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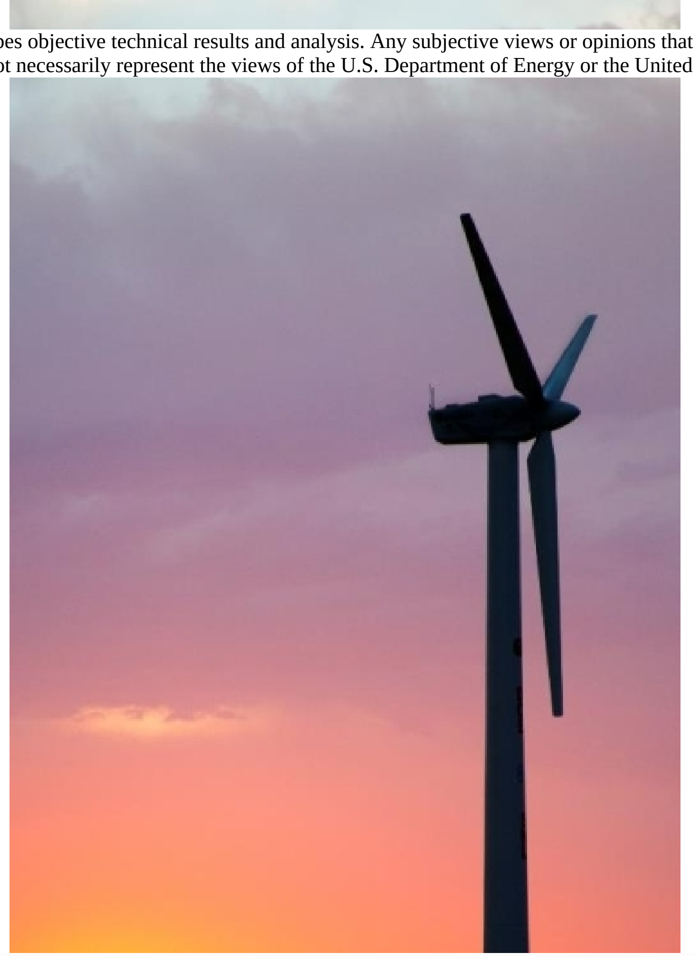

SESSION 2: US DATA COLLECTION AND DESIGN ALTERNATIVES

Sandia National Laboratories

Chair: Amy Halloran

Co-Authors: Brandon Ennis and Geoff Klise

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Data for Data-Driven Design Standards

What is needed to derive statistically representative site conditions for offshore sites as is done for land-based turbines?

- e.g., should there be one shear value for the Extreme Wind Shear (EWS) DLC 1.5?
- What shear exponent should be used for DLCs 1.1-1.3?
- Is DLC 1.4 applicable offshore?

When representing correlations between wind and wave conditions, how should this be sampled to obtain the most accurate solution for loads? This is especially important for fatigue calculations

Table 1 - Design load cases

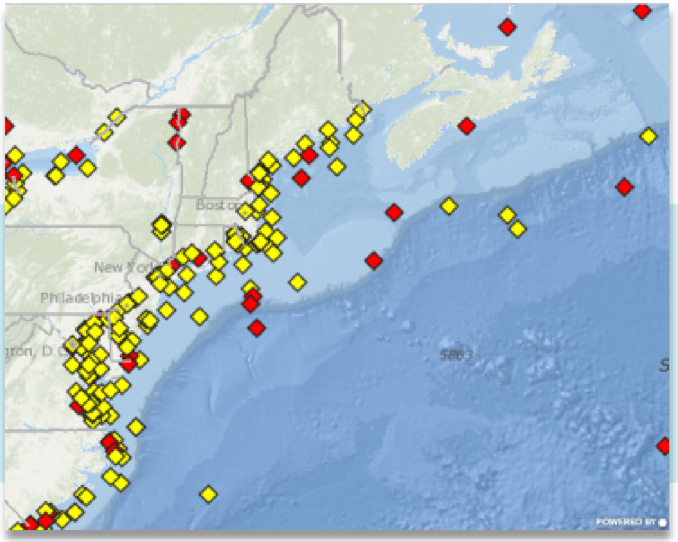
Design situation	DLC	Wind condition	Waves	Wind and wave directionality	Sea currents	Water level	Other conditions	Type of analysis	Partial safety factor
1) Power production	1.1a	NTM $V_{in} < V_{hub} < V_{out}$ RNA	NSS $H_s=E[H_s \| V_{hub}]$	COD, UNI	NCM	MSL	For extrapolation of extreme loads on the RNA	U	N (1,25)
	1.1b	NTM $V_{in} < V_{hub} < V_{out}$ Support structure	NSS Joint prob. distribution of H_s, T_p, V_{hub}	COD, UNI	NCM	NWLR	For extrapolation of extreme loads on the support structure	U	N (1,25)
	1.2	NTM $V_{in} < V_{hub} < V_{out}$	NSS Joint prob. distribution of H_s, T_p, V_{hub}	COD, MUL	No currents	NWLR or ≥ MSL		F	*
	1.3	ETM $V_{in} < V_{hub} < V_{out}$	NSS $H_s=E[H_s \| V_{hub}]$	COD, UNI	NCM	MSL		U	N
	1.4	ECD $V_{hub} = V_r - 2$ m/s, V_r, $V_r + 2$ m/s	NSS (or NWH) $H_s=E[H_s \| V_{hub}]$	MIS, wind direction change	NCM	MSL		U	N
	1.5	EWS $V_{in} < V_{hub} < V_{out}$	NSS (or NWH) $H_s=E[H_s \| V_{hub}]$	COD, UNI	NCM	MSL		U	N
	1.6a	NTM $V_{in} < V_{hub} < V_{out}$	SSS $H_s= H_{s,SSS}$	COD, UNI	NCM	NWLR		U	N
	1.6b	NTM $V_{in} < V_{hub} < V_{out}$	SWH $H = H_{SWH}$	COD, UNI	NCM	NWLR		U	N

Power production DLCs for offshore turbines (IEC 61400-3 design standard)

Data from Representative Metocean Sites

Turbine hub heights are in excess of 140m for offshore machines, with rotor top heights reaching 260m for the GE Haliade-X (plus the offset from the platform level to the mean water level)

Weather buoys typically have meteorological measurements of only 10-50m



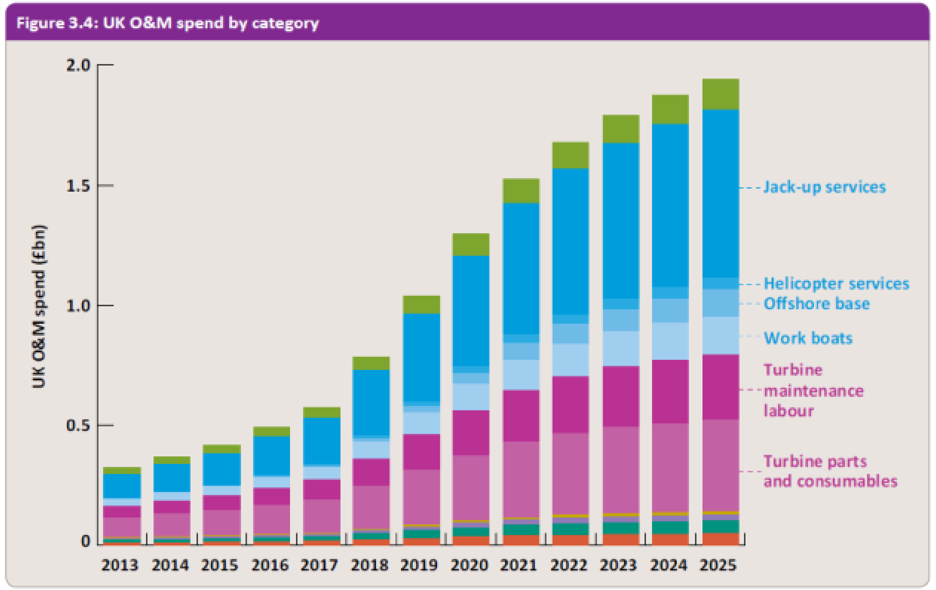
https://www.ndbc.noaa.gov/

www.lmwindpower.com

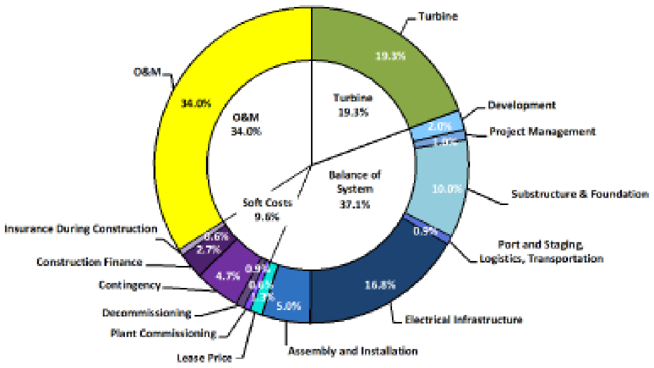
Supply Chain

Where should the supply chain be located? Should there be multiple vendors along the coast to reduce transportation costs/delays?

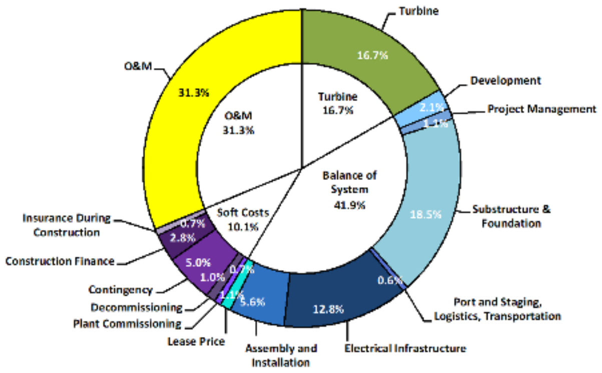
Vessel costs are significant for installation and for O&M



“A Guide to UK Offshore Wind Operations and Maintenance,” Scottish Enterprise and The Crown Estate, 2013.



Fixed-bottom LCOE ($89/MWh) estimated breakdown for a 5 MW turbine



Floating platform LCOE ($132/MWh) estimated breakdown for a 5 MW turbine

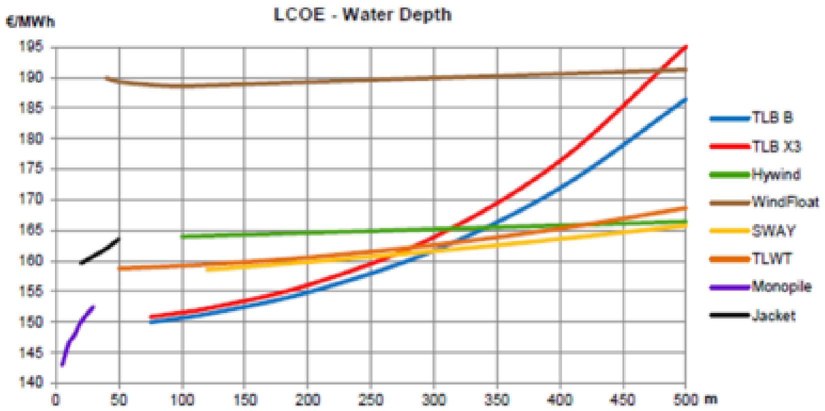
Stehly, Tyler and Beiter, Philipp, “2018 Cost of Wind Energy Review,” Tech. Rep. NREL/TP-5000-74598, National Renewable Energy Laboratory, 2019.

System Reductions on Support Structure Costs

The design should consider the coupled substructure and installation costs as the target for reduction

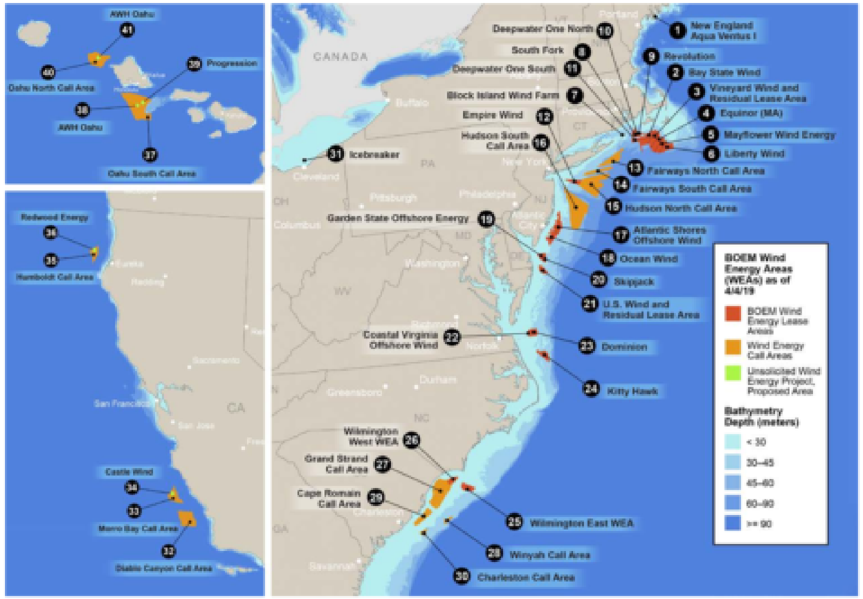
Can designs be produced that are less dependent on the local seabed conditions to reduce additional engineering costs and have more standardized concepts?

Need for materials/design innovations that can help to reduce the capital and O&M costs for support structures



LCOE for fixed-bottom and floating offshore support structures versus water depth

Myhr, A., Bjerkseter, C., Agotnes, A. and Nygaard, T. A., “Levelised cost of energy for offshore floating wind turbines in a life cycle perspective,” Renewable Energy, Vol. 66, 2014, pp. 714-728.



Musial, Walter D, Beiter, Philipp C, Spitsen, Paul, Nunemaker, Jake, and Gevorgian, Vahan, “Offshore Wind Technologies Market Report,” United States, 2019. doi:10.2172/1572771.

Current Projects Addressing Some Data Gaps

Photo from PNNL

PNNL has lidar buoys in 625 and 1000 m of water off the North and Central Coast, respectively.

Graphic by American Made Challenges

U.S. DOE and NOAA recently announced the opening of the DEVELOP Competition within the Ocean Observing Prize to spur the development of technologies to better map, monitor, and understand the ocean and improve forecasts.

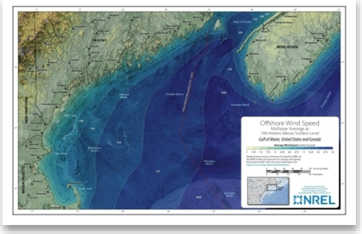


Illustration by Billy Roberts, NREL

Researchers at the National Renewable Energy Lab recently released a series of new and improved regional wind resource maps for the Northeast on WINDExchange.

Photo from Dominion Energy/Orsted

Reliability testing completed for the Dominion Energy 12-MW Coastal Virginia Offshore Wind (CVOW) project. Ørsted Energy completed the installation of the two 6-MW turbines in June and the grid interconnect is scheduled for this fall.

Session 2

Mike Optis/National Renewable Energy Laboratory (NREL)

A Validated National Offshore Wind Resource Dataset with Uncertainty Quantification

Anthony Kirincich/Woods Hole Oceanographic Institution

Development of a Metocean Reference Site near the MA & RI Wind Energy Areas

Matt Shields/NREL and **Ben Brown**/Business Network for Offshore

20GW by 2035: Supply Chain Roadmap for Offshore Wind in the US.

Jason Cotrell/RCAM Technologies

A Low-Cost Modular Concrete Support Structure and Heavy Lift Vessel Alternative.

After Jason’s talk, we will take a 10 minute break and a 40-minute virtual Q&A session