

WindGEMINI

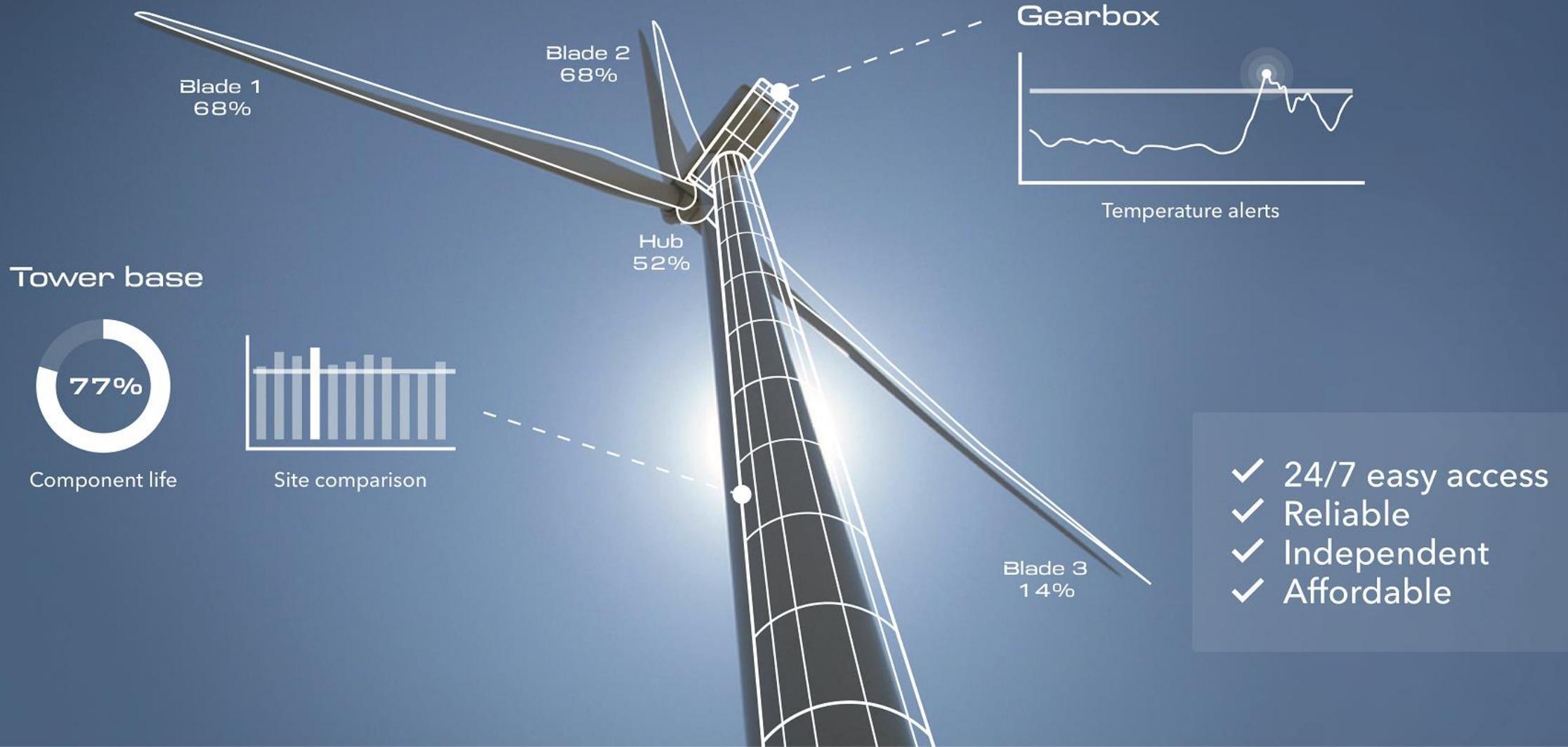
An Online Digital Twin for Wind Farm Operations

Global Wind Day Seoul

22 June 2018

WINDGEMINI

A digital twin for your wind farm by the world's renewable expert.



Introduction

The Digital Twin framework

Reliability

Drivetrain Integrity Module

Structural Integrity Module

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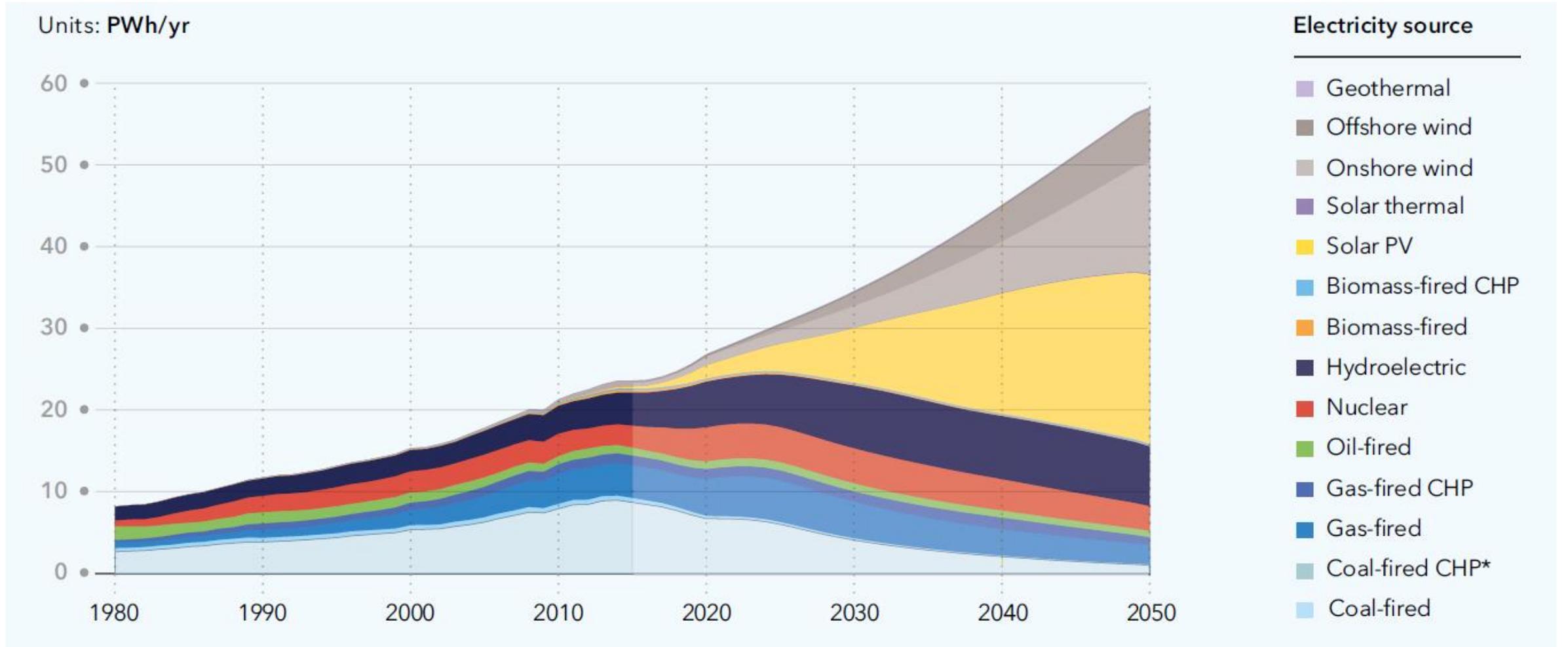
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DNV GL Energy Transition Outlook



<https://www.dnvgl.com/technology-innovation/sri/climate-action/research-projects/energy-transition-outlook.html>

How to make operations smarter?

- Typical “pains” of an Owner/Operator
 - Are my turbines operating as well as they could?
 - How many failures can I expect over the next year?
 - Which turbines should be inspected first?
 - Will I be able to operate my wind farm past year 20?
 - Is my budget realistic?
- Owners and operators have different constraints from designers:
 - Limited capability to invest in large studies or optimisation campaigns
 - Short decision making time
- WindGEMINI is a digital twin designed to increase revenue and reduce O&M costs



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What is a digital twin – and how does it help?

Digital Twins

From Wikipedia, the free encyclopedia

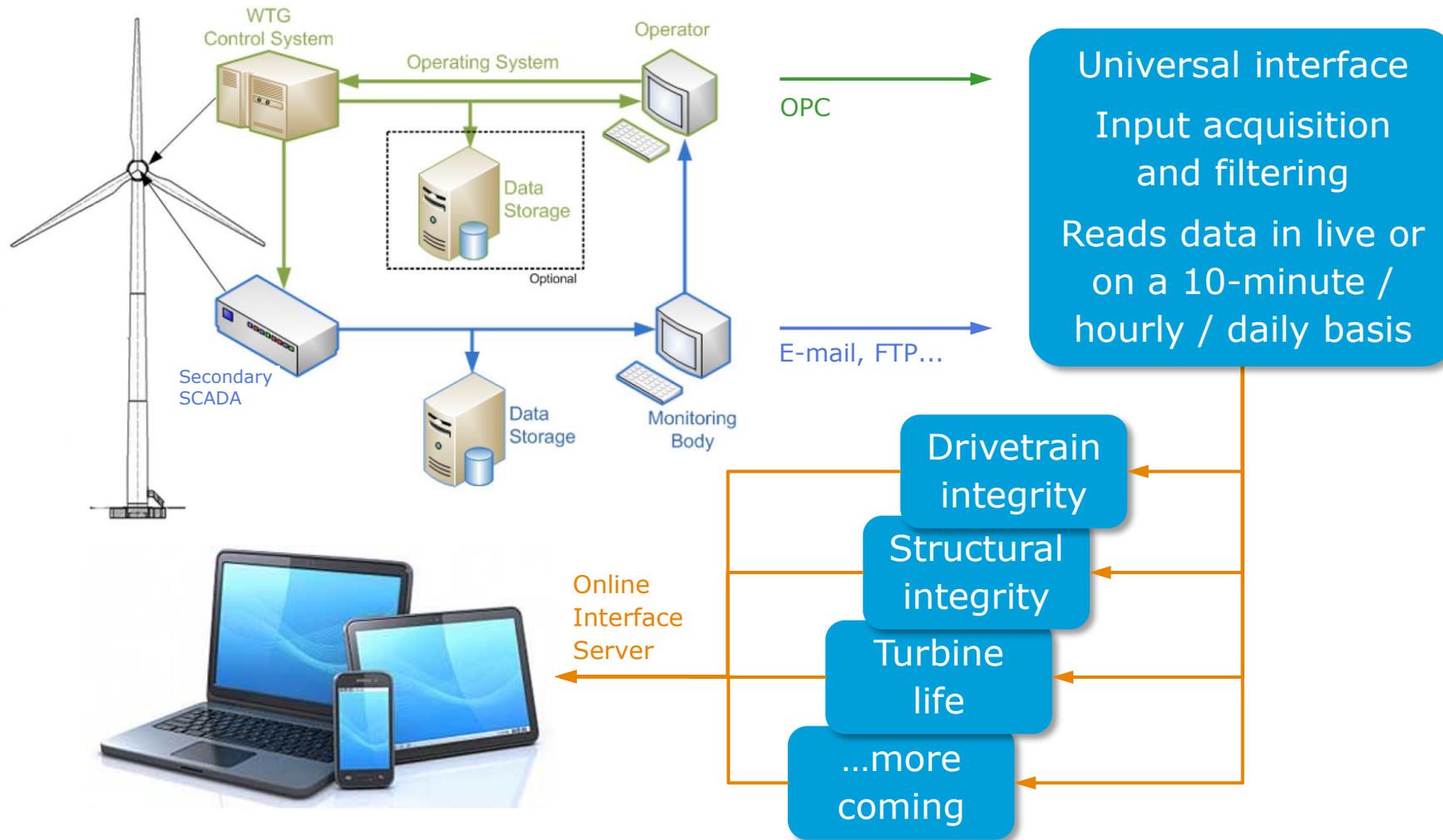
Digital twins refer to computerized companions of physical assets that can be used for various purposes.

Digital twins use data from **sensors** installed on physical objects to represent their near real-time status, working condition or position.



- WindGEMINI is a framework rather than an algorithm
- It is a physics-based “multi-system” model of an operating turbine
- Updated in “near” real-time, making use of SCADA data from the turbine and wind farm sensors
- Provides at any given time an indication of the condition and value of each individual wind turbine
- Assists owners and operators in predicting failures and in optimising servicing and inspections
- Alerts are raised automatically and can be reviewed by an analyst before being published

Structure of the online digital twin



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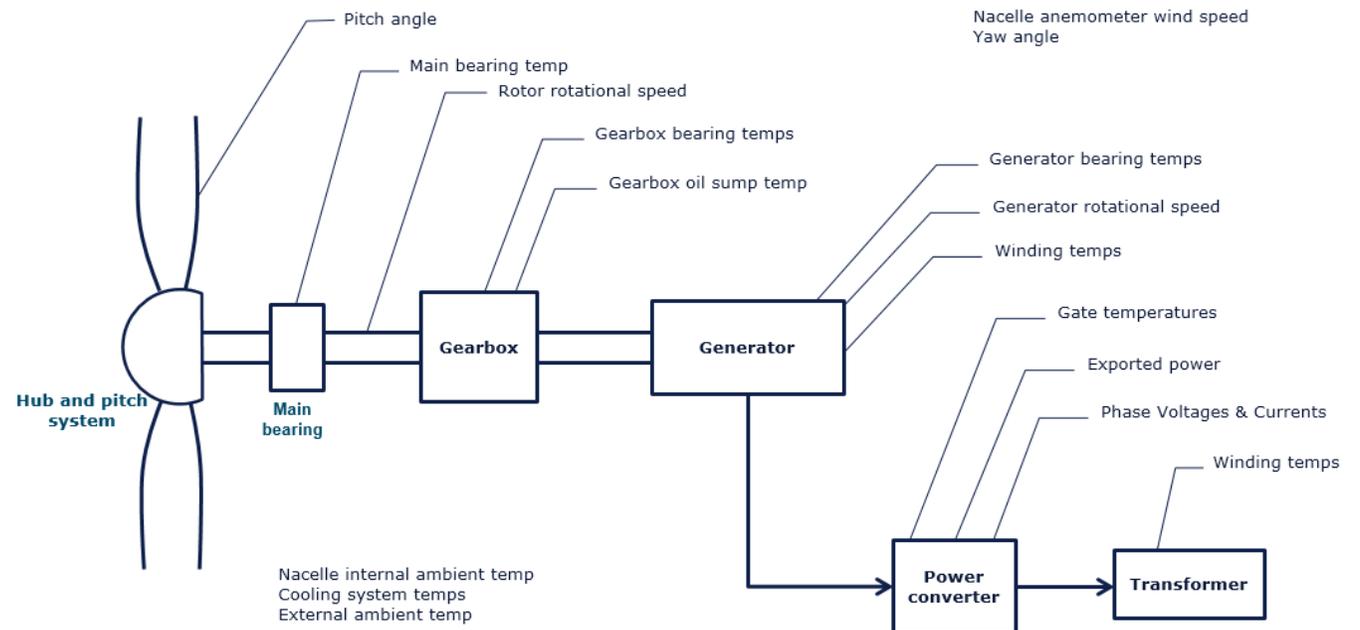
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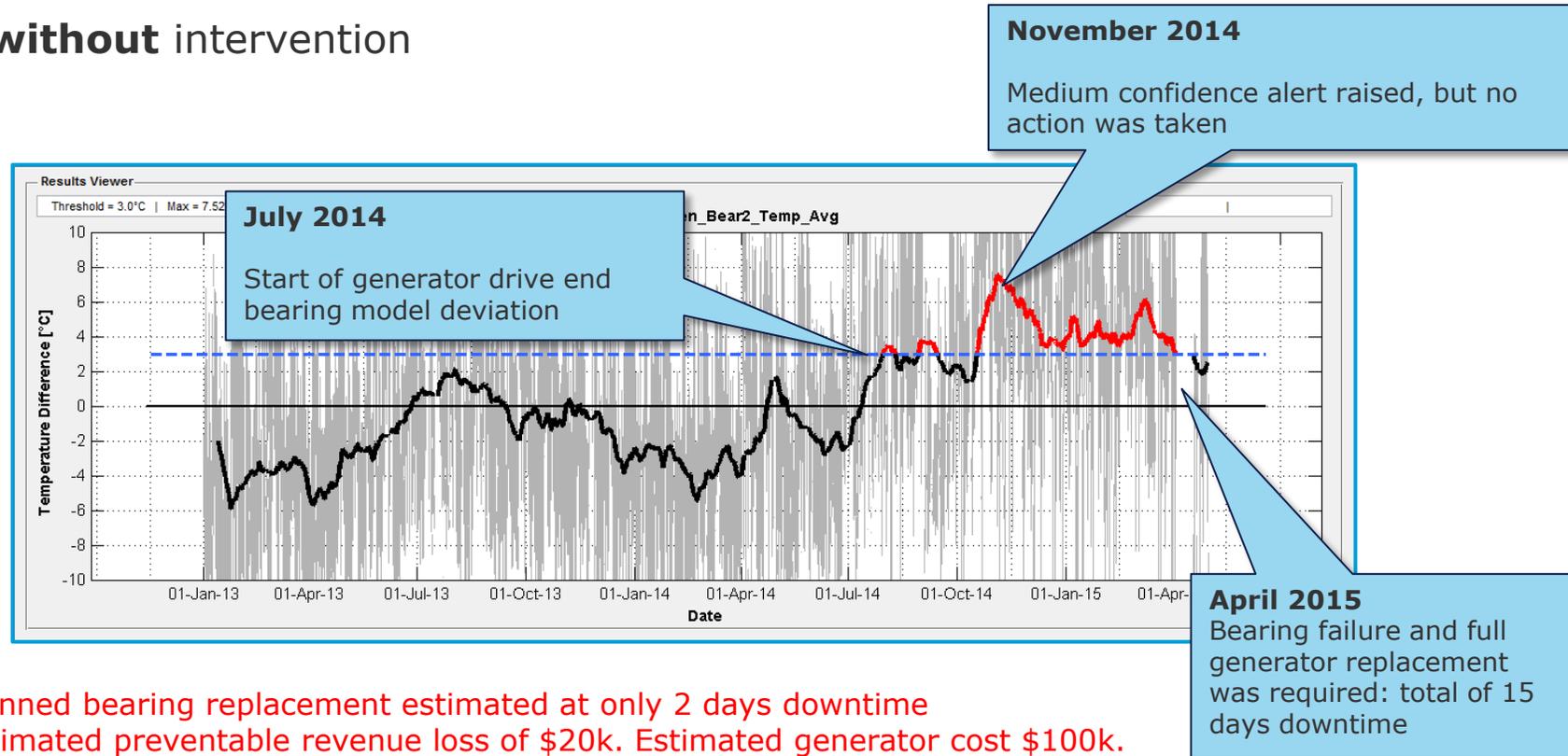
Drivetrain Condition Monitoring

- Failure detection algorithm that uses existing 10-minute SCADA data
- Based on trending of the temperature signals from the wind turbine drivetrain
- A period of normal operation is used to establish an expected relationship between input signals (power, ambient temperature, rotor speed) and the drivetrain temperatures being monitored
- This relationship is then used on an ongoing basis to monitor the real temperatures
- No additional sensors are required



Real case study 1 – Generator drive end bearing

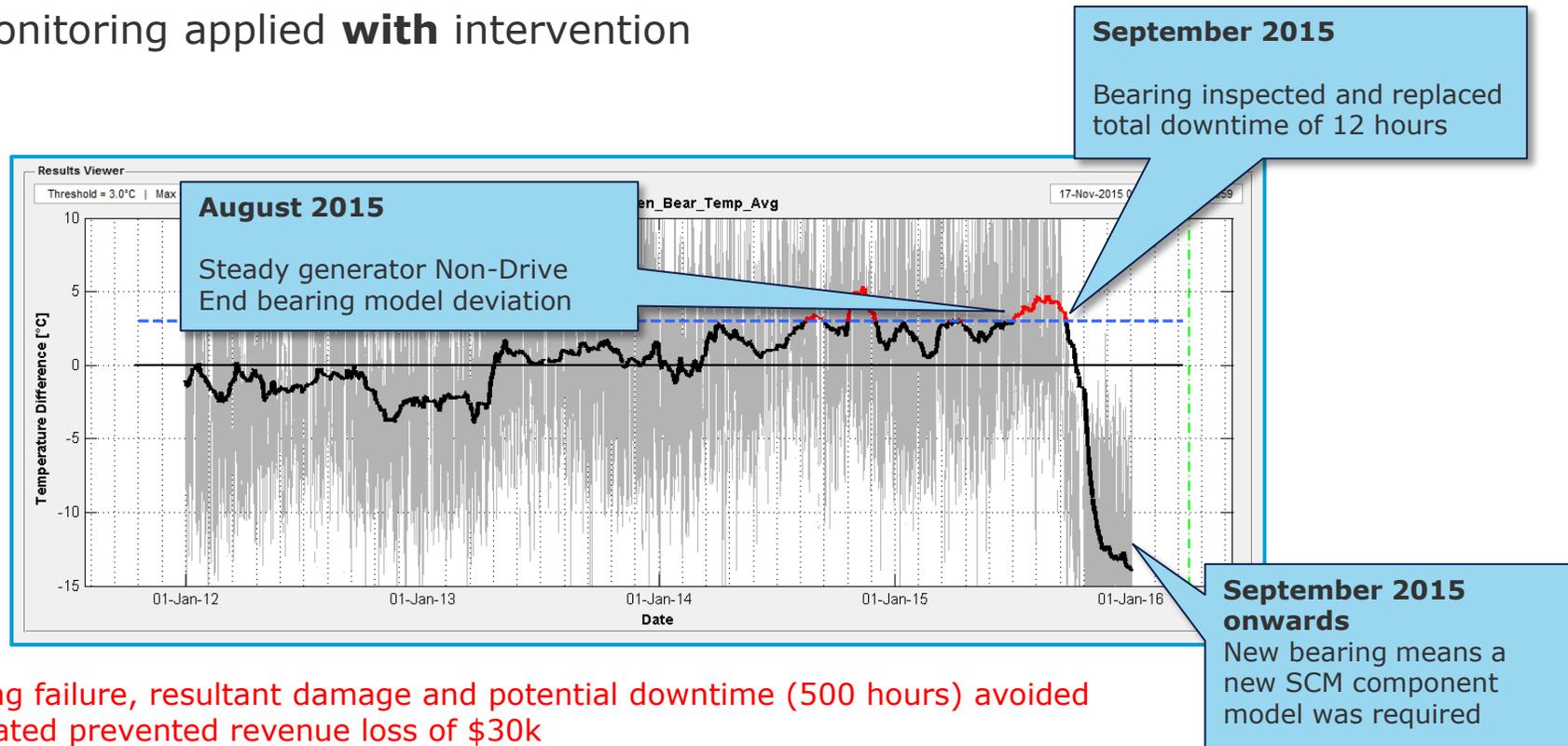
- Traditionally managed wind farm: 'Run to failure' maintenance strategy
- SCM applied but **without** intervention



- Planned bearing replacement estimated at only 2 days downtime
- Estimated preventable revenue loss of \$20k. Estimated generator cost \$100k.

Real case study 2 – Generator non-drive end bearing

- Actively managed wind farm: condition-based maintenance strategy
- SCADA Condition Monitoring applied **with** intervention



SCADA Condition Monitoring in WindGEMINI

WINDGEMINI

Home Portfolio Admin User Admin Scheduled Jobs Export Data Turbine Comparison Chan, Cegeon Log off

Analysts Notes

Note This is bad - please inspect

Recent Feb Mar

TURBINE	COMPONENT	WARNINGS	ALERT	STATUS
WTG01	Gearbox		●	✓ Pending
WTG01	Generator		○	
WTG02	Gearbox		●	📄 Published
WTG02	Generator		○	
WTG03	Gearbox		○	
WTG03	Generator	1 of 5	○	! Unchecked

Graphs

Chart Period 2 years

Sensor Bearing Oil

Sensor Oil

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Identification of structural frequencies

- Analysis of 1s SCADA allows tracking of tower & rotor frequency and power
- A convolution filter identifies frequency and energy levels of the main peaks
- Frequency analysis can identify a number of issues:
 - Shifts in foundation stiffness (degradation)
 - Rotor imbalance
 - Pitch misalignment

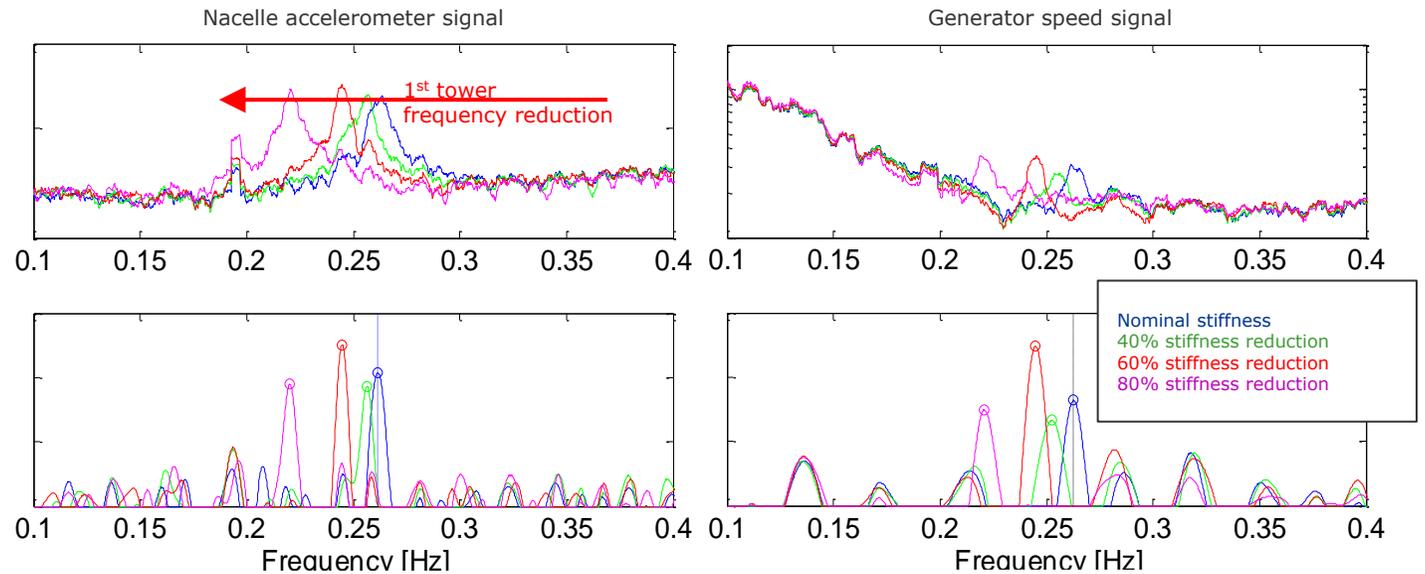
Frequency analysis of 1-s data



Filtering

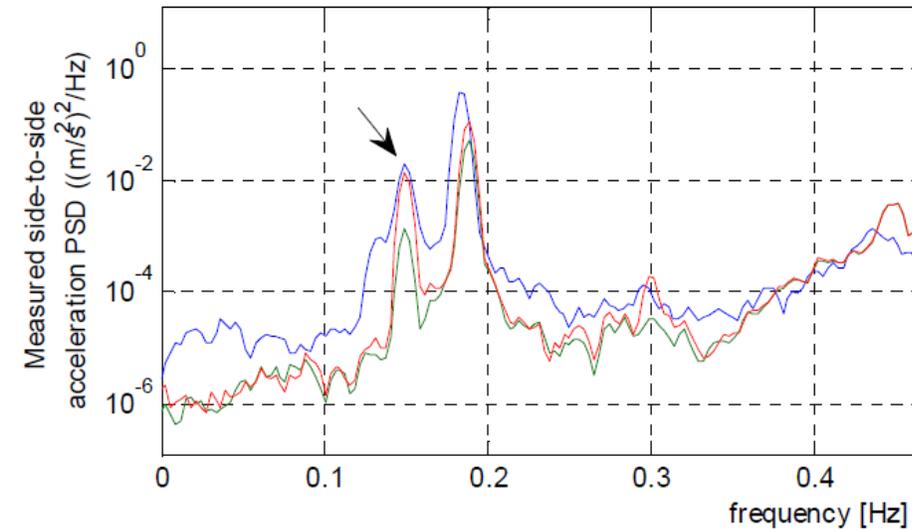
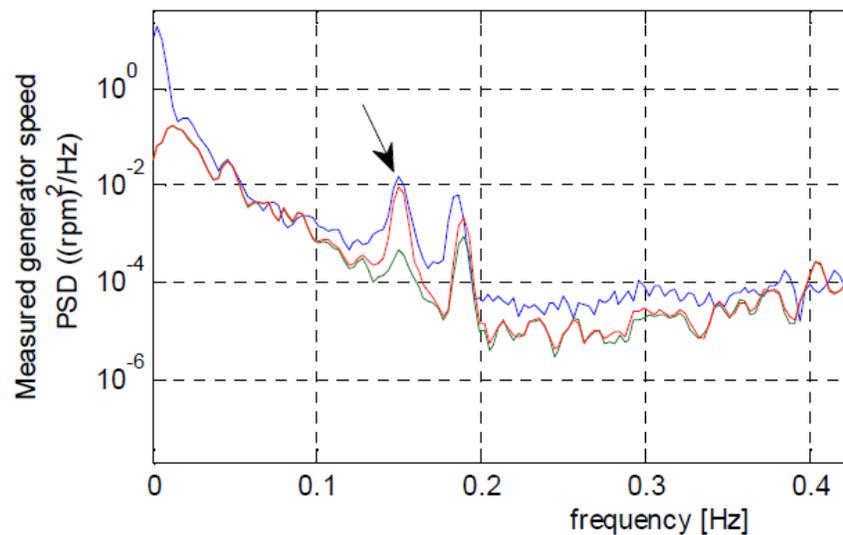


Identification of tower frequency



Real case study – identification of rotor imbalance

- 2015 study on soft-tower turbines
- **T1** autospectra shows more energy than **T2** (and other turbines) at the rotor frequency
- Speed / side-side acceleration points to aerodynamic (pitch) imbalance
- Autospectra were matched by modelling a 2° pitch misalignment
- Inspections confirmed a 1.8° pitch misalignment, later corrected



Structural condition monitoring in WindGEMINI

WINDGEMINI

Home | User Admin | Export Data | Turbine Comparison | Vanni, Francesco | Log off

Breezy Beck

Analysis period: Sep 2017 | Alert History

Map: Bracklinn Falls Bridge

Map callouts: 5, 8, 13, 10

Filter: All components

TURBINE	COMPONENT	WARNINGS	ALERT	STATUS
WTG01	Tower Frequency		●	
WTG01	Rotor Frequency		○	
WTG03	Tower Frequency		○	
WTG03	Rotor Frequency		○	
WTG13	Tower Frequency		○	
WTG13	Rotor Frequency		○	

WTG01, Tower Frequency | Turbine comparison

No automatic alert | Manual alert

Recent: Mar, Apr, May, Jun, Jul, Aug

Analysts Notes | Edit

Note

Recent

Graphs

Chart Period: 2 years

Graph showing Tower Frequency (%) from 01/10/15 to 01/10/17. The frequency fluctuates between 1.5% and 3.0%.

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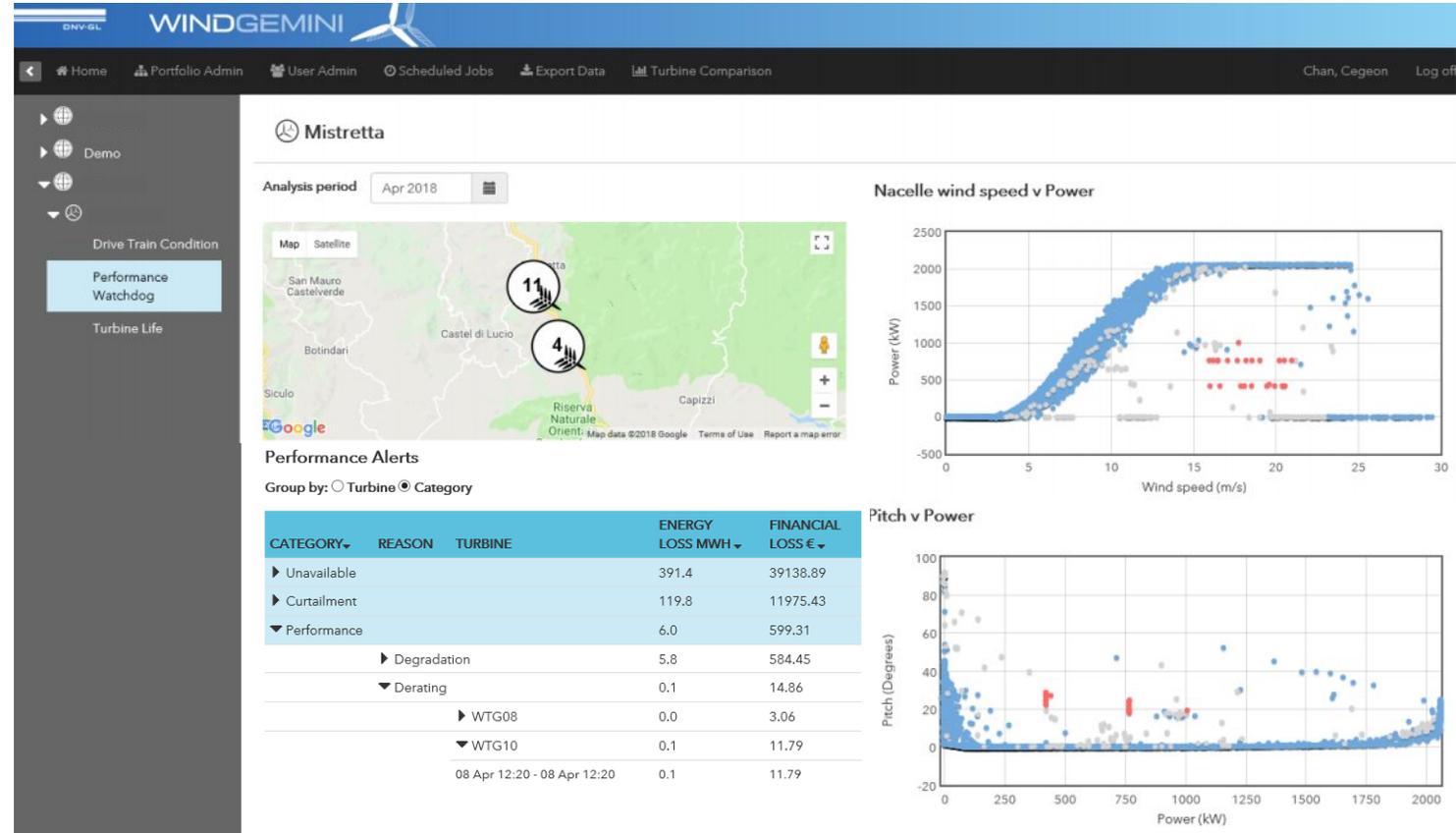
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Performance Watchdog

- DNV GL has analysed over 65 GW of SCADA data
- The Performance Watchdog leverages the knowledge of examining blade pitch vs. power and rotor speed vs. power profiles and flags these issues
- This captures sub-optimal turbine condition issues such as turbine de-rates and incorrect pitch and/or rotor torque settings



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Pattern of Production - Alerts

- Comparison of turbine production with neighbors
- Ability to compare by wind direction
- Automatic alerts of turbine production that has dipped relative to the park-average

The screenshot displays the WINDGEMINI web application interface. The top navigation bar includes 'Home', 'Turbine comparison', and 'Export data'. The user 'Francesco Vanni' is logged in. The main content area is titled 'Pattern of production' and features a map of turbine locations with color-coded alerts. A table below the map lists turbine details, and a 'T01' alert panel shows a 'Wind direction(s) alerted: 345-75°'. A 'Normalised performance' line chart shows a dip for T01, and a 'Turbine comparison: Recent vs. reference' chart compares T01's performance against other turbines.

Turbine	Alert	Status
T01	! (High)	Unchecked
T06	● (Medium)	Pending publication
T011	● (High)	Pending publication
T04	● (Information request)	Published
T02		
T03		
T05		
T07		
T08		
T09		
T10		

Pattern of Production - Analysis

- A tool to customize wind direction sectors and time periods
- Map view of the turbine production

The screenshot displays the WINDGEMINI web application interface. The top navigation bar includes 'Home', 'Turbine comparison', and 'Export data'. The user 'Francesco Vanni' is logged in. The main content area is titled 'Pattern of production' and is divided into 'Alerts' and 'Analysis' tabs. The 'Analysis' tab is active, showing filters for 'Wind direction: 345-75°' and 'Recent period: 11/11/17 to 11/02/18'. A circular wind direction selector is visible. Below the filters, there are tabs for 'Table' and 'Map'. The 'Map' view shows a terrain map with turbine icons color-coded by performance, with a legend for 'Lowest' (red) and 'Highest' (teal). A tooltip for turbine T01 indicates a '-3%' difference. To the right, a 'T01' section shows a 'March alert: Unchecked' and a wind direction indicator. Below this is a 'T01 normalised performance' line chart showing performance over time, with a dashed orange line for 'Site average'. At the bottom right, a 'Turbine comparison: recent vs. reference' line chart compares 'Recent' (blue) and 'Reference' (orange) performance across turbines T01 to T19.

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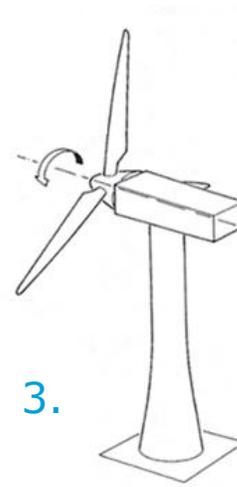
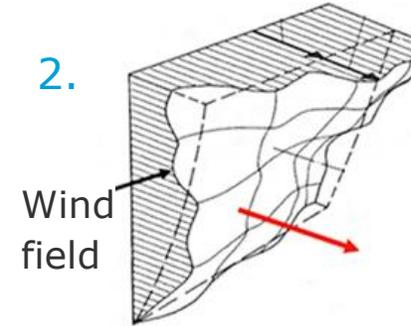
Fatigue lifetime estimator

1.



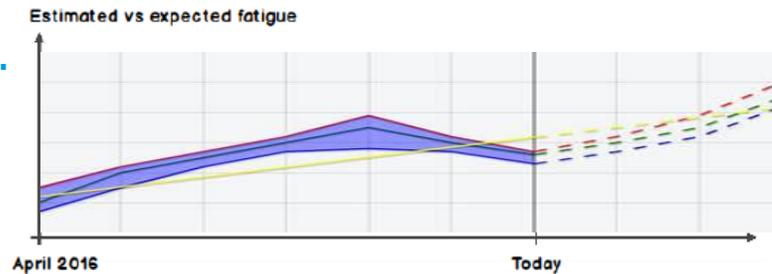
1. Acquire field data
2. Model site conditions based on real data
3. Estimate turbine state
4. Calculate loading and estimate uncertainty
5. Calculate Damage Equivalent Loads

2.



3.

5.



4.



Fatigue life estimator in WindGEMINI

The screenshot displays the WindGEMINI web application interface. At the top, the DNV-GL logo and 'WINDGEMINI' are visible. The navigation bar includes links for Home, Portfolio Admin, User Admin, Scheduled Jobs, Export Data, and Turbine Comparison. The user 'Chan, Cegeon' is logged in. A sidebar on the left lists various turbine sites, with 'Turbine Life' selected. The main content area features a map with two turbine locations marked with circled numbers 5 and 6. Below the map is a table of estimated accumulated fatigue years for various turbine components.

Estimated accumulated fatigue years

TURBINE	BLADE	STATIONARY HUB	TOWER BASE	YAW BEARING
WTG10	7.3	6.3	6.2	6.3
WTG05	7	6.1	6.2	6.1
WTG07	6.9	6	6	6
WTG03	6.9	5.8	5.8	5.8
WTG11	6.8	5.9	5.9	5.9
WTG04	6.8	5.8	5.8	5.7
WTG02	6.8	6	6.1	6
WTG06	6.6	5.7	5.7	5.7
WTG08	6.4	5.5	5.5	5.5

Below the table, there is a section for 'Analysts Notes' with an 'Edit' button and a 'Graphs' section titled 'Estimated accumulated fatigue'. The graph plots 'Fatigue age' (blue line) and 'Nominal age' (green line) from 2010 to 2019. The y-axis represents years from 0 to 10. The 'Nominal age' is a straight line starting at 0 in 2010 and reaching 9 in 2019. The 'Fatigue age' is a blue line that follows the nominal age but shows a slight deviation, reaching approximately 8.5 years by 2019.

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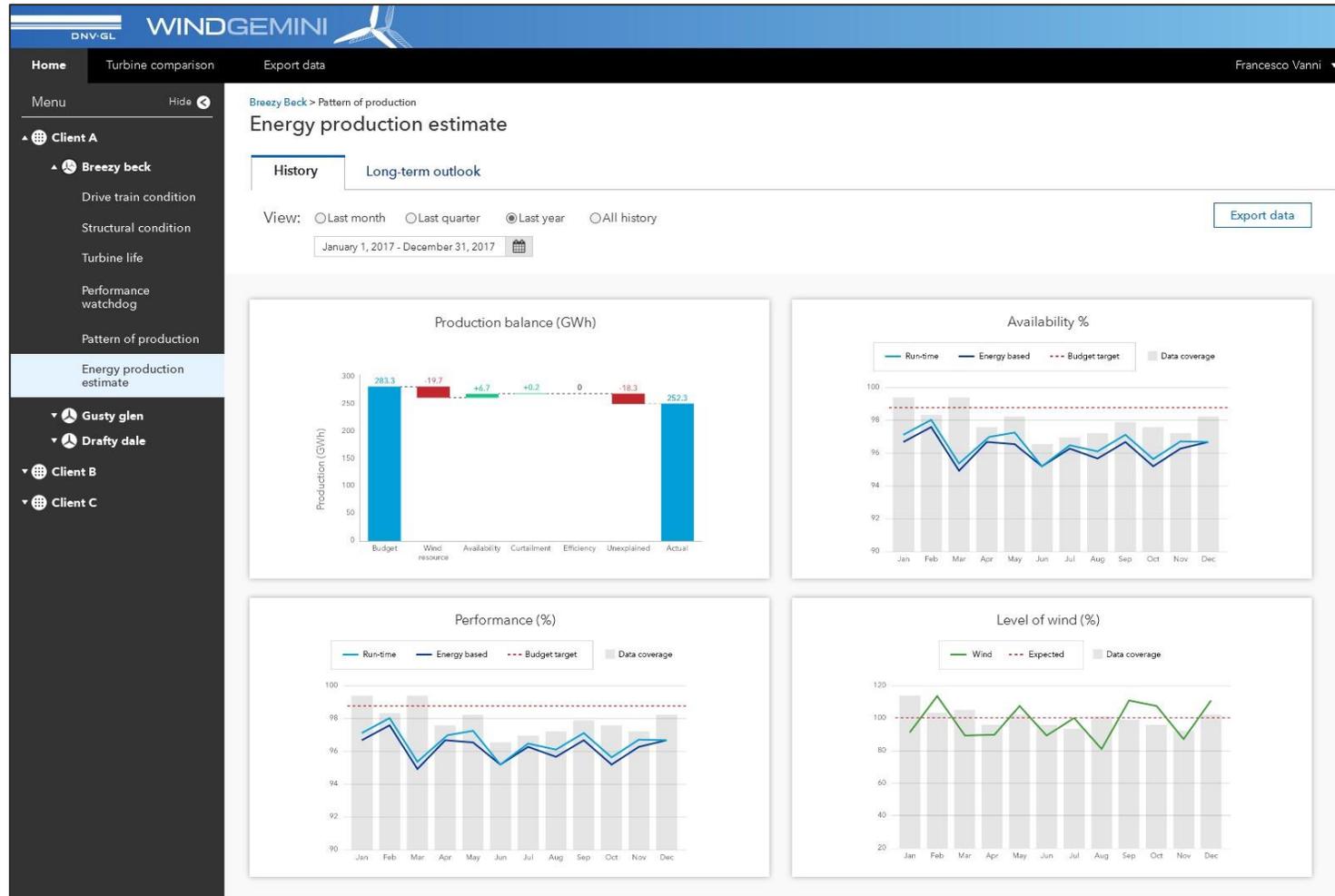
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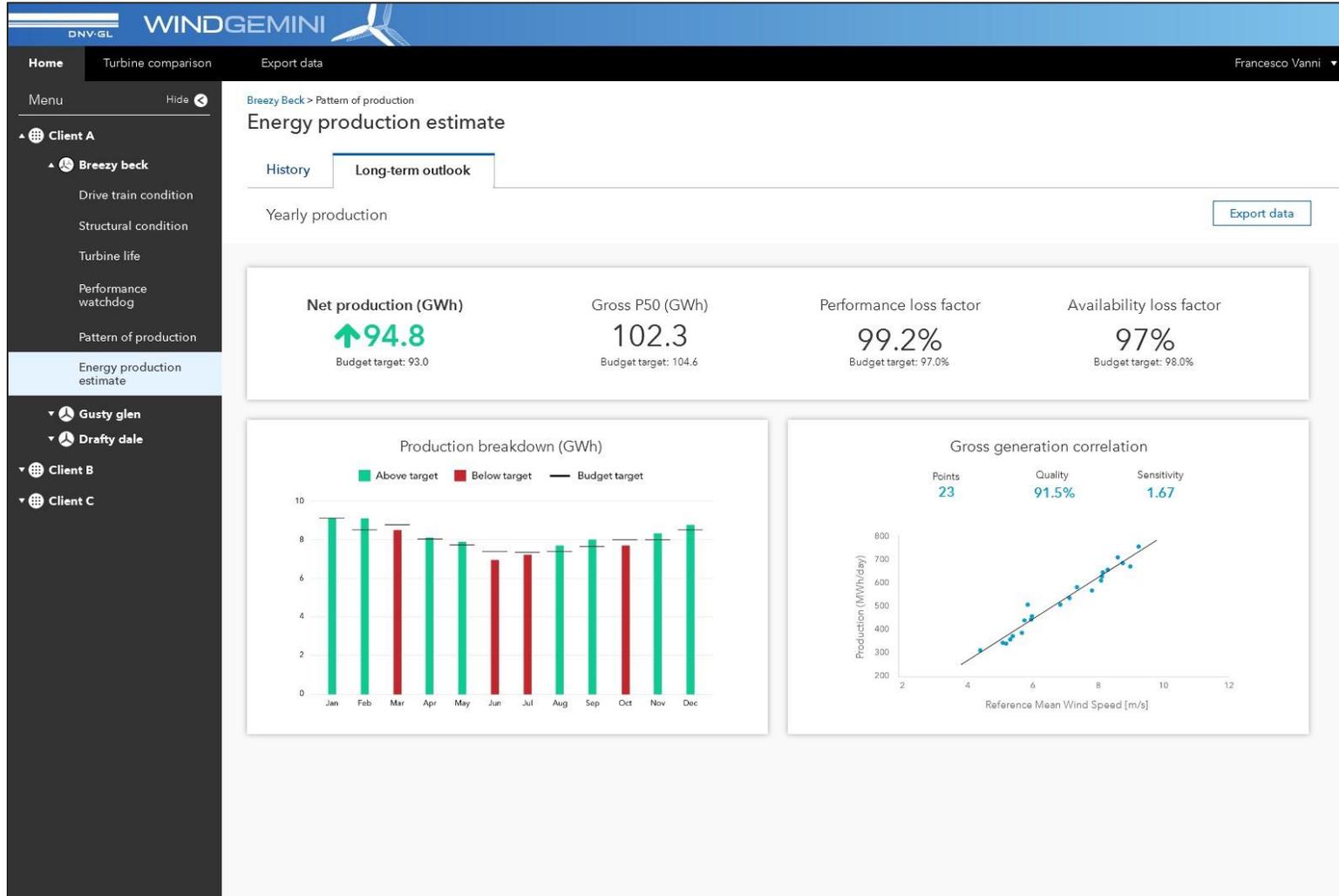
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Module In development: Energy Production Estimate – Historical Production Balance



Module In development: Energy production estimate - Long-term Outlook



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- WindGEMINI is a digital twin framework which analyzes operational data in near real time...
- ...to deliver DNV GL's engineering expertise to our customers and increase their revenue
- Four algorithms are already functional within WindGEMINI
 - More algorithms are:
 - Drivetrain integrity monitor
 - Structural integrity analysis
 - Turbine life estimator
 - Performance Watchdog
 - currently being developed or planned
 - Pattern of Production (2018)
 - Online energy assessments (2018)
 - Production balancing dashboard (2018)
 - ...other ideas are very welcome!
- For more info: <http://go.veracity.com/windgemini>

WINDGEMINI

A digital twin for your wind farm by the world's renewable expert.

Any questions?



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