SAND2014-19525C

Sandia's Deployable Wind Turbine Analysis and Decision Tool for Contingency Basing

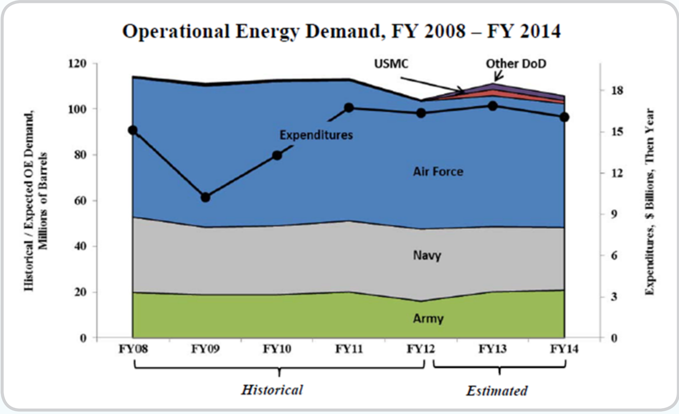
Sandia National Laboratories

Sandia National Laboratories; Albuquerque, New Mexico; Wind Energy Technologies Department

Zachary Bauer, Brandon Ennis, Jon White, Dave Minster

MILITARY APPLICATION: Wind turbines specifically purposed for contingency bases can effectively supplement diesel generators. Adding wind energy to the base energy portfolio enables renewable energy generation at night and on cloudy days. Existing turbines are not designed to operate within the constraints of a base and a customized design can reduce the high diesel transport costs and frequency at these bases.

Motivation



"More fight, less fuel; More options, less risk; More capability, less cost." –DoD's Operational Energy Strategy

Small, highly energy intensive contingency bases rely on an inefficient and volatile energy source. In Afghanistan, attacks on resupply missions to these outposts represented a significant percentage of the injury and death rate for U.S. troops. Sandia's goal is to support DoD initiatives to hedge reliance on these volatile fuel sources through addition to and diversification of renewable energy sources available to meet the military needs, reducing outside risks for soldiers.

Category	Peacetime OPTEMPO	Wartime OPTEMPO
Combat Vehicles	30	162
Combat Aircraft	140	307
Tactical Vehicles	44	173
Generators	26	357
Non-Tactical	51	51
Total	291	1040

Army Fuel consumption in peacetime and wartime (million gallons per year)

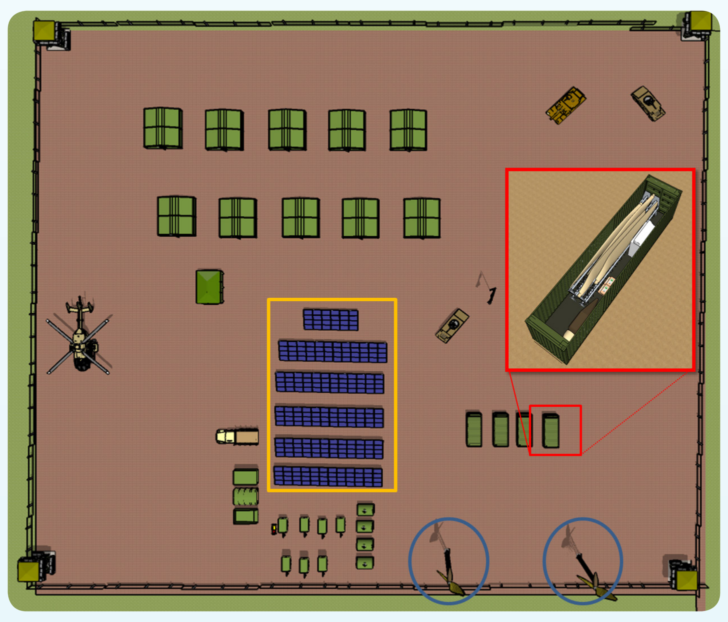
Base Energy Options

Fuel supply missions can be reduced at contingency bases when energy needs are offset with renewable energy sources deployed in appropriate locations.

ENERGY SOURCES: comparison of energy options and of wind versus solar in good resource locations.

Diesel = $15/gal	Power Capacity (kW)	Fuel Used (gal/yr)	Fuel Trips (trucks/yr)	Cost of Energy ($/kWh)	Footprint Area (m^2)	Shipping Weight (kg)
Diesel Generator	30	20,200	8	$1.17	11.3	2,166.00
Added Wind Turbines	30	-10,100	-4	$0.31	19.6	5,093.00
Added Solar Array	30	-6,060	-2	$0.41	165	2,907.00

In an averaged sense, **wind energy is seen to outperform solar when they are both in good resource.** This however is location-specific and additional differences arise in daily/seasonal distributions of the two energy sources, and **they are best viewed as complementary sources.**



A sample installation of renewables at a 200-soldier contingency base with diesel generator sets. Here 60 kW of wind energy and 85kW of solar are added to 210 kW of diesel generators. **Energy sources differ additionally in their land use and required transport.**

GRID PORTFOLIOS: comparison of proposed base energy portfolios with added renewables for a 200-soldier camp.

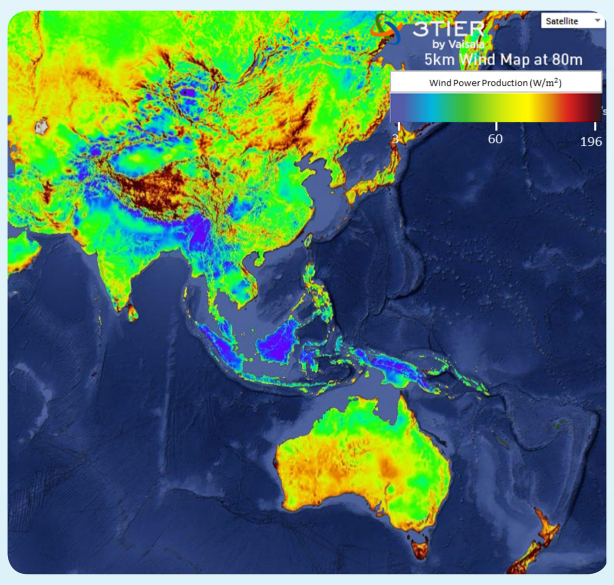
200 man base	RPS (%)	Fuel Used (gal/yr)	Fuel Trips (trucks/yr)	Cost of Energy ($/yr)	Footprint Area (m^2)	Shipping Weight (tons)
Diesel Generator (210kW)	0%	67,394	27	$1,038,097	79.0	16.7
Diesel Gen. + Wind (50kW)	25%	50,545	20 (–25%)	$852,600	112.0	24.7
Diesel Gen. + Solar (83kW)	25%	50,545	20 (–25%)	$875,200	536.0	25.6
Diesel Gen. + Wind (50kW) + Solar (83kW)	50%	33,697	13 (–50%)	$689,700	569.0	33.6

When deployed appropriately, **renewables are seen to both reduce the number of necessary fuel resupply missions and reduce the cost of energy generation,** saving lives from vulnerable fuel missions and saving money of base operational costs.

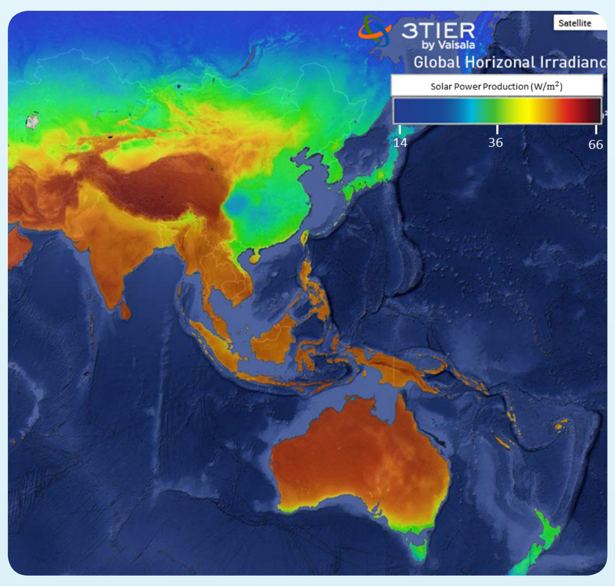
Renewables Benefit and Comparison

Renewables are dependent upon both location and resource distribution. Wind energy provides renewable power generation at night and during cloudy days/seasons.

Wind Average Resource [W/m²]

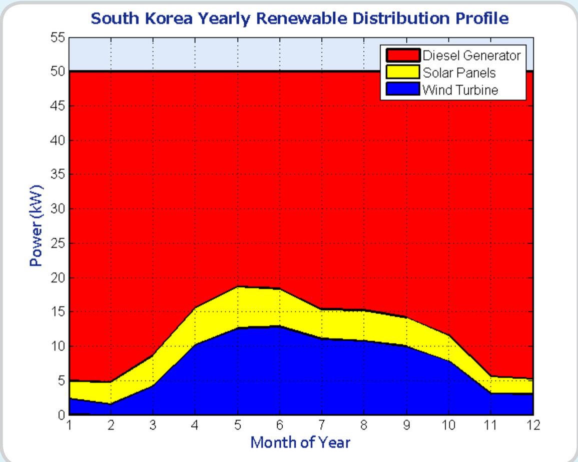


Solar Average Resource [W/m²]



Example renewable resource energy distribution is determined using actual location data for a grid portfolio with 30 kW solar and 30 kW wind energy. Distributions are shown along with annualized performance values from wind and solar to compare with location.

SOUTH KOREA: Seasonal Distribution of Renewable Resource



Adding 30 kW Wind:

- Avg speed: 4.4 m/s
- Performance: 28.6%
- Wind LCOE: $0.53/kwh

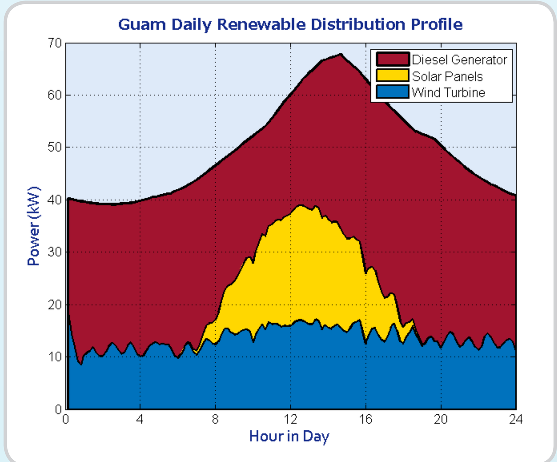
Saves 5,770 gal/year

Adding 30 kW Solar:

- Avg Irradiance: 140 W/m2
- Performance: 14.0%
- PV LCOE: $0.87/kwh

Saves 2,850 gal/year

GUAM: Daily Distribution of Renewable Resource



Adding 30 kW Wind:

- Avg speed: 6.8 m/s
- Performance: 51.5%
- Wind LCOE: $0.30/kwh

Saves 10,400 gal/year

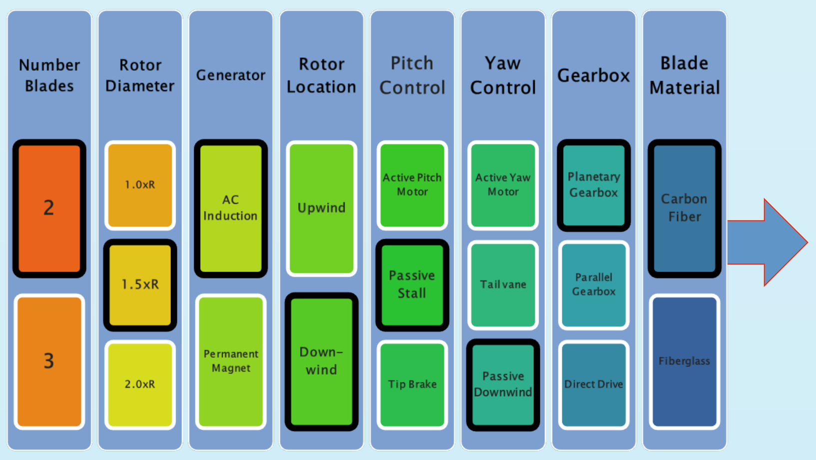
Adding 30 kW Solar:

- Avg Irradiance: 217 W/m2
- Performance: 21.8%
- PV LCOE: $0.57/kwh

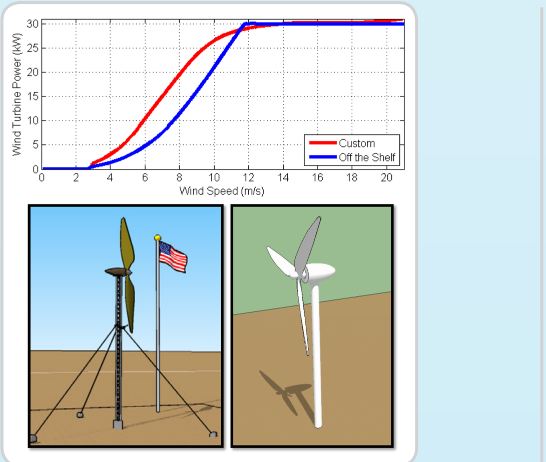
Saves 4,410 gal/year

Wind Turbine Design and Analysis

The design space of a wind turbine can yield significantly different machines based on the requirements. However, existing products are designed with emphasis on low cost of energy alone, whereas the military application values predictable fuel savings, reliability, and deployability.



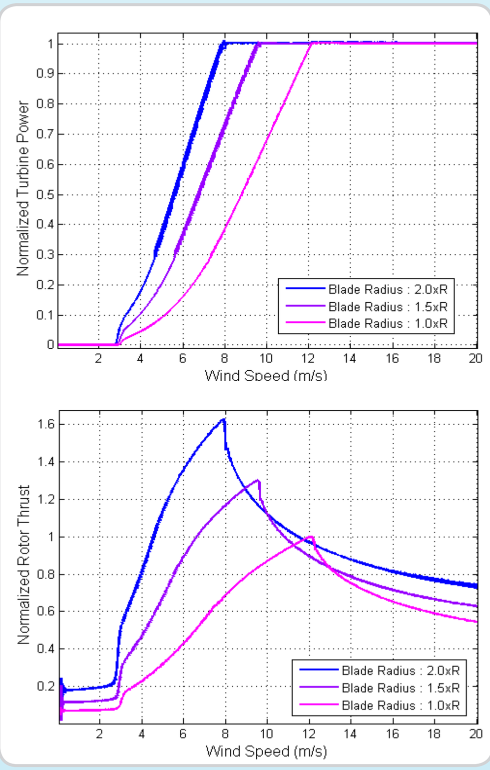
Sample of some design choices which are part of a wind turbine design space. Each decision has positive and negative consequences on different requirements, and relative weighting of the requirements drives the final application-specific design.



CUSTOMIZED VS. OFF THE SHELF

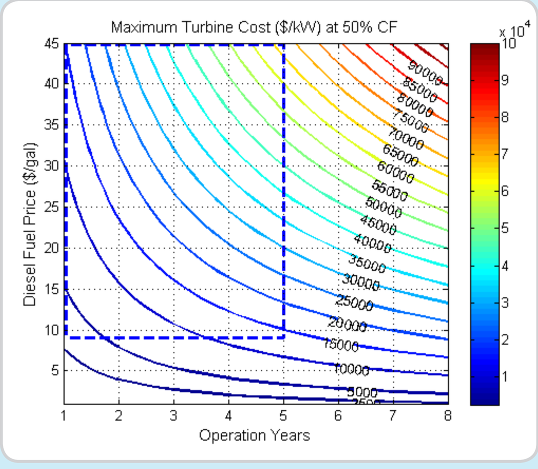
- Improved low-wind-speed operation
- Passive design with few moving parts
- Reduced failure rates and maintenance cycles
- Easily transported and installed

- Designed for short-term deployment with high reliability/ simplicity
- More costly, but with better performance and positive economics

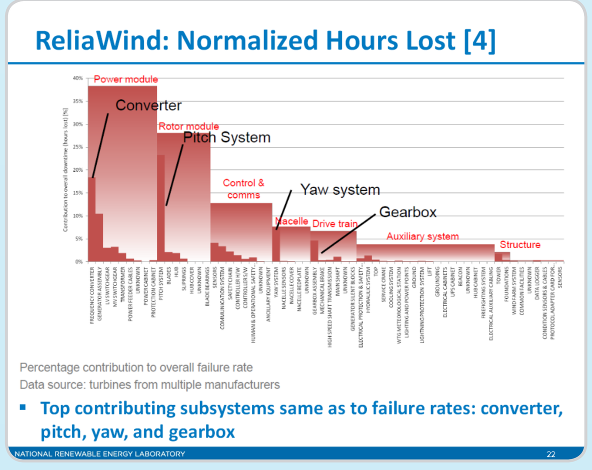


Sample results from an aeroelastic wind turbine simulator showing the design variable of rotor radius. By increasing the rotor radius, low-wind-speed operation is improved (increasing power performance %), but at a trade-off of loads. At low wind speeds, **a 2.0R rotor has up to a 300% improvement.**

For small (< 100 kW) wind turbines, a $5000-$6000/kW cost is common. **An economics analysis based on fuel costs and base life show a different operating envelope** for the military application.



Reliability and simplicity are major design constraints for the military application, which are addressed by designing passive control components, **improving reliability, and nearly eliminating maintenance cycles.**



SNL Wind Energy Technologies Department

As the nation's oldest wind energy department, Sandia has been called upon by the government to study wind energy since 1973. The SNL Wind Energy Technologies Department offers capabilities and expertise to support the DoD goal of diversifying energy production at contingency bases. Current research spans vertical-axis and horizontal-axis wind turbines, small land-based and very large offshore structural and aerodynamic rotor research, and single turbine research along with multiple turbine wind farm interaction research.

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract SAND2014-17480 D.

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration