Wind Power Today… and Tomorrow

WISCONSIN AUDUBON COUNCIL
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Baraboo, WI

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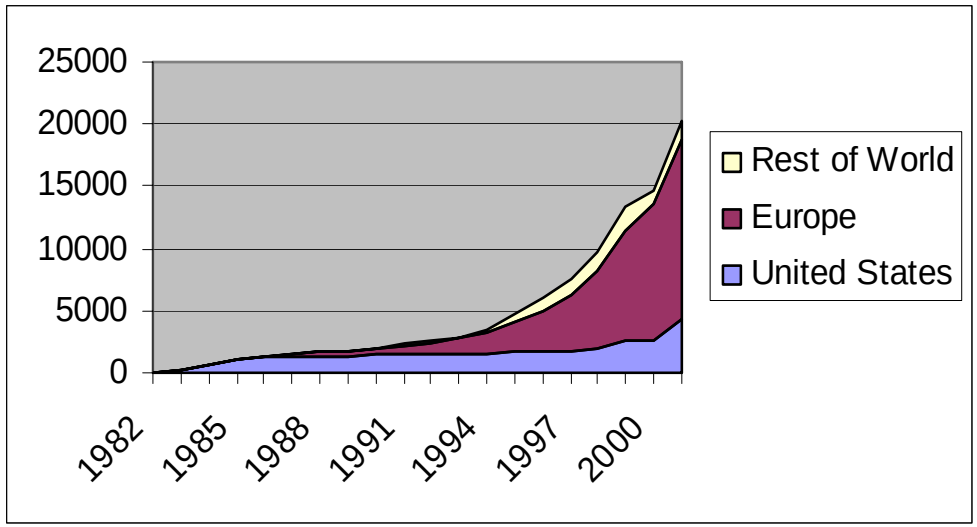
American Wind Energy Association

Wind Is Growing Worldwide

Global Wind Capacity More Than Tripled in Last Five Years

Total installed end 2005:

- **Germany: 18,400 MW**
- **Spain: 10,000 MW**
- **U.S.: 9,100 MW**
- **India: 4,400 MW**
- **Denmark: 3,100 MW**



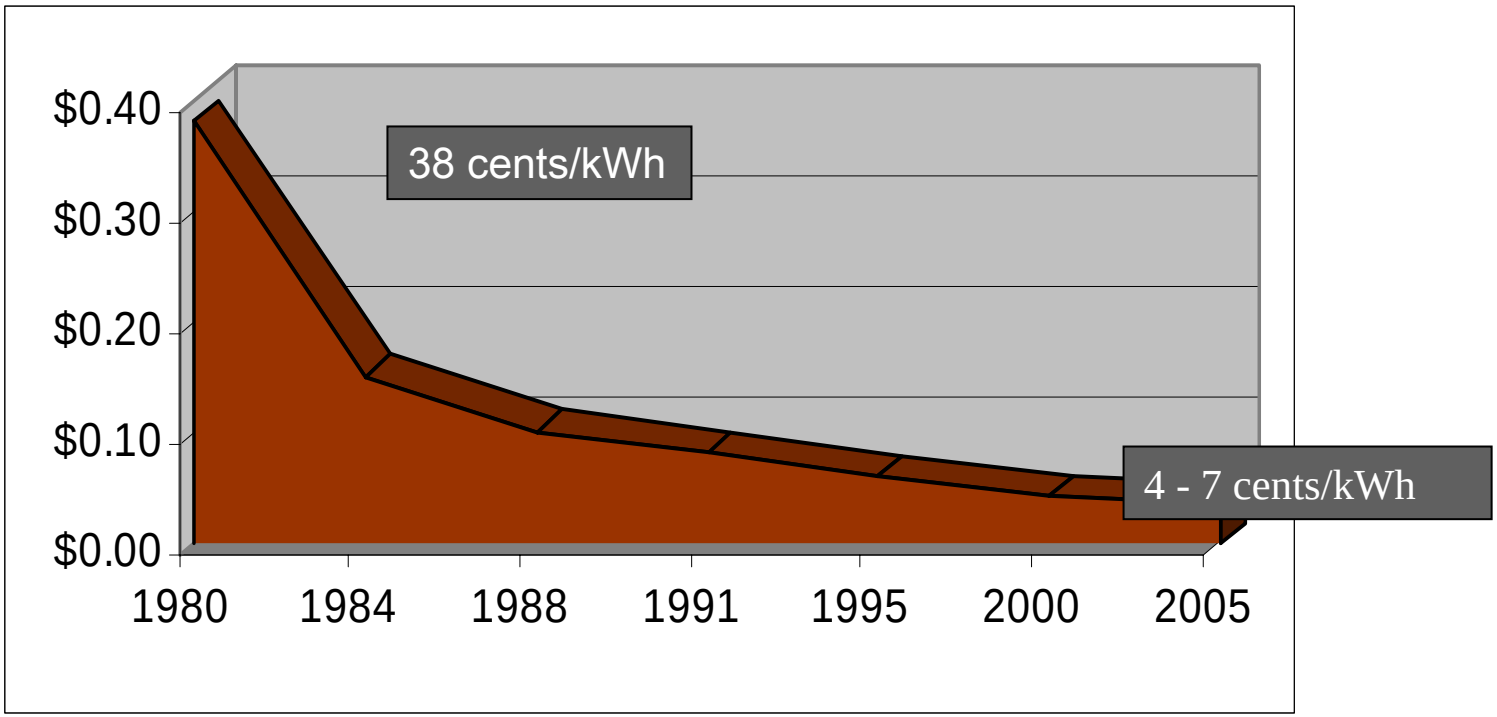
Global Cumulative Total Over **59,000 MW** at end of 2005

Source: AWEA's Global Market Report

Wind Has Hit Sustained Takeoff

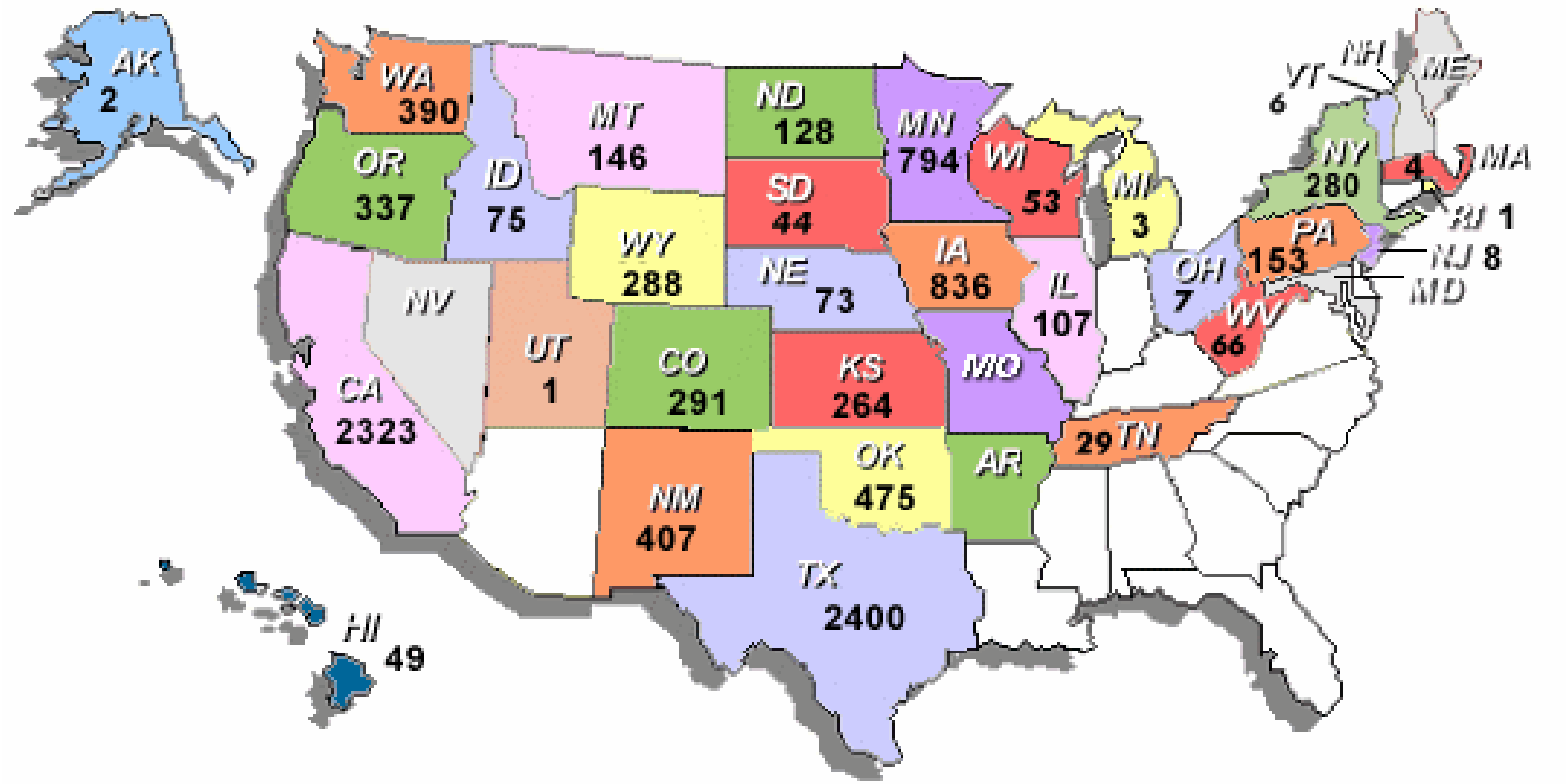
- **2005 ➔ record year in U.S. and world!**
  - 2,400 MW new capacity added in U.S.
    - **>$3 billion investment**
    - +45% over previous record year
  - 12,000 MW added Worldwide
    - +45% over previous record year
  - In 2005 U.S. was again #1 in new installations (after lagging for decade)
    - +35% greater than #2 Germany
- In **2006** over **$4 billion** investment expected in U.S.

Reduced Cost Driving Wind's Success



Levelized cost at good wind sites in nominal dollars, *including tax credit*

Wind power installed by state



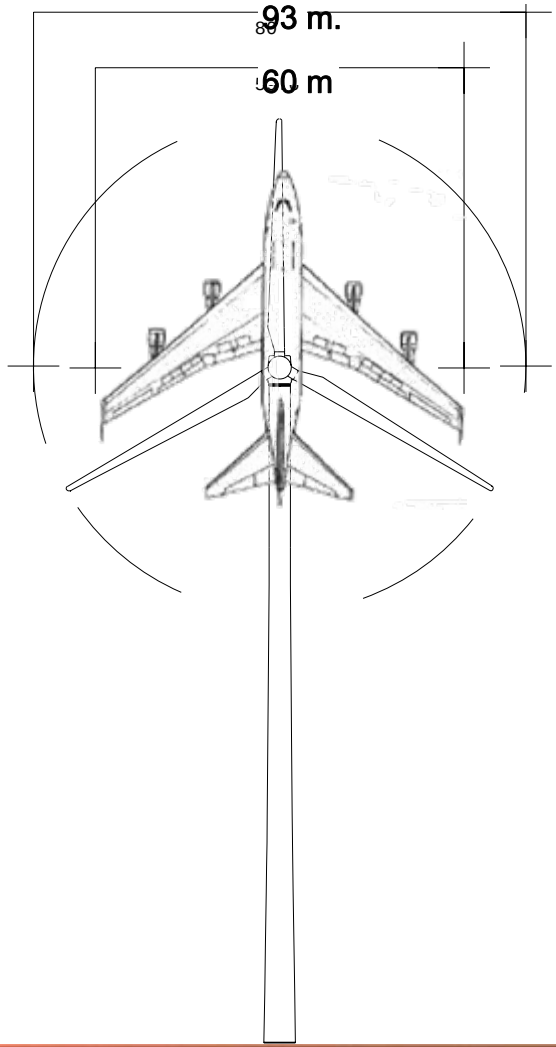
2006 July

Turbines Are Getting Bigger

...

	1981	1985	1990	1996	1999	2000	2005	2008
rotor diameter (in meters)	10	17	27	40	50	71	104	120
rated capacity (in kilowatts)	25	100	225	550	750	1,650	3,600	5,000

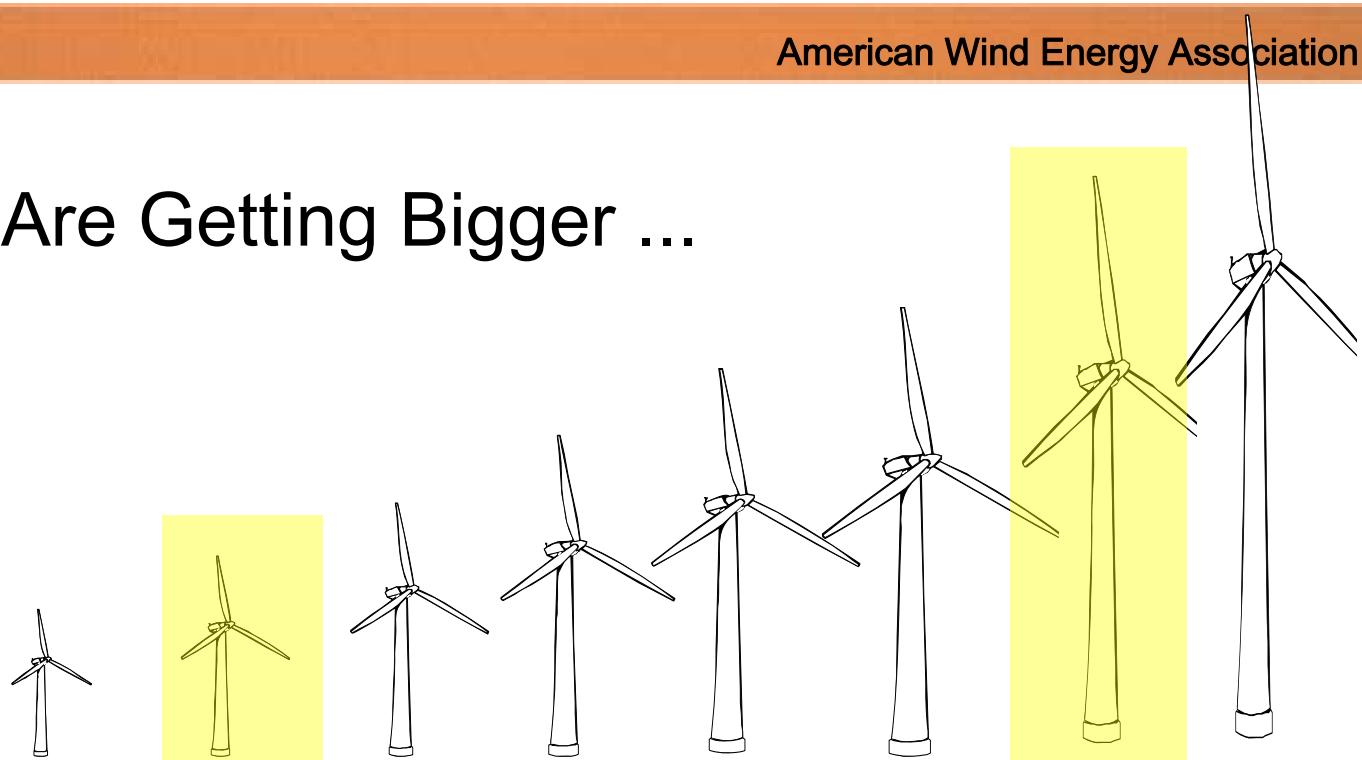
How big is a 2 MW wind turbine?



Boeing 747 –
60 m diameter

Siemens 2.3 MW turbine –
93 m diameter

Turbines Are Getting Bigger ...



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Altamont Pass Wind Development Area

Typical Early Turbine –

15 m diameter
22 m tower
65 kW

Altamont Pass, CA - 1982

- 2006 August
- Southern MN
- Also being installed in MN, ND, TX
- Siemens 2.3 MW turbine
- 93 m diameter rotor
- 80 m towers

Consequences of larger turbines

- Rotor Diameter
  - Early turbine ~ 15 m
  - Modern Turbine ~ 93 m
- Rotor Speed (function of rotor diameter)
  - Early turbine ~ 75 rpm
  - Modern turbine ~ 12 rpm (rotate every 5 seconds)
- Tower Height
  - Early Turbine ~ 22 m
  - Modern turbine ~ 80 m
- Ground Clearance
  - Early Turbine ~ 15 m (barn peak)
  - **Modern Turbine ~ 39 m (10-story building)**

Consequences of larger turbines (con't)

- Total Height at tip of blade
  - **Early Turbine** **~ 30 m**
  - Modern Turbine ~ 122 m
- Ground Shear
  - Aerodynamic "drag" of ground slows wind
- Wind Speed at tip height
  - Ratio: Modern / Early Turbine ~ 130%
- **Power-energy-revenue =~ cube of wind speed**
- Wind Power Density at tip height
  - Ratio: Modern / Early Turbine ~ 230%

Consequences of larger turbines (con't)

- Wake effects
  - Turbines spaced to minimize downstream "wind shadow"
- Distance between turbine rows
  - Early Turbines ~ 90 m
  - Modern Turbines ~ 550 m (1/3 mile)
- Turbines per 160 acres
  - Early Turbines ~ 30 turbines
  - Modern Turbines ~ 1 turbine
- Turbine cost, installed
  - Early Turbine $30,000
  - Modern Turbine $4 *million*

Most important physical and financial characteristic impact:

- Location
- Location
- Location

Benefits of Wind Power

- Energy Security
- Economic Development
- Cost Stability
- Resource Diversity
- Air Pollution
- Global Warming Pollution

The Future of Wind Power?

President Bush was correct
when he said on February 21 of this year:

“Wind can supply up to 20% of U.S. electricity”

Impact of 20% Wind Power

- Up to 350 GW of wind power installed in U.S.
  - 10 GW total wind power installed today
- To achieve 20% in 35 years – new installations need to *average* **10 GW per year**
- Investment required -- **$0.5 trillion**

Developer's Dilemma

- Wind power receives support from public
- Wind power has advantages for nation
- Wind turbines are huge
- Wind turbines are visible
- Wind turbines can impact environment

GOAL

Develop wind projects

with minimal environmental impacts

Wind Project Site Selection

Top Six Key Elements…

AND, typically, development sequence

1. Wind – Most important criteria
2. Land – Need willing landowners
3. Permits – Wildlife and siting issues
4. Transmission – Capacity and proximity
5. Buyer – Power purchase agreement with utility
6. Financing – Need all 5 above to get it

Developer Decisions

- Option land (reserve development rights)?
- Erect met towers?
- Perform preliminary environmental analysis?
- Perform preliminary transmission analysis?
- Apply for transmission interconnection
- Perform detailed wildlife studies?
- Apply for permits?
- Bid project to potential electricity buyers?
- Seek financing?

Developer is Concerned About Confidentiality

- In early stages of project, confidentiality is crucial
  - Agencies subject to Freedom of Information Act
  - Fierce competition for best sites and land
  - Until initial decision made to proceed, premature to debate potential impact issues
- Confidentiality is major cause of miscommunication and mistrust
- As developer approaches permit application, they will be more willing to discuss details

Lessons Learned by Developers

- Finding suitable and viable site very difficult
- A very small difference in wind speed can make-or-break a site (Δ 0.5 m/s $\approx$ 25% more revenue)
- The erection of a met tower does not mean that a project will be built at that location
- Mutual understanding and flexibility between developers and agencies/advocates is important

Key Siting Considerations

- Wind – most absolute requirement
- Land – owners must be willing
  - Need large, contiguous parcels
  - Compatible land uses (ranches, un-irrigated agriculture, open space)
  - Developer does not have power of eminent domain
- Transmission – high voltage
  - Capacity must be available on existing lines
  - Low voltage feeder lines more feasible with larger projects
- Market for power – utilities
  - Driven by public policy (production tax credit, renewable electricity standards)

Key Siting Considerations

- Permits and Environmental Considerations
  - Wildlife impacts is primary
  - Agencies and advocates frequently have differing priorities
  - May require consultants and information research
  - Wide variety of issues
    - Avian
    - Other wildlife (bats, ground-roosting birds, etc)
    - Wetlands
    - Habitat
    - Rare plants
    - Cultural resources
    - Visibility
    - Aviation

Opportunities for Collaboration and Compromise

Win-win solutions

- Minimize avian and wildlife impacts
  - Pre-project studies
  - Good project design
  - Post-project surveys
  - Mitigation measures
  - Adaptive management
- Knowledge and understanding
  - Technical Advisory Committees facilitate communication
- Protection of open space
  - Economic benefits of wind power reduces pressure on local government for other development
- Habitat protection and restoration
  - Developers and landowners can reach mutual agreements

Goal

Develop wind projects with minimal environmental impacts

Contact AWEA

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(with thanks to developer
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