Βελτιστοποίηση Λειτουργίας Αιολικών Σταθμών και Μονάδων Αποθήκευσης

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Wind Farm Operation Optimization

- Lifetime Estimation
- Sector Management Assessment
- Wind Farm Performance Evaluation

Lifetime estimation results

Classified into three components categories, based on the criticality of their failure:

Category 1. *Safety critical components*

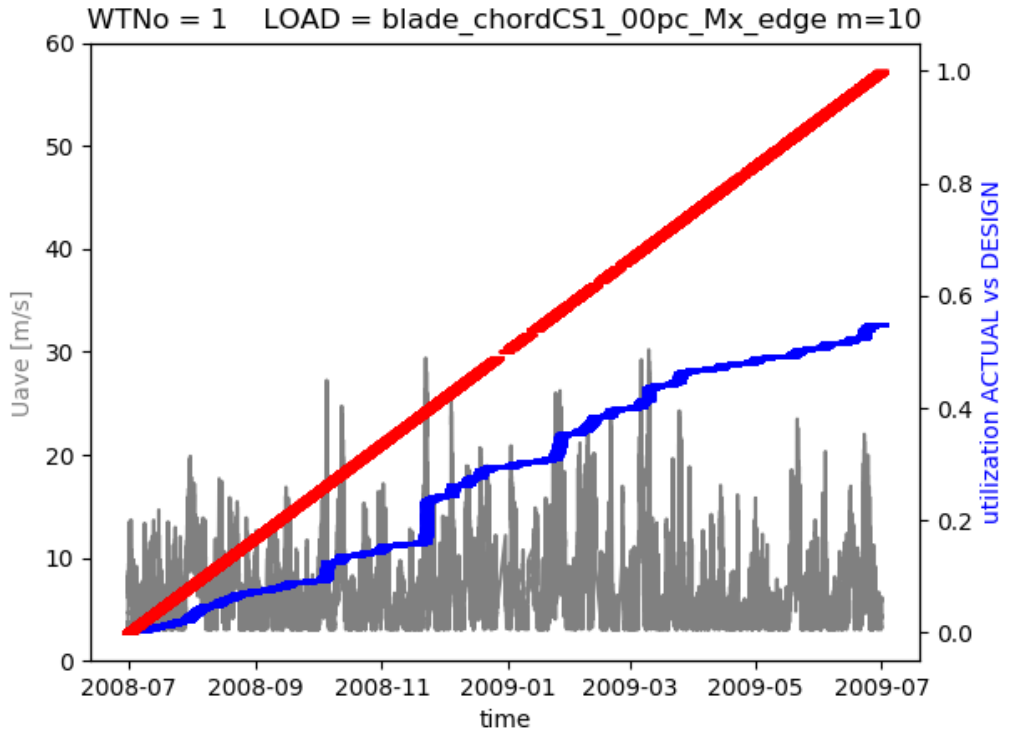
Category 2. *Blades*

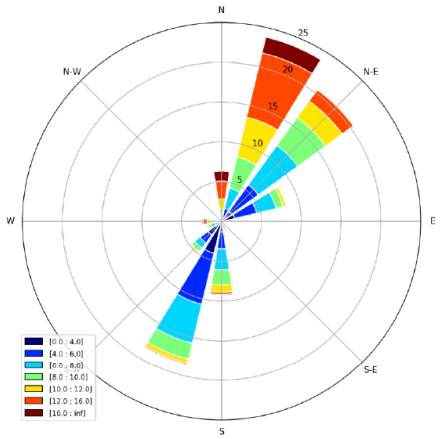
Category 3. *Replaceable components*

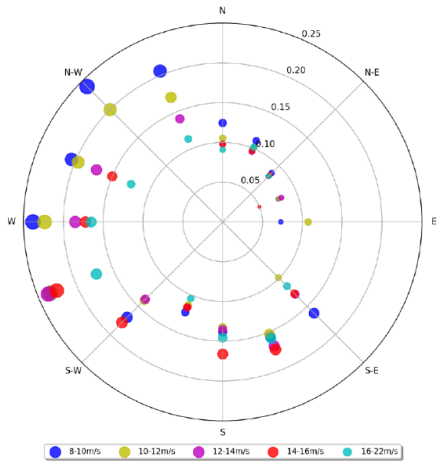
Component		WT1	WT2
Cat.1 (P90)	Tower	28.3	30.5
	Nacelle Welded	38.7	39.3
	Nacelle Cast	>40.0	>40.0
	Hub	28.0	27.8
Cat.2 (P75)	Blade Flap	>40.0	>40.0
	Blade Edge	>40.0	>40.0
Cat.3 (P75)	Pitch mechanism	>40.0	>40.0
	Blade/Hub interface	20.9	21.0
	Hub/Shaft interface	36.9	37.9
	Yaw mechanism	>40.0	>40.0
	Nacelle/Tower interface	39.2	40.0

Fatigue life consumption over time

- Real-time monitoring of life consumption
- Estimation of fatigue based on SCADA records (statistical values of wind characteristics)





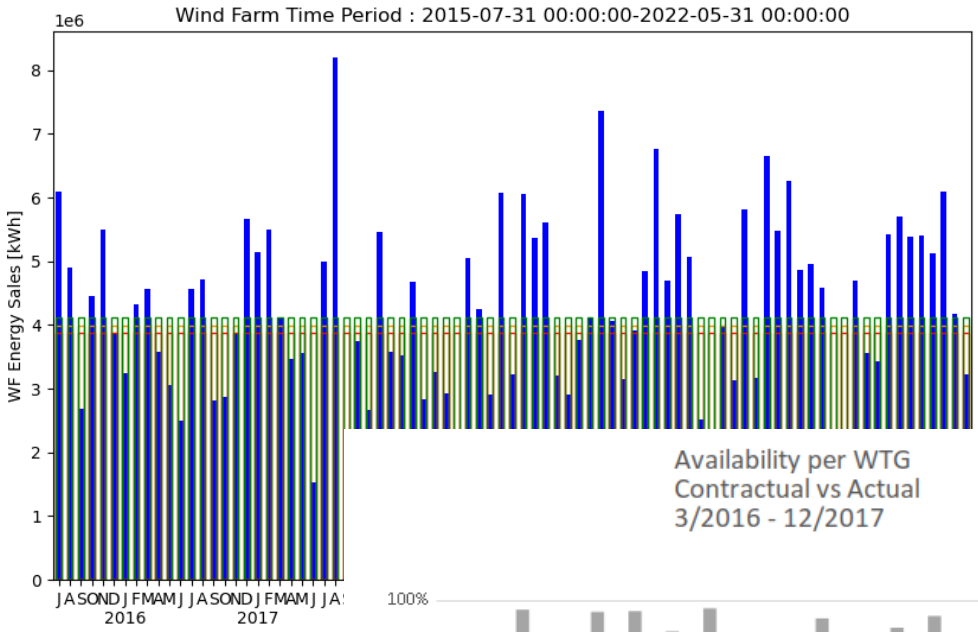


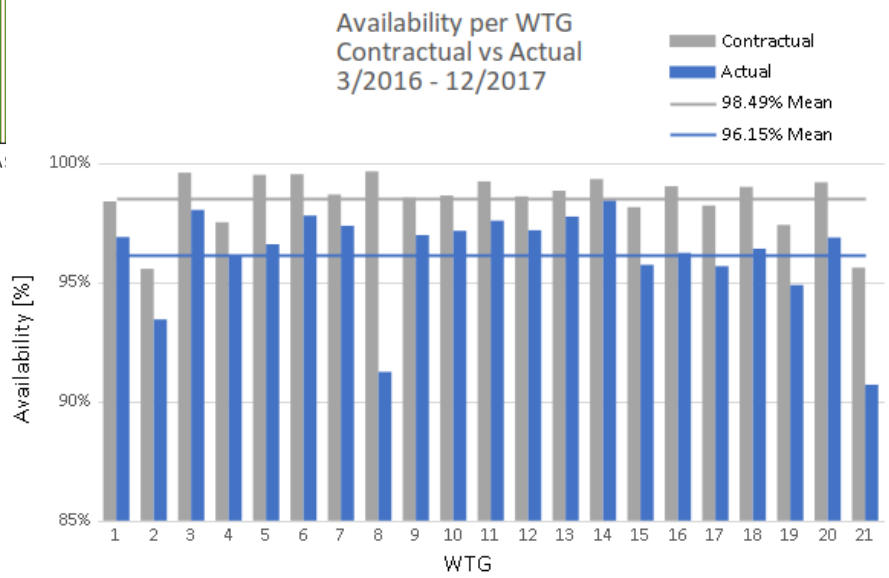
	WSM_ORI	WSM_S1	WSM_S2	WSM_S3	WSM_S4
WSM S1 [deg]	215	245	245	245	245
WSM E1 [deg]	285	285	285	285	285
WSM V1 [m/s]	7	8	9	10	11

WT1		WSM_NO	WSM_ORI	WSM_S1	WSM_S2	WSM_S3	WSM_S4
Uave [m/s]		7.23					
Density [kg/m3]		1.17					
SigmaMax [m/s]		5.17					
U_max[m/s]		23.88					
Mean Power [kW]		1594					
WSM Downtime [%]		0.0%	4.4%	2.8%	2.4%	2.1%	1.7%
Energy Loss due to WSM [%]		0.0%	6.7%	4.6%	4.2%	3.8%	3.1%
Fatigue Life Improvement m=8 [%]		0.0%	61%	57%	55%	53%	48%
Fatigue Life Improvement m=10 [%]		0.0%	69%	65%	64%	62%	57%
Fatigue Life Improvement m=14 [%]		0.0%	74%	71%	70%	69%	64%

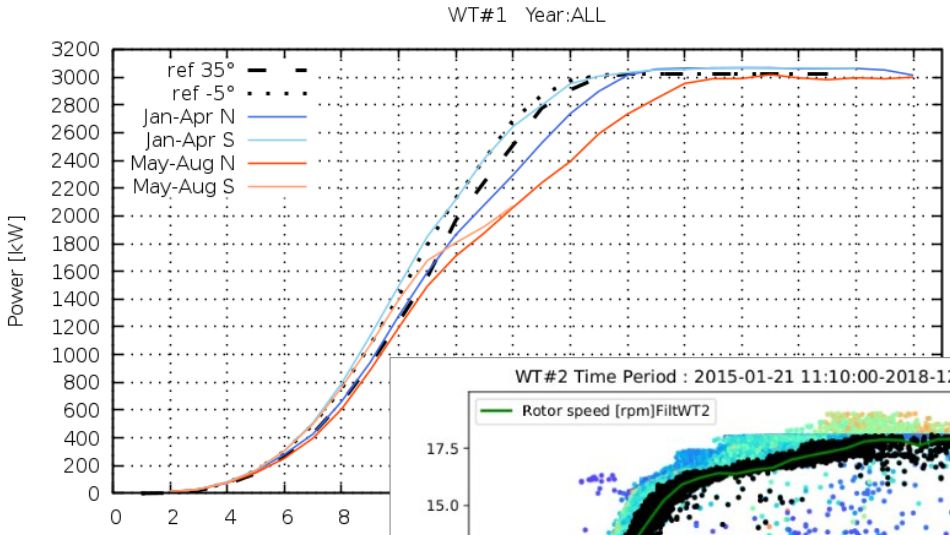
		WSM_NO	WSM_ORI	WSM_S1	WSM_S2	WSM_S3	WSM_S4
WT1	P75 m=10 Blades GI	36.5	61.5	60.3	59.7	59.1	57.2
	P75 m=14 Blades C	17.3	30.1	29.7	29.4	29.2	28.3
	P90 m=8 Steel	38.8	62.4	61.0	60.3	59.5	57.6
WT2	P75 m=10 Blades GI	30.3	51.4	49.6	48.9	47.9	46.2
	P75 m=14 Blades C	14.7	25.4	24.6	24.3	23.9	23.3
	P90 m=8 Steel	32.7	53.8	51.7	50.9	49.6	47.8
WT3	P75 m=10 Blades GI	28.3	51.4	48.6	47.8	46.2	44.1
	P75 m=14 Blades C	14.0	26.4	25.0	24.7	23.9	22.8
	P90 m=8 Steel	30.6	53.4	50.2	49.3	47.7	45.5

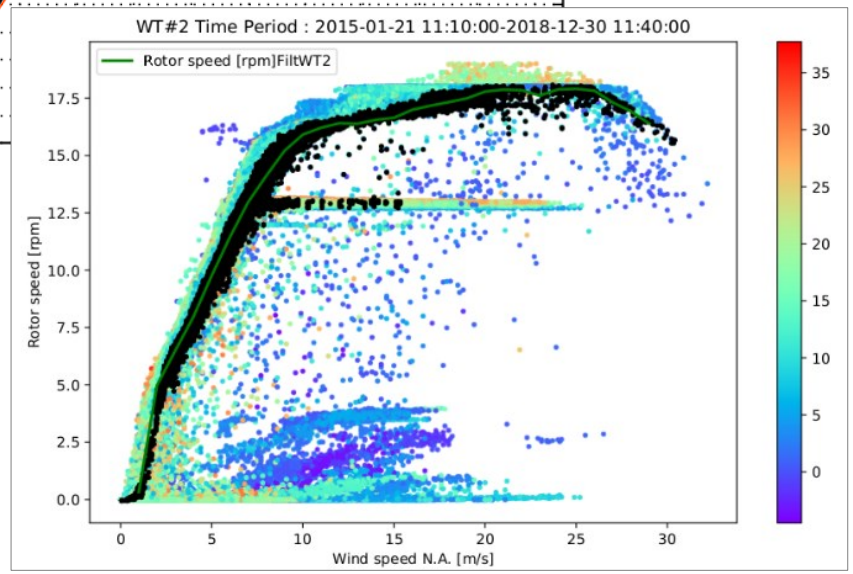
- Review of energy production, actual availability, electrical losses



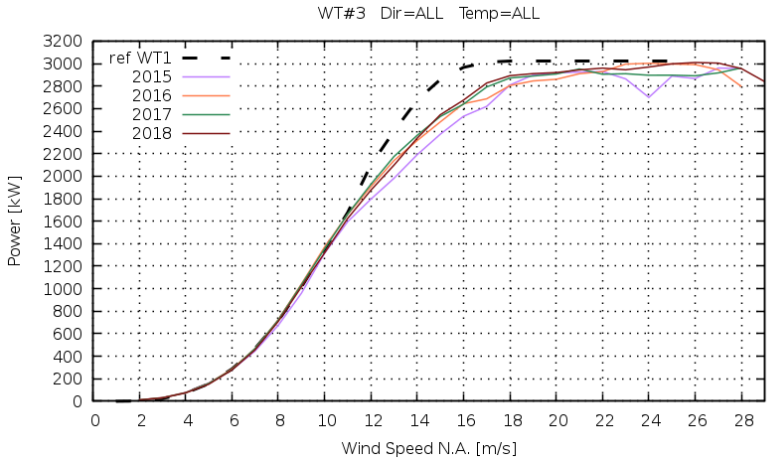


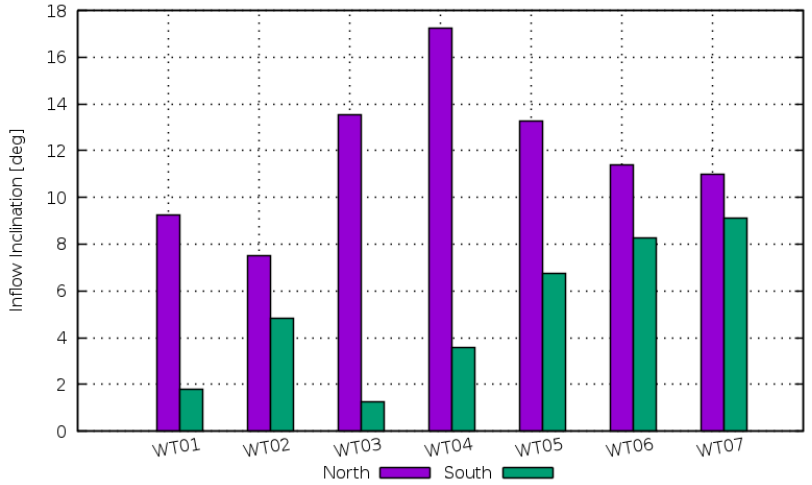
- Directional and seasonal effects identification
- Reduced operation conditions identification
- Unnecessary stoppages



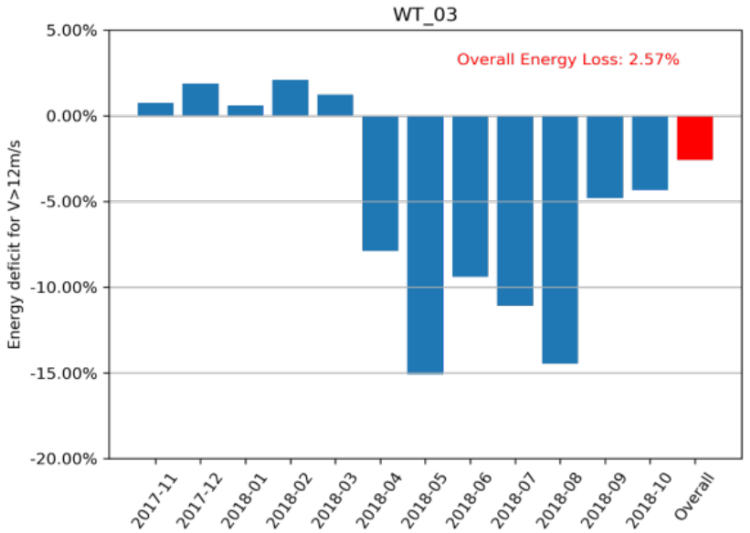


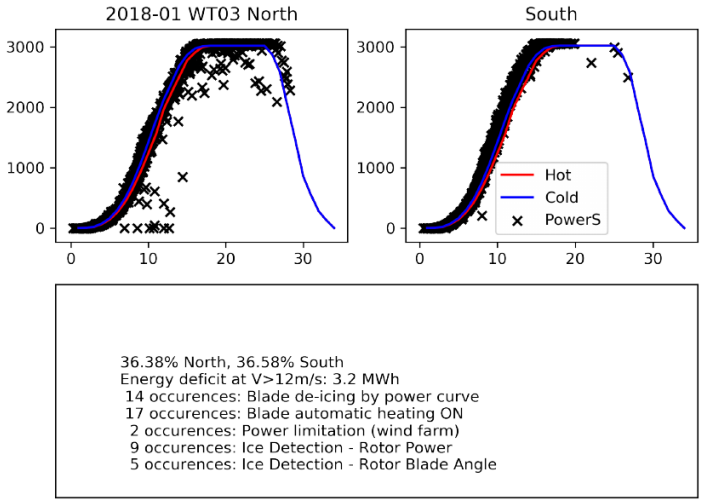
Wind Farms - Performance Evaluation

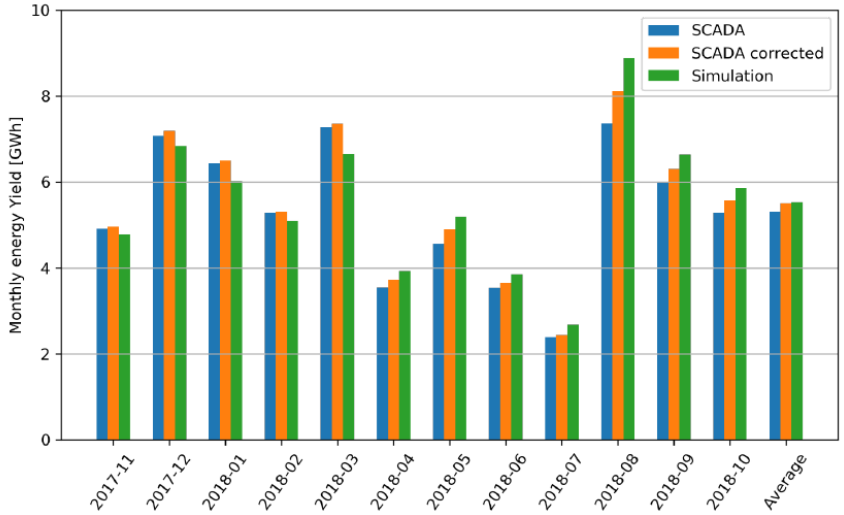




TECHNICAL AVAILABILITY							
MONTH YEAR	WT1	WT2	WT3	WT4	WT5	WT6	WT7
Jan-15	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Feb-15	82.86%	98.15%	74.20%	92.00%	96.63%	86.43%	76.42%
Mar-15	92.00%	36.79%	88.73%	88.59%	96.61%	89.82%	95.57%
Apr-15	98.76%	91.12%	93.39%	98.38%	95.65%	96.59%	97.51%
May-15	98.56%	98.53%	98.90%	98.45%	99.53%	95.27%	99.93%
Jun-15	99.10%	99.96%	99.32%	100.00%	98.04%	77.53%	95.11%
Jul-15	95.20%	95.48%	95.62%	96.89%	99.53%	94.70%	98.66%
Aug-15	98.69%	95.95%	97.29%	97.73%	99.05%	95.19%	99.98%
Sep-15	97.66%	89.15%	94.44%	99.93%	99.98%	97.06%	96.64%
Oct-15	98.81%	97.89%	98.03%	99.61%	99.06%	99.78%	98.43%
Nov-15	99.99%	100.00%	99.98%	96.09%	99.19%	99.72%	96.67%
Dec-15	95.74%	89.38%	98.51%	95.90%	99.97%	99.94%	97.19%
	96.45%	91.03%	94.87%	96.96%	98.60%	94.34%	96.01%



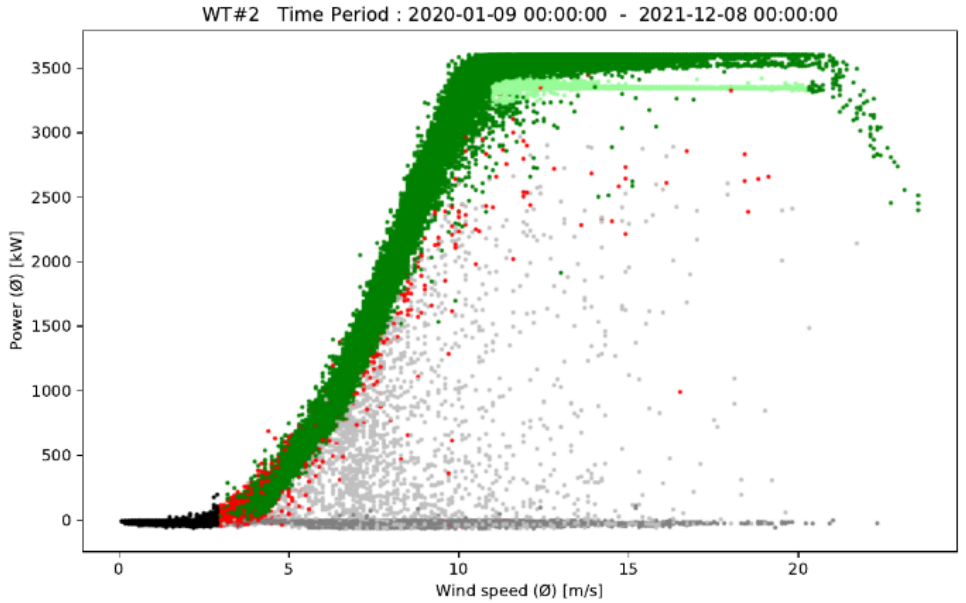


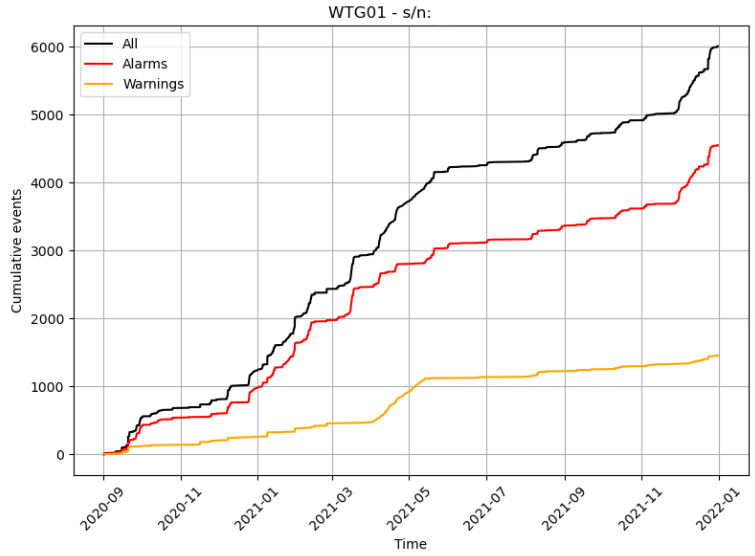


Alarm log analysis

- Categorization of stoppage events based on root cause
- Actual downtime calculation
- Identification of defective components
- Identification of conditions with sub-optimal operation

root_stop_categories	Total down_duration (h)
fault_converter, fault_electric, user	358.0903
fault_misc	262.2981
fault_misc, grid	249.7997
fault_electric, grid	64.1667
fault_yaw	63.1139
user	56.4232
fault_converter, fault_generator, fault_misc	23.7106
sensor	12.3543
fault_hub	7.7589
fault_generator	1.8268
fault_pitch	1.1544
test	0.9557
fault_tower	0.8035
fault_blades	0.438





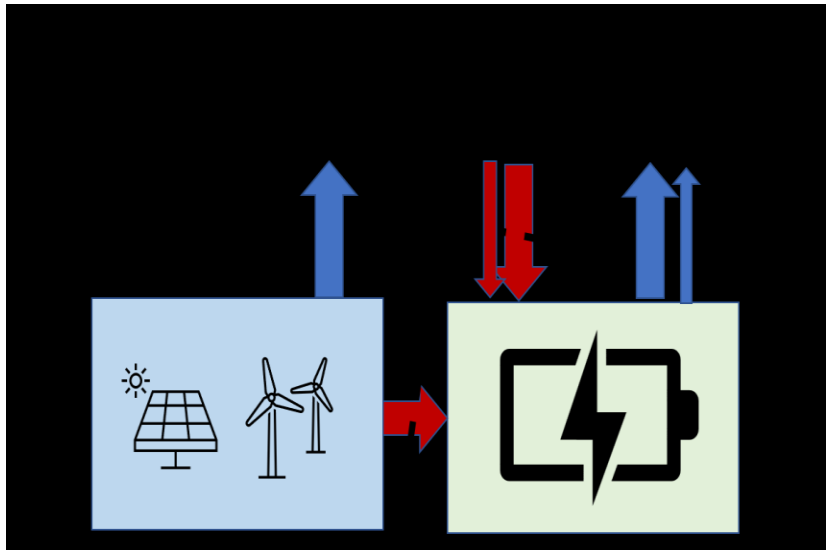
Battery Energy Storage Systems (BESS)

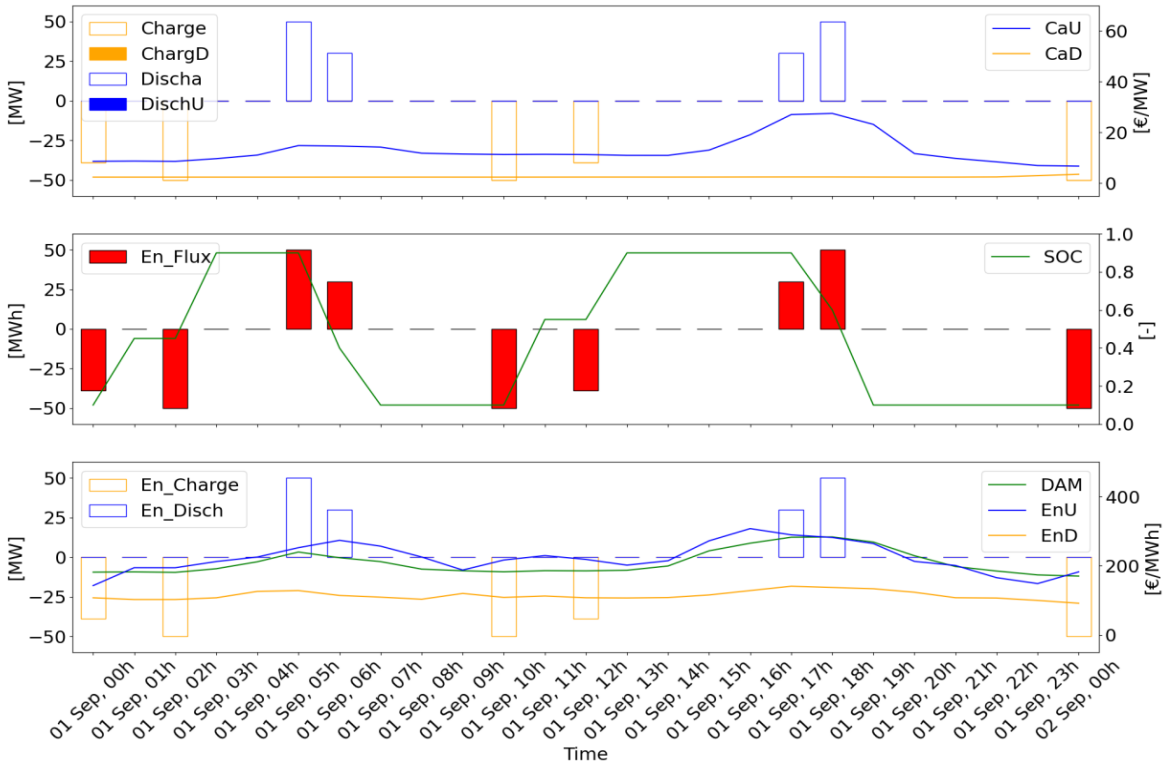
- Revenue sources
- Daily operation optimization
- Electricity prices forecast
- Parametric analysis

BESS - Revenue Sources / Operation Optimization

The most significant sources of revenue for energy storage are:

- Price spreads in Day-Ahead Market
- Balancing Capacity fees from Frequency Restoration- and Frequency Containment Reserves (“Primary Response”)
- Balancing Energy revenue from Frequency Restoration Reserves
- Synergies between RES generation and energy storage, mainly in terms reduced imbalances and increased growth opportunities
- Potential new services, including Congestion Management, Capacity Mechanisms, Black-Start- and Inertia Capacity, Voltage Control, and Fast Frequency Containment Reserves



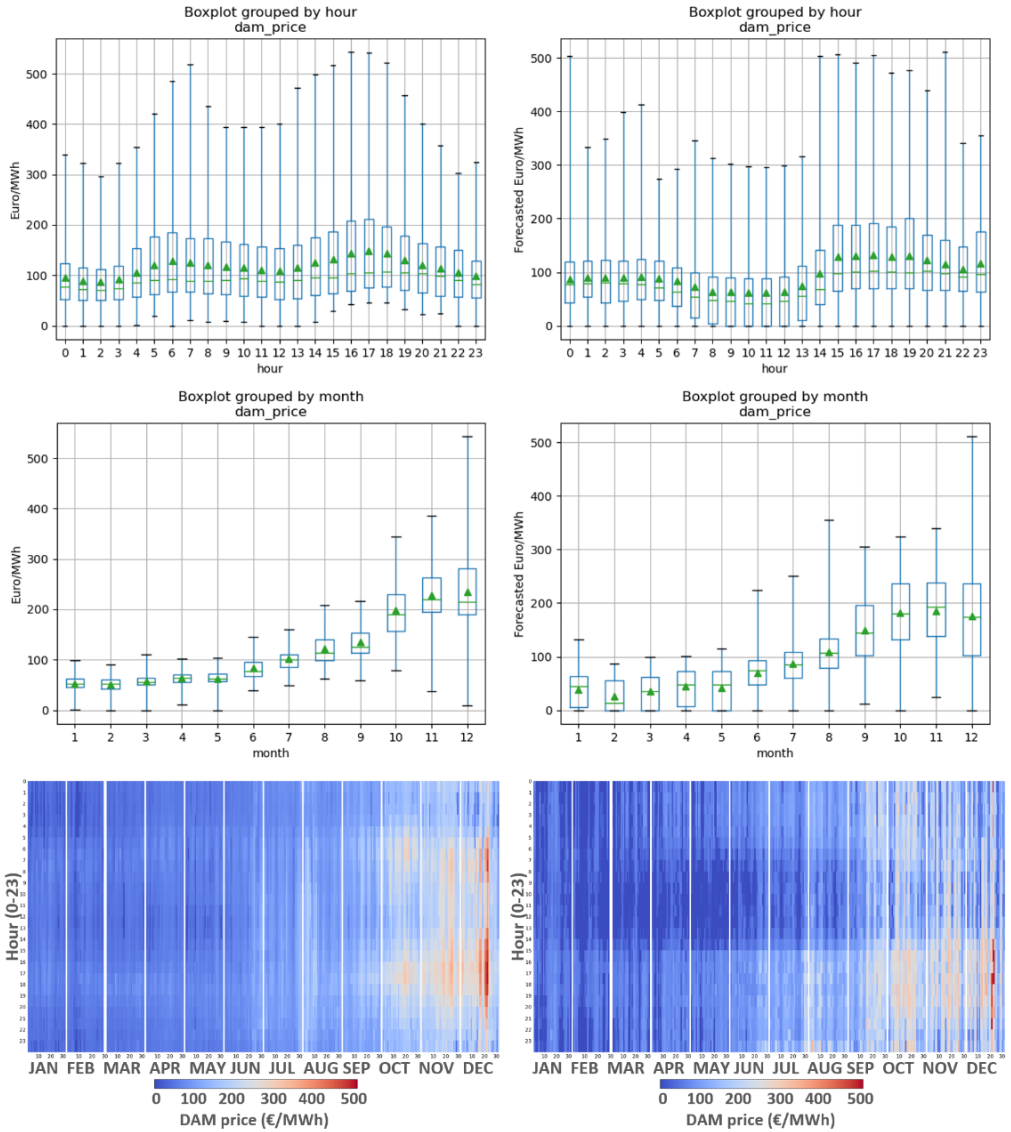


- Optimization of operation for participation in free-market (day-ahead and balancing markets)
- Charge/discharge throughput on hourly basis
- Implementation of actual or forecasted electricity prices time-series
- Maximization of revenue for given price scenario

BESS - Electricity Prices Forecast

Day-ahead and balancing market prices time-series forecast depend on:

- Energy mix (gas, coal, RES etc.)
- Energy demand
- Natural gas prices
- CO_2 emission price
- Evolution of variable RES and energy storage systems



BESS – Hybrid plant parametric analysis

BESS

- 50MW – 2h
- 85% Efficiency
- 90% Discharge Depth
- 2 daily cycles limit

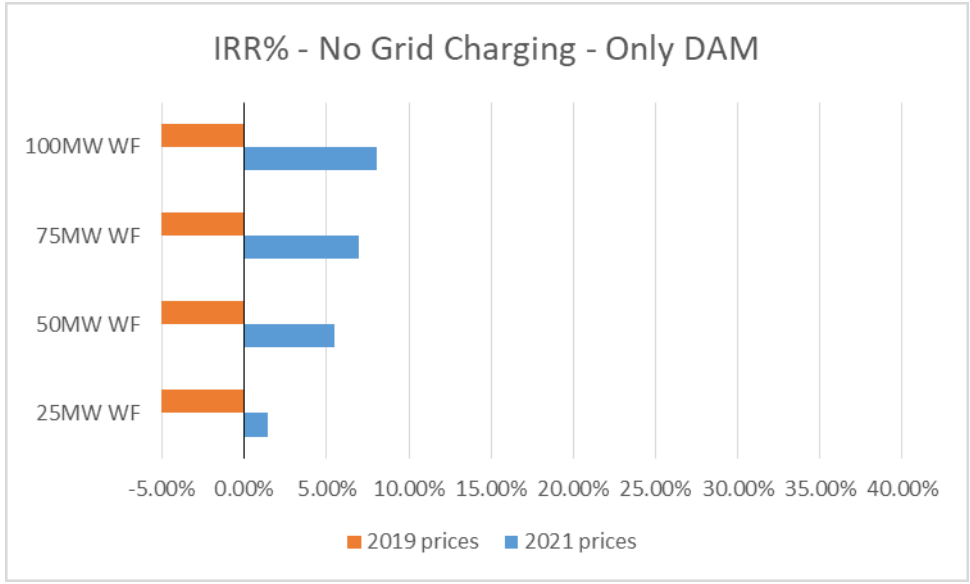
CAPEX

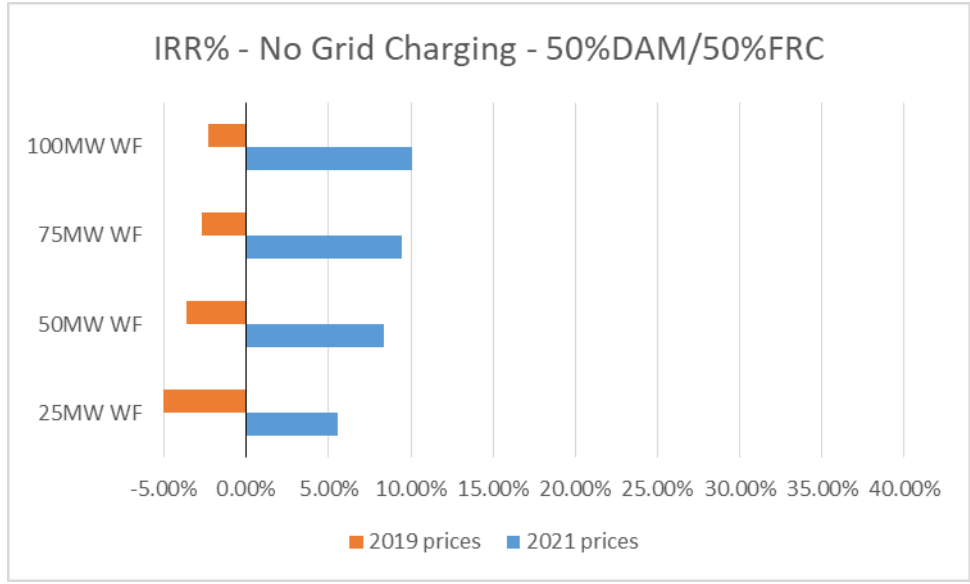
- Power 236 €/kW
- Capacity 255 €/kWh

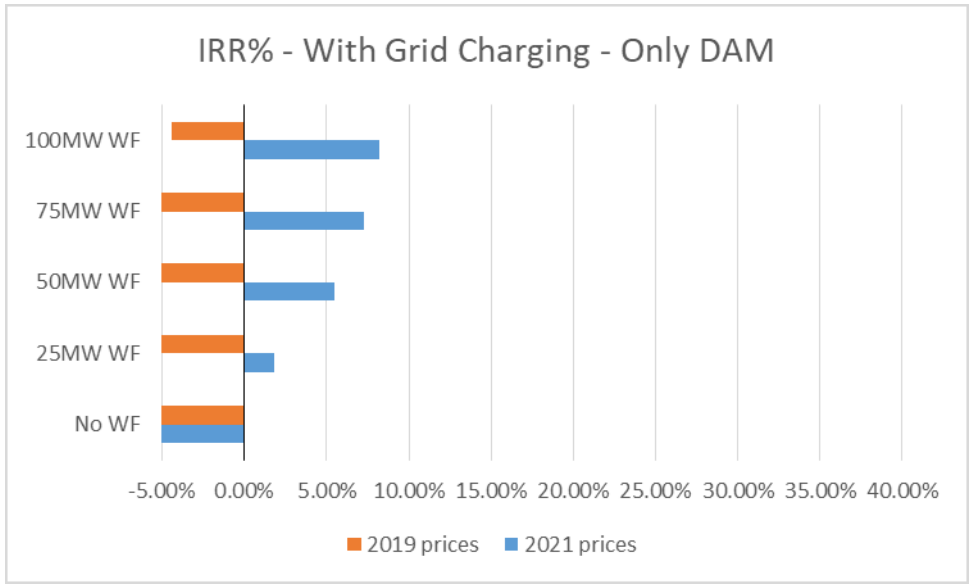
RES

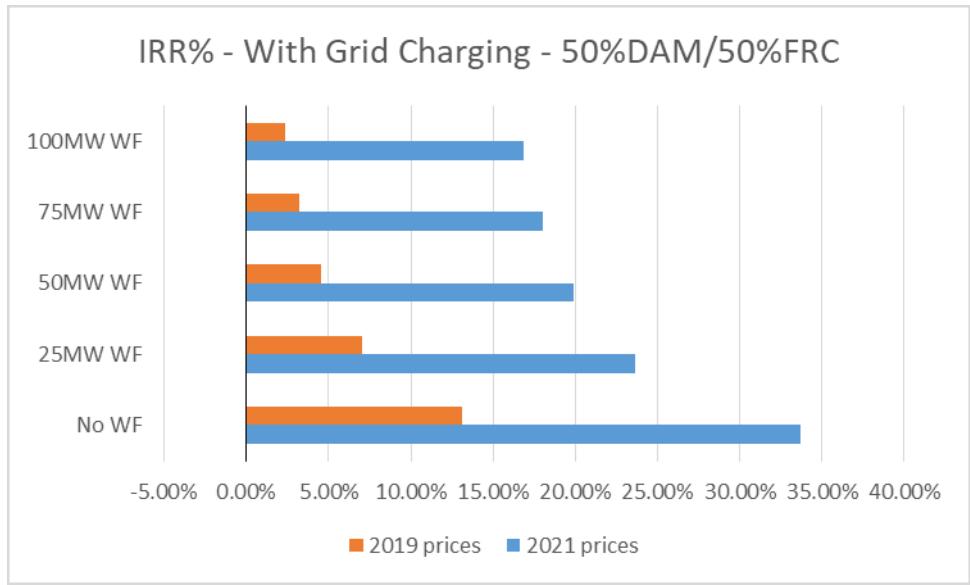
- 25 – 100 MW WF
- 23% C.F.
- 1.3 m€/MW

20 years project life









BESS – Hybrid plant parametric analysis

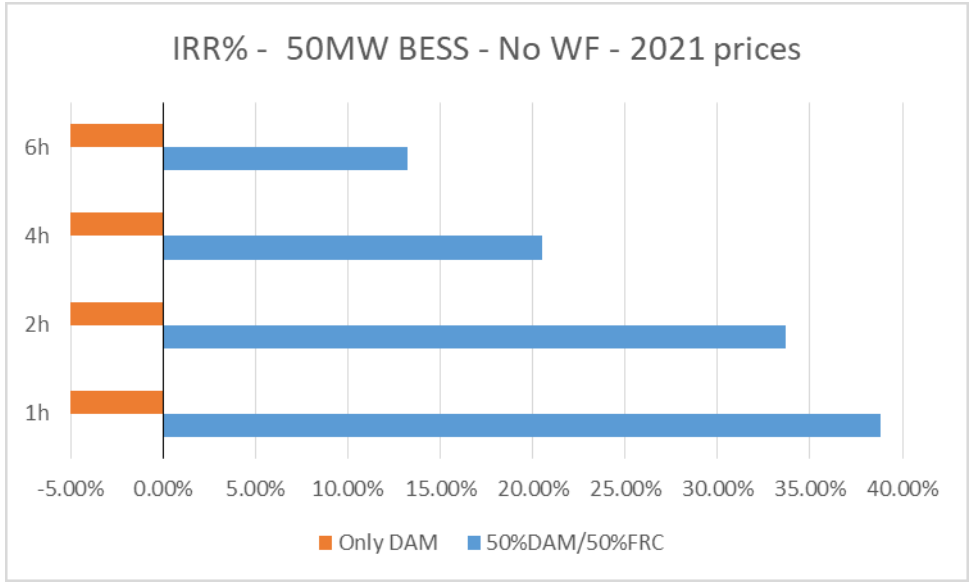
BESS

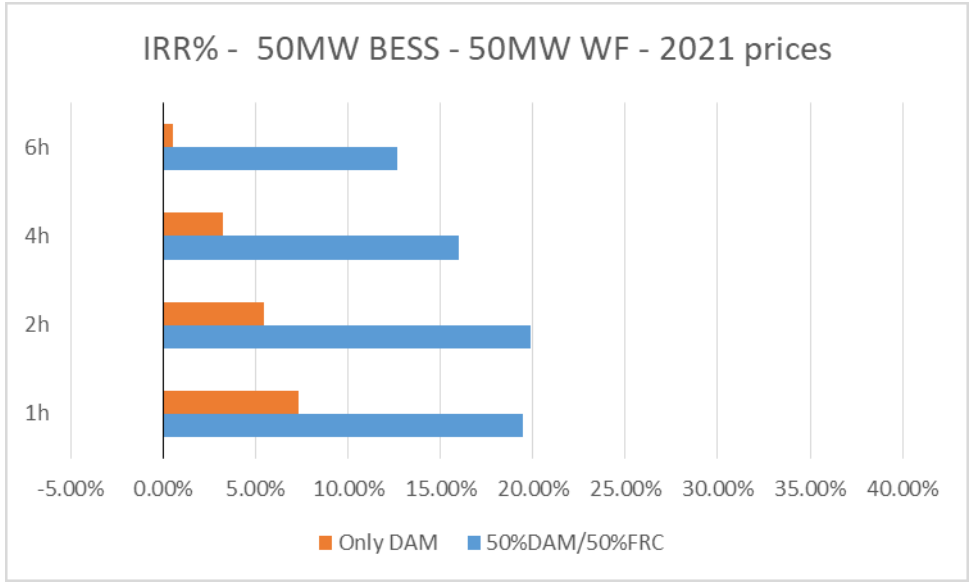
- 50MW
- Charging from grid allowed
- 1 – 6 h capacity

RES

- 0 – 50 MW WF
- 23% C.F.

2021 prices





BESS – Hybrid plant parametric analysis

BESS

- 50MW – 2h
- 2 daily cycles limit

RES

- 50 MW Plant
- WF1 - 23% C.F.
- WF2 - 42% C.F.
- PV1 - 16% C.F.
- PV2 - 19% C.F.

2021 prices