

Wind Resource

E. Power Production Estimation

1. Swept Area

$$P_{\max} = \bar{P} A = \frac{1}{2} \rho u^3 A$$

MAX POWER
POSSIBLE AT VELOCITY
 u

Actual Power

$$P(u) = \frac{1}{2} \rho u^3 A C_p \eta$$

$$C_p = \frac{\text{Rotor Power}}{\text{Dynamic Power}}$$

$$\eta = \frac{\text{GEN Power}}{\text{Rotor Power}}$$

$$\eta = \frac{\text{DRIVE-TRANSMISSION EFFICIENCY}}$$

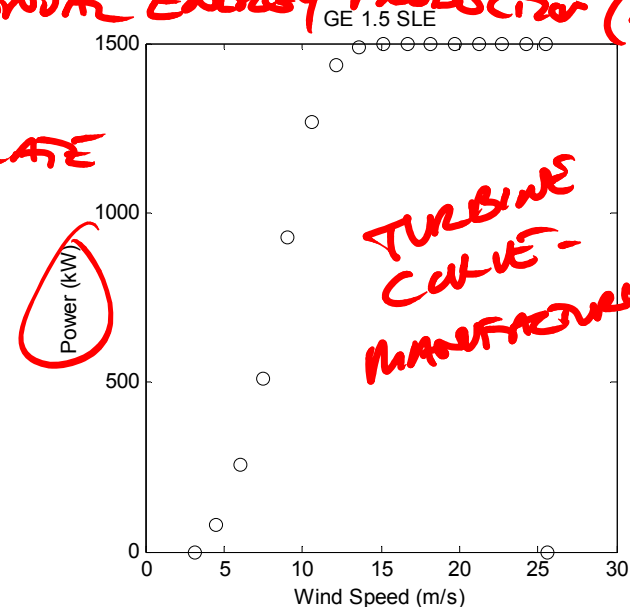
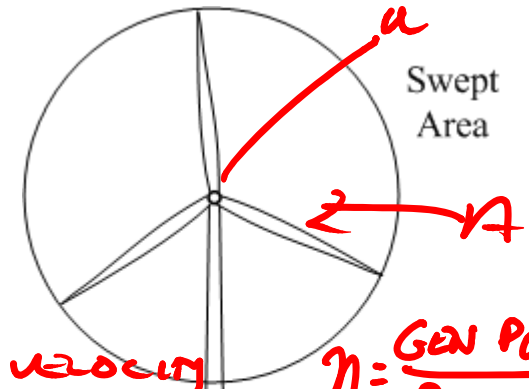
Plug in MEAN WIND SPEED u
MULTIPLY BY HOURS IN YEAR \rightarrow

ANNUAL ENERGY PRODUCER (AEP)

2. Statistical

BACK TO STATISTICS FOR BETTER ESTIMATE

$$\begin{aligned} \bar{P} &= \int_0^{\infty} p d f(u) P_T(u) du \\ &= \sum_{i=1}^N p d f(u_i) P_T(u_i) \Delta u \end{aligned}$$



Wind Resource

E. Wind Speed Instrumentation

1. Met Tower

DE TO ITS COMPLEXITY, WIND
RESOURCE IS ALWAYS MEASURED
AT "LIKELY" WIND SITES

METEOROLOGICAL OR "MET"
TOWERS ARE COMMONLY USED

MEASUREMENTS TAKEN AT
SEVERAL HEIGHTS

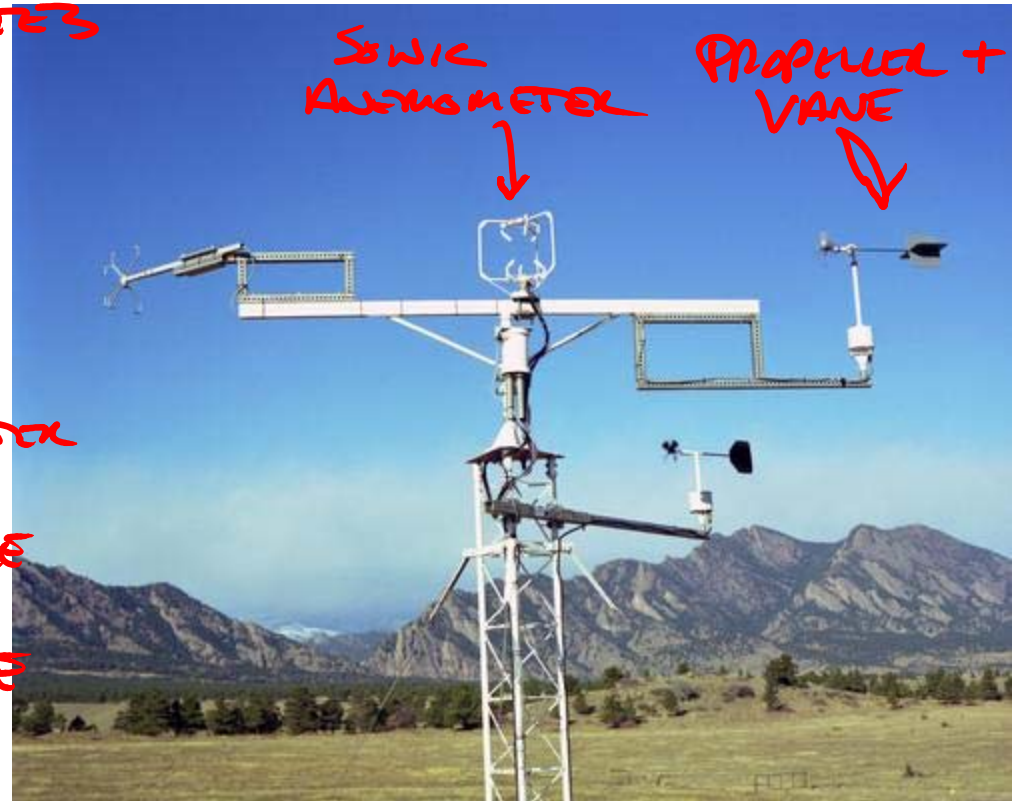
WIND VELOCITY - ANEMOMETER

WIND DIRECTION - VANE

TEMPERATURE - THERMOCOUPLE
THERMISTORS

BAROMETER - RTD
AIR PRESSURE

CUP ANEMOMETER



Wind Resource

E. Wind Speed Instrumentation

1. Remote Sensing (ADVANCED)

a) Sodar (SONIC DETECTION & RANGING)

ACOUSTIC SENSOR - DOPPLER

ACOUSTIC PULSE IS REFLECTED BY
BY SMALL TEMPERATURE
VARIATIONS

TRAVEL TIME & DOPPLER SHIFT

b) Lidar → HEIGHT & VELOCITY SAMPLE (LASER DETECTION & RANGING)

LIGHT DOPPLER SENSOR

LIGHT REFLECTED FROM PARTICLES
(AEROSOLS) OR INSECTS

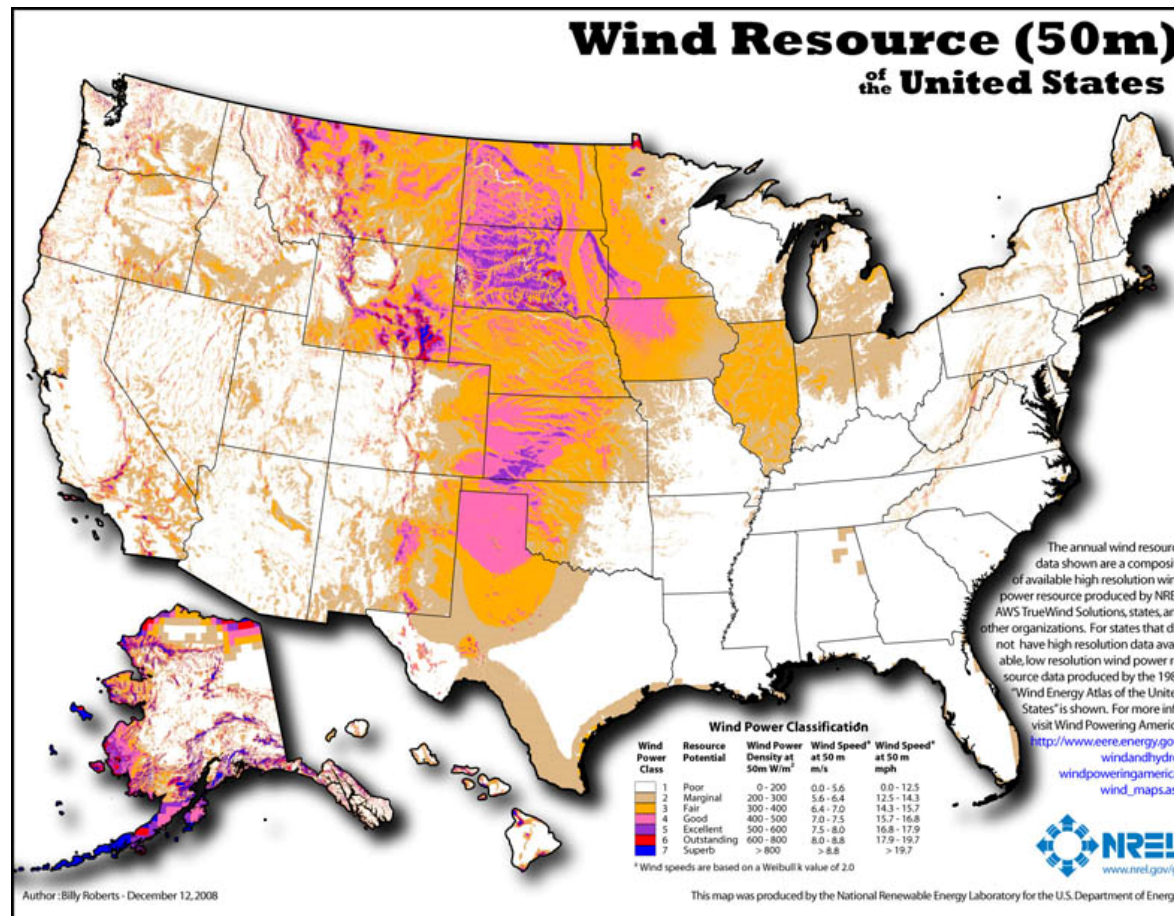
DOPPLER SHIFT FROM A PARTICULAR
LOCATION YIELDS THE WIND
SPEED



Wind Resource

E. Resources for Wind Speed Estimation

1. United States Annual Wind Resource Potential



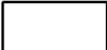






MEANS OF
ESTIMATING
(CRUDE)
THE POWER
THAT WOULD
BE PRODUCED
AT A GIVEN
SITE

Wind Resource

E. Resources for Wind Speed Estimation

1. United States Annual Wind Resource Potential

Wind Power Classification

Wind Power Class		Resource Potential	Wind Power Density at 50m W/m^2	Wind Speed ^a at 50 m m/s	Wind Speed ^a at 50 m mph
	1	Poor	0 - 200	0.0 - 5.6	0.0 - 12.5
	2	Marginal	200 - 300	5.6 - 6.4	12.5 - 14.3
	3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
	4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
	5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
	6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7
	7	Superb	> 800	> 8.8	> 19.7

^aWind speeds are based on a Weibull k value of 2.0

Wind Resource

E. Resources for Wind Speed Estimation

1. United States Annual Wind Resource Potential

FIRST STARTED IN 1970'S ANNUAL & SEASONAL
RESOURCE RELIABILITY
PERCENTAGE OF LAND
SUITABLE FOR DEVELOPMENT

FOCUS ON EFFORT IN 1980'S → CULMINATED IN THE
WIND ATLAS OF U.S.

270 WIND SITES INSTRUMENTED

SEVEN POWER CLASSES DEFINED

10 m , 30 m , 50 m

SMALL WIND COMMERCIAL WIND

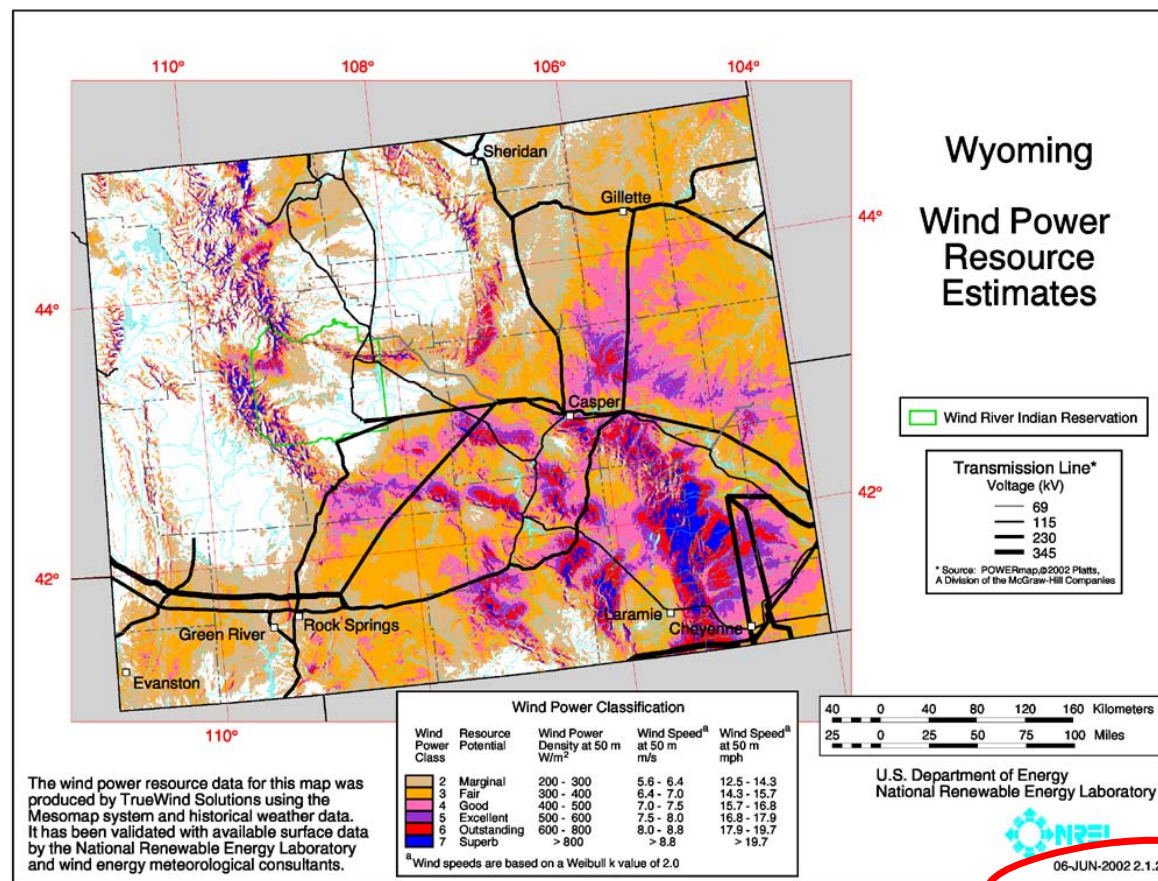
EXTRAPOLATE
USING 1/7
POWER LAW

RECENTLY MAPS HAVE BEEN UPDATED → HIGHER RESOLUTION
OTHER AREAS OF WORLD — SOME DATA EXISTS

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