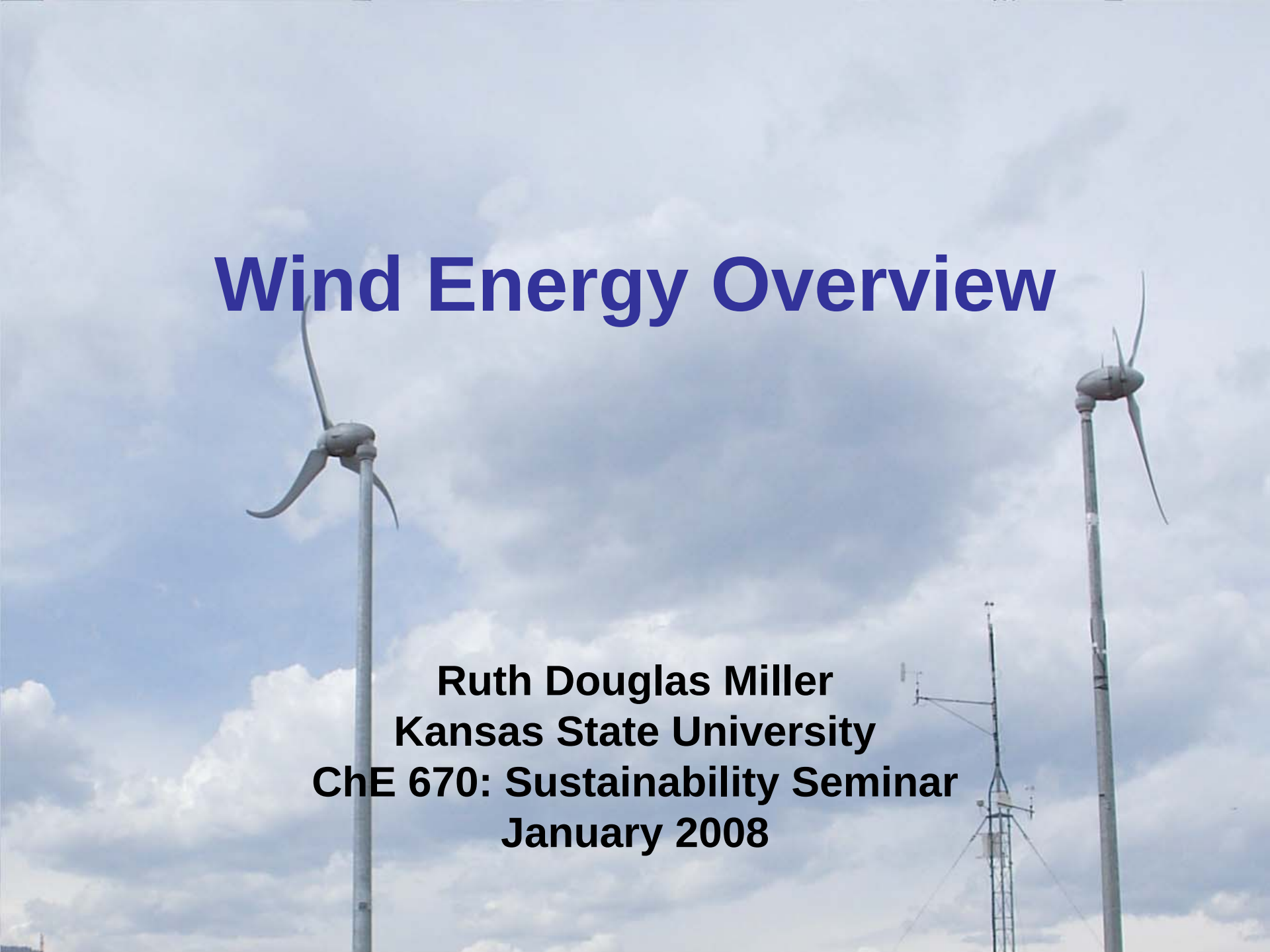
Wind Energy Overview



Ruth Douglas Miller
Kansas State University
ChE 670: Sustainability Seminar
January 2008

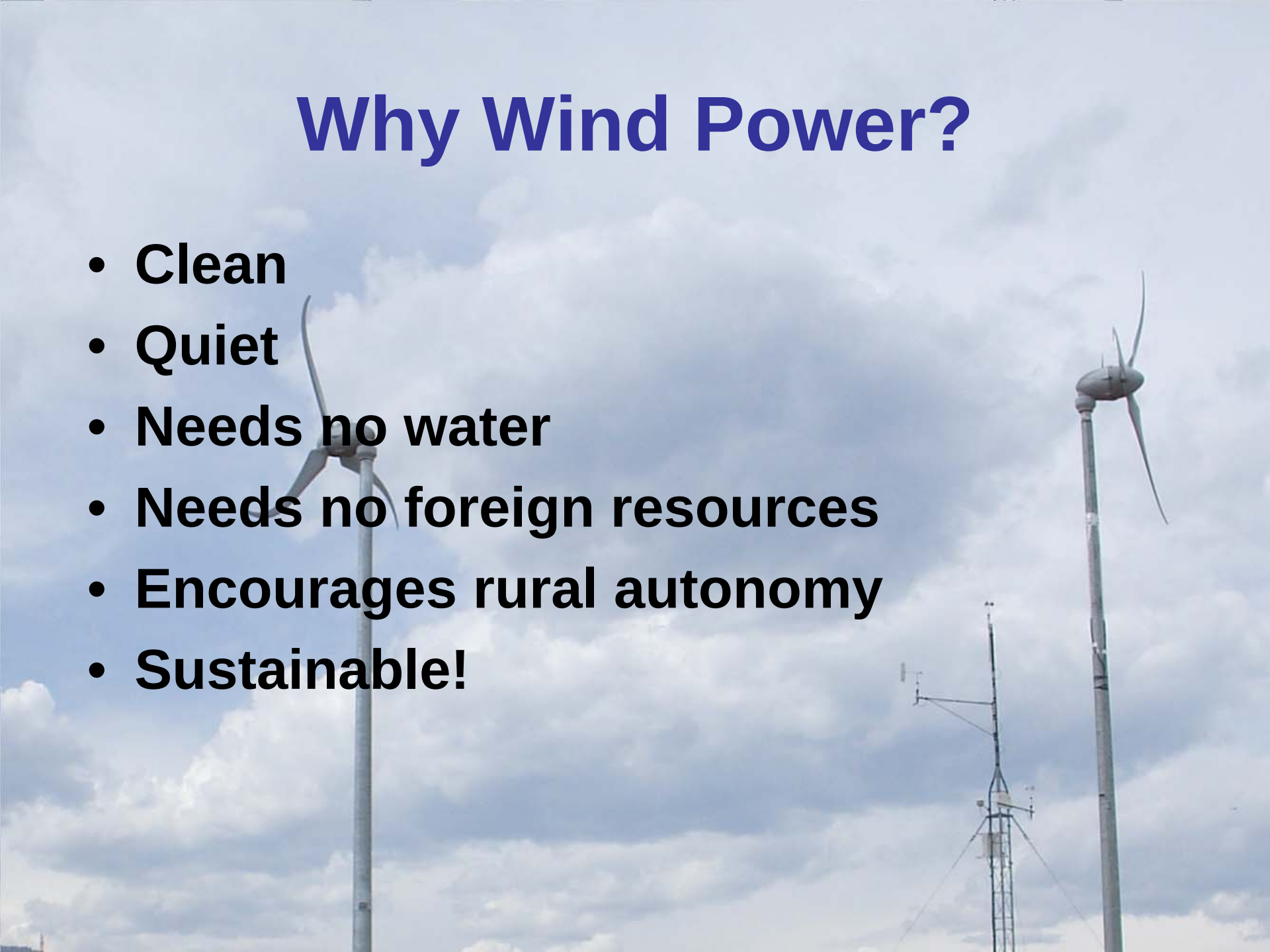
Humanity's Top Ten Problems for next 50 years

1. Energy
2. Water
3. Food
4. Environment
5. Poverty
6. Terrorism & War
7. Disease
8. Education
9. Democracy
10. Population

Source: Nobel laureate, Richard Smalley

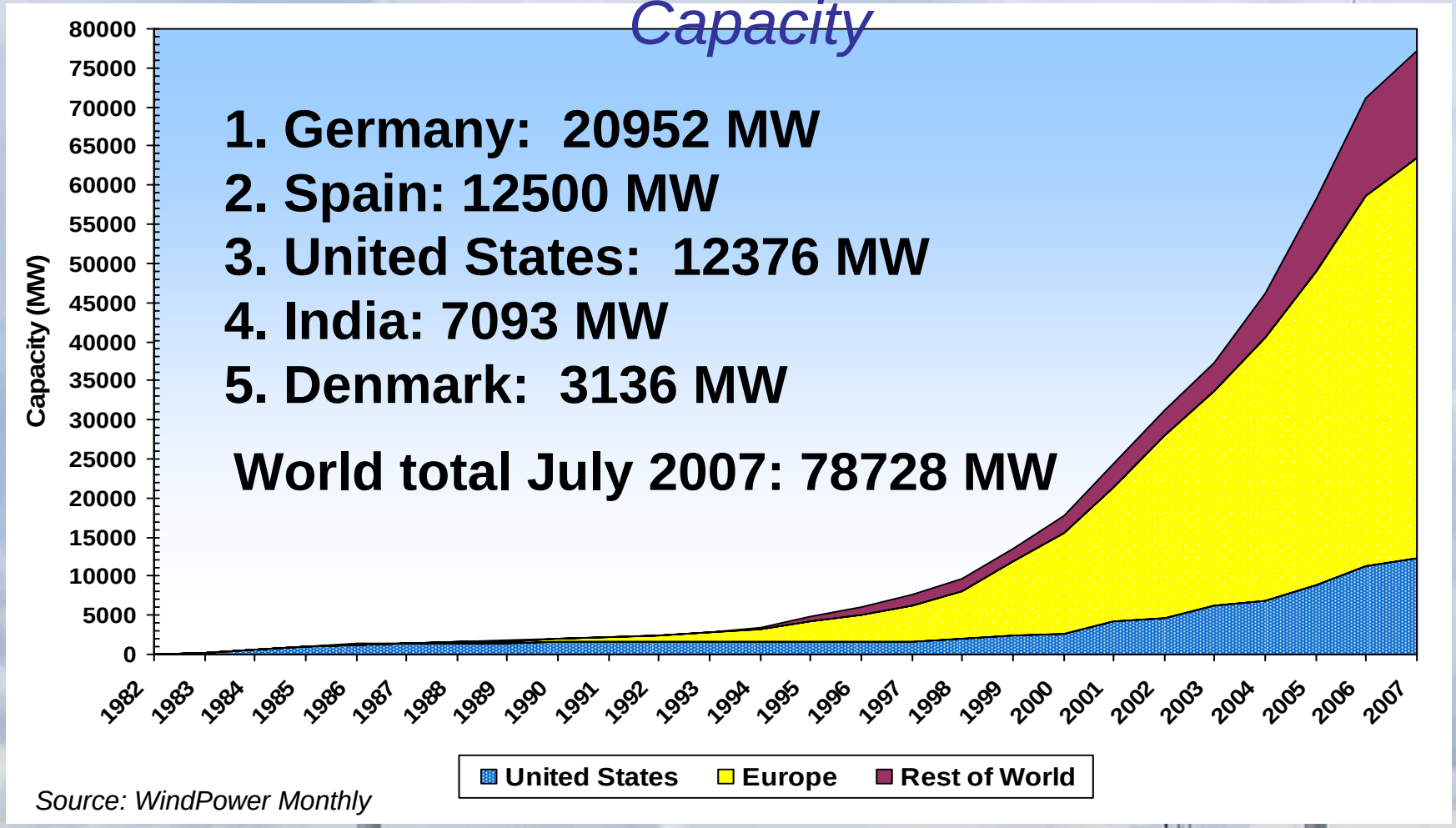
Why Wind Power?

- Clean
- Quiet
- Needs no water
- Needs no foreign resources
- Encourages rural autonomy
- Sustainable!



People Want Renewable Energy!

Total Installed Wind Capacity



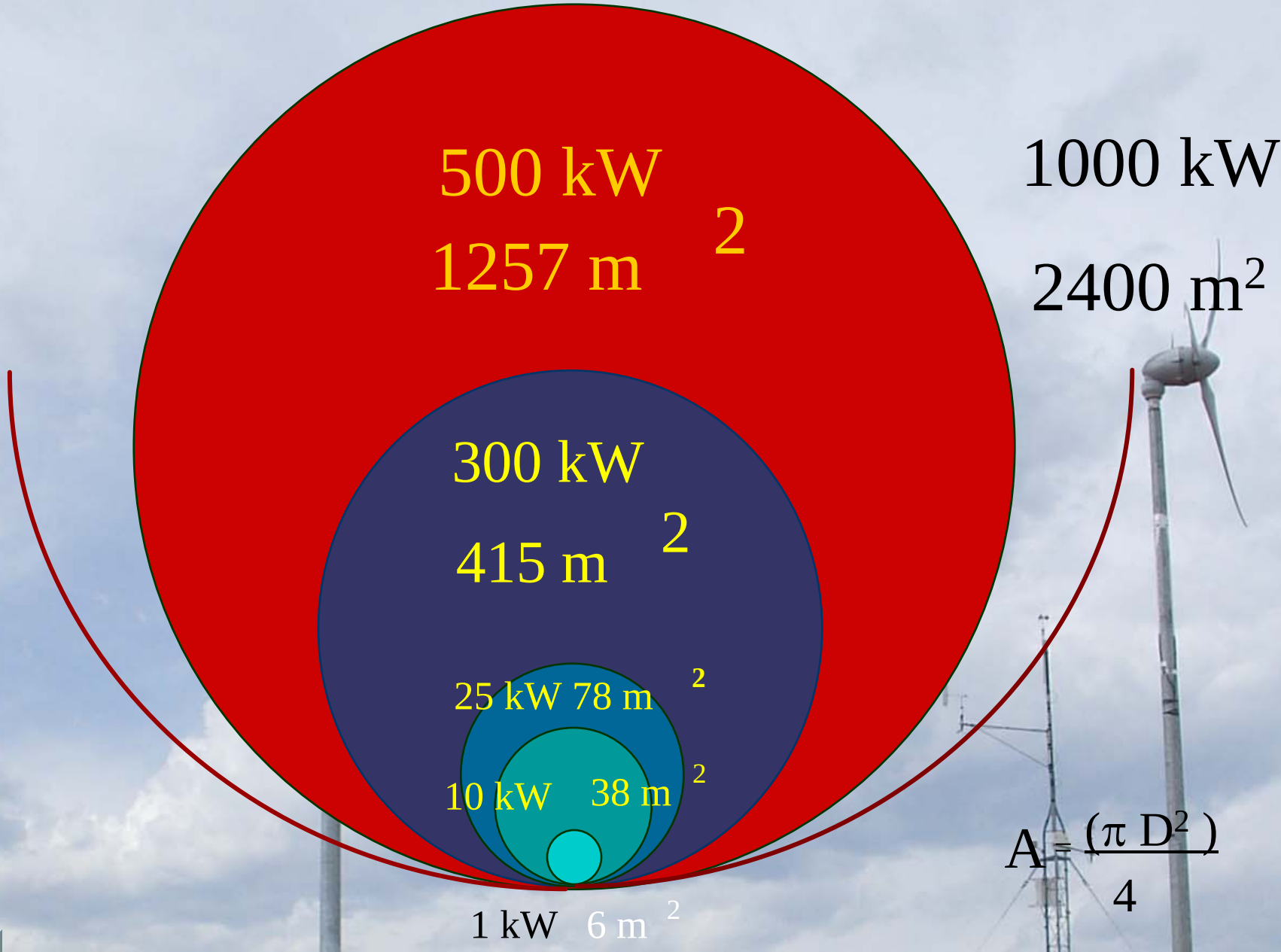
Source: WindPower Monthly

Fundamentals of Wind Power

- **Turbine is a brushless DC electric motor running backwards**
- **Power electronics converts DC pulses to AC power**
- **Synchronized to power grid**
- **Speed controlled by electronic and/or physical braking**

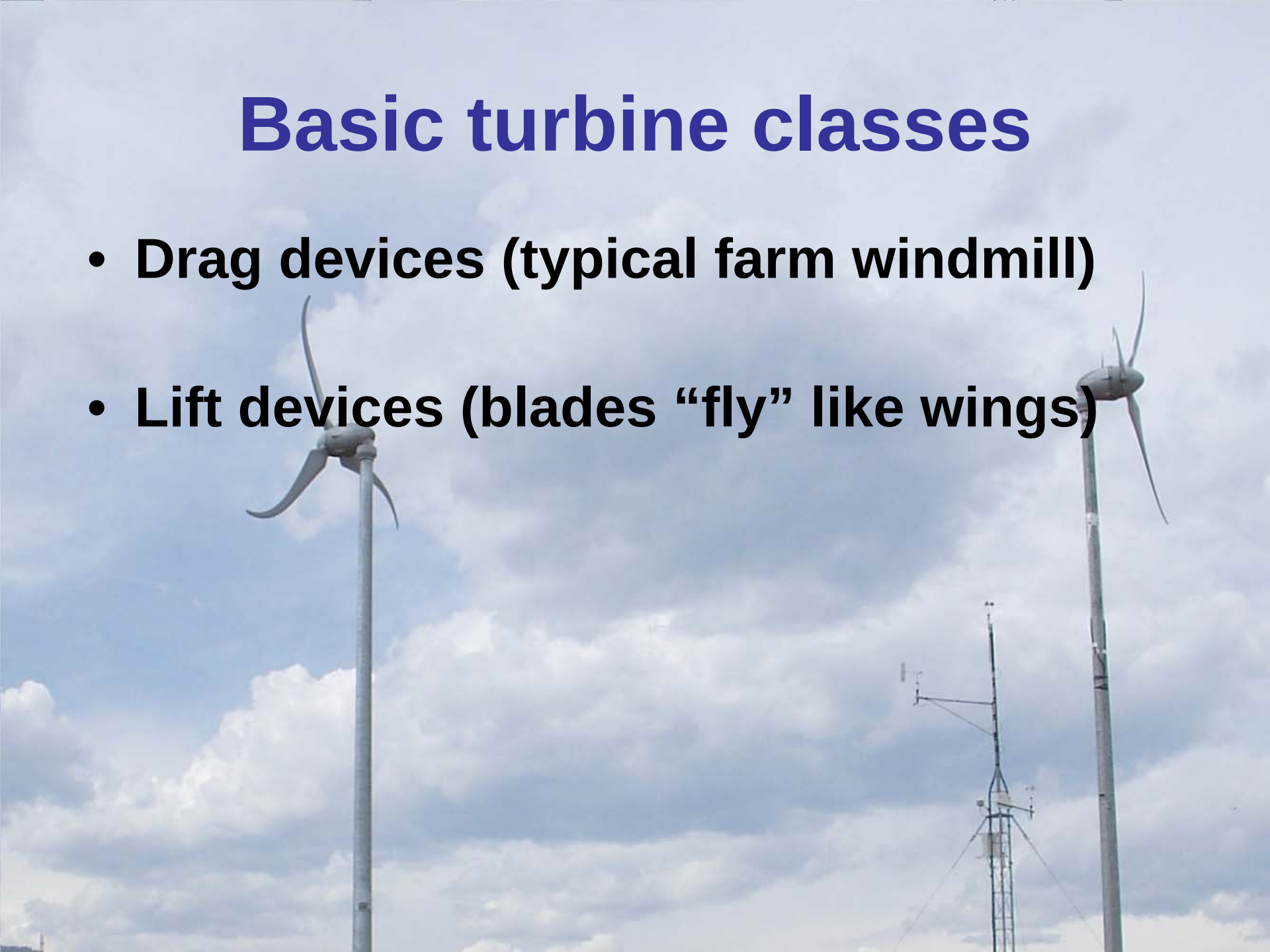
How much power?

- **Power = ½ ρ A v^3**
  - **ρ = air density**
  - **A = swept area of turbine blades**
  - **v = wind velocity**
- **Energy = Power * time**
- **Longer blades = more power**


500 kW
1257 m 2
1000 kW
2400 m2
300 kW
415 m 2
25 kW 78 m 2
10 kW 38 m 2
1 kW 6 m 2
A = (π D2) / 4

Basic turbine classes

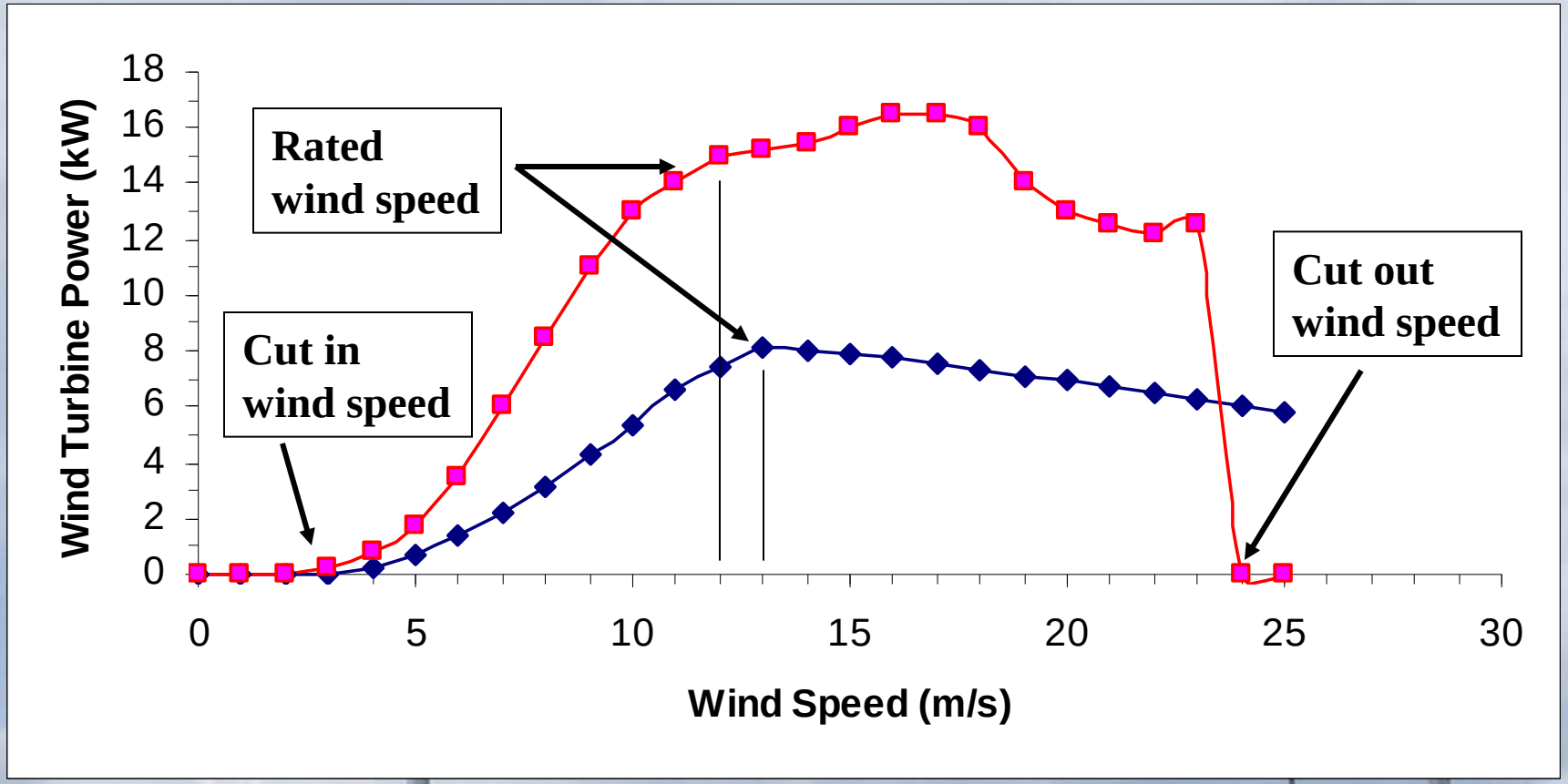
- **Drag devices (typical farm windmill)**
- **Lift devices (blades “fly” like wings)**



Basic turbine classes

- **Horizontal axis**
  - **Better understood**
- **Vertical axis**
  - **Better in turbulence?**
  - **Start-up problems**

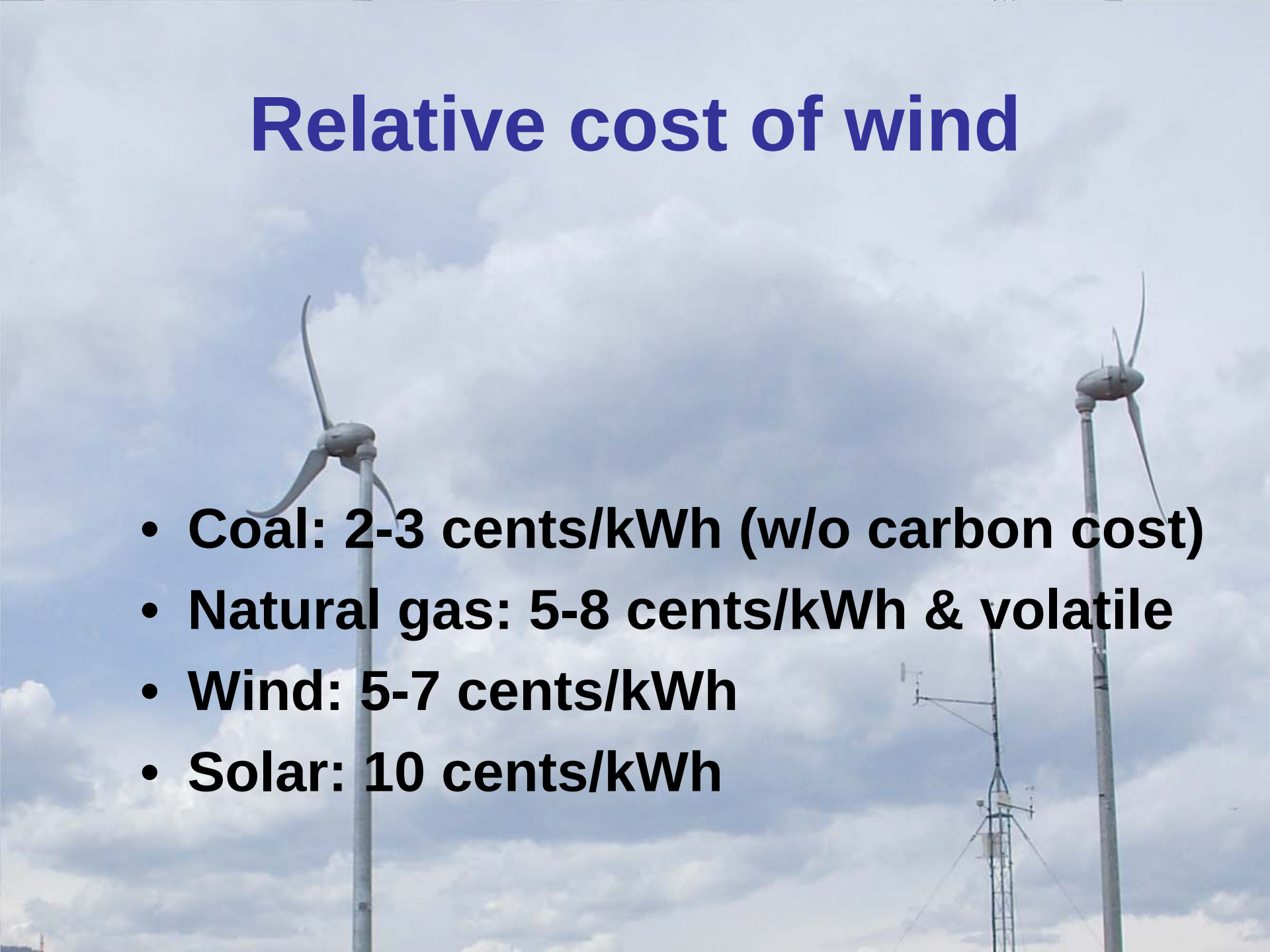
WTG Power Curve



Typical Questions

- Isn’t wind expensive energy?
- Isn’t wind intermittent, undependable?
- Don’t turbines affect wildlife, esp. birds?
- What about high wind, snow, ice?
- Where should a turbine be placed?
- What is “distributed wind”?

Relative cost of wind



- **Coal: 2-3 cents/kWh (w/o carbon cost)**
- **Natural gas: 5-8 cents/kWh & volatile**
- **Wind: 5-7 cents/kWh**
- **Solar: 10 cents/kWh**

Intermittent Wind

- **Strong winds over shorter times produce more power than steady slower winds**
- **At least 20-30% of total power can come from wind without affecting reliability (NREL)**
- **Energy storage could smooth output**
- **Strongest wind in winter; complements solar energy**

Effects on Wildlife

- **Bird kills average 2-5/turbine/year (AWEA)**
- **Turbine design and placement can minimize negative impact**
- **Guy wires are worse than towers, blades**
- **Anecdotal evidence suggests noise is not generally disturbing**
- **Typical “wind farm” uses 5% of land**

Turbines in Bad Weather

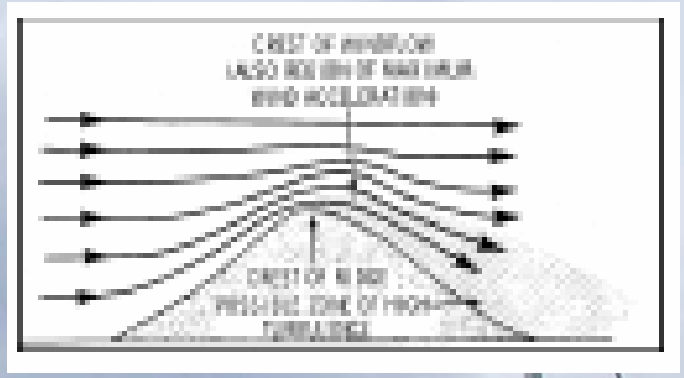
- Much research on material strength of blades (composite fiberglass)
- Some form of braking slows turbines in high winds
- Care to keep out of “cast ice” area
- Turbines work well in Alaska, Maine
- Nothing survives direct tornado hit!

Turbine Siting Requirements

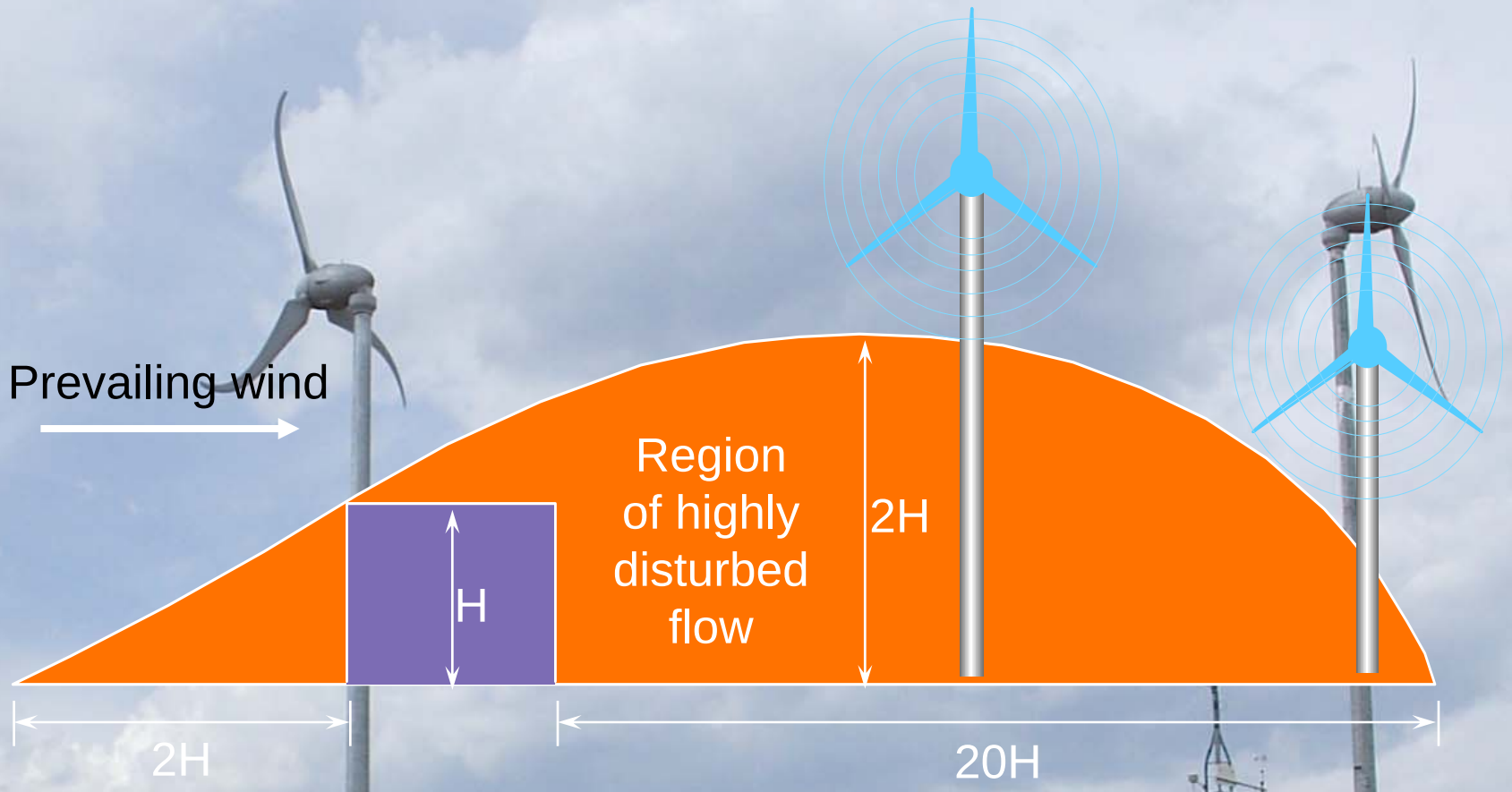
- Higher is better
- Turbulence reduces power
- 2x obstacle height in front, or 20x height behind any obstacle is turbulent
- More than 100 ft from trees, buildings
- 20 ft above obstacles within 200 ft
- Minimum wind speed for given turbine

Impacts on Wind Speed

Many things impact the speed and direction of the wind at any specific location, making local measurements important



Micro-Siting Example:
Obstruction of the Wind by a Small Building



Distributed Wind

- Small and medium turbines
- Owned by individuals, businesses, small towns
- Meet local need, sell excess
- Can be “behind meter”, meet local base load, no excess or storage
- Local ownership and control empowers rural communities

Quinter HS, Kansas:

Entegrity 50-kW turbine meets 30% of power need

Other Small-Scale Examples

- **Scott City, KS: 10-kW Bergey**
  - **Farm needs, no sell-back**
- **Rosebud, SD: Native Reservation: 750 kW turbine**
  - **Energy independence for Sioux tribe**
  - **Income from sell-back**
- **Moorhead MN Community Wind: 2 750 kW turbines**
  - **Energy and income for town**

Conclusions

- 20% wind energy penetration is possible
- 20% penetration is not going to happen under business as usual scenario
- Policy choices will have a large impact on assessing the timing and rate of achieving a 20% goal
- Key Issues: market transformation, transmission, project diversity, technology development, policy, public acceptance
- 20% Vision action plan: Fall 2007