# Design Guidelines for Deployable Wind Turbines for Defense and Disaster Response Missions

B Summerville,[1] B Houchens,[2] B Naughton,[2] T Jimenez,[1] R Preus,[1] D Reen,[3] J Gentle,[3] E Lang[4]

E-mail: brent.summerville@nrel.gov, brent.houchens@sandia.gov

[1]National Renewable Energy Laboratory
[2]Sandia National Laboratories
[3]Idaho National Laboratory
[4]University of Dayton Research Laboratory

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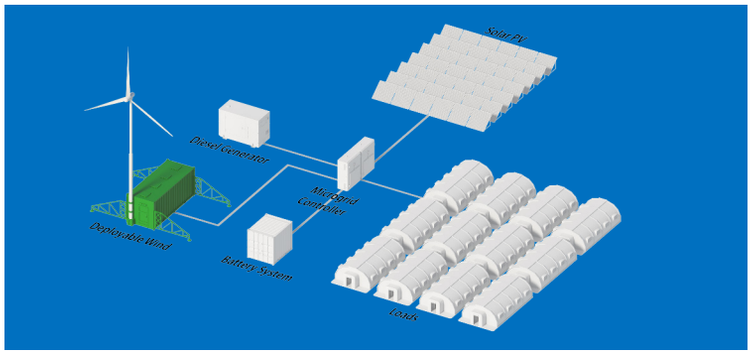
**Abstract:** Access to on-site electrical energy is critical to ensuring a successful military or humanitarian response to conflicts and disasters. These missions typically rely on access to liquid fuel that could be vulnerable to disruption or attack during transport. Generating power on location with wind technology can reduce this risk and enhance mission reach by diversifying energy sources. Common characteristics of these missions are short planning and execution time horizons and a global scope of potential locations. Compared to conventional wind turbine applications, defense and disaster response applications place a premium on rapid shipping and installation, short-duration operation (days to months), and quick teardown upon mission completion. These design drivers depart from features found in conventional distributed wind turbines, thus necessitating unique design guidance. The supporting information for this guidance comes from available relevant references, technical analyses, and input from industry and military stakeholders. This poster serves as a summary of project publications that presents the best currently available design guidance for deployable wind turbines to facilitate the effective development and acquisition of technology solutions to support mission success. This Defense and Disaster Deployable Turbine Project (D3T) is a multilaboratory effort led by Sandia National Laboratories and funded by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Wind Energy Technologies Office.




## Deployable Wind Energy Applications

Deployable wind systems can provide on-site energy at three different scales:

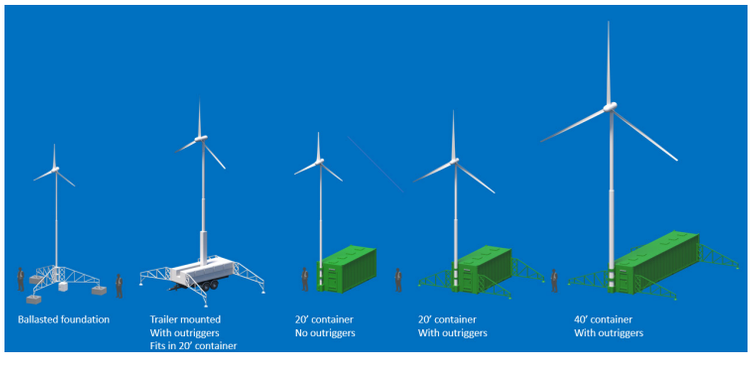
- **Mobile**. Generally, less than 3 kilowatts (kW), these are highly mobile systems transported by a backpack or small trailer that is assembled/disassembled in minutes.
- **Small**. In the range of 10-20 kW, these systems support a portion of loads for weeks to months and take hours to set up.
- **Large**. Serving larger loads for months to over a year, these systems include a wind energy system up to 100 kW, are part of a larger microgrid, and are set up in hours or days.

**Figure 1. An approximately 20-kW deployable wind energy system as part of a microgrid.** ***Graphic courtesy of NREL***

## Existing Deployable Wind Systems

We explored several deployable wind energy products; three are shown here as examples. The Hybrid Power Shelter from HCI Energy is a complete wind + solar + storage system that is transported via a 20-foot (ft) shipping container. The trailer-mounted system from Uprise Energy features a telescoping tower and a 10-kW wind turbine and fits within a standard 20-ft container for transport. The Deployable Advanced Renewable Power System (DARPS) under development by Bergey Windpower utilizes two, 15-kW Bergey Excel 15 wind turbines on a mobile microgrid structure that transports as a 40-ft container.

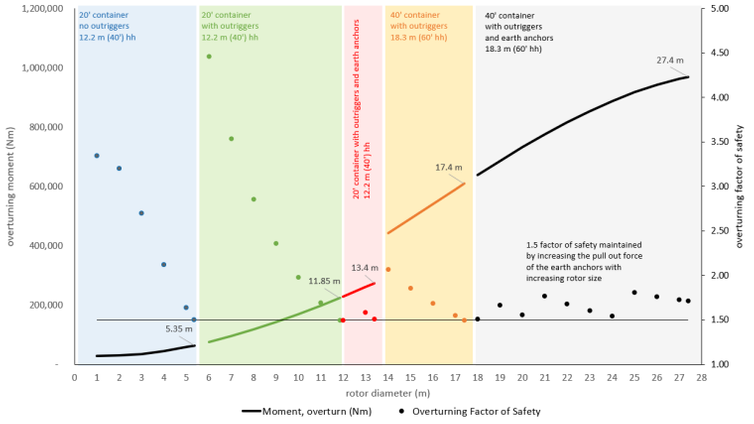
**Figure 2. (Left to right) HCI's Hybrid Power Shelter** ***(photo courtesy of HCI Energy)*****, the trailer-mounted system from Uprise Energy** ***(photo courtesy of Idaho National Laboratory)*****, and DARPS from Bergey Windpower** ***(photo courtesy of Bergey Windpower Company)***




## Transportation and Foundations

The team analyzed the maximum wind turbine that can be transported in standard 20-ft and 40-ft International Organization for Standardization (ISO) shipping containers. For the 20-ft container, the preferred size for ease of transport, the largest turbine would have a rated power ranging from 11 to 30 kW with a maximum rotor diameter of 13.4 meters (m) (43.9 ft). For the 40-ft container, the largest turbine would have a rated power of about 80 to 125 kW, with a maximum rotor diameter of 27.4 m (89.9 ft). It is preferred and sometimes required that the deployable turbine foundation cannot significantly disturb the local ground surface. Nonpermanent foundation options include ballasted, trailer-mounted, and shipping containers.

**Figure 3. Summary of nonpermanent foundation options explored in this analysis.** ***Graphic courtesy of NREL***




## Overturning Analysis

The D3T team performed an overturning analysis for the various foundation options to provide guidance on container size and use of outriggers and earth anchors to resisted toppling moments from extreme wind loading (44.7-meters-per-second (100 miles per hour)) while maintaining a minimum factor of safety of 1.5. A 20-ft container with no outriggers was found to serve as a sufficient foundation for a wind turbine with a rotor diameter up to 5.4 m (17.7 ft). For rotor diameters greater than 5.4 m (17.7 ft), outriggers, followed by earth anchors, are required to prevent overturning up to the maximum 13.4-m (44 ft) rotor diameter. A 40-ft container with outriggers will resist overturning for a rotor diameter up to 17.4 m (57 ft) or up to the maximum size that will fit into a 40-ft container if earth anchors are added to the outriggers.

**Figure 4. Summary results of overturning analysis for 20-ft and 40-ft ISO shipping containers as deployable wind turbine foundations, including outrigger and earth anchor requirements (hh = hub height).** ***Graphic courtesy of NREL***

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