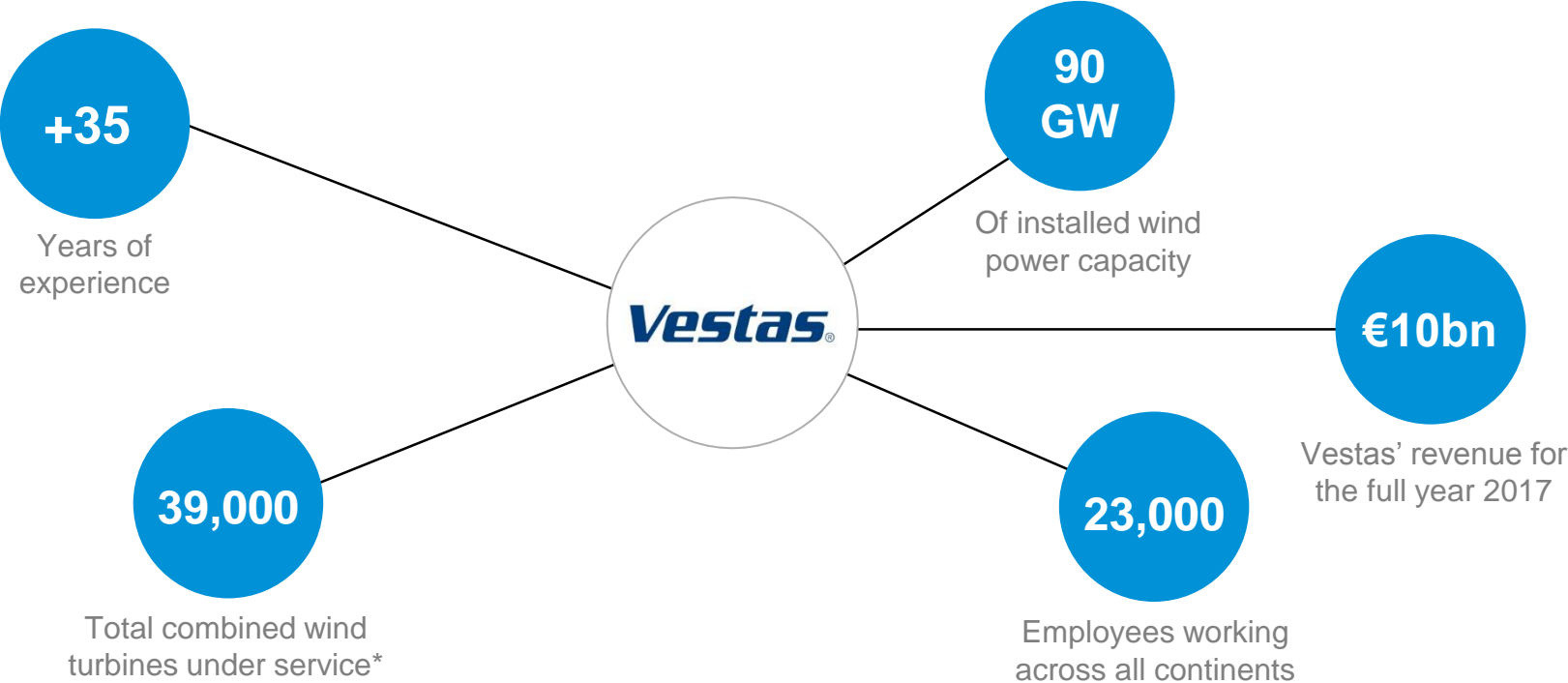




Vestas Global Experience with Hybrid Power Plants

Johannes Schiel, Head of Public Affairs, Vestas Northern & Central Europe

About Vestas



Evolved Energy Market: Complex Energy Network

New business opportunities arise from market developments

Wind energy generation is part of an increasingly complex and ever **evolving energy network**

We are all faced with **changing technical and commercial requirements**

Sustainable Energy Solutions leverage the benefits of different energy generation

Hybrid Power Plants integrate solutions into energy networks on grid and micro-grid scale



Evolved Energy Market: Supporting technologies

Supporting technologies to wind turbine energy generation holds significant potential

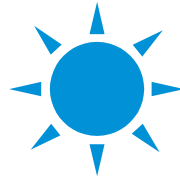
Technological advances in storage, solar, and data utilization make deployment with wind economically beneficial, depending on site specific conditions

Supporting technologies



Storage

- Technology advancements
- Different technologies suited for either power or energy applications
- Steep cost reduction curve



Solar

- Continuous cost reduction
- Complementing wind



Data

- Digitalization of grid
- Understanding supply and demand
- Requirement of data company Utopus Insights

Hybrid system potential

Wind combined with solar and/or energy storage can help secure project realization and improve project return

secure **license to operate** and/or enter into **new markets**



Increase Energy Production

- Use complementary generation to increase annual energy production and optimize supply-demand match



Improved Capacity Factor

- Complementary generation patterns
- Mitigates physical asset-related restrictions



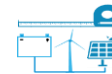
Reduce CAPEX and OPEX

- Reduction from sharing & optimizing equipment and infrastructure
- Case specific avoidance of some equipment



Fulfill grid codes and enter new revenue streams

- More stable load to comply with strict grid codes
- Higher price of energy and new ancillary service revenues



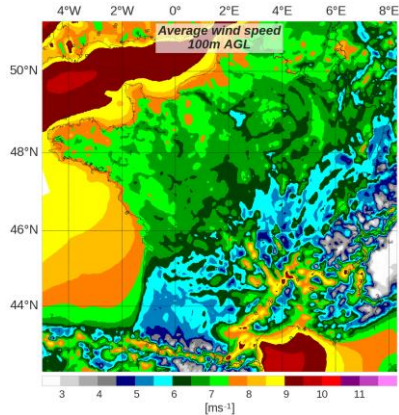
Right-sized assets improve project return

Hybrid Potential Assessment

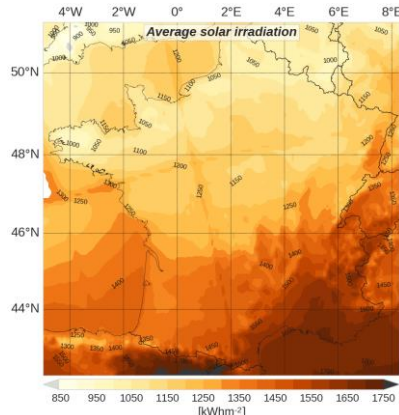
Vestas Siting has the insights and tools to assess the potential for a hybrid power plant

Vestas Siting capabilities allow for detailed hybrid potential assessment to be generated down to site specific level.

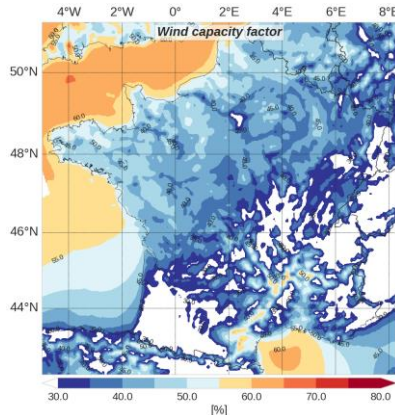
This includes wind & irradiation resources, capacity factor, and supply to demand correlation calculations



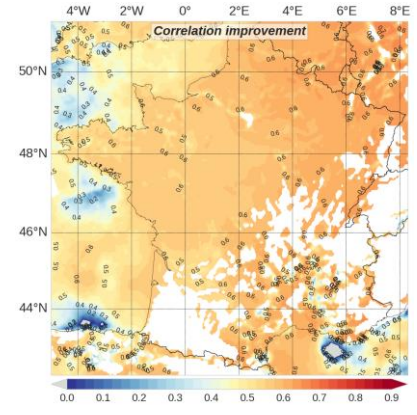
Wind resource assessment



Solar resource assessment



Capacity factor calculations
(Wind/Solar/Combined)

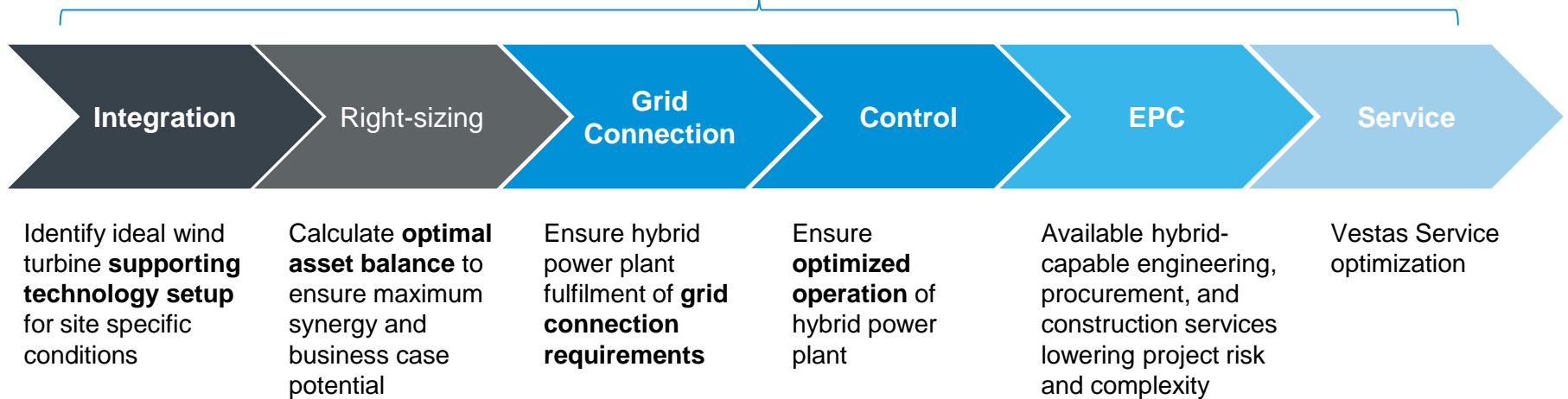


Supply/Demand correlations

Hybrid Power Plant with Vestas

From designing to servicing a hybrid power plant

Vestas[®]



Vestas Experience: Lem Kjær

5 years of experience with the first large scale battery storage & wind plant in operation

Hybrid Power Plant

- Lem Kjær, Denmark 2012
- Battery storage added to existing wind farm
- Connected to Danish transmission Grid
- Battery Management System integrated with wind plant control system

Achievements & Learnings

- Reduction in financial penalties for not meeting generation commitment
- Ramp rate reduction / power smoothing (dP/dt control)
- Improved lifetime of battery storage (rate of degradation)
- Assuring primary, secondary, tertiary reserves
- Enable black start
- Run Voltage control
- Test 2 different Lithium battery types



Vestas Experience: Greece, Louzes

5 years of experience with active power regulation of Wind & PV hybrid plant

Hybrid Power Plant

- Louzes Wind & Solar plant, Greece, 2012
- 1MW PV plant integrated in the same power line with the existing 24MW wind turbine plant.
- Local grid operator requested monitor and control of PV plant in addition to wind turbine plant.
- Active wind turbine power control dependent on PV plant power output

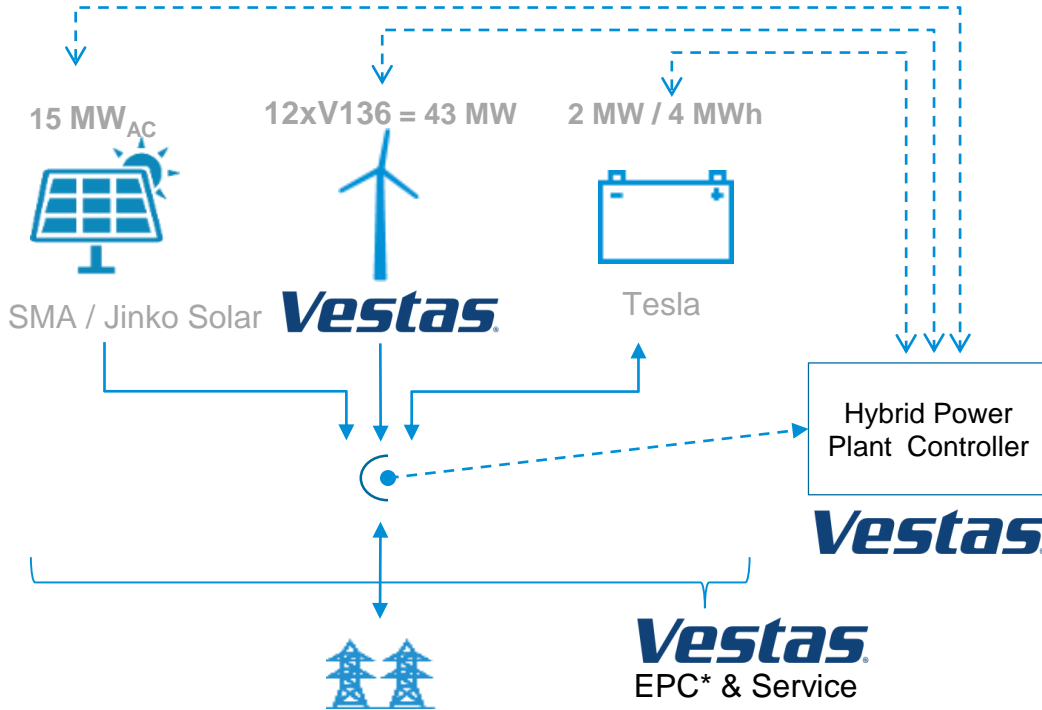
Achievements & Learnings

- Vestas supported Customer to meet local grid operator requirements
- VestasOnline SCADA platform integrates two different systems to be controlled as one common entity for active power regulation



Sustainable energy solutions: First commercial hybrid project

Kennedy Energy Park: World's first utility-scale hybrid power plant combining wind, solar & storage



KEY BENEFITS

Vestas' Hybrid Power Plant Controller enables individual technologies to operate as one integrated facility. Combining wind with solar and/or energy storage help improve project-level economics:



Increased Energy Production



Improved Capacity factor



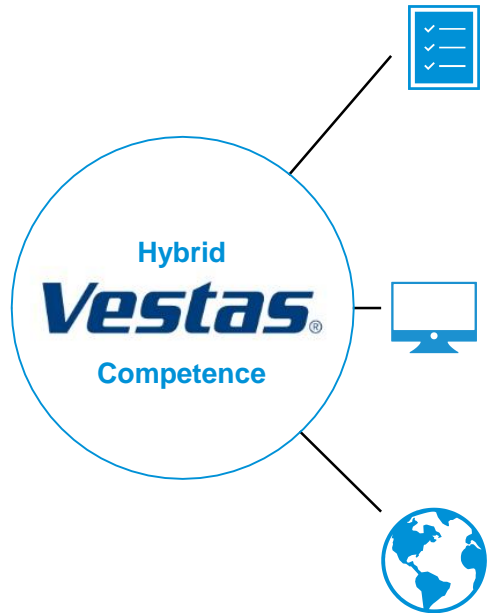
Reduced cost



Fulfillment of Grid Requirements & enable new earning opportunities

Vestas Hybrid Competence

Applying expertise and experience to hybrid power plants



Expertise

- 35 years of meeting **complex & varying grid requirements**
- Deep WTG **product knowledge** & understanding of technical synergies
- **Key components** built in-house

Systems

- **Advanced Power Plant Controller** already managing large wind plants
- **Largest wind database** in the industry
- Building hybrid controller based on **performance data of 33,000 WTGs**
- Advanced siting capabilities including **hybrid potential assessment**

Experience

- 100+ EPC projects in 26 countries
- Lem Kjær hybrid power plant since 2012 (**WTG+Storage**)
- Louzes operating since 2012 (**WTG+Solar**)
- Kennedy sold, installation in 2018 (**WTG+Solar+Storage**)

The image shows three white wind turbines of varying sizes positioned across a landscape of green trees. The sky is filled with large, dramatic clouds, with some light breaking through. The overall scene is a natural, outdoor setting.

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Thank you for your attention

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