

**Vestas**<sup>®</sup>

# PowerPlus<sup>®</sup>

Proven upgrades for the  
entire power curve

**Wind.** It means the world to us.<sup>™</sup>

# Upgrade your business case with Vestas

## PowerPlus®

As wind power technology advances, Vestas continuously invests in R&D to ensure that these advancements are made available for existing turbines. PowerPlus® is a range of innovative upgrades designed to improve operation and production efficiency of installed turbines, leading to increases in annual energy production of up to 5%.

Combining retrofits of advancements in new turbine design with a dedicated after-market R&D division, PowerPlus® is the result of Vestas' investment into the existing fleet of turbines. And for wind asset owners, it adds to a stronger bottom line.

### **Enable your turbines to work smarter...**

Vestas PowerPlus® offers upgrades across the power curve, from partial load operation to post cut out.

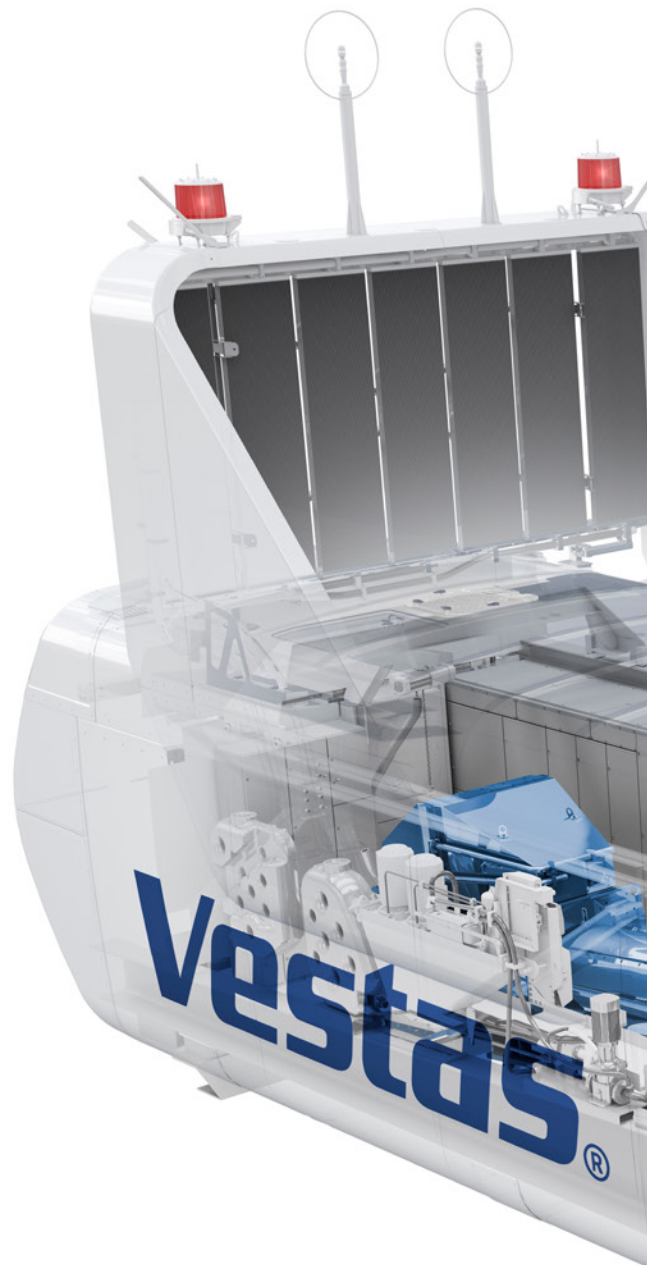
In partial load operation, new control systems and smart algorithms provide the turbines with improved intelligence through uniquely designed software features.

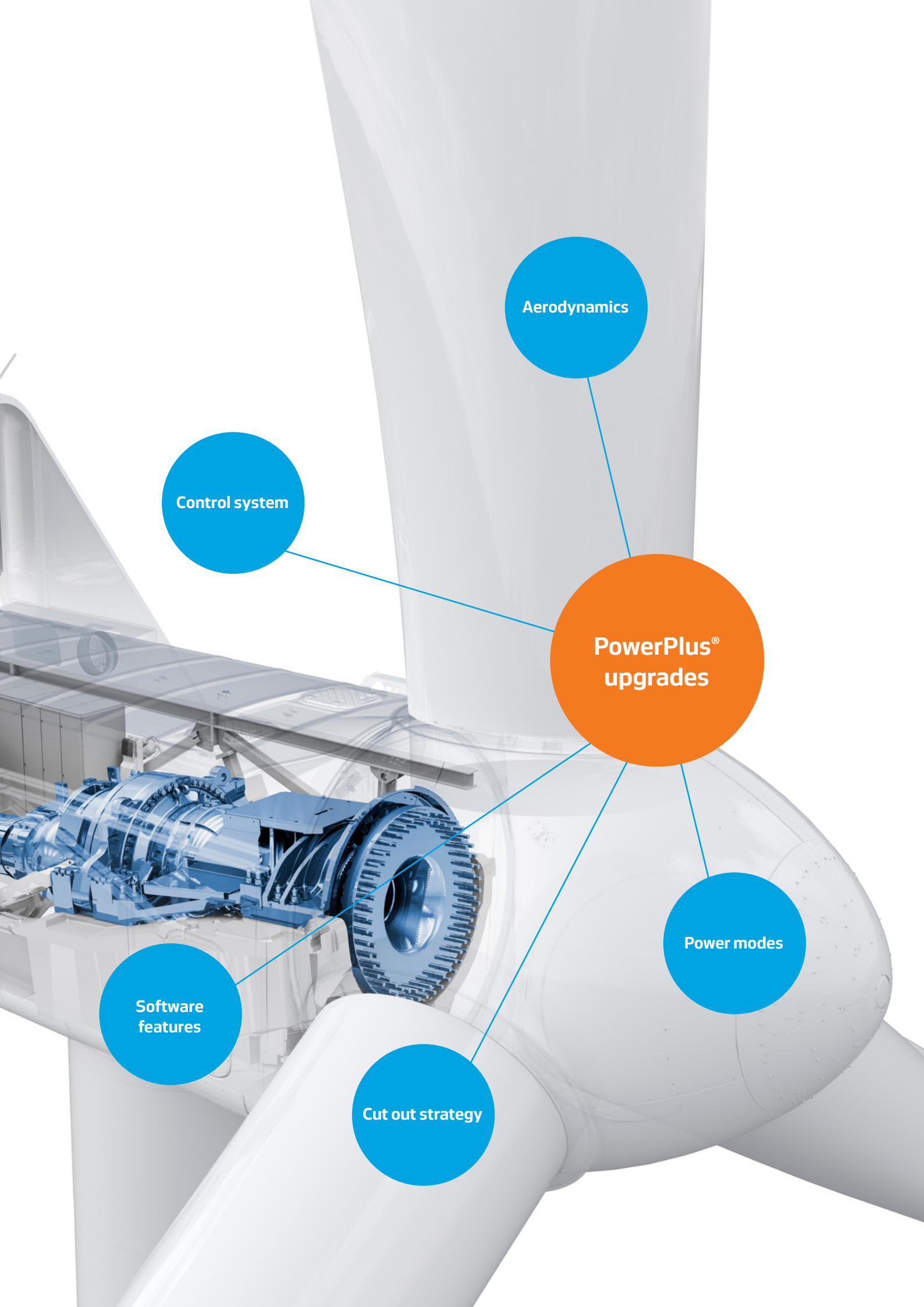
In addition, blade add-ons can improve the turbine's aerodynamics, thereby increasing the effective wind capture over the root section of the blade.

### **... and push them to work harder**

Vestas PowerPlus® also consists of proven upgrades to boost production in full load and post cut out operation, including new power modes and improved cut out strategies.

A new nominal power mode allows full exploitation of load margins, while new cut out strategies ensures that your turbines reap the full benefit of high wind speeds.





Aerodynamics

Control system

PowerPlus<sup>®</sup>  
upgrades

Power modes

Software features

Cut out strategy

# Unlock the full potential of your assets

Vestas **PowerPlus**<sup>®</sup>  
Features and applicability

	<b>Aerodynamic Upgrades</b>	<b>Power Performance Optimisation</b>	<b>Power Uprate</b>
<b>AEP GAIN FROM</b>	Increased wind capture and improved noise modes	Improved data inputs to help the controller system make better decisions	Increased nominal power
<b>AEP GAIN ESTIMATE*</b>	<b>Up to 2%</b>	<b>Up to 1.5%</b>	<b>Up to 5%</b>
<b>INSTALLATION</b>	Rope - or crane access	Software installation	Software installation
<b>VALIDATION METHOD</b>	Power-to-Power	Toggle	AEP Counter
<b>PLATFORM APPLICABILITY**</b>	***V80-1.8/2.0MW V90-1.8/2.0MW V100-1.8/2.0MW V90-3.0MW  ***Various multibrand platforms	V80-1.8/2.0MW V90-1.8/2.0MW V100-1.8/2.0MW V110-2.0MW V90-3.0MW V112-3.0/3.3MW V117-3.3MW V126-3.3MW	V47-660kW V90-1.8MW V100-1.8/2.0MW V110-2.0MW V112-3.0/3.3MW V117-3.3MW V126-3.3MW



Extended Cut Out	High Wind Operation	Controller Upgrade	PLO+1
Enabled production during high wind speeds	Enabled production during high wind speeds	Higher reliability and enabled software upgrades	Enabled power modes in partial load operation, close to the knee of the power curve
<b>Up to 5%</b>	<b>Up to 0.8%</b>	-	<b>Up to 0.5%</b>
Software installation	Software installation	Software/hardware installation	Software installation
AEP Counter	AEP Counter	-	Toggle or Power-to-Power
V47-660kW V80-1.8/2.0MW V100-1.8/2.0MW V90-3.0MW	V80-1.8/2.0MW V90-1.8/2.0MW V100-1.8/2.0MW V110-2.0MW V90-3.0MW V112-3.0/3.3MW V117-3.3MW V126-3.3MW	V47-660kW V80-2.0MW V90-1.8/2.0MW V90-3.0MW	V90-1.8/2.0MW V90-3.0MW

\*Depending on site-specific conditions

\*\*Applicability might differ across platform versions

\*\*\*Multibrand solution offered in partnership with Smart Blade

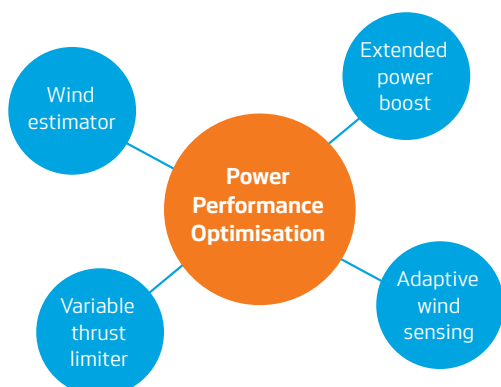
# Enable your turbines to **work smarter**

When a wind turbine is operating at wind speeds that are not sufficient to reach its nominal power, there are a variety of operational parameters that can be optimised to maximise efficiency. Vestas PowerPlus® offers a range of solutions to address production efficiency on the slope of the power curve.

## Power Performance Optimisation

Based on site-specific conditions, instrumental parameters such as wind speed measurements, wind direction measurements and yaw position can be fine-tuned to increase output on the slope of the power curve. During the development of new turbine generations, Vestas constantly seeks to achieve perfection in getting these parameters right.

This continuous innovation allows Vestas to offer Power Performance Optimisation, a range of software upgrades that enables the newest control intelligence on existing turbines. These upgrades will help the turbine act smarter based on the data inputs it receives, and thereby optimise its performance during partial load operation.



Depending on site-specific conditions, Power Performance Optimisation can improve annual energy production by 1.5%. In some cases, it can be necessary to upgrade the control system to enable Power Performance Optimisation features.

## Capture more wind with aerodynamic add-ons

In addition to the software upgrades, Vestas also offers Vortex Generators and Gurney Flaps to improve wind capture over the root section of the blades.

Wind turbine blades are designed on a compromise between aerodynamic optimum and robustness to be as effective as possible while consuming heavy loads. This design compromise is most evident at the blade's root section as it carries the highest load impact. As a result, the root section suffers from early air flow separation, which reduces the lift.

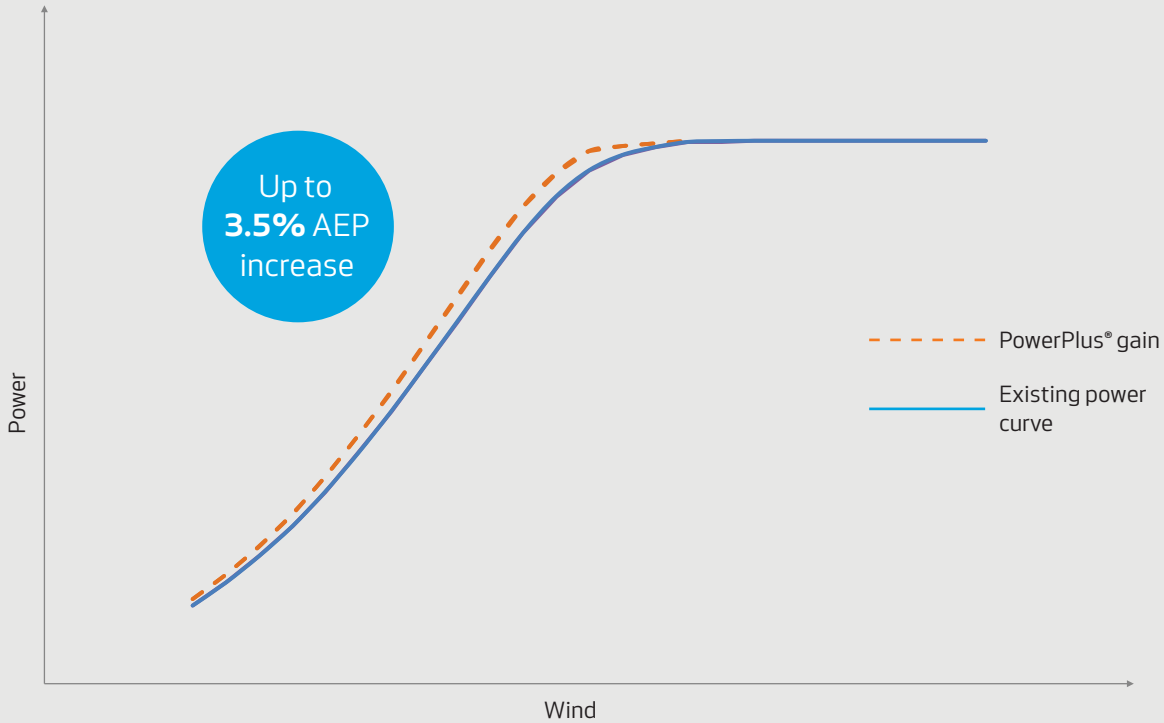
Across the industry, Vortex Generators and Gurney Flaps have been acknowledged as effective means to reduce the aerodynamic loss at the root section. The improvement from these add-ons can be seen directly on the bottom-line, adding up to 2% annual energy production.

## Serrated Trailing Edges

Another blade add-on that can enable higher annual energy production is serrations for the trailing edge. The serrations can reduce the noise output of the turbines, allowing higher production at sites with strict noise regulations. The higher energy output is achieved by operating a more aggressive noise mode strategy, which is enabled by the reduced noise output.

# Upgrades for the slope of the power curve

Shifting the slope of the power curve to the left with software upgrades and aerodynamic add-ons

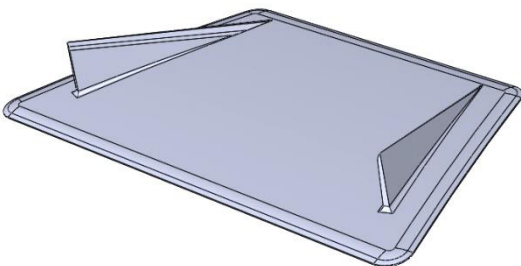


## Vortex Generators and Gurney Flaps

Add-ons to improve aerodynamic performance over the root section of the blade

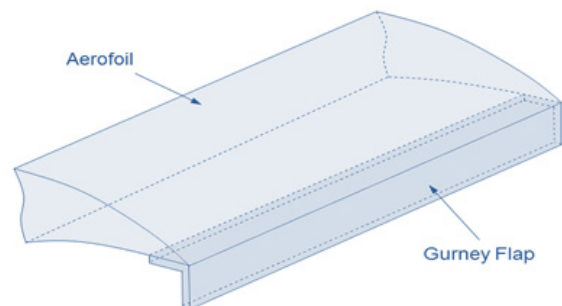
### Vortex Generators

Example of a counter-rotating vortex generator



### Gurney Flaps

Example of gurney flaps on a wind turbine blade



# Push your investment to work **harder**

Over the course of a wind turbine's life, the conditions under which it operates might change and deviate from the forecasted conditions under which it was sited. These deviations can potentially result in turbines that do not harvest the full benefits of the wind.

To help wind asset owners address this, Vestas PowerPlus® offers a few upgrades designed to enable turbines maximise production given the actual operational conditions.

## **Power Uprate**

Essentially a new power mode, Power Uprate allows the turbine to reach a higher power level under full load operation. Imagine exchanging your 1.8MW turbine with a 2MW without having to exchange or upgrade core components, but simply allow the turbine to fully exploit the climatic conditions surrounding it. The benefit is up to 5% increase in annual energy production.

Vestas' industry-leading load analyses ensure that the installed upgrades will not affect turbine lifetime and keep it within its design envelope.

## **Extended Cut Out and High Wind Operation**

Another mechanism that can be optimised to increase power output is the operational cut out strategy. All wind turbines that leave Vestas factories comes with a pre-defined set of parameters that determines when the turbine cuts in and out of the wind to protect it from extreme winds and unnecessary stop-start cycles.

However, these pre-defined parameters do not take site-specific conditions into consideration. Therefore, it is possible to adjust these parameters on existing turbines to optimise the cut out strategy according to the climatic conditions at the site.

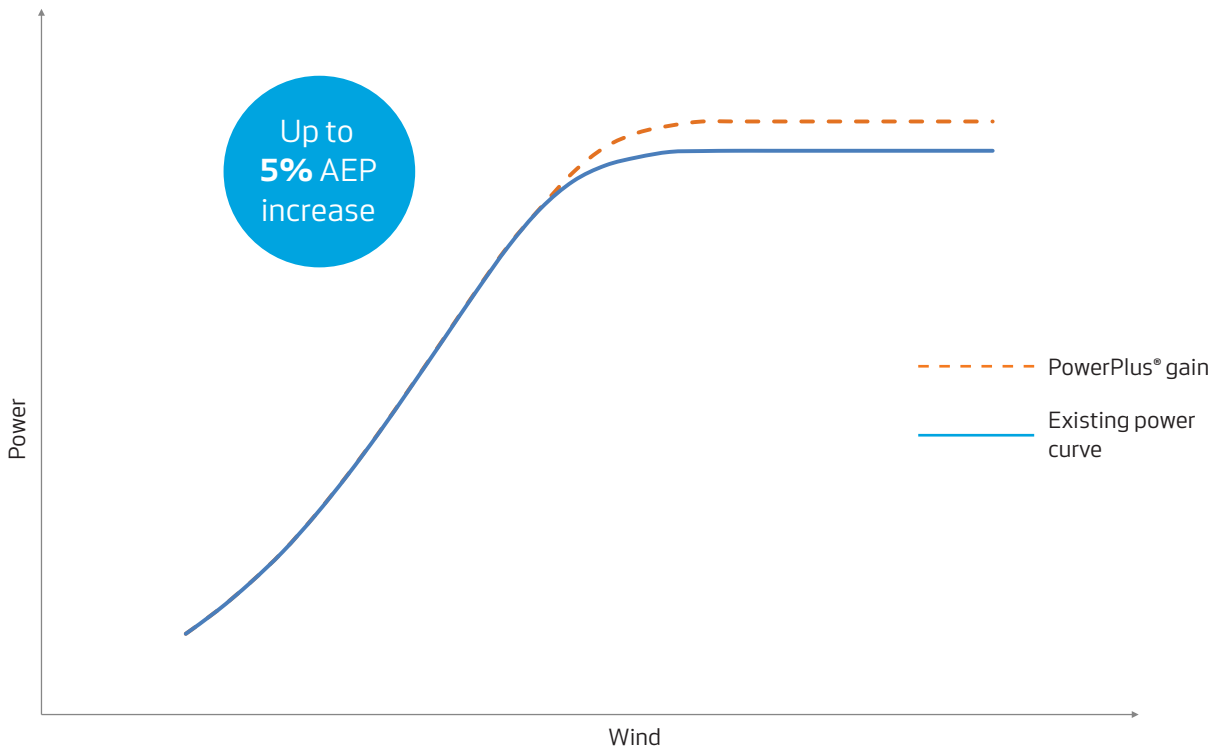
This could include increasing the cut out wind speed from 25 m/s to 27 or 29 m/s, while simultaneously increasing the cut in speed accordingly. Extended Cut Out thereby lets the turbine continue its full load operation during high wind speeds, effectively reaping the benefits as the wind grows stronger.

High Wind Operation utilises similar site-specific conditions, but instead of keeping the turbine at full load operation, it downrates as the wind speed increases. This is a very effective alternative for sites that do not meet the requirements for an extension of the cut out speed.



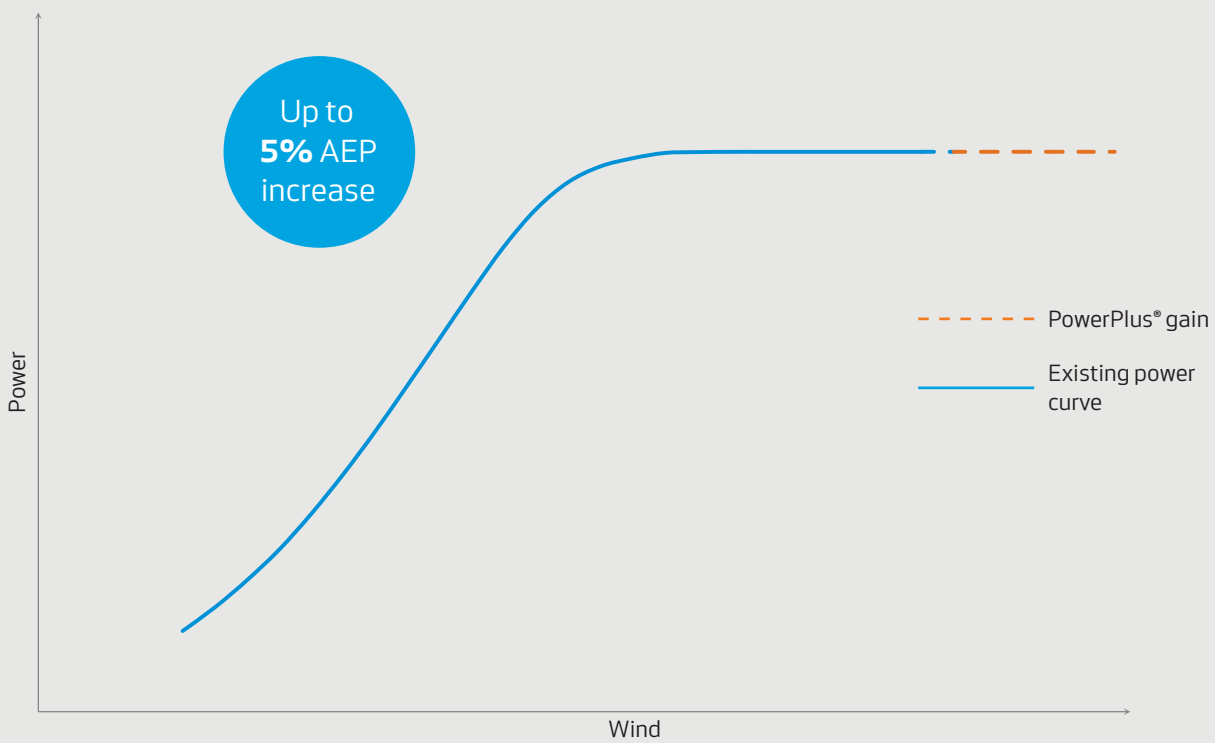
# Power Uprate

Enabling new and higher power modes in full load operation



# Extended Cut Out

Enabling production in higher wind speeds



# Proven technology, **validated** results

When it comes to investing in performance improving upgrades, we know that wind asset owners need assurance towards the return from such an investment. Therefore, Vestas has developed a number of highly effective validation methods to confirm the estimated production gains and ensure complete transparency into the actual improvements.

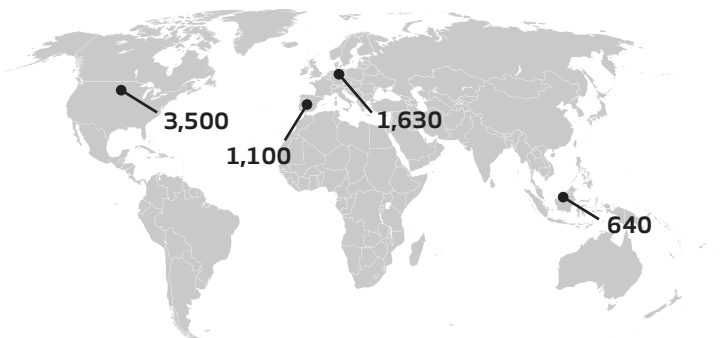
Coupling that with a global track record, Vestas PowerPlus® exclusively offers proven technology upgrades that comes with swift site-specific validation.

## Track record - improving business cases around the globe

Since its launch in 2014, Vestas PowerPlus® has increased AEP on almost 17,000 wind turbines around the world, bringing higher returns to the asset owners and more wind power to the grid. This is a solid testimonial to the effectiveness and applicability of PowerPlus® upgrades.

The track record also underlines, that Vestas PowerPlus® can be applied in all regions of the world, to the benefit of both local and global wind asset owners.

PowerPlus® installations (turbines per region)



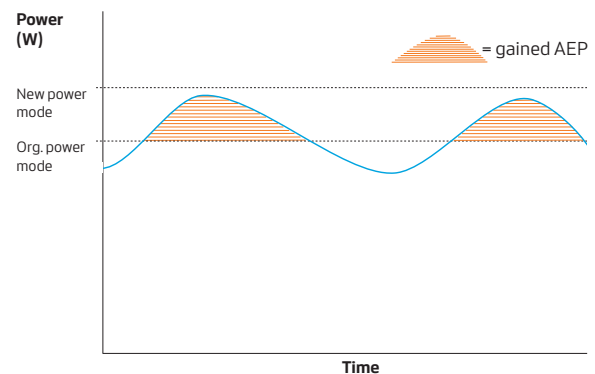
## Validating performance gains

Vestas' methods are designed to validate the actual performance gains enabled by the upgrades to establish a firm understanding of their value for the individual wind power plant.

The methods differ slightly depending on where along the power curve the upgrade has impact. For partial load operation upgrades, Vestas uses an industry-acknowledged power-to-power method or a toggle method. For full load operation, Vestas uses an AEP counter, which essentially counts production enabled by the upgrades. The below illustration show how the AEP counter works.

Through these methods, Vestas also offers value-sharing to minimise the required investment for the asset owner and virtually remove risk from the business case.

AEP Counter validation of Extended Cut Out





**Pure.** Performance

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