Offshore Wind Energy:

An Immense US Natural Resource

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HSGAC Hearing "Energy Security: An American Imperative"
July 22, 2008

Outline

Maine Heating State of Emergency

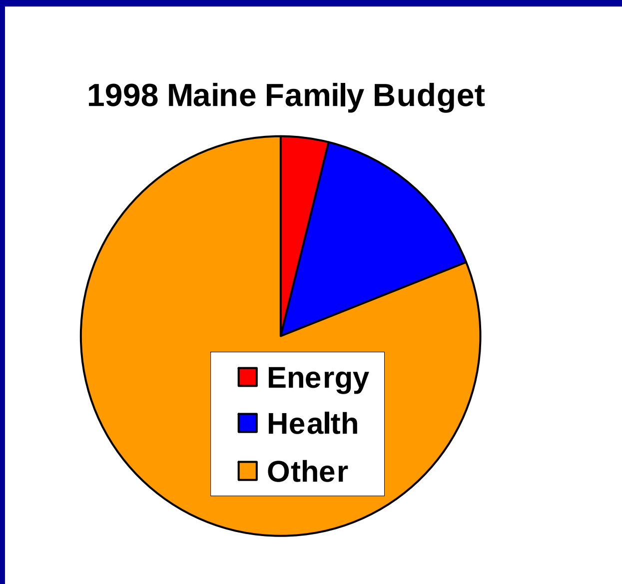
Food or heat?

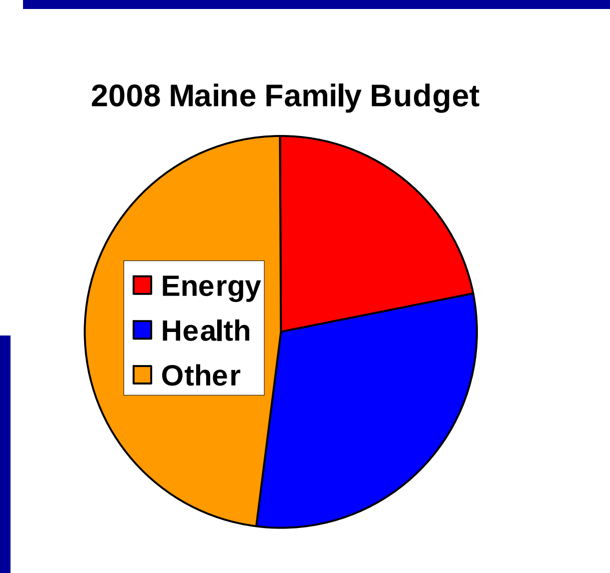
Outmigration?

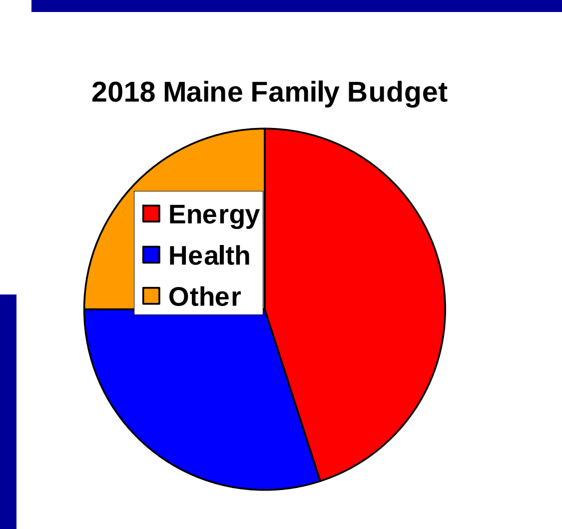
- 80% use heating oil
- Heating oil costs tracks crude
- Next winter's heating oil: $5/gallon
- Maine family heating costs next winter: $5,000
- In 2020, family heating costs: $10,000 ('08 dollars)

How to Break a ‘Maine’ Budget 1998-2018

“Energy” =
50% Transportation
40% Heating
10% Electric Power

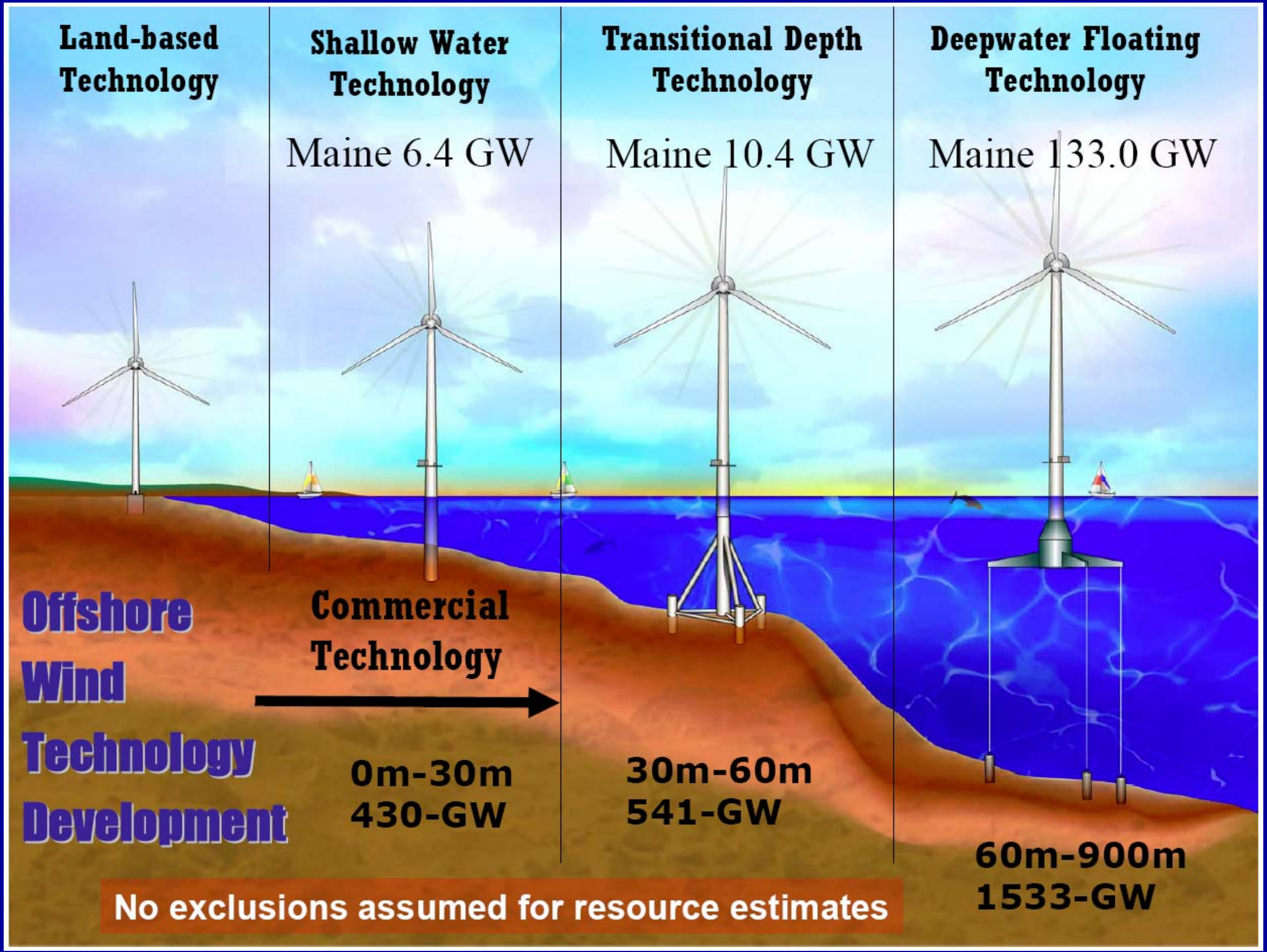




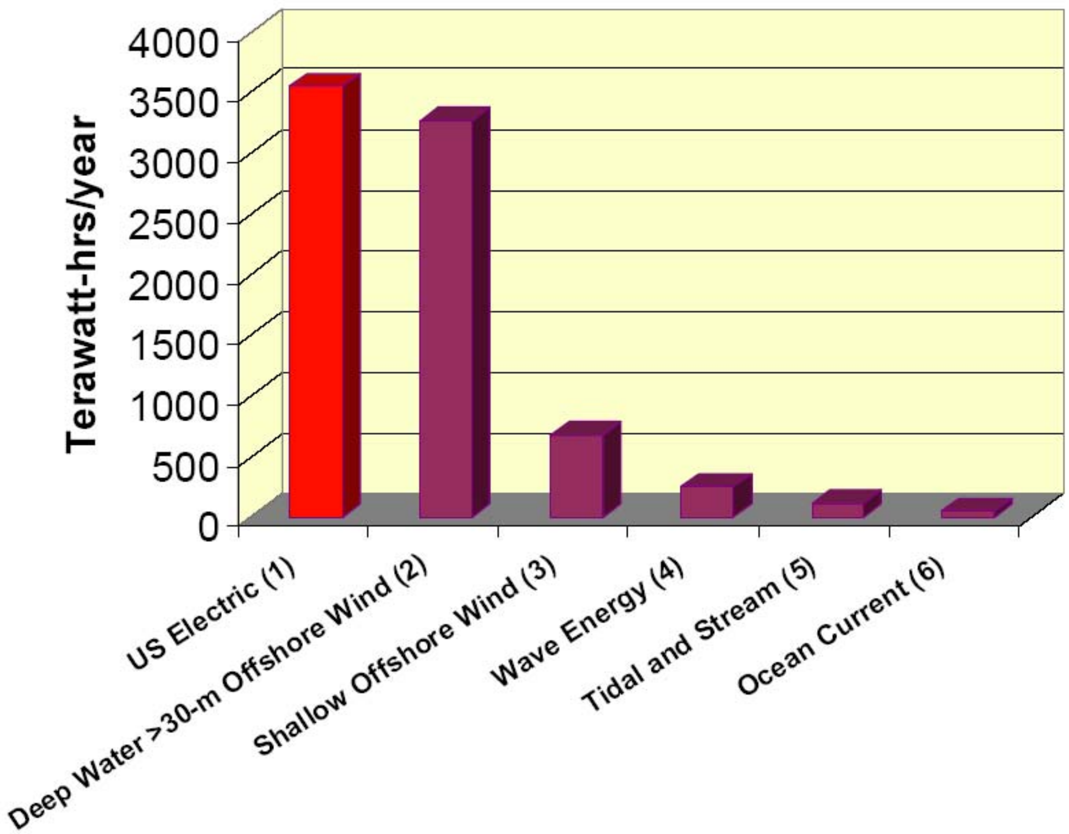


This makes the “happy” assumption that health care costs do not grow past 30% of the average family’s budget in 2008-2018

“Over-The-Horizon” Wind Turbines > 20 miles off Coast


Land-based Technology
Shallow Water Technology
Maine 6.4 GW
Transitional Depth Technology
Maine 10.4 GW
Deepwater Floating Technology
Maine 133.0 GW
Offshore Wind Technology Development
Commercial Technology
0m-30m
430-GW
30m-60m
541-GW
60m-900m
1533-GW
No exclusions assumed for resource estimates

US Marine Renewable Energy Electric Potential Estimates (7)



Assumptions

1. U.S. electric consumption based on 2005 EIA statistics.
2. Class 5 wind or better; depths between 30-m and 900-m included; 60% exclusions; HI and AK not included; 0-50nm from shore; 45% Cap factor; Source: NREL.
3. Class 5 wind or better; depths between 0-m and 30-m; included; 60% exclusions; HI and AK not included; 0-50nm from shore; 45% cap factor; Source NREL.
4. 15% of incident wave energy; 20% conversion losses; AK and HI Included; Wave climate 10kW/m or better; Source EPRI.
5. Estimated from aggregate siting studies; 15% extraction permitted; In stream river kinetic estimated by EPRI..
6. Estimated from *Coriolis Study, Aquantis,* and FAU; Miami/Gulf Stream region only, 57% capacity factor; 10-GW rated capacity.
7. OTEC, salinity gradient, marine biomass not evaluated.

NREL National Renewable Energy Laboratory

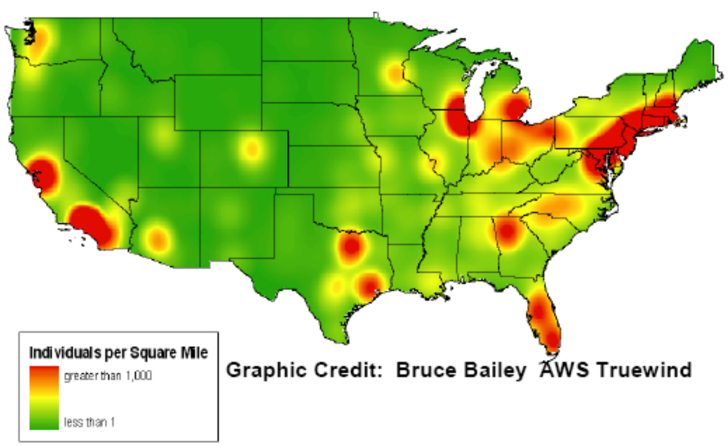
Why Marine Renewables?

28 coastal states use 78% of the electricity in US

Many Coastal Load Centers Cannot Be Served by Land-based Renewable Resources

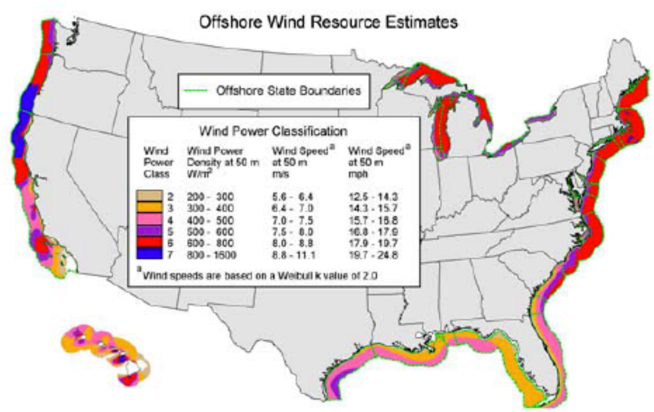
Renewable Energy Goals Cannot be Achieved Without Offshore Contributions

US Population Concentration



Graphic Credit: Bruce Bailey AWS Truewind

U.S. Wind Resource



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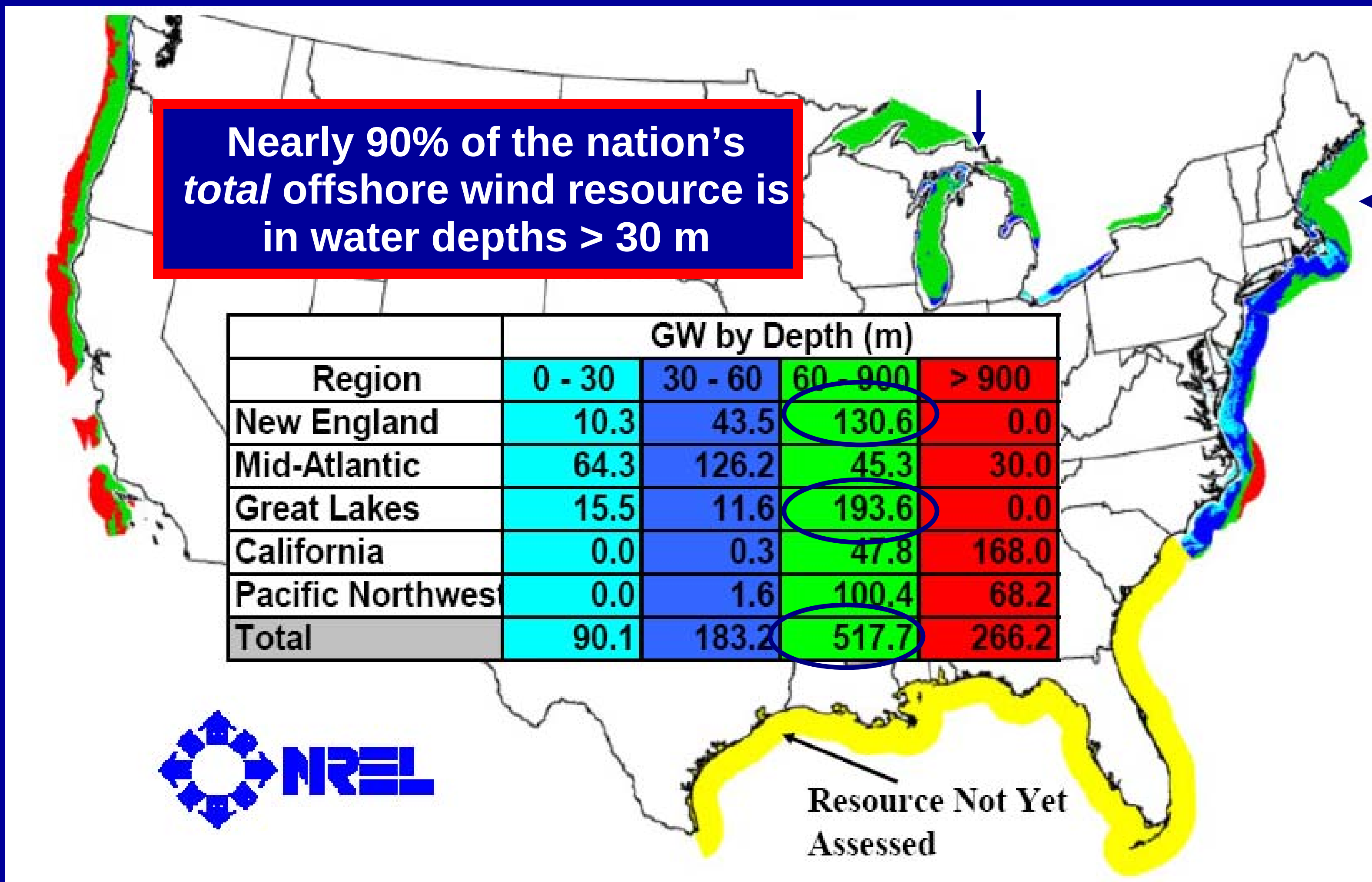
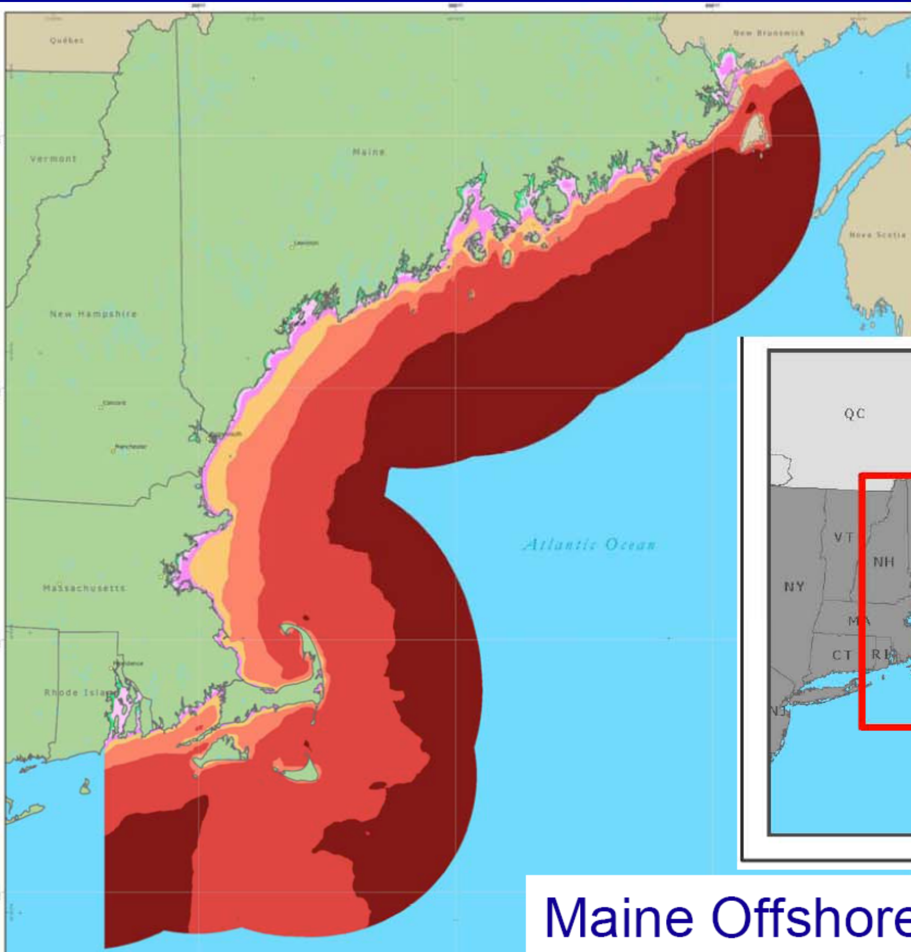
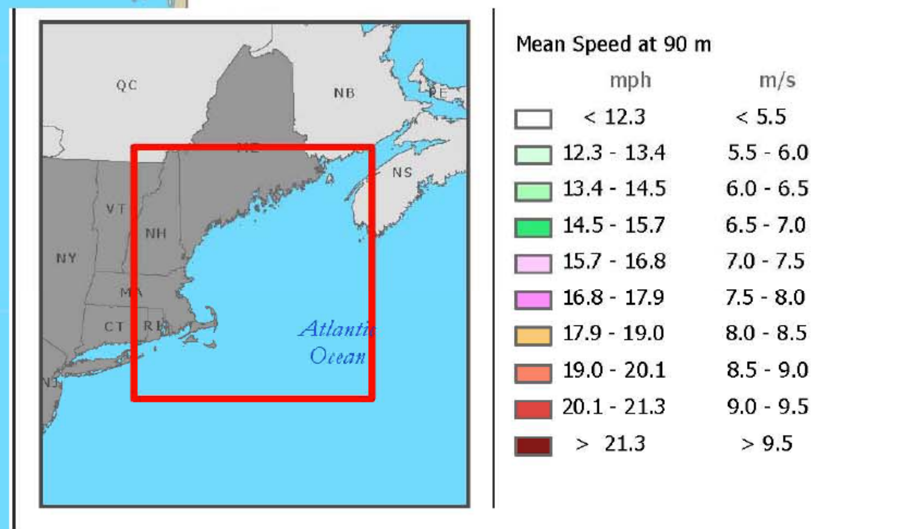
Floating Offshore Wind Technology Innovated in Gulf of Maine Exportable to Rest of US and World



	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

New England Offshore Mean Wind Speed at 90-m

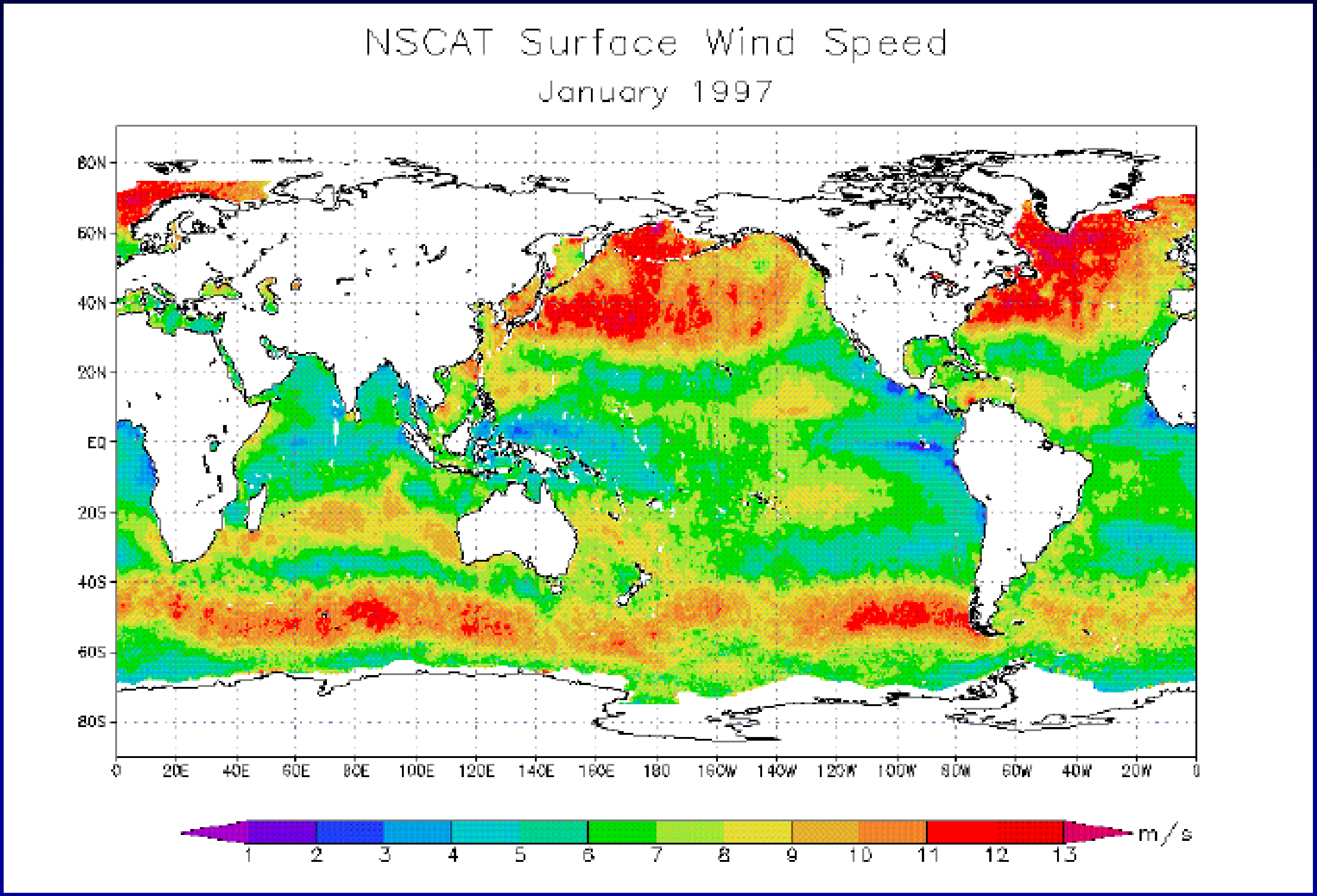




Maine Offshore Wind Potential

Maine (MW of wind potential)		Distance from Shoreline											
		0–3 nm (state waters)				3–12 nm				12–50 nm			
	Wind	Depth Category (m)				Depth Category (m)				Depth Category (m)			
	Class	0–30	30–60	60–900	> 900	0–30	30–60	60–900	> 900	0–30	30–60	60 - 900	> 900
	4	4,785	2,163	324	0	493	2,104	1,175	0	0	0	0	0
	5	3,663	2,442	1,112	0	657	2,029	3,697	0	0	0	0	0
	6	1,516	2,250	1,487	0	630	3,413	20,928	0	2	348	105,789	0
	7	0	0	0	0	0	0	0	0	0	0	41	0

Global Wind Speed Distribution in Northern Hemisphere Winter



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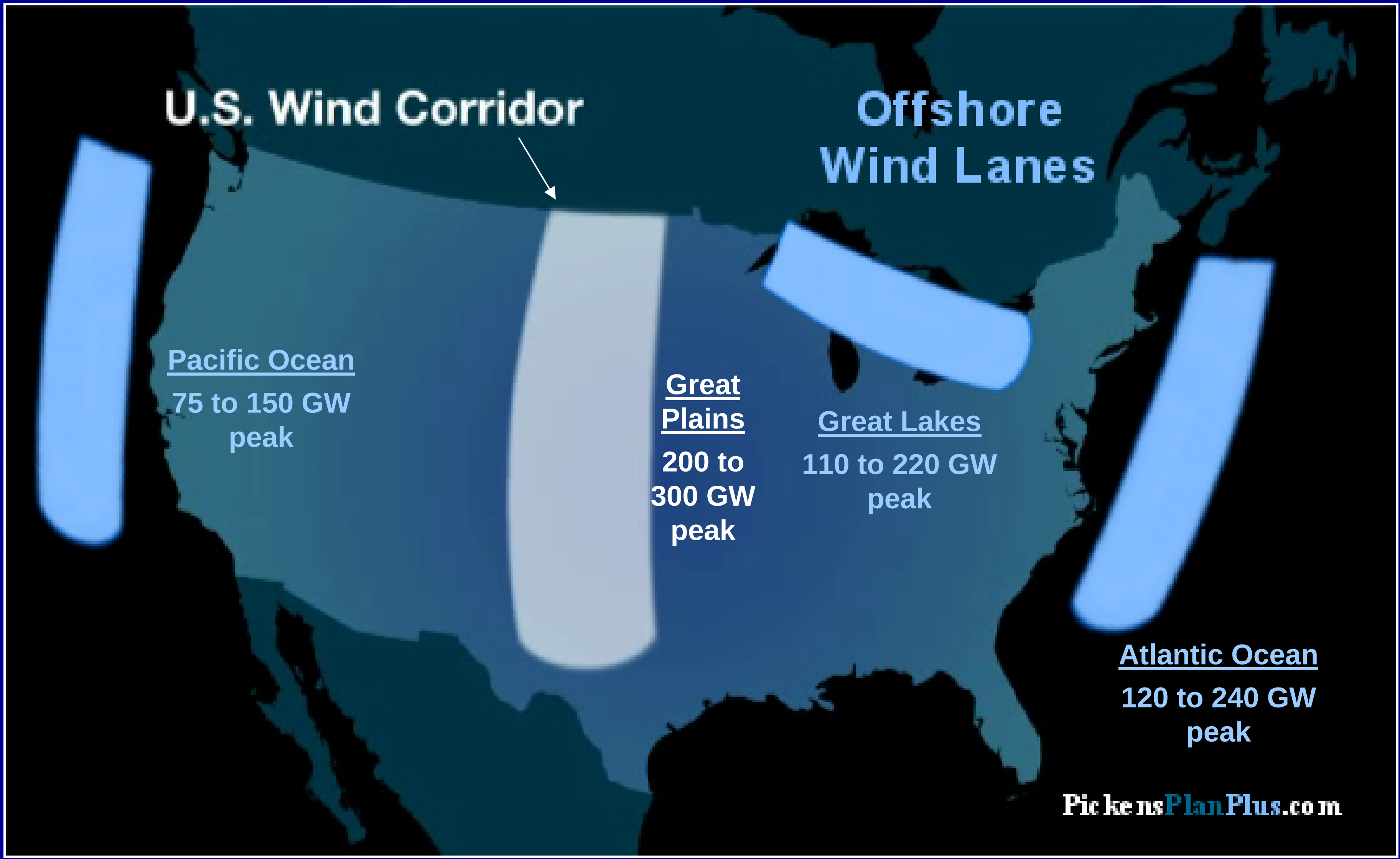
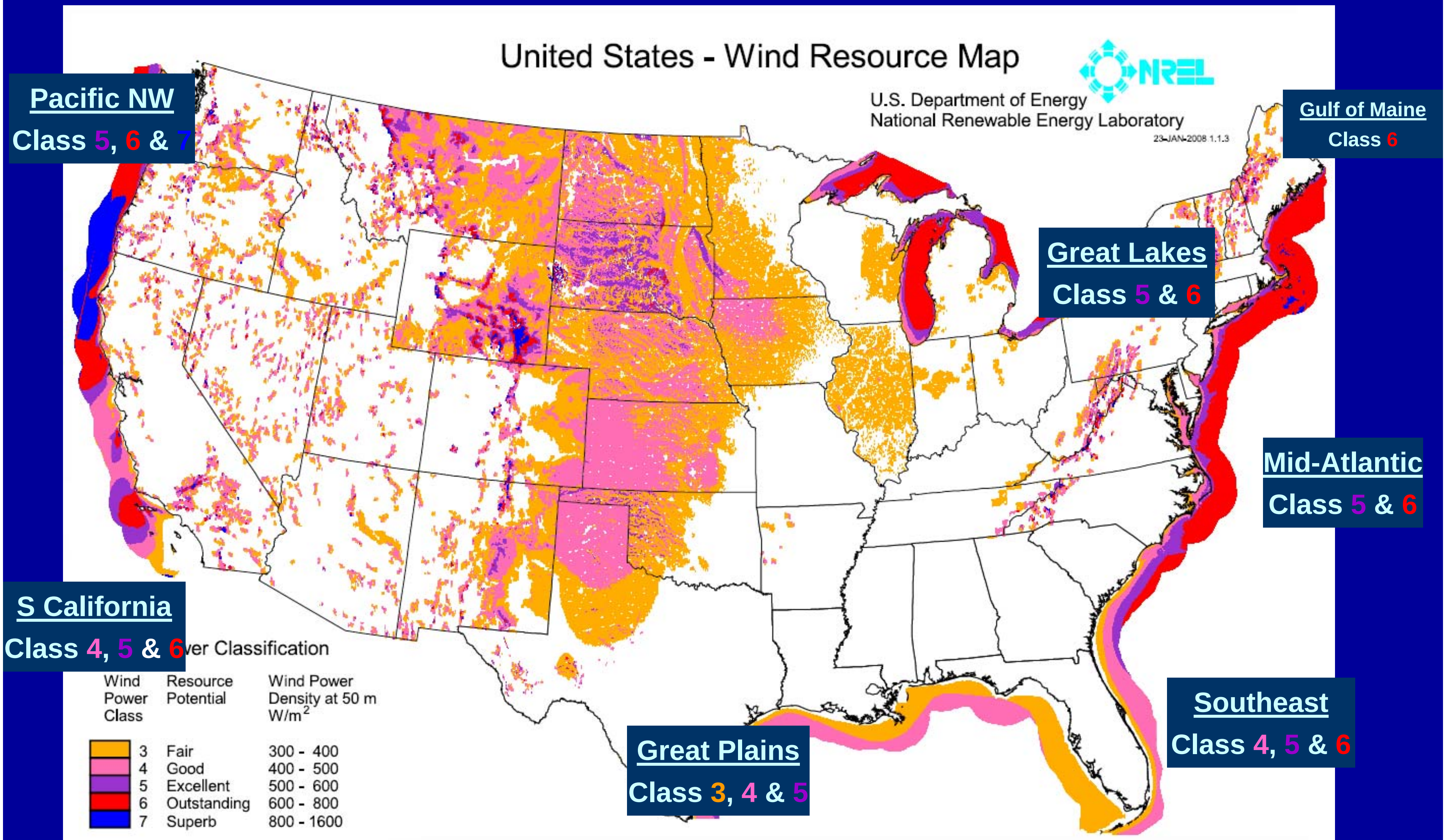
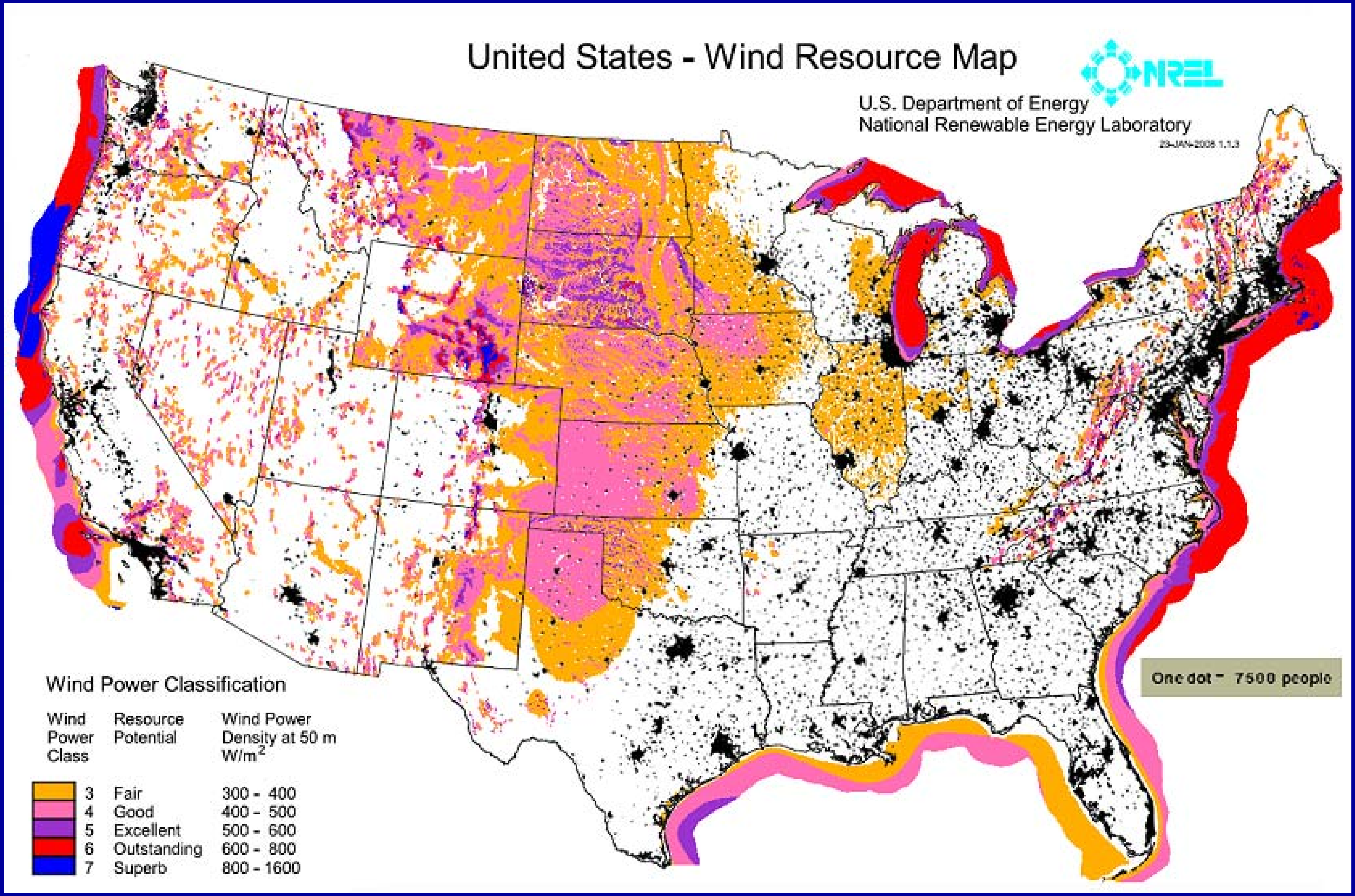
10 to 20% of Available Offshore Wind



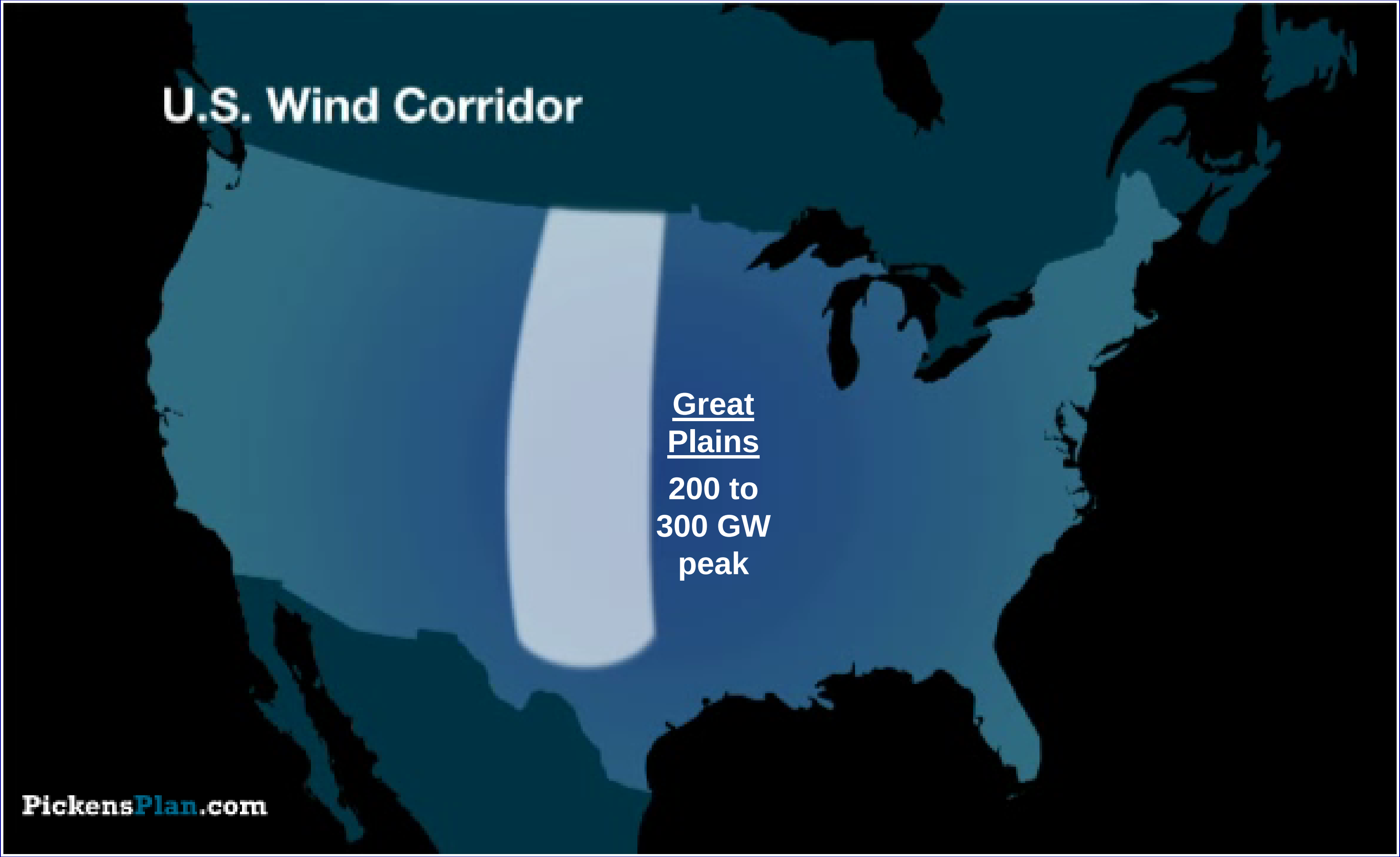
Added Value 1: Better Wind Resources



Added Value 2: Better Wind Resources Located Closer to Urban Load Centers



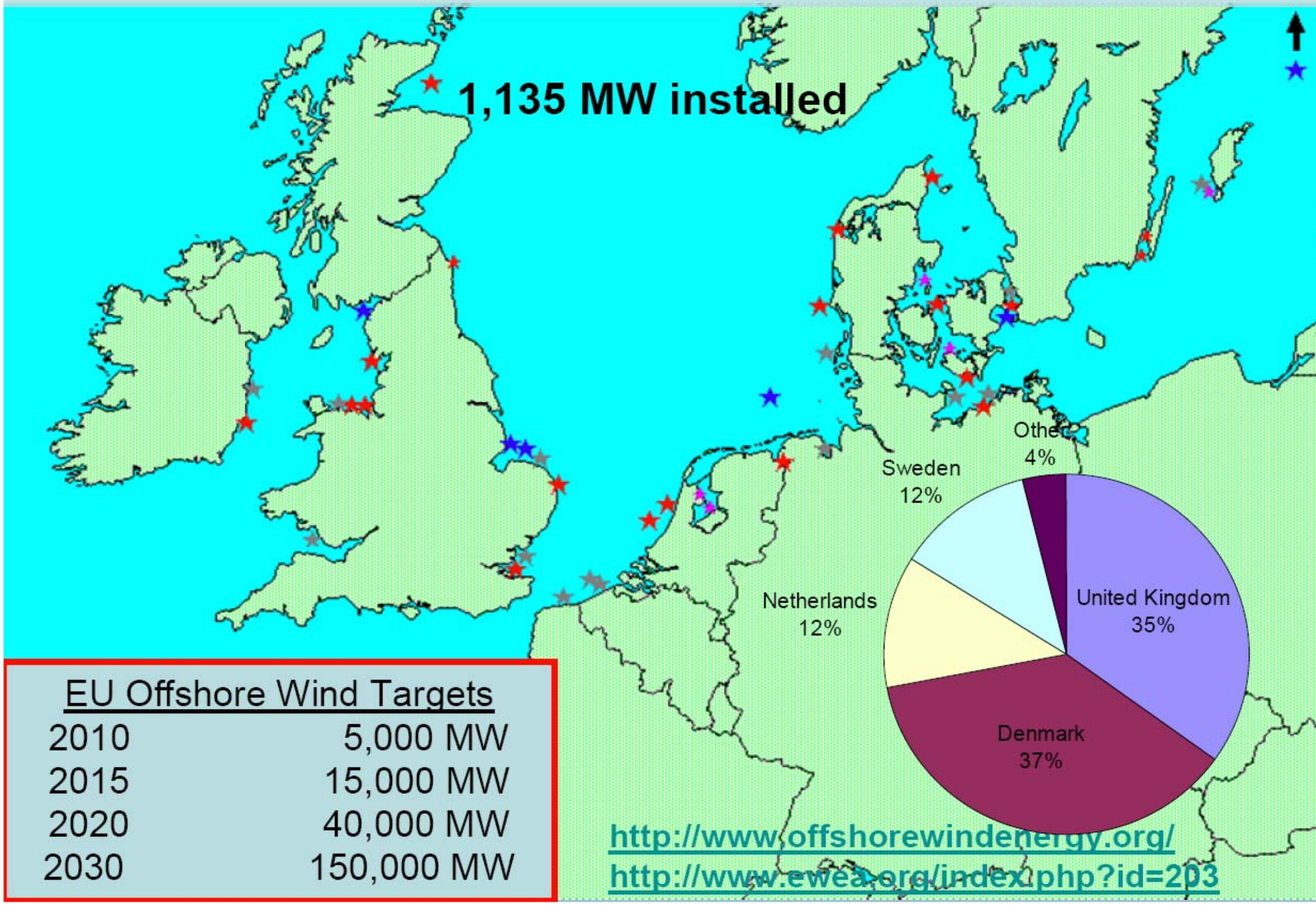
Added Value 3: Less Intermittency as Weather Moves from West to East



Great Plains

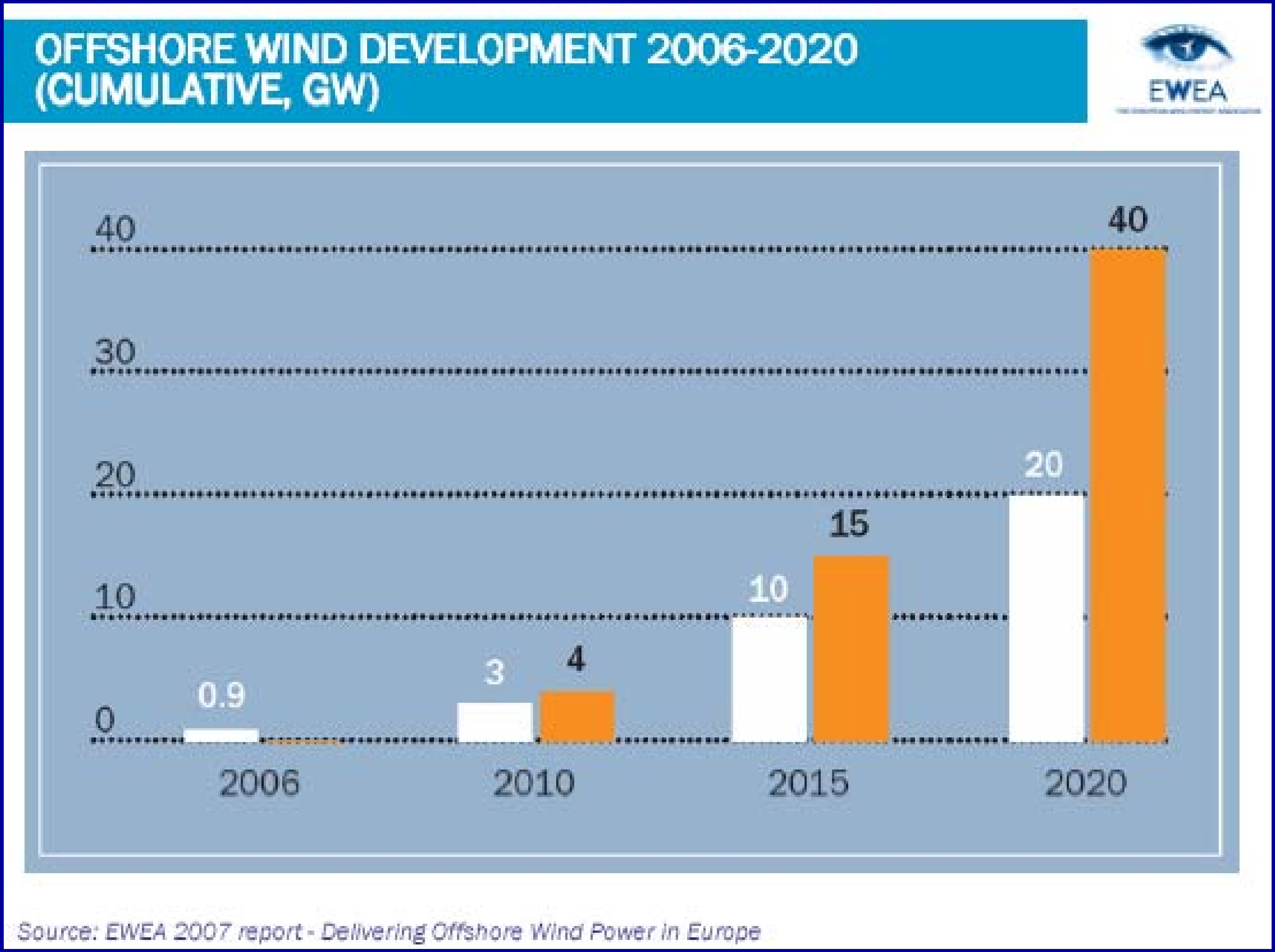
200 to 300 GW peak

European Activity Offshore

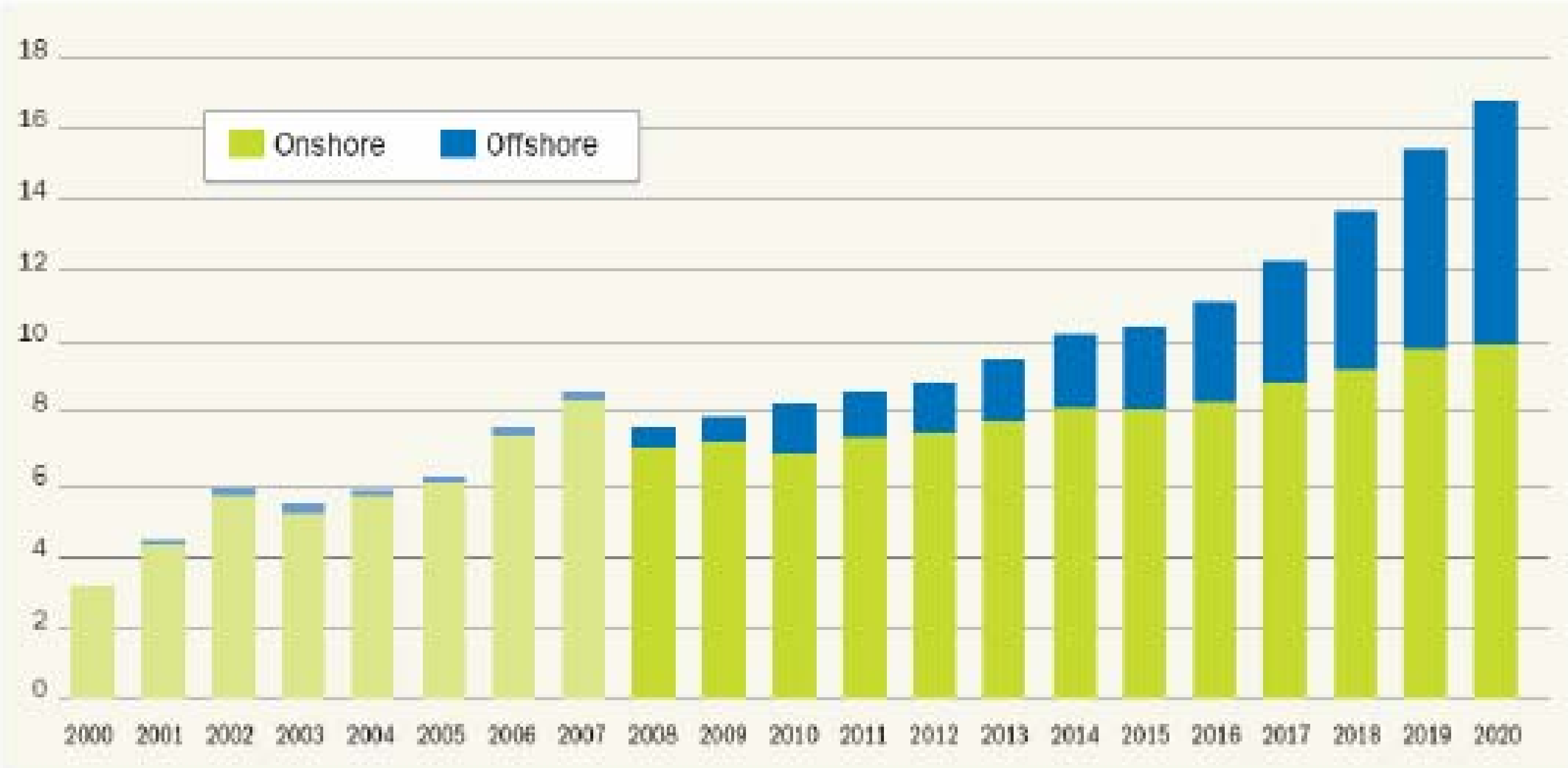


EU Offshore Wind Targets	
2010	5,000 MW
2015	15,000 MW
2020	40,000 MW
2030	150,000 MW

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

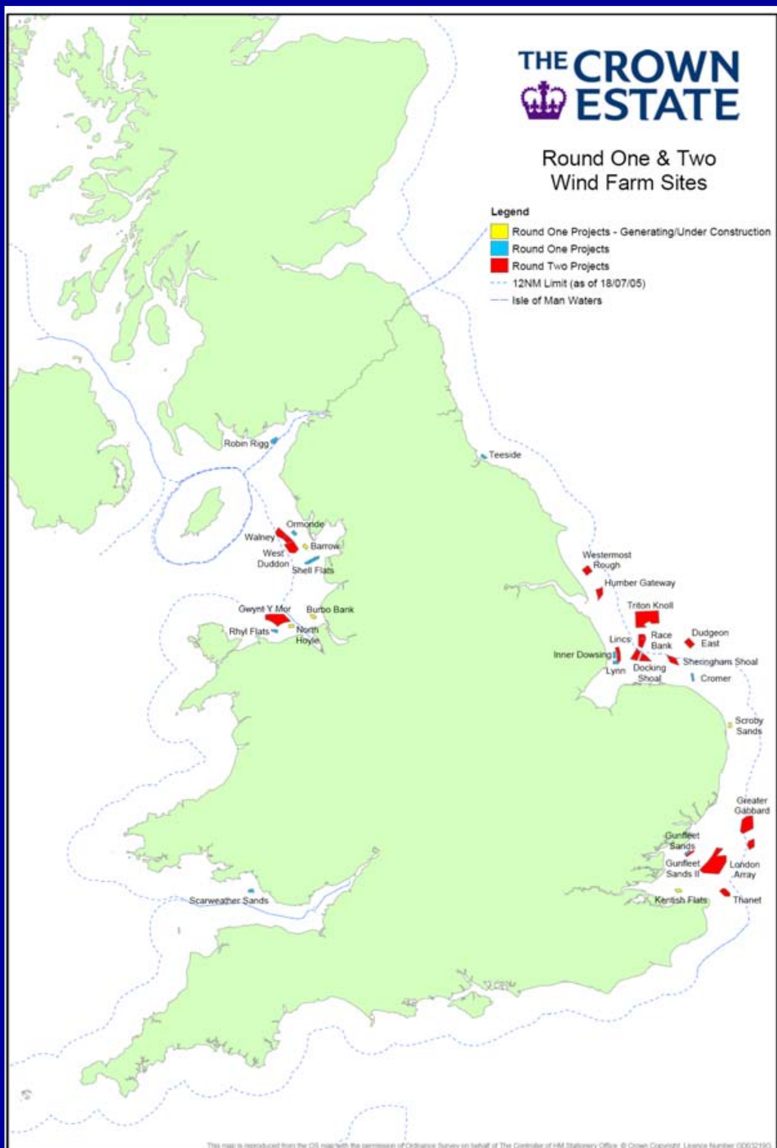

OFFSHORE WIND DEVELOPMENT 2006-2020
(CUMULATIVE, GW)
EWEA
40
30
20
10
0
0.9
3
4
10
15
20
40
2006
2010
2015
2020
Source: EWEA 2007 report - Delivering Offshore Wind Power in Europe

WIND ENERGY ANNUAL INSTALLATION 2000-2020 (IN GW)



Source: EWEA

UK Plan: 33 GW by 2020



- ✓ 7,000 offshore wind turbines around the country's coastline
- ✓ Up to 50% of Country's electricity
- ✓ Mix of sources, including nuclear to cover no-wind days

Energy Secretary John Hutton plan announced on Dec 10, 2007

http://nds.coi.gov.uk/environment/fullDetail.asp?ReleaseID=337237&NewsAreaID=2&NavigatedFromDepartment=True

Solutions for Intermittency

- Mix with traditional power generation
- Storage:
  - Pumped hydro (Norway ‘battery’ for Europe)
  - Plug-in Electric Hybrids
- Wide geographic coverage
- Smart grid technology

Plug-In Electric Hybrid Vehicles – Chevy Volt

http://www.gm-volt.com/

http://www.edmunds.com/insideline/do/Features/articleId=119088

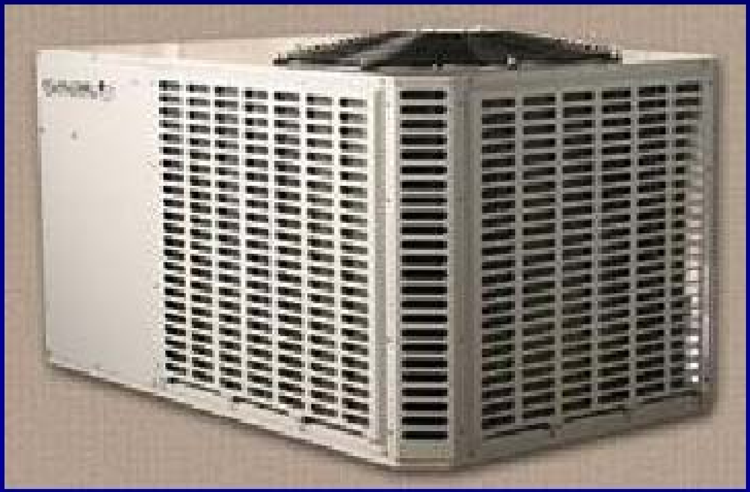
PEHV

General Motors has unveiled the Chevrolet Volt concept, the company's first plug-in hybrid vehicle, at the 2007 North American International Auto Show in Detroit. The Chevrolet Volt concept is the first vehicle to use GM's new E-flex family of propulsion systems. GM claims the Volt delivers triple-digit fuel economy and can travel up to 640 miles without a fuel fill-up or a battery recharge. Scheduled for 2010 model year.

Cold Climate Heat Pumps
Hallowell Intl Acadia® CCHP

The Acadia™

The Acadia™ was designed to provide years of comfort and reliability. Using electricity efficiently means that the Acadia™ can provide savings of up to 70% over other traditional heating systems. Even better, the Acadia™ was designed so that any HVAC contractor who currently works with air source heat pumps has all the tools and experience to install and service the system.



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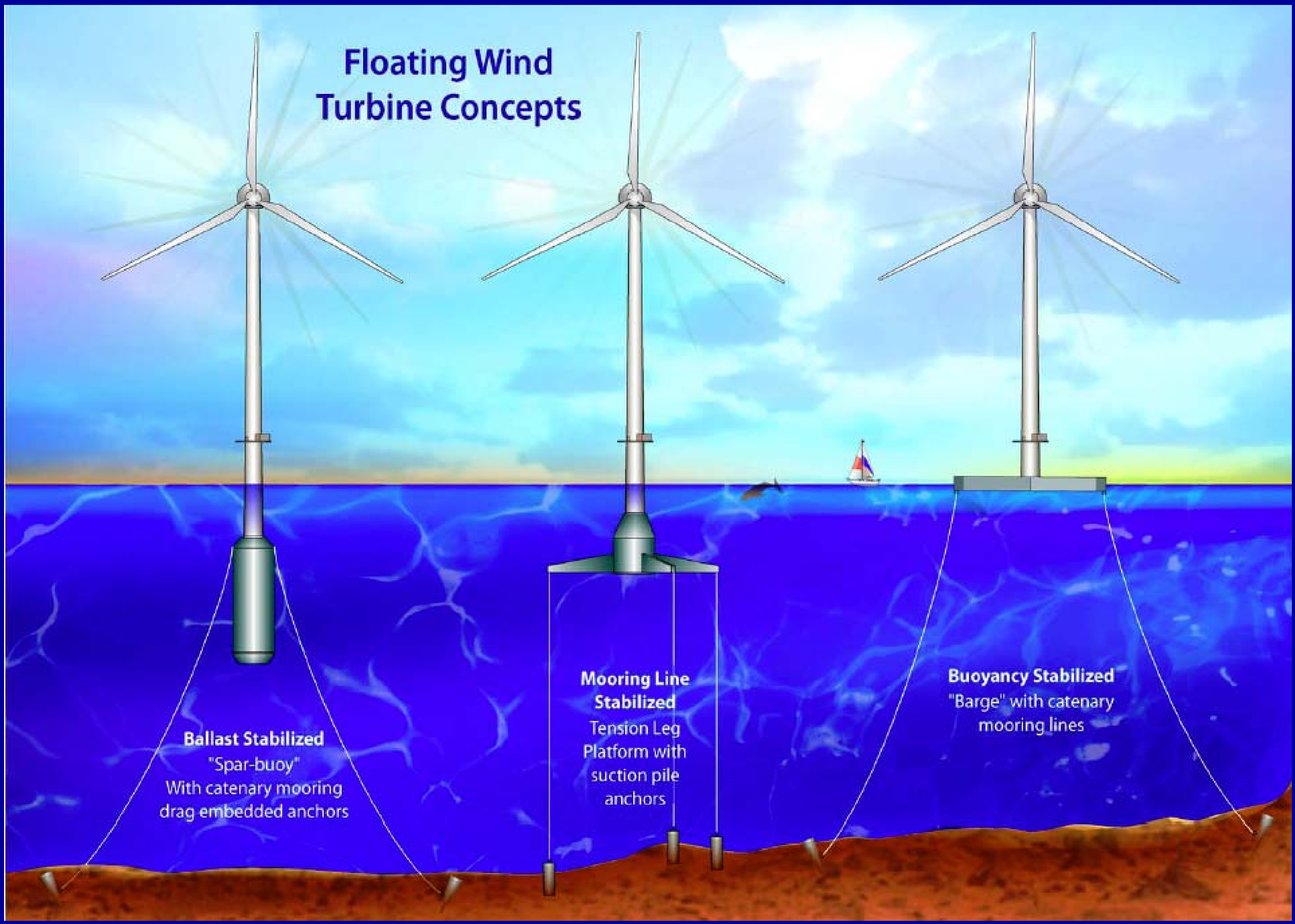
R&D Needs: Deep Water

- Deep water (30m) > 90% of US resource
- Design/deploy prototype floating turbines
  - 2011 - GEN1: refine design models
  - 2013 - GEN2: optimize design
  - 2015 - 50 MW commercial farm: logistics
- 2016 - Industrial development
- $100 million R&D effort – 1 US location
- $240 million R&D effort – 3 US locations:

R&D: Floating Wind Turbines: Design and Prototype Deployment



Summary & Recommendations

1. U.S. coastal states, including Maine, have significant offshore wind resources
   - -- Development of offshore wind creates much needed, clean electricity at stable prices; increased revenues across all jurisdictions; and manufacturing and project development jobs
   - -- over 100,000 MW potential in Maine
   - -- each 1,000 MW of wind = $2 billion in capital investment, $5 m/yr for lease payments, 1800 construction jobs, 1.8 million metric tons of carbon avoided/yr, and 18 billion cubic feet of natural gas saved/yr

2. There is a strong role for federal agencies to ensure these benefits are realized:
   - -- Technology - we need an offshore technology development and demonstration program as current wind technology cannot be used in offshore environment; need several test centers as well; R&D investment: $100 million – one demo location, $240 million – 3 demo locations
   - -- Resource Assessment -- we need to better understand the wind resource offshore at heights suitable for wind project development, vs. surface measurements
   - -- Regulatory Framework -- we need enhanced federal, state, and local regulatory framework to ensure offshore developers, investors, and customers have a clear, timely, predictable process for their projects

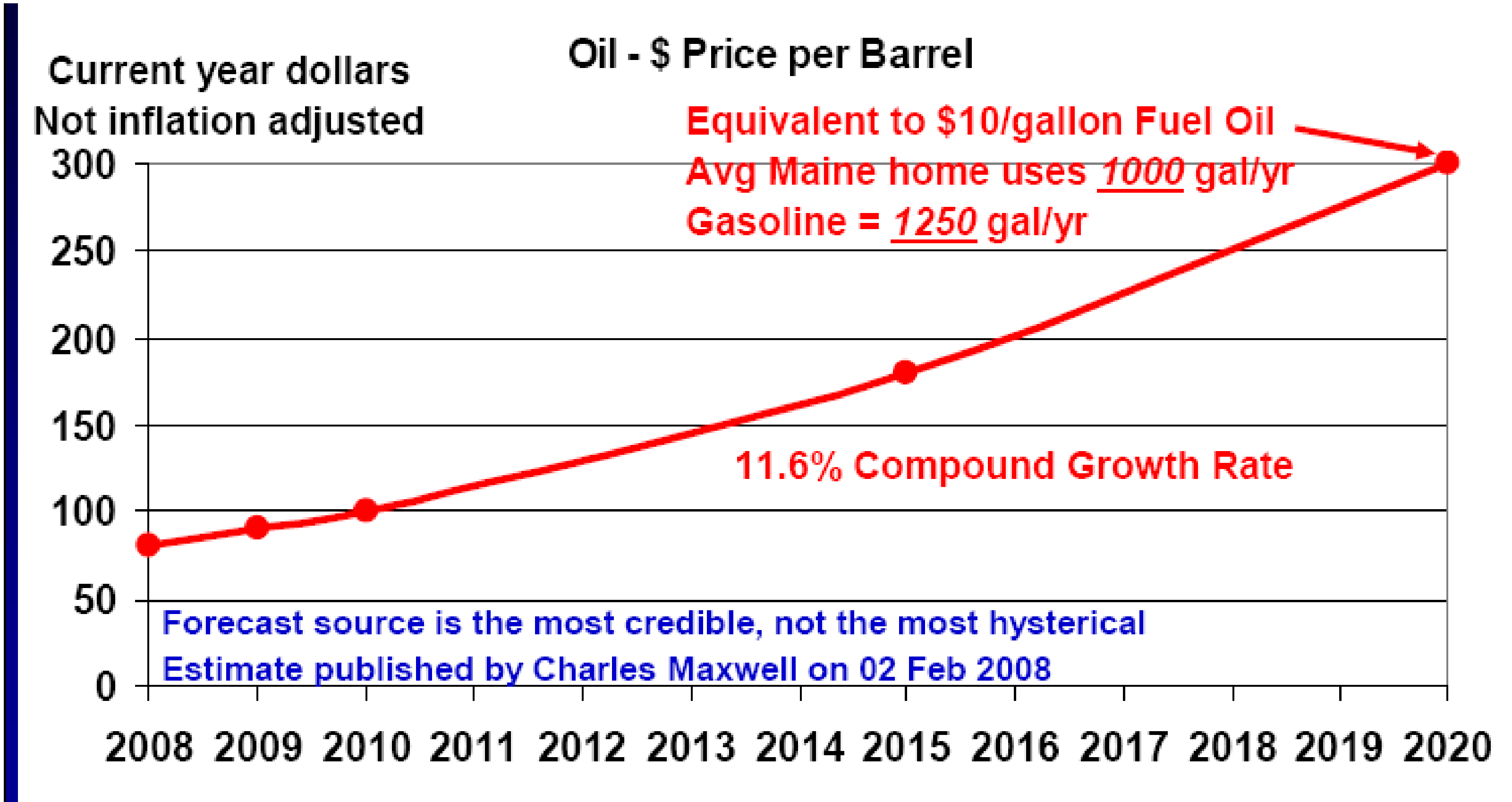
3. Role for Department of Homeland Security related to offshore wind:
   - -- DHS could also look at role offshore wind turbines-based sensors and their platforms can play as early detectors of hostile ship or airborne WMDs
   - -- Wind impact on DHS Mission -- we need to better understand and create tools to mitigate potential impacts of wind systems on DHS operations, such as long-range surveillance radars
   - -- DHS facilities could consider their role as a potential customer of wind power to meet their Executive Order requirements for all federal agencies to increase clean power purchases

Acknowledgements

- Walter Musial, Principal Engineer, National Renewable Energy Lab (NREL Slides)
- P.J. Dougherty (formerly DOE Wind Program)
  SMI Inc./Helios Strategies
- George Hagerman, Virginia Coastal Energy Research Consortium, Virginia Tech Advanced Research Institute
- Mark West, SWAY, Norway Blue H USA
- EWEA
- AWEA

ADDITIONAL BACKGROUND

Anatomy of a Granite Mountain



In polls taken by *Institutional Investor* magazine, Mr. Maxwell has been ranked by the US financial institutions as the No. 1 oil analyst for the years 1972, 1974, 1977 and 1981-1986. In addition, for the last 17 years he has been an active member of an Oxford-based organization comprised of OPEC and other industry executives from 30 countries who meet twice a year to discuss trends within the energy industry

4 *Ocean Energy Institute*

Offshore Wind Benefits

- Better wind resources
  - Less turbulence – steadier wind
  - Higher wind = better energy production
  - Higher capacity factors – load matching
- Less visual impacts than land-based.

- Proximity to load centers
  - Lowers transmission constraints
  - Serves high cost regions
  - Exploits indigenous resources
- Avoids land-based size limits
  - **Shipping** – Roadway limits
  - **Erection** – Crane limits
  - Larger machines are more economical.

45-m Depth Offshore Demonstration Project
Talisman Energy in Beatrice Fields

- 5-MW Rating
- 61.5-m Blade Length
- Worlds Largest Turbine
- Two Machines
- 45-m Water Depths

Photo Courtesy: Talisman Energy

Offshore Turbine Suppliers

Turbine Manufacturer	Turbine model & rated power	Date of availability	Offshore Operating Experience
Bard Engineering	VM - 5 MW	2008-09	Onshore prototype 2008
General Electric	GE – 3.6-MW	2003	Commercial inactive
Multibrid	M5000 - 5 MW	2005	Onshore 2005
Nordex	N90 - 2.5 MW	2006	Offshore Demo 2003
RePower Systems	5M - 5 MW	2005	Offshore Demo 2006
Siemens	SWT-2,3 - 2.3 MW	2003	Commercial
Siemens	SWT-3.6 - 3.6 MW	2005	Commercial
Vestas	V80 - 2 MW	2000	Commercial
Vestas	V90 - 3 MW	2004	Commercial

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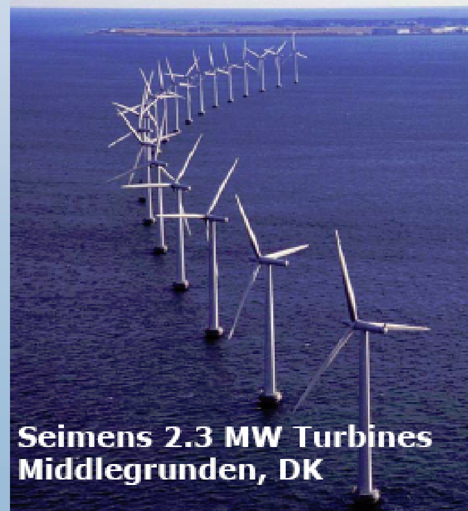
Offshore Technology Status


Vestas 2.0 MW Turbine Horns Rev, DK


Talisman Energy: Repower 5-MW Beatrice Fields, Scotland


GE 3.6 MW Turbine Arklow Banks


Seimens 2.3 MW Turbines Middlegrunden, DK

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

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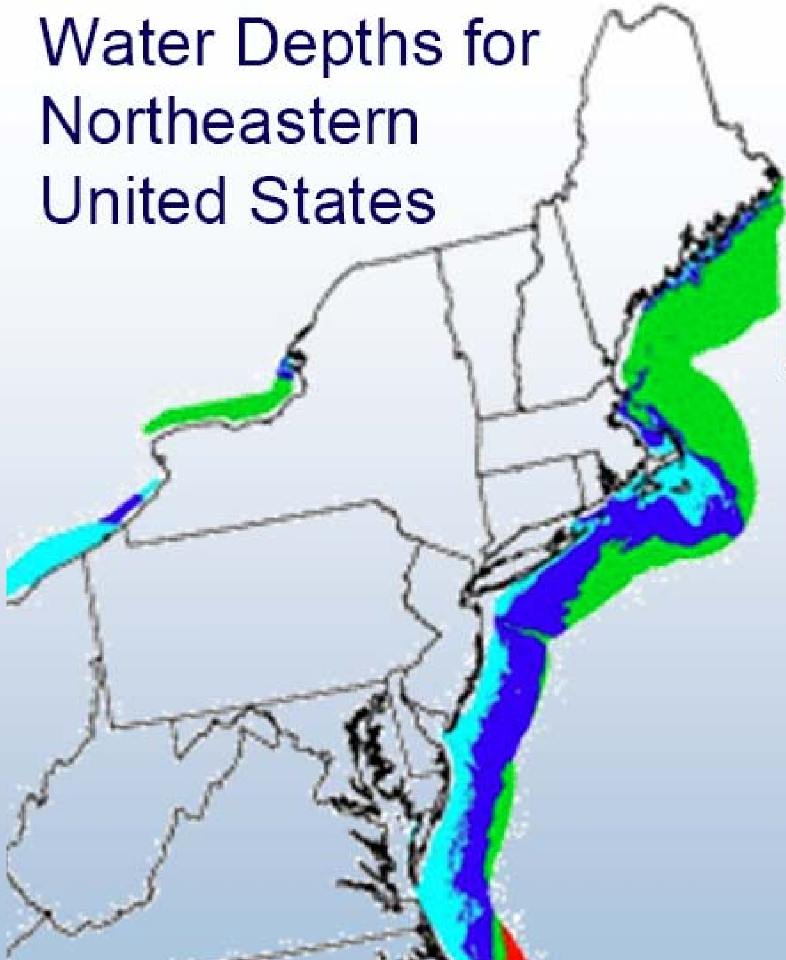
Water Depths for Northeastern United States



Water Depth Scale – meters

0 - 30	30 - 60	60 - 900	> 900
6.4 GW	10.4 GW	133.0 GW	0 GW

Maine has abundant deepwater wind resource

Resource Assumptions:

- No exclusions
- Class 5 wind and greater
- 0-50 nautical miles

Water depth will determine technology requirements

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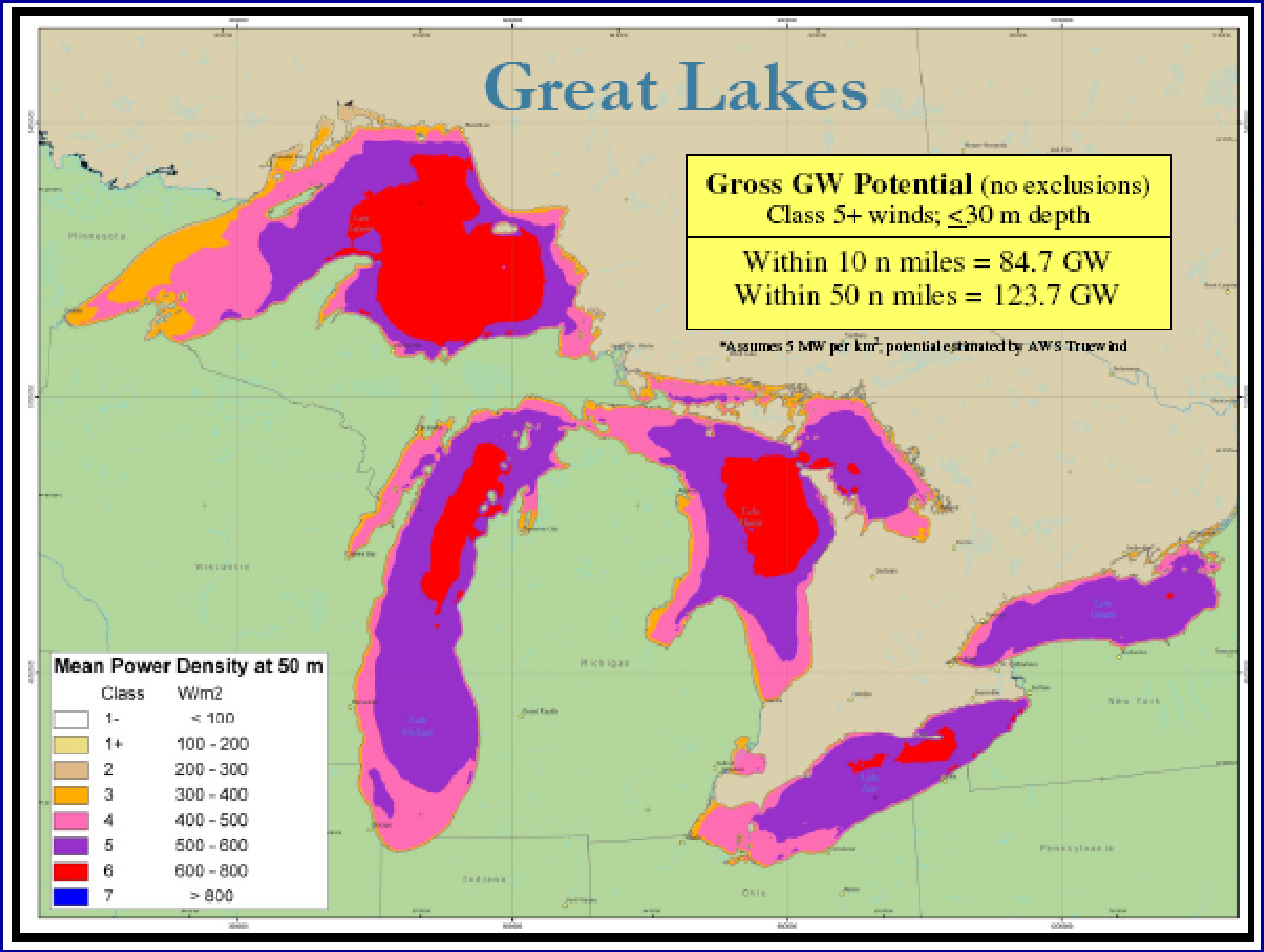
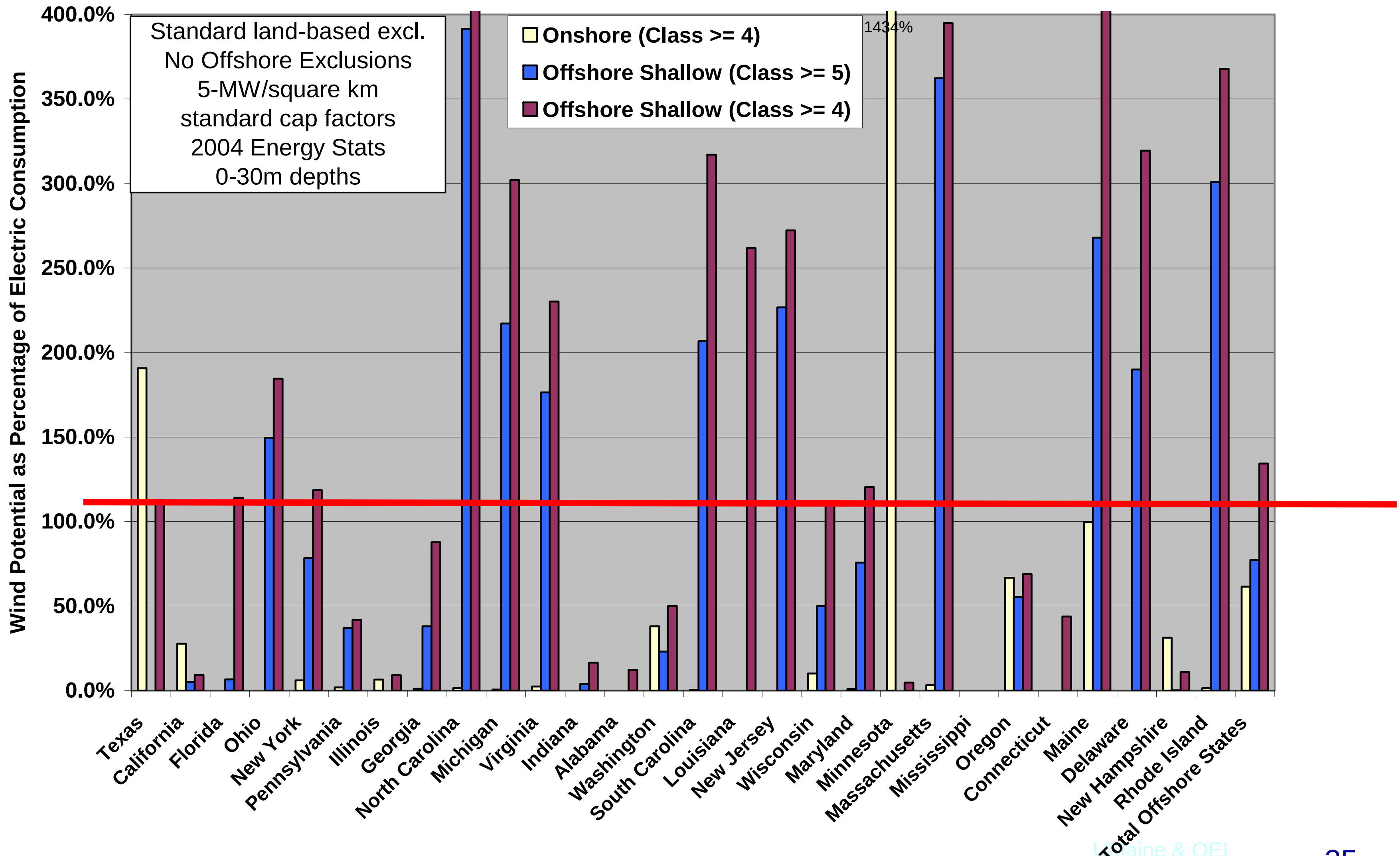
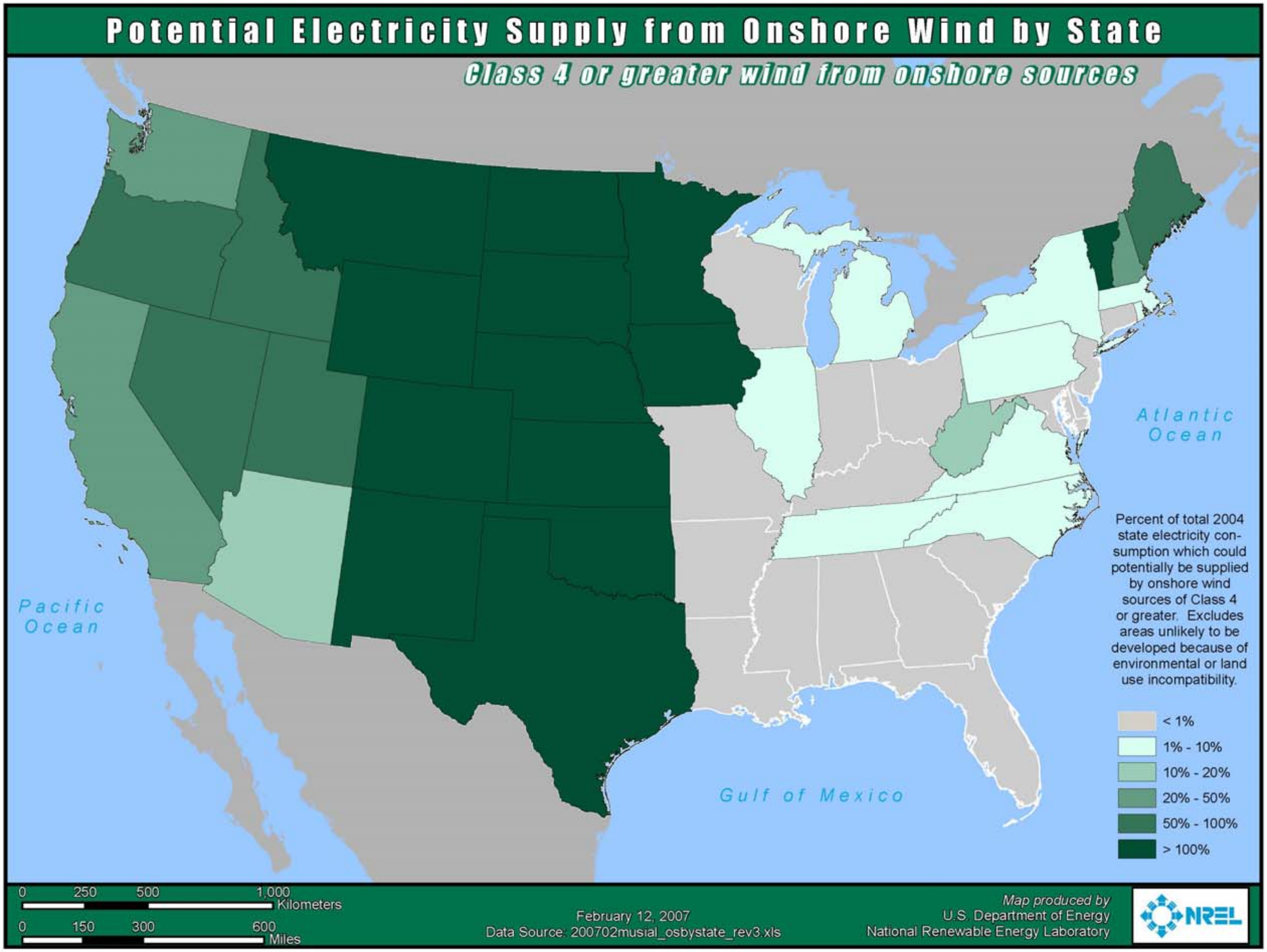

Great Lakes
Gross GW Potential (no exclusions)
Class 5+ winds; ≤30 m depth
Within 10 n miles = 84.7 GW
Within 50 n miles = 123.7 GW
*Assumes 5 MW per km²; potential estimated by AWS Truewind
Mean Power Density at 50 m
Class W/m2
1- < 100
1+ 100 - 200
2 200 - 300
3 300 - 400
4 400 - 500
5 500 - 600
6 600 - 800
7 > 800
Minnesota
Wisconsin
Michigan
New York
Ohio
Indiana
Pennsylvania

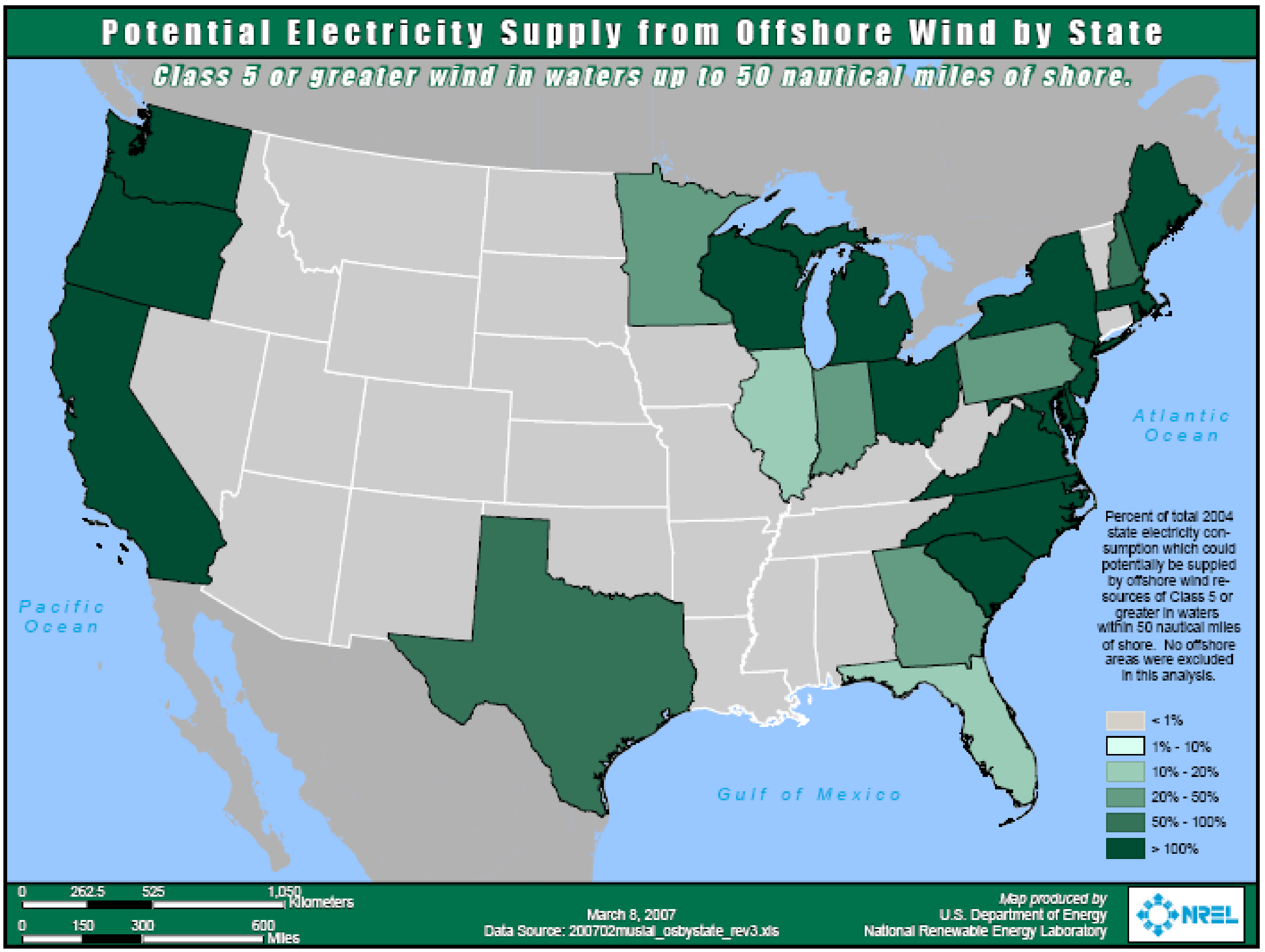
28 Offshore States Wind Energy Potential

78% of Energy Consumption

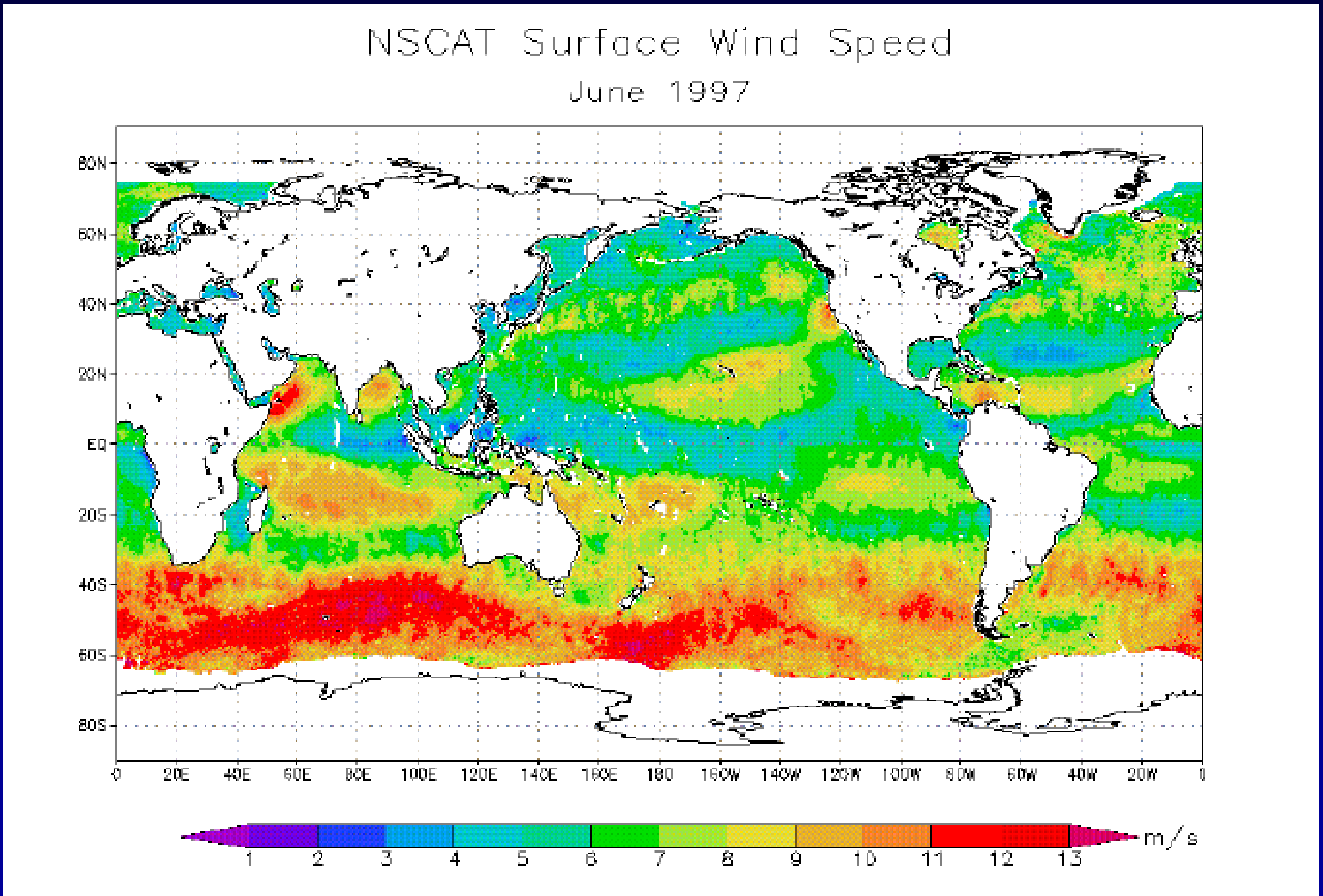


UMaine & OEI


Potential Electricity Supply from Onshore Wind by State
Class 4 or greater wind from onshore sources
Pacific Ocean
Atlantic Ocean
Gulf of Mexico
Percent of total 2004 state electricity consumption which could potentially be supplied by onshore wind sources of Class 4 or greater. Excludes areas unlikely to be developed because of environmental or land use incompatibility.
< 1%
1% - 10%
10% - 20%
20% - 50%
50% - 100%
> 100%
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
NREL


Potential Electricity Supply from Offshore Wind by State
Class 5 or greater wind in waters up to 50 nautical miles of shore.
Pacific Ocean
Atlantic Ocean
Gulf of Mexico
Percent of total 2004 state electricity consumption which could potentially be supplied by offshore wind resources of Class 5 or greater in waters within 50 nautical miles of shore. No offshore areas were excluded in this analysis.
< 1%
1% - 10%
10% - 20%
20% - 50%
50% - 100%
> 100%
0 262.5 525 1,050 Kilometers
0 150 300 600 Miles
March 8, 2007
Data Source: 200702musial_osbystate_rev3.xls
Map produced by
U.S. Department of Energy
National Renewable Energy Laboratory
NREL

Global Wind Speed Distribution in Northern Hemisphere Summer



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US Projects Proposed

US Offshore Projects		
Project	**State**	**MW**
Capewind	MA	468
Winergy (plum Island)	NY	10
Southern Company	GA	10
W.E.S.T.	TX	150
Buzzards Bay	MA	300
New Jersey	NJ	300
Hull Municipal	MA	15
Cuyahoga County	OH	20
Delmarva	DE	450
Total		1723

No Offshore wind projects Installed in U.S. yet

Building an Advanced Energy Economy through Offshore Wind Power

Great Lakes Wind Energy Center (GLWEC)

Pilot Project and Applied Research Center

David H. Matthiesen[1], A. Steven Dever[2], Richard T. Stuebi[3], and William D. Mason[2]
1) Case Western Reserve University, 2) Cuyahoga County Prosecutor's Office, 3) Cleveland Foundation

Presented at the AWEA's WindPower 2008 Houston, TX June 1-4, 2008

Verification of Predicted Wind Energy Resources

GLWEC PERMITTING TEMPLATE—MAJOR PROGRAMS

- FEDERAL
  - Army Corps of Engineers Construction Permit needed (Section 10 and/or 404 of Clean Water Act) – construction activities in lakes, rivers, streams, wetlands (33 CFR 320 to 330).
  - Construction Permit triggers National Environmental Policy Act (NEPA) and Environmental Assessment/Environmental Impact Statement Process.
  - Construction Permit also triggers need for Water Quality Certificate (Section 401 of CWA). Issued by Ohio EPA under delegated CWA authority.
  - Federal Endangered Species Consultation with US Fish and Wildlife service is tied into Construction Permit.
  - Consultation with Federal Aviation Administration depending upon proximity to airports to determine whether hazard to air traffic.
  - Coast Guard consultation re navigation issues.

PERMITTING TEMPLATE (CON'T)

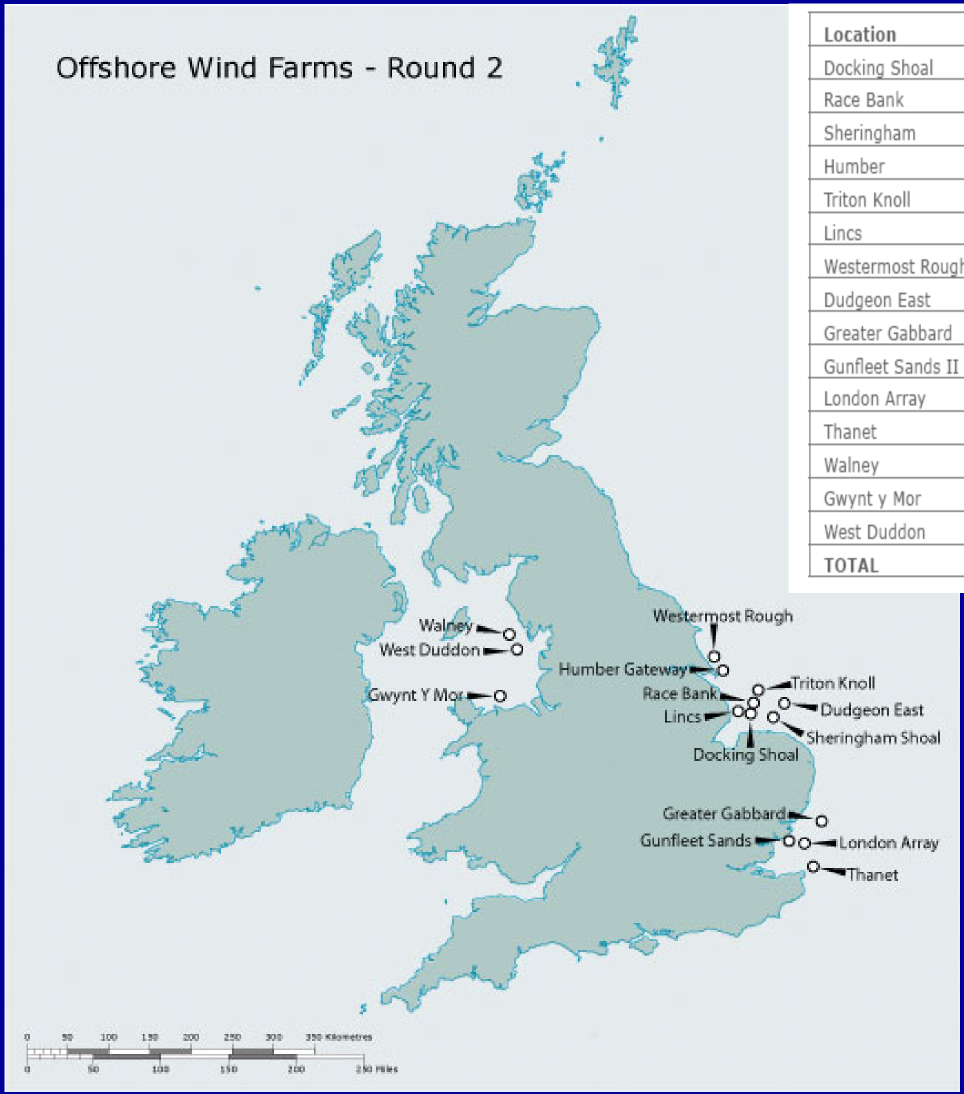
- State of Ohio
- Department of Natural Resources (ODNR) consultations
  - Divisions of Wildlife review of habitat issues.
  - Division of Watercraft review of navigation issues.
  - Division of Geological Survey re foundations and structures.
  - Division of Coastal Management re submerged land leases and coastal impacts.
- Department of Transportation
  - Office of Aviation re potential aviation hazards. Cross reference to FAA review
- Ohio Power Siting Board
  - Approval required if electric generating facilities of at least 50 megawatts and electric transmission lines of 125kV or greater.

GLWEC Progress to Date

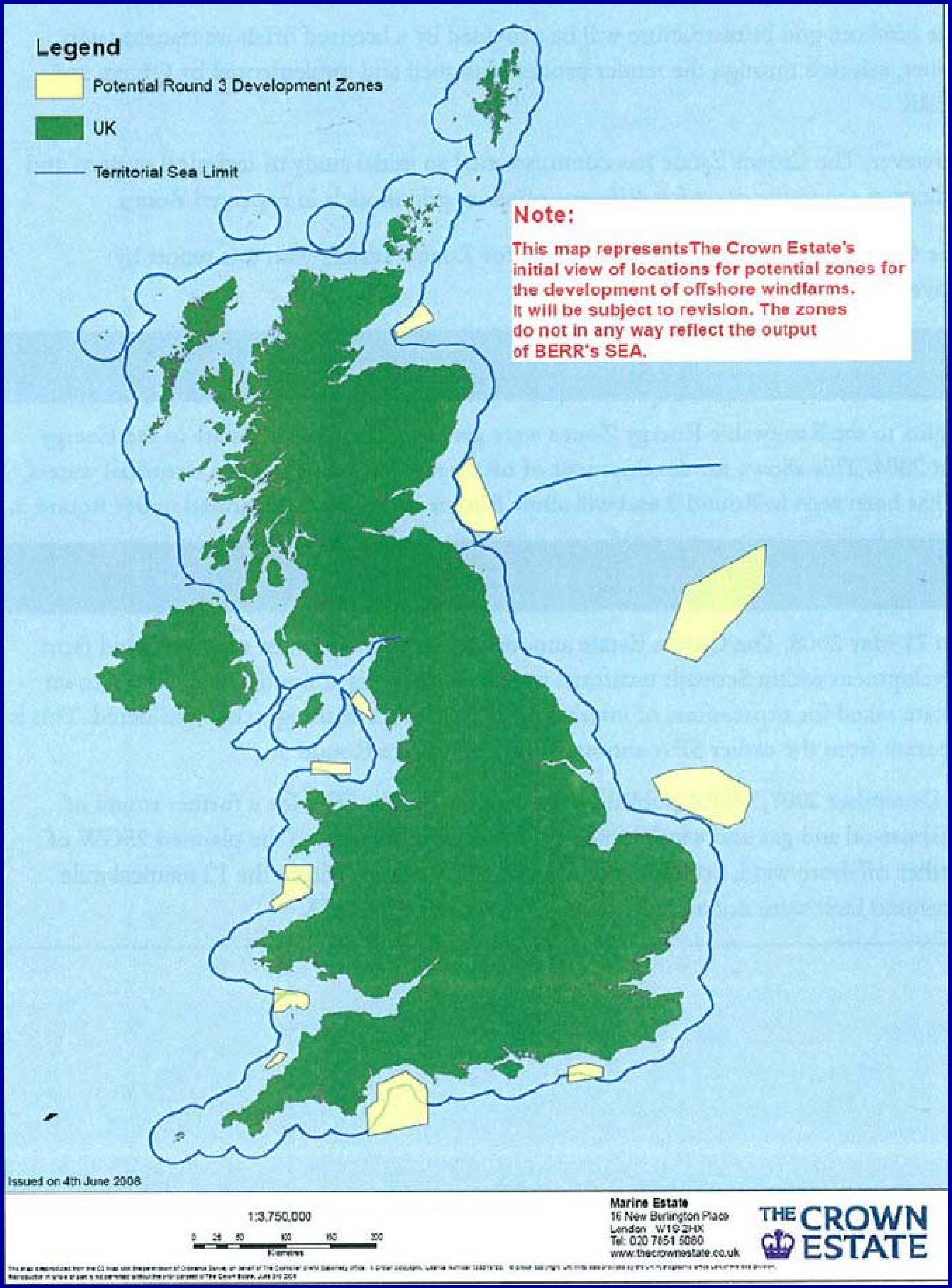
- Identification of extensive wind energy supply chain manufacturing capability within Ohio
- Data from 2-years of offshore wind measurements have verified the previously predicted potential for excellent wind in Lake Erie
- All permitting and regulatory agencies have been engaged to develop an Environmental Assessment Plan for the Pilot Project
- The award of $1,041,454 contract to juwi, Gmbh to conduct a feasibility study, which will be completed in April, 2008

UK Offshore Wind Farms

Round 2 Award Options issued 2003



Location	Maximum capacity (MW)	Developer
Docking Shoal	500	Centrica
Race Bank	500	Centrica
Sheringham	315	Ecoventures/Hydro/SLP
Humber	300	Humber Wind
Triton Knoll	1,200	npower renewables
Lincs	250	Centrica
Westermost Rough	240	Total
Dudgeon East	300	Warwick Energy
Greater Gabbard	500	Airtricity/Fluor
Gunfleet Sands II	64	GE Energy
London Array	1,000	Energi E2-Farm Energy/Shell/ E.ON UK Renewables
Thanet	300	Warwick Energy
Walney	450	DONG
Gwynt y Mor	750	npower renewables
West Duddon	500	ScottishPower
TOTAL	**7,169**	

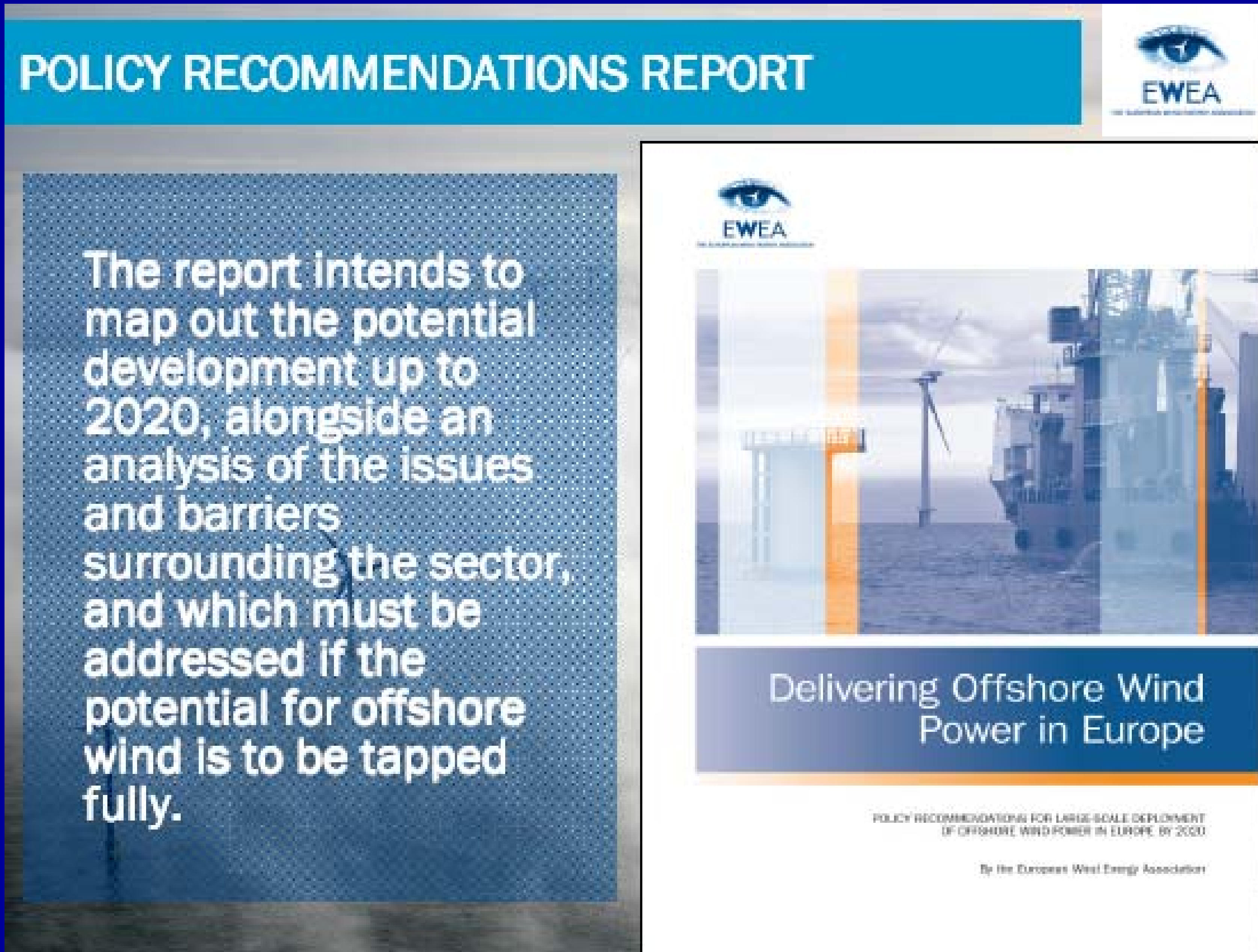


Potential UK Round 3 Locations

Construction of Kentish Flats © Elsam

Norway Offshore Winds and Pumped Hydro: 8GW, $44 Billion by 2025

- OSLO, May 26, 2008 - Norway could become "Europe's battery" by developing huge sea-based wind parks costing up to $44 billion by 2025, Norway's Oil and Energy Minister said.
- Green exports could help the European Union reach a goal of getting 20 percent of its electricity by 2020 from renewable sources such as wind, solar, hydro or wave power.
- "Norway could be Europe's battery," Oil and Energy Minister Aaslaug Haga told Reuters after she was handed the report, which will be considered by the government in coming months.
- Haga said offshore wind parks -- which would stop on calm days -- could be supplemented by hydro-power reservoirs which can be turned on and off to turn them into a battery storing power. Norway has about half Europe's reservoir capacity.


POLICY RECOMMENDATIONS REPORT
EWEA
The report intends to map out the potential development up to 2020, alongside an analysis of the issues and barriers surrounding the sector, and which must be addressed if the potential for offshore wind is to be tapped fully.
EWEA
Delivering Offshore Wind Power in Europe
POLICY RECOMMENDATIONS FOR LARGE-SCALE DEPLOYMENT OF OFFSHORE WIND POWER IN EUROPE BY 2020
By the European Wind Energy Association

THE EUROPEAN COMMISSION

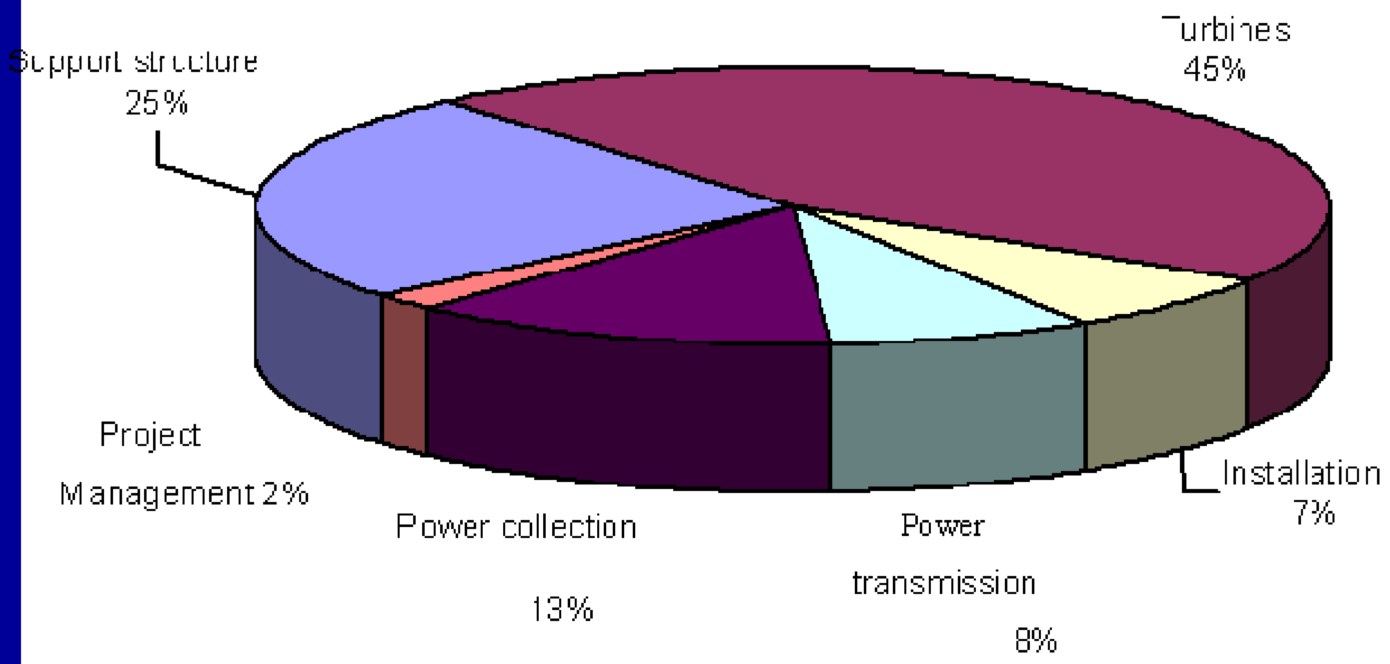
EWEA

"Wind could contribute 12% of EU electricity by 2020. One third of this will more than likely come from offshore installations"

(Commission's Energy Package 10 January 2007)

Cost of Offshore Wind Dropping

Costs have been reduced by 25% from the first Danish offshore wind farms to the Horns Rev



http://www.offshorewindenergy.org/

Benefits from Offshore Winds

Benefit	Basis	54-GW	78-GW
Energy Supplied	.4 cap factor	187.3 TWh	273.2 TWh
Percent of Current U.S. Electric Supply	3548 TWh consumed in 2004	5.3	7.7
Potential Jobs Created Construction Phase	39,000 job/yr/GW	2,110,680 job/yr	3,040,830 job/yr
Potential Jobs Created Permanent O&M	1,100 job/GW	59,532 jobs	85,767 jobs
Capital Invested	$1800/kW–$1600/kW	$97.4 billion	$124.8 billion
SO_x Avoided (metric tons/yr)	9.26 tons/yr/MW	501,151	722,002
NO_x Avoided (metric tons/yr)	3.29 tons/yr/MW	178,054	256,521
CO_2 Avoided (metric tons/yr)	3,281 tons/yr/MW	177,567,720	255,819,570

Walter Musial Data, NREL

HyWind Floating Wind Turbine Project
Spar – Ballast Stabilized

- Under development by StatoilHydro – Norway
- Needs 100-m+ depth to operate.
- Announced a $78MM demonstration project near Norway.
- Partnering with Siemens using their 2.3MW turbine.
- Costs estimated about where solar is today.
- Expectations to compete with conventional wind energy long term.

NREL National Renewable Energy Laboratory

Floating Wind Turbine Projections

- Technology will evolve from fixed bottom offshore experience.
- Floating wind turbine development must be developed as a full system with advanced engineering methods.
- Commercial floating wind systems will have optimized turbines to address platform motion, stability, weight, etc.
- Demonstration projects are needed to assess the technical issues and collect validation data.
- Commercial systems are years away but may be the endgame for wind power.

NREL National Renewable Energy Laboratory

Demonstration of Two Deep Offshore 5MW Floating Wind Turbines in the Gulf of Maine

Draft 5/1/08 **2008 Dollars**

GENI Deploy (Year 3) — GENI Monitor (Years 3–7) — GENII Deploy (Year 5) — GENII Monitor (Years 5–9) — GENI Retrieve (Year 7) — GEN II Retrieve (Year 9)

Commercial Offshore Wind Farm Construction: 1st GW (Year 8), 2d GW (Year 9), 3d GW (Year 10), 4th GW (Year 11), 5th GW (Year 12)

Task	Primary responsibility	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Total
1. Statewide site selection (analysis-based)	OEI, UM	350,000												350,000
Environmental, geophysical, wind, grid tie-in, distance														0
as close as possible to wind farm sites														0
2. Site investigation	OEI, UM	450,000	350,000	350,000	350,000									1,500,000
Environmental, geophysical, wind														0
3. Permitting	OEI, UM	200,000	300,000		300,000	200,000								1,000,000
MMS or State, Environmental														0
4. Policy	UM, OEI	250,000	250,000	250,000	150,000	150,000								1,050,000
5. Communication	UM, OEI	350,000	300,000	250,000	200,000	150,000	150,000	150,000	150,000	150,000	150,000			2,000,000
6. Design for constructability (GEN I and GEN II)														0
Modeling: Structural, Hydrodynamics/Aerodynamics	UM, BlueH	1,000,000	1,000,000											2,000,000
Advanced Composites, design and component testing	UM AEWC	3,800,000	3,200,000	4,000,000	3,000,000	2,200,000	500,000	500,000	500,000	500,000	500,000			18,700,000
Foundations	BlueH, UM	600,000	600,000	300,000	300,000									1,800,000
Constructability	Cianbro	250,000	250,000											500,000
Construction documents, plans and specifications	Cianbro	650,000	1,150,000											1,800,000
7. Construction, deployment GENI	Cianbro													0
Platform construction	Cianbro		10,500,000	10,500,000										21,000,000
Platform deployment (including blades)	Cianbro			4,000,000										4,000,000
Contingency	Cianbro		1,500,000	1,500,000										3,000,000
8. Construction, deployment GENII	Cianbro													0
Platform construction	Cianbro		10,500,000	10,500,000										21,000,000
Platform deployment (including blades)	Cianbro			4,000,000										4,000,000
Contingency	Cianbro		1,500,000	1,500,000										3,000,000
9. Certification	ABS	100,000	100,000		100,000	100,000								400,000
10. Advanced monitoring (5 years)	UMaine, OEI			2,400,000	1,500,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000				8,900,000
Environmental, fish, birds, mammals														0
Structural														0
mechanical														0
Power generation														0
11. Retrieval, salvage and disposal (optional)	Cianbro							2,000,000		2,000,000				4,000,000
Subtotal R&D, Demonstration		8,000,000	31,500,000	39,550,000	5,900,000	3,800,000	1,650,000	3,650,000	1,650,000	3,650,000	650,000			100,000,000
12. Major Wind Farms (Total of 5 GW)														
Planning, Design, financing, permitting/environmental,	Private sector													
Construction, $3.5 billion/GW	UM, OEI	50,000	50,000	100,000	200,000	300,000	300,000	300,000	$3.5 billion	$3.5 billion	$3.5 billion	$3.5 billion	$3.5 billion	$17.5 billion