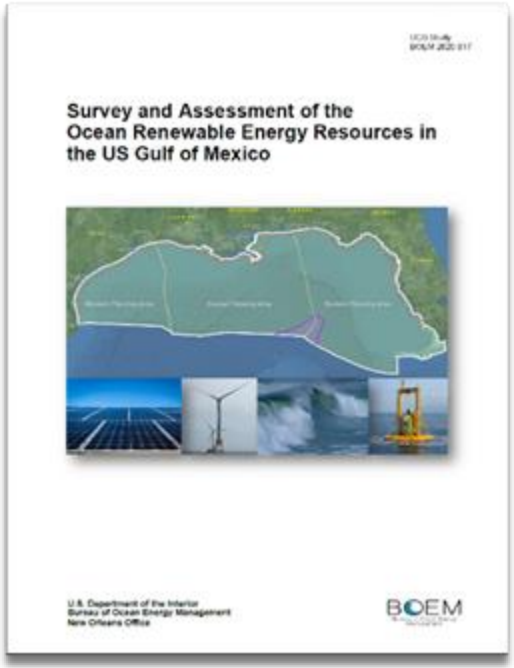
Offshore Wind in the US Gulf of Mexico

“Gulf of Mexico Data Information Resources and Ocean Users”

Walt Musial | National Renewable Energy Laboratory | Offshore Wind Lead
June 15, 2021

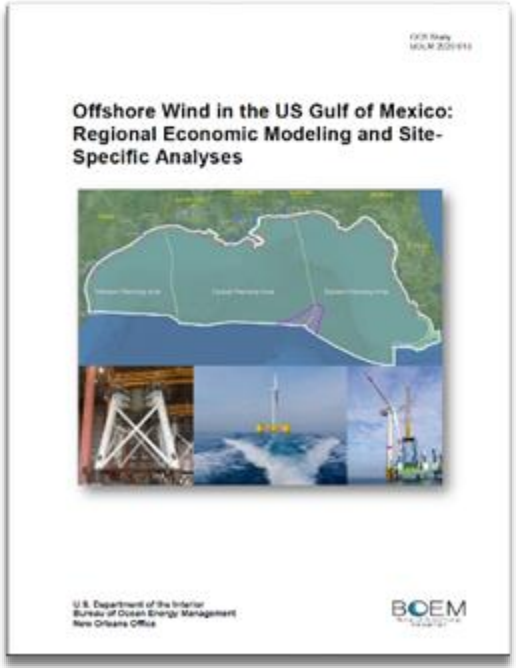
BOEM Sponsored Two NREL Studies on Gulf of Mexico (GOM) Through an Interagency Agreement – Published May 2020



Survey and Assessment of the Ocean Renewable Energy Resources in the US Gulf of Mexico

U.S. Department of the Interior
Bureau of Ocean Energy Management
New Orleans Office

BOEM



Offshore Wind in the US Gulf of Mexico: Regional Economic Modeling and Site-Specific Analyses

U.S. Department of the Interior
Bureau of Ocean Energy Management
New Orleans Office

BOEM

Special Acknowledgements:

- **Mike Celata,** BOEM's GOM Regional Director
- **Rebecca Green** for initiating the project
- **Andrea Heckman** the BOEM project manager
- **Tershara Matthews,** current coordinator

Musial W, Tegen S, Driscoll R, Spitsen P, Roberts O, Kilcher L, Scott G, and Beiter P (National Renewable Energy Laboratory and the Alliance for Sustainable Energy, LLC, Golden, CO). 2019. Survey and assessment of the ocean renewable resources in the US Gulf of Mexico. New Orleans (LA): Bureau of Ocean Energy Management. Contract No.: M17PG00012. Report No.: OCS Study BOEM 2020-017. https://espis.boem.gov/final%20reports/BOEM_2020-017.pdf

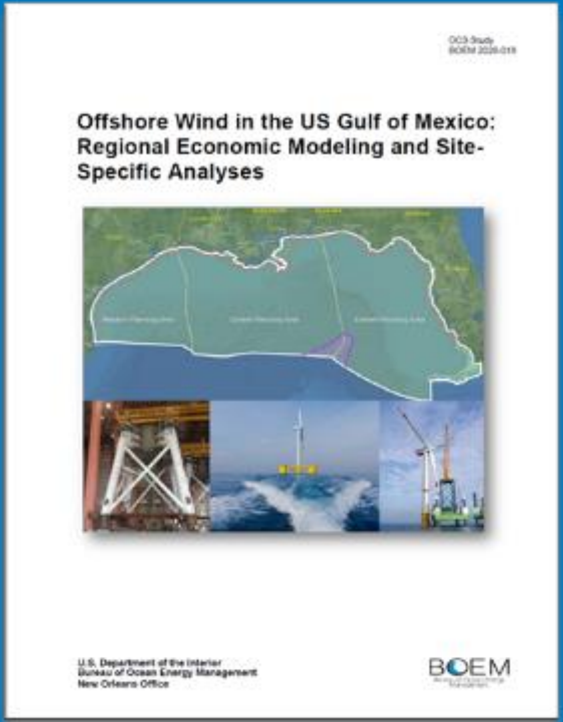
Musial W, Beiter P, Stefek J, Scott G, Heimiller D, Stehly T, Tegen S, Roberts O, Greco T, Keyser D (National Renewable Energy Laboratory and the Alliance for Sustainable Energy, LLC, Golden, CO). 2020. Offshore wind in the US Gulf of Mexico: regional economic modeling and site-specific analyses. New Orleans (LA): Bureau of Ocean Energy Management. 94 p. Contract No.: M17PG00012. Report No.: OCS Study BOEM 2020-018. https://espis.boem.gov/final%20reports/BOEM_2020-018.pdf

“Offshore Wind in the U.S. Gulf of Mexico: Regional Economic Modeling and Site-specific Analysis”

NREL Authors:

Walt Musial
George Scott
Philipp Beiter
Tessa Greco
Jeremy Stefek
Donna Heimiller
Tyler Stehly
Suzanne Tegen
Owen Roberts
David Keyser

Research conducted 2018-2019

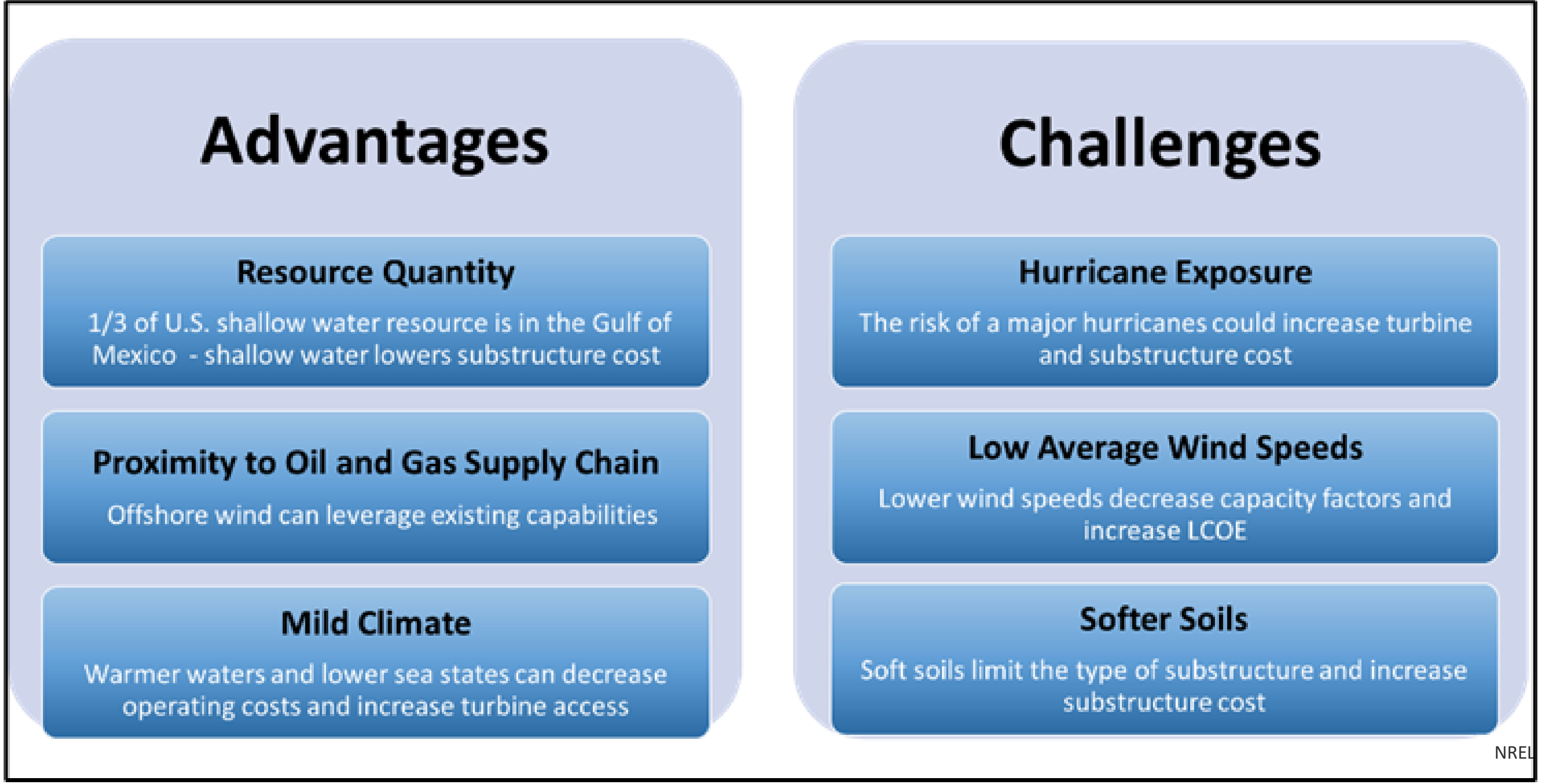


OCS Study

Offshore Wind in the US Gulf of Mexico: Regional Economic Modeling and Site-Specific Analyses

U.S. Department of the Interior
Bureau of Ocean Energy Management
New Orleans Office

Advantages and Challenges of Offshore Wind in the Gulf of Mexico



Advantages

Resource Quantity

1/3 of U.S. shallow water resource is in the Gulf of Mexico - shallow water lowers substructure cost

Proximity to Oil and Gas Supply Chain

Offshore wind can leverage existing capabilities

Mild Climate

Warmer waters and lower sea states can decrease operating costs and increase turbine access

Challenges

Hurricane Exposure

The risk of a major hurricanes could increase turbine and substructure cost

Low Average Wind Speeds

Lower wind speeds decrease capacity factors and increase LCOE

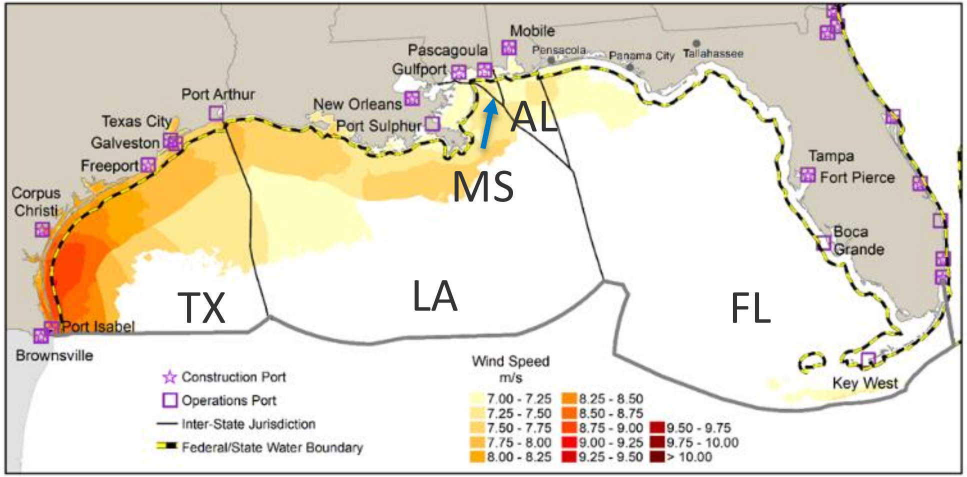
Softer Soils

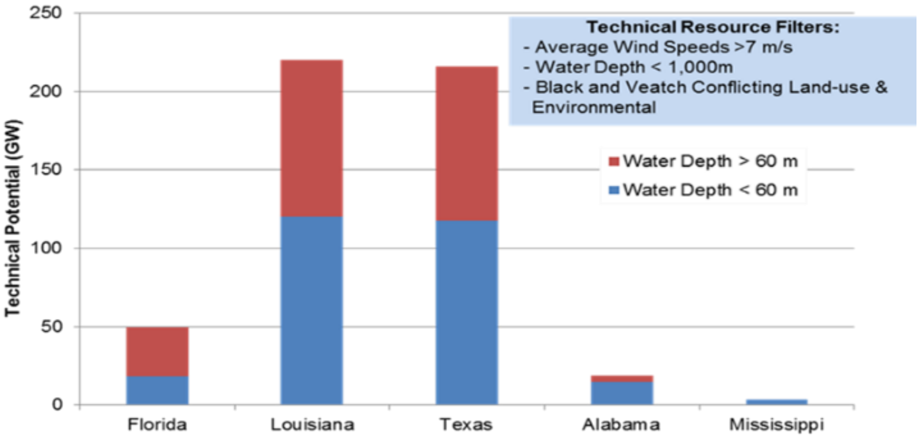
Soft soils limit the type of substructure and increase substructure cost

Gulf of Mexico Technical Offshore Wind Resources

- NREL's 2016 resource assessment identified 508 GW of technical potential[1]
  - Resource capacity based on 3 MW/km^2 array density
  - Technology filters include:
    - > 7 m/s wind speed
    - < 1000 m water depth
- This capacity has an energy-generating potential of 1,556 terawatt-hours (TWh)/year (yr) which is double the 779 TWh electric usage of the five GOM states recorded by Energy Information Agency in 2018
- Most viable wind resources in Texas and Louisiana
- Abundant shallow water resource area
- On average, lower sea states and year-round mild climate allow better service access and lower downtime
- New assessment is pending – NREL 2021

A single 15-MW turbine operating in the GOM for three years would make 1 terawatt-hour of electricity





1. Musial W, Beiter P, Heimiller D, Scott G. 2016. 2016 Offshore Wind Energy Resource Assessment for the United States (Technical Report). NREL/TP-5000-66599. National Renewable Energy Laboratory (NREL), Golden, CO (US). http://www.nrel.gov/docs/fy16osti/66599.pdf.

Gulf of Mexico – Offshore Wind Challenges

- Hurricanes
  - Site specific design requirements
  - Learn from Asian deployments (e.g., Taiwan)
  - Hurricane adapted systems
- Low windspeeds
  - Larger rotor diameter to increase energy capture (low specific power)
  - Added strength to resist extreme wind
- Soft sediments
  - Jackets with wider base/footprint
  - Best practices for Oil and Gas

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

Turbines Need to be Optimized to Maximize Energy Production at Extreme Hurricane Sites

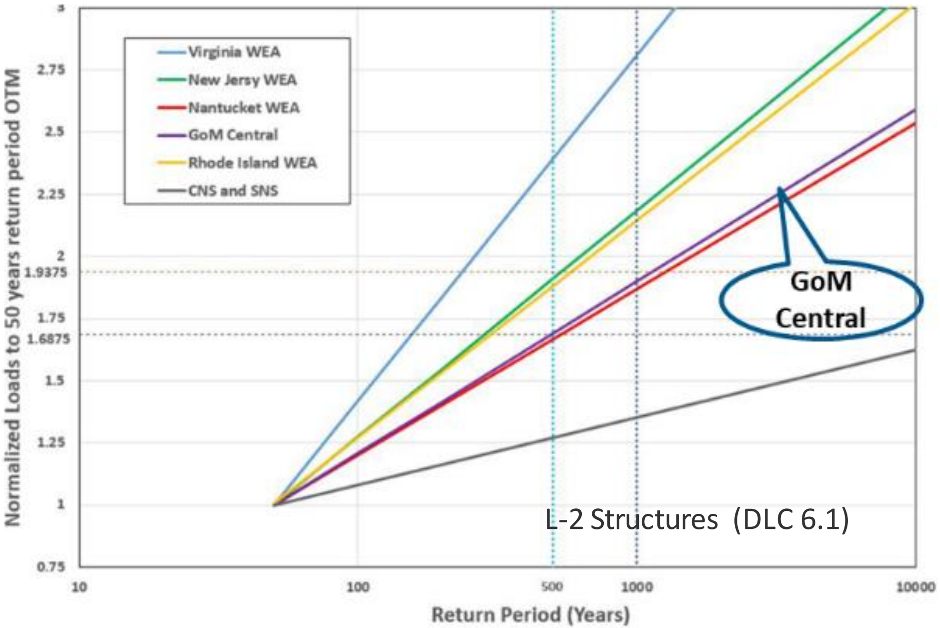
Design for Hurricane Resilience

Support Structures

- Designed to API RP 2A standards from oil and gas industry for site specific conditions (see hazard curve in figure)
- API RP-2A – robustness check was adopted by IEC 61400-03-1 edition 2 (2019)

Turbines

- Designed and type certified to IEC 61400-01 and 61400-03-1 standards
- Some site conditions may exceed IEC Class 1 design criteria (70 m/s 3 sec gust)
- IEC 61400-01 recently added Typhoon Class with 80 m/s gust condition.



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

Hall. 2015. Hurricane Design in the Standards - IEC Hurricane Classes and API Hazard Curves, Keystone Engineering. Accessed March 2020. http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&ved=2ahUKEwj4_P-Oi6foAhUygnIEHWkxAtMQFjACegQIBxAB&url=http%3A%2F%2Fusmodcore.com%2Fcontent%2Ffile%2FHall-Rudy_IECHurricaneClassesAndAPIHazardCurves.pdf&usg=AOvVaw0gB8y5QeLeOCjO3l4fBeVL

A Better Understanding of Hurricane Design is Needed for a Mature Offshore Wind Industry to Flourish in the Southern United States

Hurricane Research Needs

- Harmonization of National Hurricane Center **terminology** and IEC design criteria (e.g. Saffir-Simpson scale)

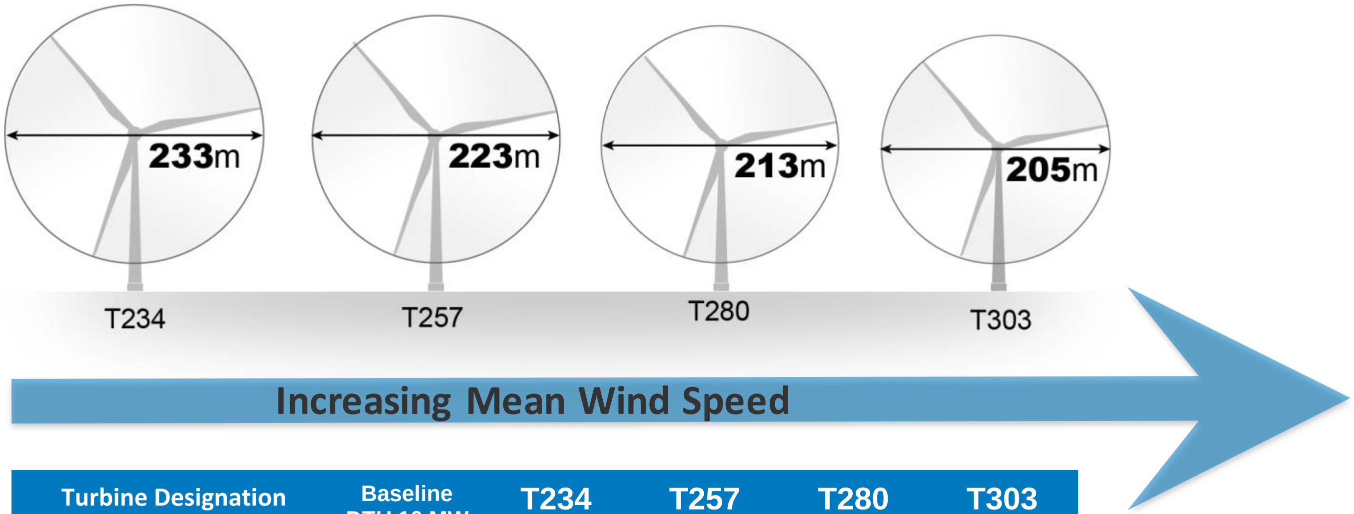
- **Geo-spatial hurricane risk assessment** of all sites (primarily, south of Cape Hatteras NC) to determine geographic boundaries of IEC design criteria

- High fidelity weather models to assess detailed **anatomy of "limit-state" hurricanes** to investigate gaps in ultimate and fatigue load cases resulting from anomalous extremes (e.g., wind shear, gust factors, veer, eye-wall vorticity or directional wind dynamics)

- Investigate **load mitigation operational strategies** that can be applied to current fleet (e.g., back-up power for yaw system, ruggedized sensors)

- Investigate **bespoke hurricane turbine designs** to optimize load reduction/low wind speed/cost (e.g., smaller blade and tower profiles, lower thrust loads, strengthened systems)

Gulf of Mexico Low Wind Speed Turbines

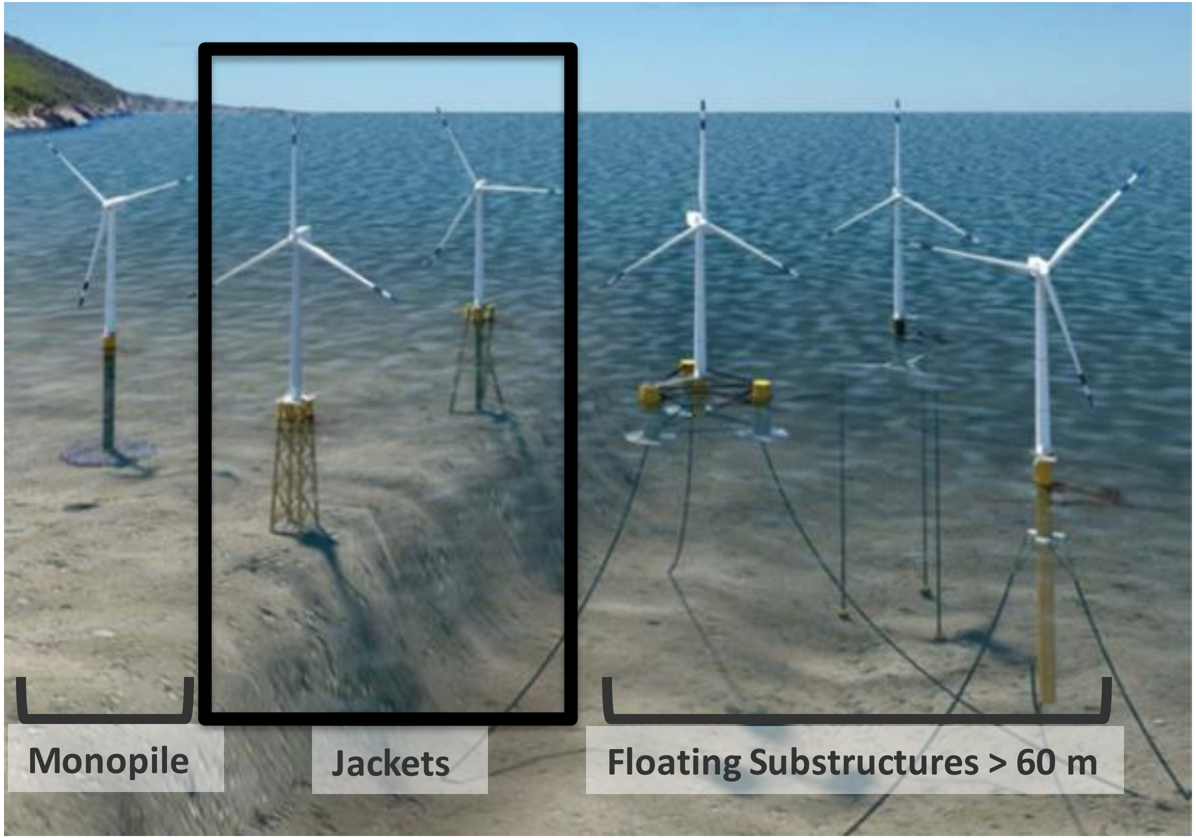


Increasing Mean Wind Speed

Turbine Designation	Baseline DTU 10 MW	T234	T257	T280	T303
Applicable Wind Speeds (m/s)	9.0	<7.25	7.25 to 7.75	7.75 to 8.25	> 8.25
Rotor Diameter (m/ft)	205/673	233/764	223/732	213/699	205/673
Specific Power (W/m^2)	303	234	257	280	303
Hub Height (m/ft)	125/410	141.5/464	136.5/448	131.5/431	126.5/415
Turbine Rating (MW)	10	10	10	10	10

Key Reference: Bak, C., Zahle, F., Bitsche, R., Kim, T., Yde, A., Henriksen, L. C., Natarajan, A. 2013. The DTU 10 MW Reference Wind Turbine. Danish Technical University. http://orbit.dtu.dk/files/55645274/The_DTU_10MW_Reference_Turbine_Christian_Bak.pdf

Soft Soils May Require Jacket Type Substructures



- Jackets will likely work best in the soft soils of the Gulf of Mexico
- Jackets have been proven by the oil and gas industry
- Monopiles may be not be feasible due to soft soils
- Cost analysis assumes jacket will be deployed in the GOM

Offshore Wind Economic and Cost Analysis for the Gulf of Mexico Region

NREL’s Cost Model Description

- NREL’s cost model is the **O**ffshore **R**egional **C**ost **A**nalyzer (**ORCA)**
- Developed in 2015; maintained by NREL (funded by DOE)
- Enables geo-spatial cost estimation of offshore wind projects in U.S. and future costs over time
- Fixed-bottom and floating capability
- “bottom-up” tool; sums individual component costs and spatial cost variables
- Updated when new data become available
- Three categories of cost elements:
  - **Fixed costs** are site independent
  - **Variable costs** have distinct relationships with spatial parameters (water depth, wind climate, distances, etc.)
  - **Cost multipliers** vary in general with total project cost

Beiter, P., W. Musial, A. Smith, L. Kilcher, R. Damiani, M. Maness, S. Sirnivas, T. Stehly, V. Gevorgian, M. Mooney, and G. Scott. 2016. *A Spatial-Economic Cost Reduction Pathway Analysis for U.S. Offshore Wind Energy Development from 2015–2030* (Technical Report). NREL/TP-6A20-66579. National Renewable Energy Laboratory (NREL), Golden, CO (US). www.nrel.gov/docs/fy16/66579.pdf.

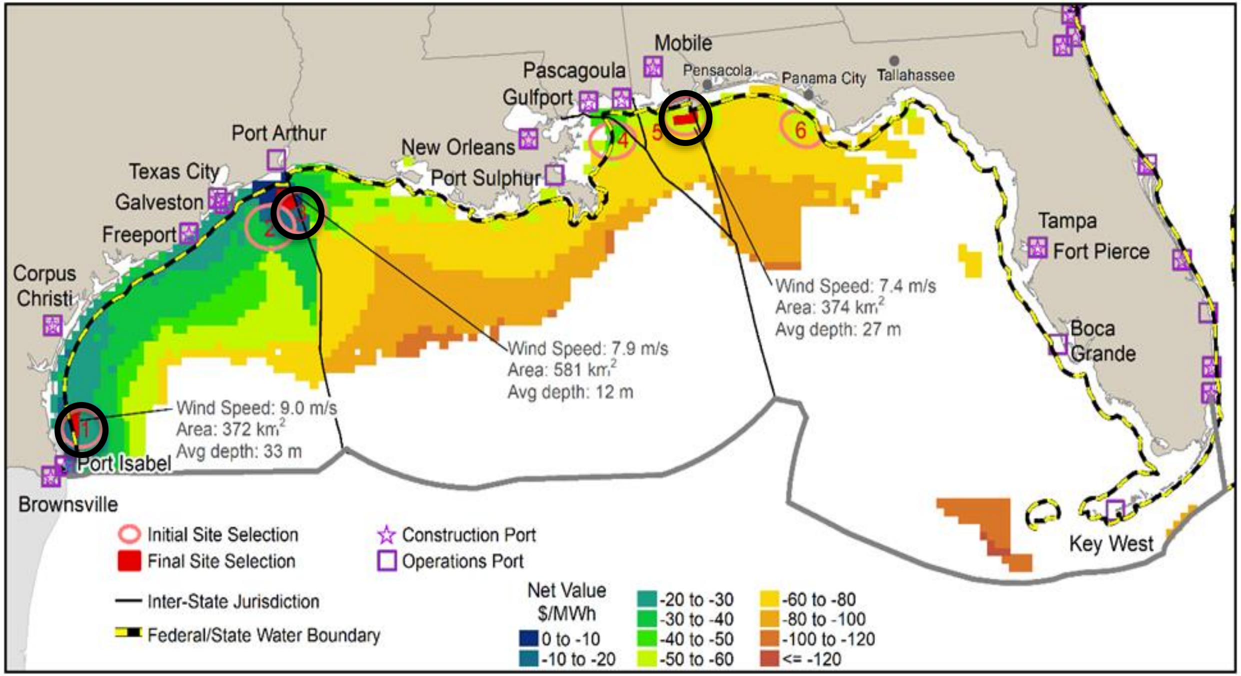
Six Sites Were Selected for Further Analysis

Primary Site Selection Criteria

- Relatively High Net Value
- Large enough (i.e., at least 350 km^2) to support a 1000-MW wind plant
- Relatively low LCOE
- Site in federal waters (BOEM jurisdiction)
- Respect setbacks needed for viewshed
- Take advantage of shallow waters (less than 40 m)

Six sites identified (see map)

Sites 1, 3, and 5 selected for further analysis

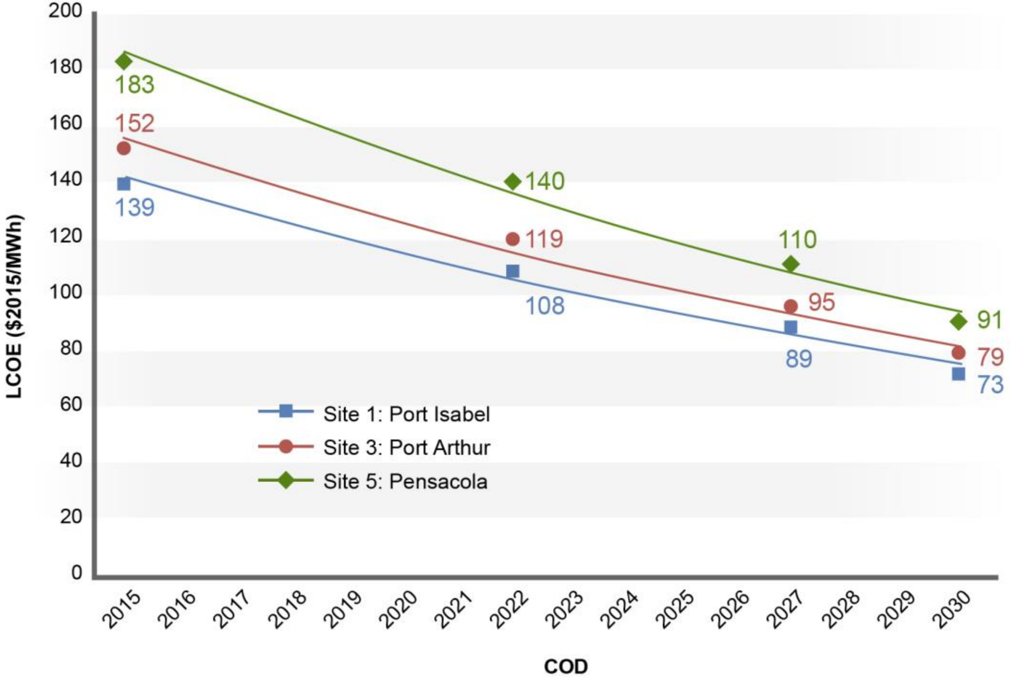


Net Value of Offshore Wind in Gulf of Mexico (2030 COD) with 6 Selected Sites

2030 Data were extrapolated from modeled data for 2015, 2022, and 2027 in Beiter et al. (2017).

Cost Trajectories for Gulf of Mexico Study Sites

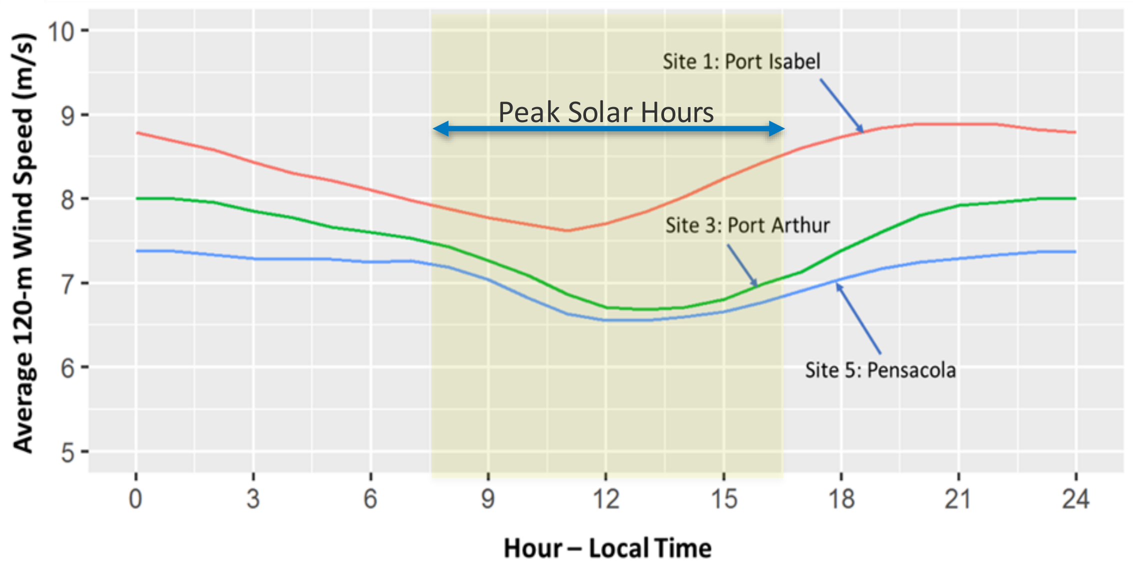
- Cost model estimates show a range of LCOE for 2030 between $73/MWh (Port Isabel) and $91/MWh (Pensacola)
- 2030 costs are extrapolated from 2015, 2022, and 2027 model years
- Costs may be conservative (high) because turbine growth is limited to 10-MW (15-MW) and Fixed Charge Rate (finance) to 9.1% (7.2%).
- Gulf of Mexico could potentially have cost competitive utility scale offshore wind by early 2030s (e.g., positive net value)



Commercial Operations Date

Diurnal Wind Characteristics in the Gulf of Mexico

- Diurnal wind cycles exhibit similar day/night characteristics at all sites.
- All three sites have peak winds in the late evening.
- Port Isabel shows an earlier peak at about 21:00 while the other sites are around midnight.
- The low point of the cycle corresponds with mid-day for all sites.
- Lower wind at noon could be advantageous in avoiding over-production during peak solar hours.
- Deeper dive when new resource data arrives.



Average Diurnal Wind Characteristics in Gulf of Mexico sites modeled at 120-m

Summary of JEDI Findings for Gulf of Mexico

- Total jobs and gross revenue will benefit Gulf of Mexico states, but analysis is not state specific
- Gross economic impacts do not consider changes in other industries
- Manufacturing of jacket substructures was the largest economic driver
- Job impacts due to supply chain support for other regions is additive (e.g., Block Island Wind Farm)
- **Scaling to DOE/DOI Wind Vision scenario (or higher)** 8,600 MW of offshore wind in the GOM region: About Fourteen - 600-MW plants would be built.

4470 total jobs during construction

150 annual jobs during operating years

$445 million GDP during construction

$14 million GDP during operating years

Economic activity supported from the construction and operation of a 600-MW Gulf of Mexico offshore wind project at Port Arthur site.

Major Findings and Next steps

Major Findings

- By 2030, the model estimates LCOE between $70/MWh and $80/MWh off the Houston, south of Corpus Christi, and in Western Louisiana.
- Estimated cost are conservative: Gulf of Mexico could potentially have cost competitive utility scale offshore wind by early 2030s
- Significant gross job creation based on 600-MW plant

Next Steps

- Economic model needs updating; e.g., address current larger turbines and lower finance rates
- New wind resource data is coming in 2021 (20 year – 5-minute time series)
- Hurricane risk assessment and design method evaluation
- Hurricane resilient turbine research to mature technology and lower project risk
- Jobs study for coming U.S. offshore industry in northeast (estimated $12B/year)

Thank you for your attention!

Walt Musial
Offshore Wind Research Platform Lead
National Renewable Energy Laboratory
walter.musial@nrel.gov

Photo Credit : Dennis Schroeder-NREL