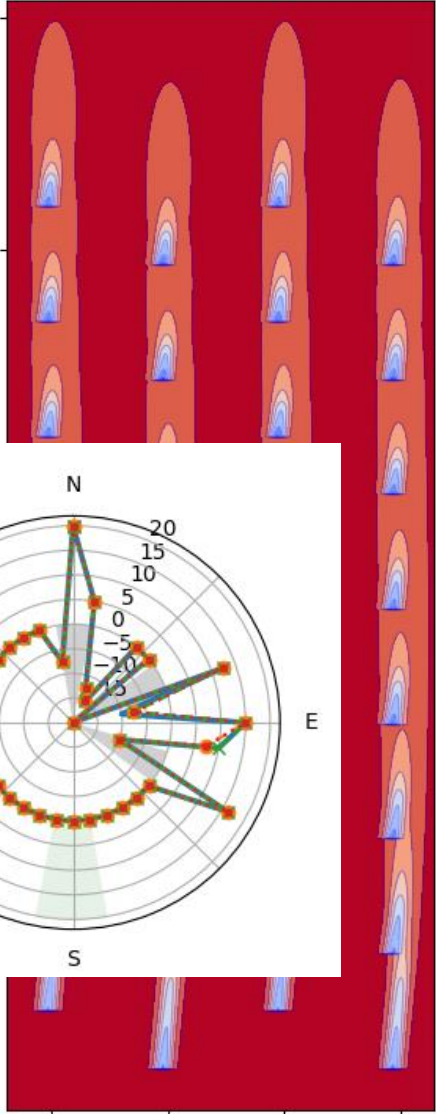
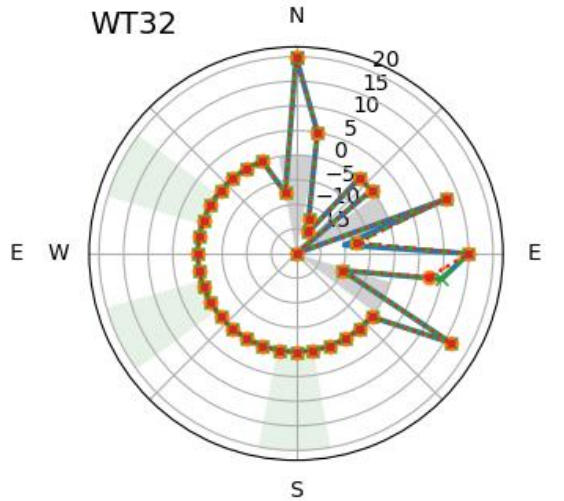
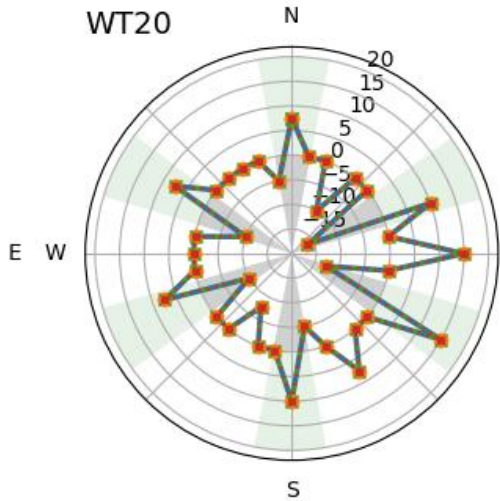
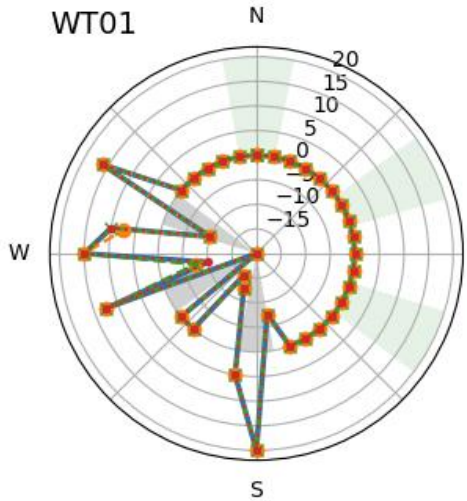
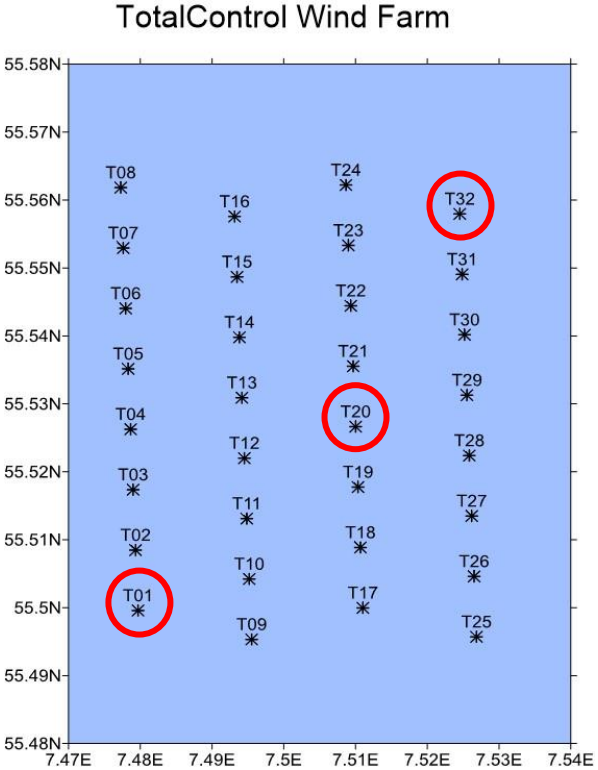


TotalControl Wind Farm



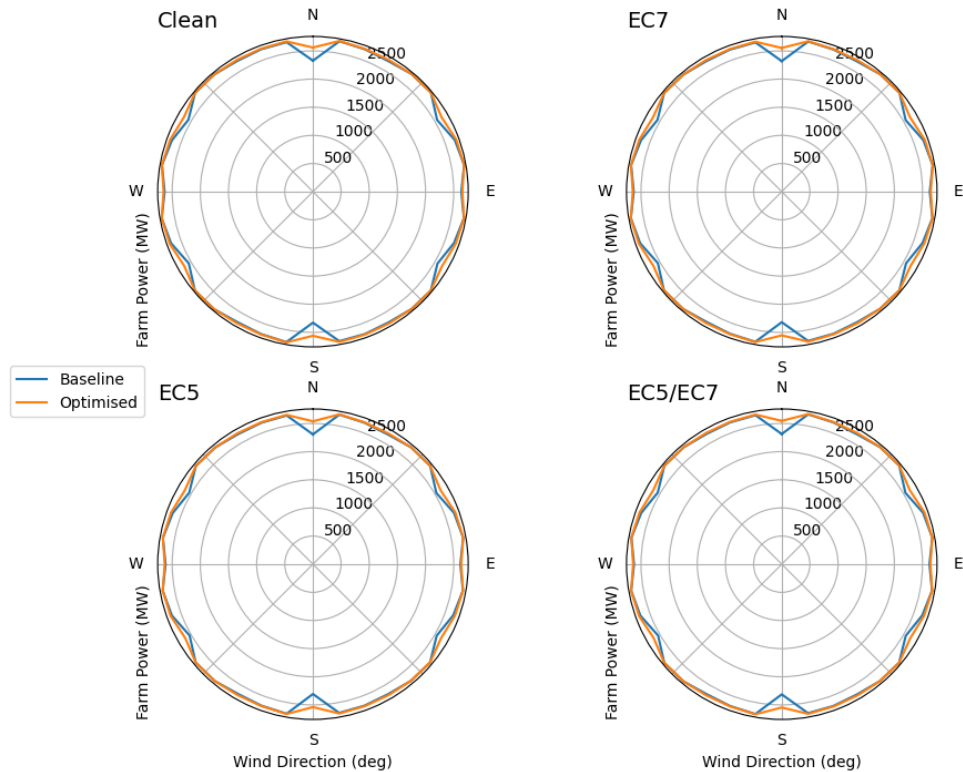
CASE STUDY

➤ Optimal yaw angles for 7 m/s wind speed:



CASE STUDY

Baseline and optimised farm power



Wind farm erosion type	Baseline AEP [GWh]	Baseline AEP erosion loss [%]	Optimised AEP [GWh]	Optimised AEP erosion loss [%]
Clean	1623.73	-	1663.16	-
EC7 (less eroded)	1615.70	0.49	1654.55	0.52
EC5/EC7 (mixed)	1607.27	1.01	1645.28	1.08
EC5 (more eroded)	1598.52	1.55	1635.85	1.64

Wind farm erosion type	AEP loss due to wakes [%]	AEP gain from baseline to optimised [%]
Clean	7.58	2.43
EC7	7.54	2.40
EC5/EC7	7.49	2.36
EC5	7.46	2.34

Erosion ↑ ➤ Wakes ↓ ➤ AEP loss due to wakes ↓ ➤ AEP gain with optimisation ↓

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CONCLUSIONS



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CONCLUSIONS

- Similar yaw setpoints for different erosions
- AEP of eroded wind farms slightly lower than AEP of clean farm (baseline and optimised)
- Similar wake losses in all configurations → Slightly smaller as erosion increases
- Static yaw optimisation improves AEP → Gain gets slightly smaller as erosion increases
- Overall, it can be concluded that, for the analysed case, erosion does not have a significant impact in static wake steering WFFC strategies

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- [9] <https://github.com/OpenFAST/openfast>
- [10] <https://github.com/NREL/floris>

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