Wind Resource Assessment

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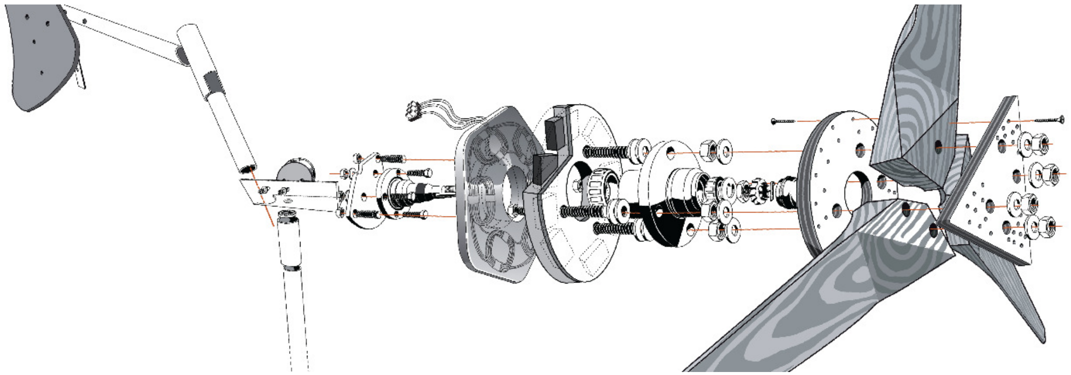
Renewable Energy Innovation

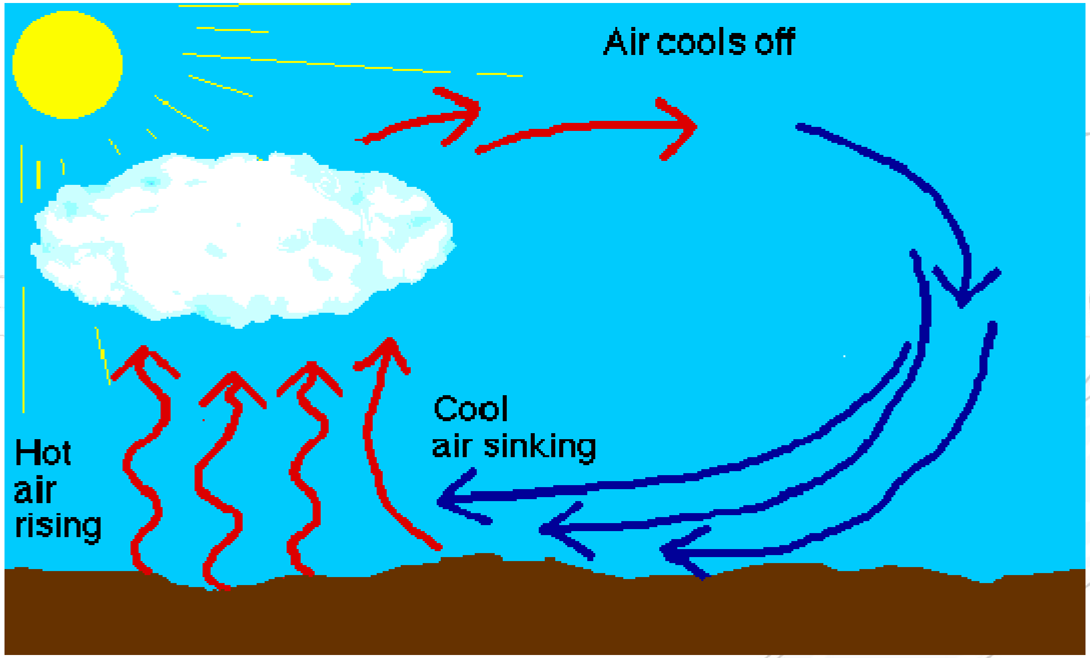


Overview

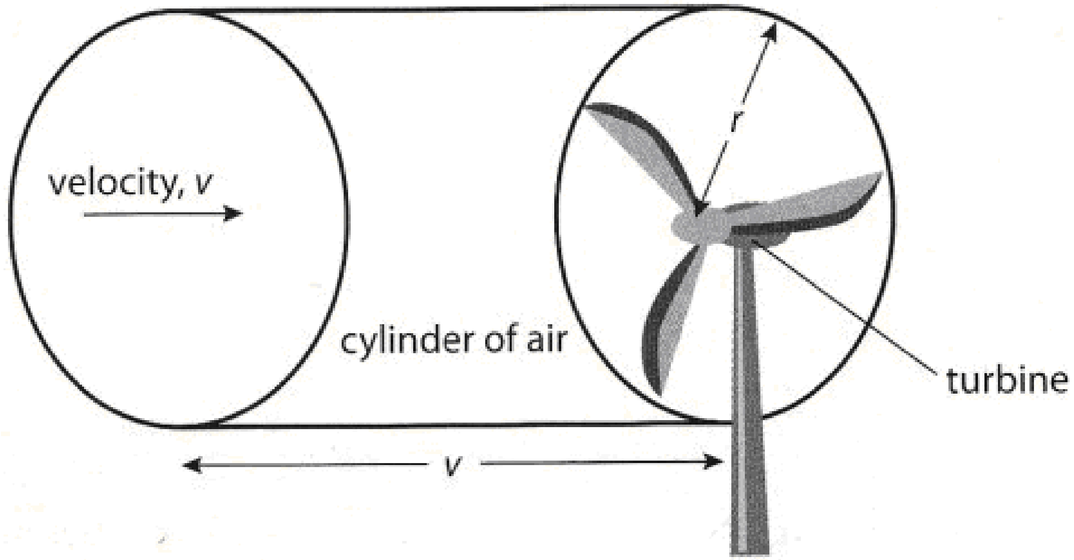
- Wind Power
- Wind Energy
- Wind Speed and its characteristics
- Initial wind resource analysis
- Detailed site assessment
- Detailed wind resource analysis
- Estimating annual energy production

Wind

Wind is movement of air due to
thermal effects causing pressure differences



Wind Power



$$Power,\ P = 1/2\, \rho\, A\, v^3$$

ρ = air density (1.22kg/m^3)

A = Swept area

v = Wind velocity

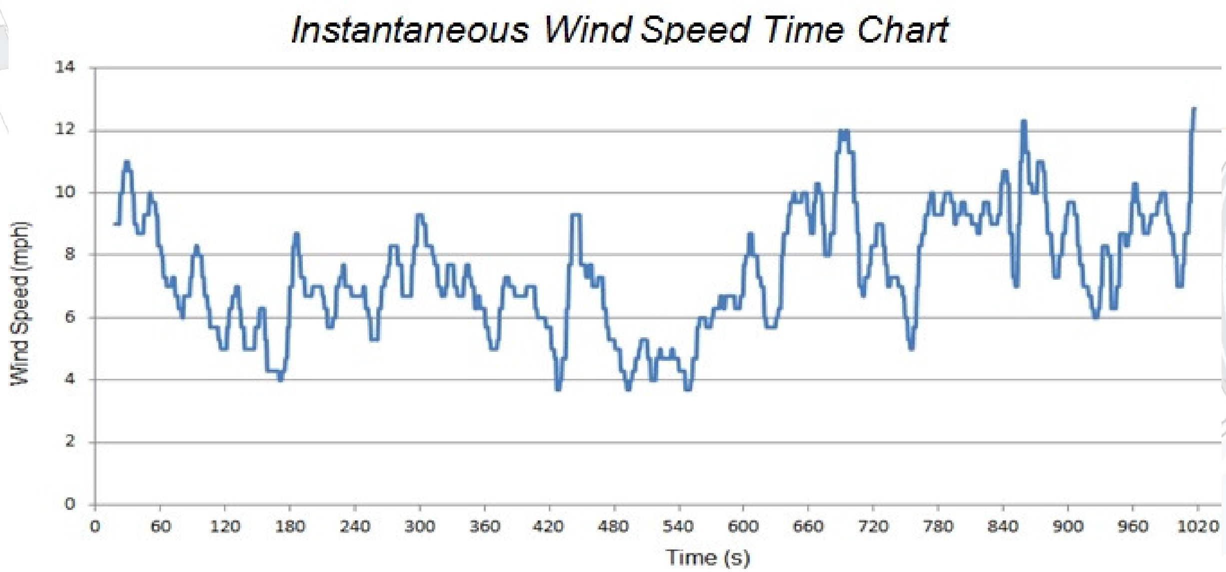
Wind Energy

Energy = Power x Time

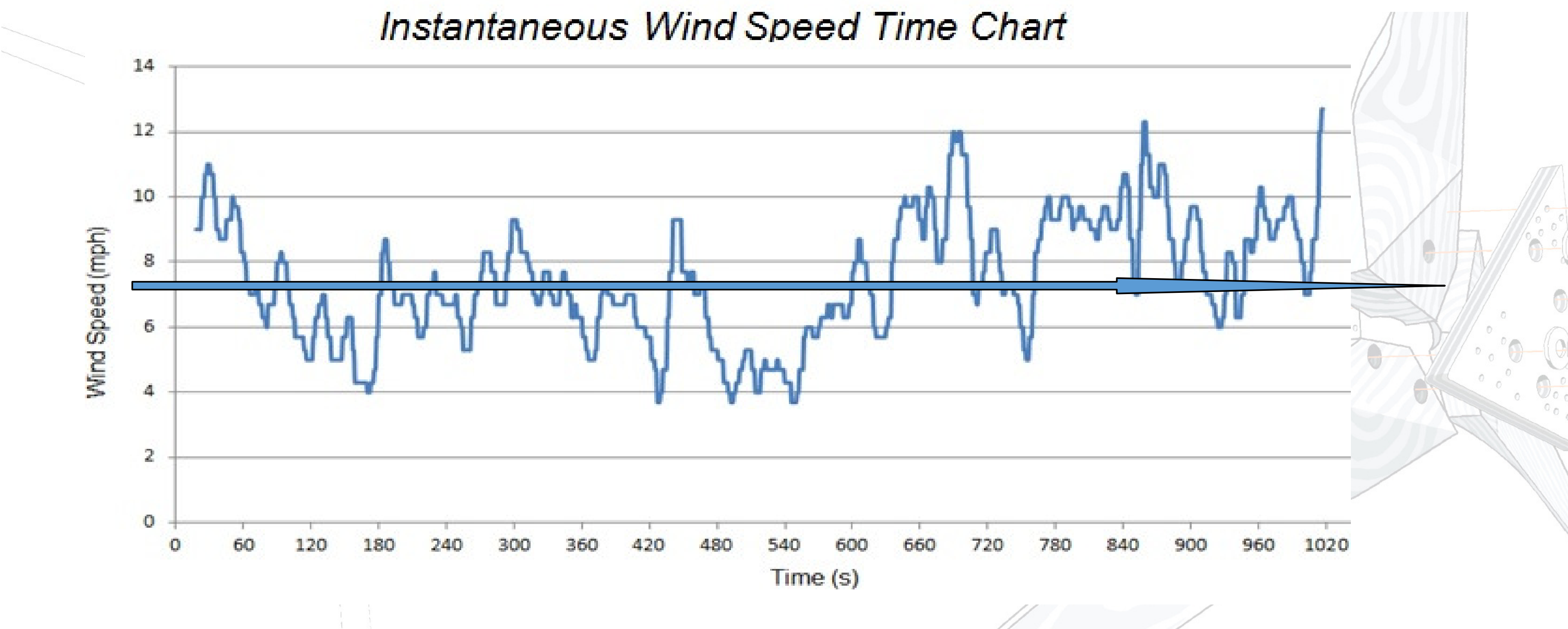
So annual wind energy is average wind speed at the site x hours in year

Wind Speed

- Wind resource is highly variable and site specific



Average Wind Speed



Average Wind Speed

- The most useful factor to use to assess the wind resource at a particular site
- Usually given in m/s
- Monthly or yearly
- Cubic relationship between wind speed and energy generation
- An increase of wind speed from 6m/s to 7m/s gives a 58% increase in energy production.

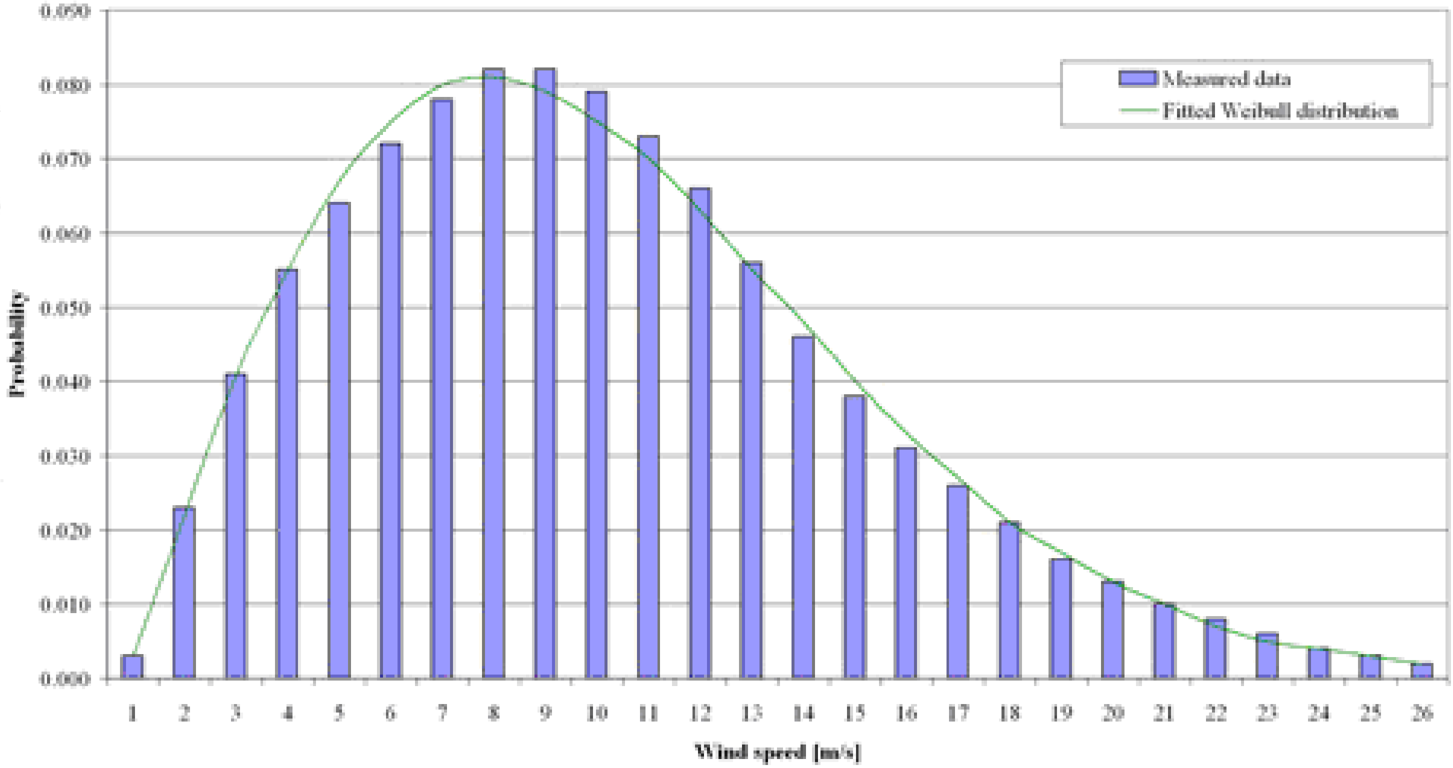
Suitable Wind Speeds

Generally annual average

>4.5m/s is required for SWT

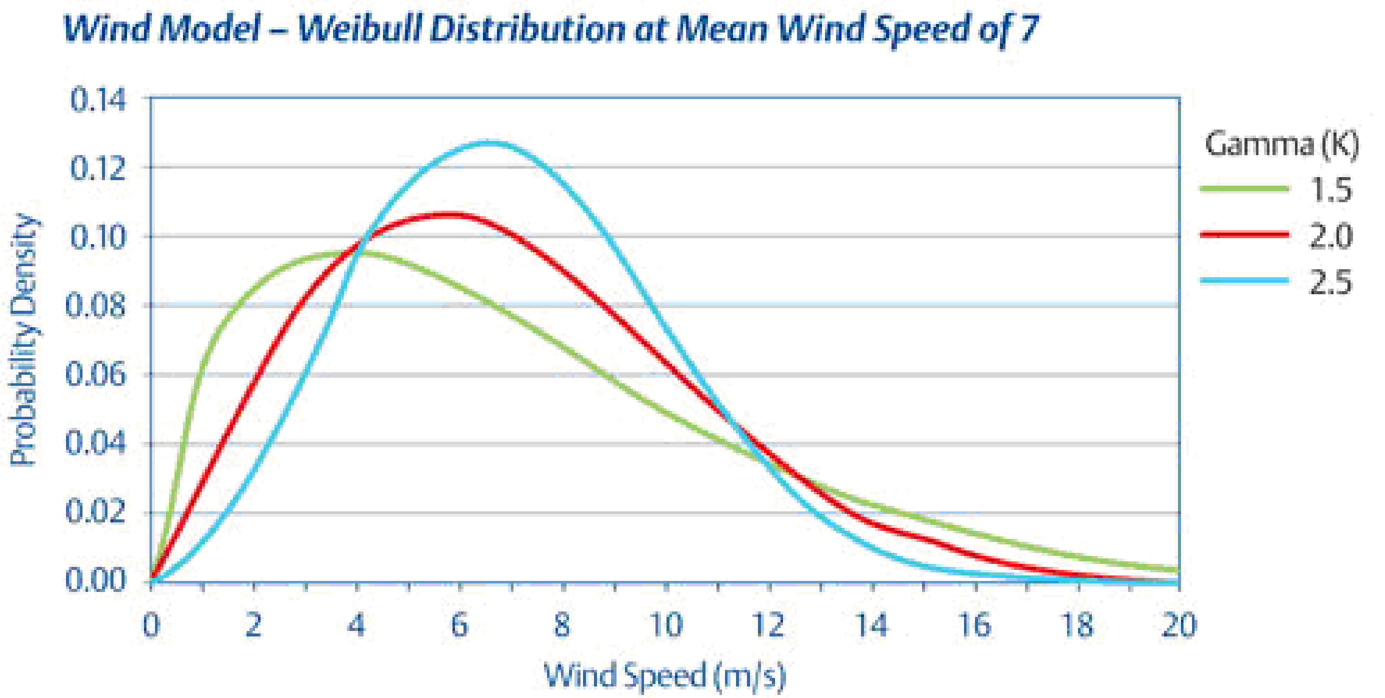
Rating	Wind Power Class*	10 m (33 ft) Wind Power Density (W/m²)	10 m (33 ft) Speed[b] m/s (mph)	30 m (164 ft) Wind Power Density (W/m²)	30 m (164 ft) Speed[b] m/s (mph)
Poor	1	0	0	0	0
Marginal	2	100	4.4 (9.8)	160	5.1 (11.4)
Fair	3	150	5.1 (11.5)	240	5.8 (12.8)
Good	4	200	5.6 (12.5)	320	6.5 (14.6)
Excellent	5	250	6.0 (13.4)	400	7.0 (15.7)
Outstanding	6	300	6.4 (14.3)	480	7.4 (16.6)
Superb	7	400	7.0 (15.7)	640	8.2 (18.3)

Wind Speed Probability Distribution



Wind is typically a Weibull Distribution

Shape Parameter

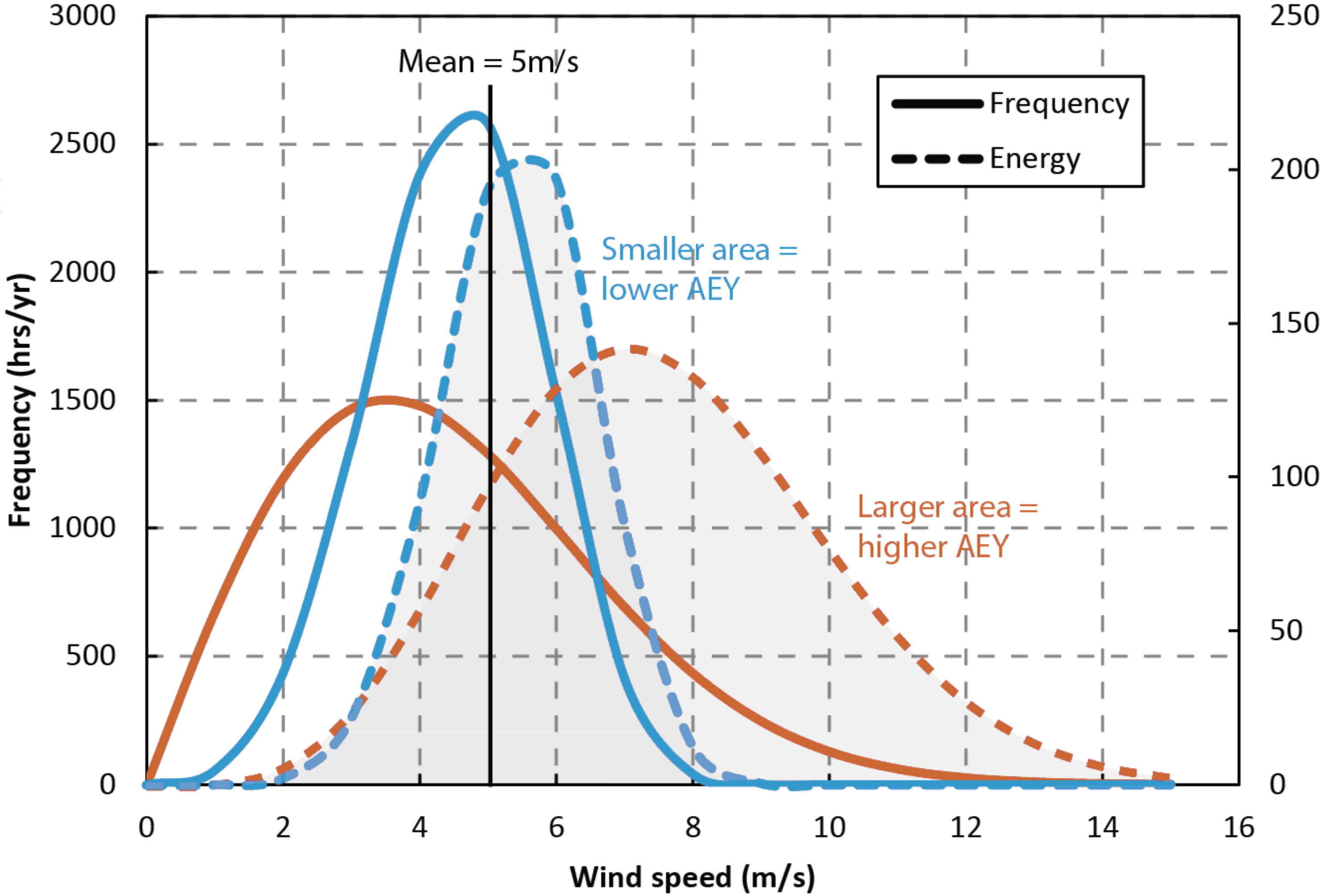


Shape parameter – called 'K'

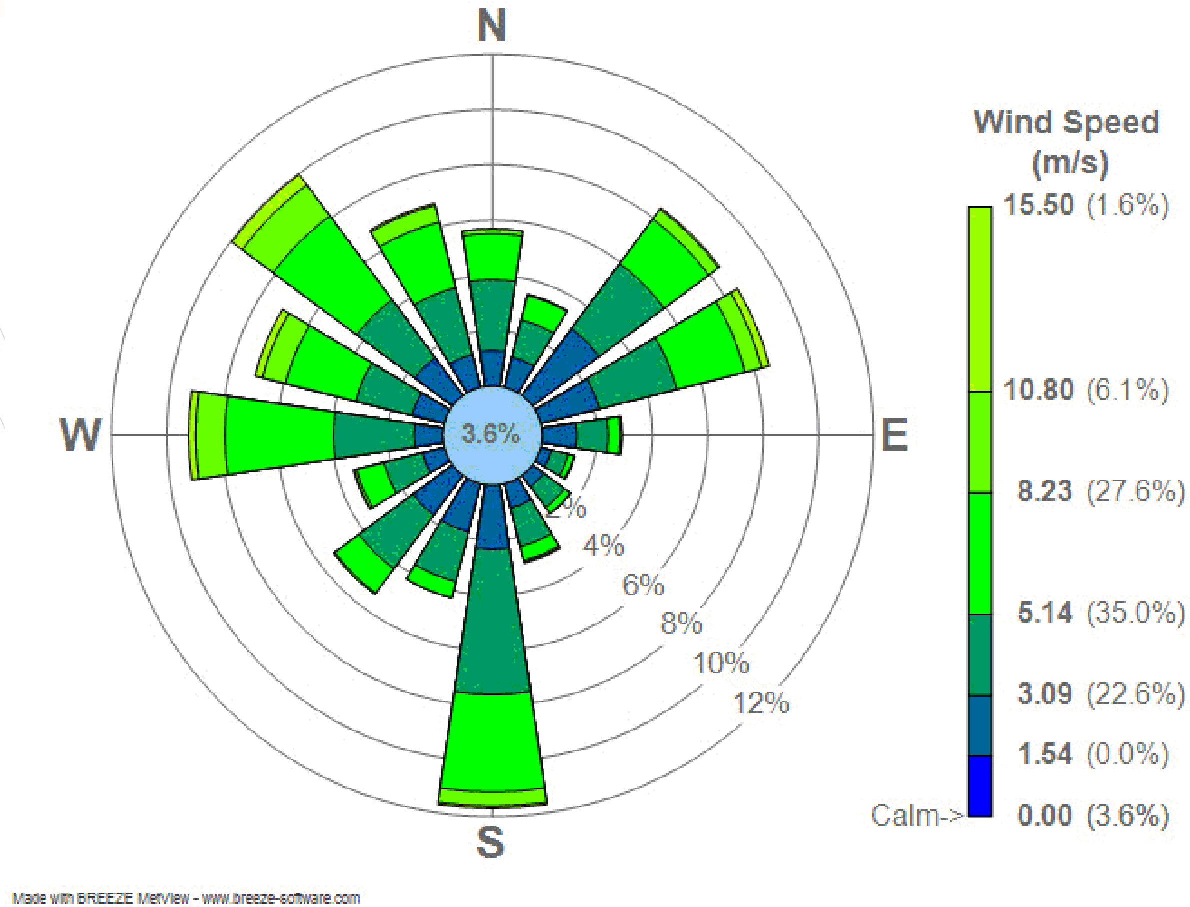
If K factor is not known for a site use:

- K = 2 for inland locations
- K = 3 for sea coasts
- K = 4 for islands

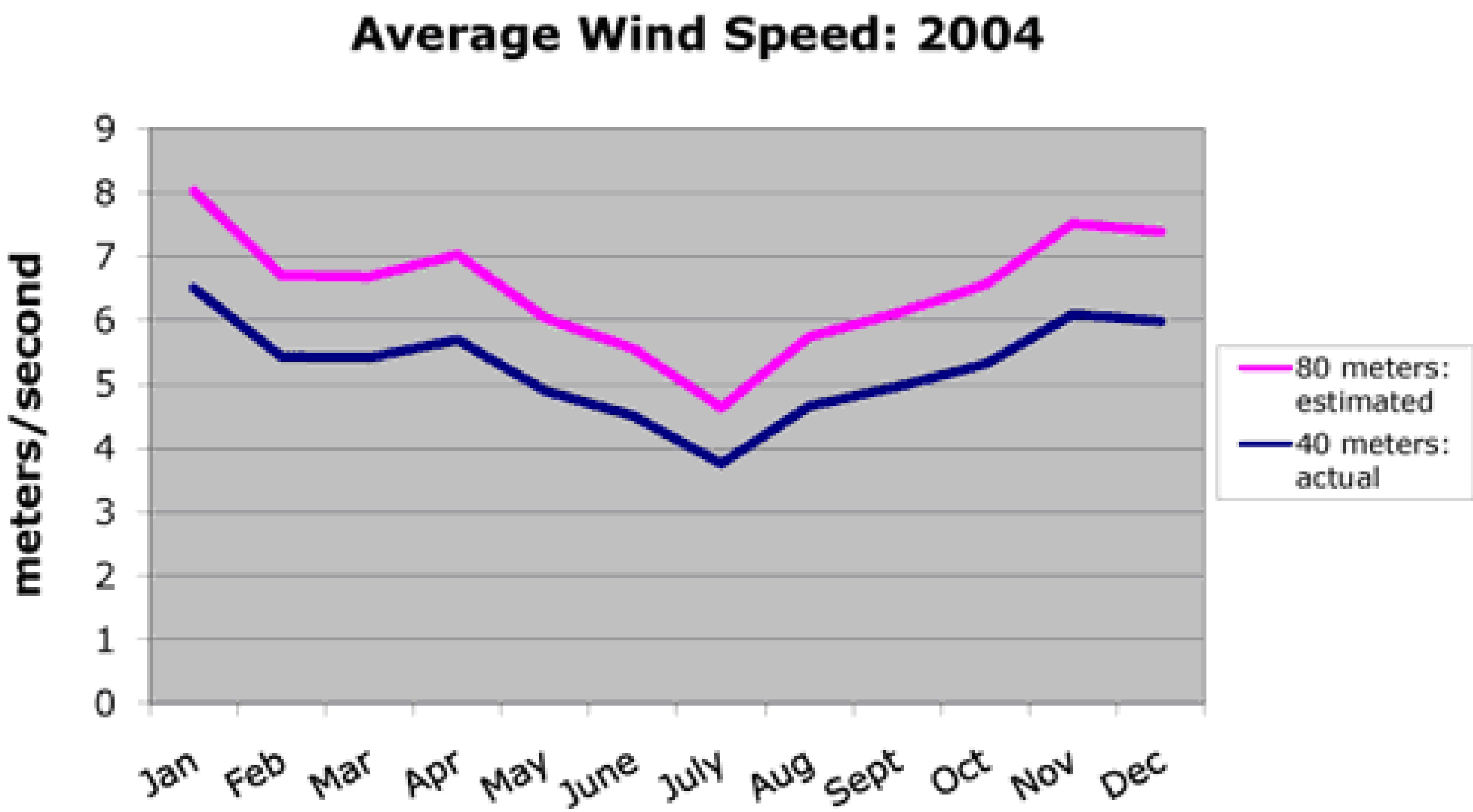
Wind Energy Distribution Graph



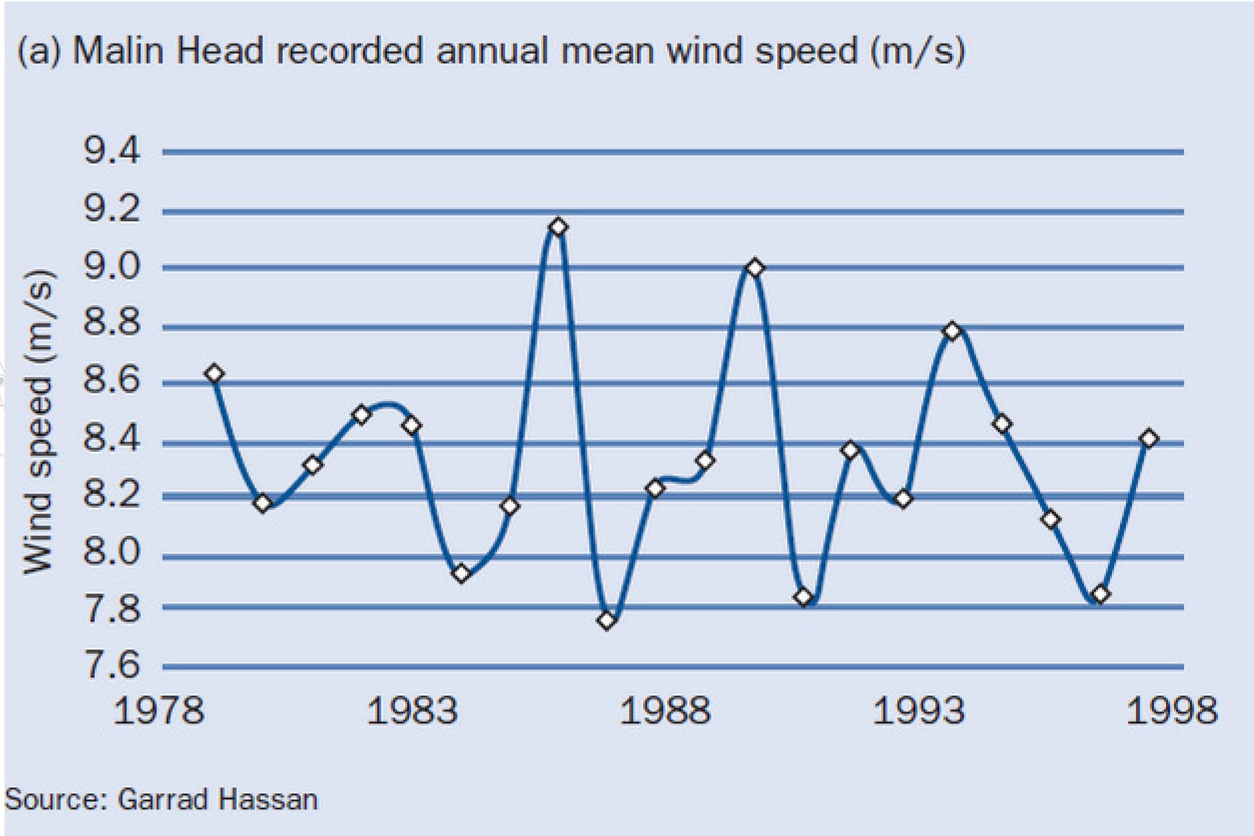
Wind Rose


N
E
S
W
3.6%
2%
4%
6%
8%
10%
12%
Wind Speed (m/s)
15.50 (1.6%)
10.80 (6.1%)
8.23 (27.6%)
5.14 (35.0%)
3.09 (22.6%)
1.54 (0.0%)
Calm->
0.00 (3.6%)
Made with BREEZE MetView - www.breeze-software.com

Seasonal Variation



Inter-Annual Variation



Log Law

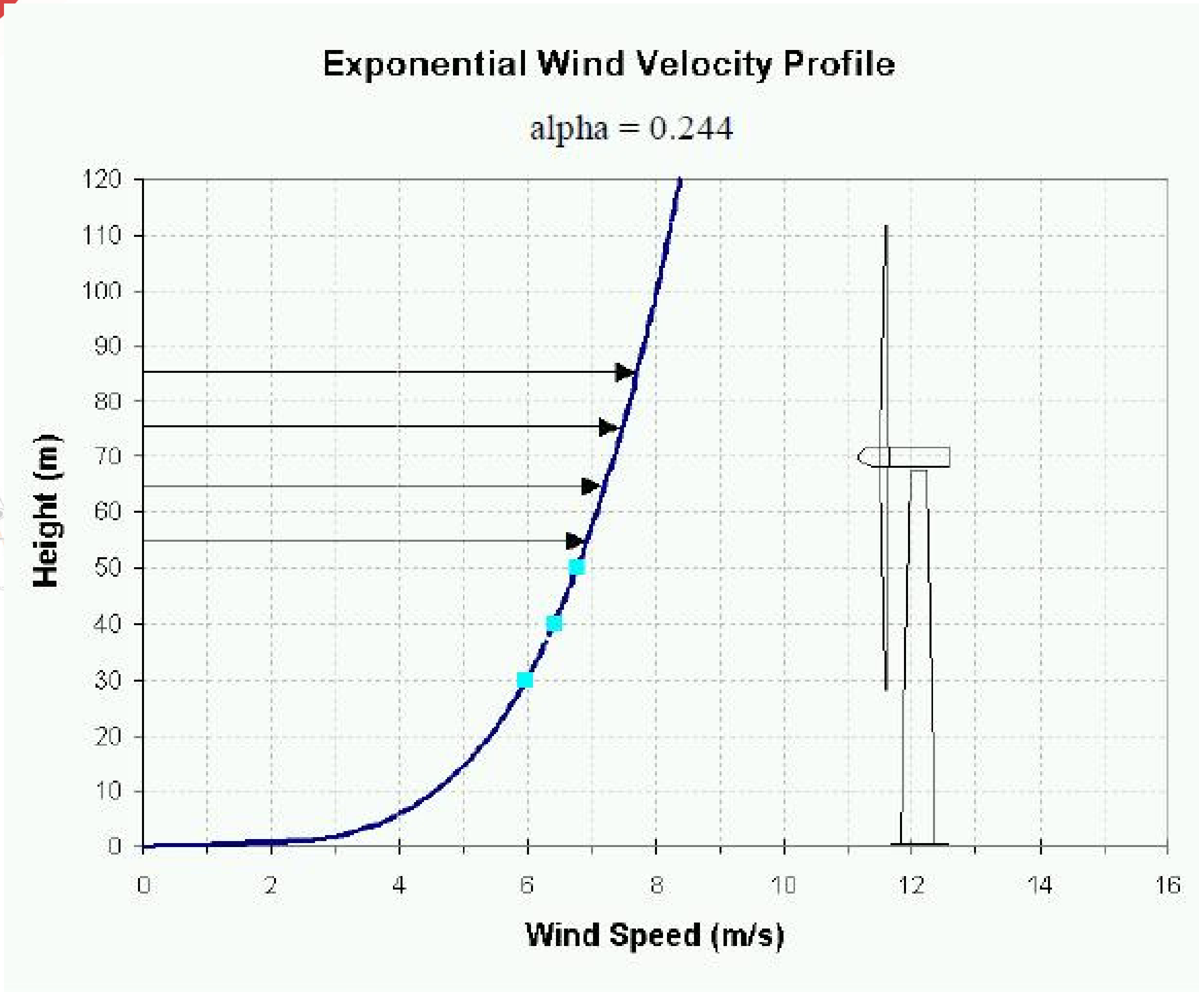


Figure 3 Annual Average Wind Shear at WCROC Site

Log Law

$$v \approx v_{ref} \cdot \frac{\ln\left(\frac{z}{z_0}\right)}{\ln\left(\frac{z_{ref}}{z_0}\right)}$$

- V = velocity to be calculated at height Z
- Z = height above ground level for velocity v
- V_{ref} = known velocity at height Z_{ref}
- Z_{ref} = reference height where v_{ref} is known
- Z_0 = roughness length in the current wind direction

Roughness Length

Depends upon the topology of the area

Roughness Class	Roughness Length m	Energy Index (per cent)	Landscape Type
Roughness Classes and Roughness Length Table			
0	0.0002	100	Water surface
0.5	0.0024	73	Completely open terrain with a smooth surface, e.g.concrete runways in airports, mowed grass, etc.
1	0.03	52	Open agricultural area without fences and hedgerows and very scattered buildings. Only softly rounded hills
1.5	0.055	45	Agricultural land with some houses and 8 metre tall sheltering hedgerows with a distance of approx. 1250 metres
2	0.1	39	Agricultural land with some houses and 8 metre tall sheltering hedgerows with a distance of approx. 500 metres
2.5	0.2	31	Agricultural land with many houses, shrubs and plants, or 8 metre tall sheltering hedgerows with a distance of approx. 250 metres
3	0.4	24	Villages, small towns, agricultural land with many or tall sheltering hedgerows, forests and very rough and uneven terrain
3.5	0.8	18	Larger cities with tall buildings
4	1.6	13	Very large cities with tall buildings and skycrapers

Altitude Effect

- Air density reduces at higher altitudes.
- This affects power in the wind

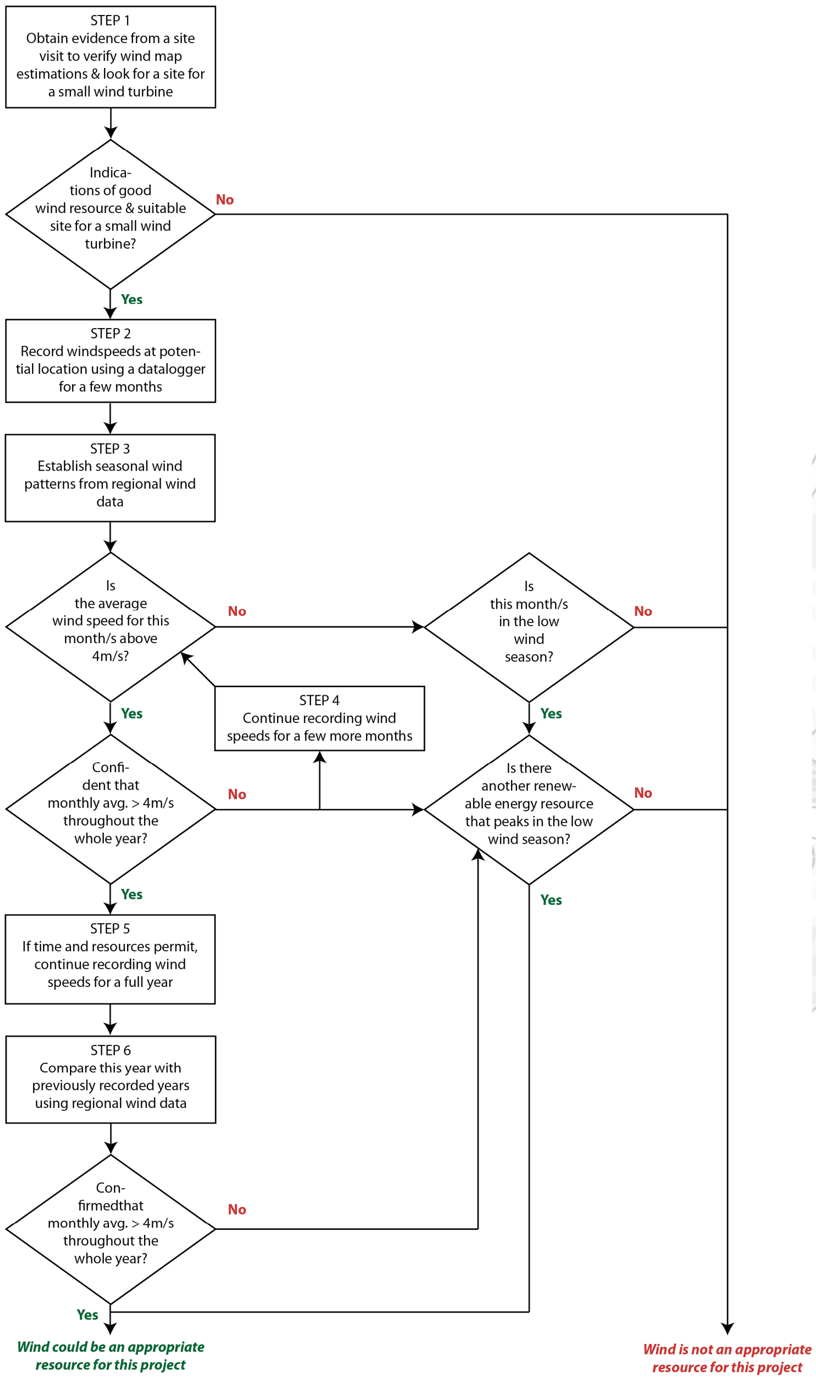
Elevation (m)	Relative Performance
0 (sea level)	100%
600	94%
1,200	88%
1,500	85%
2,100	79%
2,400	76%
2,700	73%
3,000	70%

Temperature and Humidity Effects

- Higher temperatures reduce the air density
- Higher temperatures reduce the power available

- Increased humidity reduces air density
- Higher humidity reduces the power available

Wind Resource Assessment



Limitations

- Cost of data-logging
- Local data hard/impossible to find
- Gaps in data
- Variation in topology
- Inaccuracy in data
- Data-logging time period

Initial Resource Assessment

Use online resources and data as an initial check

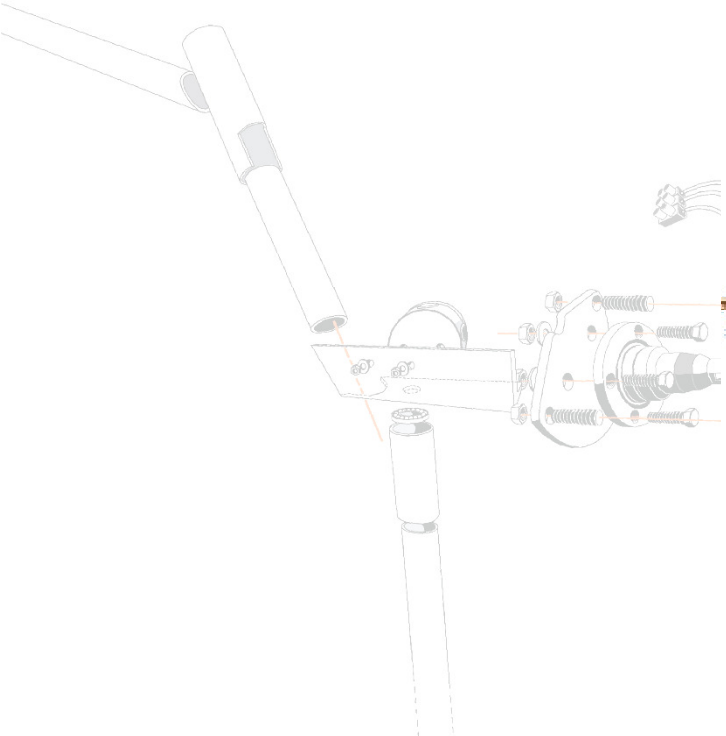
- IRENA
  - http://irena.masdar.ac.ae/
- NASA
  - https://eosweb.larc.nasa.gov/sse/
- 3 TIER
  - http://www.vaisala.com/en/energy/support/Resources/Pages/Free-Wind-And-Solar-Resource-Maps.aspx
- NREL
  - http://www.nrel.gov/wind/international_wind_resources.html

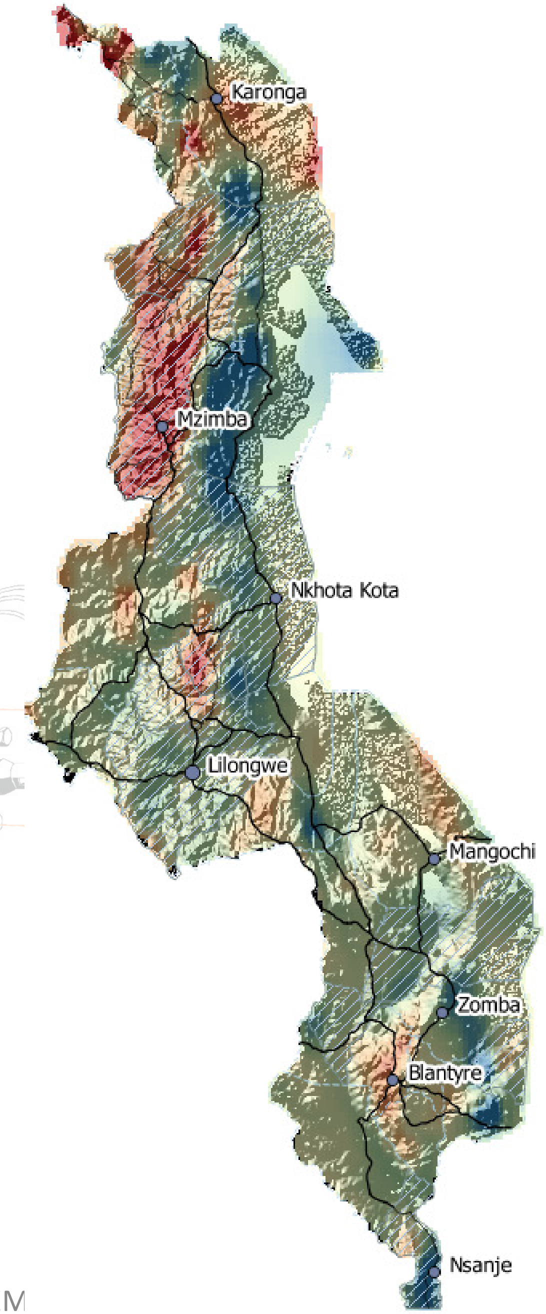
Initial Resource Assessment

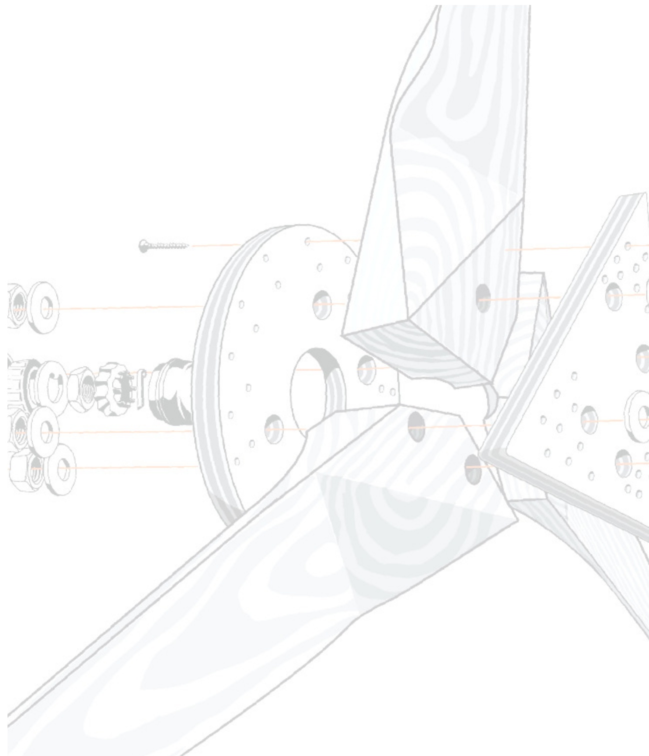
- Review any available reports/literature
- Check for other factors (access, grid infrastructure, protected areas etc).
- The desk-based research will give an indication of suitable areas for more investigation
- Can use GIS methods to review data

Do any areas look suitable?

Community Energy Malawi







Initial Site Visit

- Found some suitable locations
- Arrange a site visit
- Good to have a previous relationship with the community

Anecdotal Evidence

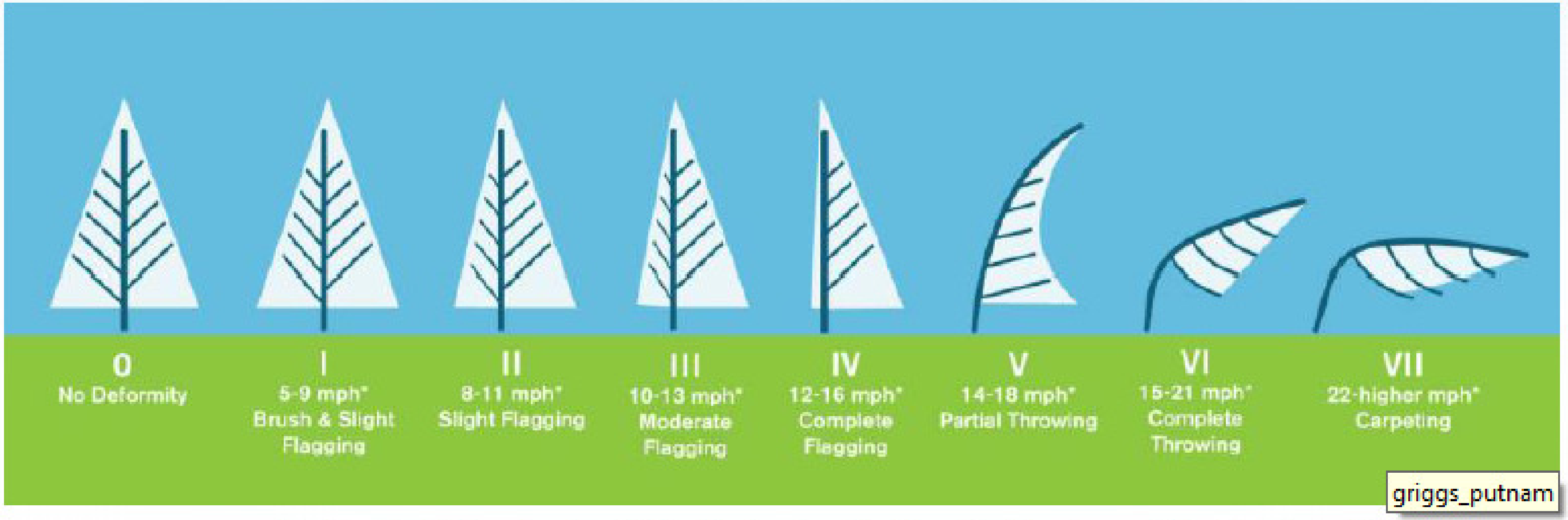
- Discussion with the local community
- Interview a representative proportion
- Trying to get a fair view of weather conditions

But…

- Be careful of general comments
- Be careful of over-enthusiastic assessment

Observation

Look for local signs of high wind speeds

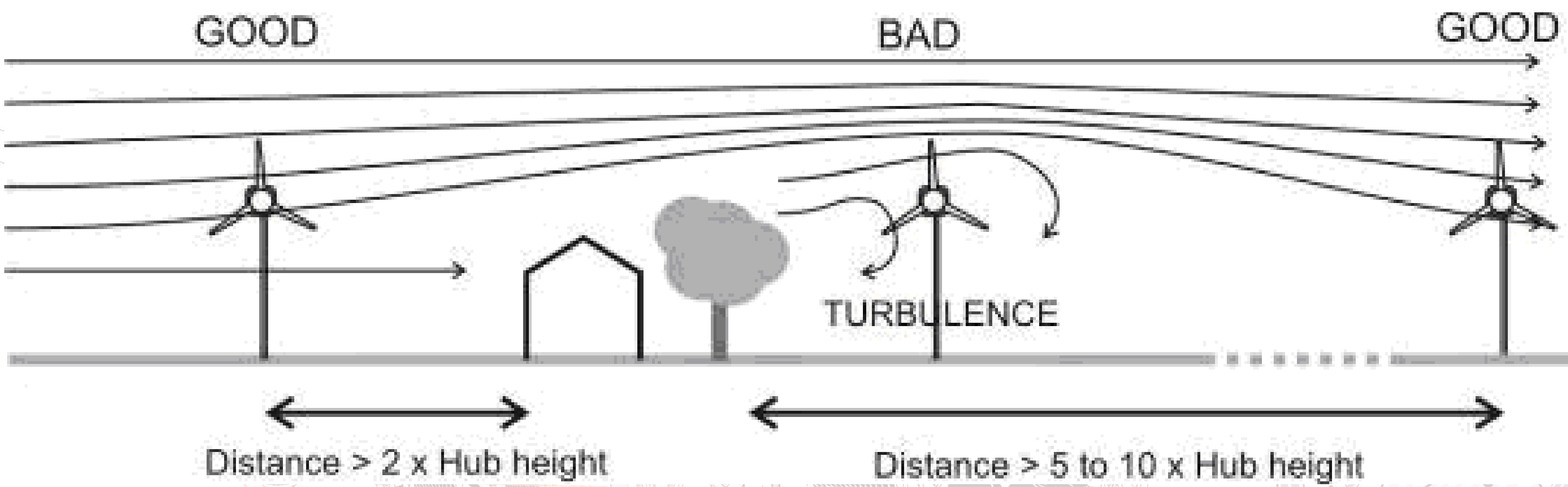


2 – 4 m/s 3.5 – 5 m/s 4.5 – 6m/s 5 – 7 m/s 6 – 8 m/s 6.5 – 9 m/s 10 m/s +

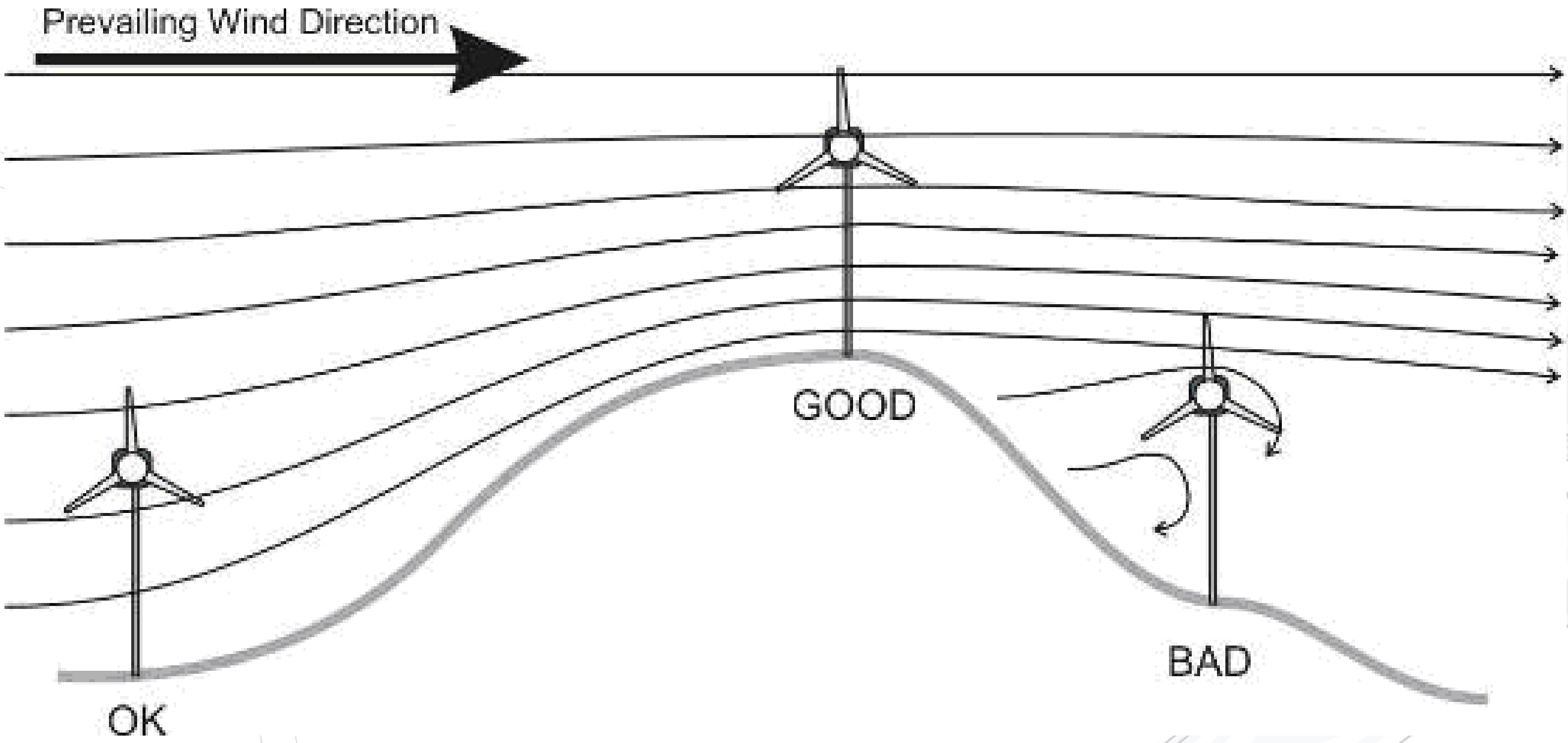
Topology

- Perhaps hills or mountains funnel the wind?
- Are there local obstructions such as trees or houses close by?
- Can the prevailing wind direction be assessed?
- Is the site near the sea?
- How many meters above sea level is the site?
- What is the local terrain?
- Look for initial sites to place the wind turbine.
- Check land ownership issues.

Topology


GOOD
BAD
GOOD
TURBULENCE
Distance > 2 x Hub height
Distance > 5 to 10 x Hub height

Topology



Data Logging

- Monitor a site with data-logging equipment
- Need to take data for as long as possible
- Typically 6 months or more is best
- Ensure calibrated accurate monitoring equipment

- This can be an expensive task

Note: additional presentation on data-logging systems

Review Data

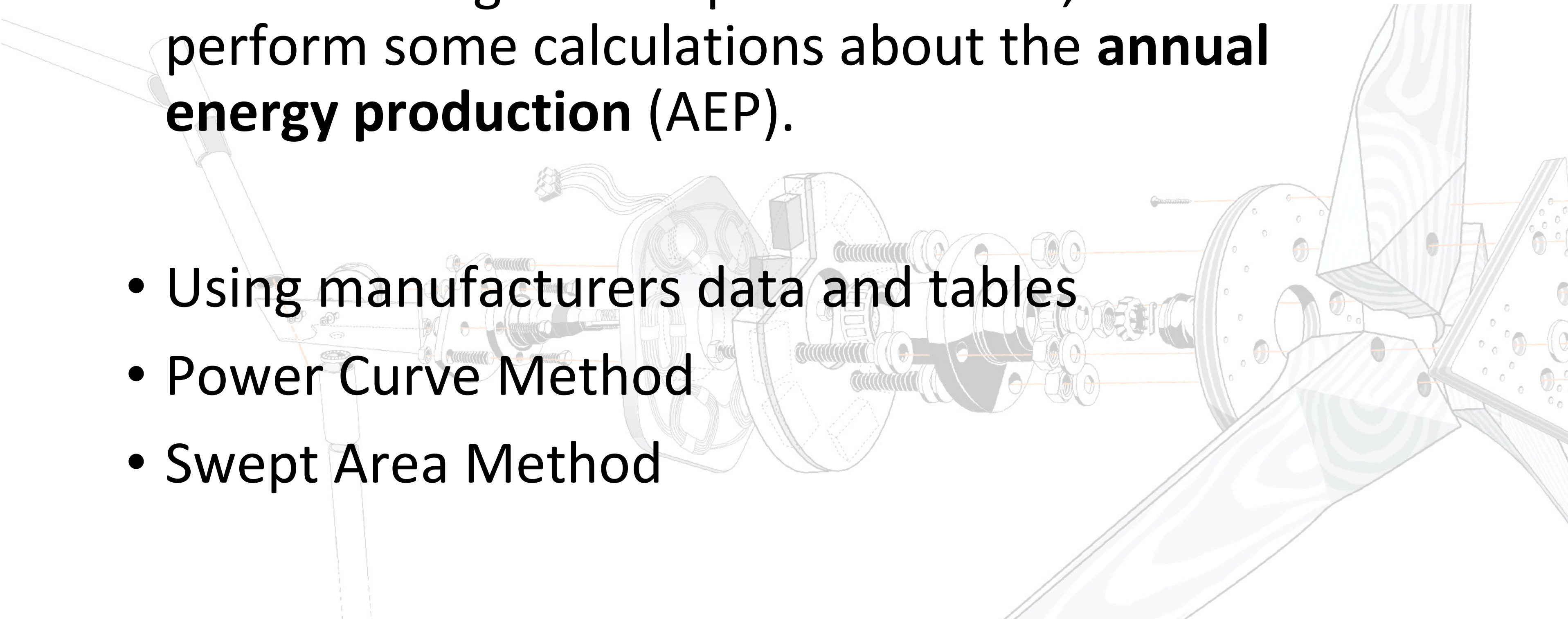
- Analyse data recorded
- Adjust for seasonal variation
- Adjust for inter-annual variation (if possible)
- Adjust for turbine hub height
- Find average wind speed
- Find wind speed probability distribution curve

We can then:

- Find annual energy production

Annual Energy Production

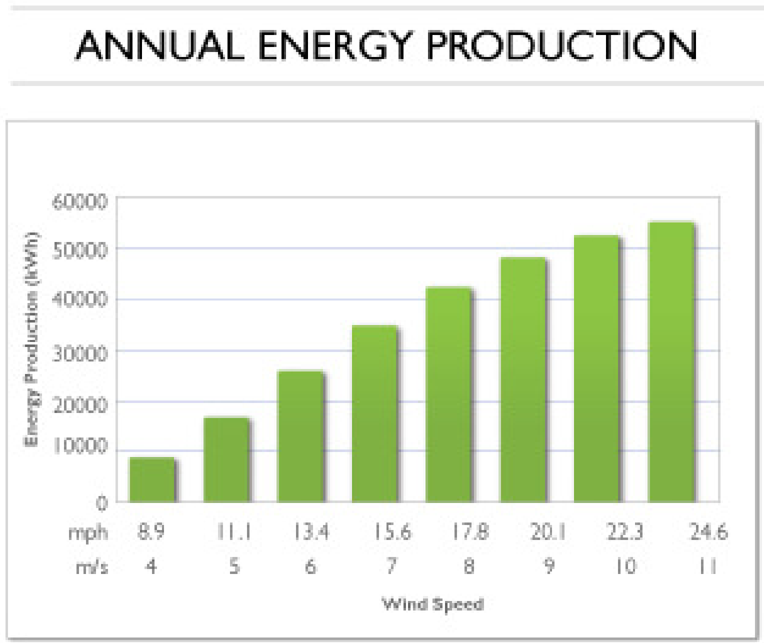
With an average wind speed estimate, we can perform some calculations about the **annual energy production** (AEP).



- Using manufacturers data and tables
- Power Curve Method
- Swept Area Method

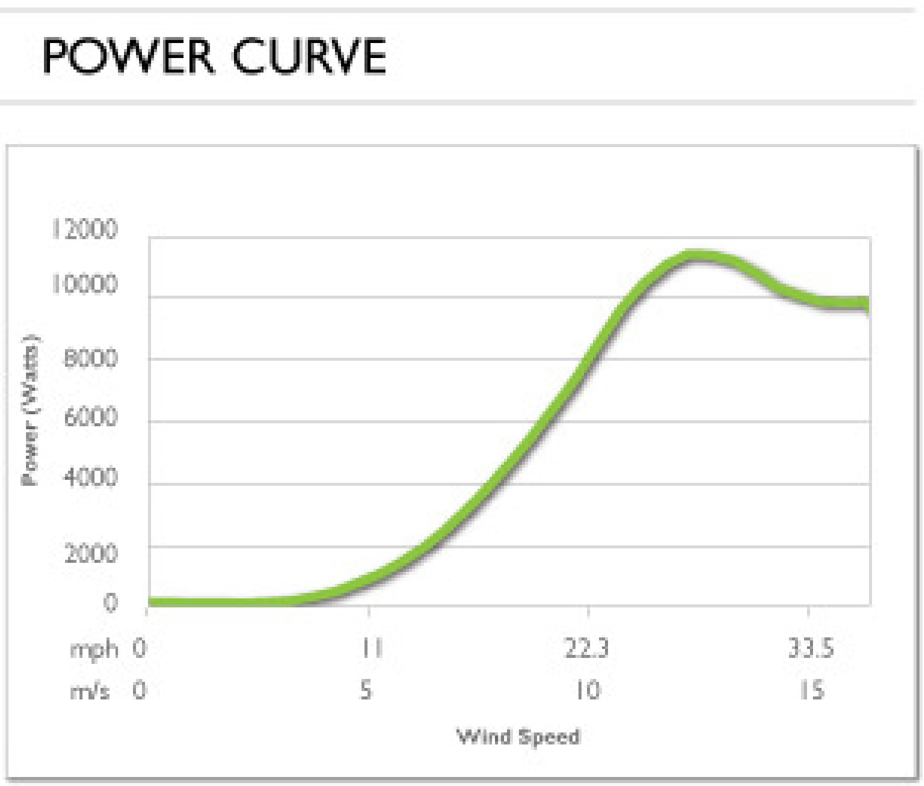
AEP – Manufacturers Data

- Use estimates from manufacturers
- Sales data – sometimes over estimated or ideal data.
- Might not take into account shape factor



AEP – Power Curve Method

- Use a power curve and wind speed data
- Multiply together at each wind speed to give energy distribution graph
- Integrate area under energy distribution to find total energy



AEP – Swept Area Method

Energy = 1/2 ρ A v^3 * efficiency * time

- ***A = Swept area***
- ***ρ = Air density (adjust for altitude)***
- ***v = Annual average wind speed***
- Use efficiency value of around 0.25
- Time is hours in a year = 8760 hours

Summary

- Accurate knowledge of wind resource is essential for assessing a site for SWT
- Small variations in wind speed can make a big difference to energy calculations
- Difficult to obtain accurate data
- Find as much data and information as possible

Worked Example

- Site is: Mchinji : 13°49′ S 32°54′ E
- Data collected:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
?	?	4.6	4.3	3.7	?	?	?	?	?	?	?

Worked Example

- Data from NASA website:

Monthly Averaged Wind Speed At 10 m Above The Surface Of The Earth For Terrain Similar To Airports (m/s)													
Lat -13.49 Lon 32.54	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
10-year Average	3.26	3.18	3.41	3.31	3.31	3.61	3.91	4.23	4.76	4.84	4.58	3.68	3.84

- Need to find scale factor
- Then extrapolate data

Worked Example

- Then need to adjust for inter-annual variation:
- Data from previous years (from 10m height):

May 2005	May 2007	May 2008	May 2009	May 2010	May 2011	May Average
4.6	4.9	3.7	5.1	4.9	4.8	4.66

- The data for May this year is 4.4m/s
- Calculate the adjustment factor for inter-annual variation.

Questions?