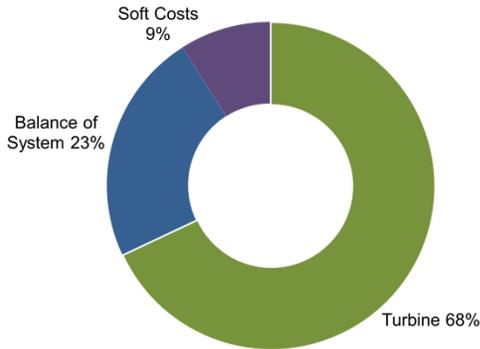


Introduction



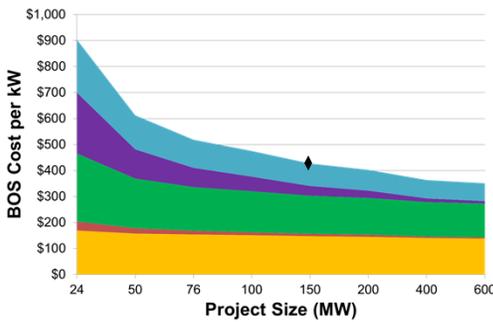
- Balance-of-system (BOS) and soft costs for land-based wind plants are almost one-third of the total project investment cost; as such, there is a need to identify and test sensitivities to BOS cost drivers to ascertain the best strategies for reducing levelized cost of energy.
- The National Renewable Energy Laboratory (NREL) has developed a new land-based wind plant BOS cost model based on developer-provided data to explore these drivers and sensitivities. The data was generated from multiple cost methods including historical, commodity, indices, and projections.
- This model demonstrates how various factors such as turbine size and project size can affect BOS costs for land-based wind projects using the NREL Cost and Scaling Model to estimate top tower mass (nacelle and rotor) for various turbines.
- Results of these analyses are based on typical value ranges for projects built in the central United States using complex turbine layouts.
- All analyses use common baseline project parameters (see Table 1) while each variable under investigation is changed in turn.
- Because of the high level of variability in project parameters and uncertainty of site-specific elements, the results of these sensitivity analyses should be taken as representative only.

Table 1. Common baseline project parameters

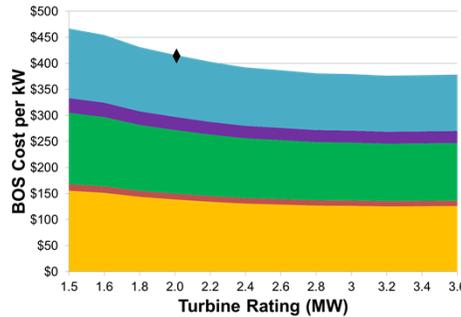
Project Size (MW)	150
Turbine Rating (MW)	2.0
Hub Height (m)	80
Interconnect Voltage (kV)	137
Distance to Interconnect (mi)	10
Site Terrain	Flat/Rolling
Turbine Layout	Complex
Pad Mount Transformer Required (Y/N)	Yes
New Switchyard Required (Y/N)	Yes
Rock Trenching Required (% of collection cable length)	10%
Contingency (%)	3%
Warranty Management (%)	0.02%
Overhead (%)	5%
Profit Margin (%)	5%

Sensitivities

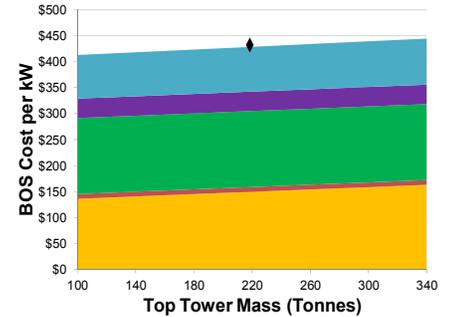
1. Sensitivity to Project Size



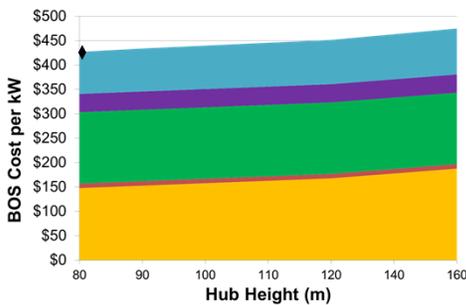
2. Sensitivity to Turbine Size



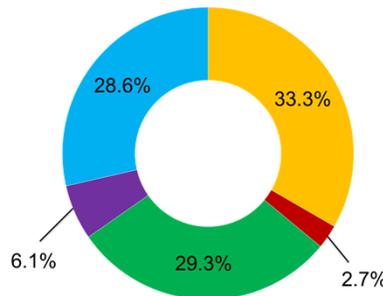
3. Sensitivity to Top Tower Mass



4. Sensitivity to Hub Height



5. Breakdown of BOS & Soft Costs*



- Development, Project Management, & Soft Costs
- Transmission & Interconnection Cost
- Electrical Interface System
- Temporary & Permanent Facilities
- Foundation, Installation, Roads, & Remainder of Civil Work
- ◆ Baseline Project

Conclusions

- Total land-based BOS costs are reduced with larger project size.
 - This effect is largely associated with fixed costs (e.g., crane mobilization and facilities) being distributed over many megawatts (MW).
 - Further reductions come from increased order sizes that reduce per-item costs.
 - The electrical costs represent a significant percentage of project costs at small project sizes. At larger project sizes, the foundation and erection costs dominate.
- The total BOS cost on a per-kilowatt (kW) basis is generally reduced as turbine size increases. Larger MW turbines require fewer foundations for the same project size, lowering the overall cost, even considering the additional electrical system costs.
- The combined mass of the nacelle and rotor assembly directly impacts the foundation costs caused by the additional mass of the components, the tower, local structural codes, and the requirements of the original equipment manufacturer for structural stability.

- The combined mass of the nacelle and rotor assembly has a larger effect on BOS costs than the hub height, up to 140 m, at which point the tower steel for the additional height has a greater effect on the foundation, assuming an all-steel tower.
- Development and project management costs are estimated as a percentage because they vary greatly due to sunk costs, length of time until a project begins construction, weather delays, risks, and project contingencies.
- Transmission and interconnection costs decrease more quickly for larger projects than distance to the substation (e.g., 50-mi T-line on a 200-MW project has less impact than the 10-mi T-line on a 50-MW project).
- Additional conclusions from our analysis not depicted above.
 - Permanent operation and maintenance facilities are a very minor cost (less than 2%) compared to the project contingencies, margins, and other soft costs in the total BOS costs.
 - Initial engineering costs and metrological masts are very minor costs (less than 2.5%) in the total BOS budget that have long term benefits