empowering a sustainable future **together**

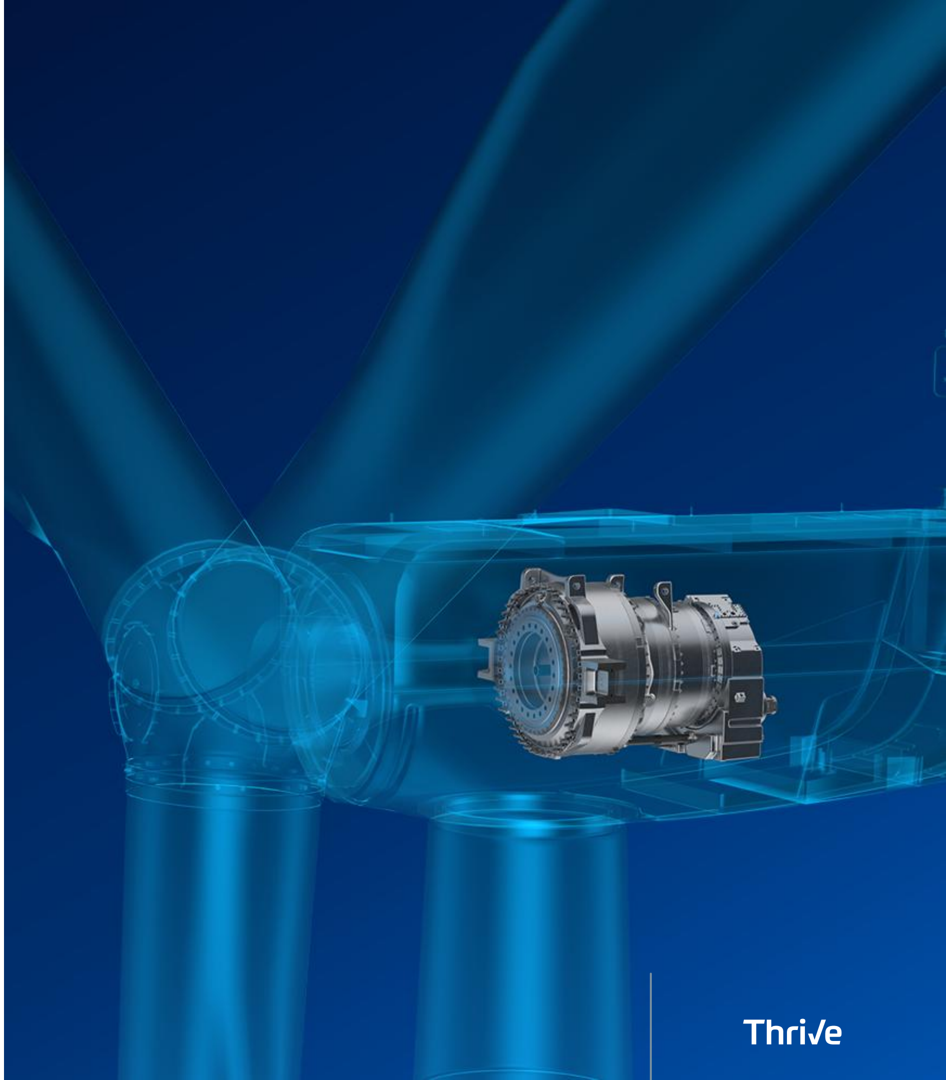
ZF Wind Power

46 Years since **1979**

205 GW installed

85,000 turbines with ZF Gearboxes

24/7 **Thrive** for continuous availability



Thrive for Continuous Availability

Gearbox Pool

Spare Parts Management

Field Repair

Workshop

Partner Training

Digitalization

Thrive

Services Powered by Analytics

Reducing the cost of energy, using data:

- Increase Power Output and Turbine Availability
- Enable Lifetime Extension
- Reduce Operational Expenditures
- Minimize greenhouse gas emissions

Services Powered by Analytics

SPARE PARTS OPTIMIZATION SERVICE

FAST RETURN TO OPERATIONS

Performance data
and SCADA data

LIFE CYCLE MONITOR

GEARBOX EXPERTISE

Failure modes
and solutions

LIFE CYCLE ANALYTICS

Consumed and remaining
Lifetime analytics

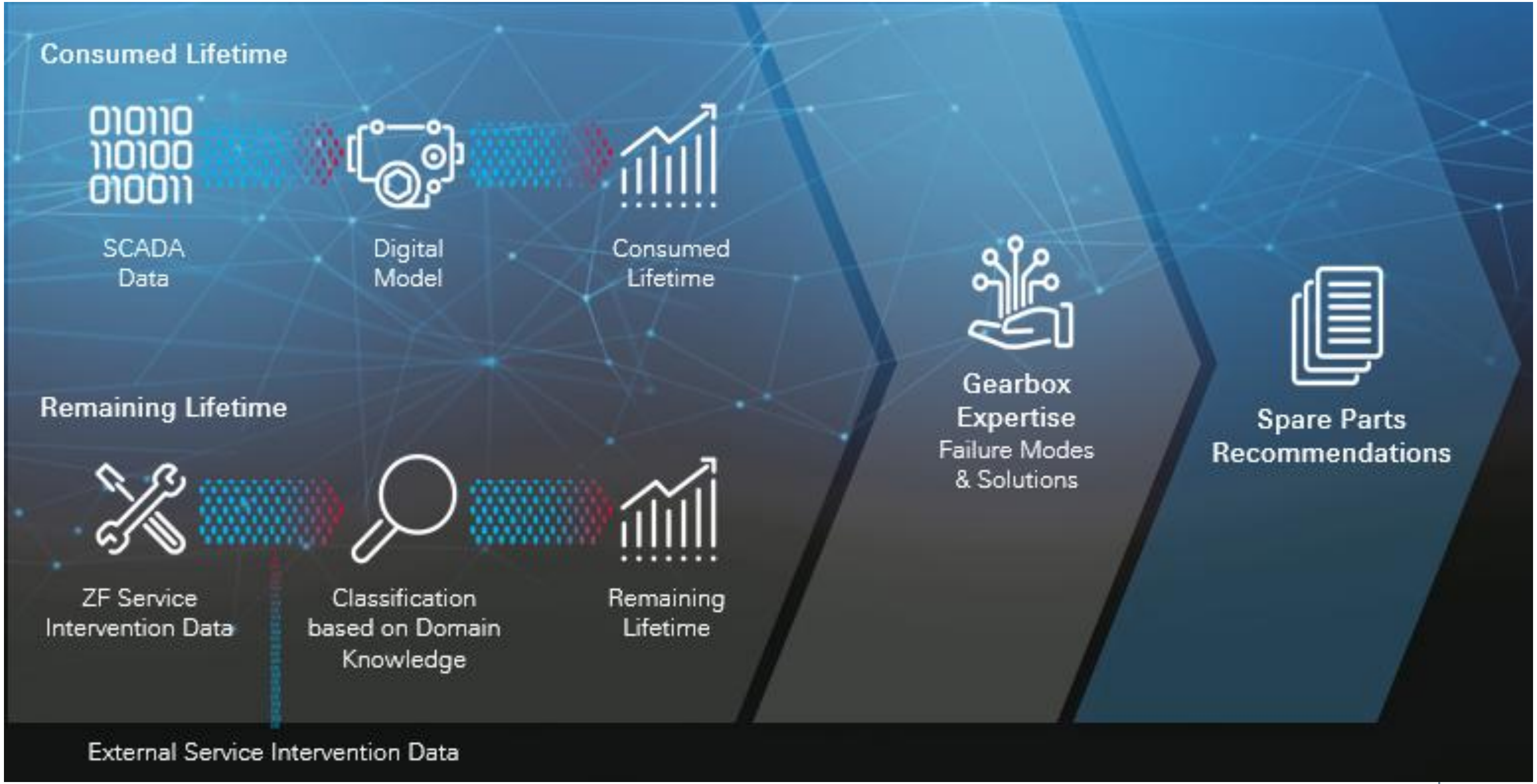
DIGITAL BIRTH CERTIFICATE

Design models,
as-built gearbox information

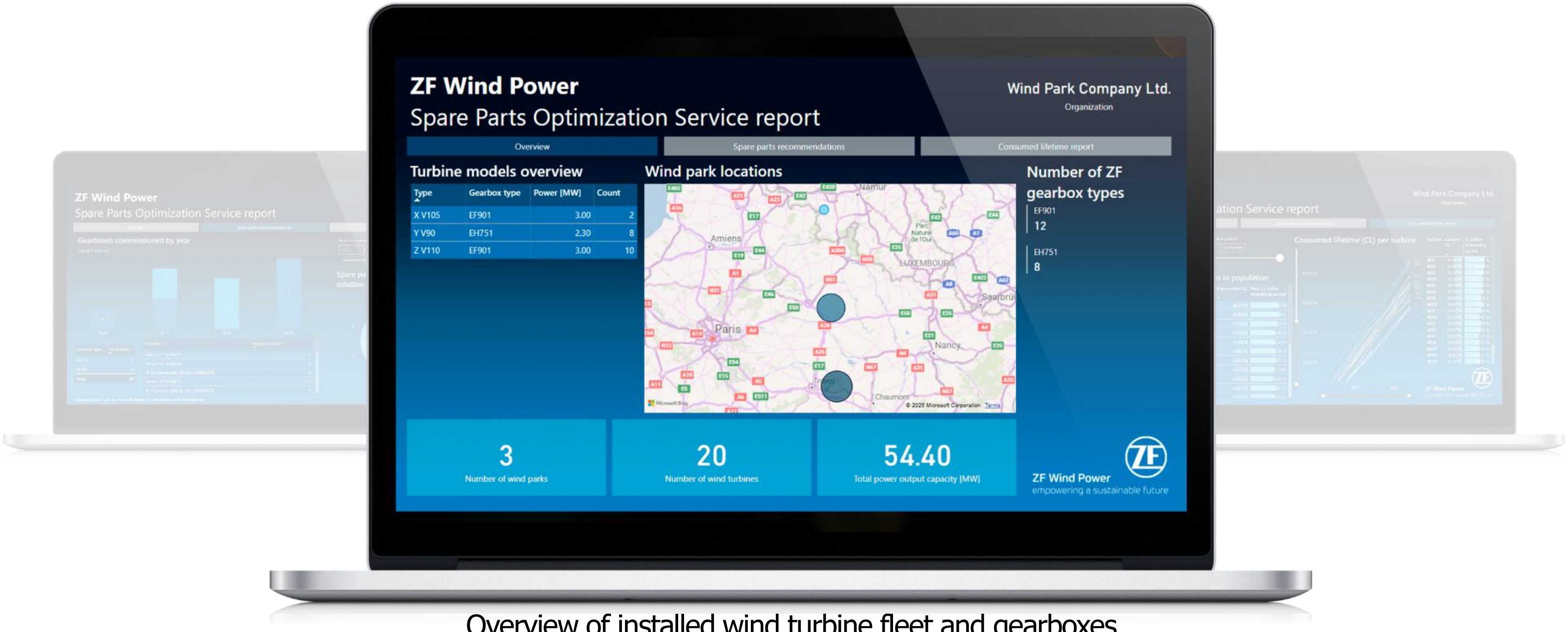
Spare Parts Optimization (SPOS)

Services Powered by Analytics

Spare Parts Optimization



ZF Cloud based platform
Spare Parts Optimization Service



Overview of installed wind turbine fleet and gearboxes

ZF Cloud based platform

Spare Parts Optimization Service

Consumed lifetime calculations based on actual load history

Thrive

ZF Cloud based platform
Spare Parts Optimization Service

Spare parts recommendations are visualized in interactive dashboards

Fast Return To Operations (FRTO)

Process for typical error handling

CMS alert

Fault notification processing:
2 days

Fault inspection time:
2 weeks

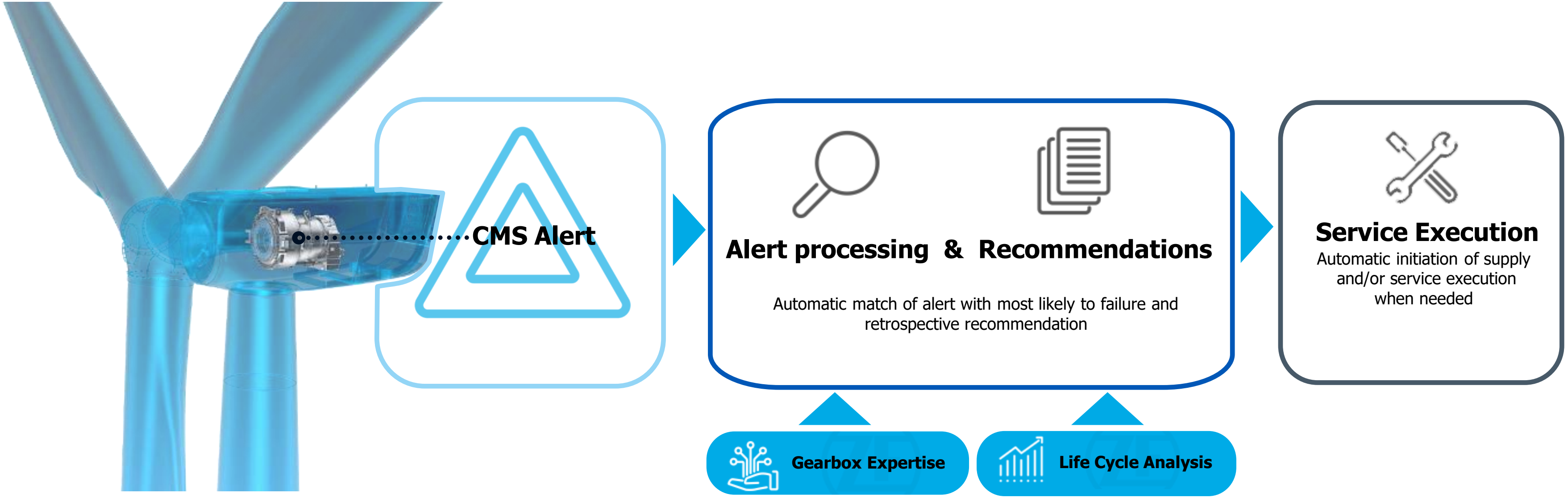
Order the right components:
6 weeks

Plan & execute repairs:
2 weeks

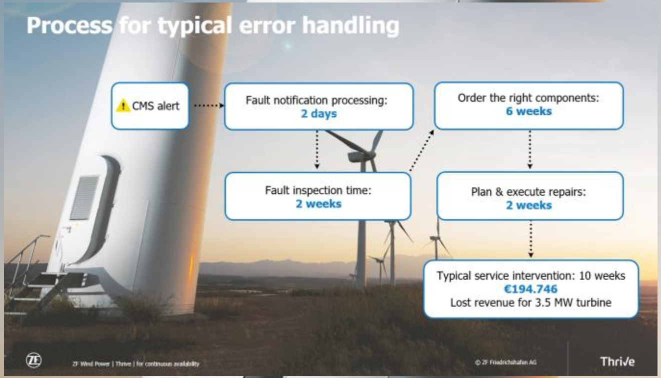
Typical service intervention: 10 weeks
€194.746
Lost revenue for 3.5 MW turbine

Services Powered by Analytics

Fast Return To Operations

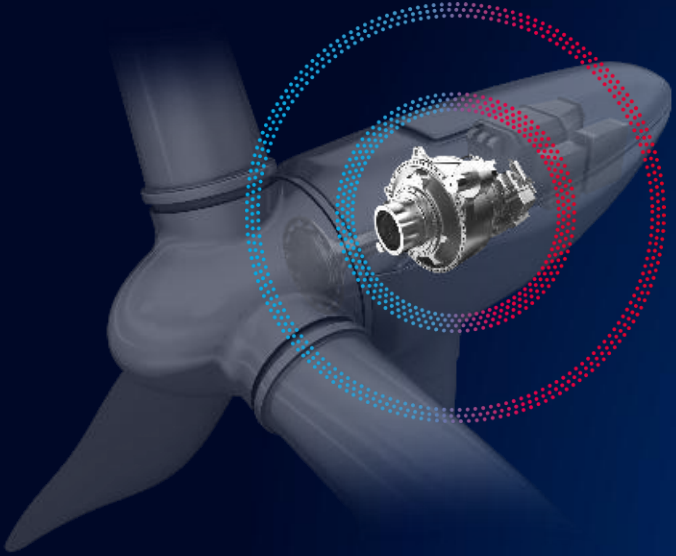


Services powered by Analytics
Savings Calculator

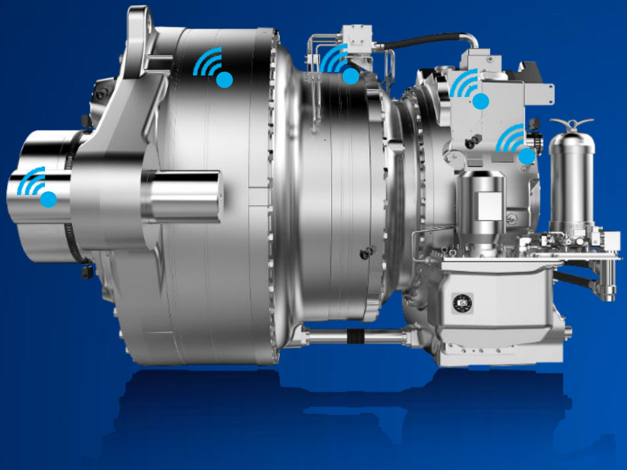


Running Cost Budget Calculator

Input	Response options	Value based on choice	
Fleet size range	Small <100		
	Medium 100-500		
	Large>500	200	
Spare parts intensity slider (spare per 100 turbines)	(1-10)	5	
Average inventory value range	<100kEUR	80	
	100-200 kEUR	150	
	200-500kEUR	350	x
	>500kEUR	500	
Cost of capital slider	(5%-10%)	8.30%	
Choose expected % reduction in inventory	(20%-80%)	60%	
Results	**Current**	**As per Thrive**	**Notes**
Spares quantity	10		
Average annual Inventory value	3,500,000 €	1,400,000 €	
WACC	8.30%	8.30%	Weighted average cost of capital
Capital Cost	290,500 €	116,200 €	
Warehousing rate	2.5%	2.5%	
Storage Cost	87,500 €	35,000 €	
Insurance rate	0.50%	0.50%	
Insurance cost	17,500 €	7,000 €	
Obsolescence	1.5%	1.5%	Obsolete stock
Obsolescence cost	52,500 €	21,000 €	
Handling/Admin/Labor rate	2%	2%	
Handling cost	70,000	28,000	
Inventory quality shrinkage	0.50%	0.50%	Risk associate to damages, defects etc.
Shrinkage cost	17,500	7,000	
Total cost of inventory	518,000.01 €	207,200.01 €	
Net Benefit		**310,800.00 €**	



Case studies THRIVE



SPOS - Turbine downtime prevented with digitalization

- Large utility with wind capacity of 1.4 GW
- ZF supports with Service and Digitalization
- **SPOS** contract with over 70 ZF gearboxes in more than 10 wind parks

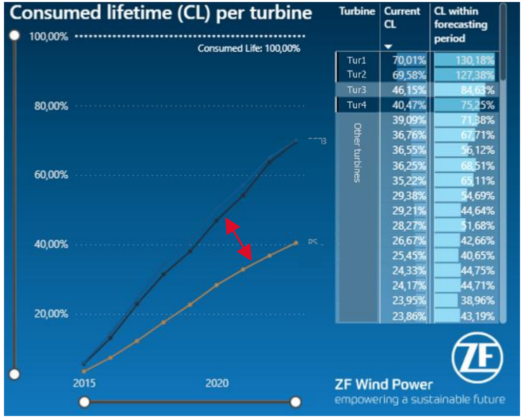
- SPOS report showed increased consumed lifetime of two EH804 (comm. 2012)
- Installed CMS on both, with no alarms
- Last inspection for one 2019 and other in 2022
- ZF advised inspection of both gearboxes

- Gearboxes found not in good condition:
    - metal debris, micropitting on planet wheels and sun pinions of helical and planet stage
- Recommendation inspection team: change one gearbox in 3, other in 6 months
- Recommendation ZF specialist: change both immediately to avoid further damage

→ Reduced **repair costs** due to **proactive** insights

→ Downtime prevented

→ Planning **optimization** for both customer and ZF



Fast Return To Operation case study

European market

Approximately 100 wind turbines

Joint project SKF and ZF

Fast Return To Operation – case study

	CMS ONLY		CMS + ZF FRTO	
	Method	**Duration**	**Method**	**Duration**
Anomaly detected	Automated	N/A	Automated	N/A
Diagnostic of component affected	Manual by Monitoring Expert	HSS GS2	Automated alert processing	HSS GS2
ZF Quotation	Manual request by Procurement	Jan 2020	Automated proactive quotation	Jan 2021
Field service activity recommendation	Manual by Field Service Team	GPV 451-T exchange HSS-TRB (GS-55)	Automated alert-based recommendations	GPV 451-T exchange HSS-TRB (GS-55)
Lead time for parts	Procurement	12 - 14 weeks	Automated proactive optimum stock planning	0 days (parts proactively in stock)
Repair date	Field Service Team	May 2020	Field Service Team	Jan 2021
Total lead time to repair	12 - 14 weeks		0 – 2 weeks	

Realized improvements:

FRTO - Optimizing O&M after main shaft failure with digitalization

- Large utility with over 5 GW renewable energy capacity
- ZF supports with Service and Digitalization
- **FRTO** contract with over 21 ZF gearboxes

- Installed CMS of several turbines show increased overall vibrations
- Request to ZF for indication of severity and impact on drive train components
- ZF informs that higher axial loads will lead to premature gearbox failure
- Customer asks for further evaluation and shares CMS data

- ZF report shows indication of damage in gearbox planet carrier bearings
- Customer borescope report confirms results from ZF investigation
- Damaged raceway and rollers of main bearing, smearing damage initiation
- Conclusion: gearbox replacement while exchange of main bearing

→ Two **EH851** gearboxes sold due to insights

→ **Optimized** planning for customer and ZF

→ **Insights** on main shaft failure and impact on gearbox

Thrive Partnership Agreements

Benefits		Thrive L1	Thrive L2	Thrive L3	Thrive L4
Services Powered By Analytics	Spare Parts Optimization Service (SPOS) - Spare parts recommendation report - ZF gearbox expertise and support - Gearbox O&M documentation	○	●	●	●
	Fast Return To Operations (FRTO) - SPOS benefits included - Alert based recommendations	○	–	●	●
Spare Parts & Inventory	Online gearbox pool access	●	●	●	●
	Spare parts management	●	●	●	●
	Optimized spare parts planning	–	●	●	●
	Guarantee short lead times	–	–	–	●
	Delivery support	–	●	●	●
Business Benefits	Preferential service rates	–	●	●	●
	Warranty extensions	–	●	●	●
Gearbox Repair	Field Service	●	●	●	●
	Workshop repair	●	●	●	●
Trainings & Technical Support	Partner Training	–	●	●	●

○ Available upon request

empowering a sustainable future **together**

Matthias Vittinghoff
Global Lead Thrive Partnership Agreements
matthias.vittinghoff@zf.com
+49 172 6897316

Thrive