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Deployable Wind Power for Defense and Disaster Response Workshop Summary

Brent C. Houchens, Sandia National Laboratories
Brent Summerville and Tony Jimenez, National Renewable Energy Laboratory
Dylan W. Reen and Jake Gentle, Idaho National Laboratory
Eric J. Lang, University of Dayton Research Laboratory

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico
87185 and Livermore,
California 94550

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ABSTRACT

On June 17, 2022, the multi-laboratory, U.S. Department of Energy (DOE)-funded Defense and Disaster Deployable Turbine (D3T) project team held a virtual workshop with technology developers and stakeholders from defense and disaster response communities to discuss the needs for demonstrating and deploying wind-hybrid deployable energy systems.

About 90 participants joined the half-day meeting, which was kicked off by Bret Barker of DOE Wind Energy Technologies Office (WETO). The Distributed Wind Program under WETO invests in research and development (R&D) to advance wind technology as a distributed energy resource (DER) and accelerate its deployment. Bret opened the meeting with an overview of the D3T project objectives:

- Evaluate the market potential for rapidly deployable wind energy technologies
- Develop wind turbine design requirements for operational applications
- Assess commercially available wind technologies against operational design requirements to identify R&D opportunities.

The goals of the workshop were to:

1. Connect solution providers and researchers with stakeholders from the defense and disaster response communities
2. Learn about solutions already on the market or coming soon
3. Understand the needs of the defense and disaster response communities with respect to deployable, renewable hybrid energy systems, particularly distributed wind.

The workshop successfully brought together potential end users and technology providers. There was a clear consensus from both sides that deployable wind solutions need to be easy to use. Reliability and robustness were deemed critical for both military and disaster response applications. Technology suppliers highlighted financing, low wind speed performance, and streamlined certification procedures as critical needs.

Throughout, the theme of integration resurfaced many times. This included integration with solar solutions and other microgrids. There was unanimous support for the establishment of a test bed for industry and stakeholders to advance deployable wind solutions, integration, and evaluation.

ACKNOWLEDGEMENTS

The D3T team would like to thank the many companies that presented technology solutions in the lightning round, Will Heegaard and Colonel Perkins for sharing their perspectives on disaster relief and defense needs, respectively, and the many attendees who contributed to the lively discussions during the workshop.

This work was supported by the Wind Energy Technologies Office of the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy.

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ACRONYMS AND TERMS

Acronym/Term	Definition
AWE	airborne wind energy
CIP	Competitiveness Improvement Project
D3T	Defense and Disaster Deployable Turbine
DARPS	Deployable Advanced Renewable Power Systems
DER	distributed energy resource

1. WORKSHOP DETAILS

The Defense and Disaster Deployable Turbine (D3T) project team held a virtual workshop for stakeholders on June 17, 2022. D3T project details are archived at

- Sandia National Laboratories (Sandia) D3T website:

https://energy.sandia.gov/programs/renewable-energy/wind-power/national-security/defense-and-disaster-deployable-turbine/

- National Renewable Energy Laboratory (NREL) D3T website:

https://www.nrel.gov/wind/defense-disaster-deployable-turbine-project.html

1.1. Schedule and Logistics

- Date: June 17, 2022
- Start: 10 a.m. EDT
- End: 1:30 p.m. EDT
- Participants: ~ 90
- Platform: MS Teams (Sandia Account)
- Meeting recorded for internal project team use only
- The team agreed to send the list of registrants to workshop participants
- The team did not commit to posting presentations; rather, this workshop summary report will be made available on the Sandia D3T website.

2. D3T PROJECT OVERVIEW

Wind energy has the potential to support defense and disaster response missions, but the key drivers are quite different compared to conventional wind energy applications. To characterize some unique aspects of deployable wind for defense and disaster relief, the D3T team first provided an overview of several project topics including the microgrid analysis framework, an airborne wind energy assessment, a container and foundation analysis, and procurement specifications. More details of the D3T project can be found in Naughton *et al.*, 2022 [1].

2.1. D3T Overview and Microgrid Analysis, Brent Houchens

Traditional wind markets focus on minimizing the levelized cost of electricity (LCOE) over a 20- to 30-year life span of the device. In contrast, military and disaster response applications value ease of transport and fast assembly. In these shorter-duration missions, cost is much less of a concern. Figure 1 below highlights the differences in drivers.

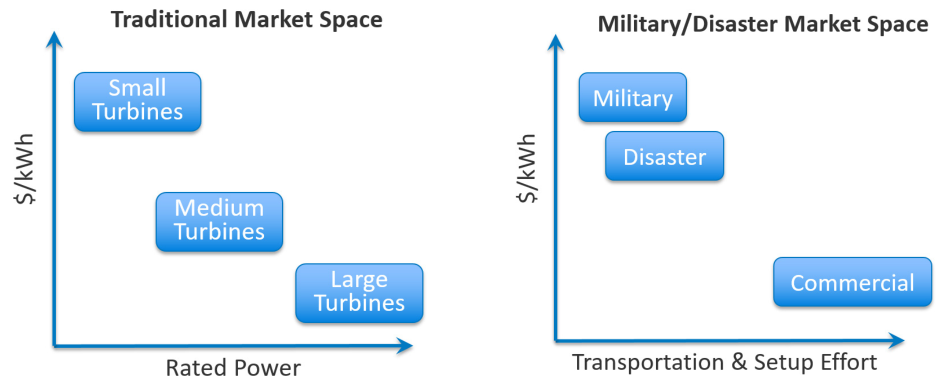

Figure 1: Cost per kilowatt-hour (kWh) is the key metric in traditional markets. Military and disaster response markets favor ease of transport and setup over levelized cost of energy.

2.2. D3T Airborne Wind Energy, Eric Lang

Dr. Lang introduced airborne wind energy (AWE) systems. Currently, sail and wing systems are the most common types of airborne wind energy systems.

Compared to traditional towered wind energy, airborne wind systems benefit from greater wind speeds because they operate at higher elevations where the wind speeds are generally higher (Figure 2). Higher wind speeds can lead to higher capacity factors. Generally, the total land area where wind is feasible is greater for airborne wind as compared to towered wind energy.

a) b)

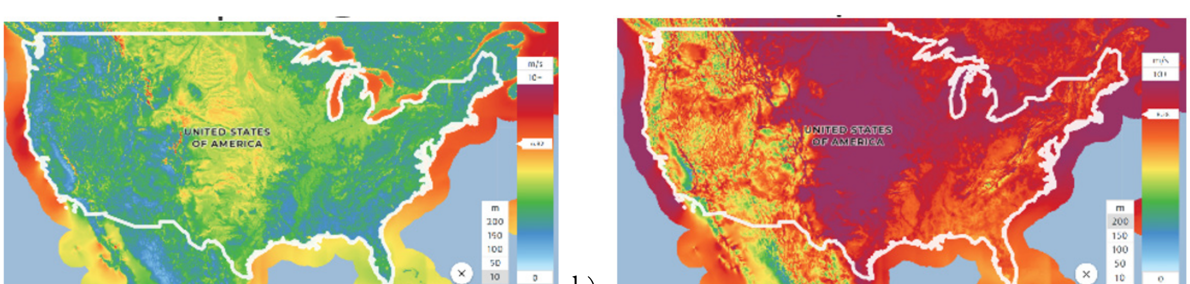

Figure 2: Average wind speeds at (a) typical deployable heights (10 m) and (b) potential airborne heights (200 m). (https://globalwindatlas.info/en)

Dr. Lang introduced the concept of logistical burden. The logistical burden of an energy technology can be reduced to the number of truck trips needed to supply the equipment and any fuel for a given amount of energy production. As demonstrated in Figure 3, the logistical burden for diesel generators is the combination of the generators and the ongoing need for fuel. For renewable sources such as wind and solar, the logistical burden is only the initial shipment of the equipment. While generators have the smallest initial logistical burden, over time renewable sources will have less total logistical burden. The optimal mix of solar, wind and diesel generators would depend on site-specific solar and wind resources. By using average values for these resources, it was shown that AWE has the shortest breakeven period compared to diesel generators, followed by solar and finally traditional towered wind. Here the capacity factor was assumed the same for both towered and airborne wind. With full automation, AWE should have higher capacity factors than towered wind due to higher wind speeds aloft. Further, it is important to note that a skilled operator is *not* assumed for AWE. Through personal communications, one AWE company verified that they demonstrated operation by military personnel after only a brief training in a deployed context. The military personnel were actually more efficient than the engineers at setting up and running the system.

However, while AWE systems have been tested for thousands of hours, they have not yet been tested in continuous operation. Thus, while airborne wind energy has large potential, because the technology is very new and at a low technology readiness level (TRL), it should be studied and tested further.

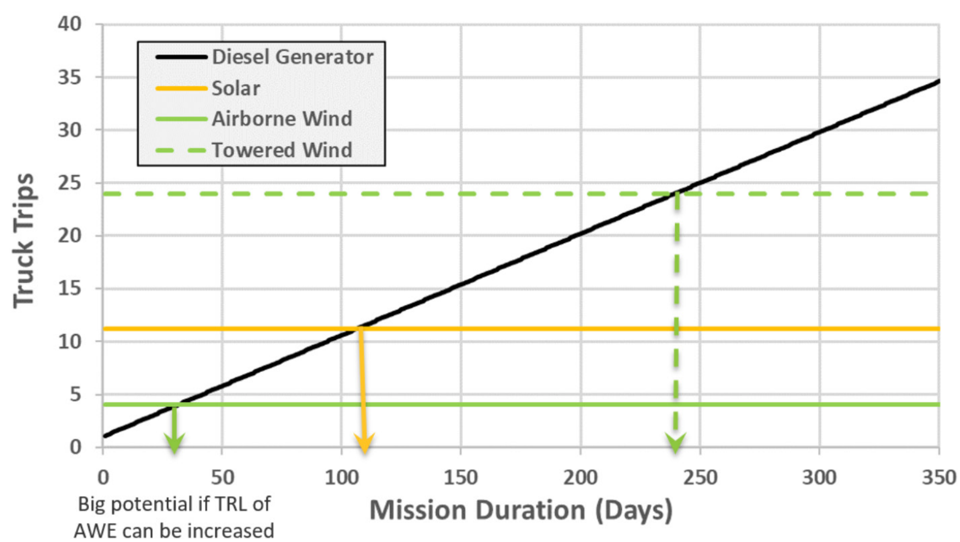

Figure 3: Effectiveness of towered wind and solar energy compared to diesel alone, measured in breakeven number of days of the mission. The potential of airborne wind energy (AWE) for military and disaster response applications is also indicated if the technology readiness level (TRL) of such devices were advanced.

2.3. D3T Container/Foundation Analysis, Brent Summerville

Mr. Summerville provided an overview of two analyses performed by the D3T team: one on the maximum wind turbine that will fit into standard 20-foot (ft) and 40-ft ISO shipping containers and one on nonpermanent foundation options for deployable wind energy systems.

For the 20-ft container, the rated power of the maximum rotor size could range from the 11-kilowatt (kW) Gaia turbine to the 30-kW BestWatt turbine. For the 40-ft container, the rated power of the maximum rotor size could range from about 80 kW to 125 kW. While blade length is a key determining factor, hub extenders can be used to increase the maximum rotor diameter per container.

For the foundation analysis, a variety of options were pursued, including ballasted foundations, trailer-mounted systems, and shipping containers used as foundations, as shown in figure 4. Overturning analysis was performed for existing systems from HCI Energy, Bergey Windpower, and Uprise Energy. A generic overturning model was developed, which resulted in guidance on container size and outrigger and earth anchor use for the full range of wind turbine rotor diameters to safely prevent overturning and sliding.

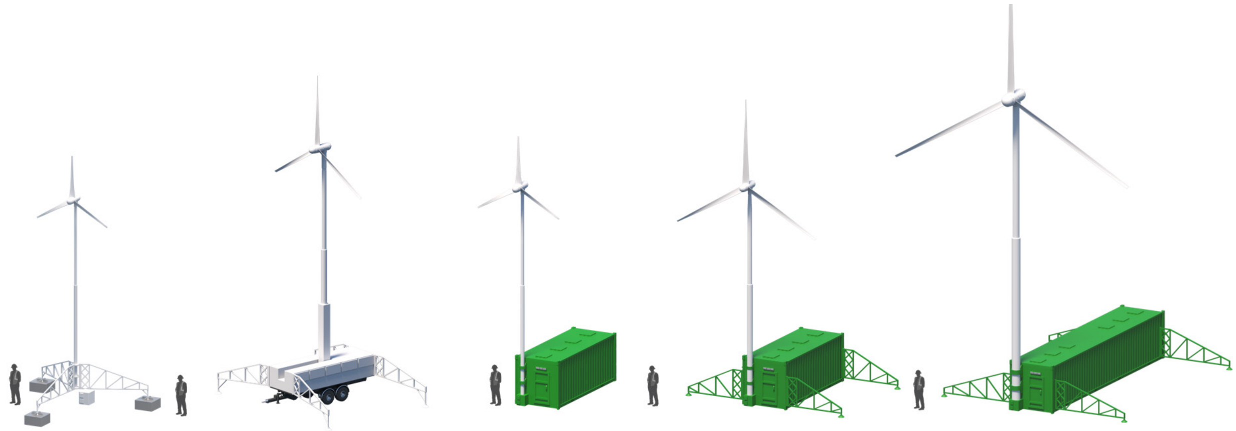

Figure 4: Foundation options considered in the analysis.

2.4. D3T Procurement Specifications, Dylan Reen

Through conversations and meetings with the wind community and U.S. Department of Defense (DoD) personnel, the D3T team identified a need for a document that would allow wind manufactures to better understand what the DoD requirements would be for a deployable wind turbine. The D3T team assembled an advisory board meeting consisting of personnel from the Airforce Research Laboratory, Army Research Laboratory, National Guard units, operational energy experts, and wind turbine manufacturers. The advisory board met twice to review the specification, identify needs, and offer critiques.

The advisory board helped identify military standards and standard practices that would be applicable to the turbine. Items like transportation requirements for trains, trucks, trailers, boats, fixed wings, and helicopters were included, but so were nonstandard items like electromagnetic interference tests, salt spray endurance testing, large temperature swings, and vibration and shock testing. The published performance specification contains the military standard identification number and a short description of each applicable standard that a deployable turbine would be adherent to and the testing it would require. Any manufacturer looking to create a turbine or renewable generation system for the DoD should consider reviewing this document.

3. LIGHTNING ROUND OF INDUSTRY/TECHNOLOGY SUPPLIERS

The following 11 technology suppliers participated in a lightning round, which provided a cross-sectional sample of solutions available for the deployable energy market. Presentations included certified horizontal-axis wind turbine systems in deployable microgrid applications, trailer-mounted wind and battery energy storage systems, small-scale hybrid power systems, and airborne wind energy systems in development.

3.1. Bergey Windpower Company, Mike Bergey

http://www.bergey.com/

Bergey presented on their Deployable Advanced Renewable Power Systems (DARPS), a microgrid technology demonstration project funded by the DOE through NREL's Competitiveness Improvement Project (CIP). DARPS features two tilt-up monopole towers with two certified Excel 15 turbines and a complete microgrid using second-life Nissan Leaf battery packs, Intergrid wind turbine interface, Oztek power electronics, and a 30-kW advanced medium mobile power source (known as "AMMPS") generator. The focus of the design is simplifying system deployment while maximizing the rotor-swept area in a standard 40-ft shipping container at a cost competitive with diesel generator technology.

3.2. Primus Windpower, Ken Kotalik

https://www.primuswindpower.com/

Primus offers a family of certified, micro battery-charging wind turbines from 160 watts (W) to 400 W in rated power with 46-inch rotor diameters. The U.S.-made "Air" family of products have been in production since 1995 with more than 175,000 units in the field. The six available models cover land and marine applications and low, moderate, and high wind resource regimes and are typically installed in hybrid systems.

3.3. APRS World, Jim Jarvis

http://www.aprsworld.com/

APRS presented on their U.S.-made WT1X micro wind turbine (1.0 meter diameter, 1 kW maximum power) for extreme, remote, battery-charging applications. Hundreds of their turbines are operating in the Arctic and Antarctic. APRS offers complete hybrid, microgrid system designs to deploy in standard shipping containers.

3.4. Ryse Energy, Liam Griggs

https://www.ryse.energy/

Ryse Energy is a wind turbine supplier based in the United Kingdom with a variety of turbine offerings from 3 kW to 60 kW. They offer hybrid, microgrid solutions and have more than 4,000 systems deployed globally covering rural, remote, telecom, industrial, wind-to-water, and island applications. Ryse presented a video of their Sustainable Resilience Unit, a containerized, deployable wind-solar-generator-battery storage microgrid solution utilizing their 4-kW turbine on a telescoping crane/tower.

3.5. Uprise Energy, Jonathan Knight

https://upriseenergy.com/

Uprise is developing a portable, trailer-mounted wind-solar-battery system, optimized for low wind regimes. The system includes a 10-kW wind turbine and transports in a standard 20-ft shipping container. The Idaho National Laboratory D3T team members have worked with Uprise Energy on testing and evaluation of their technology.

3.6. Aeromine Technologies, Carsten Westergaard

https://www.aerominetechnologies.com/

Aeromine is developing a novel 5-kW wind turbine with no external moving parts for industrial and commercial rooftop deployment. The Aeromine system can be transported in 20-ft shipping containers.

3.7. Nomad Transportable Power Systems, Chris McKay

https://www.nomadpower.com/

Nomad offers a range of transportable battery energy storage systems from 250 kW/664 kWh to 1,000 kW/1,993 kWh. Their trailer-mounted systems provide remote power or integrate into a microgrid based on renewable energy.

3.8. Kitepower, Joep Breuer

https://thekitepower.com/

Kitepower is a Dutch supplier of an airborne wind energy system. Their kite-based system produces an average power of 100 kW and deploys in a 20-ft shipping container. The presentation included a pilot deployment of their Falcon system in Aruba for training and demonstration.

3.9. Windlift, Rob Creighton

https://windlift.com/

Windlift is a U.S.-based supplier of a tethered-drone airborne wind energy system. At a windy location, their SBIR-funded 4-kW, 50-pound unit can charge about 500 pounds of NATO 6T lithium batteries in a day as well as provide ancillary sensory and communication services. Windlift is also developing a towable 25-kW unit in a 20-ft container and a 100-kW unit in a 40-ft container.

3.10. SkySails Power, Mark Hoppe

https://skysails-power.com/

SkySails is a Germany-based supplier of a kite-based airborne wind energy system. They have one pilot system installed in Germany with plans for a second pilot system. Their design features a 100–200-kW rated power and transports in a 30-ft container, which also serves as the system base.

3.11. Solar Stik, John Gumpf

https://www.solarstik.com/

U.S.-based Solar Stik offers portable power systems incorporating solar, storage, and sometimes wind energy technology for serving loads from <3 kW to >10 kW.

4. DISASTER RESPONSE PERSPECTIVE

4.1. Will Heegaard, Operations Director, Footprint Project

https://www.footprintproject.org/

Footprint Project is a nonprofit disaster response organization based in Minneapolis, Minnesota. Their current efforts are focused on providing clean energy solutions for disasters in the Gulf of Mexico and Pacific coast regions. As the scale, intensity, cost, and frequency of disasters—including drought, freeze, tropical storms, wildfires and flooding—are increasing, the typical portable fossil fuel generator solution has become more unsustainable and problematic for these communities. The primary Footprint solution includes solar plus battery storage systems. Active programs include deploying mobile solar generators for disaster response, training local partners on the operation of solar generators for community resilience, and utilizing second-life solar components, diverting waste into active systems. To date, Footprint has deployed systems in more than 15 disaster missions with 150 kW of solar and 550 kWh of battery storage, providing sustainable emergency power for more than 25,000 survivors. Some recent examples include Hurricane Ida, tornadoes in Kentucky, Puerto Rico earthquakes, tornadoes in Tennessee, COVID-19 field clinics, and California wildfires.

Moving forward, Footprint is working to expand their efforts by developing national networks of sustainable, deployable energy infrastructure, training a workforce of volunteer and professional responders, and piloting new models of community resilience through equipment rental and training/education.

Mr. Heegaard presented a few case studies to provide a cross section of technology solutions deployed but stressed that there is a large gap in activation of clean energy technology solutions due to lack of training in the operation of these new and different systems. While open-source, online training is being offered via Heatspring, there remains a need to bundle training with equipment and work to increase awareness and competency. Secondly, the logistics of deploying solutions to disaster sites remains a challenge in terms of transportation, storage, staging, remote monitoring, operations, and maintenance. Third, reporting of energy and human impacts, including positive and negative impacts, remains a vital component for continued funding, including grants and sponsorship, and ongoing operations sustainability.

As an example, positive feedback was received from a deployment in Steamboat Springs, where a solar trailer was deployed to power a trailer park where grid infrastructure failed. For this relatively long-term deployment (months), the solar trailer provided a viable solution where a liquid fuel generator would not be feasible, helping the local fire station see the value in this type of new tool for disaster response.

Footprint expressed excitement in the “new toys” presented in the lightning round and a desire for demonstration units to be deployed to increase awareness and provide training opportunities.

5. DEFENSE PERSPECTIVE

5.1. Colonel John Perkins, Director of Construction Facilities Management Office, Iowa National Guard

Colonel John Perkins has spent 25 years in the military negotiating multimillion-dollar procurements and large-scale construction contracts, managing base operations, and handling logistics at a host of bases worldwide. His expertise is derived from deploying, operating, and maintaining operational energy at permanently installed, temporary, and disaster relief scenarios. He has seen firsthand the hardship a fuel supply convoy can face in a disaster scenario or theater of war.

The risk mitigation matrix that Col. Perkins uses considers the severity of the impact versus the frequency of occurrence. Priorities are placed on events with low and medium impact and moderate to high frequency. These less severe events take priority in disaster planning and are a driving factor on purchasing decisions. Examples of these events are floods, tornadoes, winter storms, and kinetic events at substations. The objective is to provide backup power and to stabilize the affected area and return power to normal in 72 hours.

High-impact, low-frequency events are often difficult to plan for and would cause long-term outages. Examples of high-impact events are such as extreme solar flares that produce enough geomagnetic disturbance to disrupt power grids and computing systems, cyberattacks, and high-altitude electromagnetic pulses. Extreme events of this nature would damage more critical infrastructure than is feasible to store. Such events are ignored for this exercise.

In the event of power generation deployment, the objective of the National Guard is to reduce resupply missions and keep troops focused on the larger task at hand. This reduces the number of unprotected troops outside the safety of a base and is the goal in training exercises, forward operating bases, and natural disaster deployments. The DoD is focused on extending the time between resupplies with the largest emphasis on extending generator run time and reducing fuel usage. Often, during disaster scenarios and war-time operations, diesel fuel can only be delivered to affected areas by helicopter due to washed-out roads or unsecured areas in combat zones; this can be quite expensive. These are the types of logistic operations the DoD believes renewable energy sources can drastically impact by reducing generator runtimes.

While deployable wind products are still in their infancy, the DoD has tested solar assets of all sizes. Col. Perkins has partnered with Iowa State University to design and deploy solar storage cubes that can be used in disaster scenarios. His driving criteria for these units is that a minimum crew of soldiers who have received little to no training should be able to assemble the unit in 5 hours. This same standard should be used for a guide as deployable wind assets are designed and tested.

Further breaking down the ideal disaster relief power generation systems, Col. Perkins described three generation sizes to optimize power delivery and meet the 72-hour disaster window—the Crate-O-Energy, the Pallet-O-Energy, and the Bucket-O-Energy. The Crate-O-Energy is a generation system delivered by a truck that could power hospitals, water treatment centers, and other large facilities. The Pallet-O-Energy could power shelters, homes, and convenience stores. The Bucket-O-Energy is a system designed to shelter in place that would provide medical device charging, energy for cold food storage, and other essentials.

This power delivery method attempts to reduce a common issue in disaster relief—providing too much power and having too little of a load. A common scenario is finding an individual who is safe and secure in their dwelling but has a medical device that requires power. This results in a logistic burden where the individual would need to move to an evacuation facility or, conversely, a generator and fuel resupplies would need to be deployed to that individual's location. With storage and generation systems of multiple sizes, the needs of individuals, small facilities, and large facilities can be met.

It could be argued by government officials that it is hard to justify such a large investment in renewable generation and storage systems that sit in storage for "what if" disaster scenarios. However, Col. Perkins rebuts that while not in use for disaster relief scenarios, these renewable and storage systems could be strategically stored and actively used as grid-scale batteries. This would allow communities to store excess solar and wind generation to use during times of peak loads and disturbances while verifying that the units are operational. Such a system could, for example, have significantly reduced the impact of the 2021 Texas freeze in which power lines were fully operational, but there was not enough power being generated.

6. OPEN DISCUSSION

The final session provided an opportunity for open discussion and to collect feedback via in-meeting, online polling.

6.1. Q&A Summary

- Innovative Energy Solutions for Military Applications, part of NATO's Smart Energy Initiative, was brought to the attention of the group.
- Q: Is there a special military standard for these deployable systems in addition to the applicable International Electrotechnical Commission (IEC) standards? A: The D3T team lists other relevant standards in our D3T Design Guidelines [2], including the DoD Tactical Microgrid Standard, which is in development and addresses microgrid integration and operation.
- Q: Is there guidance on the siting of wind energy systems and methods to calculate the percentage of wind/solar contributions to the microgrid? A: This type of analysis was part of the D3T Microgrid Analysis, showing the optimal mix of distributed energy resources based on the duration of the deployment and the solar and wind resources. This analysis was performed using the HOMER® (Hybrid Optimization of Multiple Energy Resources) software. Primus Windpower described their method of estimating the wind resource for a given location and deciding if wind is appropriate. Primus reports that on average, solar contributes 70%–80% of energy input with wind contributing 20%–30%. APRS deploys to sites with very low solar resource, where the wind contributes to the vast majority of the microgrid energy input. Uprise Energy reports that their system is optimized for sites with a low wind resource (4.5 m/s average) but can be tailored for sites with a higher wind resource.
- Q: Is hydrogen still a viable solution for energy storage? A: Hydrogen/fuel cell systems still exist but are less popular than in the past, although there seems to be renewed interest. It was noted that Toyota announced that it plans to make hydrogen fuel cell modules available in the United States starting in 2023. In our presentations today, lithium-iron-phosphate battery chemistry appears to be dominating in this space.
- Q: Are there recommendations on small, portable hybrid controllers? A: Bergey Windpower mentioned the use of Oztek and Intergrid power electronics for small microgrids. Intergrid reported on current work with Bergey Windpower on residential-scale wind plus storage microgrids.
- Q: What wind resource maps are available? A: Some dealers, like Primus Windpower, subscribe to paid services (e.g., UL/AWS) and can assist in wind map lookups. The NREL Tools Assessing Performance (TAP) project was described for the attendees. Joep Breuer from Kitepower noted that they utilize the Global Wind Atlas.
- Q: Are there any vertical-axis wind turbines in deployable designs? A: Ian Brownstein from XFlow Energy expressed some interest in this market space but noted they have not pursued it yet.
- Dion Johnson from ARE Telecom shared their line of ballasted, deployable tower solutions, including the Necker Island case study featuring a NPS 100 wind turbine, a system using 6-kW SD Wind Energy turbines, and a small hybrid system using a micro wind turbine.

- Q: What is the maximum deployable turbine size? A: An assessment of the loads will inform the optimal hybrid system design. In our D3T Design Guidelines, we include a container analysis that describes the largest wind energy system per standard shipping container size (e.g., 11 kW to 30 kW turbine for the 20-foot container).
- Q: How does LCOE factor into system design decisions? A: While typical long-term/permanent distributed wind projects are very focused on LCOE to remain competitive, short-term deployable systems have different or additional goals such as improved safety and logistics. LCOE and being competitive with other forms of deployable energy resources remain important factors.
- Garrette Smith of Wind Fisher shared their early-stage "wind power in a box" system, which is an airborne wind energy concept using the Magnus effect.
- Regarding training, Joep from Kitepower notes that they strive for simplicity and automation in their design to reduce the complexity of system operation and to make training easier.

6.2. Polling Questions and Results Summary

The following eight polling activities were prepared in advance of the workshop and accessed in the workshop via pollev.com/nrelwebinars303.

- Q1 In what areas would you potentially utilize a deployable wind energy system?
- Q2 What are the key features of a deployable wind energy system for disaster response?
- Q3 What are the key features of a deployable wind energy system for military operations?
- Q4 For technology suppliers, what are the biggest challenges in designing/supplying a deployable wind energy system?
- Q5 Should we have a test bed for industry and stakeholders to interact?
- Q6 How would industry and stakeholders utilize a deployable wind test bed?
- Q7 Who might fund a deployable wind test bed?
- Q8 Thank you all for participating today. What one word would you use to describe deployable wind systems?

Twenty-nine workshop participants participated in the polling with an average of 58% engagement and 34 responses per activity.

6.3. Polling Questions and Responses

Q1 In what areas would you potentially utilize a deployable wind energy system?

Participants clicked on a world map (92 responses) showing widespread global activity.

Q2 What are the key features of a deployable wind energy system for disaster response?

Participants were able to input a response and vote to move other responses up or down with respect to importance. Below are the 26 responses (spelling corrected) from 15 unique participants in rank order.

Responses	Upvotes	Downvotes
Ease of use	11	0
Simple and reliable	8	0
Microgrid integration	8	0
Field serviceable by local, semiskilled technicians	7	0
Few operators	5	0
Easy to transport	5	0
Reliability	5	0
Setup time	4	0
Cost-effective compared to a gas genny [generator] and fossil fuel supply chain. Otherwise, no responders will fund them past the proof of concept.	3	0
No heavy equipment needed	3	0
Don't forget EV charging!!	3	0
Logistics	3	0
Transportability	3	0
Deployable without cranes	2	0
Reliable	2	0
Backup power supply	2	0
Ease of use, enough power to meet needs	2	0
Mechanical power take-off	1	0
Minimal number of bolted fasteners	1	0
Plug-and-play	1	0
Interested in what we do for EMP resistance	1	0
Certified equipment	1	0
Power on demand	1	0
Straightforward business model	1	0
Cost of energy vs. diesel	1	0
Access to wind	1	0

Q3 What are the key features of a deployable wind energy system for military operations?

Participants were able to input a response and vote to move other responses up or down with respect to importance. Below are the 29 responses from 14 unique participants in rank order.

Responses	Upvotes	Downvotes
Robust	9	0
Cargo volume	7	0
Hybrid mix	5	0
Cybersecurity	5	0
No training for deployment	4	0
Survivability in varied climates and conditions	4	0
Survivable	4	0
Minimal bolted fasteners	4	0
Small-to-charge radio	2	0
18-year-old proof	2	0
Fits in a container	2	0
Electromagnetic pulse (EMP) resistance	2	0
Logistics	2	0
Clandestine operation	2	0
Field serviceable	1	0
Civilian field service opportunity may be limited due to conflict—the ability to change out modules becomes important	1	0
Ease of repair	1	0
Mil spec [conforms to military specifications]	1	0
Signature	1	0
Making water	0	0
Transportable with standard military vehicles	0	0
Deciwatt turbines also interesting	0	0
Pinned fasteners; quick assembly like cranes	0	0
Should be more turbines per compound	0	0
Ground-level service and maintenance	0	0
MIL spec	0	0
Interoperability	0	0
Harnesses wind power to dig a bunker	0	0
Quiet	0	0

Q4 For technology suppliers, what are the biggest challenges in designing/supplying a deployable wind energy system?

Participants were able to input a response and vote to move other responses up or down with respect to importance. Below are the 24 responses from 13 unique participants in rank order.

Responses	Upvotes	Downvotes
Financing	8	0
Low wind speed performance	5	0
Certification	5	0
Consistent market demand	5	0
Cost-effective control systems	4	0
R&D expense including certification	4	0
Associated energy storage	3	0
Low wind speed regimes	2	0
Providing realistic capacity assessments	2	0
Easy-to-use optimization software	2	0
Surviving extreme wind conditions	2	0
Mechanical structure that doesn't break down with use	2	0
No established market of any scale	2	0
U.S. economic sources for generators	2	0
SCADA ready [SCADA = supervisory control and data acquisition]	1	0
CRADA opportunities [CRADA = cooperative research and development]	1	0
System should be used when in "storage"	1	0
Regulation	1	0
Energy storage	1	0
Airborne wind test area	1	0
Cost	1	0
Realistic wind resource assessment	0	0
Awareness that it is an option next to fossil fuels	0	0
SCADA ready	0	0

Q5 Should we have a test bed for industry and stakeholders to interact?

This was a yes/no choice with 19 'yes' responses and zero 'no' responses.

Q6 How would industry and stakeholders utilize a deployable wind test bed?

This was an open-ended question with the following 29 responses from 17 unique participants.

Responses

- Integrating with other distributed generation technologies and storage
- Use wind to directly process raw materials into items needed in a disaster
- Deployable wind club demo site
- Small-scale testing to avoid testing full scale and associated cost
- Test edge conditions—e.g., transitions to/from grid, loss of grid, etc.
- Fail quick, fail often
- Verify microgrid control integration
- Accurate and consistent standard data collection on performance ... standards
- Tests to failure
- Controls between different assets
- Evaluate tower designs and provide feedback
- Ability to connect to various electronic equipment
- Standard metrics (i.e., power curves and conditions)
- Standardize hardware
- Optimization
- Demo for potential users
- Testing in varied environments
- Test and fail prototypes quickly
- Certification testing
- Research
- Power curve verified
- Pilots
- Survivability/reliability
- Windborne turbine testing
- Product demonstrations
- Get independently verified power production curves
- Exhibiting
- Establishing industry standards
- Long-duration test.

Q7 Who might fund a deployable wind test bed?

Participants were able to input a response and vote to move other responses up or down with respect to importance. Below are the 26 responses from 16 unique participants in rank order.

Responses	Upvotes	Downvotes
Military	7	0
Government	5	0
Telecom companies	4	0
Crowdfunding	3	0
Congress (how do we organize a lobby?)	3	0
Private companies	3	0
UN [UN = United Nations]	3	0
WETO	3	0
FEMA [FEMA = Federal Emergency Management Agency]	2	0
California Conservation Corps collaboratively	1	0
Leverage autonomous aerial system testing infrastructure	1	0
Grid companies to support outage works	1	0
State of California	1	0
Elon [Musk]	1	0
Disaster relief charities	1	0
Insurance companies	1	0
WETO	1	0
In kind	1	0
D3T	1	0
State of NC [NC = North Carolina]	0	0
It would be very helpful to first get a summary of requirements for such a facility before contacting funding sources	0	0
#BuildBackBetter	0	0
State-level sponsorship is possible	0	0
Google	0	0
CERL [U.S. Army Construction Engineering Research Laboratory]	0	0
Joe [Biden]	0	0

Q8 What one word would you use to describe deployable wind systems?

This was a word cloud activity with 30 responses from 19 unique participants.

6.4. Poll Participants

The following 29 screen names participated in the polling (typed as entered).

- Eric Lang – University of Dayton
- Garrett SMITH
- Dylan Reen
- paul pavone
- Ken Visser
- Liam Griggs
- guest579
- Brent Houchens (Sandia)
- Joseph M Spossey
- Michael Leitman
- Joep (Youp) Breuer Kitepower
- Paddy Jones
- Ryan Crampton
- guest079
- Ben Leape
- Michael Bergey
- Ken Kotalik
- KENNETH MURRAY
- Jonathan Knight – Uprise Energy
- Frits
- cw
- Robert Wills (Intergrid)
- Steven
- Rob Creighton
- Will Heegaard
- Eduardo Ortiz-Rivera
- Giovanni Cordova
- jack
- Joe Clark

REFERENCES

[1] B. Naughton, B. Houchens, B. Summerville, T. Jimenez, R. Preus, D. Reen, J. Gentle, E. Lang. 2022. Design Guidelines for Deployable Wind Turbines for Defense and Disaster Response Missions. *J. Physics: Conf. Series* **2265** 042074.

[2] B. Naughton, T. Jimenez, R. Preus, B. Summerville, B. Whipple, D. Reen, J. Gentle, and E. Lang. 2021. Design Guidelines for Deployable Wind Turbines for Military Operational Energy Applications. Albuquerque, NM: Sandia National Laboratories. https://energy.sandia.gov/wp-content/uploads/2022/01/Deployable-Wind-Turbine-Design-Guidelines-SAND2021-14581-R-1.pdf

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