NREL
NATIONAL RENEWABLE ENERGY LABORATORY

SEPTEMBER 18-19, 2018
Ocean Renewable Energy Conference
LEADERSHIP. EXPERIENCE. SOLUTIONS
LEFTBANK ANNEX PORTLAND, OREGON





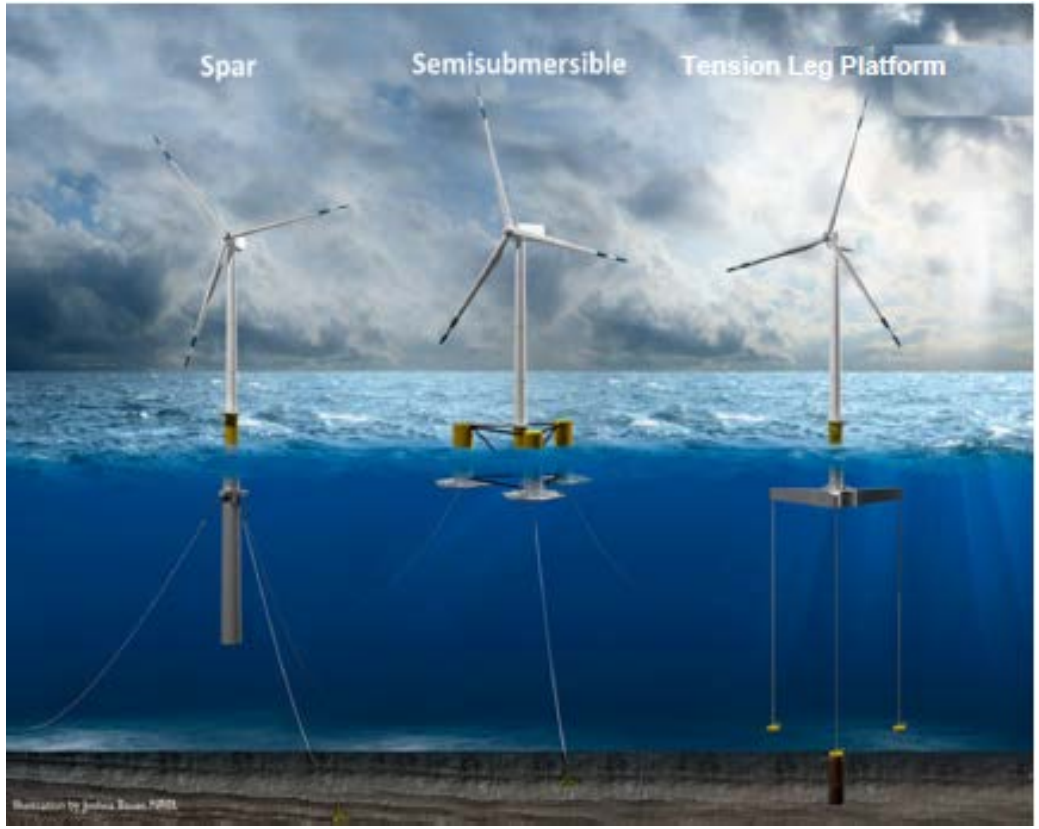
Floating Offshore Wind: State of the Technologies

Amy Robertson
Senior Engineer
National Renewable Energy Laboratory

September 19, 2018

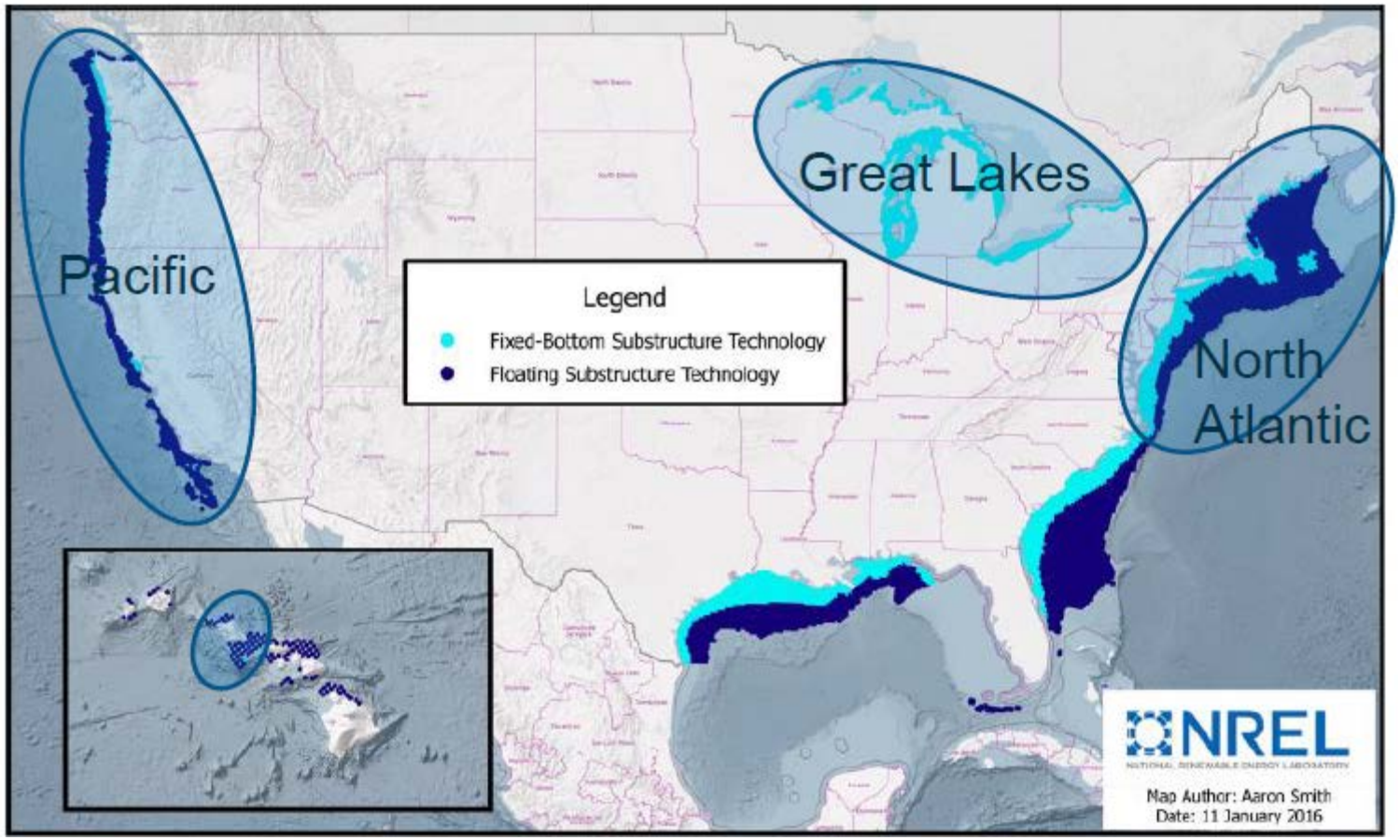
Floating Offshore Wind Technology Introduction

- 58% of the US technical offshore wind resource is too deep for conventional fixed bottom offshore wind
- Floating wind is in pre-commercial stage
- Variations of three principal archetypes comprise most design concepts but optimization strategies have not yet been implemented
- Floating wind are less constrained by water depth and show promise as an equal alternative to fixed bottom structure in areas with suitable resource



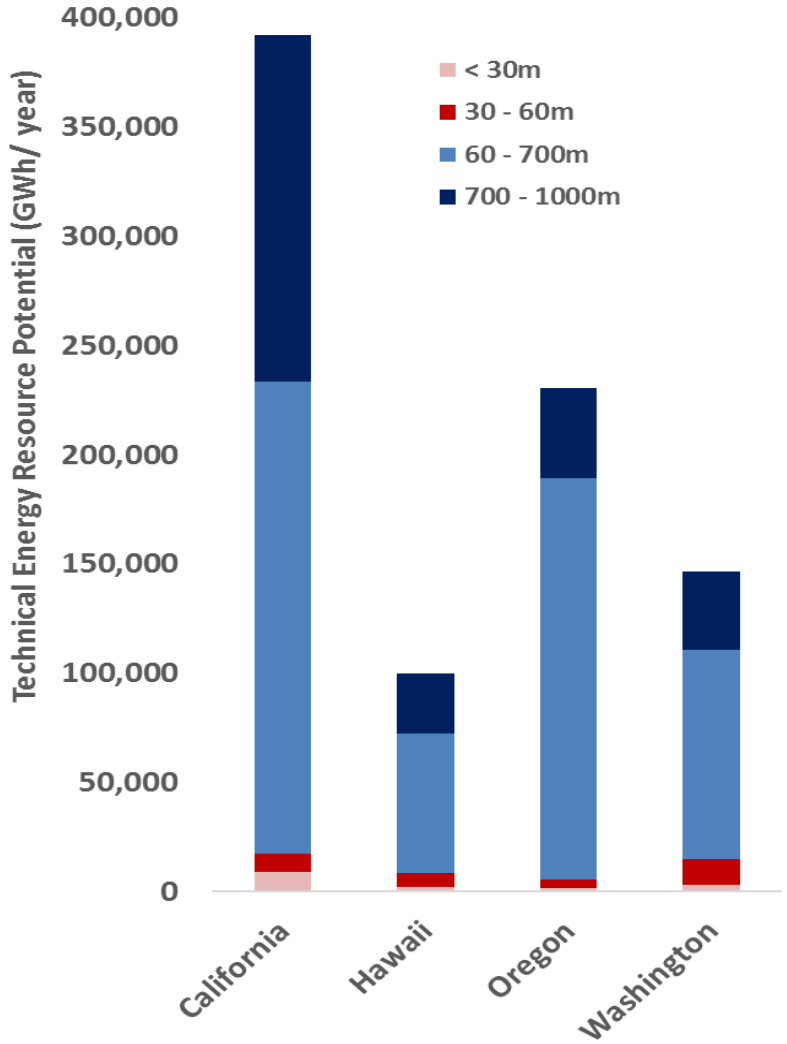
Three floating offshore wind energy platform archetypes derived from oil and gas experience (spar, semisubmersible, tension leg platform) guide the development of the next generation of optimized floating wind energy systems.

Floating Offshore Wind Technology: Floating Regions



58% of the U.S. offshore wind resource is in water depths > 60m - floating foundations

Pacific Regions: Deep Water Energy Resource



Offshore Wind Resource for Pacific States

- 868 TWh/year total offshore wind technical energy resource
- 95% of the resource (823 TWh/year) is in water deeper than 60 m
- <u>Key technology challenges:</u>
  - ❑ Minimizing visual impacts while remaining in waters below 1000 meters depth: project sites may be limited to water depths 500 to 1000 m
  - ❑ High wave climate may require enhanced O&M strategies to increase accessibility

Data Source: Musial, W. et al. ***2016 Offshore Wind Energy Resource Assessment for the United States***. NREL/TP-5000-66599. http://www.nrel.gov/docs/fy16osti/66599.pdf

Floating Wind Industry: Progress Toward Commercialization

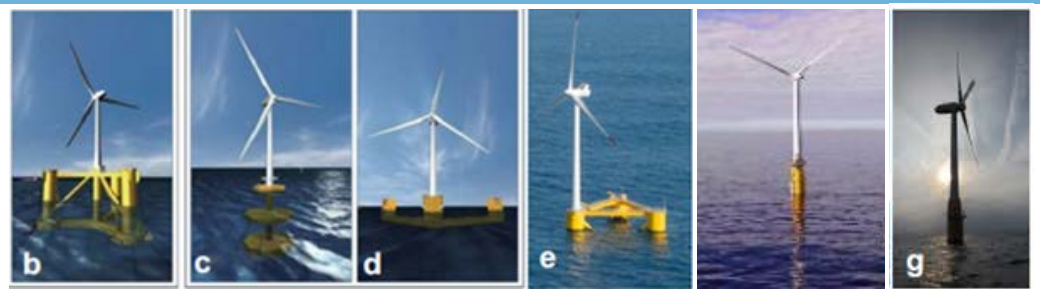


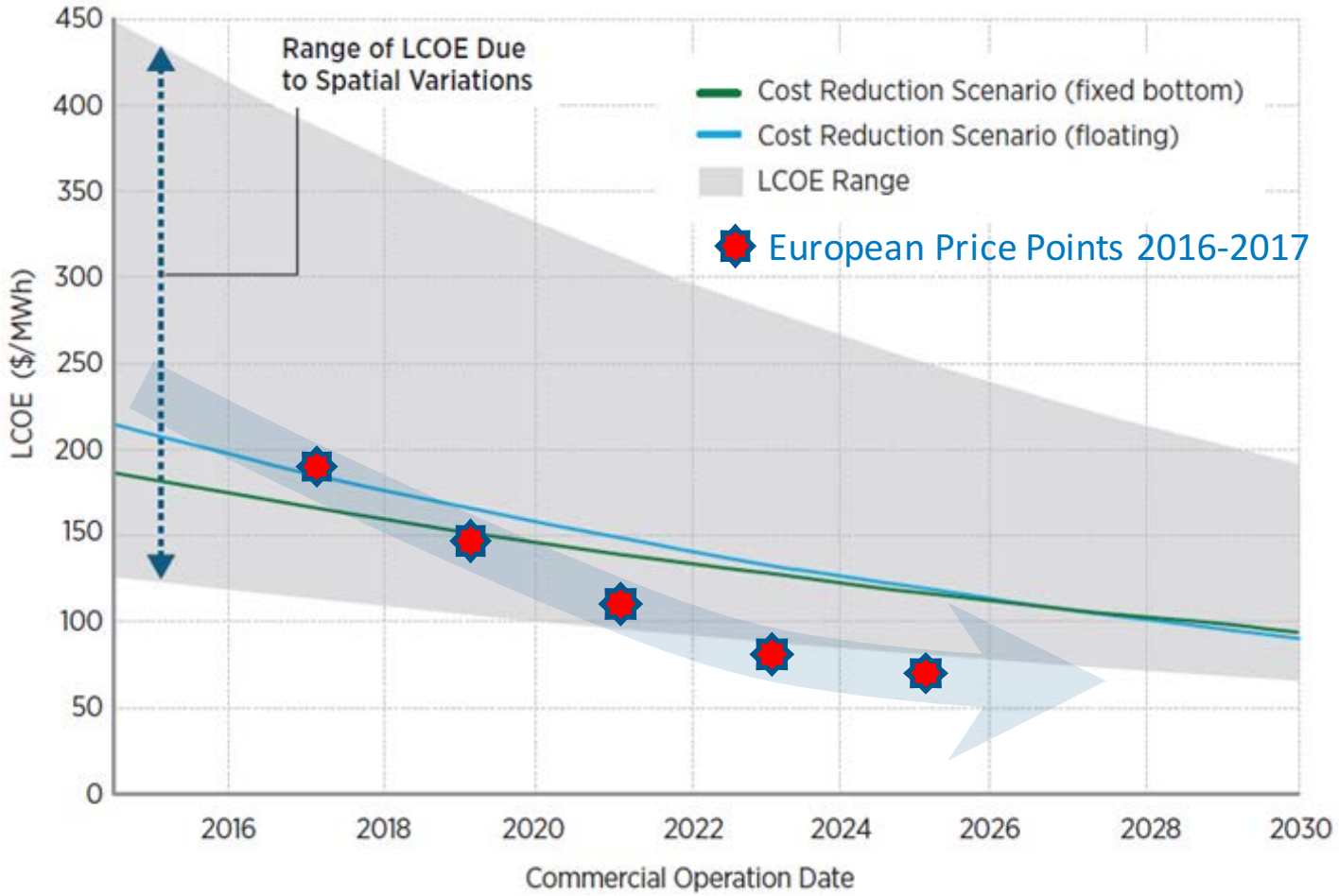
Photo: Statoil Scotland
30 MW 5 Turbines
Øyvind Gravås /
Woldcam - Statoil ASA

Proof of Concept Phase
2009 to 2016
6 prototypes totaling about 20-MW
2 - 7 MW

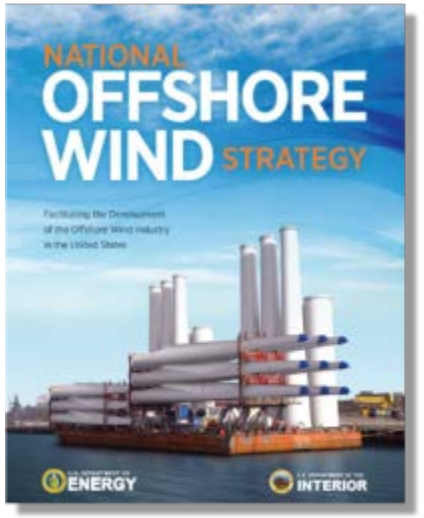
Pre-commercial Phase
2017 to 2023
Multi-turbine commercial machines
12 – 50 MW Projects
11 projects totaling 229-MW

Commercial Floating Arrays
2024 and beyond
400-MW+ arrays proposed
Alpha Wind - Hawaii
Principle Power– Hawaii/California
Progression - Hawaii
Equinor - TBD
Trident Wind – California
Dyfed/Kantanes – United Kingdom

Floating Offshore Wind has the Potential for Low Cost



September 2016



http://energy.gov/sites/prod/files/2016/09/f33/National-Offshore-Wind-Strategy-report-09082016.pdf

LCOE (unsubsidized) for potential offshore wind power projects from 2015-2030 (COD) for U.S. technical resource area
Reference scenarios from offshore wind strategy show floating LCOE can be lower than fixed bottom

Can these same Euro cost reductions be achieved in the United States?

Amy Robertson
Amy.Robertson@nrel.gov

Business Case for Floating Offshore Wind

- **Resource Abundance:** 58% of U.S. OSW resource is > 60 meters
- **Reduce Siting Conflicts:** Major siting conflicts are likely to be reduced in deeper water, which tends to be farther from shore (12 nm – 50 nm)
- **Wind Vision:** Floating technology may be needed to help meet the goals of the DOE/DOI strategy (e.g. Pacific)
- **Cost Reduction Potential:** Cost models have shown that floating wind technology has the potential to achieve the same cost (or lower) as fixed bottom OSW by 2030
- **Rapid Global Industry Pace:** The pace of floating technology advancement has been accelerating world-wide
- **Consistent Policy:** Floating OSW, expected to be commercialized within the next decade, may support U.S. “all of the above” policy
- **Leadership:** There is a significant economic opportunity in establishing national leadership in floating OSW technology

Oil and Gas Experience Helped Accelerate First Generation

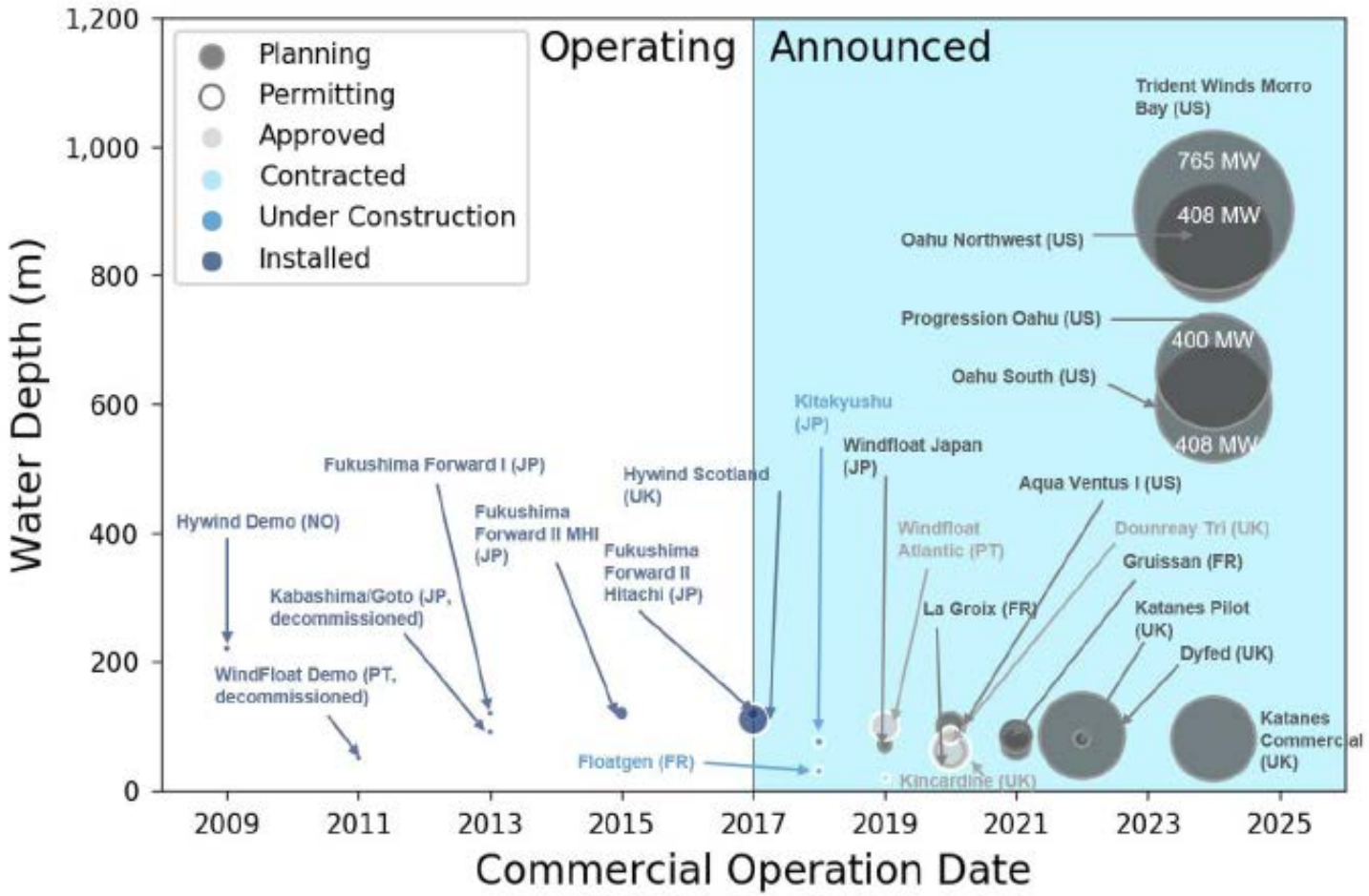
- Oil & gas design criteria have resulted in successful, but expensive designs
- Until October 2017 there were only 6 utility-scale floating wind systems
- In Oct. 2017, Equinor installed the first multi-turbine pre-commercial project in Scotland – 30-MW Statoil
- Optimized engineering approach will yield commercial systems

Knowledge Transfer

Job Transfer

Global Floating Offshore Wind Project Pipeline

Market trends indicate transition from proof-of-concept, single-turbine deployments to multiturbine, precommercial pilot projects. 55 MW of floating projects are installed or are currently under construction.



Note: Projects that are included in the graph but not labeled include GICON SOF Pilot (Germany), Faraman (France), FLOCAN5 (Spain), and Leucate (France).