Turbine Class Selection and Layout Design According to Site Conditions

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Turbine Selection and Layout Affects Reliability and Lifetime

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Rainflow Counting Methodology

- **Reduces a spectrum of varying stress into a set of simple stress reversals**
- **Allows application of Miner's Rule**

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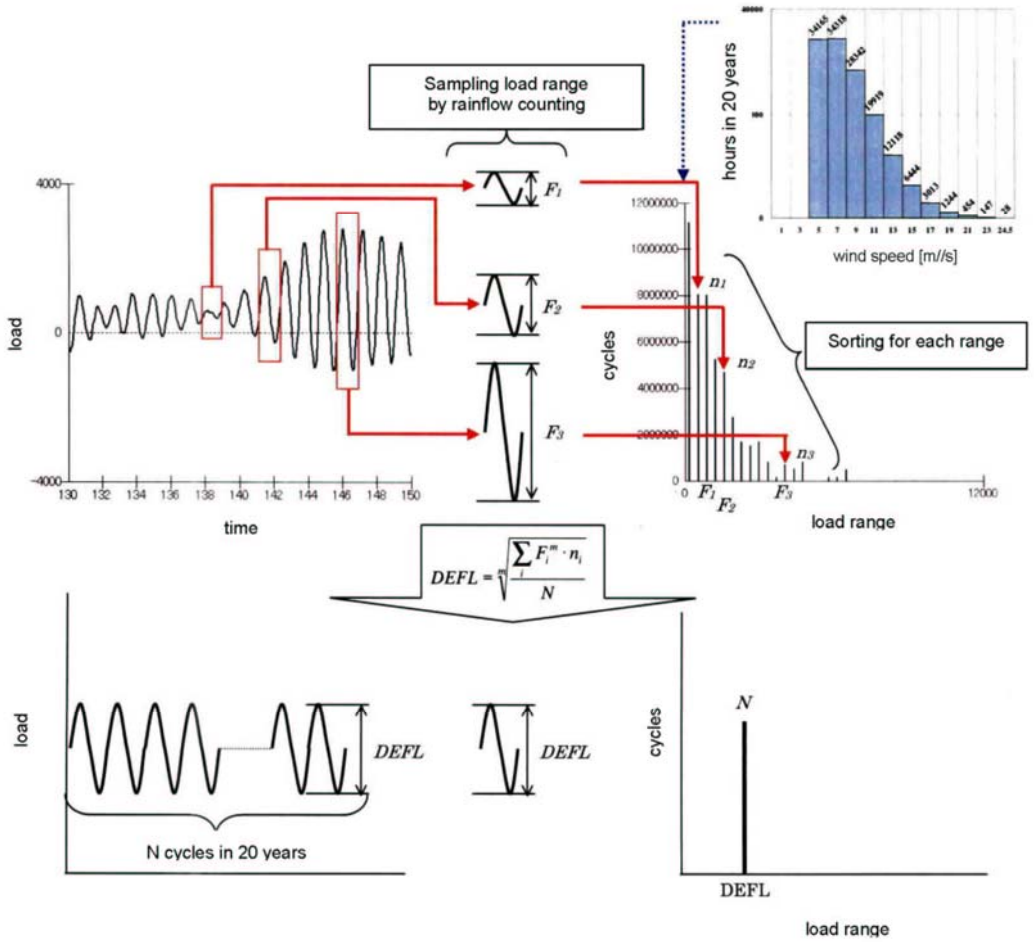
Rainflow Counting Methodology



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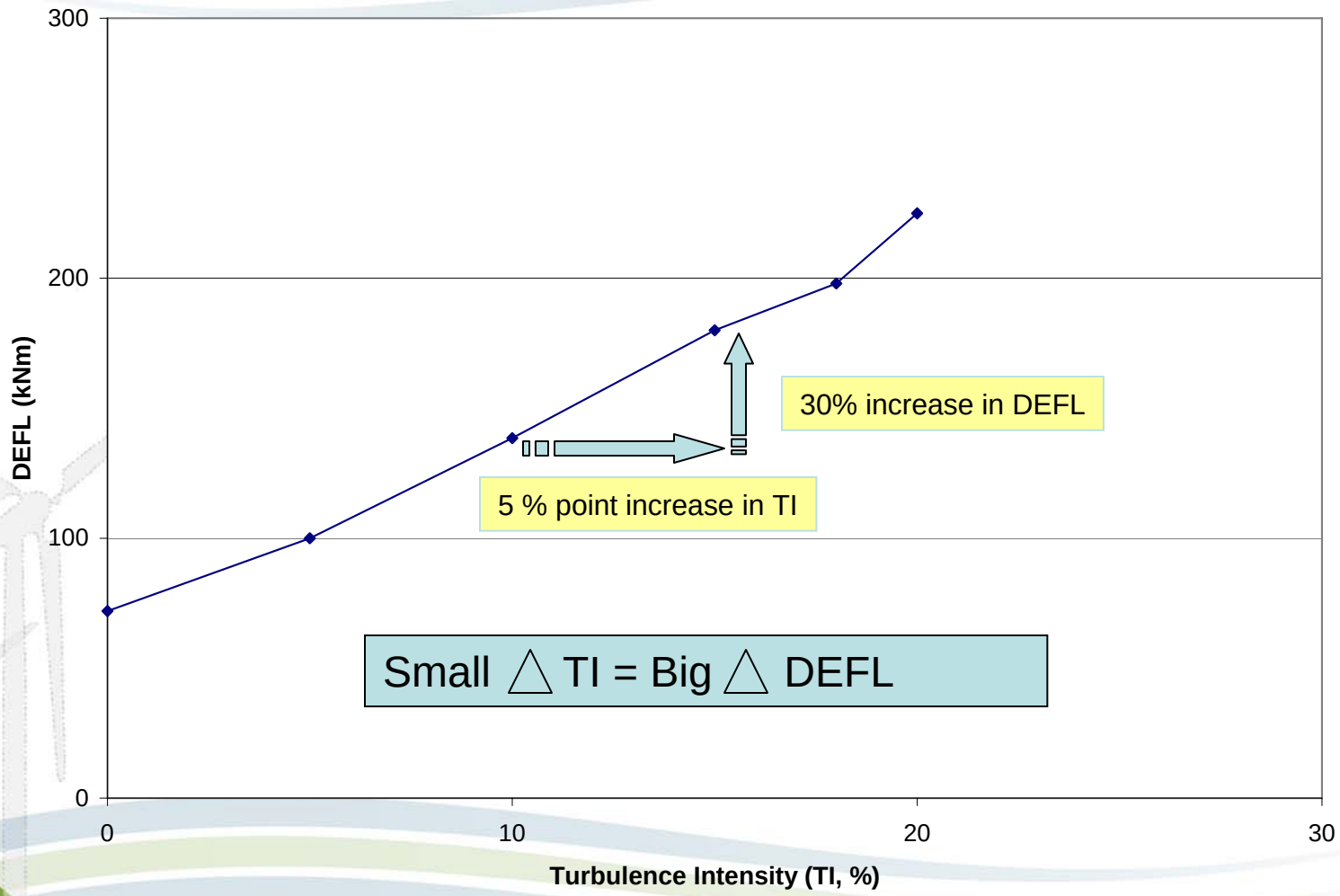
Damage Equivalent Fatigue Load
(DEFL)



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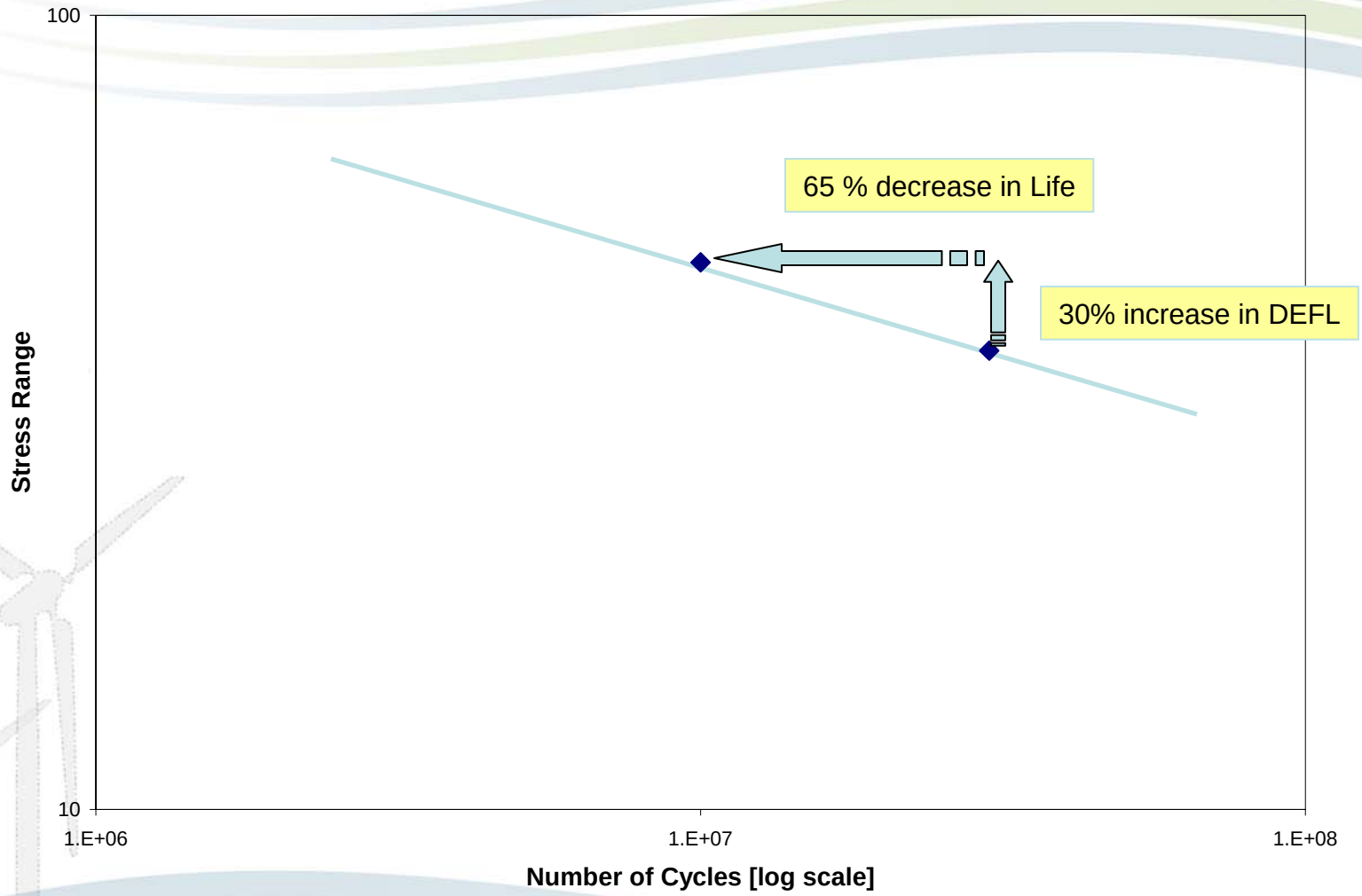
Reduction of Fatigue Life



△DEFL = even bigger △ life

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IEC Turbine Safety Classifications

Wind Turbine Class	I	II	III	IV
V_{gust} (m/s)	50	42.5	37.5	30
A I_{15}	0.16	0.16	0.16	0.16
B I_{15}	0.14	0.14	0.14	0.14
V_{ave} (m/s)	10	8.5	7.5	6

(source: IEC 61400-1,3rd edition, dated 2005-08)

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Turbine Layout Design

- **Windiest and/or Most Turbulent Turbine**
- **Adjust for Density**
- **V Density Adjusted=V* $(\rho_{site}/\rho_{standard})^{1/2}$**
- **TI Ambient= average of 15 m/s TI**

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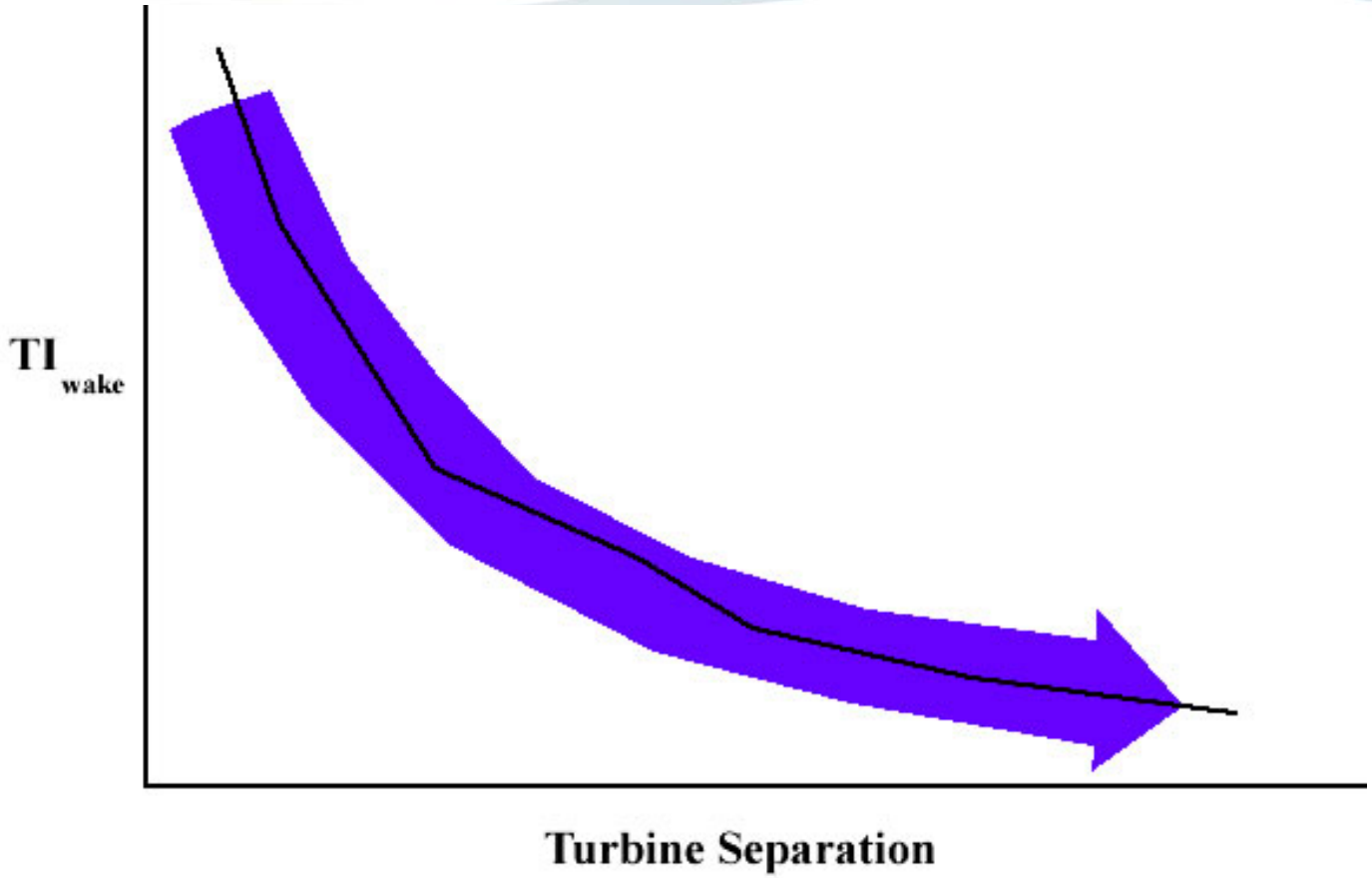
Wake Turbulence



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Wake Turbulence

$$TI_{wake} = \frac{1}{\left(1.5 + 0.3 * s\sqrt{u}\right)}$$

- **Need 6x6 spacing for Class A (without ambient)**
- **or 8x8 for Class B (without ambient)**
- **Turbulence is weighted by time spent in wake (spread wind rose and few affected turbines helps)**

Equation from Sten Frandsen and Morten L Thorgersen, Wind Engineering, Volume 23 No. 6 1999.

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Total Turbulence

$$TI_{Total}^{2} = TI_{Amb}^{2} + TI_{Wake}^{2}$$

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Allowable Wind Speed

$$V_{Allow} = \frac{V_{Max(IECclass)} * TI_{Max(IECclass)}}{TI_{Total}}$$

$$V_{DensityAdjusted} < V_{Allow} \ ?$$

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Turbine Spacing

Approach	Conservative	Normal	Aggressive
Turbine Density (MW/km^2)	6.8	8	10
Omni-directional	6 x 6	5 x 5	4 x 4
Sector	5 x 8	4 x 6	3 x 5
Uni-Directional	3 x 12	3 x 8	2 x 8

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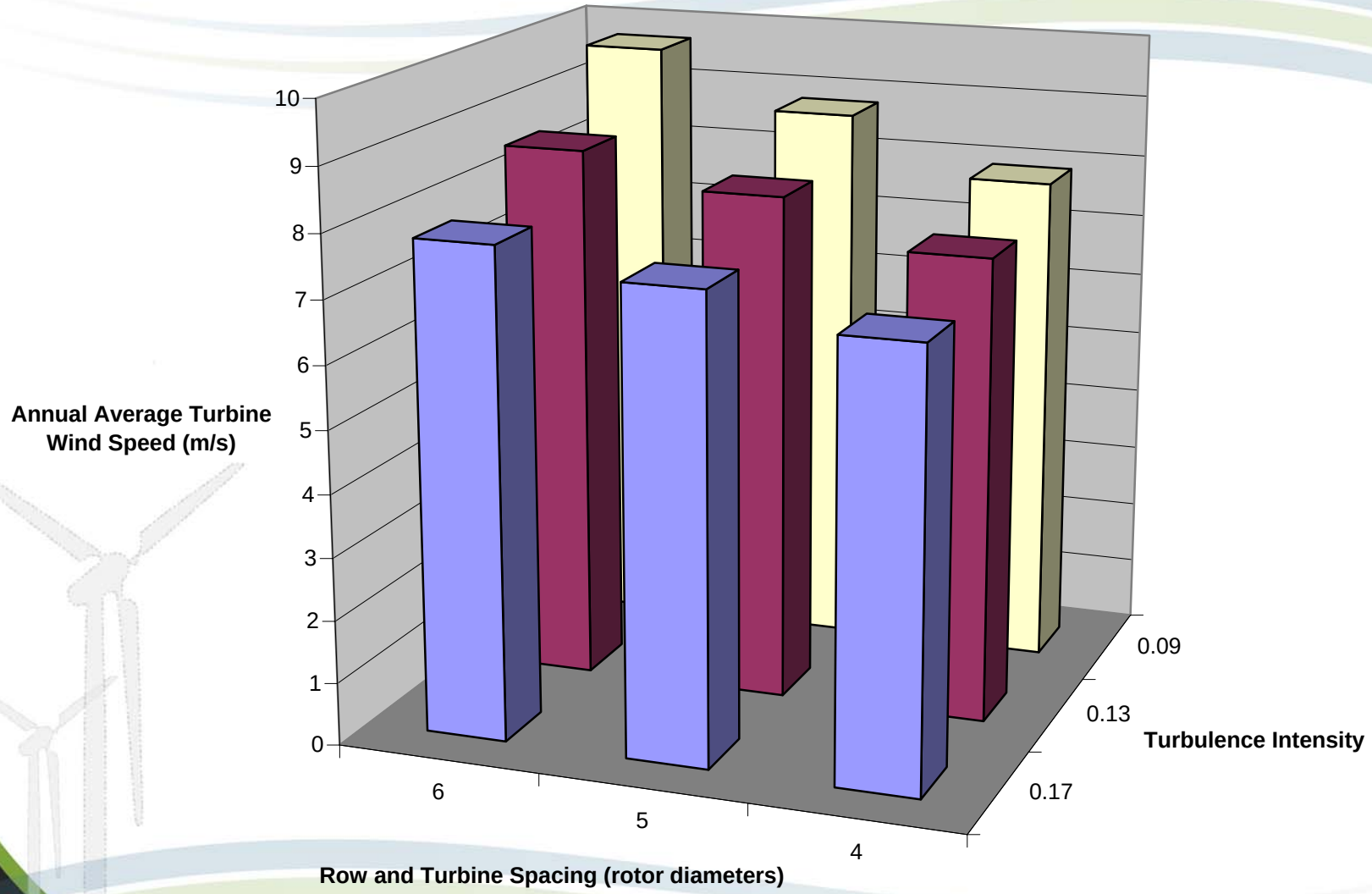
Suitable Wind Speeds as a Function of Layout and Site Conditions



Turbines at High Speed or High Turbulence Sites Need Larger Spacing!!!

Directional Curtailment

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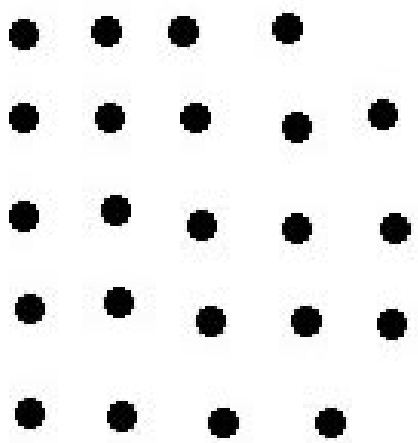
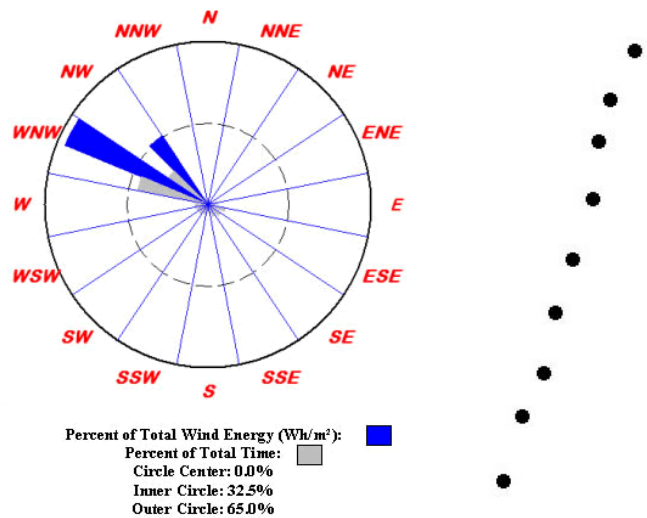
Large Loss

Multi-row Array



Small Loss

Single Row Array with Uni-Directional Wind Rose



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Conclusions

- **0.5 RD can cause 65% lifetime reduction!**
- **Ambient TI is important, but is only dominate for very conservative spacing (above 6 x 6)**

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