Wigton WINDFARM LTD Renewable Energy Training Lab

CARIBBEAN CENTRE FOR RENEWABLE ENERGY & ENERGY EFFICIENCY

Training Manual for Wind Resource Assessments

Date of Delivery :	February 16th, 2020
Delivered by :	Mr. Sanjá A. Simmonds, MPhil.
Length of Delivery:	Three (3) Hours
Email:	sanja.Simmonds@wwfja.com

Disclaimer

Wigton Windfarm Ltd. Renewable Energy Training Laboratory

traininglab@wwfja.com

Outcomes and Deliverables

1a. Outcome: To introduce participants to the wind energy resource

Deliverables: the main deliverables of this section are to:

1. Outline the source of wind energy
2. Explore the factors affecting wind energy throughout the Caribbean Region
3. Examine the requirements for harvesting wind energy and their potential effects on the environment

1b. Outcome: To review and perform common wind resource assessments

Deliverables: the main deliverables of this section are to:

1. Outline the steps in assessing wind resource
2. Outline the steps and tools used in wind data collection
3. Perform common wind data assessments

Outcomes and Deliverables

1c. Outcome: To introduce participants to the best practices for high level wind resource assessments

Deliverables: the main deliverables of this section are to:

1. How measured data can be used to model more general wind atlas
2. Difference in data quality for planning vs site implementation
3. Various requirements necessary for creating a bankable report

1d. Outcome: To review feasibility considerations and climate vulnerability impacts

Deliverables: the main deliverables of this section are to:

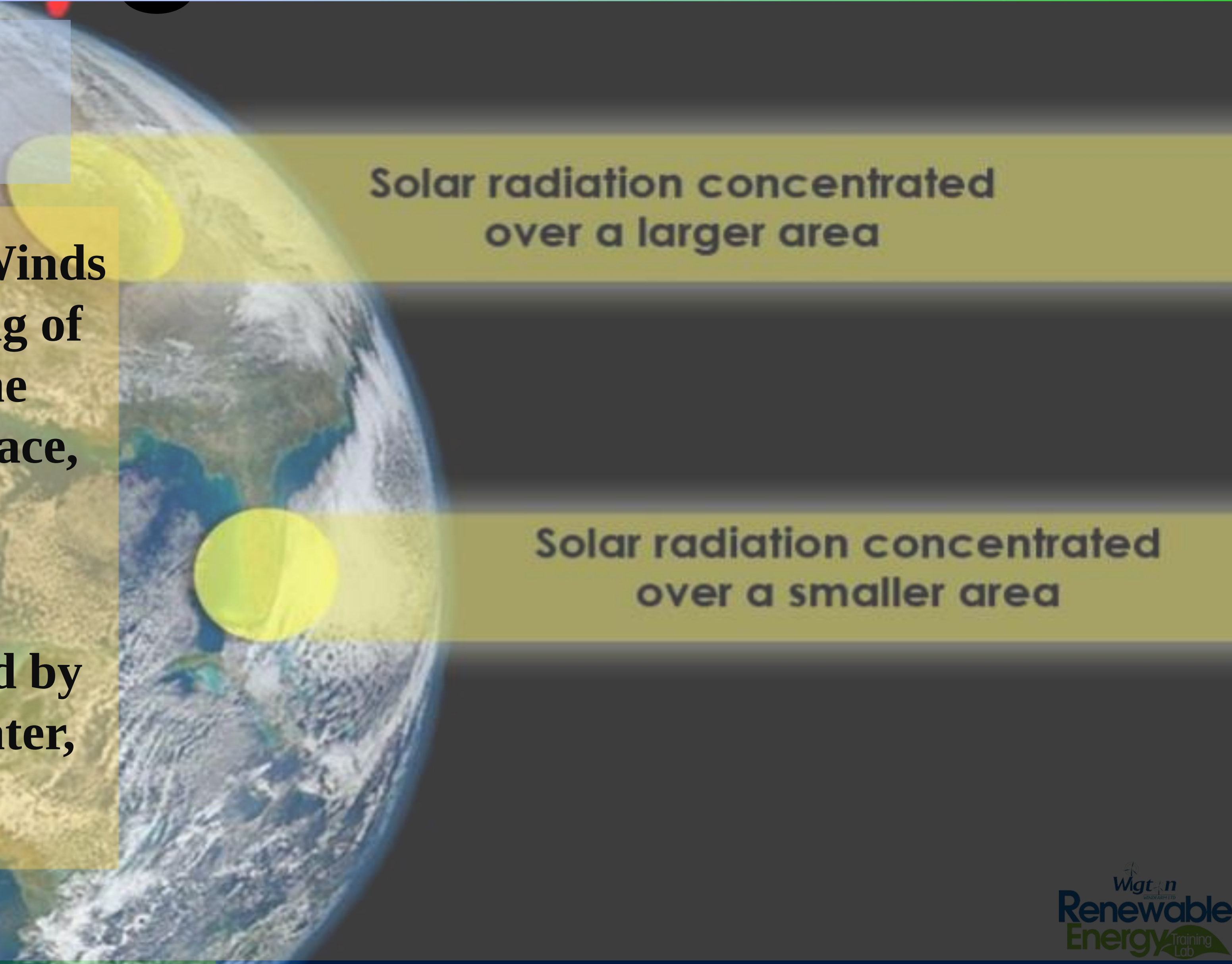
1. Outline the steps in wind development planning
2. Analyze the various environmental impacts to determine feasibility and implementation

THE WIND RESOURCE

Wind Energy

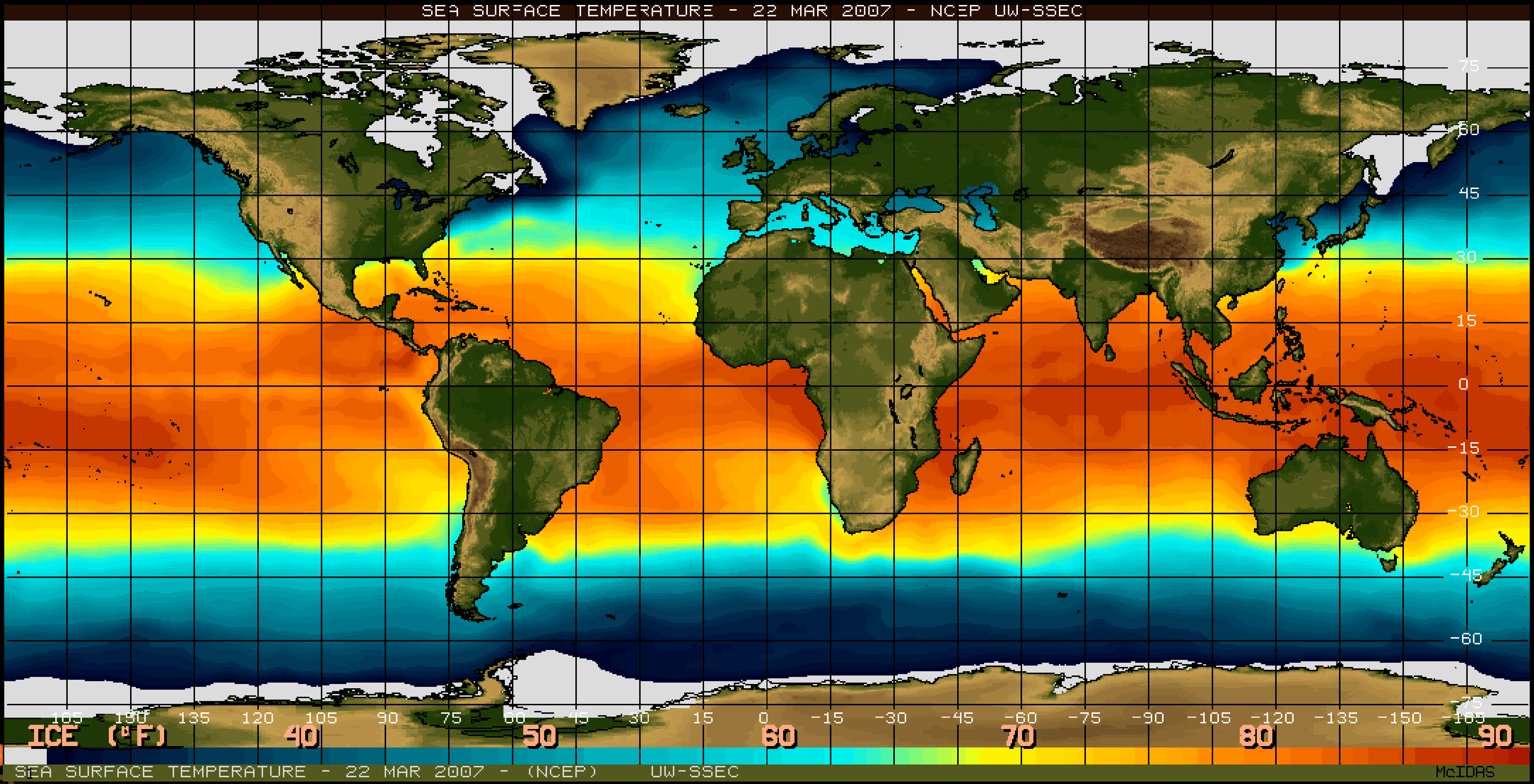
Wind is a form of solar energy. Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth.

Wind flow patterns are modified by the earth's terrain, bodies of water, and vegetative cover.



Kirby, Lawrence (2017). *Introduction to wind and hydroelectric energy.*
Image: *Climate Science Investigations (CSI).* http://www.ces.fau.edu

Introduction to the Wind Energy Resource



BIOS Systems International Ltd. http://www.bios.co.nz/index.asp?menu=seasurfacetemp

Factors affecting Wind Energy

- Pressure gradient force
- Topography
- Coriolis effects
- Friction

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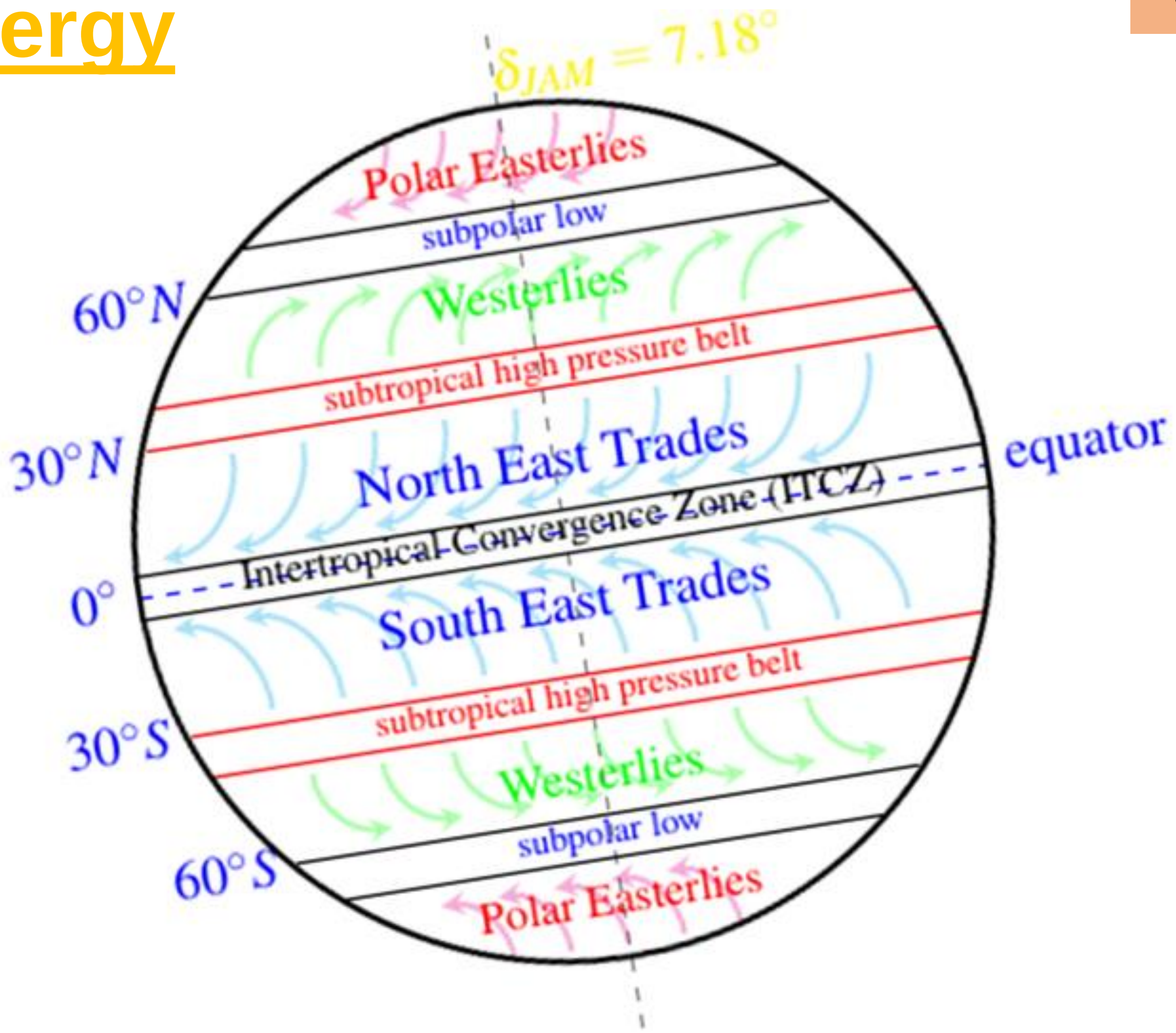
Factors affecting Wind Energy

Globally

Pressure gradient:

The air pressure difference between two locations is called the **pressure gradient**, and the force that actually drives the air from high pressure areas to low pressure areas is called the ***pressure gradient force***.

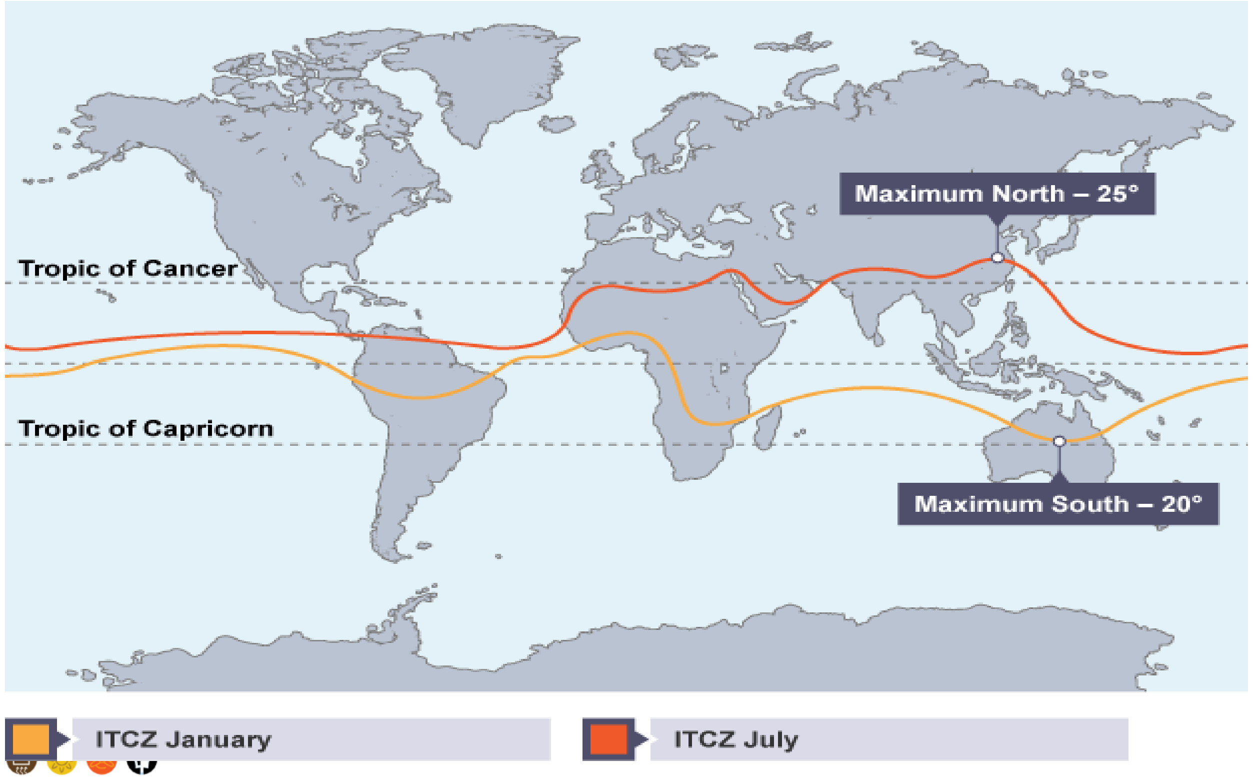


Kirby, Lawrence (2017). *Introduction to wind and hydroelectric energy*
Image: Dennis Nullet. Kapiolani Community College Geography. laulima.hawaii.edu

Factors affecting Wind Energy

Localized (Regional)

The trade winds meet (or converge) in the zone of low pressure in equatorial regions. This zone is called the **Inter-Tropical Convergence Zone (ITCZ)**.



There are strong currents of rising air known as up-draughts. As the air rises, the moisture within it condenses, clouds form and it rains. The UNSTABLE conditions in the ITCZ make equatorial regions some of the wettest in the world. These areas often experience heavy rainfall and thunderstorms. It moves NORTH of the equator during the northern hemisphere summer. It then moves SOUTH, crossing the Equator and moving into the southern hemisphere.

https://http://tropic.ssec.wisc.edu/real-time/dlmmain.php?&basin=atlantic&sat=wg8&prod=dlm2&zoom=&time=

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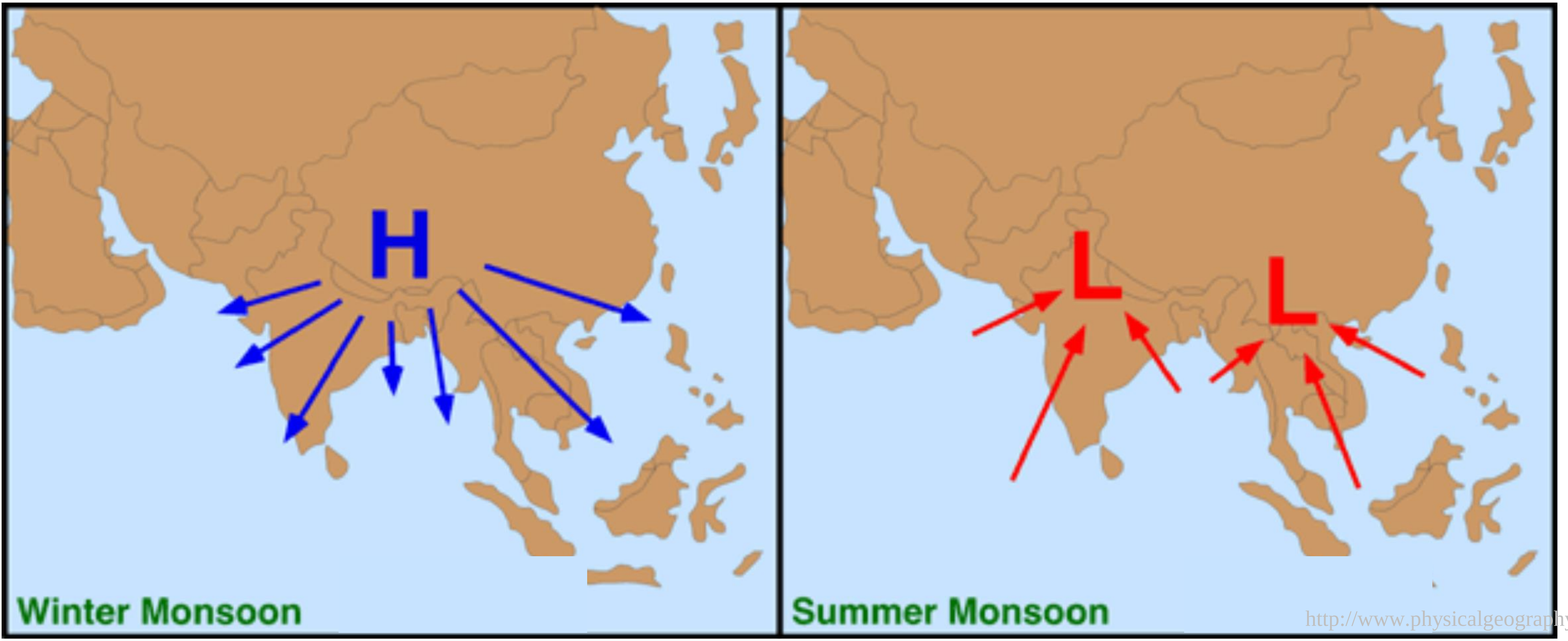
Localized (Regional)

Factors affecting Wind Energy



http://www.physicalgeography.net/fundamentals/7o.html

Land – Sea Wind Patterns (Seasonal)

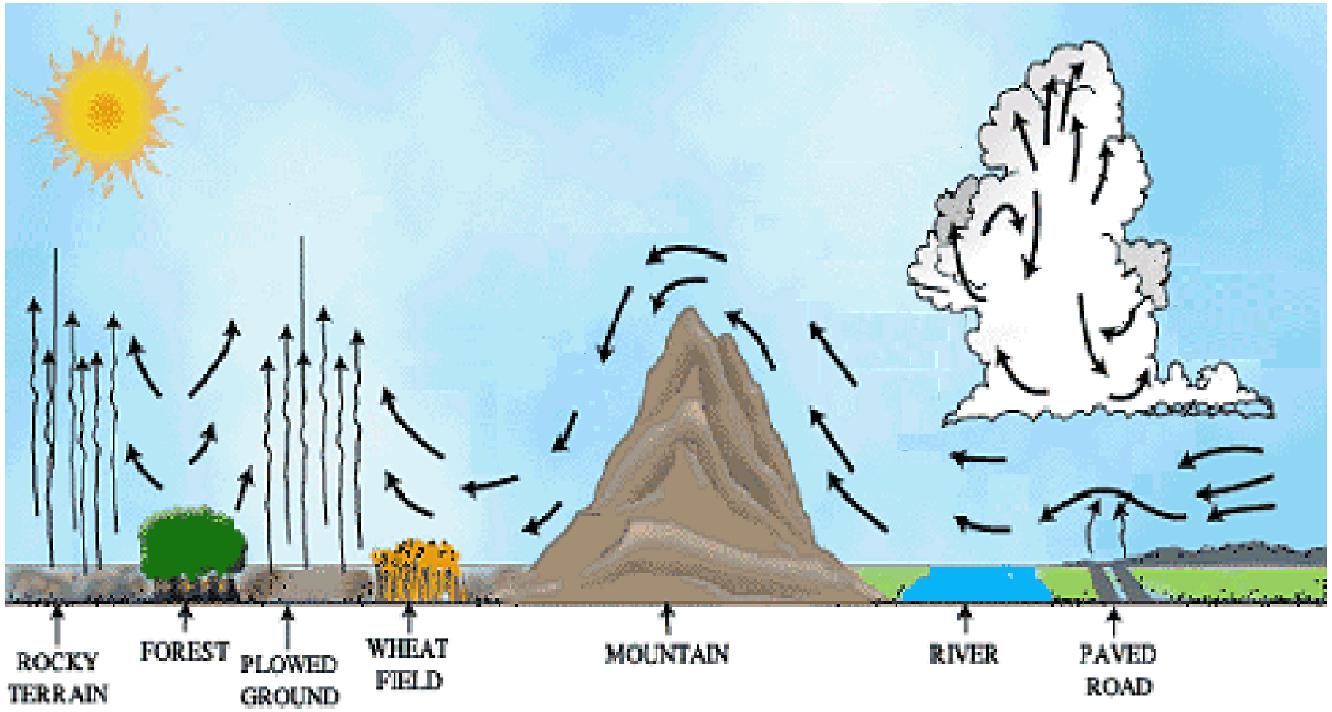
Wind is the result of a complex climatic interaction between the distribution of land and water, topography, and much more. In the summer, a low pressure centre forms over land. Warm moist air is drawn into the thermal lows from air masses over oceans. During winter the thermal extremes between land and ocean decrease and the flow pattern shifts

Localized (Regional)

Factors affecting Wind Energy

Air Motion (Topography)

As warm air rises, it expands and cools. It then sinks back down to fill the space the warm air left behind. This **convection current**, or circulation of warm air rising and cool air sinking, has some interesting effects on **wind**. Wind is horizontally moving air - so, any air that moves left to right instead of up and down. **Topography** plays a crucial role in air motion



Air currents effect on local air circulation.

https://diegofdezsevilla.wordpress.com/2018/03/14/wind-14-march-2018-by-diego-fdez-sevilla-phd/

Factors affecting Wind Energy

Localized (Regional)

https://www.weather.gov/source/zhu/ZHU_Training_Page/winds/Wx_Terms/Flight_Environment.htm

Air Motion (Topography)

Mountain Wave: Air flowing across a mountain range usually rises relatively smoothly up the slope of the range, but, once over the top, it pours down the other side with considerable force, bouncing up and down, creating turbulence and powerful vertical waves that may extend for great distances downwind of the mountain range. This phenomenon is known as a mountain wave.

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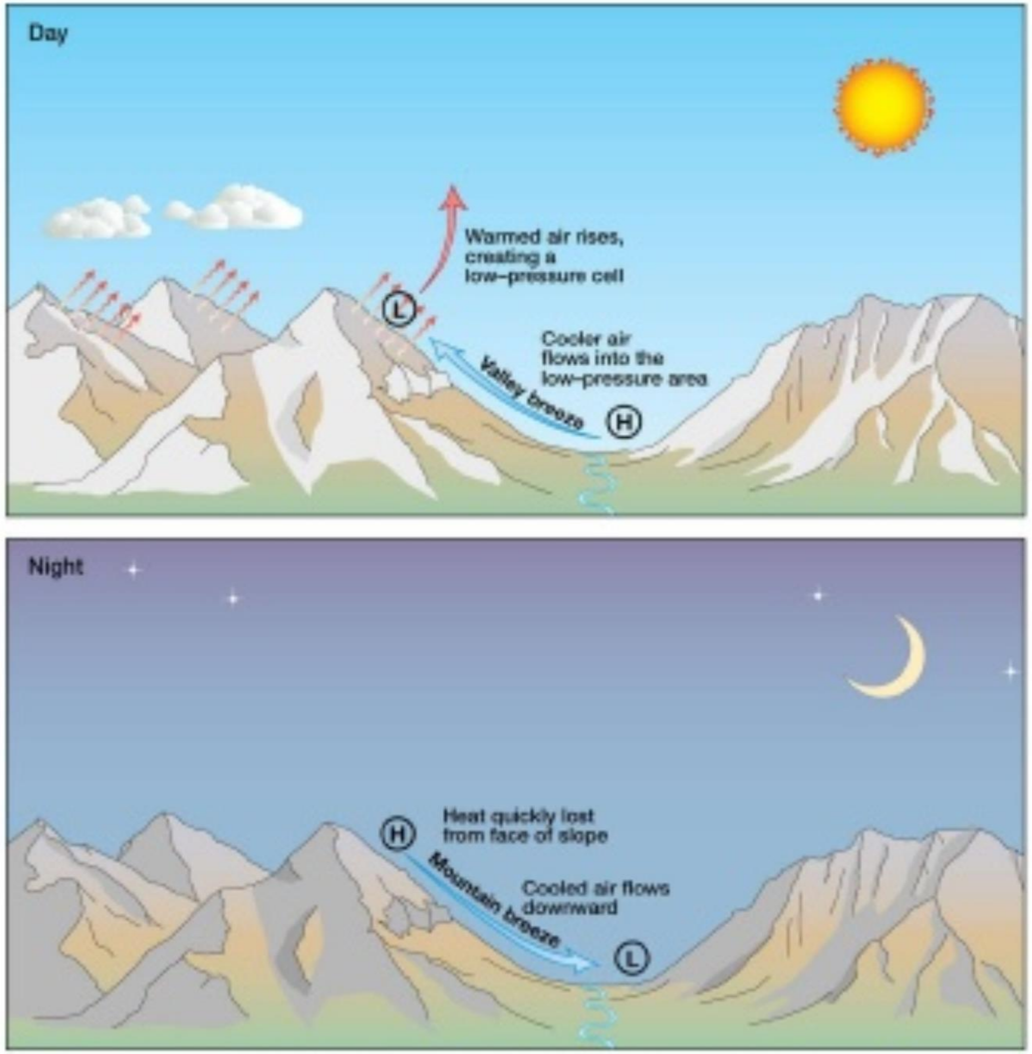
Factors affecting Wind Energy

Localized (Regional)



Air Motion (Topography)

Valley Breeze: the slopes are warmed during the day. The air in contact with them becomes warmer and less dense and, therefore, flows up the slope. This is called valley breeze.

Mountain Breeze: At night, the sides of the hills cool by radiation. The air in contact with them becomes cooler and therefore denser and it blows down the slope into the valley.

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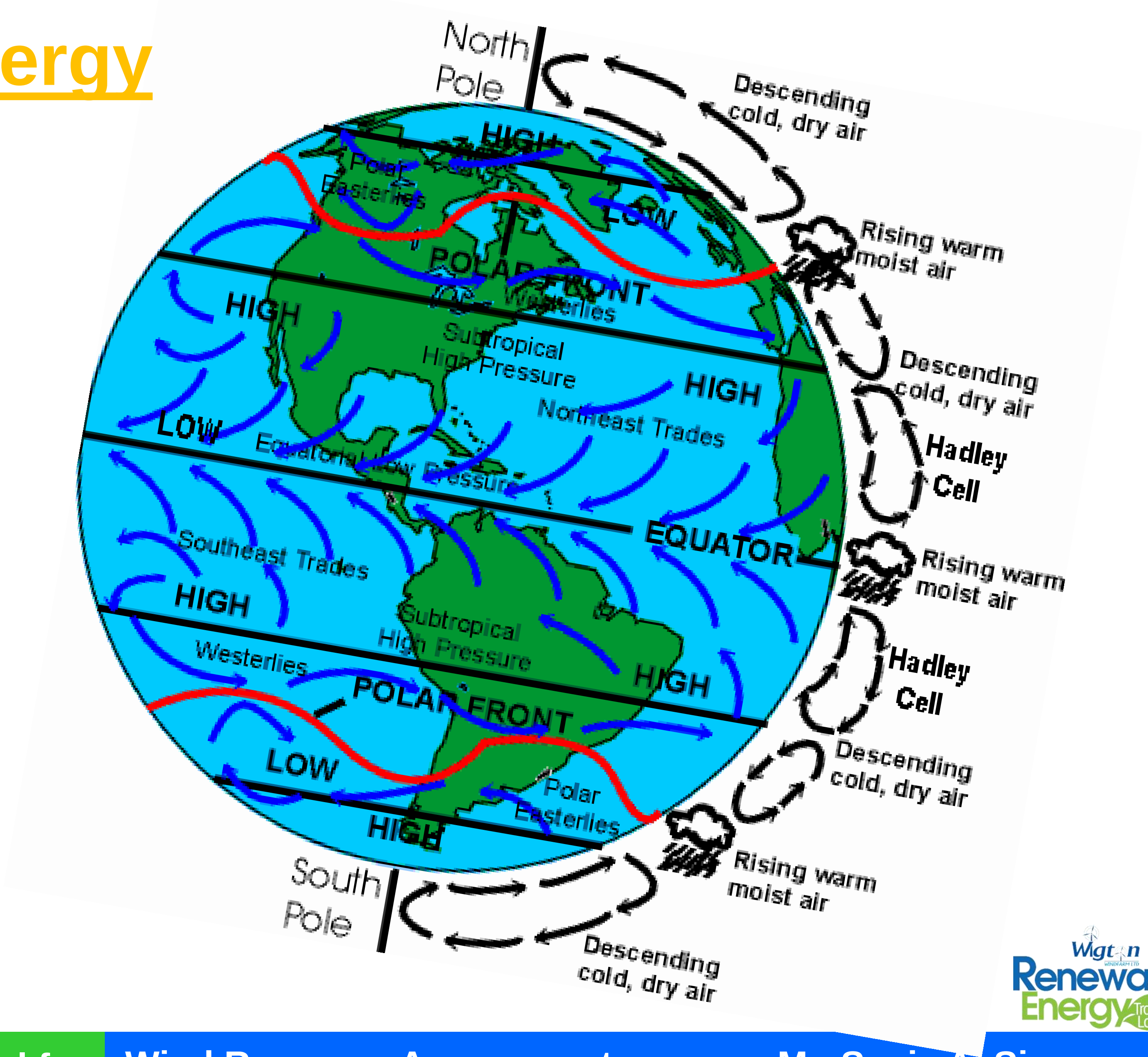
Factors affecting Wind Energy

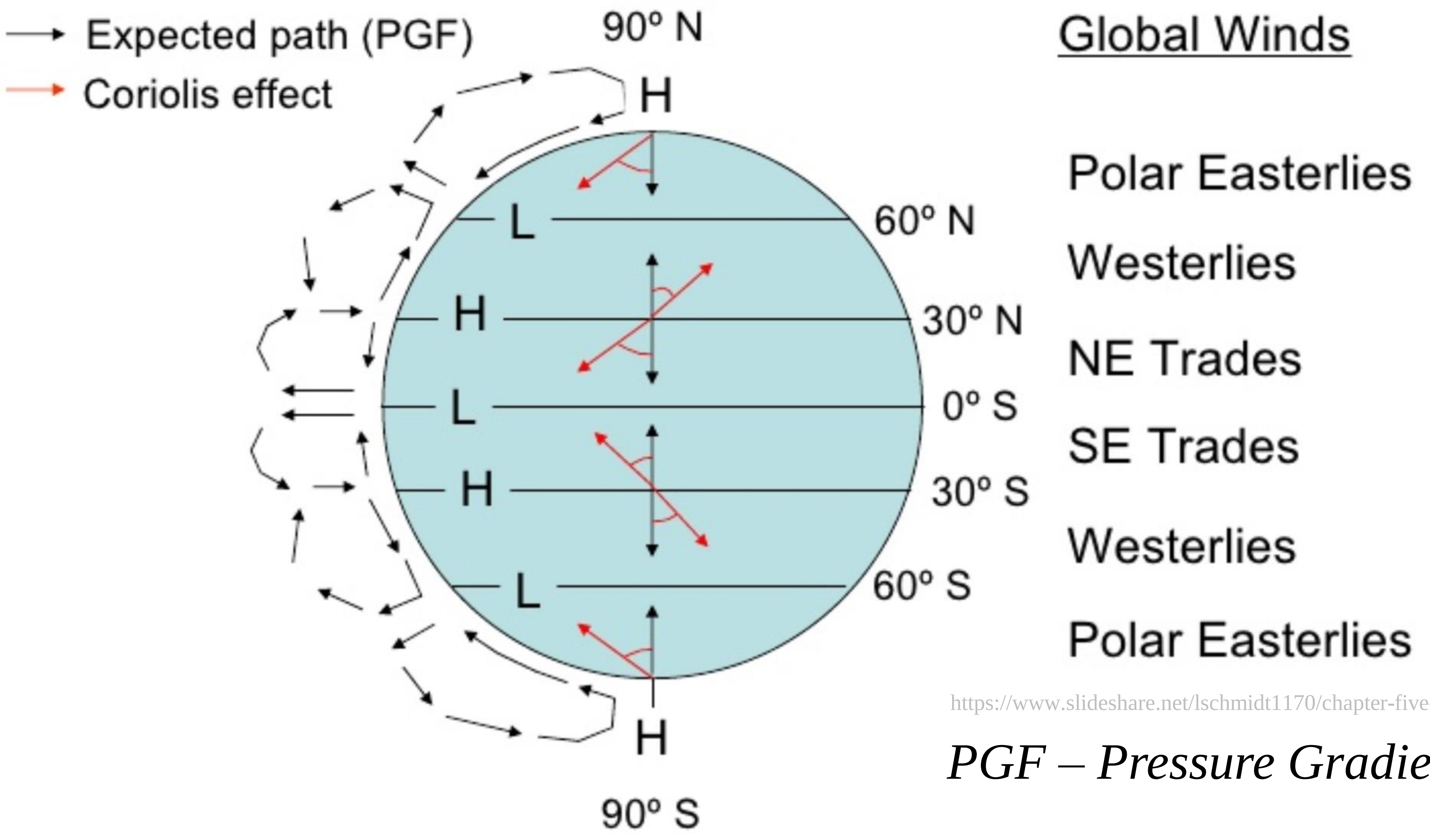
The Coriolis Effect

This deflection of wind from the Earth's rotation is called the **Coriolis Effect**. The Coriolis Effect does not impact the wind speed, only the wind direction.



Kirby, Lawrence (2017). *Introduction to wind and hydroelectric energy*
Image: Dennis Nullet. Kapiolani Community College Geography. laulima.hawaii.edu

Factors affecting Wind Energy



https://www.slideshare.net/lschmidt1170/chapter-five-5084368

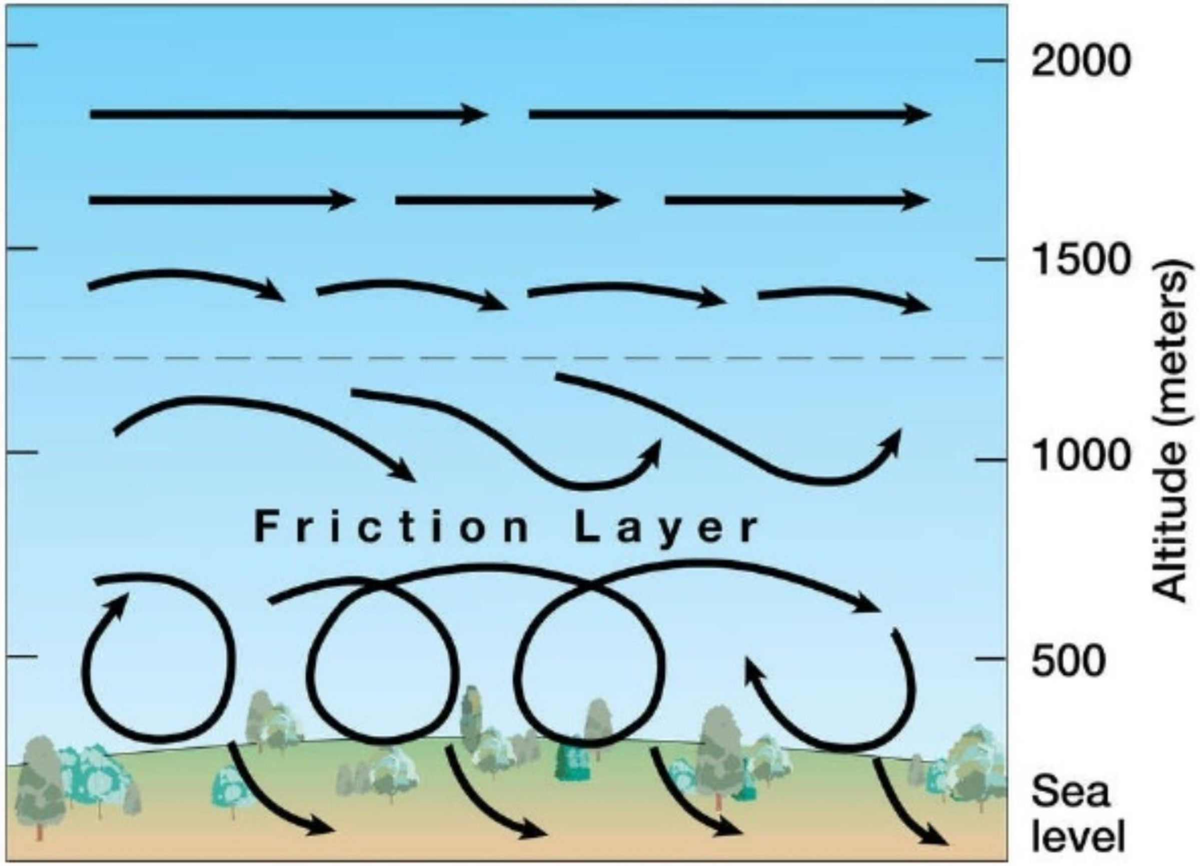
PGF – Pressure Gradient Force

Factors affecting Wind Energy

Friction decreases the wind speed and it also changes the direction of the wind.

Two types of friction occur in the atmosphere. **Molecular friction** (friction between individual air molecules (called viscosity)) & **Friction between two surfaces** (i.e. friction between air and land).

The frictional force causes the wind to slow down about 20%.



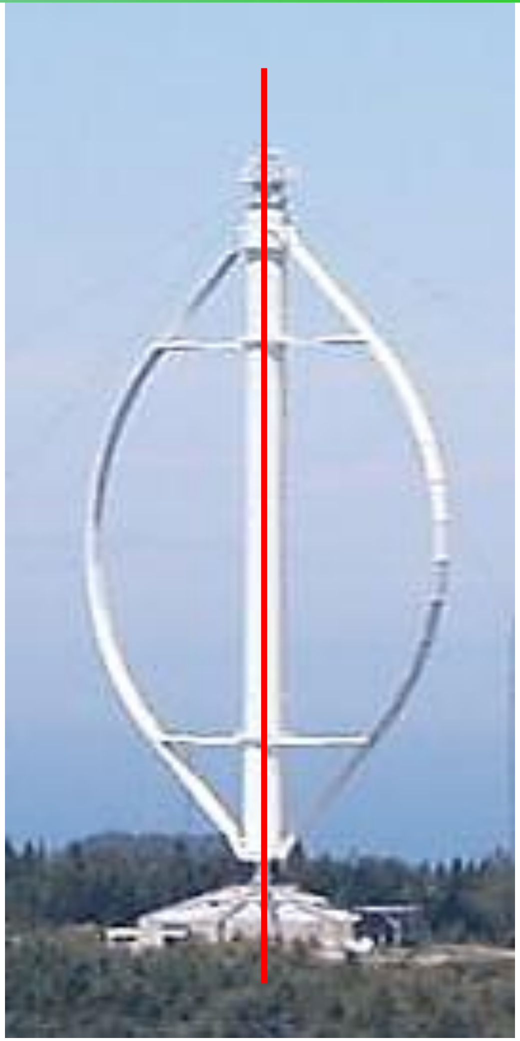
Kirby, Lawrence (2017). *Introduction to wind and hydroelectric energy*
Image: https://www.slideshare.net/lschmidt1170/chapter-five-5084368

WIND ENERGY EXTRACTION DEVICES

What is a *Wind Turbine*?

A **wind turbine** is a device that converts the **wind's** kinetic energy into electrical **power.**

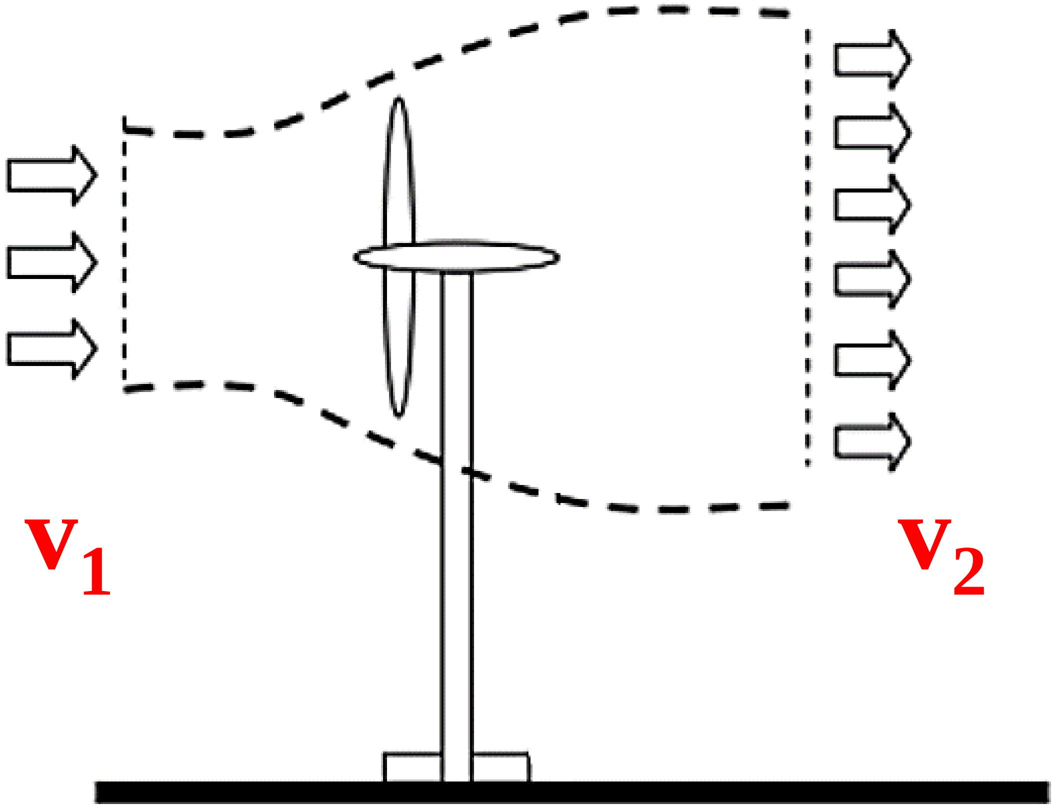
There are two main kinds of wind generators, those with a *vertical axis*, and those with a *horizontal axis*. Wind turbines can be used to generate large amounts of electricity in wind farms both onshore and offshore.



- 2006-2017 design by Alex Ramon
- 2008 Top-Alternative-Energy-Sources.com
- www.quora.com/Why-arent-Vertical-Axis-Wind-Turbines-more-popular

Introduction to Wind Turbines

How do turbines capture the wind's kinetic energy to generate electricity?



$$P_{wind} = \frac{1}{2}\dot{m}{v_1}^2$$

$$But\ \frac{d}{dt}m = \dot{m} = \rho v_1 A$$

$$\therefore P_{wind} = \frac{1}{2}\rho A {v_1}^3$$

Finally, $P_{wind} = \frac{1}{2}\rho A {v_1}^3 C_{Pmax}$

i.e. $Cpmax\ is\ the\ power\ coefficient$

$called\ Betz\ Limit, 59.3\%$

http://www.chegg.com/homework-help/questions-and-answers/consider-large-propeller-type-wind-turbine-shown-sketch-approaching-flow-contained-within--q3712240

Wind Energy in Jamaica

1996	2004	2010	2010	2016	2016
0.225 MW	20.7 MW	18 MW	3 MW	24 MW	36 MW

Munro College

Wigton I

Wigton II

JPS - Munro

Wigton III

BMR

- ~100.7 MW of Utility Scale Wind
- Also some houses & businesses
  - Usually < 6 kW wind installations

Wind Energy in the Caribbean

Belize - No windfarm

a) However, a wind map has been produced to highlight potential areas

Guyana – No windfarm

a) Currently the GEA is undertaking wind speed measurements at Kato and Quarrie

b) Will also be taking measurements at Kurukubaru, Chenapao, Onverwagt, Leguan and 2 other sites

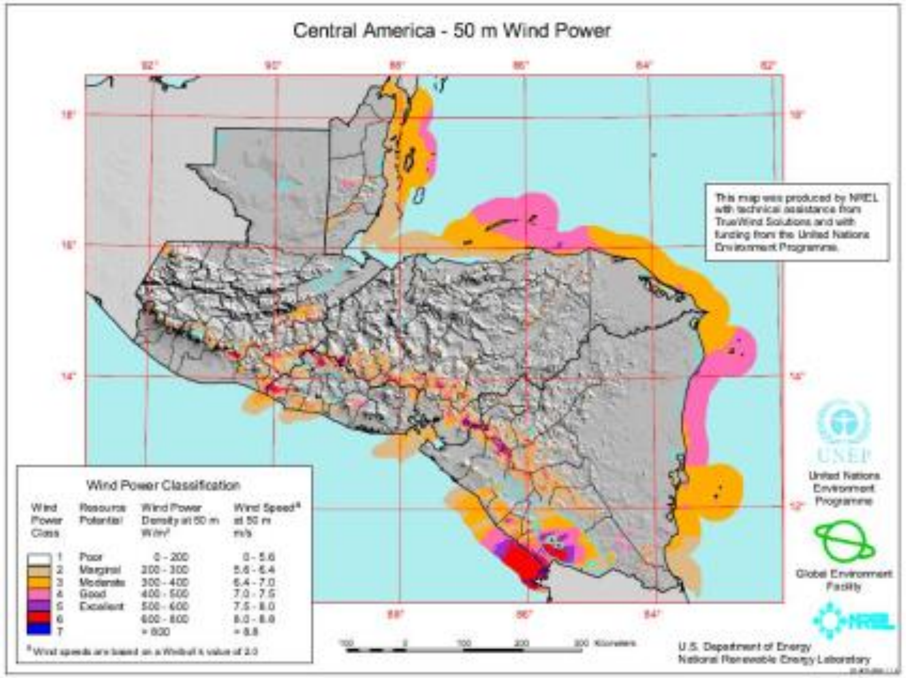
Trinidad and Tobago – No windfarms

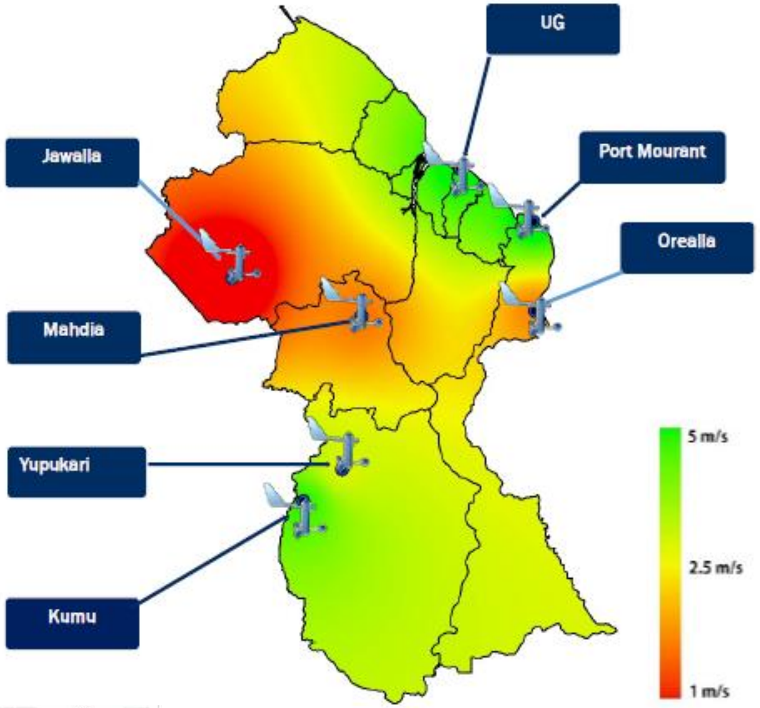
a) Dialogue continues to commence an island-wide assessment of Wind Energy potential across the two islands

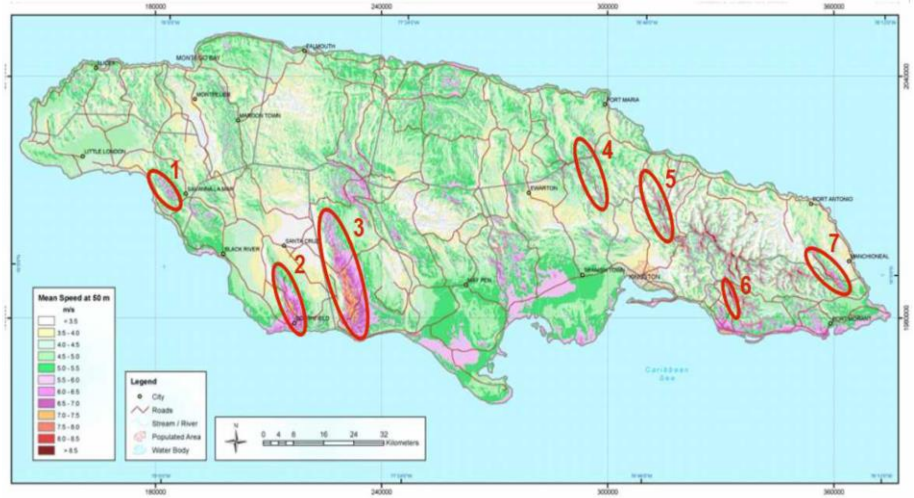
St. Lucia – No windfarm

a) Plans continue surrounding the development of a wind farm at Anse Cannot, Dennery

Wind Energy in the Caribbean

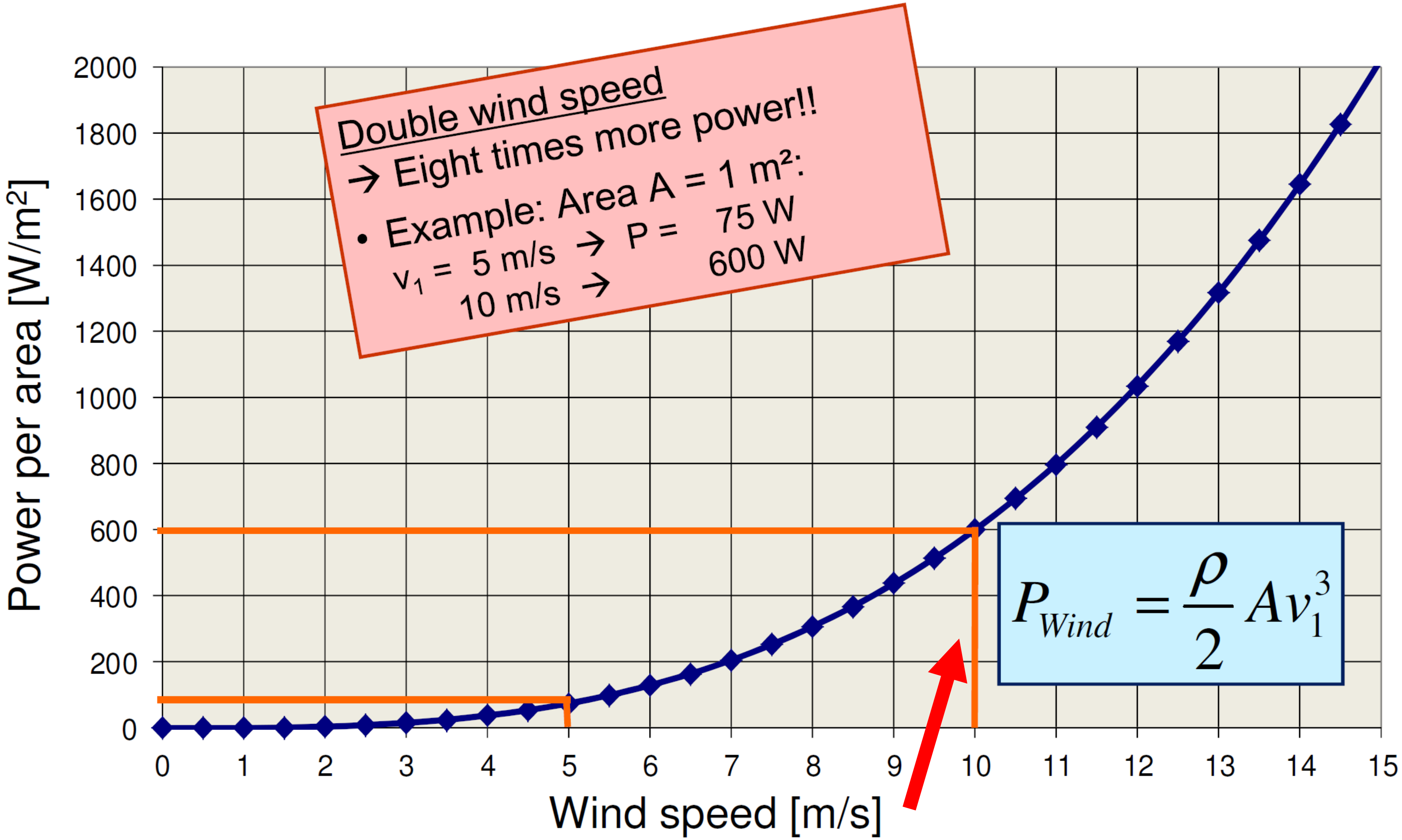






Introduction to Wind Turbines

As expected, **wind speed** is crucial for energy generation but it is not the only factor. How can we quantify wind and the other factors involved; **temperature**, **wind direction**, **air density** and **air pressure**?



WIND RESOURCE ASSESSMENTS

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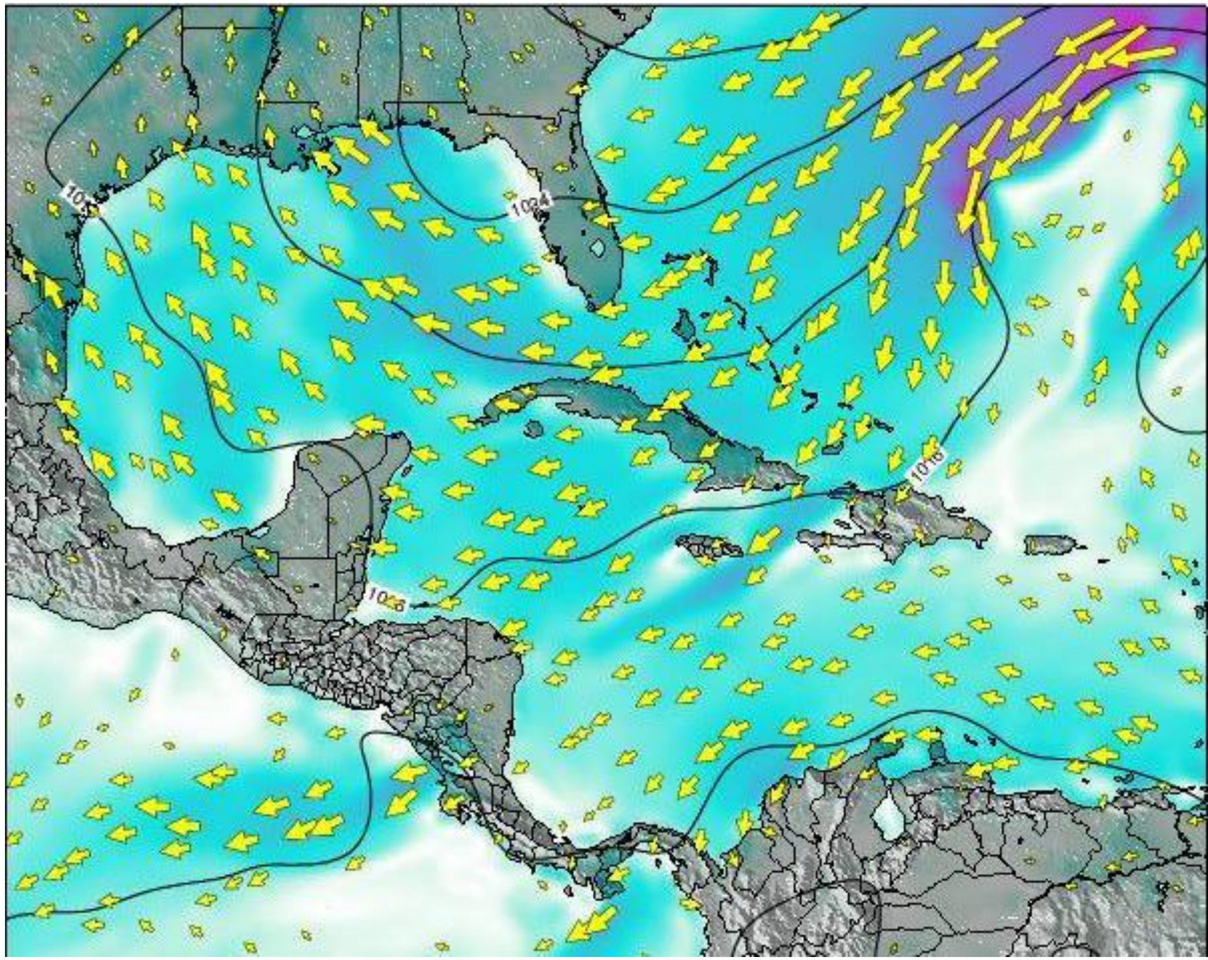
Steps in Assessing the Wind Resource

- Prospecting – preliminary site selection
  - Previous Data
  - Flagging
  - Immediate Surroundings
- Data Collection
- Data Manipulation/Presentation
- Meteorological Mast Assembly

Steps in Assessing the Wind Resource

Prospecting

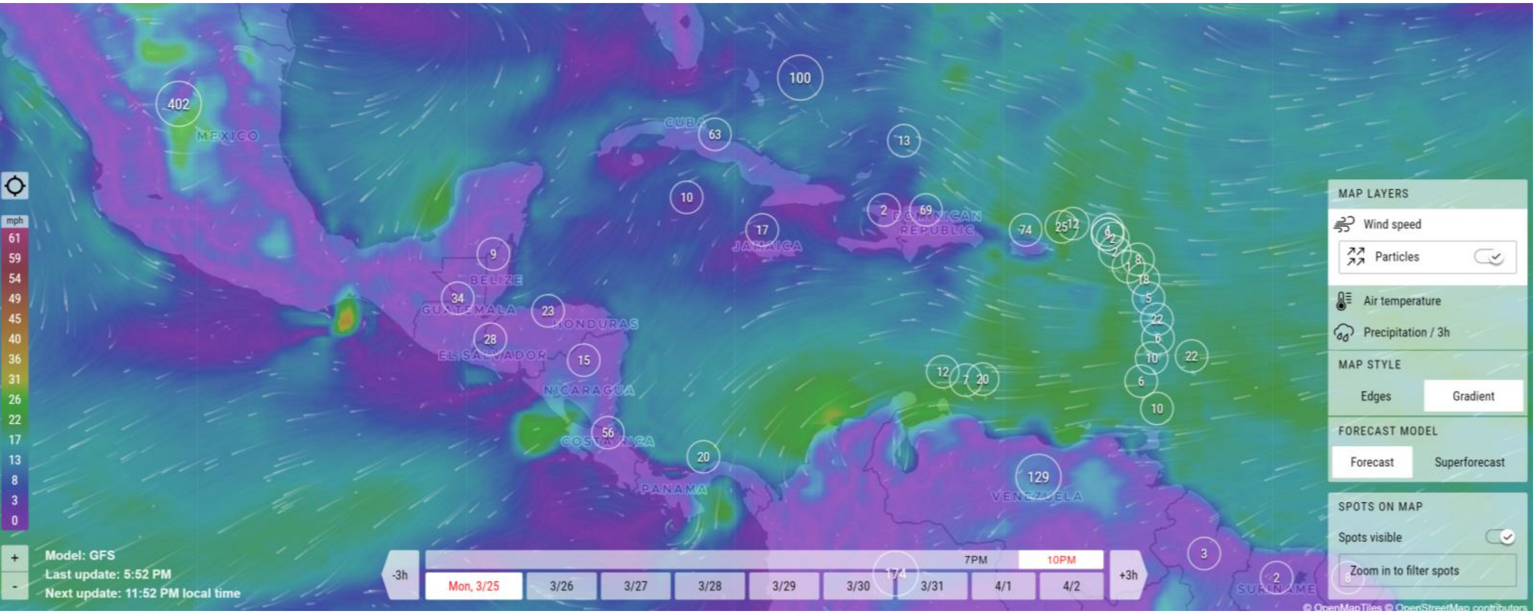
As discussed previously, global, regional and local weather/geographic maps can be used to identify potential wind farm sites. Let's look at the Caribbean region:

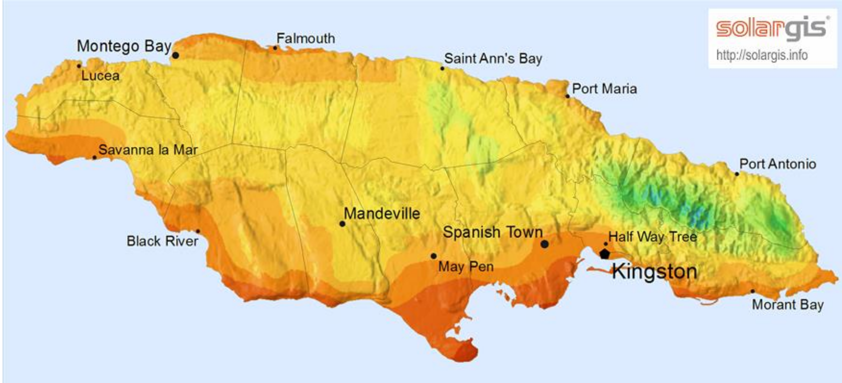


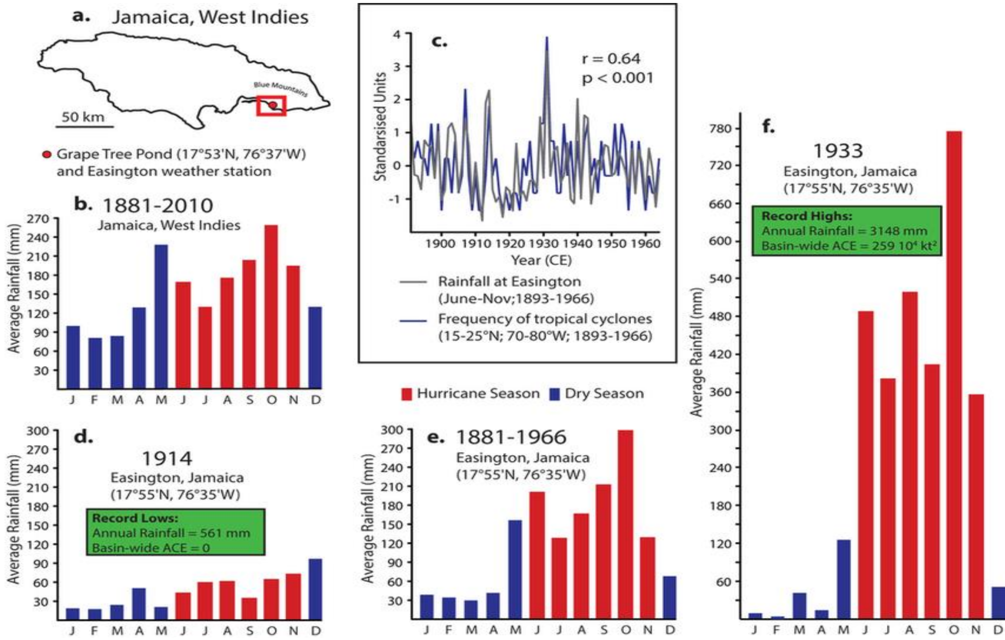
What do you observe about the prevailing winds?

Steps in Assessing the Wind Resource

Prospecting







There are *decades* of meteorological data available at the local Met Office(s)

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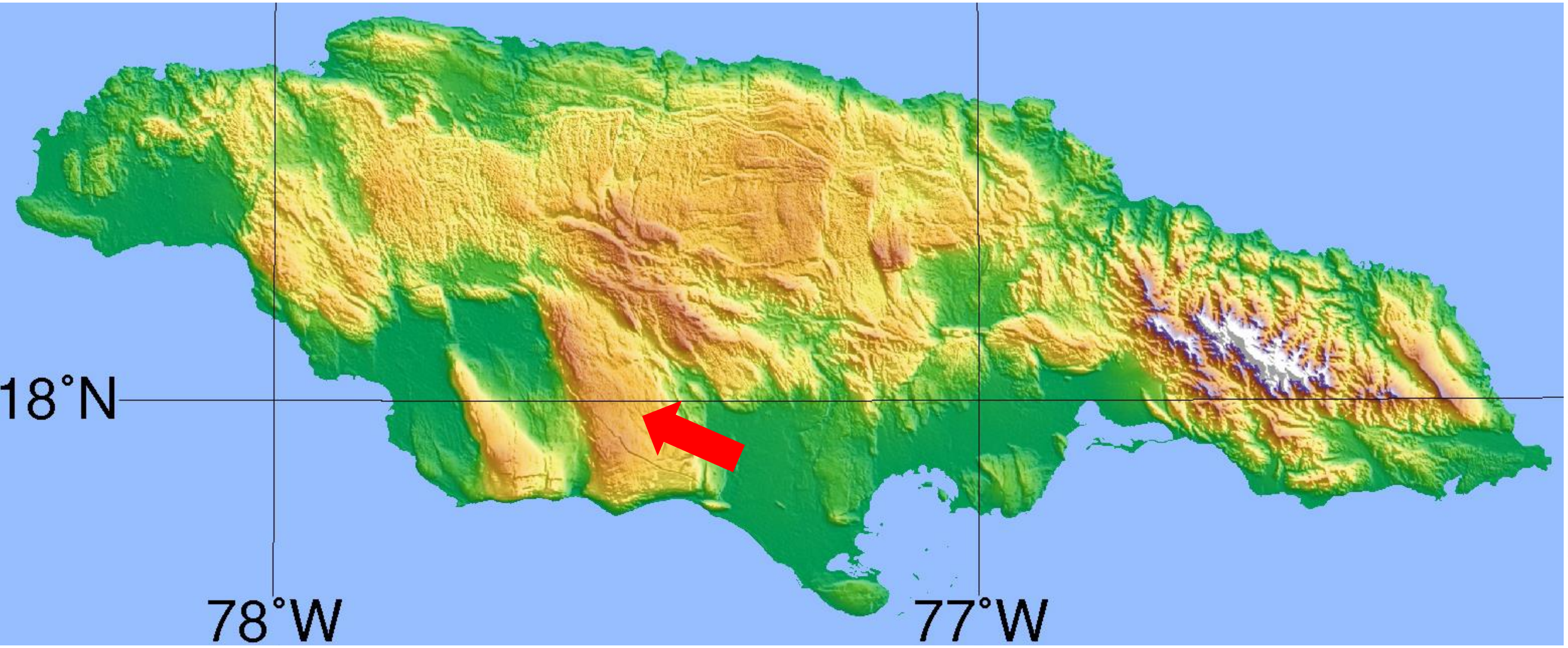
https://www.researchgate.net/figure/Precipitation-data-for-Jamaica-a-Map-showing-location-of-Grape-Tree-Pond-in-Jamaica_fig1_280911486

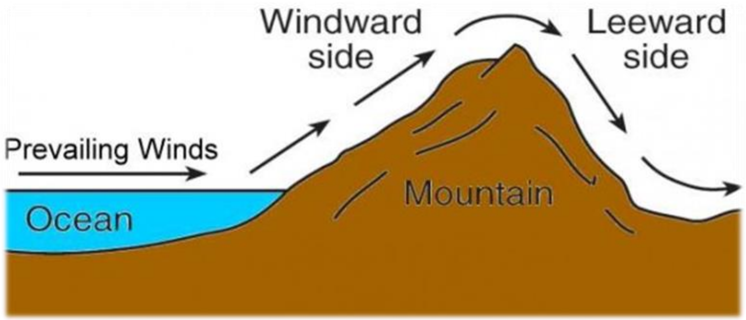
https://www.windfinder.com/#5/18.2500/-77.5000

Steps in Assessing the Wind Resource

Prospecting

A closer look at Jamaica's topography reveals how Rose Hill's ideal properties for wind energy developments





Steps in Assessing the Wind Resource

Flagging

Trees can be used as indicators of Prevailing Wind Direction. One technique for determining the mean wind direction is tree flagging. Trees have been used for hundreds of years as an ecological indicator of wind direction, wind exposure and as a measure of the severity of wind.

This technique is particularly useful in mountainous areas, where winds are often complex and the available wind data are limited and provide little information on wind direction/speed.

https://www.notechmagazine.com/2011/09/trees-as-indicators-of-prevailing-wind-direction.html

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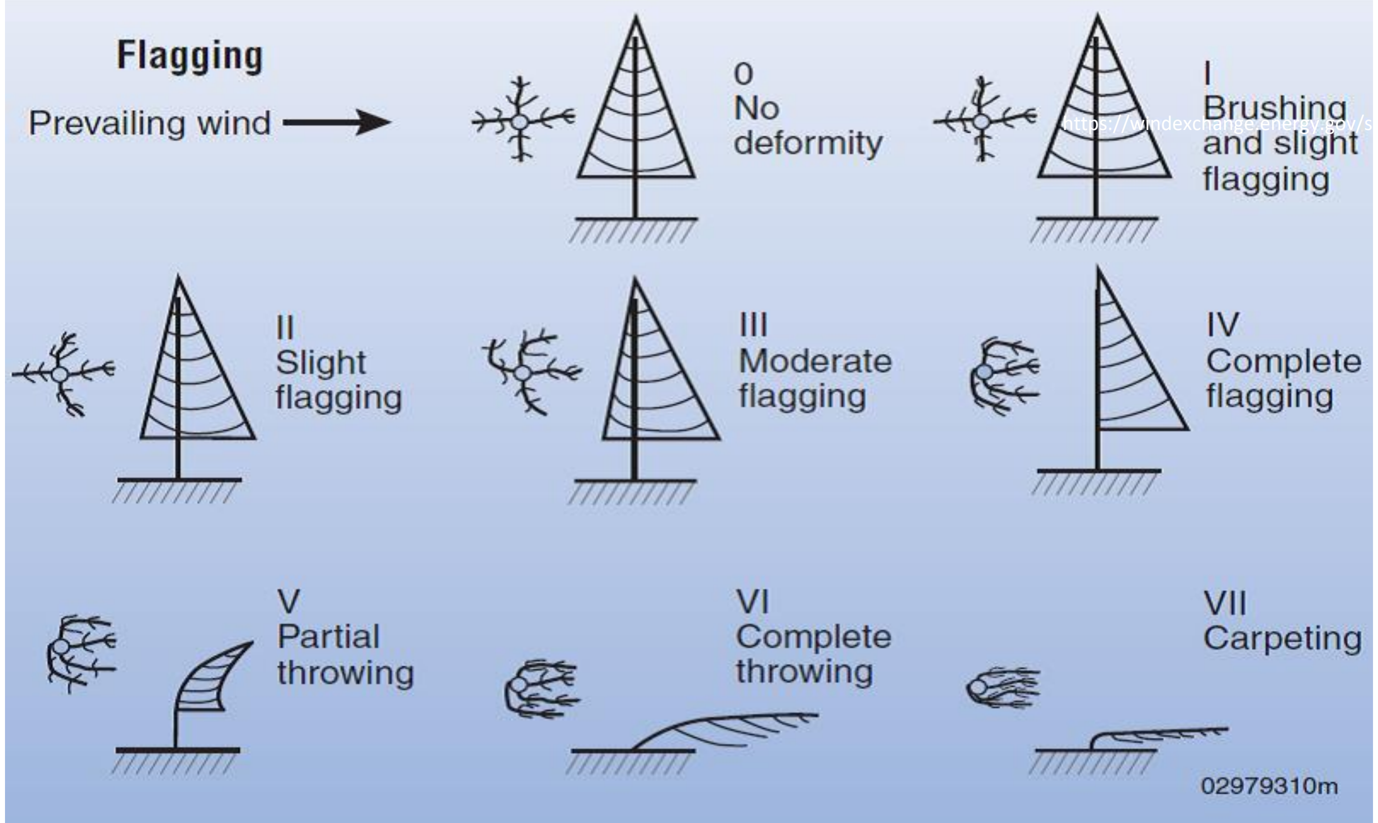
Steps in Assessing the Wind Resource

Flagging

Wind Flagging Classifications

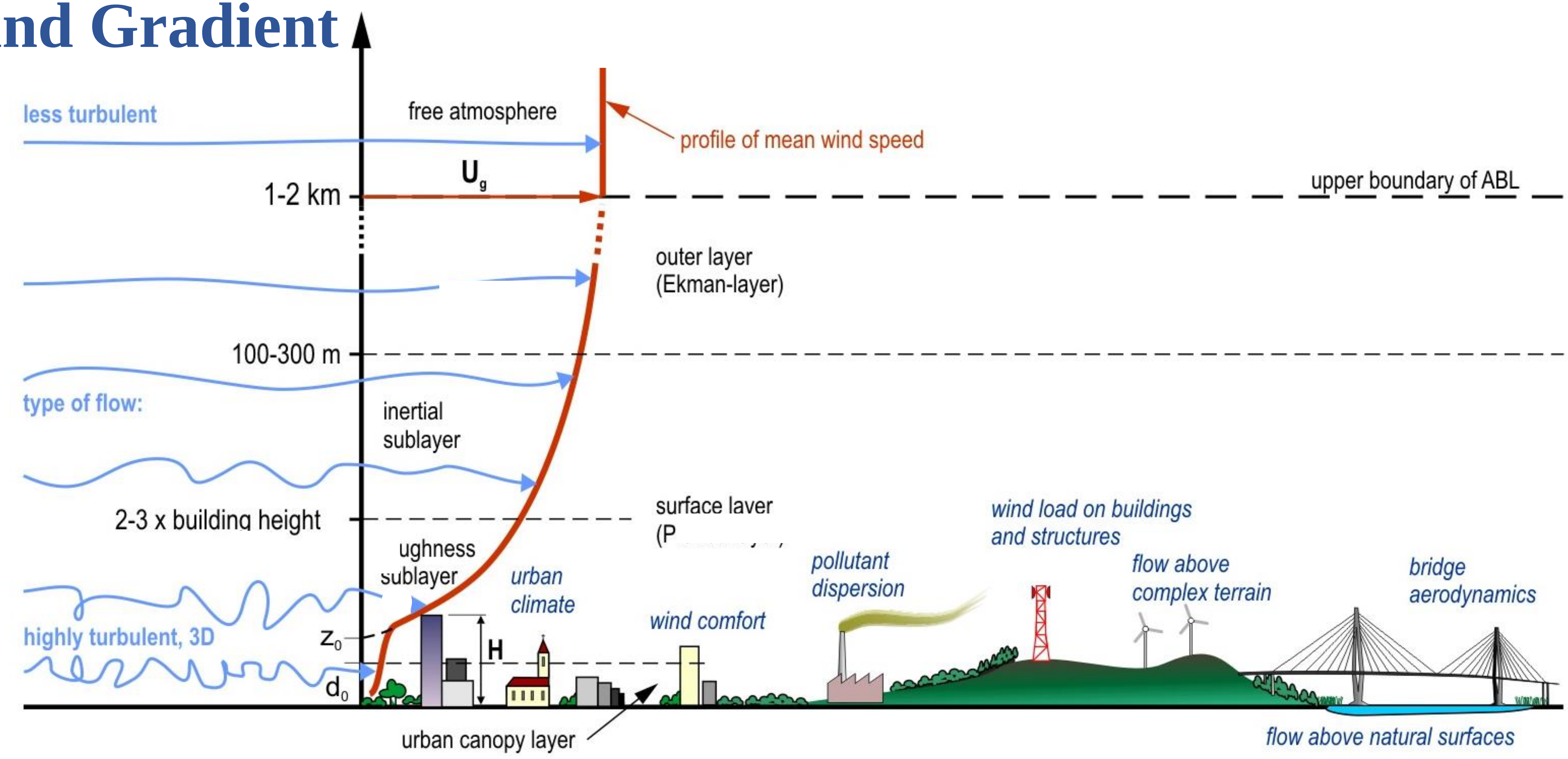


Griggs-Putnam Index of Deformity

Index	I	II	III	IV	V	VI	VII
Wind mph	7-9	9-11	11-13	13-16	15-18	16-21	22+
Speed m/s	3-4	4-5	5-6	6-7	7-8	8-9	10

Steps in Assessing the Wind Resource

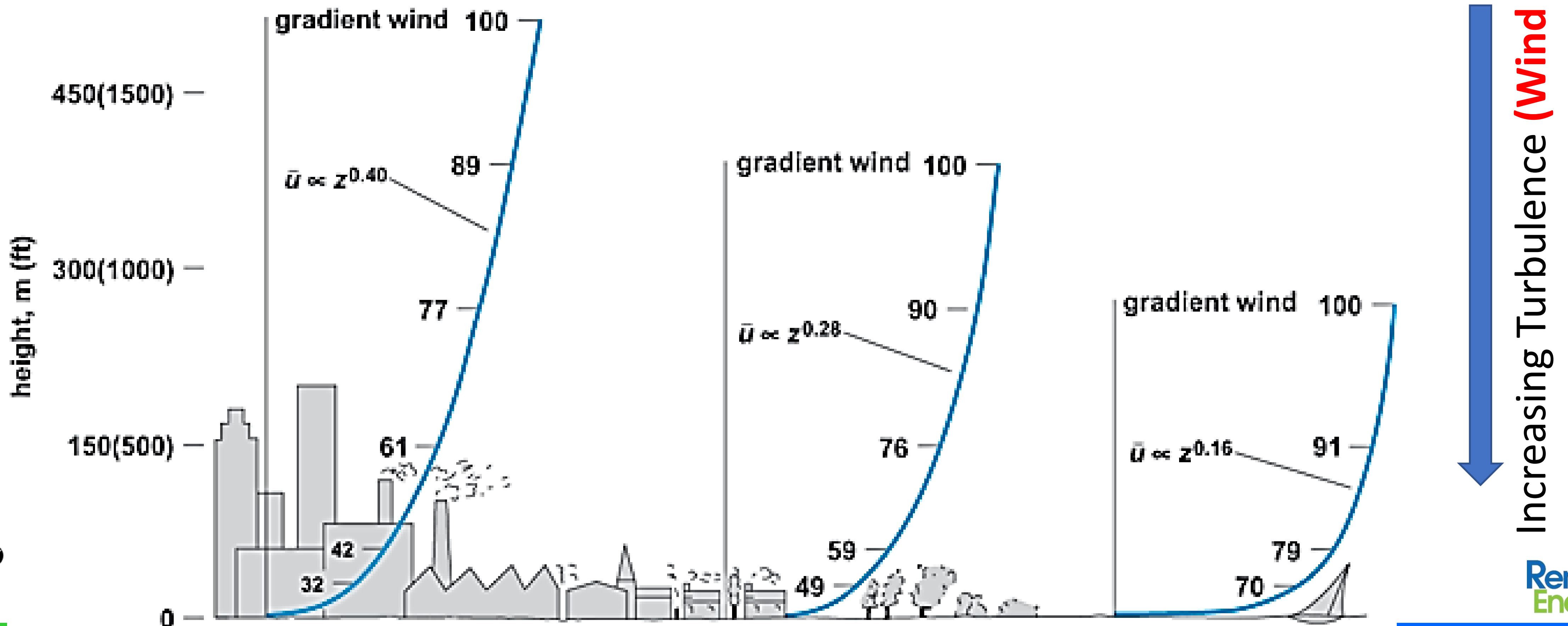
Wind Gradient



https://bmeafl.com/the-project-proposal/

Steps in Assessing the Wind Resource

Wind Gradient



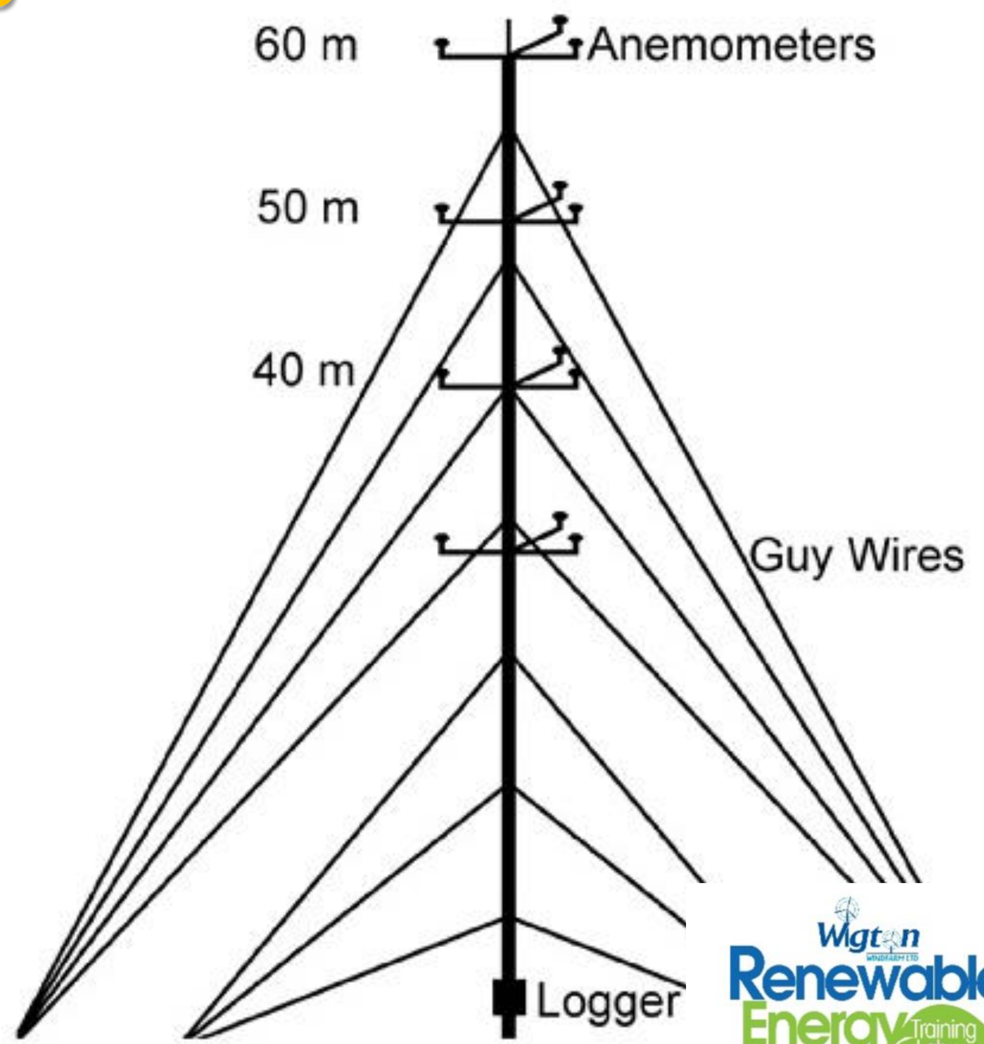
http://rockets2sprockets.com/issue-cross-winds-wind-tunnels/

WIND DATA COLLECTION

Meteorological (Met.) Masts

The met mast is a tower (usually) made of steel where measuring equipment is installed.

Ideally the met mast should have the same height as the wind turbines that are going to be installed in the area – however, to save money sometimes shorter masts are used.



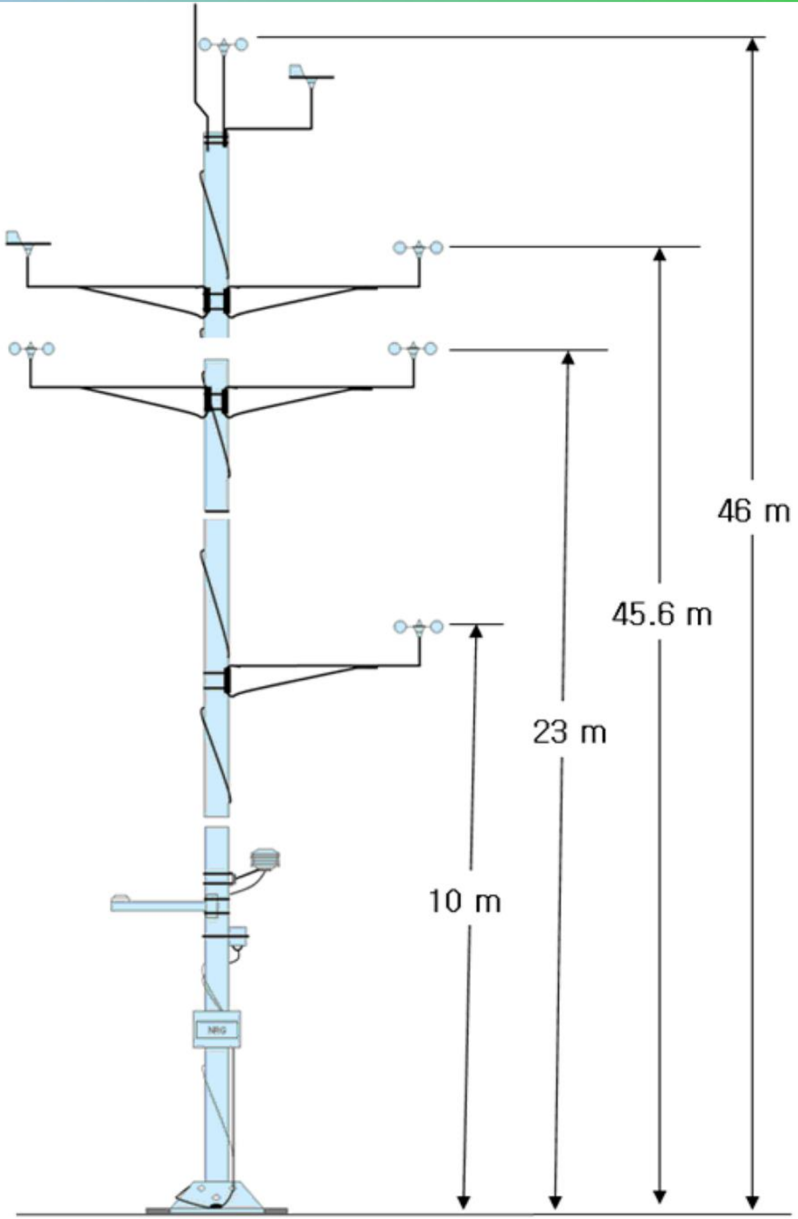
http://www.windfarmbop.com/category/met-mast/

Introduction to Wind Data Collection

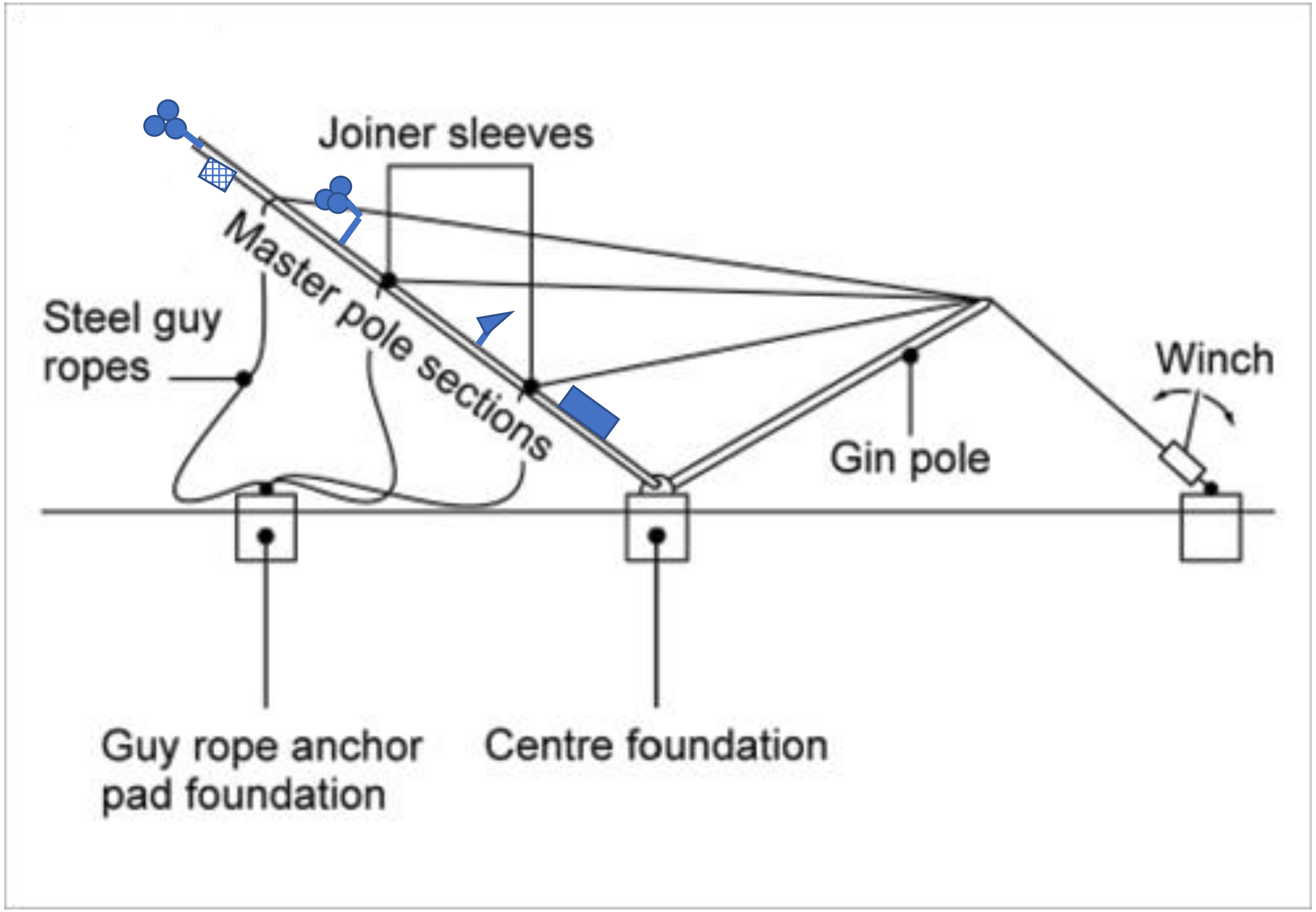
Met Masts

The equipment installed on the met mast include:

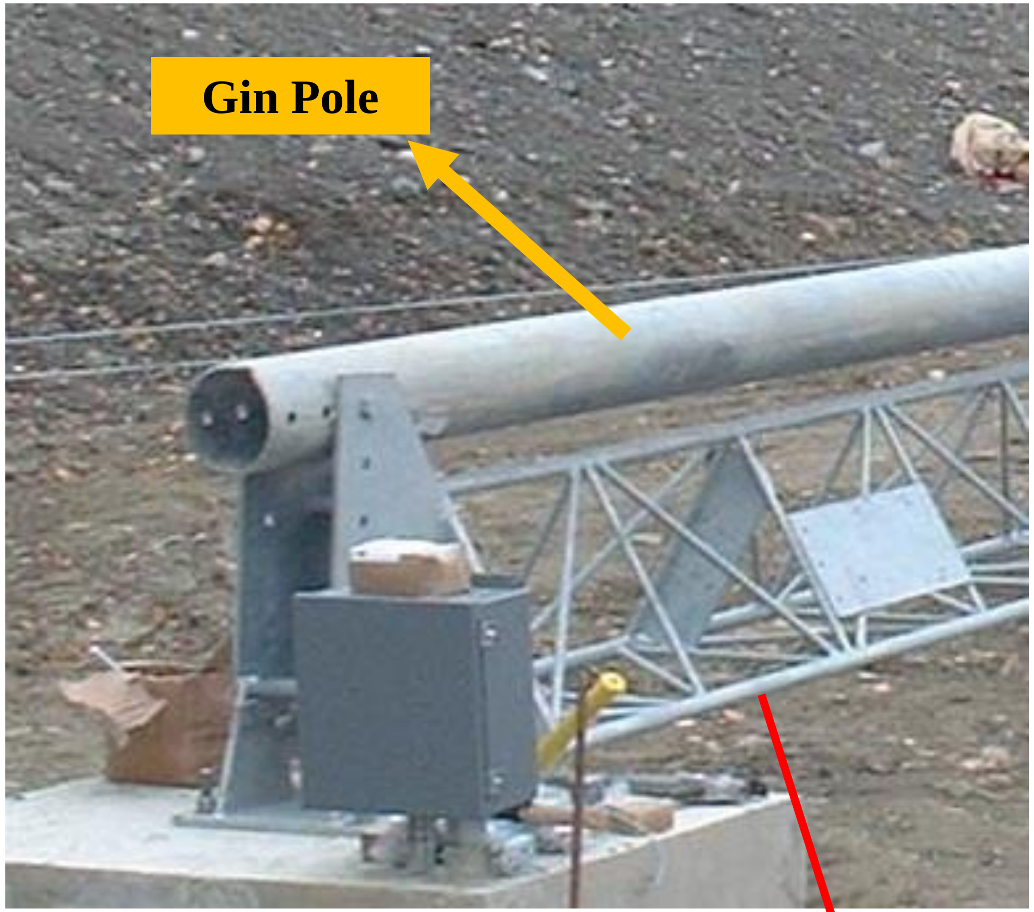
- **Anemometers** (usually there are several anemometers at different heights)
- **Weather Vane** (to record the direction of the wind)
- **Barometer** (measures pressure)
- **Thermometer** (measures temperature)
- **Pyranometer** (measures solar irradiance)
- **Solar Panel** (energy source)
- **Data Logger** (stores/transmits measurements)

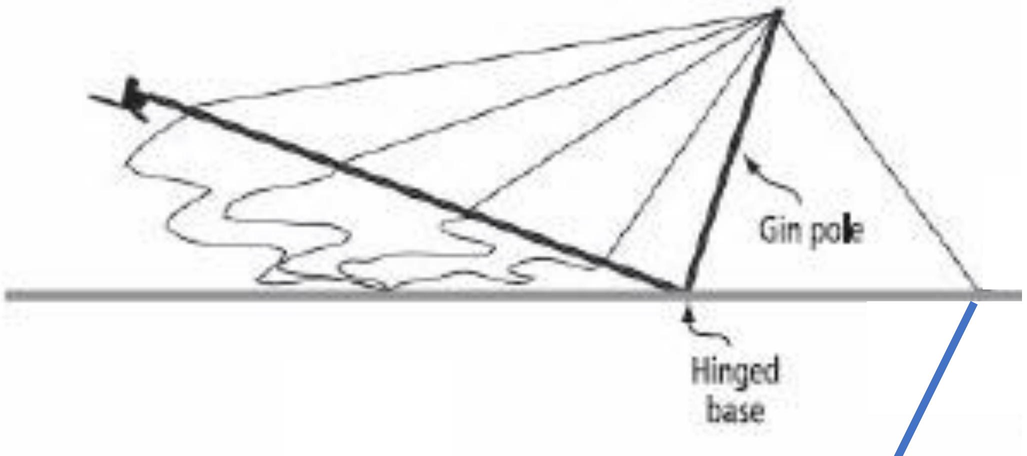


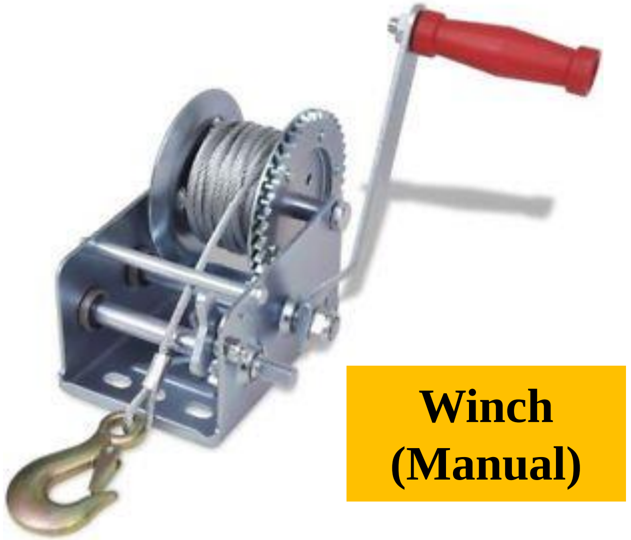
Meteorological (Met.) Masts



Introduction to Wind Data Collection

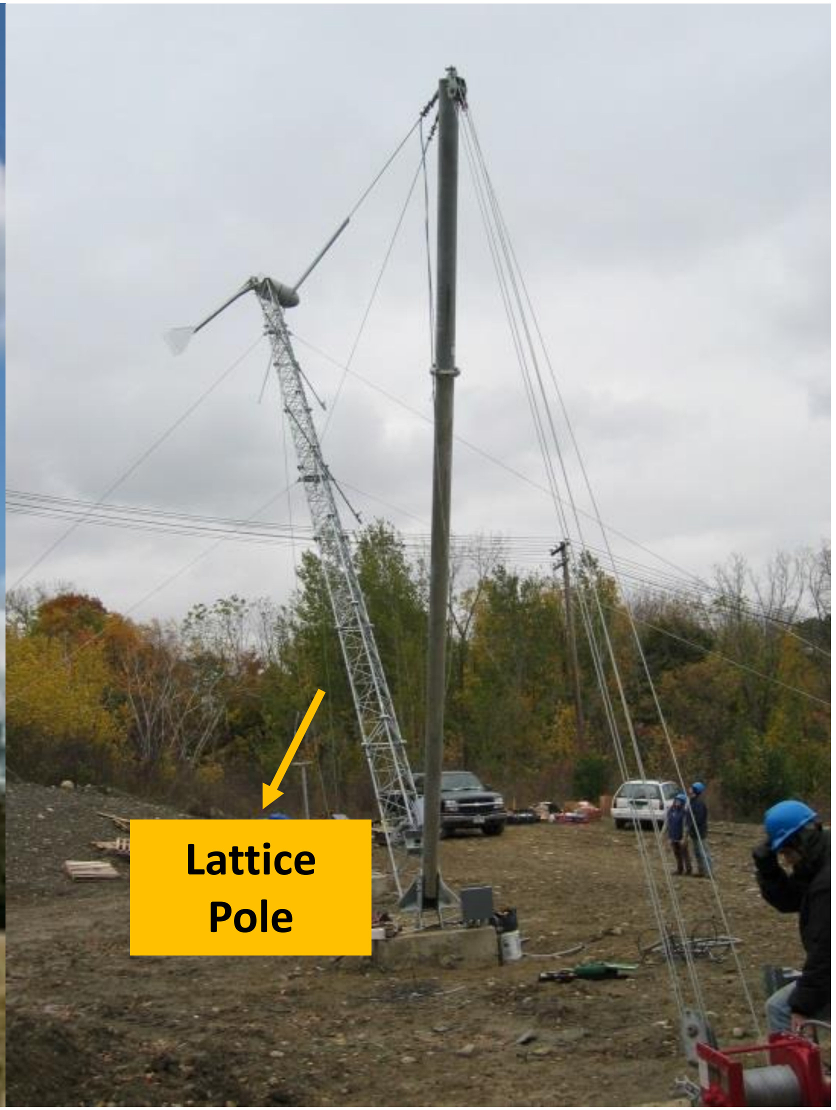






Note: this is a ***Lattice Tower*** met mast, a *tilt-up* is just a pole (similar to the gin pole)

Introduction to Wind Data Collection



The winch is used as a pulley to lift the met mast. The pole has to be monitored, and cable lengths adjusted during lifting to ensure symmetry and stability.

Introduction to Wind Data Collection

Introduction to Wind Data Collection

The finished product

Gin Pole and Winch are secured at a separate foundation

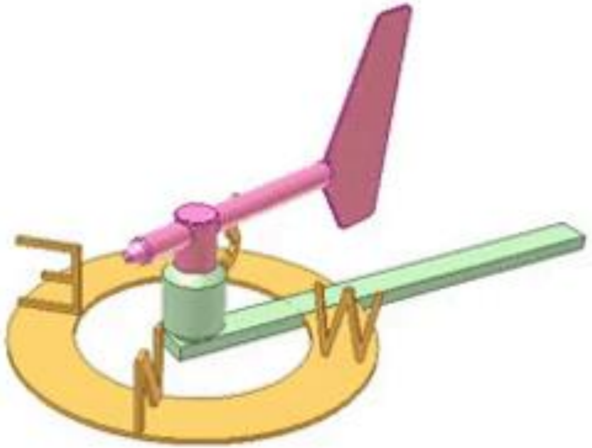
Instrumentation - Anemometer

Air flow past a *cup anemometer* in any horizontal direction turns the shaft at a rate that is proportional to the *wind speed*. Other types include:

- Vane Anemometers
- Ultrasonic Anemometer

Instrumentation – Wind Vane

A *wind vane* (also known as a *weathervane*) is an instrument that indicates the *wind direction*. Specifically, a wind vane shows what direction the wind originates.



ht… rite.com/learn/what-is-a-wind-vane

Instrumentation - cont’d

Temperature and Relative Humidity

Pressure Sensor

Data logger

All measurements are recorded on the data logger:

- Must be stored in enclosure to protect from elements
- Requires a remote power source (normally a PV module) and/or a battery
- For the wind power industry, ***average measurements*** recorded every 10min
- Data collection either by GSM modem or manual recovery via USB or SD memory card
- **Complete and precise data is essential for wind farm design software (and for acquiring financing)**

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Data logger

So, how much data is collected in 1 year?

10 min averages of: wind speed + direction (at ~3 heights), relative humidity, temperature, pressure, time and battery level **(11 readings)**:

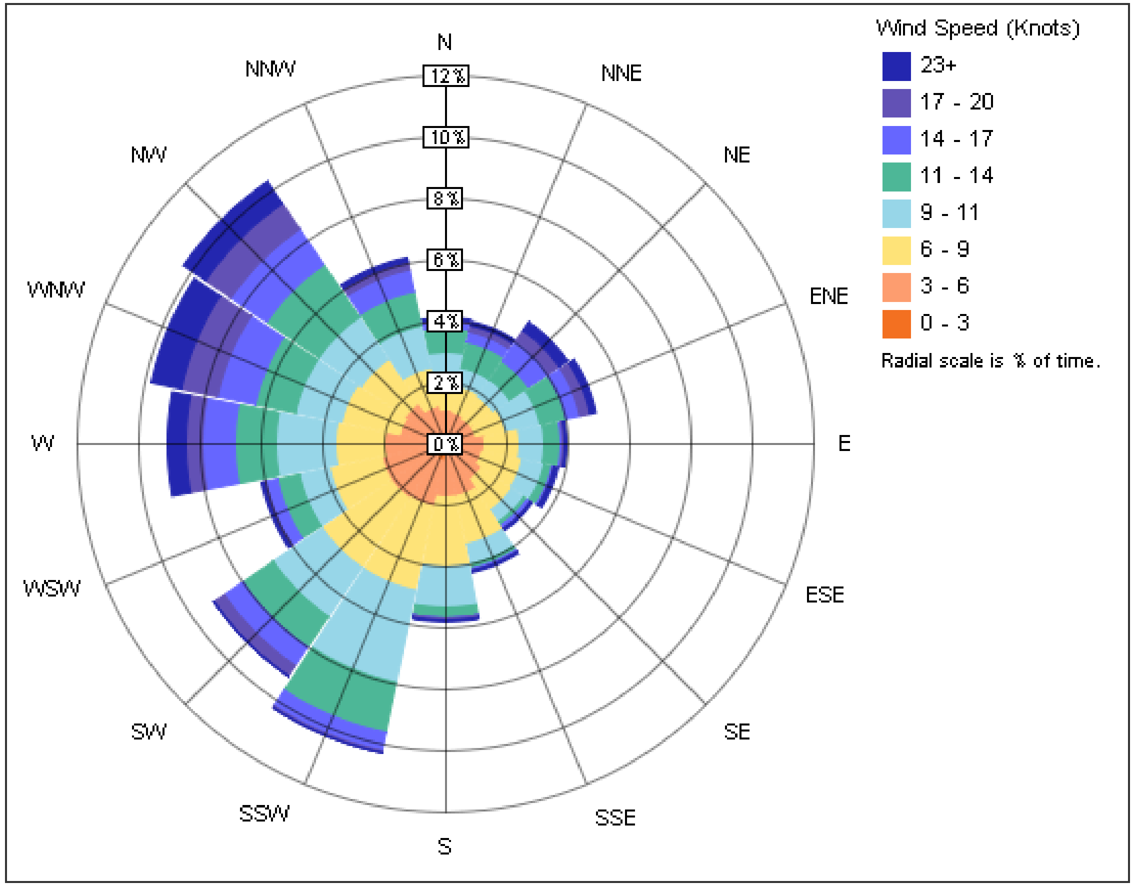
10 x 11 x 6 x 24 x 365 =
5,781,600 different values

How can we represent all of this data clearly and effectively?

Presenting data – Wind Rose

What is a Wind Rose?

A diagram showing the relative frequency of *wind directions.*



htt… e.autodesk.com/support/revit-products/learn-explore/caas/CloudHelp/cloudhelp/2014/ENU/Revit/files/GUID-2AACFEA1-16BD-4A01-BD75-81B12E56A57C-htm.html

WIND DATA ANALYSIS

Introduction to Wind Data Analysis

Wind Profile Power Law

$$\frac{u_2}{u_1} = \left(\frac{z_2}{z_1}\right)^{\propto}$$

where u1 and z1 are the known wind speed and height respectively and α is an exponent that is a function of both atmospheric stability and the underlying surface characteristics.

Logarithmic Wind Profile Law

$$\bar{u}_z = \left(\frac{u*}{k}\right)\left[ln\left(\frac{z - zd}{z_0}\right) + \Psi_M\left(\frac{z}{L}\right)\right]$$

Assuming neutral stability, α in the wind profile power law is 0.143 and Ψ_M is equal to zero

where u* is the friction velocity, k is von Karman's constant (0.4), z_0 is the surface roughness length, z_d is the zero-plane displacement height, L is the Obukhov stability length and Ψ_M is a dimensionless function that accounts for the change in the wind profile away from the neutral profile.

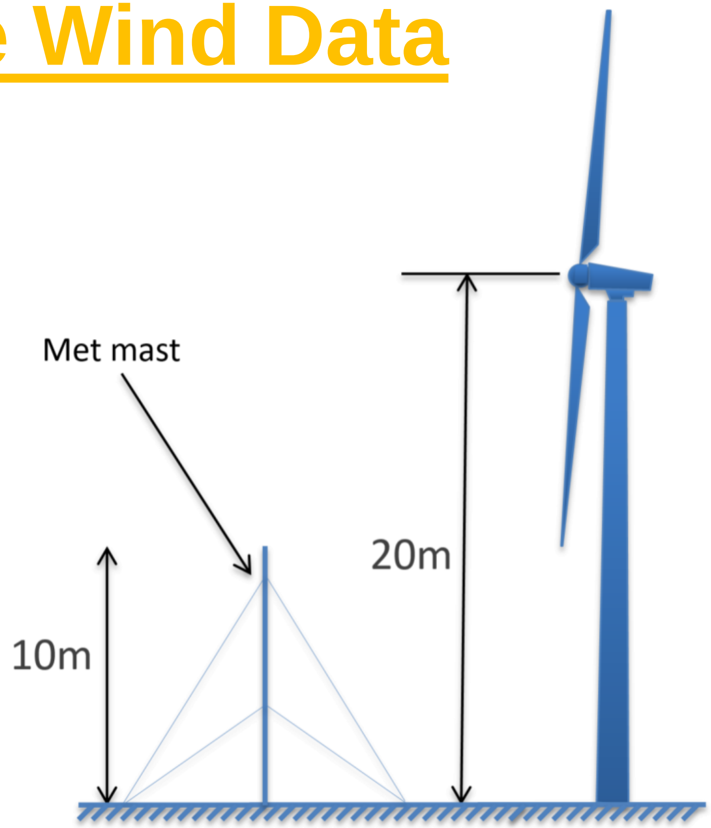
Steps in Assessing the Wind Resource

Surface Roughness Length

Roughness class	Roughness length, z_0 (m)	Wind shear exponent, α	Energy Index (%)	Landscape
0	0.0002	0.09	100	Water surface
0.5	0.0024	0.14	73	Completely open terrain with a smooth surface, such as concrete runways in airports or mowed grass
1	0.03	0.21	52	Open agricultural area with fences and hedgerows and very scattered buildings. Only softly rounded hills.
1.5	0.055	0.24	45	Agricultural land with some houses and 8m tall sheltering hedgerows within a distance of about 1,250m.
2	0.1	0.29	39	Agricultural land with some houses and 8m tall sheltering hedgerows within a distance of about 500m.
2.5	0.2	0.31	31	Agricultural land with many houses, shrubs and plants, or 8m tall sheltering hedgerows within a distance of about 250m
3	0.4	0.43	24	Villages, small towns, agricultural land with many or tall sheltering hedgerows, forests and very rough, uneven terrain
3.5	0.8	0.50	18	Larger cities with tall buildings.
4	1.6		13	Very large cities with tall buildings and skyscrapers.

Source:
http://www.windpower.org/en/

Scaling the Wind Data



'Power law' used to extrapolate wind speed

$$v = v_0 \left(\frac{H}{H_0} \right)^{\alpha}$$

v = wind speed (m/s)
v_0 = reference wind speed (m/s)
H = Height (m)
H_0 = Reference height (m)
α = Wind shear exponent (see slide 9)

Example: Assuming a roughness class 2

$H = 20m$, $H_0 = 10m$, $v_0 = 7.8m/s$ and $\alpha = 0.29$

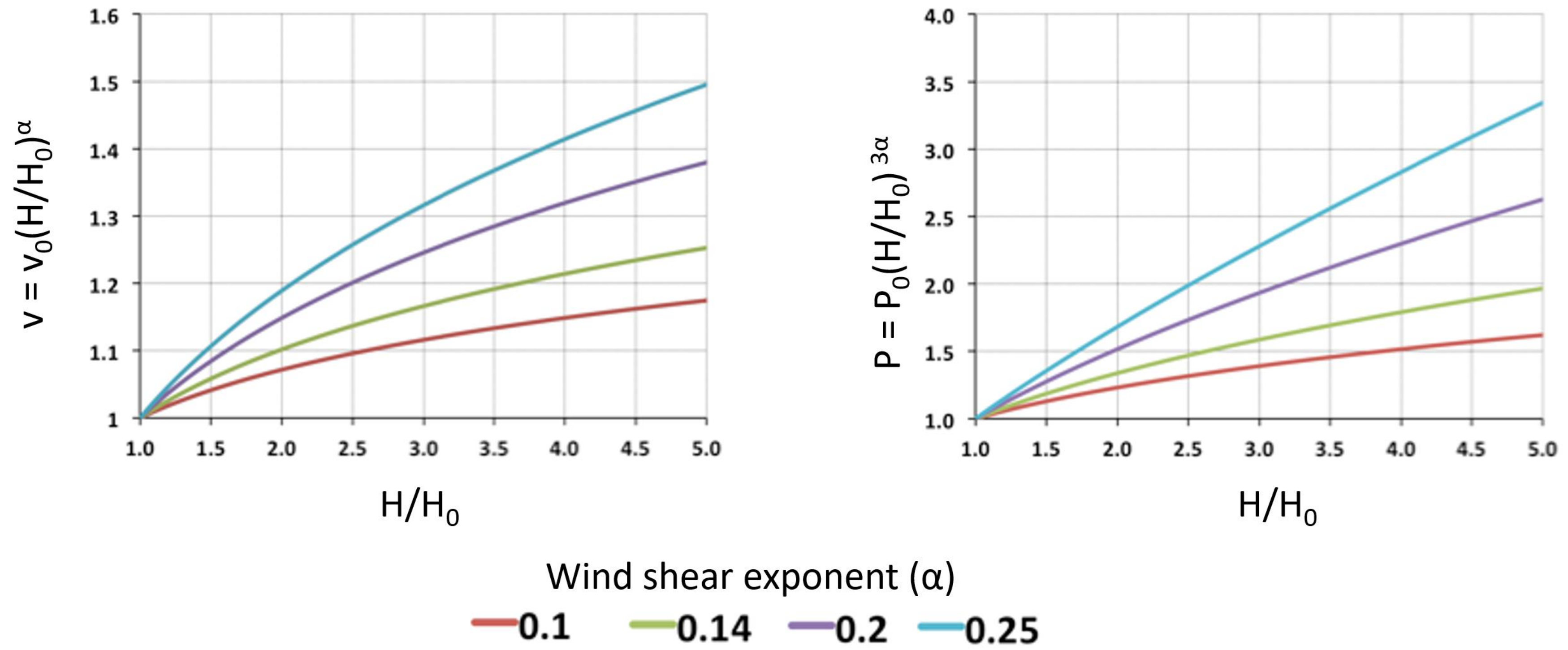
Therefore wind speed at 20m = 9.5 m/s

Height at which wind speed is measured is critical, and met mast are typically much shorter than turbines. Met mast data can be scaled up using the 'Power Law' equation given below (note: if met mast height is not mentioned, a height of 10m is normally assumed):

Scaling the Wind Speed; Wind Shearing

RECALL: Why is *wind shear* important?

Small increases in wind speed give large increase in available power **($P = ½\rho Av^3$)**



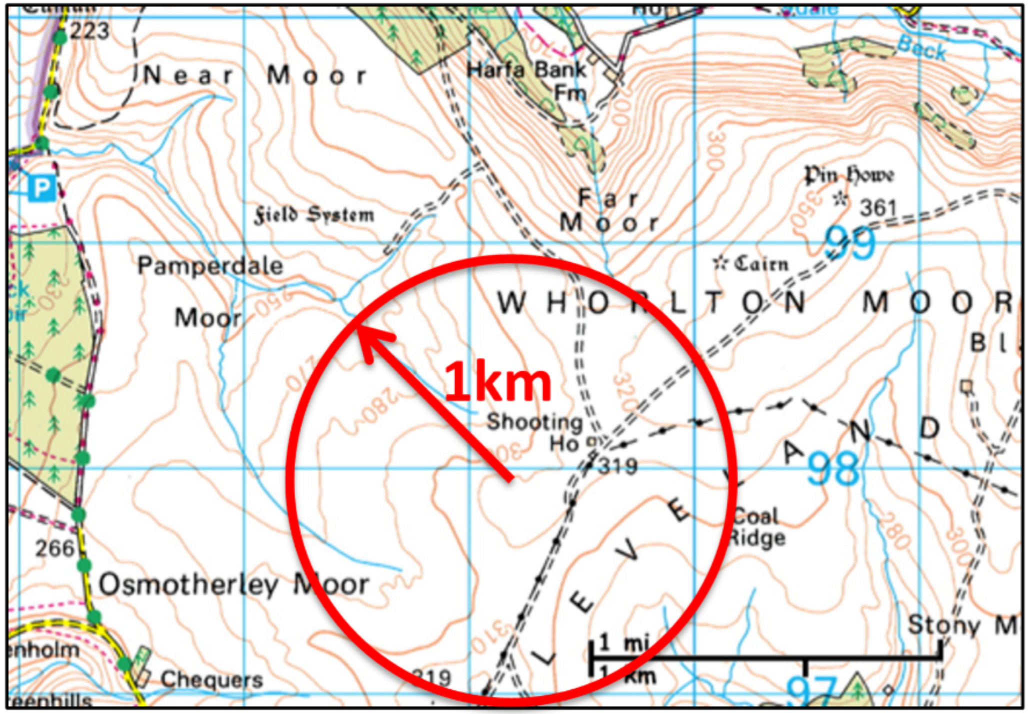
Rule of thumb – Doubling tower height often increases power available by 25%; therefore - use as tall a tower as possible!

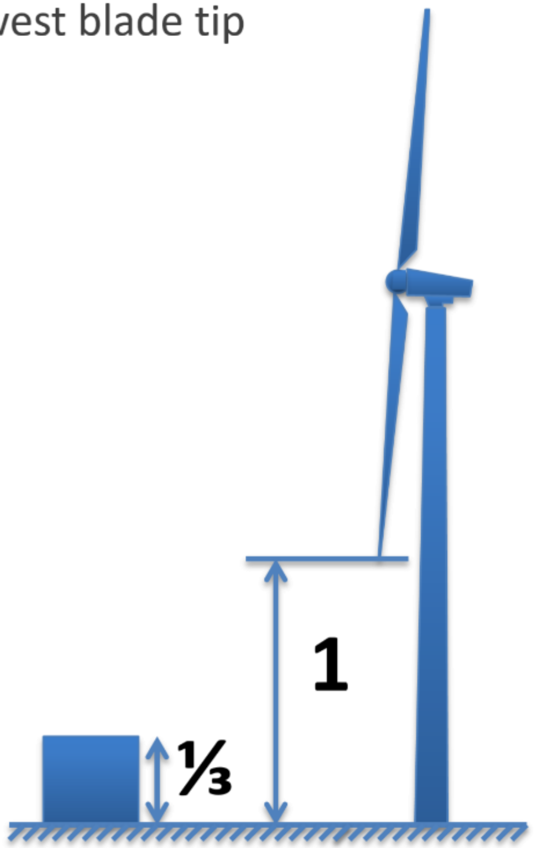
Source: Gipe, P. (2009). "Wind Energy Basics" – 2nd Edition

Scaling the Wind Speed; Wind Shearing

Obstacles should be no higher than 1/3 of height of the lowest blade tip

Rule of thumb: For a radius of 1km around the potential site location obstacles should be no higher than 1/3 of height of the lowest blade tip





Height of relevant obstacles = 1/3

Source: Gipe, P. (2009). "Wind Energy Basics" – 2nd Edition

QUANTIFYING WIND DATA FOR WIND FARM DEVELOPMENTS

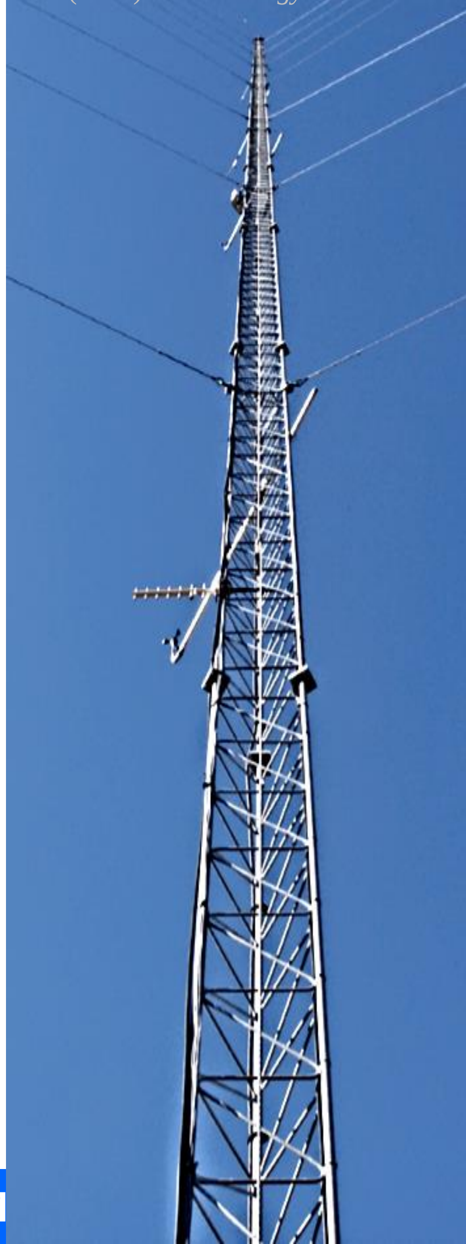
Quantifying Wind Resource

NYSERDA (2017). *Wind Energy Site Selection.*

Once a potential site is identified, the developer will install **meteorological towers** and remote sensing equipment to record weather information, such as wind speed, wind direction, gusts, and temperature (for at least a year).

This information, in combination with regional climatic reference station data, can be used to characterize the ***long-term wind resource*** at the site.

To be considered attractive for project development, a site's annual average wind speed should be 14.5 miles per hour (mph) or 6.5 meters per second (m/s) or stronger at a wind turbine's hub height.



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Quantifying Wind Resource

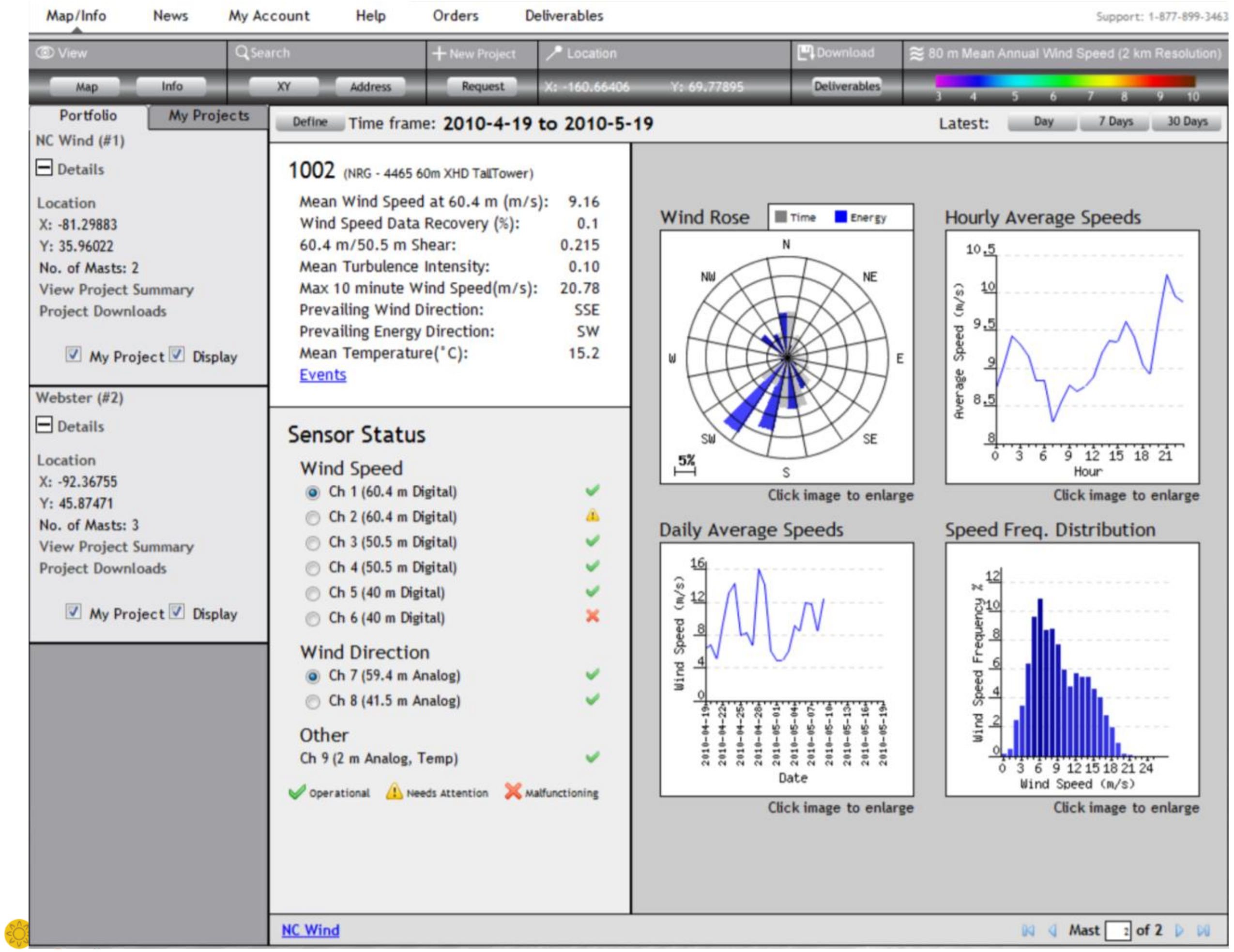
Wind Power Class		Wind Speed m/s	Wind Power Density W/m2	Resource Potential
	1	<4	0-100	Poor
	2	4. -6.4	100-300	poor
	3	6.4 - 7.0	300-400	Fair
	4	7.0-7.5	400-500	Good
	5	7.5 - 8.0	500-600	Excellent
	6	8.0 -9.8	600 - 800	Outstandig
	7	8.8 - 11.1	800-1000	Superb

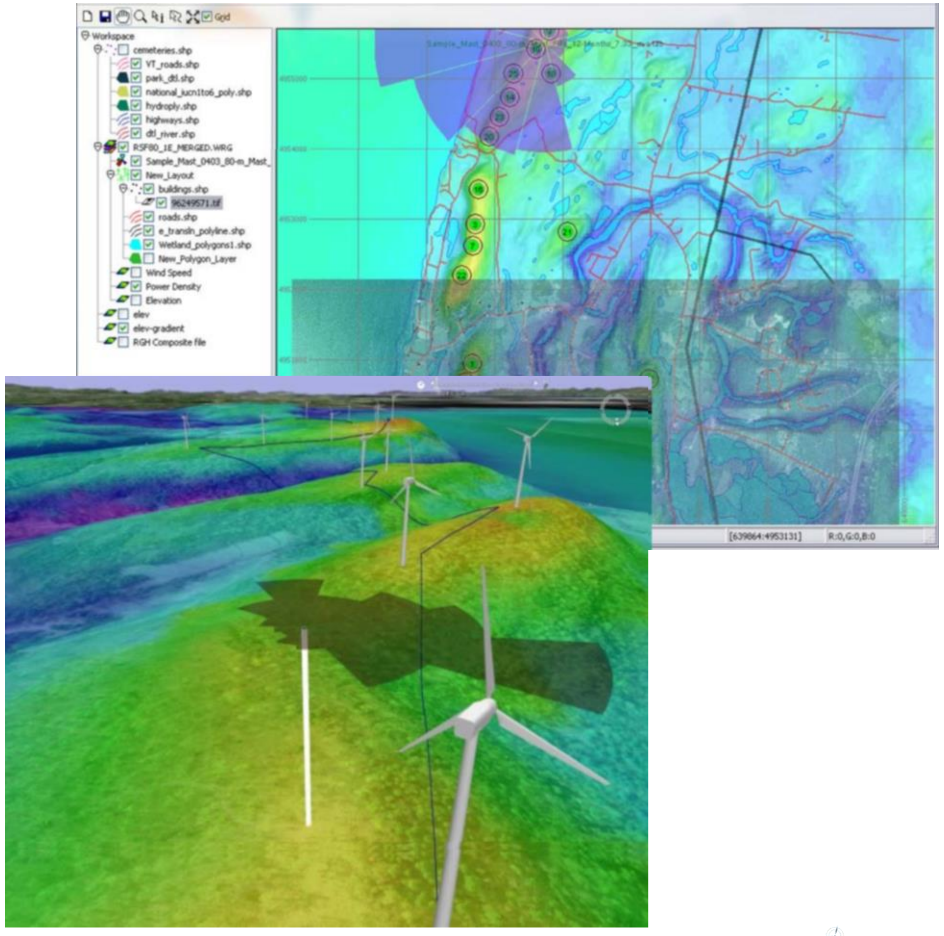
Developers can use software tools (many available online) to estimate the wind resource at a specific project site and begin the process of designing the turbine layout. Once the layout has been created, developers calculate how much energy will be created on an annual basis. **Project investors rely on an accurate estimate of generation in deciding how to finance a project.**

NYSERDA (2017). *Wind Energy Site Selection.*
USAID (2013). *Wind Projects: Optimizing Site Selection.*

Quantifying Wind Resource

Wind Farm Design Software





https://aws-dewi.ul.com/assets/Wind-Resource-Assessment-Practical-Guidance-for-Developing-a-Wind-Project-Brower-Dec20122.pdf.

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Site Planning/ Access/ Terrain

Site access: adequacy of local access roads to facilitate construction works and transportation of large machinery and turbine parts to the site

Wind Turbine Transportation Logistics

83 m Rotor blade transported to Scotland

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Site Planning/ Access/ Terrain

Land use issues: information regarding the ownership of the lands on which the wind turbines, transformer station, cabling will be installed, and regarding land which needs to be accessed during the construction phase (for cranes and other equipment) and associated remedial works thereafter

Grid connection: capacity of grid-connection, distance to suitable point of connection to the electricity grid

Kirby, Lawrence (2017). *Introduction to wind and hydroelectric energy*
Images: *[www.mercurynews.com], [www.nal.usda.gov],[windrocks.wordpress.com]*

Site Planning/ Access/ Terrain

- Ground conditions, including soil stability, site drainage
- Potential interference issues with regard to air traffic and radio/television broadcasting
- ***Local environmental impact***: noise, shadow flicker, impact of the project on natural heritage, and visual impact (size, scale and layout and the degree to which the wind energy project - wind turbines, transformer stations and access roads - is visible)
- Disposal or elimination of waste and surplus material from the construction site as well as clearance and decommissioning considerations.

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Local Environmental Impact

When conducting site planning for a wind farm, the following need to be taken into consideration from the beginning:

- Noise

- Shadowing

- Low conflict areas

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Environmental Impact - NOISE

Noise

What causes noise in wind turbines?

- Aerodynamic noise
    - Rotor blade interrupt air flow when passing the tower
    - Rotor blade motion causes turbulence
- Rotating of main shaft
- Vibration of Generator and other moving mechanisms
- Cooling system (noise from fans)

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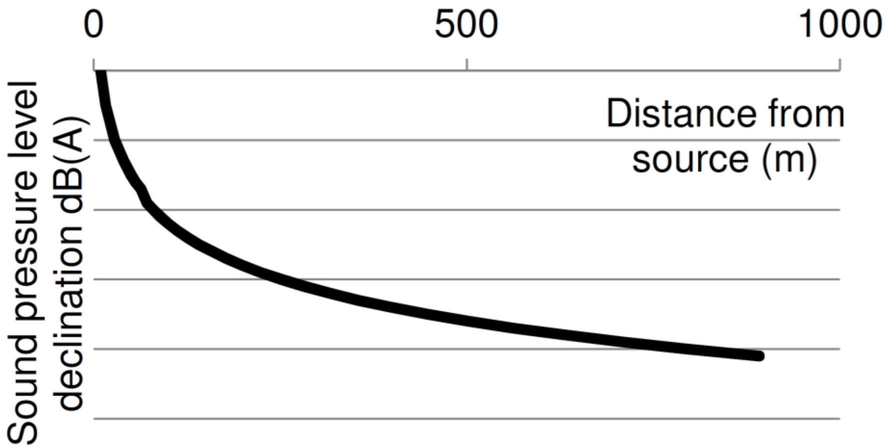
Environmental and Climate Impact

Environmental Impact - NOISE

150 dB	Starting rocket
140 dB	Starting airplane
130 dB	
120 dB	
110 dB	Diskothek
100 dB	Jackhammer
90 dB	Main road, vacuum cleaner
80 dB	
70 dB	Car
60 dB	
50 dB	Normal conversation
40 dB	Flip pages of a book
30 dB	Very quit room
20 dB	
10 dB	Breathing

Typical limit values for wind turbines <45dB(A) at day and <35 dB(A) at night for residential areas/neighbourhoods (*Measurement according to* ***IEC 61400-11***)

Sound pressure decreases with distance to a source. Doubling the distance to a wind turbine reduces the sound pressure level by 6dB

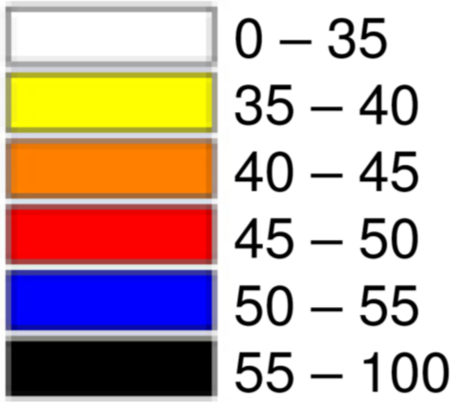


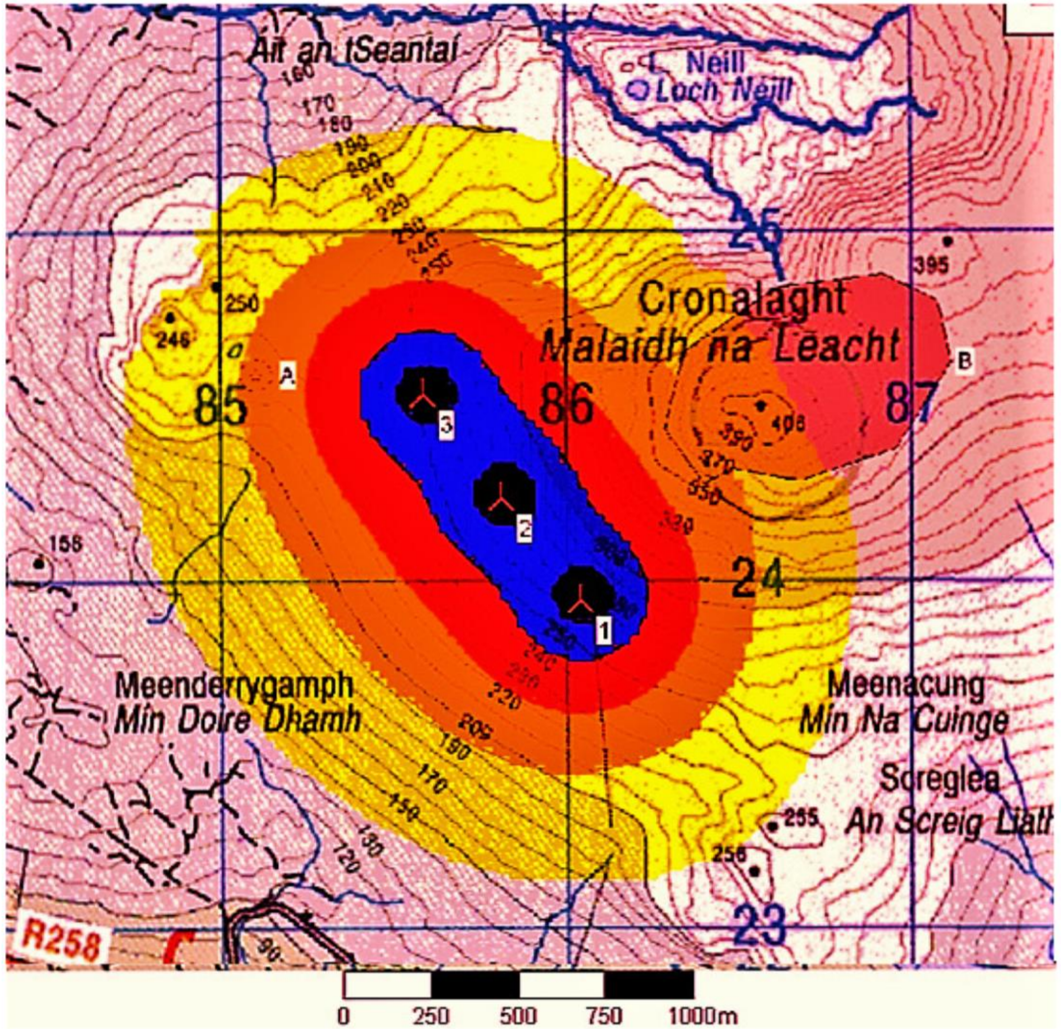
Environmental and Climate Impact

Environmental Impact - NOISE

Planning assumes the “worst case” scenario: wind turbine at full load, operation at night

Map (right) shows three wind turbines and noise emissions measured in dB sound pressure level





Low Conflict site Identification

Wind farm site identification has Outcomes to avoid conflicts right from the beginning of the project planning. This has the following advantages:

- Reduced work load for project planers
- Reduced work load for licensing authorities
- Increasing public acceptance for projects

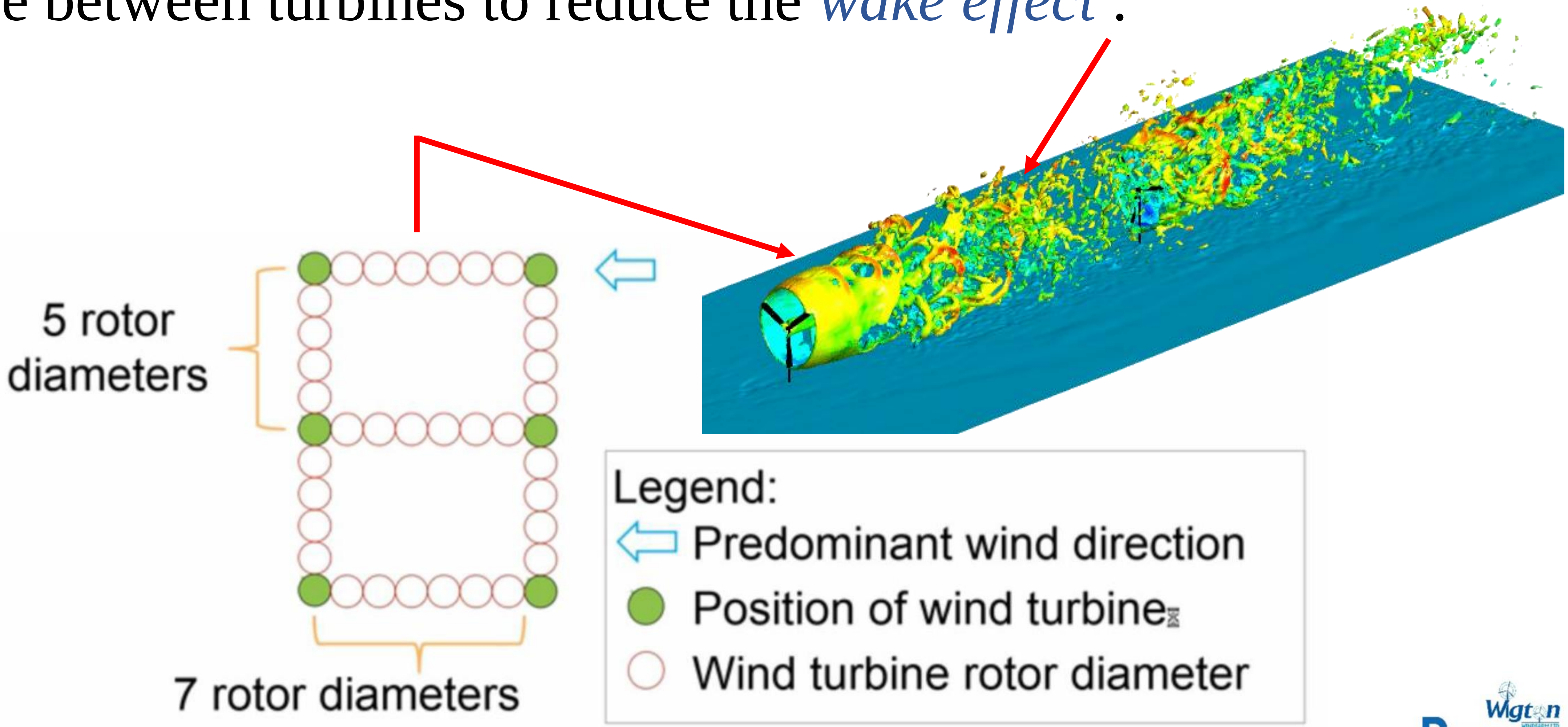
Identify priority low conflict areas by:

1. Excluding from maps all areas for settlements, nature protected areas, airports, industry, roads, overhead lines, military, etc.
2. Adding buffer zones to maps for noise protection around settlements, nature protection and infrastructure safety
3. Use visual impact criteria to avoid encircling of settlements by wind farms

Environmental and Climate Impact

Priority Low Conflict Areas

Distance between turbines to reduce the *wake effect* :



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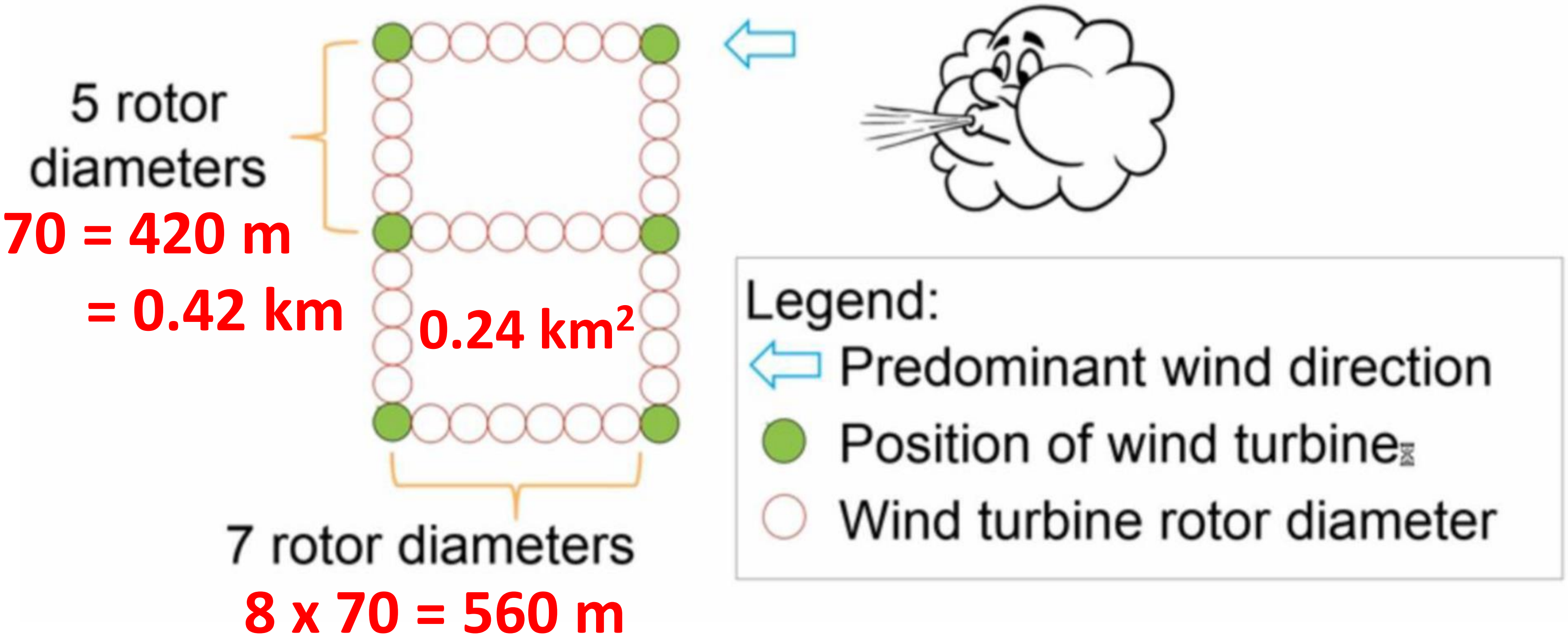
Environmental and Climate Impact

Priority Low Conflict Areas

Area needed for four 70m turbines:



6 x 70 = 420 m

= 0.42 km

0.24 km^2

8 x 70 = 560 m

= 0.560 km

Environmental and Climate Impact

Priority Low Conflict Areas

	1980	1985	1990	1995	2000	2005	2008	2011	2013
Rated power:	30 kW	80 kW	250 kW	600 kW	1.500 kW	3.000 kW	6.000 kW	7.500 kW	8.000 kW
Rotor diameter:	5 m	20 m	30 m	46 m	70 m	90 m	126 m	127 m	164 m
Hub height:	30 m	40 m	50 m	78 m	100 m	105 m	135 m	135 m	site specific (offshore)

Let's use a medium sized turbine with a rotor diameter of **70m**

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Stakeholders within the Process

Various Local and Private Agencies Involved in Pre-Construction, Construction and Post-Construction Phases

- Jamaica
  1) Jamaica Public Service Company
  2) National Environmental and Planning Agency
  3) Office of Utilities Regulation
  4) Ministry of Science, Energy and Technology
  5) Jamaica Customs Agency
  6) Port Authority of Jamaica

- Trinidad and Tobago
  1) Regulated Industries Commission
  2) Environmental Management Authority
  3) Customs and Excise Division
  4) Port Authority of Trinidad and Tobago
  5) Trinidad and Tobago Electricity Commission
  6) Ministry of Energy and Energy Affairs

Stakeholders within the Process

Various Local and Private Agencies Involved in Pre-Construction, Construction and Post-Construction Phases

- Belize
  1) Belize Customs and Excise
  2) National Environmental and Planning Agency
  3) Public Utilities Commission
  4) Ministry of Energy, Science & Technology, and Public Utilities
  5) Belize Electricity Limited
  6) Belize Port Authority

- St. Lucia
  1) National Utilities Regulatory Commission
  2) St Lucia Electricity Services
  3) Ministry of Infrastructure, Ports, Energy and Labour
  4) St Lucia Air and Sea Ports Authority
  5) Customs and Excise St. Lucia
  6) Environmental Protection Agency

Stakeholders within the Process

Various Local and Private Agencies Involved in Pre-Construction, Construction and Post-Construction Phases

- Guyana
    1) Guyana Power and Light
    2) Guyana Environmental Protection Agency
    3) Public Utilities Commission
    4) Ministry of Public Infrastructure and Guyana Energy Agency
    5) Hinterland Electrification Company Incorporated
    6) Guyana Revenue Authority

Stakeholders within the Process - SWOT Analysis

S STRENGTHS (Internal)	W WEAKNESSES (Internal & External)	O OPPORTUNITIES (External)	T THREATS (External)
What advantages does the project/technology have? What does the project do better than competitors? What unique or lowest-cost resources can you draw upon that others can't? What do people in your market see as your strengths? What factors mean that you "get the sale/customers"?	What could you improve? What should you avoid? What are people in your market likely to see as weaknesses? What factors lose you sales/customers/ opportunities?	What good opportunities can you spot? What interesting trends are you aware of? *Useful opportunities can come from such things as:* - Changes in technology and markets - Changes in government policy related to your field - Changes in social patterns, population profiles, lifestyle changes, and so on - Local events	What obstacles do you face? What are your competitors doing? Are quality standards or specifications for your field changing? Is changing technology threatening your position? Could any of your weaknesses seriously threaten your business?

Climate Change Impacts

Will a change in the future climate of the Caribbean bring any benefit or detriments to Renewable Energy?

- **Increase in Temperature?**
  - Can result in an increase in wind speeds; what is critical however, is the type of wind that is generated from this increase.
    - If the winds generated are too gusty, then it increases the maintenance costs of your turbines.
    - If it varies diurnally, will lead to an inconsistency in power generation from your turbines
- **Increase in Hurricanes or other Tropical Systems?**
    - Will lead to an increase in the capital costs of any wind energy developments as investors will now have to consider the foundations required to withstand a category five hurricane.
    - Can deter an investor from developing a wind farm as the frequency of systems may increase which would lead to an high exposure during the hurricane period.

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Climate Change Impacts

Will a change in the future climate of the Caribbean bring any benefit or detriments to Renewable Energy?

- **Increase in Rainfall?**
  - Can result in a constant delay of construction (whether pre-stage or during) and as such can increase your capital expenditure
  - Can result in delays of large-scale projects (whether repairs or various assessments) which will lead to an increase in your maintenance and crane costs

Are there any impacts during the development and implementation of a windfarm?

1) Family Displacement

- As windfarms utilize large amounts of land, it may be possible that some residences and/or agricultural lands may be displaced or disturbed.
  - This can disrupt a family's livelihood as they may be dependent on agriculture to supplement their needs. Normally persons or families are compensated but this does not remove from the psychological or social impact which can be developed in relocating one's home or lands.

Are there any impacts during the development and implementation of a windfarm?

2) Job Imbalances

- During the development of a windfarm, favour is normally granted to more male workers as they are deemed stronger and more agile than their female counterparts. This then leads to temporary constructs of restaurants, bars and shops that supplement the construction workers being operated by women.

- Post-construction and implementation stage of a windfarm normally does not require the hiring of non-technical persons involved in the construction phase of the windfarm, who are normally from surrounding communities as the operations and maintenance of a windfarm does not require a large staff.

ANY QUESTIONS