A Technical Update on Wind

West Virginia

Wind Energy Symposium

Canaan Valley Resort

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Wind Turbine Sizes and Applications

Small (≤10 kW)

- Homes (Grid connected)
- Farms
- Remote Applications

(e.g. battery changing, water pumping, telecom sites, icemaking)

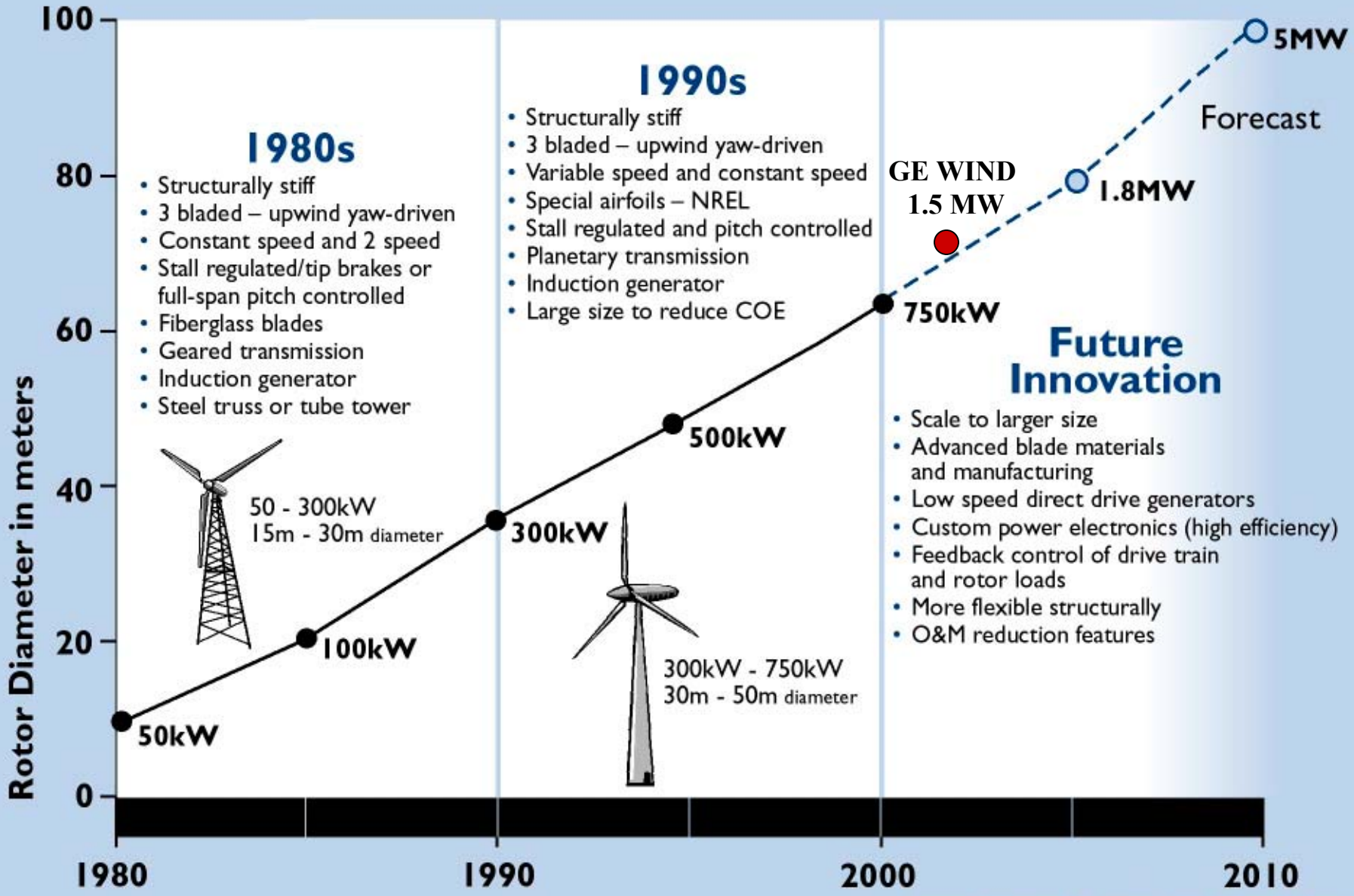
Intermediate (10-500 kW)

- Village Power
- Hybrid Systems
- Distributed Power

Large (500 kW – 6 MW)

- Central Station Wind Farms
- Distributed Power
- Offshore Wind Generation Stations

The Evolution of Commercial U.S. Wind Technology



Source: Thresher & Dodge, Wind Energy Journal 1998

Rotor Diameter and Rated Capacity

747-400

50 m

66 m

85 m

100 m

120 m

0.75 MW

1.5 MW

2.5 MW

3.5 MW

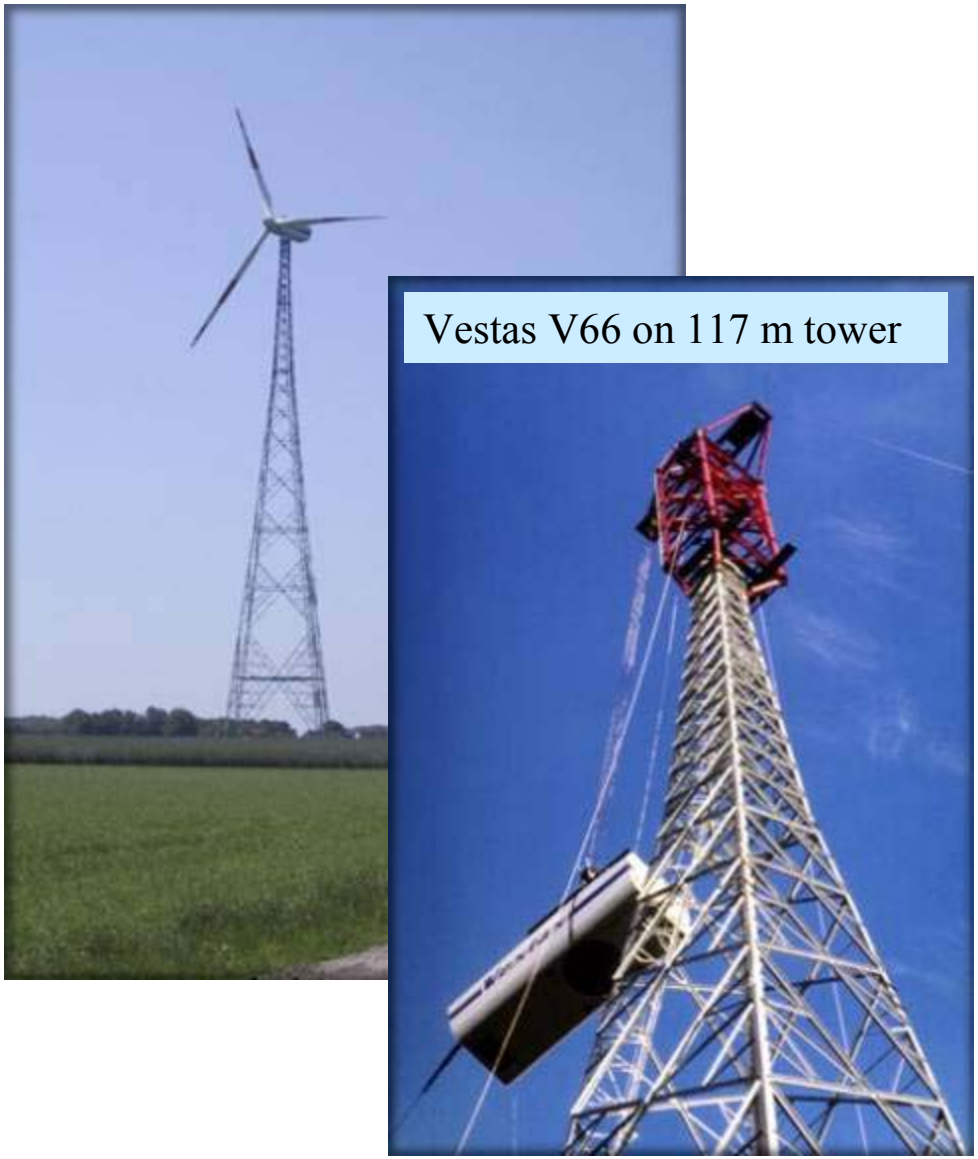
5.0 MW

DOE Goal for Utility Scale Wind Systems

Low Wind Speed Technology Program

- 3 ¢/kWh in Class 4 (13 mph) site by 2012, for land-based windfarm
- Make more wind sites available close to load centers
- Increase the area for wind development by a factor of 20
- Support development of offshore wind energy near load centers
- Accelerates meeting the National Energy Policy (NEP) and the DOE Program Strategic Performance Goal (PSPG) for increasing domestic energy sources

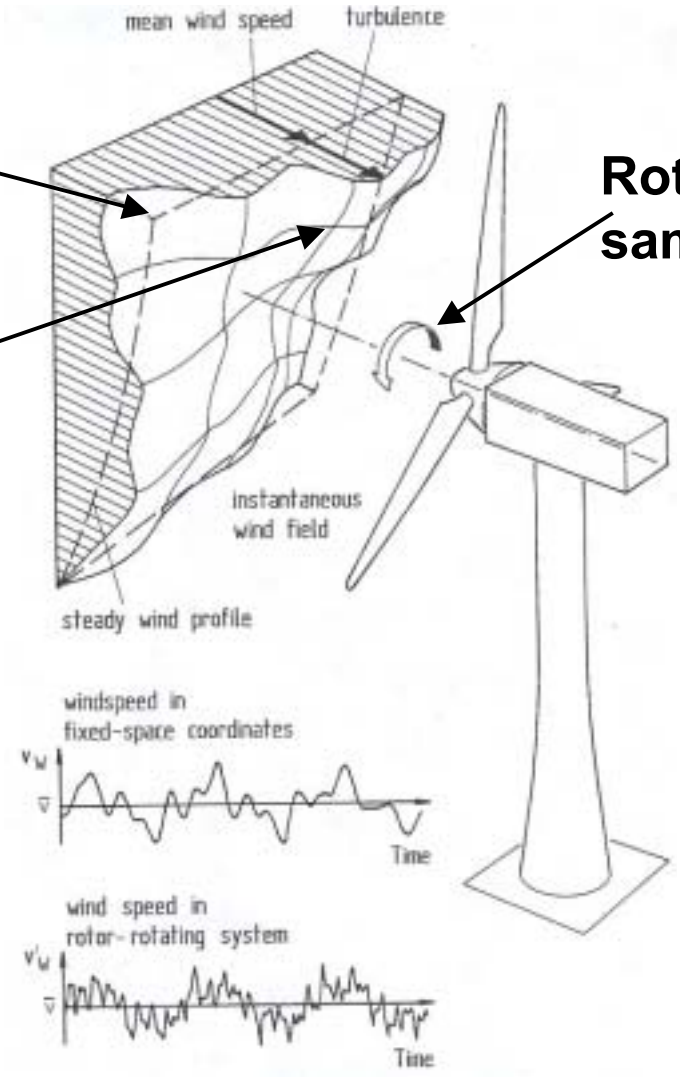
Tall Towers



Tall Tower Concepts

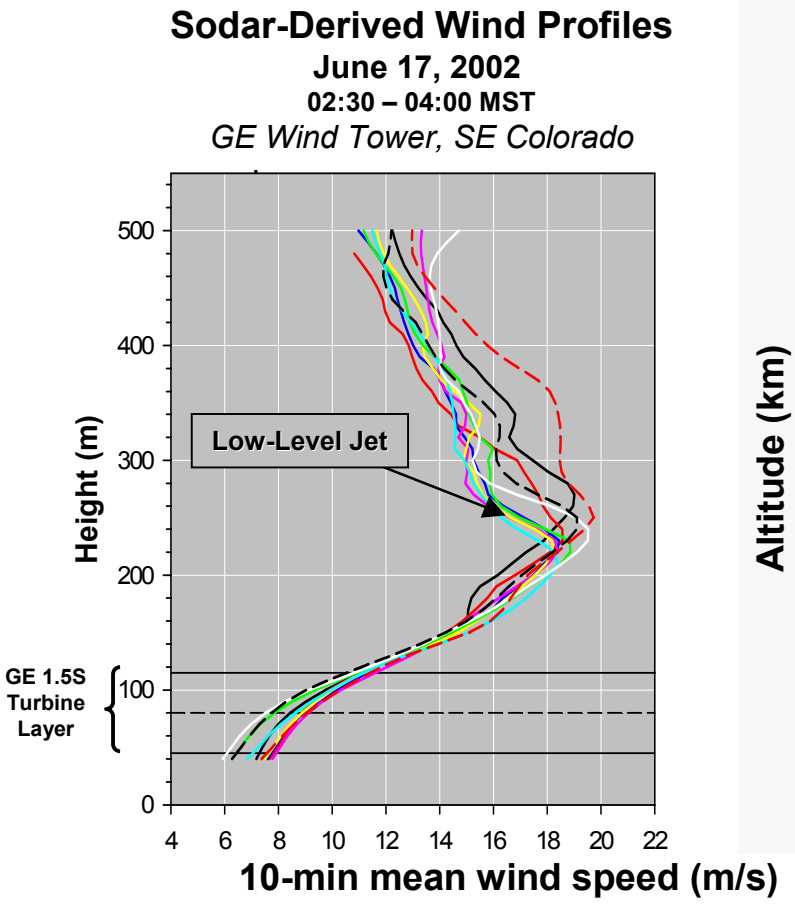
- Novel steel tubes
- Truss towers
- Pre-stressed concrete
- Composite
- Hybrid towers
- Self-erecting/no cranes
- On-site manufacturing
- Tower load feedback control

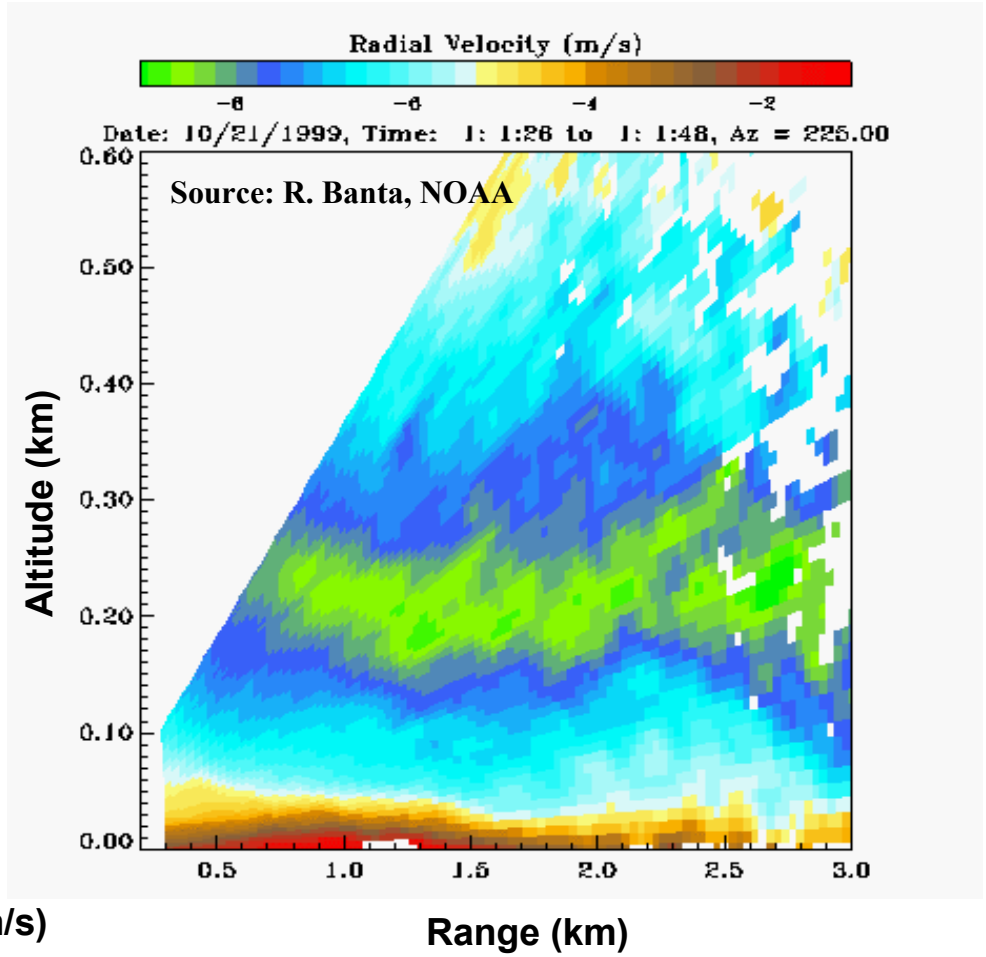
Dynamic Loading Environment



- Wind conditions are complex, site specific
- IEC specifies design standards for generic turbine classes
- Aerodynamics, gravity drive structural loading

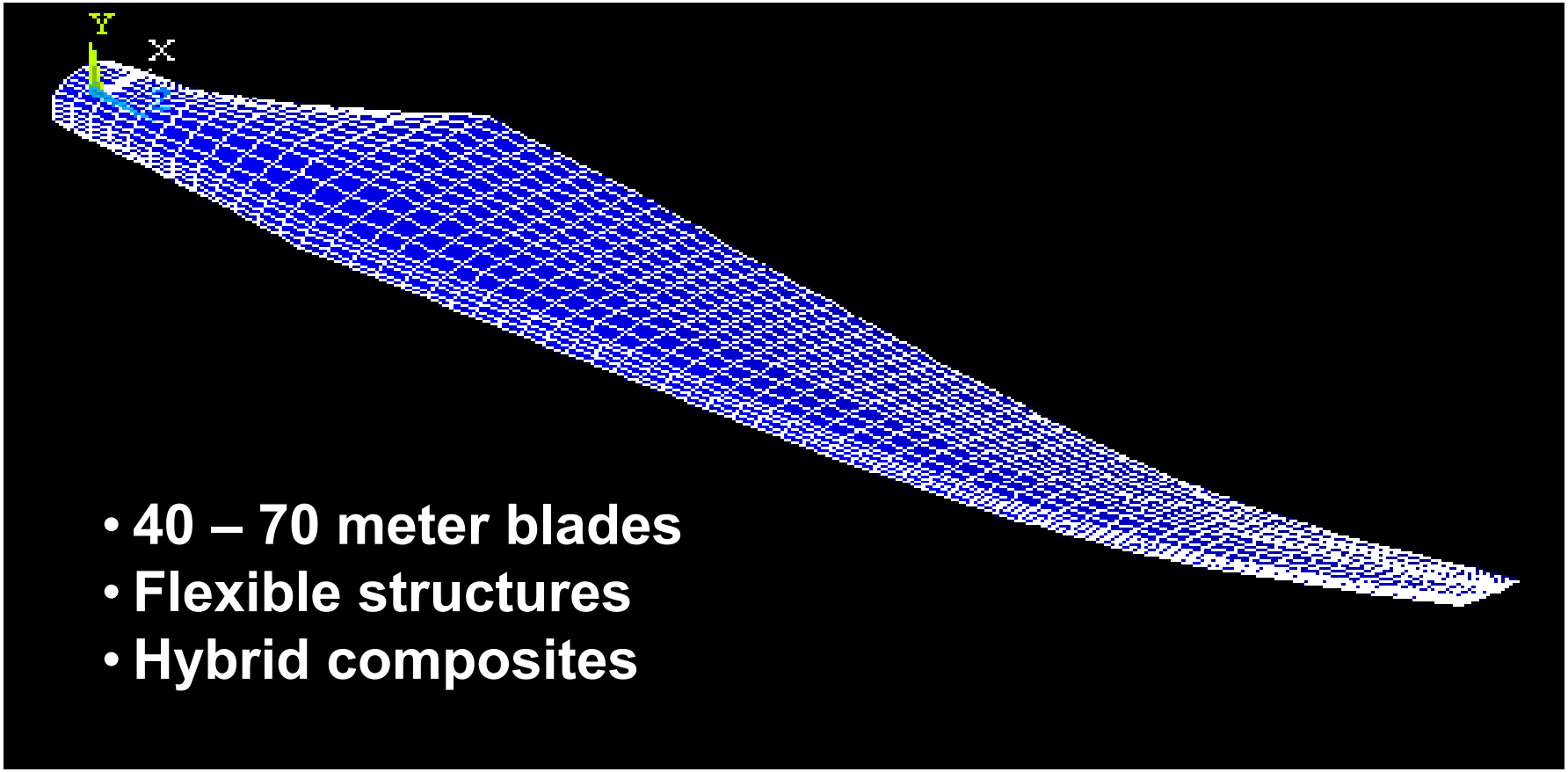
Taller Turbines ➡ Unexplored Inflow





- Characterize inflow features that can impact turbine operation
- Simulation for machine design and operational forecasting

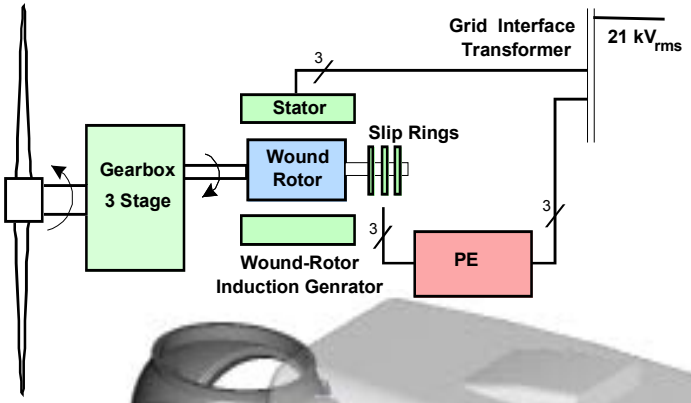
Advanced Blade Structure Designs

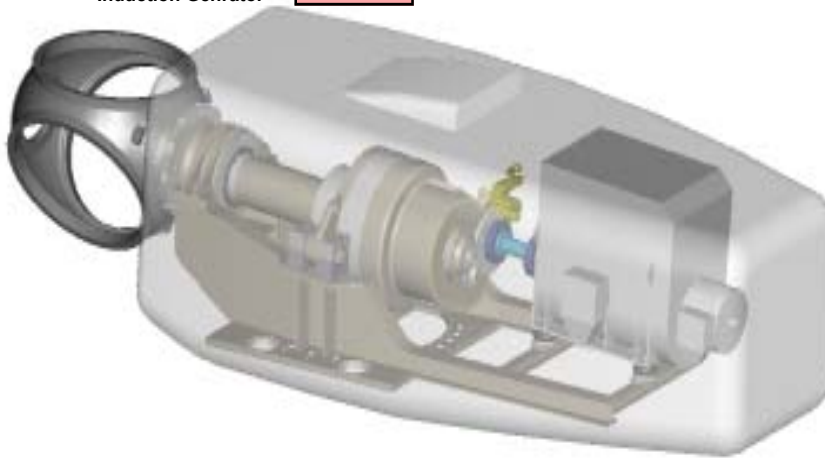


- 40 – 70 meter blades
- Flexible structures
- Hybrid composites

Promising Drive Train Concepts

1.5 MW Baseline





1.5 MW Direct Drive

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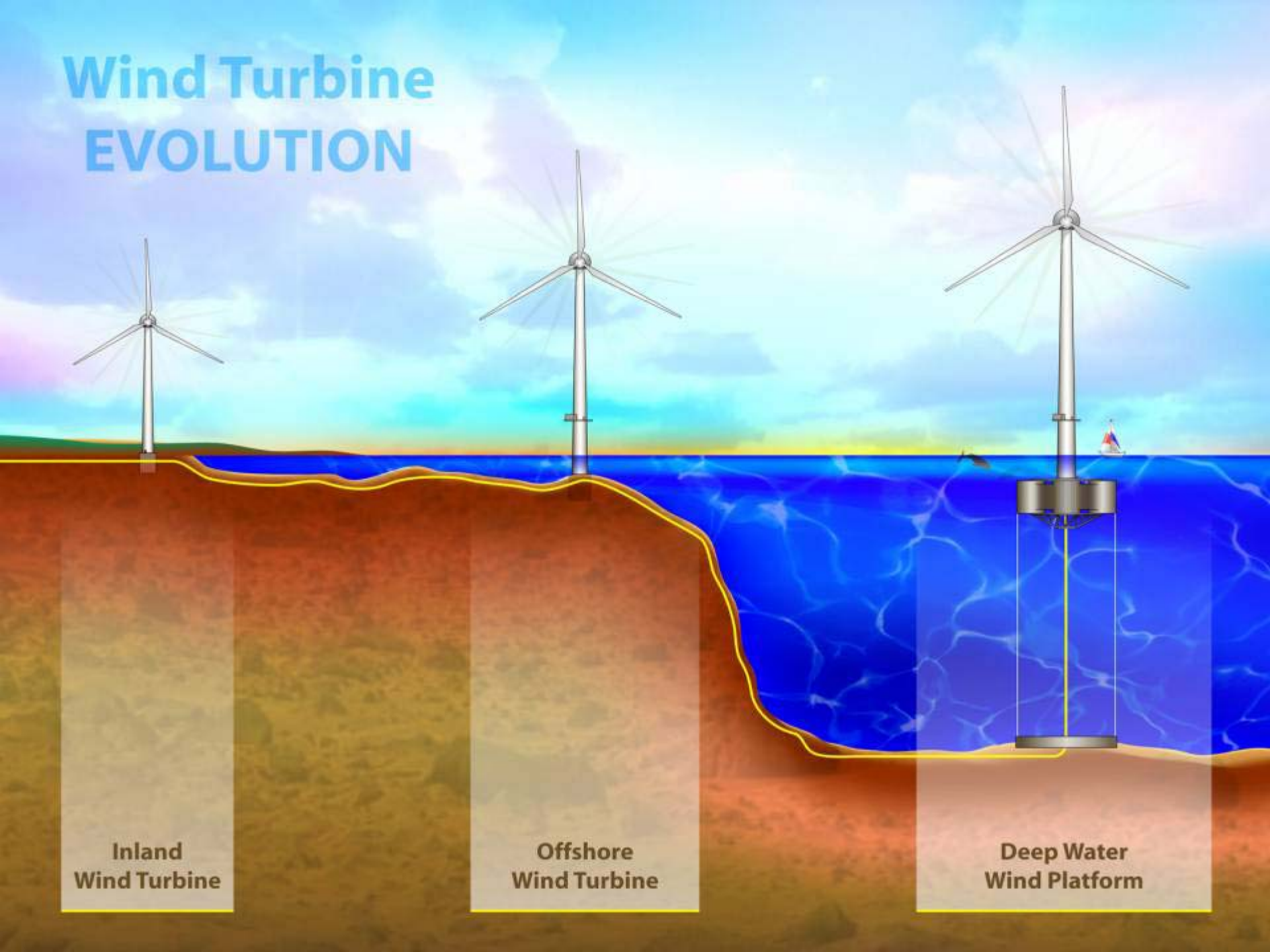

Wind Turbine
EVOLUTION
Inland
Wind Turbine
Offshore
Wind Turbine
Deep Water
Wind Platform

A Future Vision for Wind Energy

2003

Bulk Power Generator
4-6¢ at 15mph

- Land Based
- Bulk Electricity
- Wind Farms

Potential 20% of Electricity Market

Future

Land Based Technology Path

Land Based LWST
Large – Scale
2 - 5 MW

Transmission Barriers

Low Wind Speed Technology
3¢/kWh at 13mph
20% of Electricity
2010

Offshore Technology Path

Offshore Turbines
5 MW & Larger

Cost and Regulatory Barriers

Unique Offshore Designs
- Shallow water
- ***Deep water***

Higher Wind Sites
2010 & Beyond

Wind-Hydrogen Path

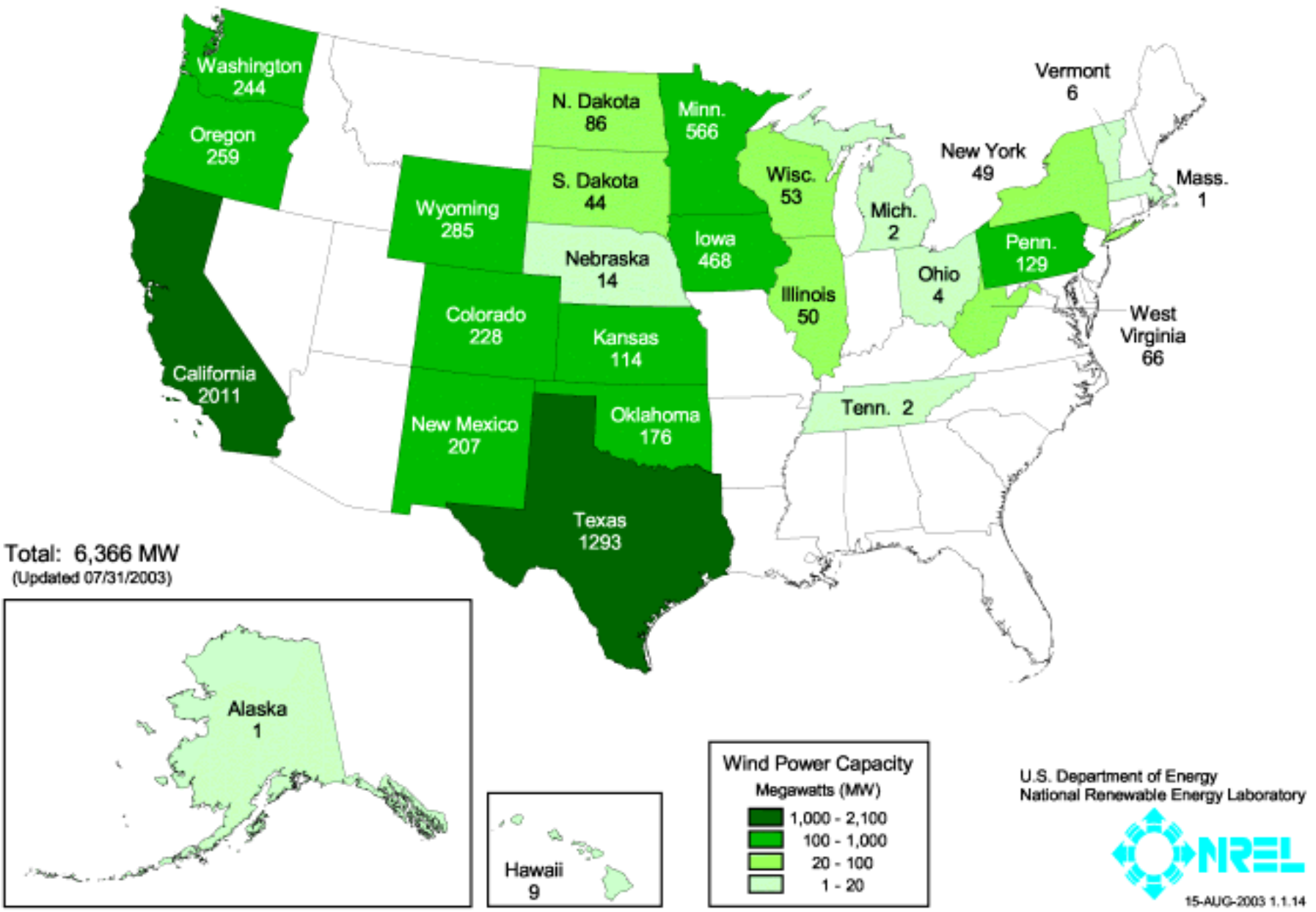
Land & Ocean
Large & Small
"Hydrogen Turbines"

Cost and Infrastructure Barriers

Dual Output Turbines
- Transportation
- Firm Electricity
- Industrial
- Residential

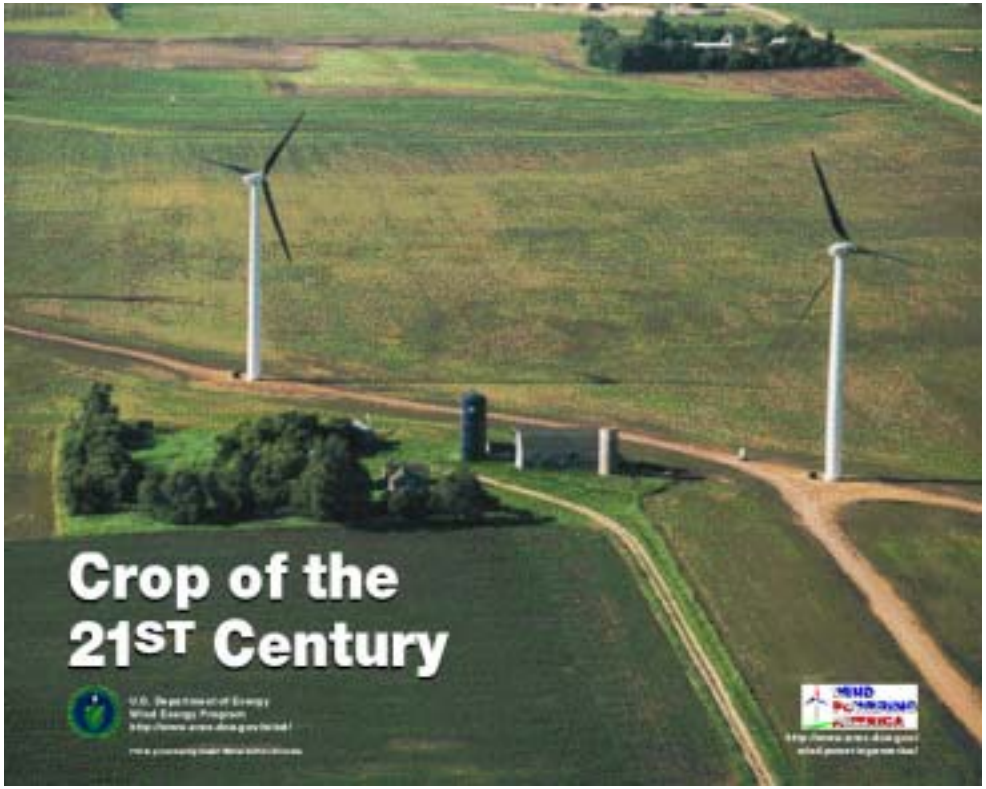
Multi-sector Market
2030 & Beyond

United States - 2003 Expected Year End Wind Power Capacity (MW)



Drivers for Wind Power

- Declining Wind Costs
- Fuel Price Uncertainty
- Federal and State Policies
- Economic Development
- Green Power
- Energy Security



Cost of Energy Trend

1979: 40 cents/kWh

2000:
4 - 6 cents/kWh

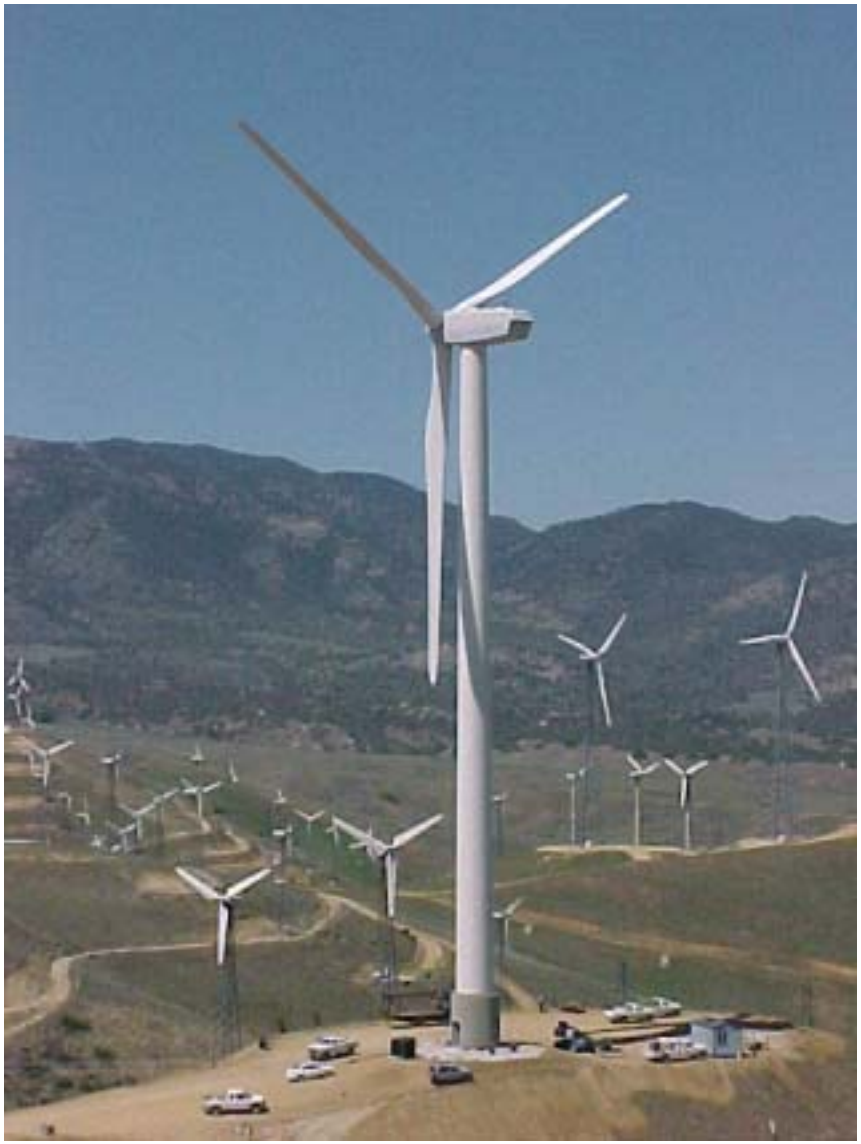
NSP 107 MW Lake Benton wind farm
4 cents/kWh (unsubsidized)

- Increased Turbine Size
- R&D Advances
- Manufacturing Improvements

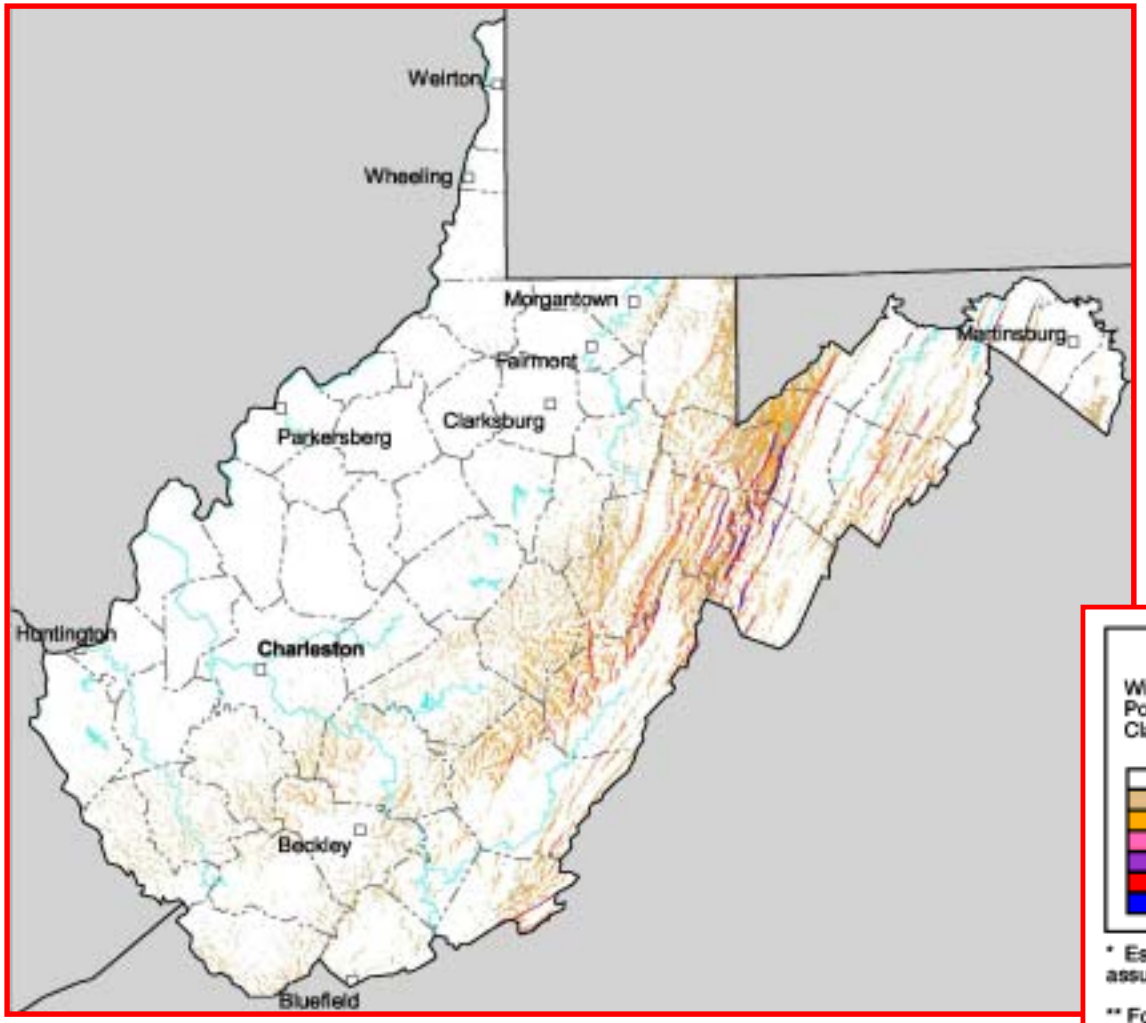
2004:
3 – 4.5 cents/kWh

Wind Economics - Determining Factors

- Wind Resource
- Financing and Ownership Structure
- Taxes and Policy Incentives
- Plant Size: equipment, installation and O&M economies of scale
- Turbine size, model, and tower height
- Green field or site expansion
- What is included: land, transmission, ancillary services



West Virginia Wind Resource Map



- Around 10 GW of potential
- Some of the best developable potential near eastern load centers

Small Wind Turbine Productivity Estimates*

Wind Power Class	Productivity per m² of swept area** (kWh/year)	Wind Power Density at 33 ft (10 m) (W/m²)	Wind Speed at 33 ft (10 m) (mph)	(m/s)
1	< 350	<100	< 9.8	< 4.4
2	350 - 500	100 - 150	9.8 - 11.5	4.4 - 5.1
3	500 - 610	150 - 200	11.5 - 12.5	5.1 - 5.6
4	610 - 690	200 - 250	12.5 - 13.4	5.6 - 6.0
5	690 - 770	250 - 300	13.4 - 14.3	6.0 - 6.4
6	770 - 880	300 - 400	14.3 - 15.7	6.4 - 7.0
7	880 -1170	400 -1000	15.7 - 21.1	7.0 - 9.4

* Estimates are based on different models and sizes of wind turbines assuming a tower height of 80 ft (24 m).

** For systems of different sizes, multiply the estimated productivity by the total swept area of the turbine.

Wind Power's Natural Characteristics

- ***Remote:*** Wind resources often distant from major markets
- ***Variable:*** Plant output varies with variations in the wind
- ***New:*** Operators more comfortable with established power technologies with known characteristics

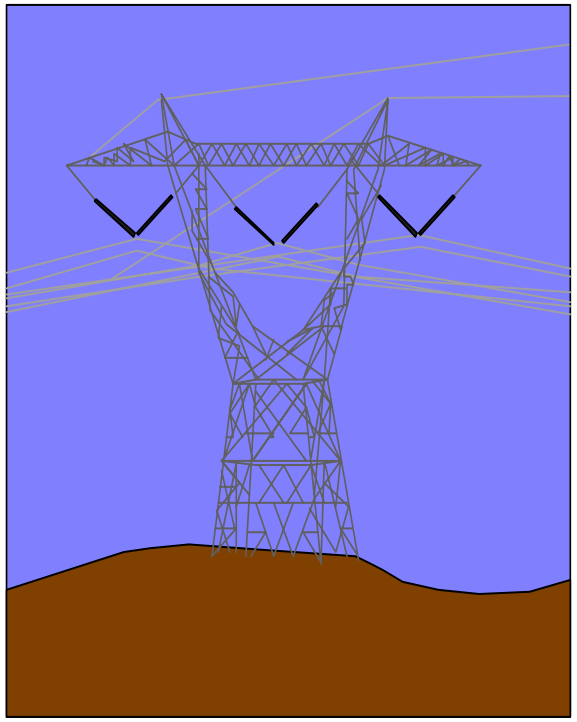
Key Issue: How do you fairly account for wind's natural characteristics?

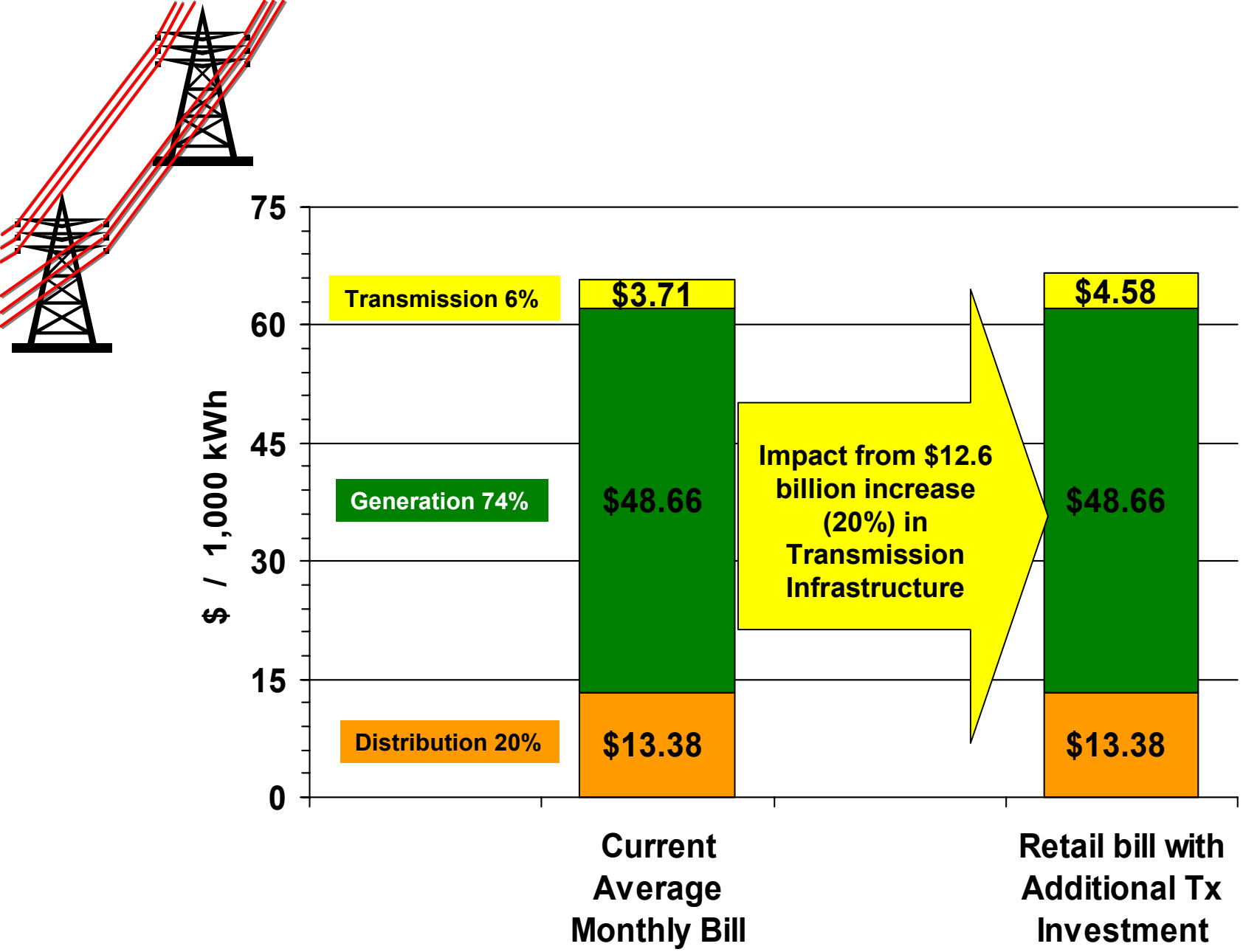
Key Issues for Wind Power

- Transmission: access, RTO formation and rules, new lines
- Operational impacts: intermittency, ancillary services, allocation of costs
- Siting and Permitting: avian/wildlife, noise, visual, federal land
- Restructuring, regulatory, and market uncertainty
- Accounting for non-monetary value: green power, no fuel price risk, reduced emissions

Transmission is Most Critical Long-term Issue Facing Wind

- Current transmission system is increasingly stressed: new wires needed
- Transmission Policy
  - Tariffs and Operational Rules: difficult for non-dispatchable generators
  - Rules are evolving through FERC and RTO processes



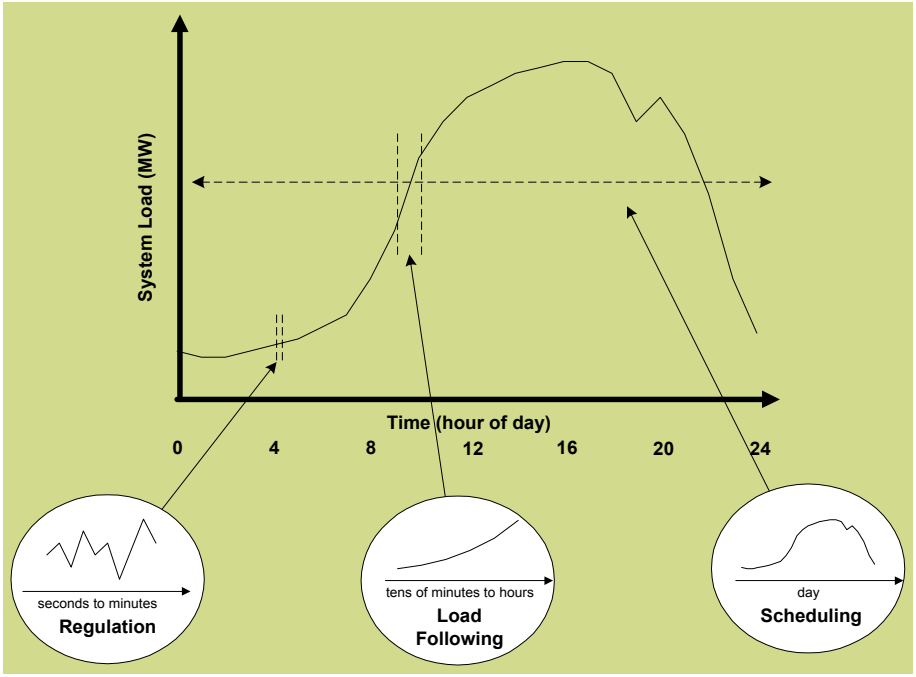

75
60
45
30
15
0
$ / 1,000 kWh
Transmission 6%
Generation 74%
Distribution 20%
$3.71
$48.66
$13.38
Impact from $12.6 billion increase (20%) in Transmission Infrastructure
$4.58
$48.66
$13.38
Current Average Monthly Bill
Retail bill with Additional Tx Investment

Variability Can Increase Operating Costs

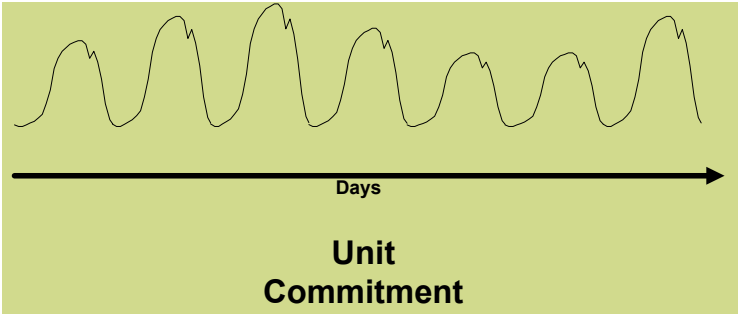
- Committing unneeded generation
- Scheduling unneeded generation
- Allocating extra load-following capability
- Violation of system performance criteria
- Increased cycling operation
- **These are reflected in *ancillary services* costs**

Incremental cost added by wind's variability:
Is it ~0.1¢/kWh or ~1¢/kWh?

Power-System Operation Impacts



- Regulation -- seconds to a few minutes -- similar to variations in customer demand (loads)
- Load-following -- tens of minutes to a few hours -- usage follows predictable patterns, wind less so



- Scheduling and commitment of generating units -- one to several days -- wind impacts unclear

Wind controlled by nature, not power-plant operators!

Mitigating Factors (not accounted for)

- Actual wind farm power output characteristics
  - Multiple generator smoothing (intra- and inter-site)
  - New generator and farm interface abilities
- Large scale geographic diversity
- *System* characteristics (loads and generators) and statistical, not deterministic nature
- Ability to forecast
- Evolution of competitive wholesale markets (near real time operations and unscheduled deviation practices)

Need for in-depth data and analysis

Recently Completed Wind Integration Studies

- UWIG/Xcel Energy North (Electrotek)
  - $1.85/MWh for regulation, imbalance & forecasting with about 4% wind (280 MW)
- Bonneville Power (Hirst)
  - Under $5.00 per MWh for day ahead forecast error, regulation, and load following with 1000 MW wind
- PacifiCorp
  - $5-6/MWh for imbalance and reserves with up to 20% penetration
- PJM (Hirst) – scaling did not account for geographic diversity
  - $0.70-2.80/MWh for imbalance payments, reduced with improved scheduling
  - $0.05-0.30/MWh for regulation, load paid $0.60/MWh
- WE Energies (Electrotek)
  - $1.90 to $2.92 per MWh for spinning reserves, regulating reserves, and intra-hour load following reserves with 3.5% to 28.5% wind
- Scandinavia (Nordel) – very large penetration simulated, up to 21GW & 63%
  - No added regulation in aggregated N Europe; no impact on contingency reserves
  - 3-8% load following burden (did not consider geographic diversity or aggregation system)
- Ireland (Garrad Hassan) – studied 4,000 MW wind on a 6,500 MW island

Typical Issues for Wind Siting

- Visual impact
- Avian and Wildlife concerns
- Noise
- Construction impact
- Cultural/historic resources
- TV, microwave, radar interference
- Permitting processes: private and public land

Wind Power Provides Rural Economic Benefits

- 240 MW of wind in Iowa
  - $640,000/yr in lease payments to farmers ($2,000/turbine/yr)
  - $2 million/yr in property taxes
  - $5.5 mil/yr in O&M income
  - 40 long-term O&M jobs
  - 200 short-term construction jobs
  - Doesn't include multiplier effect
- 107 MW wind project in MN
  - $500,000/yr in lease payments to farmers
  - $611,000 in property taxes in 2000 = 13% of total county taxes
  - 31 long-term local jobs and $909,000 in income from O&M (includes multiplier effect)

Recent Developments

- The wind industry is delivering < 3 cent/ kWh, including PTC for large projects
- Many large projects completed last 2 years
  - 300 MW Stateline (WA/OR)
  - 109 MW Utilicorp (KS)
  - 4>100 MW in West Texas
- Around 1500 MW expected to be installed in 2003
- Gas price increases and the power crisis
  - CO: 162 MW of wind wins all-source bid on economics alone
  - “wind is the lowest cost resource”
  - serious consideration of GW (BPA, Austin, Pacificorp)
- Energy security and resource diversity issues
- Transmission and grid impacts to the forefront
- Serious consideration of off-shore wind for New England and Mid-Atlantic markets
- Farm Bill provisions passed

Resources: On The Web

- AWEA Web site: http://www.awea.org
- NWTC Web site: http://www.nrel.gov/wind
- National Wind Coordinating Committee: http://www.nationalwind.org
- Utility Wind Interest Group site: http://www.uwig.org
- WPA Web site:

  http://www. Windpoweringamerica.gov
- Homepower Web Site: http://www.homepower.com
- Windustry Project: http://windustry.org
- Best Links: www.me3.org