Offshore Wind Energy Overview

- The Opportunity
- Technology Overview
- Cost of Energy
- National Strategy
<table>
<thead>
<tr>
<th>Energy</th>
<th>Environment</th>
<th>Economy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large renewable resource close to demand centers</td>
<td>Reduced emissions of GHG and air pollutants</td>
<td>Jobs manufacturing, installing, operating, and maintaining systems</td>
</tr>
<tr>
<td>Availability matches peak load</td>
<td>Reduced water consumption</td>
<td>Economic recovery and industrial development</td>
</tr>
<tr>
<td>Energy diversity &amp; security</td>
<td>Reduced need for new land-based transmission</td>
<td>Potential for cost-competitive electricity in high-price markets</td>
</tr>
</tbody>
</table>
Price of Electricity

This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.
Total U.S. electric generating capacity = 1028 GW

Great Lakes: 734 GW
Atlantic: 1256 GW
Pacific: 930 GW
Gulf Coast: 594 GW
Hawaii: 637 GW

Total gross resource potential does not consider exclusion zones or siting concerns
## NC Wind Resource Potential

<table>
<thead>
<tr>
<th></th>
<th>Land-based</th>
<th>Shallow (0-30 m)</th>
<th>Transition (30-60 m)</th>
<th>Deep (60+ m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1,156 km²</td>
<td>28,006 km²</td>
<td>15,544 km²</td>
<td>15,942 km²</td>
</tr>
<tr>
<td>Total Capacity</td>
<td>0.8 GW</td>
<td>140 GW</td>
<td>78 GW</td>
<td>80 GW</td>
</tr>
</tbody>
</table>

### North Carolina - Annual Average Wind Speed at 80 m

- **Wind Speed:**
  - m/s (meters per second)
  - mph (miles per hour)


### North Carolina - 90 m Offshore Wind Speed

- **Contours:**
  - Water Depth (Meters)
  - Distance from Shore (Nautical Miles)

The offshore wind resource data was originally estimated by AWS Truewind as part of an onshore wind mapping project. These data have been interpolated to 90 m and extrapolated to 50 nautical miles by NREL.
The Opportunity

Technology Overview

Cost of Energy

National Strategy
Turbine Components

- Blades
- Rotor Hub
- Gearbox
- Generator
- Nacelle
- Tower
- Transition Piece
- Foundation

Foundation Designs
- Monopile
- Gravity Base
- Suction Bucket
Evolution of Wind Power Technology

The 1980's
- Altamont Pass, CA Kenetech 56-100kW 17m Rotor
- San Clemente, CA Micon 700-225/40 29.6m Rotor

The 1990's
- Mehuen, Norway Vestas V52-850kW 52m Rotor
- Liverpool Bay, UK Siemens SWT-3.6MW 107m Rotor

2000 & Beyond
- Medicine Bow, WY Clipper 2.5MW 93m Rotor
- Aberdeen, Scotland North Sea (45m water depth) REpower 5MW 126m Rotor

Rotor Diameter in meters

- 180
- 160
- 140
- 120
- 100
- 80
- 60
- 40
- 20
- 0

Facility Layout

- Turbines
- Collection Cabling
- Offshore Substation
- Power Export Cable
- Grid Interconnection Point

Not drawn to scale
Example: Nysted Windpark

- 166 MW capacity
- 72 turbines
- 6 m depth
- 132 kV export cable
- 92600 homes powered

6 miles to shore

Approx. 3 miles
Offshore Wind Industry

- 3,000 MW installed in European waters, ~135 MW in China
- 2 – 5 MW capacity turbines
- Turbine technology largely adapted from land-based turbines
- 70+ meter tower height on monopiles and gravity bases
- Mostly fixed-bottom foundations in shallow water (0-30m)
- Mature submarine power cable technology
- Leverage existing oil and gas experience
- Early growing pains: reliability shortfalls and turbine shortages
- European industry:
  - 1,000 to 1,500 MW of new offshore wind in 2011
  - 19,000 MW currently fully consented
  - $3.75B in investments in 2010
  - 6370 jobs in 2007
Development, Construction, and Operations

Development
- Wind resource measurement
- Geotechnical & environmental data collection
- Permitting
- Power sale agreement
- Financing

Construction
- Portside staging areas
- Turbine installation vessels
- Cabling vessels
- Narrow weather windows
- Interface issues between multiple contracts

Operations
- Challenging maintenance environment
- Difficulties accessing turbines
- Boat access vs helicopter
- Remote sensing and preventative maintenance are critical
The Opportunity

Technology Overview

Cost of Energy

National Strategy
Cost of Offshore Wind Energy

Cost of Energy =

Lifetime cost ($)

Lifetime energy capture (kWh)

Power & Scale

Availability

Array Losses

Access to Resource

O&M, 20%

Other Variable Costs, 11%

Turbine, 27%

Electrical Infrastructure, 11%

Support Structure, 13%

Logistics and Installation, 10%

Other Capital Costs, 3%

Project Development and Permits, 4%

Other Variable Costs, 11%

Cost of Offshore Wind Energy
Capital Cost for Offshore Wind

Offshore wind plant capital cost per kilowatt

- Installed Cost for Operating European Project
- Announced Cost for Proposed U.S. Project
- Announced Cost for Proposed European Project
- Capacity-Weighted Average Project Cost

Source: NREL Database
Offshore Wind Life-Cycle Costs

- O&M
- Other Capital Costs
- Project Development and Permits
- Logistics and Installation
- Support Structure
- Electrical Infrastructure
- Turbine

Percentage of Capital Cost

Fingersh et al. 2006
Ernst & Young 2009
Blanco 2009
Duvind 2001
Carbon Trust 2008
Krohn et al. 2009
Junginger Morgan et al. 2003
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National Offshore Wind Strategy

- Department of Energy & Department of the Interior

- Commitment by federal government to developing offshore wind energy resources in a responsible manner

- Supported by $50.5 M in funding for offshore wind research and development

www1.eere.energy.gov/windandhydro/pdfs/national_offshore_wind_strategy.pdf
Cost of Energy

- **Reduce capital costs**
  - Larger-scale systems with greater capacities
  - Innovative foundations and platforms
- **Decrease IO&M costs**
  - Ruggedized designs to reduce maintenance
- **Decrease financing costs**
  - Design codes & standards to reduce deployment risks
  - Offshore wind characterization to improve output projections
- **Increase energy capture**
  - Larger rotors, longer blades, and taller towers

Deployment & Infrastructure

- **Support effective permitting**
  - Provide technical input & assistance to federal & state agencies
  - Applied research on key issues
  - Policy and economic analysis to inform decision-makers
- **Support resource planning**
  - Gather wind resource data for CMSP
  - Provide technical input and data
- **Promote infrastructure development**
  - Domestic supply chain development
  - Interconnect planning
  - Research on specialized vessels and IO&M technology.
DOE Offshore Wind Strategy

**Scenarios**
- 54 GW at 7 ¢/kWh by 2030 (10 GW at 10 ¢/kWh by 2020)

**Critical Objectives**
- Reduce COE
- Reduce deployment timeline

**Program**
- Offshore Wind Innovation and Demonstration (OSWInD)

**OSWInD**
- Technology Development
- Market Barrier Removal
- Advanced Technology Demonstration
  - Computational Tools Development
  - Siting and Permitting Analysis
  - Innovative Turbine Design
  - Infrastructure Optimization
  - Marine Systems Engineering
  - Resource Planning Support

**Projected Installed Offshore Capacity**
- **26.9 ¢ / kWh**
- • Atlantic Wind Connection (transmission backbone) opens
- • Cape Wind deployed
- • First U.S. offshore turbine installed
- • First turbines in Great Lakes

**Cost of Energy (¢/kWh)**
- 0.0
- 10.0
- 0.1
- 25.0
- 0.5
- 30.0
- 0.9
- 5.0
- 1.6
- 10.0
- 2.1
- 15.0
- 4.4
- 20.0
- 6.8
- 25.0
- 9.0
- 30.0

**Cumulative Capacity (GW)**
- 0.0
- 2.0
- 4.0
- 6.0
- 8.0
- 10.0
- 12.0
- 14.0
- 16.0
- 18.0
- 20.0
- 22.0
- 24.0
- 26.0
- 28.0
- 30.0

**FY11** 0.0 26.9¢
**FY12** 0.1
**FY13** 0.5
**FY14** 0.9
**FY15** 1.6
**FY16** 2.1
**FY17** 4.4
**FY18** 6.8
**FY19** 9.0
**FY20** 10.0
Thank You

Offshore Wind
A Part of our Clean Energy Future
1. The environmental & economic benefits of offshore wind energy are significant.

2. The offshore wind resource is substantial.

3. The challenges facing offshore wind deployment are daunting:
   – High capital & financing costs.
   – Lack of specialized infrastructure.
   – Lack of site data and experience with permitting processes.

4. To realize these benefits in spite of the challenges, DOE will:
   – Reduce the levelized cost of energy from 26.9 ¢/kWh to 7 ¢/kWh by 2030.
   – Help reduce project deployment timelines.
   – Partner in the installation of the first demonstration-scale projects.
Activities to Date

- **FY09 ($1.6 M)**
  - Lab support on environmental impacts and technology assessments.
  - Broad solicitations including offshore awards.
- **Recovery Act ($77.0 M)**
  - Large Blade Test Facility, $25M: facility will test up to 90-m blades for offshore wind turbines to ensure reliability and performance.
  - Large Drivetrain Test Facility, $45M: facility will test up to 15 MW drivetrains for large offshore turbines to validate designs.
  - U-Maine Floating Turbine Development, $7M: developing innovative floating turbine platforms for deepwater deployment (2450 GW resource).
- **FY10 ($8.8 M)**
  - Signed MOU with DOI-BOEMRE to facilitate offshore wind deployment.
  - NREL published *Large-Scale Offshore Wind Power in the United States*.
  - Awarded $500k for research to fill critical data gaps in the permitting process.
- **FY11 ($49.1 M requested)**
  - Published *National Offshore Wind Strategy* in conjunction with DOI.
  - Issued $50.5 M in solicitations for offshore wind R&D.
Offshore Technology is Dynamic: 7+ MW Power, Vertical Axis Turbines, Tripod, Floating, and Jacket Foundations are already in prototype stage.
Offshore Wind Platform Development

<table>
<thead>
<tr>
<th>Type</th>
<th>Depth</th>
<th>Resource (GW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land-based</td>
<td>Estimated</td>
<td>US Resource</td>
</tr>
<tr>
<td>Shallow Water</td>
<td>0m-30m</td>
<td>430</td>
</tr>
<tr>
<td>Transitional Depth</td>
<td>30m-60m</td>
<td>541</td>
</tr>
<tr>
<td>Deepwater Floating</td>
<td>60m-900m</td>
<td>1533</td>
</tr>
</tbody>
</table>

Commercially Proven

Demonstration Phase
Environment Drives the Design

Credit: NREL