Vestas Product Offering – V150-4.2 MW at a Glance

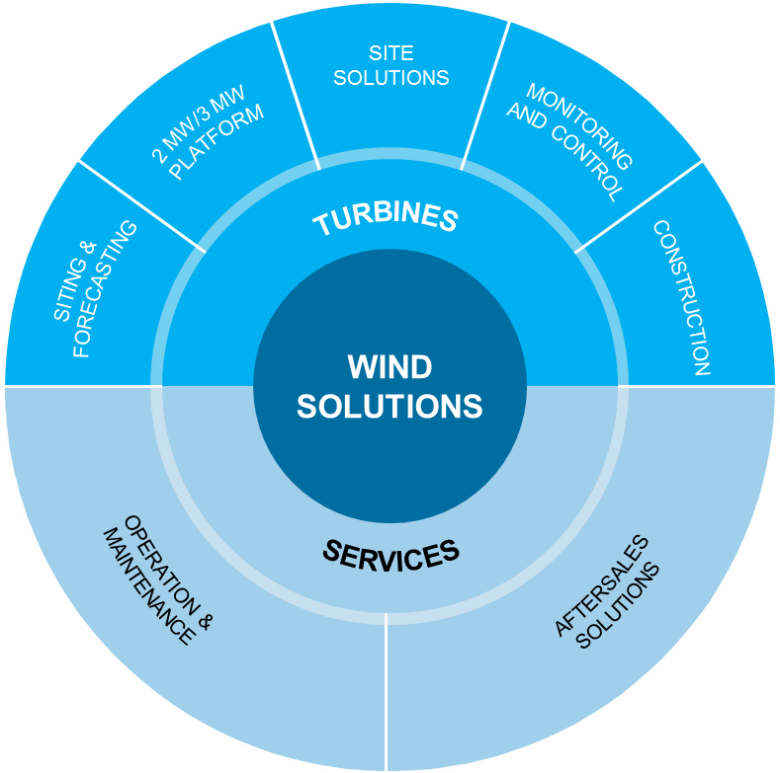
Renato Loureiro Gonçalves – Wind & Site Engineer

Content

The Vestas' portfolio of wind solutions

From siting to aftersales, our offering spans across turbines and services

Expertise
built from more than 35 years of wind industry experience



Vestas

The Vestas' 2 MW and 4 MW platforms

Mature platforms with proven track records

2 MW PLATFORM

- Introduced in 2000 and incrementally improved over the years
- + 20,500 units installed globally*
- Well suited for sites with infrastructure constraints

4 MW PLATFORM

- Introduced in 2010, now fourth generation
- + 5,500 units installed globally*
- Grid compliant across the world due to full converter solution

* As of 31 March 2018

4 MW: Next step in the evolution of a proven platform

Significant AEP increase driving down Cost of Energy

	3.0 MW	3.3 MW	3.45 MW	4.2 MW
				
	• V112-3.0 MW first member of new 3 MW Platform	• Upgrade to 3.3 MW • New rotors: 105/117/126m	• Upgrade to 3.45 MW • New rotor: 136m • 3.6 MW Power Mode	• Upgrade to 4 MW • New rotor: 150m • 4.2 MW Power Mode • New Segment: Typhoon Class
IEC I	V90-3.0 MW®	V105-3.3 MW® V112-3.3 MW®	V105-3.45 MW™ V112-3.45 MW™ V117-3.45 MW™	V117-4.2 MW™ (incl. Typhoon)
IEC II	V112-3.0 MW®	V117-3.3 MW®	V126-3.45 MW™	V136-4.2 MW™
IEC III		V126-3.3 MW®	V136-3.45 MW™	V150-4.2 MW™
YEAR OF ANNOUNCEMENT	2010	2012/13	2015/16	2017-…

Vestas

Vestas®

4 MW Platform

Wind. It means the world to us.™

Vestas 4 MW Platform Portfolio

One common platform, powering 8 turbine variants for broad wind spectrum coverage

WINDCLASSES – IEC

Standard IEC conditions* Site dependent*

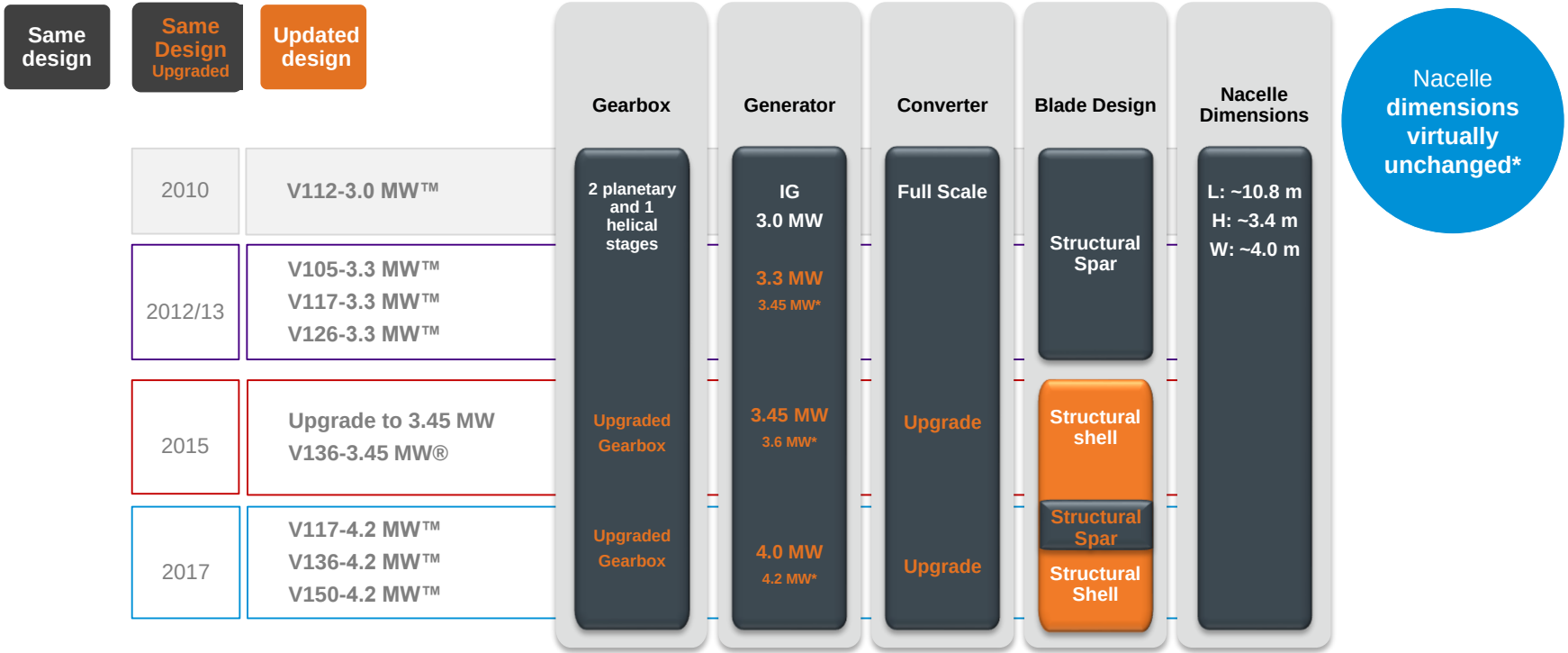
TURBINE TYPE	**IEC III** (6.0 – 7.5 m/s)	**IEC II** (7.5 – 8.5 m/s)	**IEC I** (8.5 – 10.0 m/s)	**Above 10.0 m/s**
4 MW TURBINES				
V105-3.45 MW™ IEC IA Power Optimised Mode up to 3.6 MW				
V112-3.45 MW® IEC IA Power Optimised Mode up to 3.6 MW				
V117-3.45 MW® IEC IB/IEC IIA Power Optimised Mode up to 3.6 MW				
V117-4.2 MW™ IEC IB/IEC IIA/IEC S/IEC T 4.2 MW Power Optimised Mode				
V126-3.45 MW™ IEC IIB/IEC IIA Power Optimised Mode up to 3.6 MW				
V136-3.45 MW™ IEC IIB/IEC IIIA Power Optimised Mode up to 3.6 MW				
V136-4.2 MW™ IEC IIB/IEC S 4.2 MW Power Optimised Mode				
V150-4.2 MW™ IEC IIIB/IEC S 4.2 MW Power Optimised Mode				

*Based on nominal rating

Vestas

Platform Evolution

Incremental step-wise performance upgrades



*Power Optimised Mode

Vestas

Vestas®

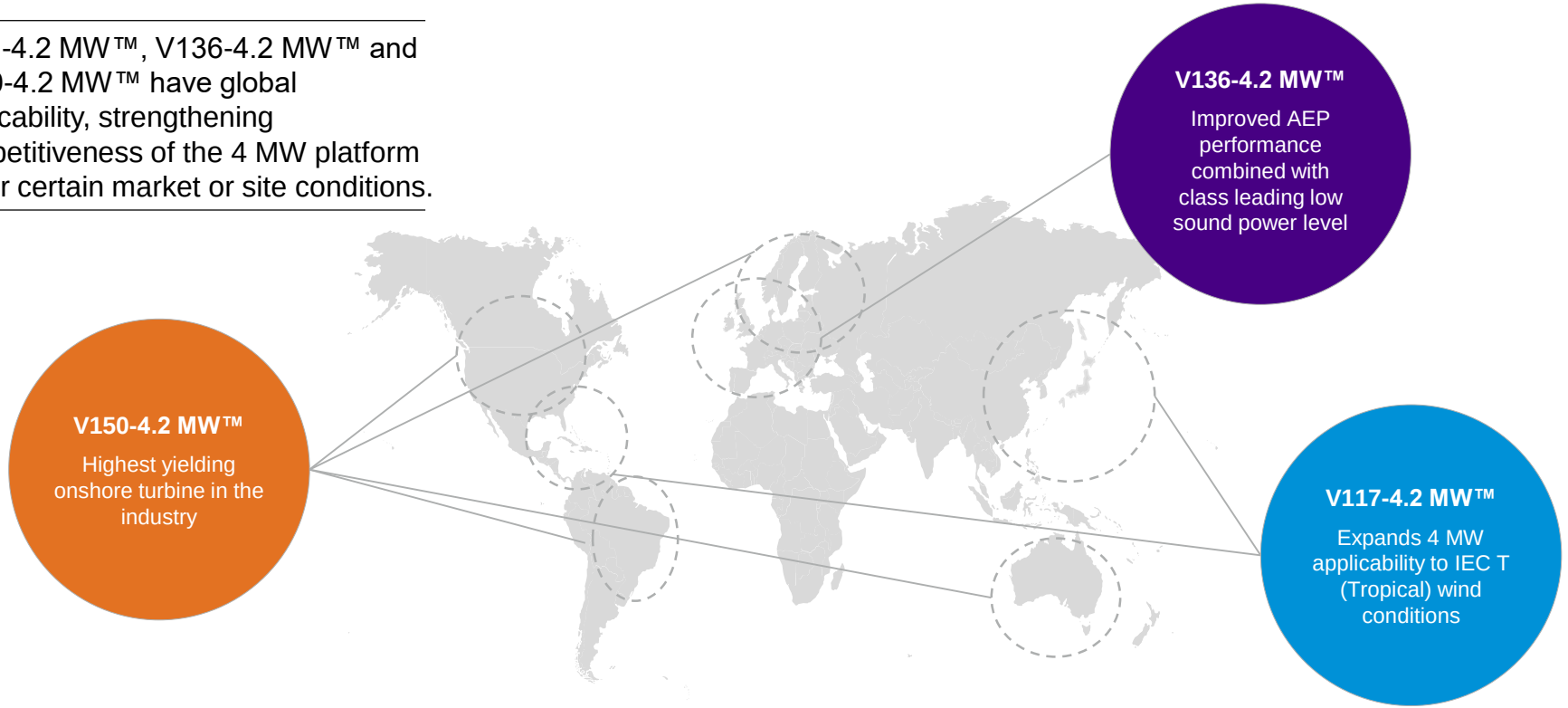
4 MW platform provides **industry-leading** track record and performance

Wind. It means the world to us.™

Strengthened market coverage

V117-4.2 MW™, V136-4.2 MW™ and V150-4.2 MW™

V117-4.2 MW™, V136-4.2 MW™ and V150-4.2 MW™ have global applicability, strengthening competitiveness of the 4 MW platform under certain market or site conditions.



Vestas

Global Product

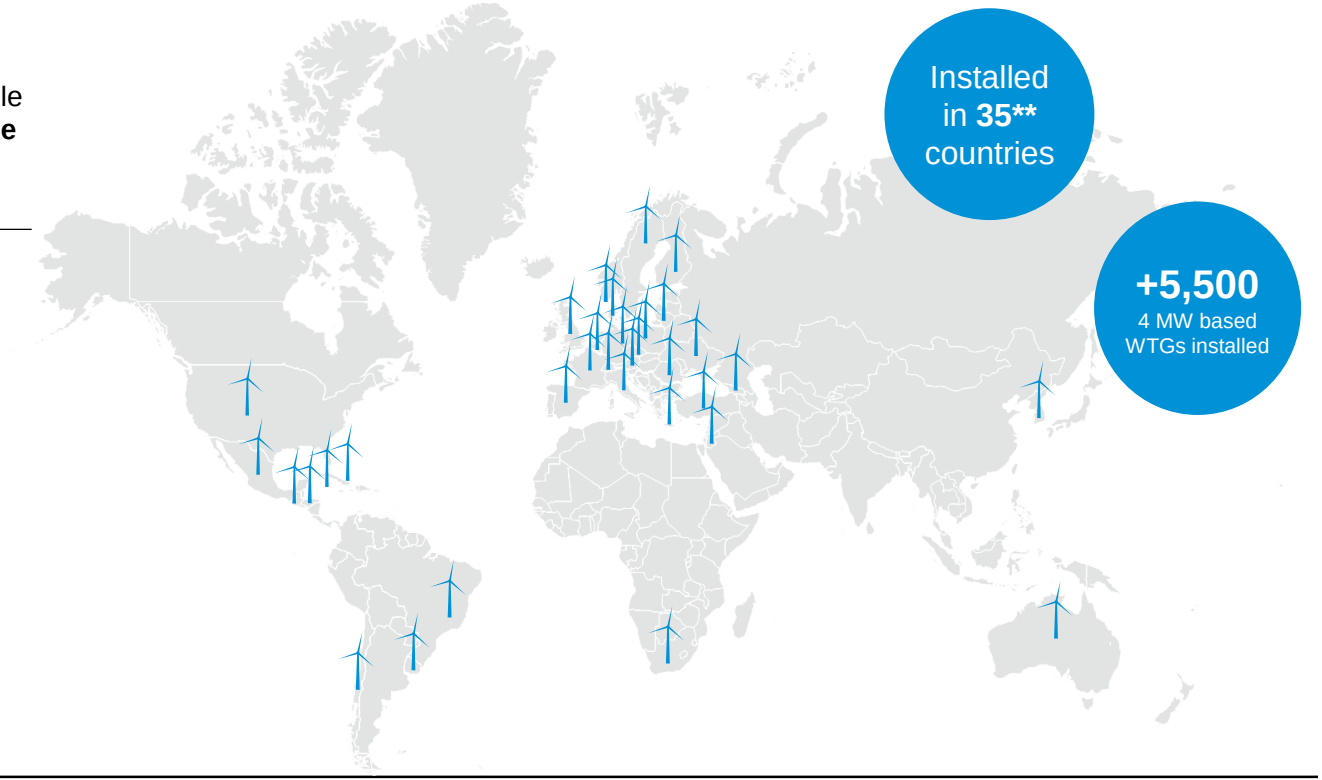
4 MW turbine variants, installed in various sites and market conditions across 6 continents

Operational data, generated every 10 minutes from more than **3,000 turbine sites*** across the globe, providing valuable insights for Vestas' engineers to **fine-tune performance** - in unrelenting pursuit of **lower cost of energy**.

Americas
Brazil
Chile
Dominican Republic
Guatemala
Honduras
Jamaica
Mexico
Uruguary
USA

Europe/Middle East/Africa
Austria
Belgium
Czech Republic
Croatia
Denmark
Finland
France
Georgia
Germany
Greece
Italy
Jordan
Netherlands
Norway
Poland
Romania
Serbia
Spain
Sweden
Switzerland
Turkey
Ukraine
United Kingdom
South Africa

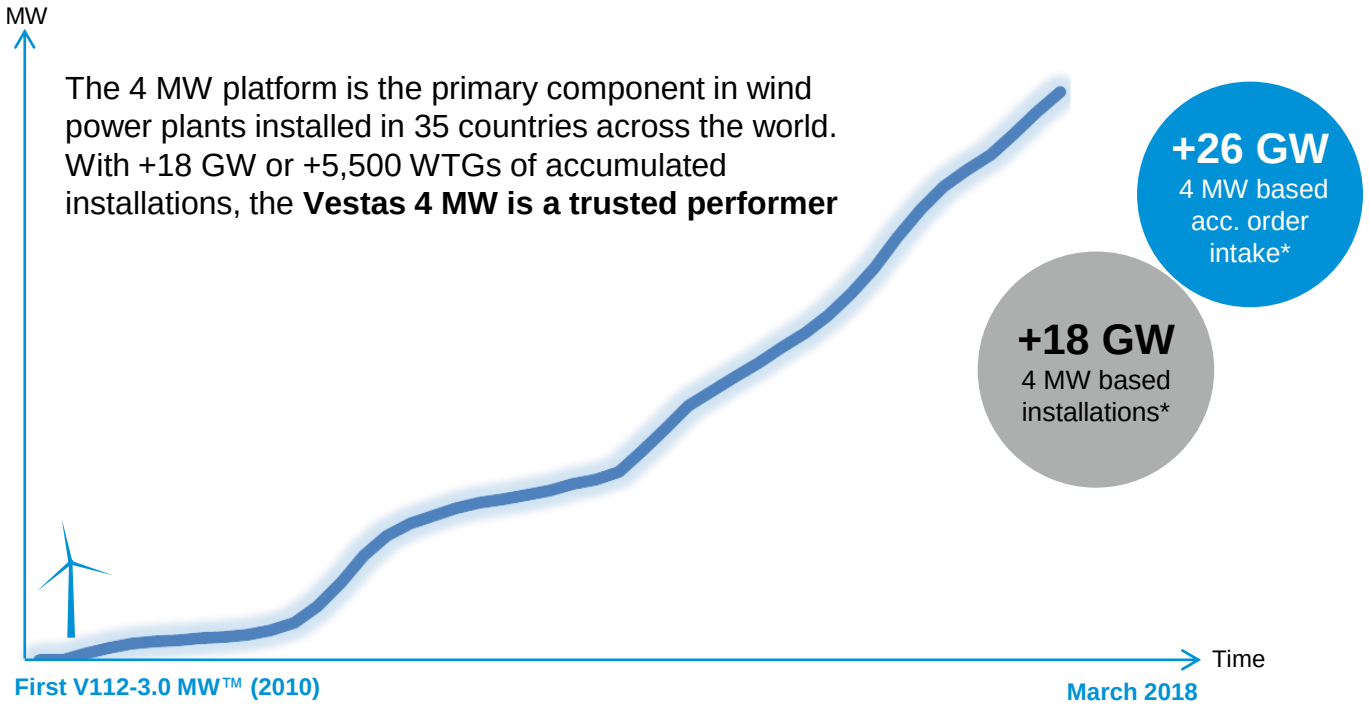
Asia-Pacific
Australia
South Korea



* All Vestas turbines, not specific to 4 MW
** As of 31 March 2018

Platform Installation Track Record

The 4 MW platform is proven, already performing in volumes across the world



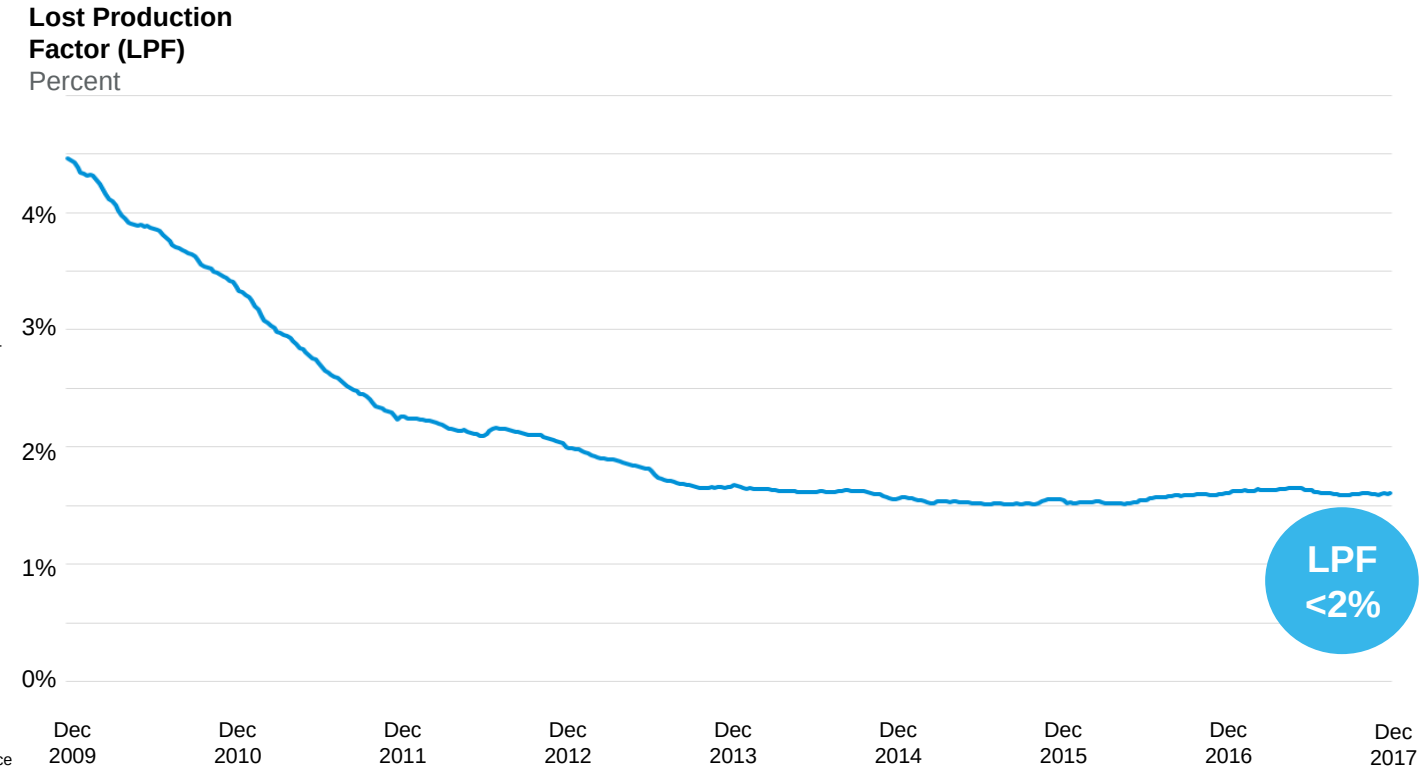
* As of 31 March 2018

Vestas

Advantage of evolutionary approach: steady performance

Continued reliable performance across Vestas-serviced fleet

While the number of Vestas installed turbines increase, **fleet Lost Production Factor (LPF) has stabilised at a very low level.** This is the result of the Vestas evolutionary product development approach



Includes 2 MW variants, 4 MW variants, and legacy turbines under Vestas service

Vestas®

Latest Performance Upgrades

Wind. It means the world to us.™

Latest Performance Upgrades

New variants enabled by strengthened platform components

For V117-4.2 MW™, V136-4.2 MW™ and V150-4.2 MW™, the 4 MW platform has been strengthened through **upgrades to existing proven component and systems**.

4.0 MW nominal rating

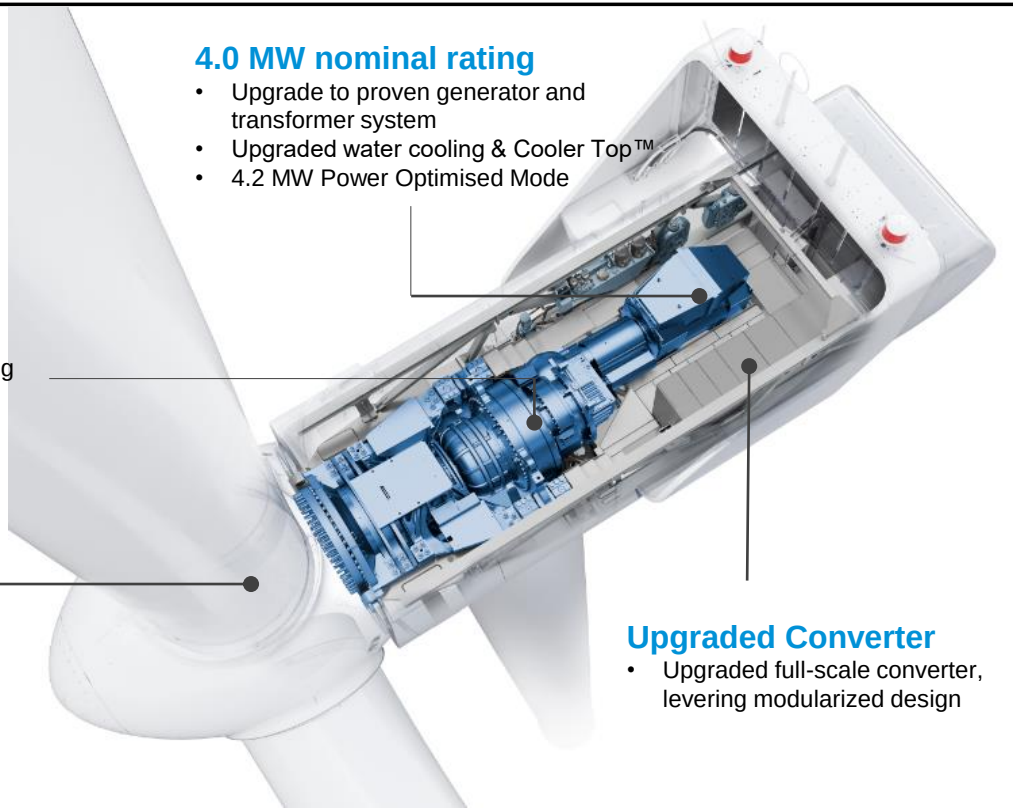
- Upgrade to proven generator and transformer system
- Upgraded water cooling & Cooler Top™
- 4.2 MW Power Optimised Mode

More Torque

- Upgraded gearbox, same proven design. Powering V136-4.2 MW™ and V150-4.2 MW™
- Application of known gearbox in V117-4.2 MW™

Upgraded Blades & Hub

- Vestas most advanced blade design & advanced materials applied to 73.7 m blades (V150-4.2 MW™)
- Strengthened 57.2 m (V117-4.2 MW™) blade
- Enforced blade bearings & pitch capacity (V150-4.2 MW™)

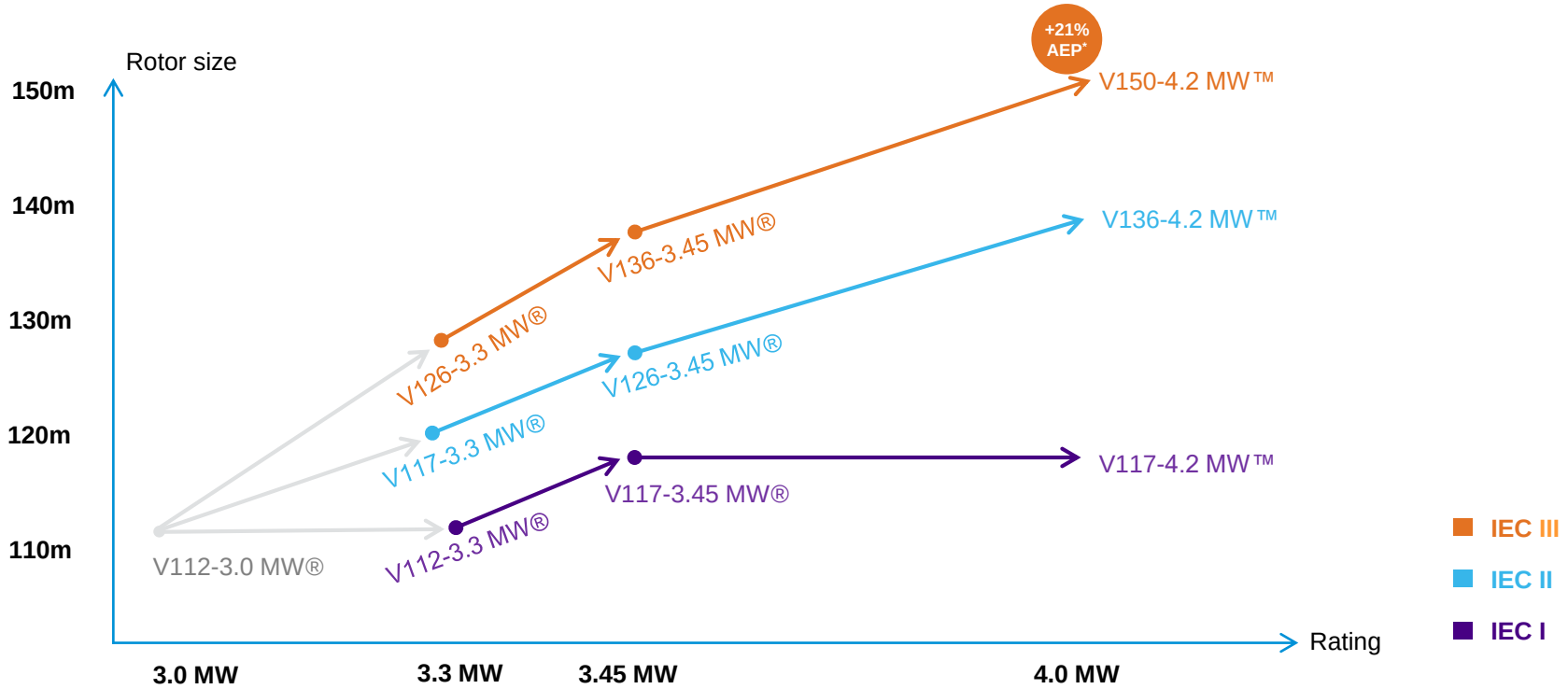


Upgraded Converter

- Upgraded full-scale converter, levering modularized design

Increased Annual Energy Production

Latest upgrade enables double-digit AEP gains in all standard wind classes



*AEP=Annual Energy Production. V150-4.2 MW™ with 4.2 MW Power Optimised Mode in IEC III Compared to V136-3.45 MW™ Actual figures depend on site specific conditions.

Vestas

V150-4.2 MW™ turbine variant

Highest yielding onshore turbine in the industry

Segment leading **Energy Production**

Up to 241 m tip height

Larger Swept Area
Blade length increased to 73.7 m using Vestas most advanced aerofoil design and materials

17,671 m² swept area

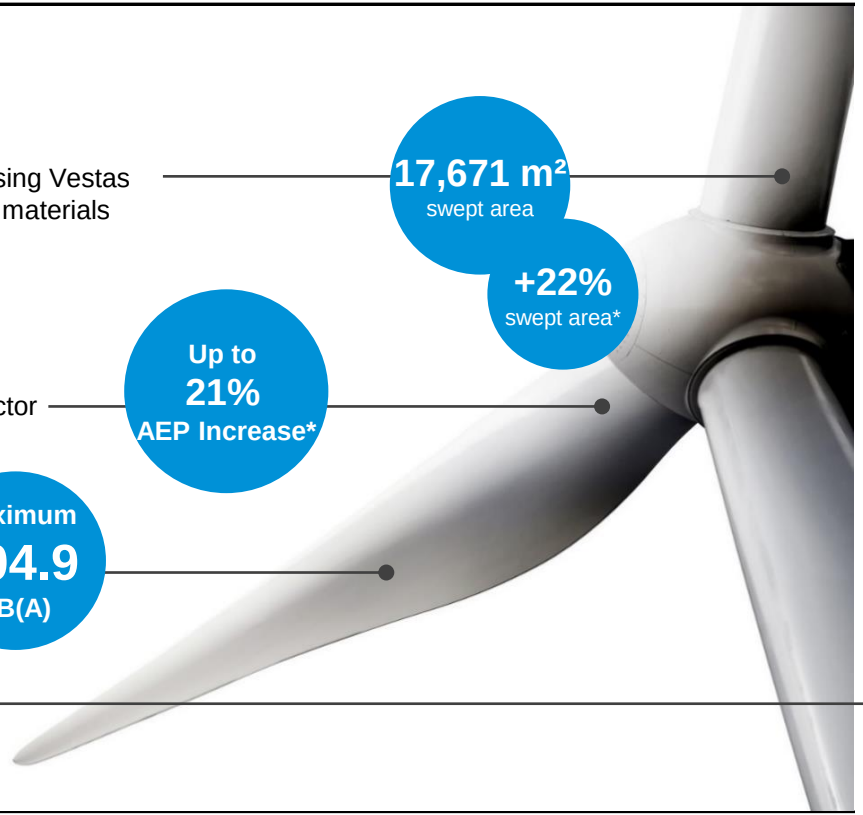
+22% swept area*

Higher Energy Production
Combined with increase in capacity factor

Up to 21% AEP Increase*

Reduced Sound Power Levels
Segment leading energy production combined with very low 104.9 dB(A)

Maximum 104.9 dB(A)



Tower Portfolio

- Site specific tower portfolio to meet tip heights ranging from 180-241 meter leveraging industry leading 166 m hub height

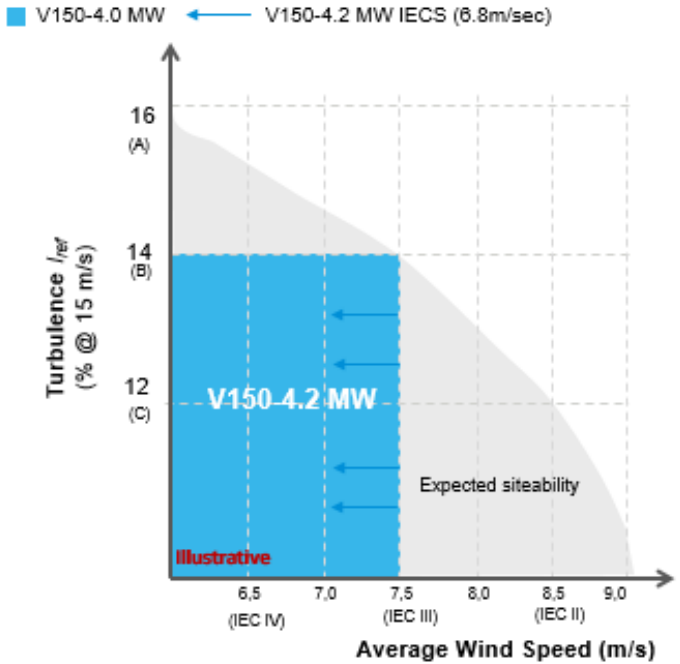
*Compared to V136-3.45 MW. Depending on wind condition

Vestas

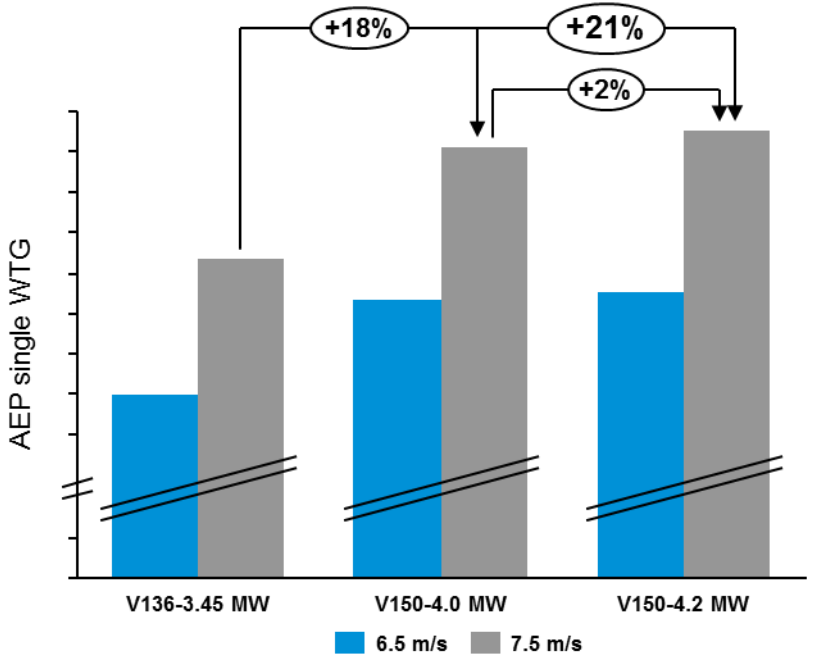
V150-4.2 MW™ offering

Operating strategy for maximizing siting capability and power performance

Application Space



Energy Production



K-factor 2.0, standard air density

Vestas

Vestas track record

Really proven performance – deliver what we promised

Vestas has asked third party to review our performance in operational fleet

UL cover page to Vestas Fleet Performance Document

Daniel W. Bernadett, P.E. – AWS Truepower, a UL Company

Harald Mellinghoff – DEWI, a UL Company

Confidentiality: To be distributed at the discretion of Vestas

Date: 20 December 2017

UL was contracted by Vestas to review the document they developed entitled "Vestas Fleet Performance" (Document number 0071-1372 V00) (the Document). UL has reviewed the Document and confirms that we understand and agree with the calculation methodology used to create this summary, and that we have been able to conduct spot checks of the original reports upon which the summarized results are based. These reports cover projects beginning in 2005 and were conducted by ISO 17025 accredited laboratories following IEC 61400-12-1, Edition 1. These spot checks verify that the results are a fair, accurate, and comprehensive representation of the power curve data held by Vestas.

UL staff (Bernadett and Mellinghoff) reviewed the database used to develop the Document. During three days of on-site review in Vestas offices in Aarhus (7-9 November 2017), Bernadett and Mellinghoff were provided with a draft of the Document, an Excel-based, tabular, numeric summary of the randomized and anonymized data used to create the Document, and visual access to the PDF reports from the Independent Engineer (IE) that completed the IEC compliant power performance tests that make up the database. The Vestas power curve database presents a convincing body of evidence to support the claim that Vestas has demonstrated their capability to predict the power performance of their turbines with a satisfactory degree of accuracy. In particular, the measured curves were found to consistently agree with published curves. This agreement can give confidence that the performance of new turbine models are likely to meet the expectations set by the published curves.

Signed,

Daniel W. Bernadett, P.E.

Global Service Line Leader for Power Performance Testing

Harald Mellinghoff

Global Subject Matter Expert for Power Performance Testing

AWS TRUEPOWER DEWI

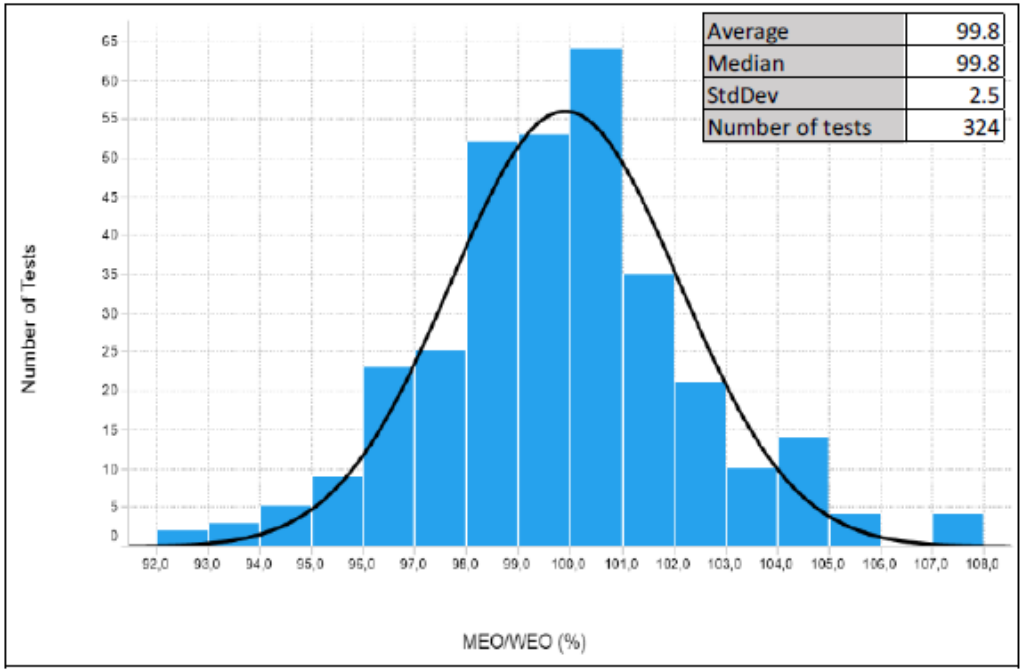


Figure 1: Vestas Fleet performance as expressed by MEO/WEO

Vestas

Grid compliance

Grid compliance for both plant and turbines

Grid Compliance

- The grid performance for the V150-4.0/4.2 MW will be similar to the V136-3.45 MW with 3.6 MW Power Optimised Mode.

Plant Compliance – Grid Stabilisation

- Synthetic inertia ie. Overboosting
- Frequency response
- Ramp-up requirement
- Fault ride through (up to 450 msec with 0.0 pu)

Turbine Compliance

- Consumption (active/reactive power)
- Power quality conditions ie. Flicker and harmonics
- Temporary overvoltage (TOV)

Calibrated turbine input ensures optimal production

Adaptive Wind Sensing and Wind Speed Estimator provides up to 0.6% more AEP*

- Adaptive Wind Sensing and Wind Speed Estimator uses advanced algorithms to **calibrate upwind yaw position and more accurately measure wind speed** in front of the rotor. The increased accuracy results in more power and less loads.

*Actual AEP (Annual Energy Production) depends on turbine type and site conditions

- **Adaptive Wind Sensing** continuously and automatically calibrates its upwind yaw positions, updating the wind correlation parameters for each individual wind turbine
- The algorithm uses the natural variation in wind direction (+/- 6 degrees) to calculate optimum yaw position based on power production
- The improved upwind yaw accuracy leads to improved operation, reduced loads, and enables accurate performance according to warranted power curves

- **Wind Speed Estimator** reverses the measurement process by calculating the wind speed from the turbine‘s pitch, speed, and power readings
- Also, it continuously and automatically corrects the wind correlation parameters for each individual wind turbine
- The algorithm allows Vestas to more accurately measure the wind speed in front of the entire rotor, resulting in optimized operational settings

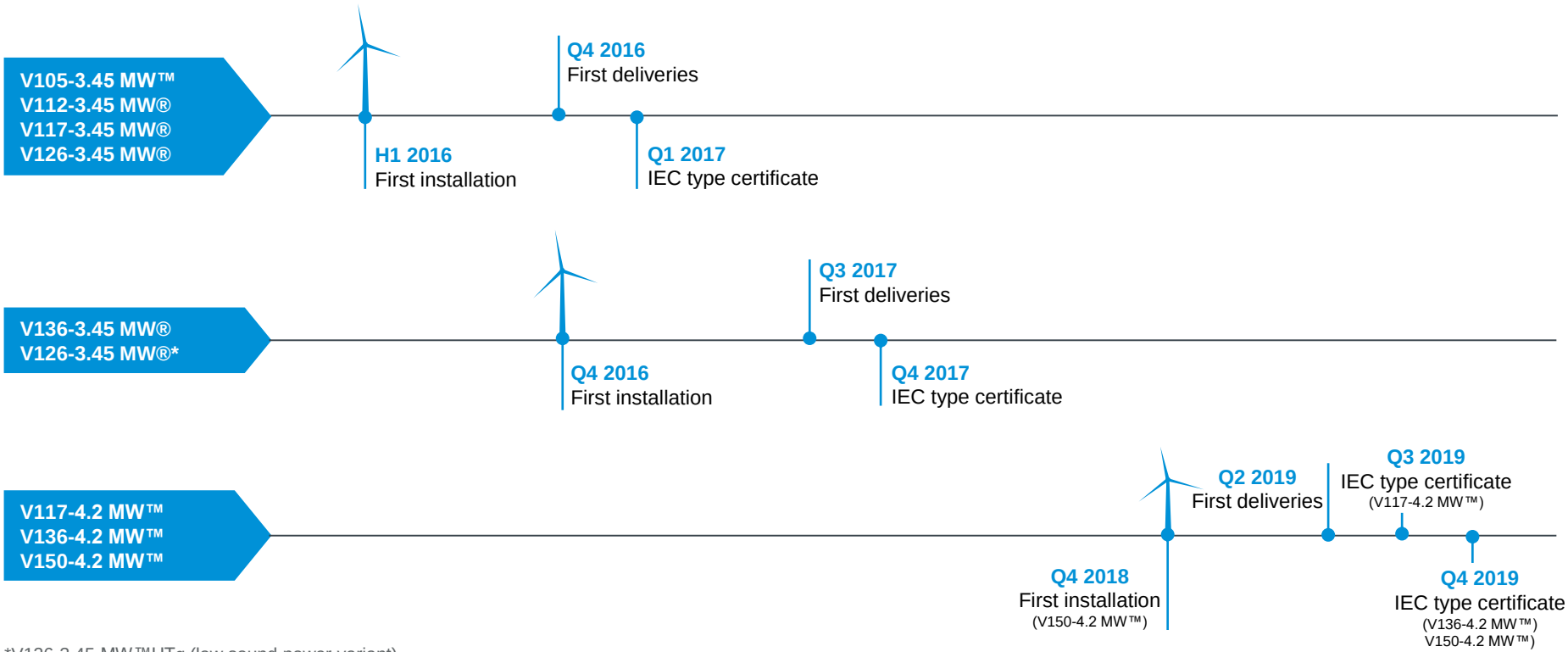
Vestas®

Market Timing

Wind. It means the world to us.™

Time to market

Overview



*V126-3.45 MW™HTq (low sound power variant)

Vestas®

Q&A

Wind. It means the world to us.™