lmwindpower.com

TESTING OF LARGE BLADES – CHALLENGES AND TRENDS

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By John Korsgaard, Sr. Director, Eng. Excellence

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A little bit about LM Wind Power*

- Since 1978, LM Wind Power has produced more than **205,000** blades corresponding to a capacity of approximately **93W**
- Contributing to saving more than **189 million** tons of CO_2 per year
- **~10,000**** employees**, 15** manufacturing facilities in **8** countries on **4** continents
- Rotor solutions are supplied to **10 global and national** wind turbine manufacturers, for Onshore and Offshore wind

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LM Wind Power: a leading blade supplier to the wind industry.

*Acquisition completed on April 20, 2017
* *Employee number does not include contractors

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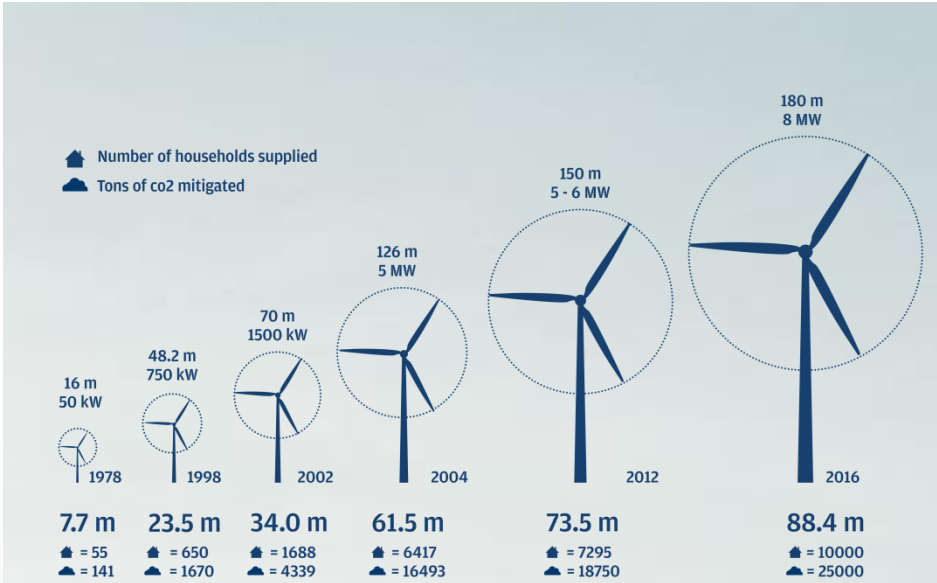
Big,
Bigger,
Biggest



Calculations are based on European data

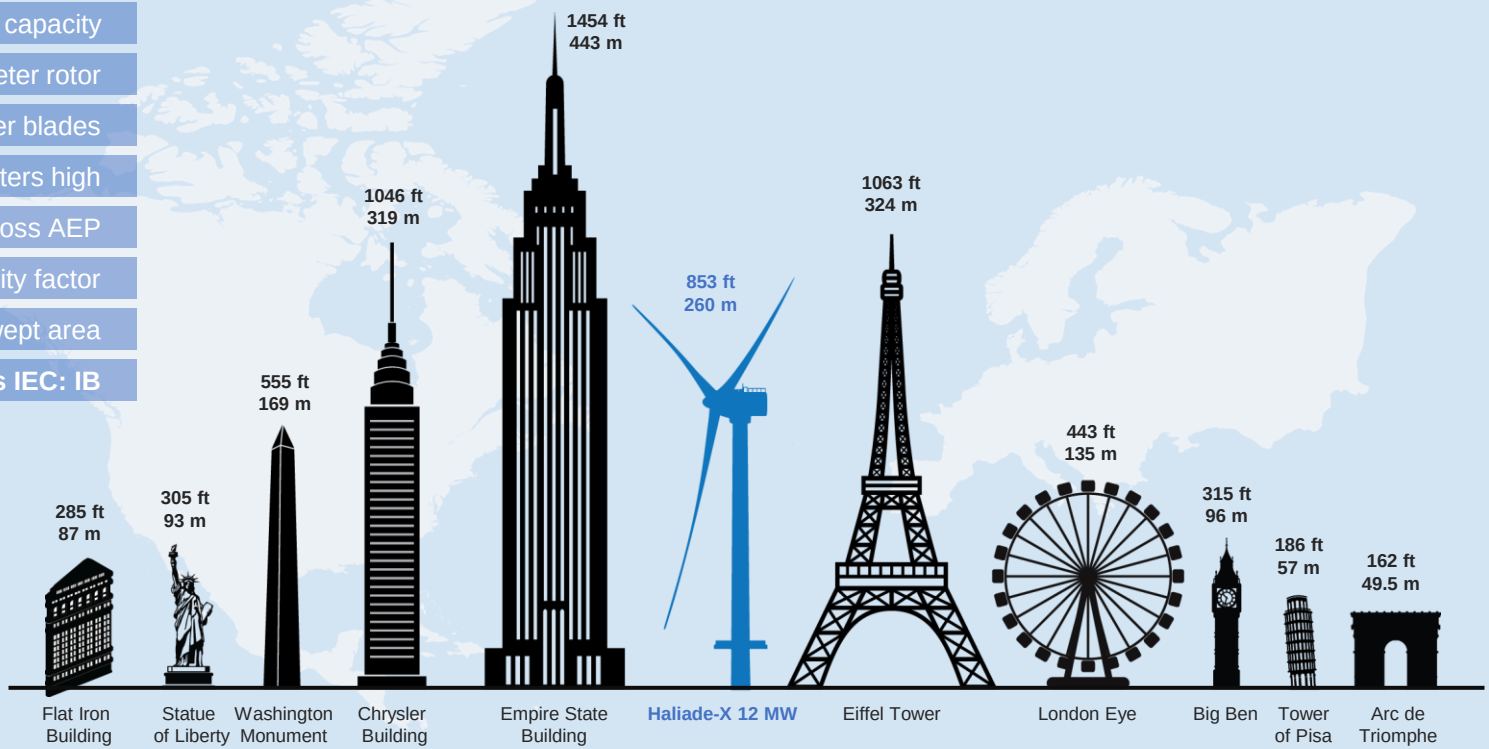
HALIADE-X 12 MW

GE Renewable Energy is developing **Haliade-X 12 MW**, the biggest offshore wind turbine in the world, with **220-meter rotor**, **107-meter blade**, leading capacity factor **(63%)**, and **digital capabilities**, that will help our customers find success in an increasingly competitive environment.

One **Haliade-X 12 MW** can generate **67 GWh annually**, which is **45% more** annual energy production (AEP) than most powerful machines on the market today, and twice as much as the Haliade 150-6MW.

The **Haliade-X 12 MW** turbine will generate enough clean power for up to **16,000** European households per turbine, and up to **1 million** European households in a 750 MW configuration windfarm.

- **12 MW** capacity
- **220**-meter rotor
- **107**-meter blades
- **260** meters high
- **67 GWh** gross AEP
- **63%** capacity factor
- **38,000** m^2 swept area
- **Wind Class IEC: IB**



Blade design is not just aerodynamics, materials and structure

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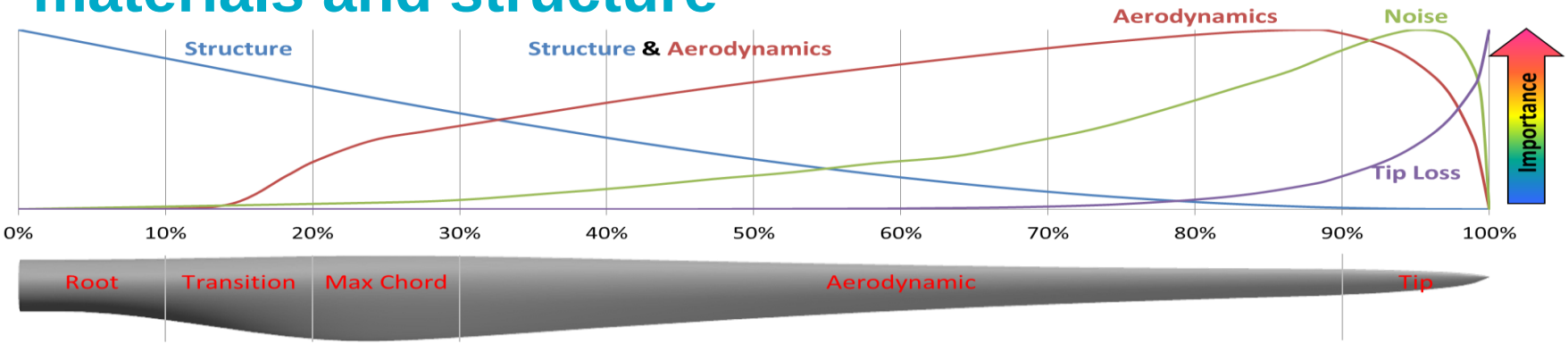

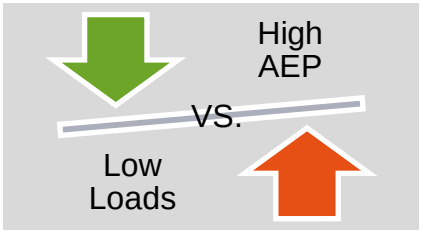

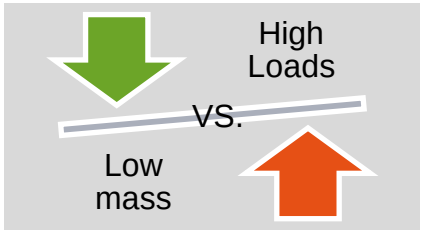

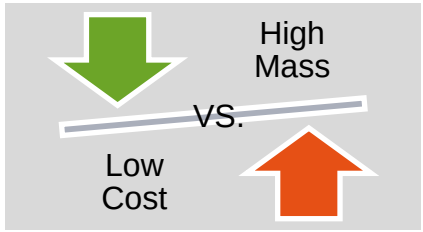

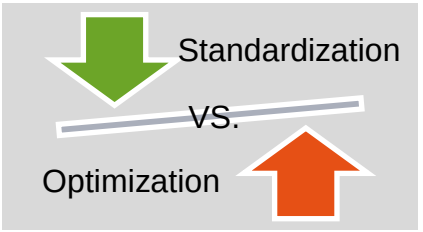

… it's Cost of Energy and Reliability

Cost-effectiveness and reliability through understanding of interaction between materials, process and design

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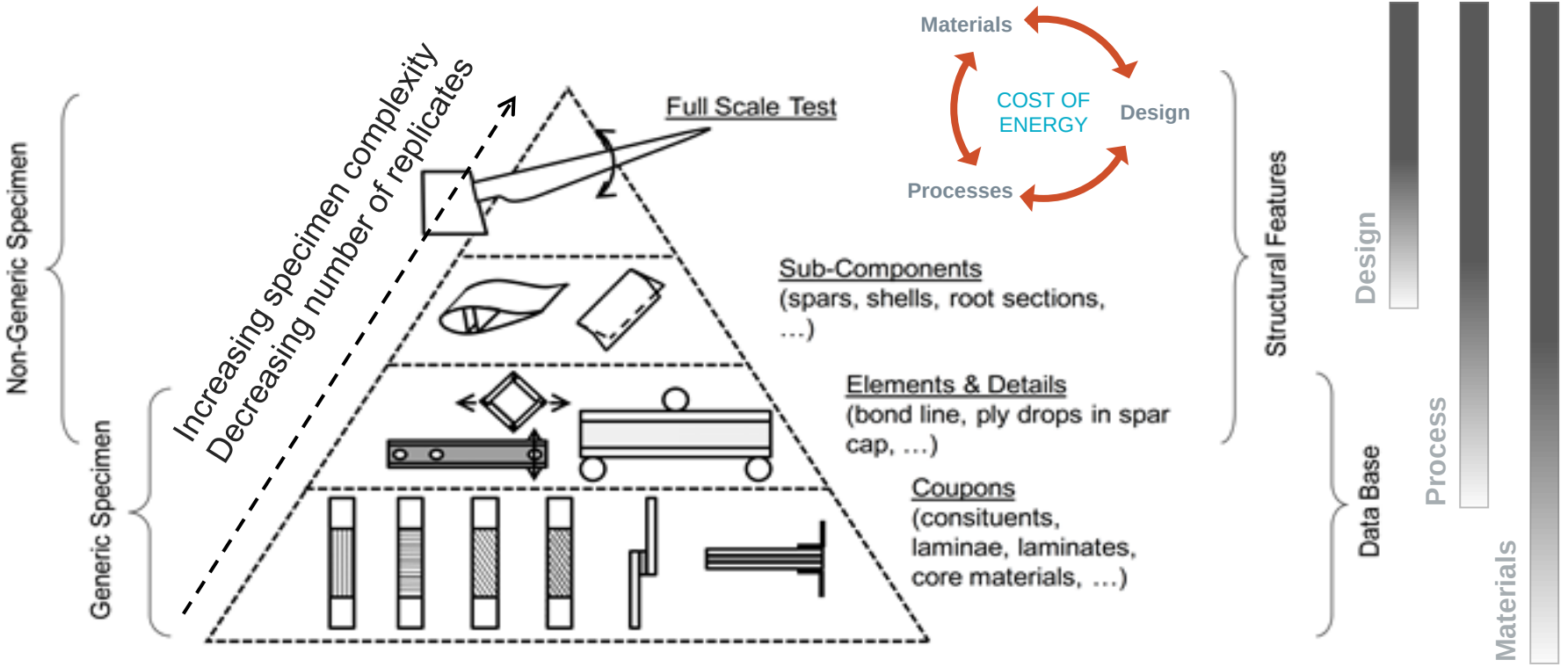

Test pyramide picture from IEA task 35

Final validation through full scale static and fatigue testing

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- Measurement of blade eigen-frequencies and mode shape
- Static test in min. four direction with extreme loads distribution applied to the blade
- Fatigue testing in flap- and edgewise direction simulating operational lifetime
- Post-fatigue static test to demonstrated blade strength after end of lifetime
- Extensive non destructive testing programme using infrared and ultrasound scanning
- Also full scale crash tests are performed in order to determine durability and scale effects

Is there a benefit of advanced full scale blade testing?

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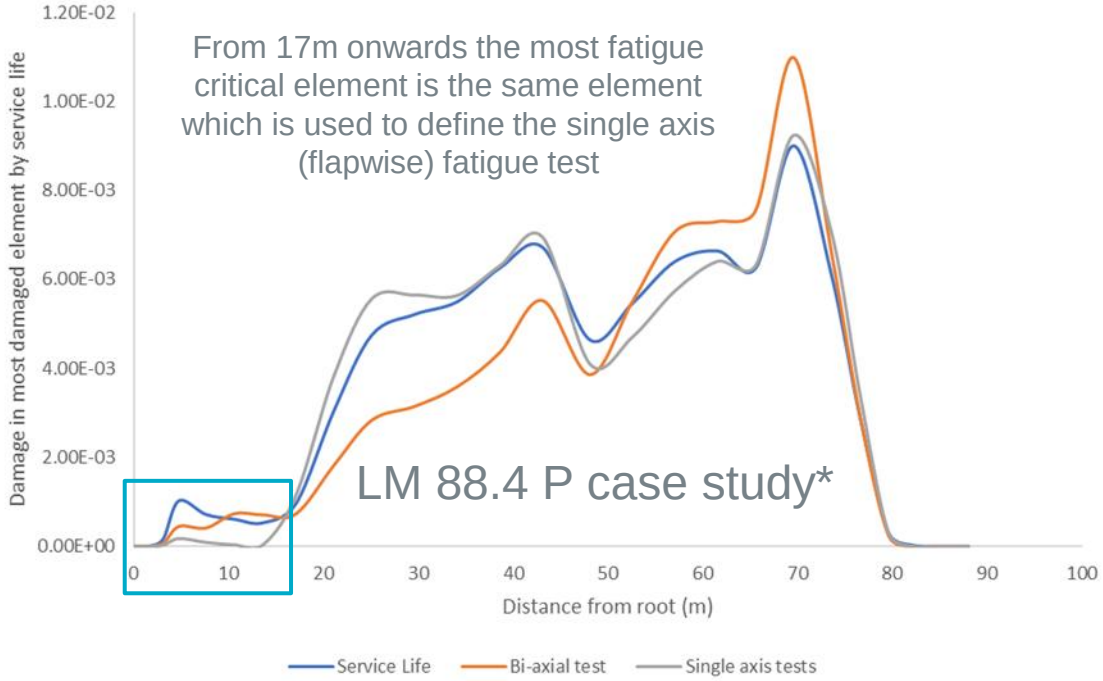

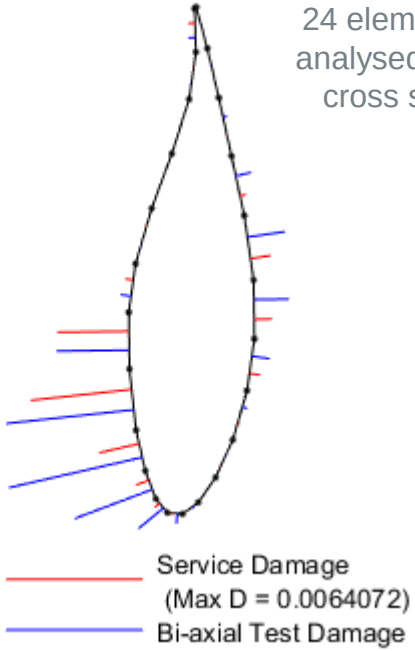

In terms of Palmgren-Miner damage sum, this blade will not benefit from bi-axial testing except near the root

*Work performed by ORE Catapult, UK in the XL-Blade project (DemoWind)

Trends - future test paradigm

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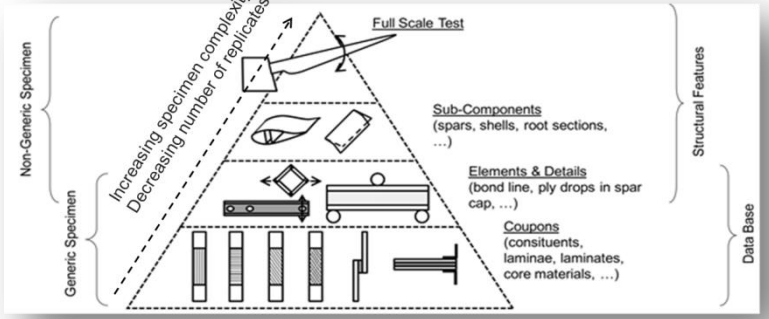
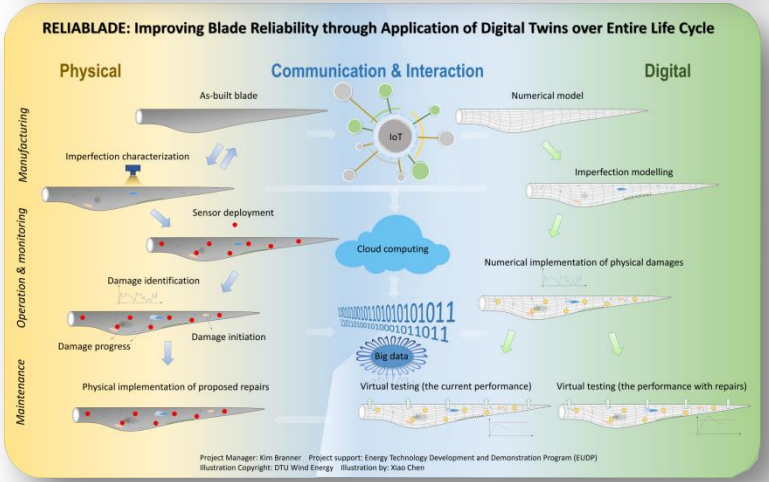
- Reduce cost and time for testing
- Replace full scale testing by more sub-component testing
- Learn about fatigue behavior on all levels – the devil is in the details
- Perform virtual full scale testing through a digital twin representation of physical blades including imperfections





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Thank you for your time

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