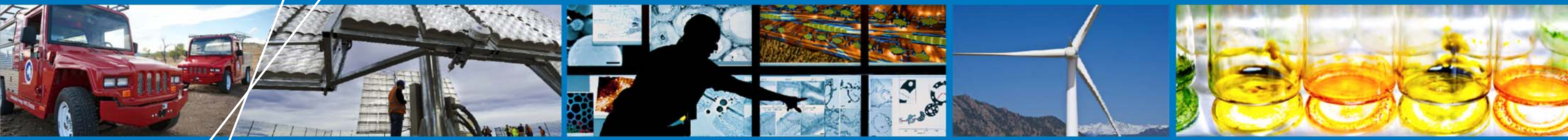
NATIONAL RENEWABLE ENERGY LABORATORY

# U.S. Balance-of-Station Cost Drivers and Sensitivities



## AWEA OFFSHORE WINDPOWER 2012

**Ben Maples**

**October 10, 2012**

**NREL/PR-5000-56480**

# Acknowledgments


## National Renewable Energy Laboratory (NREL)

Genevieve Saur
Maureen Hand
Walt Musial
Rebecca Meadows
Aaron Smith

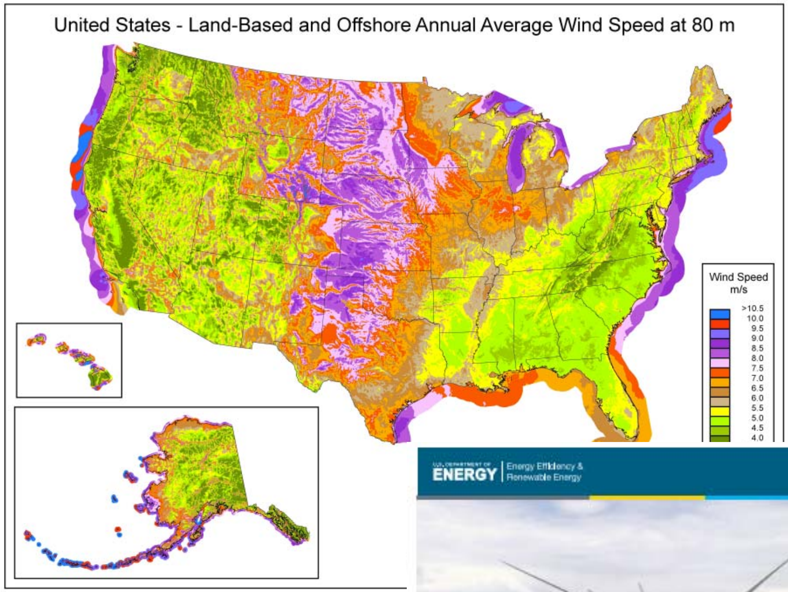
## GL Garrad Hassan

Chris Elkinton
Jules Clayton
Chris Garrett
Nestor Castillo
Ellen Crivella

# Why We Are Here

- **Estimates show shallow (0–30 m) and transitional depth (30–60 m) waters to have a net resource of 773 gigawatts (GW)**
- **If including deep waters that would require floating sub-structures, the total net U.S. offshore wind resource is estimated to be well over 2,000 GW**

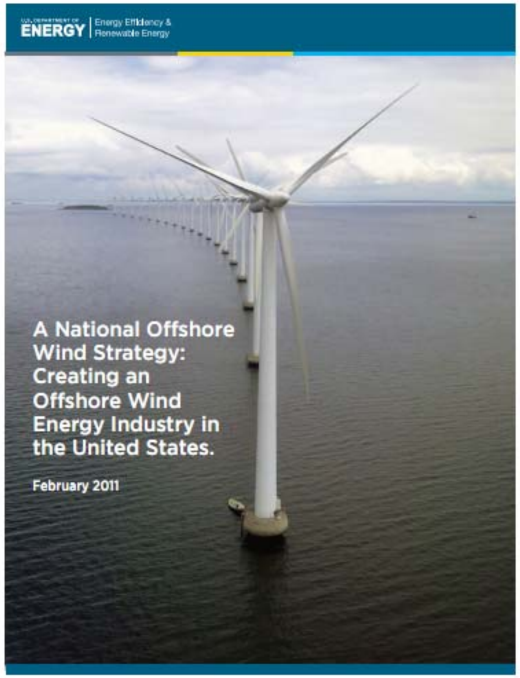
http://www.nrel.gov/wind/resource_assessment.html




- **The U.S. Department of Energy has adopted a National Offshore Wind Strategy to support the development of an offshore wind industry in the United States**
- **The strategy sets goals for deployment and cost reduction**

  Deployment: 10 GW by 2020 and 54 GW by 2030

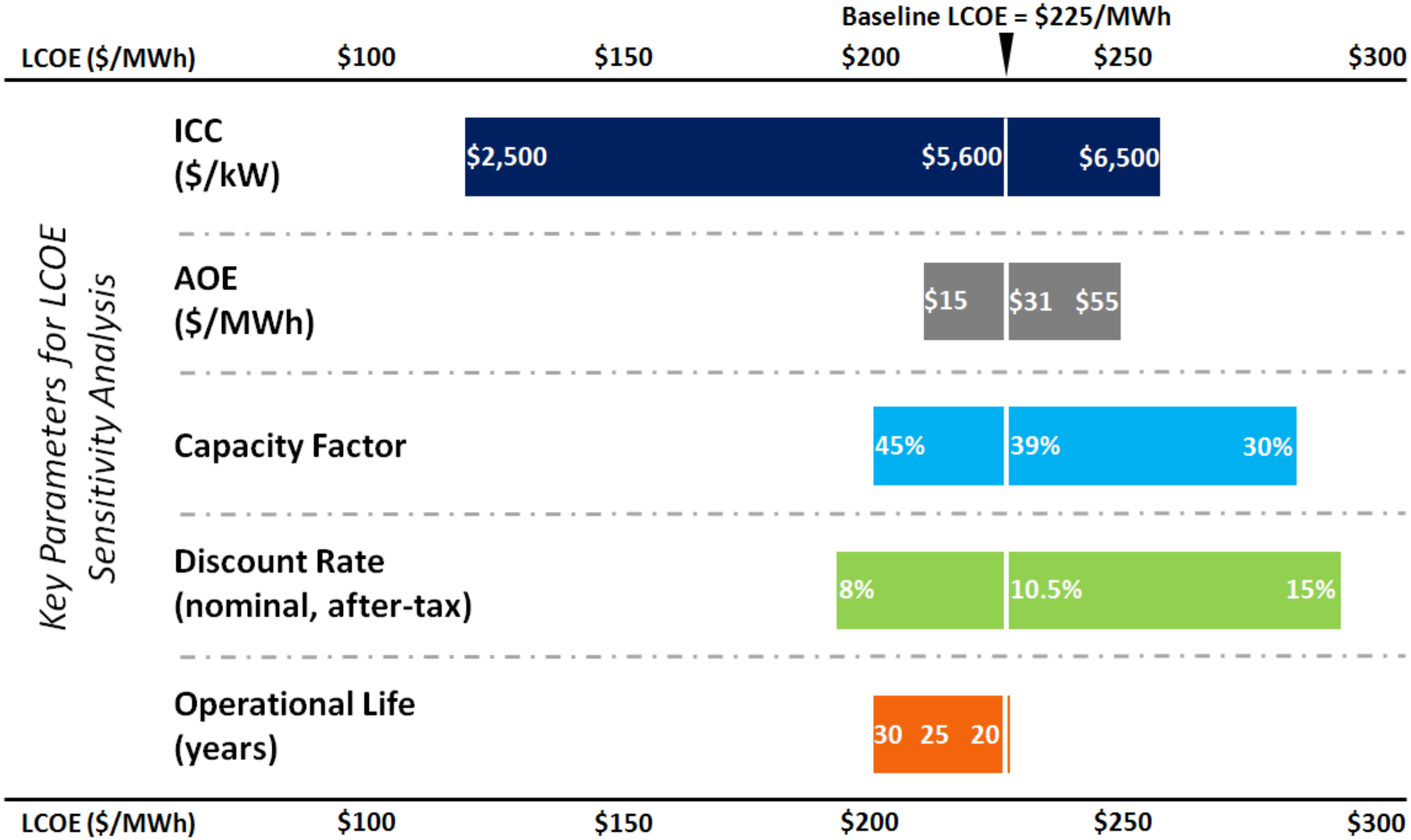
  Levelized cost of energy (LCOE): $100/ megawatt-hours (MWh) by 2020 and $70/MWh by 2030




http://www1.eere.energy.gov/wind/pdfs/national_offshore_wind_strategy.pdf

# Variability in LCOE

- **Range of reported offshore wind project installed capital cost introduces significant variability in LCOE**

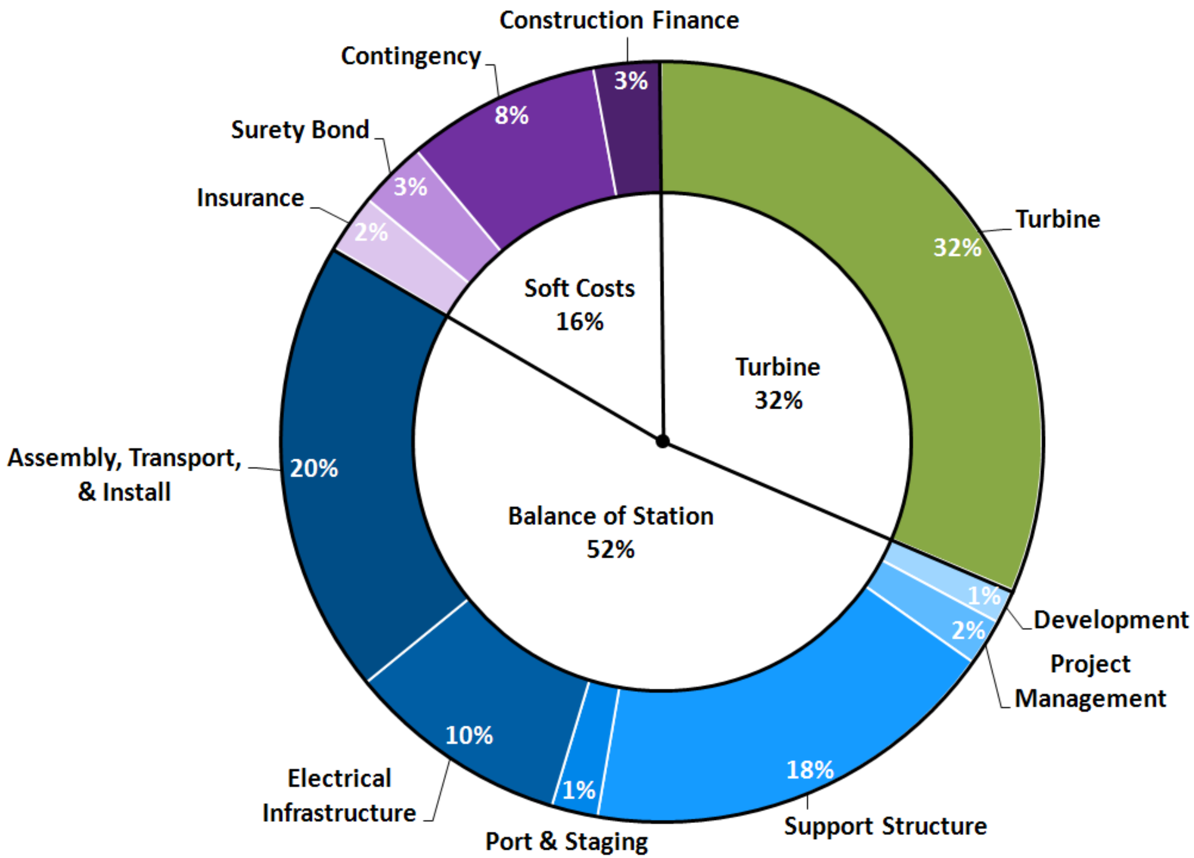



Source: Tegen, S.; Hand, M.; Maples, B.; Lantz, E.; Schwabe, P.; Smith, A. (2012). 2010 Cost of Wind Energy Review. 111 pp.; NREL Report No. TP-5000-52920.

**ICC = Installed Capital Cost** **AOE = Annual Operating Expenses**

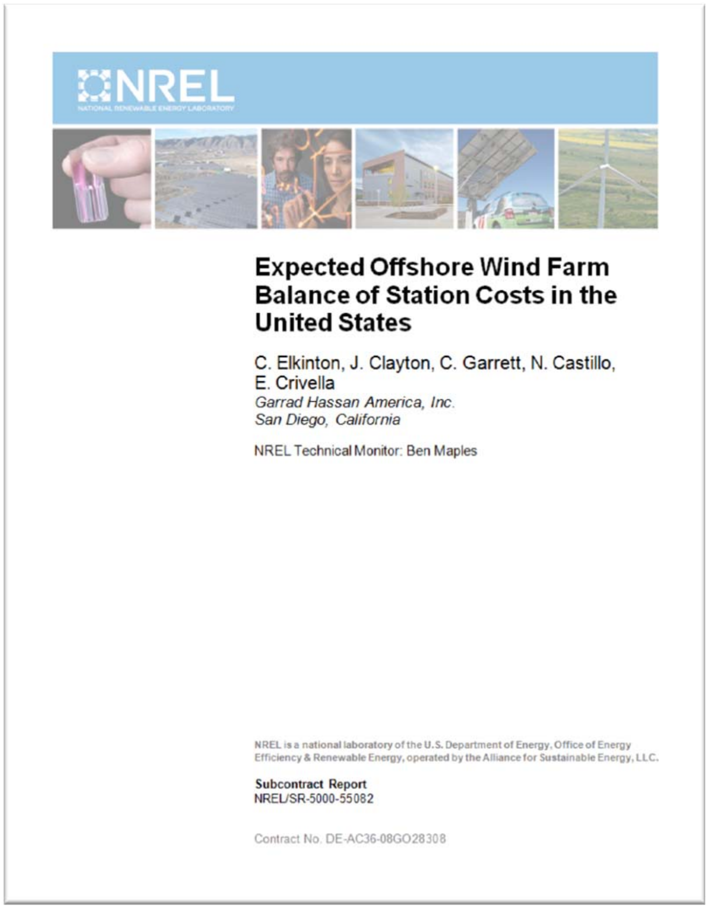
# Installed Capital Costs (ICC)

- **Balance-of-station (BOS) costs dominate ICC for offshore wind projects**
- **There are three primary BOS contributors:**
  - *Support structure*
  - *Electrical infrastructure*
  - *Assembly, transport, and install*
- **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.

# NREL BOS Model


NREL

**Expected Offshore Wind Farm Balance of Station Costs in the United States**

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NREL Technical Monitor: Ben Maples

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.

**Subcontract Report**
NREL/SR-5000-55082

Contract No. DE-AC36-08GO28308

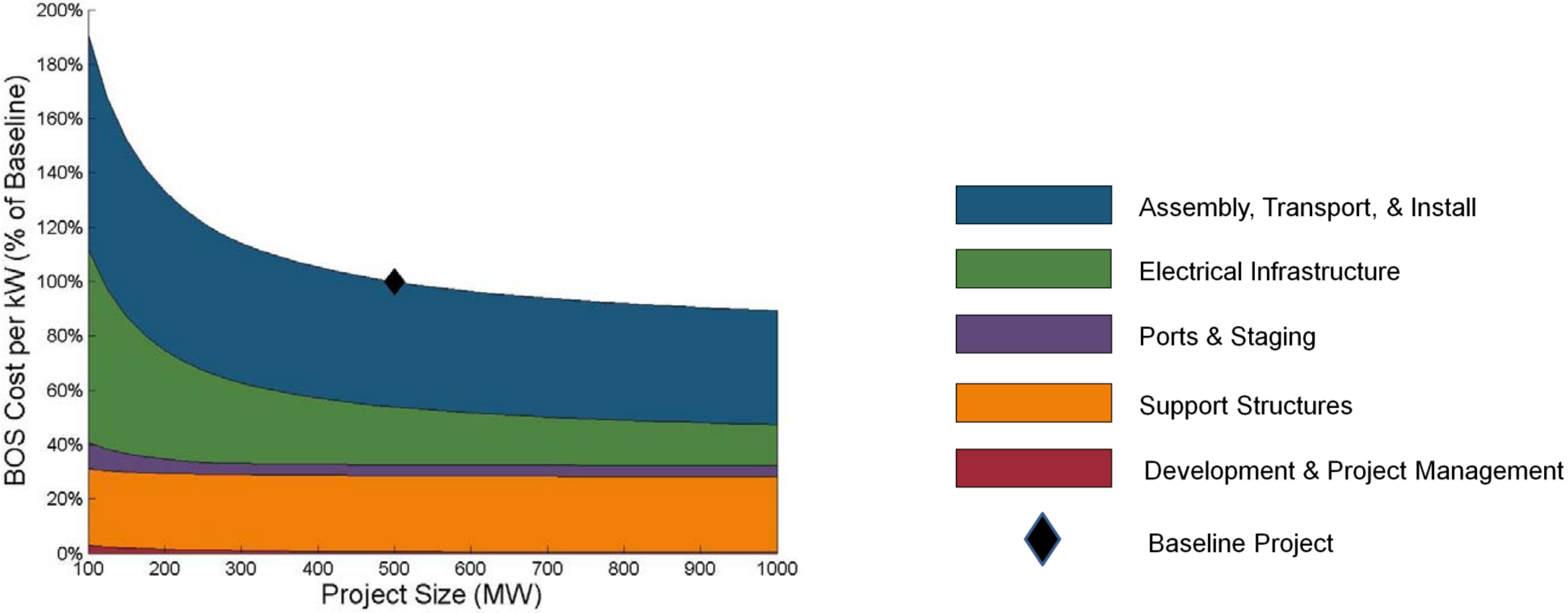
- The BOS cost model is based on data provided by GL Garrad Hassan America, Inc. (GL GH)
- Data draws from GL GH's active participation in offshore wind projects in Europe and their experience in the onshore wind industry in the United States
- The model demonstrates how various factors, such as turbine size and vessel rates, can affect BOS costs for offshore wind projects
- Due to the high level of variability in project parameters and uncertainty of site-specific elements, results of the model should be taken as representative only

# Parametric Sensitivity Analysis

| Baseline project parameters | |
|---|---|
| Project Size (MW) | 500 |
| Turbine Rating (MW) | 4.5 |
| Rotor Diameter (m) | 126 |
| Hub Height (m) | 90 |
| Distance to Shore (km) | 30 |
| Water Depth (m) | 15 |
| Foundation | Monopile |
| Array Spacing (Rotor Diameters) | 8x8 |
| Array Voltage (kV) | 33 |
| Transmission Voltage (kV) | 220 |
| IEC Wind Turbine Class | II |

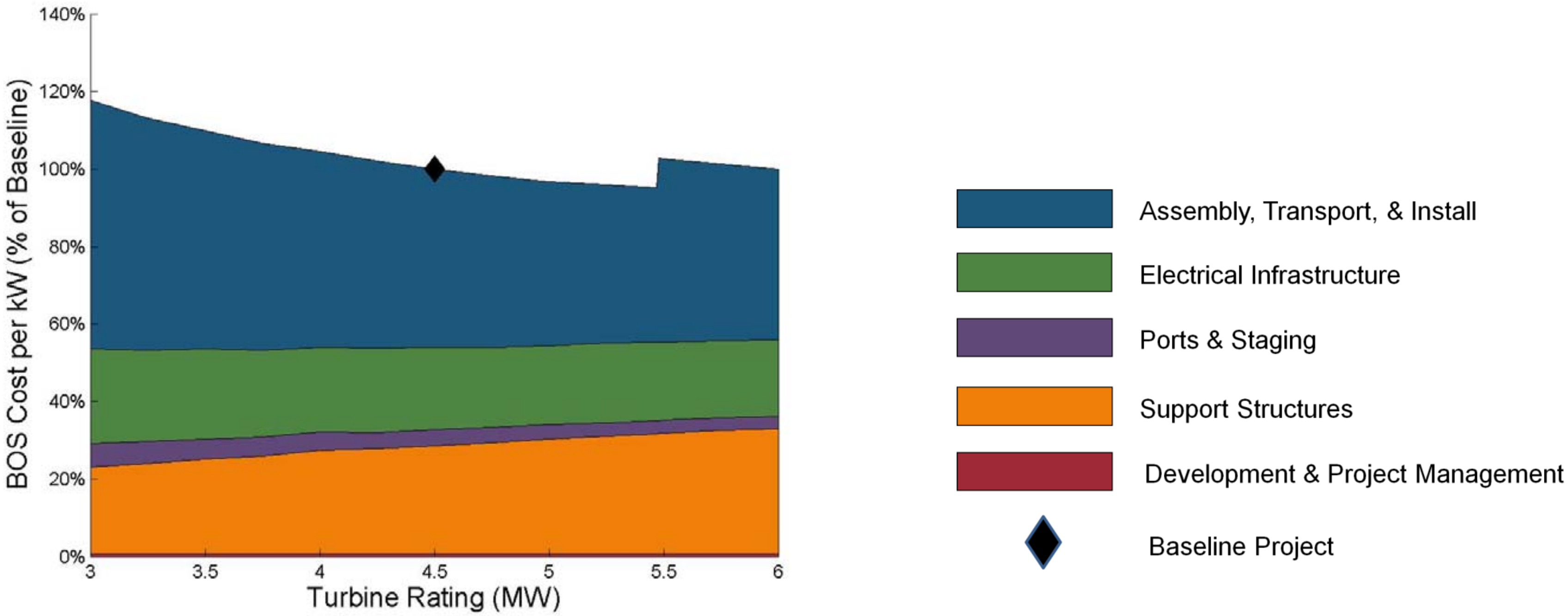
- Baseline parameters were chosen to reflect a representative offshore wind project in the mid-Atlantic
- To represent the impact of altering a single variable, all analyses use common baseline project parameters while the variable under investigation is changed.

# Sensitivity to Project Size



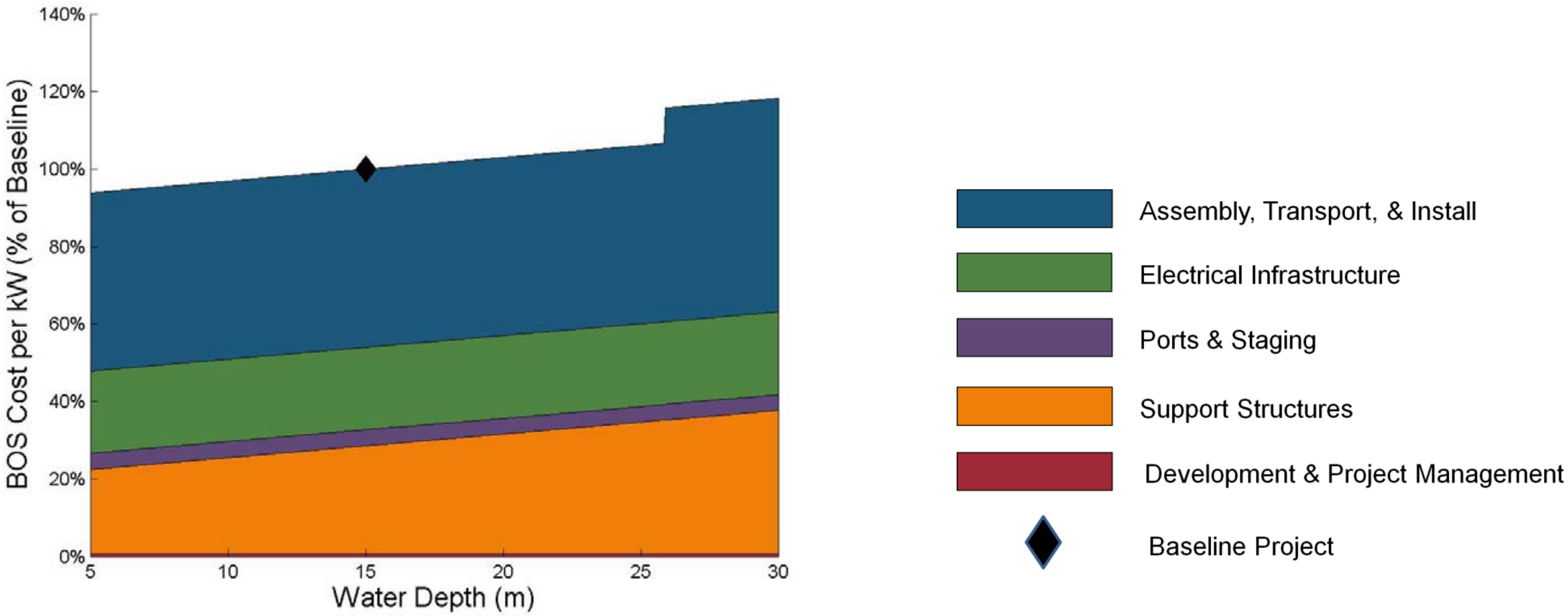

- Fixed costs such as vessel mobilization, export cable landfall operations, and others can dominate smaller project costs.
- Further reductions come from increased order sizes that reduce per item costs.
- The electrical costs represent a significant percentage of project costs at low project sizes. At larger project sizes, the support structure and assembly, transport, and install costs dominate.

# Sensitivity to Turbine Size



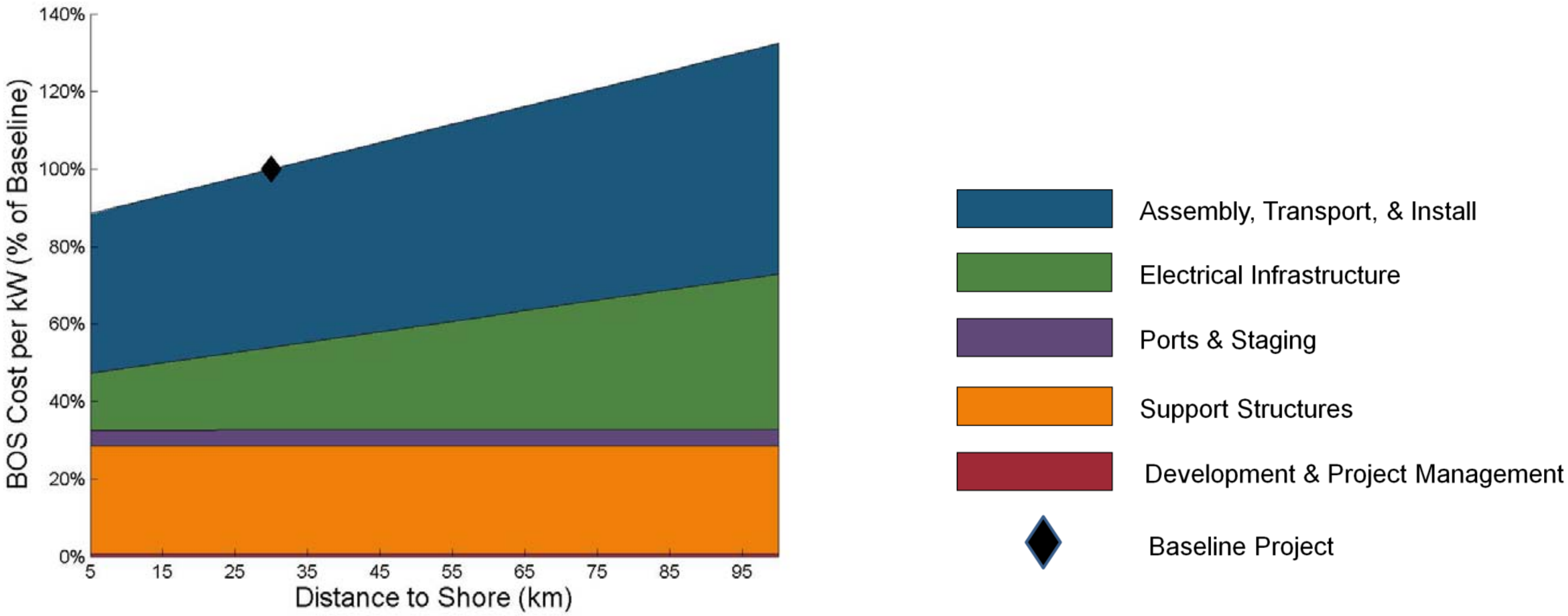

- The total BOS cost is generally reduced as turbine size increases. Monopile support structure costs increase as the turbine rating increases, but the cost increase is outweighed by the reduction in electrical infrastructure and assembly, transport, and install costs.
- The step change increase in assembly, transport, and install cost is associated with a change to a larger class of vessels. This change is needed to handle the increased monopile size required for the higher loads that are associated with larger turbines.

# Sensitivity to Water Depth



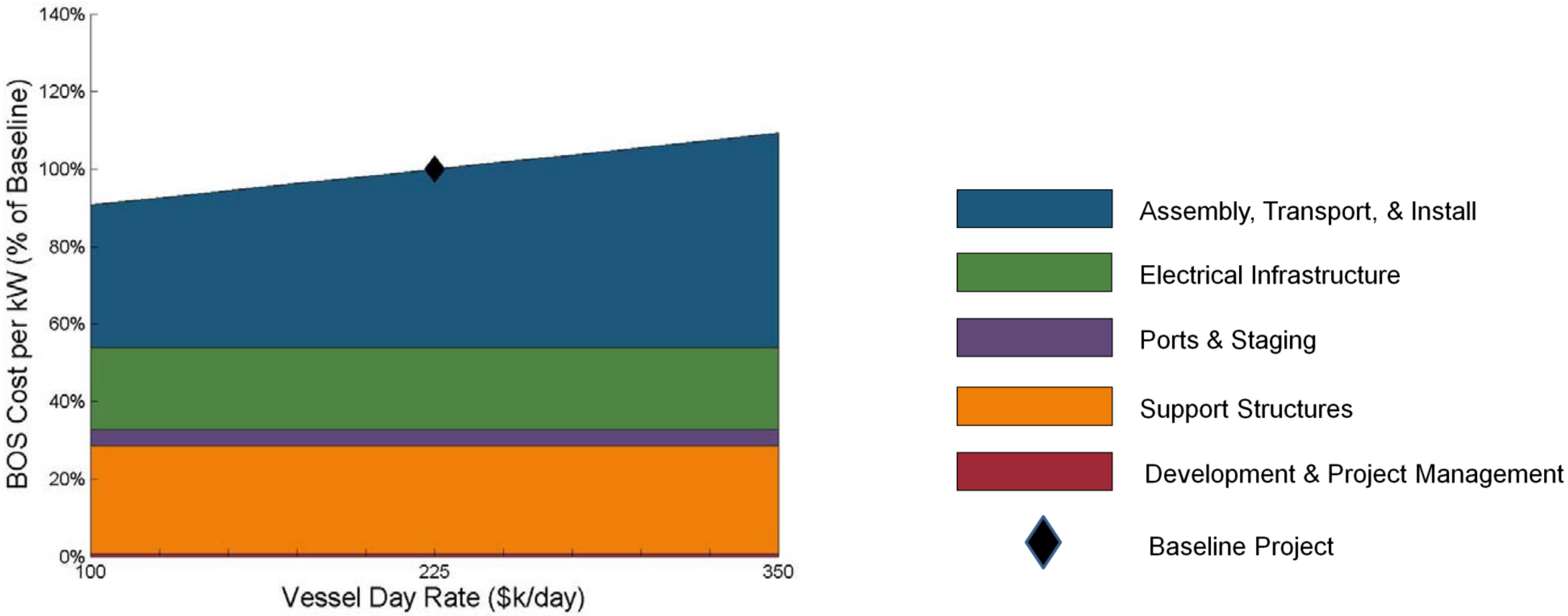

- Water depth shows no impact to electrical costs. However, it does impact support structure costs, which leads to increased total BOS cost.
- At shallow water depths, the assembly, transport, and install costs are unaffected by water depth. As the water depth increases, the monopile gets substantially heavier, which triggers a step change in costs due to the need to use a larger and more expensive class of installation vessels.

# Sensitivity to Distance to Shore




- As distance to shore increases, BOS costs can rise significantly because of the high costs of the long electrical cabling needed to connect the offshore wind project to the land-based grid.
- For projects sited farther from shore, the assembly, transport, and install costs increase as a result of transporting the turbines and foundations over greater distances.

# Sensitivity to Vessel Day Rates




- Variation of installation vessel day rates alone can substantially alter the assembly, transport, and install costs as well as total BOS costs.
- Yet-unverified U.S. installation vessel costs and the exceptionally up-and-down history of European installation vessel costs lead to highly variable assembly, transport, and install costs.

# Conclusions

- Electrical infrastructure, support structure, and assembly, transport, and install are the primary contributors to offshore BOS costs.
- The largest uncertainty in near-term offshore BOS costs is in vessel rates, which is the primary driver of the largest BOS cost: assembly, transport, and install.
- Choices made in the project planning phase (such as project location and turbine size) can play a large role in the final LCOE for the project.
- Development of new, innovative technologies that reduce or eliminate step changes in project costs can provide significant cost savings.

# Thank You

*NREL PIX 17856*