NREL
Transforming ENERGY

Updated Oregon Floating Offshore Wind Cost Modeling

Walt Musial, Patrick Duffy, Donna Heimiller, Philipp Beiter

September 24, 2021

Project Overview

- The study provides heat maps showing updated estimates of the levelized cost of energy (LCOE) for floating offshore wind energy off the coast of Oregon.
- This project builds on a 2019 National Renewable Energy Laboratory (NREL) floating offshore wind power cost study in Oregon (Musial et al. 2019) and a recent NREL California cost analysis (Beiter et al. 2020).
- Floating wind power cost data, modeling methodology, and resource data are updates to the 2019 Oregon study (Musial et al. 2019).
- LCOE is estimated through 2032 using 2019 as a reference year.
- Comparisons are made to previous offshore wind energy cost studies (Musial et al. 2019; Beiter et al. 2020).
- The study does not prioritize specific sites or make judgments about marine spatial planning viability.

Cost Modeling Methodology

Focus: Levelized Cost of Energy

LCOE is the cost to produce one unit of electricity in megawatt-hours (MWh) for an offshore wind energy project averaged over the 25-year life cycle of the project.

$$LCOE = \frac{FCR(C_{turbine} + C_{BOS}) + C_{O\&M}}{AEP}$$

- LCOE: $/megawatt-hour (MWh)
- FCR: Fixed charge rate
- $C_{turbine}$: Turbine capital expenditures, $/kilowatt (KW)
- C_{BOS}: Balance of system (BOS) capital expenditures, $/KW
- $C_{O\&M}$: Operation and maintenance (O&M) annualized costs, $/KW/year
- AEP: Annual energy production, MWh.

LCOE is helpful to compare projects/technologies with <u>different cash flow profiles and over time.</u>
LCOE does <u>not</u> capture the locational and time <u>value</u> of the generated energy and other services.

Methodology

LCOE is calculated by doing the following:

1) Defining floating technology and plant characteristics

Turbine and substructure characteristics (e.g., turbine rating, power curve) and plant size and turbine spacing

2) Collecting geospatial and cost data

Wind speed, water depth, wave height, distance to port and grid infrastructure and technology limitations (e.g., water depth limits)

3) Computing reference year LCOE with NREL's Offshore Regional Cost Analyzer (ORCA) model

LCOE component costs and AEP

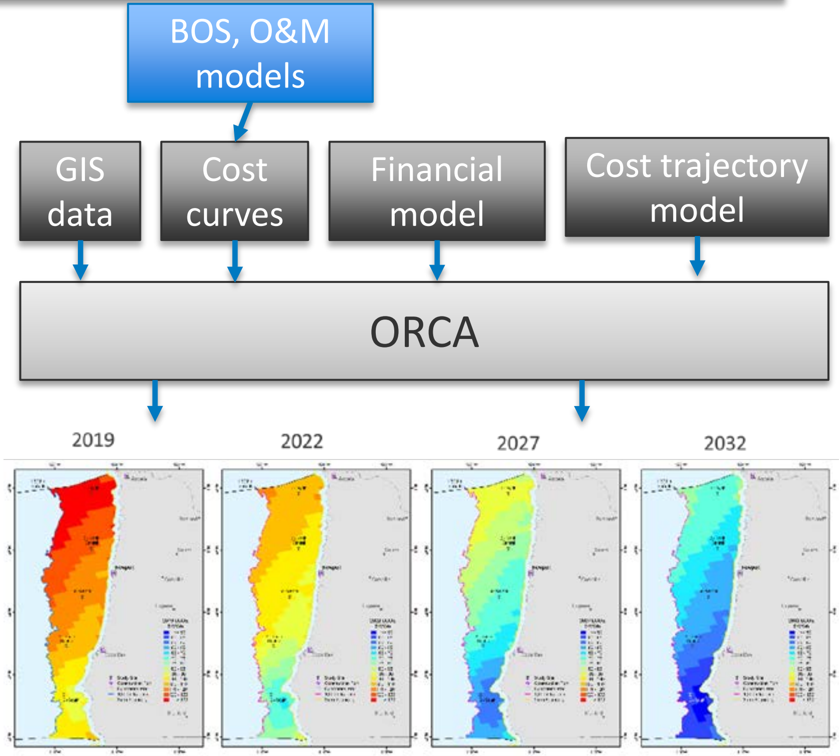
4) Project future costs

Anticipated learning in supply chain, growth in turbine rating, and technology innovation.

Description of ORCA Model: Offshore Regional Cost Analyzer

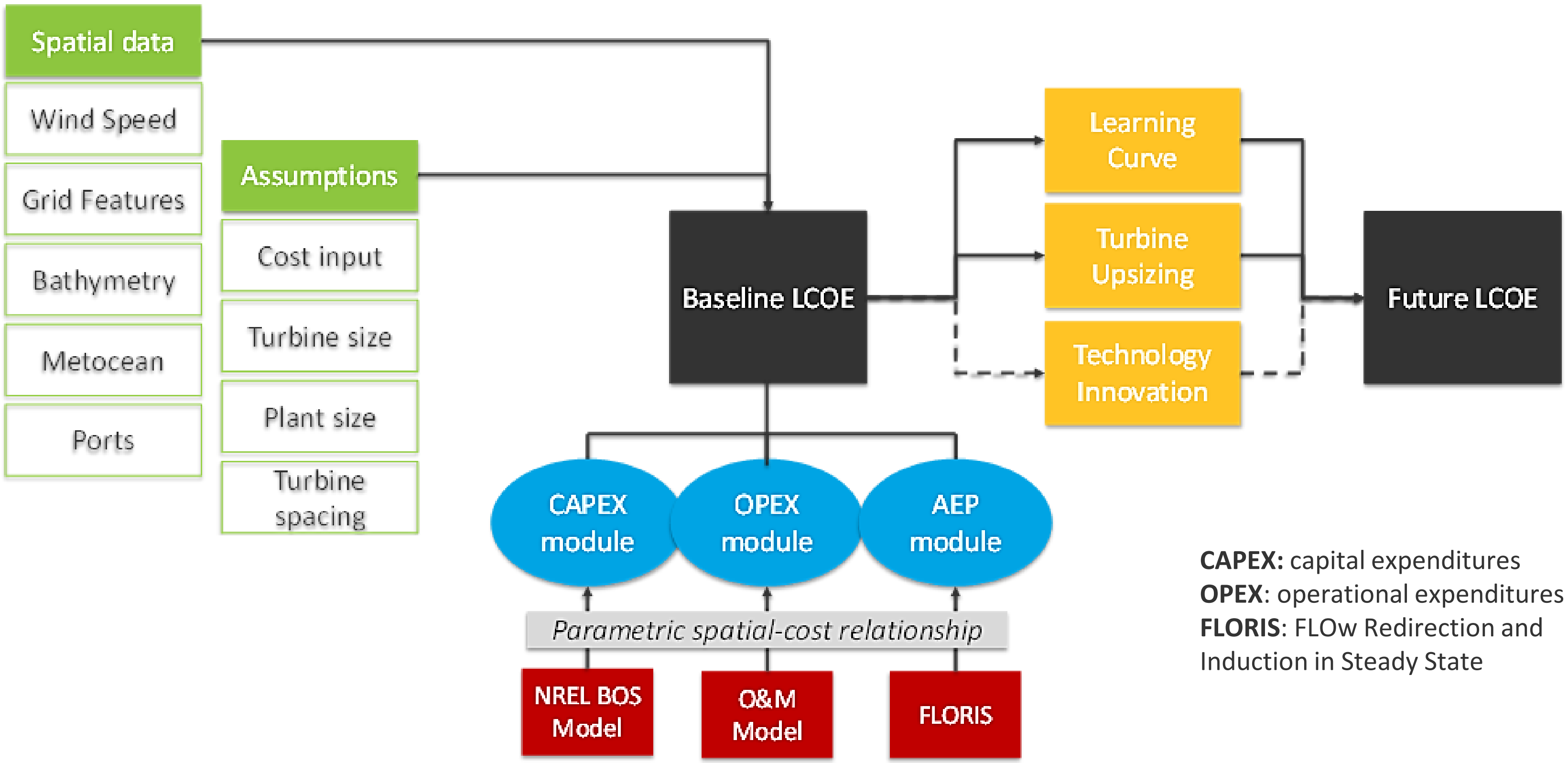
Techno-economic model calculates the spatial and temporal variation of offshore wind costs.

- The bottom-up model uses current cost and wind resource data.
- The **geospatial** cost variables help assess potential offshore wind energy sites on the Outer Continental Shelf (OCS); e.g., depth, distance, resource.
- The **temporal** model estimates the future costs for operation dates up to 2032 based on technology timelines and learning curve.
- The model evaluates the impact of technological, financial, and O&M decisions on LCOE.
- The model is continuously updated to reflect changing market conditions.



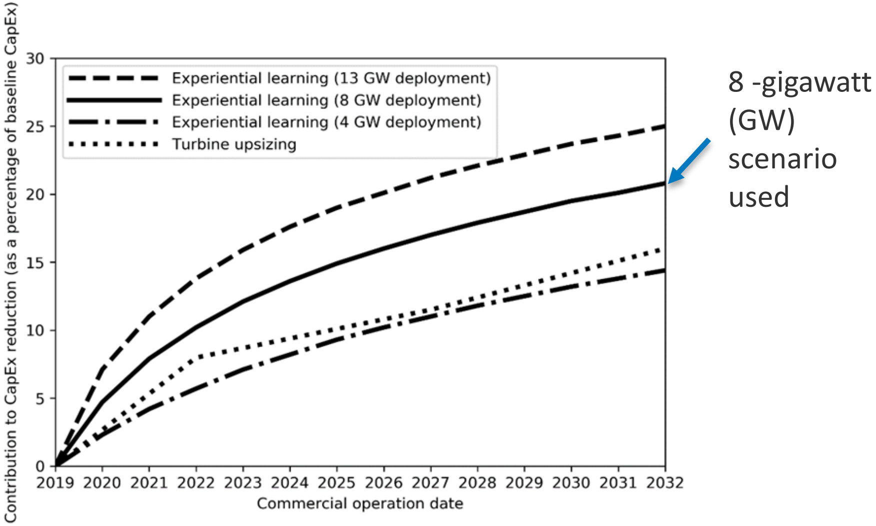
Spatial and temporal LCOE results

ORCA Input-Output Flow Diagram

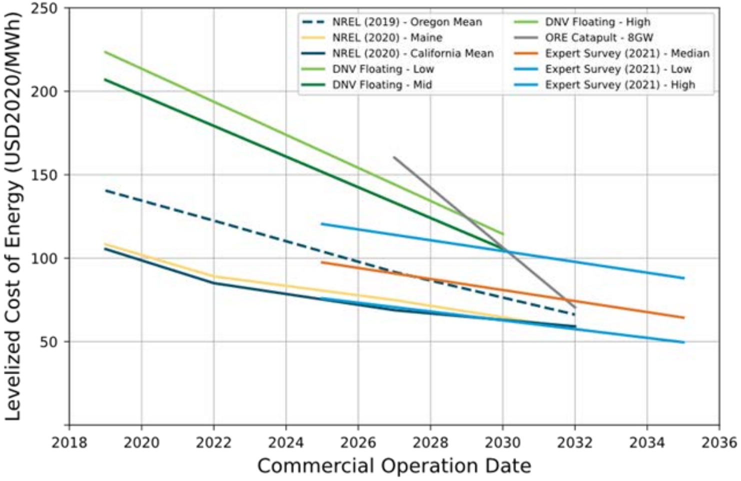


CAPEX: capital expenditures
OPEX: operational expenditures
FLORIS: FLOw Redirection and Induction in Steady State

Projecting Future Floating Offshore Wind Costs



CapEx cost is reduced by turbine upsizing and experiential learning curves. *Graph from Beiter et al. (2020)*



Floating offshore wind energy costs from literature are compared. *Graph from Musial et al. (2020)*

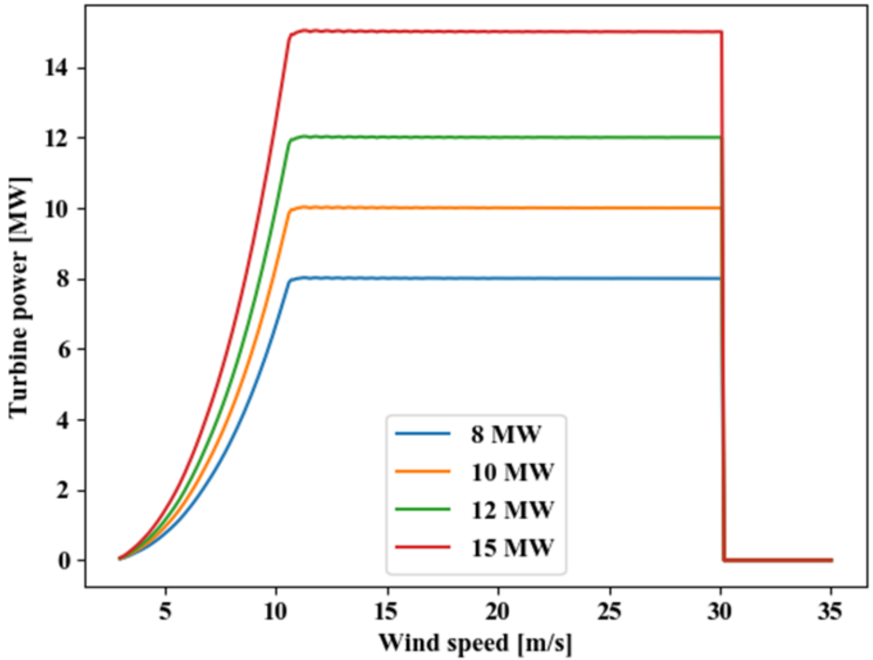
Future offshore wind energy costs are calculated based on learning curves derived by Beiter et al. (2020) from historical offshore wind power project data (Musial et al. 2020).

- The floating wind market is nascent and commercial cost data are sparse.
- Fixed-bottom offshore wind energy market data is utilized because the floating offshore wind energy industry shares many of the same components and supply chains.
- There is a 7.5% cost reduction for each doubling of the cumulative installed floating offshore wind energy capacity.
- The learning curve (left figure above) assumes 8 GW of floating wind energy is deployed globally by 2030 (Beiter et al. 2020).

Modeling Assumptions

Offshore Wind Technology Assumptions

- All wind turbines in the model are based on the International Energy Agency (IEA) Wind 15-MW offshore reference turbine (Gaertner et al. 2020).
- Turbine capacities are assumed to increase over time from 8 MW to 15 MW based on market trends:
  - 8 MW (2019)
  - 10 MW (2022)
  - 12 MW (2027)
  - 15 MW (2032)
- Cut-out wind speed was increased from 25 meters/second (m/s) to 30 m/s in all turbines to account for the higher wind speeds in southern Oregon.



Offshore wind turbine power curves correspond to 2019, 2022, 2027, and 2032

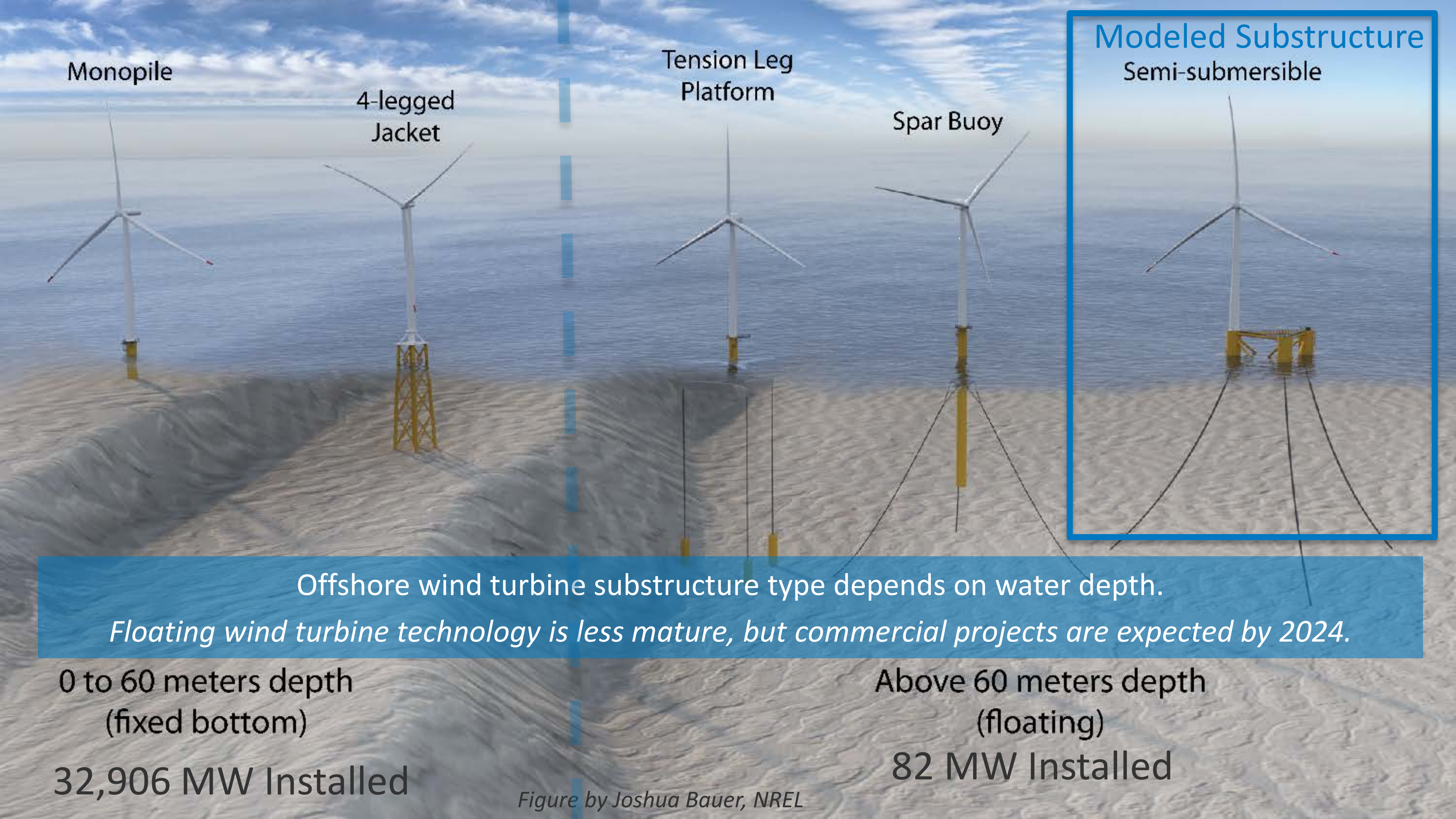
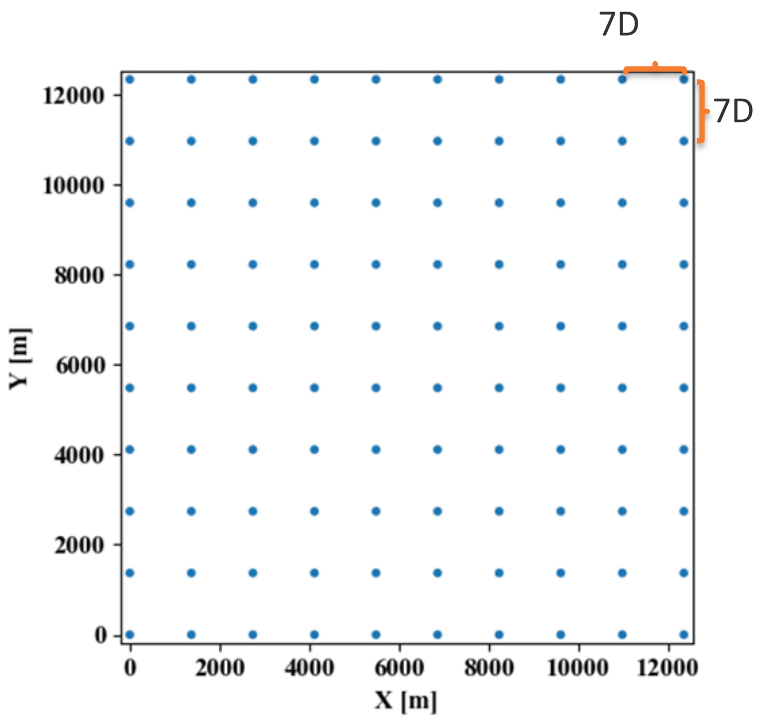


Figure by Joshua Bauer, NREL

Wind Power Plant Assumptions

- A nominal wind plant capacity of 1,000 MW is assumed.
  - Actual plant capacity varies due to integer wind turbine capacity in the commercial operation date (COD):
    - 2019: 1,000 MW (125 x 8 MW)
    - 2022: 1,000 MW (100 x 10 MW)
    - 2027: 1,008 MW (84 x 12 MW)
    - 2032: 1,005 MW (67 x 15 MW)
- Turbines are laid out on a square grid with 7-rotor-diameter (7D) spacing (see figure).*
- AEP and wake losses are calculated using NREL's wake modeling toolbox, FLORIS (NREL 2021).
- Export cable costs include the cost of a 3-kilometer (km), land-based spur line after landfall (likely not a full accounting of interconnection costs).

* Note that 7D spacing is not recommended from this analysis as a layout option for Oregon. The spacing was a conservative layout option chosen to calculate the wake losses. A site optimization of projects in Oregon will likely show lower wake losses.



Plant layout for COD 2022 (10-MW wind turbines) has a dot radius representing a 1-rotor diameter.

Floating Offshore Wind Financing Assumptions

The financial parameters (see table) are based on the following underlying market conditions:

- Project sponsors are experienced and supply chains are coordinated with development.
- Proven technology exists and has been demonstrated with prototypes and rigorous due diligence.
- A low revenue risk is assumed.
- A strong insurance coverage and ample contingency budgets are assumed.
- A strong contract management system is assumed.

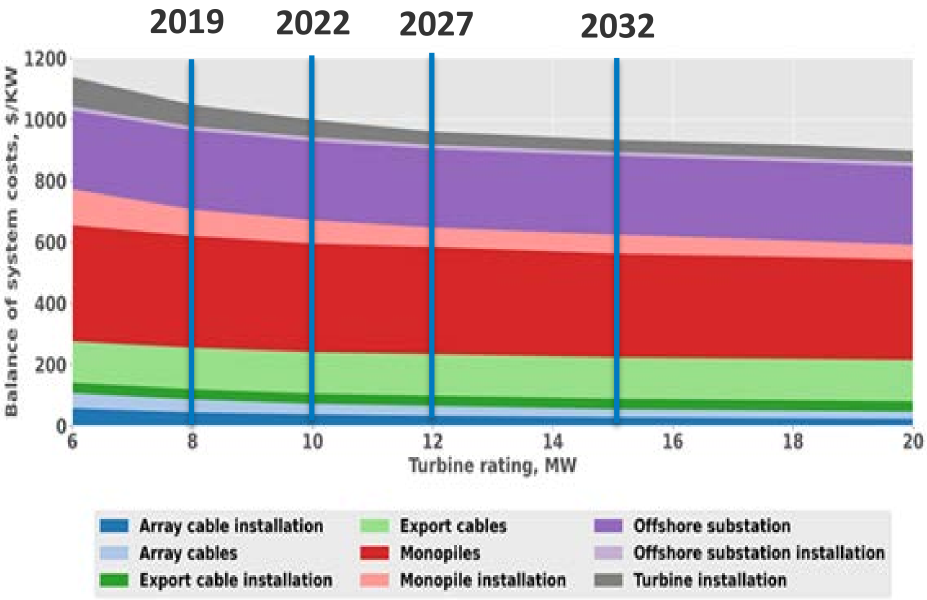
Table of Financial Assumptions (Same as Beiter et al. 2020)

Finance	FCR (nominal) (after tax)	%	7.2%
	FCR (real) (after tax)	%	5.3%
	WACC (nominal) (after tax)	%	5.4%
	WACC (real) (after tax)	%	2.9%
	Capital Recovery Period	yr	30
	Share of debt	%	75%
	Debt rate (nominal)	%	4.4%
	Equity Return (nominal)	%	12.0%
	Tax rate	%	26%
	Inflation	%	2.5%
	CRF (nominal) (after tax)	%	6.8%
	CRF (real) (after tax)	%	5.0%
	Project Finance Factor	%	105%
	Depreciation Basis	%	100%
	Depreciation Schedule		5-year MACRS
	Present Value of Depreciation	%	86%

WACC = weighted-average cost of capital
CFR = Code of Federal Regulations
FCR = Fixed Charge Rate

Main Capital Expenditure Drivers

- Turbine upscaling is a primary driver for BOS cost reduction (see figure).
- Increasing plant size has a large cost benefit due to economies of scale.
- Substructure costs are based on proprietary developer vendor quotes for 1,000-MW projects.
- Lower BOS costs have a cascading effect on soft costs (calculated as percent of BOS).
- Port and bulk transmission upgrade costs are not included in the LCOE or CapEx numbers.



This graph shows the impact of turbine size from Offshore Renewables Balance-of-System and Installation Tool (ORBIT). ***Graph from Shields et al. (2021)***

Note: Labor cost multipliers are not used in this study.

Local Port Requirements for a Viable Floating Offshore Wind Energy Industry in Oregon

Image by Harland and Wolff Heavy Industries

Wharf

Serial turbine, substructure assembly, and component port delivery due to depth, waves off coast.

Navigation Channel and Wet Storage

Storage and wet tow-out of assembled turbines with year-round access. Width/depth varies by substructure design.

Upland Yard

50- to 100-acre storage and staging of blades, nacelles, and towers and possible fabrication of floating substructures.

Crane

Minimum 600-ton lift capacity at 500 feet height to attach components.

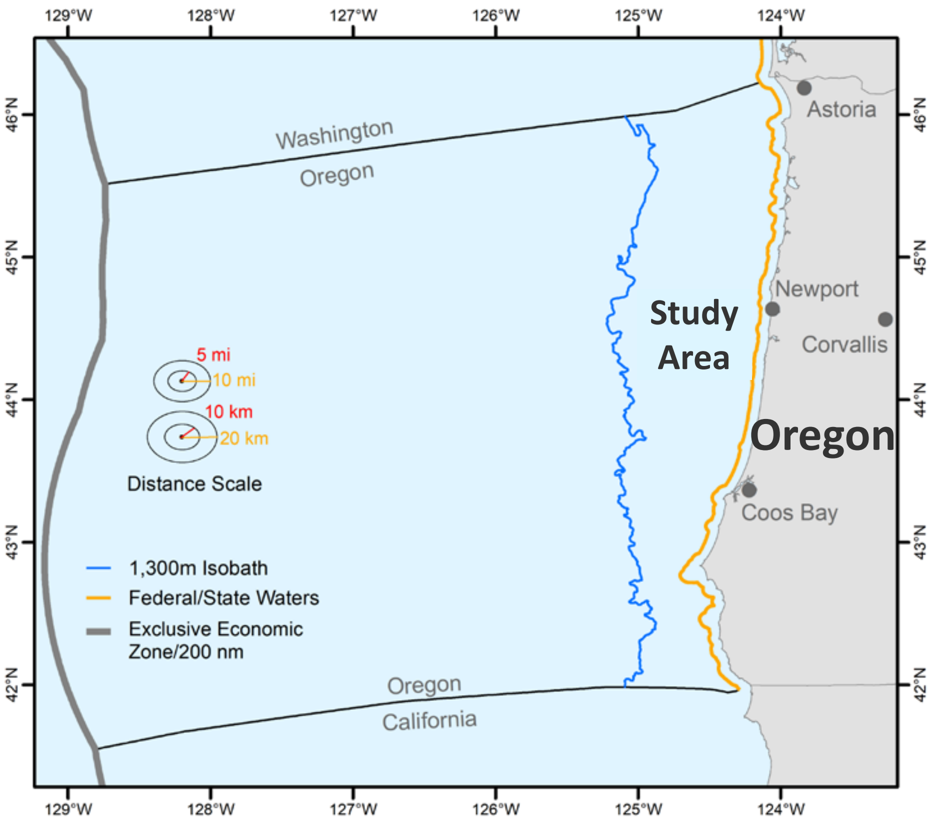
Crew Access & Maintenance

Moorage for crew access vessels. O&M berth for major repairs of full system.

Physical Site Characteristics

Oregon Study Area

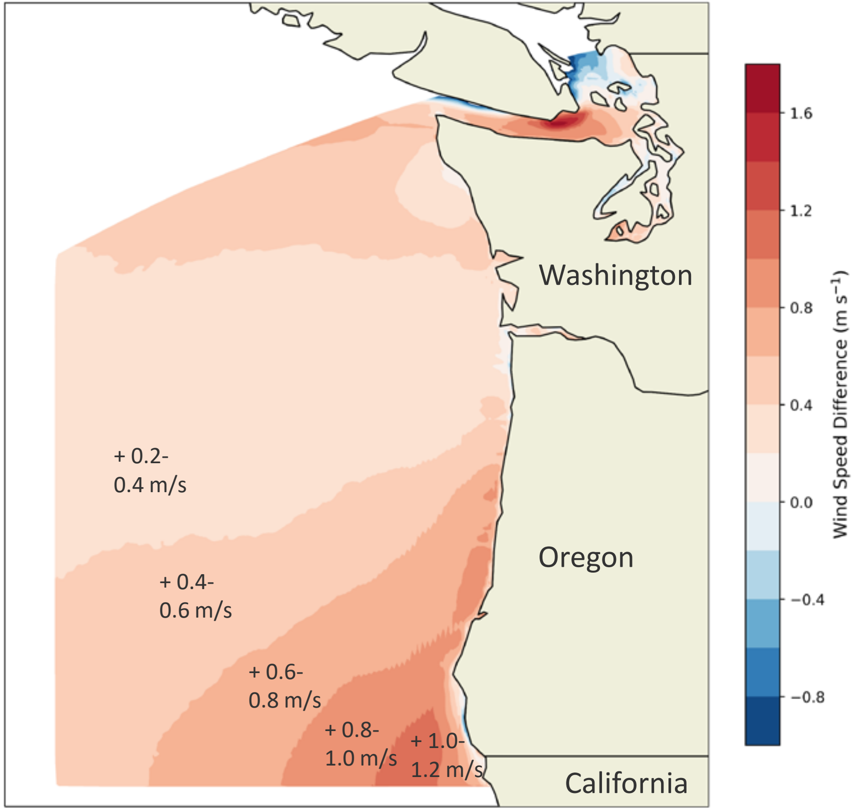
- Study area is bounded by:
  - A 1,300-m isobath to the west, based on present technology limits
  - Washington and California state borders to the north and south
  - 3 nautical miles (nm) federal/state water boundary to the east.
- All ocean space has at least a 7-m/s annual average wind speed.
- No additional areas were excluded (e.g., for conflicting use or environmental reasons).
- Note: the study is not intended to address marine spatial planning or stakeholder concerns; those will be part of a later public review.



This map shows the study area used. Map created by *NREL*

Oregon Offshore Wind Resource

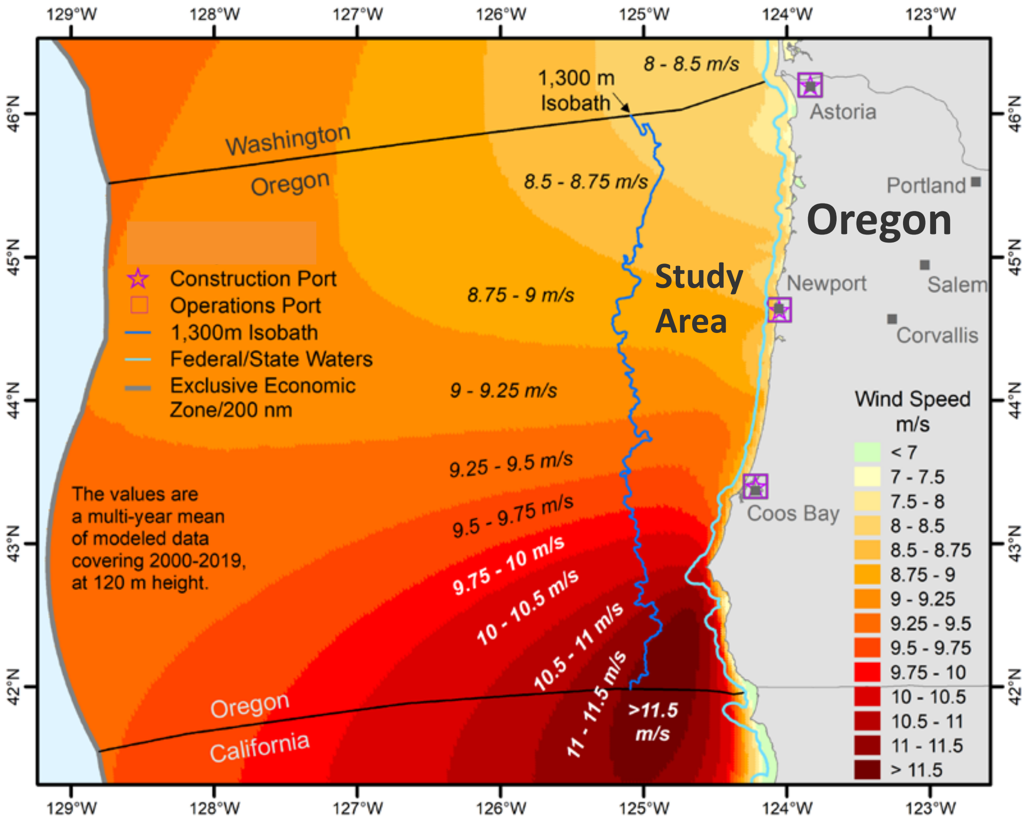
- The 2021 study uses state-of-the-art OR-WA20 offshore wind resource data developed by NREL.
- It uses the same methods as CA20 data set from Optis et al. (2020).
- The OR-WA20 data set improves on the Wind Integration National Dataset (WIND) Toolkit data set (Draxl et al. 2015) by implementing advancements in atmospheric modeling, including:
    - Updating the planetary boundary layer scheme in the Weather Research and Forecasting model
    - Designing the new model to impact vertical wind profiles and how atmospheric turbulence distributes momentum
    - Covering a 20-year period (2000–2019) instead of a 7-year period (2007–2013) in the WIND Toolkit
- This is the best assessment of offshore wind resources in the Pacific Northwest to date.
- The study provides higher predicted wind speeds than the WIND Toolkit in most regions (by up to 1.8 m/s; see figure).



This is a 120-m wind resource difference map. *Sourced from OR-WA20 – WIND Toolkit*

Oregon Offshore Wind Resource Map

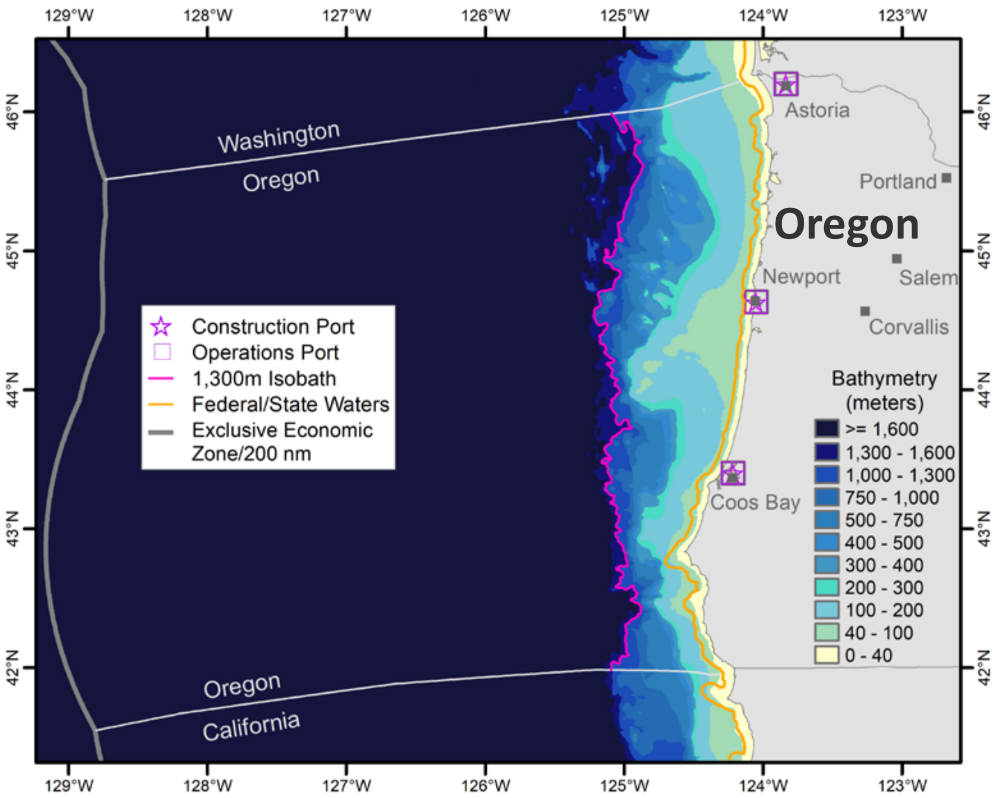
- This work produced a 120-m wind resource map (see figure).
- The OR-WA20 data set uses 20 years of data.
- The data shows a strong north/south gradient (8 m/s to 11 m/s), with the best wind resources being in the south.



Wind Resource Offshore Oregon – source NREL

Bathymetry Offshore Oregon

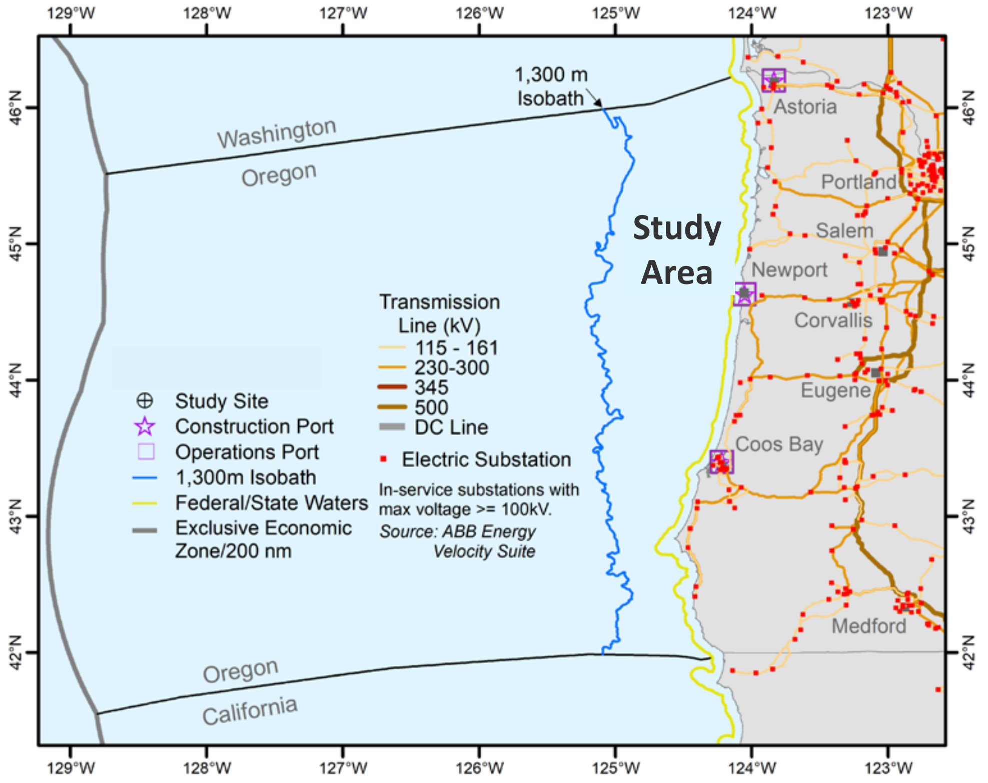
- 97% of the waters on the OCS off the state of Oregon are greater than 60 m in depth, indicating a need for floating wind turbine foundations with the present technology.
- Most of the technical resource area is less than 30 miles from the shore due to steep slopes on the OCS.



Bathymetry Offshore Oregon – source NREL

Coastal Oregon Electrical Infrastructure

- Almost all power generation in Oregon is currently inland.
- Electric power flows from the east to the west to serve the coastal communities.
- Offshore wind would reverse the direction of power flow and reduce impacts on inland grids.
- Additional studies are underway (Novacheck et al. 2021) to assess the impact of offshore wind to the Oregon power grid.



Electric Infrastructure in Oregon Relative to Study Site – source NREL

Oregon Offshore Wind Levelized Cost of Energy: Heat Map Analysis

Oregon Offshore Wind – Levelized Cost of Energy

- LCOE heat maps show strong north-south variations and dependence on distance from shore.
- LCOE geographic variations are mostly due to wind speed.
- By 2032, LCOE is expected to range between $75/MWh in the north to as low as $50/MWh in the south.

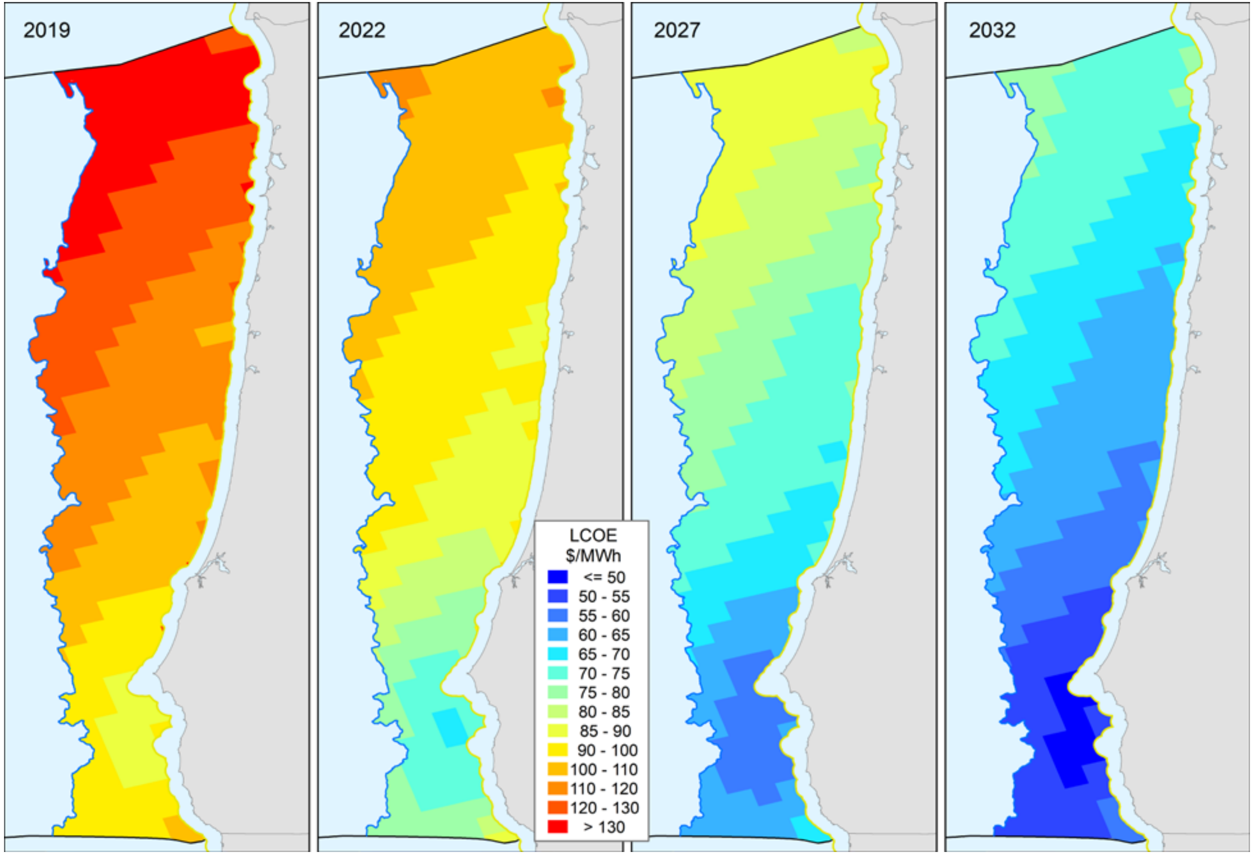


Image source: NREL

Oregon Offshore Wind Capital Expenditures

- CapEx heat maps show strong dependence on distance from shore but little north-south variations.
- CapEx values drop below $3,000/KW in many areas by 2032.

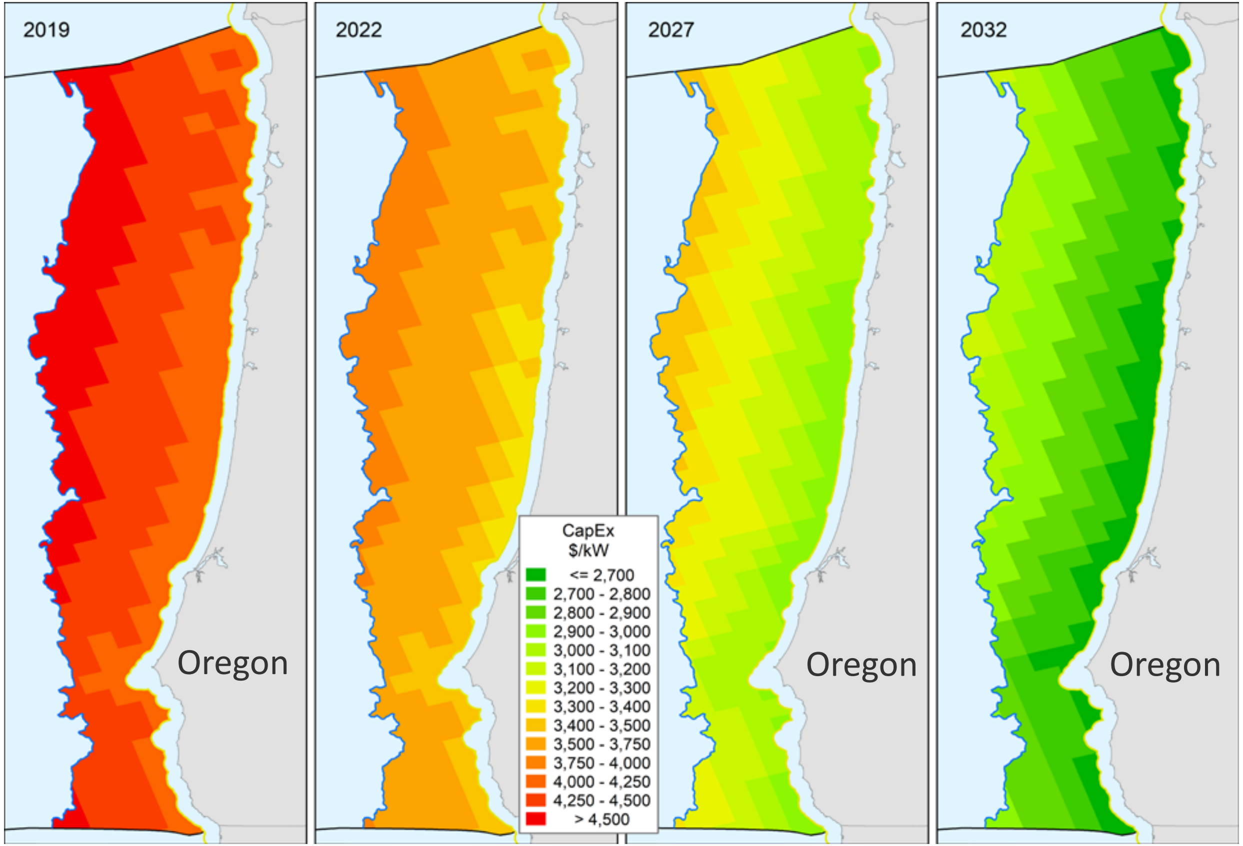


Image source NREL

Oregon Offshore Wind Operating Expenditures

- Operating expenditures (OpEx) heat maps show strong dependence on distance from shore but little north-south variations.
- OpEx costs will drop below $55/kW/year by 2032 in many regions.

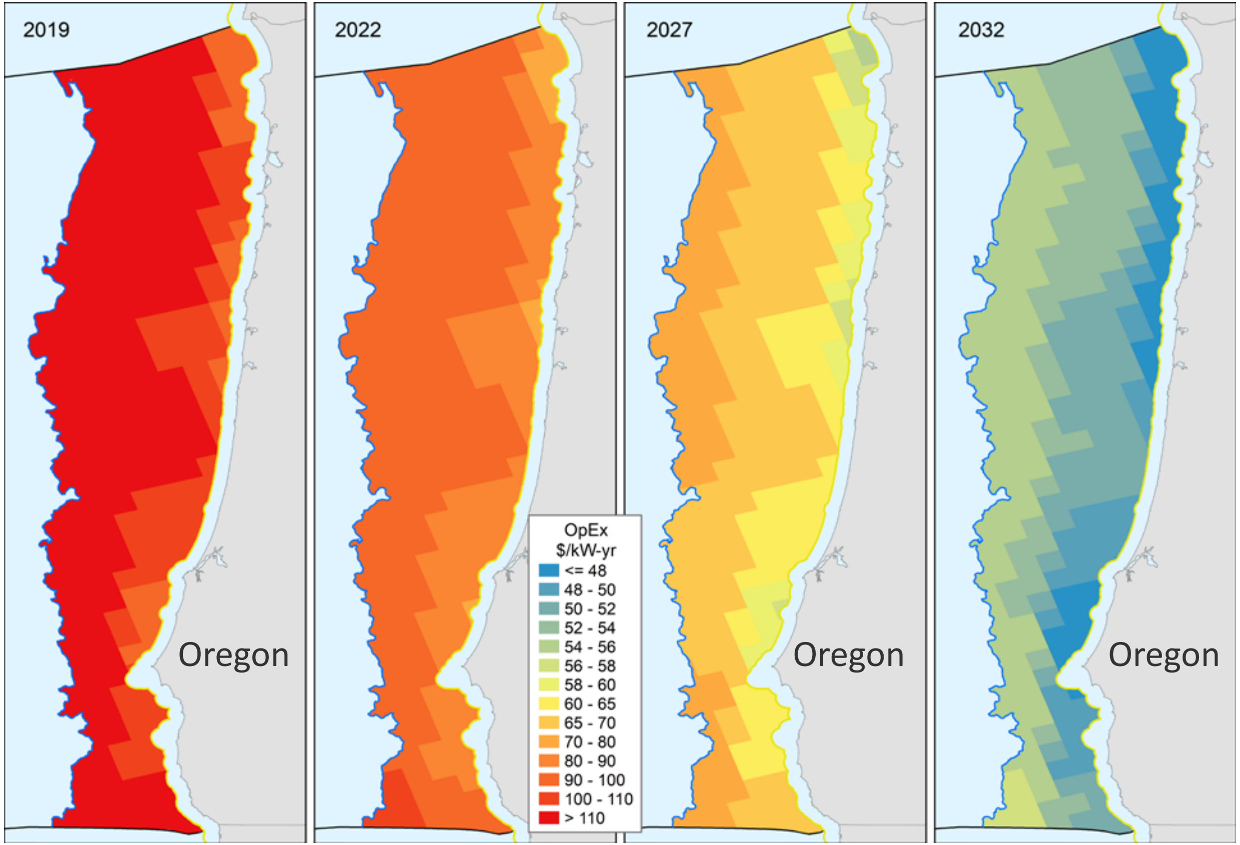


Image source NREL

Oregon Offshore Wind Net Capacity Factor

- Net capacity factor (NCF) heat maps show strong north-south variations, which are mostly due to wind resources.

- NCF values are expected to range between 39% (in the north) and 57% (in the south) by 2032.

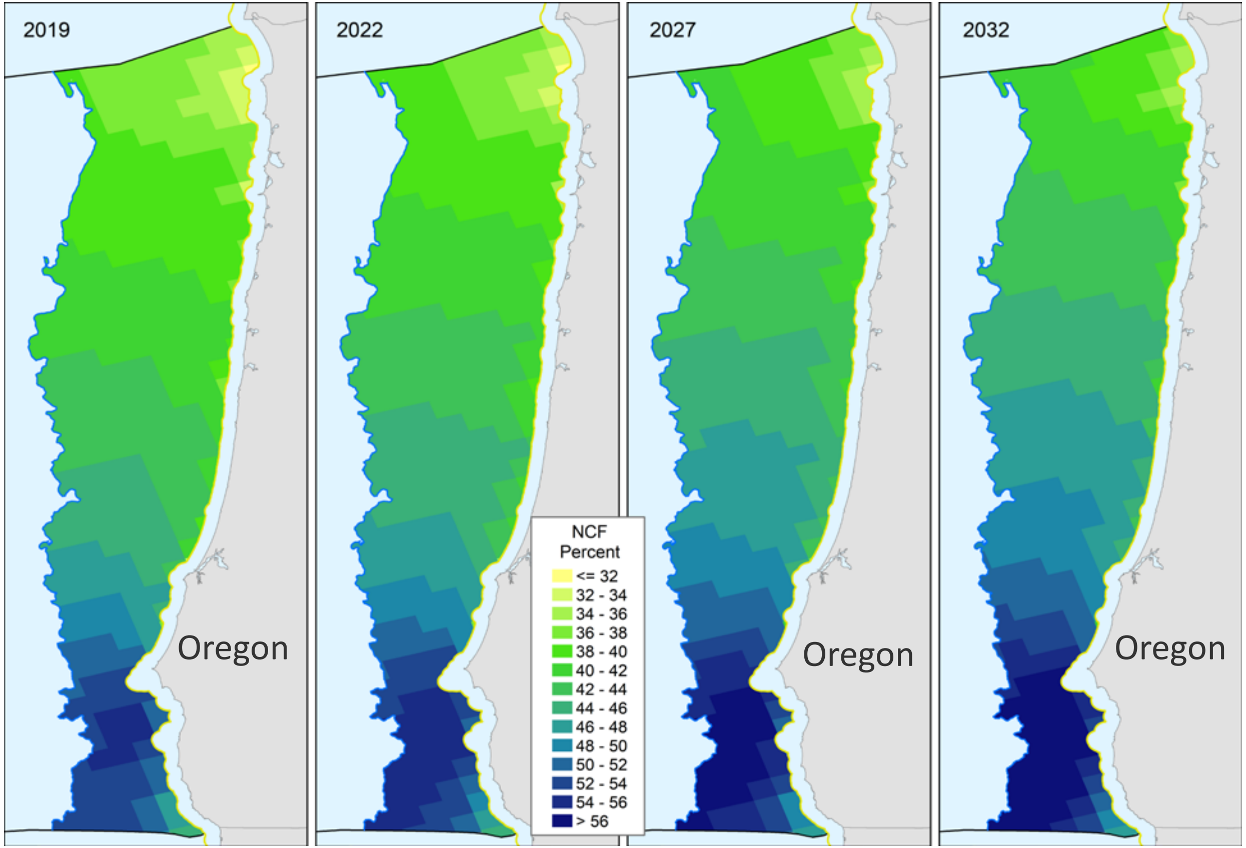


Image source NREL

2019 Levelized Cost of Energy

- The baseline model year is 2019. Inputs are from prototypes and precommercial project data.*
- 8-MW wind turbines are assumed for the 2019 model (e.g., the WindFloat Atlantic).
- Floating technology is still precommercial, with commercial projects becoming possible by 2024.
- LCOE geospatial characteristics show strong correlation with a north-south wind speed gradient.
- The LCOE gradient is from north to south, ranging from about **$134/MWh to $92/MWh**.++

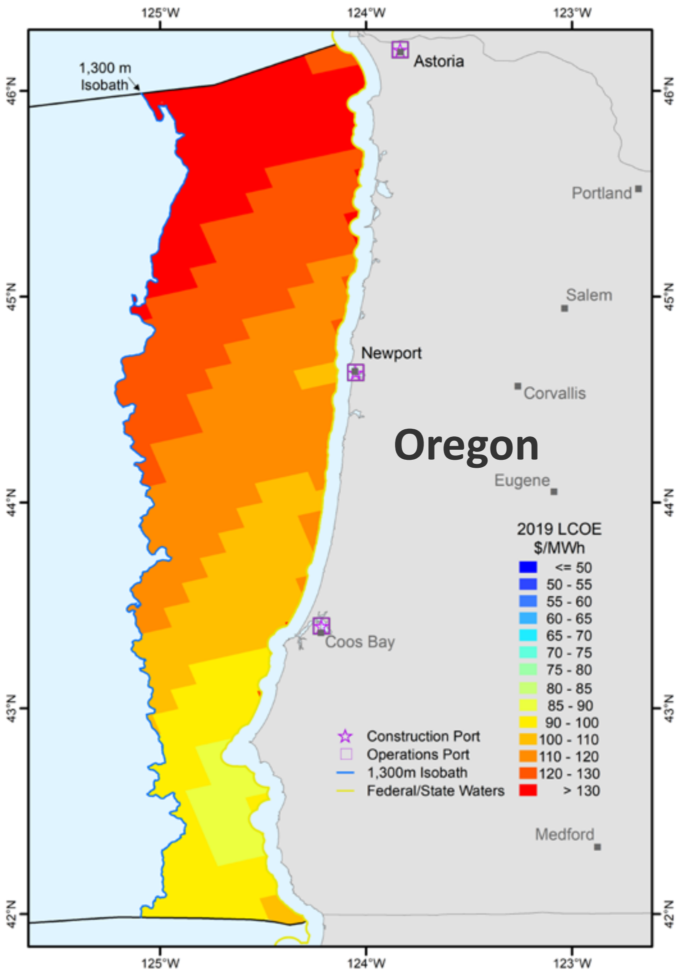


Image source: NREL

* Precommercial projects are smaller (at less than 100 MW in size) than the optimum size needed to achieve cost competitiveness and use immature technology.
++ All LCOE values are in 2019 U.S. dollars.

2022 Levelized Cost of Energy

- Current technology is assumed for 2022, given a financial close in 2020.
- Current technology options are 10-MW wind turbine installations.
- Technology in 2022 is still precommercial, because no commercial projects will exist yet, and total deployments globally will not exceed a few hundred MW.
- LCOE characteristics show strong north-to-south correlation with wind speed.
- The LCOE gradient from north to south ranges from about **$107/MWh to $74/MWh.**++

++ All LCOE values are in 2019 U.S. dollars.

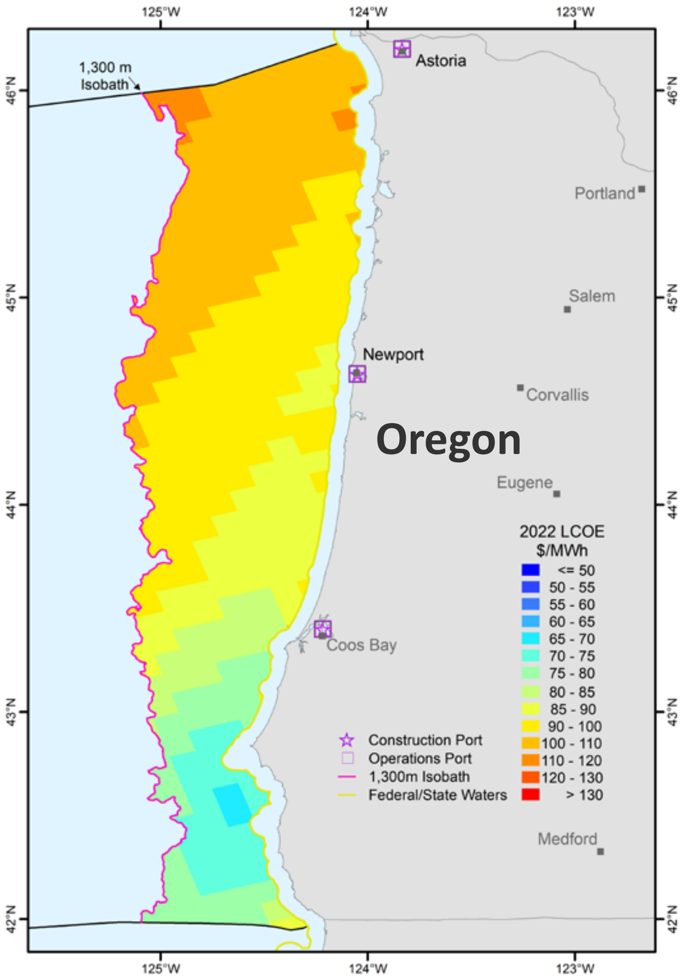


Image source: NREL

2027 Levelized Cost of Energy

- Market data suggest a big commercial upswing between 2023 and 2025.
- 12-MW wind turbines are assumed to be commercially available in 2025 based on turbine original equipment manufacturer announcements.
- 2027 is the year that early-stage commercial technology is expected globally, assuming a financial close in 2025.
- The early phases of global commercialization will have started, and this the earliest year technology could be available for Oregon markets.
- The LCOE gradient from north to south ranges from about **$87/MWh to $60/MWh**.[++]

[++] All LCOE values are in 2019 U.S. dollars.

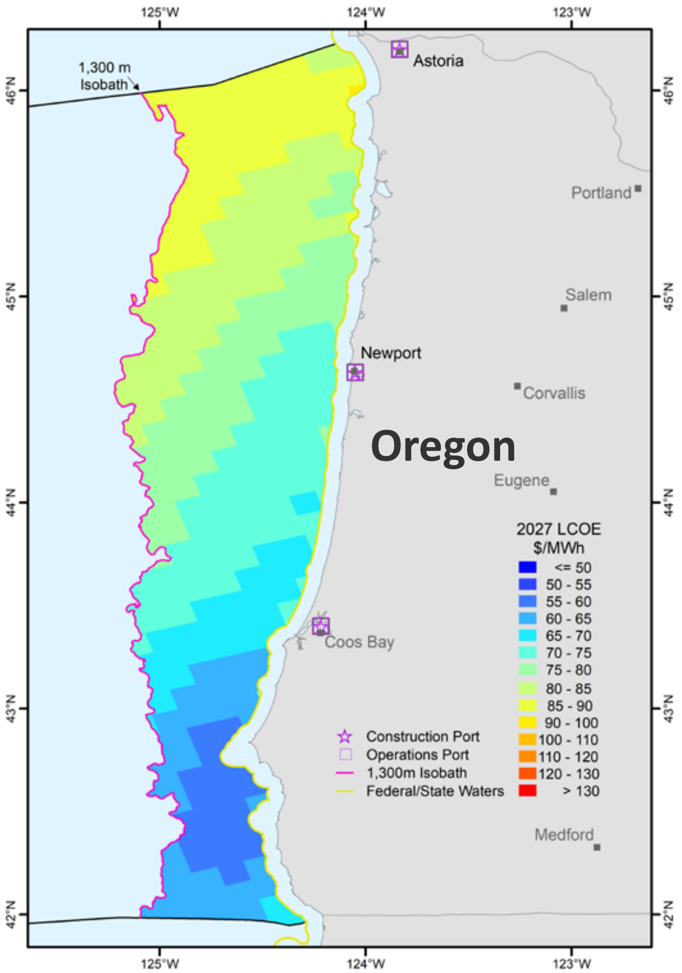


Image source: NREL

2032 Levelized Cost of Energy

- 2032 represents fully commercial technology available, assuming a financial close in 2030.
- 15-MW wind turbines are assumed to be available for deployment in 2030.
- Global technology will be commercially available, with the estimated floating market being about 8 GW.
- Some early-stage U.S. commercial projects may exist outside of Oregon (e.g., California, Maine).
- Oregon's supply chain and ports will need to be developed beforehand.
- The LCOE gradient from north to south ranges from about **$74/MWh to $51/MWh**.++

++ All LCOE values are in 2019 U.S. dollars.

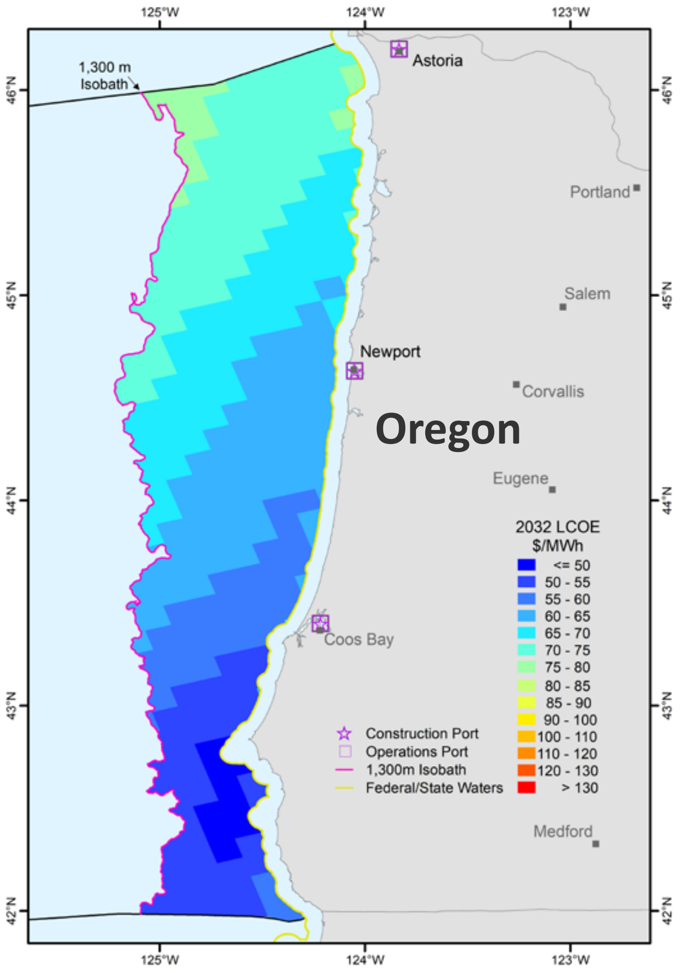


Image source: NREL

Possible Economic Benefits of Offshore Wind Energy in Oregon

- The development of offshore wind energy in Oregon would create a new, industrial economy comprising new ports and infrastructure for project construction, manufacturing, turbine assembly, and services.
- An electric grid study conducted by NREL in 2021 found that over 2,500 MW of offshore wind power could be installed without the need for major grid upgrades (Novacheck et al. 2021).
- 2,500 MW of offshore wind power would require revenues of $8–$10 billion, much of which would flow through the state's economy.
- 2,500 MW of offshore wind energy would generate enough electricity to power 1 million Oregon homes, significantly reducing the state's carbon footprint.

Comparison With Musial et al. (2019)

Musial, W., P. Beiter, J. Nunemaker, D. Heimiller, J. Ahmann, and J. Busch. 2019. *Oregon Offshore Wind Site Feasibility and Cost Study*. National Renewable Energy Laboratory (NREL). NREL/TP-5000-74597. https://www.nrel.gov/docs/fy20osti/74597.pdf.

Oregon Study Sites

- Costs were calculated at five study sites (see figure) presented in Musial et al. (2019):
  1. North
  2. North-central
  3. Central
  4. South-central
  5. South.
- Sites were selected to represent technically feasible wind energy locations distributed from north to south.
- All sites are at least 10 miles from shore but have not been vetted through a marine spatial planning process.
- LCOE data were extracted from the 2021 heat maps to compare with the 2019 study.

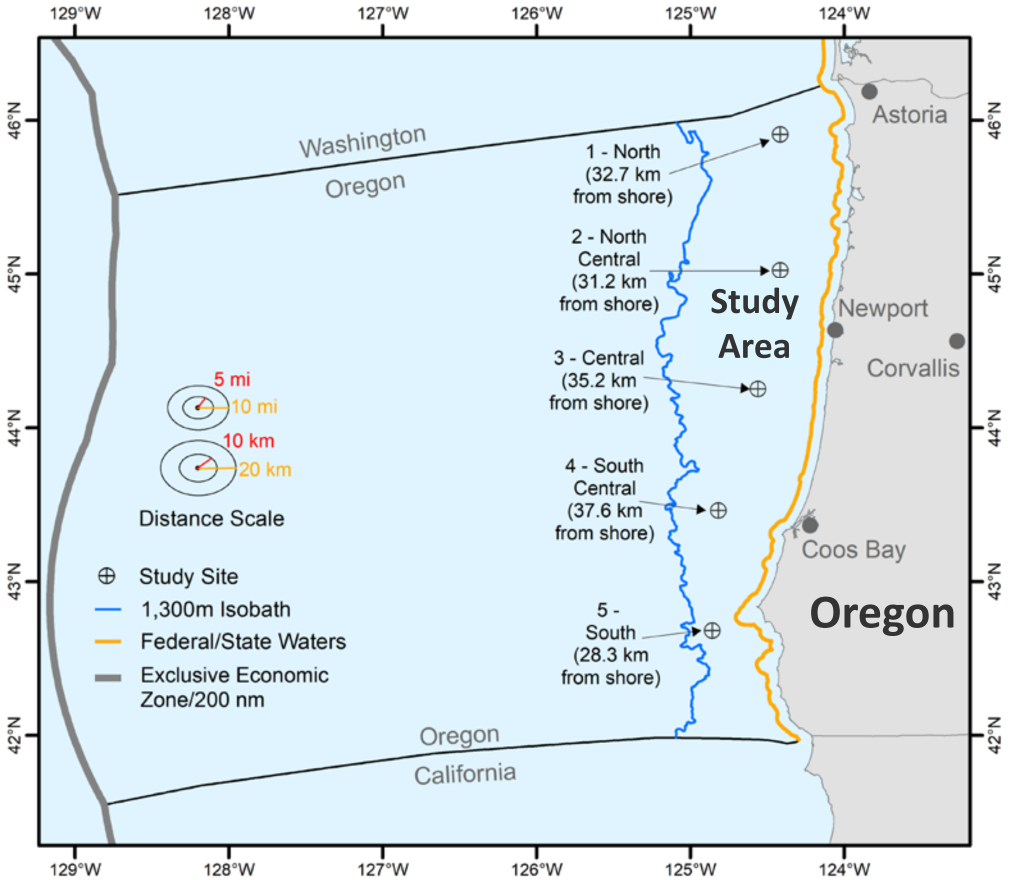


Image source: NREL

Summary of Key Updates to 2019 Cost Report

Modeling assumptions were updated to reflect industry and modeling advances.

Item	Current 2021 Study	Musial et al. (2019)
Plant Capacity	1,000 MW	600 MW
Reference Year Turbine Capacity	8 MW	6 MW
Onshore Spur Line Distance	3 km	0.6–5.4 km
Wake Modeling Code	FLORIS	Openwind
Study Area Boundaries	State borders, 3 nm to shore, max water depth of 1,300 m, mean wind speed of >7 m/s	State borders, 10 nm to shore, max water depth of 1,000 m, mean wind speed of >7 m/s
Wind Resource Data	OR-WA20 (NREL) update to WIND Toolkit	WIND Toolkit (Draxl et al. 2015)
Regional Labor Cost Multiplier	Excluded	Included
Cost Projection Methodology	Learning curve and turbine upscaling (Beiter et al. 2020)	Technology innovation (Hundleby et al. 2017)

Levelized Cost of Energy Comparisons: 2021 Update With 2019 Report

Study	COD	1. North	2. North-Central	3. Central	4. South-Central	5. South
2019 Study	2019	159	152	146	136	114
	2022	141	133	127	118	97
	2027	104	99	95	89	75
	2032	75	71	68	64	54

Study	COD	1. North	2. North-Central	3. Central	4. South-Central	5. South
2021 Update Study	2019	134	121	113	107	92
	2022	107	98	91	86	74
	2027	87	79	73	70	60
	2032	74	67	63	59	51

Note: all costs reported in 2019 U.S. dollars. (Results from 2019 study inflated from 2018 U.S. dollars.)

Levelized Cost of Energy Drivers: Comparing Updated Study to Musial et al. (2019)

Major Differences Between the Studies

- Higher wind speeds in the OR-WA20 resource data lead to larger NCFs and lower LCOEs in the current study.
- Higher losses were modeled in 2021 but were offset by stronger wind resources.
- Lower CapEx values in the updated 2021 study for a 2019 (COD) base year gave a lowered CapEx in future years.
  - Cost reductions in the base year were driven by a higher 2019 turbine capacity (6 MW versus 8 MW) and increased plant capacity (600 MW versus 1,000 MW).
  - By excluding the labor CapEx multiplier, the total CapEx was reduced by 3%–4%.
  - Modeling methodology estimates future costs using a learning curve (which is dependent on future market projections).
- Operating cost estimates were similar between the two studies.

Next Steps

- We will complete a grid study (Novacheck et al. 2021) to determine the impact of offshore wind energy on the transmission infrastructure of Oregon and investigate "no-wires" alternatives that may be possible from offshore wind in Oregon.
- A study is needed to locate a marshalling port that can be built or upgraded that is sufficient for floating offshore wind energy.
- Supply chain, workforce training, and employment impact analyses are needed to assess the economic benefits, costs, and advantages of Oregon offshore wind energy.

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Carpe Ventum!

Thank you

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NREL/PR-5000-80908

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of the Interior, Bureau of Ocean Energy Management, Pacific OCS Region, through Interagency Agreement M19PG00025 with the DOE National Renewable Energy Laboratory. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

NREL Transforming ENERGY

Supplemental Slides:
Additional Results at the Five Study Sites

Capital Expenditures (CapEx; $/kilowatt [kW])

Note: all costs reported in 2019 U.S. dollars. (Results from the 2019 study are inflated from 2018 U.S. dollars.)
Note: 2019 turbine size was increased for the 2021 update to 8 megawatts (MW).

Study	Commercial Operation Date (COD)	Site 1. North	Site 2. North-Central	Site 3. Central	Site 4. South-Central	Site 5. South
2019 Study	2019	5,298	5,295	5,332	5,348	5,268
	2022	4,488	4,483	4,525	4,538	4,458
	2027	3,884	3,879	3,921	3,924	3,855
	2032	2,967	2,963	3,003	2,991	2,943
2021 Update	2019	4,297	4,284	4,311	4,386	4,280
	2022	3,546	3,531	3,559	3,614	3,522
	2027	3,122	3,108	3,134	3,180	3,097
	2032	2,803	2,788	2,815	2,852	2,776

Operational Expenditures (OpEx; $/kW/year)

Note: all costs reported in 2019 U.S. dollars. (Results from the 2019 study are inflated from 2018 U.S. dollars.)

Study	COD	Site 1. North	Site 2. North-Central	Site 3. Central	Site 4. South-Central	Site 5. South
2019 Study	2019	129	129	128	131	135
	2022	91	91	91	92	93
	2027	76	76	76	77	80
	2032	53	53	53	53	55
2021 Update	2019	114	114	112	115	119
	2022	93	92	91	93	97
	2027	67	67	66	67	70
	2032	52	52	52	53	55

Net Capacity Factor (%)

Study	COD	Site 1. North	Site 2. North-Central	Site 3. Central	Site 4. South-Central	Site 5. South
2019 Study	2019	36	38	40	43	51
	2022	36	38	40	43	52
	2027	38	40	42	46	53
	2032	40	42	44	47	55
2021 Update	2019	36	40	43	46	53
	2022	37	40	44	47	54
	2027	38	42	45	49	56
	2032	39	43	46	50	57

Differences in Spatial Parameters Between the 2019 Study (Musial et al. 2019) and this 2021 Updated Study

Parameter	Distance (kilometers [km]) Construction Port		Distance (km) Operations port		Distance (km) Land-Based Spur Line		Distance (km) Export Cable		Mean Wind Speed (meters per second [m/s]) at 120 meters (m)		Significant Wave Height Average (m)		Water Depth (m)	
Source	2021 Update	2019 Study	2021 Update	2019 Study	2021 Update	2019 Study	2021 Update	2019 Study	2021 Update	2019 Study	2021 Update	2019 Study	2021 Update	2019 Study
1. North	55.6	55.2	55.6	61.9	3	1	33.2	35.8	8.1	8.1	2.58	2.52	147.3	147.7
2. North-Central	52.7	52.3	52.7	54.9	3	0.6	30.9	32.2	8.6	8.3	2.58	2.53	279.3	279.3
3. Central	58.6	58.2	58.6	58.2	3	5.4	35.0	48.4	9.0	8.5	2.53	2.52	100.8	100.8
4. South-Central	49.1	48.7	49.1	57.4	3	1	37.8	44	9.6	9.0	2.61	2.57	594.6	594.7
5. South	95.7	95.4	95.7	95.4	3	1.4	28.5	33	11.0	10.2	2.62	2.58	601.7	601.7

Site	**Port (Construction and O&M)**
1-North	Astoria
2-N Central	Newport
3-Central	Newport
4-S Central	North Bend
5-South	North Bend

What Drives Capital Expenditure Differences Between Study Sites in the 2021 Study?

- Installation costs: distance to construction port and depth

Reference Site	Installed CapEx	Distance from Port to Shore (km)	Depth (m)
1. North	278	55.6	147
2. North-Central	271	52.7	279
3. Central	281	58.6	101
4. South-Central	275	49.1	595
5. South	259	95.6	602

- Array cable and export cable costs: Distance to point of interconnect (POI) (cable lengths based on straight line distance)

Reference Site	Export Cable CapEx ($/kW)	Distance to POI (km)	Array Cable CapEx ($/kW)	Depth (m)
1. North	387	33.2	208	147
2. North-Central	370	30.9	222	279
3. Central	400	35.0	202	101
4. South-Central	418	37.8	254	595
5. South	352	28.5	254	602

What Drives Operation and Maintenance (O&M) Cost Differences Between Study Sites?

Geospatial cost variations in OpEx between the sites from Musial et al. (2019) are primarily driven by distance from site to O&M port and wave regime (i.e., significant wave height and weather windows).

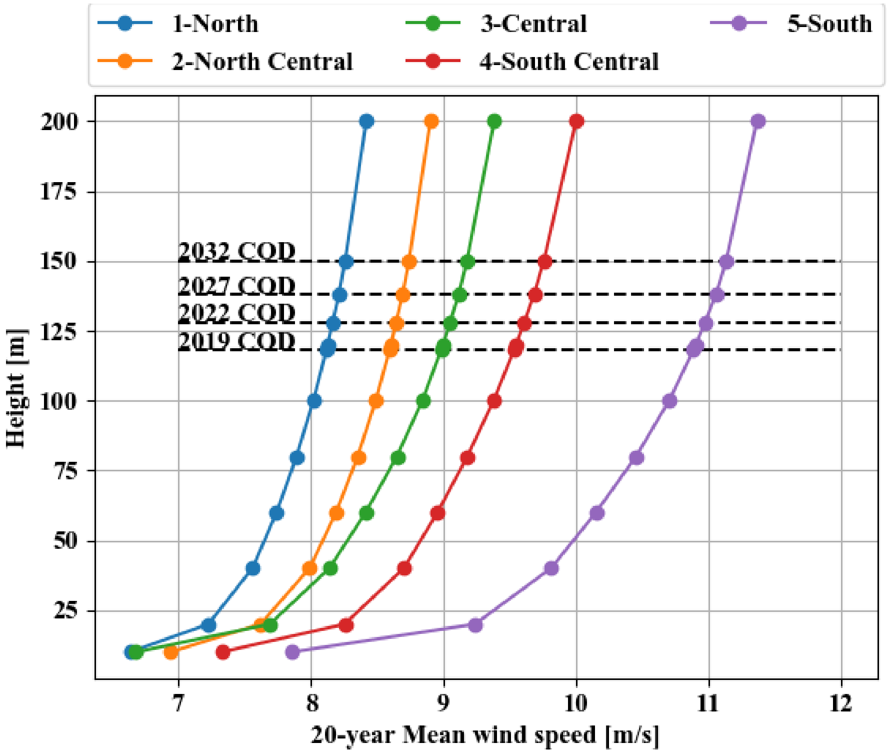
Average Maintenance Cost Across Each Reference Site

Site	Maintenance Cost ($/kW)	Distance Operations Port to Site (km)	Average Significant Wave Height (m)
1. North	85	55.6	2.58
2. North-Central	85	52.7	2.58
3. Central	83	58.6	2.53
4. South-Central	86	49.1	2.61
5. South	90	95.7	2.63

Wind Resource Characterization at the Five Oregon Study Sites

Oregon Offshore Vertical Wind Shear

- The heights at each of the five reference site centroids are shown.
- All profiles use the new, 20-year OR-WA20 data set.
- The hub heights and turbine sizes assumed for each COD year are:
  - 2019: 118 m for 8 MW
  - 2022: 128 m for 10 MW
  - 2027: 138 m for 12 MW
  - 2032: 150 m for 15 MW.
- There is a stronger vertical wind shear in the south.



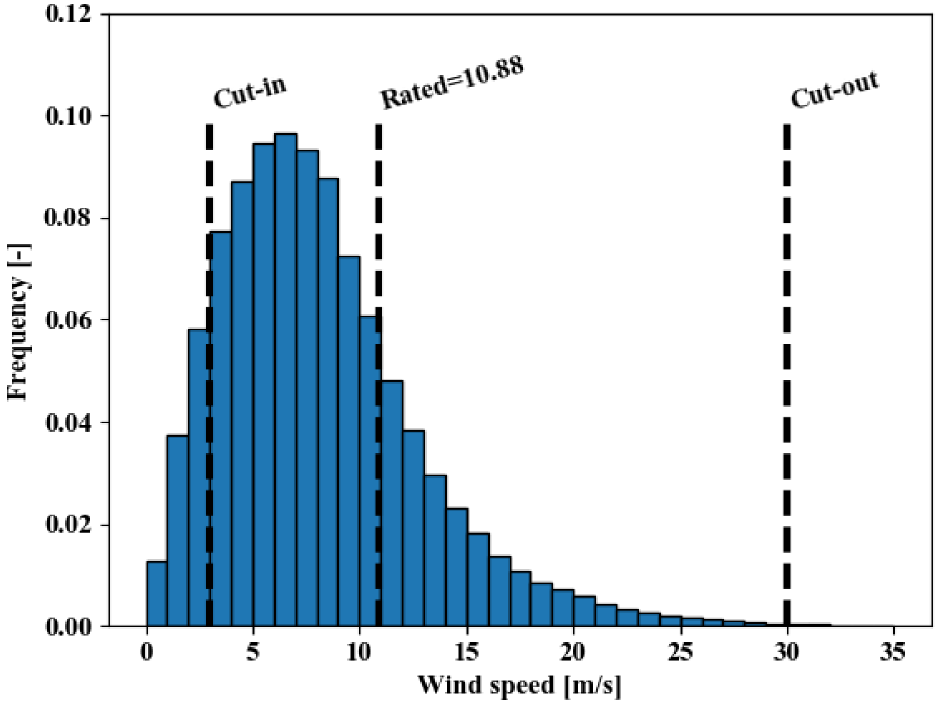
Vertical wind shear was modeled for five study sites in Oregon

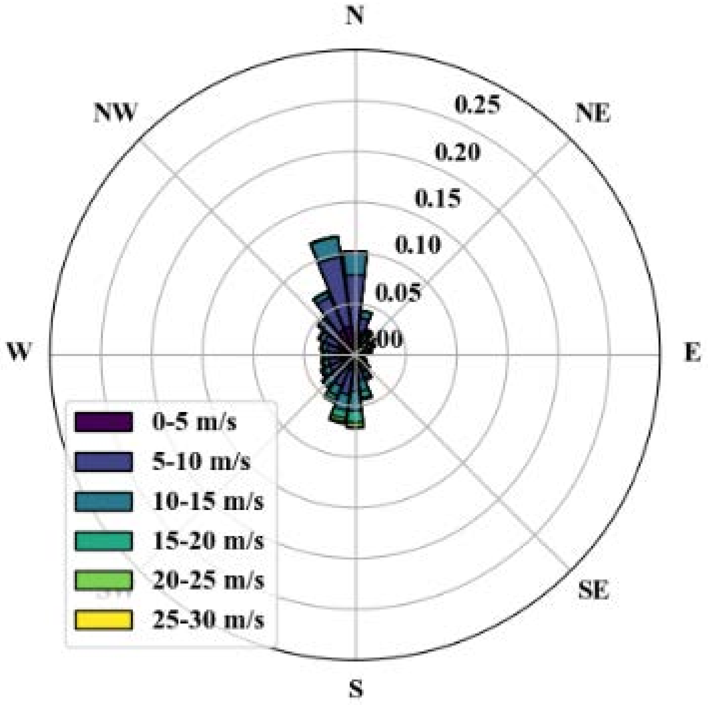
Wind Distributions and Wind Roses

- Wind speed distributions and wind roses were plotted (see next five slides) for the centroids at each reference location (sites 1–5) shown on the maps.
- All distributions use the new, 20-year OR-WA20 data set at 120 m above the surface.
- Wind directions are relatively consistent from the north and the south.

Site 1. North

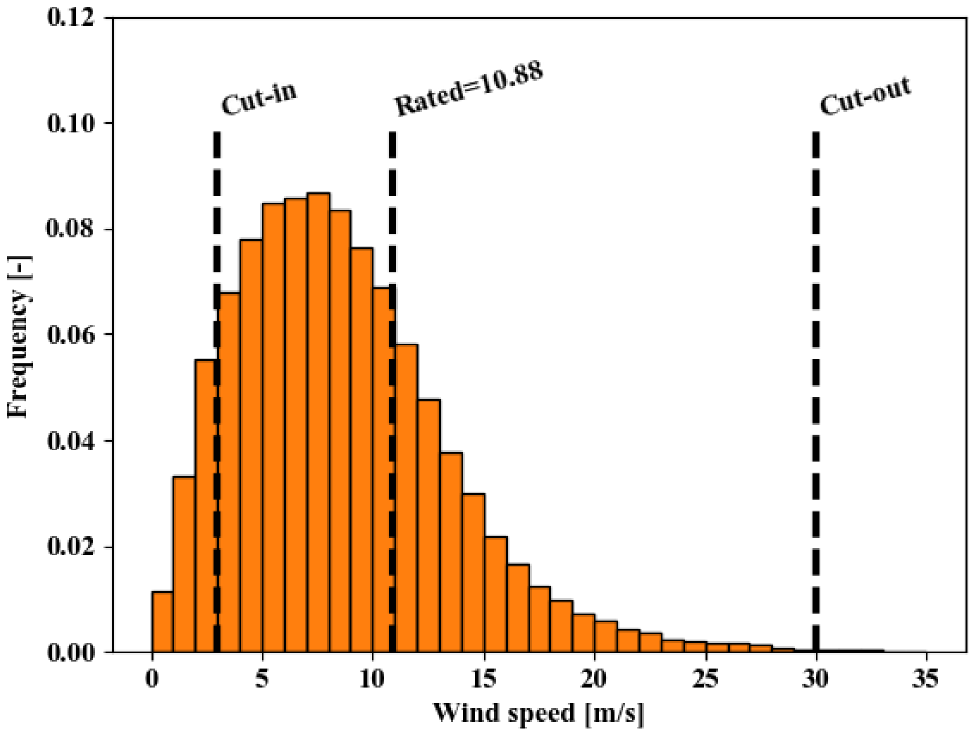
The 120-m wind resources are shown at the site centroid over a 20-year period.

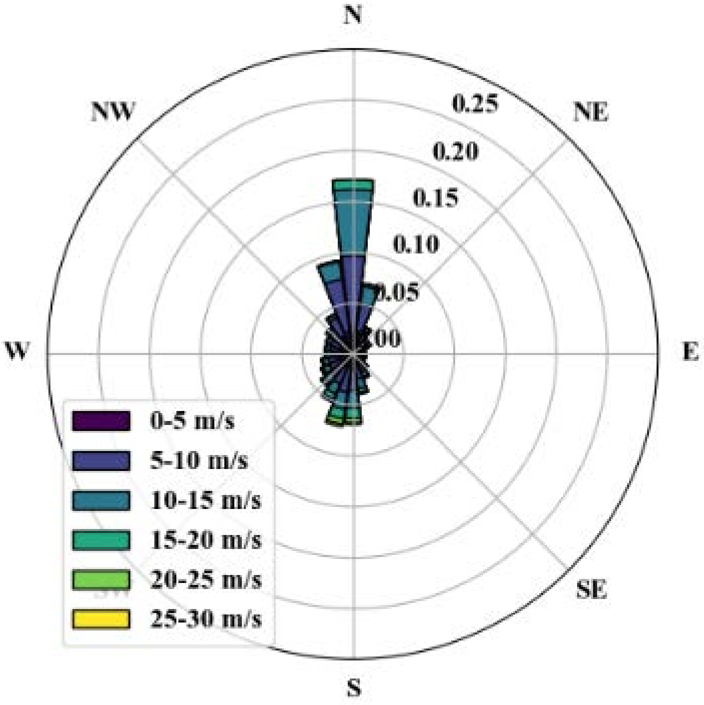




Site 2. North-Central

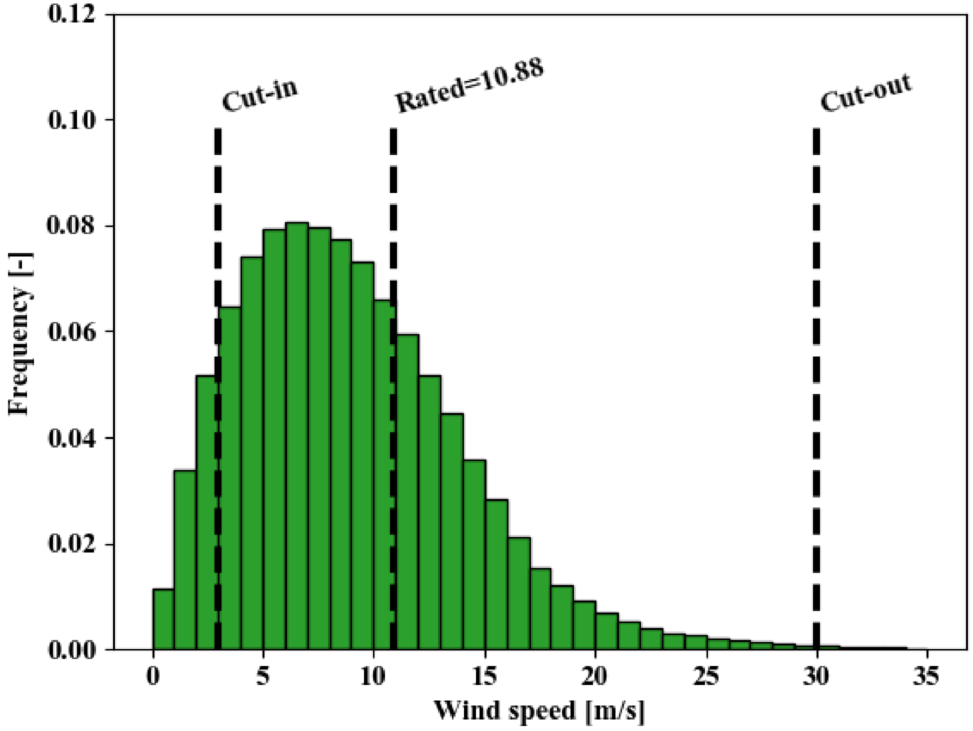
The 120-m wind resources are shown at the site centroid over a 20-year period.

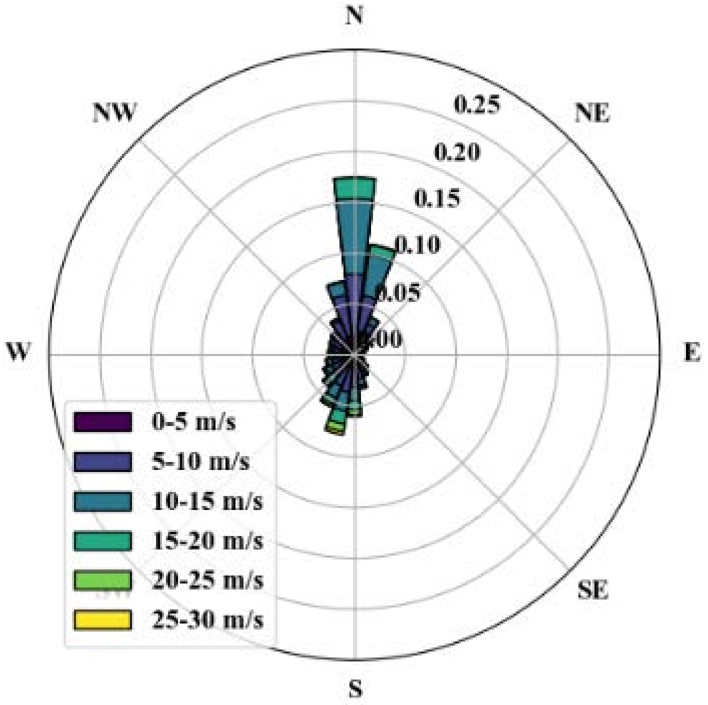




Site 3. Central

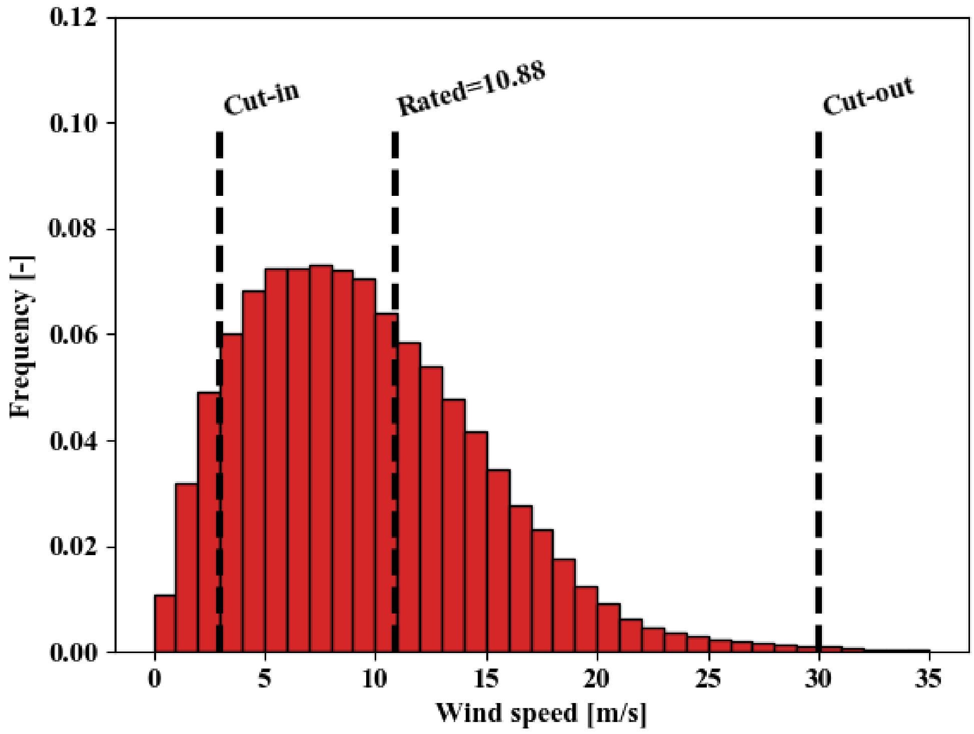
The 120-m wind resources are shown at the site centroid over a 20-year period.

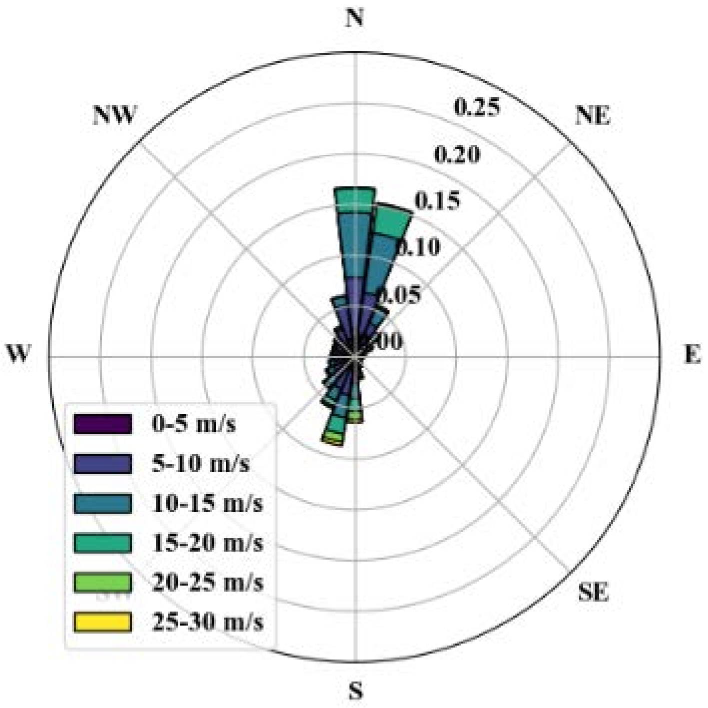




Site 4. South-Central

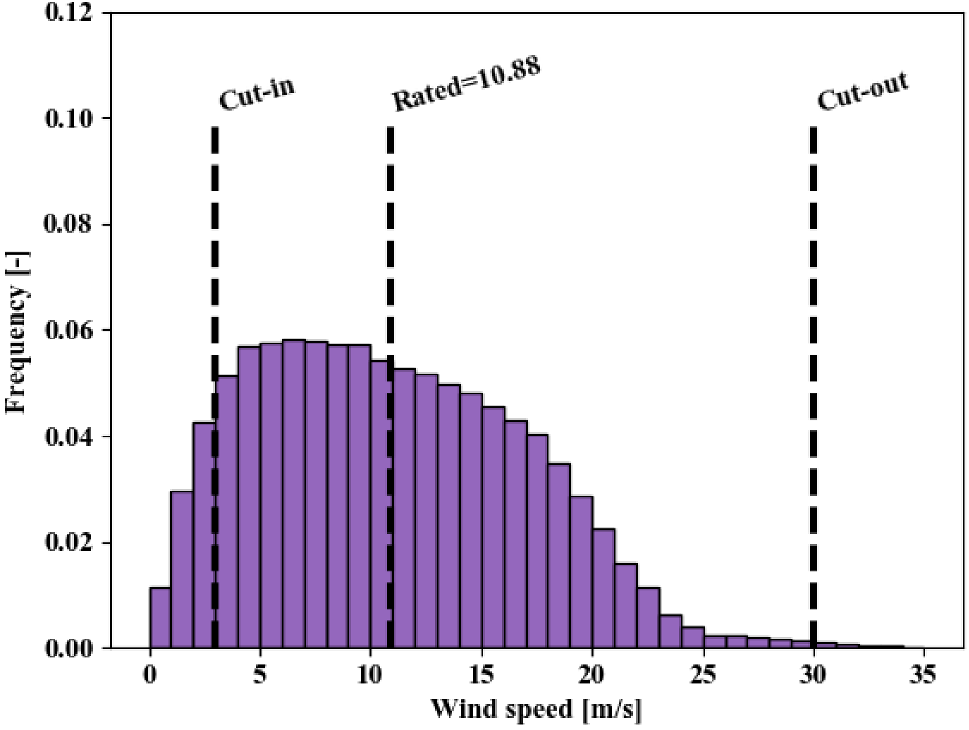
The 120-m wind resources are shown at the site centroid over a 20-year period.

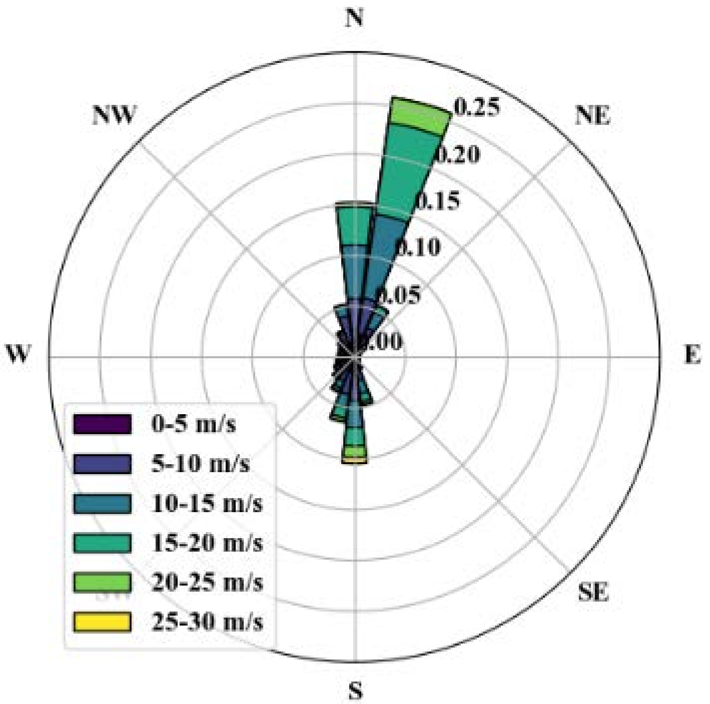




Site 5. South

The 120-m wind resources are shown at the site centroid over a 20-year period.



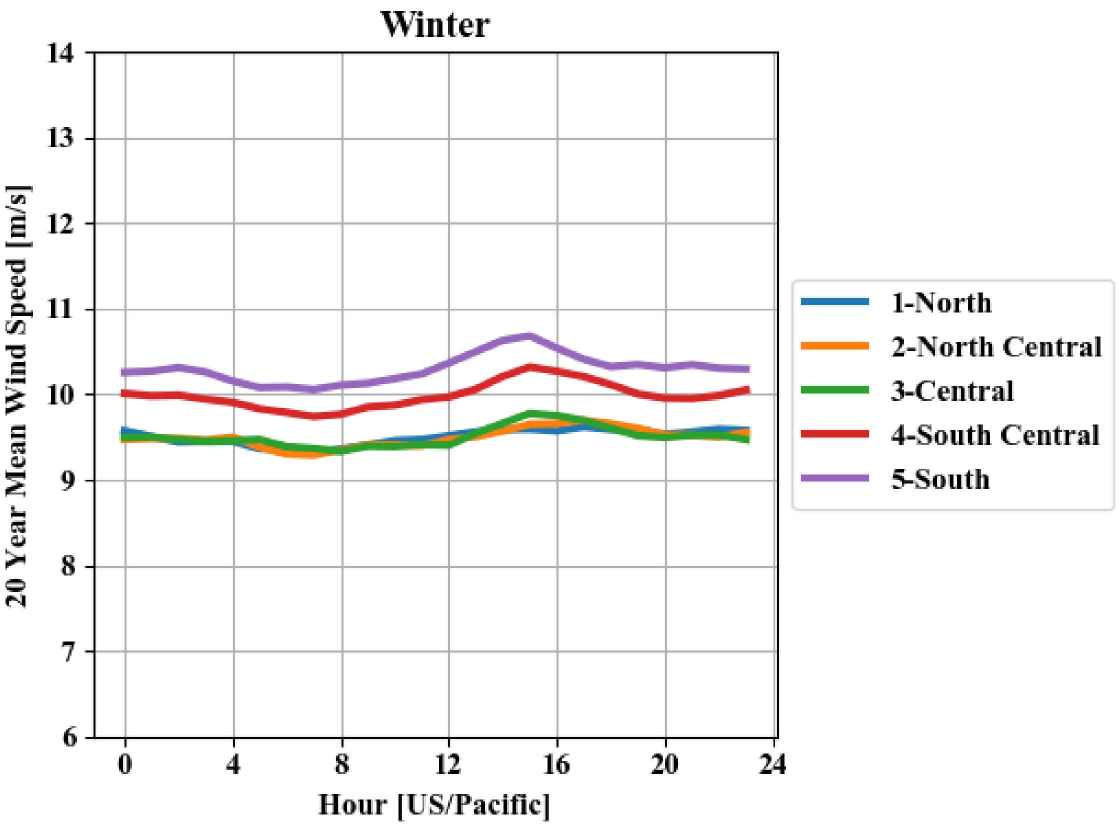


Diurnal and Seasonal Wind Resource Data

- The diurnal characteristics of the offshore wind resources are important for estimating the compatibility of offshore wind energy to serve the load.
- Although solar power currently represents a small portion of Oregon's in-state power generation, offshore wind energy is compatible with solar resources because it peaks in the evening when solar is not generating.
- Summer winds are much stronger in the southern parts of the state.

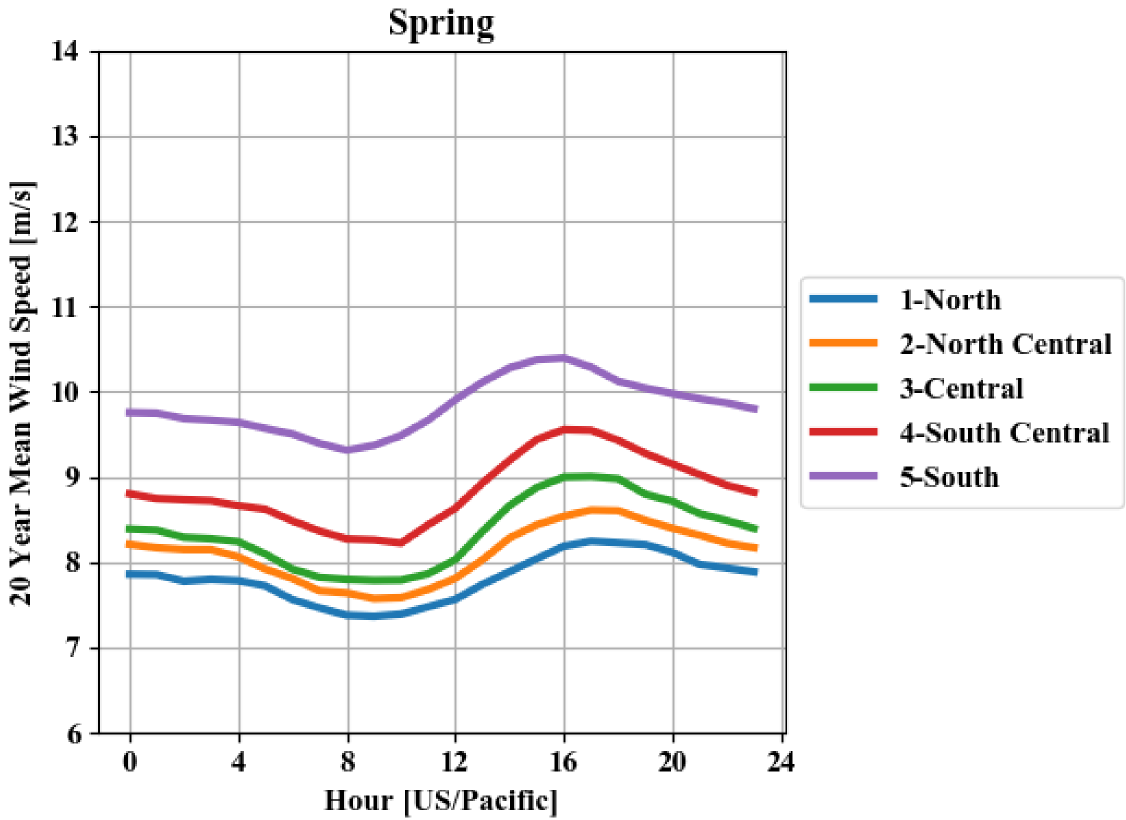
Seasonal Diurnal Profiles

The 120-m wind resources are shown at the site centroid over a 20-year period.



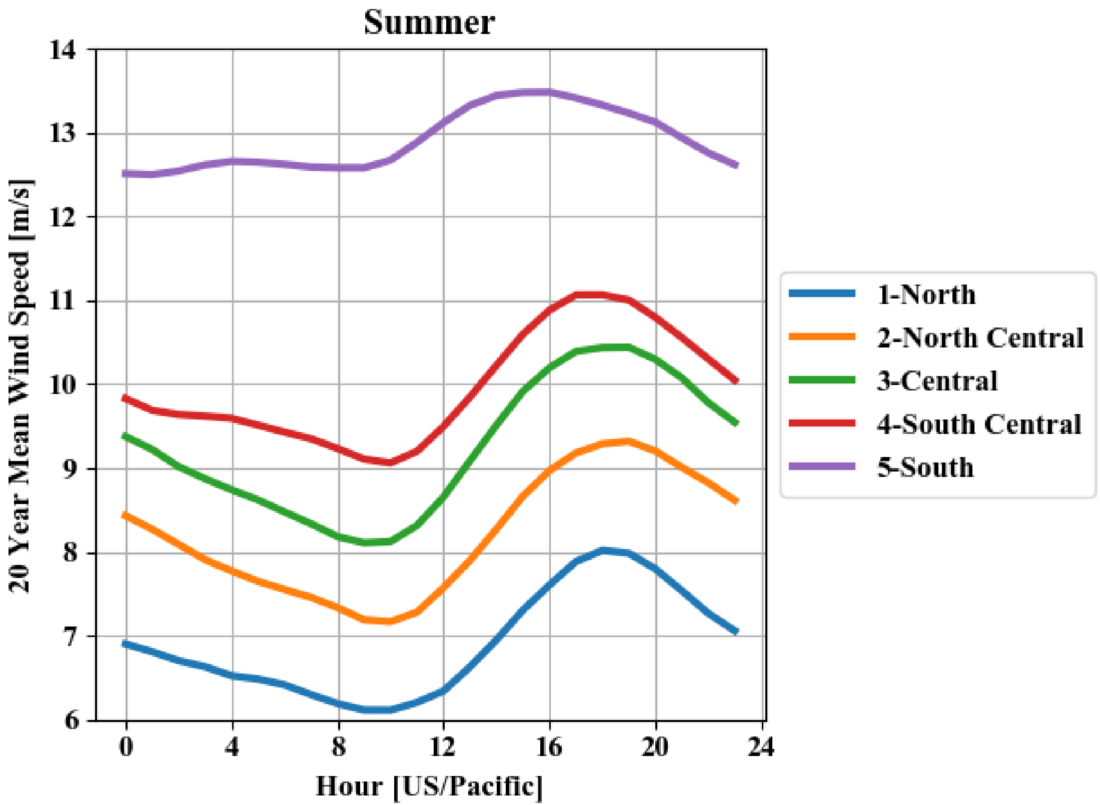
Seasonal Diurnal Profiles

The 120-m wind resources are shown at the site centroid over a 20-year period.



Seasonal Diurnal Profiles

The 120-m wind resources are shown at the site centroid over a 20-year period.



Seasonal Diurnal Profiles

The 120-m wind resources are shown at the site centroid over a 20-year period.