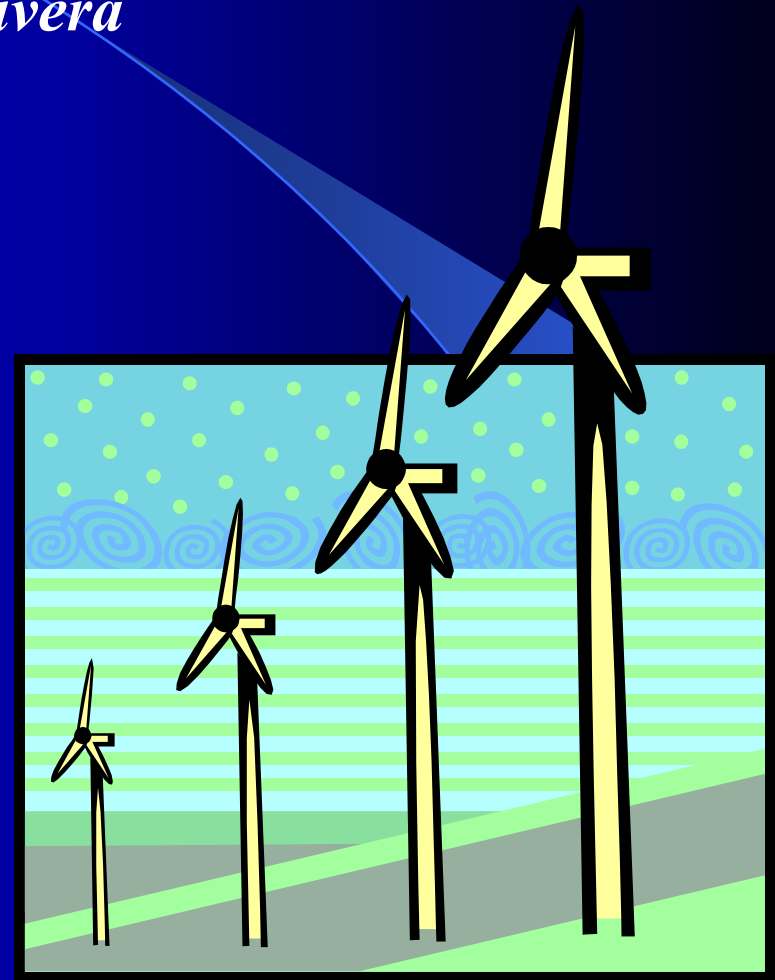


WIND POWER

By: *Roger Rivera*

- What is it?
- How does it work?
- Efficiency
- U.S. Stats and Examples

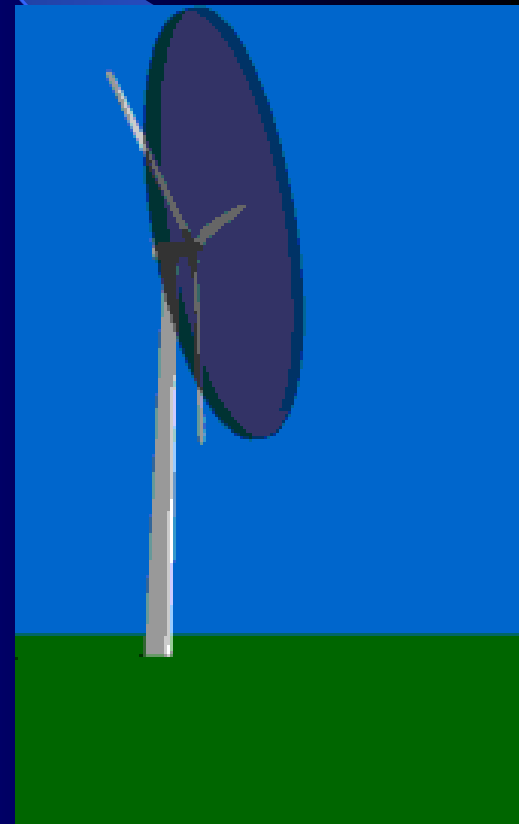


WIND POWER - What is it?

- All renewable energy (except tidal and geothermal power), ultimately comes from the sun
- The earth receives 1.74×10^{17} watts of power (per hour) from the sun
- About one or 2 percent of this energy is converted to wind energy (which is about 50-100 times more than the energy converted to biomass by all plants on earth)
- Differential heating of the earth's surface and atmosphere induces vertical and horizontal air currents that are affected by the earth's rotation and contours of the land → WIND.
~ e.g.: Land Sea Breeze Cycle



- Winds are influenced by the ground surface at altitudes up to 100 meters.
- Wind is slowed by the surface roughness and obstacles.
- When dealing with wind energy, we are concerned with surface winds.
- A wind turbine obtains its power input by converting the force of the wind into a torque (turning force) acting on the rotor blades.
- The amount of energy which the wind transfers to the rotor depends on the density of the air, the rotor area, and the wind speed.
- The kinetic energy of a moving body is proportional to its mass (or weight). The kinetic energy in the wind thus depends on the density of the air, i.e. its mass per unit of volume. In other words, the "heavier" the air, the more energy is received by the turbine.
- at 15° Celsius air weighs about 1.225 kg per cubic meter, but the density decreases slightly with increasing humidity.

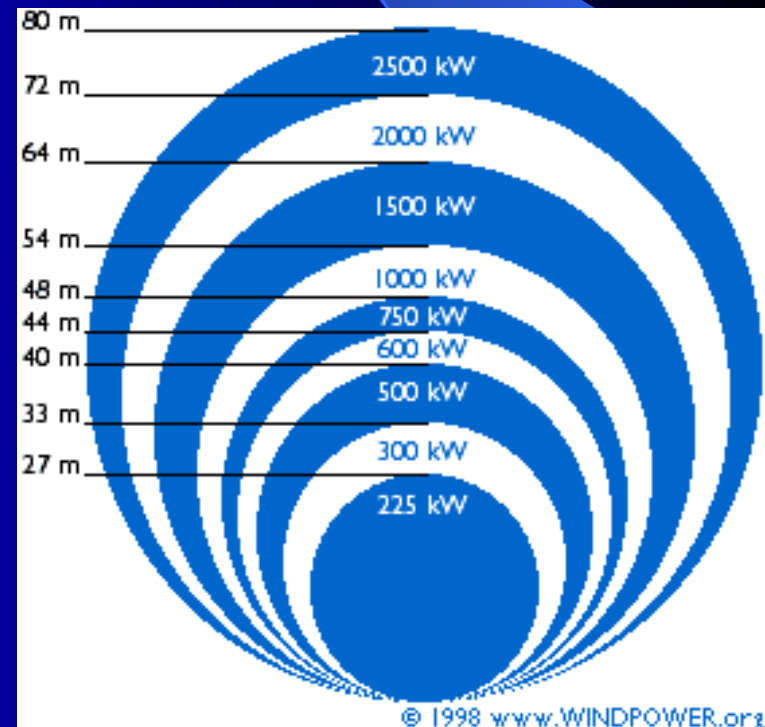


➤ A typical 600 kW wind turbine has a rotor diameter of 43-44 meters, i.e. a rotor area of some 1,500 square meters.

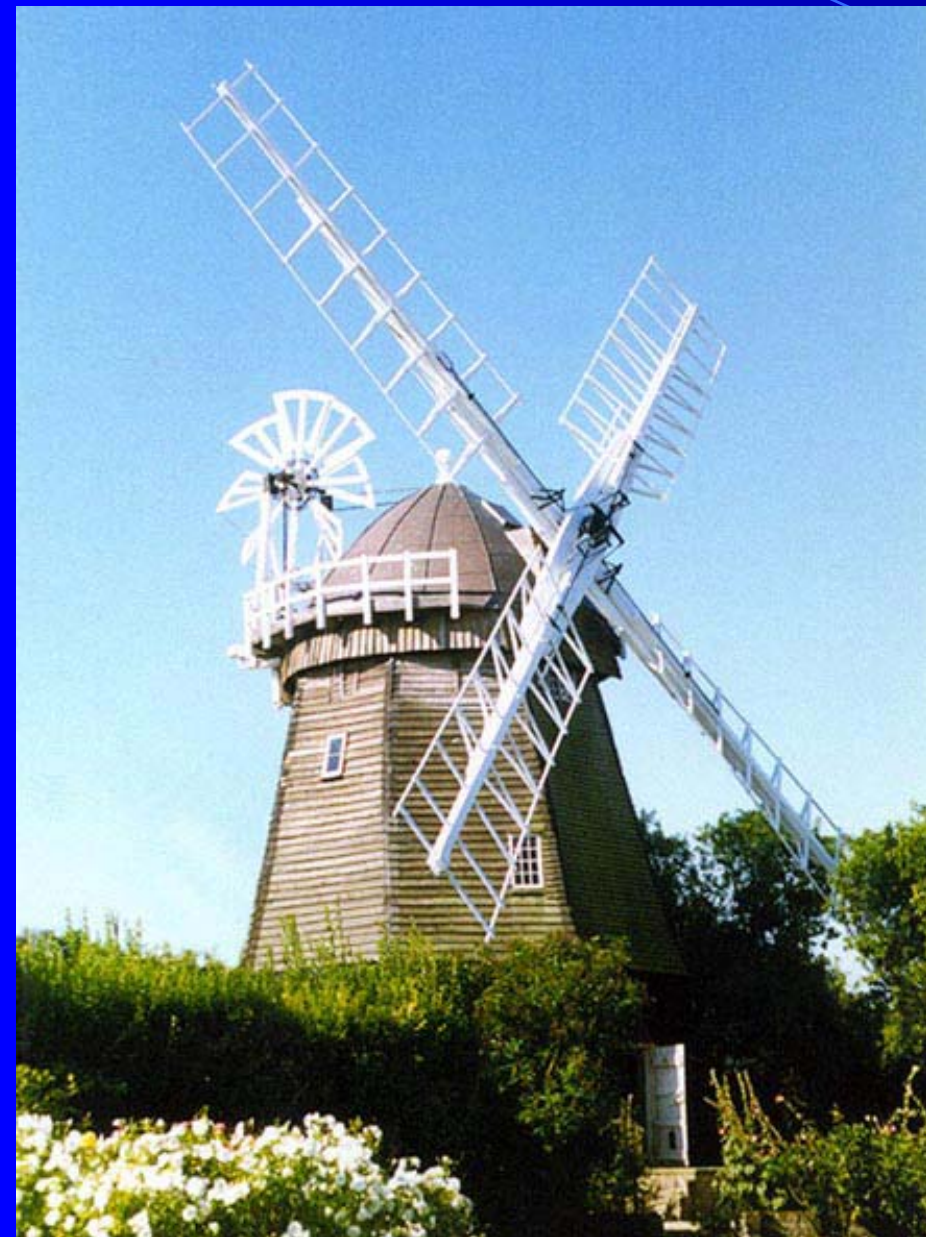
➤ The rotor area determines how much energy a wind turbine is able to harvest from the wind.

➤ Since the rotor area increases with the square of the rotor diameter, a turbine which is twice as large will receive $2^2 = 2 \times 2 =$ four times as much energy.

➤ To be considered a good location for wind energy, an area needs to have average annual wind speeds of at least 12 miles per hour.



WINDMILL DESIGN



- A Windmill captures wind energy and then uses a generator to convert it to electrical energy.
- The design of a windmill is an integral part of how efficient it will be.
- When designing a windmill, one must decide on the size of the turbine, and the size of the generator.

Wind Turbines

LARGE TURBINES:

- Able to deliver electricity at lower cost than smaller turbines, because foundation costs, planning costs, etc. are independent of size.
- Well-suited for offshore wind plants.
- In areas where it is difficult to find sites, one large turbine on a tall tower uses the wind extremely efficiently.



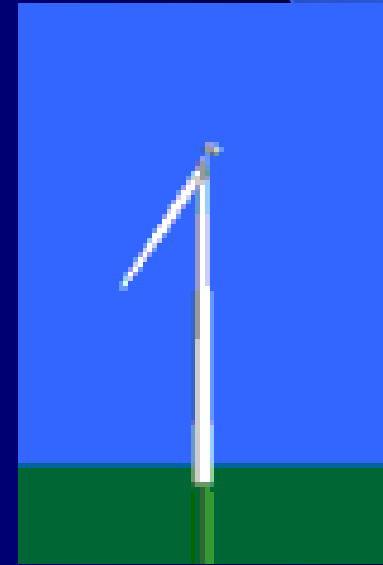
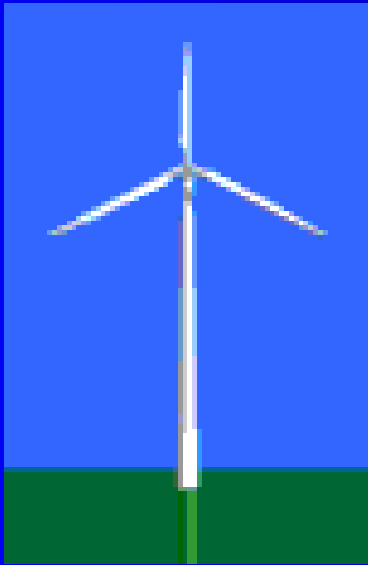
SMALL TURBINES:

- Local electrical grids may not be able to handle the large electrical output from a large turbine, so smaller turbines may be more suitable.
- High costs for foundations for large turbines may not be economical in some areas.
- Landscape considerations

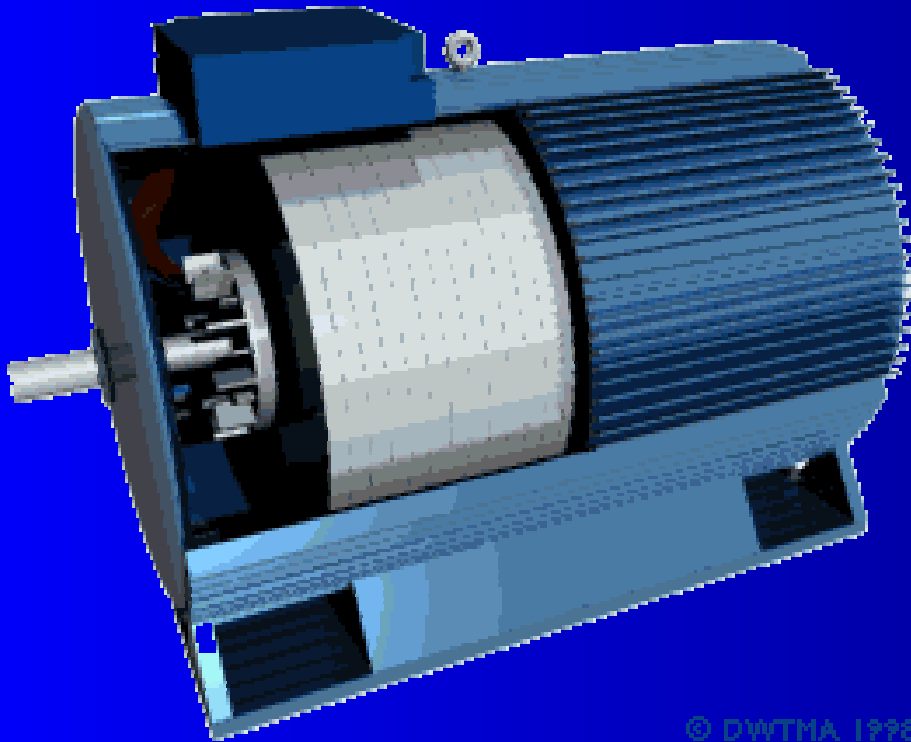


Wind Turbines: Number of Blades

- ❑ Most common design is the three-bladed turbine. The most important reason is the **stability** of the turbine. A rotor with an odd number of rotor blades (and at least three blades) can be considered to be similar to a disc when calculating the dynamic properties of the machine.
- ❑ A rotor with an even number of blades will give stability problems for a machine with a stiff structure. The reason is that at the very moment when the uppermost blade bends backwards, because it gets the maximum power from the wind, the lowermost blade passes into the wind shade in front of the tower.



Wind Turbine Generators



© DWTHA 1998

- Wind power generators convert wind energy (mechanical energy) to electrical energy.
- The generator is attached at one end to the wind turbine, which provides the mechanical energy.
- At the other end, the generator is connected to the electrical grid.
- The generator needs to have a cooling system to make sure there is no overheating.

SMALL GENERATORS:

- Require less force to turn than a larger ones, but give much lower power output.

- Less efficient

i.e. If you fit a large wind turbine rotor with a small generator it will be producing electricity during many hours of the year, but it will capture only a small part of the energy content of the wind at high wind speeds.

LARGE GENERATORS:

- Very efficient at high wind speeds, but unable to turn at low wind speeds.

i.e. If the generator has larger coils, and/or a stronger internal magnet, it will require more force (mechanical) to start in motion.

Other Design Considerations

- **A windmill built so that it too severely interrupts the airflow through its cross section will reduce the effective wind velocity at its location and divert much of the airflow around itself, thus not extracting the maximum power from the wind.**
- **At the other extreme, a windmill that intercepts a small fraction of the wind passing through its cross section will reduce the wind's velocity by only a small amount, thus extracting only a small fraction of the power from the wind traversing the windmill disk.**
- **Modern Windmills can attain an efficiency of about 60 % of the theoretical maximum.**

Power of Wind

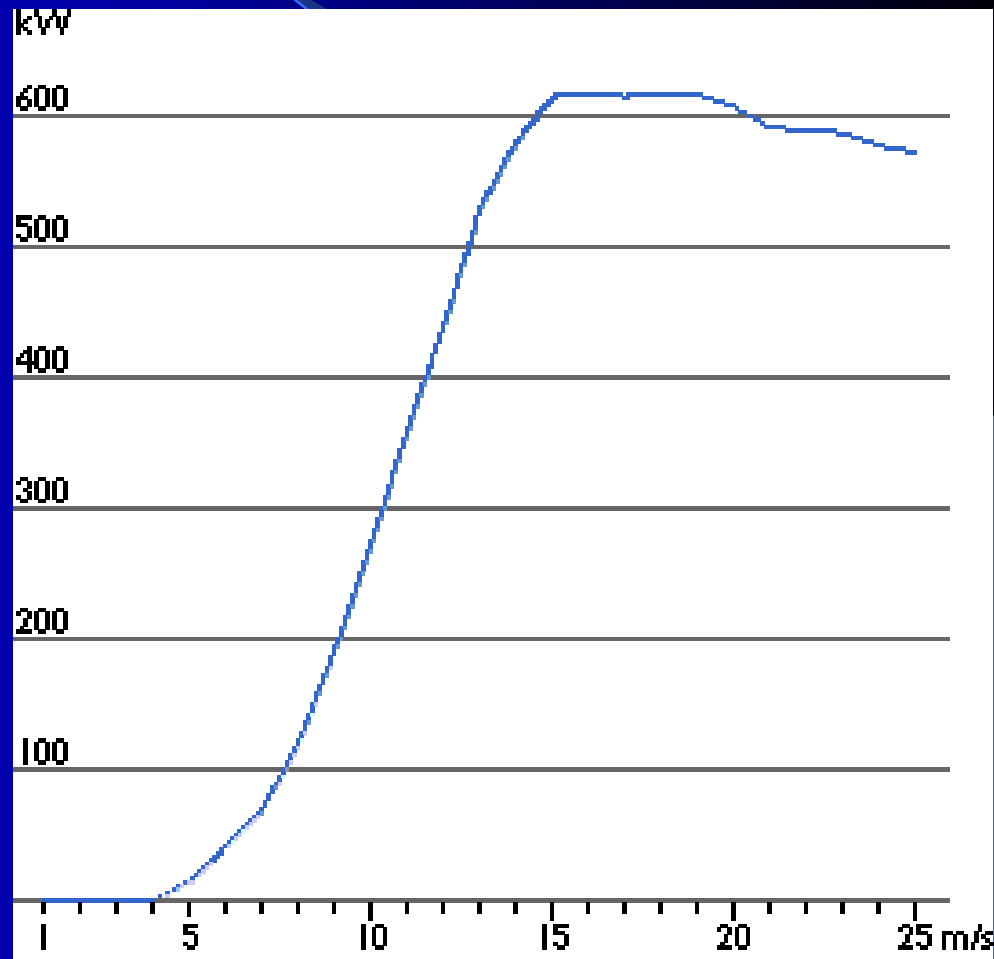
$$P/m^2 = 6.1 \times 10^{-4} v^3$$

*The power in wind is proportional to the cubic wind speed (v^3).

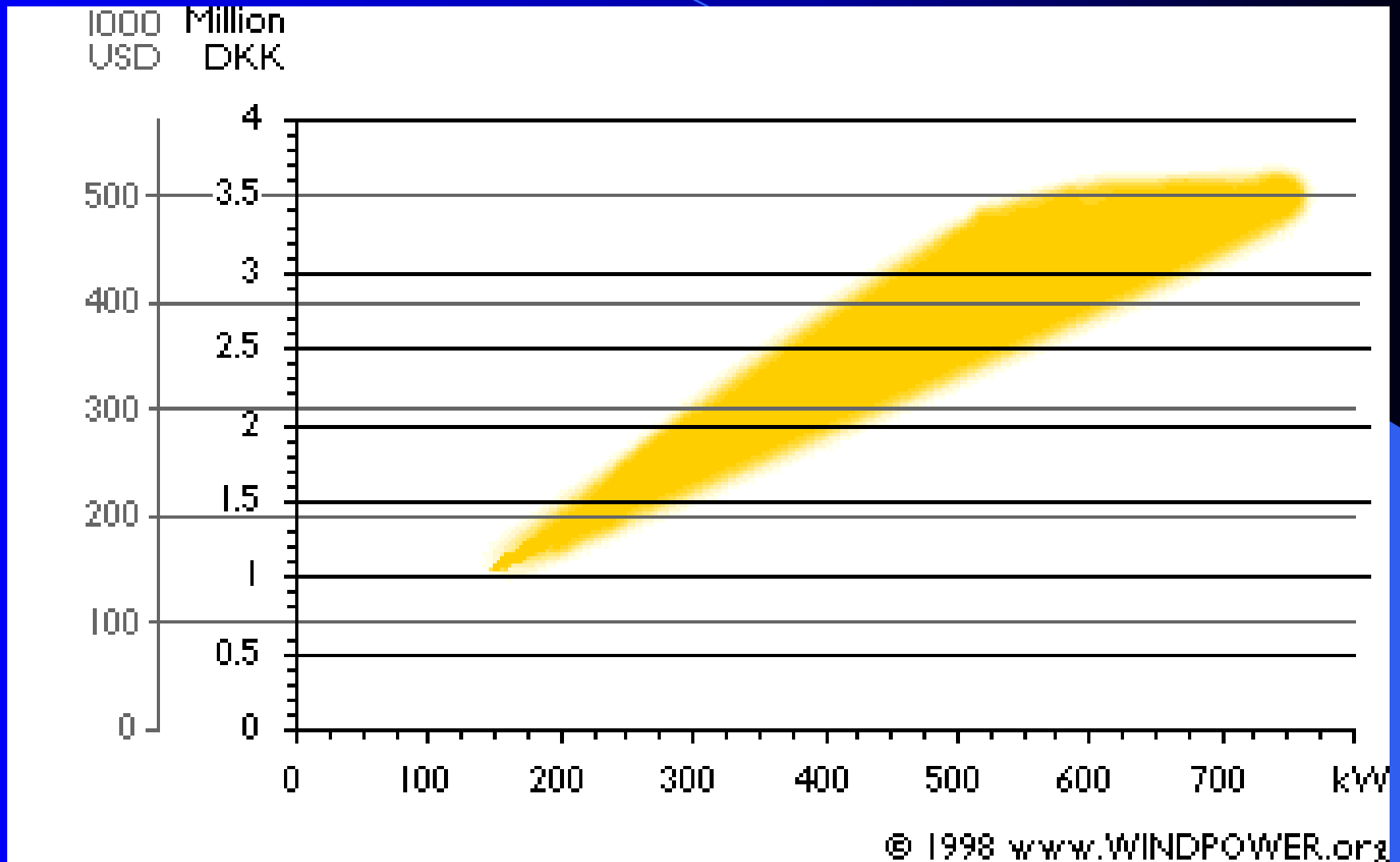
WHY?

~ Kinetic energy of an air mass is proportional to v^2

~ Amount of air mass moving past a given point is proportional to wind velocity (v)



Costs of a Wind Turbine



* An extra meter of tower will cost roughly 1,500 USD.

- **A typical 600 kW turbine costs about \$450,000.**
- **Installation costs are typically \$125,000.**
- **Therefore, the total costs will be about \$575,000.**

- **The average price for large, modern wind farms is around \$1,000 per kilowatt electrical power installed.**

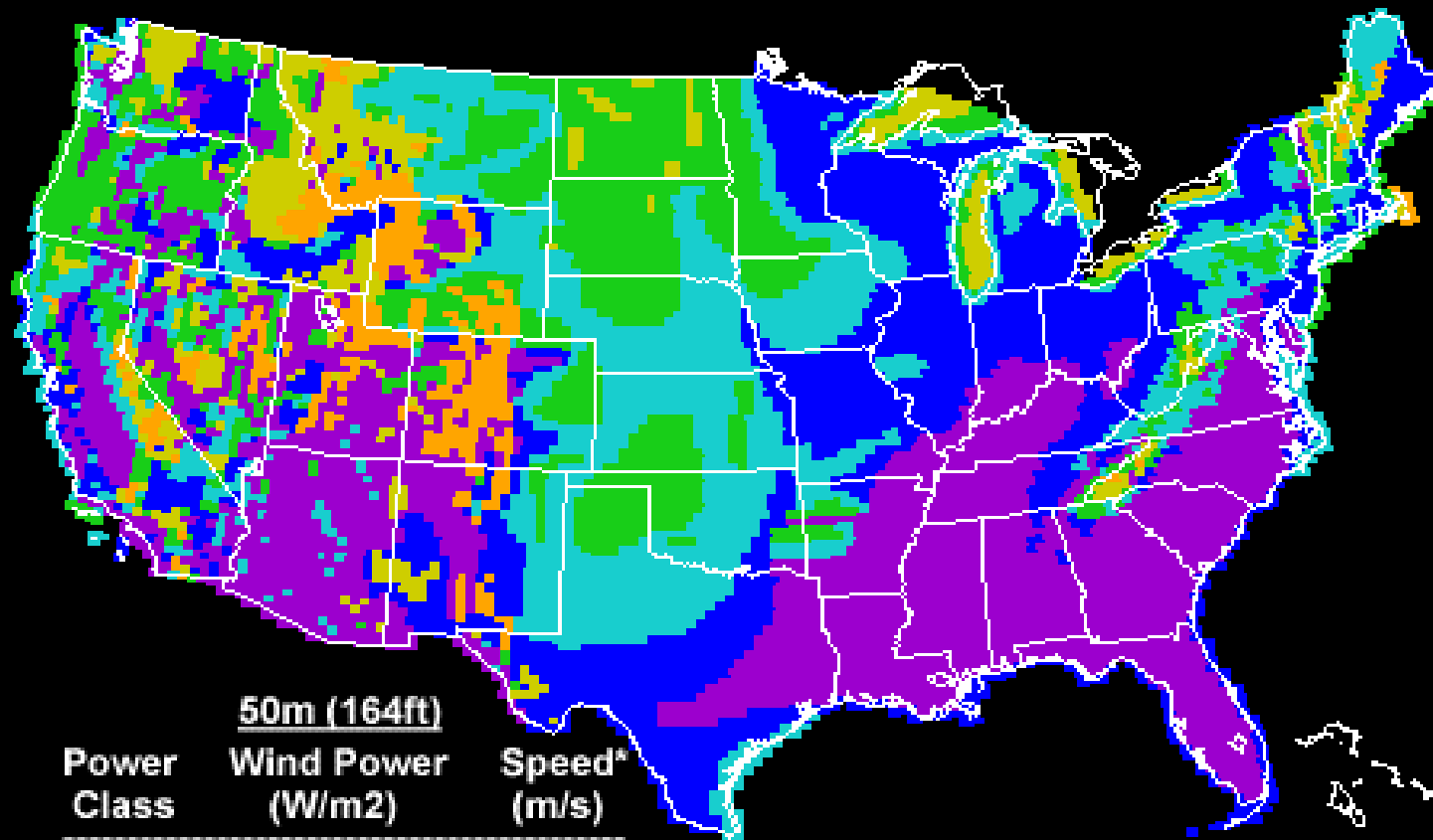
- **Modern wind turbines are designed to work for some 120,000 hours of operation throughout their design lifetime of 20 years. (13.7 years non-stop)**

- **Maintenance costs are about 1.5-2.0 percent of the original cost, per year.**

U.S. Wind Energy Use

- ❖ The U.S. currently has more than 1,600 MW of installed capacity and produces about 3 billion KWh of electricity each year.
- ❖ This is enough to meet the annual residential needs of 1 million people.
- ❖ More than 90 percent of this power is produced by three wind farms in California (Altamont Pass, Tehachapi and Palm Springs).

Annual Wind Power Resource - US Mainland

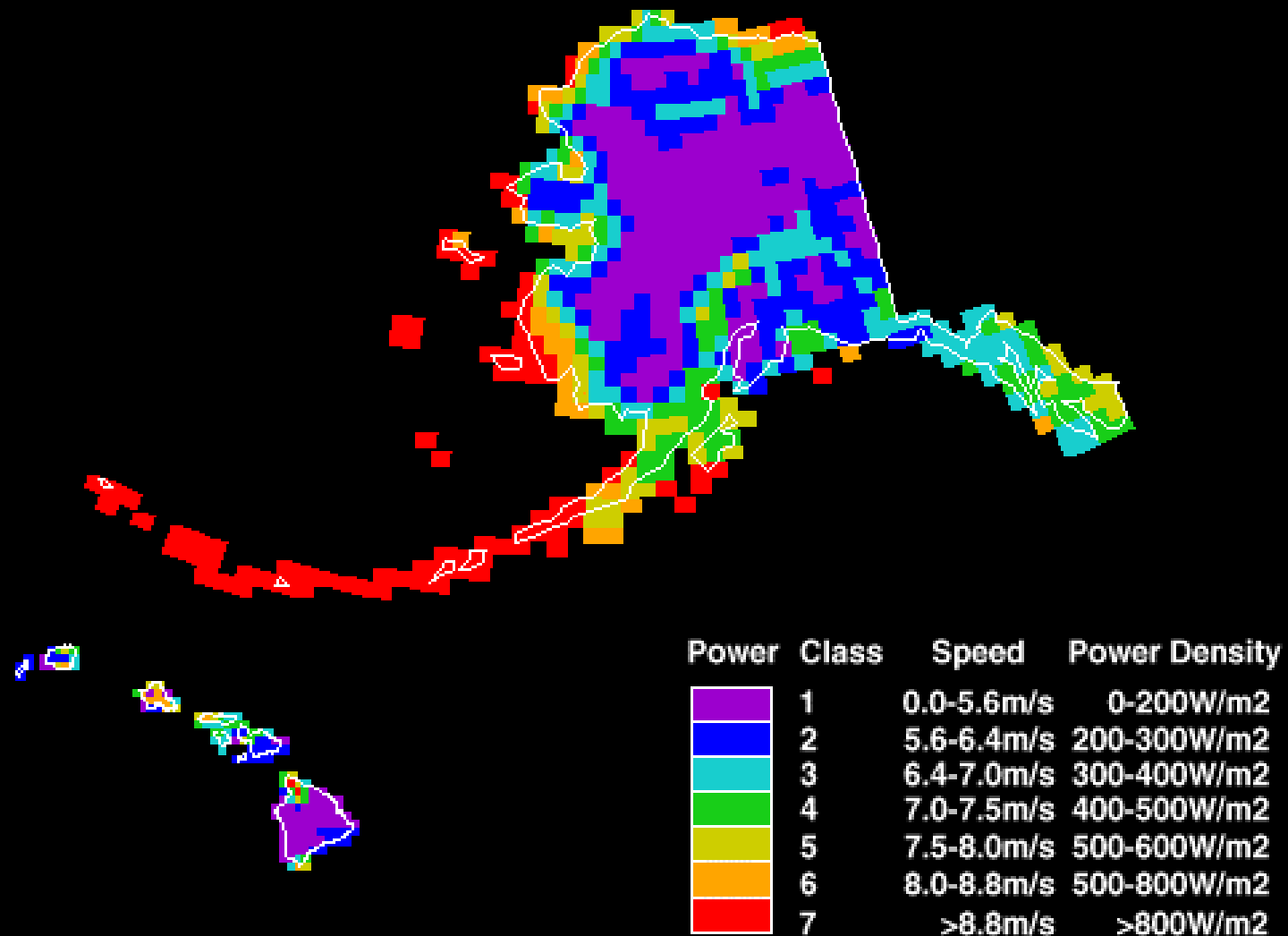


	<u>50m (164ft)</u>	
Power Class	Wind Power (W/m ²)	Speed ^a (m/s)

	1	<200	<5.6
	2	200-300	5.6-6.4
	3	300-400	6.4-7.0
	4	400-500	7.0-7.5
	5	500-600	7.5-8.0
	6	600-800	8.0-8.8
	7	>800	>8.8

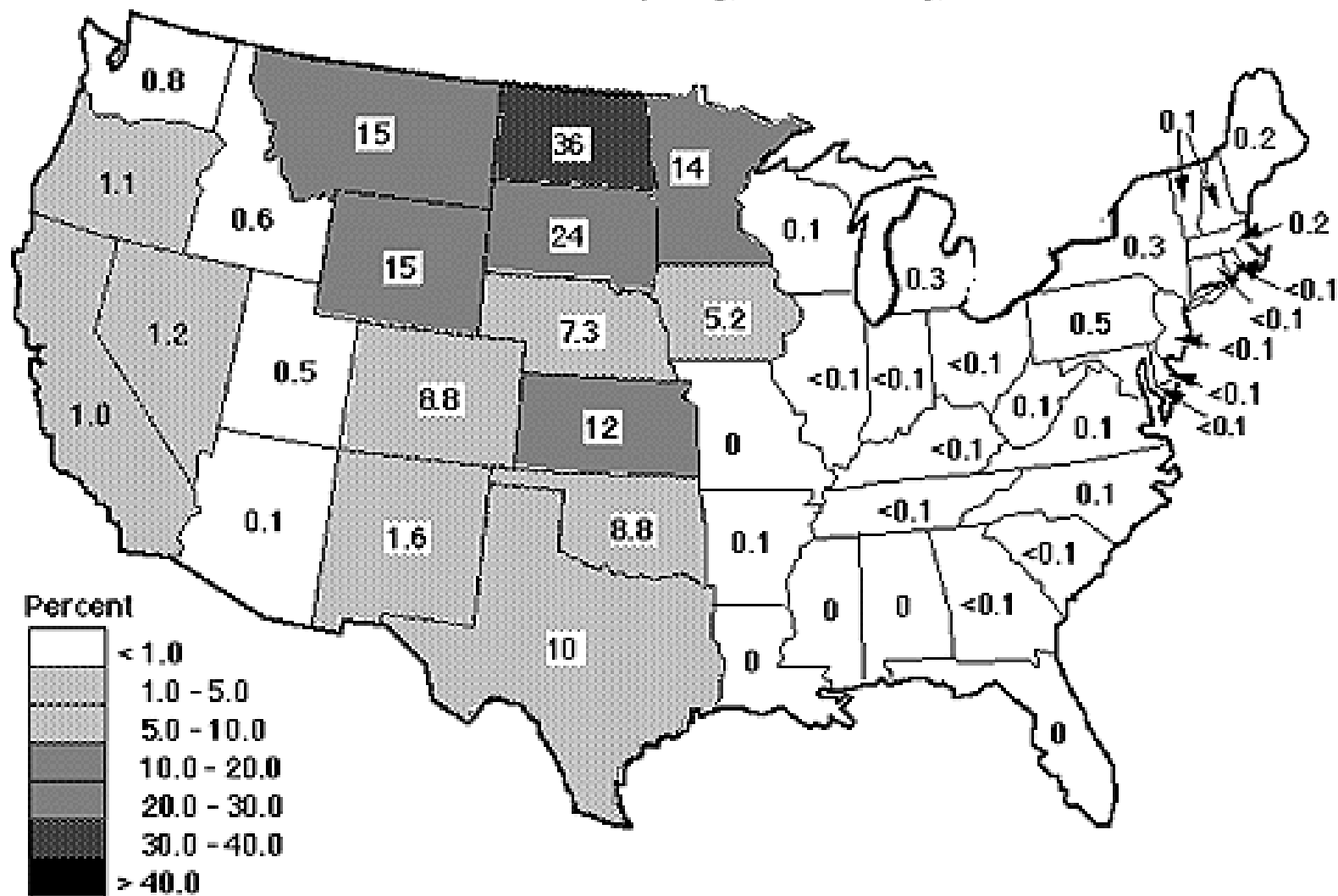
Annual Wind Power Resource - Alaska and Hawaii

Annual Wind Power Resource



Wind Electric Potential as a Percent of Contiguous U.S. 1990 Total Electric Consumption

Specifications: Wind Resource > Class 4 at 30m (>320W/m²), 30m hub height, 10D x 5D Spacing, 25% Efficiency, 25% Losses



Excluded Land Area: 100% Environmental, 100% Urban, 50% Forest, 30% Agricultural, 10% Range

Striking Facts About Wind Energy Potential in the US

- **The U.S. contains enough useable wind resource to produce more electricity than the nation currently uses.**
- **The majority of this usable resource is in the Great Plains region. North Dakota alone has enough suitable wind resource to supply 36 percent of the electricity consumed in the U.S.**
- **In addition, development of major global wind energy markets could significantly impact jobs—recent studies show that each billion kilowatt-hours of annual wind energy generation creates between 440 to 460 jobs.**

Advantages of Wind Power

- The wind blows day and night, which allows windmills to produce electricity throughout the day. (Faster during the day)
- Energy output from a wind turbine will vary as the wind varies, although the most rapid variations will to some extent be compensated for by the inertia of the wind turbine rotor.
- Wind energy is a domestic, renewable source of energy that generates no pollution and has little environmental impact. Up to 95 percent of land used for wind farms can also be used for other profitable activities including ranching, farming and forestry.
- The decreasing cost of wind power and the growing interest in renewable energy sources should ensure that wind power will become a viable energy source in the United States and worldwide.

Wind Power and the Environment

➤ Wind Turbines and the Landscape

- Large turbines don't turn as fast → attract less attention
- City dwellers “dwell” on the attention attracted by windmills

➤ Sound from Wind Turbines

- Increasing tip speed → less sound
- The closest neighbor is usually 300 m → experiences almost no noise

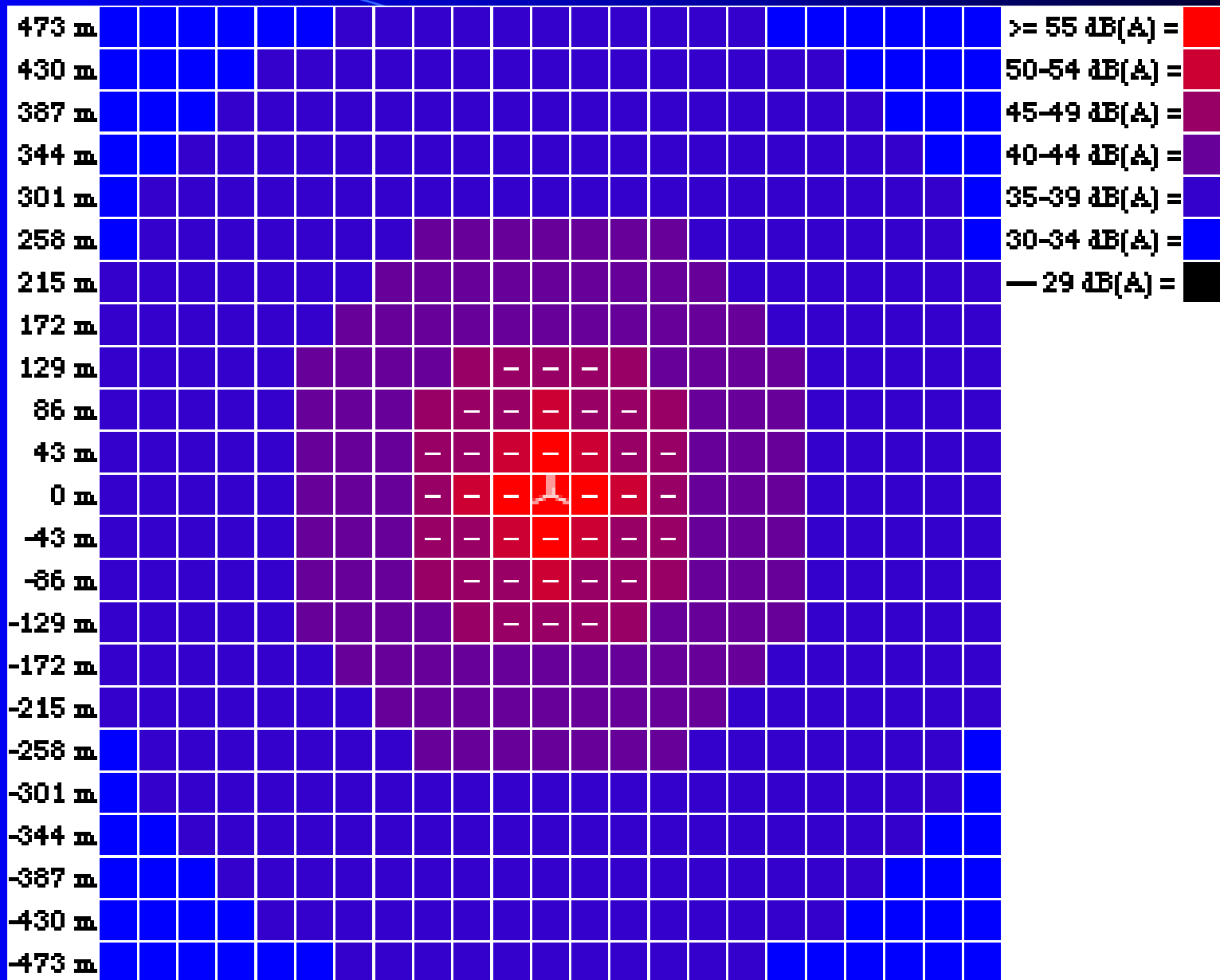
➤ **Birds** often collide with high voltage overhead lines, masts, poles, and windows of buildings. They are also killed by cars in traffic. However, birds are seldom bothered by wind turbines.

➤ The only known site with bird collision problems is located in the Altamont Pass in California.

➤ Danish Ministry of the Environment study revealed that power lines are a much greater danger to birds than the wind turbines.

➤ Some birds even nest on cages on Wind Towers.

Planning Wind Turbine Installation in Regard to Sound



THE END

*** Most of the information and data in this presentation was taken from *www.windpower.org***