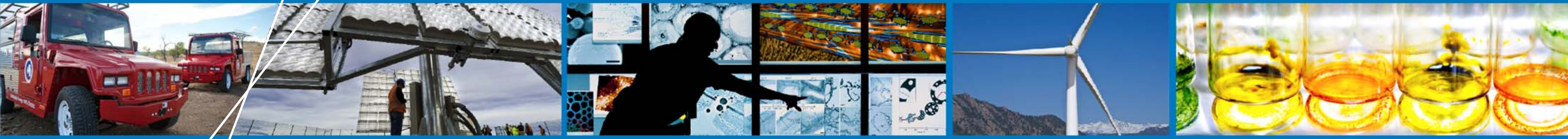
NATIONAL RENEWABLE ENERGY LABORATORY

Offshore Wind Energy Market Overview



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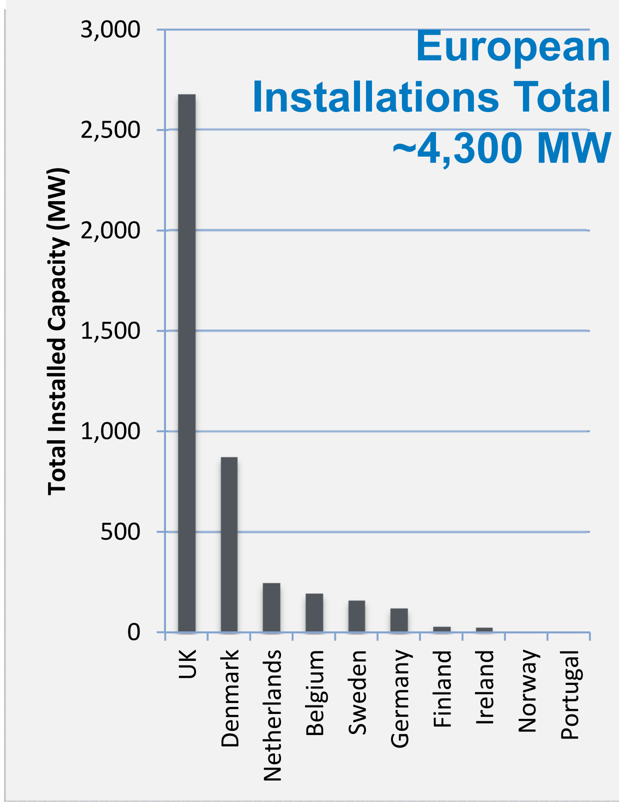
National Renewable Energy Laboratory

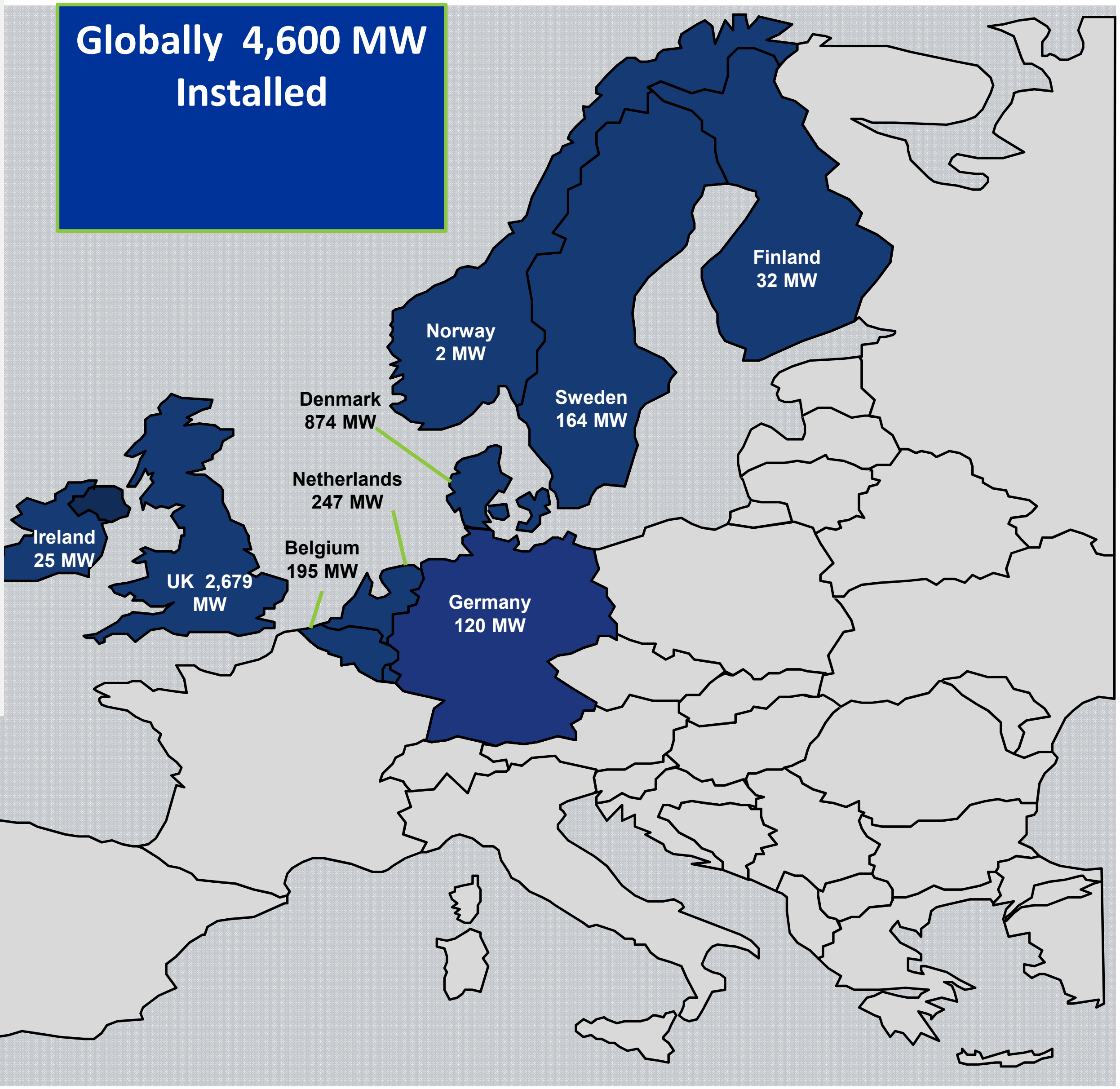
May 15, 2013

NREL/PR-7A20-58974

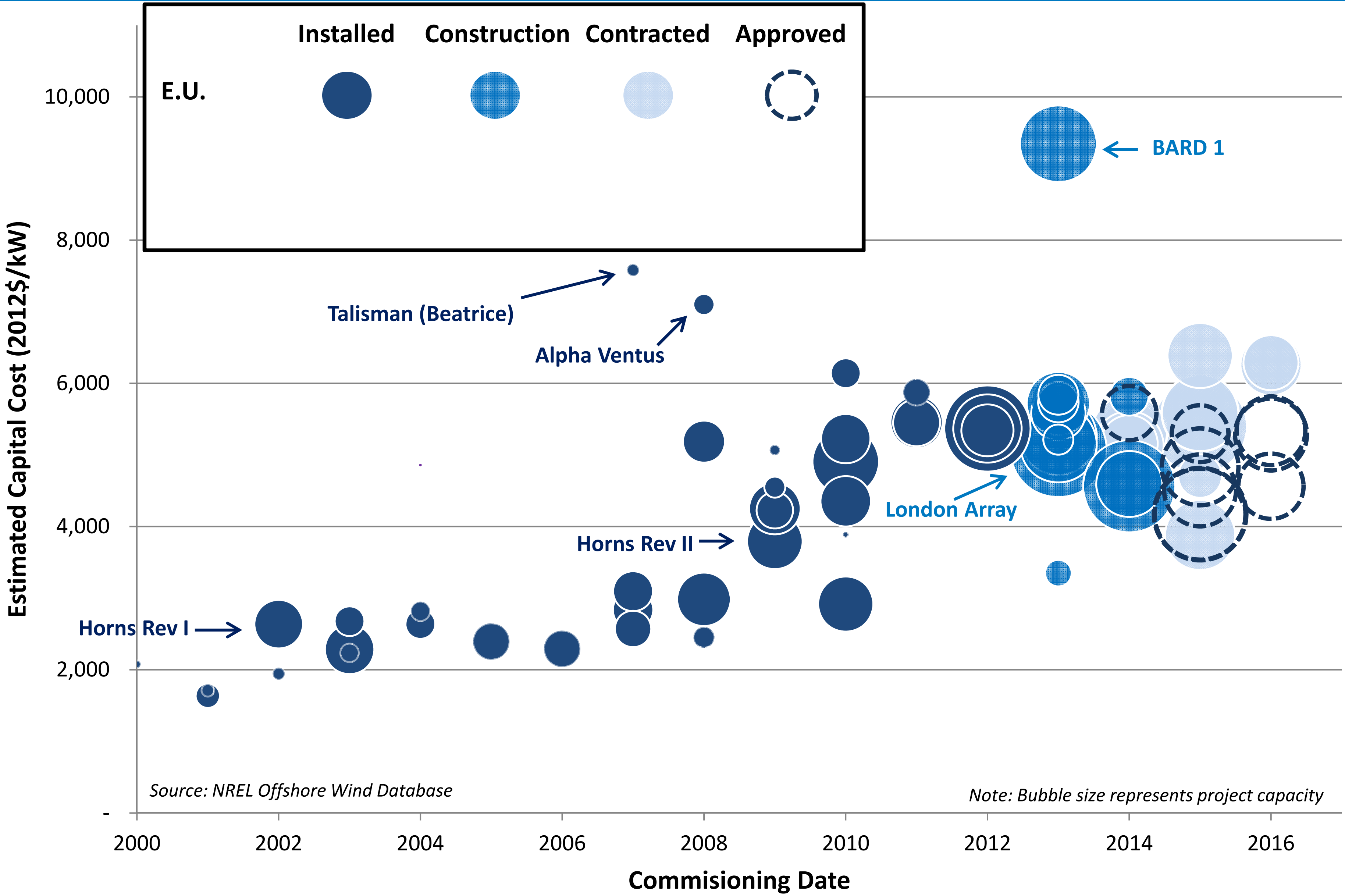
All Offshore Wind Projects Are in Europe and Asia, with European Nations Leading Deployment



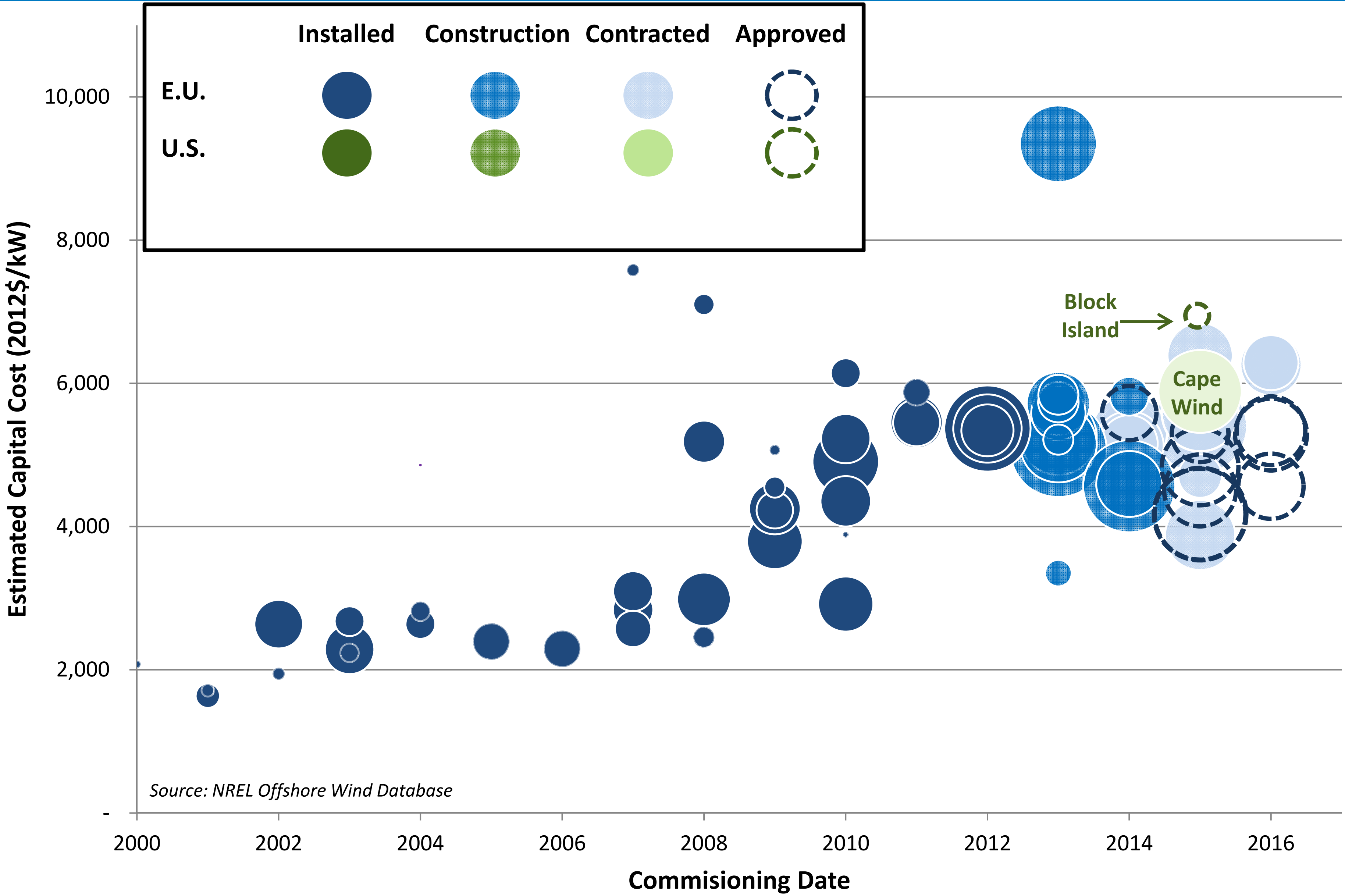
Globally 4,600 MW Installed



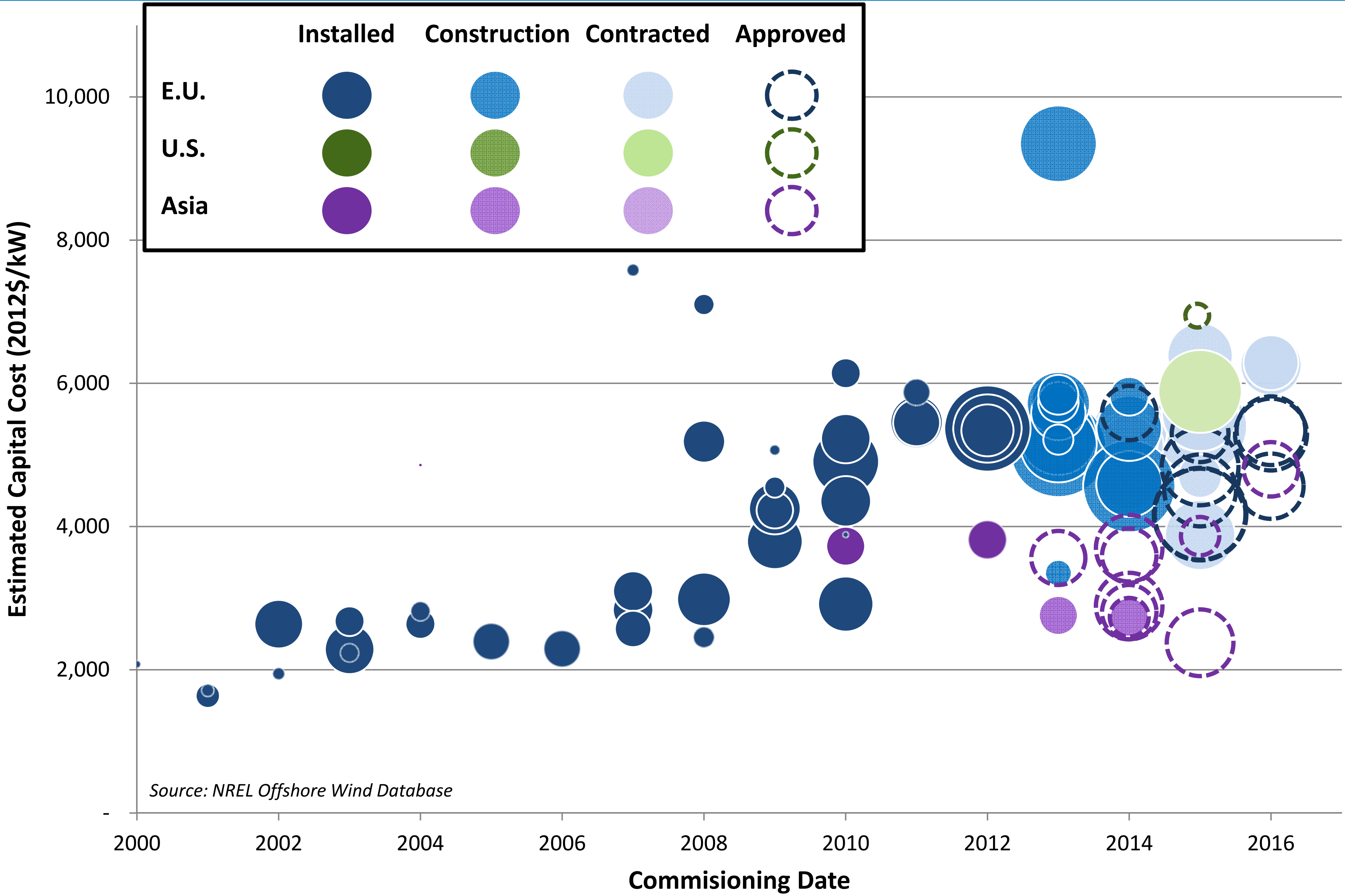
Capital Costs Have Risen; Appear to Be Stabilizing



U.S., EU Projects Expected to Have Similar Costs



Asian Projects Projecting Lower Costs



Installed Capital Costs (ICCs)

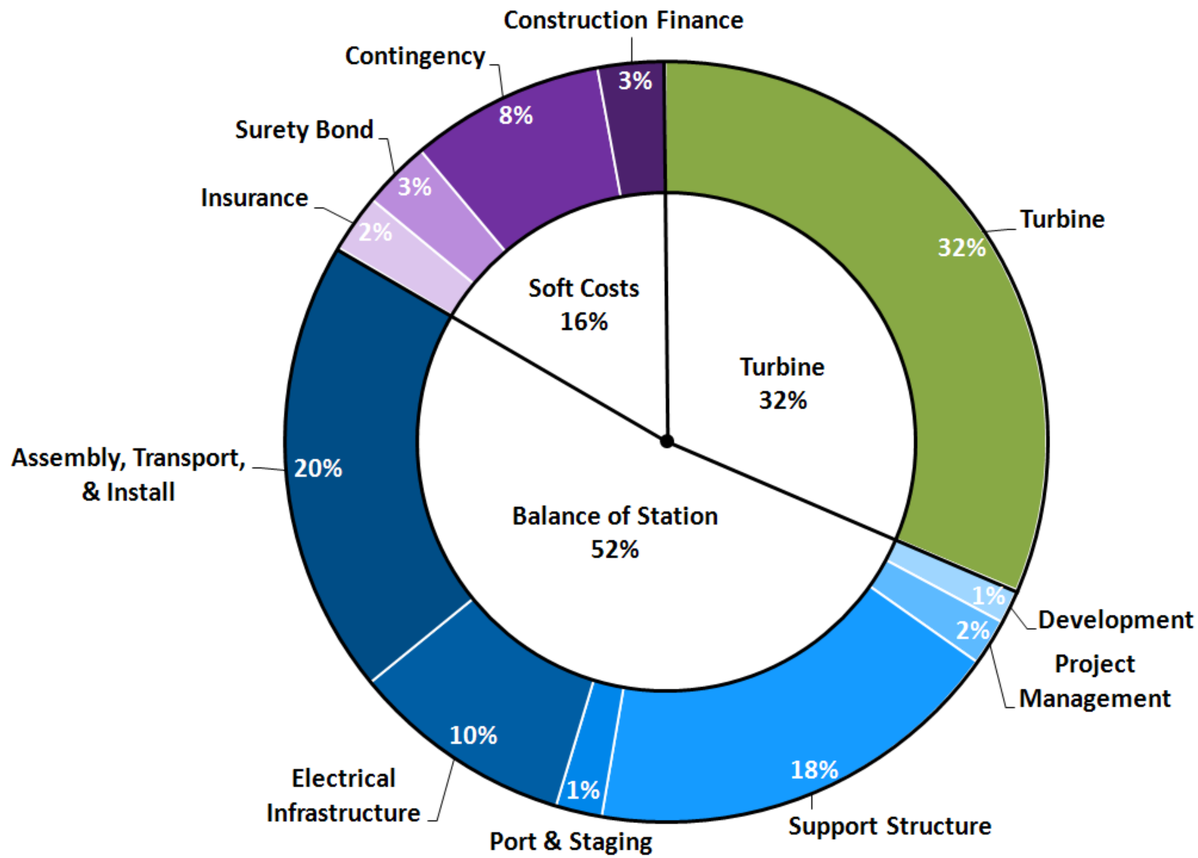
- **Balance-of-station (BOS) costs dominate ICCs for offshore wind projects**
- **There are three primary BOS contributors:**

    Support structure

    Electrical infrastructure

    Assembly, transport, and installation.

- **Component contribution can vary significantly from one project to another**



Source: Tegen, S.; Hand, M.; Maples, B.; Lantz, E.; Schwabe, P.; Smith, A. (2012). 2010 Cost of Wind Energy Review. 111 pp.; NREL Report No. TP-5000-52920.

How Do We Reduce Costs?

Scale

Increase

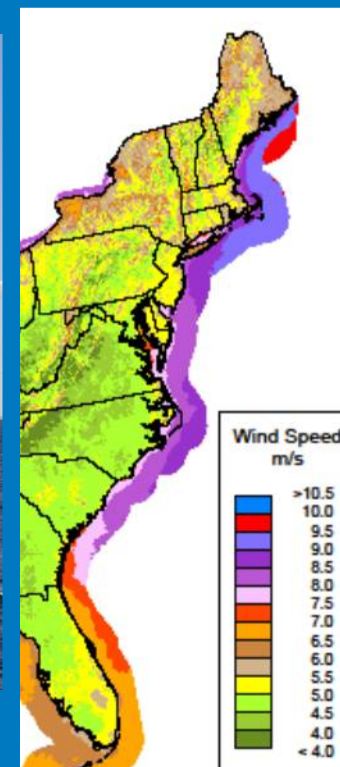
Turbine Capacity

Photo from Ben Barden Photography/ Vattenfall

Wind Plant Size

Photo from Middelgrunden Wind Turbine Cooperative, NREL 17856

National and Global Deployment

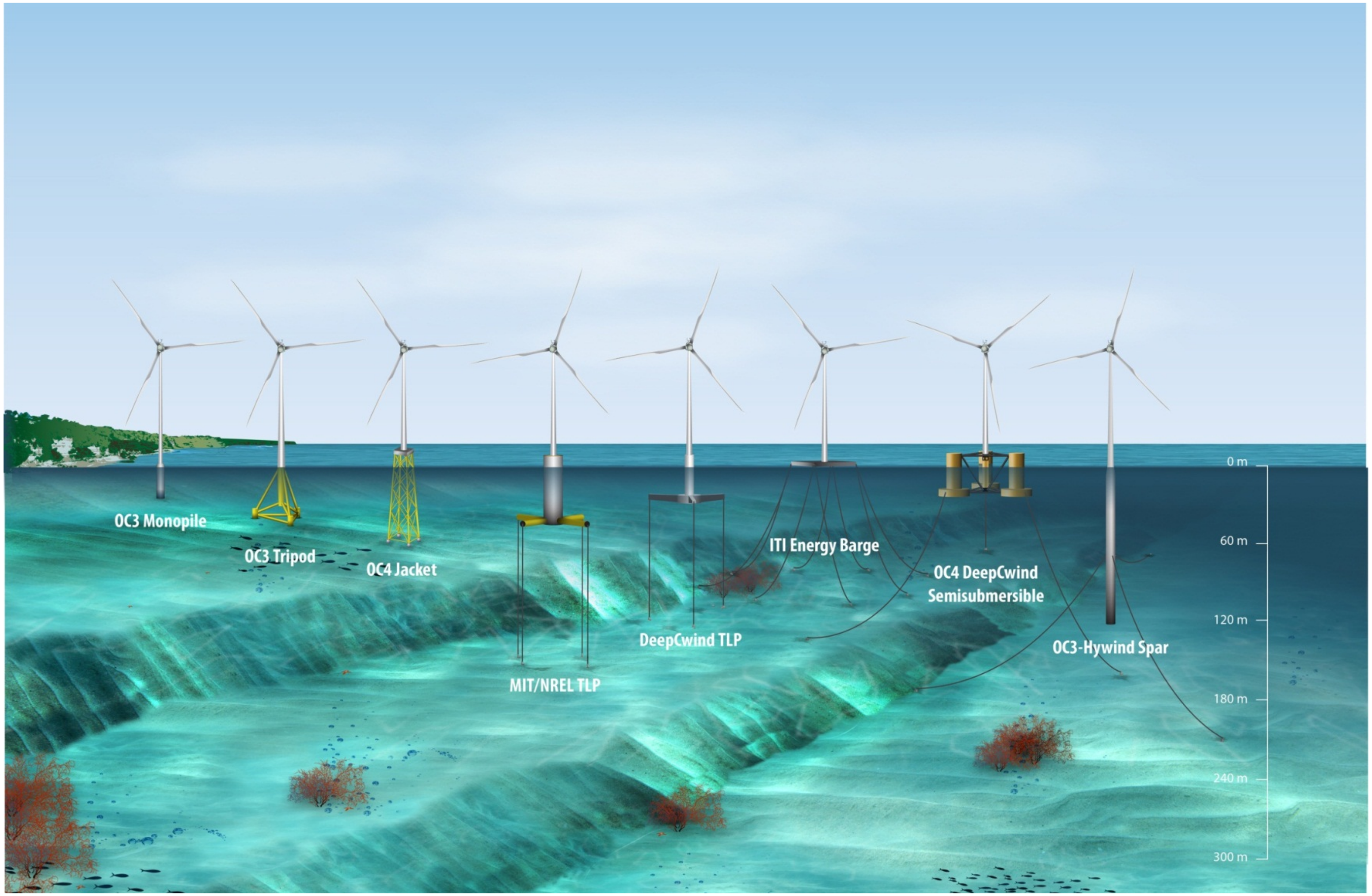


Increasing Size Is Desirable at All Scales

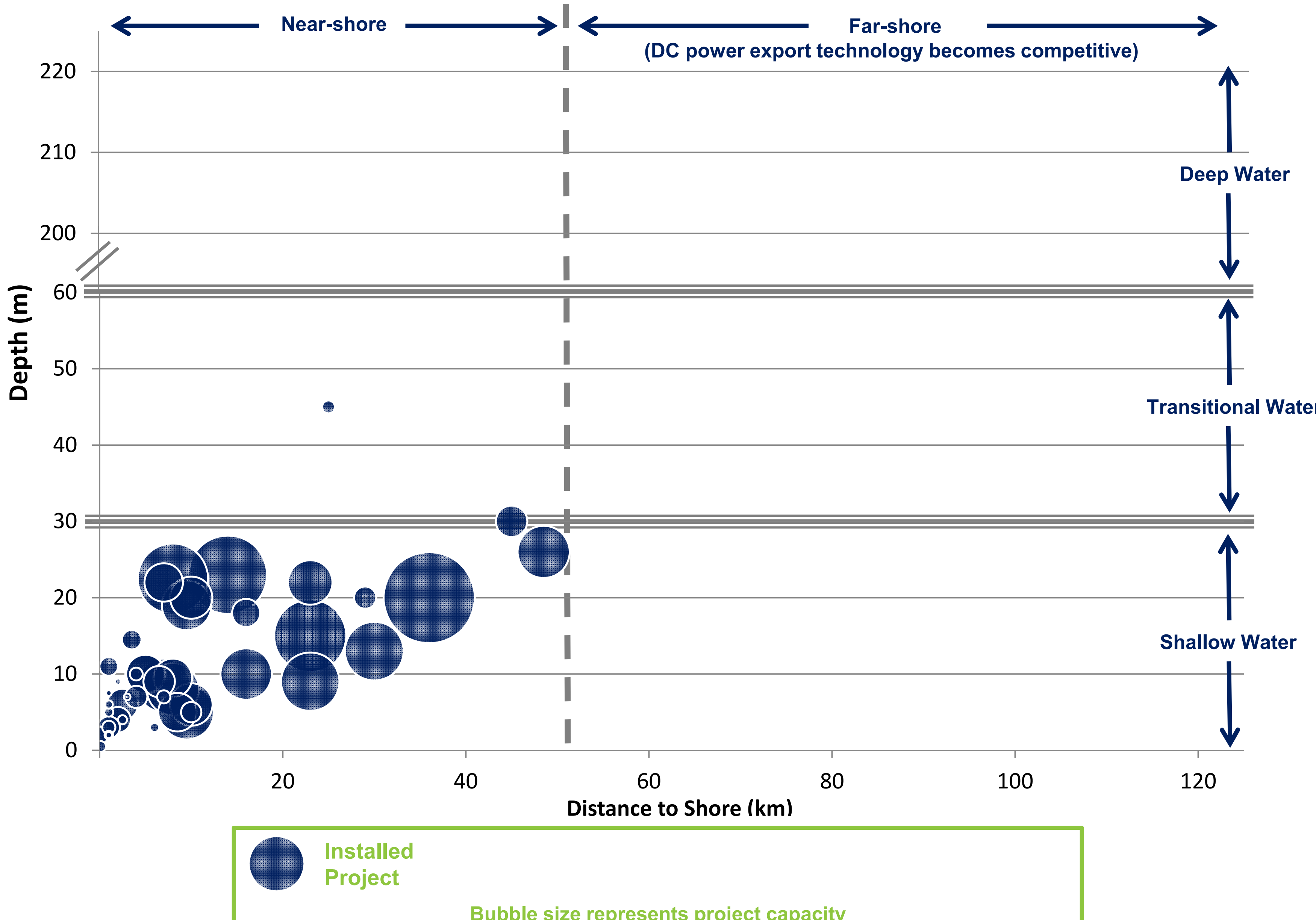
Physical Siting Considerations

- Water depth
- Distance to shore
- Geotechnical/geophysical soil conditions
- Wave climate: sheltered vs. open ocean
- Extreme climate conditions (e.g., tropical storms)
- Availability of grid connections/load proximity
- Supply chain
- Competing-use issues
- Environmental impacts

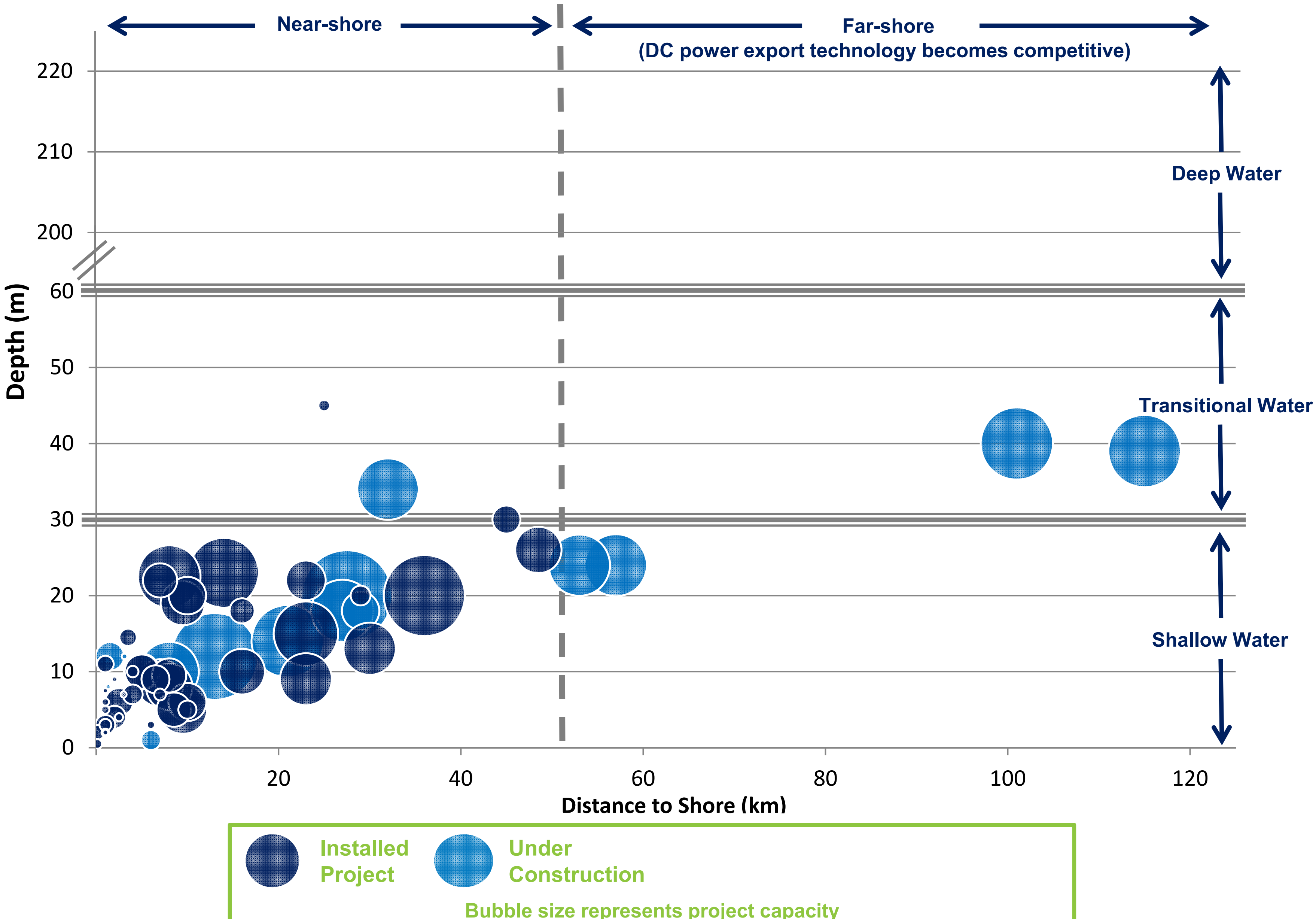
Technology Evolution to Deeper Water



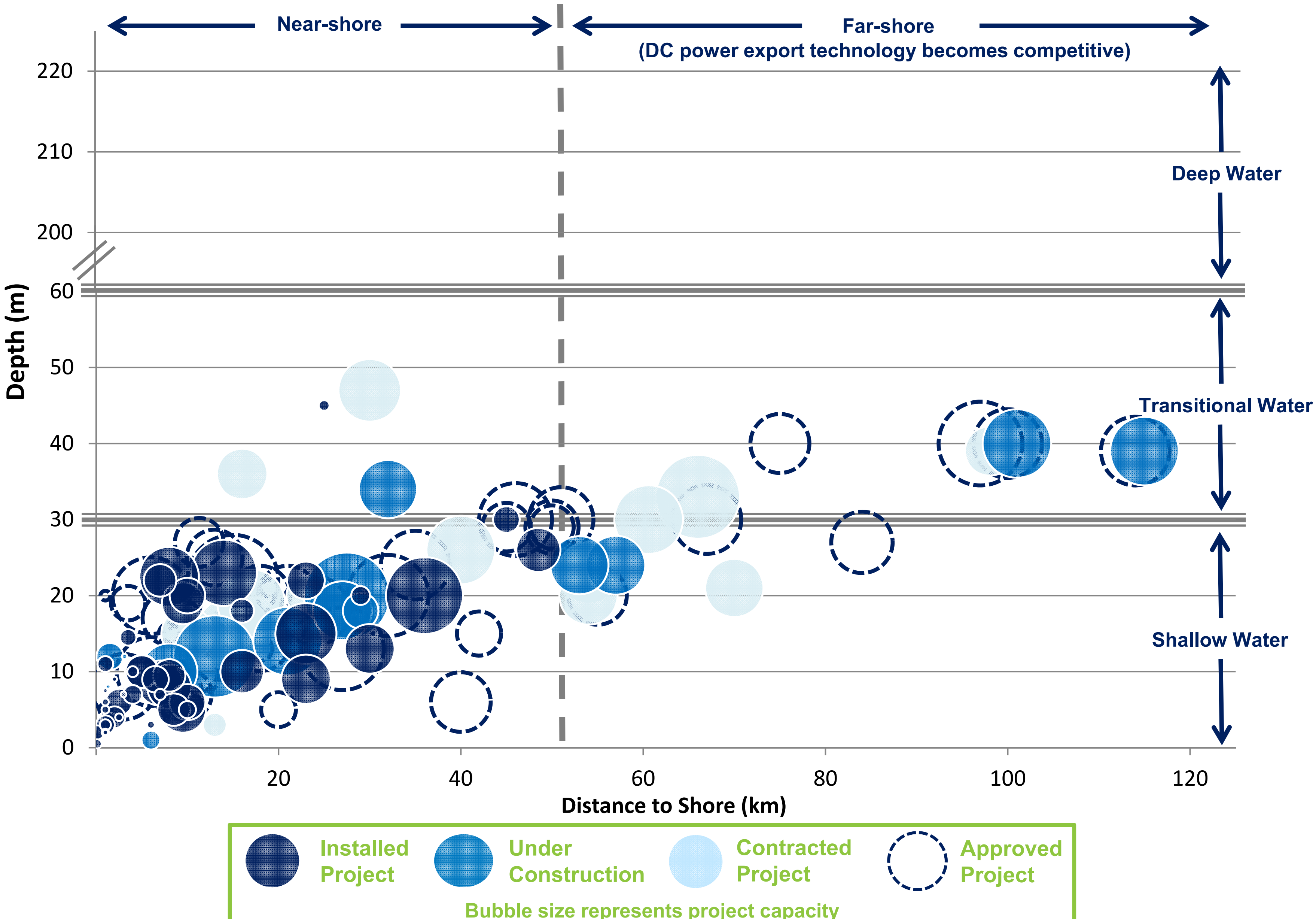
Installed Offshore Wind Projects Are Typically Sited in Shallow Water, Close to Shore



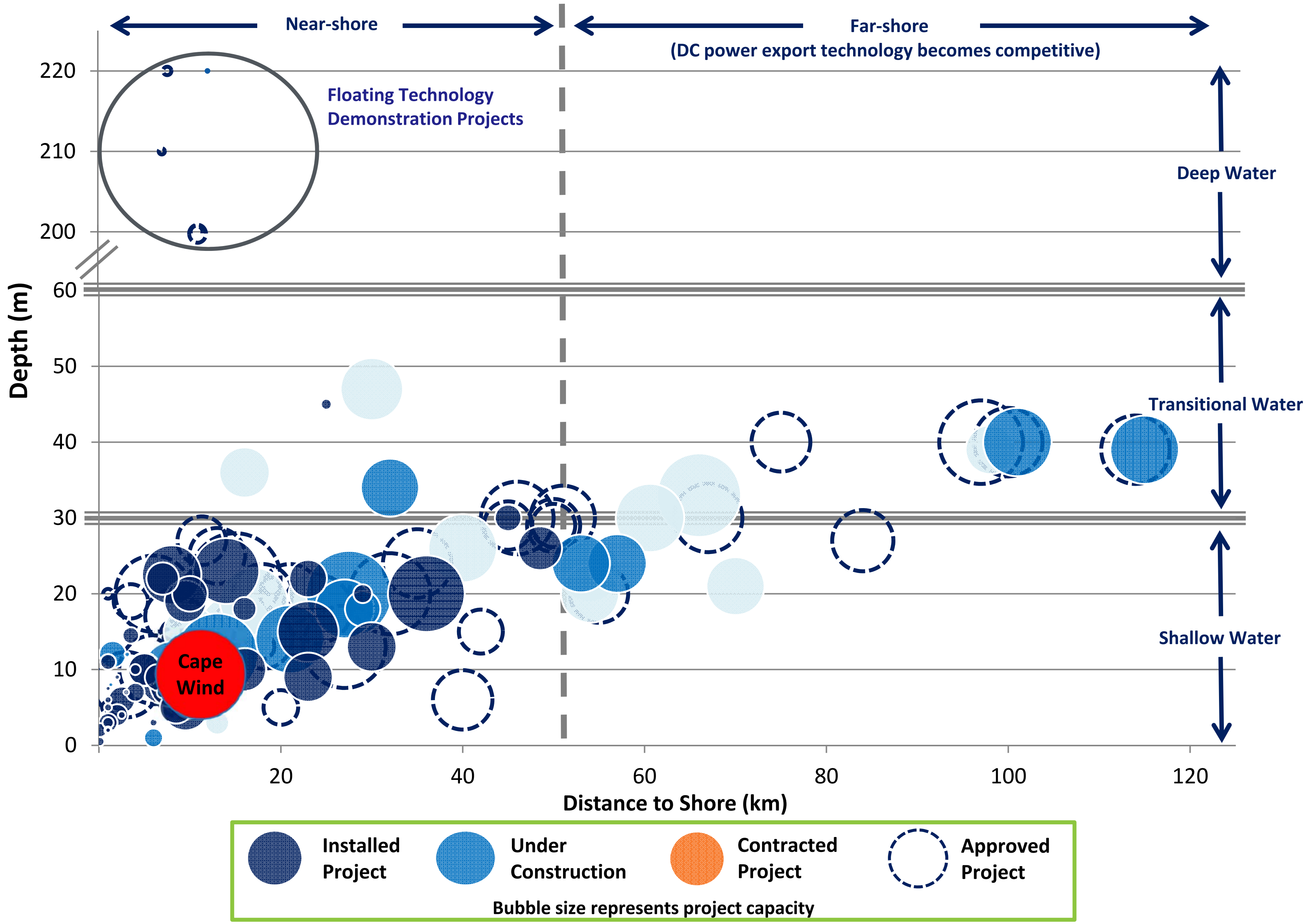
A Few Projects under Construction Are Expanding into Transitional Water Depths, Farther from Shore



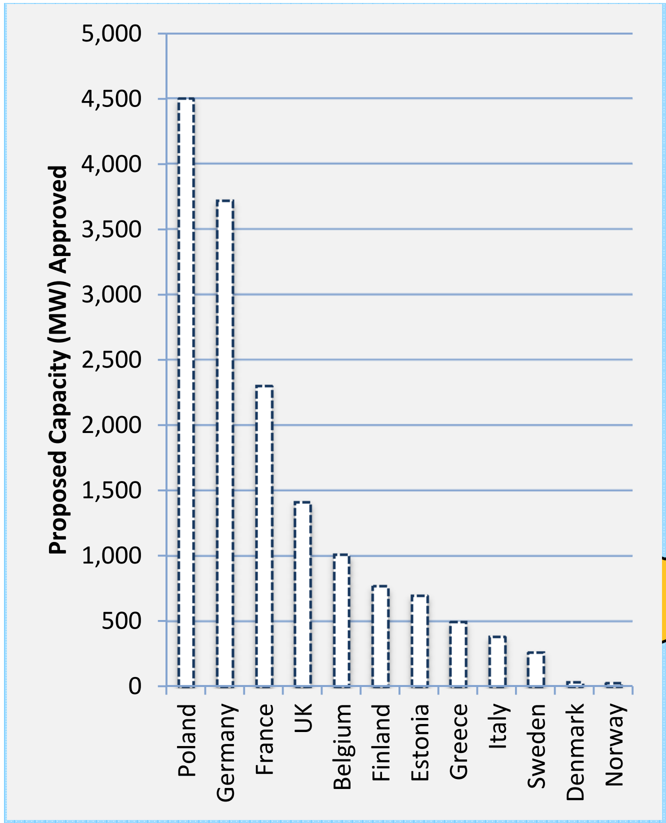
Near-Term Pipeline Suggests this Trend Will Continue, with Projects Moving Beyond the 30-m by 50-km Design Envelope

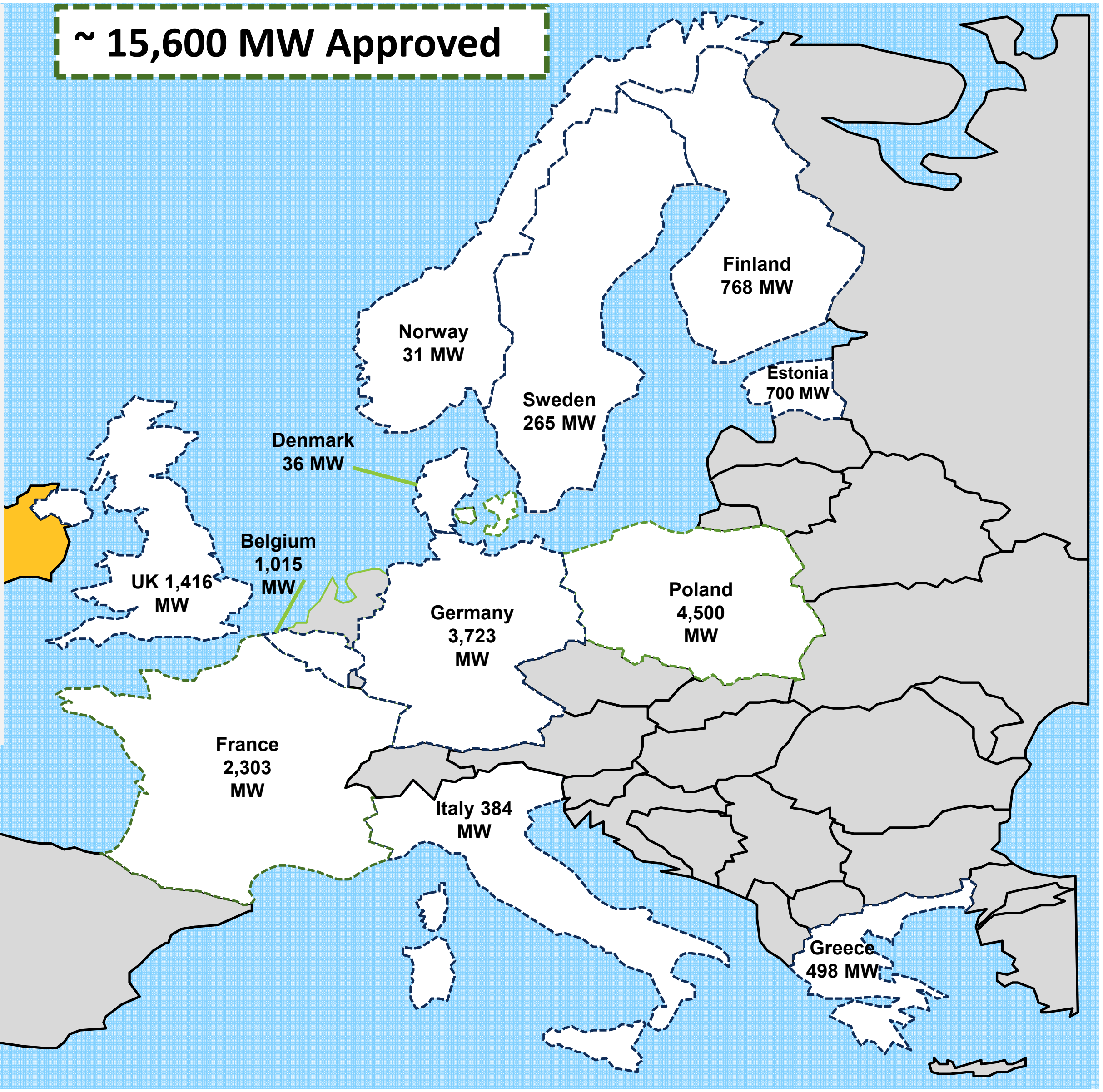


Several Projects Are Demonstrating Floating Substructures, Which Could Enable Development of Deep Water Sites



The Majority of Existing and Planned Global Offshore Wind Developments are in Europe



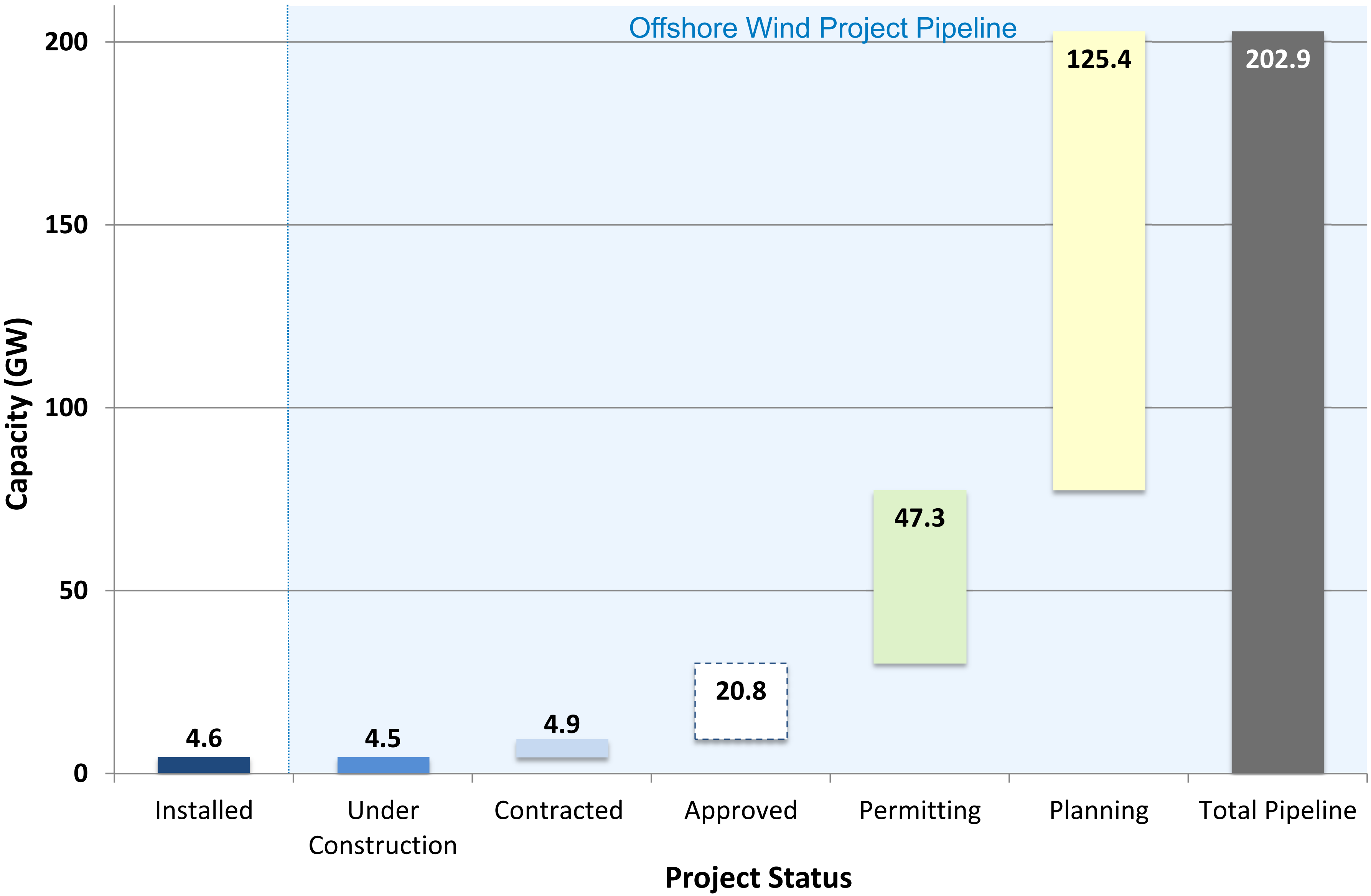


Offshore Wind Drivers & Developments in Asia

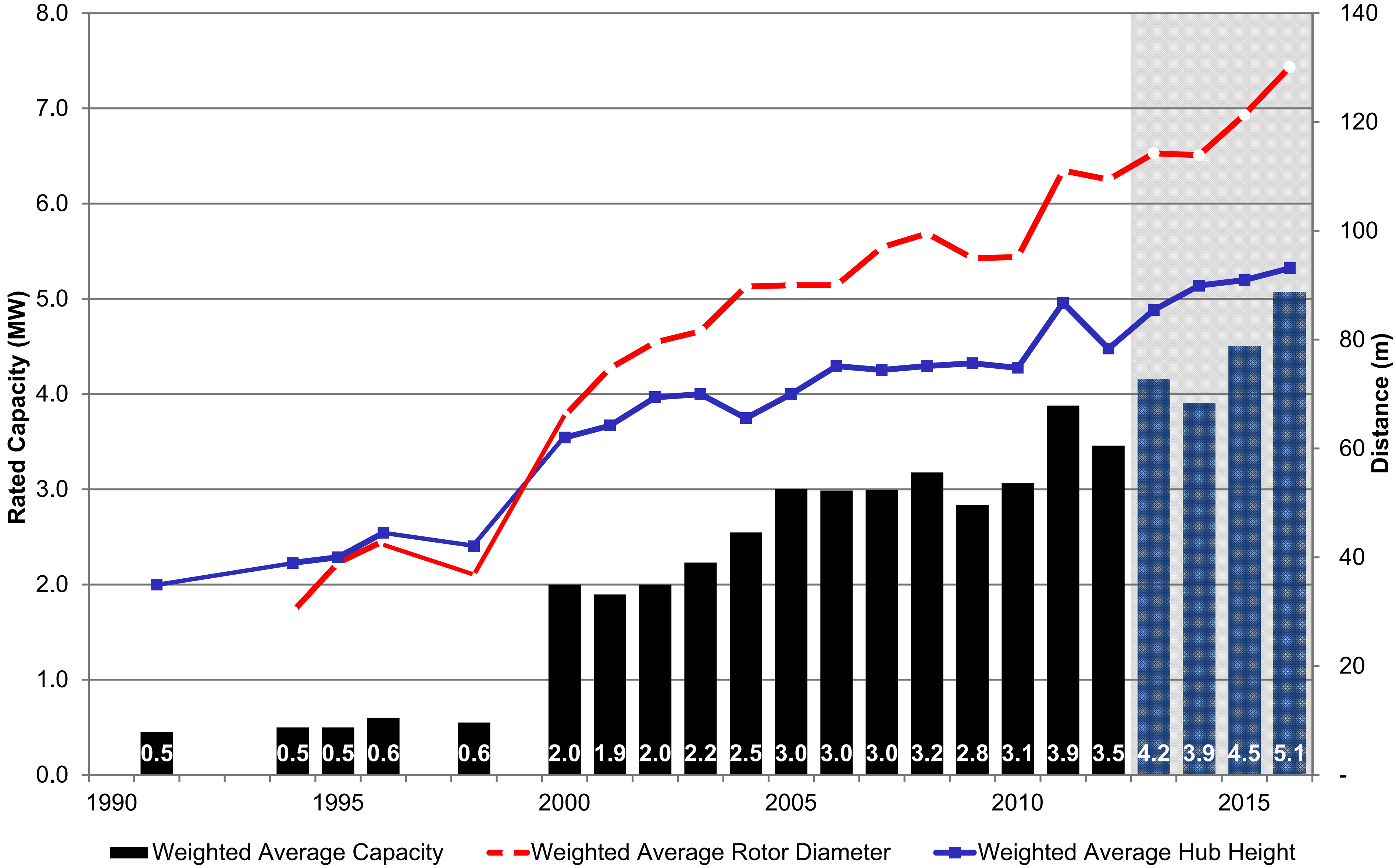
- **China:** Issued *12th Five-Year Development Plan for Renewable Energy* (2012) targeting 5 GW installed by 2015 and 30 GW installed by 2020
- **Japan:** As part of the Fukushima recovery efforts, the government plans to phase out nuclear power by 2040, which previously provided more than 30% of the country's electricity. New feed-in tariffs for wind announced in 2012, ~25 cents/kWh
- **South Korea:** 5-MW offshore demonstration project (Jeju Island) in operation, plus a government target of 2 GW in operation by 2019
- **Taiwan:** Launched the *Thousand Wind Turbines Promotion* program, targeting 3 GW installed by 2030

Total Global Offshore Wind Project Pipeline Exceeds 200 GWs

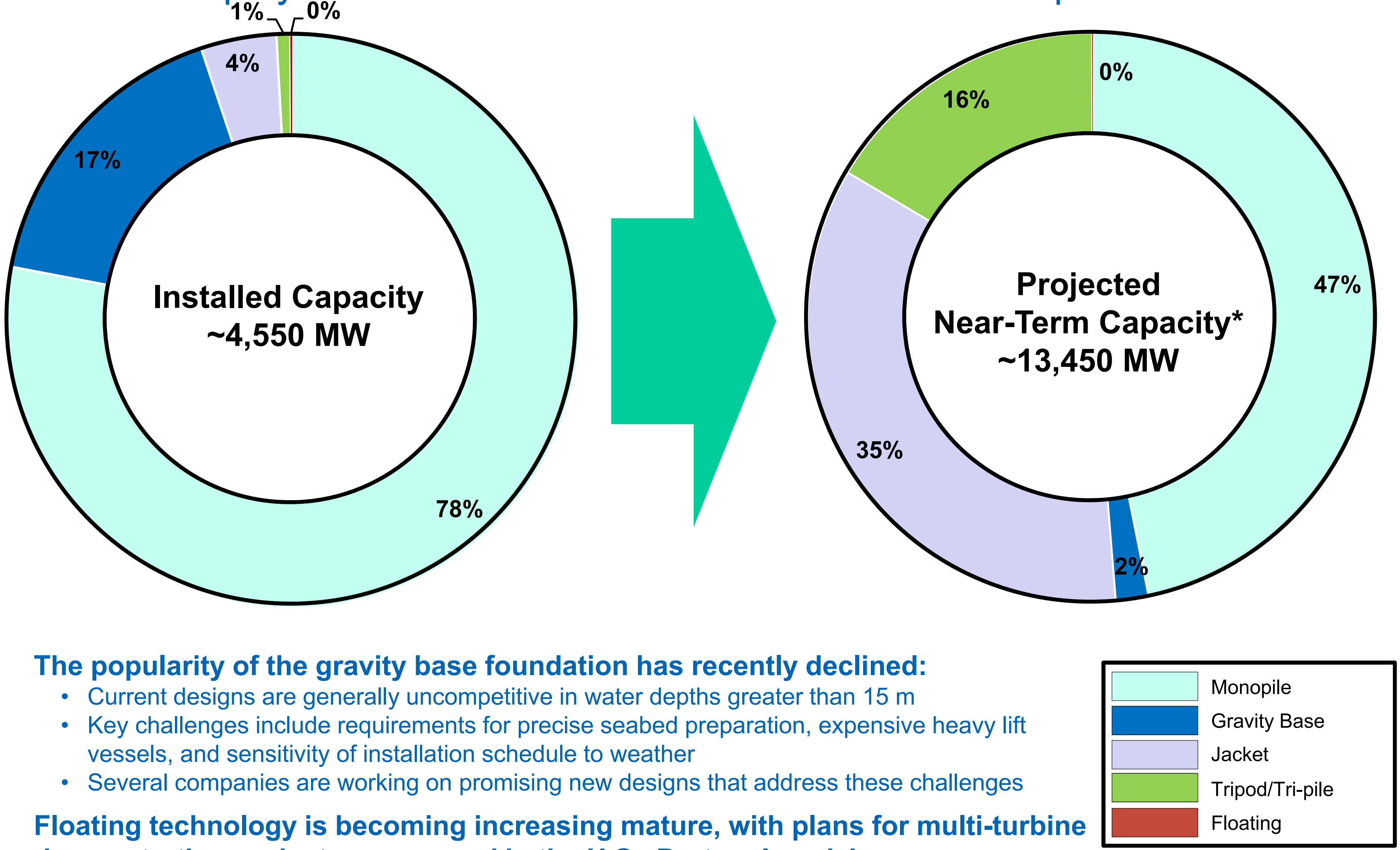
(Total U.S. Generating Capacity ~1,000 GWs)



Average Offshore Wind Turbine Capacities, Rotor Diameters, & Hub Heights Are Expected to Continue to Increase



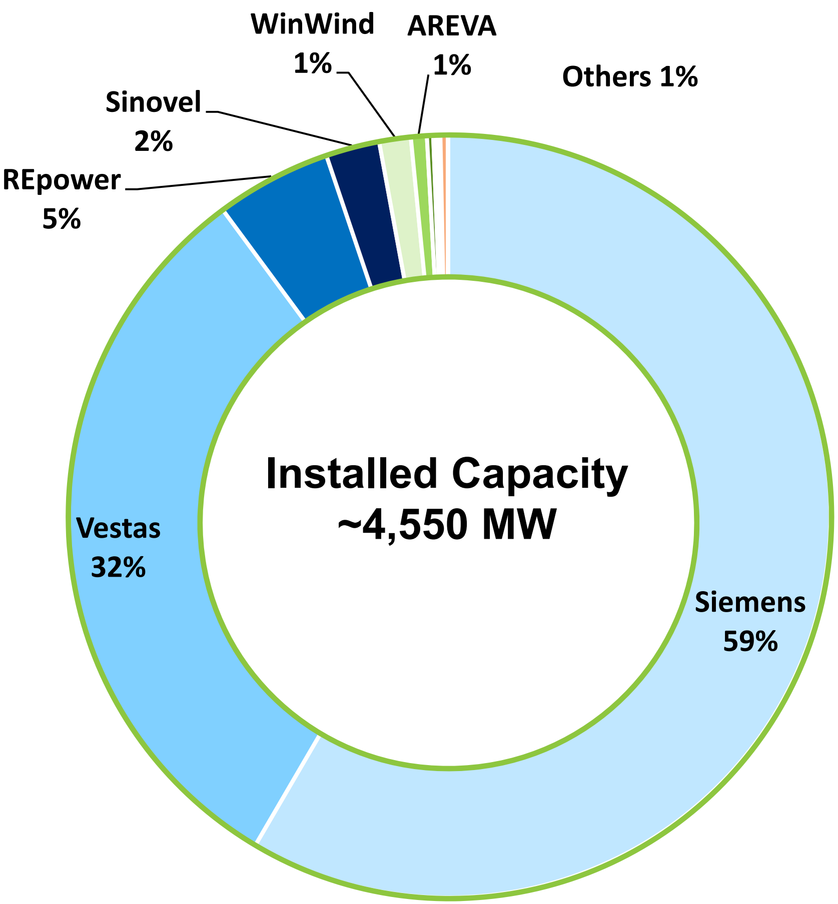
Multi-Pile Foundations Will Gain Market Share as Larger Turbines Are Deployed and as Wind Farms Are Installed in Deeper Water



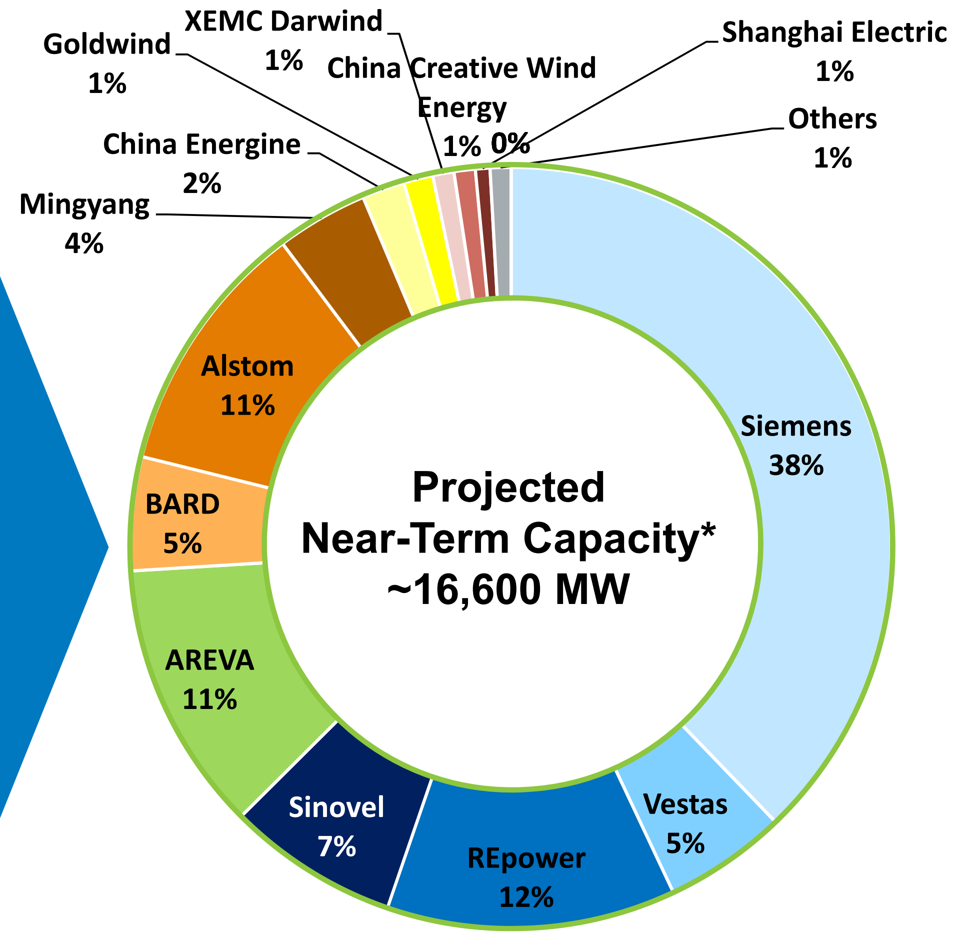
- **The popularity of the gravity base foundation has recently declined:**
  - Current designs are generally uncompetitive in water depths greater than 15 m
  - Key challenges include requirements for precise seabed preparation, expensive heavy lift vessels, and sensitivity of installation schedule to weather
  - Several companies are working on promising new designs that address these challenges
- **Floating technology is becoming increasing mature, with plans for multi-turbine demonstration projects announced in the U.S., Portugal, and Japan**

* Includes projects under construction and approved projects that have announced a foundation design

The Global Offshore Wind Turbine Market Is Expected to Become Increasingly Fragmented



Turbines from Siemens and Vestas represent a combined 91% of capacity installed to date.



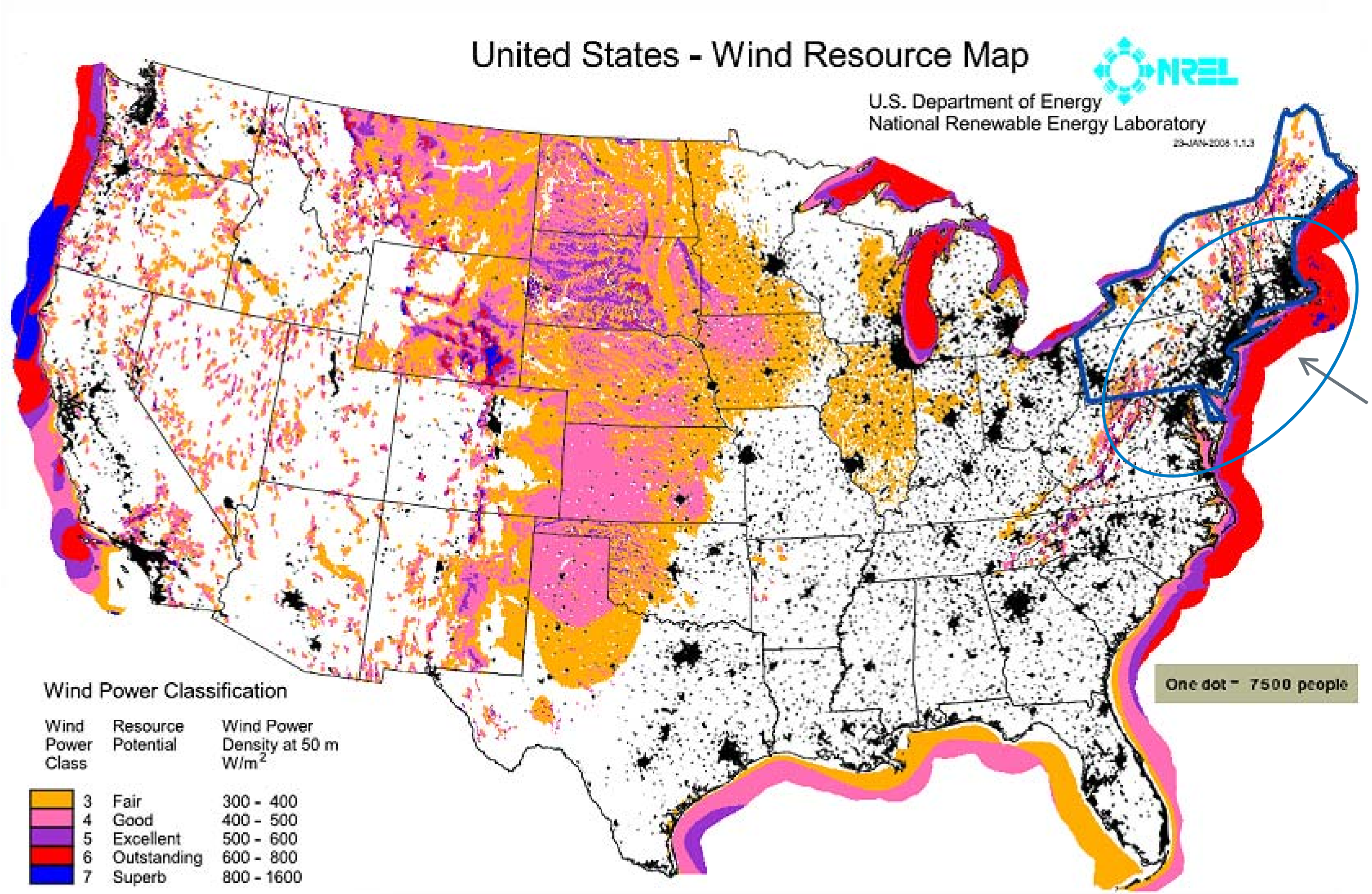
Some OEMs have developed strong pipelines, reducing projected Siemens/Vestas share to 43% of near-term market

OEMs gaining share tend to 1) offer turbine models in the 5 MW+ class or 2) are well positioned to take advantage of growth in the Chinese market.

* Includes projects under construction and approved projects that have announced a turbine manufacturer.

Offshore Wind Resource Is Near Population Centers

Map of Annual Average Wind at 80 m



55 million people in Northeast

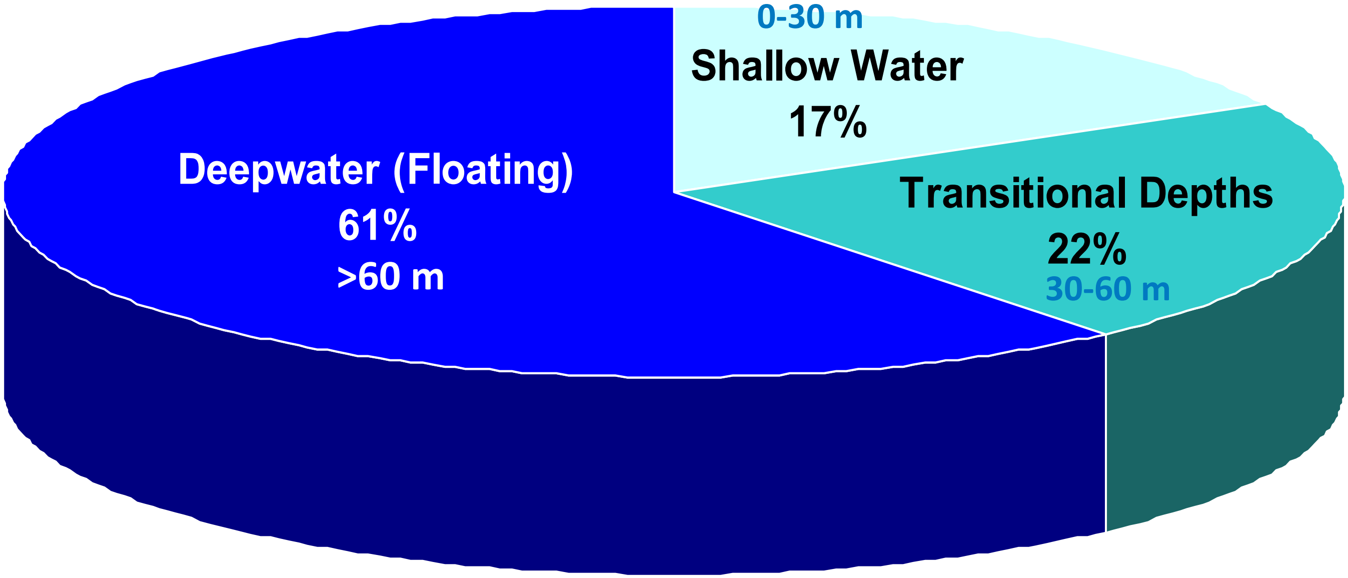
18% of U.S. population

Highest electricity costs

Credit: Dr. H. J. Dagher

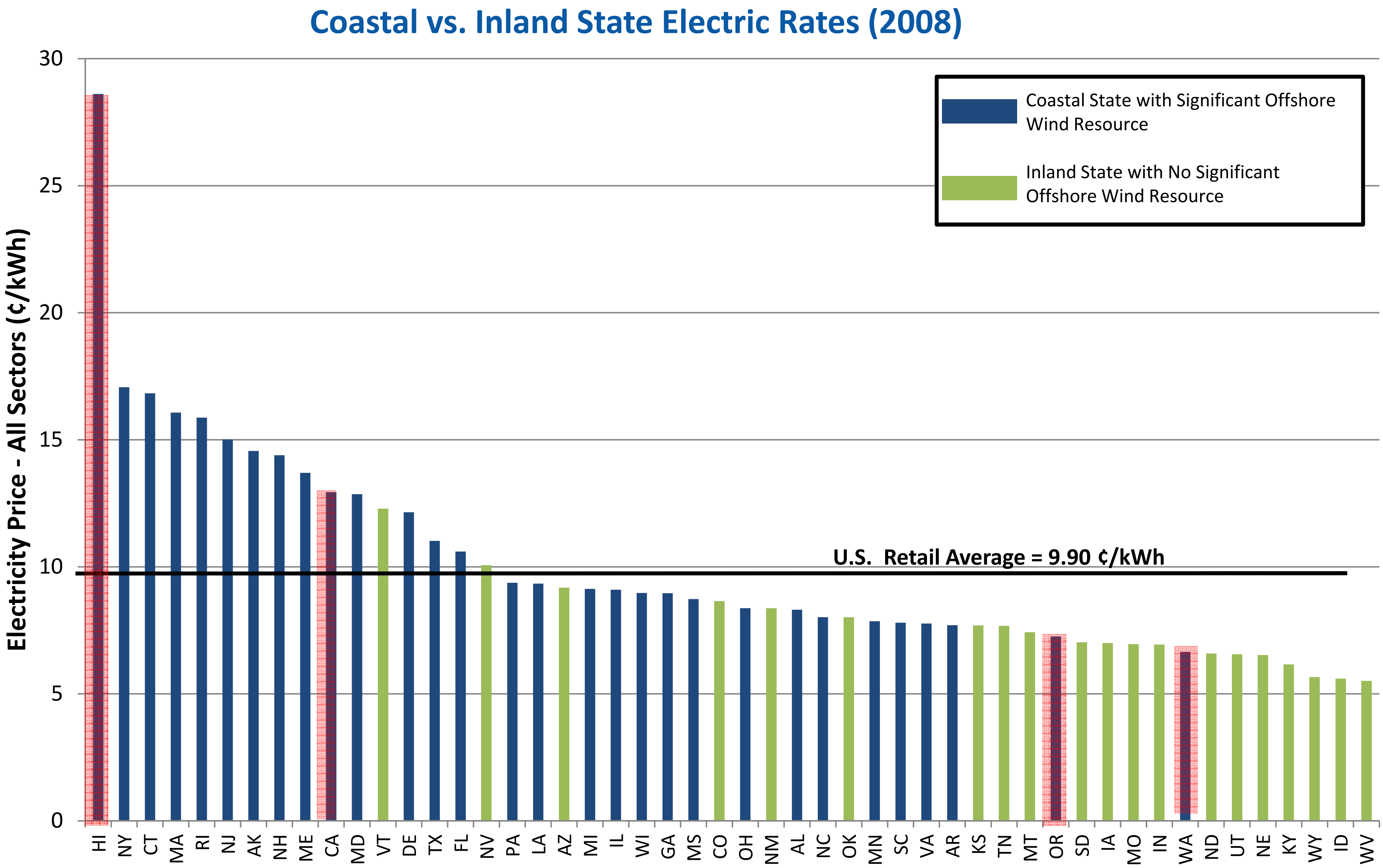
U.S. Offshore Resource

~4,000 GWs Total Technical Potential

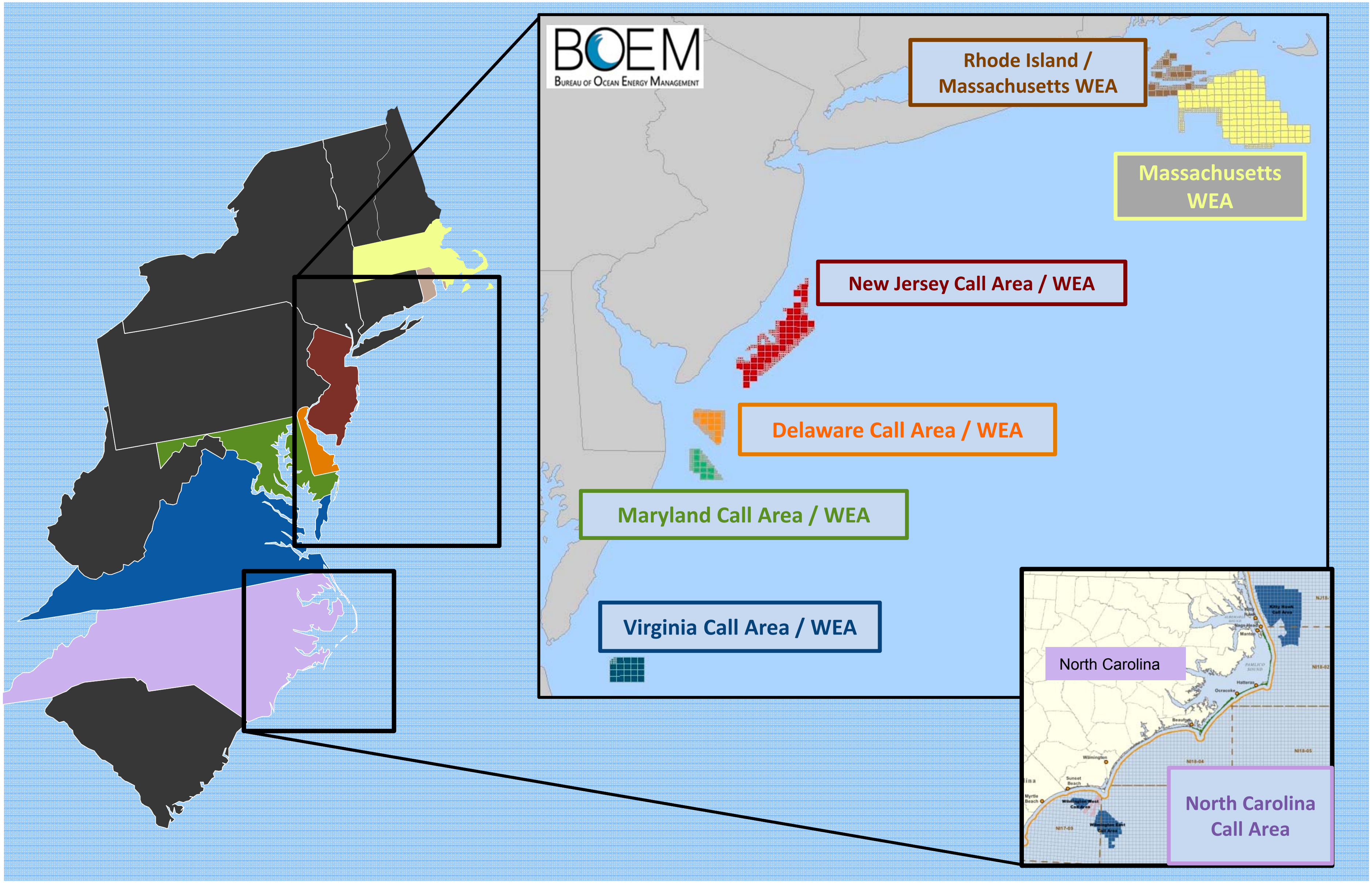


Approximate Percentage of Gross Offshore Wind Resource Area for Three Technology Stages (based on NREL estimates: 0-50 nm from shore, 60% of resource excluded, AK and HI not included, Class 5 winds and above only)

Coastal States Usually Have High Electricity Prices, Making Offshore Wind More Competitive



Three New Wind Energy Areas (WEAs) and Call Areas in 2012; There Are Now 6 WEAs Plus a Call Area in North Carolina



Technology Challenges for United States

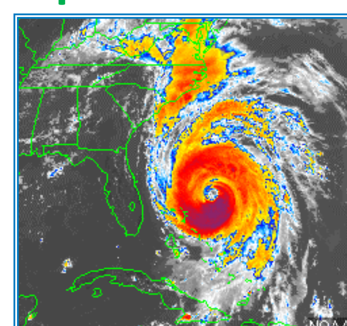
Standards are being updated to address U.S. issues.

Deep Water

Freshwater Ice and Ice

Deep Water

Tropical Storms



In General, Primary Stakeholder Concerns about Offshore Wind Power Are Site Specific

Marine animal populations:

European studies suggest minimal impacts. U.S. studies are required to better understand potential risks and develop mitigation strategies. Pile driving during construction has highest impact.

Visual effects:

Coastal residents near offshore wind farms may be concerned about visual impacts. More research is needed to better understand coastal communities and their ability to accept changes to the seascape.

Property values:

Studies conducted on land-based wind projects show minimal to no impact on real estate prices and property values as a result of the presence of wind turbines; however, extensive studies have not been conducted on the impact of offshore wind turbines on coastal communities.

Noise:

The most significant environmental impact is noise associated with pile driving during construction. Mitigation strategies may be effective in reducing this temporal risk. Alternative technology can also be implemented if appropriate to avoid some of the pile-driving activity.

Tourism:

Impacts on tourism may concern some communities dependent on beach vacationers and the resulting local revenues and tax base. The evidence is ambiguous, and actual effects appear to be minimal or positive.

Marine safety:

The possibility of a ship colliding with a turbine could pose a risk to the marine environment from fuel leaks or to human safety should the turbine collapse. No reported incidents have occurred to date.

Siting Must Account for Potential Environmental Impacts

- Protected sites and species
- Benthic ecology
- Fish and shellfish/ fisheries
- Marine birds
- Marine mammals
- Seabed sediments
- Marine and coastal processes
- Seabed contamination
- Water quality

Photo courtesy of eGuide Travel, Flickr

NREL 04698

Photo courtesy of Thespis377, Flickr

Photo courtesy of Travis S, Flickr

One of the largest environmental impacts found is sea mammal disturbance due to pile-driving noise.

Marketing Summary

- European markets dominate so far.
- Asian markets promise lower costs, but as of now this is undemonstrated.
- The U.S. offshore wind industry is ready to begin deployment.
- Stable, coordinated policy is needed to offset high initial costs and drive deployment.
- A robust project pipeline is needed to encourage investment in technologies and infrastructure that will lower the cost of energy.
- Costs are high for first adopters and must be reduced through risk reduction, new technology, and increasing scale (turbine, project, and national deployment).

Contact Information

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Thank You!

http://www.nrel.gov/tech_deployment/wind.html