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Offshore Wind Research Summary
California Study Results

Walt Musial | Principal Engineer | National Renewable Energy Laboratory

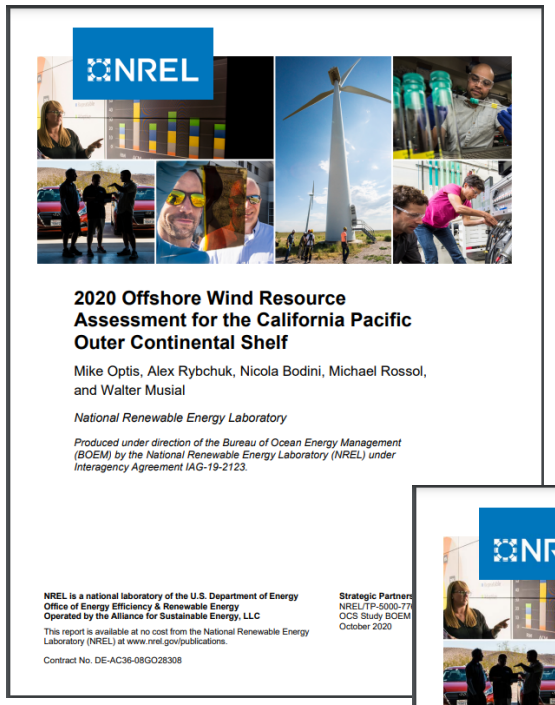
June 27, 2022

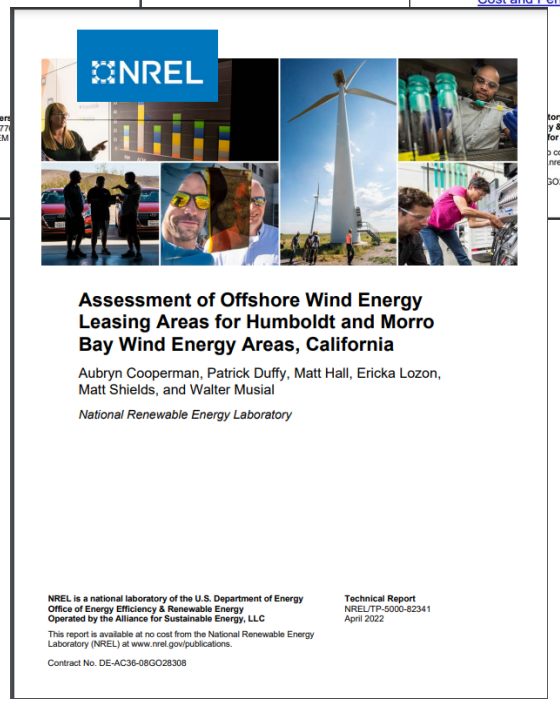
Three NREL Offshore Wind Studies from 2020 to 2022

1. 2020 Offshore Wind Resource Assessment for the California Pacific Outer Continental Shelf
   https://www.nrel.gov/docs/fy21osti/77642.pdf

2. The Cost of Floating Offshore Wind Energy in California Between 2019 and 2032
   https://www.nrel.gov/docs/fy21osti/77384.pdf

3. Assessment of Offshore Wind Energy Leasing Areas for Humboldt and Morro Bay Wind Energy Areas
   https://www.nrel.gov/docs/fy22osti/82341.pdf



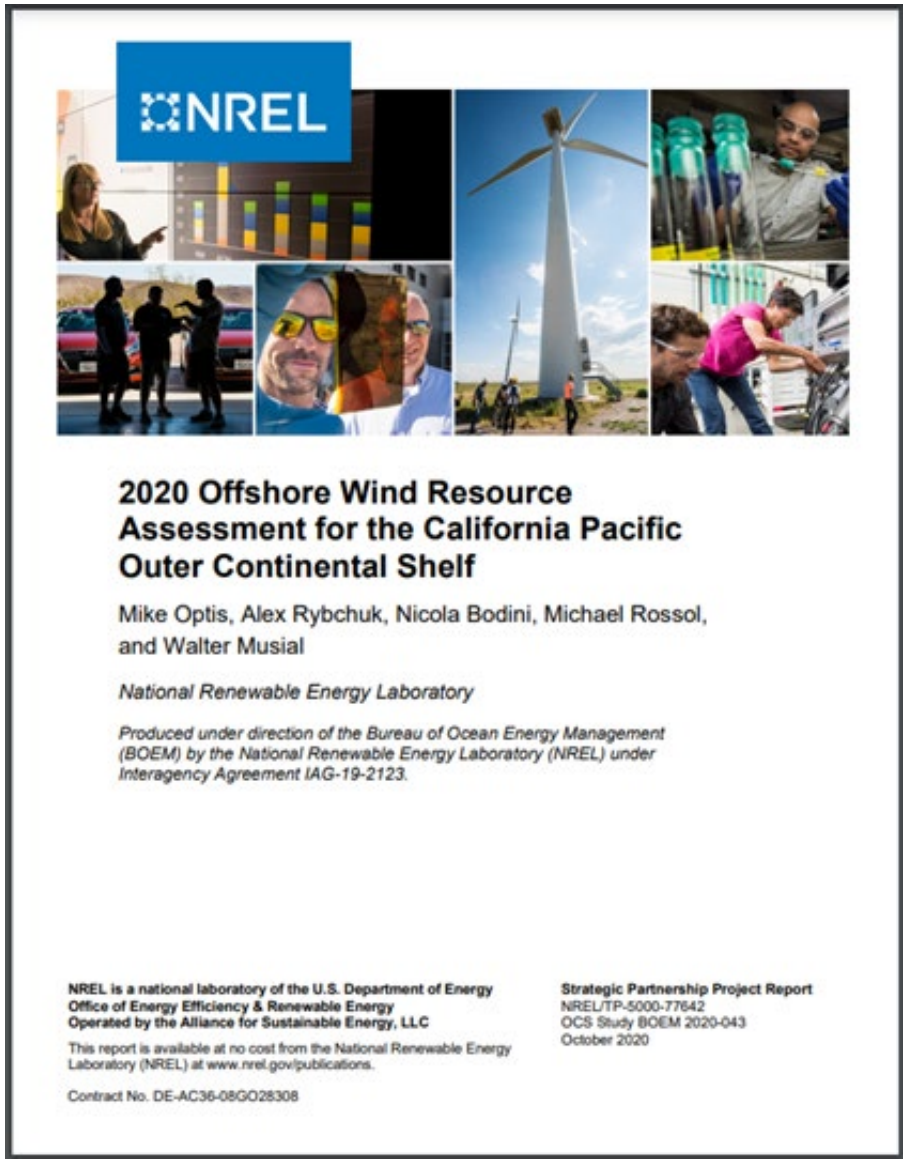


All Studies Funded by the Bureau of Ocean Energy Management

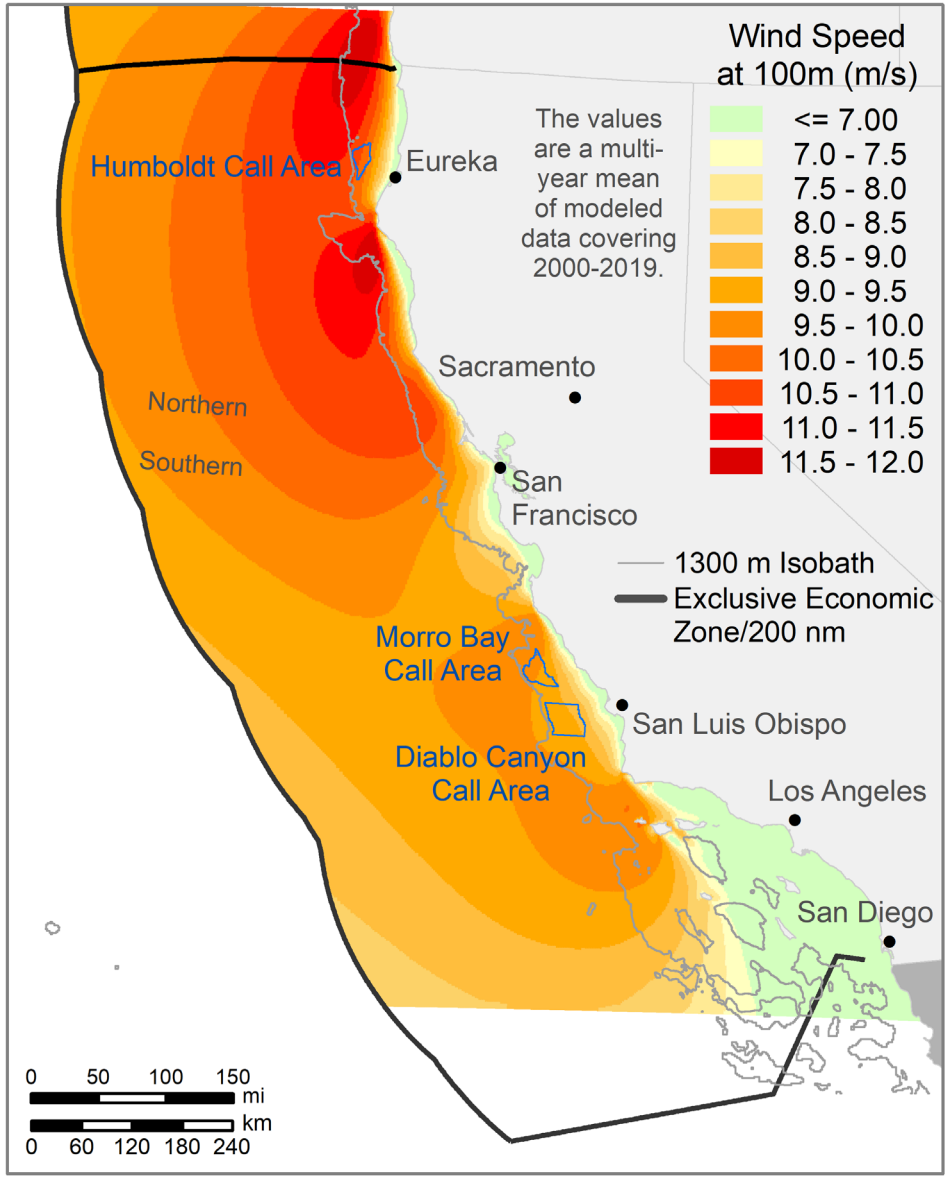
BOEM
Bureau of Ocean Energy Management

California 2020 (CA20) Wind Resource Dataset

- The study estimated the offshore wind energy resource in California based on 20 years of hindcast data from 2000 - 2019
- Coordinated with Pacific Northwest National Labs (PNNL) and the National Center for Atmospheric Research (NCAR) using high fidelity Weather Research and Forecasting (WRF) model.
- Ensemble approach updated model setup using state-of-the-art science with approval of expert advisory group
- 5-minute time resolution, 2-km spatial resolution
- https://www.nrel.gov/docs/fy21osti/77642.pdf



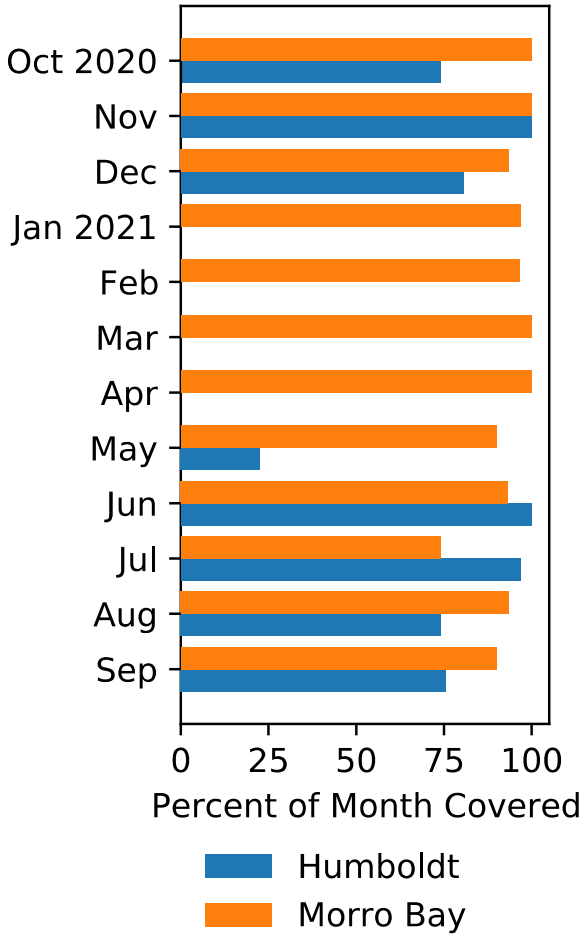
California 2020 (CA20) Dataset - Findings



Mean annual wind resource at 100 m from the CA20 dataset

- Large increase in mean winds from 2013
- CA20 data was validated using coastal radar and near-surface buoy measurements.
- Measurements at hub height were not available in 2020.
- **Technical Resource Potential over 200-GW**; winds greater than 7 m/s; depths less than 1300-m.
- No exclusions were assumed for human use or environmental conflicts. (e.g., distance from shore, military, wildlife sanctuaries)
- **2021 validations with LIDAR show high bias.**

2021 Lidar Validation: CA20 Dataset Bias



- In 2021 CA20 dataset was validated against observations from two floating lidars.
- Significant bias suggest wind speeds are over estimated – Humboldt area has highest bias.
- Further investigations over the next 9 months will confirm results.
- A revised CA20 dataset is likely.
- Results may lower capacity factors and increase costs.

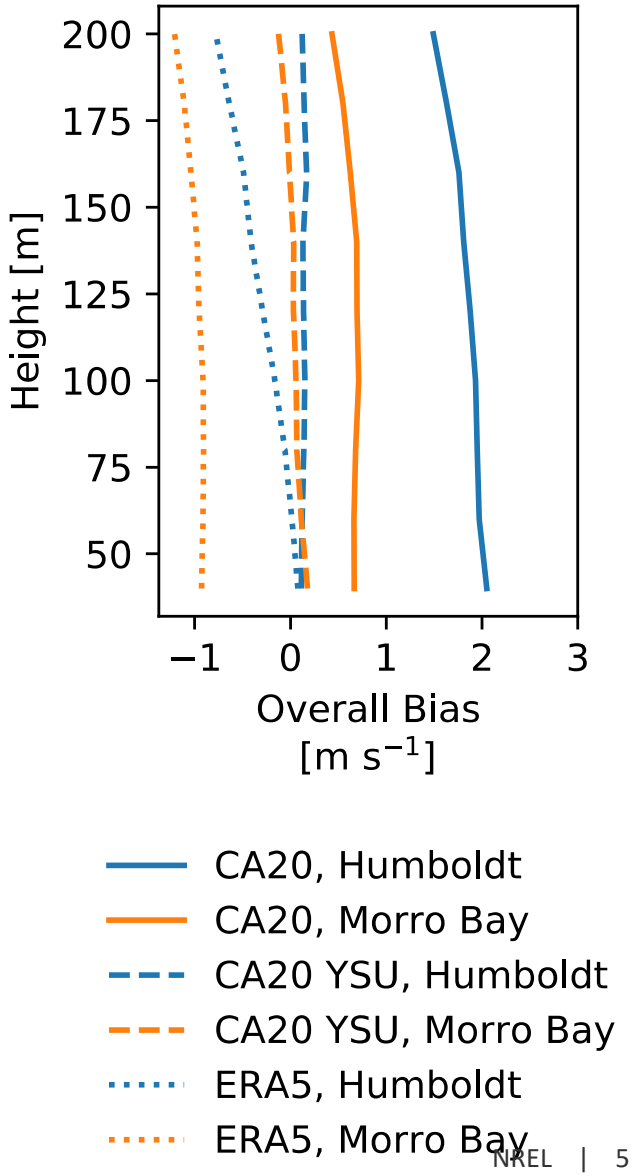


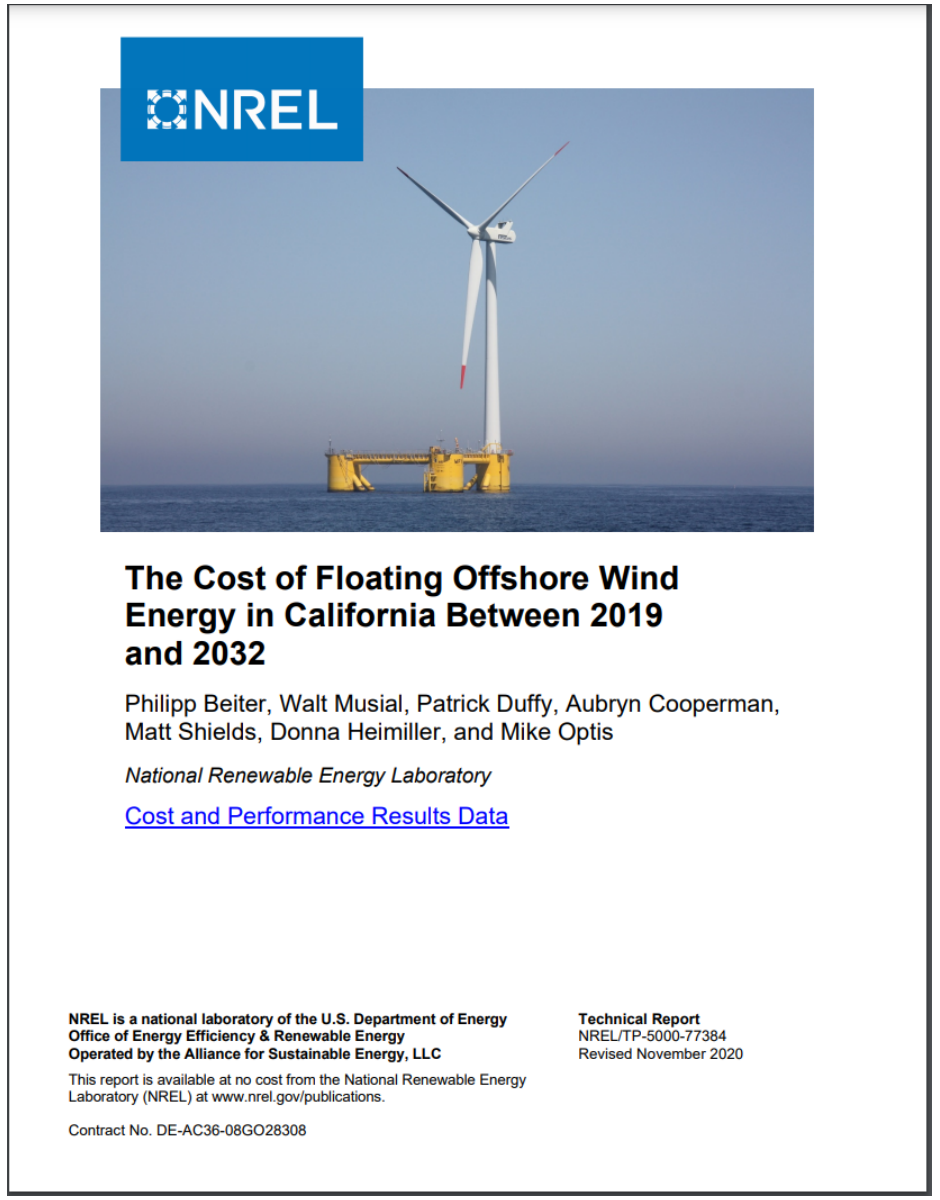
Figure Above: Availability of lidar observations used in the CA20 validation analysis

Right Figure: Vertical profile of bias between lidar data and a) original CA20 dataset, b) CA20 dataset with the YSU turbulence scheme, c) ERA5 reference reanalysis

Floating Offshore Wind Cost Study Results

- The study estimated the cost of floating offshore wind in California out to 2032
- Coordinated with the California Public Utilities Commission and CAISO for input to the IRP process.
- Five study areas were chosen for cost modeling reference and analysis.
- Study examined levelized cost of energy, CapEx, OpEx, capacity factors, annual energy production
- Not a marine spatial planning exercise.

https://www.nrel.gov/docs/fy21osti/77384.pdf


NREL

The Cost of Floating Offshore Wind Energy in California Between 2019 and 2032

Philipp Beiter, Walt Musial, Patrick Duffy, Aubryn Cooperman, Matt Shields, Donna Heimiller, and Mike Optis

National Renewable Energy Laboratory

Cost and Performance Results Data

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

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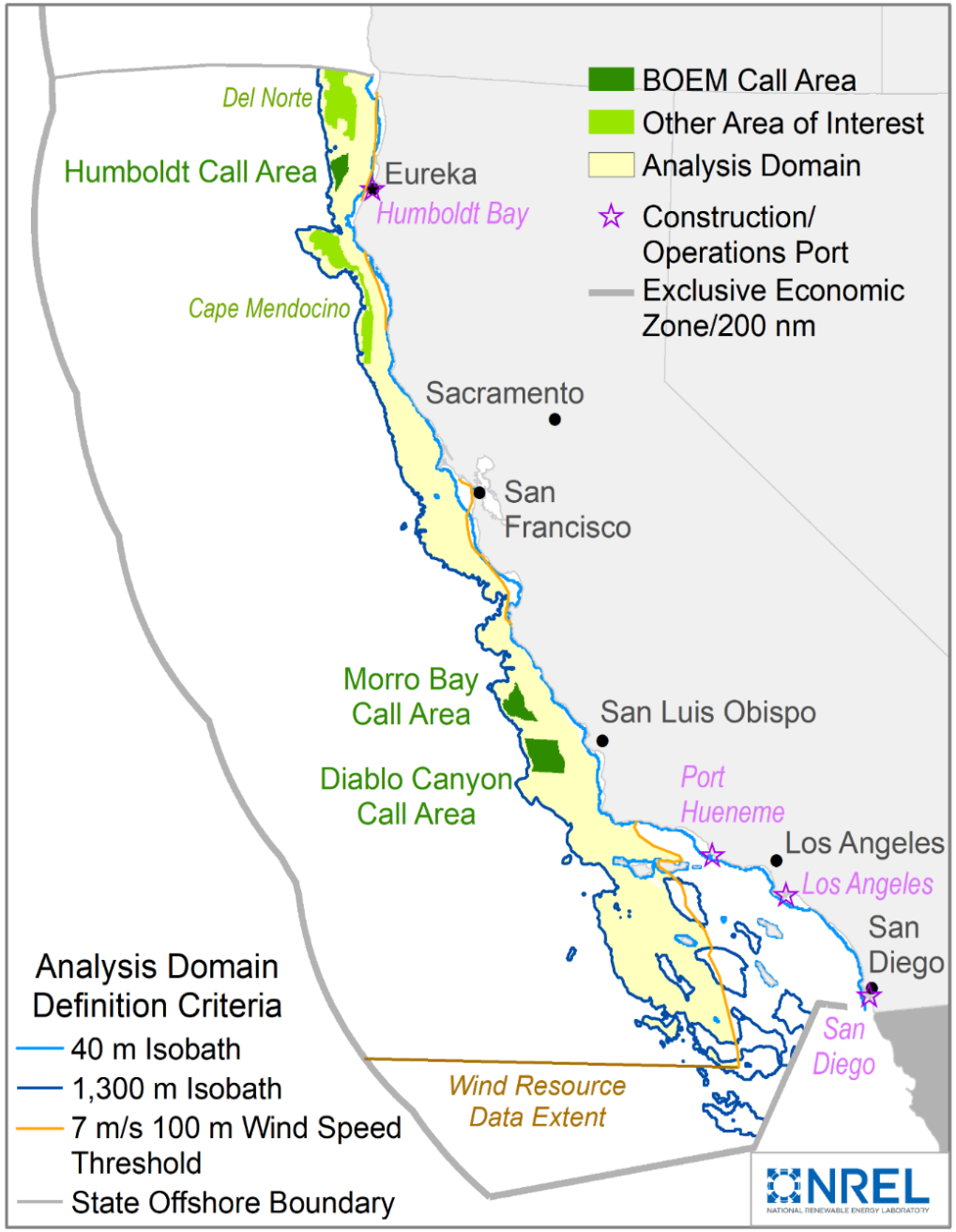
Technical Report
NREL/TP-5000-77384
Revised November 2020

California Cost Study Areas



- Within the analysis domain, five study areas were chosen (<1,300 meters depth)
- These study areas are representative locations for possible offshore wind in CA.
- Areas were chosen from BOEM Call areas and prior studies (Collier et al. 2019 and Musial et al. 2016)

Five study areas

- **Humboldt (WEA)**
- **Morro Bay (WEA)**

} **Current Wind Energy Areas**

- Diablo Canyon (Dormant Call Area)
- Del Norte – Study Area
- Cape Mendocino – Study Area

Floating Cost and Capacity Findings

- Costs range $68/MWh to $57/MWh
- Costs assume a viable port located on the Central and North coasts (Humboldt Bay, TBD near Morro Bay)
- Morro Bay has adequate transmission connection.
- Humboldt WEA/North Coast will need transmission build.
- Five study areas can conservatively support 21,172 MW at 3 MW/km^2
- Industry norms suggest developers may increase power density to 5 MW/km^2 or more.

Nameplate Capacities (MW) for California Offshore Wind Energy Areas and Study Areas

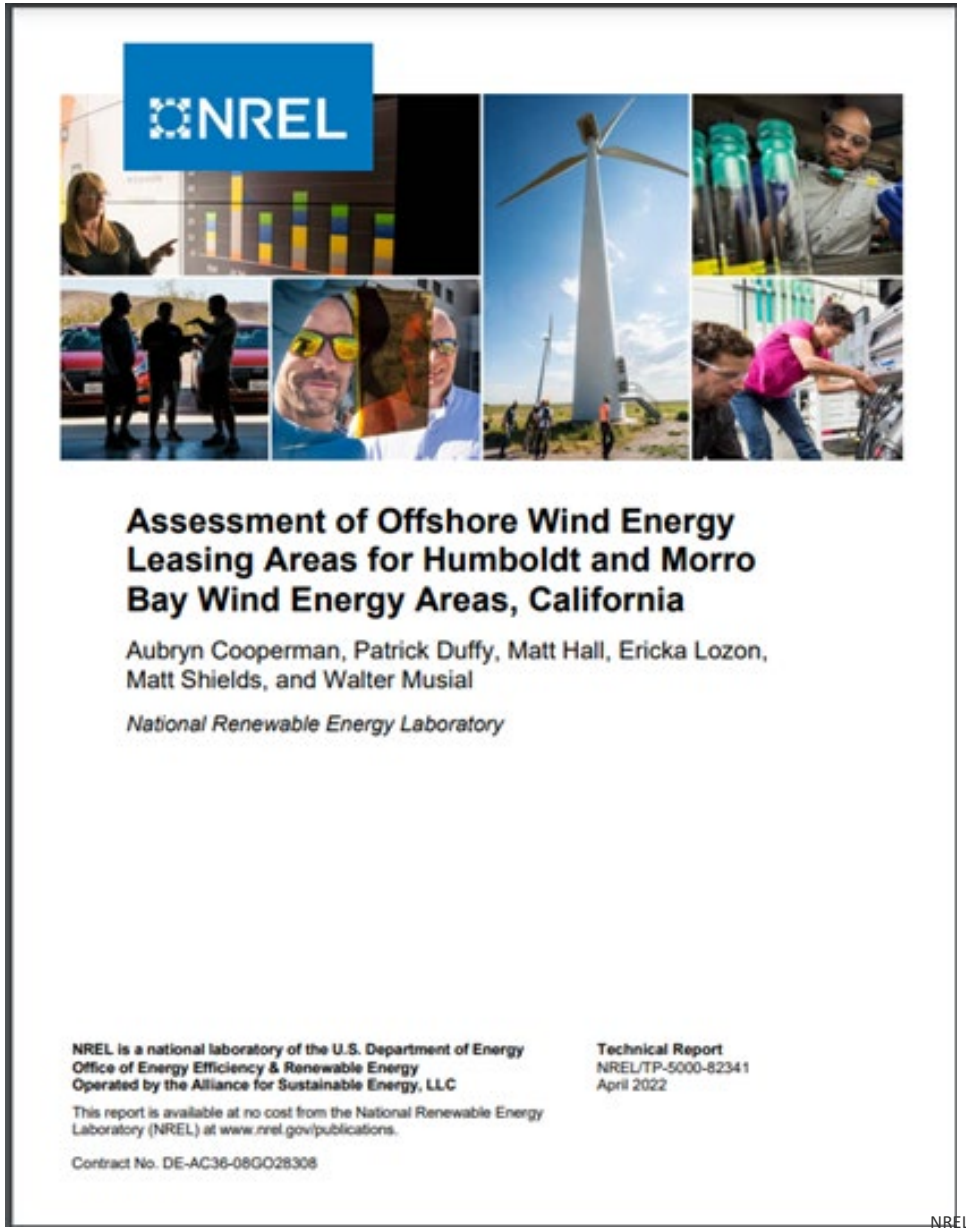
		2020 Modeled Scenario			Probable Scenario	
	Area (km^2)	Capacity (MW) 3 MW/km2	Capacity (MW) 4 MW/km2	Capacity (MW) 5 MW/km2	Capacity (MW) 4 MW/km2	Capacity (MW) 5 MW/km2
		NREL Study			No Diablo	No Diablo
Diablo Canyon Call Area	1,441	4,323	5,764	7,205	0	0
Morro Bay WEA	975	2,925	3,900	4,875	3,900	4,875
Humboldt WEA	536	1,608	2,144	2,680	2,144	2,680
Cape Mendocino Study Area	2,072	6,216	8,288	10,360	8,288	10,360
Del Norte Study Area	2,202	6,606	8,808	11,010	8,808	11,010
Totals (MW)	7,226	21,678	28,904	36,130	23,140	28,925

Empire Wind (NY): 6.5 MW/km^2
Dominion CVOW (VA): 5.8 MW/km^2

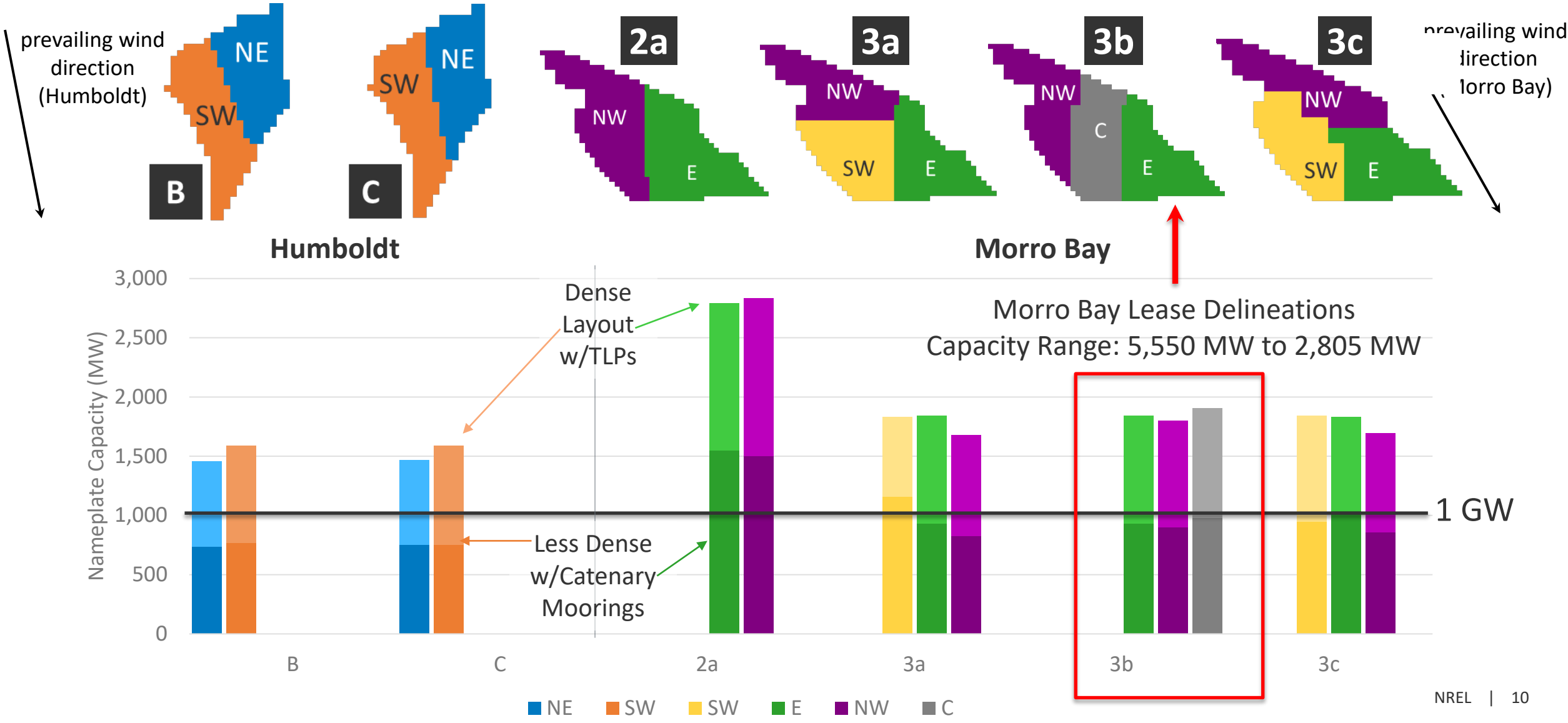
Assessment of Offshore Wind Leasing Areas in California

- Study objectives were to recommend delineation options for Humboldt and Morro Bay WEAs with approximately 1 GW capacity and equal value.
- Balanced advantages and disadvantages among lease areas; wind direction, and access to infrastructure, geohazards, etc.
- Iterated with BOEM on various options.

https://www.nrel.gov/docs/fy22osti/82341.pdf



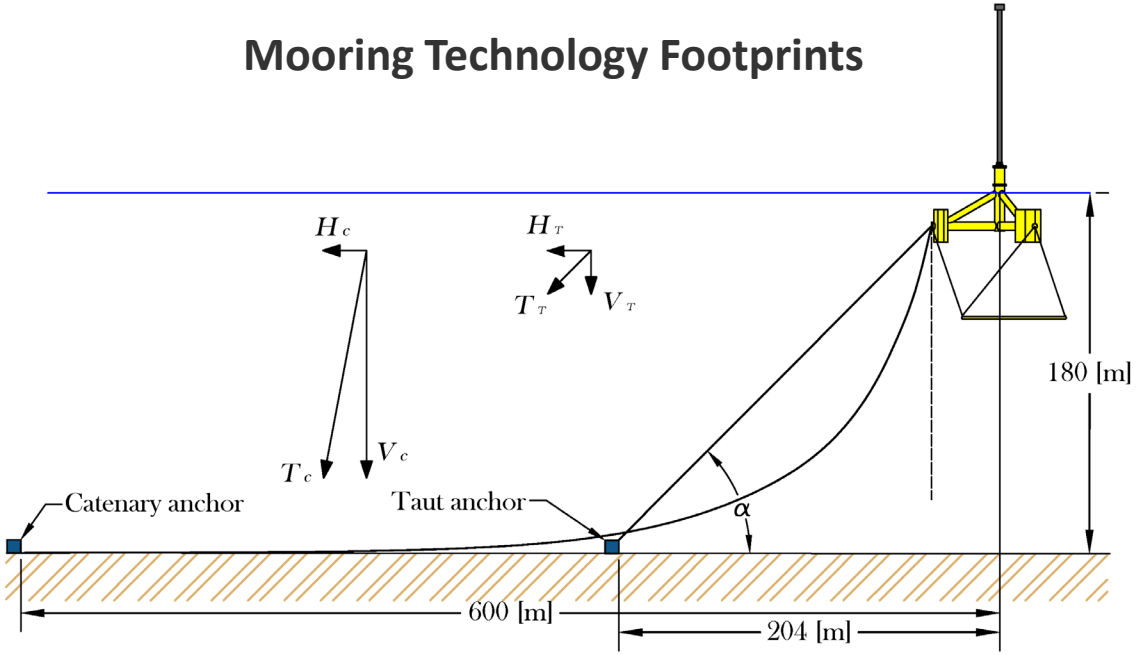
Delineation Results

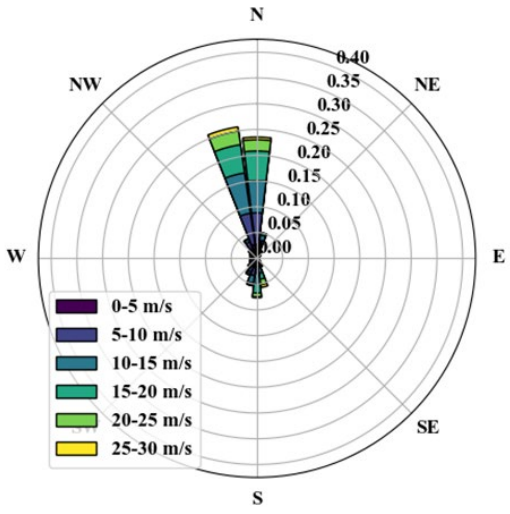


Wind Energy Area Delineations: Key Findings

- Lease area capacity estimates are highly sensitive to the **choice of mooring technology**.
- **Inter-array wake effects** were a key parameter. Consistent wind direction will enable denser turbine spacing.
- **Geohazards** were within WEA boundaries were not found to be a major concern for developers.
- Access to **transmission and ports** is essential and will impact the value of the lease areas.

Mooring Technology Footprints





Humboldt WEA Wind Rose

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