

Vestas®

Wind. It means the world to us.™



Fun facts on Wind power and Vestas Wind Turbines

Global Marketing – Value Marketing

Agenda

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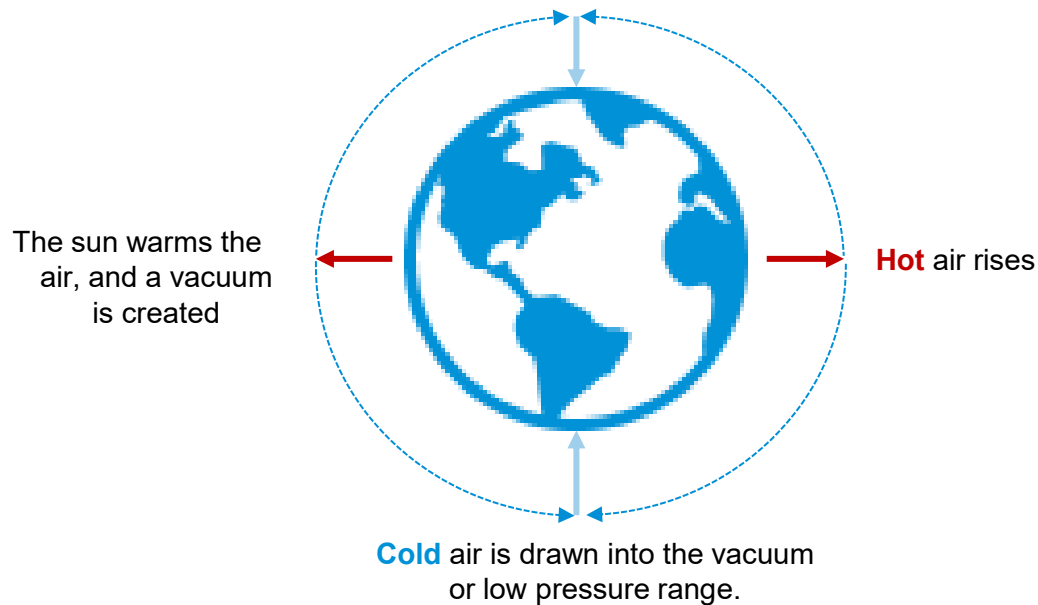
What is the wind?

The physics of the wind

Wind is caused naturally by an **uneven heating of the atmosphere** by the sun, the irregularities of the earth's surface and the rotation of the Earth. The sun is the main factor in the wind creation process.

The **wind flow** is the **motion energy caused by the movement of the air**, which is modified by the earth's terrain (mountains, valleys, cliffs...), bodies of water, and the vegetative cover.

Air circulation on the earth (without rotation).



The air moves

because it has different temperatures, and cold air is heavier than hot air.

174,000,000 GWh

Energy received by the earth from the sun every hour (approx.)

1%-2%

Of the energy transmitted from the sun is converted to wind energy

Wind power

Why the wind has energy and how do we capture it

What is the wind power?

Wind power is the **electricity generated** by harnessing the energy of wind. The **more velocity** and density the wind has, the **more energy** it will carry.

Every wind turbine is designed to **capture wind of a particular range of speeds**. For that reason, it is very important to know what is the range of wind speeds of every area with precision.

If we know where the wind blows harder...

we can place the wind turbines in the location where they can **produce more electricity**.



Macarthur Wind Farm, Australia

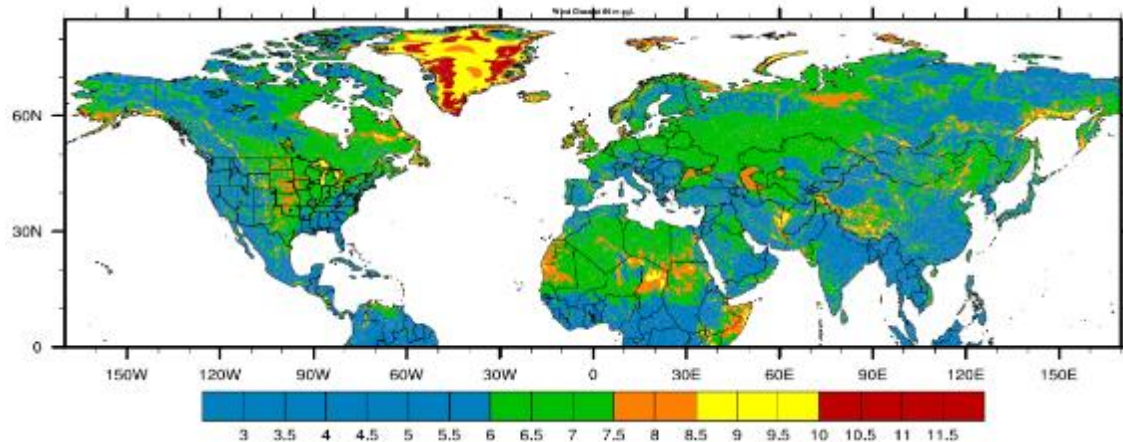
Wind Flow

Vestas monitors the wind flow across the globe

How do we know where the wind blows harder?

The **wind blows differently in every part of the world** because of the rotation of the earth and due to the irregularities of the landscape, which modify the wind flow.

In order to know the **range of speeds** and the **direction of the wind** in a certain area, Vestas' scientific team takes **millions of observations** of the atmosphere every day across the world.



Wind Speed (m/s). Vestas' Climate Library

50 million

Observations of the atmosphere are taken every day across the world by Vestas, building the **largest Wind & Climate Library in the world**

billions

of calculations per second are done by **Vestas' Super Computer**, facilitating the precision of our sites' planning

3 m/s

Speed from which a wind turbine can start to **generate electricity**

Wind Turbine placement

Where should we place the wind turbines to be able to capture more energy

Park Layout

As a rule of thumb, turbines in wind parks are usually spaced somewhere **between 5 and 9 rotor diameters** apart in the wind stream's direction, and between 3 and 5 diameters apart in the direction perpendicular to the wind stream.

Before determining where the turbines should be placed, Vestas siting experts realise **site assessments** for more than one year, placing measurement masts over the wind park area in order to obtain accurate information about wind speed and temperature.



As the measurement point vertically increases, **the wind's speed is higher**. But if there are two obstacles, such as mountains, the wind gets compressed and its speed increases considerably.

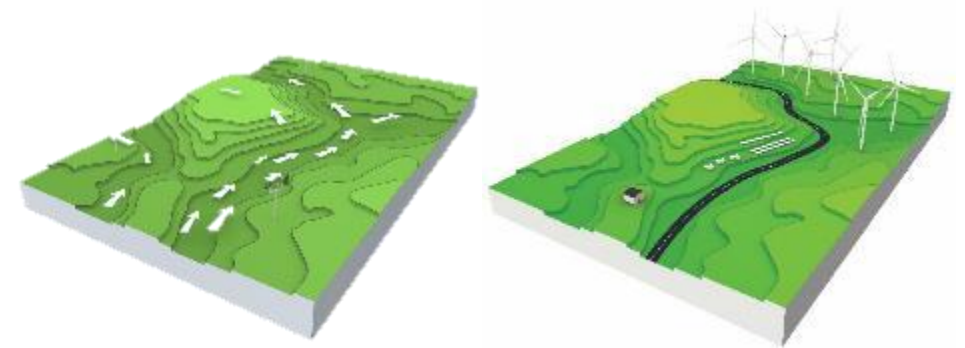
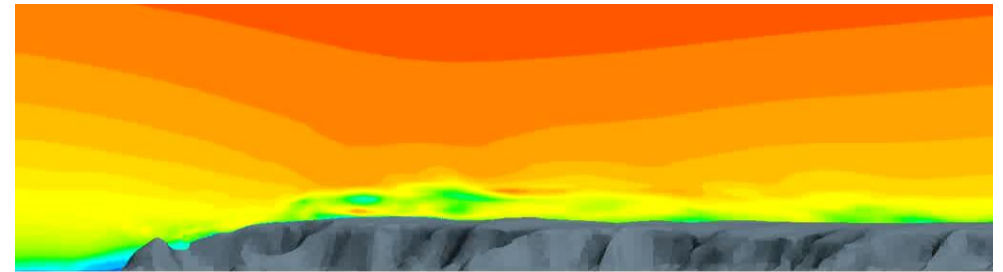


The wind is **strongly influenced by the presence of obstacles** in the landscape, such as buildings or hills.



The effect extends vertically to approximately **three times the height of the obstacle**, and downstream to 30 to 40 times the height.

Accelerated life-time simulation. Wind speed (m/s) depending on the landscape's irregularities.



Wind map for optimal met mast placement

The rotation of the blades

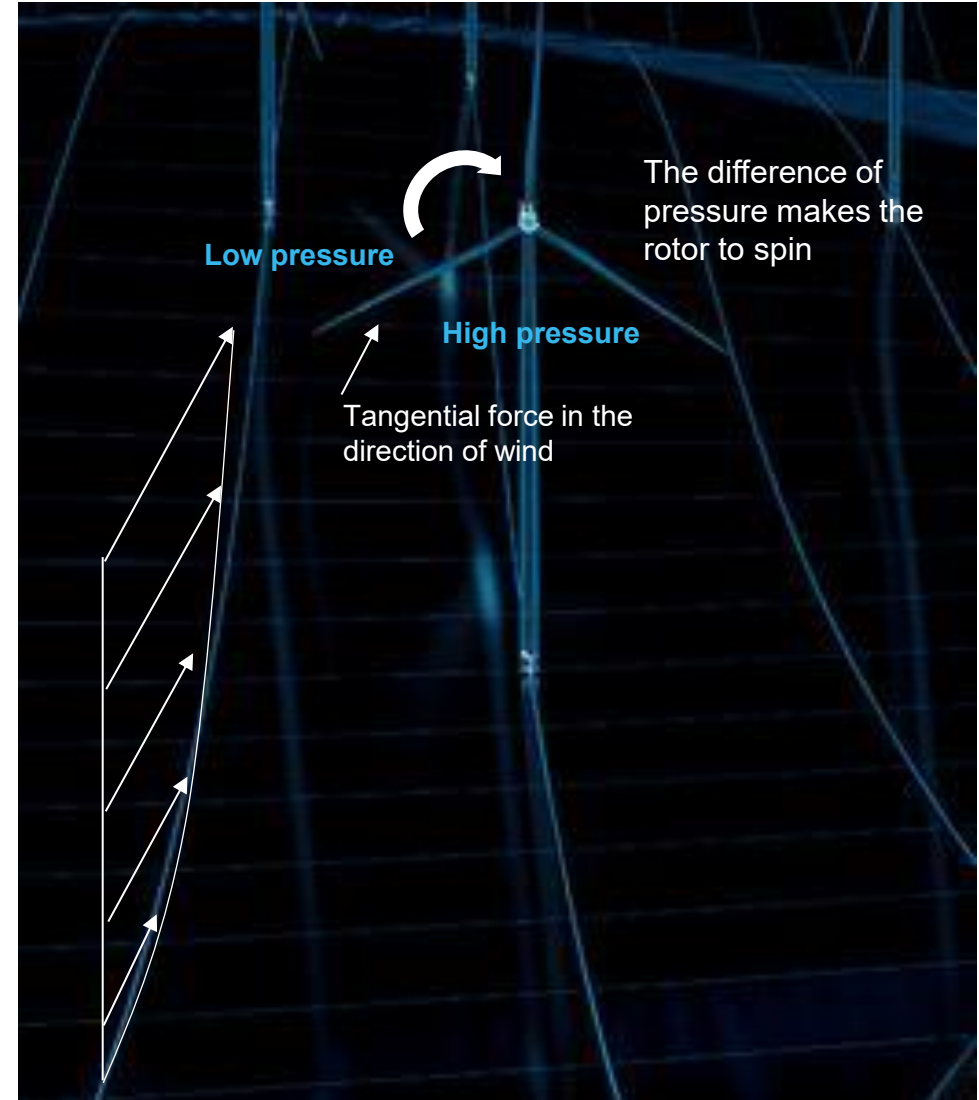
Aerodynamics of wind turbines

The more velocity and density the wind has...

the more **power** is carried by the wind stream. Also, the **longer the blades** are, the more power they can capture.

For this reason, the higher the wind turbines are, the larger the swept area of the blades is, and more energy they can capture.

However, there is a limitation to that: no wind turbine can capture more than **59% of the energy of the wind** (Albert Beltz Law).



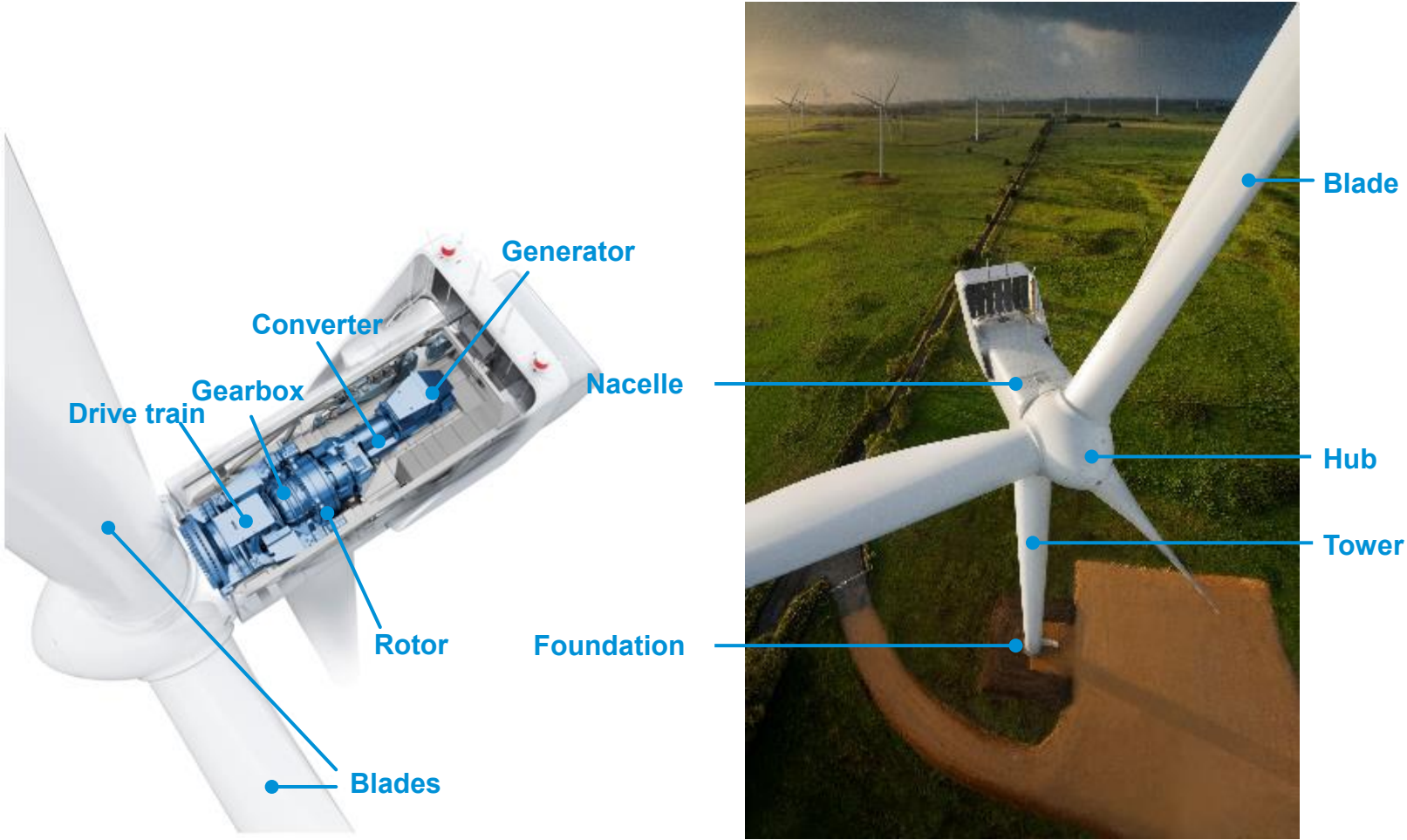
Wind speed distribution at this point

Capturing the power of wind

How does power go from blades to generator

The Wind power

is captured by the blades of a wind turbine, which provoke the spinning of the rotor. Then, the generator placed inside the turbine's nacelle, converts the energy captured by the blades to electricity.



The transmission of power inside a wind turbine

How is wind power converted to electricity

How does the generator convert the movement of the blades into electricity?

- ✓ When the **blades spin**, they activate the movement of the **drive train** inside the nacelle, which provokes the movement of the **rotor** at a certain speed.
- ✓ Then, following the electromagnetism principles, **electricity is created** by the rotation of some magnets (rotor) inside a coil.
- ✓ The electric current generated by the engine has alternate direction, but to be able to **transport it to our homes**, we need it to have the same direction all the time. For that reason, the nacelles have a **converter** that transforms the direction of the electric current generated to the one we need.

Wind power

is the **electricity generated** by harnessing the energy of wind.

100 times

The **rotation speed of the rotor** multiplied by the gearbox to a 100 times the **blades' speed**.

250 km/h

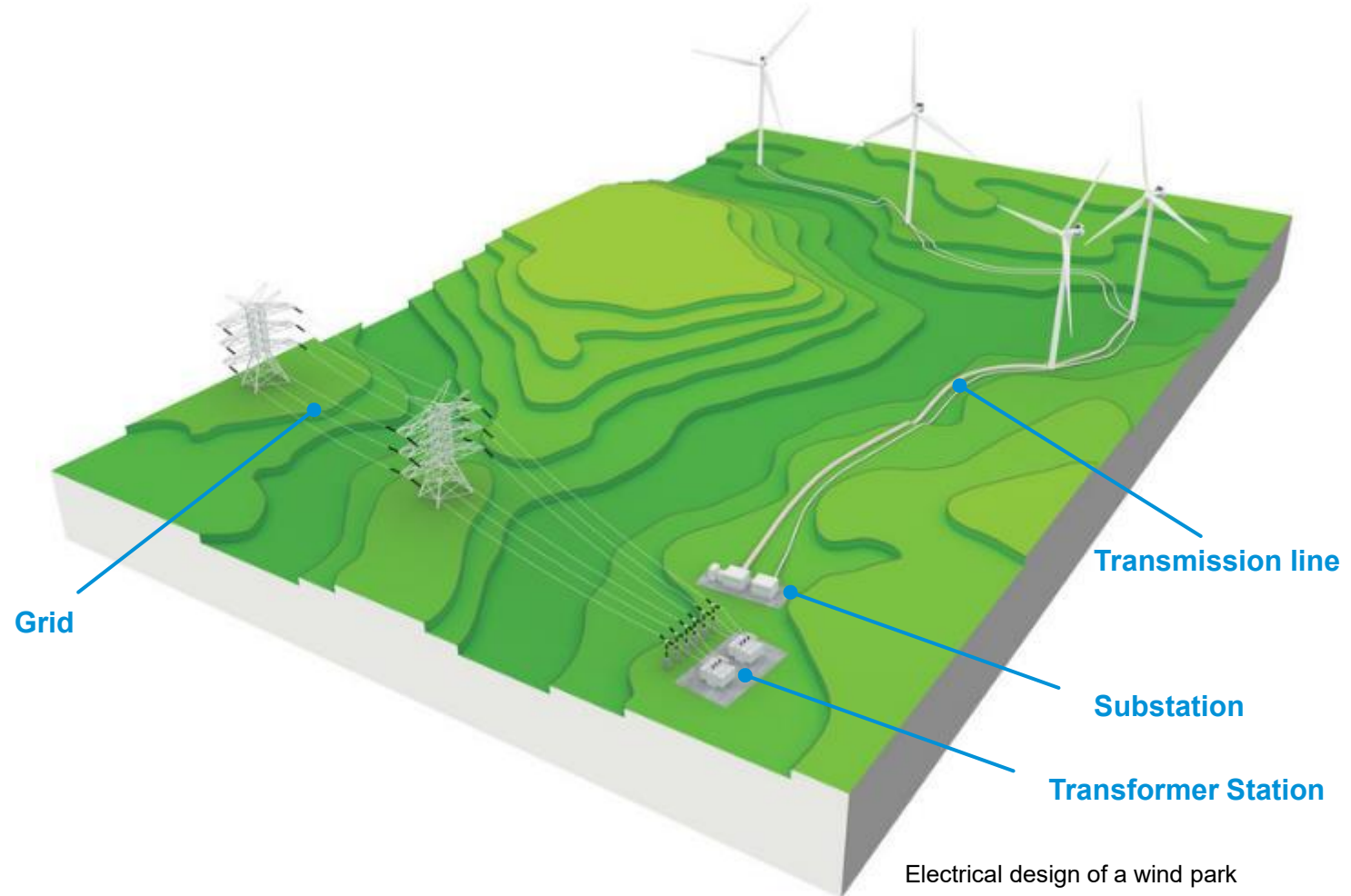
Average speed of the tip of a blade.

From the power plant to the end user

Transmission line and grid

How is the electricity brought to our homes?

- ✓ The **electricity** generated by the wind turbines is transmitted through wires underground, called, the **transmission line**, to a **grid management substation**, placed in the wind site. There, the voltage of the electric current is adapted to the grid, and directly connected to it grid.
- ✓ Once the electricity is in the **grid**, it travels all the way through the cables sustained by the voltage towers until it reaches every home. Then it is accessible by us, and we can use it through the sockets, light bulbs, electrical appliances... making our daily life better.



History of Wind Energy

From early systems to modern energy

The first wind energy systems

were built and used by an Ancient Civilisation in the Near East, Persia. They used sails connected to a **vertical** shaft, which moved a grinding stone for milling.

Horizontal axis wind mill

Was first introduced in Northern Europe in the Middle Ages. It was the first system to translate horizontal into rotation motion **through encasing gears and axles**.

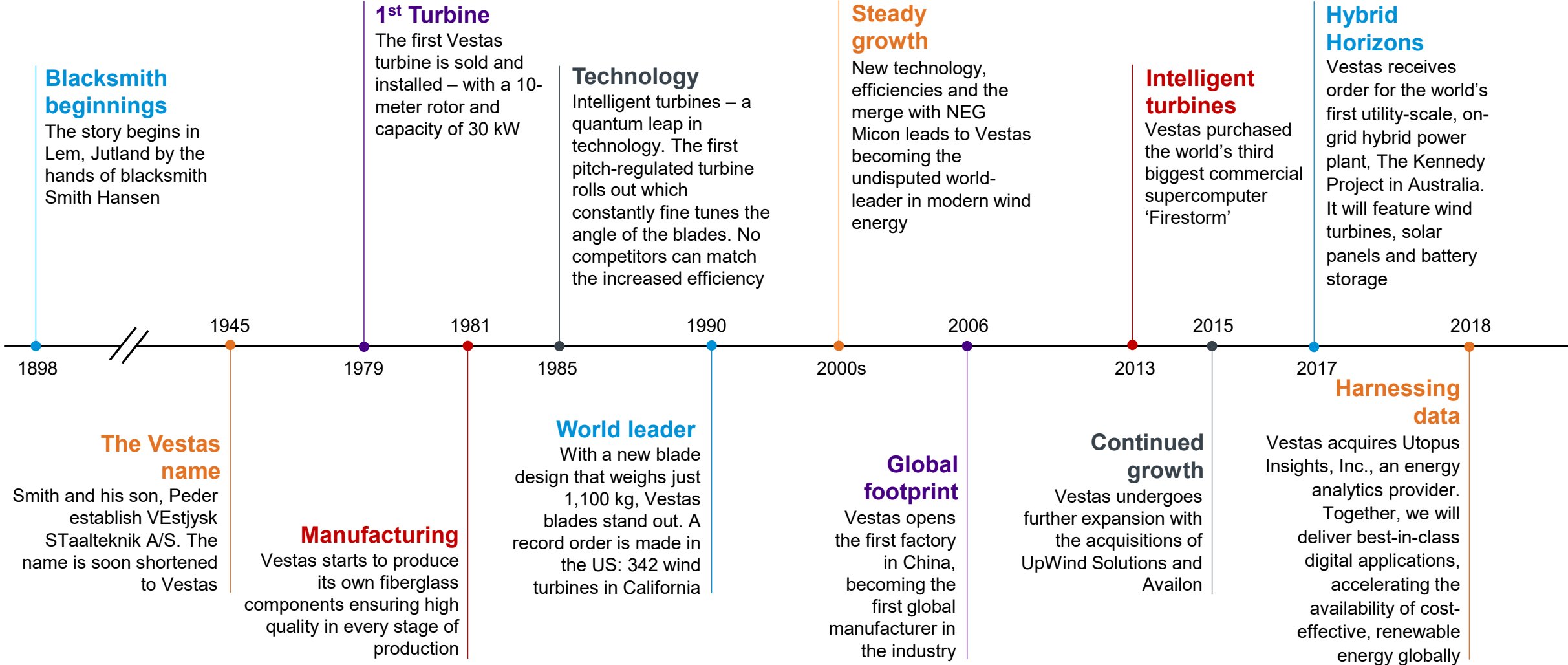
Electricity generation from wind energy

Was achieved with the first wind turbines around **1880s**



The Vestas story

Technology, vision and leadership build the strongest brand in the industry

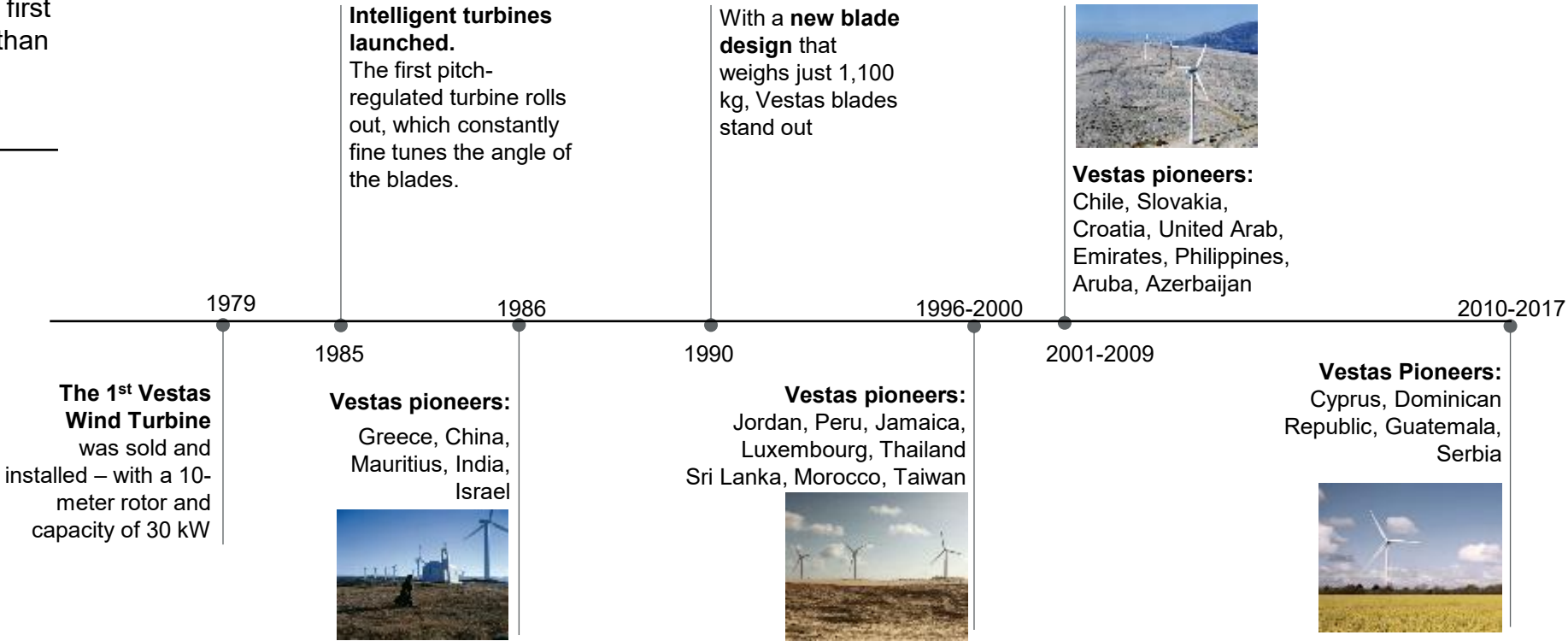


Vestas has pioneered the industry over the past 35 years

Vestas has succeeded in bringing renewable energy to 38 markets

Vestas is a wind power pioneer

since 1986 Vestas has installed the first wind power plant in more countries than anyone else



History of wind energy and Vestas Wind Turbines



Case Story: The first ever Wind Power Plant in China

Rongcheng, China, 1986

In 1986 Vestas installed three turbines in Rongcheng, Shandong Province, marking the establishment of the first ever wind power plant in China. These turbines ran safely for 29 years until retirement in 2015.

The success of the first wind power plant in China facilitated the establishment of the first Vestas office in Beijing in 1999. In 2005, Vestas began to build our largest integrated manufacturing complex in the world in Tianjin, producing generators, blades, nacelles and control systems.

Today, Vestas has installed more than 5,000 turbines in China. With our unparalleled track record, industry-leading know-how and proven experience, we will continue to be reliable and trustworthy partners of Chinese customers.



Site at a Glance		
M100-110 kW Turbine model	0.11 MW capacity	1986 Installation Date

History of wind energy and Vestas Wind Turbines



The largest wind park in Africa

Kenya, March 2017

The 310 MW Lake Turkana wind park, the largest in Vestas' history by number of turbines, is a true testament to Vestas' strong capabilities in emerging markets.

The project will add more than 1,400 GWh of clean, reliable power to the Kenyan national grid per year. Based on current figures, Lake Turkana will supply approximately 15 percent of Kenya's electricity consumption. Early engagement meant greater optimization opportunities, ultimately arriving at one of the highest park efficiencies in the world.

Additionally, the project has improved access to the Lake Turkana area by establishing more than 200 km of roads. With a strong culture of safety, Vestas, along with its partners, ensured that the around 2,500 truckloads travelled the 1,200 km from Mombasa to the site seamlessly.



Site at a Glance

V52-850 kW Turbine model	16 million tonnes of CO2 saved	310 MW Installed capacity	8.4 million average household needs will be covered
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Vestas Wind Turbines, Today

Electricity supplied and CO2 saved with only 1 V136-3.45 MW™ year's production



+4,000 households*

Can be powered every year, in Europe, with only one **V136-3.45 MW™** Vestas Wind Turbine.



+110,000 tons of CO2*

Can be saved every year in Europe with only one **V136-3.45 MW™** Vestas Wind Turbine.

That's equivalent to...



The yearly carbon consumption of around **11 million trees**

*Assumptions: One wind turbine, 100% availability, 0% losses, at an average wind speed of 7.5 m/s, k factor =2, Standard air density = 1.225, wind speed at hub height

Optimising the production of wind energy

How data is used to keep a turbine spinning

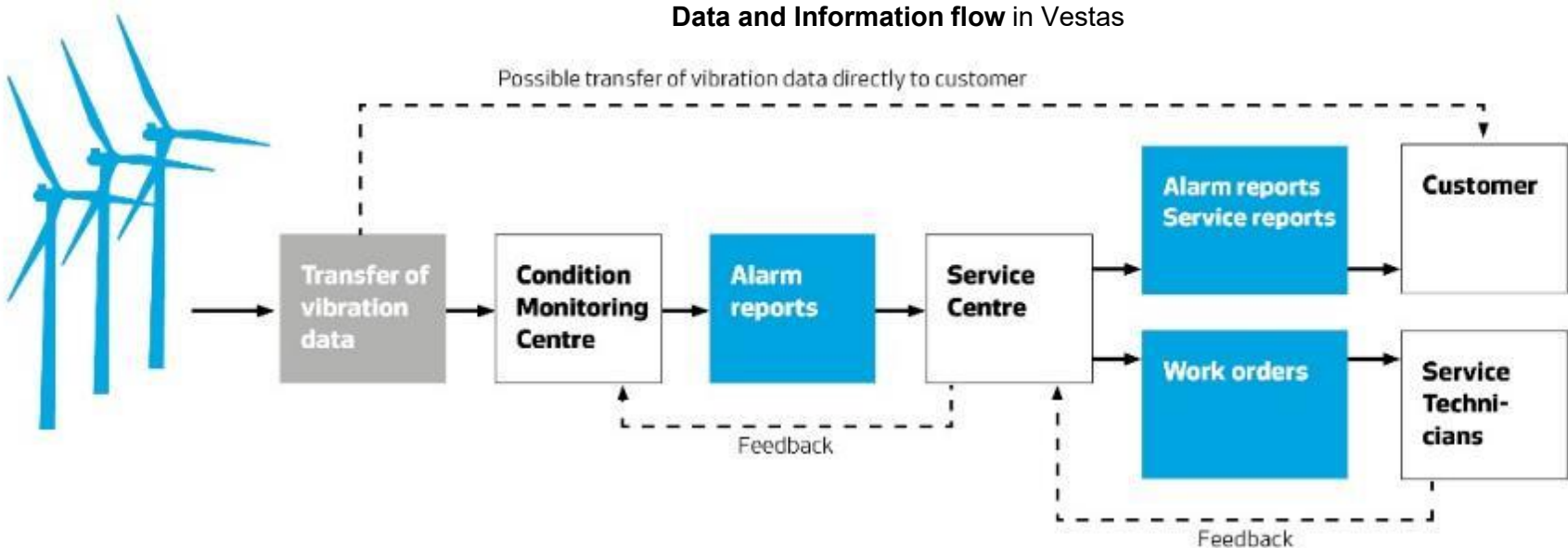
Vestas Wind Turbines have **sensors** that allow us to monitor their production. Vestas processes the data from more than 50 million sensors placed in wind turbines connected to the grid.

With this information it is possible to:


- **forecast** if the turbine will have a **technical problem** and prevent it before it actually happens
- **monitor the energy production** at all times.
- design better **innovative products**.

+50

Million sensors from connected wind turbines



Manufacturing Wind Turbines

A large, white, cylindrical wind turbine nacelle is positioned horizontally in a spacious industrial factory. The nacelle is supported by a large, circular, brown metal flange at its right end. The factory has a high ceiling with exposed pipes and fluorescent lighting. The floor is a light-colored concrete with some markings. In the background, there are several windows and a doorway leading to another area.

The parts of a wind turbine

Are produced separately at different locations across the globe, ensuring its high quality and reliability.

Vestas manufacturing at a glance

Vestas wind turbines are produced in 22 manufacturing facilities across the globe

Nacelles

Including hubs and drivetrains, are produced in **6 locations**: US, Spain, Denmark, India, China and Brazil.

Blades

Are produced in **8 locations**: US (2), China, Germany, Denmark, India, Italy and Spain.

Generators

Are produced in **3 locations**: Denmark, Germany and China.

Converters & Controls

Are produced in **2 locations**: Denmark and China.

Towers

Are produced in **1 locations**: US.



Transporting Wind Turbines



Transport of wind turbines

From production to installation site

Access to sites

Can become an important challenge when transporting large wind turbine parts such as blades, nacelles and towers. **Trucking** is the usual mean of transport used in the last delivery phase.

Shipment of parts

Vessel transportation is usually the most efficient way to transport big components from one point to another, but it requires high expertise and technology for unloading the parts.

Innovating to reduce challenges

Vestas has developed, and continues to develop **smart solutions** for transport of wind turbine parts, reducing the risks, as well as focusing on safety and quality.



Installing Wind Turbines

An aerial photograph showing the construction of a wind turbine. A large yellow lattice crane is positioned on the ground, lifting a section of the turbine's nacelle or hub. The turbine's tower is visible on the right, and its blades extend across the frame. The background shows a rural landscape with fields and trees under a clear sky.

Heavy-weight supporting cranes

are required to install the wind turbines. Sometimes this technology has to be carried from neighbor countries.

Maintaining Wind Turbines

+7,000 Service Technicians
around the world monitor, repair and
prevent failures of wind turbines scattered
across **more than 60 countries**





Vestas®

Wind. It means the world to us.™

Thank you for your attention

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