A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy

NREL National Renewable Energy Laboratory

Innovation for Our Energy Future

Deepwater Offshore Wind Technology Research Requirements

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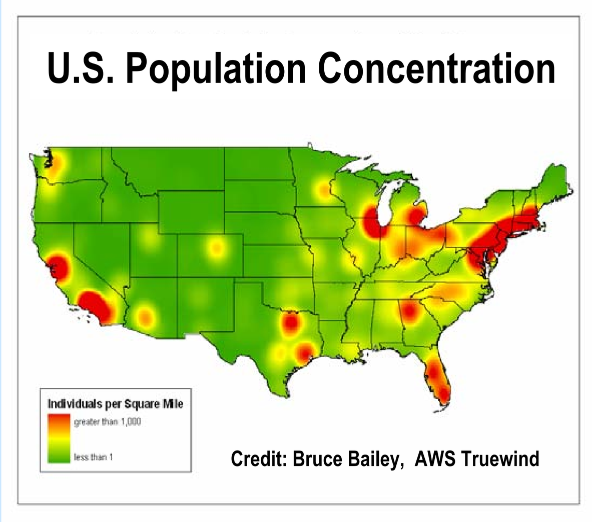
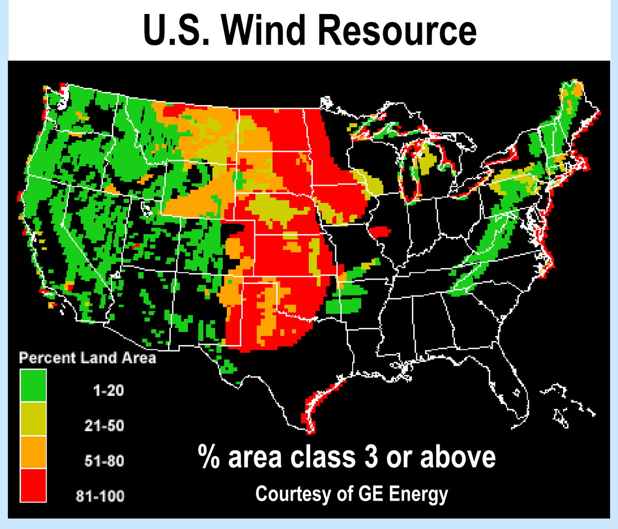
Offshore Wind — U.S. Rationale Why Go Offshore?

Windy onshore sites are not close to coastal load centers

The electric utility grid cannot be easily set up for interstate electric transmission

Load centers are close to the offshore wind sites



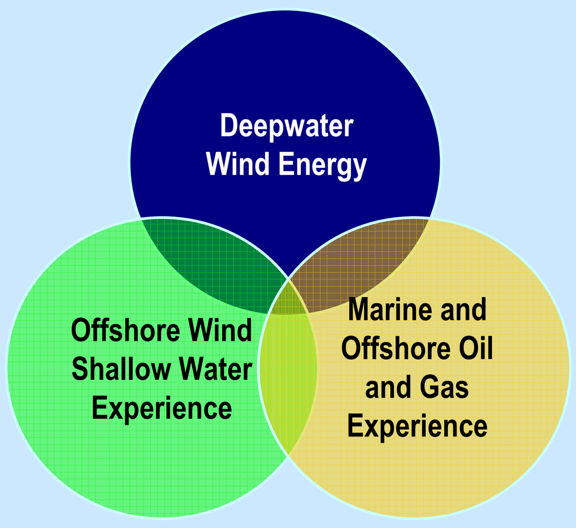


DOE Deepwater Wind Energy Workshops

Washington D.C. Oct. 15-16, 2003 – Washington D.C. Oct. 26-27, 2004

Workshop Objectives

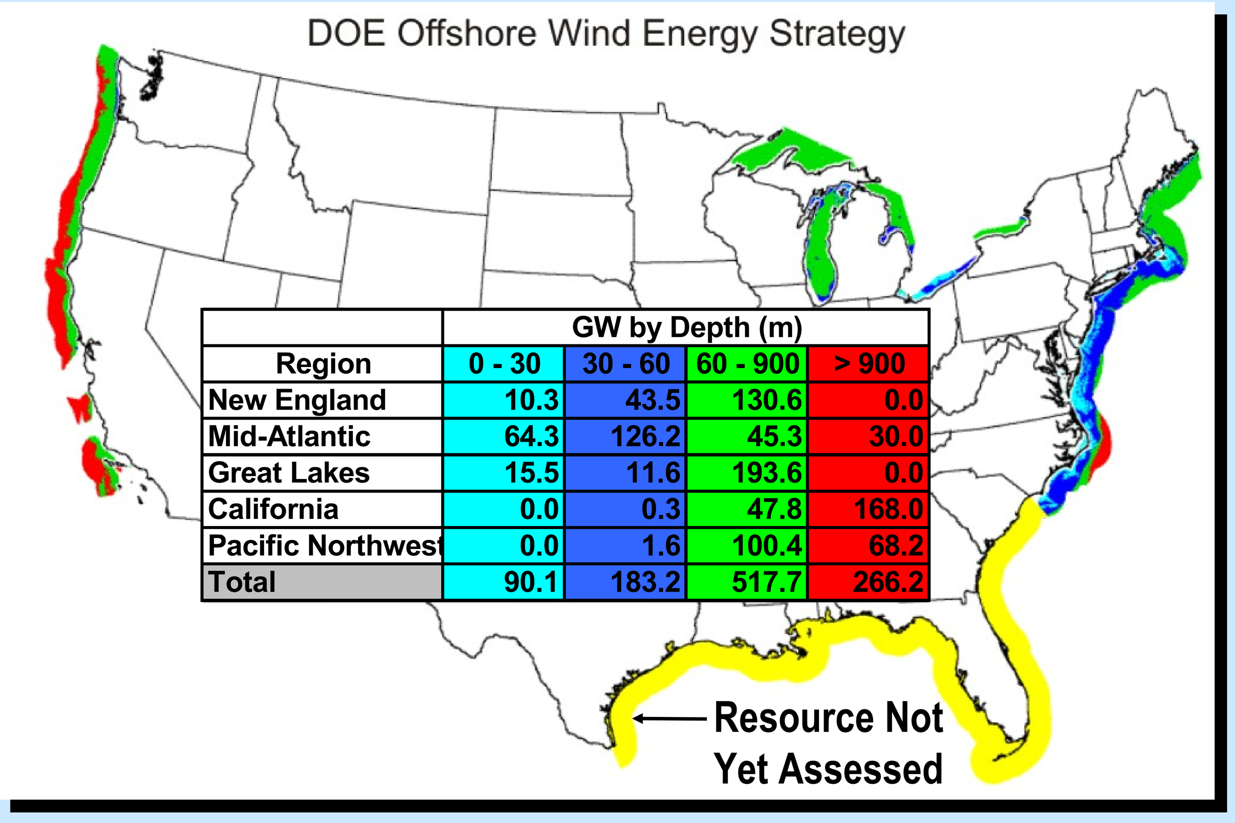
- Leverage experience and expertise from offshore industries such as oil and gas, marine engineers, offshore wind, ocean climatologists, ecologists, and oceanographers.
- Identify technology gaps to achieve a mature offshore wind industry in the United States.



Key Technology Findings

- Monopiles are limited to 25-m depths due to limits in structural stiffness and installation equipment capacity.
- Fixed bottom tripod or space frame substructures can transition into greater depths – e.g. Talisman Energy 42-meters.
- Floating platforms will be more economical in deep water but the cross-over depth must be determined by careful study.
- Added difficulties working at sea will become the major cost driver and must be minimized by new technology.
- MET-Ocean measurement techniques must be enhanced to accurately predict loads and energy production.
- Demonstration projects in the ocean will be essential to establish a basis for design.

U.S. Offshore Wind Energy Resource

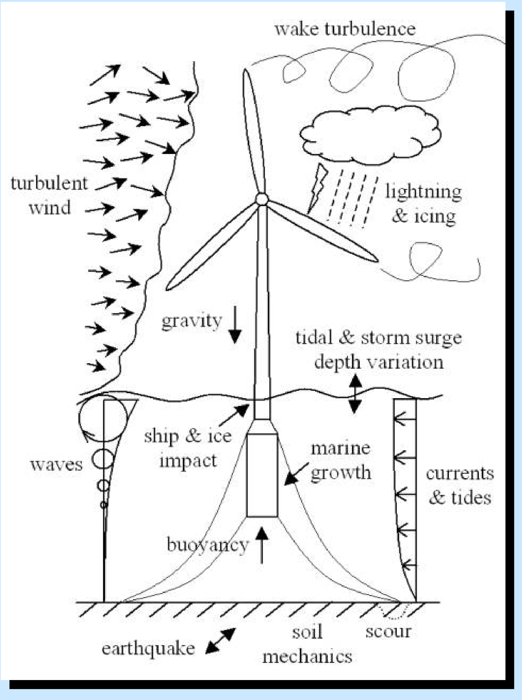


	GW by Depth (m)			
Region	0 - 30	30 - 60	60 - 900	> 900
New England	10.3	43.5	130.6	0.0
Mid-Atlantic	64.3	126.2	45.3	30.0
Great Lakes	15.5	11.6	193.6	0.0
California	0.0	0.3	47.8	168.0
Pacific Northwest	0.0	1.6	100.4	68.2
Total	90.1	183.2	517.7	266.2

Offshore Turbine Design Basis

Define external conditions

Measurements – Extreme wind, extreme wave, wind/wave combinations, sea state, wind shear, ice, currents, tide, soil mechanics, ship collisions, turbulence, wind farm turbulence.



Design studies – Narrow the options

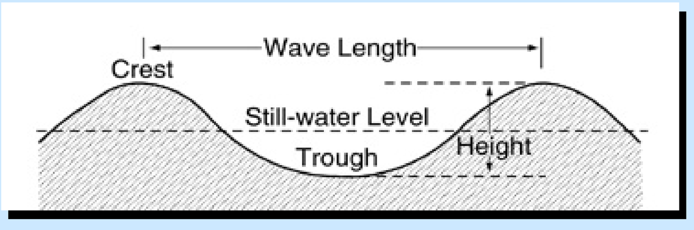
- What is the design load envelope
- What foundations achieve the lowest cost?
- What are the design drivers?

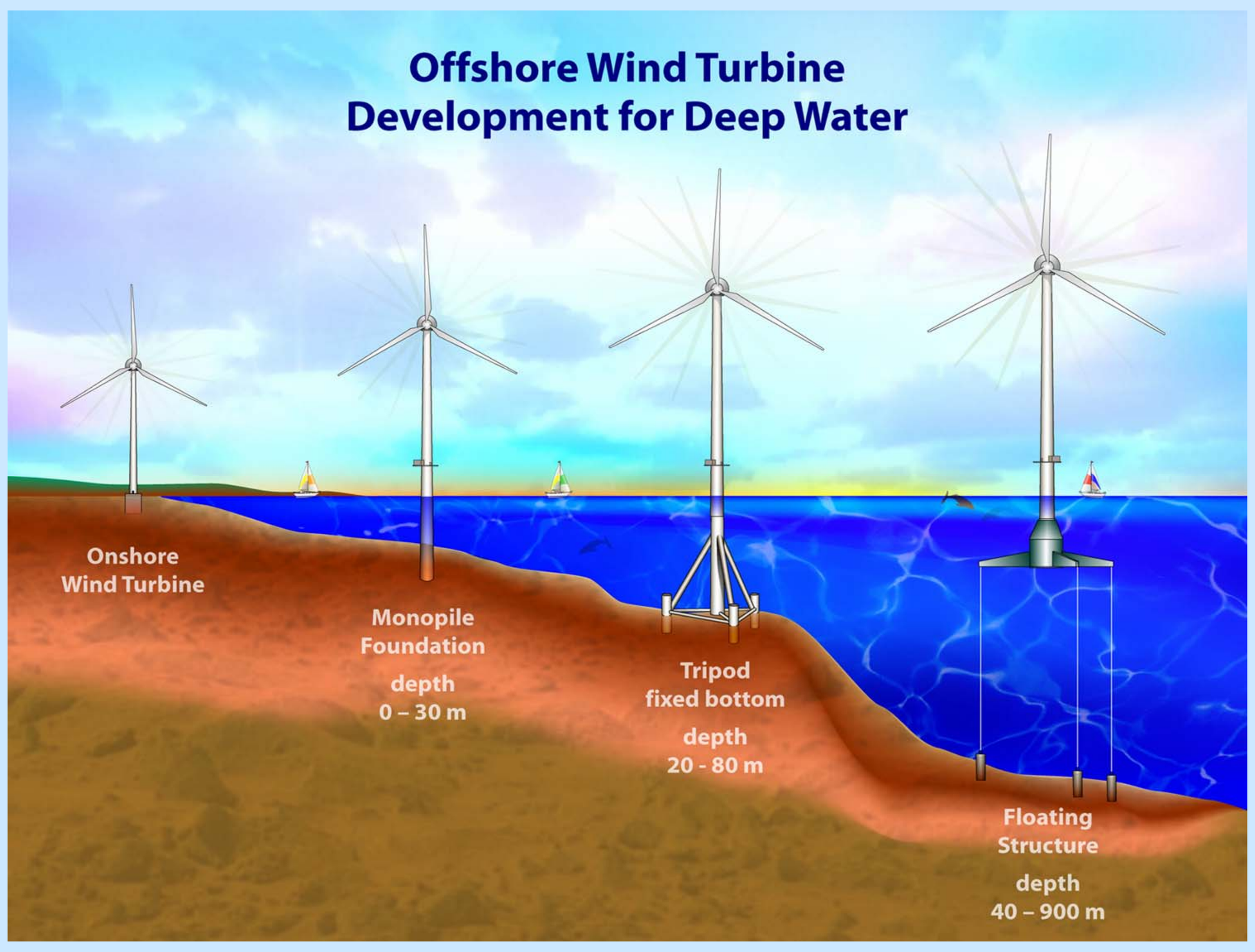
Code development

- Coupled platform/turbine responses
- Ocean Test Bed Validation

Design standards

IEC, ABS, DNV, GL, API





Minimize Work at Sea

Offshore labor and equipment costs are key drivers. Current turbine designs use onshore practices.

High offshore availability will require turbine designs that are tolerant of inaccessible periods

Installation Strategies

- Standardize and mass-produce platforms and substructures
- Float-out whole systems
- Reduce large vessel dependency
- Develop low cost mooring systems

Operation and Maintenance Strategies

As machines get larger and more remote smarter systems will become economical.

- Offshore turbines must close the loop between O&M and turbine design.
- High reliability designs
- Designs for in-situ repair
- Remote condition monitoring
- Turbine self diagnostics
- Safer and faster personnel transport

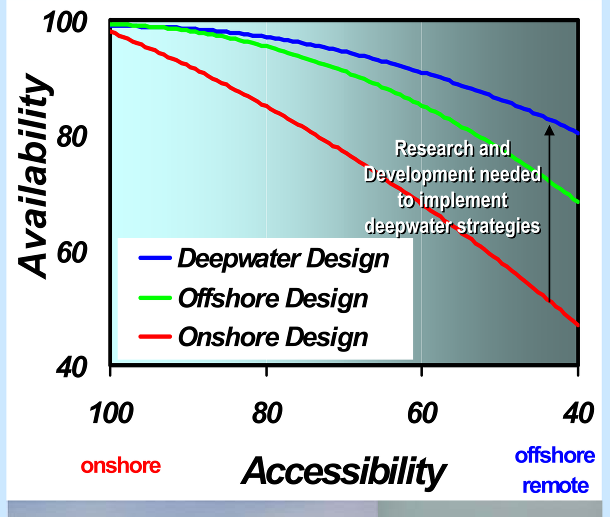
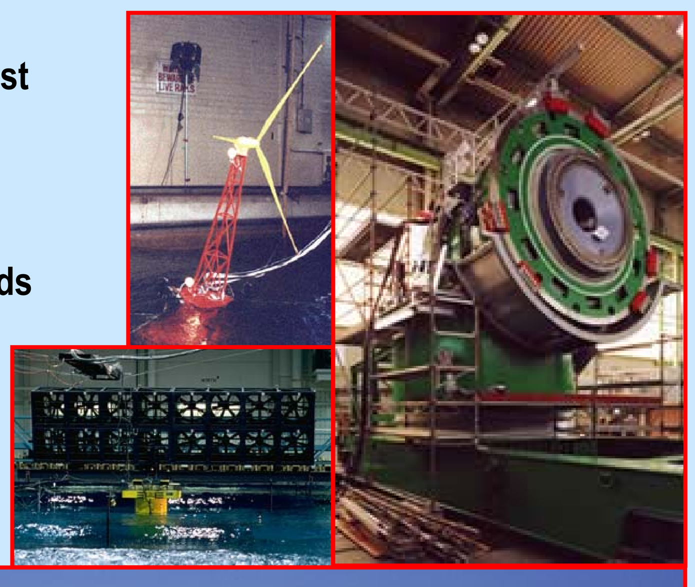


Photo Courtesy of GE Energy

Testing and Validation

- Scale model testing – Configuration tradeoff studies in wind/wave tank.
- Hybrid testing – Wave simulations can be conducted in a subscale test-bed on land under real wind conditions to measure turbine response to rare load combinations.
- Full-scale blade and drivetrain test facilities – Large wind turbine components must be tested and verified before field deployment.
- Field testing – Full-scale test loads in real ocean environments are essential.
  - Certification
  - Code validation
  - Safety verification



FY 2005 DOE Offshore Wind Energy Activities and Funding

Offshore Wind Research and Analysis Activities - $225K

- *Deepwater Workshops – Research Gap Analysis*
- *IEA Offshore Annex 23 – Modeling Needs for Deepwater*
- *Deepwater Technology R&D – Codes/Reference Turbine*
- *Technology Characterization – COE, Technology Impact*
- *Offshore Standards Development – IEC 61400-03*

Offshore Wind Collaborative - $100K

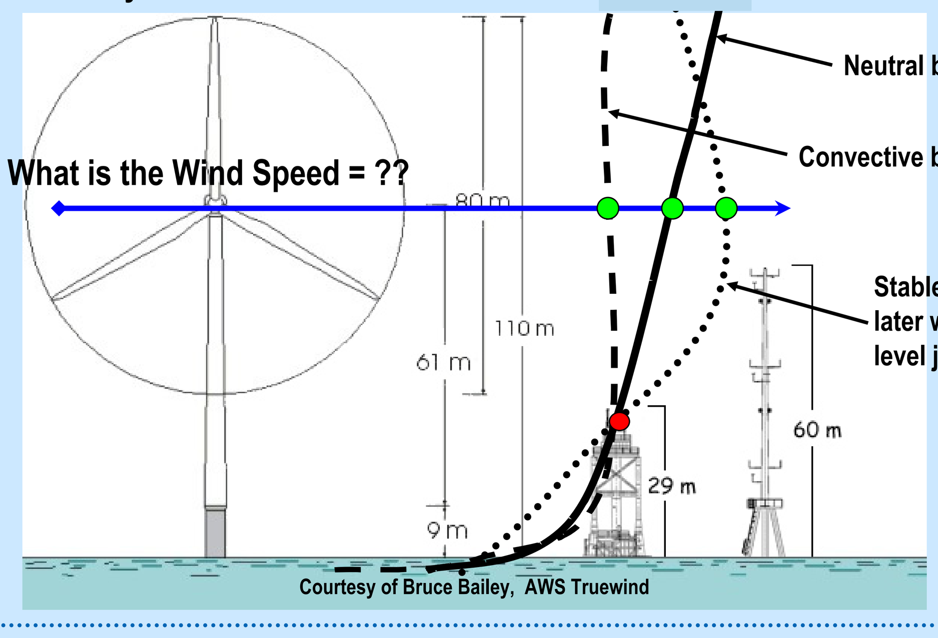
Offshore Wind Resource Assessment Wind Mapping & Validation - $400K

5 Offshore R&D Subcontracts – $ 11M (multi-year)

Environmental and Regulatory Issues - $200K

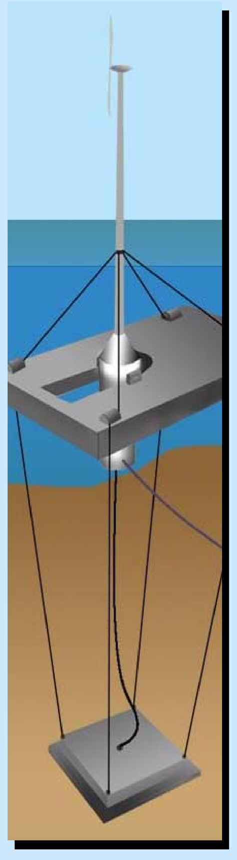
Understanding Offshore Wind

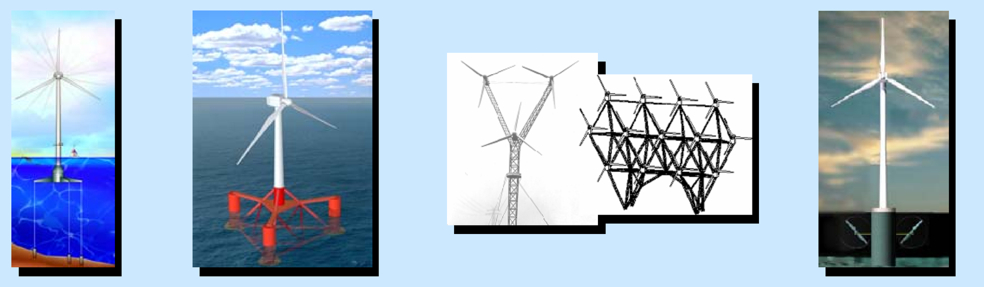
- Develop new measurement techniques and sensors for accurate wind speeds at heights where wind turbines operate – Without MET towers!
- Understand and utilize available offshore data sets – Offshore MET measurements may come from many sources.
- Validate wind speed/potential – From meso-scale to micro-scale.
- Validate profile variations (wind shear) – Profiles may change with wind speed, season, and time of day.



Offshore System Optimization

- Higher speed rotors (lower aerodynamic noise constraints) will lower system weight and increase energy capture.
- Larger turbine sizes can lower offshore balance of station and operation and maintenance costs.
- Lower shipping and erection constraints may favor direct drive, yawing platforms, etc.
- Greater weight penalties on floating systems will drive use of lighter materials (e.g. extended use of composites in towers, hubs, bedplates, shafts) and multi-rotor systems.
- Wind/wave/hydrogen/storage energy technology convergences may spawn new energy supply models





Prepared for the American Wind Energy Association (AWEA)
WindPower 2005 Conference, 15-18 May 2005, Denver, Colorado
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Summary

- U.S. offshore wind energy potential is over 1000-GW.
- U.S. offshore wind resource is complementary to the on-shore wind resource due to geographic separation.
- U.S. deepwater wind technology is necessary for full offshore wind energy deployment.
- Offshore experience in shallow water is essential for deepwater technology to move forward.
- Expanded R&D (technological and environmental) is necessary for cost-effective deepwater wind energy.
- Commercial deepwater technology will take10–15 years to develop.