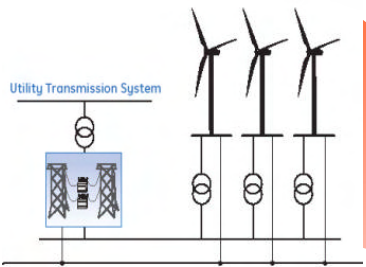


Wind Technology

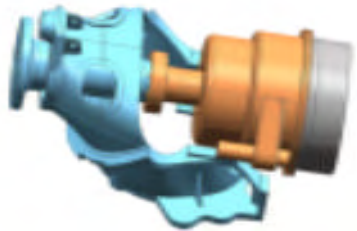


Capture the Wind Energy...

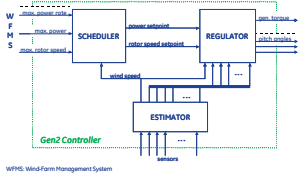
Technology to increase energy capture at the right COE



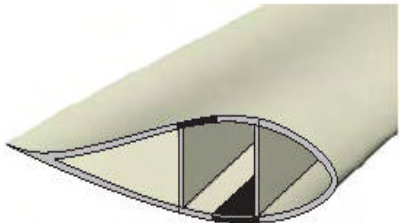
Grid Interface and Energy Conversion



Light & Compact Drive-train



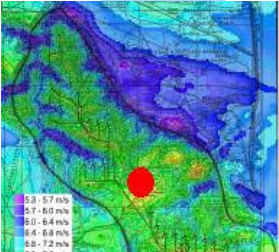
Advanced Controls



Advanced Blades



Logistics



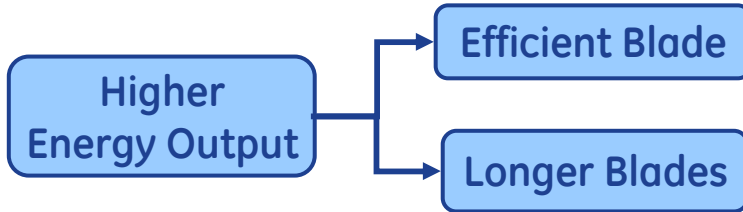
Wind Farm Optimization



Materials & Manufacturing

Technology Roadmap - Blades

Increase capacity factor



Controlling cost

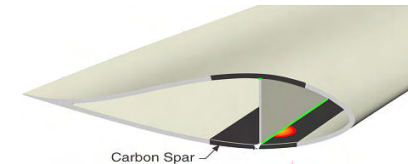
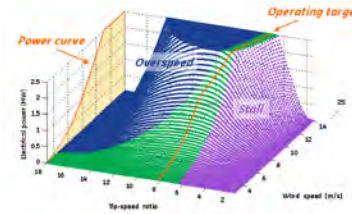
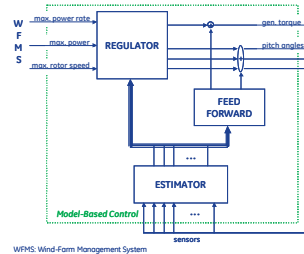
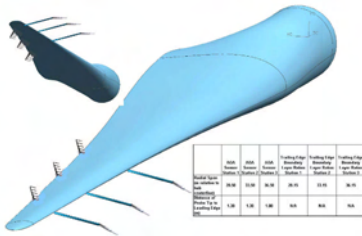


Key enablers:

- Aero efficiency
- Noise control
- Torque capacity

Key enablers:

- Aero-elasticity
- Carbon composite spars
- Controls strategy



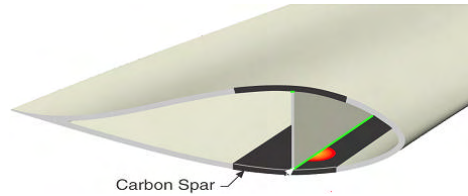
Technical Challenge: Longer, more efficient blade with same loads

Current Blade Technology Roadmap

Blade Technology Assessment

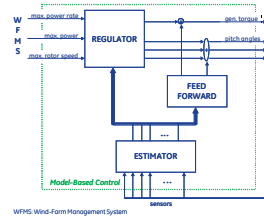
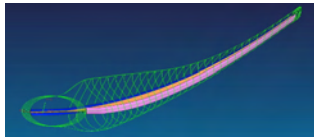
Jointed Blade

Carbon Spar



Aero-Elastic Blade

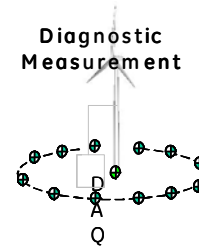
Model Based Control



Aero & Acoustics Technology

DTM

Diagnostic Measurement

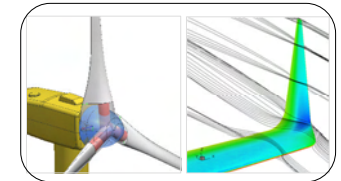
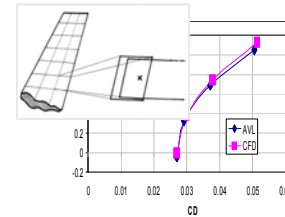


BOAM

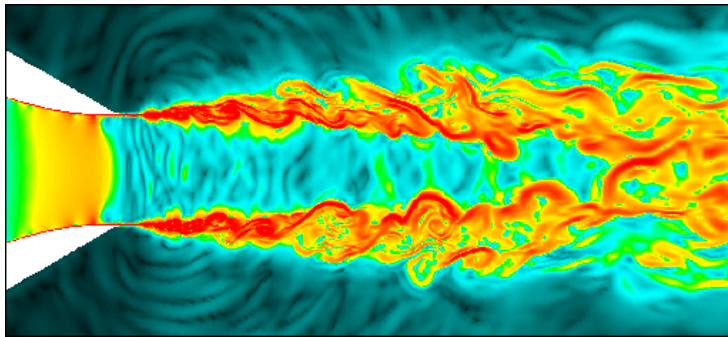
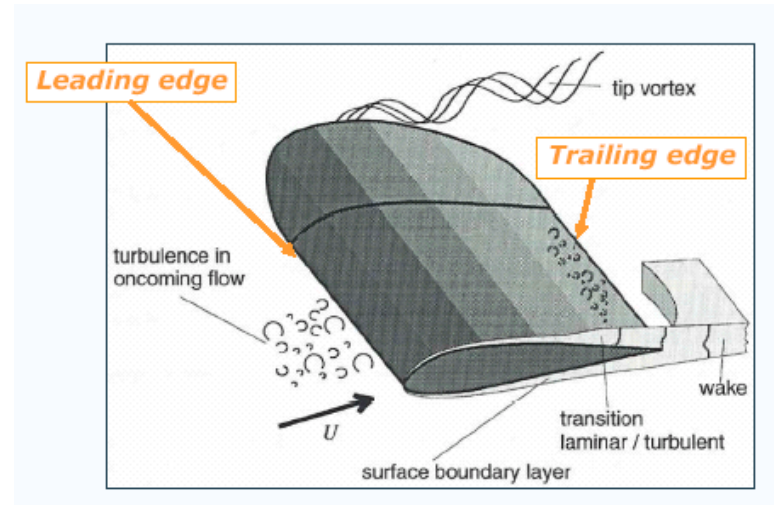
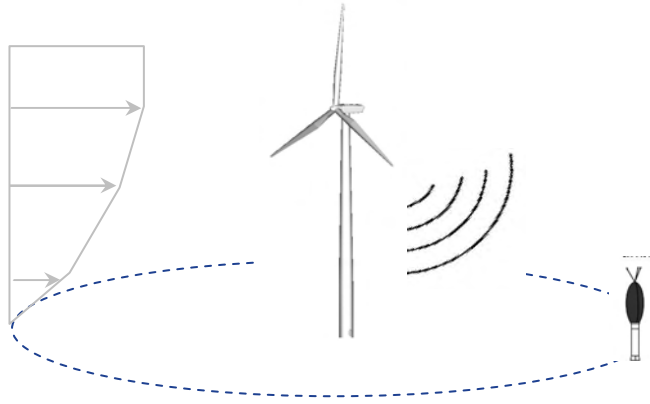


Acoustic Tools

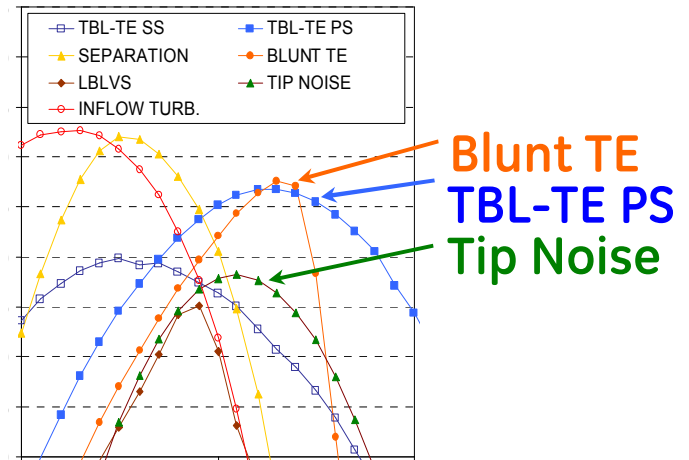
Aero Tools



Noise Constraints...Aero-Acoustics

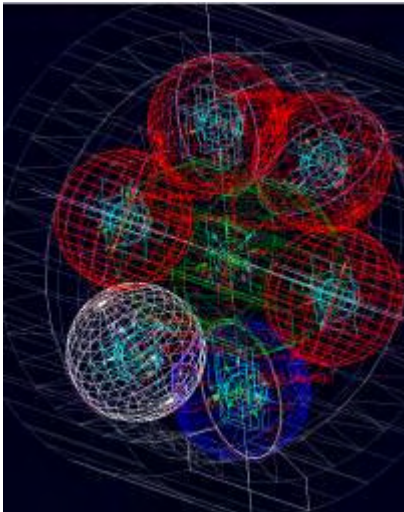
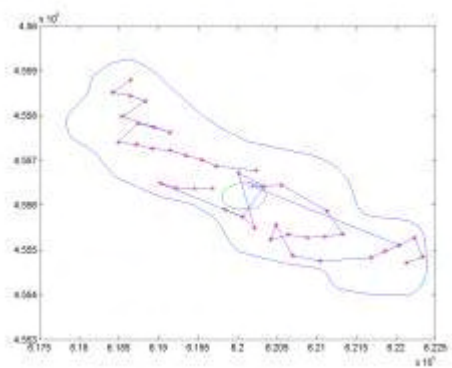
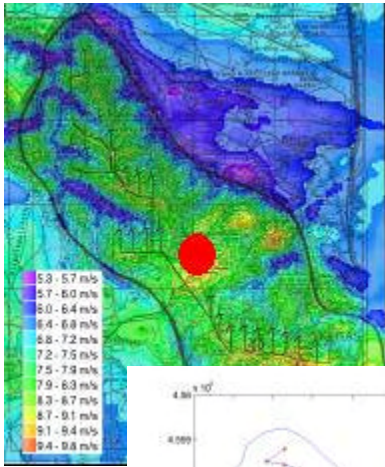


Vortices & Acoustic Waves outside Jet Flow



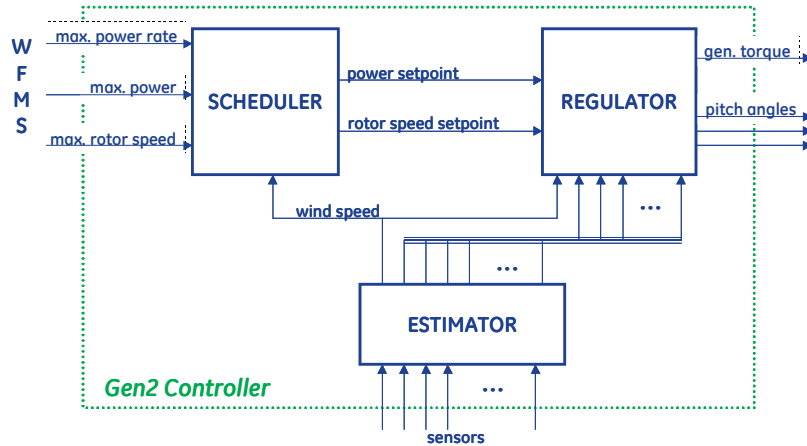
Create new airfoils to balance noise and performance

Reach the Wind Energy...



Technology to deliver turbines where they want to be

Control Wind Energy Capture



Component	% of turbine cost	↑10% blade length	
		Fatigue Loads	Extreme Loads
Tower	21%	↑3%	↑20%
Gearbox	14%	↓14%	↑4%
Pitch system	2%	↑120%	↓5%
Blade flange (hub)	2%	↑53%	↑23%
Hub flange / yaw	4%	↑29%	↑35%
AEP		+8%	

independent effects					
Passive				Active	
Carbon spar		Blade sweep		Model Based Control	
Fatigue Loads	Extreme Loads	Fatigue Loads	Extreme Loads	Fatigue Loads	Extreme Loads
0%	↓20%	↓10%	↑3%	↓10%	↓14%
↑26%	↓11%	↓13%	↑16%	0%	0%
↓50%	↓2%	↑38%	↓29%	0%	↓25%
↓50%	↓4%	↑10%	↓3%	↑1%	↓1%
↓1%	↓13%	↓18%	↓6%	↓9%	↓15%
0%		-0.5%		+1%	

Longer Blade... Carbon Introduction



- Advanced manufacturing development
- Low cost Carbon composite development
- High volume production

