

Offshore Wind Technology



Jason Jonkman
Senior Engineer
National Renewable Energy Laboratory
Golden, Colorado

Webinar: Offshore Wind Potential
for the Great Lakes

January 30, 2009



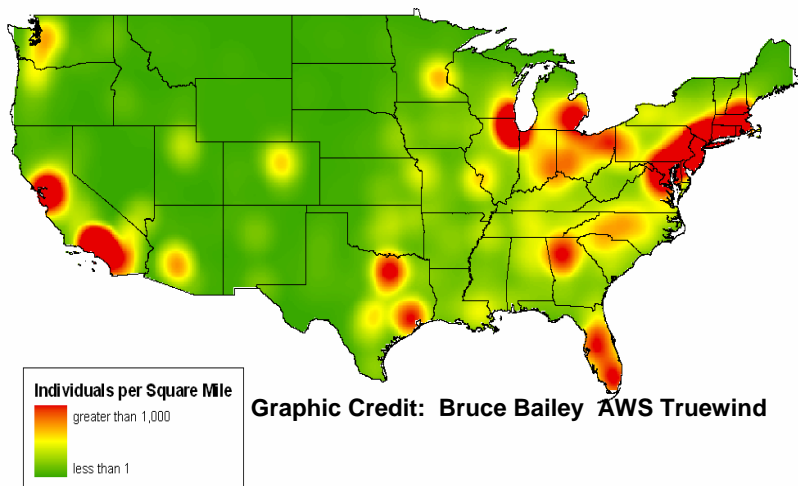
Why Offshore Wind?

28 coastal states use 78% of the electricity in US

Coastal load centers are transmission constrained and cannot be easily served by land-based wind.

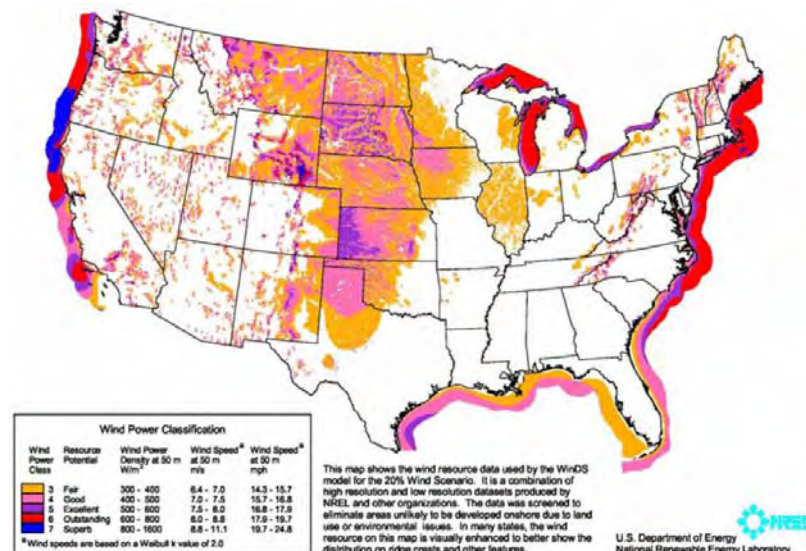
Wind energy goals cannot be achieved without offshore contributions

US Population Concentration

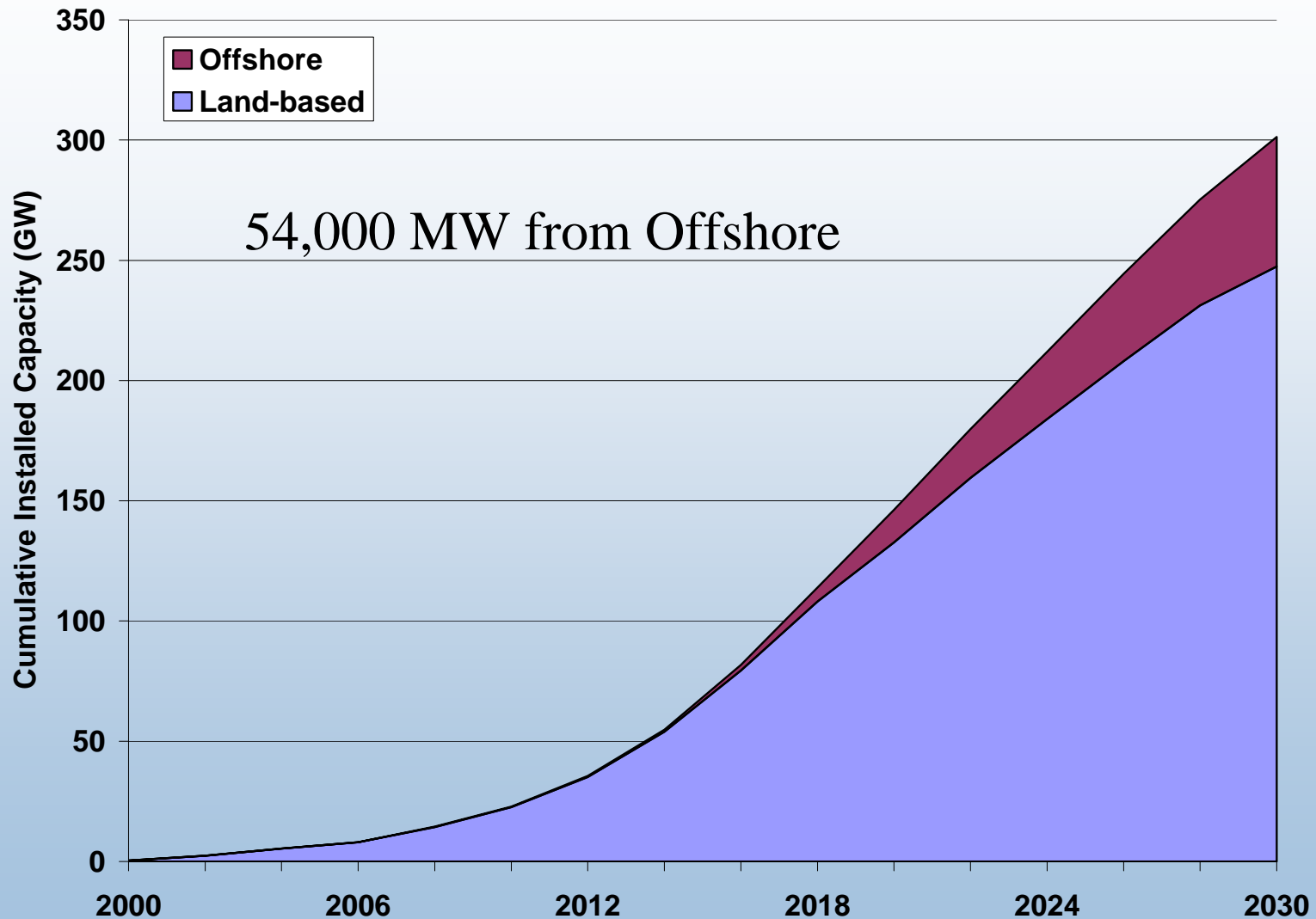


Graphic Credit: Bruce Bailey AWS Truewind

U.S. Wind Resource

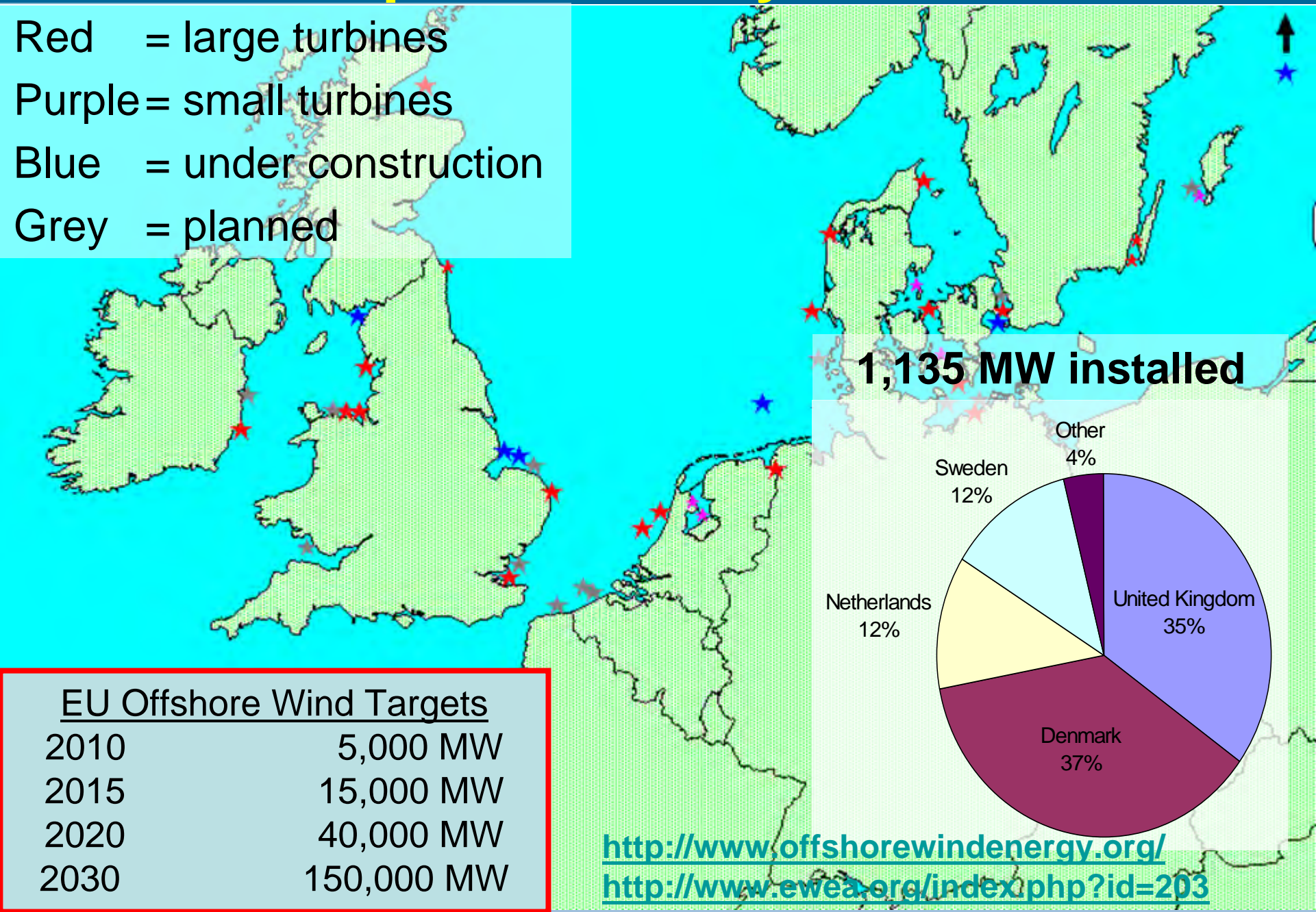


20% US Electricity from Wind by 2030



European Activity Offshore

Red = large turbines
Purple = small turbines
Blue = under construction
Grey = planned



EU Offshore Wind Targets

2010	5,000 MW
2015	15,000 MW
2020	40,000 MW
2030	150,000 MW

<http://www.offshorewindenergy.org/>
<http://www.ewea.org/index.php?id=203>

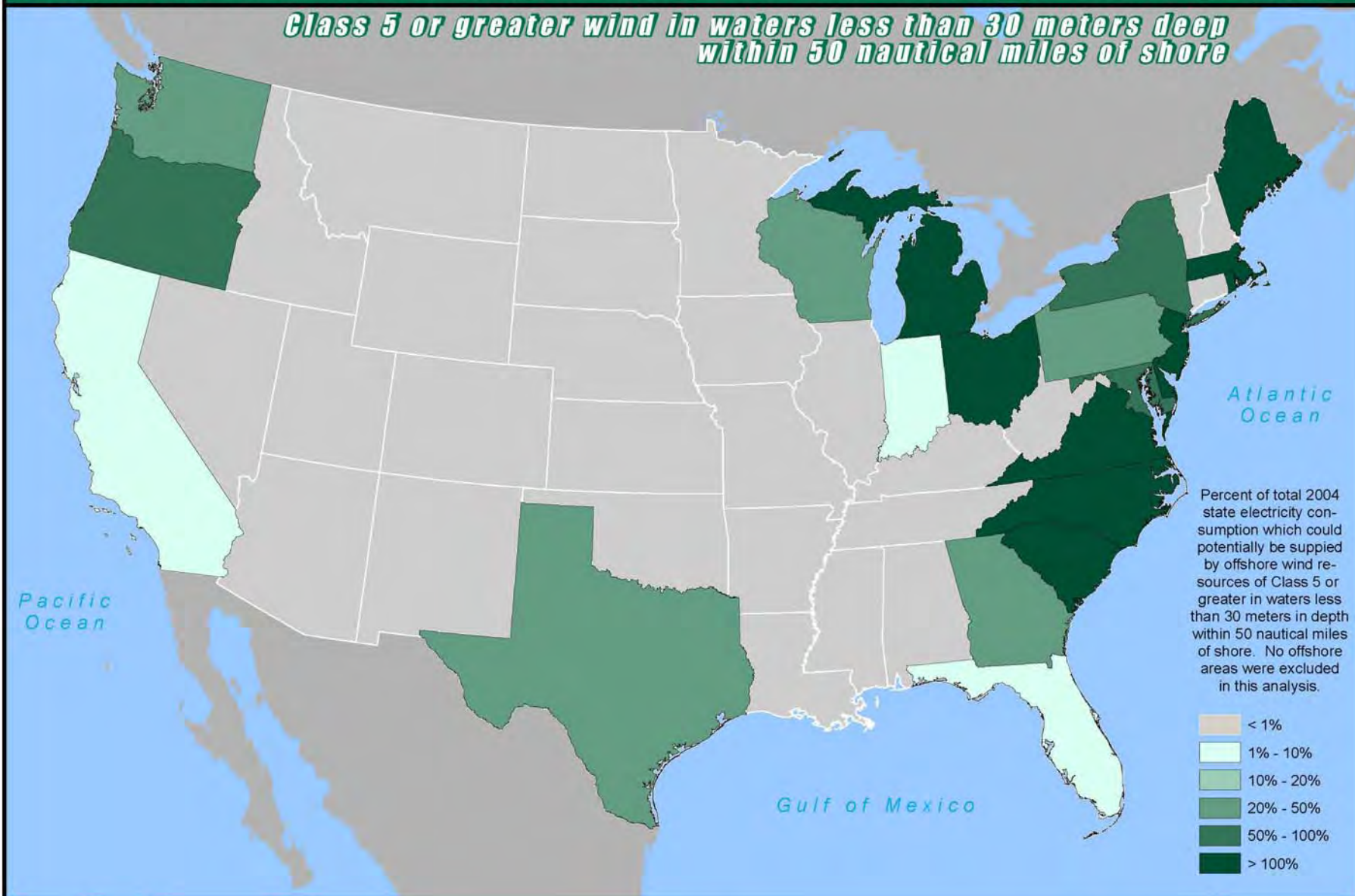
Offshore Wind



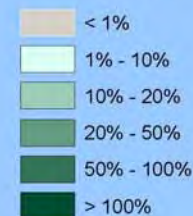
Horns Rev

Potential Electricity Supply from Shallow Offshore Wind by State

*Class 5 or greater wind in waters less than 30 meters deep
within 50 nautical miles of shore*



Percent of total 2004 state electricity consumption which could potentially be supplied by offshore wind resources of Class 5 or greater in waters less than 30 meters in depth within 50 nautical miles of shore. No offshore areas were excluded in this analysis.



0 250 500 1,000
Kilometers
0 150 300 600
Miles

February 12, 2007
Data Source: 200702musial_osbystate_rev3.xls

Map produced by
U.S. Department of Energy
National Renewable Energy Laboratory



US Offshore Wind Initiatives		
Project	State	MW
Cape Wind	MA	468
Hull Municipal	MA	15
Buzzards Bay (Patriot)	MA	300
RI OER (Deepwater)	RI	400
Winergy	NY	10
NJ BPU (Garden State)	NJ	350
Delmarva (Bluewater)	DE	450
Southern Company	GA	10
W.E.S.T.	TX	150
Cuyahoga County	OH	20
Total MW		2173

US Offshore Wind Projects Proposed



No Offshore
Wind Projects
Installed In
U.S. Yet

Offshore Wind Turbine Suppliers

Turbine Manufacturer	Turbine model & rated power	Date of availability	Offshore Operating Experience
Vestas	V90 - 3 MW	2004	Commercial
Siemens	SWT-3.6 - 3.6 MW	2005	Commercial
Siemens	SWT-2,3 - 2.3 MW	2003	Commercial
Vestas	V80 - 2 MW	2000	Commercial
RePower Systems	5M - 5 MW	2005	Offshore Demo 2006 Borkum West pilot
Multibrid	M5000 - 5 MW	2005	Onshore 2005 Borkum West Pilot
General Electric	GE – 3.6-MW	2003	Commercial inactive
Bard Engineering	VM - 5 MW	2008-09	Onshore prototype 2008
Nordex	N90 - 2.5 MW	2006	Offshore Demo 2003
Clipper Windpower	Liberty 2.5 MW	NA	Not yet offshore ready
Clipper Windpower	Britannia 7.5 MW	NA	Drawing board

Land-based

**Shallow
Water**

**Transitional
Depth**

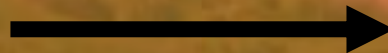
**Deepwater
Floating**



**Offshore
Wind
Technology**

**Commercially
Proven
Technology**

**Demonstration
Phase**



**Estimated
US Resource**

**0m-30m
430-GW**

**30m-60m
541-GW**

**60m-900m
1533-GW**

No exclusions assumed for resource estimates

Offshore Wind Technology Today



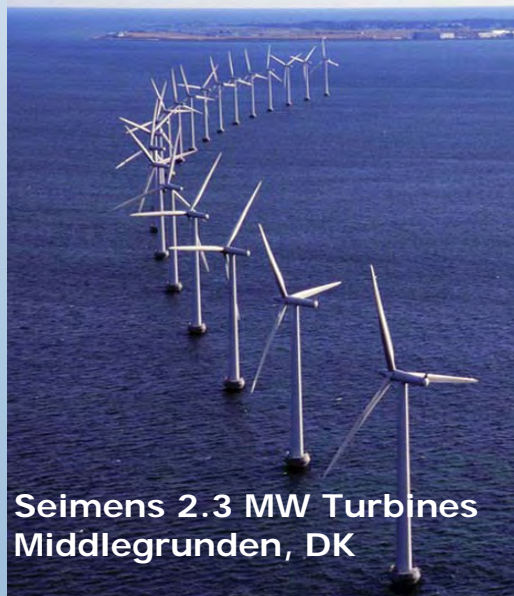
Vestas 2.0 MW Turbine
Horns Rev, DK



GE 3.6 MW Turbine
Arklow Banks



Talisman Energy:
Repower 5-MW
Beatrice Fields,
Scotland



Seimens 2.3 MW Turbines
Middlegrunden, DK

- Initial development and demonstration stage; 22 projects, 1135 MW installed
- Fixed bottom shallow water 0 - 30 m depth
- 2 – 5 MW upwind rotor configurations
- 70+ m tower height on monopoles and gravity bases
- Mature submarine power cable technology
- Existing oil and gas experience is essential
- Reliability problems and turbine shortages have discouraged early boom in development
- Cost are not well established in the US

Offshore Wind Energy Cost Factors



↑ Upward Cost Pressures

- ↑ Turbine Supply Shortages
- ↑ Steel and copper price increases
- ↑ Regulatory Uncertainty
- ↑ Euro/\$ Currency Exchange Rates
- ↑ Project Risk Uncertainty (public acceptance, reliability issues, insurance, unstable policy)
- ↑ Increasing fossil prices

↓ Downward Cost Drivers

- Deployment
 - ↓ Learning Curve Effects
 - ↓ Mass production
 - ↓ Infrastructure development
 - ↓ Experience lowers uncertainty
- Technology Improvements
 - ↓ Land-based learning
 - ↓ High reliability components
 - ↓ Multi-megawatt turbines
 - ↓ Optimized offshore systems

Monopile Foundations



Pile Hammer
Credit: DONG Energy

- ❑ Most common type
- ❑ Driven or drilled 25 - 30 m embedment
- ❑ Stiff soils only (e.g. sand)
- ❑ 4.5 - 6 m diameter steel tube typical
- ❑ Wall thickness 30 - 60 mm
- ❑ Minimal footprint
- ❑ Water depth experience to 25 m



Transition Pieces
Credit: DONG Energy

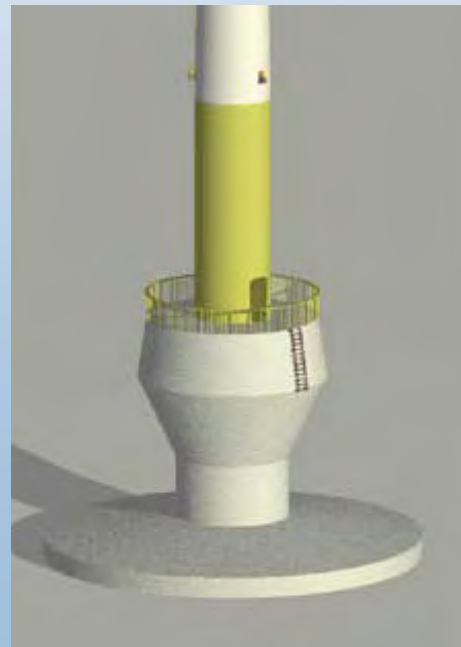
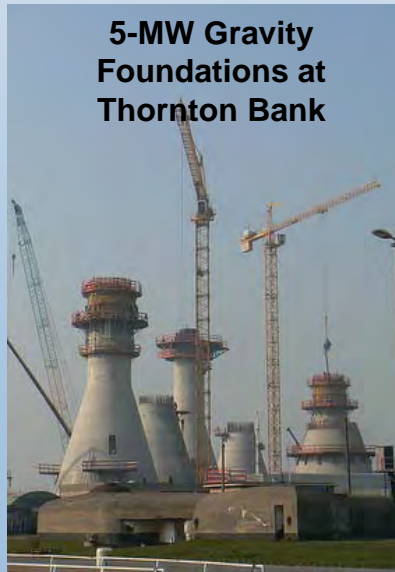


Credit: GE Energy

Gravity Base Foundations



- ☐ Steel or concrete
- ☐ Relies on weight of structure to resist overturning
- ☐ Ballast added after placement
- ☐ Shallow water with proper seabed preparation essential
- ☐ Examples: Siemens turbines at Nysted and Samso.
- ☐ New project underway at Thornton Bank in Belgium.



Multi-Pile Foundations

Wind Industry Experience is Limited

Jackets (welded truss towers) are the Oil and Gas Standard

Applicable in Softer Soils and Deeper Waters



**Bard Engineering
Tripod Variation**

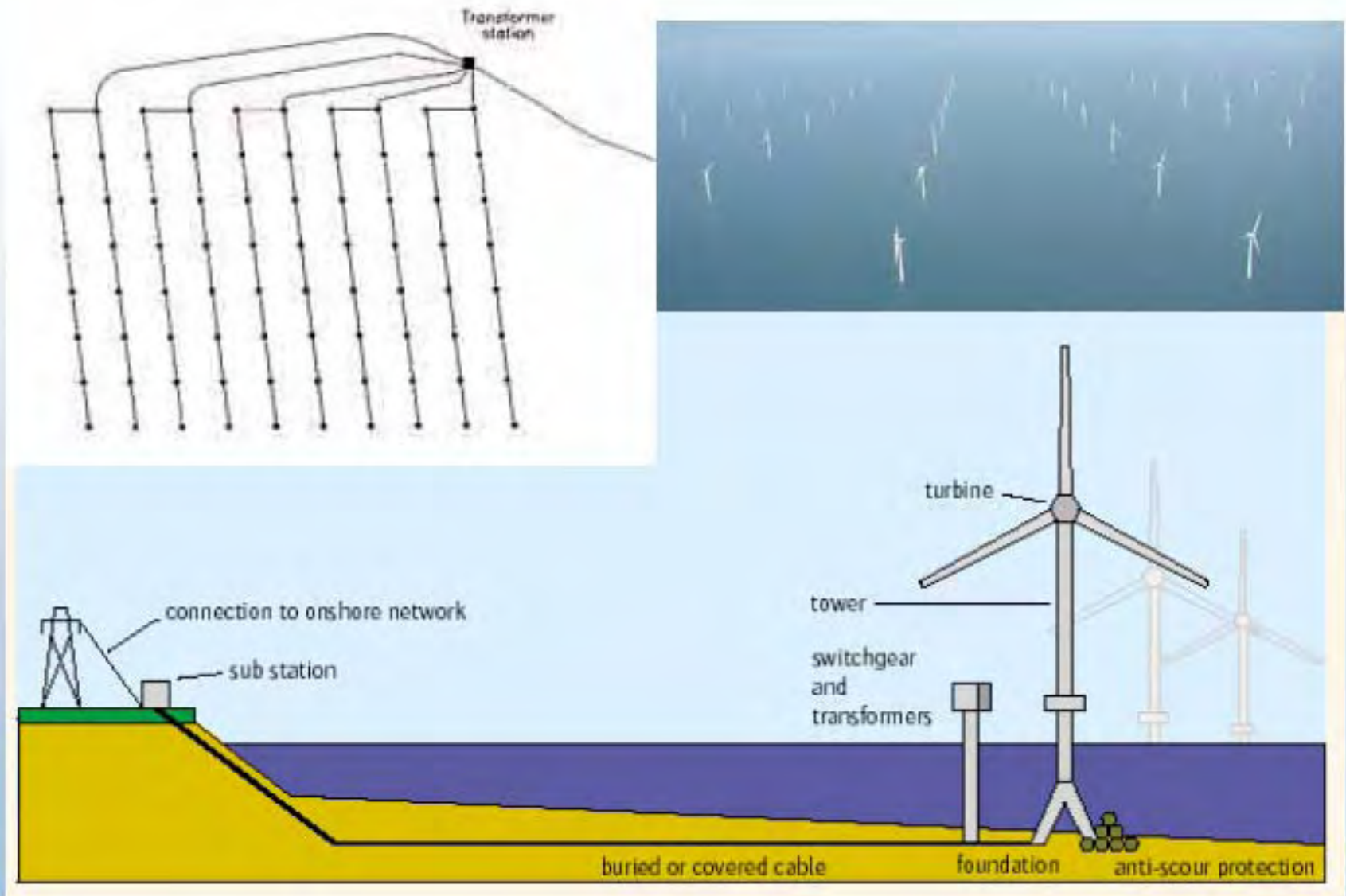


**Multibrid M5000
Prototype on Tripod**



**Repower 5MW
Demonstration
at Beatrice
Four-pile jacket**

Offshore Wind Electric Distribution



Offshore Wind Turbines

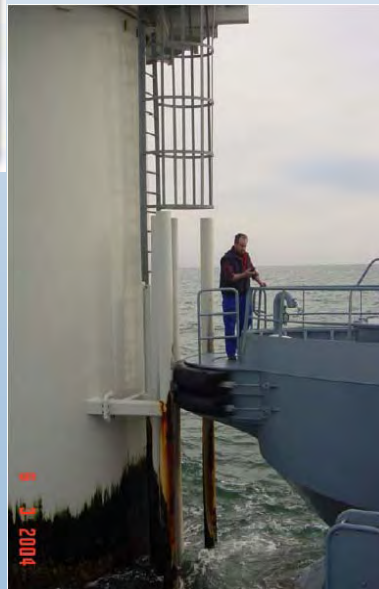
Accessibility is a Challenge



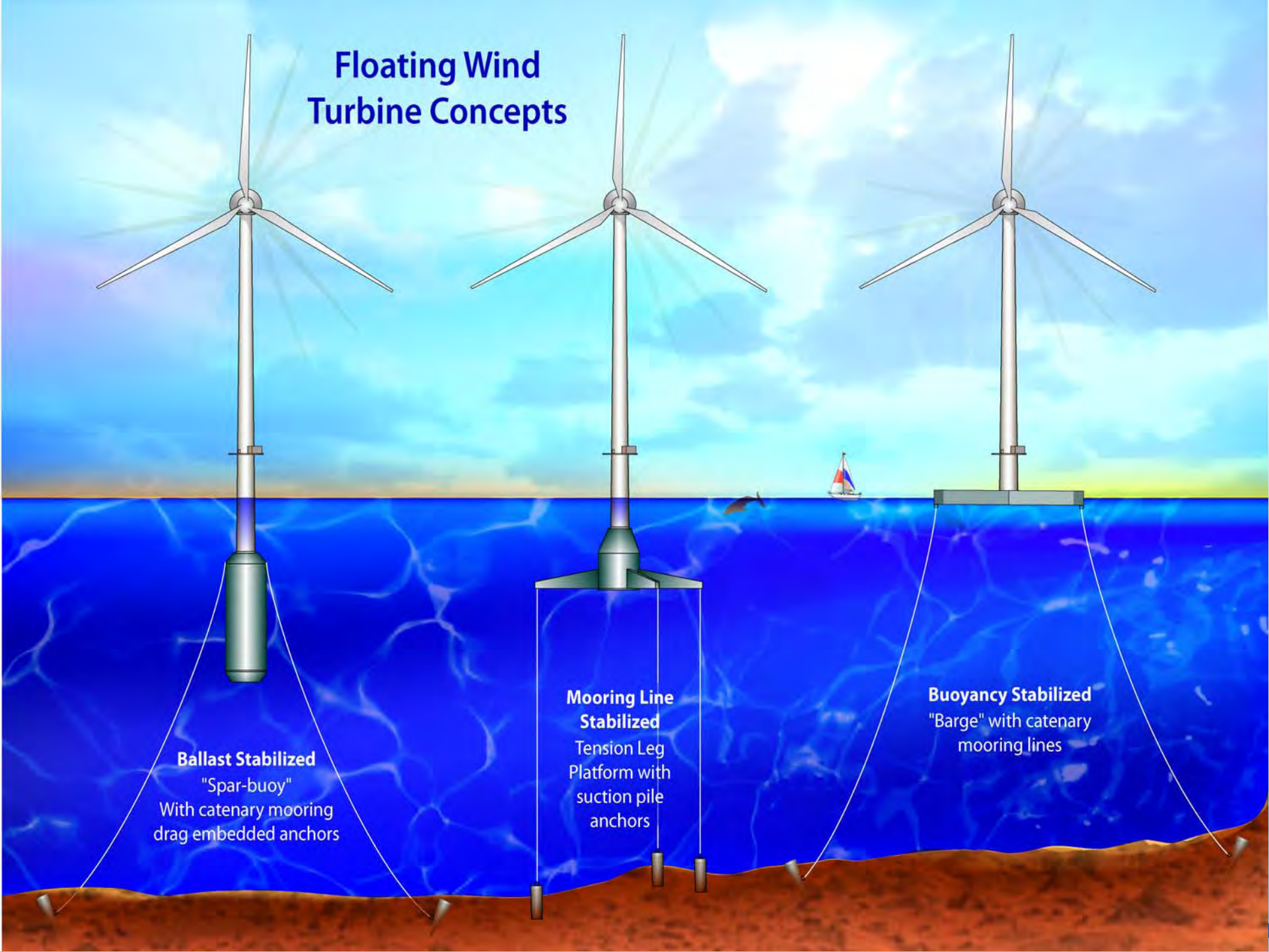
Credit: GE Energy



Credit: GE Energy



Floating Wind Turbine Concepts



The diagram illustrates three different floating wind turbine concepts against a background of a blue sky with clouds and a blue sea. In the distance, a small sailboat and a dolphin are visible on the horizon. The sea is shown in cross-section, revealing the seabed and the mooring systems for each turbine.

Ballast Stabilized
"Spar-buoy"
With catenary mooring
drag embedded anchors

**Mooring Line
Stabilized**
Tension Leg
Platform with
suction pile
anchors

Buoyancy Stabilized
"Barge" with catenary
mooring lines

Floating Wind Turbine Projects



- HyWind is under development by StatoilHydro – Norway
- Spar-buoy needs 100+ m depth to operate.
- Announced a \$78MM demonstration project in North Sea.
- Partnering with Siemens using their 2.3MW turbine.
- Costs estimated about where solar is today.
- Expectations to compete with conventional wind energy long term.

- BlueH is the first company to claim “in-the-water” floating wind turbine status.
- Deployed tension leg concept with an 80kW turbine near Italy in summer 2008.
- Currently building a 2MW unit for deployment in 2009.
- Is receiving funding from the Energy Technology Institute (ETI) for UK-based projects.



Offshore Technology Summary

- Over 1000-MW deployed in Europe but none yet in the USA.
- Offshore wind resources are abundant in the USA.
- Over 2100-MW of offshore projects are underway in USA.
- Transmission-constrained load centers are beginning serious development.
- Demand for turbines is exceeding supply as land-based markets flourish, and projects await regulatory process development.
- Shallow water wind (<30m) will evolve first due to siting advantages.
- Deeper water wind energy has many advantages but will require new technology.

Thank you!

Jason Jonkman
Senior Engineer
National Renewable Energy Laboratory
jason_jonkman@nrel.gov



Photo credit: <http://www.owen.eru.rl.ac.uk/images/seaside.jpg>