National Wind Technology Center

Technology Overview
Fundamentals of Wind Energy
AWEA Pre-Conference Seminar
WindPower 05
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NREL

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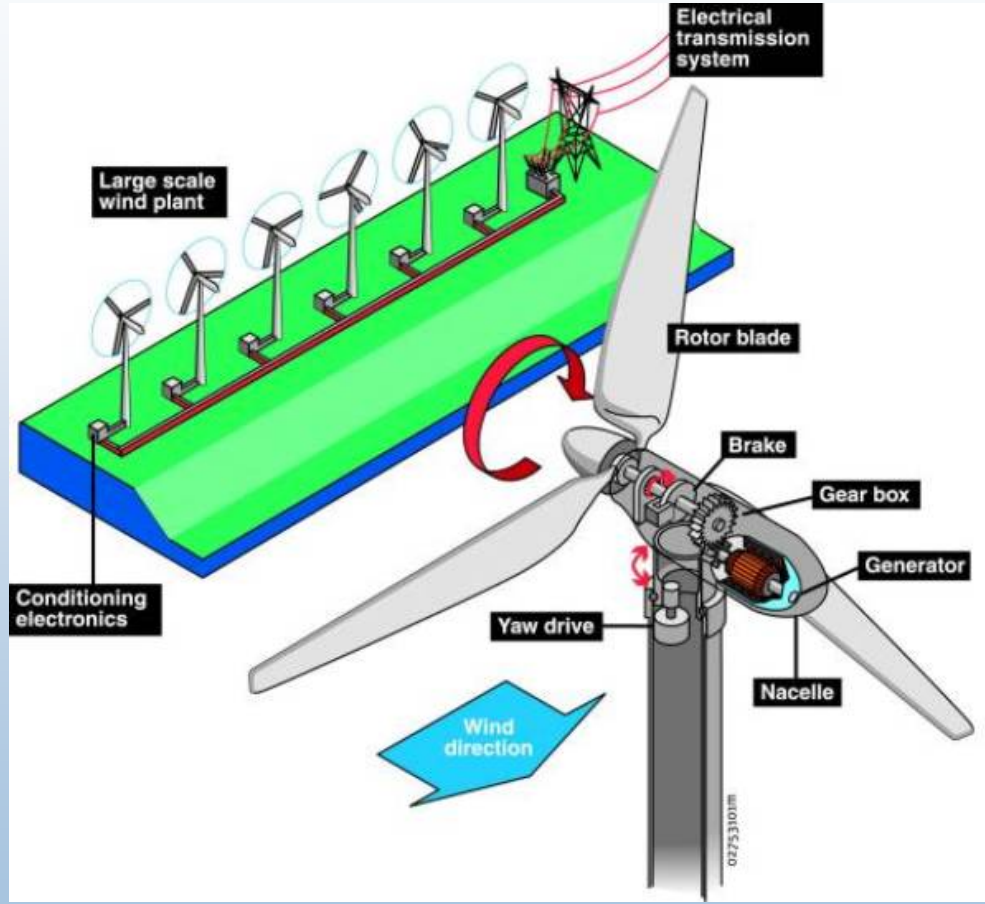
- Technology Description
- Costs and Trends
- Future Developments

Fundamentals

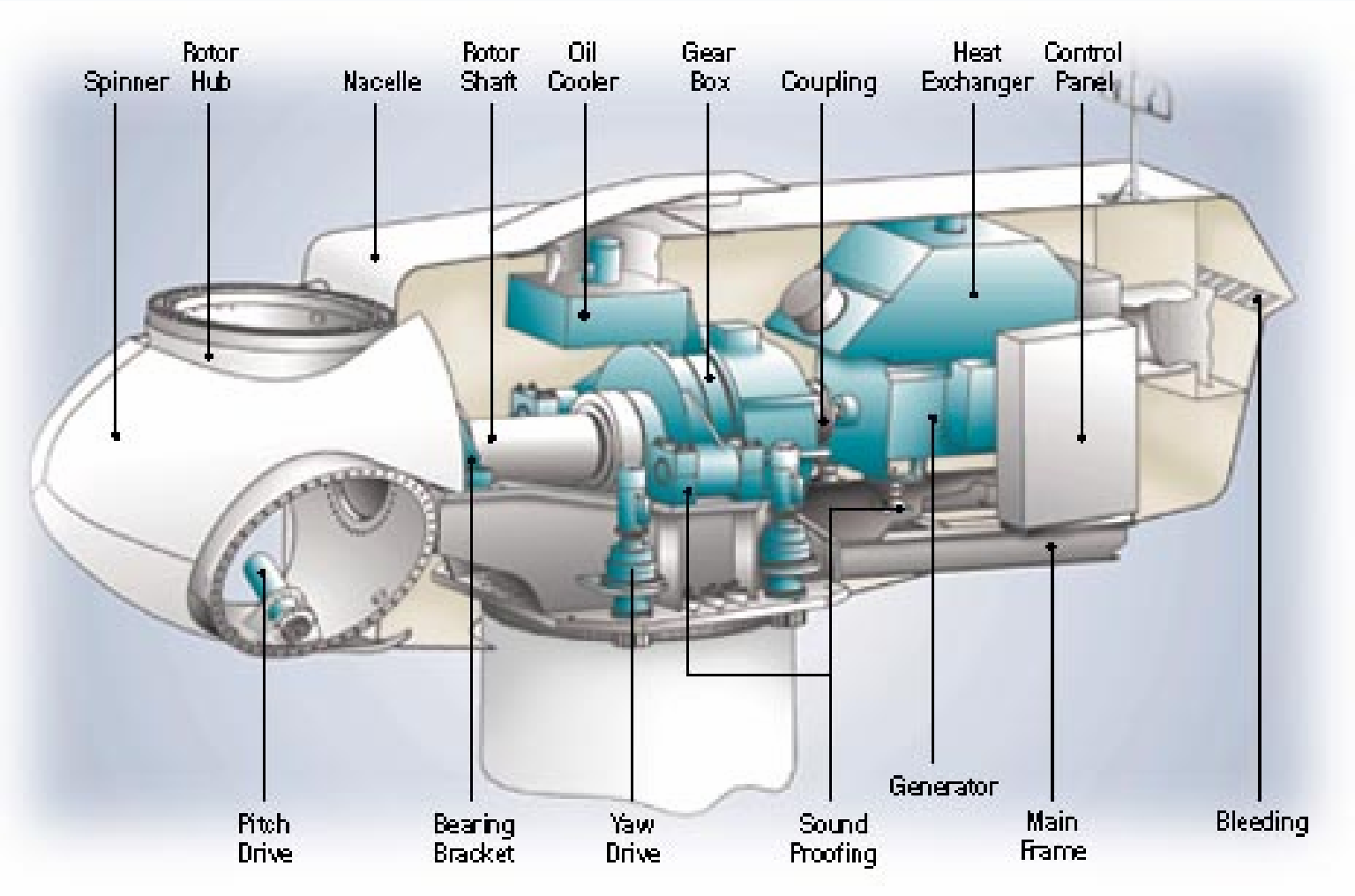
- Rotor
- Nacelle
- Tower

Wind Energy Technology

At it's simplest, the wind turns the turbine's blades, which spin a shaft connected to a generator that makes electricity. Large turbines can be grouped together to form a wind power plant, which feeds power to the electrical transmission system.



What's in there?



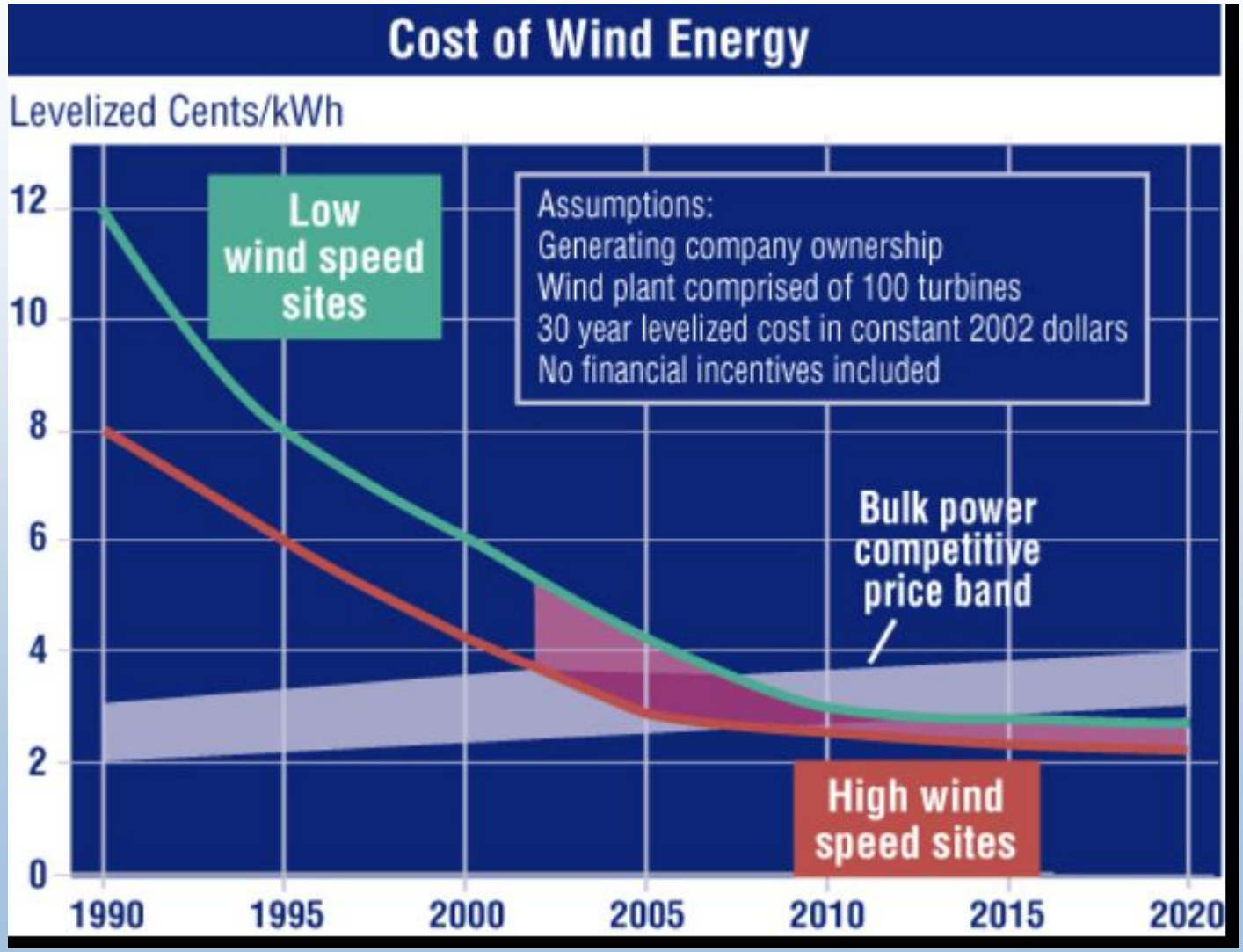
Configuration Choices

- Fixed pitch or variable pitch
- Turbine rating
- Tower height
- Variable speed or not
- Lattice, tubular or guyed tower
- Special climate packages

Wind Farm Characteristics

- Rapid Construction Time
- Shared Land Use
- No Emissions
- No Fuel Payments
- Economies of Scale
- More Efficient Maint. Opts.

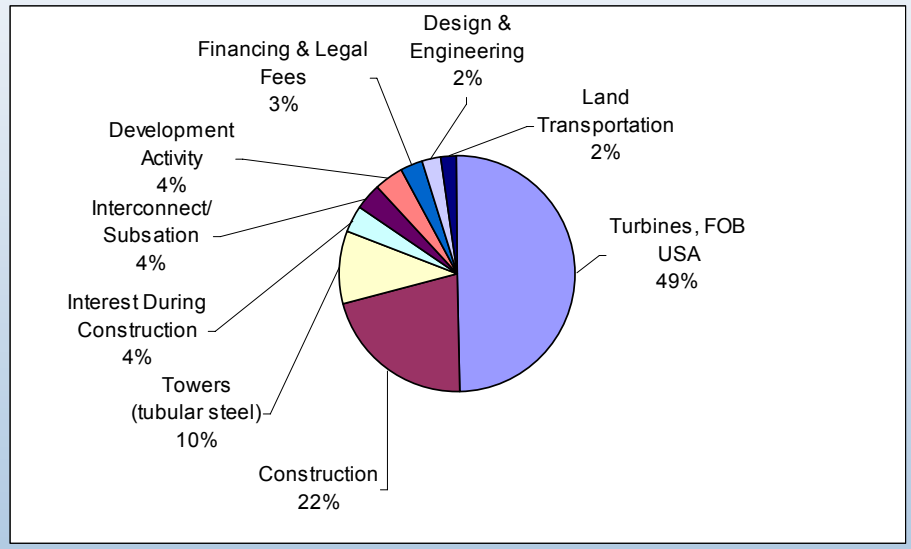
Reducing the Cost of Energy



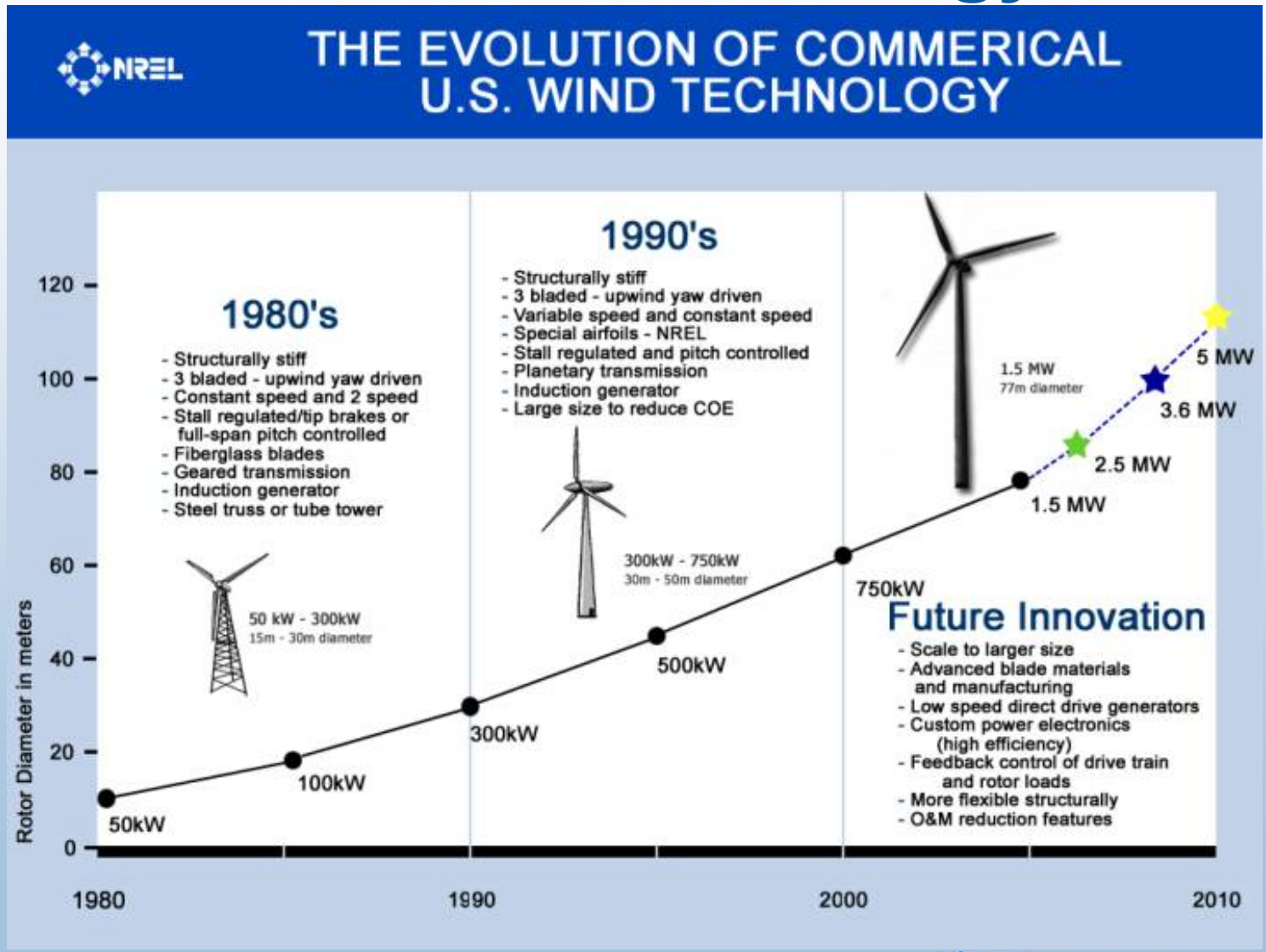
Cost of Energy Drivers

- Initial costs
- Project size & location
- Financing mechanism
- Taxes and other incentives
- Operating expenses
- Energy Production
  - Wind resource
  - Project performance
  - Project reliability

Initial Cost Elements



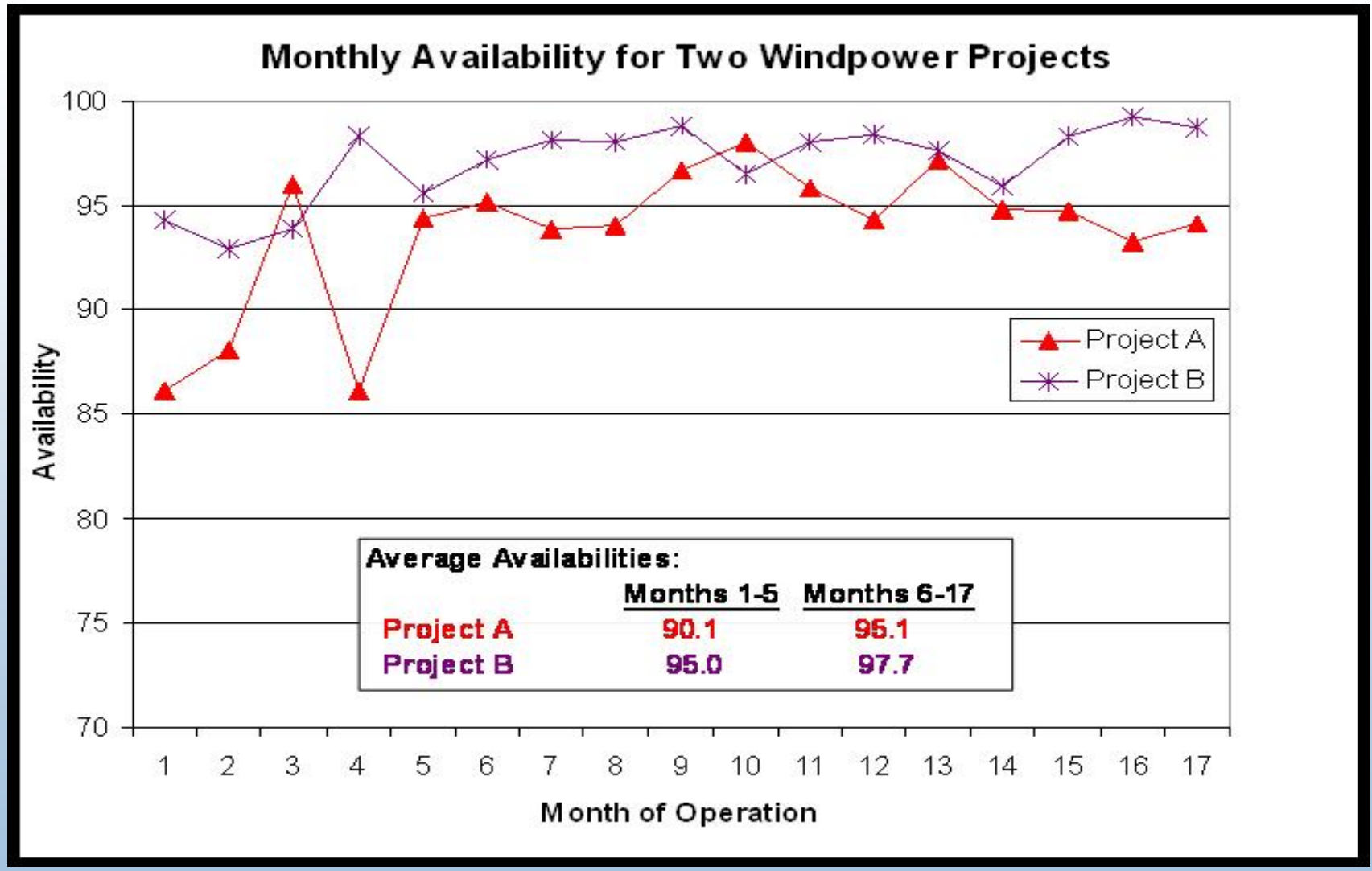
Evolution of Commercial U.S. Wind Technology



Do bigger turbines have lower COE?

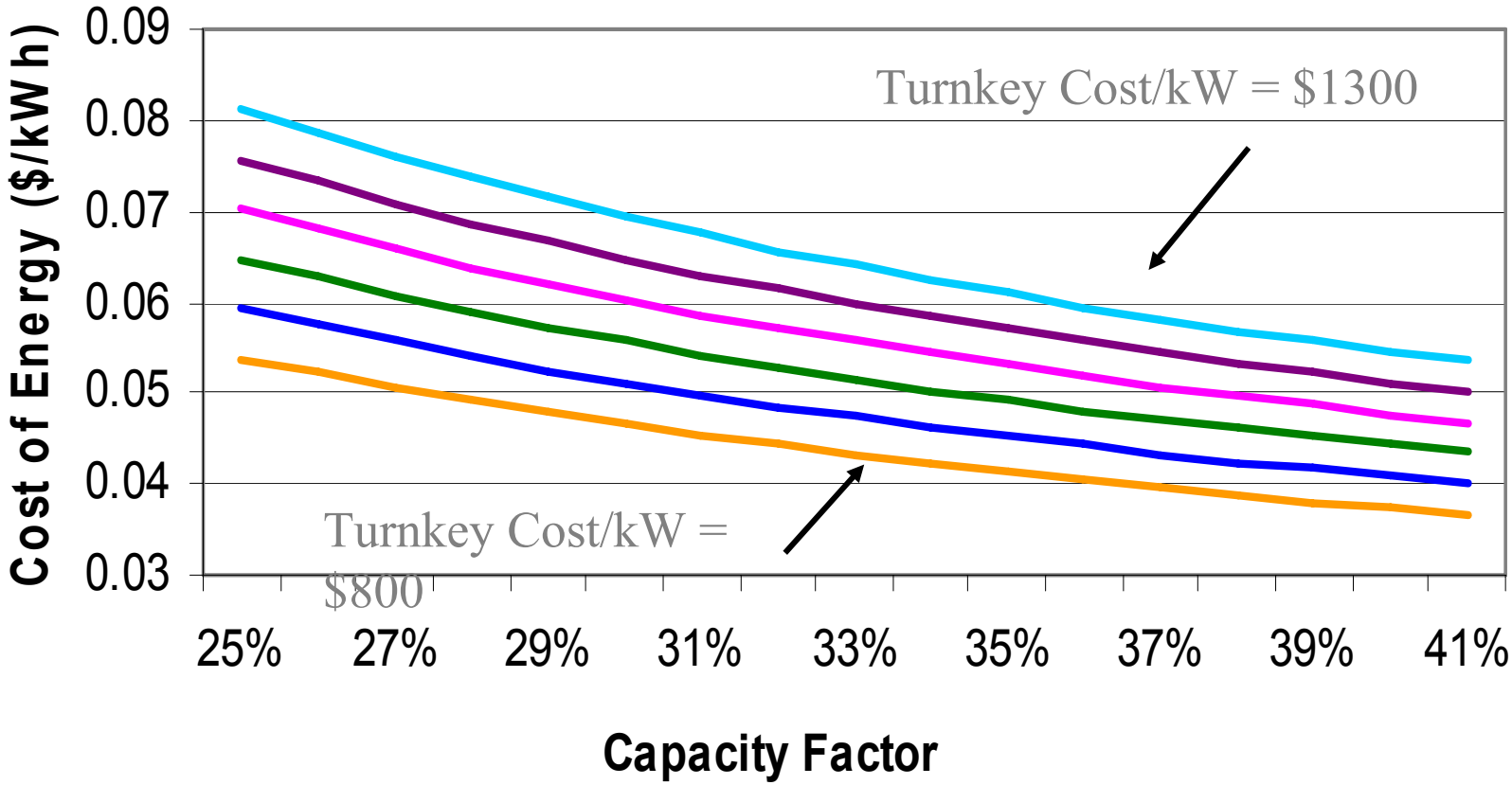
- No simple answer
- Size range matters
- Balance of many factors
  - Equipment costs
  - Wind shear
  - Tower height
  - Terrain/Crane/Construction
  - Transportation costs
  - Operations and maintenance costs

Reliability

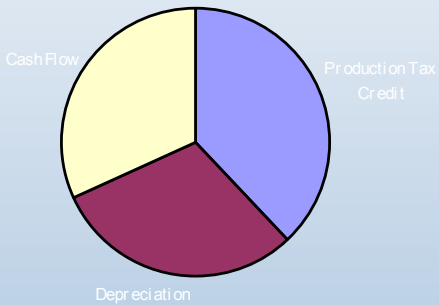


Cost of Energy

Average Cost of Money 12%; O&M $0.01/kWh



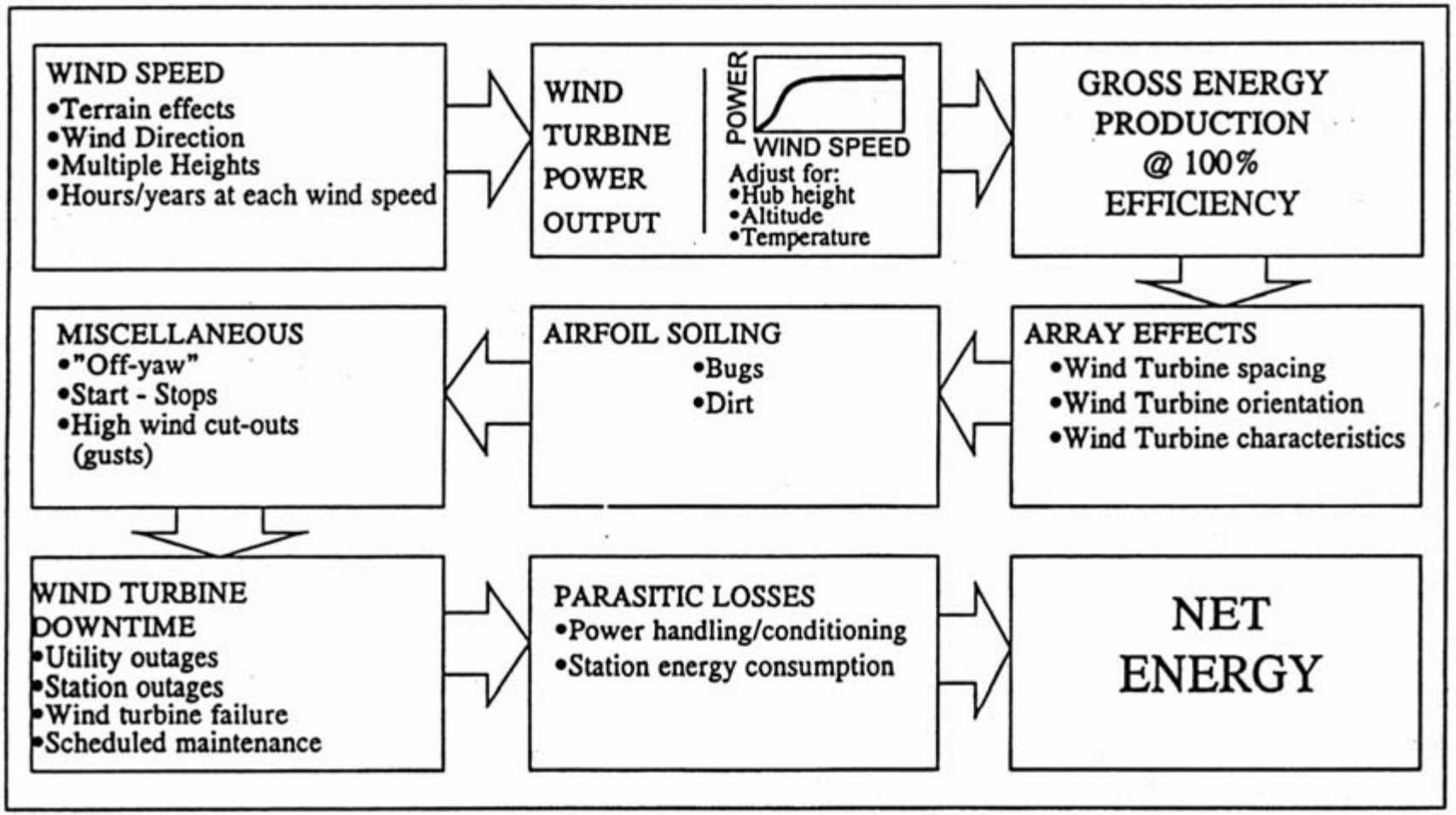
Where is the Money!?



Multiple sources of value:

- Operating Cash Flow
  - Power Purchase Agreement
  - Green attributes
  - Other incentives
- Depreciation
  - 5-6 year
- Tax Credits
  - Federal Production Tax Credits
  - State tax credits

Net Energy Calculations



Future Cost Reductions

- Financing Strategies
- Manufacturing Economy of Scale
- Site Specific Turbine Design
- Technology Improvements

Future Technology Developments

- Offshore
- Drive Train Innovations
- Transportation or construction limitations
- Blade Design Innovations
- Controls
- Improved Design Tools

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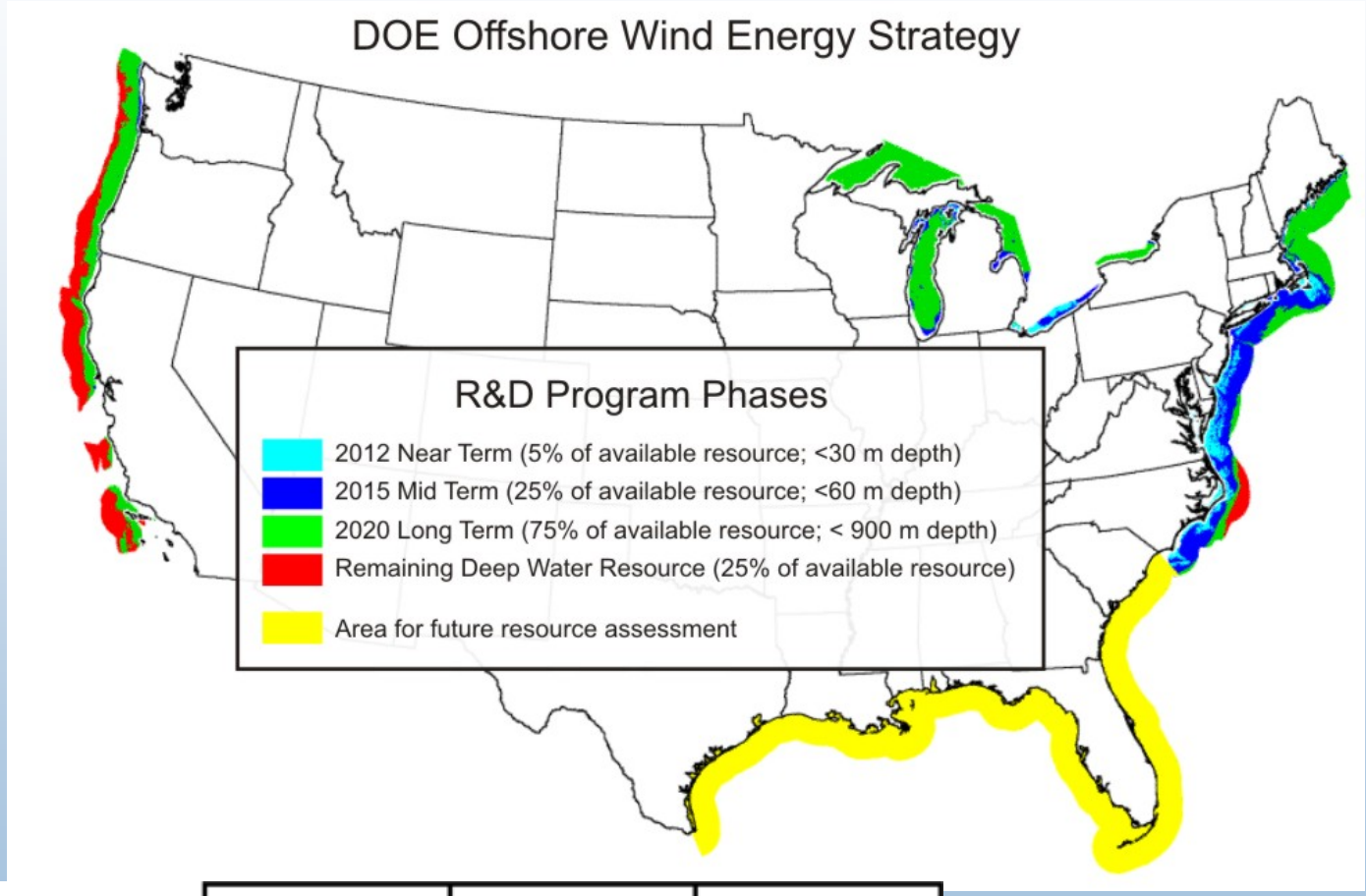
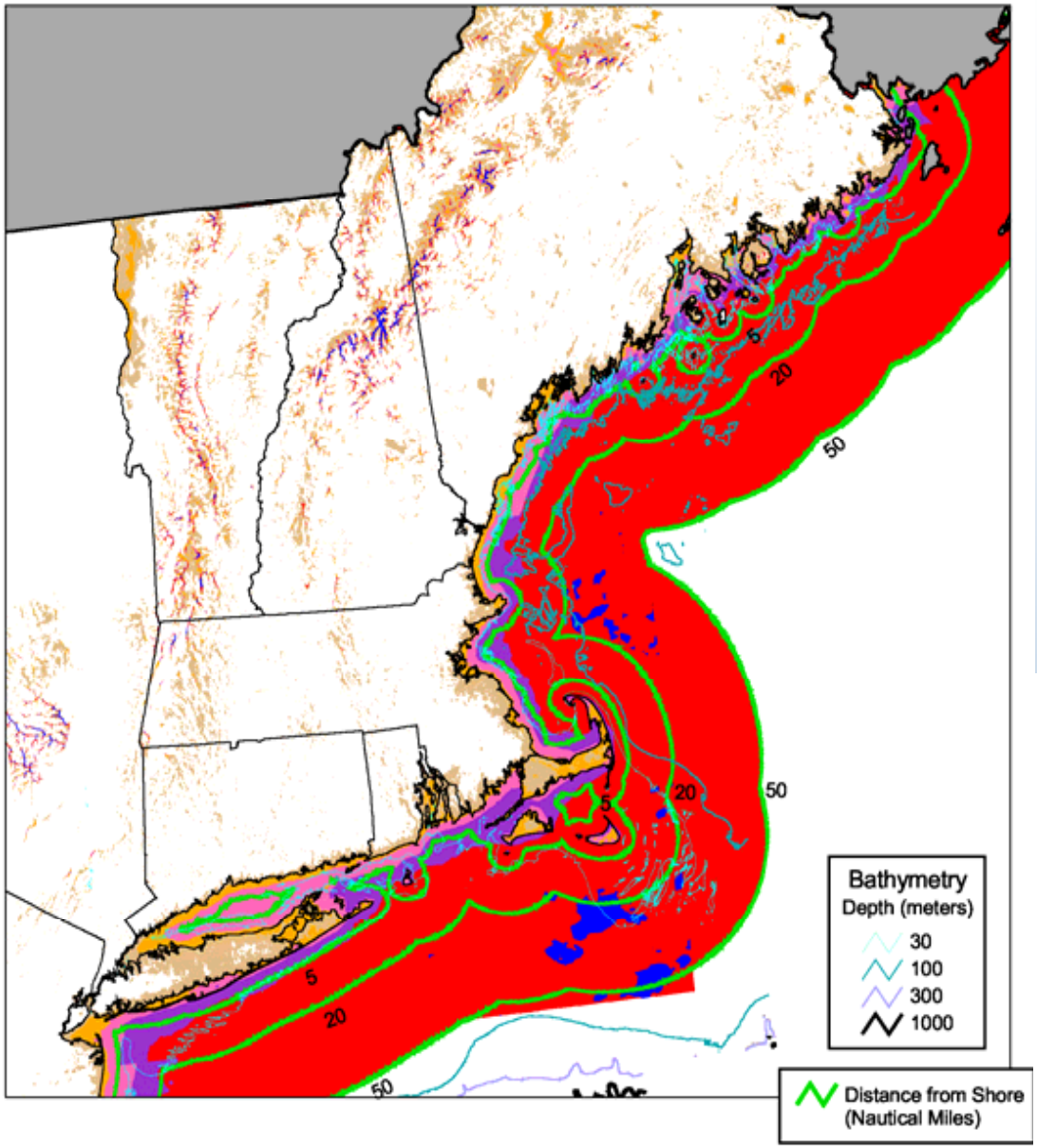
U.S. Offshore Wind Energy Opportunity



Depths	<30M	30-60M	60-900M
Resource Estimates	50GW	200GW	750GW
Exclusion Criteria	67%	33-67%	67%

New England Offshore Resource

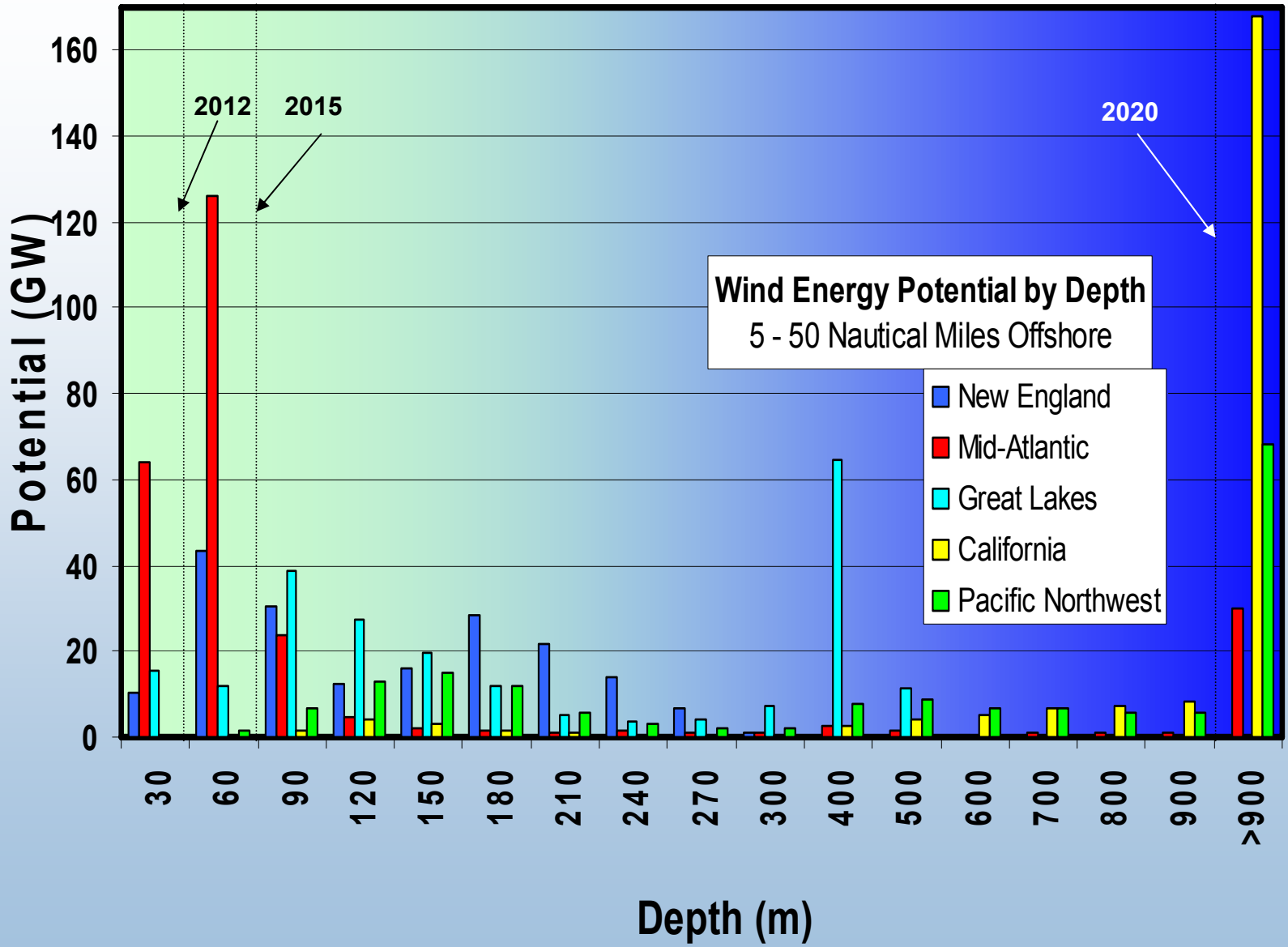


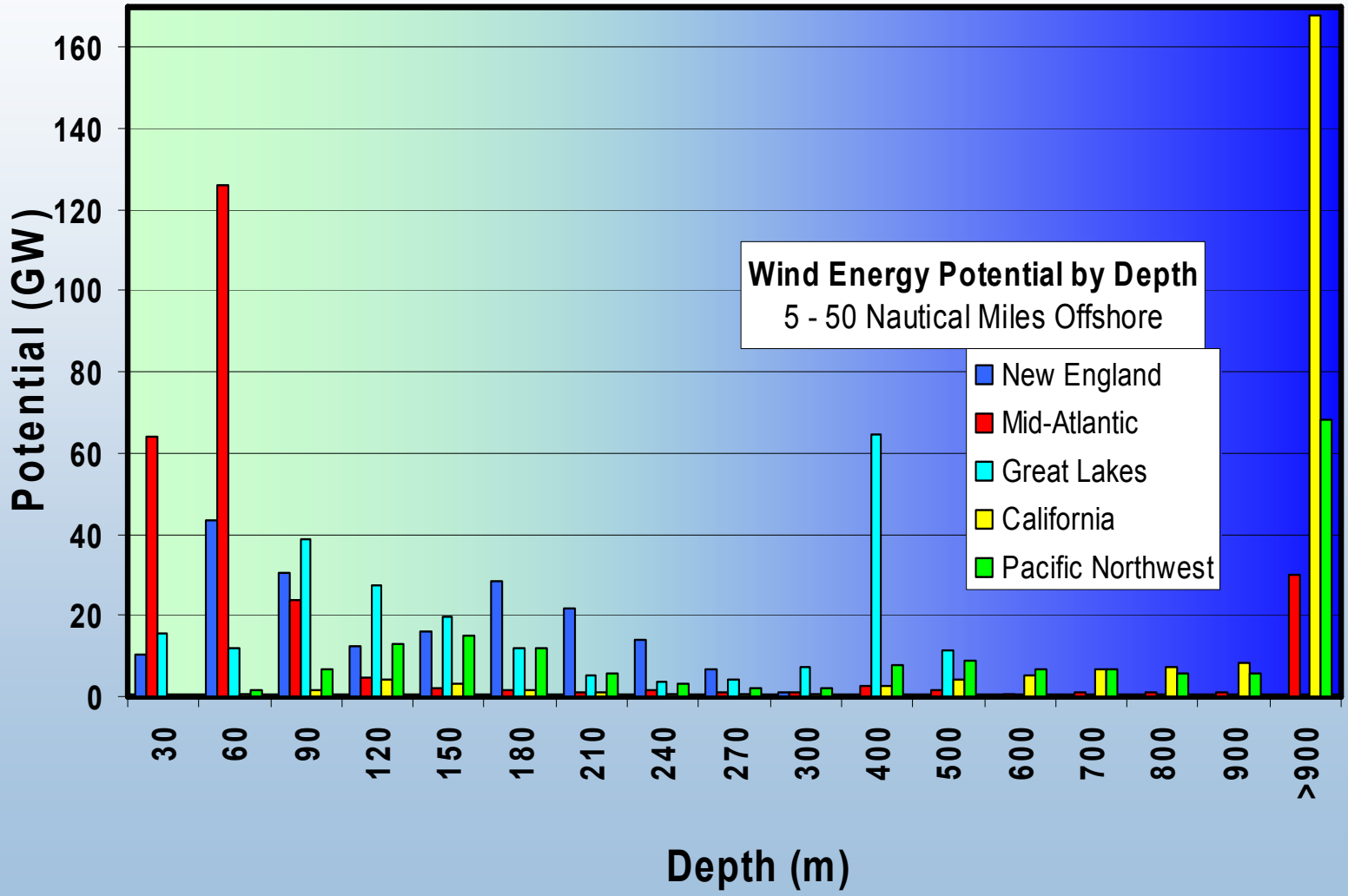
Wind Power Classification

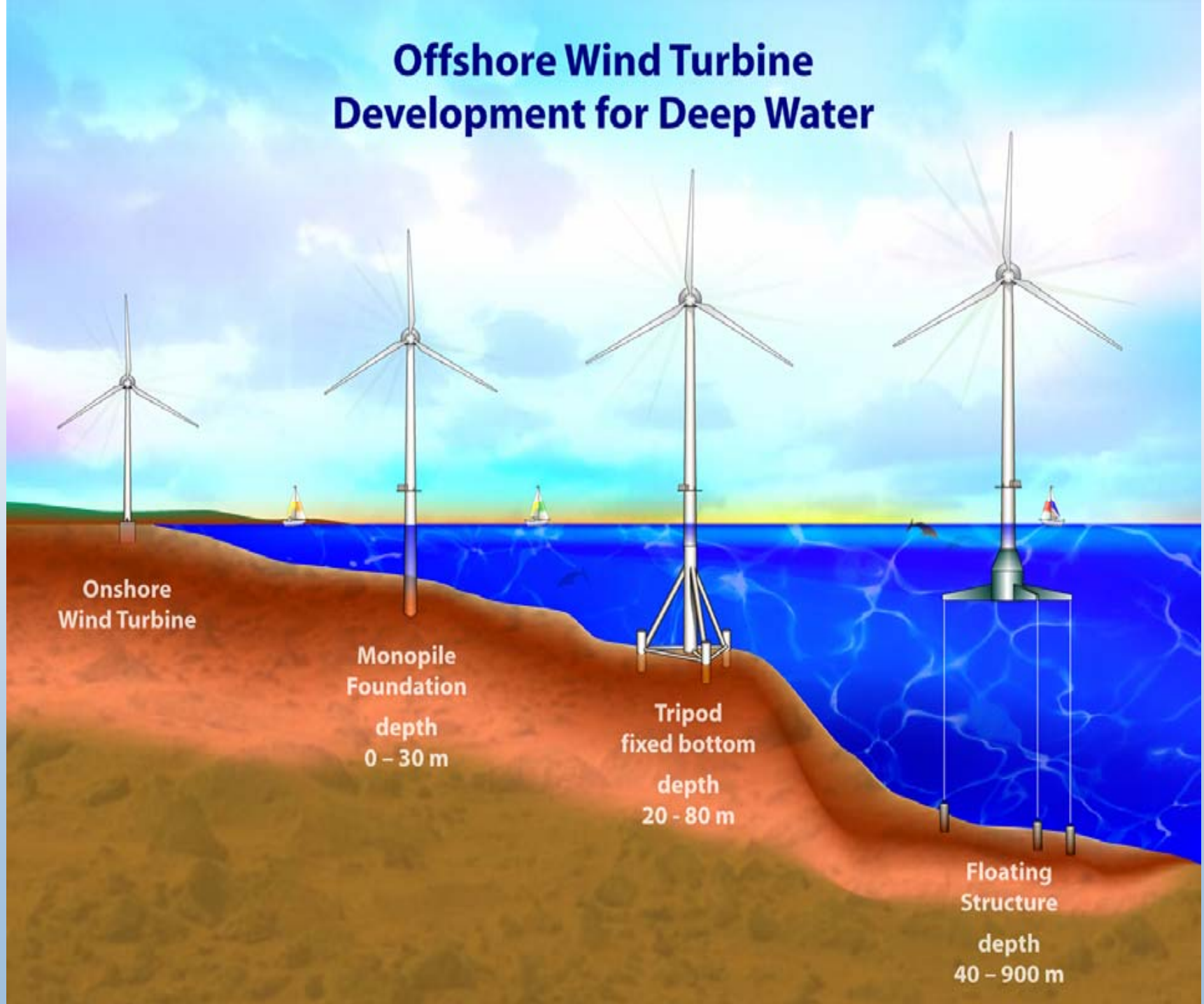
Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m^2	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m mph
2	Marginal	200 - 300	5.6 - 6.4	12.5 - 14.3
3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7
7	Superb	> 800	> 8.8	> 19.7

[a] Wind speeds are based on a Weibull k value of 2.0

U.S. Department of Energy
National Renewable Energy Laboratory


Potential (GW)
160
140
120
100
80
60
40
20
0
2012
2015
2020
Wind Energy Potential by Depth
5 - 50 Nautical Miles Offshore
New England
Mid-Atlantic
Great Lakes
California
Pacific Northwest
30
60
90
120
150
180
210
240
270
300
400
500
600
700
800
900
>900
Depth (m)

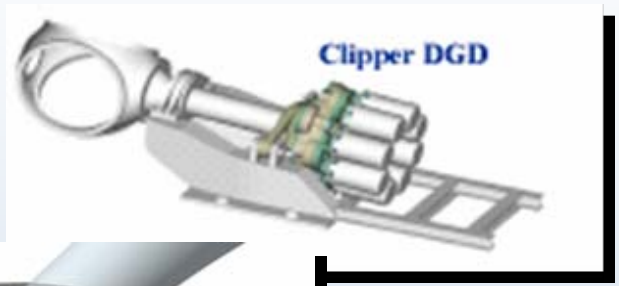

Wind Energy Potential by Depth
5 - 50 Nautical Miles Offshore
New England
Mid-Atlantic
Great Lakes
California
Pacific Northwest
Potential (GW)
0
20
40
60
80
100
120
140
160
30
60
90
120
150
180
210
240
270
300
400
500
600
700
800
900
>900
Depth (m)

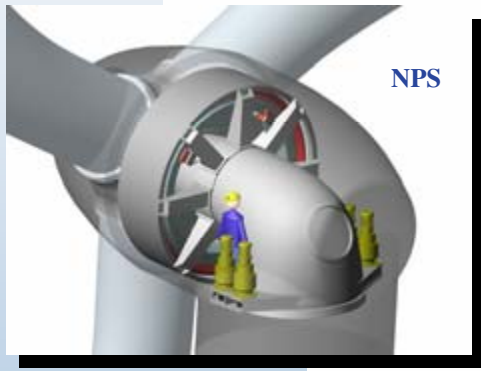

Offshore Wind Turbine
Development for Deep Water
Onshore
Wind Turbine
Monopile
Foundation
depth
0 – 30 m
Tripod
fixed bottom
depth
20 - 80 m
Floating
Structure
depth
40 – 900 m

GE Wind Energy
3.6 MW Prototype

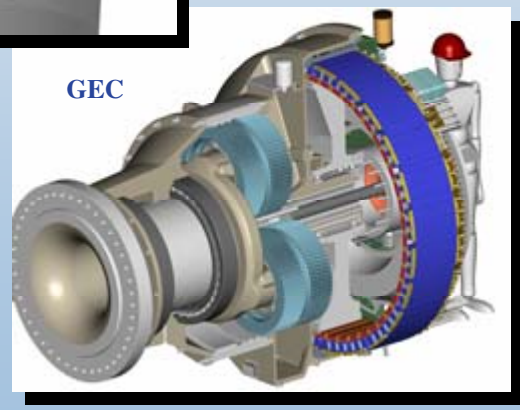
- Design concept similar to offshore GE 1.5 / 70.5
- Offshore GE 3.6 MW
  104 meter rotor diameter
- Offshore design requirements considered from the outset:
  - Crane system for all components
  - Simplified installation
  - Helicopter platform

Advanced Drivetrain R&D



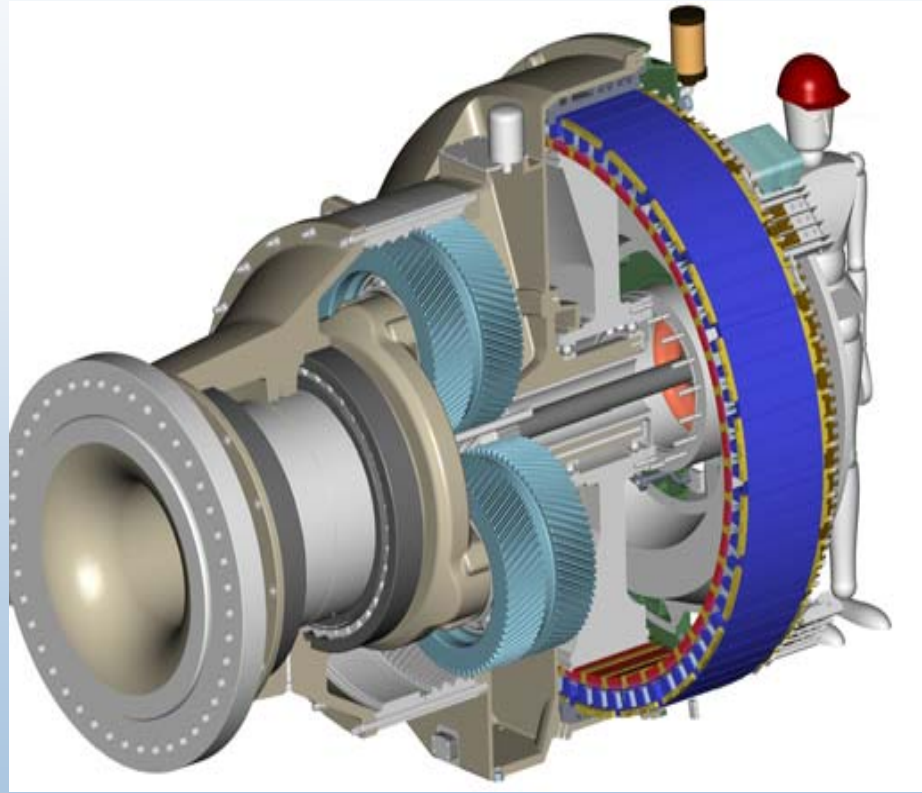


Tomorrow

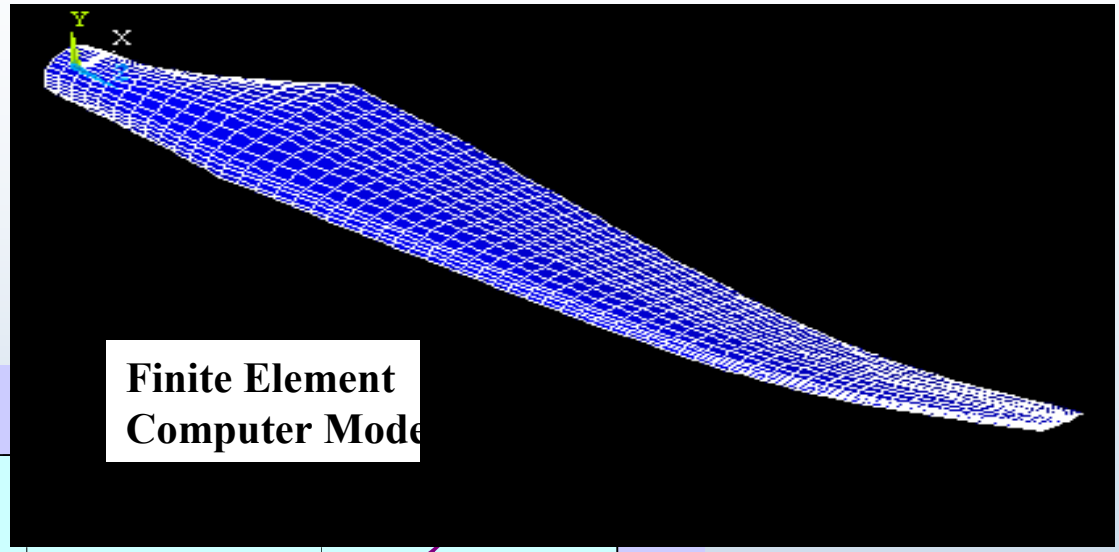


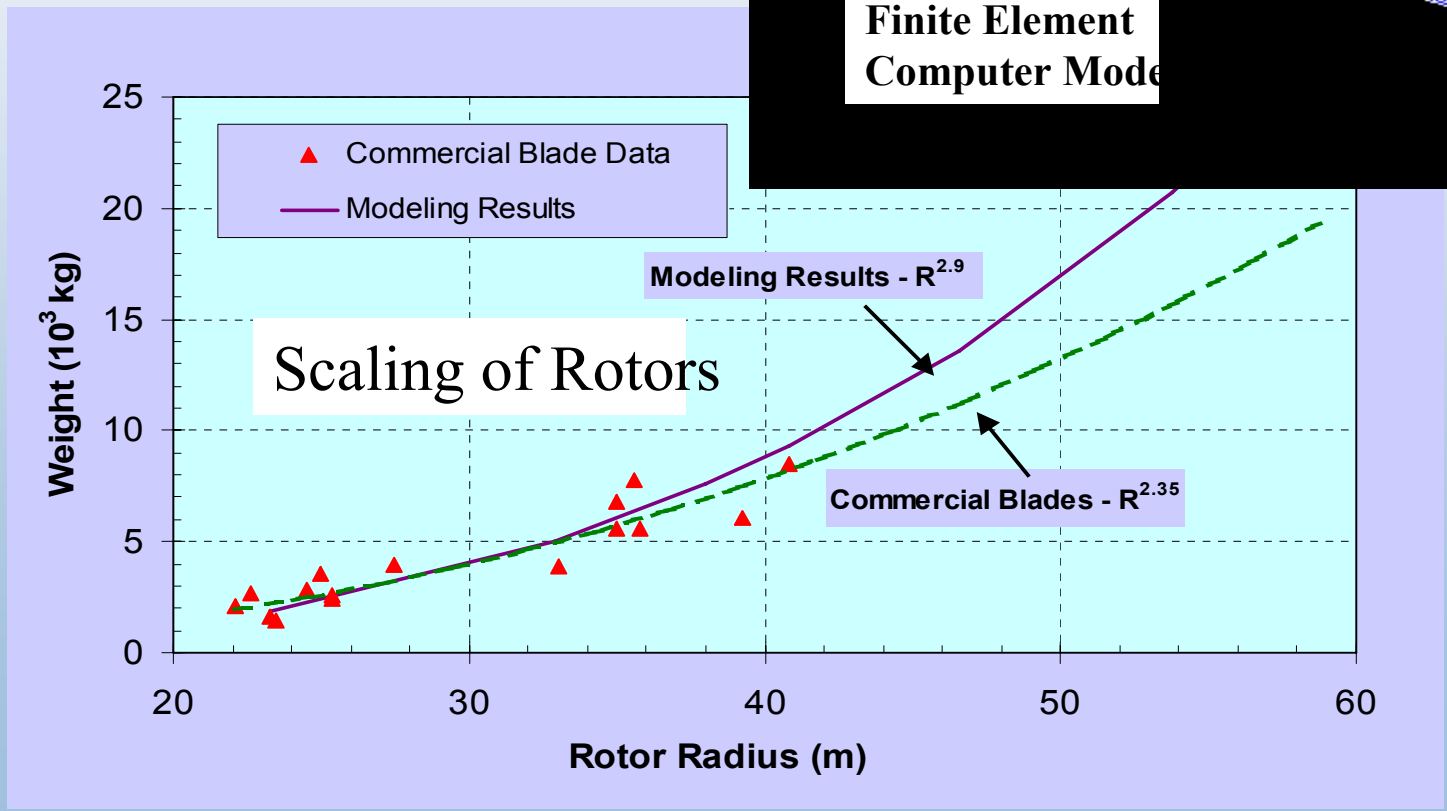
Future Technology Developments

- Reduced Loads, Lower Costs and Improved Performance
  - Rotors
  - Controls
  - Drive Train/ Power Electronics
  - Towers



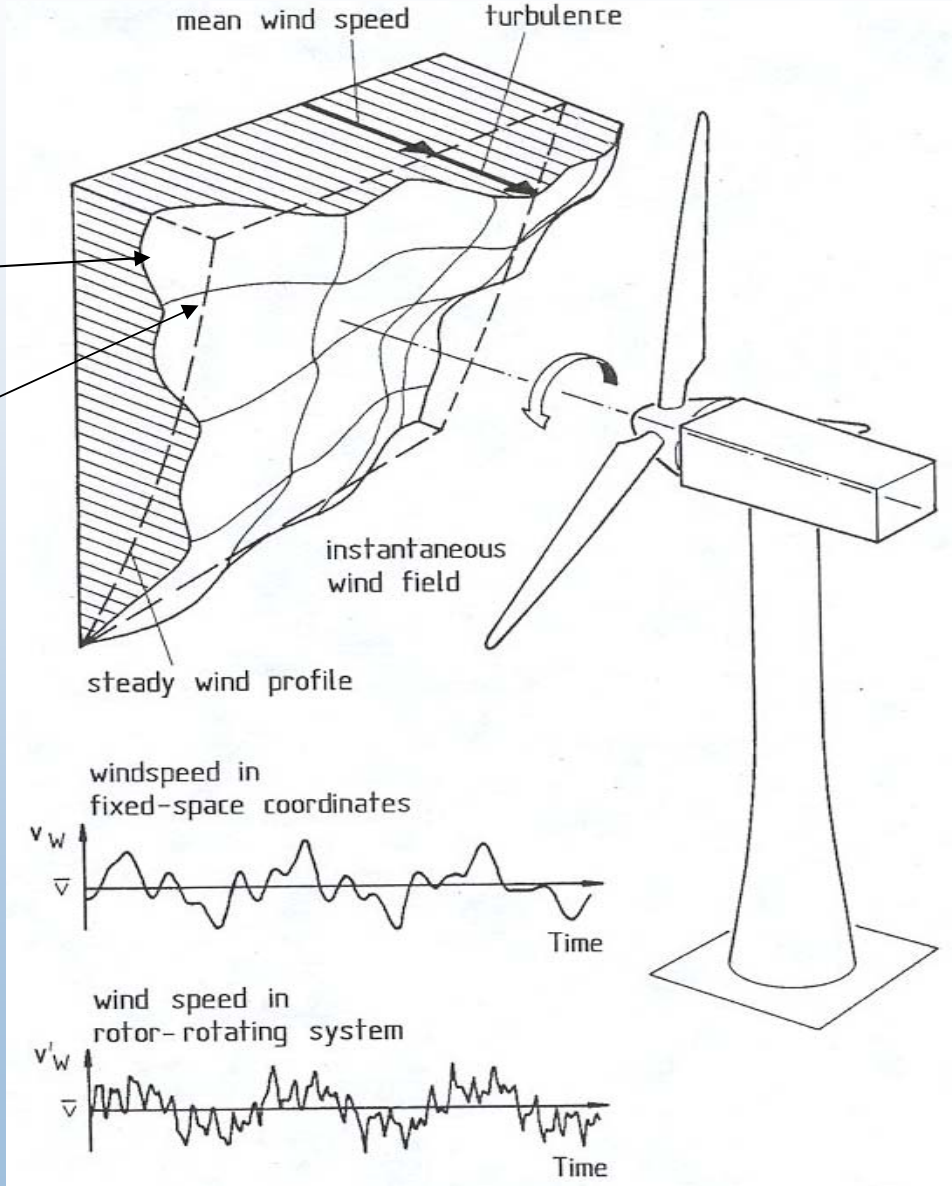
Technology Challenges: Blade scaling for multi-megawatt designs onshore & offshore



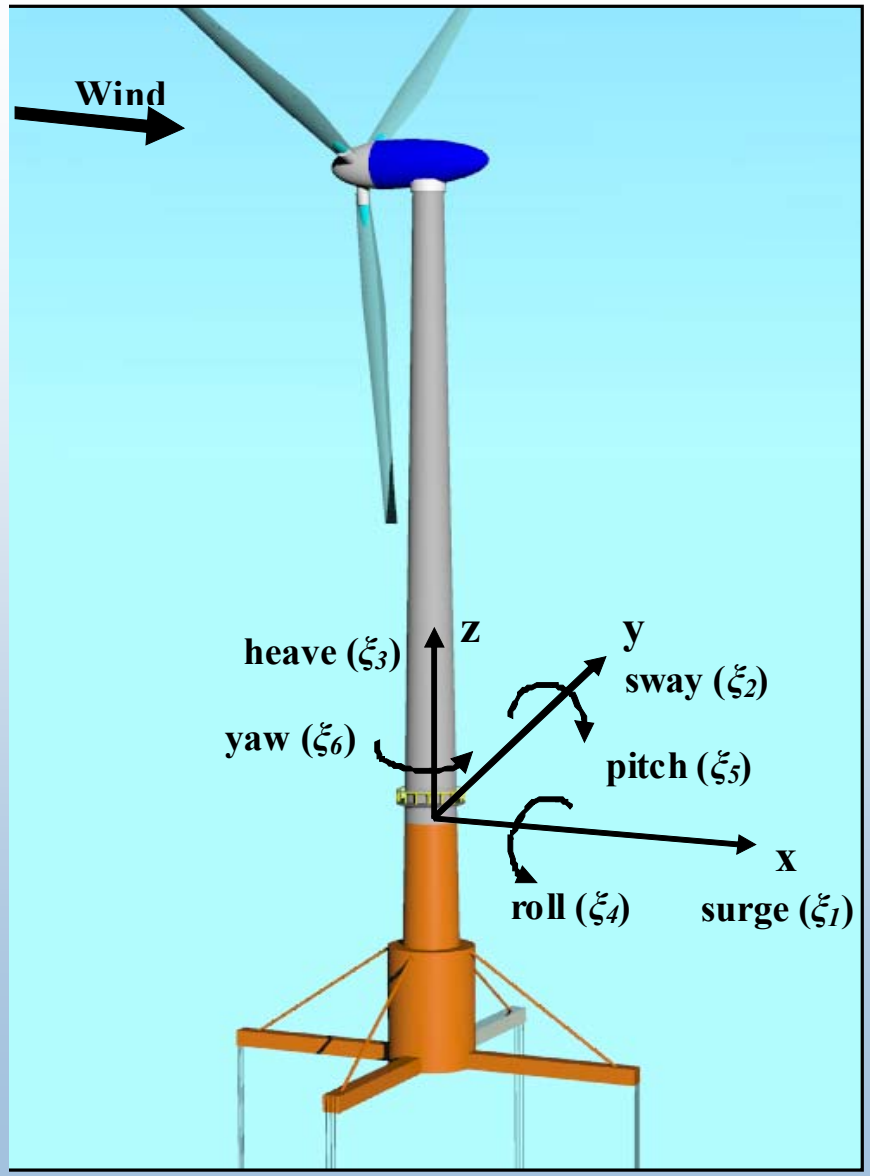


Dynamic Loading Environment

- **Wind field = U (y,z,t)**
- **Steady wind shear superimposed**
- **Rotational sampling effect increases effective wind fluctuations**



Future Key Research Areas



- Developing offshore deep water resources
- Integrating wind into utility grid
- Opening federal lands to renewable energy production
- Using wind and hydropower to produce hydrogen and clean water.

Current 45-Meter Fatigue Test

Single-axis Flap Fatigue Test Using B-REX Test System.

45-meter Blade Root Mount

- Testing is facility limited – blade extends out of building 40-ft.
- Damping higher than expected. Wind was a factor
- Test stand load capacity is at maximum.
- Building may be too narrow for two axis testing.
- Stop-gap solutions are underway.
- Long term solutions have been planned by DOE but funding is uncertain.

controls