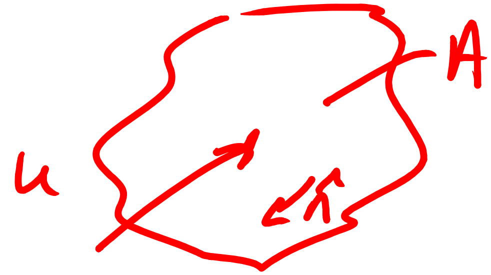
Wind Resource



D. Characterization of the Wind

3. Kinetic Energy and Power in the Wind

MEAN WIND SPEED DOES NOT TELL THE ENTIRE STORY

FIRST CONSIDER LOCAL KINETIC ENERGY IN THE WIND PER UNIT VOLUME (KINETIC ENERGY DENSITY)

$$\frac{KE}{\forall} = \frac{1}{2}\rho u^2 \qquad \left[\frac{KE}{\forall}\right] = \frac{J}{m^3}$$

DETERMINE THE WIND POWER DENSITY – CONSIDER THE FLUX OF KINETIC ENERGY DENSITY THROUGH A SURFACE NORMAL TO WIND.

$$\dot{W} = \int_A \frac{1}{2}\rho u^2 \underbrace{(\vec{u}\cdot\hat{n})}_{u}\, dA = \frac{1}{2}\rho u^3 A$$

$$[P] = \frac{W}{m^2}$$

$$\boxed{\frac{\dot{W}}{A} = P = \frac{1}{2}\rho u^3}$$

WIND POWER DENSITY

DEPENDS ON DENSITY LINEARLY

VELOCITY CUBICALLY

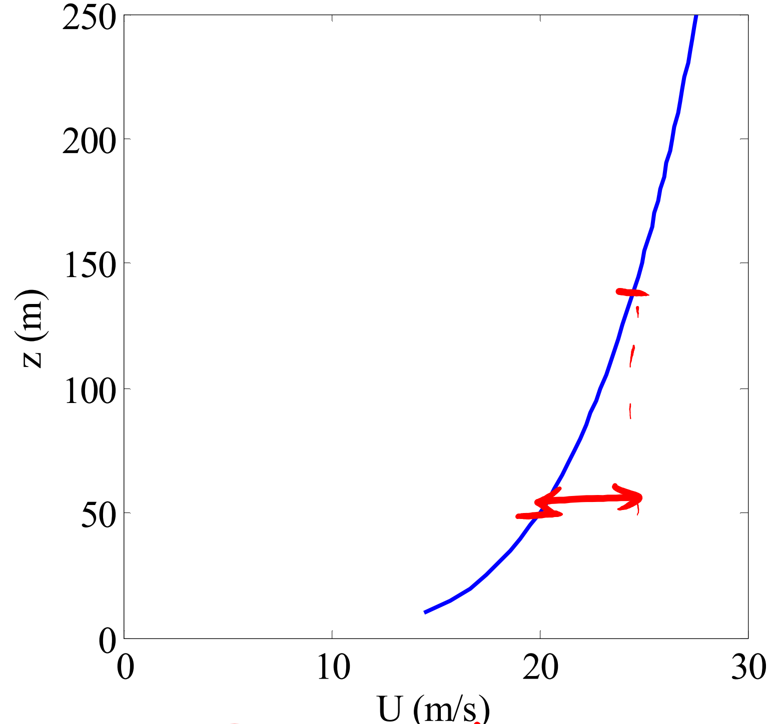
Wind Resource

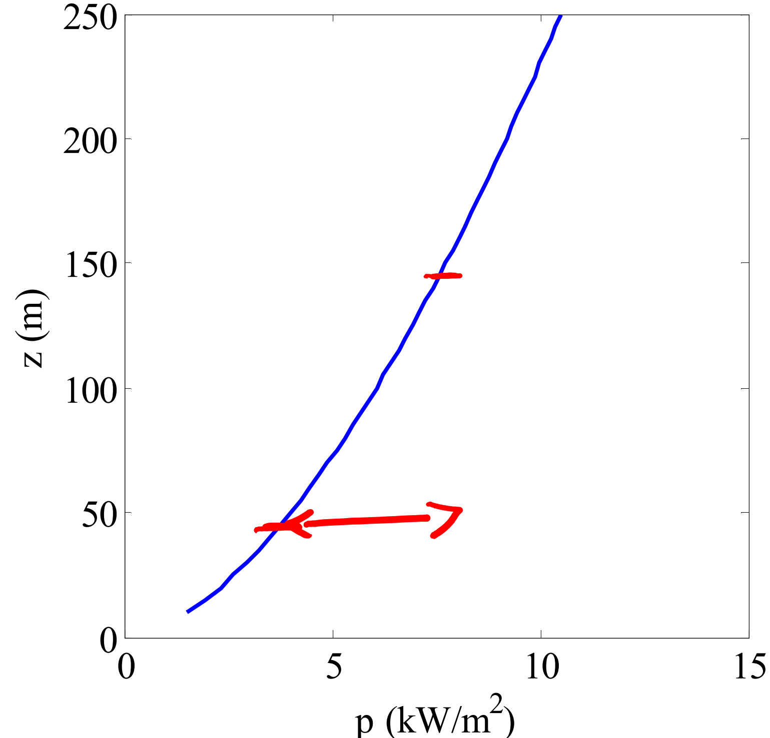
PUT YOUR TURBINE UP AS HIGH AS PRACTICAL

D. Characterization of the Wind

3. Kinetic Energy and Power in the Wind

$U_{ref} = 20$ m/s $h_{ref} = 50$ m





z	U
50 m	20 m/s
150 m	25 m/s

z	P
50 m	4 kW/m²
150 m	7.7 kW/m²

Wind Resource

D. Characterization of the Wind

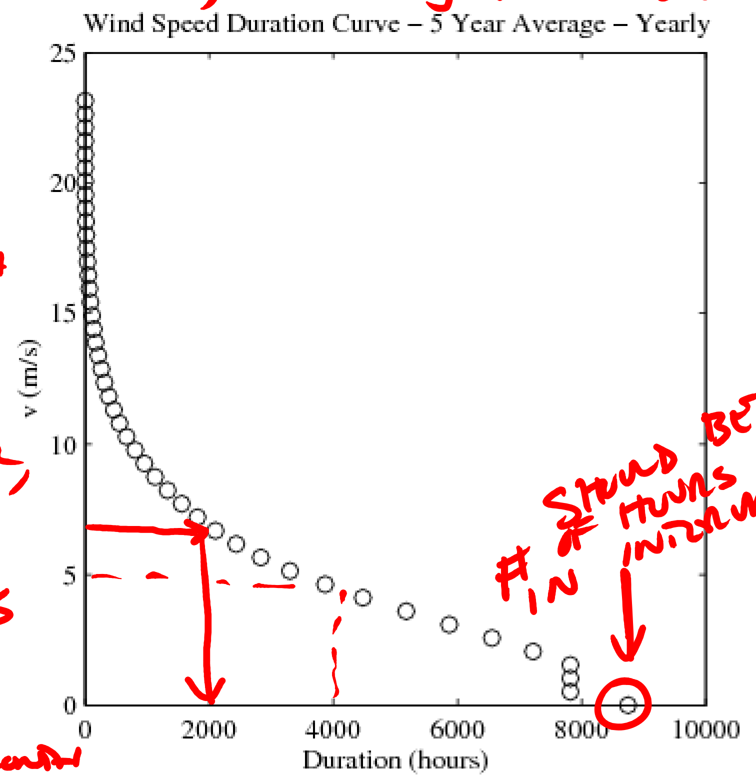
4. Statistical Description of the Wind

MEAN WIND SPEED - FALLS SHORT - DOES NOT TELL HOW THE WIND VARIES

HISTORICAL APPROACH → WIND SPEED DURATION CURVE

STANDARD STATISTICS → PROBABILITY DENSITY FUNCTION

a. Wind Speed Duration Curve



- BREAK VELOCITY INTO "BINS"
- PERFORM A HISTOGRAM OF VELOCITY USING THOSE BINS
- FOR EACH VELOCITY, SUM ALL BINS WITH VELOCITIES LESS THAN OR EQUAL TO THE CURRENT BIN VELOCITY
- IF THE DATA INTERVAL IS NOT 1 HOUR, DIVIDE RESULT BY 1/INTERVAL
- CORRECT TO MONTHLY OR YEARLY BASIS DIVIDE BY

  # HOURS

  # HOURS IN YEARS OR MONTH

Wind Resource

MEAN $U = \int_{-\infty}^{\infty} u \, pdf(u) \, du$

$\sum u_i \, pdf(u_i) \, \Delta u$

VARIANCE $\int_{-\infty}^{\infty} (u-U)^2 \, pdf(u) \, du$

D. Characterization of the Wind

4. Statistical Description of the Wind

b. Probability Density Function

- DETERMINE "BINS" FOR VELOCITY
- PERFORM HISTOGRAM USING THOSE BINS
- NORMALIZE

$$pdf(u) = \frac{hist(u)}{N \, \Delta u}$$

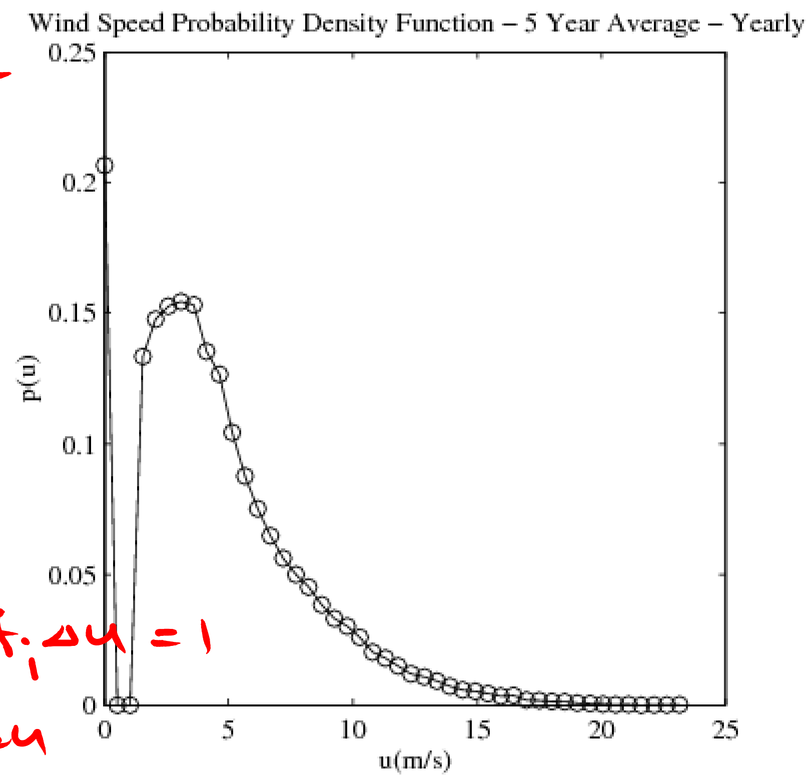
N - NUMBER OF DATA POINTS

Δu - BIN SPACING

$pdf(u) \geq \phi$

$\int pdf(u) du = 1 \rightarrow \sum_{i=1}^{N} pdf_i \, \Delta u = 1$

$p(\text{VELOCITY} < u) = \int_{-\infty}^{u} pdf(u) du$



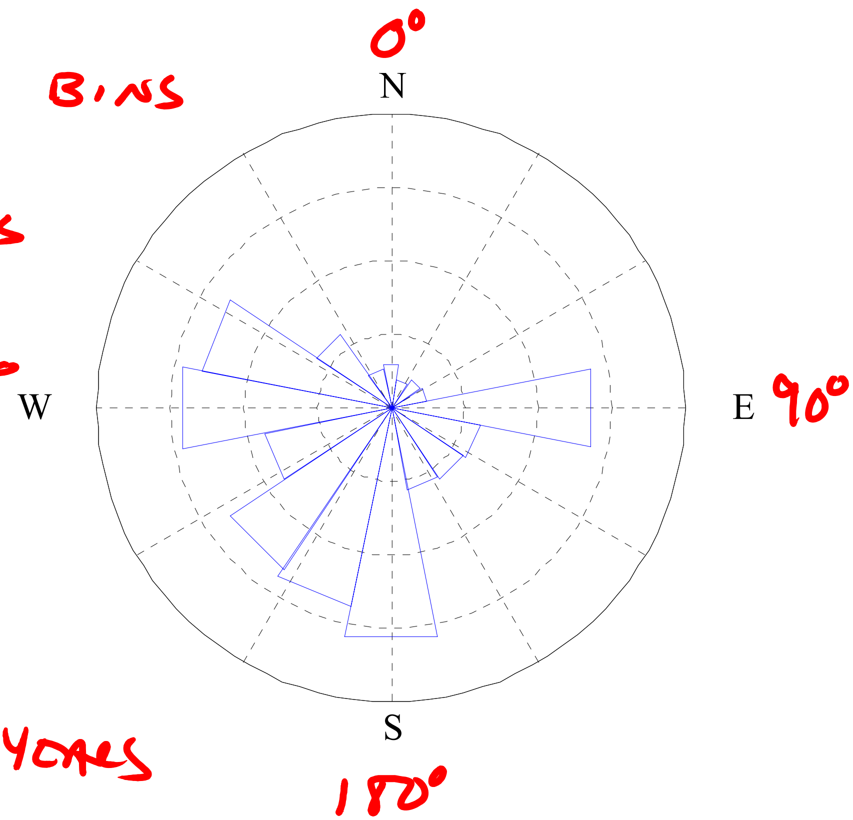
Wind Resource

D. Characterization of the Wind

4. Statistical Description of the Wind

c. Wind Rose (direction)

- BREAK WIND DIRECTION INTO BINS
  16 SECTORS - 22.5° EACH
- PERFORM HISTOGRAM USING BINS
- NORMALIZE BY TOTAL # OF SAMPLES USED N



VISUAL REPRESENTATION OF PREVAILING WIND DIRECTION

CAN BE DONE FOR MONTHS OR YEARS

Wind Resource

D. Characterization of the Wind

4. Statistical Description of the Wind

d. Statistical Models of the Wind

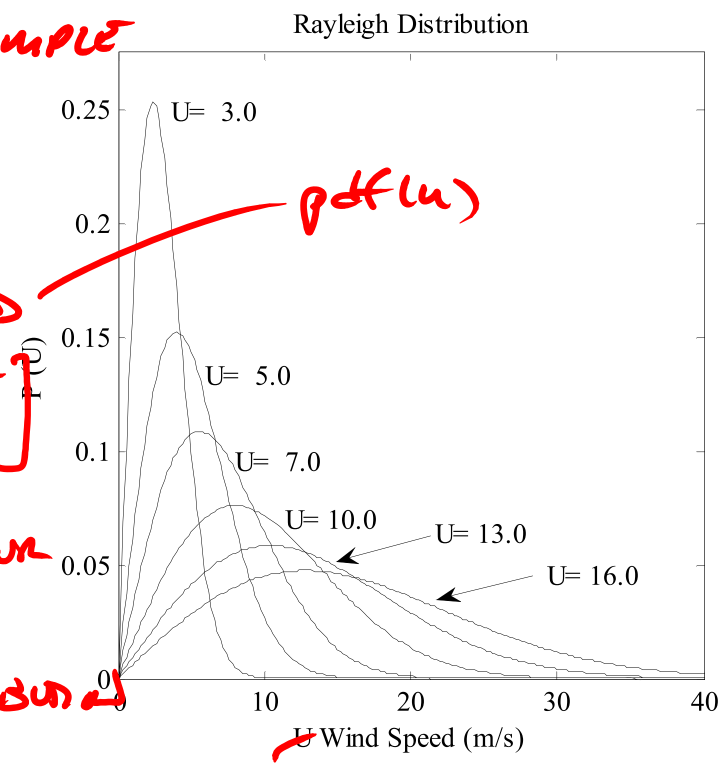
SKEWED DISTRIBUTION

RAYLEIGH DISTRIBUTION IS A SIMPLE DISTRIBUTION THAT CAN BE USED AS MODEL

DEPENDS ON ONLY 1 VARIABLE
U – MEAN WIND SPEED

pdf(u)

$$pdf(u) = \frac{\pi}{2}\left(\frac{u}{U^2}\right)\exp\left[-\frac{\pi}{4}\left(\frac{u}{U}\right)^2\right]$$



ONCE A GOOD APPROXIMATION OF YOUR pdf DETERMINED FROM DATA IS ACHIEVED, THEN USE "MODEL" DISTRIBUTION FOR OTHER CALCULATIONS

Wind Resource

D. Characterization of the Wind

4. Statistical Description of the Wind

d. Statistical Models of the Wind

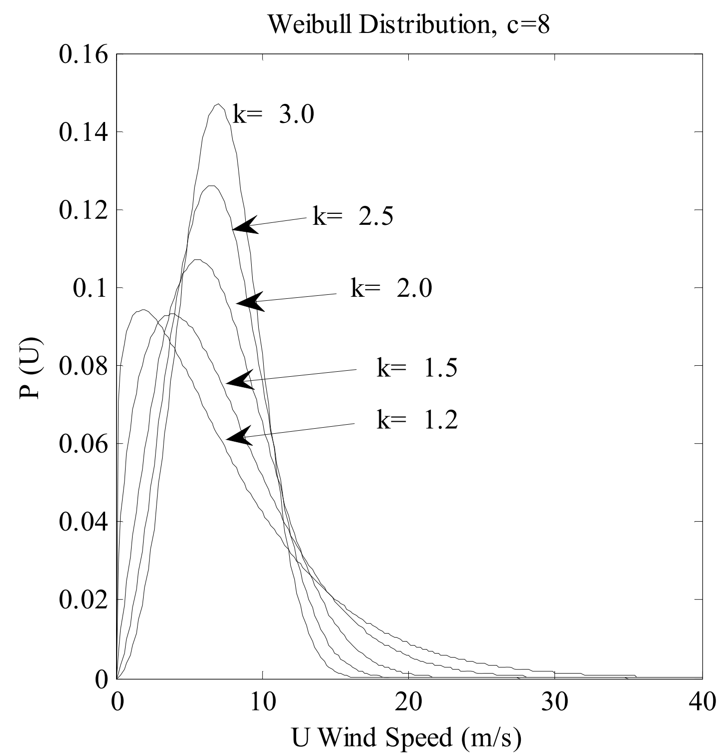
$k \equiv$ SHAPE FACTOR

$c \equiv$ SCALE

WEIBULL DISTRIBUTION IS 2 PARAMETER MODEL

$$pdf(u) = \left(\frac{k}{c}\right)\left(\frac{u}{c}\right)^{k-1} \exp\left[-\left(\frac{u}{c}\right)^{k}\right]$$

AS K INCREASES, PEAK GROWS NARROWER



k & c CAN BE DETERMINED FROM

$u \rightarrow S_u$ SEE BOOK