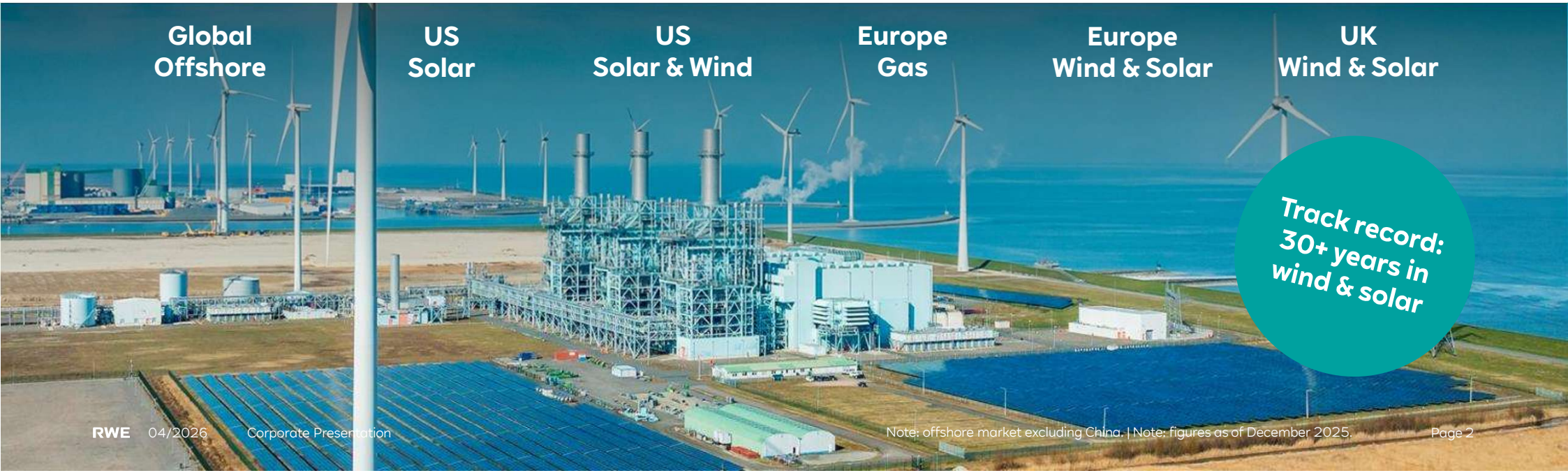
Performance Comparison of Four Shut-Down-on-Demand Systems

Valentina Peronace, Biodiversity Manager - RWE Renewables Italia

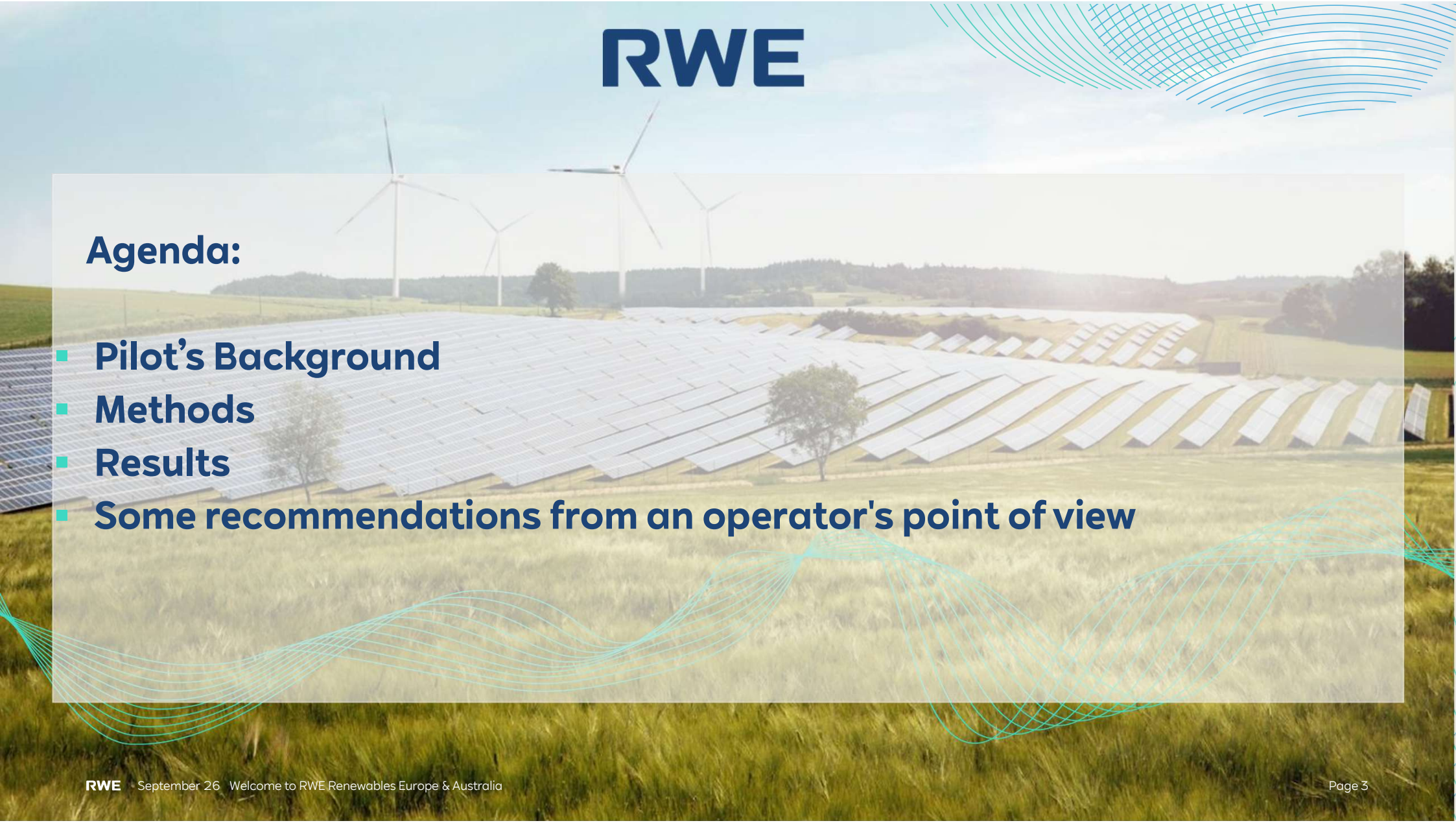
Field tests and data analysis: Agustina Gomez-Laich, Sebastian Cannarella, Giacomo dell'Omo - ***Ornis Italica***
Scientific supervision: Alberto Sorace - ***ISPRA (Italian Institute for Environmental Protection and Research***

Sept.10 2026 - ***Webinaire de l'Observatoire n°2 - Eolien terrestre et SDA***

RWE is one of the world's leading companies in gas, wind & solar.



Note: offshore market excluding China. | Note: figures as of December 2025.



Agenda:

- Pilot’s Background
- Methods
- Results
- Some recommendations from an operator's point of view

Background

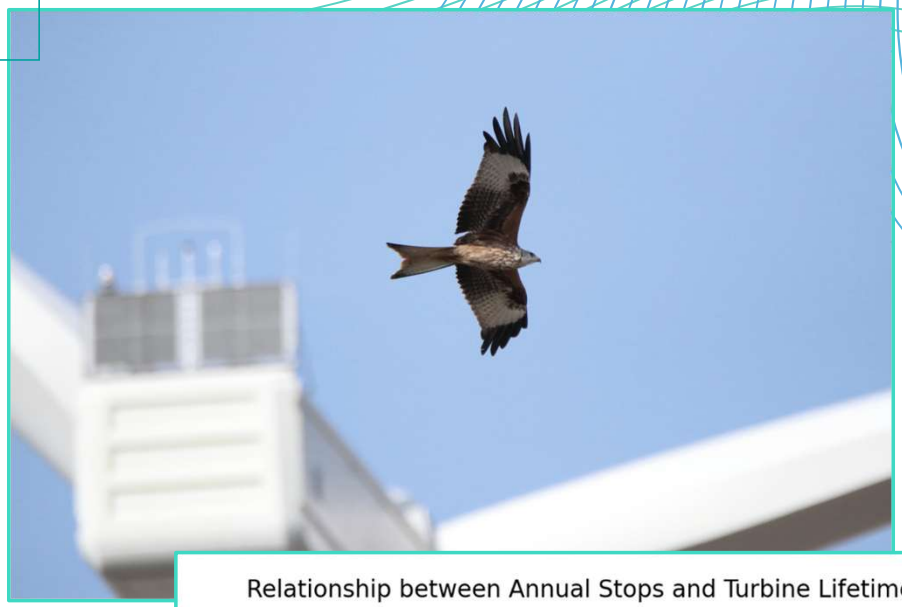
Why this pilot study?

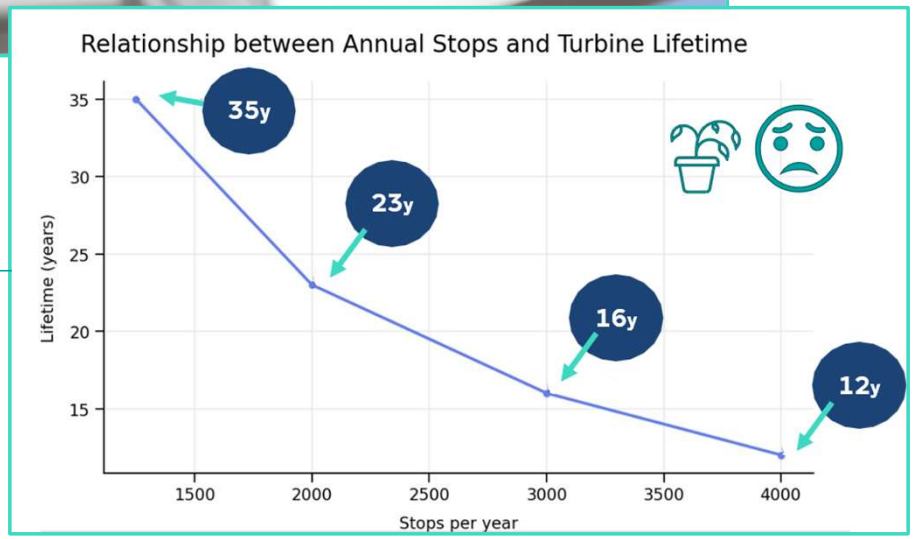
Bird Detection Systems (BDS) with Shut Down on Demand (SDoD) functionality increasingly required to mitigate bird collision risk, which solution should be selected?

They cause AEP losses and WTG lifetime impacts due to the additional stop and restart cycles.

Our challenge, as developers and operators:

Protect birds while minimizing operational impacts





RWE Pilot Study on Bird Detection Systems

- Ornis italica team of ornithologists and radar experts collected field data. We wanted to compare BDS data with radar tracks and direct field observations.
- Field tests at REA WF in Spain in 2024.
- ISPRA, the Italian Institute for Environmental Protection and Research, provided scientific supervision to the Study.
- Four BDS technologies were installed on the same WTG.

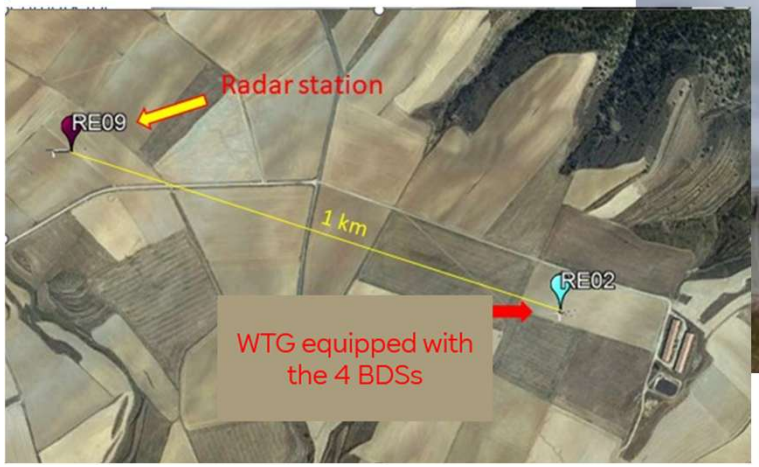


Radar Installation

- A **Radar Station** was installed approximately 1000 meters from the WTG to track birds and provide a benchmark for BDS performance.
- Ornithologists conducted 21 days of observations from strategic points near the turbines, **validating each radar track.**









Radar Setup and Functionality

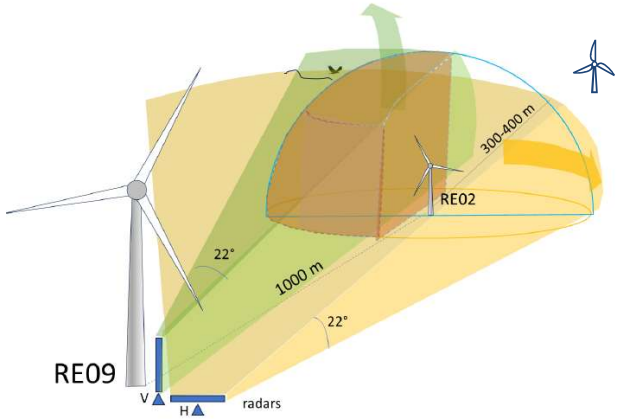
Horizontal radar:

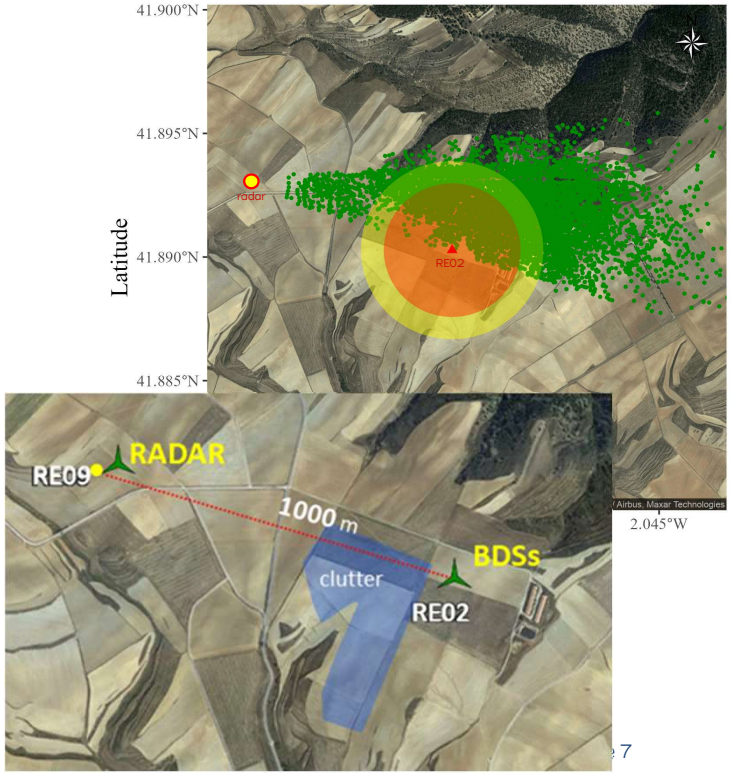
- tracks bird movement in 2D
- maps the precise trajectory (track) of a flying bird and calculate the speed and direction of multiple birds simultaneously
- The positional data of the echoes are also accompanied with info on wind speed and direction obtained from the nearby anemometer.

➢ cannot provide information on flight altitude

Vertical radar:

- Placed ~8 m away, scanning vertically only 22° field
- Determines flight altitude of a bird, used in combination with horizontal radar in overlapping zone (3D Radar Zone)
- Altitude data can only be associated with a point on the trajectory within the overlapping detection zone of the two radars
- This overlapping zone (or "3D radar zone") **was used as reference for comparison with the BDSs performance** since here it was available a complete set of information on the bird position and height.





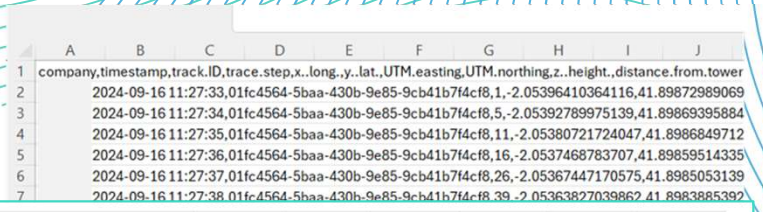
BDS configuration and data limits

To establish uniform parameters for performance evaluation:

- The warning distance for activating acoustic deterrents was set at **400 meters** from the turbine, while the shutdown trigger distance was set at **300 meters**.
- The BDSs were required to provide daily data in a standardized CSV format, including coordinates, timestamps, and, where available, information on bird species and size class.

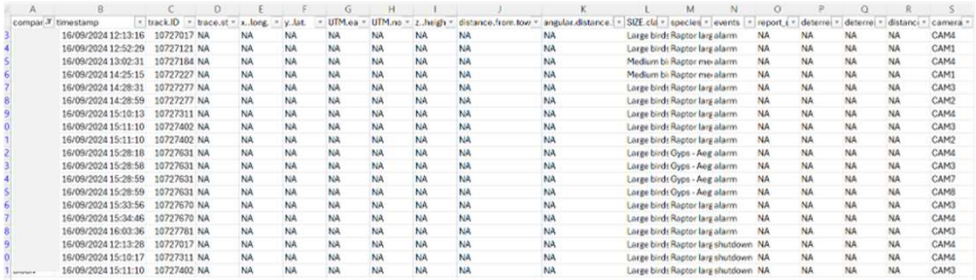
Heterogeneity of the received data (due to different algorithms of different BDS) was crucial for the comparison

- The parameters available for direct comparison were substantially reduced with respect to the expectations, necessitating the use of indirect methods to derive missing data.
- → For some BDS the Track ID do not correspond to a single bird track but, for example to several birds flying in the detection zone at the same time; for other, several ID may correspond to the same bird triggering SD from several cameras.

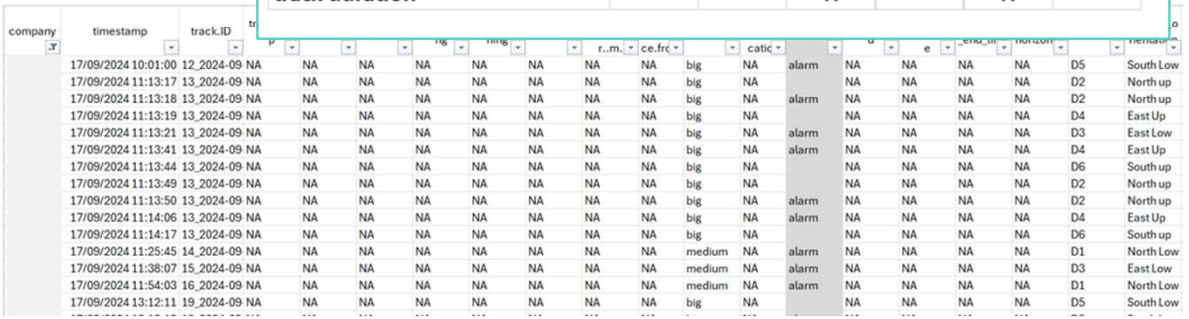


	A	B	C	D	E	F	G	H	I	J
1	company,timestamp,track.ID,trace.step,x..long.,y..lat.,UTM.easting,UTM.northing,z..height.,distance.from.tower									
2	2024-09-16 11:27:33,01fc4564-5baa-430b-9e85-9cb41b7f4cf8,1,-2.05396410364116,41.89872989069									
3	2024-09-16 11:27:34,01fc4564-5baa-430b-9e85-9cb41b7f4cf8,5,-2.05392789975139,41.89869395884									
4	2024-09-16 11:27:35,01fc4564-5baa-430b-9e85-9cb41b7f4cf8,11,-2.05380721724047,41.8986849712									
5	2024-09-16 11:27:36,01fc4564-5baa-430b-9e85-9cb41b7f4cf8,16,-2.0537468783707,41.89859514335									
6	2024-09-16 11:27:37,01fc4564-5baa-430b-9e85-9cb41b7f4cf8,26,-2.05367447170575,41.8985053139									
7	2024-09-16 11:27:38,01fc4564-5baa-430b-9e85-9cb41b7f4cf8,39,-2.05363827039862,41.8983885392									

	(A)	(B)	(C)	(D)	RADAR	OBSERVER
track ID/bird	X	X	X	X	X	X
coordinates	X		X		X	
first detection coordinates	X		X		X	
first detection time	X	X	X	X	X	
alarm @400 m coordinates	X		X		X	
alarm @400 m time	X	X	X	X	X	
shutdown @ 300 m coordinates	X		X		X	
shutdown @ 300 m time	X	X	X	X	X	
distance from tower	X		X		X	
angular distance			X		X	
altitude			X		X	
automatic species recognition						X
automatic size recognition			X	X		X
track length			X		X	
track duration			X		X	



A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
compar	timestamp	track.ID	trace.st	x..long.	y..lat.	UTM.ea	UTM.no	z..heigh	distance.from.towe	angular.distance	SIZE_cla	species	events	report_a	determi	determi	distanc	camera
3	16/09/2024 12:13:16	10727017	NA	NA	NA	NA	NA	NA	NA	NA	Large birds	Raptor lar	g alarm	NA	NA	NA	NA	CAM4
4	16/09/2024 12:52:29	10727121	NA	NA	NA	NA	NA	NA	NA	NA	Large birds	Raptor lar	g alarm	NA	NA	NA	NA	CAM1
5	16/09/2024 13:02:31	10727184	NA	NA	NA	NA	NA	NA	NA	NA	Medium bi	Raptor me	alarm	NA	NA	NA	NA	CAM4
6	16/09/2024 14:25:15	10727227	NA	NA	NA	NA	NA	NA	NA	NA	Medium bi	Raptor me	alarm	NA	NA	NA	NA	CAM1
7	16/09/2024 14:28:31	10727277	NA	NA	NA	NA	NA	NA	NA	NA	Large birds	Raptor lar	g alarm	NA	NA	NA	NA	CAM3
8	16/09/2024 14:28:59	10727277	NA	NA	NA	NA	NA	NA	NA	NA	Large birds	Raptor lar	g alarm	NA	NA	NA	NA	CAM2
9	16/09/2024 15:10:13	10727311	NA	NA	NA	NA	NA	NA	NA	NA	Large birds	Raptor lar	g alarm	NA	NA	NA	NA	CAM4
0	16/09/2024 15:11:10	10727402	NA	NA	NA	NA	NA	NA	NA	NA	Large birds	Raptor lar	g alarm	NA	NA	NA	NA	CAM3
1	16/09/2024 15:11:10	10727402	NA	NA	NA	NA	NA	NA	NA	NA	Large birds	Raptor lar	g alarm	NA	NA	NA	NA	CAM2
2	16/09/2024 15:28:18	10727631	NA	NA	NA	NA	NA	NA	NA	NA	Large birds	Gyps - Aeg	alarm	NA	NA	NA	NA	CAM4
3	16/09/2024 15:28:58	10727631	NA	NA	NA	NA	NA	NA	NA	NA	Large birds	Gyps - Aeg	alarm	NA	NA	NA	NA	CAM3
4	16/09/2024 15:28:59	10727631	NA	NA	NA	NA	NA	NA	NA	NA	Large birds	Gyps - Aeg	alarm	NA	NA	NA	NA	CAM7
5	16/09/2024 15:28:59	10727631	NA	NA	NA	NA	NA	NA	NA	NA	Large birds	Gyps - Aeg	alarm	NA	NA	NA	NA	CAM8
6	16/09/2024 15:33:56	10727670	NA	NA	NA	NA	NA	NA	NA	NA	Large birds	Raptor lar	g alarm	NA	NA	NA	NA	CAM3
7	16/09/2024 15:34:46	10727670	NA	NA	NA	NA	NA	NA	NA	NA	Large birds	Raptor lar	g alarm	NA	NA	NA	NA	CAM4
8	16/09/2024 16:03:36	10727781	NA	NA	NA	NA	NA	NA	NA	NA	Large birds	Raptor lar	g alarm	NA	NA	NA	NA	CAM3
9	16/09/2024 12:13:26	10727017	NA	NA	NA	NA	NA	NA	NA	NA	Large birds	Raptor lar	g shutdown	NA	NA	NA	NA	CAM4
0	16/09/2024 15:10:17	10727311	NA	NA	NA	NA	NA	NA	NA	NA	Large birds	Raptor lar	g shutdown	NA	NA	NA	NA	CAM4
1	16/09/2024 15:11:10	10727402	NA	NA	NA	NA	NA	NA	NA	NA	Large birds	Raptor lar	g shutdown	NA	NA	NA	NA	CAM3



company	timestamp	track.ID																	
	17/09/2024 10:01:00	12_2024-09	NA	NA	NA	NA	NA	NA	NA	NA	big	NA	alarm	NA	NA	NA	NA	D5	South Low
	17/09/2024 11:13:17	13_2024-09	NA	NA	NA	NA	NA	NA	NA	NA	big	NA		NA	NA	NA	NA	D2	North up
	17/09/2024 11:13:18	13_2024-09	NA	NA	NA	NA	NA	NA	NA	NA	big	NA	alarm	NA	NA	NA	NA	D2	North up
	17/09/2024 11:13:19	13_2024-09	NA	NA	NA	NA	NA	NA	NA	NA	big	NA		NA	NA	NA	NA	D4	East Up
	17/09/2024 11:13:21	13_2024-09	NA	NA	NA	NA	NA	NA	NA	NA	big	NA	alarm	NA	NA	NA	NA	D3	East Low
	17/09/2024 11:13:41	13_2024-09	NA	NA	NA	NA	NA	NA	NA	NA	big	NA	alarm	NA	NA	NA	NA	D4	East Up
	17/09/2024 11:13:44	13_2024-09	NA	NA	NA	NA	NA	NA	NA	NA	big	NA		NA	NA	NA	NA	D6	South up
	17/09/2024 11:13:49	13_2024-09	NA	NA	NA	NA	NA	NA	NA	NA	big	NA		NA	NA	NA	NA	D2	North up
	17/09/2024 11:13:50	13_2024-09	NA	NA	NA	NA	NA	NA	NA	NA	big	NA	alarm	NA	NA	NA	NA	D2	North up
	17/09/2024 11:14:06	13_2024-09	NA	NA	NA	NA	NA	NA	NA	NA	big	NA	alarm	NA	NA	NA	NA	D4	East Up
	17/09/2024 11:14:17	13_2024-09	NA	NA	NA	NA	NA	NA	NA	NA	big	NA		NA	NA	NA	NA	D6	South up
	17/09/2024 11:25:45	14_2024-09	NA	NA	NA	NA	NA	NA	NA	NA	medium	NA	alarm	NA	NA	NA	NA	D1	North Low
	17/09/2024 11:38:07	15_2024-09	NA	NA	NA	NA	NA	NA	NA	NA	medium	NA	alarm	NA	NA	NA	NA	D3	East Low
	17/09/2024 11:54:03	16_2024-09	NA	NA	NA	NA	NA	NA	NA	NA	medium	NA	alarm	NA	NA	NA	NA	D1	North Low
	17/09/2024 13:12:11	19_2024-09	NA	NA	NA	NA	NA	NA	NA	NA	big	NA		NA	NA	NA	NA	D5	South Low

Performance Metrics

- **Shutdown number & duration:** number and length of turbine shutdowns.
- **False Positive Rate:** incorrect detections/classifications leading to unnecessary shutdowns and avoidable production losses.

Compared with Radar data

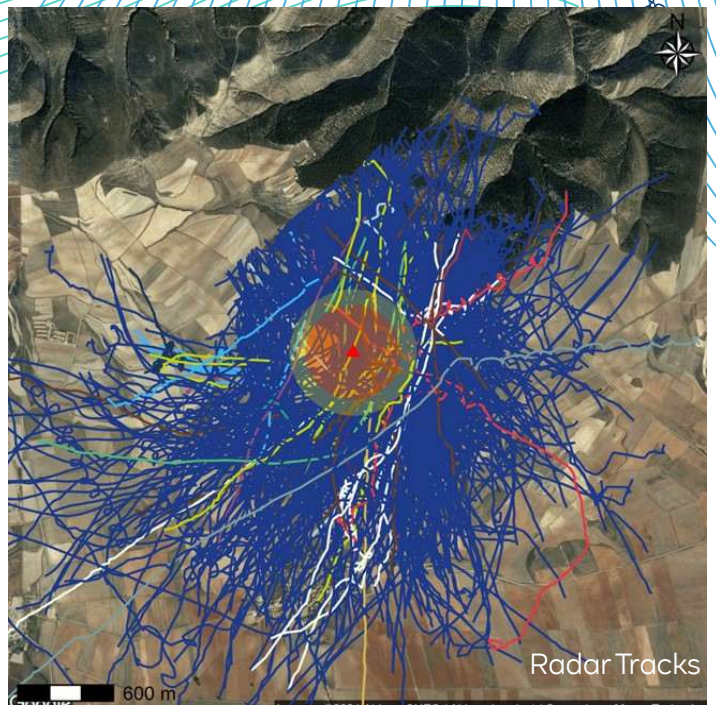
- **False Negative Rate:** failures of a BDS to trigger Alarms and Shutdowns.
- **First Detection, Alarms and Shutdown distances:** distances at which a bird was i) detected for the first time ii) triggered the alarm signal and iii) triggered the shutdown signal.

Results – Radar data

- Fieldwork was conducted for a total of 21 days, from September 16th to October 6th 2024, data were collected from 9:00 AM to 5:00 PM.
- Radars operated for a total of 157 hours.
- Ornithologists validated **1,086** radar tracks , 674 of which included 3D information
- The 89% of these tracks were Griffon Vulture, the most frequent species in the Study area
- **110 tracks** as sample size for the comparison

SPECIES		N° individuals	N° tracks 2D	N° tracks 3D	Size class
Griffon vulture	*Gyps fulvus*	1109	962	601	large
Passeriformes	*Passeriformes*	193	1	1	small
Wood pigeon	*Columba palumbus*	137	7	4	small
Red kite	*Milvus milvus*	85	10	7	large
Kestrel	*Falco tinnunculus*	63	1	1	small
Cormoran	*Phalacrocorax carbo*	54	7	6	large
Common buzzard	*Buteo buteo*	47	8	4	medium
Starling	*Sturnus vulgaris*	42	11	2	small
Raven	*Corvus corax*	39	2	2	small
Short-toed eagle	*Circaetus gallicus*	33	17	13	large
White stork	*Ciconia ciconia*	29	1	1	large
Harrier *(Circus sp)*	*Circus sp.*	25			medium
Marsh harrier	*Circus aeruginosus*	20			medium
Booted eagle	*Aquila pennata*	12	7	0	large
Crane	*Grus grus*	11	2	2	large
Sparrohawk	*Accipiter nisus*	9			small
Peregrine falcon	*Falco peregrinus*	9			medium
Honey buzzard	*Pernis apivorus*	8	3	2	medium
Black kite	*Milvus migrans*	7			medium
European turtle dove	*Streptotelia turtur*	6			small
Cinereus vulture	*Aegypius monacus*	1	1	0	large
Golden eagle	*Aquila chrysaetos*	1			large
Black stork	*Ciconia nigra*	1			large
small-size bird		117	16	7	small
medium-size bird		42	27	19	medium
large-size bird		3	3	2	Large
TOTAL		2103	1086	674	
	Proportions				
Large size birds (n° and %)		1339 (64%)	1010 (93%)	632 (94%)	
Medium size birds (n° and %)		158 (7%)	38 (3%)	25 (4%)	
Small size birds (n° and %)		606 (29%)	38 (3%)	17 (2%)	

Table 4. Species and individuals communicated by the ornithologists (N individuals) and associated with the radar tracks (Tracks 2D). Tracks 3D refers to the tracks tagged in the overlapping zone between the horizontal and the vertical radar, therefore for these tracks the altitude of the echoes was also known. In blue the proportion of the size classes in the total observations.



94% of the track were large wingspan classes, preventing to have a statistically sounding sample size for performance evaluation between the size classes.

Pilot's Results:

One brand excelled, followed by two other systems, one system ranked lowest

Minimize unwanted stops (and AEP losses):
Low False positive rates (0-3%)



Minimize bird collision risk:
False negative rates (for shutdowns 6%, 12%, 26% up to 91%)

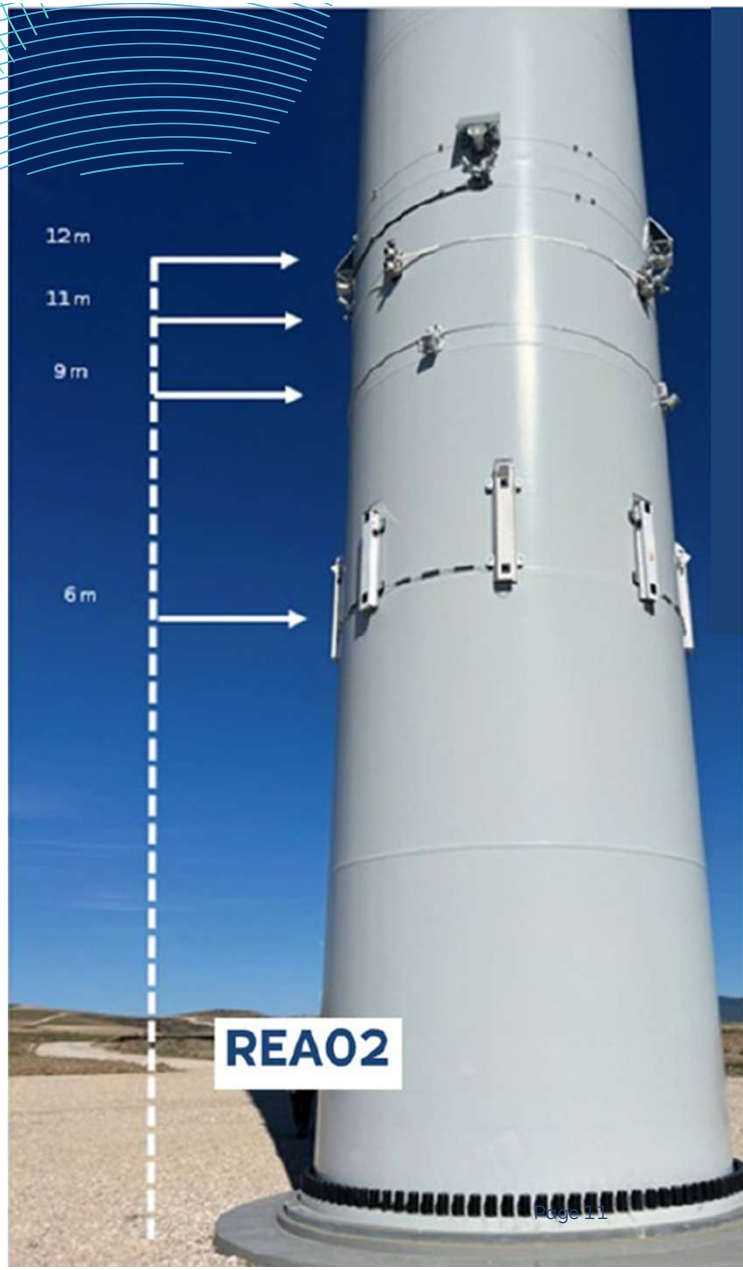




Minimize bird collision risk:
Detection distance (>500m for large birds)



Space of improvements:
Anticipation of alarms and shutdowns
Trajectory integration



Importance of bird trajectory estimation
how it impacts stop number



6 birds

Shut down distances:

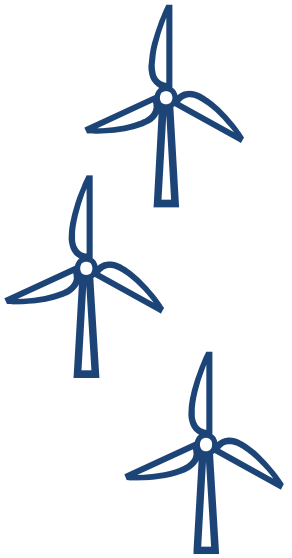
300-400-500 mt

Stop nr:

- 300mt → 2 stops
- 400mt → 3 stops
- 500 mt → 6 stops

(birds avoid turbines 99% of the time)

Recommendations from Operators experience:
Adaptive management and continuous improvement



- ✓ **Biodiversity protection and renewable energy deployment are shared objectives.**
- ✓ **SDOD/BDS systems are effective mitigation tools, but no technology can eliminate risk entirely.**
- ✓ **The objective should be to achieve the highest practicable level of risk reduction, based on monitoring and continuous improvement.**
- ✓ **Deploy SDOD/BDS systems only when justified by a site-specific risk assessment, rather than as a standard requirement for all wind projects: the broader operational impacts of frequent turbine stops should not be ignored.**
- ✓ **As developers and operators, we continuously invest in testing and innovation to identify the most effective mitigation solutions (i.e. blade patterning).**
- ✓ **Regulatory frameworks should support innovation, performance improvement and allow adaptive management to optimize system settings over time to maximize bird protection and minimize operational impacts.**

RWE

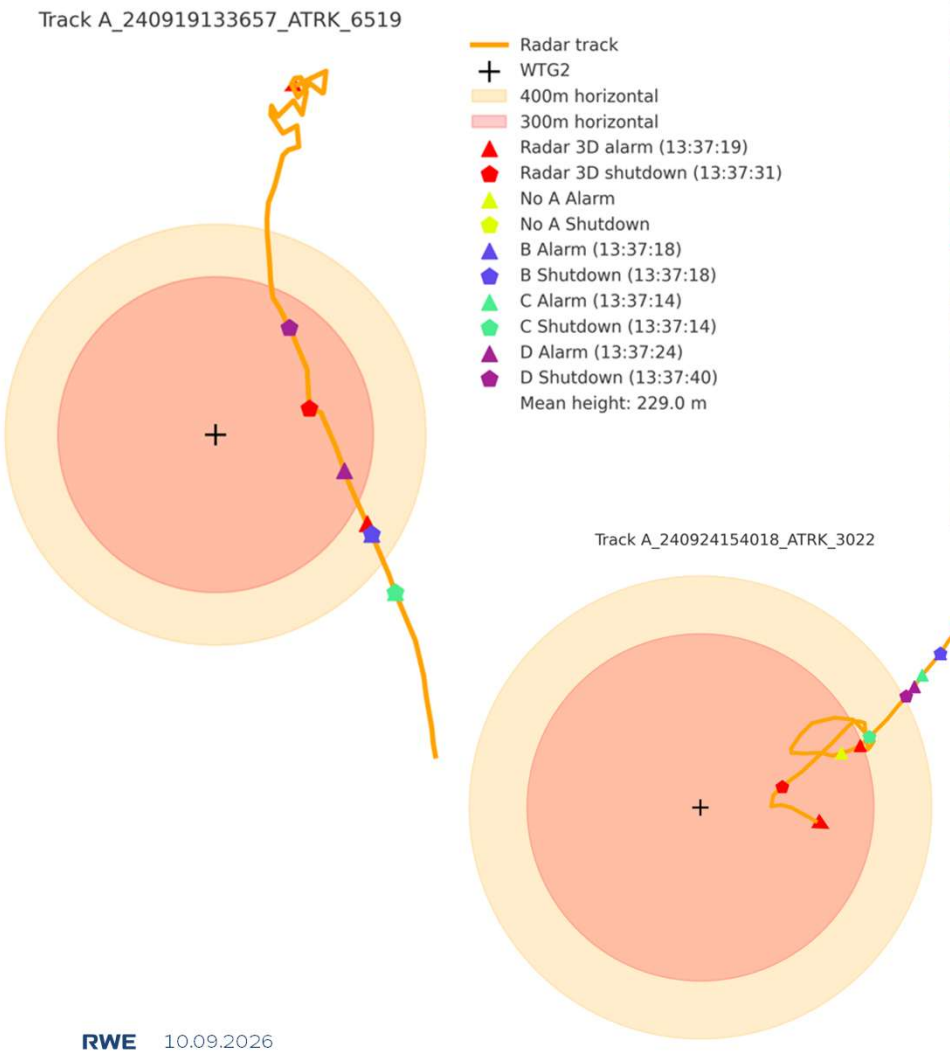
Merci!

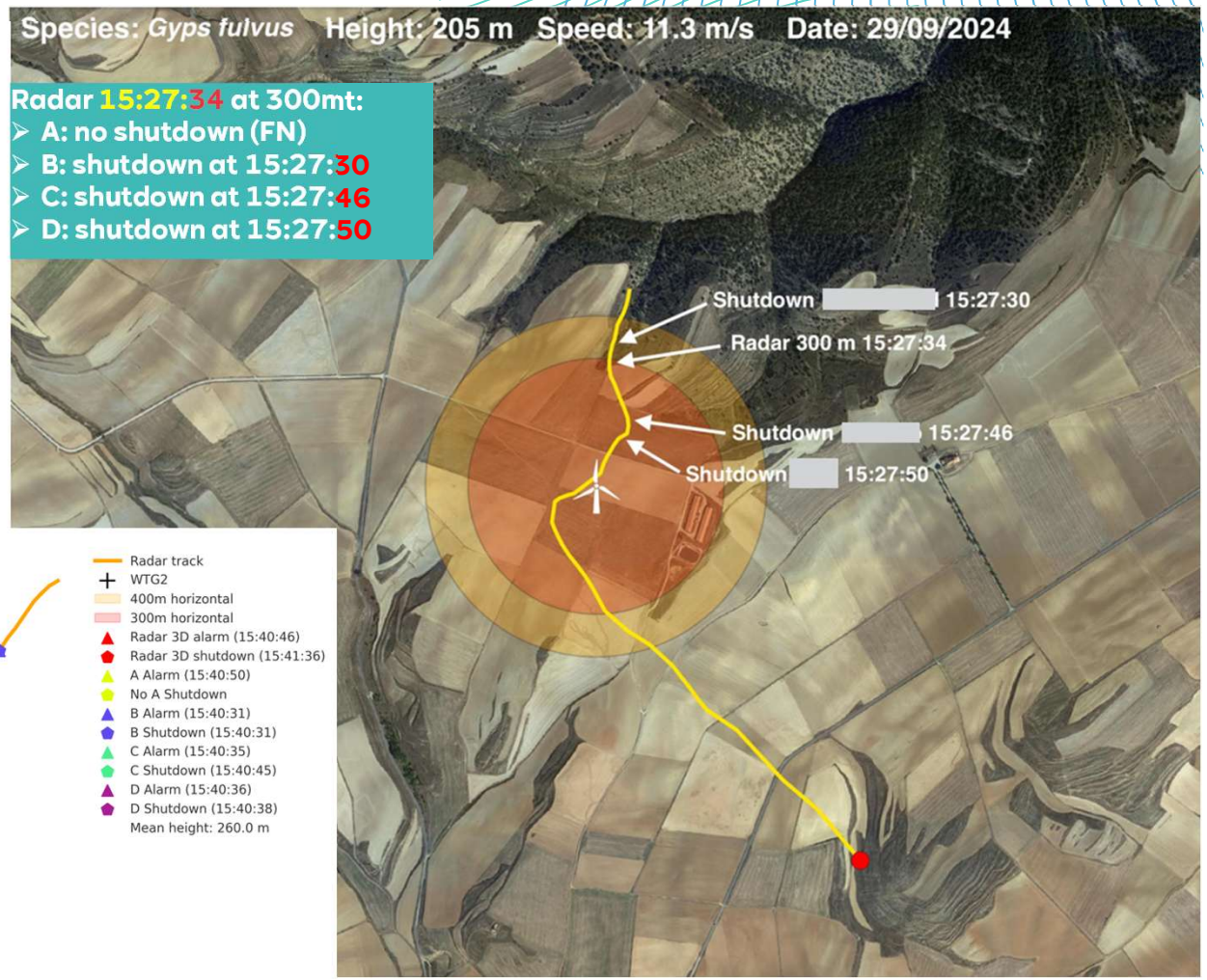


Contacts: valentina.peronace@rwe.com

Backup slides

Results – Example of radar track



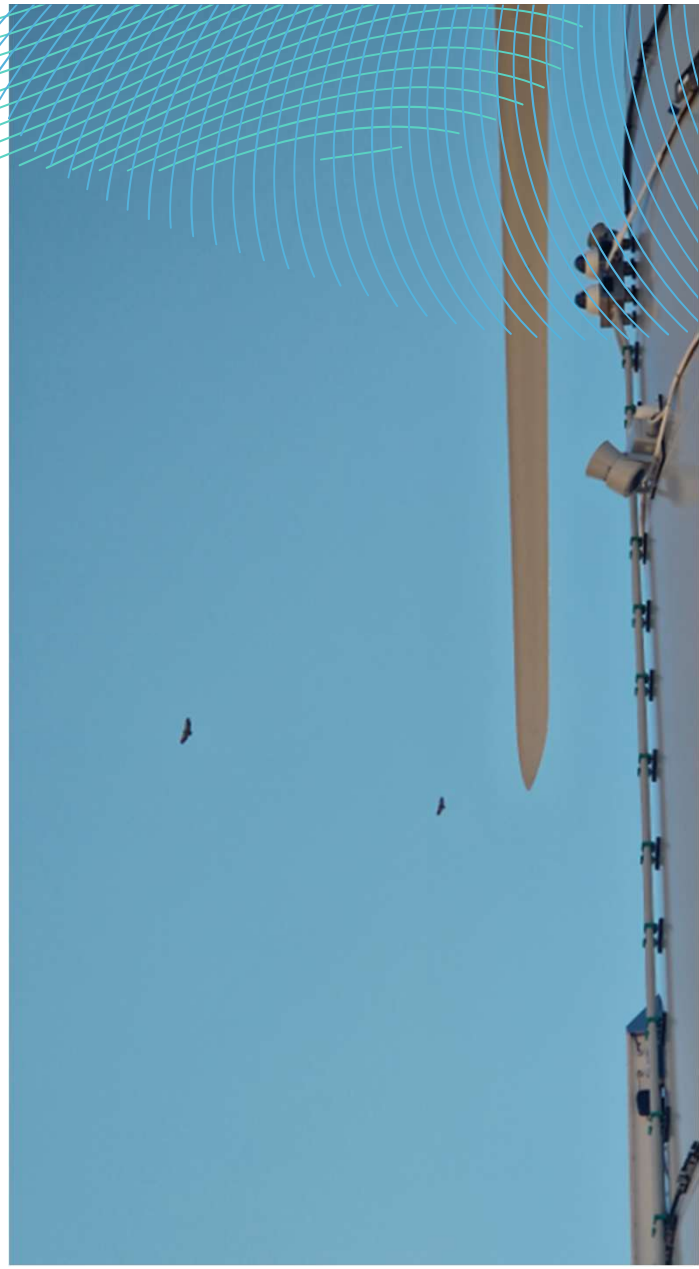


Results

Number of Shutdowns and duration:

- **No significative differences between B, C and D** – clearly A underperformed
- Comparison of shutdown counts with radar data was not feasible due to multiple birds, signal clutter, etc.

Company	Total nr of shutdowns	Nr of shutdowns/ day	Total Downtime (min)	Downtime/day (min)
A	68	3,2	257	12,2
B	333	15,9	1260	60,0
C	381	18,1	1441	68,6
D	243	11,6	919	43,8



Results – False Positive rate

Company	N of shutdown videos	N of false positives	False positive rate (%)
A	99	3	3.03
B	752	1	0.13
C	1,136	15	1.32
D	449	0	0.00

1	planes
4	blade
10	clouds
52	incorrect bird size
67	**5.9% of false positive**

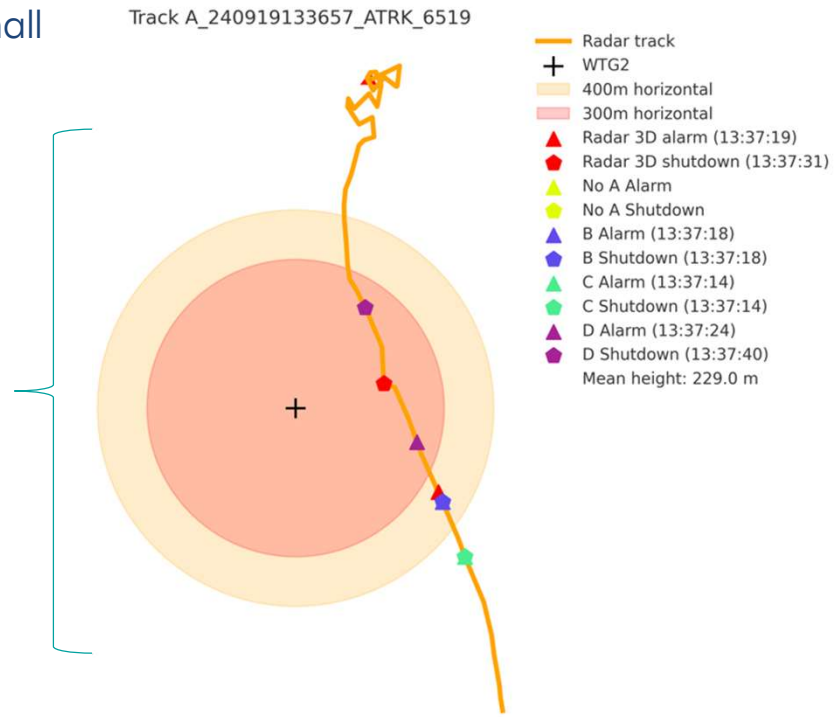


- In total were analyzed a number of **2'436 videos** related to shutdowns
- (D) and (B) showed virtually no false positives (! their video footage was delivered later).
- For (A) approximately 3% false positives were blades mistaken as birds. This system did not differentiate bird size classes
- For (C) of the 52 cases due to incorrect bird size classification, the majority of these (46) involved small birds being misclassified as medium-sized birds

Results - Shutdowns False Negative Rate - Griffon Vulture

- In triggering shutdowns when birds were at 300 m from the WTG, (A) clearly underperformed, with a false negative rate (FNR) of 91%; (C) performed best overall, with an FNR of 6%; however, the difference was not statistically significant when compared with Systems (B) and (D).
- Interval between L1 (lower limit) and L2 (upper limit) depends to the small sample size (n = 34).

Company	Nr of SD from the radar	Nr of SD	Missing SD	False Negative rate	L1	L2
A	34	3	31	**0.91**	0.76	0.98
B	34	30	4	**0.12**	0.04	0.27
C	34	32	2	**0.06**	**0.01**	**0.2**
D	34	25	9	**0.26**	0.15	0.43

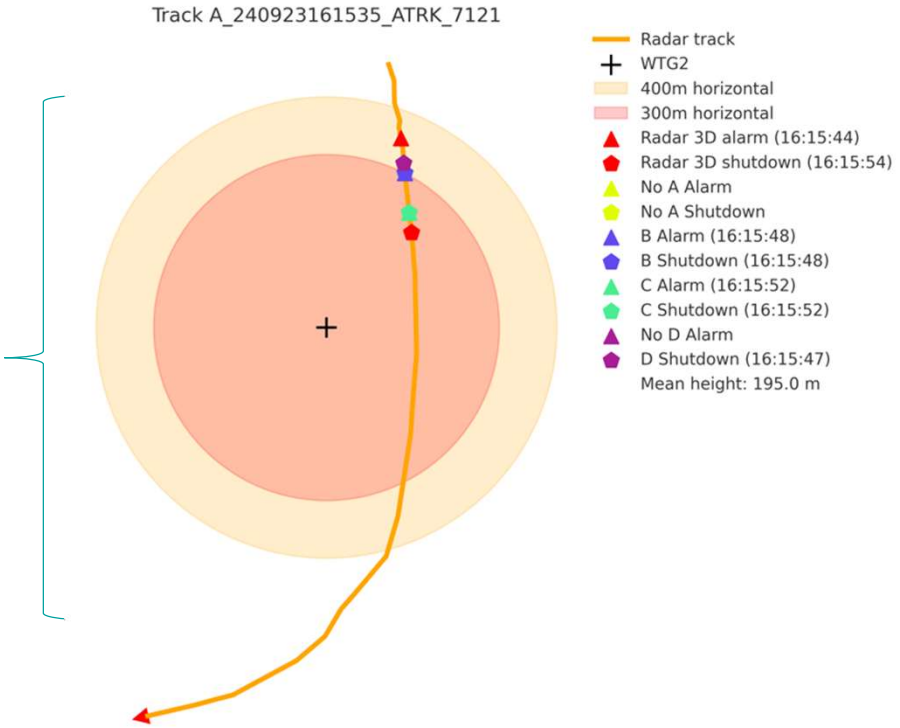


- false negative frequency (plus 95% CIs; Agresti-Coull) for the griffon vulture single tracks analysis

Results - Alarms False Negative Rate - Griffon Vulture

- In triggering alarms when birds were at **400 m** from the WTG, (A) clearly underperformed, with a false negative rate (FNR) of 81%; (D) performed best overall with an FNR of 3%; however, the difference was not statistically significant when compared with Systems (B) and (C), although there was a trend toward significance (p = 0.054).

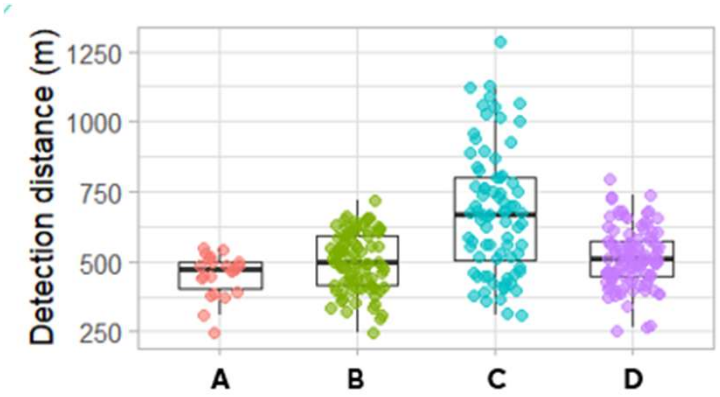
Company	Nr of Alarms from the radar	Nr of Alarms	Missing Alarms	False Negative rate	L1	L2
A	79	15	64	0.81	0.71	0.88
B	79	70	9	0.11	0.06	0.21
C	79	70	9	0.11	0.06	0.21
D	79	77	2	0.03	0.00	0.09



- false negative frequency (plus 95% CIs; Agresti-Coull) for the griffon vulture single tracks analysis

Results – Distance of first detection

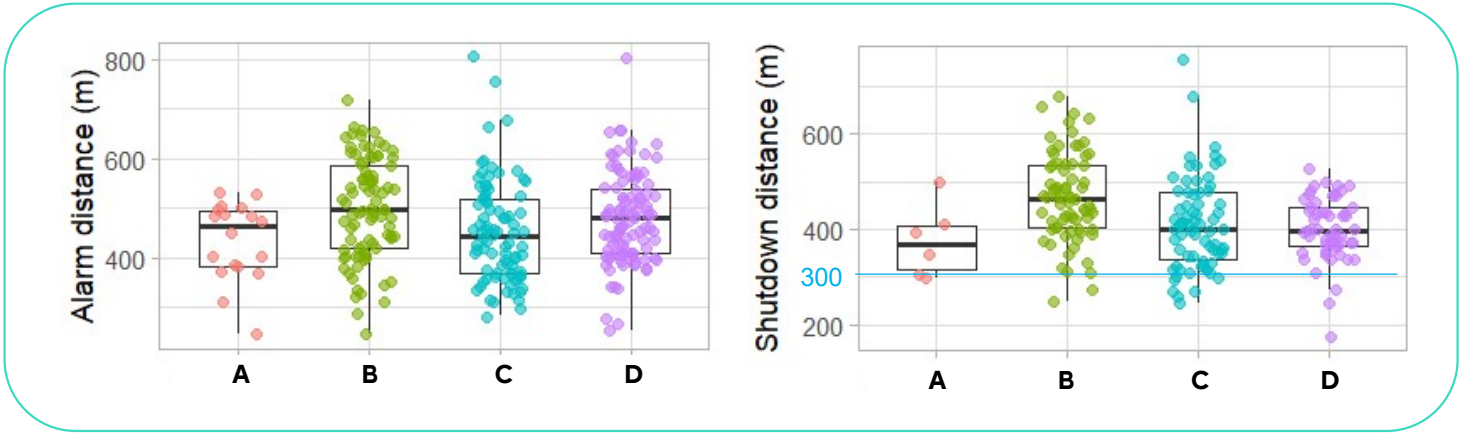
- This represents the mean absolute distance (min, max, DS) at which the first detection of griffon vultures (Gyps fulvus) was recorded by each BDS.
- Systems (B), (C), and (D) showed a consistent ability to detect large birds at distances > 500m.



Company	N of tracks	Mean absolute first detection Distance (m)	Min (m)	Max (m)	SD (m)
A	22	452	245	547	76
B	88	501	247	718	103
C	80	675	307	1285	222
D	100	515	252	794	105

Results – Alarms and shutdowns Distances

- The **absolute distance** (from the BDS to the bird) at which **alarm** and **shutdown** triggering events occurred was also calculated.
- In this case, the performance of the different systems was broadly comparable.
- The boxplots showed **a general tendency for all systems to anticipate the events** relative to the 400 m (alarm) and 300 m (shutdown) set thresholds.



boxplot with actual data representing the distance of activation of the various commands (detection, alarm and shutdown) by each BDS.

Example of adaptive management approach

In a site you have No target species but a list of sensitive birds, mainly large wingspan classes.

A SDoD device, proven to be effective for such birds, is installed.

Monitoring data show that the number of stops during certain seasons and/or hours of the day is higher than in other periods. **There is the operational need to minimize the nr of stops to reduce WTG stress**.

Model or test which configuration provides the lowest WTG stress while maintaining the same level of bird protection.

For example:

- set *larger stop duration* for period of higher bird activity (e.g. during feeding hours, the WTG pause duration is 10 minutes instead 3min…)
- Decrease shutdowns triggering distances if initially have been set using precautionary approaches
- Always monitor any changes and adapt