Wind. Clean & mainstream energy.

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About Vestas & MHI-Vestas

- Onshore wind focus
- 40 years of experience
- +100 GW installed
- +78 GW under service
- 24,000 employees

- Offshore wind focus
- 50/50 JV with Mitsubishi Heavy Industries
- First commercially available double-digit wind turbine – the V164-10.0 MW
The Vestas story

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

1898

The Vestas name
Smith and his son, Peder establish VEstjysk STaalteknik A/S. The name is soon shortened to Vestas

1945

Blacksmith beginnings
The story begins in Lem, Jutland by the hands of blacksmith Smith Hansen

1979

1st Turbine
The first Vestas turbine is sold and installed – with a 10-meter rotor and capacity of 30 kW

1981

Technology
Intelligent turbines – a quantum leap in technology. The first pitch-regulated turbine rolls out which constantly fine tunes the angle of the blades. No competitors can match the increased efficiency

1985

World leader
With a new blade design that weighs just 1,100 kg, Vestas blades stand out. A record order is made in the US: 342 wind turbines in California

1990

Steady growth
New technology, efficiencies and the merge with NEG Micon leads to Vestas becoming the undisputed world-leader in modern wind energy

2000s

Continued growth
Vestas undergoes further expansion with the acquisitions of UpWind Solutions and Avalon

2006

Manufacturing
Vestas starts to produce its own fiberglass components ensuring high quality in every stage of production

2013

Global footprint
Vestas opens the first factory in China, becoming the first global manufacturer in the industry

2015

Intelligent turbines
Vestas purchased the world’s third biggest commercial supercomputer ‘Firestorm’

2017

Harnessing data
Vestas acquires Utopus Insights, Inc., an energy analytics provider. Together, we will deliver best-in-class digital applications, accelerating the availability of cost-effective, renewable energy globally

2018

Hybrid Horizons
Vestas receives order for the world’s first utility-scale, on-grid hybrid power plant, The Kennedy Project in Australia. It will feature wind turbines, solar panels and battery storage
About Vestas in Korea

- Vestas Korea since 1997, +40 employees
- 430 MW installed, 405 MW under service
- Working with more than 150 Korean suppliers in and outside of Korea
Denmark 40 years ago
- energy was imported and fossil based

• Before the 1973 oil crisis: Denmark were 99% dependent on imported fossil fuelled energy generation

• Oil crisis caused a severe economic crisis, rising unemployment - and no non-commercial driving on Sundays!
40 years later
- a totally different energy system

Quick facts:

- Net export of oil and gas (only EU-country)
- Lowest energy consumption per GDP-unit in EU
- Highest level of wind integration in the world: 43% in 2017
- Most efficient clean coal technology in the world
- Highest export share of energy technology in the EU: Almost 12% of total export of goods in 2016 of which almost 60% were green energy technology
- Leading nation of advanced energy solutions (district heating and CHP, wind turbines, biomass plants, energy saving technologies, etc.)
Why wind is now mainstream
Competitive cost of energy already today

Levelized cost of energy, $/MWh

- Onshore wind: 26 $/MWh
- Offshore wind: 71 $/MWh
- Solar PV tracking: 32 $/MWh
- Solar PV fixed axis: 34 $/MWh
- Nuclear: 52 $/MWh
- Natural gas CC: 40 $/MWh
- Coal: 40 $/MWh

- Onshore and offshore wind are getting more and more and cost-competitive.

- Reduction are mainly driven by declining wind turbine prices and increased power output.

Source: BNEF 1H 2018 Wind LCOE Update
And wind will be even more cost competitive in the future.

Source: Wood Mackenzie 2018
Technology development
Onshore wind technology are more powerful than ever before

► The reduction in cost of energy is driven by technological progress and scale

► Taller turbines with longer blades capture more wind and can support more powerful generators
Larger turbines for increased energy production

- Double-digit energy production improvements in low and medium wind speed conditions

Energy Production*
Vestas applies learnings from 33,000 WTGs worldwide to deliver quality products, world-class siting capabilities, and maintenance.

Turbines under surveillance feed back data to the rest of Vestas value chain.

- **PRODUCT DESIGN**
  - Data is the fundamental prerequisite for a design life of 20+ years

- **VALIDATION TESTING**
  - Data ensures that accelerated lifetime simulations on key components are as realistic as possible

- **PROJECT SITING**
  - Data enables siting to optimise component loads and production

- **SOURCING & PRODUCTION**
  - Data ensures that the most significant CQs (critical-to-quality) are thoroughly managed in manufacturing

- **OPERATIONS & MAINTENANCE**
  - Data allows us to (through condition monitoring) implement timely predictive maintenance, thereby minimising lost production
Lessons learned from Europe
Lessons learned

<table>
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<tr>
<th>Onshore wind</th>
<th>Offshore wind</th>
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<tr>
<td>- Investing in <strong>wind energy is a safe bet</strong>. Not only from a climate change perspective, but also from a pure cost perspective.</td>
<td>- Offshore wind is not onshore wind. It requires a <strong>larger, stronger and different infrastructure</strong> in order for offshore to realise its full potential.</td>
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<td>- Onshore wind is today among the <strong>most cost-efficient power generating technologies</strong>, mainly due to declining wind turbine prices, O&amp;M optimisation and increased power output.</td>
<td>- Wind maps, seabed conditions, infrastructure, <strong>supply chain</strong>, ports, ships and manufacturing centres, to support construction and maintenance activities, are key enablers for the industry.</td>
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<td>- National and local <strong>planning frameworks</strong> have spurred growth in onshore wind strengthening European energy security.</td>
<td>- In order to accelerate the build out, arrive at scale and hence the pace of cost reductions, <strong>long term market visibility</strong> and early planning is key.</td>
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In conclusion

1. Wind is today mainstream and cost competitive
2. Technology, data and scale are driving down cost
3. Long-term and predictable policy frameworks as well as system flexibility will be key to get the best out of wind
Thank you.
Transformation of European power

Europe power supply mix

Key outcomes

- **Coal**: Enacted by national governments. High coal and carbon prices continue to challenge.
- **Nuclear**: Persistent operational issues. Accelerated plans to remove capacity across several markets. New-build delivery & cost risk point to downside.
- **Renewables**: Despite reduction/removal of subsidies, cost reductions and competitive markets allow subsidy-free renewable to become a reality.
- **Gas**: Lower coal and nuclear output offset more bullish renewables. Loss of coal capacity narrows the coal-to-gas switching range – offering more certainty for gas.

Source: Wood Mackenzie 2018
Offshore wind is gaining momentum

- The cost of generating electricity through wind off the coast of Europe, the one region where the industry has gained critical mass, has decreased sharply.

- Increased energy production per wind turbine will add greater value for many projects and save on capital expenditure (CAPEX) costs as fewer machines will be needed to meet the park capacity.
Renewable energy system integration
- from centralized to decentralized power generation

Wind parks (MW)
- Offshore, 5-40
- Offshore, 40-400
- Onshore, 2 - 40
- Onshore, 40-75

Central Power plants (MW)
- 50,0 - 100,0
- 100,1 - 500,0
- 500,1 - 1000,0
- 1000,1 - 1500,0

Decentral power plants (MW)
- 2,0 - 20,0
- 20,1 - 100,0
- 100,1 - 110,0
Proces for a Decentralised Wind Project in Denmark
- From siting to construction

1. Wind assessment and siting, before developer applies for a project
2. Environmental impact assessment
3. Public consultation and meetings with neighbours
4. Municipal approval and commissioning
5. Detailed project description
6. Municipal approval of final project
7. Construction
Framework for Environmental assessments in Denmark

Environment and Landscape

Large and uniform landscapes will usually be more suitable for large wind turbines. Regarding nature and environment it should be underscored that wind power is a clean way to produce electricity as there are no fuel emissions during operation.

Local Wind Assessment

Regardless the type of landscape – experience shows that any location requires customized planning including tailored wind farm patterns.

Shadow effects

A minimum distance to housing in the regulation reflects the visual impact of the wind turbines (shadows and flicker effects).

Noice

The developer must demonstrate that the limits for noise in habituated areas are met before the wind turbines can be set up.
Framework for Community engagement in Denmark

- 4 Schemes to ensure public engagement

- Local citizens’ option to purchase wind turbine shares

- Guarantee fund to support financing of preliminary investigations by local wind turbine cooperatives.

- Compensation for loss of value to neighbouring real estate.

- Green scheme to enhance local scenic and recreational values.
Recommendations
- Based on the Danish Case

Grid planning
- Timely planning
- Fair and balanced cost-sharing framework for grid connection of wind turbines.

Siting and Environment
- Consider designating areas to wind turbines through a local planning process with due consideration to optimal wind, distance to neighbours etc
- Cluster wind turbines in the landscape by placing them in wind farms

Public engagement and acceptance
- Public consultation early stage of a project proposal.
- Consider incentives and measures to sustain or increase public acceptance.
Wind creates local jobs
- A wind project is a large investment in local jobs, even without local content requirements

- A considerable part of a wind farm investment will always create local jobs (civil works, cabling, O&M etc.)
- The size of components is in itself a driver to localize manufacturing
- Vestas will hire local staff to do service and maintenance