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December 5, 2017

MEMORANDUM

TO: **Power Committee**

FROM: **Gillian Charles, Mike Starrett**

SUBJECT: **Update on ocean energy resources action items and analysis of offshore wind**

BACKGROUND:

Presenter: Gillian Charles, Mike Starrett

Summary: The Seventh Power Plan identified ocean energy (namely offshore wind, wave, and tidal) as a suite of emerging technologies that has potential in the future Northwest power system.

The action plan identified two action items where further work could be done to explore and analyze ocean energy resources further. Action item ANLYS-14 directs Council staff to monitor and track development, costs, potential, significant milestones, early demonstration projects and commercial deployments of emerging technologies inclusive of ocean energy as well as other technology types. Action Item ANLYS-15 directs Council staff to further explore the potential specifically of ocean energy development in the region.

Staff will present an update on the action items, as well as a technical analysis of offshore wind and its potential in the Pacific Northwest.

Relevance: Fulfilling Seventh Power Plan action items; Prepping for the development of the Eighth Power Plan

Workplan: Power Division A.4.3 – Implement Seventh Power Plan and related Council priorities – Generation Resources

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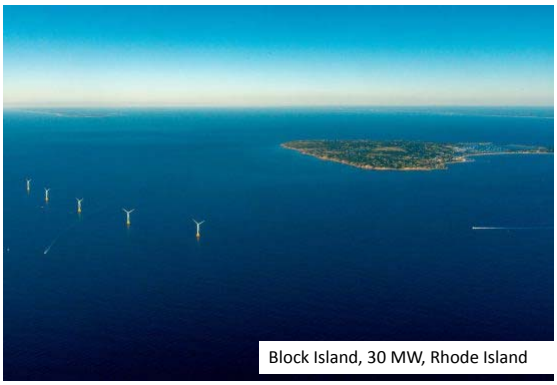
Update on Ocean Energy Resources: Action Items and Analysis of Offshore Wind

Power Committee

December 12, 2017

Northwest Power and Conservation Council



Block Island, 30 MW, Rhode Island

Seventh Power Plan and Action Items

OCEAN ENERGY RESOURCES AS EMERGING TECHNOLOGIES

Northwest Power and Conservation Council

Treatment of Emerging Tech in Seventh Plan

- Resources that may have long term potential in the PNW, but are not yet commercially available or deployable on a large scale at the beginning of the power planning period
- Qualitative assessment of technology
- "Maximum carbon reduction – Emerging Tech" scenario for the draft Seventh Plan
  - No new gas, based on availability/potential rather than least cost

Seventh Power Plan Resources

Primary	Secondary	Long-Term/Emerging
Natural Gas Combined Cycle	Biogas (landfill, wastewater treatment, animal waste, etc.)	Enhanced Geothermal Systems (EGS)
Natural Gas Simple Cycle (aero, frame)	Biomass – woody residues	Offshore Wind
Natural Gas Reciprocating Engine	Conventional Geothermal	Small Modular Reactors (SMR)
Onshore Wind (Gorge and MT)	Hydropower (New)	Storage Technologies*
Solar PV	Hydropower (upgrades to existing)	Tidal Energy
	Storage Technologies*	Wave Energy
	Waste Heat Recovery and Combined Heat and Power (CHP)	

* Energy storage comprises many technologies at various stages of development and availability

Action Item ANLYS-14

Monitor and track progress on the emerging technologies that hold potential in the future PNW power system.

Track significant milestones in development, cost and technology trends, lifecycles, potential assessments, and early demonstration and commercial projects.

Prep for the Eighth Power Plan

Progress so far…

- Council and GRAC have had series of presentations and discussions on emerging technologies
  - **Enhanced Geothermal Systems** (EGS) - tour of Newberry volcano site and AltaRock/PNNL presentation
  - **Small Modular Reactor** (SMR) presentation from NuScale/Energy Northwest and tour of NuScale facility and demo
  - **Energy storage** – various panels and presentations; tour of PGE's smart center 5MW battery; white paper
    - **Pumped storage** – several project-specific presentations
  - **Ocean Energy** – panel presentation to Council, tour of OSU's wave energy test facility

Action Item ANLYS-15

Scope and identify ocean energy technologies and potential in the region, determine cost-effectiveness, and develop a road map w/ specific actionable items the region could collaborate on *should* development be pursued.

Initial Council Priority

a) Scope emerging ocean technologies and identify cost and realistic potential in the region

b) Develop set of regional priorities and action items needed *should* development be pursued

c) Foster coordination of utility efforts and investments in ocean energy

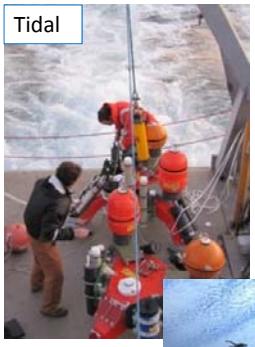
GRAC work session

GRAC Workshop: Ocean Energy

- Held afternoon workshop on ocean energy as part of November 2 GRAC meeting
- Heard about industry updates from Pacific Ocean Energy Trust (POET)
- Facilitated discussions between GRAC members and ocean energy industry stakeholders
  - Beyond the facts → "what ifs" and "if so, how"

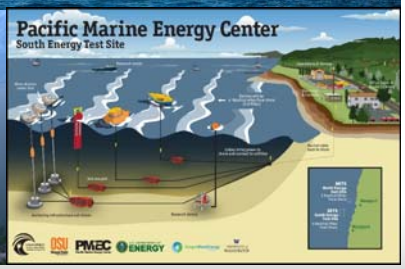
Types* of Ocean Energy

Tidal



Offshore wind

Wave

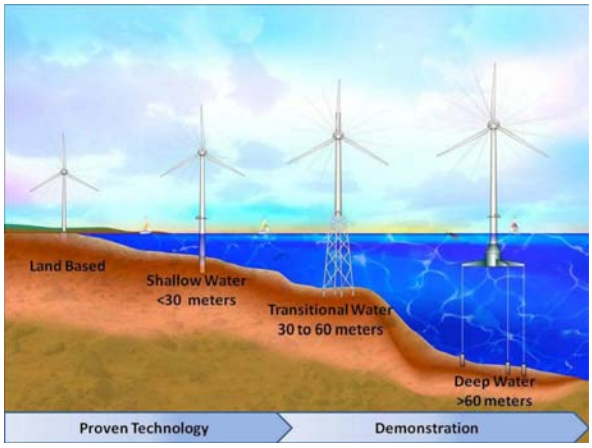


*Potentially reasonable/viable in the Pacific Northwest

Outcomes

- Council staff to continue monitoring progress of ocean energy resources, in particular offshore wind, in preparation for the Eighth Power Plan
- Council staff to participate in a BOEM*/NREL study on economics of floating offshore wind in Oregon
- GRAC members interested in continuing the development discussion directed to POET; POET will convene discussions/meetings
- Action item ANLYS-15: completed

*Bureau of Ocean Energy Management

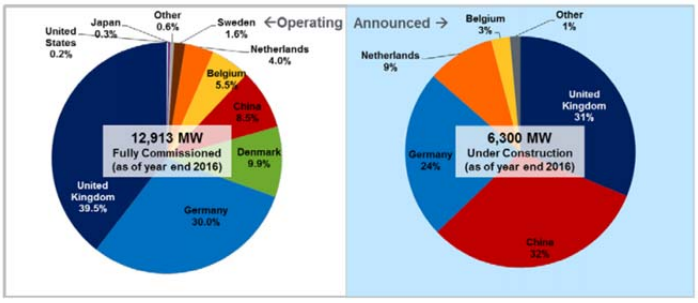


Cost, Potential, Development

OFFSHORE WIND

Global Picture of Offshore Wind

- 111 Offshore Wind projects, ~13 GW



Recent Commissioning:

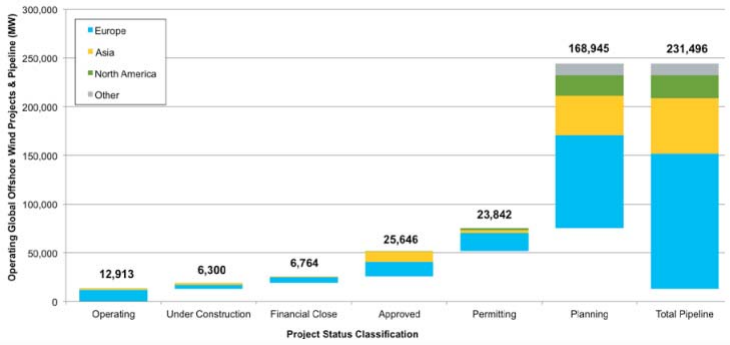
- 4 GW in 2015
- 1.2 GW in 2016

Primarily fixed bottom located in shallower waters in Europe

https://energy.gov/sites/prod/files/2017/08/f35/2016%20Offshore%20Wind%20Technologies%20Market%20Report.pdf

Global Pipeline of Offshore Wind

- Global pipeline shows active development



https://energy.gov/sites/prod/files/2017/08/f35/2016%20Offshore%20Wind%20Technologies%20Market%20Report.pdf

Costs of Offshore Wind

- Past project prices difficult to distill
- Summer 2017 U.K. Auction in deeper waters (but still fixed-base):

2021-2023
850 MW at 100 $US/MWh
(Triton Knoll from INNOGY/STATKRAFT)

2022-2023
2.3 GW at 75 $US/MWh
(1.4 GW Hornsea Two from DONG & 950 MW Moray Offshore Windfarm (East) from EDPR/Engie)

- Shallow water projects are even lower

2020
450 MW at 70 $US/MWh
(Vattenfall)

Global Picture of Offshore Wind

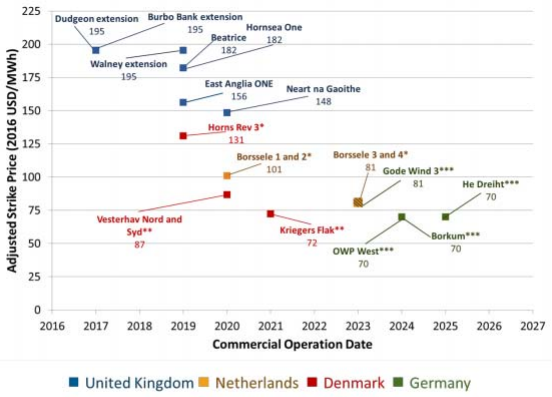


Figure 16. Adjusted strike prices from European offshore wind auctions

Sources: Garlick et al. (2017) and NREL analysis

Notes: *Grid and development costs added; **Grid costs added and contract length adjusted; ***Development costs added[55]

https://energy.gov/sites/prod/files/2017/08/f35/2016%20Offshore%20Wind%20Technologies%20Market%20Report.pdf

U.S. Offshore Wind Development

- **Rhode Island:** 30 MW "Block Island" Offshore Wind c0mmissioned December 2016 with a PPA of **244 2016$/MWh**
- **Massachusetts:** 400 MW RFP Issued in Summer 2017
- Many other North East States have set policies to encourage offshore wind

Block Island Wind Farm

U.S. Offshore Wind Potential

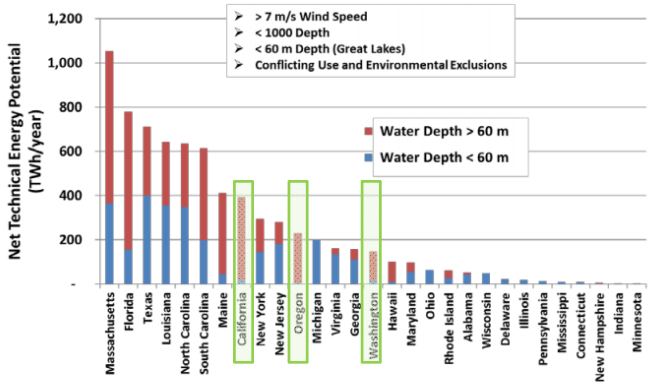


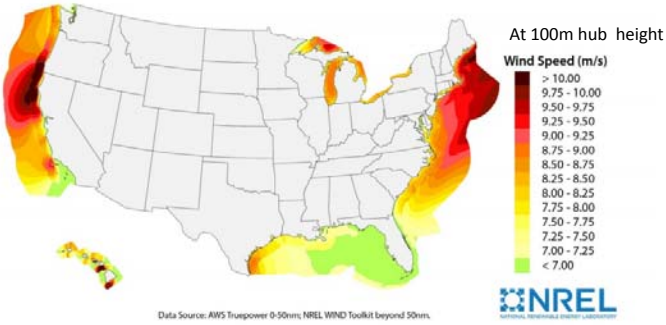
Figure ES-4. Offshore wind net technical energy potential (7,203 TWh/year) by state for depths of more than and less than 60 m

Pacific Offshore Wind would Likely Need to be Floating

- In US, about 58% of resource potential is offshore depths greater than 60 meters
- In Pacific, that jumps to 90%

https://www.nrel.gov/docs/fy16osti/66599.pdf

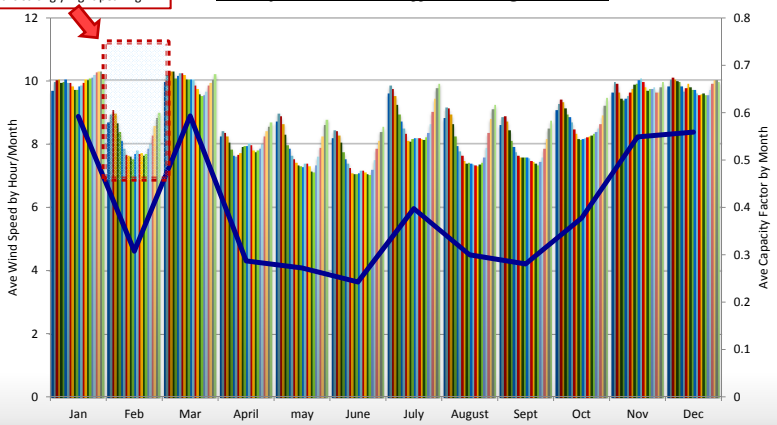
U.S. Offshore Wind Potential



Seasonal & Hourly Offshore Wind Data

- Colored bar groups show hours 0-24 for each month
- *Ex.* Feb is strongly night peaking

Example wind site off the Oregon Coast



Data source: Principle Power

Seasonal & Hourly Offshore Wind Data

- California Sites: Summer evening peaking

Monthly Average:

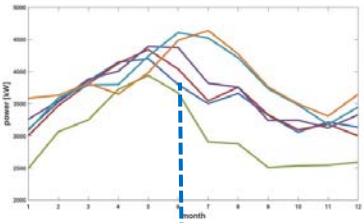


Figure 18. Average monthly power output for a single 6-MW offshore wind turbine at six California offshore reference sites (starting with month 1 [January])[34]

June

Hourly Output in March:

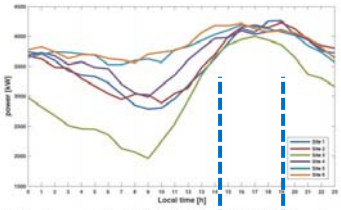


Figure 17. Diurnal power output for a single 6-MW offshore wind turbine in the sample month of March

2PM 6PM

https://www.boem.gov/2016-074/

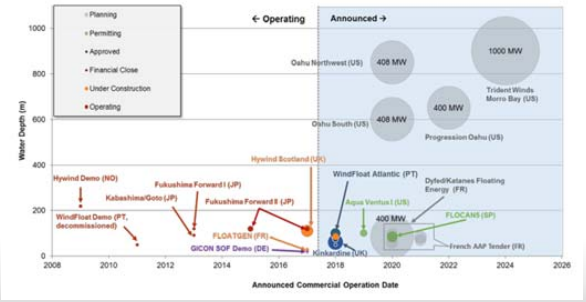
Floating Offshore Wind

Statoil Spar Buoy

Principle Power WindFloat semi-submersible

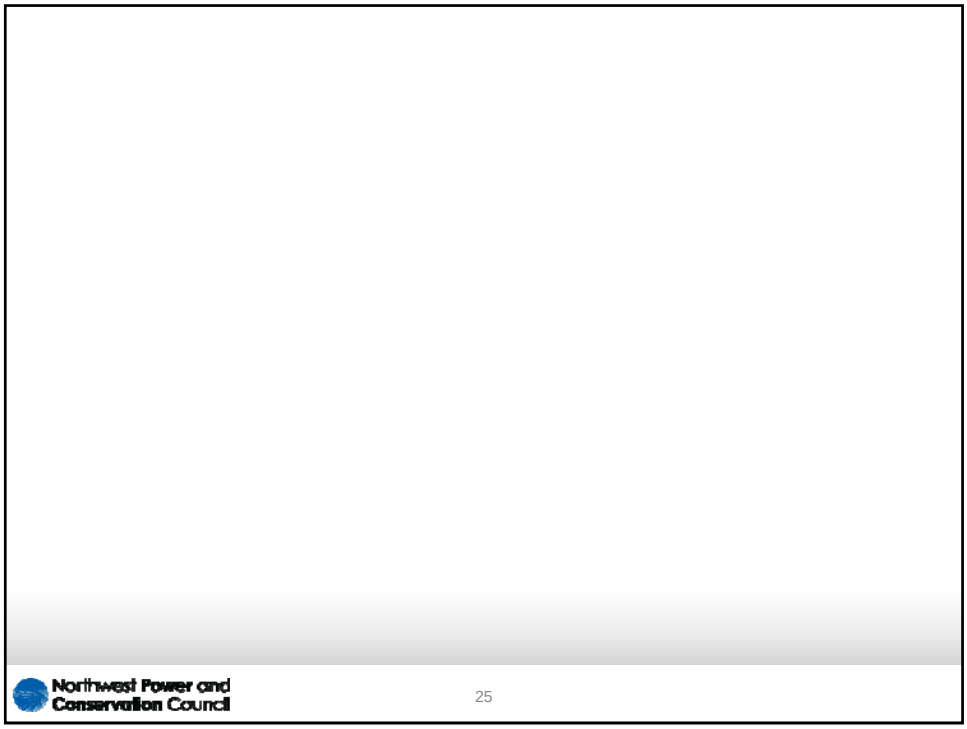
Much less global experience with **Floating** Offshore Wind

- Several single turbine pilots have been completed
- First array just went live (30 MW by Statoil)



Floating Offshore Wind Price Forecast

- Council staff has been working with GRAC and we are not ready to make forecast for floating offshore wind costs
  - Eighth Power Plan
- Will continue to track development and determine all-in cost of development and transmission before subsidies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