



Offshore Wind Energy Outlook for the Gulf of Mexico

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Information Transfer Meeting

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Photo Credit : Lee Jay Fing

National Renewable Energy Laboratory (NREL)

NREL Program Portfolio

Strategic Analysis

Efficient Energy Use
- Vehicle Technologies
- Buildings Technologies

Renewable Resources
- Wind and Water
- Solar
- Biomass
- Hydrogen
- Geothermal

Delivery & Storage
- Smart Grid and RE Grid Integration
- Battery and Thermal Storage

- Federal Energy Management
- Integrated Deployment
- International
- Other Intergovernmental

Foundational Science

Gulf of Mexico Offshore Renewable Technologies

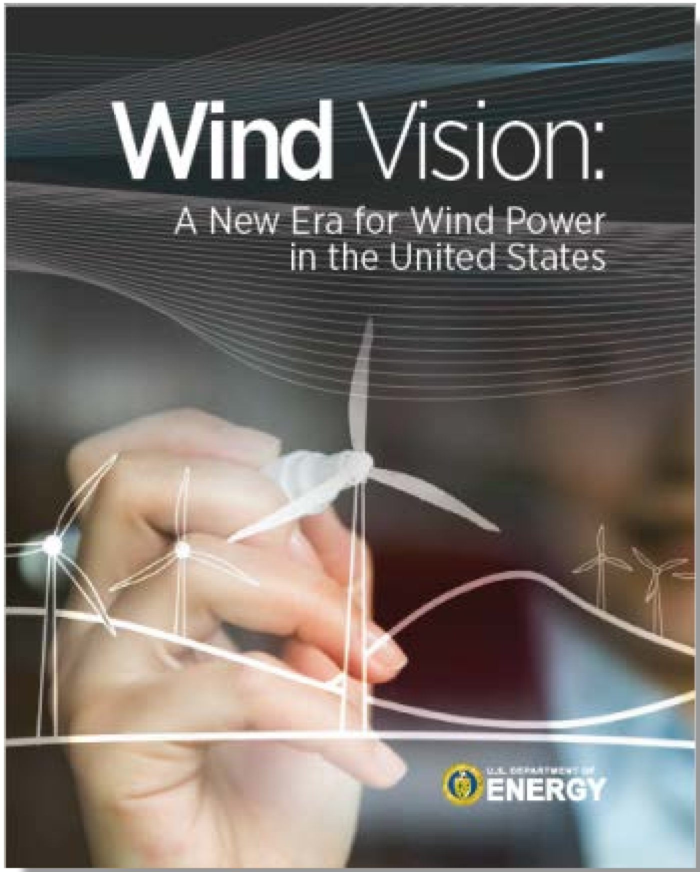
- Eight renewable energy technology types to be evaluated for GoM in terms of resource, technology readiness and cost:

  - ✓ ***Offshore wind energy***
  - ✓ Wave energy
  - ✓ Tidal energy
  - ✓ Ocean current energy (Loop Current)
  - ✓ Ocean-based solar energy (PV)
  - ✓ Ocean thermal energy conversion (OTEC)
  - ✓ Deep water source cooling
  - ✓ Hydrogen conversion and storage.

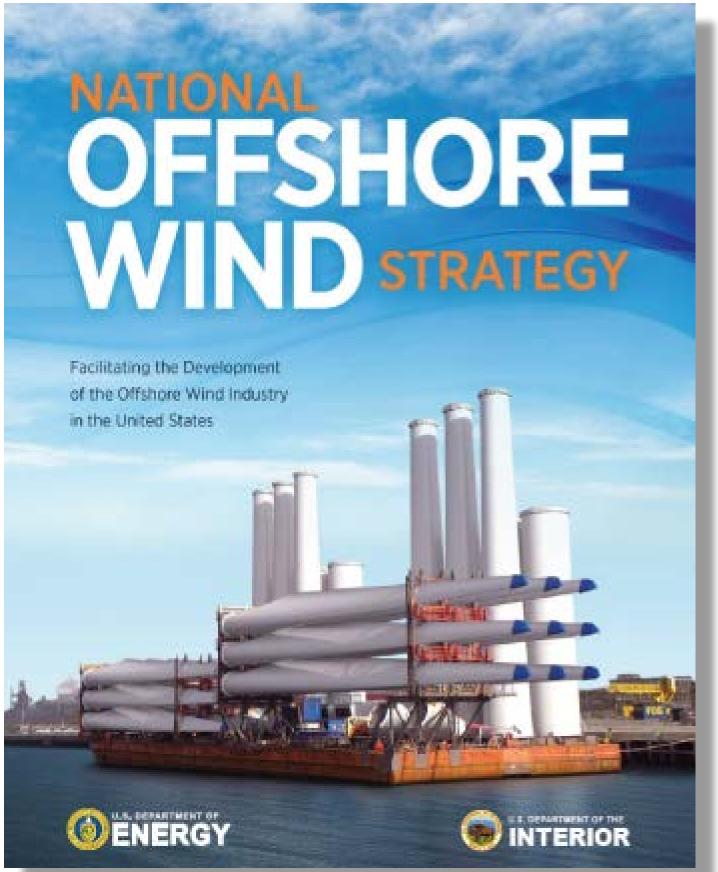
Offshore Wind shows the most promise in the Gulf of Mexico

Offshore Wind Targets from Strategy Documents

March 2015



September 2016

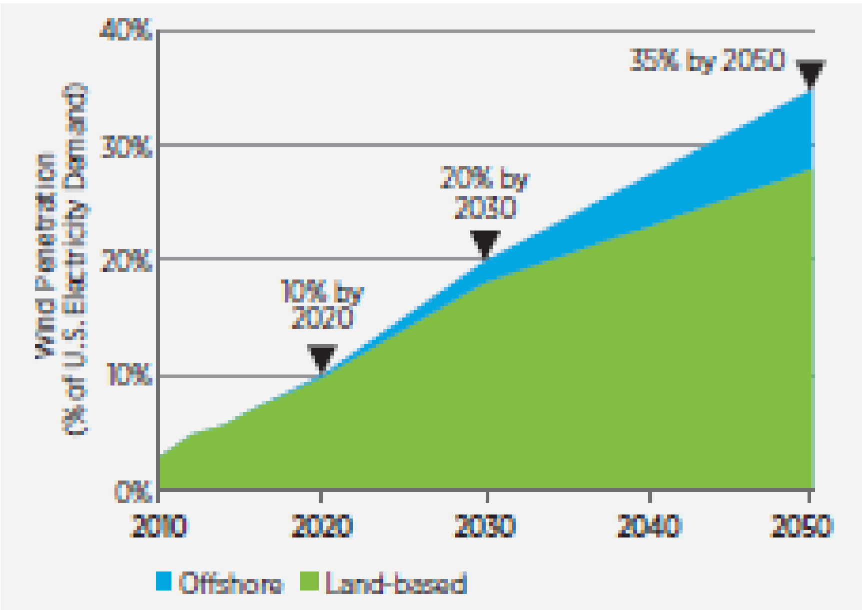


http://energy.gov/eere/wind/downloads/wind-vision-new-era-wind-power-united-states

http://energy.gov/sites/prod/files/2016/09/f33/National-Offshore-Wind-Strategy-report-09082016.pdf

National Offshore Wind Strategy Follows
2015 DOE *Wind Vision* for 35% Electricity from Wind Power

The *Study Scenario* consists of 10% wind generation by 2020, 20% by 2030, and 35% by 2050 compared against the *Baseline Scenario*.

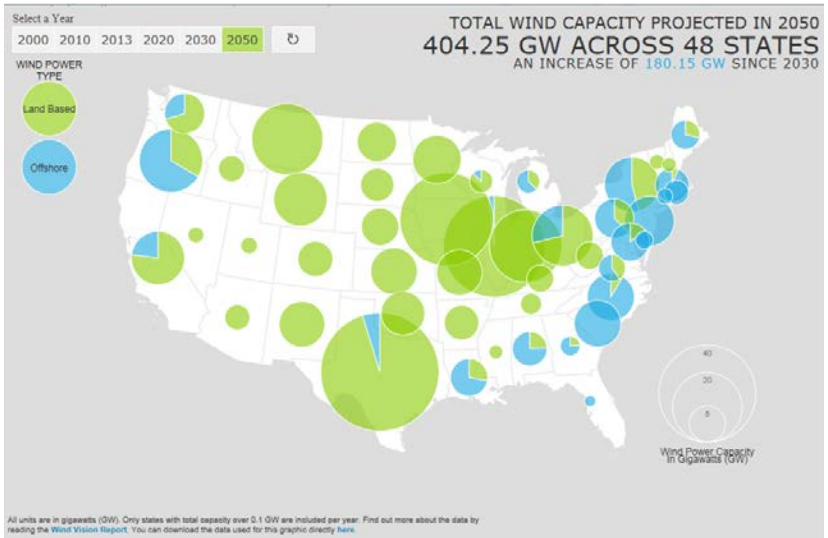


Cumulative Wind Capacity (GW)		2013	2020	2030	2050
Baseline Scenario	Land-based	61			
Central Study Scenario	Land-based	61	110	202	318
	Offshore	0	3	22	86
	Total	**61**	**113**	**224**	**404**

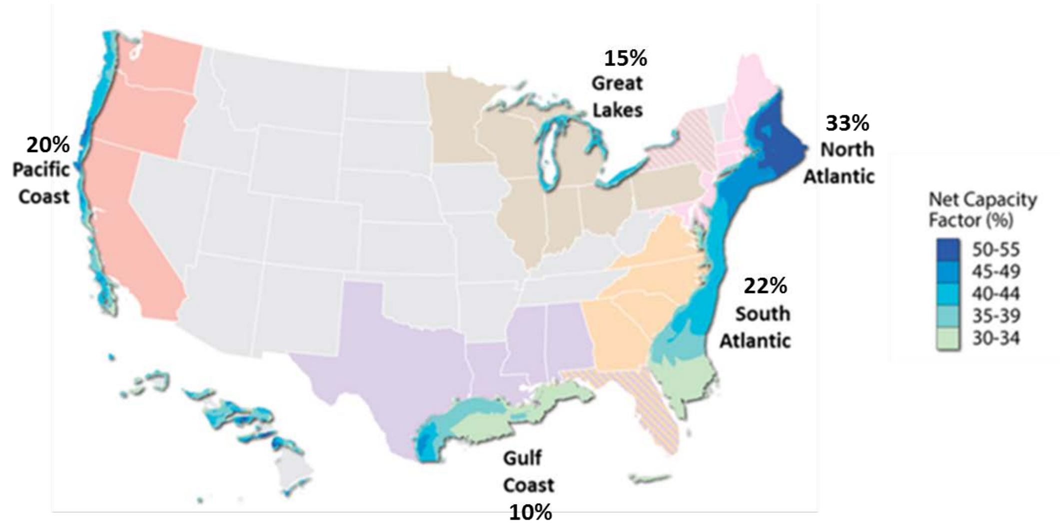
82,132 MW installed wind capacity in the USA as of January 2017

Offshore Wind Grows to 21% of Total Wind by 2050
7% of U.S. Electric Supply

DOE *Wind Vision* 2050 Deployment Scenario



DOE *Wind Vision* Scenario for 2050 Showing Land-based and Offshore Wind Contributions



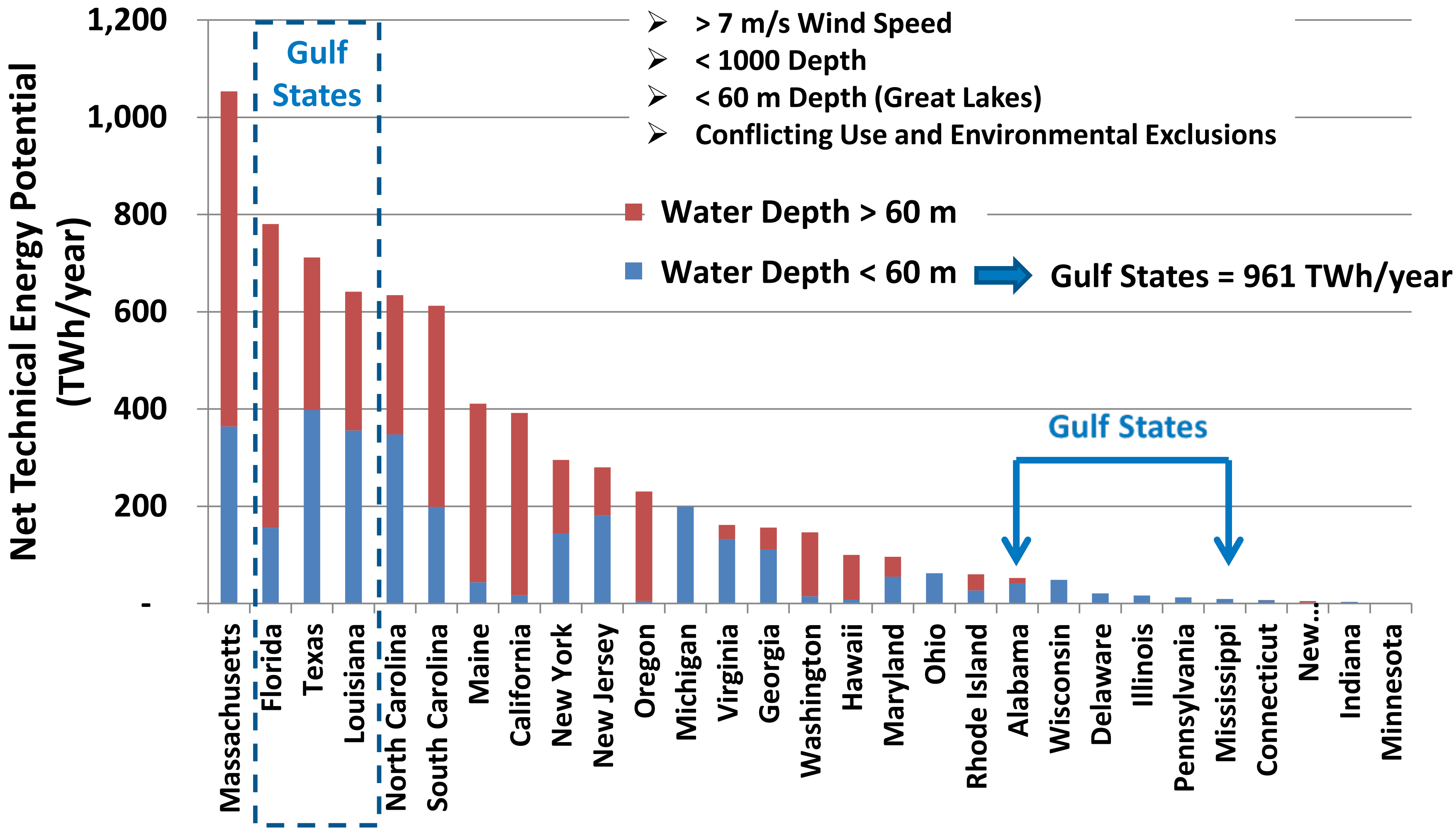
DOE *Wind Vision* Regions and Offshore Wind Percentages for 2050

DOE *Wind Vision* has Gulf Coast region contributing 10% of U.S. offshore wind energy (8.6 GW) by 2050

Unique Offshore Wind Issues in the Gulf of Mexico

Abundant Quantity of Offshore Wind Resource

Net Technical Energy Potential (by Depth Class)

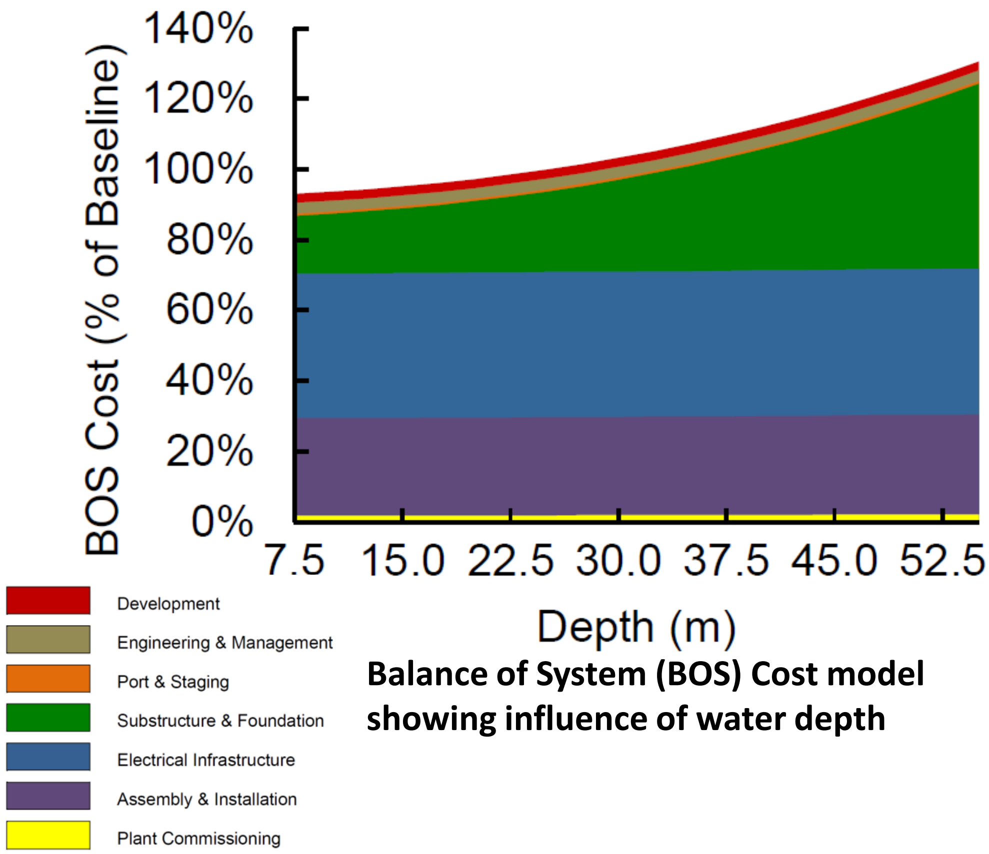


Musial, W. et al. ***2016 Offshore Wind Energy Resource Assessment for the United States***. NREL/TP-5000-66599.
http://www.nrel.gov/docs/fy16osti/66599.pdf

Gulf States have 32% of Shallow Offshore Wind Resource Potential

Cost Increases With Water Depth due to Substructure

Gulf of Mexico States have approximately 1/3 of the U.S. Shallow Water Offshore Wind Resource Technical Potential water depth less than 60 meters is 961 TWh/year



Balance of System (BOS) Cost model showing influence of water depth

Cost Reduction Drivers

- **Shallower Water - modeled**
- Warmer water
- Lower sea states
- Proximity to supply chain

Warmer water and lower sea states → Greater Accessibility

Possible Cost Adder

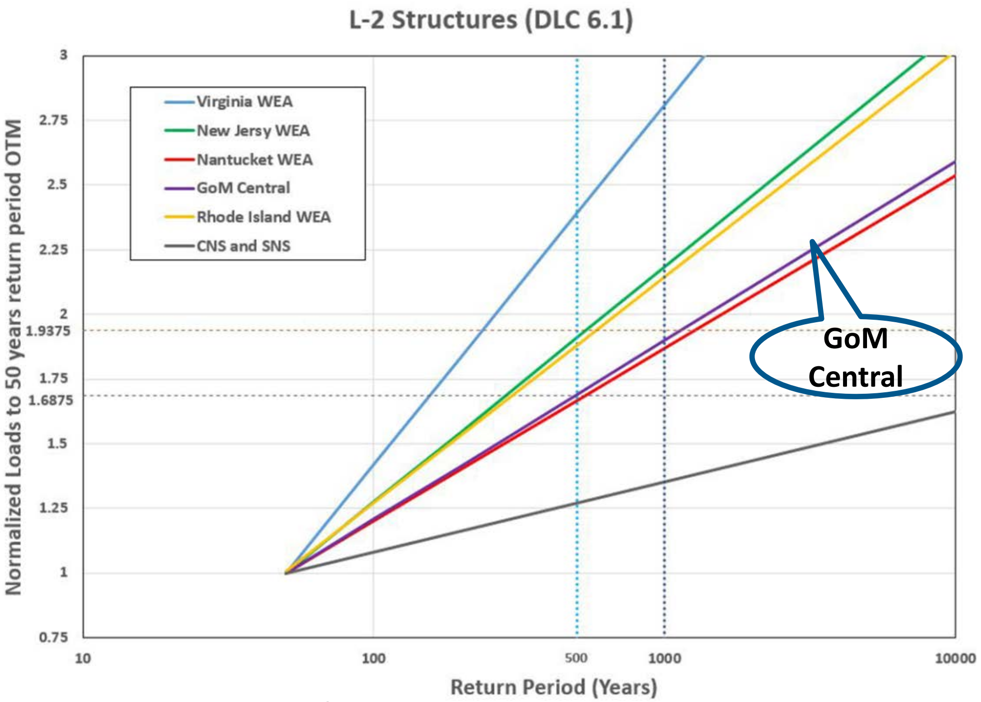
- Softer soils

Maness M., Maples, B., and Smith, A. "**NREL Offshore Balance-of-System Model**", *National Renewable Energy Laboratory, Technical Report; NREL/TP-6A20-66874, January 2017, https://www.nrel.gov/docs/fy17osti/66874.pdf*

Hurricane Resiliency – Engineering for Robustness

- Offshore wind turbines are designed using IEC 61400-01 and IEC 61400-03 standards
  (3 sec max gust = 70 m/s (156 mph)
- Substructures are designed using API RP 2A hazard curves – proven in the GOM oil and gas industry
- Current requirements will not be sufficient for all locations – site specific risk assessment needed
- New edition of IEC 61400-01 has a Typhoon class to upgrade 3 sec gust to near 80 m/s (179 mph)
- GoM hazard curves (from API RP 2A) are less steep than mid-Atlantic
- Possible additional survival design provisions
  - Aux Power to maintain yaw authority
  - Lower profile rotor designs

Hurricane Katrina 2005, Central Gulf of Mexico 400 Year Return Conditions (courtesy of Keystone Engineering)

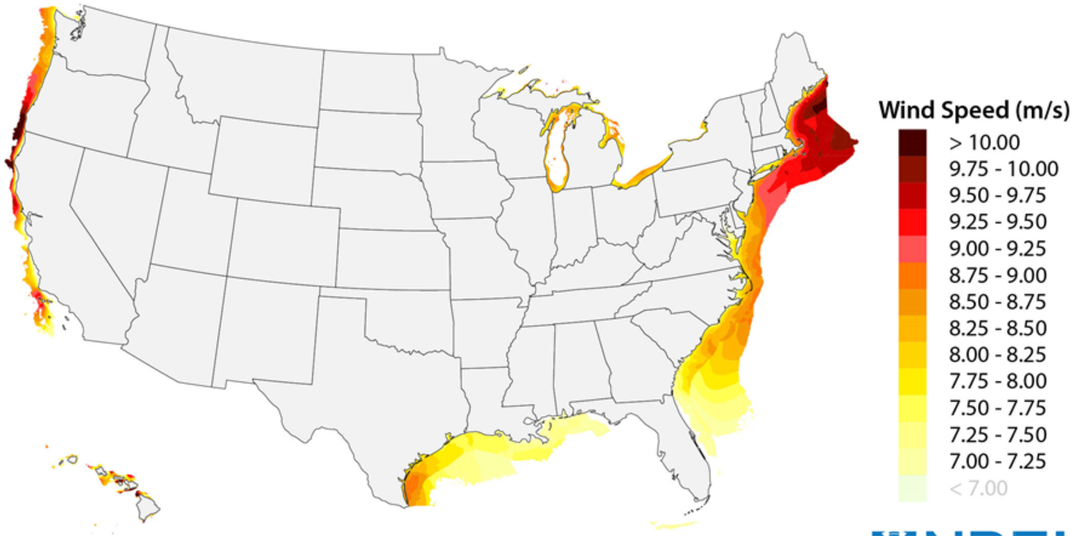


Hazard Curves for various US locations and North Sea
(Courtesy of Keystone Engineering)

Low Wind Speed Technology to Address **Resource Quality**

- Current technology would yield net capacity factors 30% to 40%
- Only Texas has significant areas with average wind > 8 m/s
- Land-based trend is toward larger rotors at lower wind sites
- Energy capture can improve with larger rotors but extreme wind exposure also increases

Optimal performance for low wind (7 m/s to 8 m/s) sites with hurricanes may require new large rotor technology with strengthened turbine components in some areas.



Lower 48 Data Source: AWS Truepower 0-50nm; NREL WIND Toolkit beyond 50nm.
Hawaii Data Source: AWS Truepower 0-12nm; Vaisala/3Tier 12-50nm; linear extraction by NREL to 200nm.

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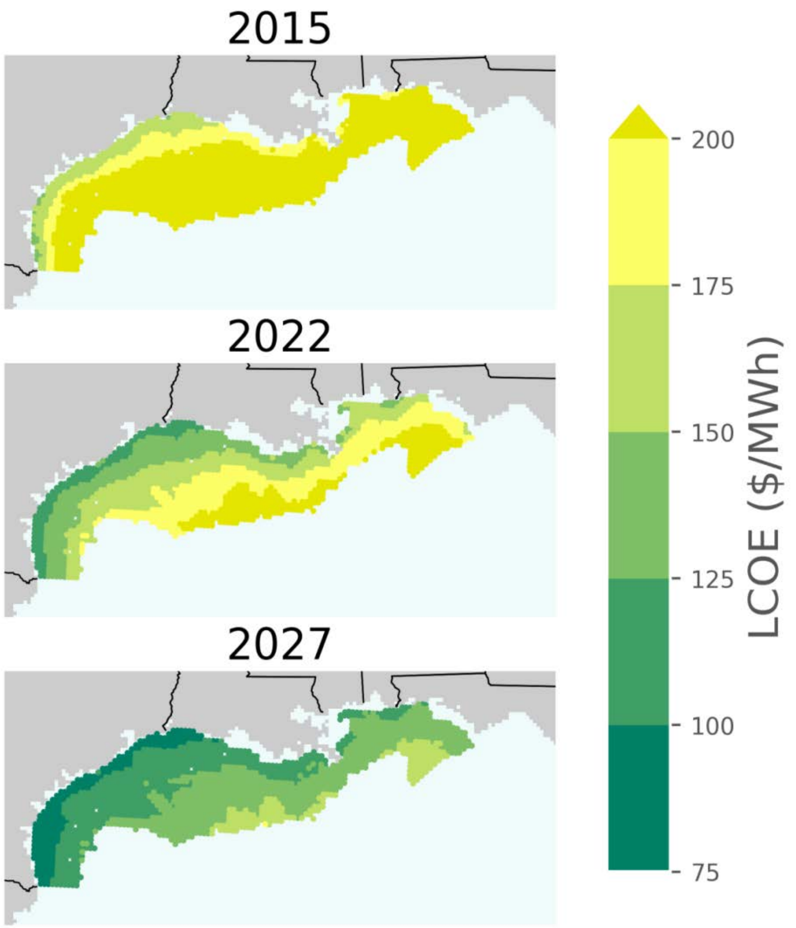
Wind Speed Map For The U.S. Offshore Wind Energy Technical Resource Area

Levelized Cost of Energy (LCOE) Analysis for Gulf Coast

- Estimated LCOE using NREL Geo-spatial Offshore Wind Cost Model (Beiter et al 2016)
- Geo-spatial cost variables include water depth, wind resource, substructure type, turbine size, distance to port, distance to cable interconnect, installation method, sea state
- Temporal cost variables - estimated cost reduction potential through 2030
- Results were vetted against literature and industry data
- Scenarios show LCOE below 100 MWh by 2025 in some sites.



Estimated LCOE in the Gulf Coast region

Is this LCOE low enough for cost competitiveness without subsidies in the Gulf of Mexico?

Beiter, P. et al . ***A Spatial-Economic Cost Reduction Pathway for U.S. Offshore Wind Energy Development from 2015–2030*** , NREL/TP-6A20-66579. http://www.nrel.gov/docs/fy16osti/66579.pdf

Can Offshore Wind Achieve Economic Potential in the Gulf?

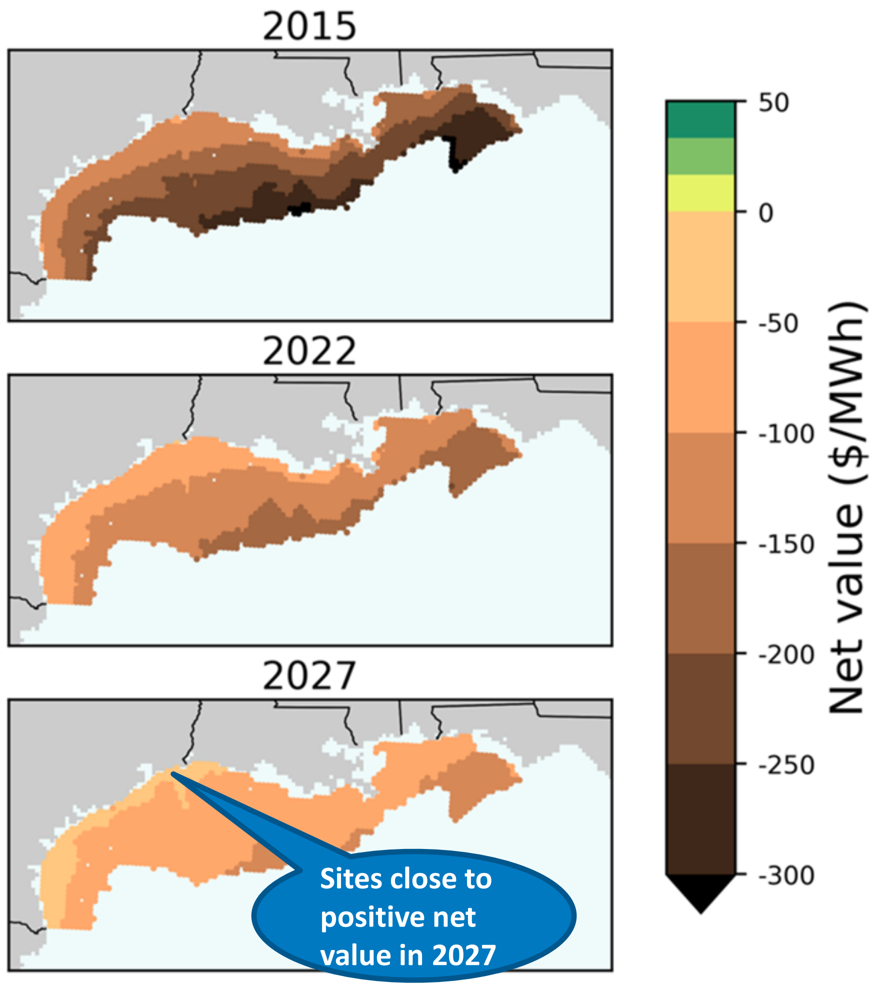
Definitions

LACE = Levelized Avoided Cost

LCOE = Levelized Cost of Energy

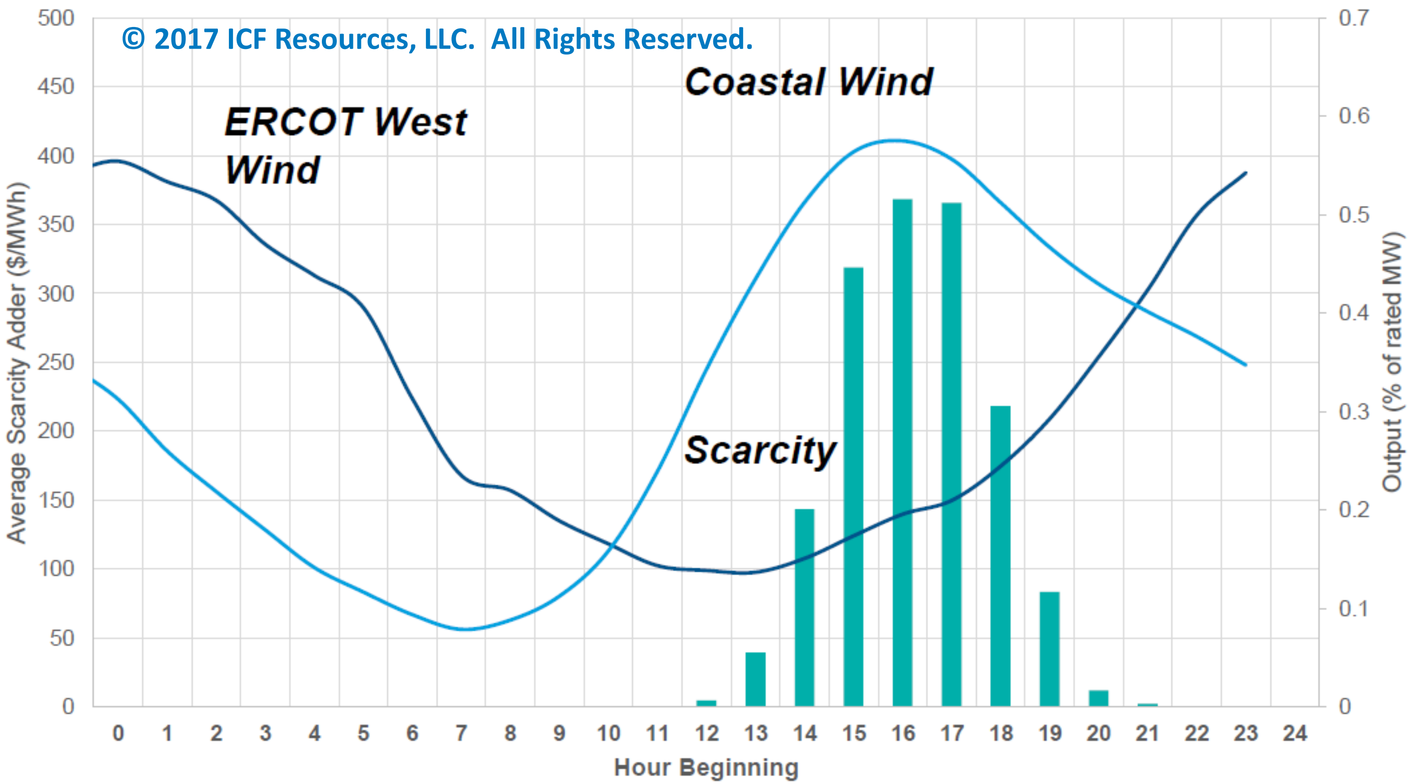
Net Value = LACE – LCOE

- Positive "Net Value" defines economic potential
- No sites achieve positive net value by 2027 but many sites come close (< $50/MWh over)
- Commercial market for offshore wind in GOM may be 10 years away
- North Atlantic timelines suggest regulatory planning should begin now



Gulf Coast net value distribution (2015–2027)
(Assumes Zero Subsidies)

Coastal Wind Load Matching May Add Value in ERCOT



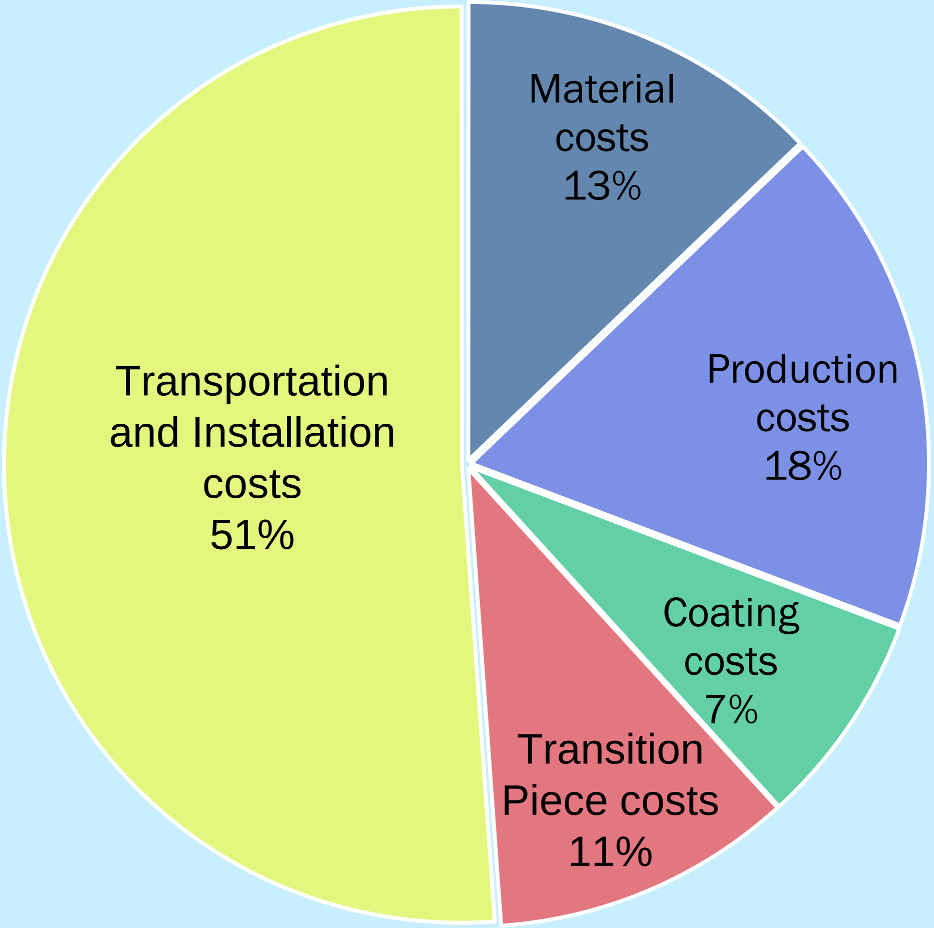
Source: ICF, ERCOT

Comparison of Diurnal Cycles for Interior Wind and Coastal Wind within ERCOT

- In ERCOT, favorable hourly output for coastal winds relative to the hourly price curve can result in higher realized energy prices
- ICF estimates possible 26% higher energy revenues in spite of lower CF

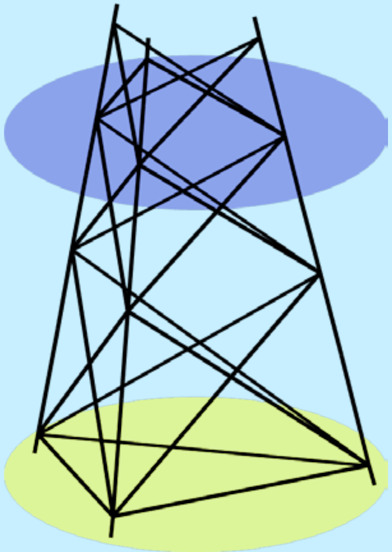
ICF AWEA Webinar – "Beyond the PPA –Understanding Market Complexities and Wind Margins", Presented by: Ken Collison, Vice President, Himanshu Pande, Manager, Pat Milligan, Associate

GoM Should Prepare Domestic Supply Chains for Offshore Wind



Jacket Cost Breakdown for 5 MW System

Block Island Wind Farm – Commissioned Dec 2016



Jacket Computer Model Representation

(Jan Häfele, Raimund Rolfes (2016): Approaching the ideal design of jacket substructures for offshore wind turbines with a Particle Swarm Optimization algorithm, Proceedings of the Twenty-sixth International Ocean and Polar Engineering Conference, Rhodes, pp 156-163).

Summary of Gulf of Mexico Outlook – Unique Opportunities

- ***Resource Quantity*** - abundant
  - 961 TWh/yr in waters less than 60 m
  - Warm water and lower sea states may result in lower cost
- ***Resource Quality*** is lower due to low winds
- ***Hurricane Resiliency*** and low winds should be addressed together with technology solutions for optimal performance
- ***Economics*** show some sites may achieve LCOE below $100/MWh by 2027 without subsidies; approaching possible market viability in 10 years
- ***Resource/Load matching*** *may enhance the value* of offshore wind in some GoM regions
- **Outlook:** DOE *Wind Vision* models 8.6 GW of offshore wind in Gulf of Mexico (only 1% of total technical resource) – ***10% of National Offshore Wind by 2050***
- ***Existing supply chain*** should ramp up **TODAY** for emerging offshore wind industry in the North Atlantic.
- NREL/BOEM technology feasibility study underway

Thank you for your attention

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Photo Credit : Dennis Schroeder-NREL