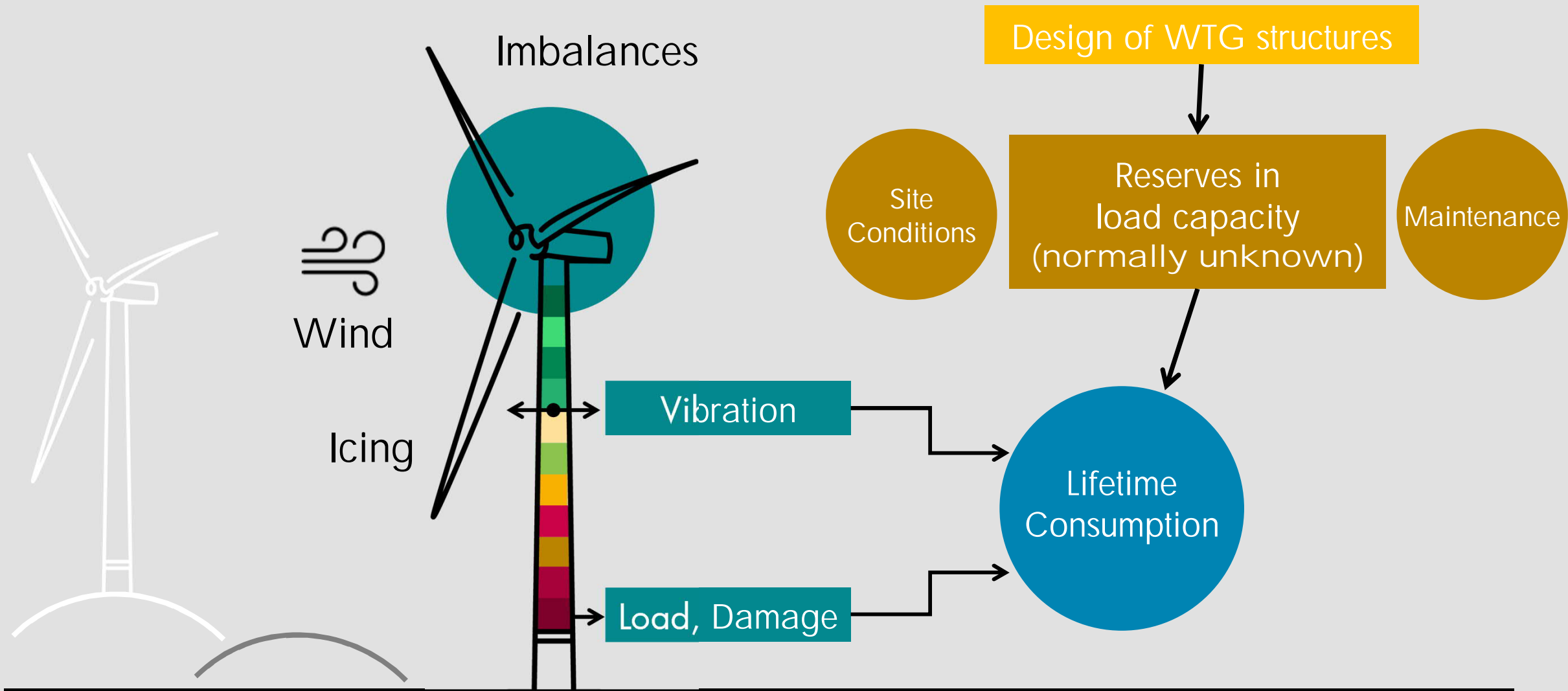




# EFFECT OF HEAVY ROTOR BLADE ICING TO LIFETIME CONSUMPTION OF TOWER AND FOUNDATION

DR. CARSTEN EBERT, DR. MANUEL ECKSTEIN

# MOTIVATION – OPTIMIZE THE LIFETIME OF YOUR WTGS

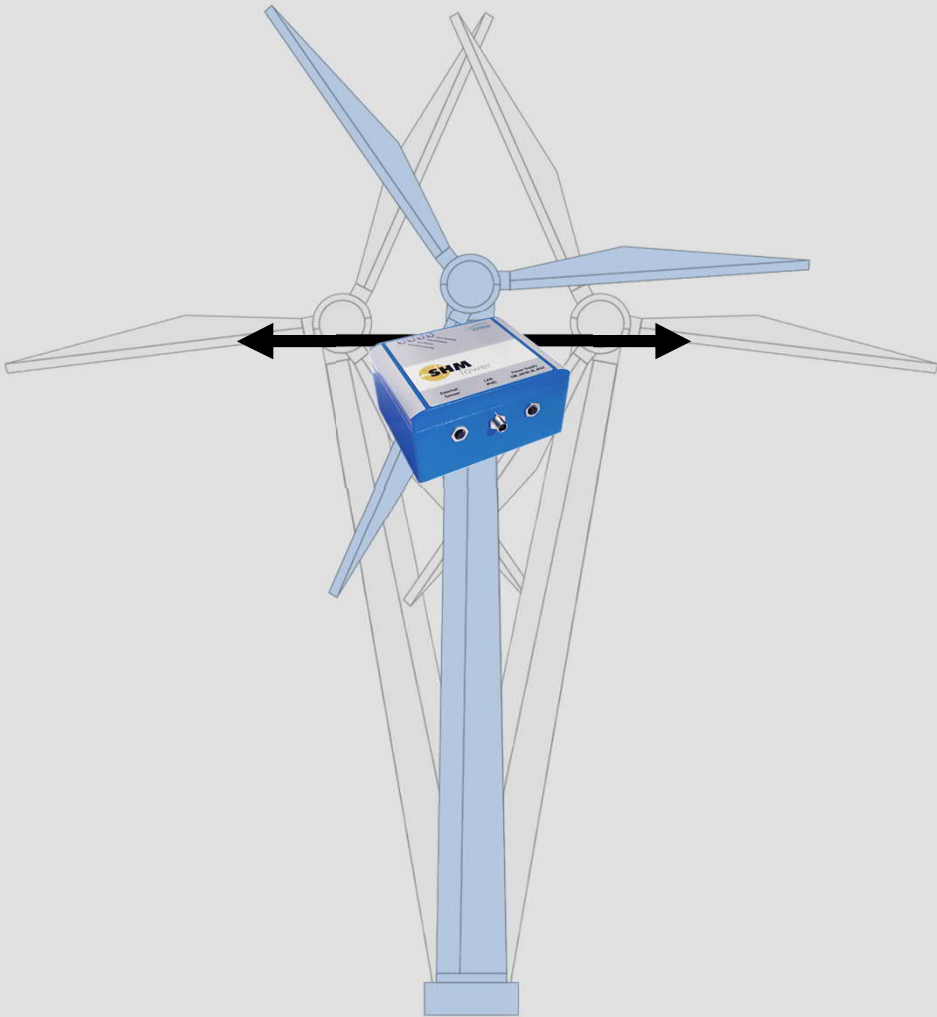






# WHAT IS TO DO TO MONITOR THE RESERVES IN LOAD CAPACITIES





## SHM.Tower – Accelerometer for tower monitoring

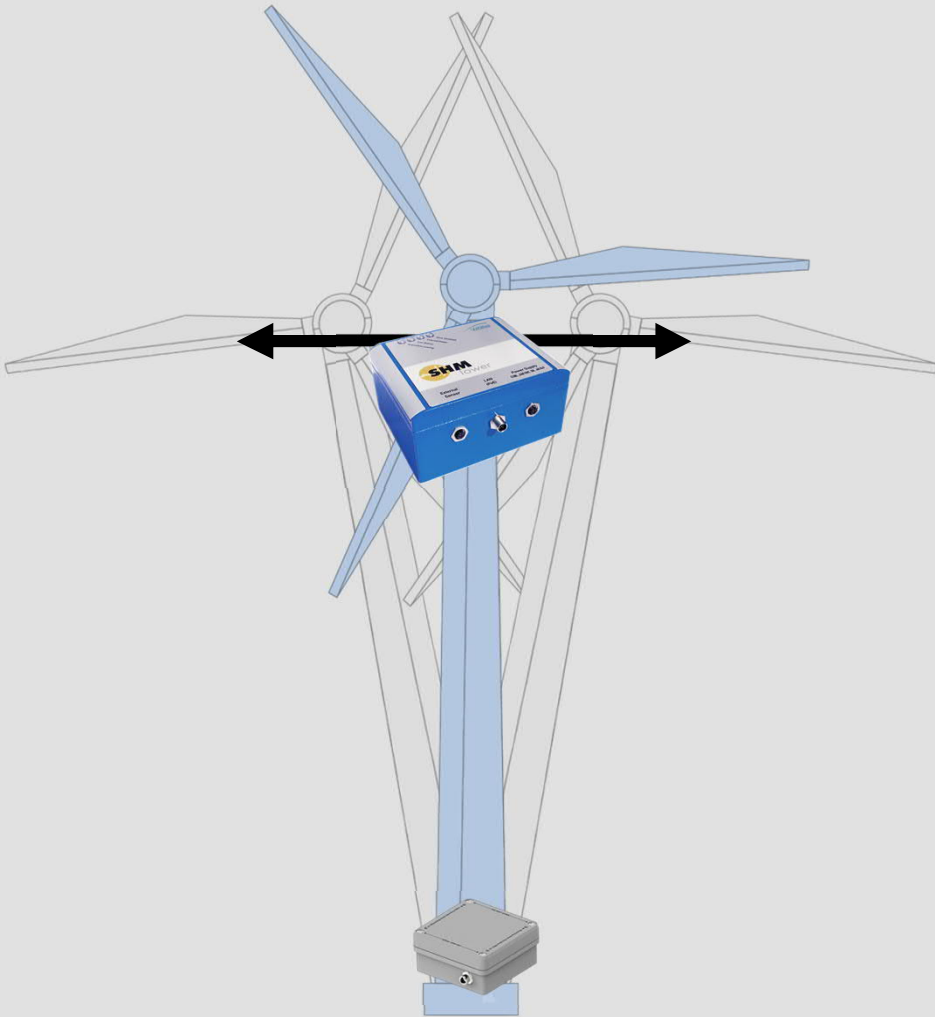
- Vibration and load monitoring
  - Battery inside for self-sufficient operation
- During the entire service life, the stored and directly evaluated data provides precise information on all modules.



Measuring range	$\pm 2g$
Frequency range	0.1 – 10 Hz
Sampling rate	$f_s = 25.6 \text{ Hz}$
Noise level	$\leq 50 \mu g/\sqrt{\text{Hz}}$

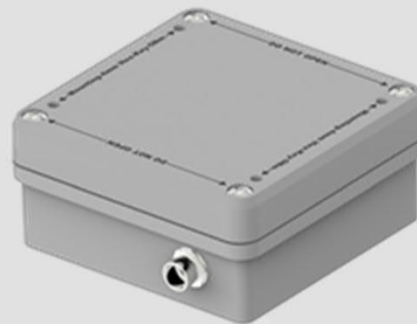


# RELIABLE SOLUTION FOR TOWER AND FOUNDATION MONITORING



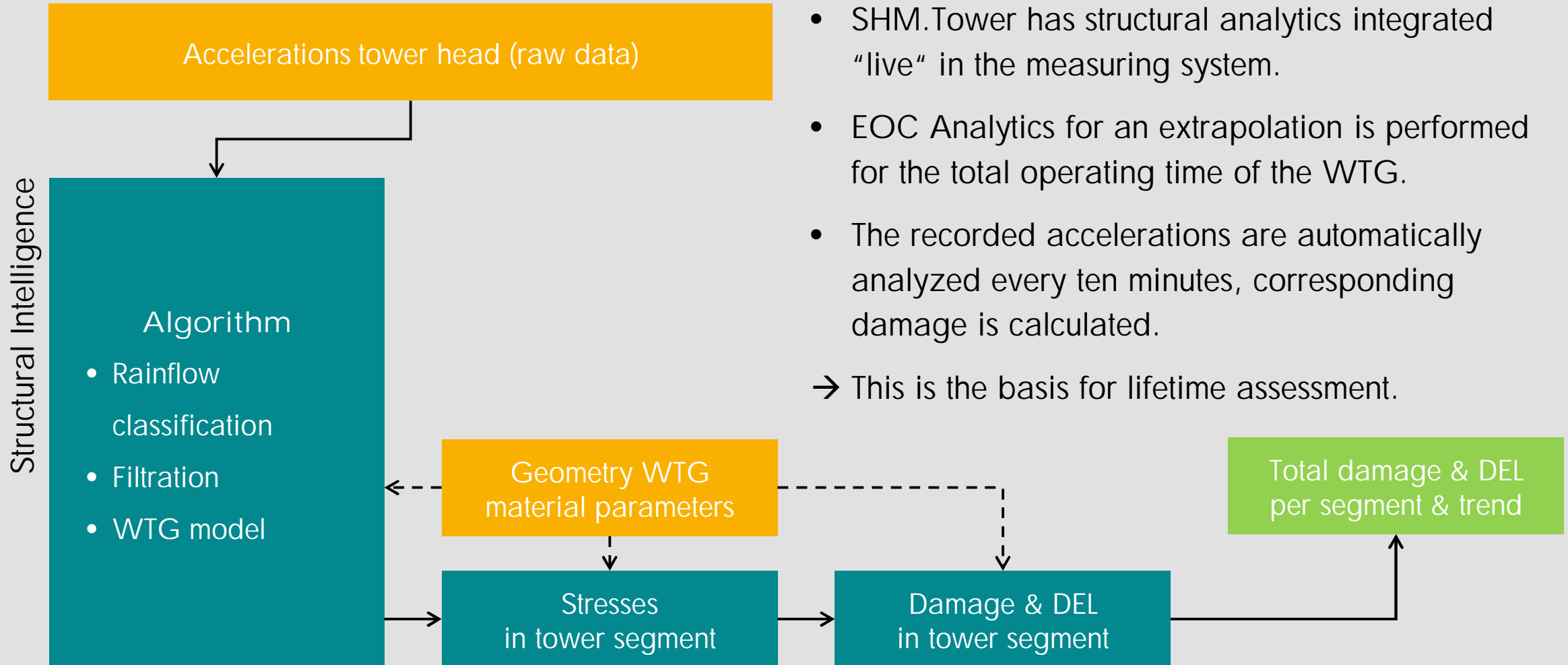
## **Inclinometer for** additional foundation monitoring

- Inclination of tower
- Static inclination
- Status of foundation



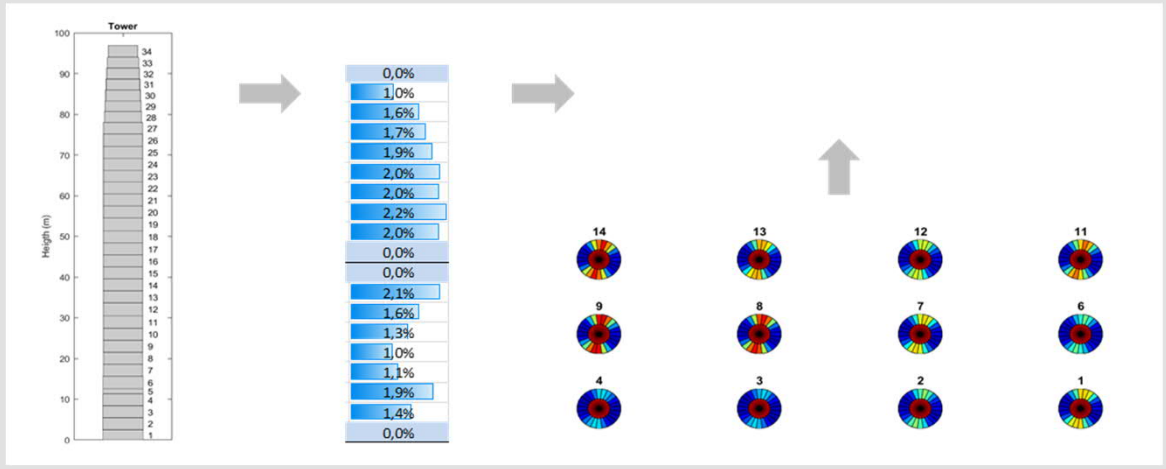
Measuring range	+/- 15°
Sensitivity	0.555 mA/°
Resolution	0.0015°
Noise level	0.0005°/√Hz

# LIFETIME MONITORING FOR LIFETIME ASSESSMENT AND EXTENDED OPERATION



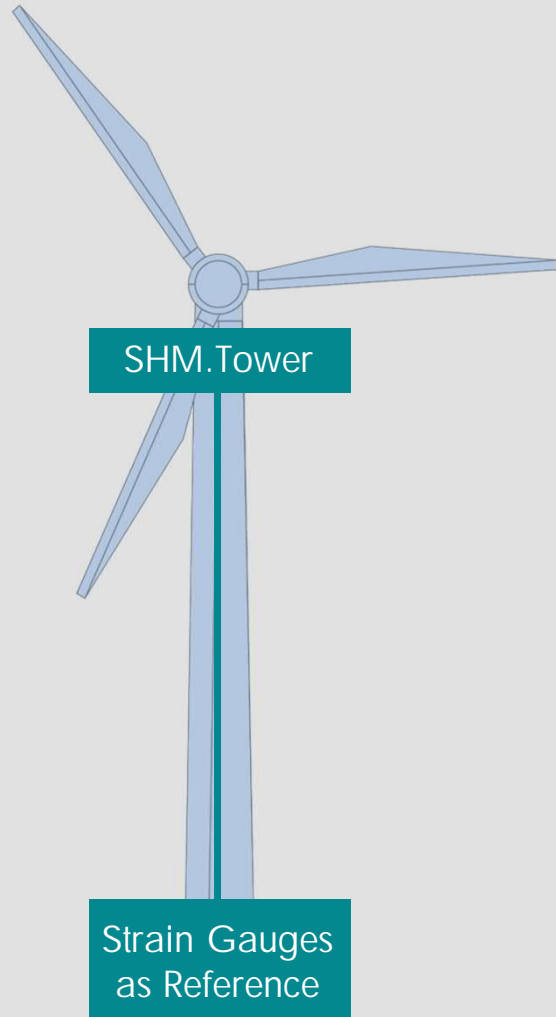
- SHM.Tower has structural analytics integrated “live” in the measuring system.
  - EOC Analytics for an extrapolation is performed for the total operating time of the WTG.
  - The recorded accelerations are automatically analyzed every ten minutes, corresponding damage is calculated.
- This is the basis for lifetime assessment.

# LIFETIME MONITORING AND EXTENSION TO RAISE YOUR REVENUE

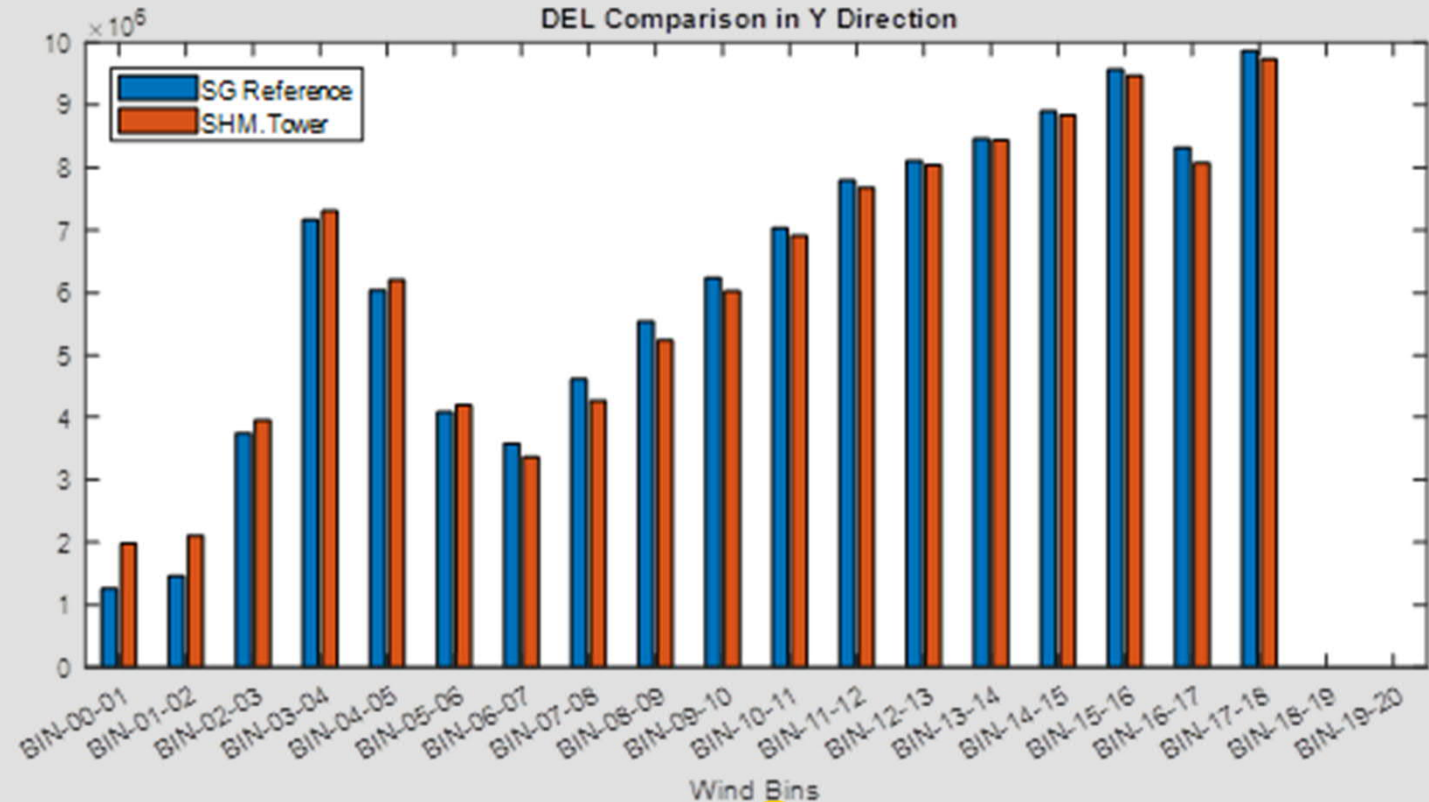


- Trend of consumed lifetime for each tower segment – daily/monthly WTG check
- Windfarm portfolio analysis: Detection of individual WTG's problems
- Catching the total potential for the lifetime extension of your turbine
- Easy lifetime extension using real load data for re-certification after 20 years

# VALIDATION OF SHM.TOWER FOR PRODUCT CERTIFICATION



Bending Moments Tower Bottom	Strain Gauges (Reference)	SHM.Tower Acceleration Sensor
DEL	5748.6 kNm; 100 %	5735.0 kNm; 99.8 %
Damage	100 %	98.8 %

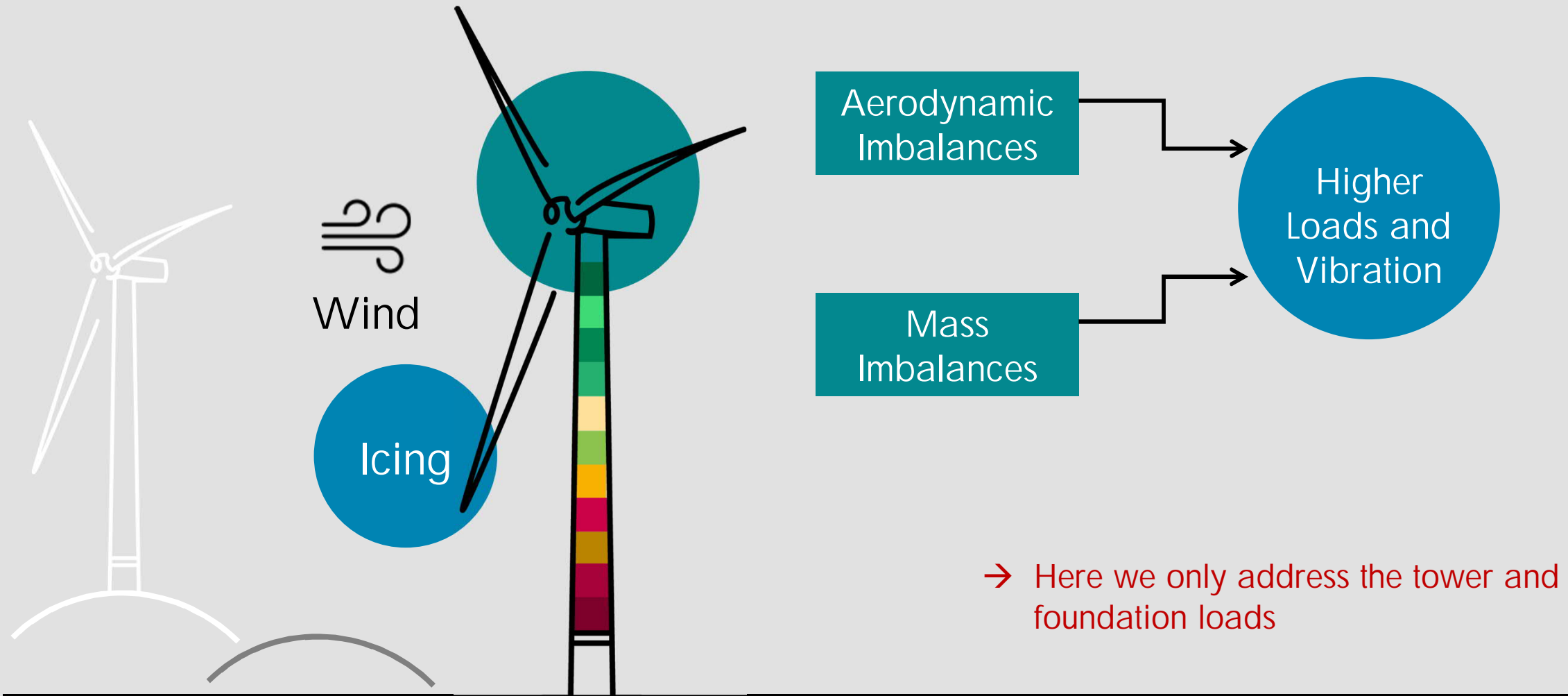






# EFFECT OF ROTOR BLADE ICING TO TOWER VIBRATIONS

# EFFECTS OF ROTOR BLADE ICING



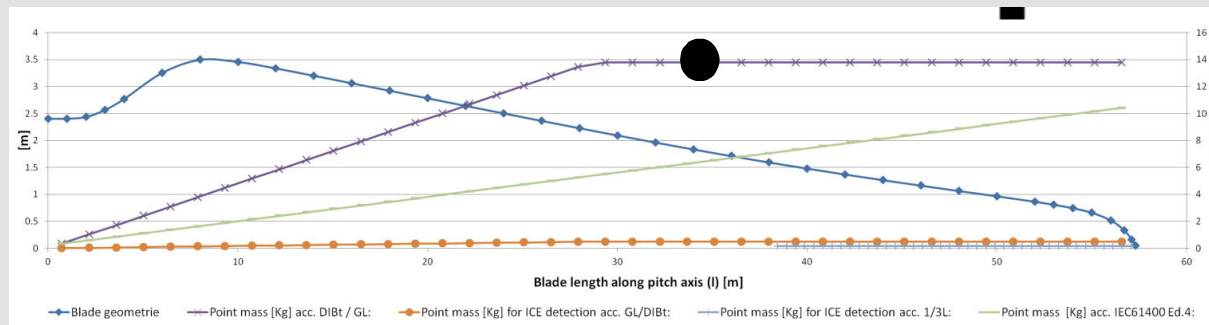


# IMBALANCES DUE TO ROTOR BLADE ICING

- As a rule, ice loads must be taken into account during the design
- The load assumptions for ice loads differ in the various guidelines (radial distribution; ice mass)

→ Example for a typical 2.5 MW turbine

100 % → 610 kg @ 35.5 m; 80 % → 490 kg

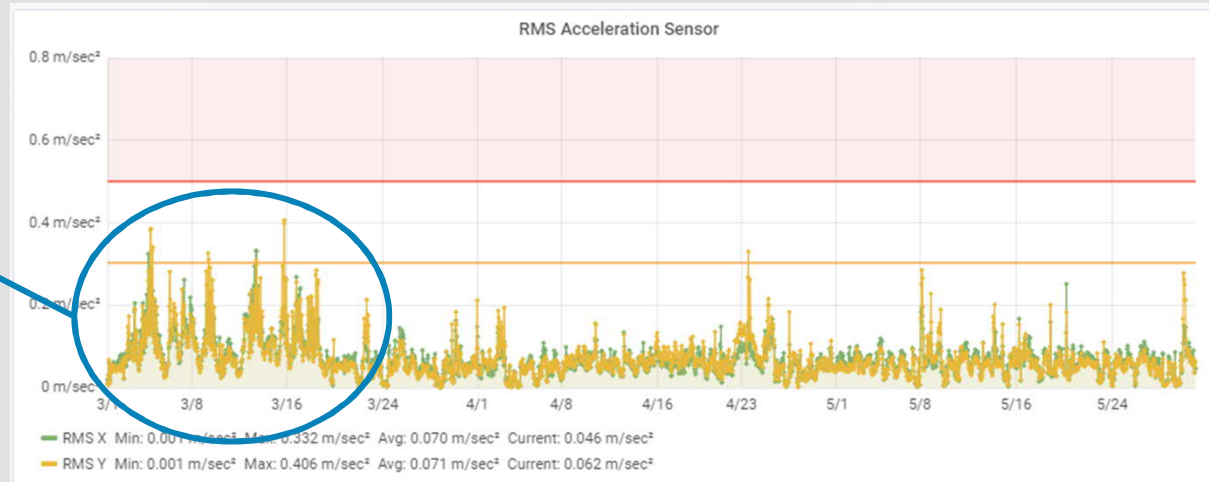


Resulting mass imbalance: ~ 4.300 kgm !!

For normal operation (without ice) normally ~ 150...300 kgm are expected (depending on design; turbine type; blade size and mass; ...)



Ice Induced  
Vibration  
Increase



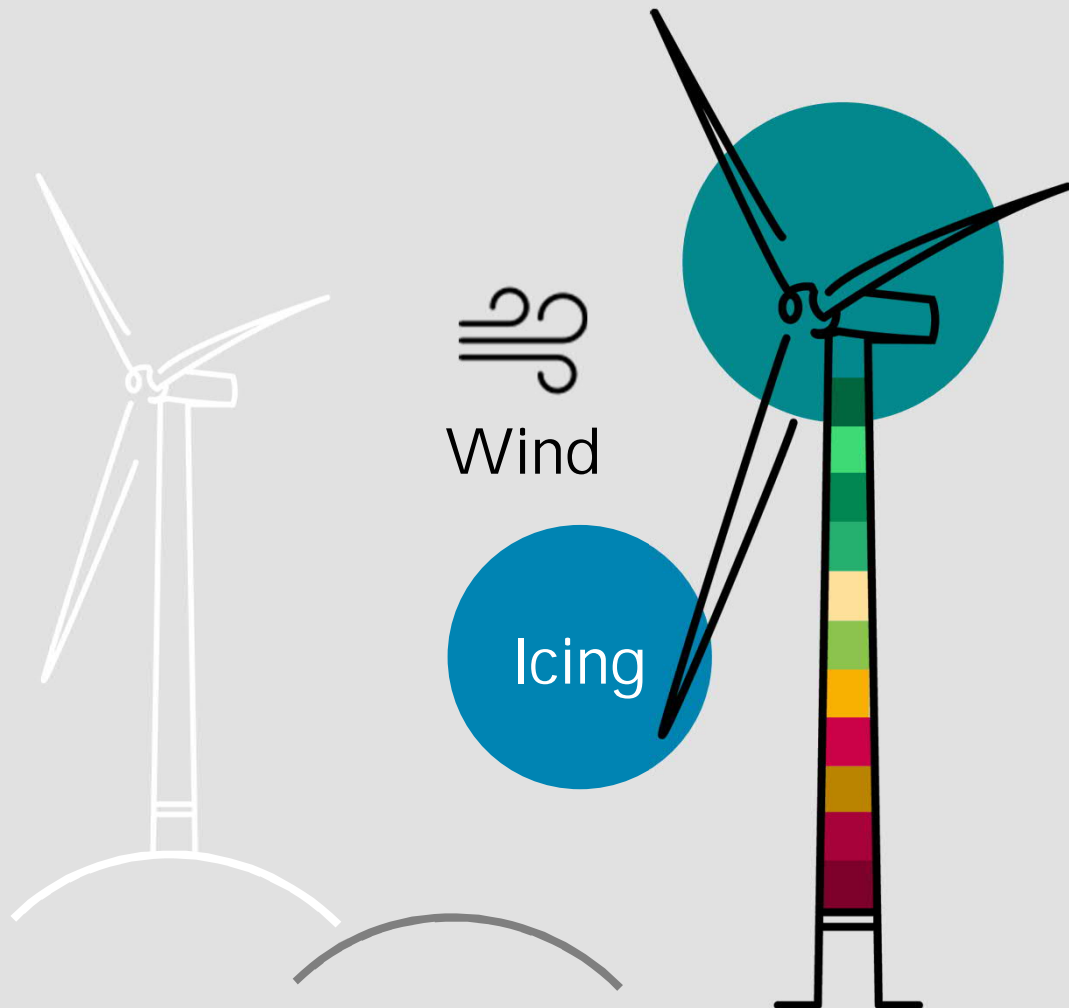
Example with 4.300 kgm mass imbalance:

→ ~ 90 mm/s (unbalanced quality group)

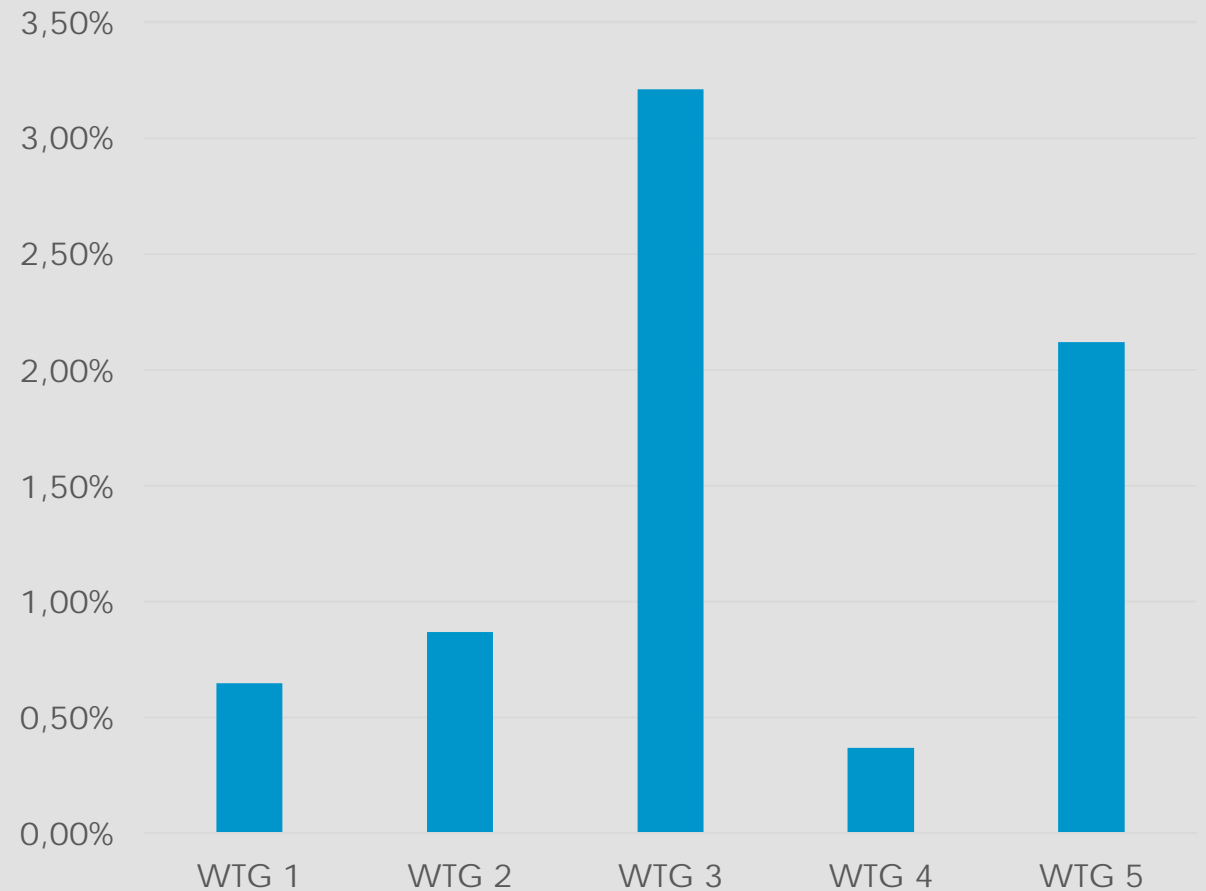
*Typical expected unbalanced quality groups for wind turbine rotor are G1.0 ... G16 (mm/s) (depending on turbine type)*

➡ Linear behaviour between unbalance and tower vibration ratio

Vibration Level of WTG Tower	Extension / Reduction of Tower Lifetime
50 %	+1500 %
75 %	+ 216 %
90 %	+ 52 %
95 %	+ 23 %
100 % (Design)	0 %
110 %	- 32 %



Lifetime consumption for a winter season







# STRUCTURAL INTELLIGENCE PORTFOLIO





# SHM.TOWER ADDS MORE YEARS OF INCOME

SHM.Tower – Vibration-based Tower Monitoring

Natural Frequencies

Moments, Loads and Stresses

Lifetime

Rotor Imbalances

Foundation



**SHM**  
Blade  
Vibration-based  
Blade Monitoring

**SHM**  
Tower  
Vibration-based  
Tower Monitoring

**SHM**  
Foundation  
Vibration-based Monitoring  
of Onshore Structures

- Specialized for monitoring of the complete structure
- References throughout the whole wind industry
- Supplier to more than 10 OEMs
- Global install base: 1,800 systems



# DO YOU WANT TO MAXIMIZE THE LIFETIME OF YOUR WTG?



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