SMILE TEACHER WORKSHOP

RENEWABLE ENERGY: WIND

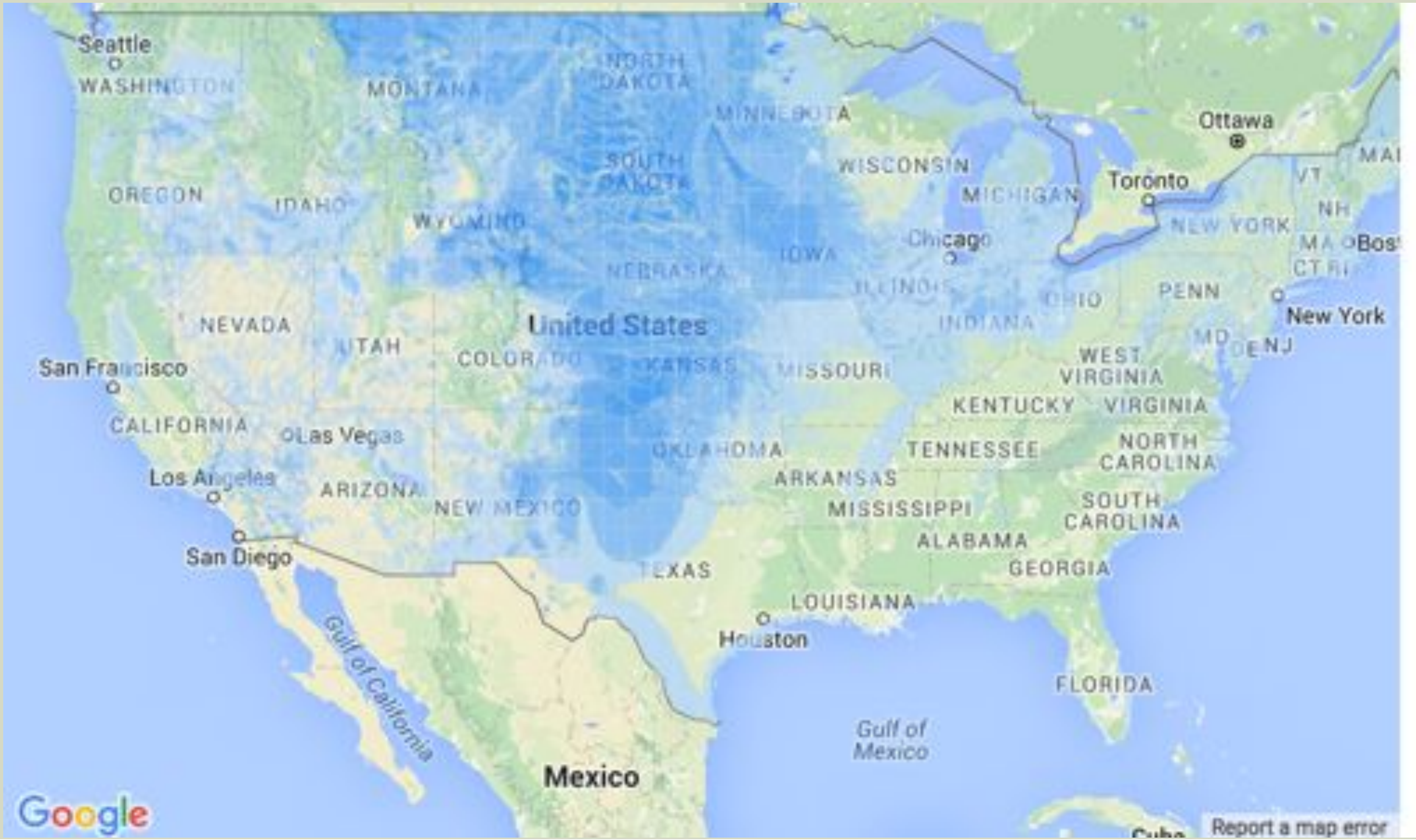
Winter 2016

MIKE BASICH – OFF-GRID CABIN

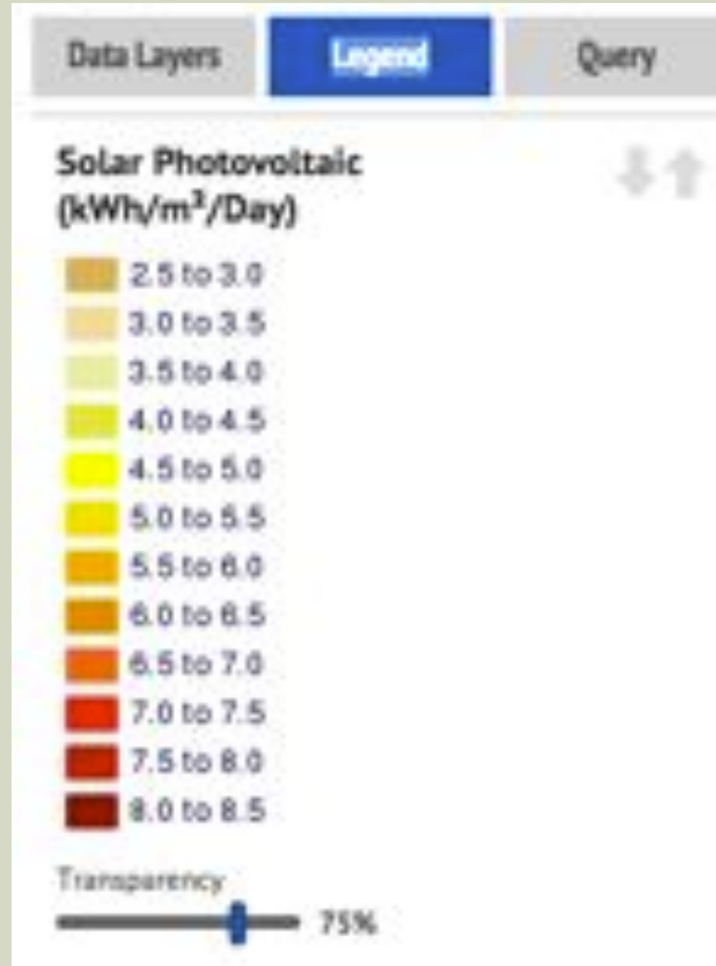
GEOGRAPHIC INFORMATION SYSTEMS

- Energy Living Lab
- Layers
- Legend
- Query
- What renewable energy source is best for your area

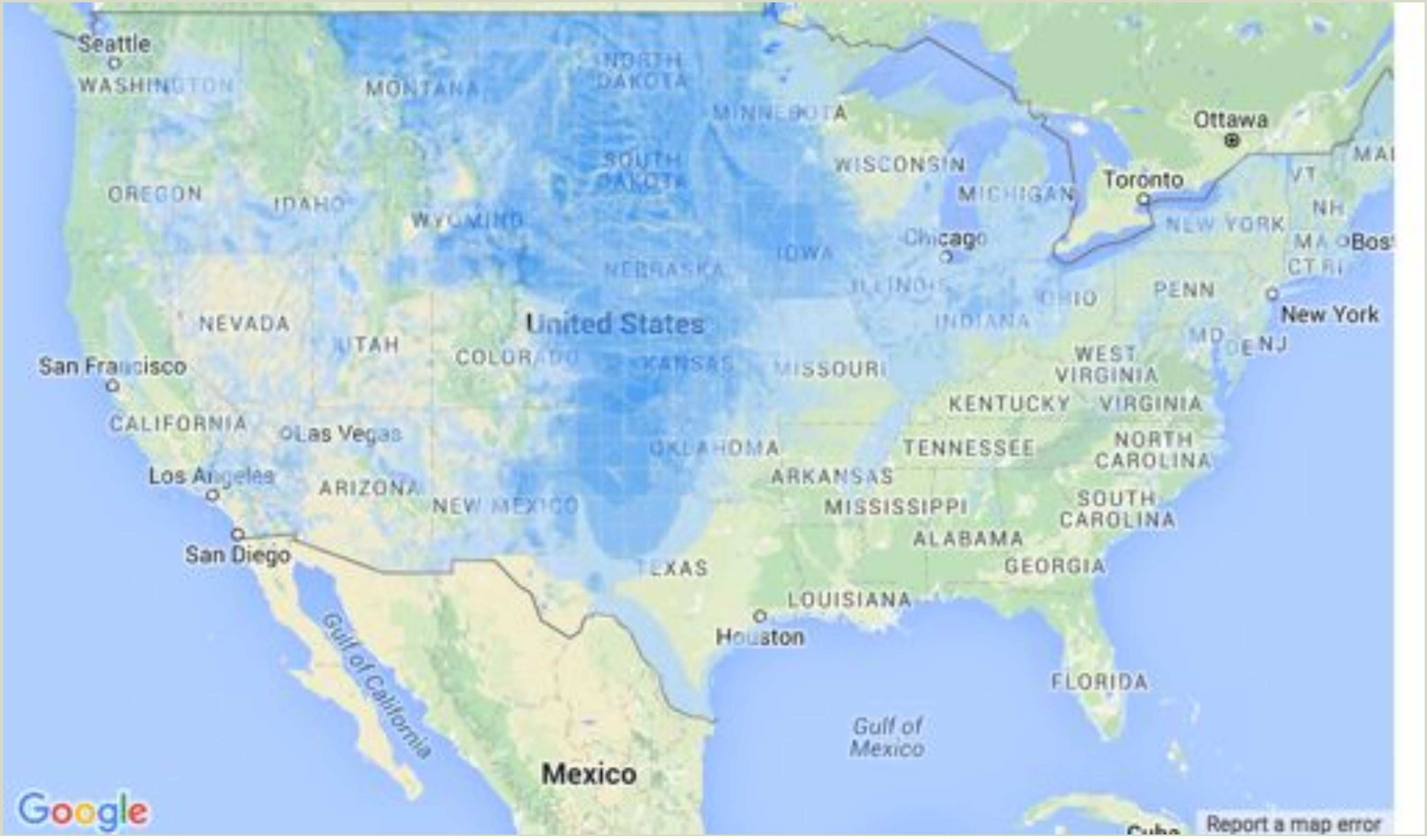
BEST LOCATION FOR WIND



QUERY / LEGEND



BEST LOCATION FOR WIND



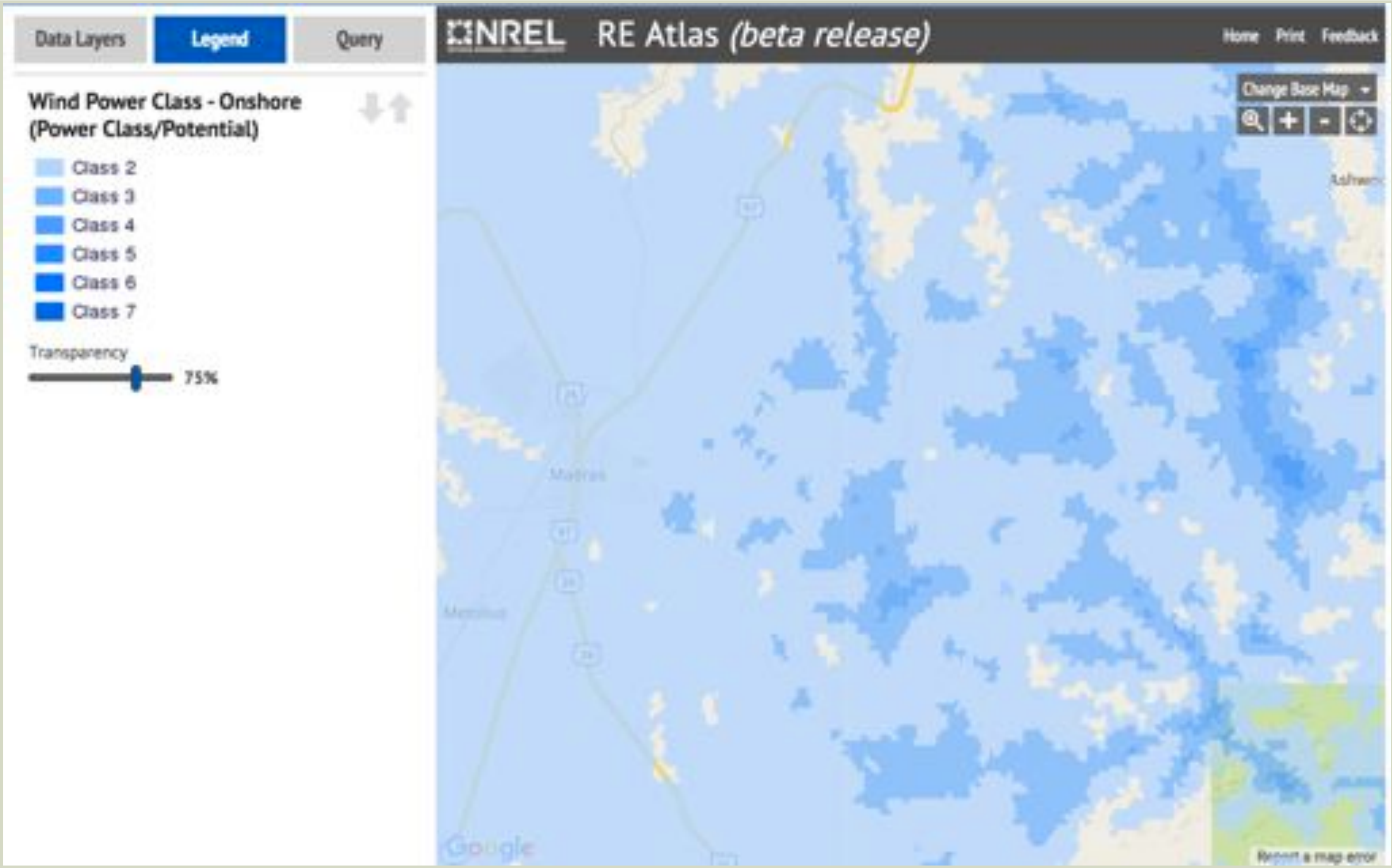
WIND IN OREGON

HOW TO MEASURE WIND ENERGY

Wind Power Class	At a height of 10 meters (33 ft)		Height of 50 meters (164 ft)	
	Wind Power Density (W/m2)	Speed m/s (mph)	Wind Power Density (W/m2)	Speed m/s (mph)
1	0 – 100	0 – 4.4 (9.8)	0 – 200	0 – 5.6 (12.5)
2	100 - 150	4.4 (9.8) – 5.1 (11.5)	200 - 300	5.6 (12.5) - 6.4 (14.3)
3	150 - 200	5.1 (11.5) – 5.6 (12.5)	300 - 400	6.4 (14.3) – 7.0 (15.7)
4	200 - 250	5.6 (12.5) – 6.0 (13.4)	400 - 500	7.0 (15.7)– 7.5 (16.8)
5	250 - 300	6.0 (13.4) – 6.4 (14.3)	500 - 600	7.5 (16.8) – 8.0 (17.9)
6	300 - 400	6.4 (14.3) – 7.0 (15.7)	600 - 800	8.0 (17.9) – 8.8 (19.7)
7	400 - 1000	7.0 (15.7) – 9.4 (21.1)	800 - 2000	8.8 (19.7) – 11.9 (26.6)

http://sizes.com/natural/wind_power_classes.htm

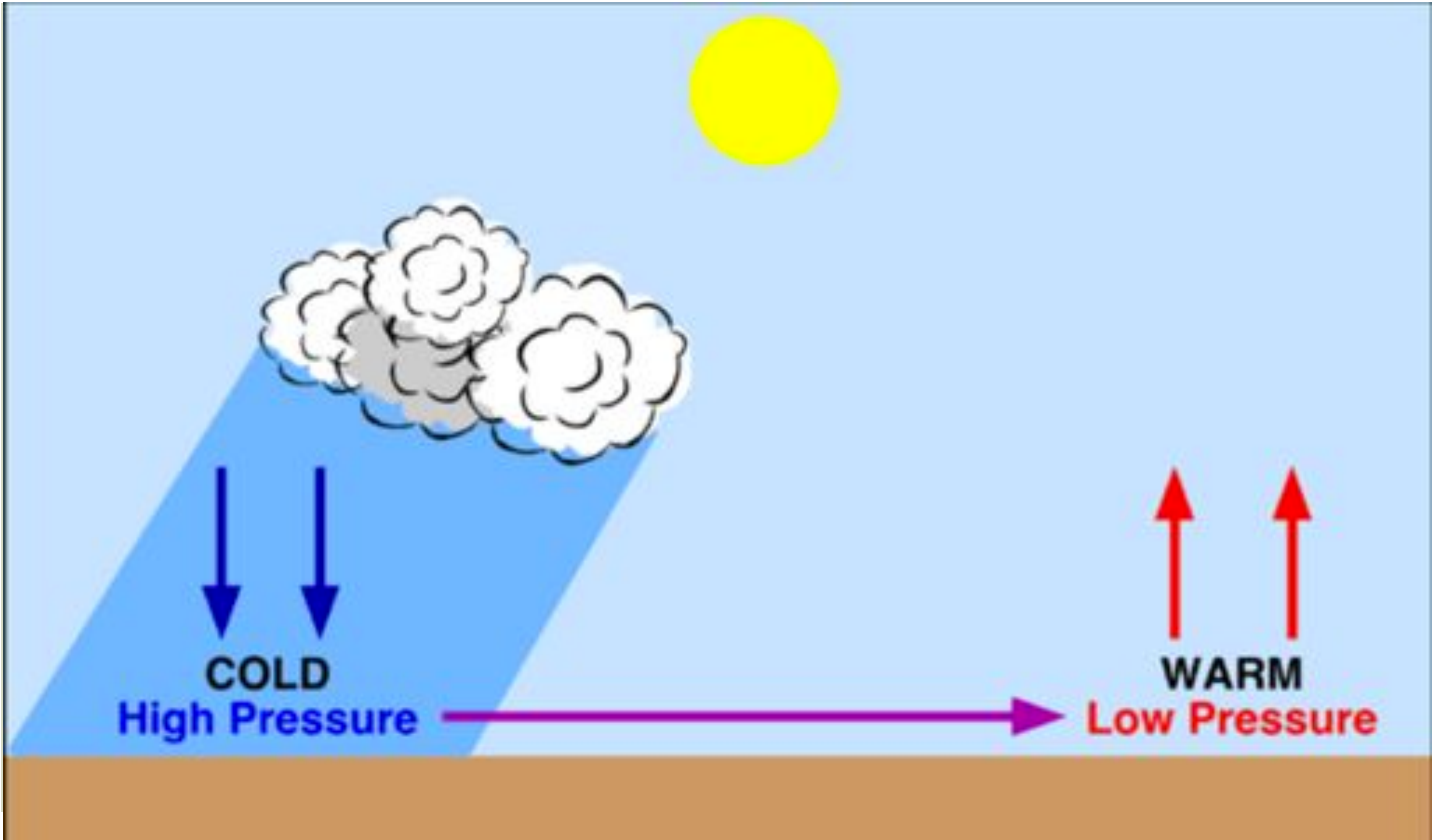
WIND IN YOUR AREA



WHAT CAUSES WIND?

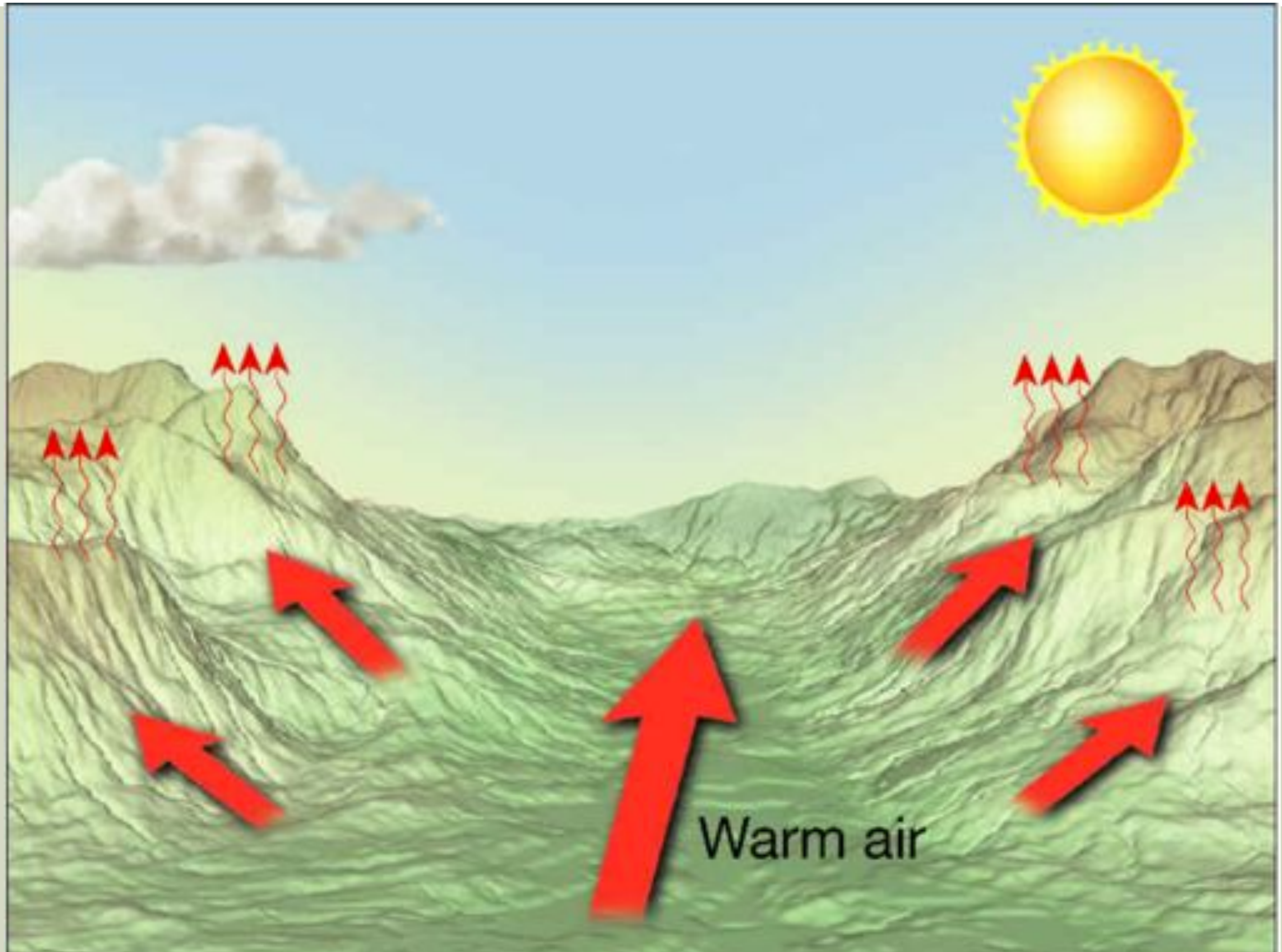
- Bottle Demo
- Groups: How would you explain what is happening?
- Groups: How could you apply this demo to wind?

WHAT POWERS THE WIND?

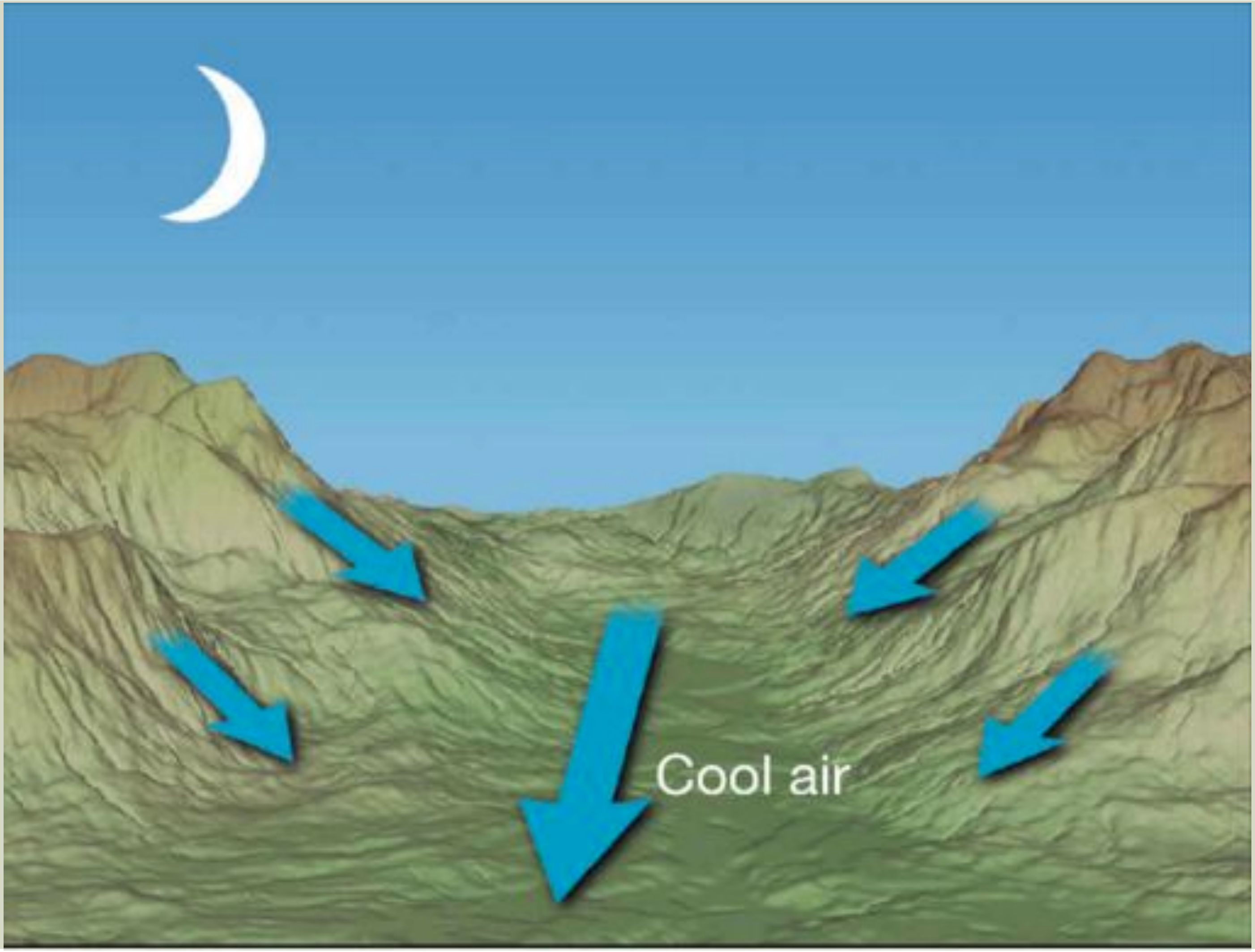


WHERE IS WIND HIGH?

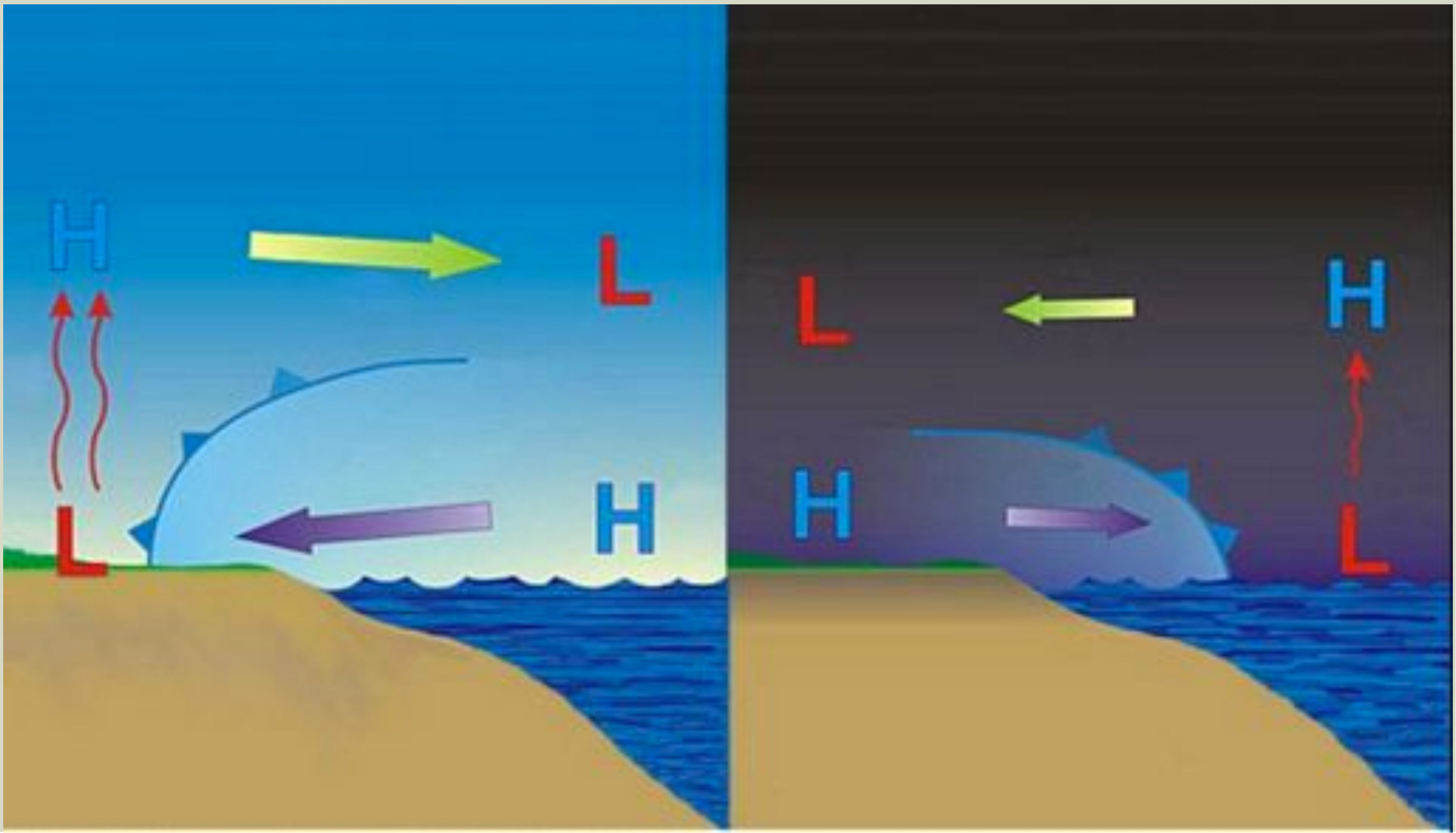
SCENARIO: VALLEY-MOUNTAIN DAY



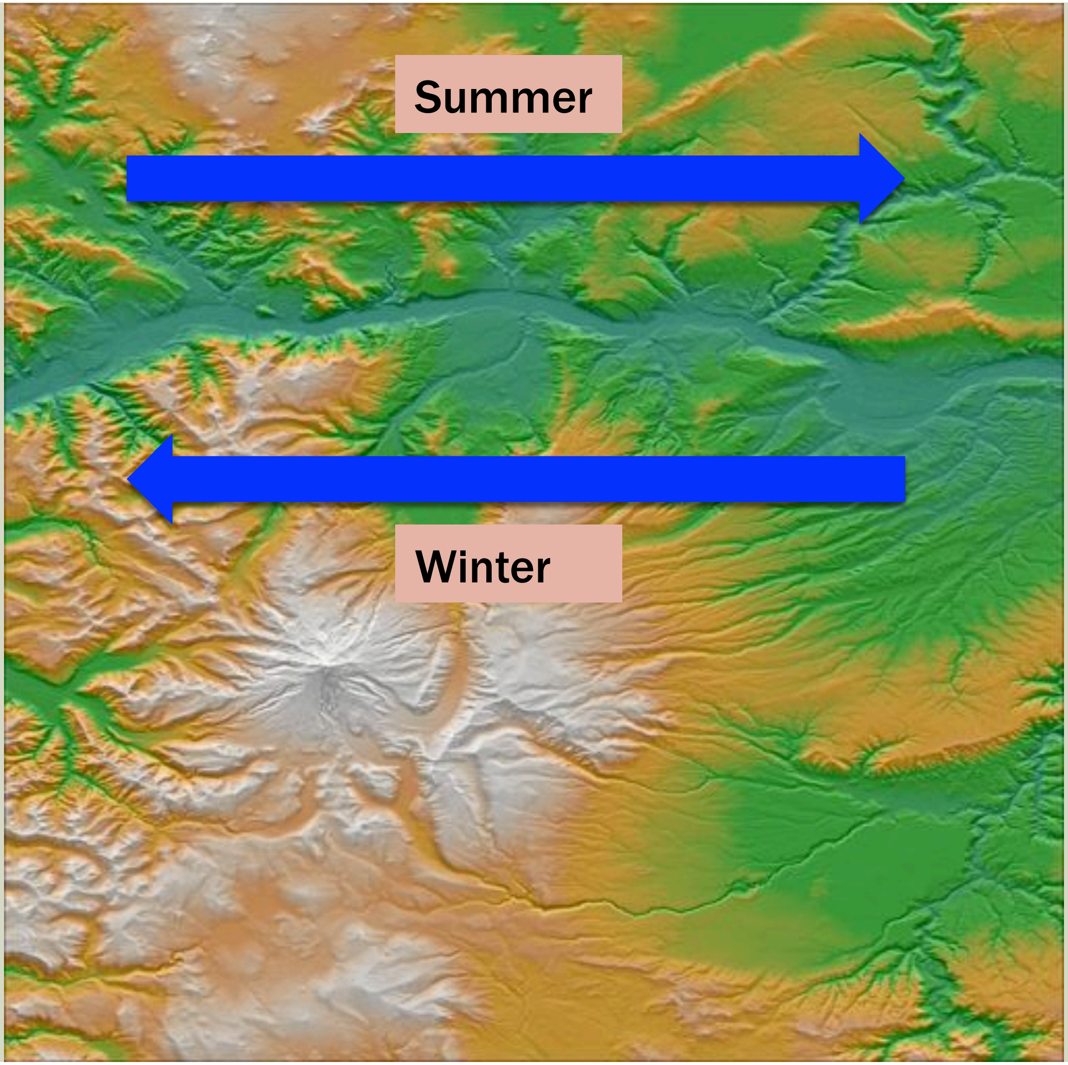
SCENARIO: VALLEY-MOUNTAIN NIGHT

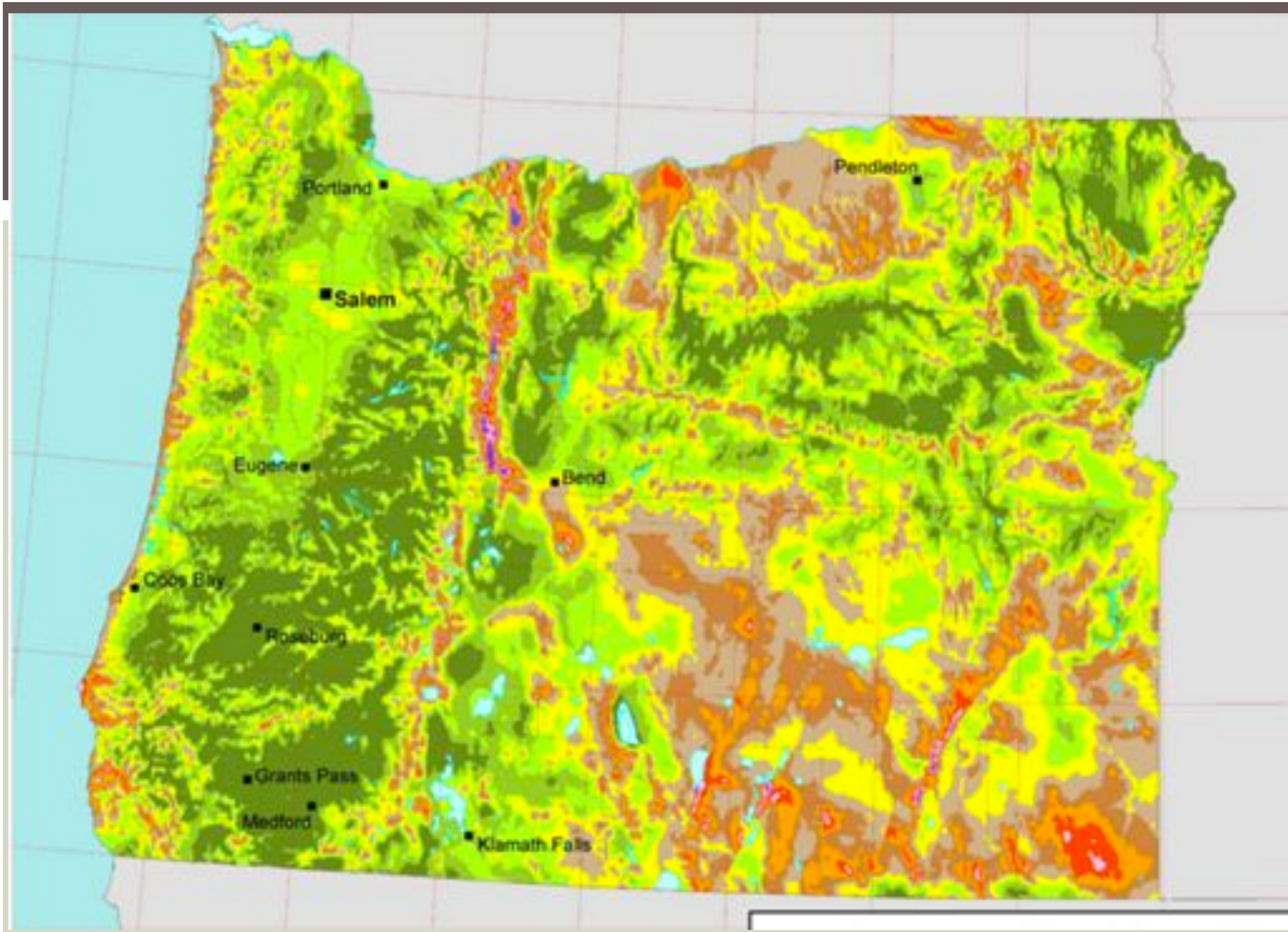


SCENARIO: COASTAL WIND



SCENARIO: COLUMBIA RIVER WIND




Portland
Pendleton
Salem
Eugene
Bend
Coos Bay
Roseburg
Grants Pass
Medford
Klamath Falls

WINDPOWER OREGON

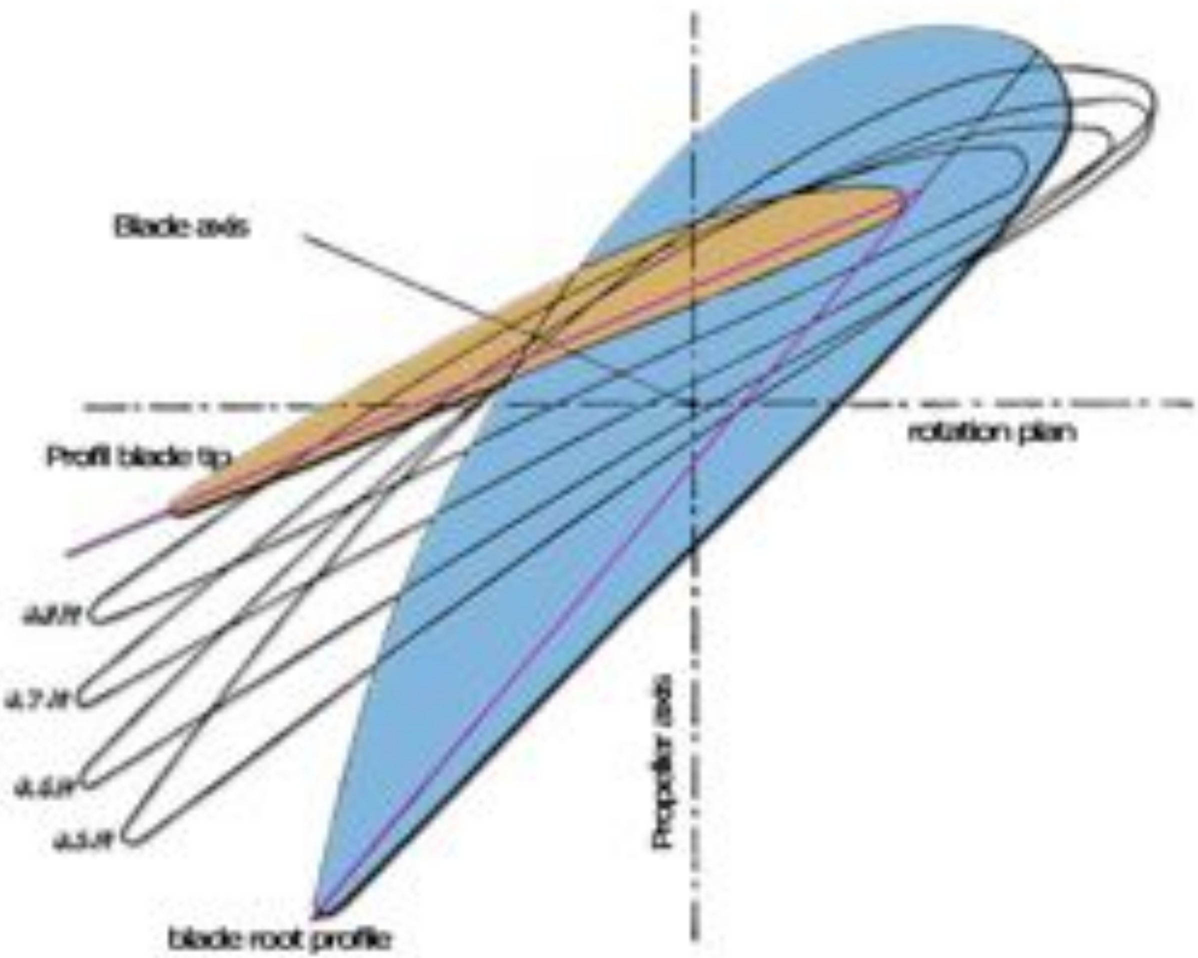
WHAT TYPE OF ENGINEER DESIGNS WIND TURBINES?

GROUP: HOW TO MEASURE POWER OUTPUT, CRITERIA?

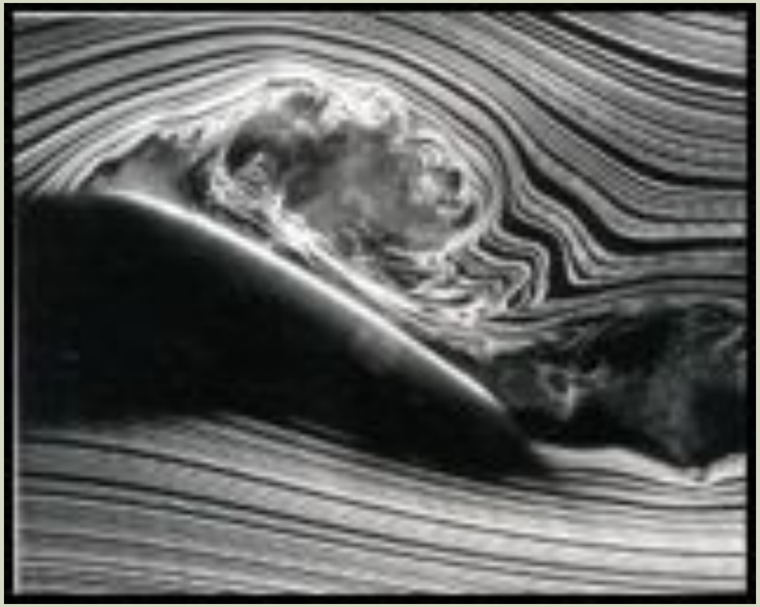
GROUP: WHAT VARIABLES IMPACT TURBINE POWER?

EXPERIMENT: WHAT PITCH IS OPTIMAL?

- Build wind kit
- Build 3 blade turbine
- Figure out multimeter
- Test:
  - Extreme
  - Mid
  - Extreme
  - Others

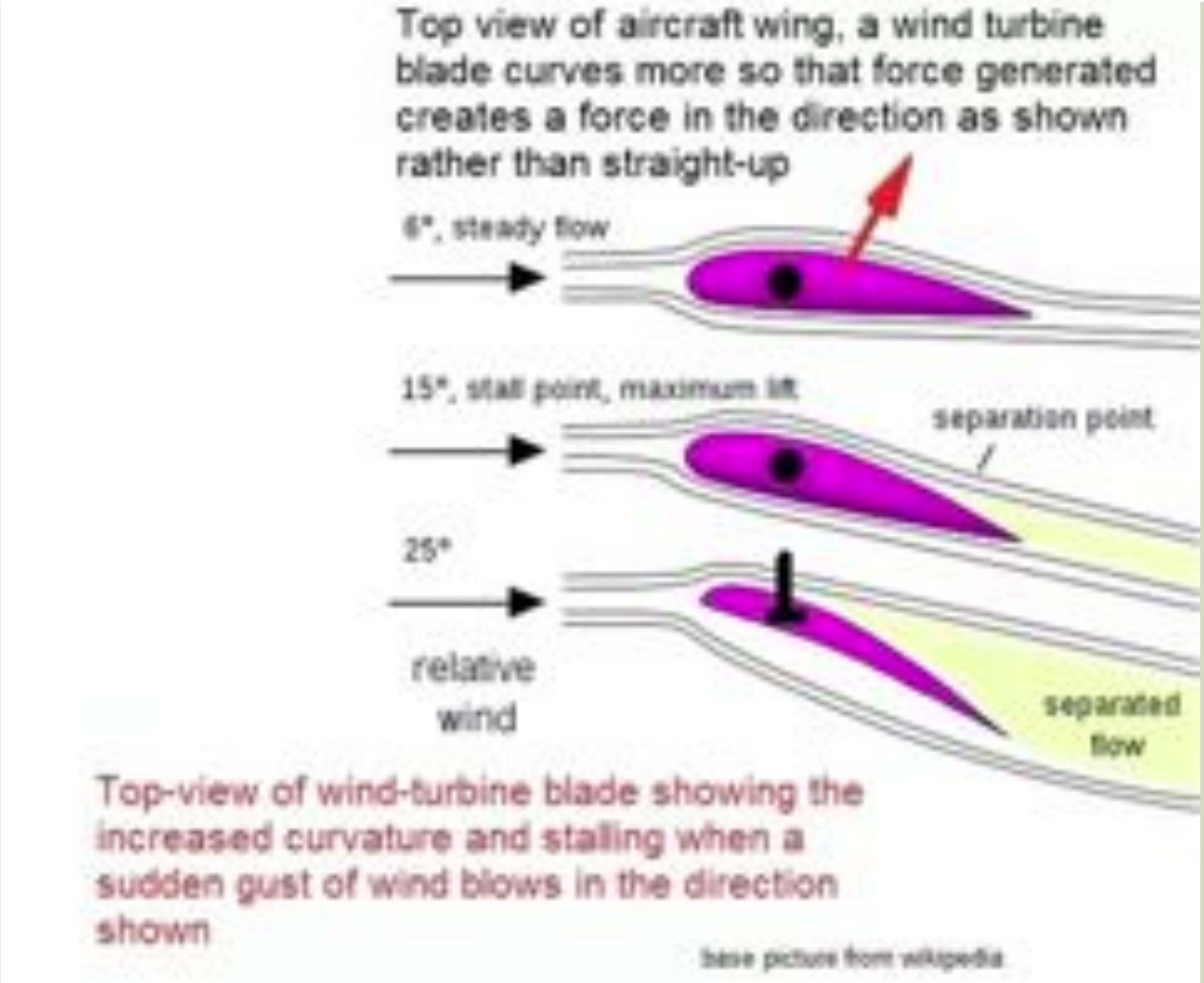


Airfoil in stall



- Stall arises due to separation of flow from airfoil

AIRCRAFT WING



LIFT & DRAG FORCES

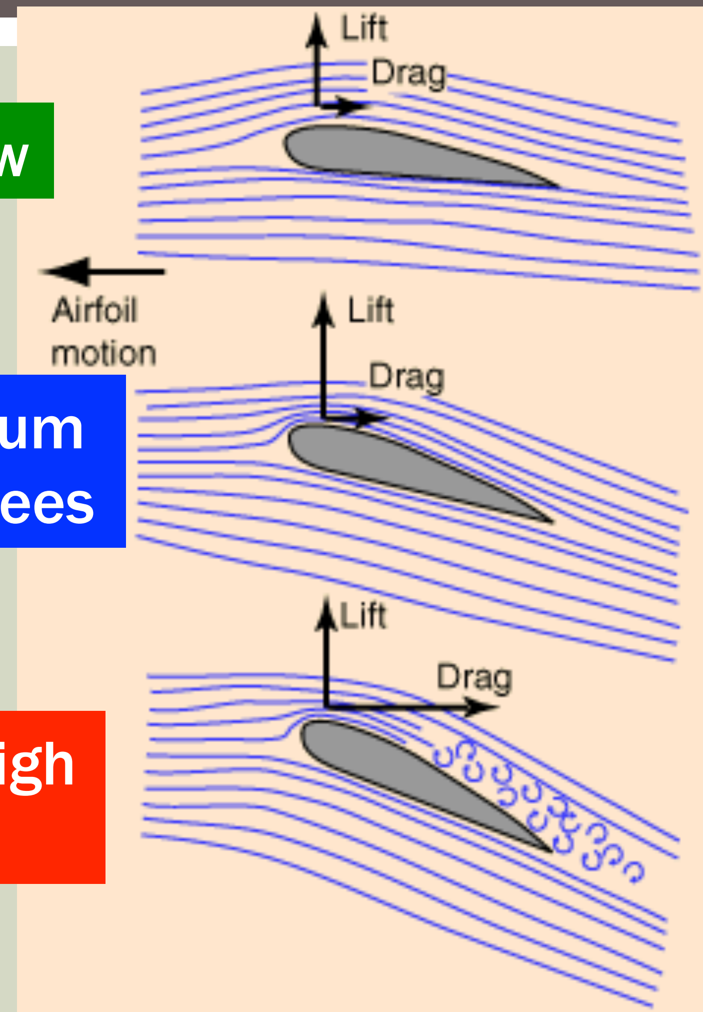
- The *Lift Force* is perpendicular to the direction of motion. We want to make this force BIG.

- The *Drag Force* is parallel to the direction of motion. We want to make this force small.

α = low

α = medium
<10 degrees

α = High
Stall!!



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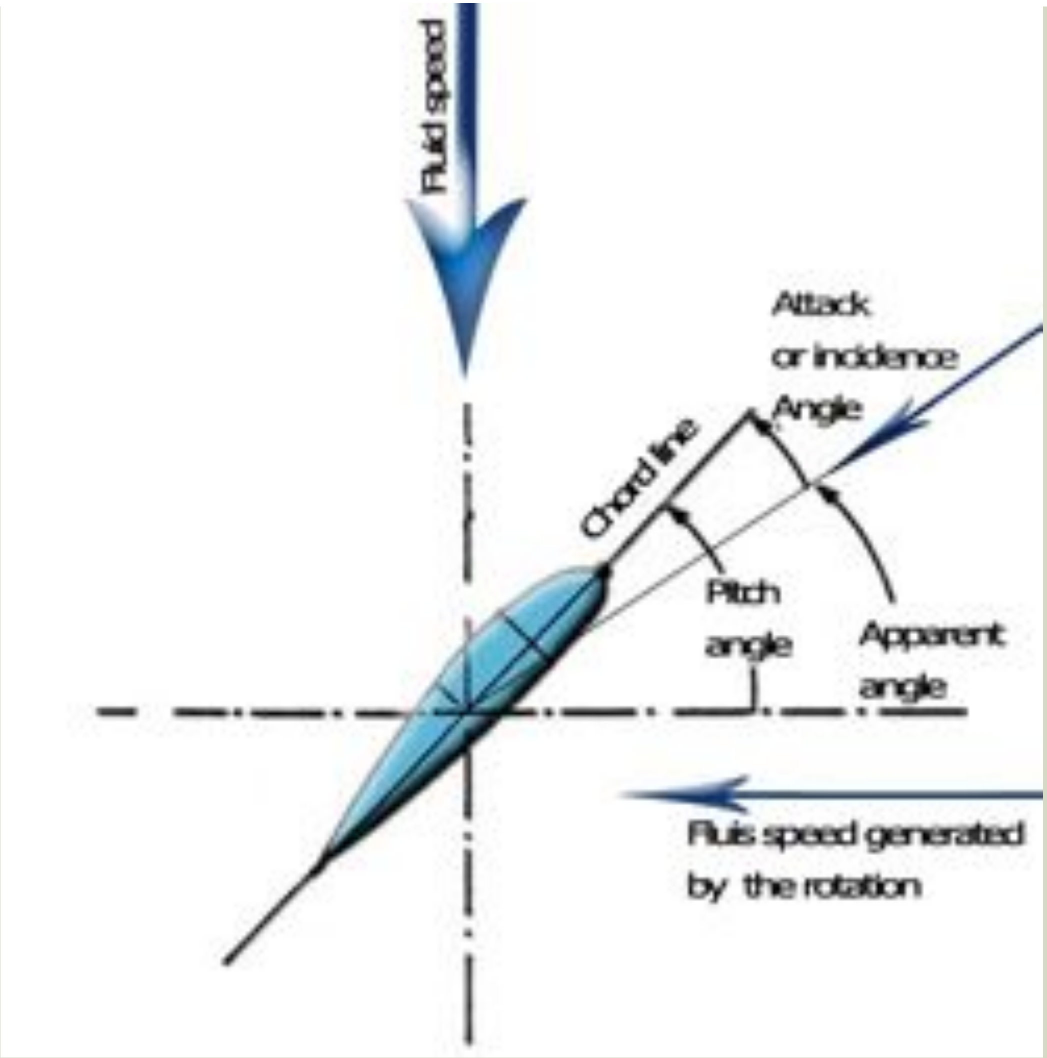
APPARENT ANGLE OF ATTACK



EXPERIMENT:
WHAT IS THE OPTIMAL # BLADES

NUMBER OF BLADES – ONE

- Rotor must move more rapidly to capture same amount of wind
  - Gearbox ratio reduced
  - Added weight of counterbalance negates some benefits of lighter design
  - Higher speed means more noise, visual, and wildlife impacts
- Blades easier to install because entire rotor can be assembled on ground
- Captures 10% less energy than two blade design
- Ultimately provide no cost savings

NUMBER OF BLADES - TWO

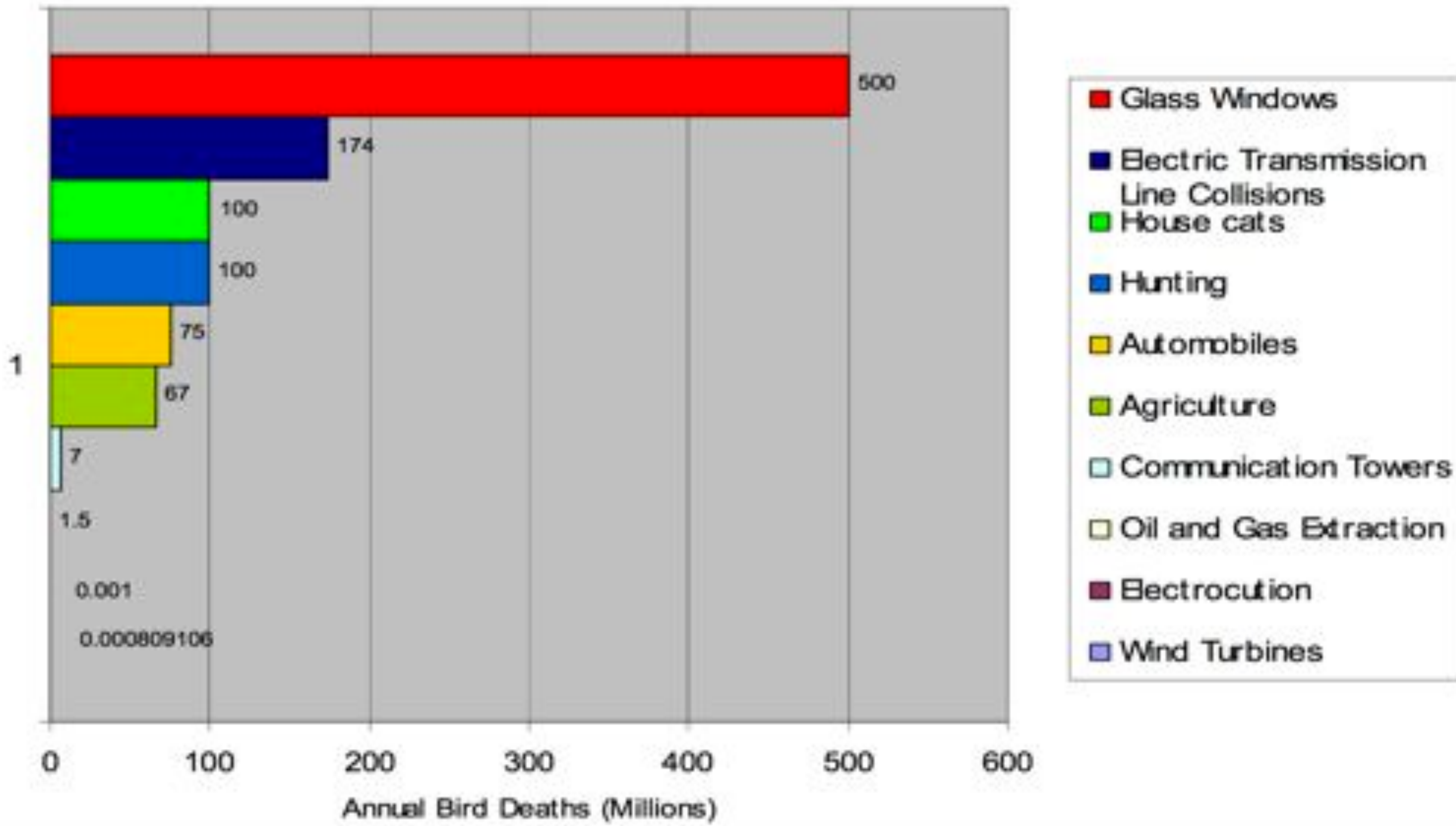
- Advantages & disadvantages similar to one blade
- Need teetering hub and or shock absorbers because of gyroscopic imbalances
- Capture 5% less energy than three blade designs

NUMBER OF BLADES - THREE

- Balance of gyroscopic forces
- Slower rotation
  - increases gearbox & transmission costs
  - More aesthetic, less noise, fewer bird strikes

PUTTING IT TOGETHER

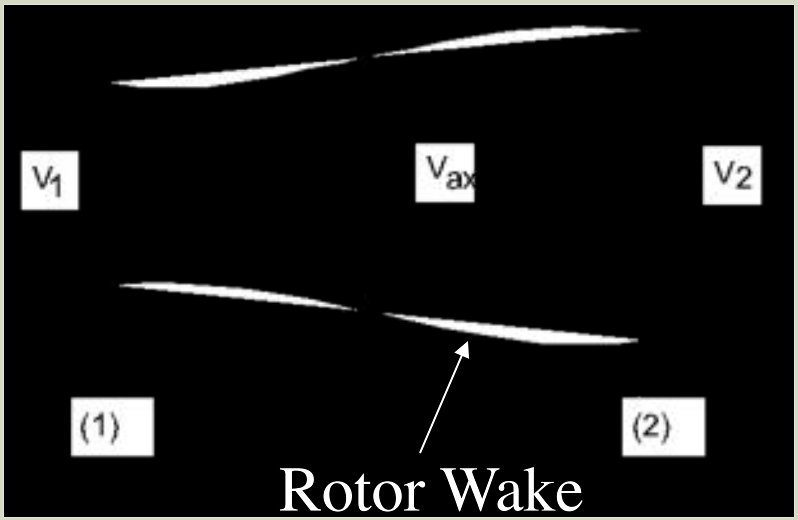
PROBLEMS WITH WIND POWER?



ADVANCED: BETZ LIMIT

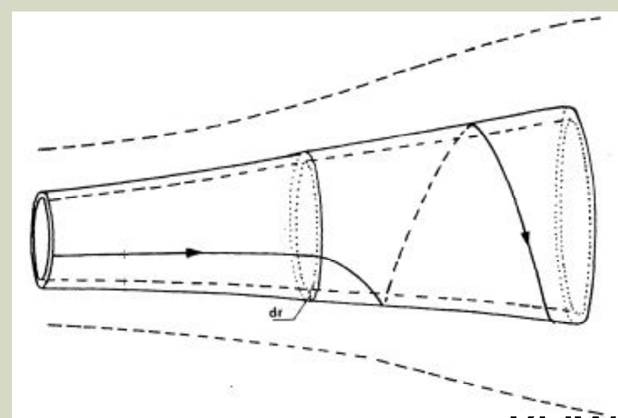
- All wind power cannot be captured by rotor or air would be completely still behind rotor and not allow more wind to pass through.
- Theoretical limit of rotor efficiency is 59%

Rotor Disc

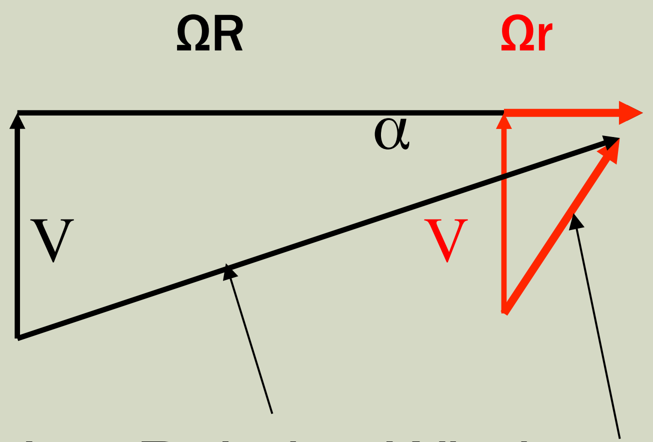


Betz Limit

$$C_{p,max} = \frac{16}{27} = .5926$$



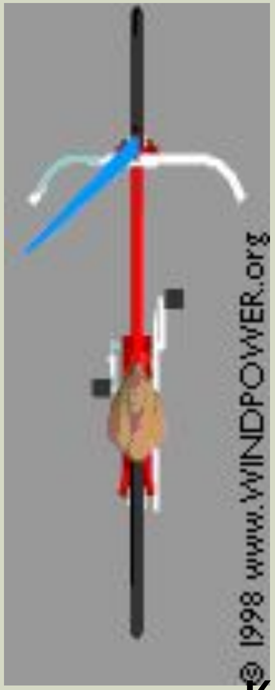
APPARENT WIND & ANGLE OF ATTACK



V_R = Relative Wind

α = angle of attack = angle between the chord line and the direction of the relative wind, V_R .

V_R = wind speed seen by the airfoil – vector sum of V (free stream wind) and ΩR (tip speed).



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TIP-SPEED RATIO

- Tip-speed ratio is the ratio of the speed of the rotating blade tip to the speed of the free stream wind.
- There is an optimum angle of attack which creates the highest lift to drag ratio.
- Because angle of attack is dependant on wind speed, there is an optimum tip-speed ratio

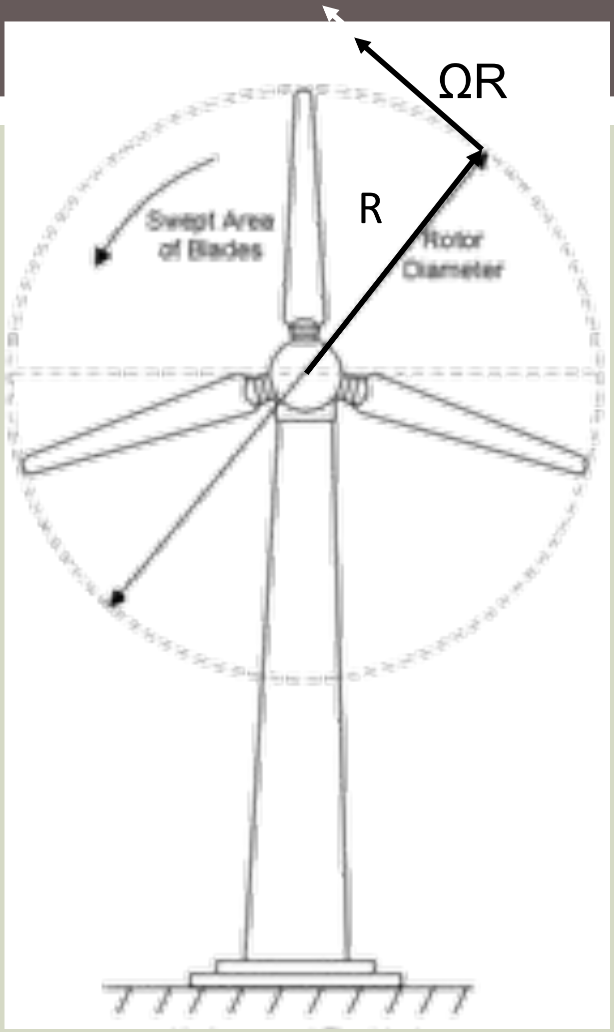
$$TSR = \frac{\Omega R}{V}$$

Where,

Ω = rotational speed in radians /sec

R = Rotor Radius

V = Wind "Free Stream" Velocity



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