



Thoughts About Small Wind Energy Siting (Philosophy/Tools/Needs)

Bringing together people, data and knowledge to improve the health and performance of equipment



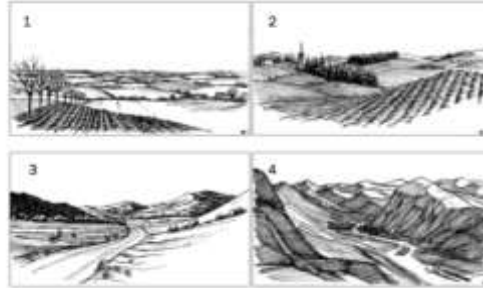
Estimating Energy Production

Project Siting as A Balance

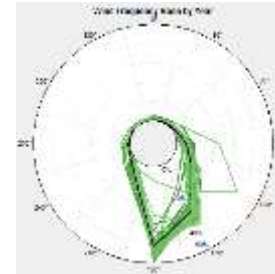
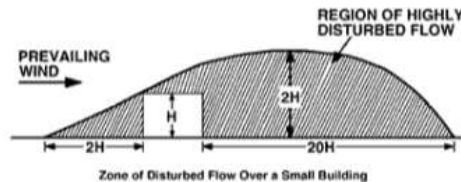
Energy, Setbacks, First Costs, Access/Risk, Neighbors, Promotional Value

- Wind Speed
- Terrain
- Landscape
- Obstructions

Terrain Classifications



Landscape Classifications



WIND RESOURCE OF THE UNITED STATES

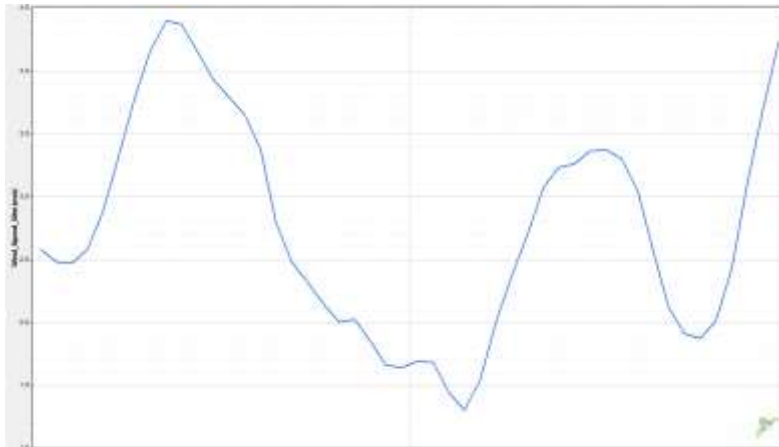
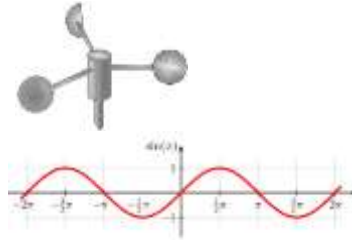


$$\text{Power} = \frac{1}{2} \rho A v^3$$

Estimating Energy Production

■ Measurement Fundamentals

- Sensitivity (can you see what you're looking for)
- If time-related and cyclic, watch for aliasing (Nyquist)

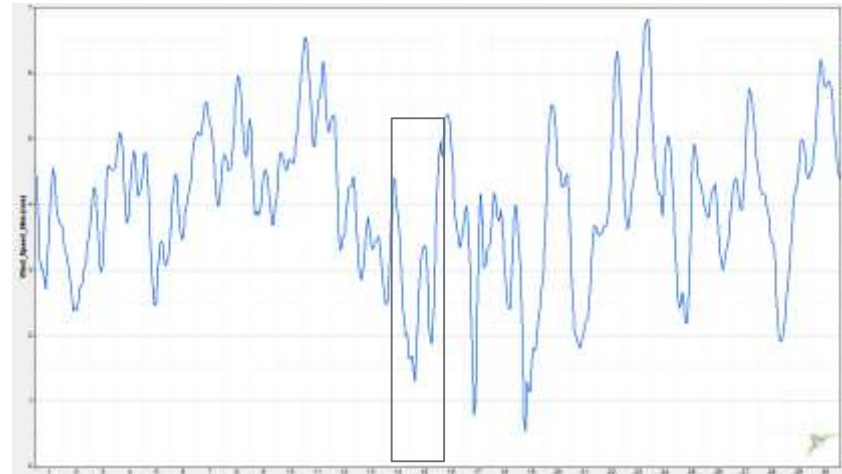
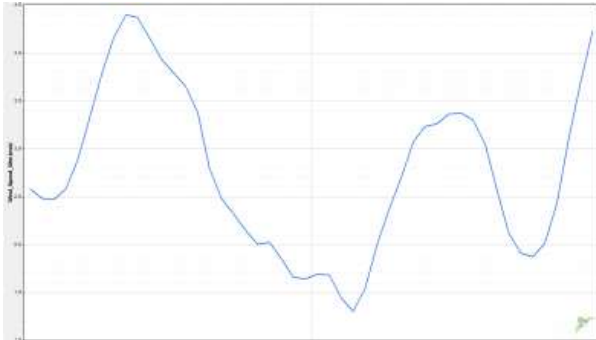


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Estimating Energy Production

■ Measurement Fundamentals

- Sensitivity (can you see what you're looking for)
- Understand your bias
- A longer averaging interval is needed to remove temporal bias

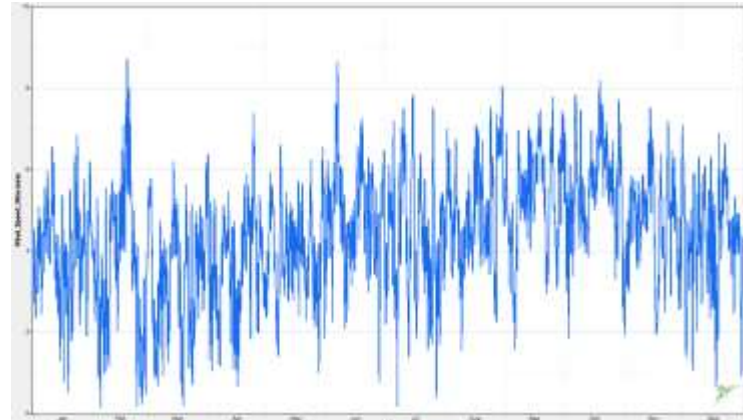
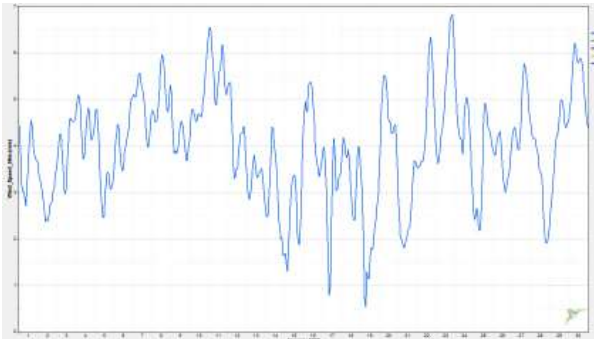
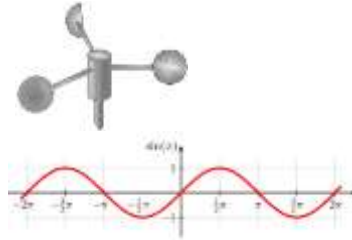


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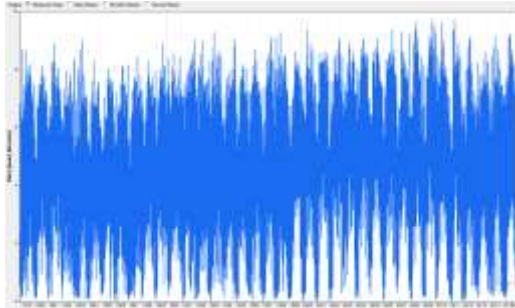
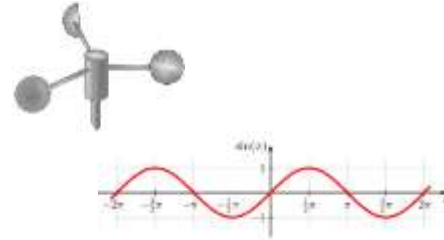


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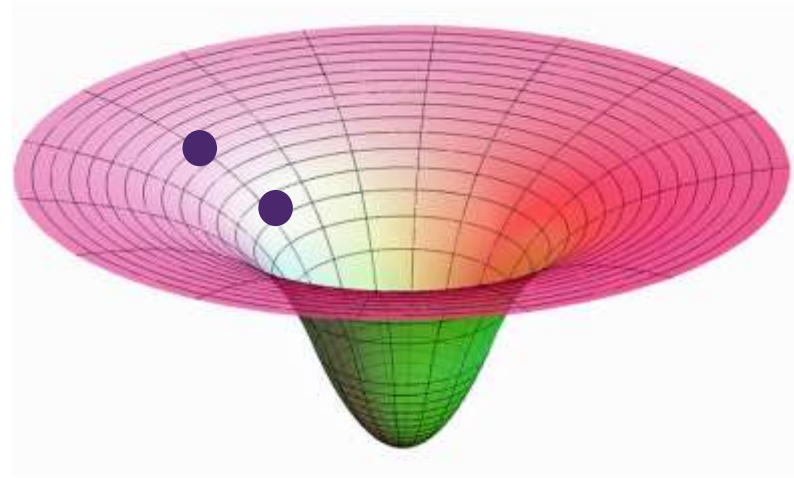
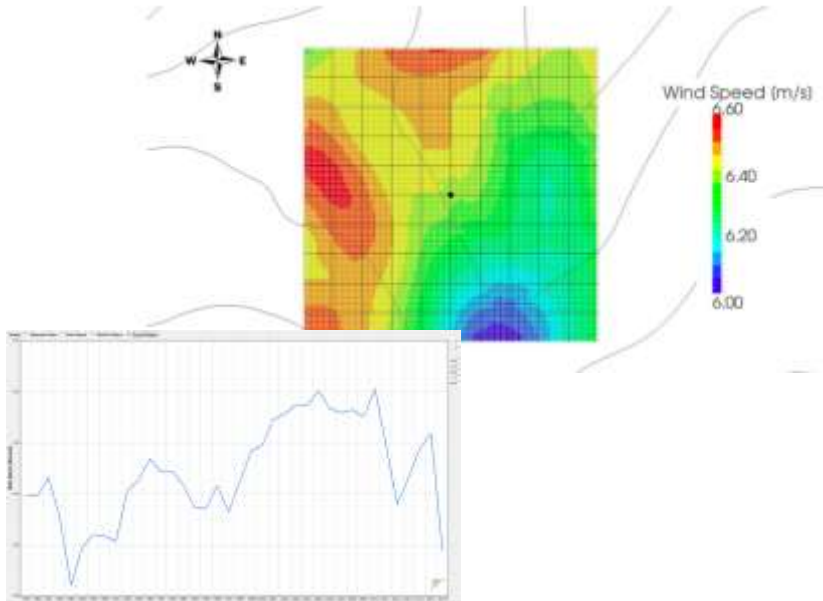
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$$\text{Power} = \frac{1}{2} \rho A v^3$$

Estimating Energy Production

- MCP (A Lay Perspective)
- Objective: “Know Where I AM”



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Estimating Energy Production

- MCP (A Lay Perspective)
- Objective: “Know Where I AM (on a map)” (Why? (Scale))



$$\text{Power} = \frac{1}{2} \rho A v^3$$

Estimating Energy Production

- Objective: “Know Where I AM”



- X, Y, Z



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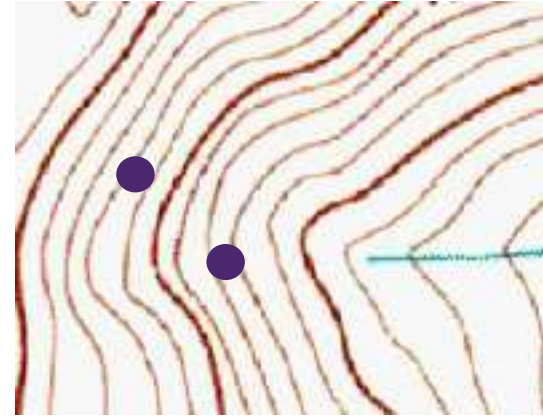
Estimating Energy Production

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- X1, Y1, Z1

- X2, Y2, Z2



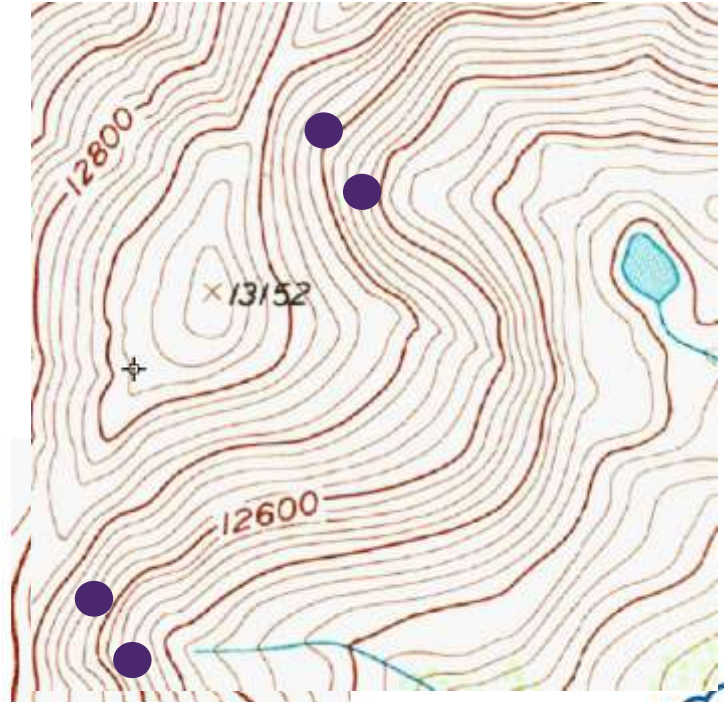
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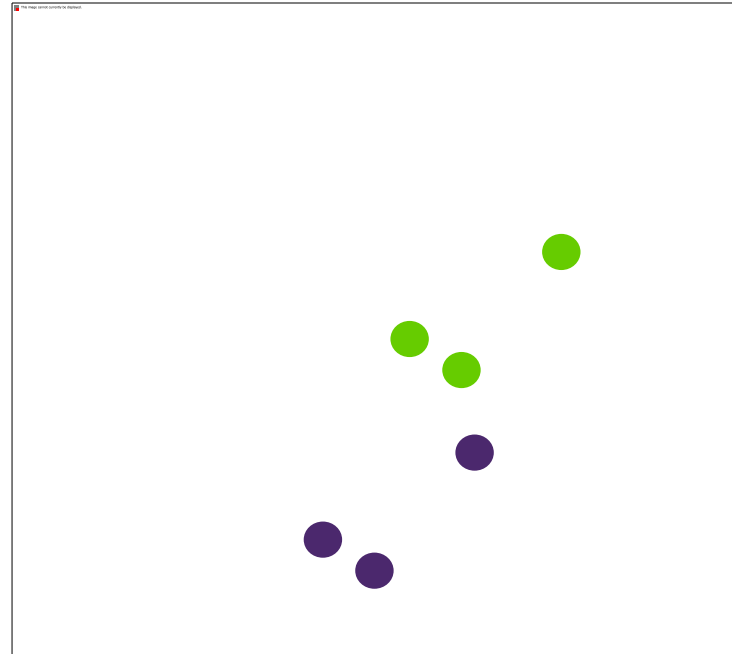
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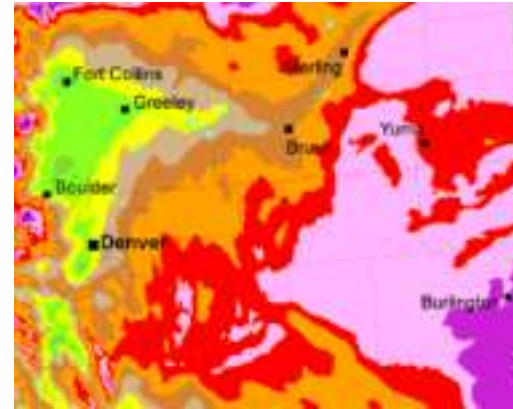
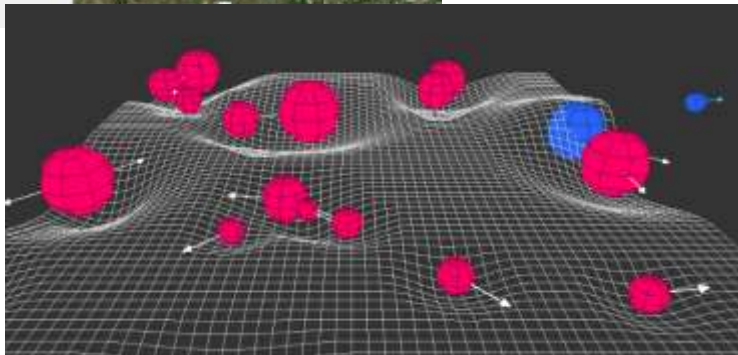
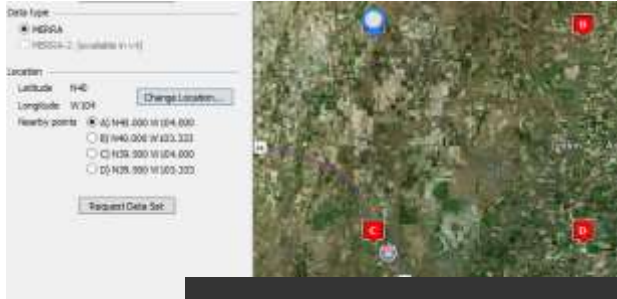
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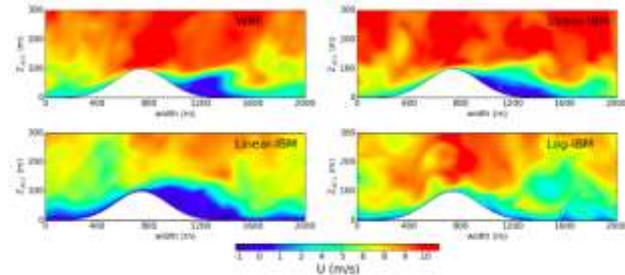
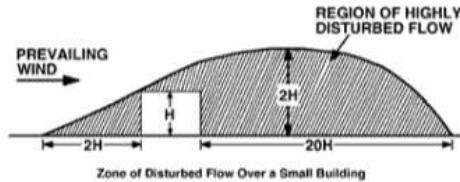
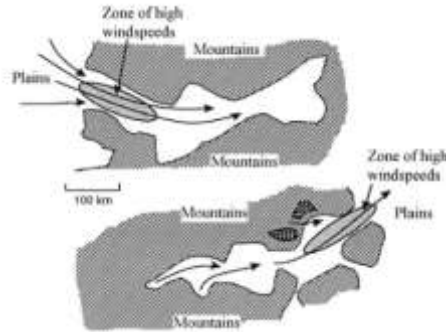
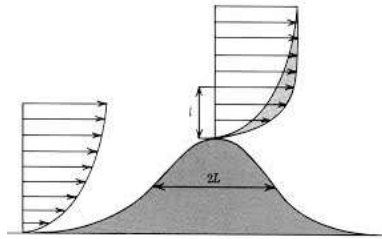
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Estimating Energy Production

Terrain

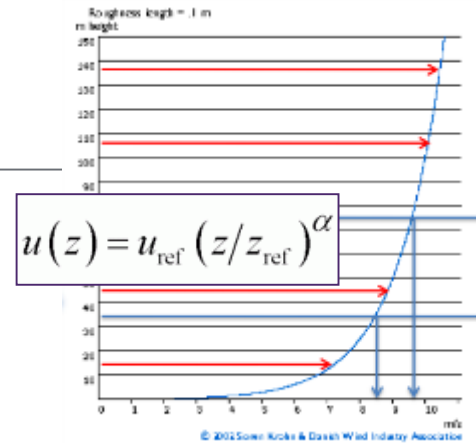
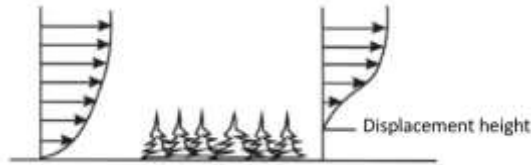
- Good
- Bad
- Can look like a Big Obstruction



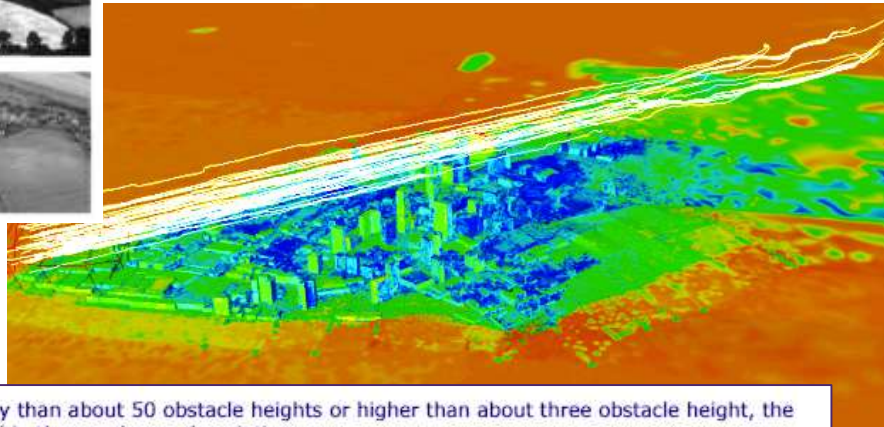
Landscape

Shear as a function of

- Ground Cover
- Mixed Obstructions

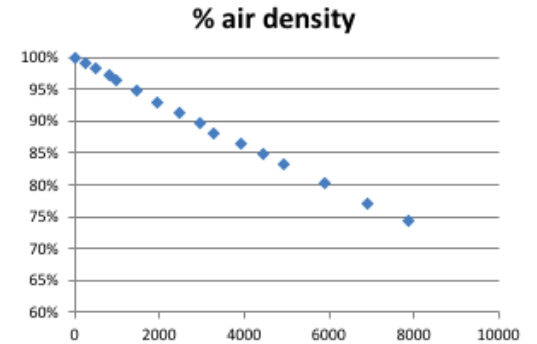
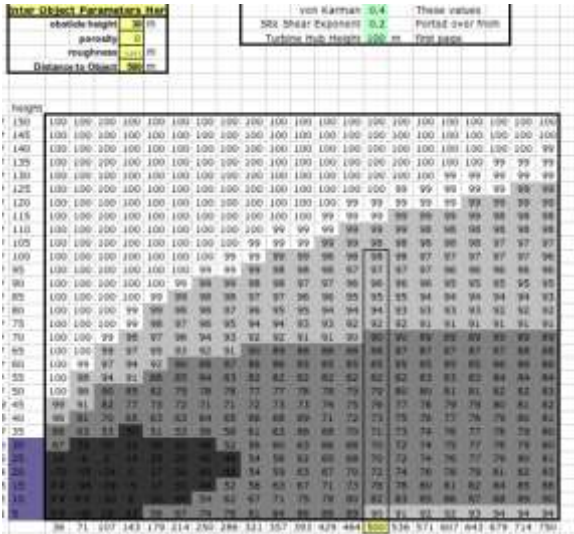


Landscape Classifications



- if the point of interest is further away than about 50 obstacle heights or higher than about three obstacle height, the object should most likely be included in the roughness description.

Estimating Energy Production (spreadsheet tools)



Displacement Height Tool	
Canopy Height	15.0 m
Displacement Scale	0.7
Original Tower Height	60.0 m
Wind Resource Model Height	50.0 m
model wind speed	6.0 m/s
shear exp	0.27
Effective Tower Height	50 m
Effective Hub Ht Wind Speed	6.00 m/s

Estimating Energy Production

Map Inputs		Metric	English	Site Estimates	Metric	Imperial
wind speed		6.2	13.888	wind speed	6.33	14.17 mph
map/anno height		50	164.05	hub height	60	196.86 ft
roughness length		0.007				
Estimated TI		11.04	%			
Elevation above Sea Level		300	m			
Air Density Adj		96.41%				
Wind Production Estimator				Gross AEP	2,026,851	
K				Losses	0.16	
C				Net AEP	1,702,555	
gamma	7.14					
m/s	0.89					
	PDF	Hours	Rated Power Curve	Adjusted PC	Production (kWh)	
1	0.0294	258	0	0	0	
2	0.0637	558	0	0	0	
3	0.0942	825	16	15	12,692	
4	0.1160	1,017	39	38	38,310	
5	0.1266	1,109	78	75	82,935	
6	0.1255	1,100	139	134	147,116	
7	0.1146	1,004	219	211	211,956	
8	0.0971	851	328	316	269,005	
9	0.0767	672	469	452	303,682	
10	0.0566	496	612	590	292,616	
11	0.0392	343	730	704	241,353	
12	0.0254	222	826	796	176,946	
13	0.0154	135	880	848	114,665	
14	0.0088	77	896	864	66,641	
15	0.0047	41	904	871	35,987	
16	0.0024	21	904	871	18,096	
17	0.0011	10	904	871	8,542	
18	0.0005	4	904	871	3,784	
19	0.0002	2	904	871	1,573	
20	0.0001	1	904	871	614	
21	0.0000	0	904	871	225	

		Tower Height		35	40	46	50	69	75
		Weighted Turbulence		16.9%	16.5%	16.1%	15.9%	15.2%	15.0%
Wind Rose		Enter		Enter	Enter	Enter	Enter	Enter	Enter
Direction	Enter	Adjusted	Roughness	Weighted	Weighted	Weighted	Weighted	Weighted	Weighted
	Estimate	Figures	Length	Turbulence	Turbulence	Turbulence	Turbulence	Turbulence	Turbulence
	Her			Estimate	Estimate	Estimate	Estimate	Estimate	Estimate
N	4	4%	0.055	0.7%	0.6%	0.6%	0.6%	0.6%	0.6%
NNE	3	3%	0.085	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
NE	2	2%	0.085	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
ENE	1.5	2%	0.1	0.3%	0.3%	0.3%	0.3%	0.2%	0.2%
E	2	2%	0.1	0.4%	0.4%	0.3%	0.3%	0.3%	0.3%
ESE	3	3%	0.055	0.5%	0.5%	0.5%	0.5%	0.4%	0.4%
SE	4	4%	0.055	0.7%	0.6%	0.6%	0.6%	0.6%	0.6%
SSE	5	5%	0.1	0.9%	0.9%	0.9%	0.8%	0.8%	0.8%
S	6	6%	0.1	1.1%	1.1%	1.0%	1.0%	1.0%	1.0%
SSW	6.5	7%	0.085	1.1%	1.1%	1.1%	1.1%	1.0%	1.0%
SW	9	9%	0.2	1.8%	1.8%	1.7%	1.7%	1.6%	1.6%
WSW	12	13%	0.2	2.4%	2.4%	2.3%	2.3%	2.2%	2.1%
W	15	16%	0.085	2.6%	2.6%	2.5%	2.5%	2.4%	2.3%
WNW	10	11%	0.055	1.6%	1.6%	1.6%	1.5%	1.5%	1.5%
NW	6.5	7%	0.055	1.1%	1.0%	1.0%	1.0%	1.0%	0.9%
NNW	5.5	6%	0.055	0.9%	0.9%	0.9%	0.8%	0.8%	0.8%
	95	100%							

Estimating Energy Production

Wind Turbine Model	DW52	DW54	DW61	
Rotor Diameter (m)	52	54	61	
	Enter Rotor Diameter		52 m	
	Enter Wind Speed		6.5 m/s	
Multiple Turbine Shading Estimate				
	Separation	Wind Speed	Net Energy	Wake Diameter
	(rotors)	6.50	Behind Turbine	(m)
	3	5.4	70%	75
	5	5.6	76%	91
	7	5.8	81%	107
	8	5.9	82%	114
	9	5.9	84%	122
	10	6.0	85%	130
	11	6.0	87%	138
	12	6.0	88%	146
	13	6.1	89%	153
	14	6.1	89%	161
	15	6.1	90%	169

Terrain Type	Roughness Class	Surface Roughness Length z_0 (m)	Windshear Exponent α (Textbook)
Ice		0.00001	0.07
Snow on flat ground	0	0.0001	0.09
Calm Sea	0	0.0001	0.09
Coast with onshore winds		0.0010	0.11
Snow-covered crop stubble		0.0020	0.12
Open, smooth surface (ie concrete)	0.5	0.0024	
Cut Grass		0.007	0.14
Short-grass prairie		0.020	0.16
Open agriculture without hedges/fences	1	0.030	
Crops, tall-grass prairie		0.050	0.19
Agriculture with homes, hedges @ 1250m	1.5	0.055	
Hedges		0.085	0.21
Agriculture with homes, hedges @ 500m	2	0.10	
Scattered trees and hedges		0.15	0.24
Agriculture with homes, hedges @ 250m	2.5	0.2	
Trees, hedges, a few buildings		0.3	0.29
City Suburbs, villages, scattered forests	3	0.4	0.31
Larger cities with tall buildings	3.5	0.8	
Woodlands		1.0	0.43
Very large cities, skyscrapers	4	1.6	

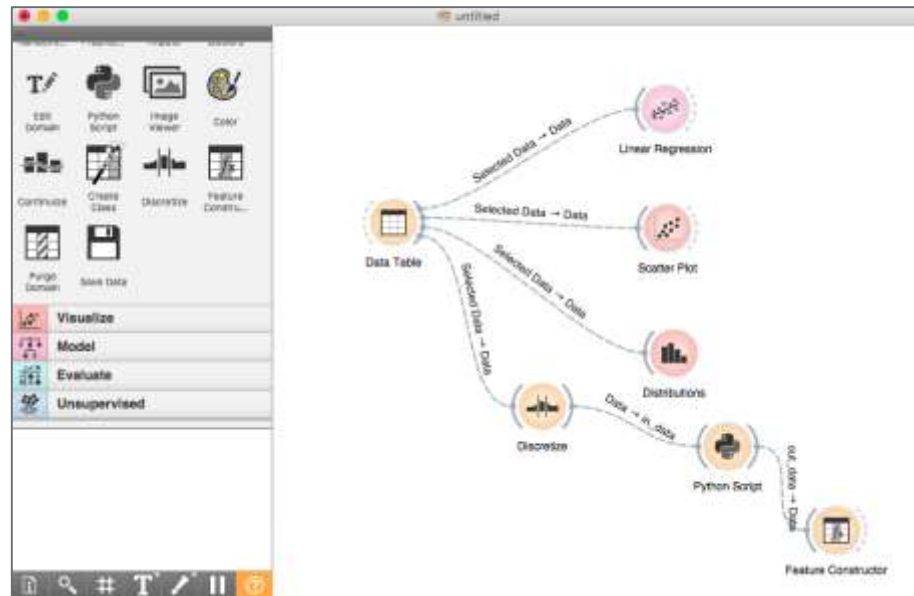
Estimating Energy Production

Wiki ?

Could NREL/DWIC (or someone else) house validated Excel tools?

What about scripts?

- Thinking about Python/Orange



Thank You

