GE Power & Water

Wind Turbine Layout & Performance Optimization
A manufacturer's perspective

NREL Wind Energy Systems Engineering Workshop
Wind Plant Design and Optimization

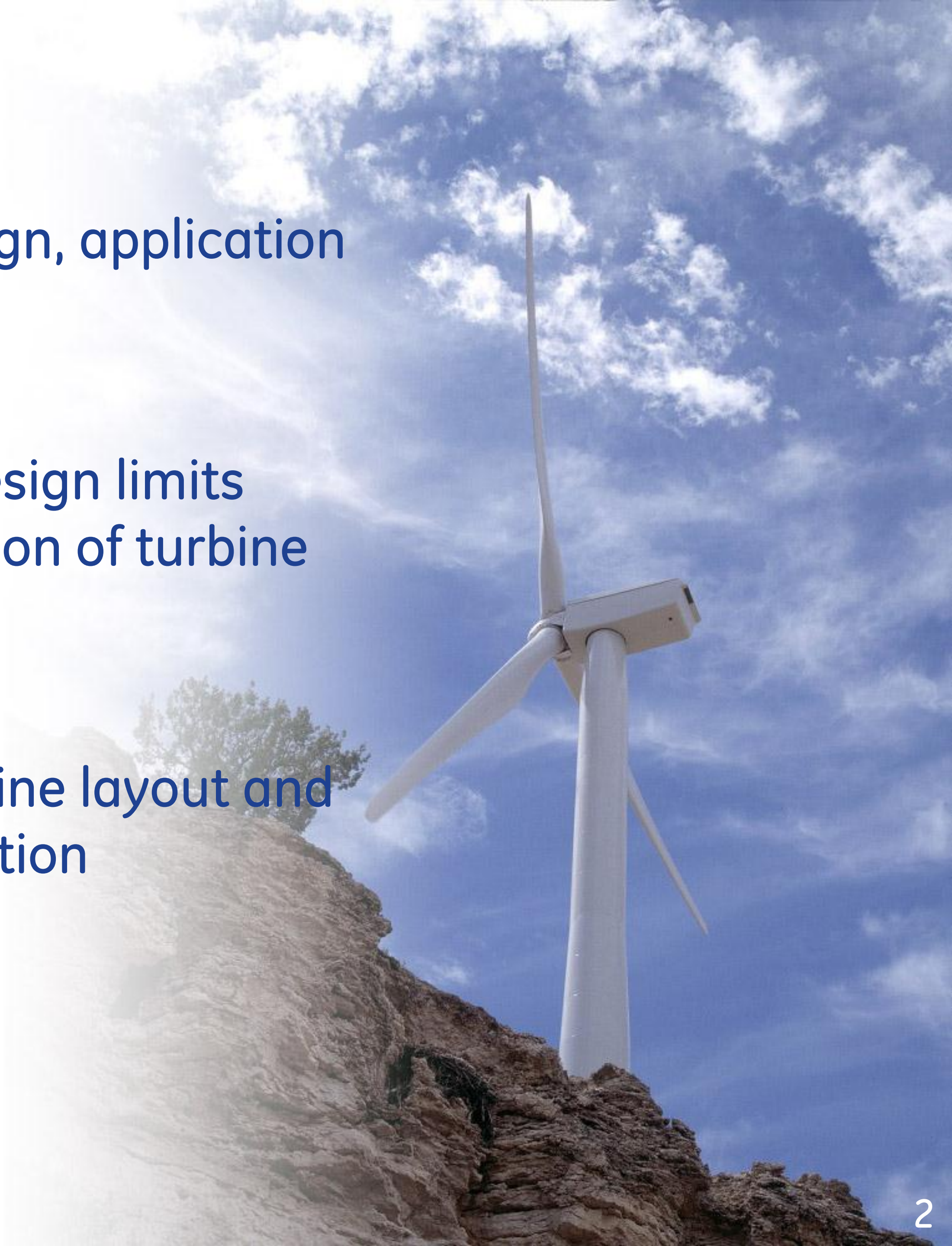
imagination at work

Key Message

- IEC wind class for design, application space for siting

- OEMs knowledge of design limits enabler for full utilization of turbine potential

- OEMs can benefit turbine layout and performance optimization



OEM Engagement

Wind Analysis	Customer typically has options
↓	
Turbine Selection & Layout Optimization	Customer typically has options Can benefit from OEM detail design knowledge
↓	
Final AEP & Loads Assessments	Turbine suitability analysis and power curves for AEP
↓	
Plant Construction	Turbine installation or turn key
↓	
Wind Plant Operation	O&M Can benefit from OEM detail design knowledge

imagination at work

AEP Annual energy production

Turbine Selection – IEC Wind Classes

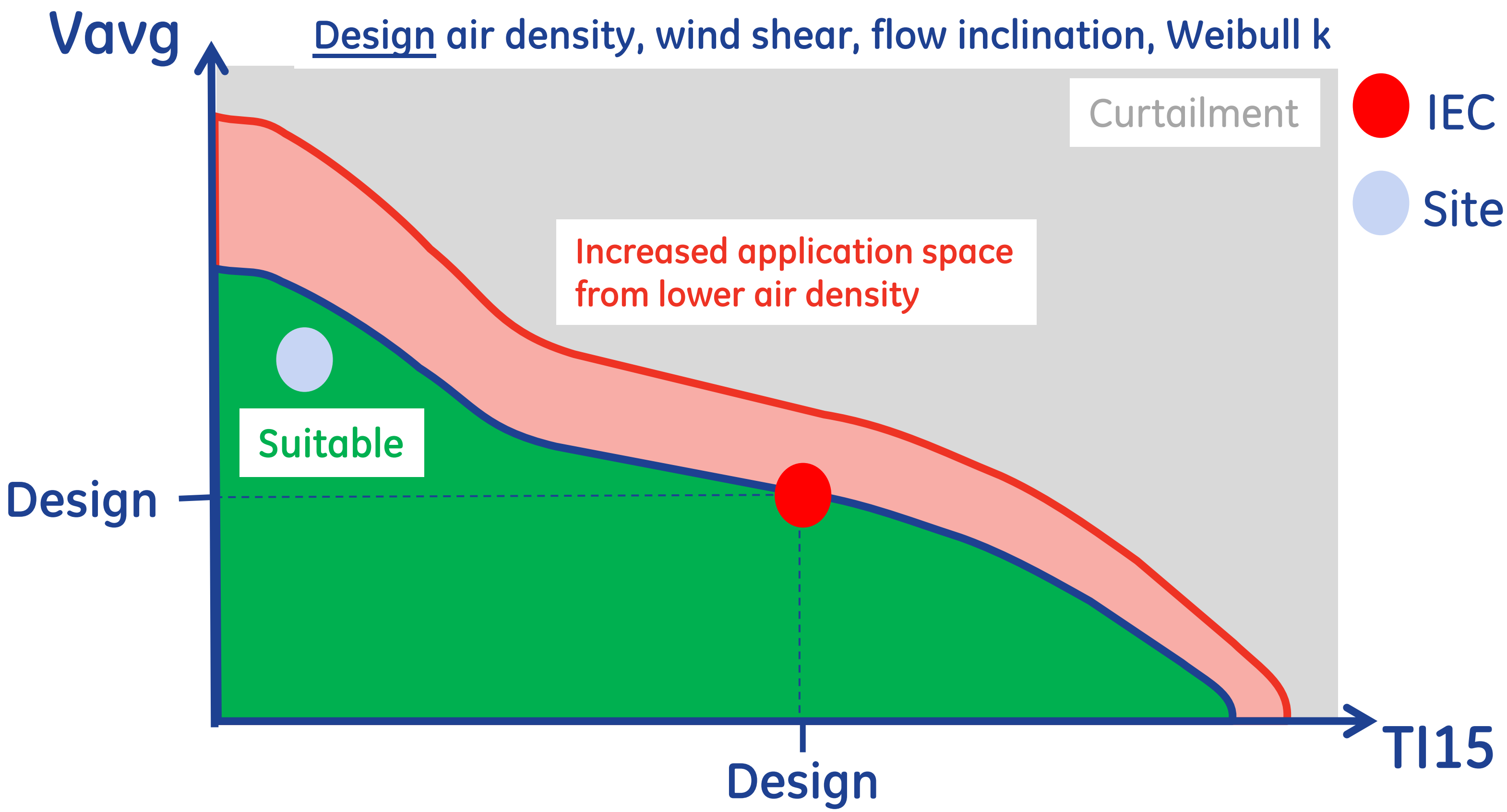
Parameter	Label	IEC Example	Site Example	Site vs. IEC
Reference wind speed [m/s]	Vref	37.5	32	<
Average wind speed [m/s]	Vavg	7.5	8	>
Turbulence intensity at 15 m/s [%]	TI15	16%	12%	<
Air density [kg/m^3]	ρ	1.225	1.16	<
Wind shear exponent [-]	α	0.2	0.23	>
Flow inclination angle [deg.]	θ	8	4	<
Weibull shape parameter [-]	k	2	2.4	>

All site conditions < design → suitable but optimum?
All site conditions > design → not suitable
Otherwise (most common) → can't conclude

imagination at work

Turbine Selection – Application Space

Example – Fatigue Loads

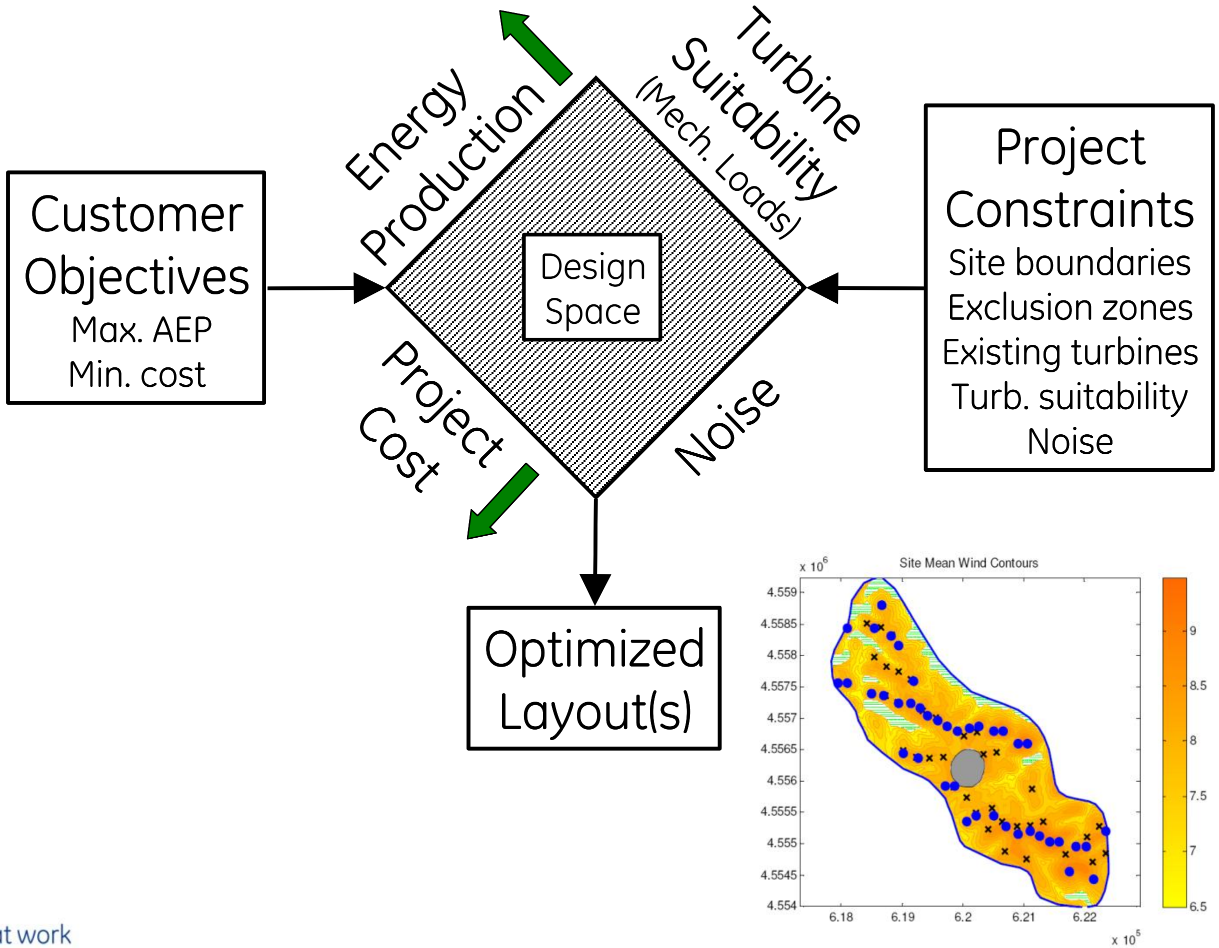


Turbine application space is best for siting

imagination at work

Layout Optimization - Method

- Multi-objectives, multi-constraints problem
- Loads analysis in optimization loop



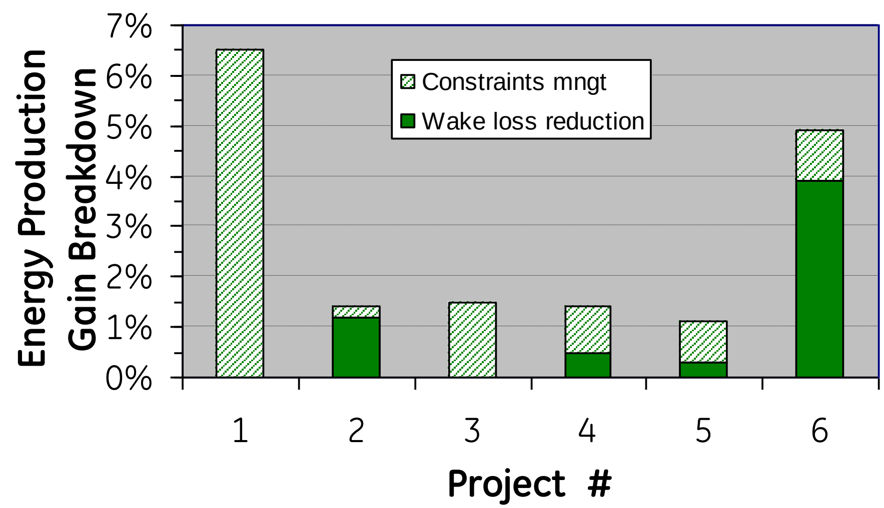
Ref.: 2009 EWEA Conf. Poster entitled "Turbine Layout Optimization - A Manufacturer's Perspective"

imagination at work

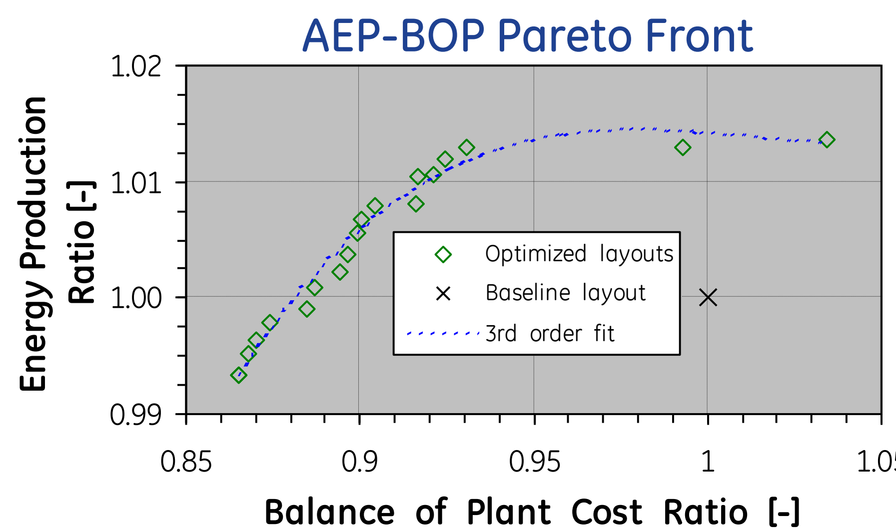
Layout Optimization – Sample Results

- 6 projects

Project #	# Turbines
1	41
2	80
3	166
4	32
5	160
6	75



- Site conditions and baseline layout from customer
- Turbine loads within design limits
- Average AEP gain of 2.8%
- Multi-objective optimization AEP-BOP Pareto front



imagination at work

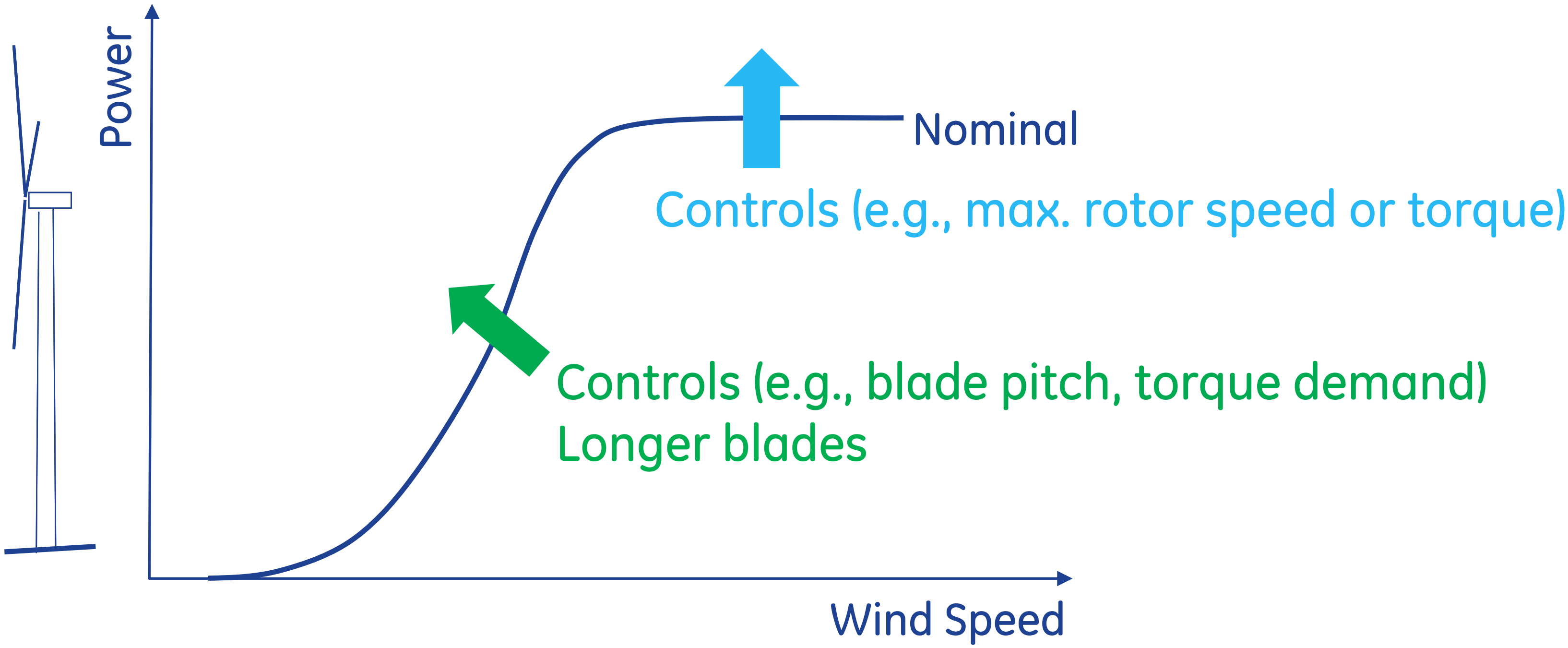
BOP Balance of plant

Ref.: 2009 EWEA Conf. Poster entitled "Turbine Layout Optimization - A Manufacturer's Perspective"

Turbine Performance Optimization

OEMs can “move” the power curve within design limits

- Address performance variations
- Take advantage of design margins
- Compensate for winds << predicted



Loads & controls modeling are enablers

imagination at work

Challenges

Pre-construction

- Wind resource assessment preferences vary, no standard
- Wake modeling preferences vary & accuracy
- Balance of plant cost modeling
- Due diligence of OEM loads

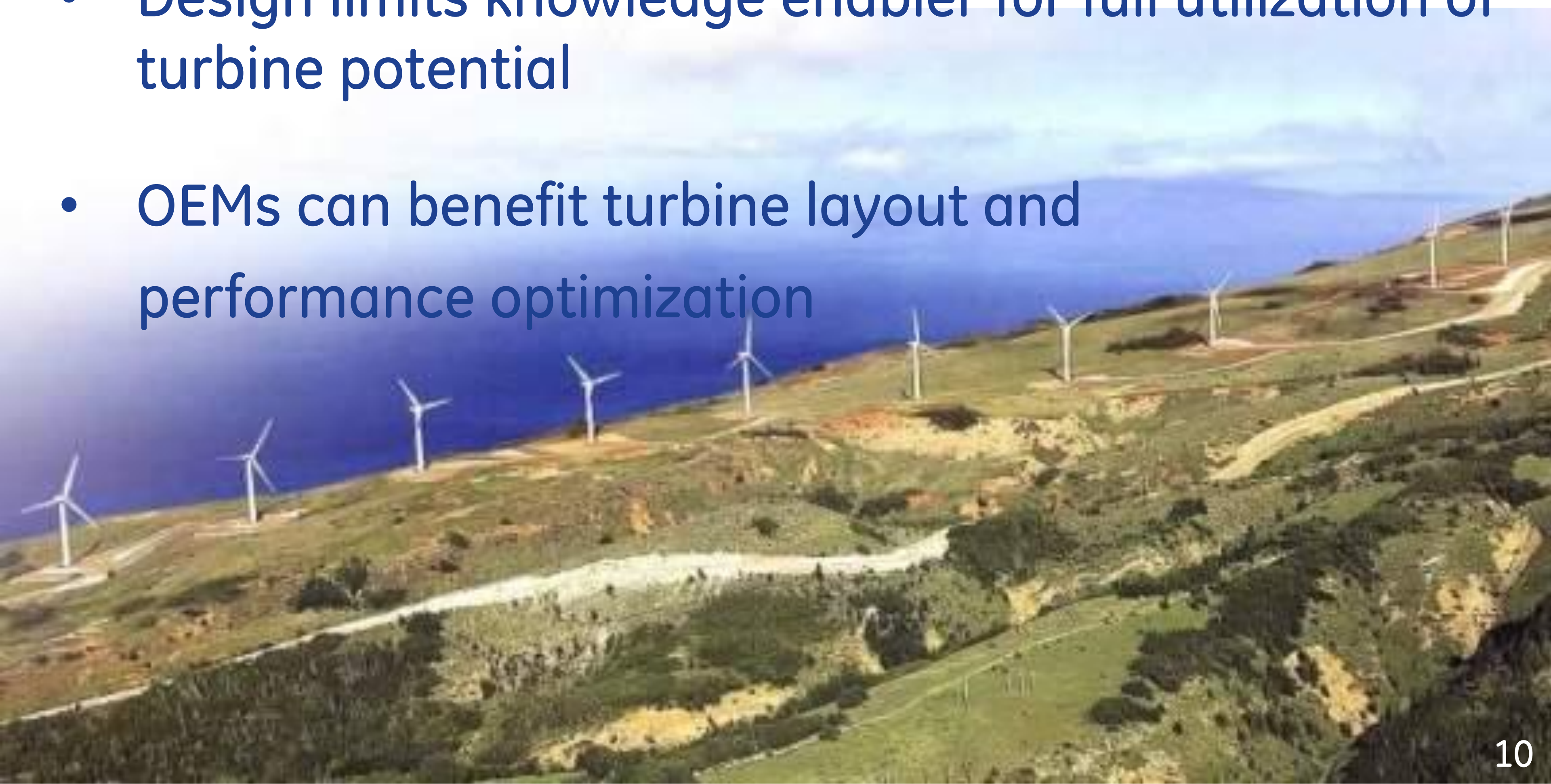
Post-construction

- Post-warranty turbine data access
- Nacelle wind speed accuracy (absolute)
- Turbine wakes impacting met mast measurements
- Due diligence of turbine upgrade

imagination at work

Conclusions

- Site turbines per application space
- Design limits knowledge enabler for full utilization of turbine potential
- OEMs can benefit turbine layout and performance optimization



imagination at work