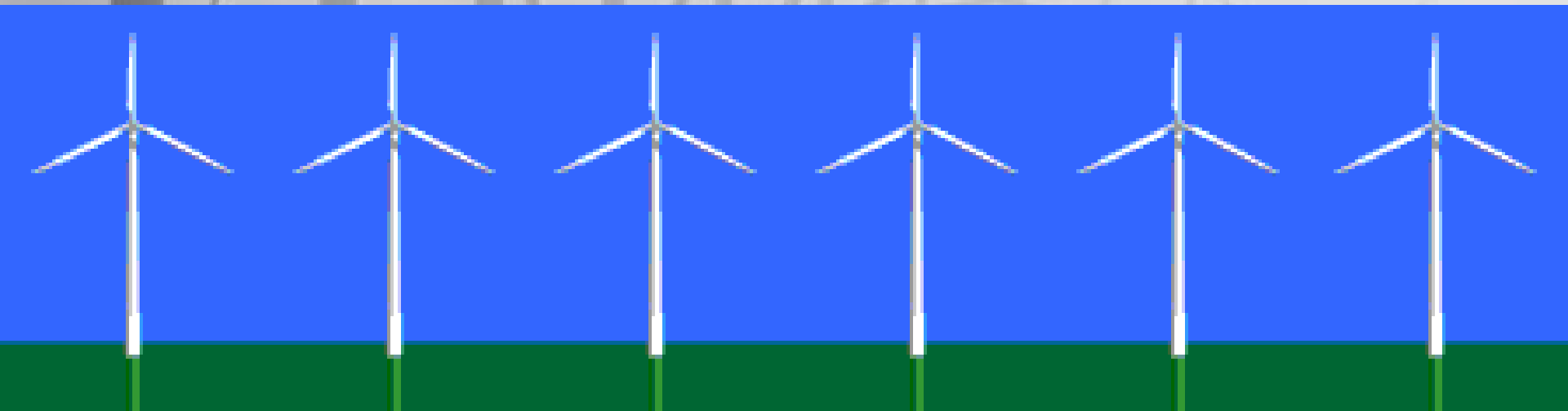
Wind 101

An Introduction to Wind Energy

Richard Lawrence

Cape & Islands Self-Reliance



“Windmills have fascinated us for centuries and will continue to do so. Like campfires or falling water, they’re mesmerizing; indeed, entrancing.”

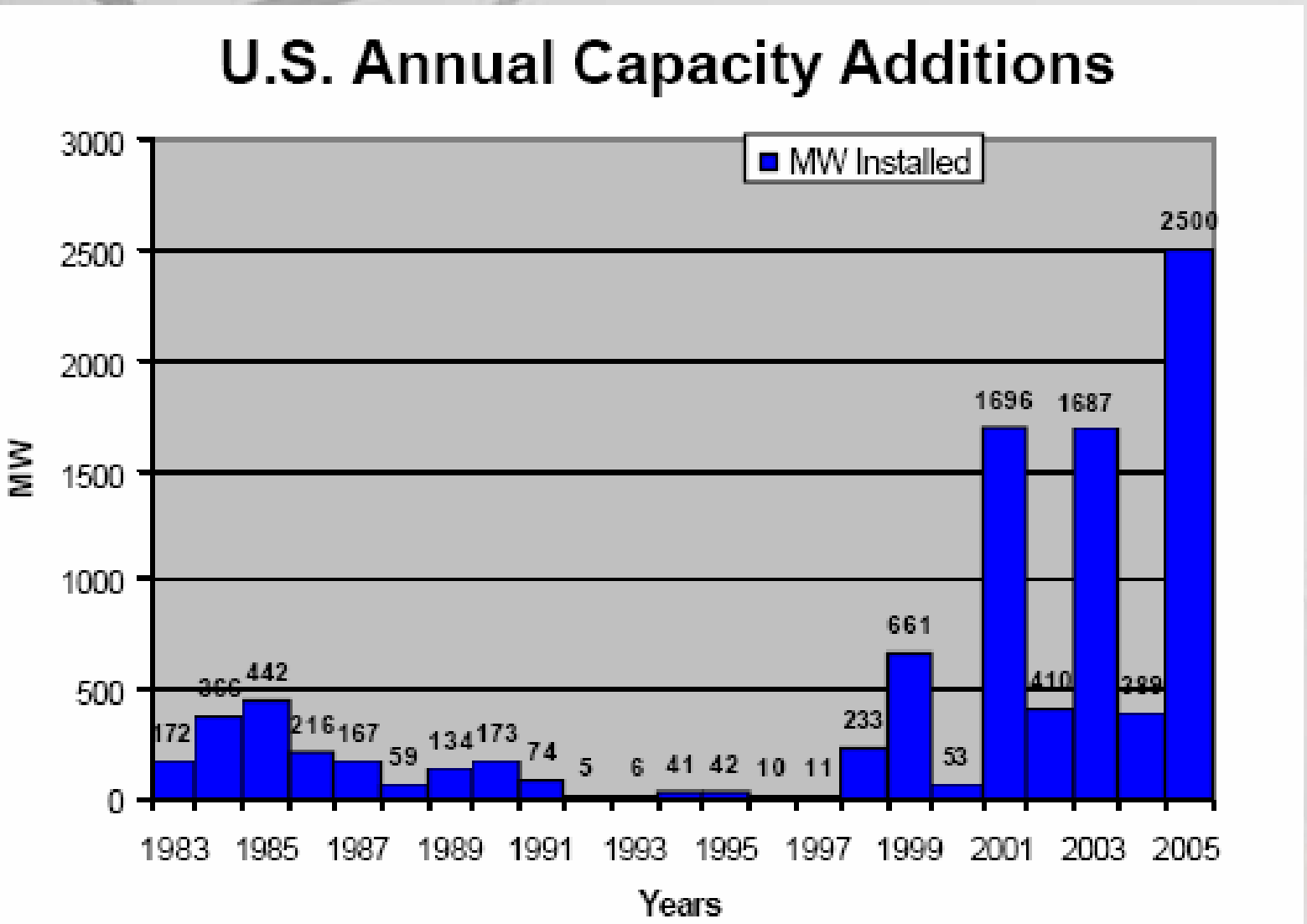
Paul Gipe, Wind Power for Home, Farm, & Business

Drivers for Wind Power

- Rising Fuel Price and Uncertainty
- Declining Wind Costs
- Federal and State Policies & Incentives
- Local Economic Development
- Environmental Stewardship
- Energy Security
- Consumer Demand

US Capacity is Growing

(In fits and starts due to lack of consistent long term federal policies and diverse state policies)



Types of Wind Turbines

Small (≤10 kW)

- Homes
- Farms
- Remote Applications

$5,000-$50,000

Medium (10-250 kW)

- Village Power
- Hybrid Systems
- Distributed Power

$50,000-$500,000

Large (250 kW – 5 MW)

- Central Station Wind Farms
- Distributed Power

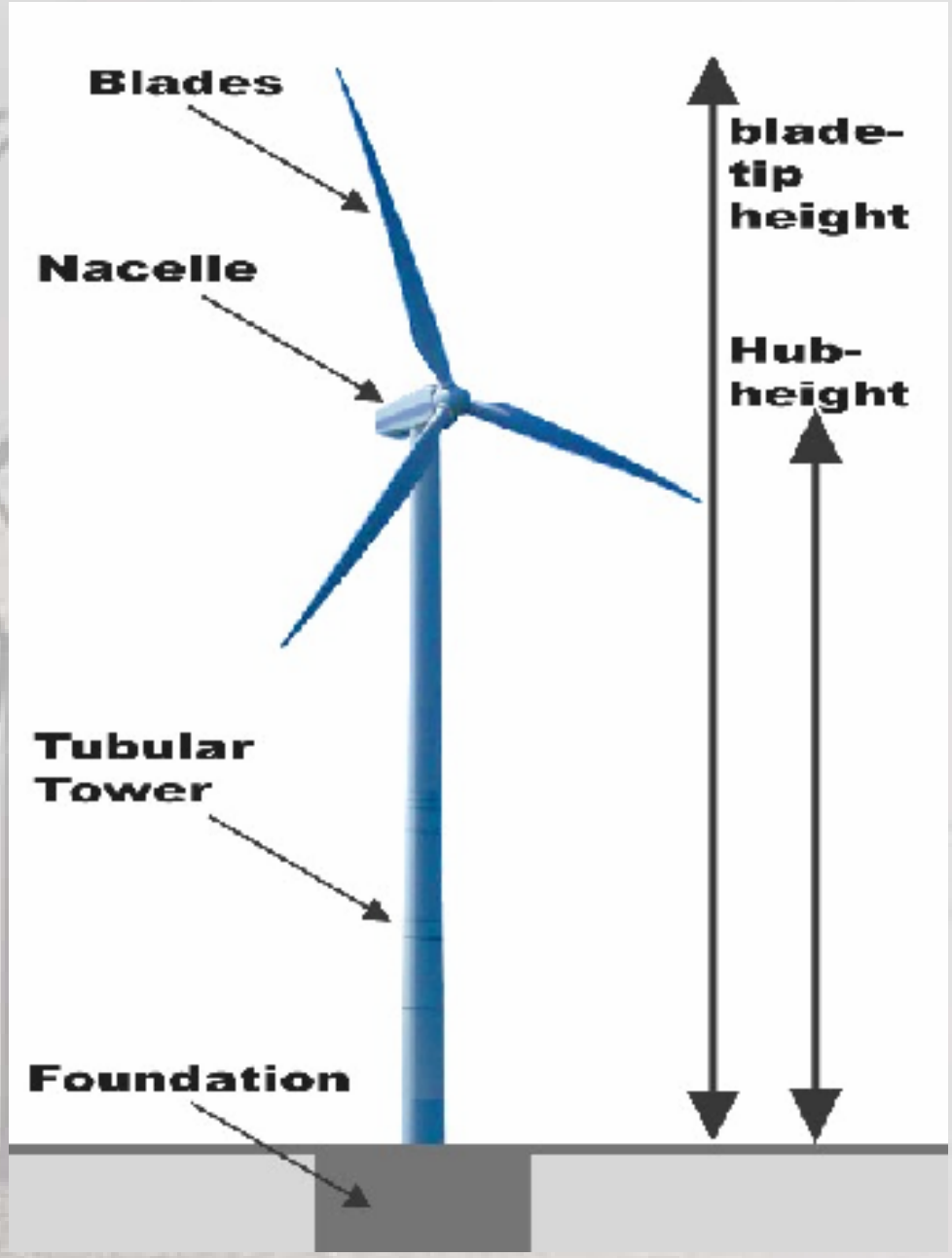
$500,000 - >$5,000,000

Small & Medium Turbines

- Micro
  - <1.25 m (4 ft) rotor diameter
- Mini / Cabin-size
  - 1-3 m (3-10 ft) rotor diameter
- Household
  - 4-10 m (13-33 ft) rotor diameter
- Medium
  - 10-60 m (33-200 ft) rotor diameter

Large Wind Turbines

- Hub height :
  - 160’ - 260’
- Blade tip height:
  - 240’ - 390’



Wind Turbine Perspective

Workers

Blade
112’ long

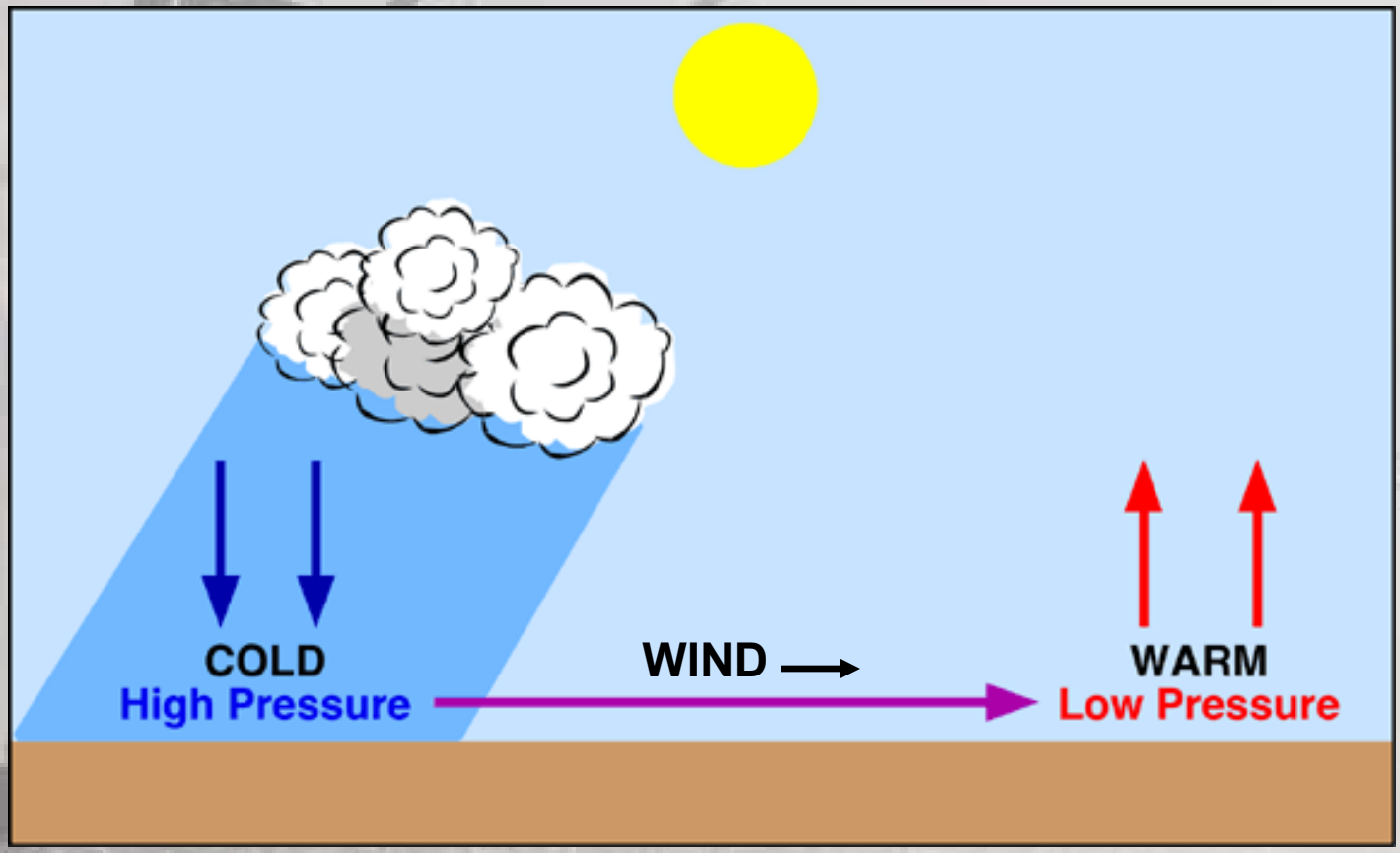
Nacelle
56 tons

Tower
3 sections

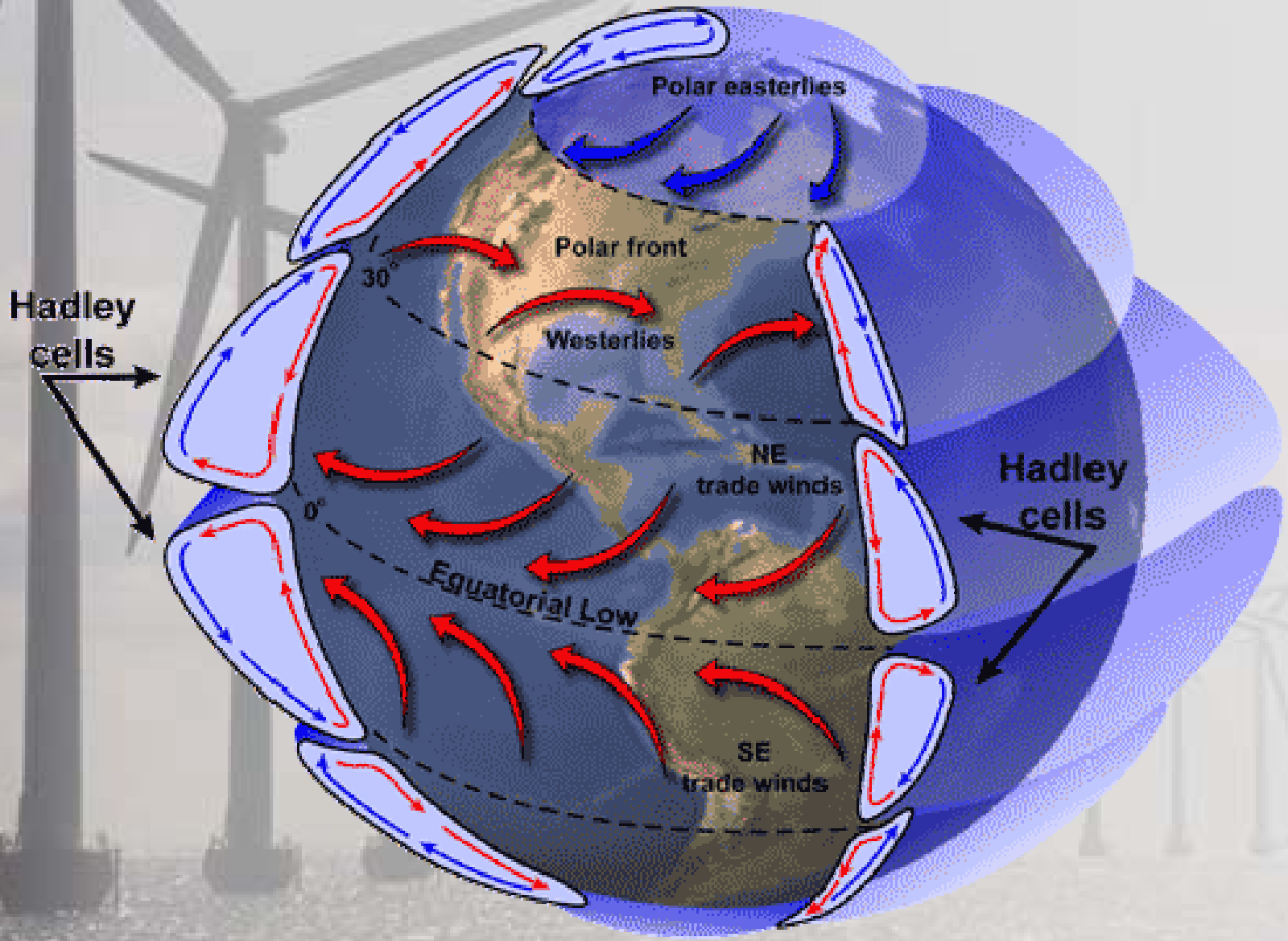
Wide Sweep

How Wind Works

Wind energy is created by uneven heating of the earth's surface.

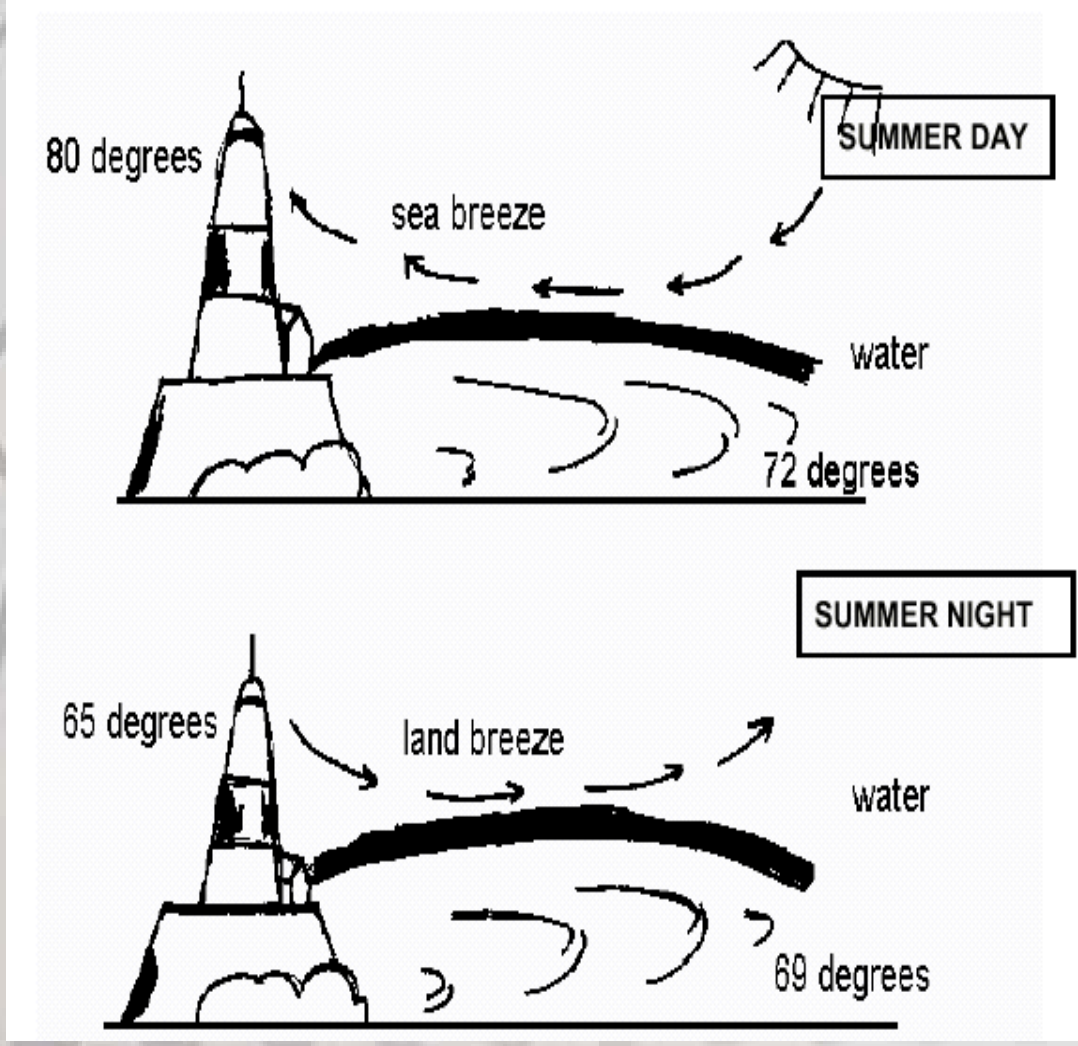


Global “Geostrophic” Winds

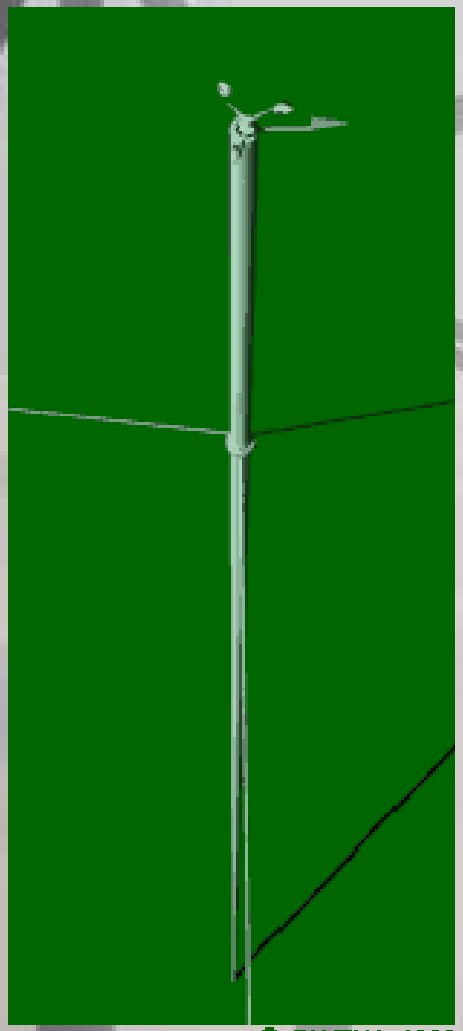


Local Land-Sea Breezes

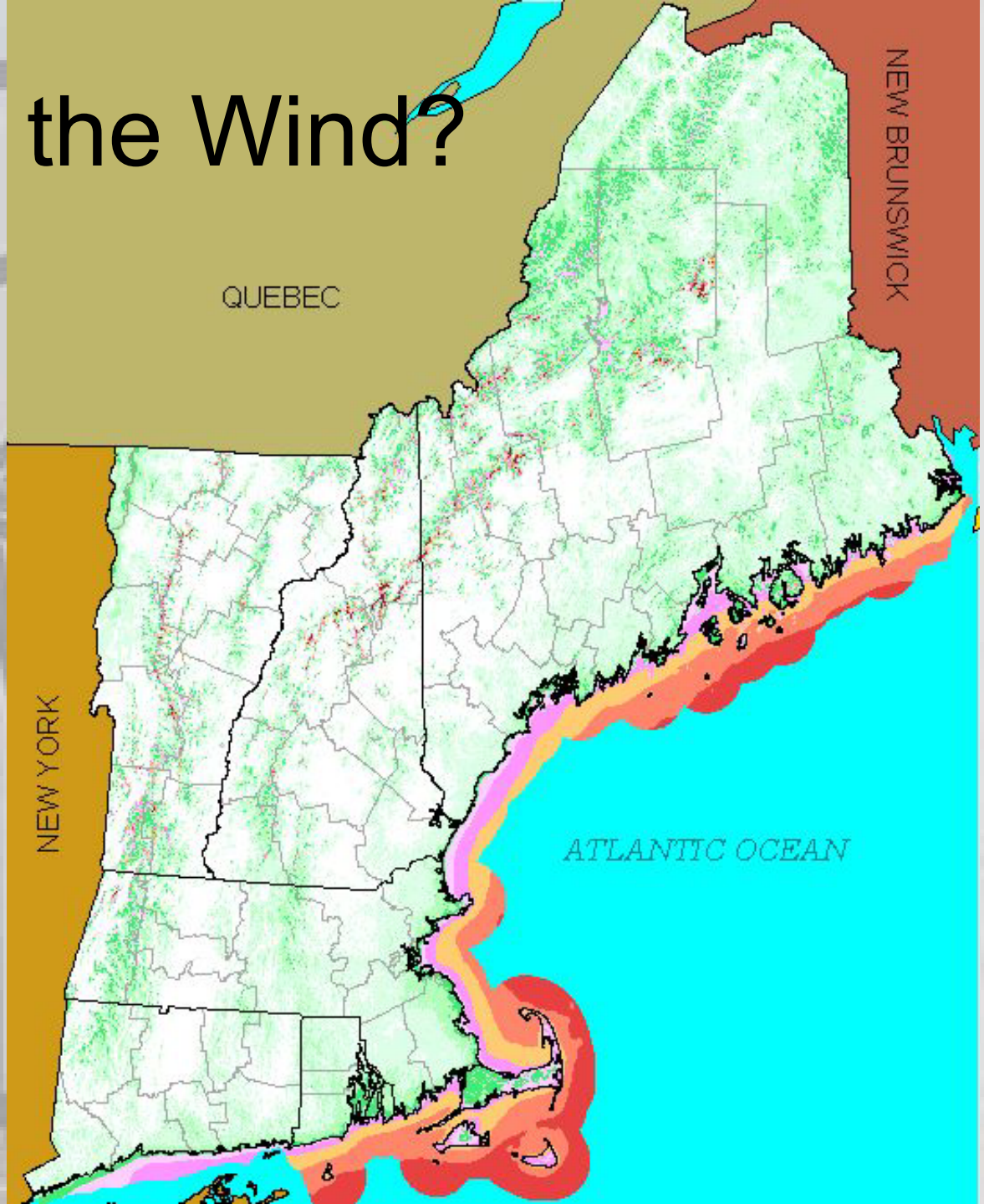
- Land-sea breezes created by temperature differentials between land and water
- Winds also stronger near shore because of long unobstructed fetch
- Cape Cod has a “dual sea breeze”



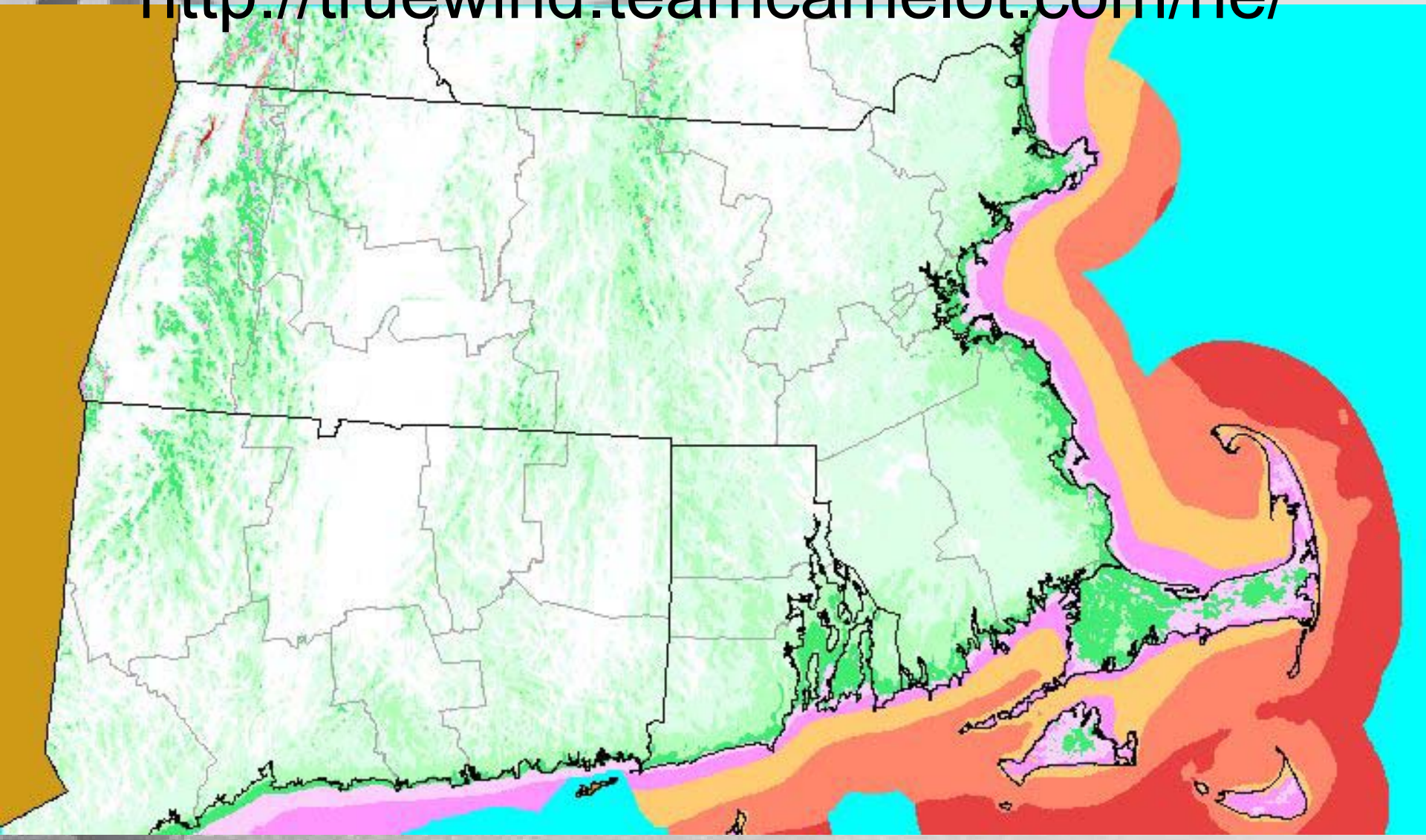
Where is the Wind?

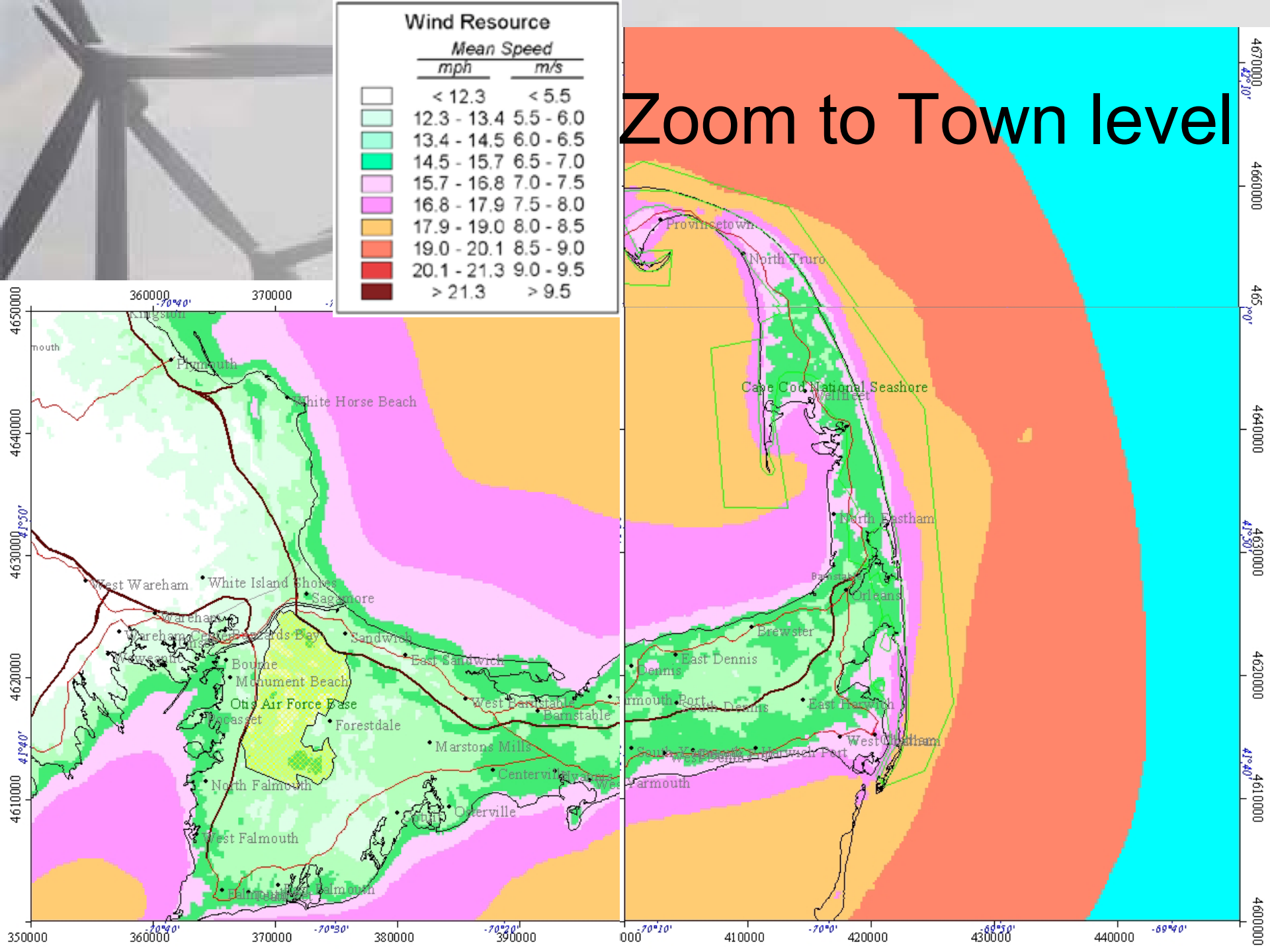


Anemometers measure wind speeds

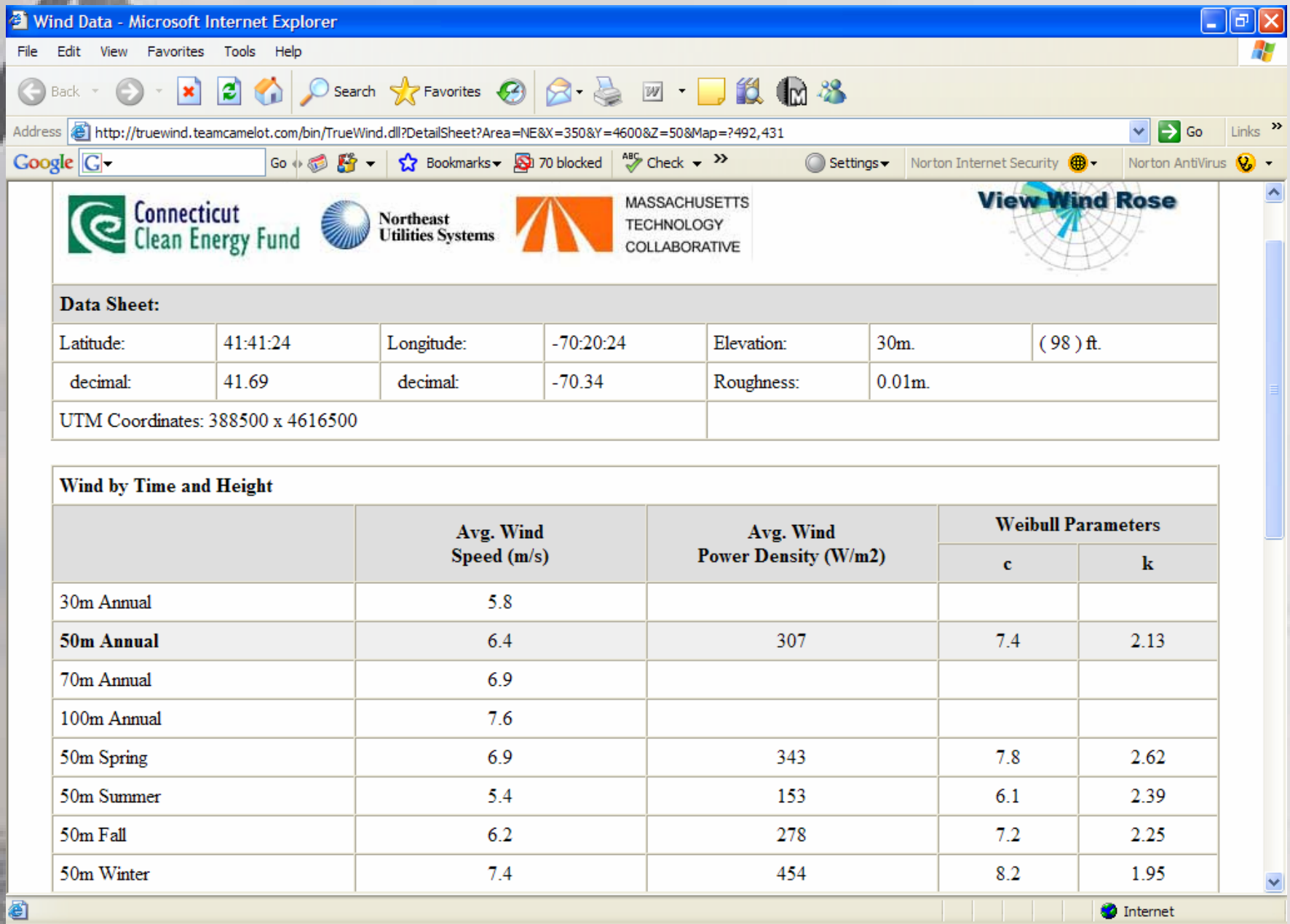


Online Wind Map of New England
http://truewind.teamcamelot.com/ne/




Wind Resource
Mean Speed
mph
m/s
< 12.3
< 5.5
12.3 - 13.4
5.5 - 6.0
13.4 - 14.5
6.0 - 6.5
14.5 - 15.7
6.5 - 7.0
15.7 - 16.8
7.0 - 7.5
16.8 - 17.9
7.5 - 8.0
17.9 - 19.0
8.0 - 8.5
19.0 - 20.1
8.5 - 9.0
20.1 - 21.3
9.0 - 9.5
> 21.3
> 9.5
Zoom to Town level
Provincetown
North Truro
Cape Cod National Seashore
Wellfleet
North Eastham
Orleans
Brewster
East Dennis
Dennis
East Harwich
West Harwich
Harwich Port
Yarmouth
Barnstable
West Barnstable
Hyannis
Marstons Mills
Centerville
Osterville
North Falmouth
West Falmouth
Falmouth
Otis Air Force Base
Forestdale
Monument Beach
Bourne
Sandwich
East Sandwich
Sagamore
White Island Shores
West Wareham
Wareham
Plymouth
White Horse Beach
360000
370000
380000
390000
410000
420000
430000
440000
4650000
4640000
4630000
4620000
4610000
4600000
4670000
4660000
4630000
4620000
4610000
4600000
-70°40'
-70°30'
-70°20'
-70°10'
-70°0'
-69°50'
-69°40'
41°50'
41°40'
42°10'

Get Data on Specific Location

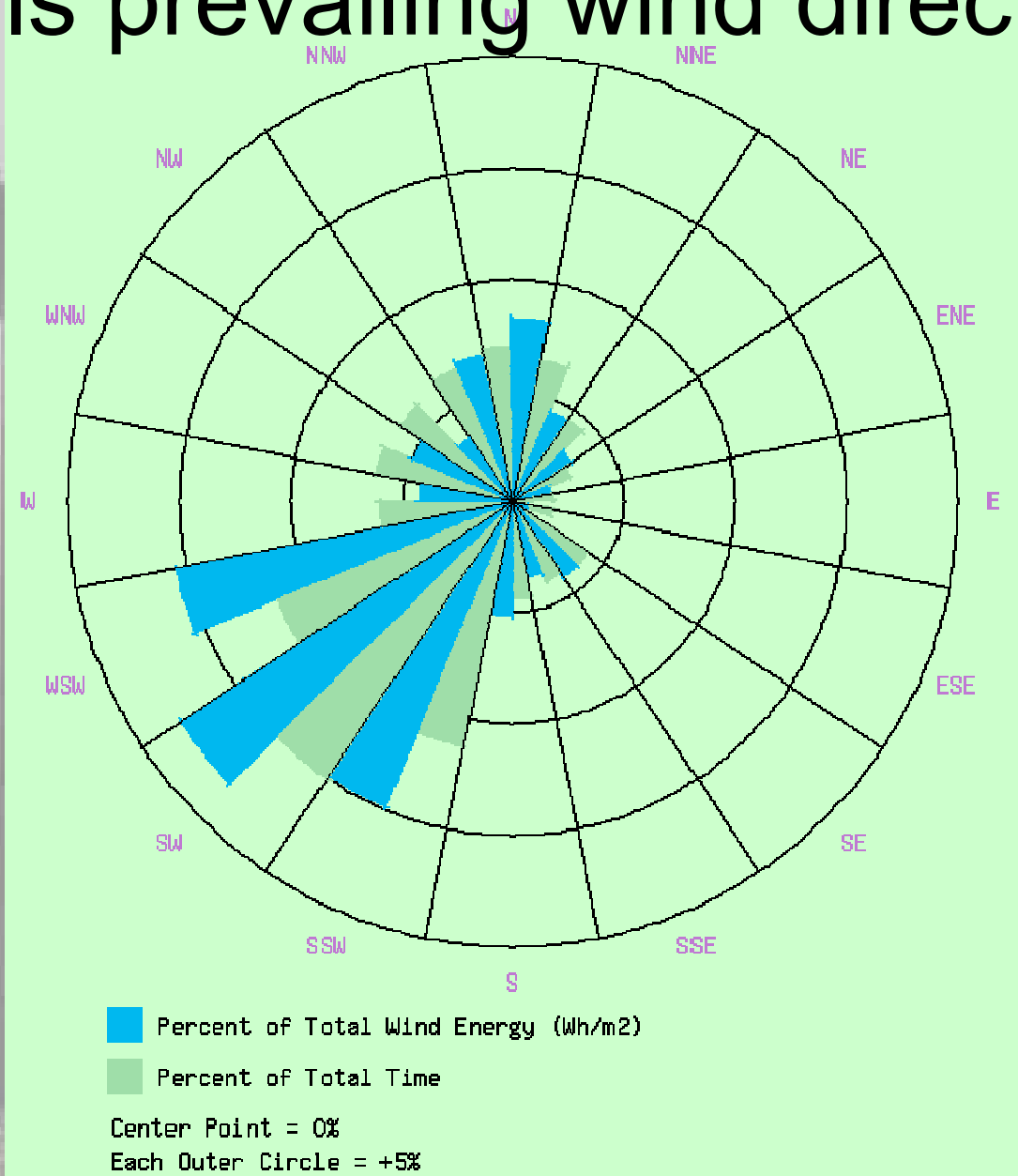


Data Sheet:						
Latitude:	41:41:24	Longitude:	-70:20:24	Elevation:	30m.	(98) ft.
decimal:	41.69	decimal:	-70.34	Roughness:	0.01m.	
UTM Coordinates: 388500 x 4616500						

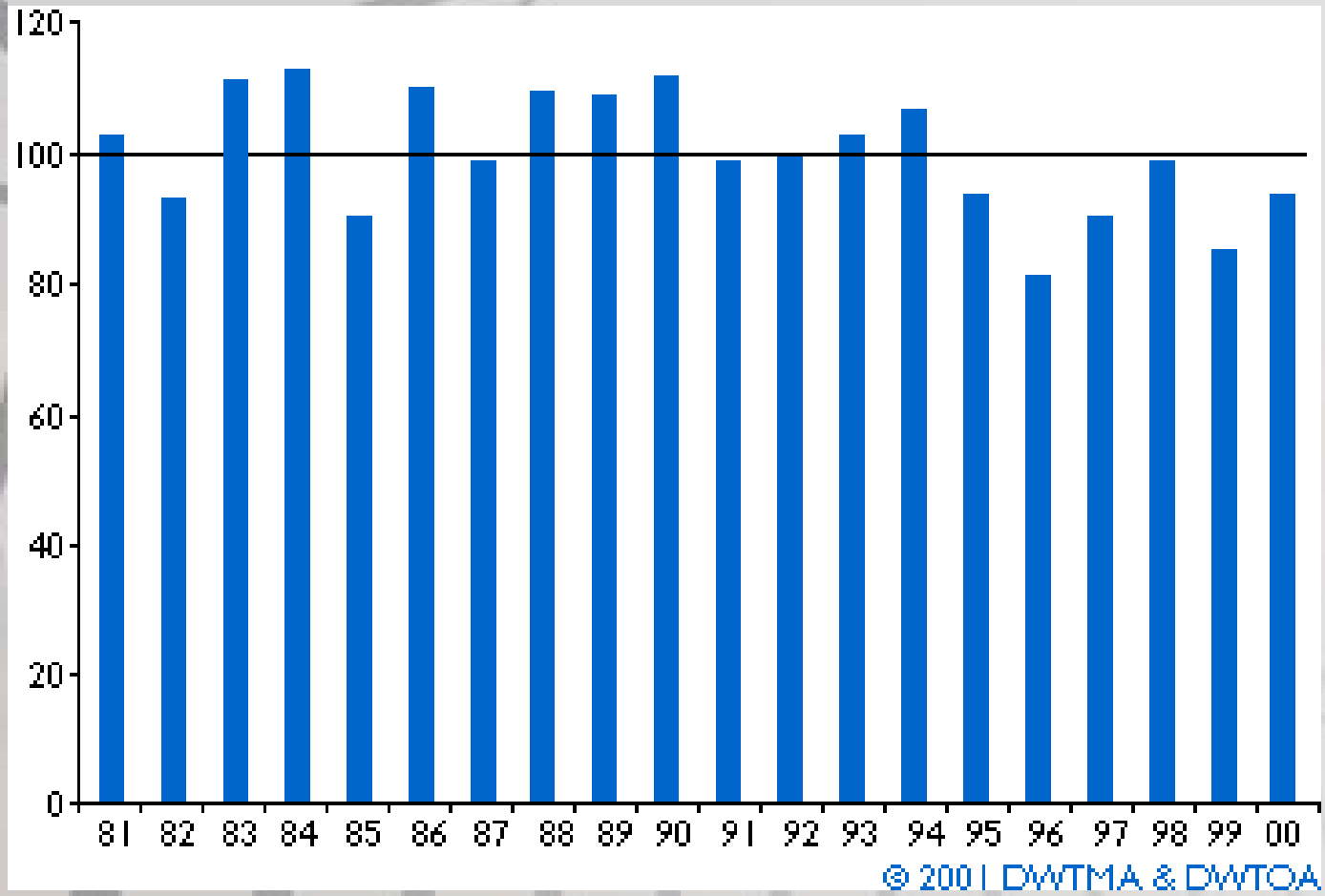
Wind by Time and Height

	Avg. Wind Speed (m/s)	Avg. Wind Power Density (W/m2)	Weibull Parameters	
			c	k
30m Annual	5.8			
50m Annual	6.4	307	7.4	2.13
70m Annual	6.9			
100m Annual	7.6			
50m Spring	6.9	343	7.8	2.62
50m Summer	5.4	153	6.1	2.39
50m Fall	6.2	278	7.2	2.25
50m Winter	7.4	454	8.2	1.95

Wind Rose Diagram
Tells prevailing wind directions

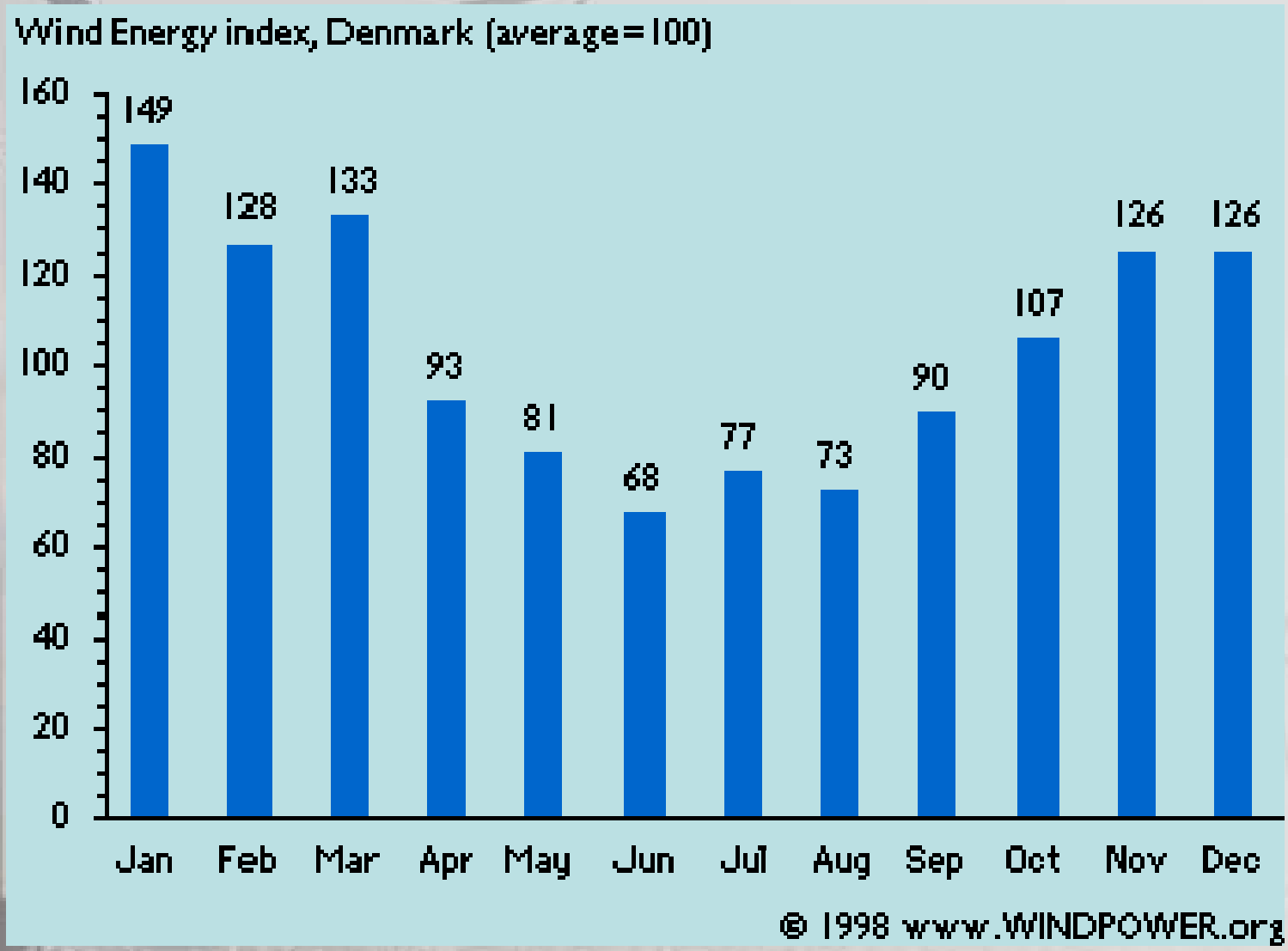


Wind Varies Annually

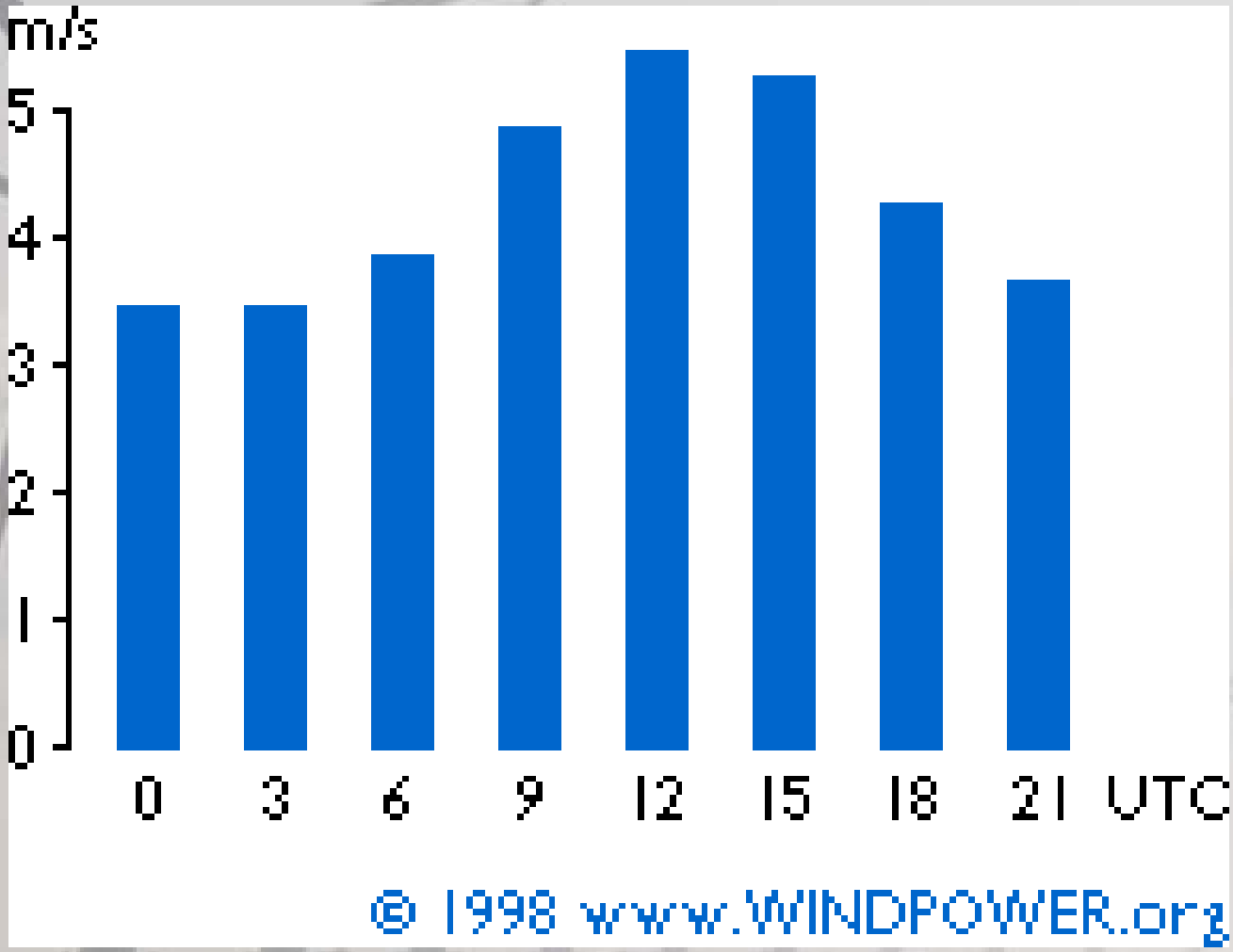


Average annual wind speeds may vary as much as 25% from year to year

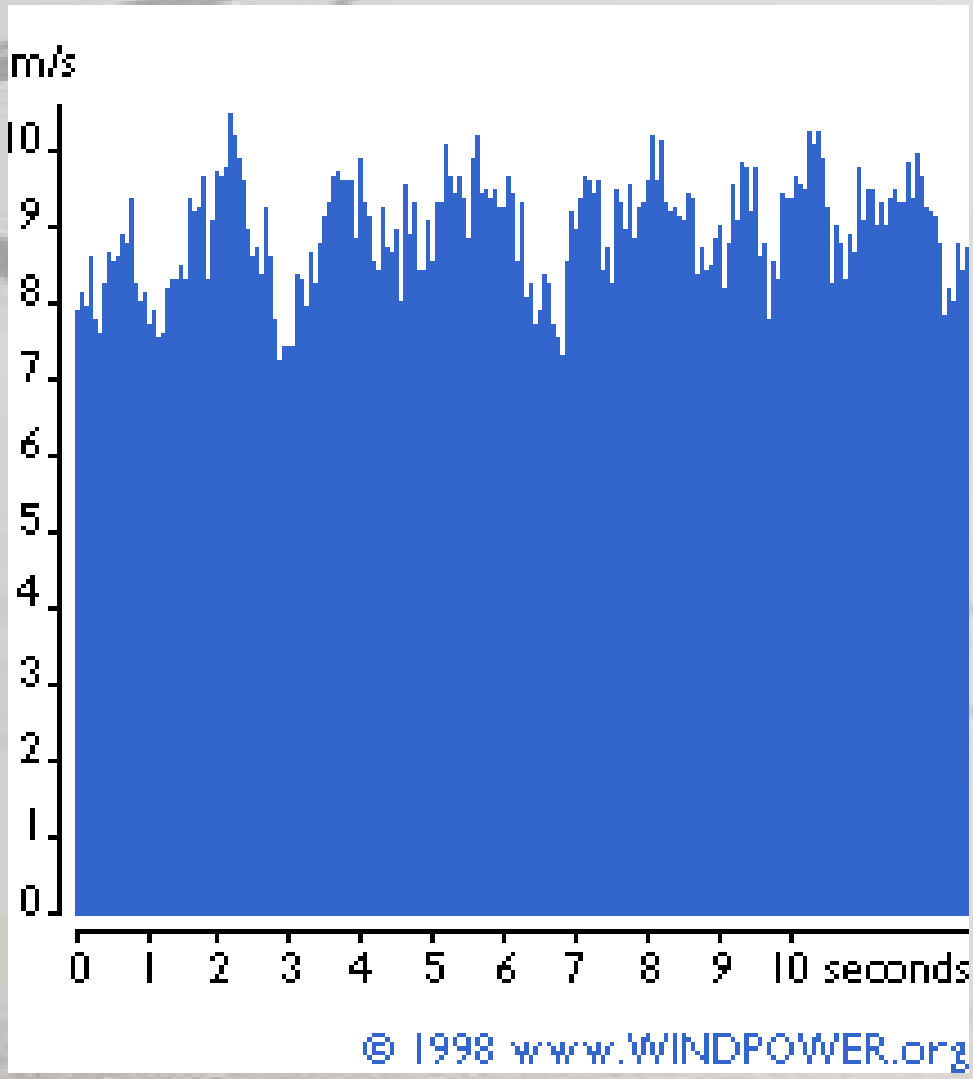
Wind Varies Seasonally



Wind Varies Hourly



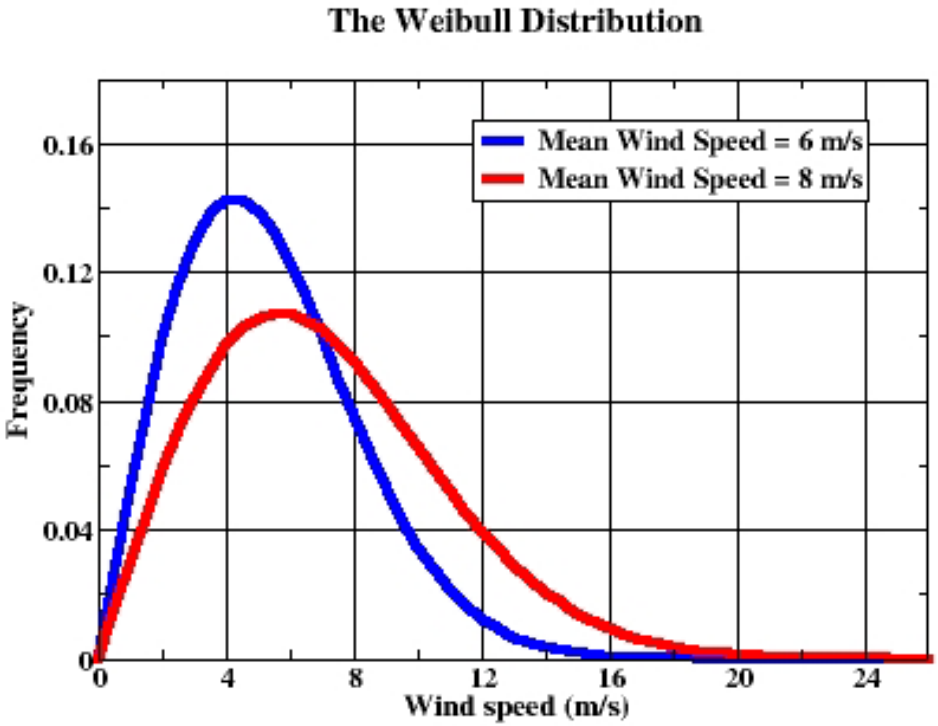
Wind Varies Instantaneously

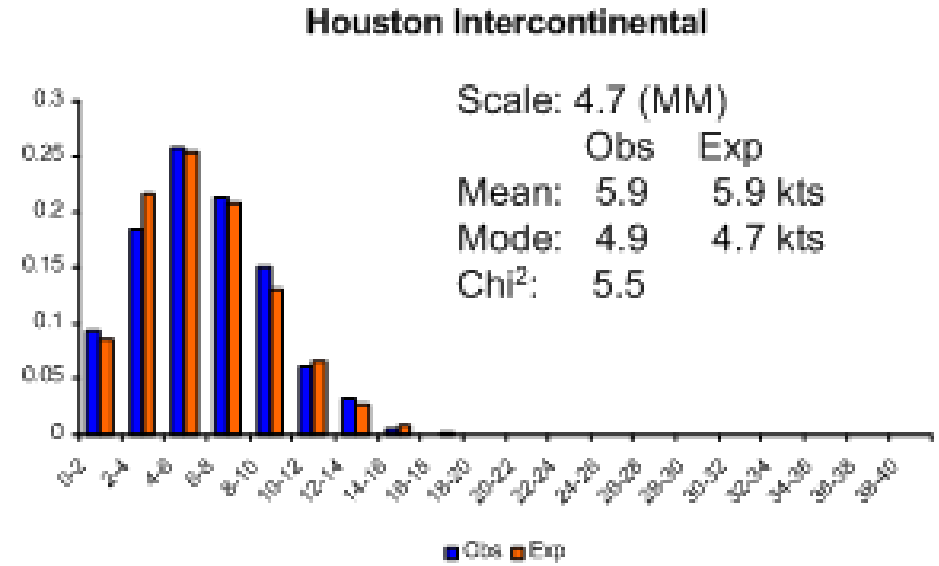


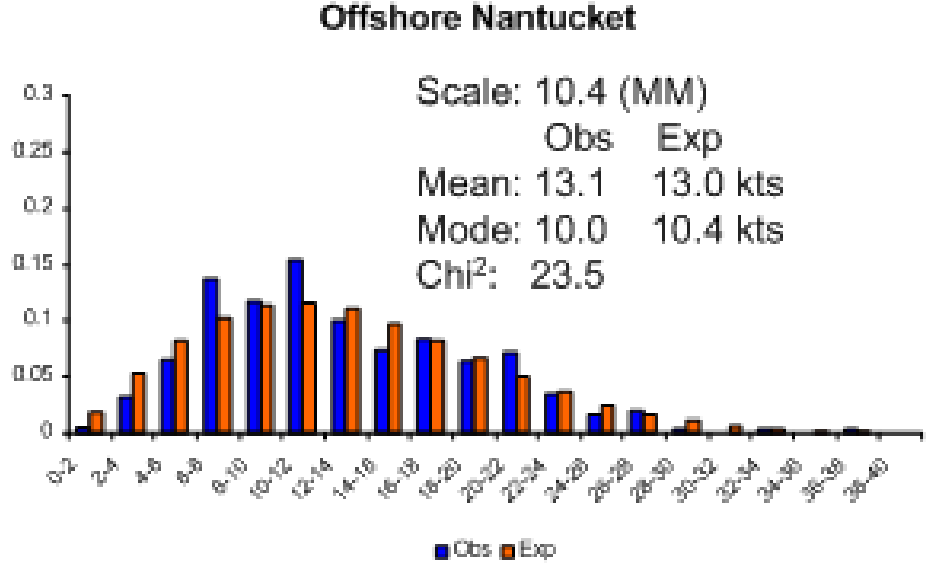
Importance of Distribution

"Because speed distribution plays such an important role in determining power, it's always preferable to use an actual measured distribution."

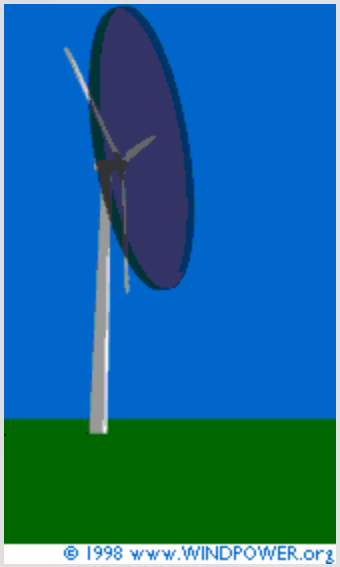
Paul Gipe, Wind Power







Wind has Kinetic Energy which can be captured



Kinetic Energy = Work = ½mV^2

Where:

M= mass of moving object

V = velocity of moving object

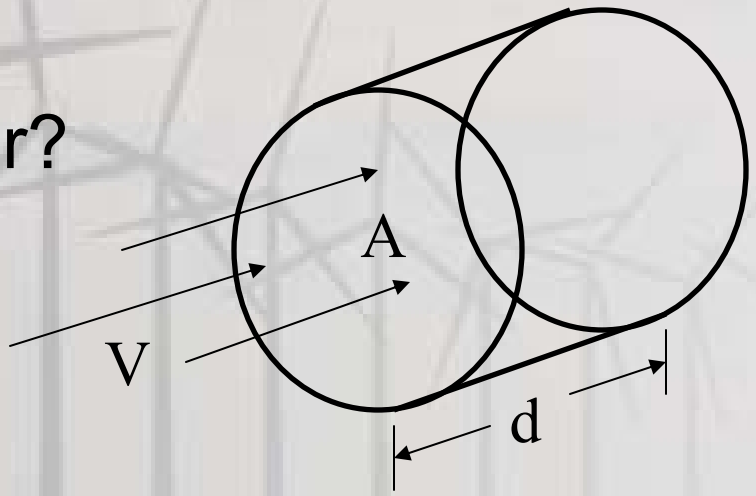
What is the mass of moving air?

= density (ρ) x volume (Area x distance)

= ρ x A x d

= (kg/m^3) (m^2) (m)

= kg



Calculation of Wind Power

- Power in the wind

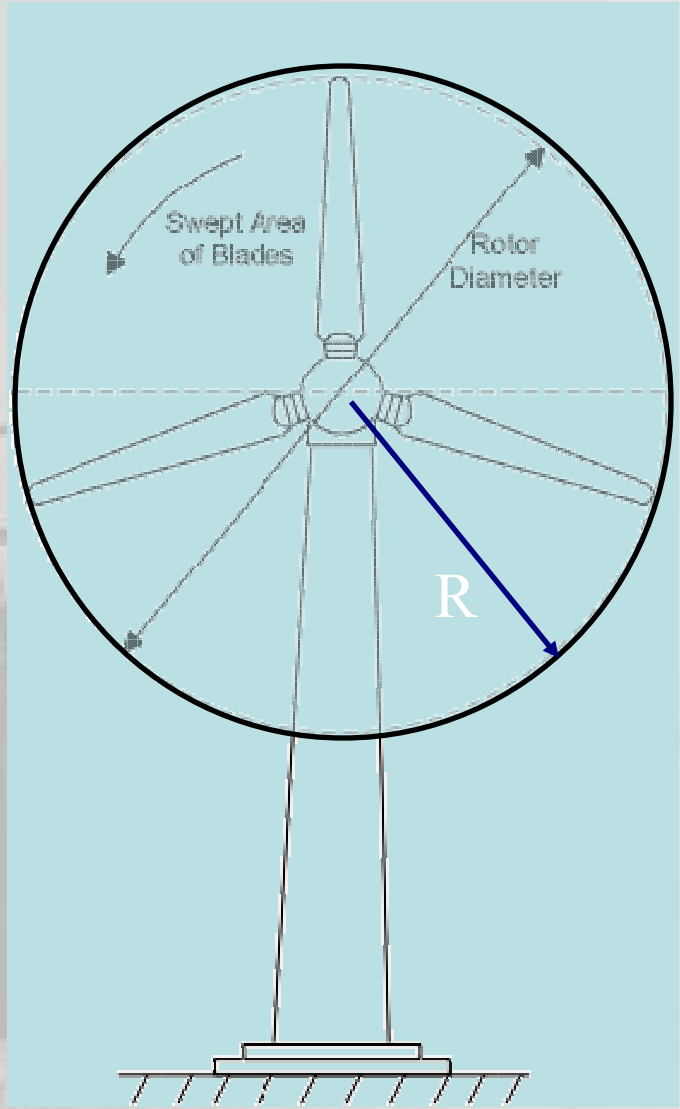
  $= \frac{1}{2} \rho A V^3$

  – Effect of air density, ρ

  – Effect of swept area, A

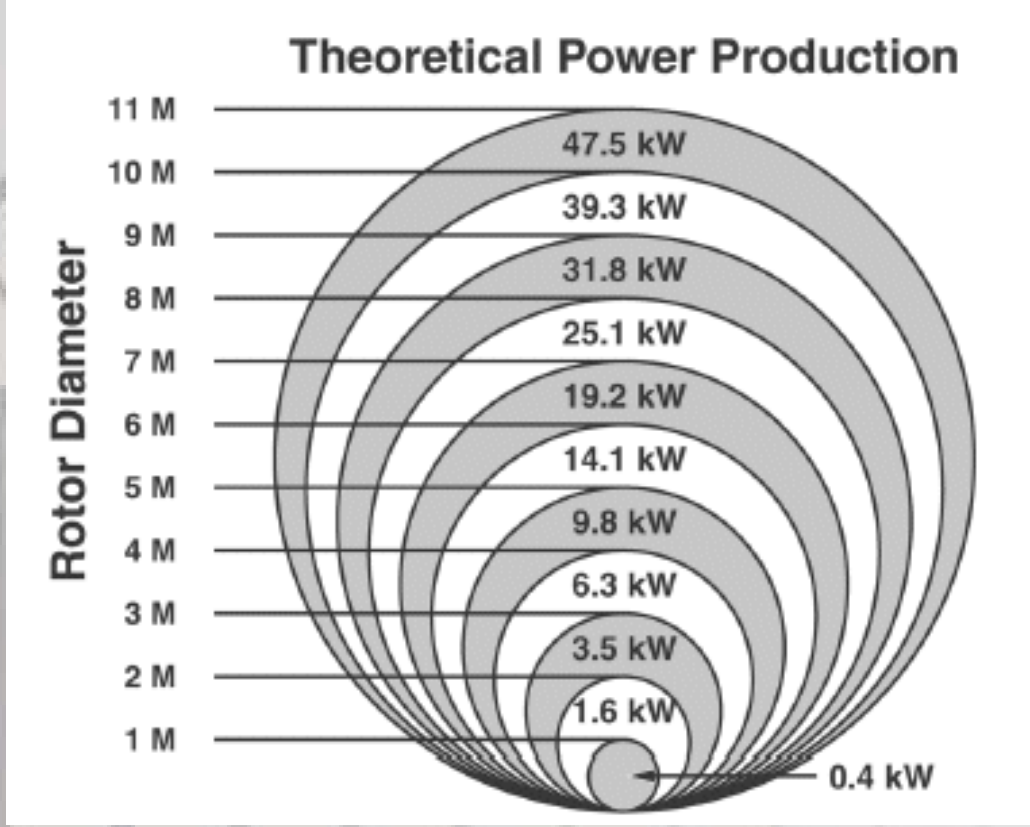
  – Effect of wind speed, V

Swept Area: $A = \pi R^2$
Area of the circle swept by the rotor (m^2).



Importance of Rotor Diameter

- Swept are is proportional to square of the rotor diameter
- 20% increase in rotor diameter increases area by 44%
- Doubling diameter increases area 4 times



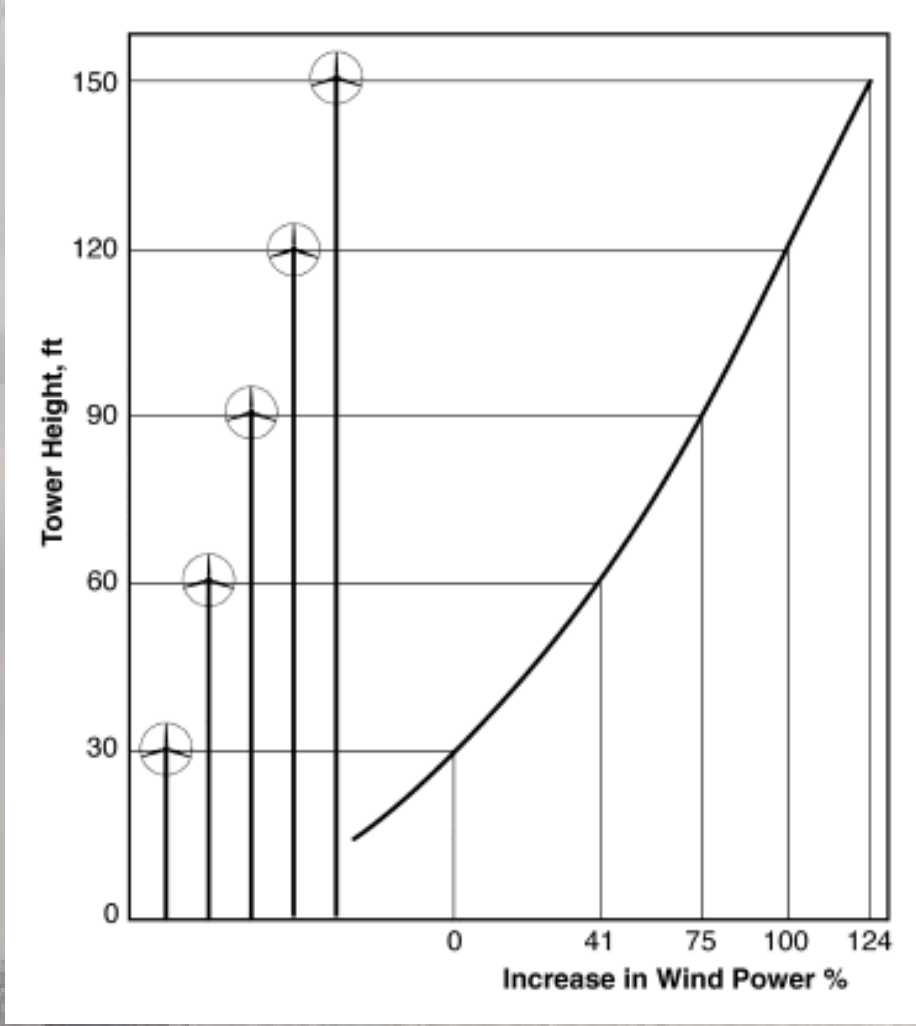
Importance of Wind Speed

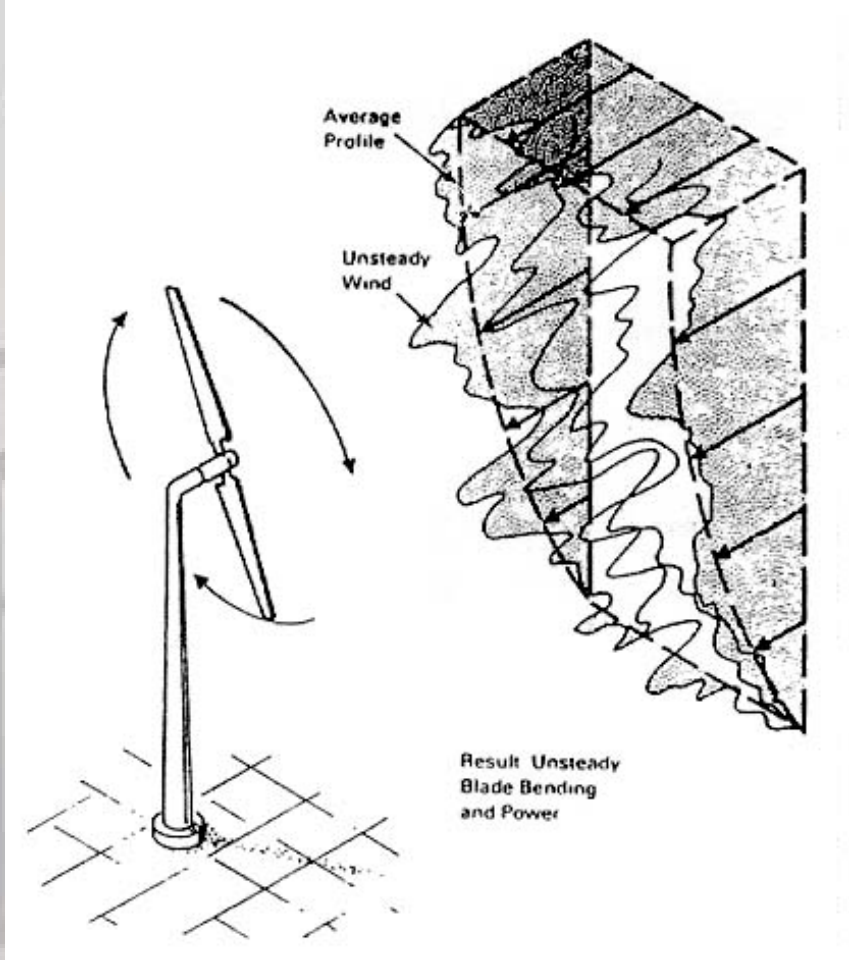
- **No other factor is more important to the amount of power available in the wind than the speed of the wind**
- Power is a cubic function of wind speed

  V x **V** x **V**
- 20% increase in wind speed means 73% more power
- Doubling wind speed means 8 times more power

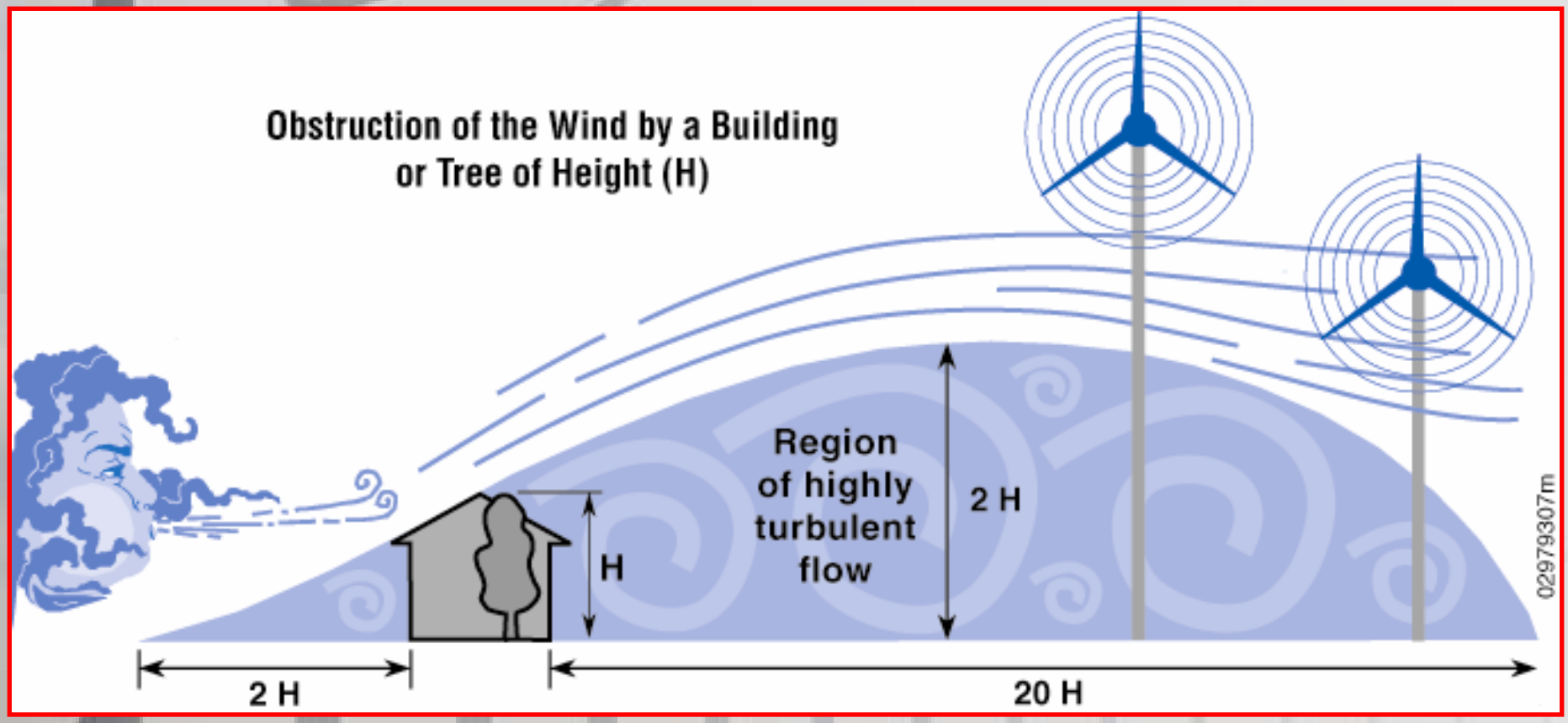
Wind Speed & Height

Higher means stronger, smoother wind





Effect of Obstructions



Some Concerns about Wind

(that can be addressed with proper information)

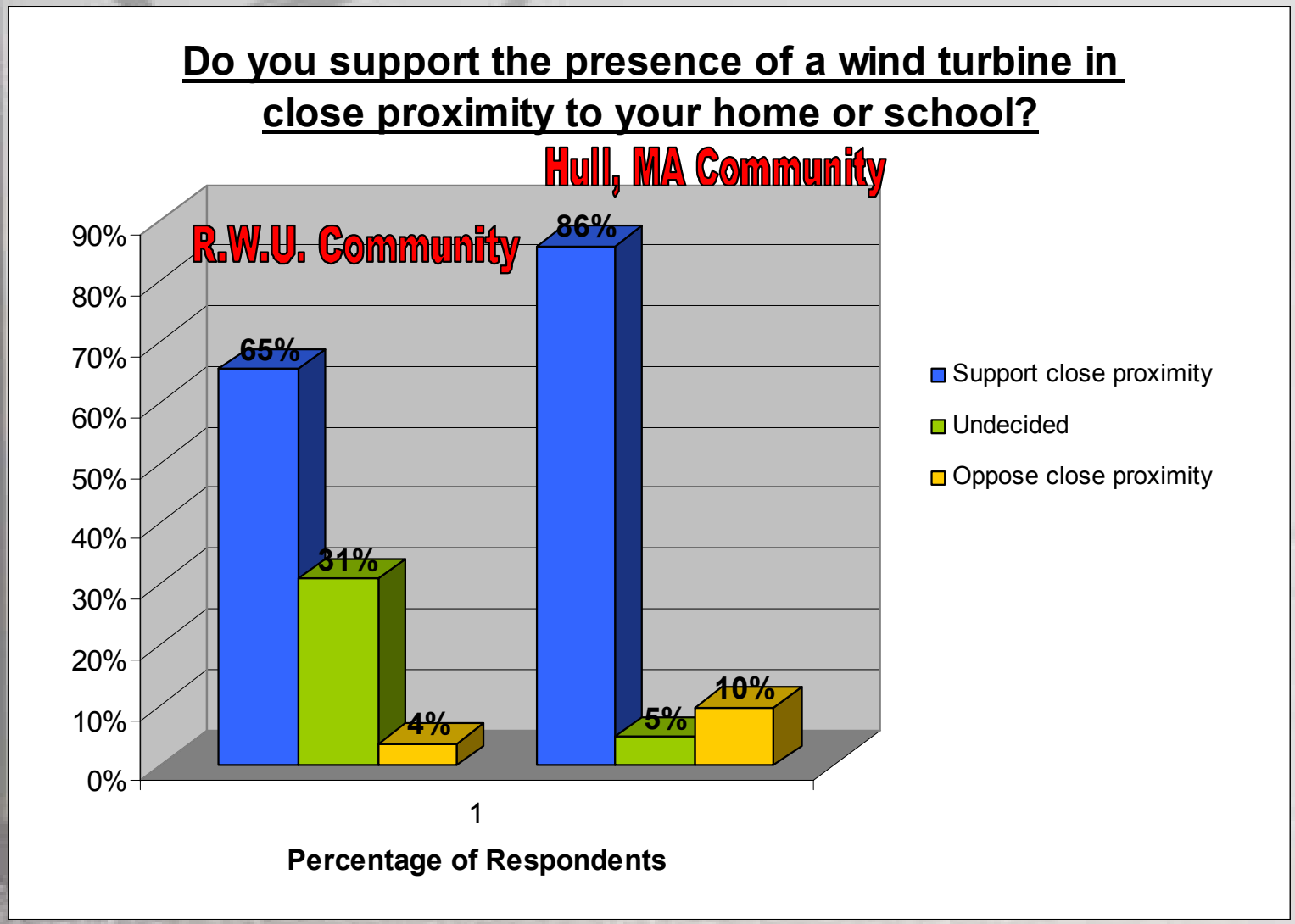
- Visual / Aesthetic
- Property Values
- Noise
- Birds
- Safety
- Are benefits real?

We should not compare wind energy to no wind energy

Visual Impact

- Many people think wind turbines are graceful, kinetic sculptures.”
- People who have never seen modern wind turbines in person are more likely to think they will be an eyesore.
- There are always people who complain about visual impacts before a project is built.
- Approval rates are higher after projects are built and in areas that already have turbines.

Approval Rates Increase with Actual Exposure to Technology



REimaginations
the beauty of power

celebrating the beauty of wind

Mark Beasley

Vermont Wind – Sabra Field

Quilt by Kathie Alyce

Power Plant by Alekxander Rodic

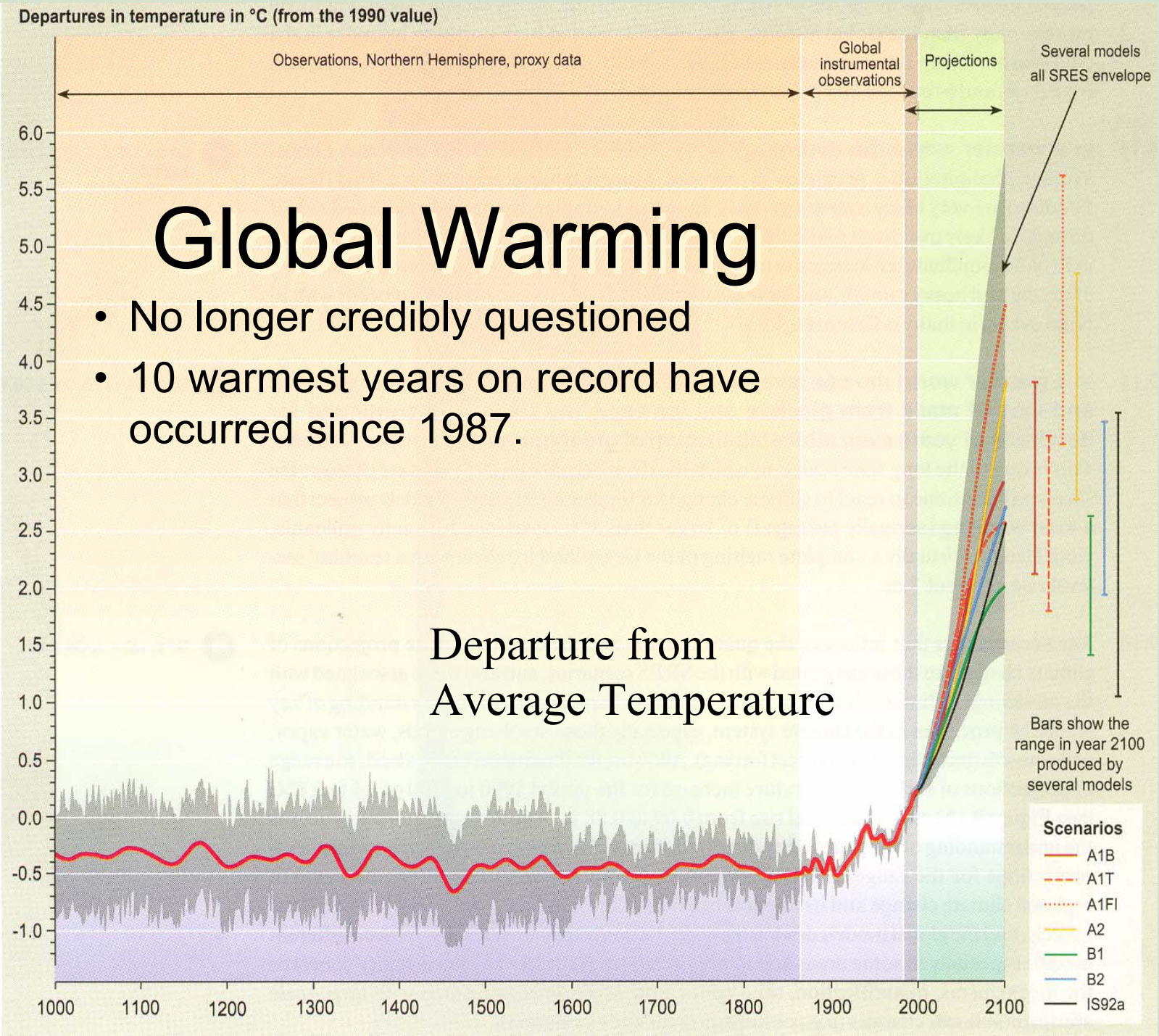
What about the birds?

- Wind Turbines kill very few birds compared to other human activities
- Estimates are ~1-2 bird deaths per turbine per year
- **Global warming is the single biggest threat to wildlife today**
- A recent study in Nature found that more than 1/3 of species worldwide will be extinct by 2050 if global warming trends continue

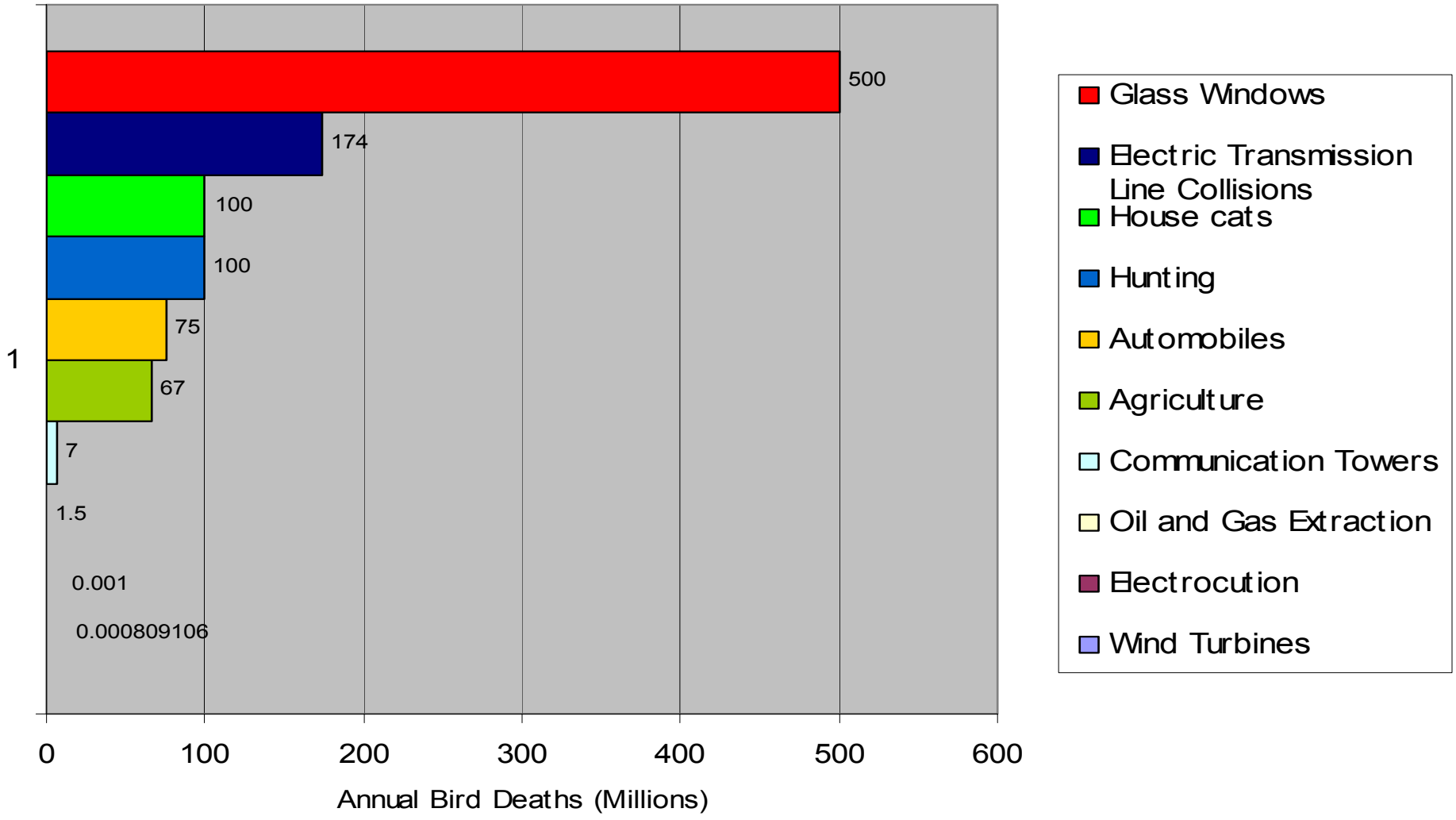
"As responsible citizens, stewards, and advocates, Mass Audubon strongly supports public policies and private projects that advance energy conservation and efficiency. We also support the development of wind farms, as a renewable energy source to offset the effects of global climate change produced by the burning of fossil fuels." *Sept. 21, 2004*

Global Warming

- No longer credibly questioned
- 10 warmest years on record have occurred since 1987.

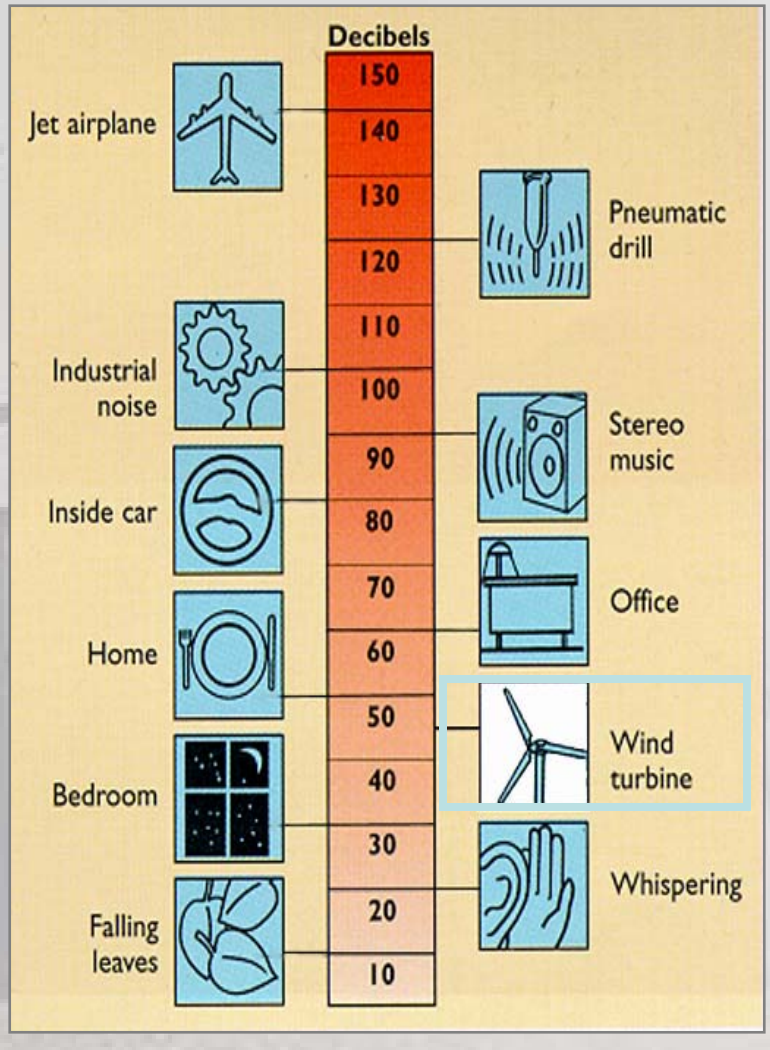


Bird deaths in perspective



Turbines are noisy, right?

- Older wind turbines are louder. Newer machines turn slower and are much quieter
- It is possible to hold a quiet conversation at the base of a modern wind turbine
- Go to MMA or Hull and listen!



Do wind farms impact tourism and property values?

Yes -- Positively.

There is **NO** evidence from existing wind facilities anywhere in the world (including locations very similar to Cape Cod that have offshore turbines) that wind turbines have a negative impact on property values or tourism.

In fact, the majority of studies conducted after wind farms have been built show that both tourism and property values increase!

Are Wind Turbines Unsafe?

- Not a single passerby has ever been injured by wind turbines
- There have been no collisions with turbines by any type of vehicle
- Ice shedding is very rare
  - When it occurs Ice falls near base of turbine -- not thrown far distances
- Only one member of the public has been killed by a wind turbine (a German parachutist on her first solo jump)

Wind turbine at Exhibition Place, Downtown Toronto

Are the benefits real?

- Back up Power?
  - Turbines do not require any new back up generation or spinning reserves.
- Emission reductions?
  - Wind energy is accepted on the grid before any other source when it is available, offsetting the need for more polluting sources. Each MWh of wind is one less MWh of electricity from a fossil fuel plant
- Economics?
  - Wind provides long-term price stability and is competitive with today's energy costs. Economic benefit is realized by whoever buys (and sells) the power.

What does it take to install a Turbine?

- Utility Engineers
- Geophysical Engineers
- Concrete/Structural Engineering
- Turbine Engineering (ME/EE/Aerospace)
- Site/Civil Engineering
- Microelectronic/Computer Programming
- Business Expertise (Financial)
- Legal Expertise
- Meteorologists

Carpe Ventum!