

# Design Development and Testing of the Ground Renewable Expeditionary **EN**ergy System

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NSWC Carderock, 5/4/2011

# Battery Technology Group

- Three Primary Work Areas
  - Lithium Battery Safety Testing
  - Advanced Battery Development
  - **Renewable Energy Testing and Evaluation**
- Personnel
  - Physicists (2)
  - Mechanical Engineers (4)
  - Chemical Engineers (3)
  - Materials Engineers (2)
  - Technicians (3)



# Outline

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- Program Goals
- Design Goals
- Technology Selection
- Prototype Development
- Proof of Concept Testing and Validation
- Battery Design/Development
- USMC procurement and fielding
- Conclusions

# Ground Renewable Expeditionary ENergy System (GREENS)

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- Jointly funded renewable energy development effort (USMC, ONR)
- The scope of the work encompasses two efforts
  - Develop a 300W continuous renewable energy system
  - Test and evaluate COTS systems
- The focus of this presentation will be the developmental efforts associated with the 300W system

# GREENS 300W System Design Goals

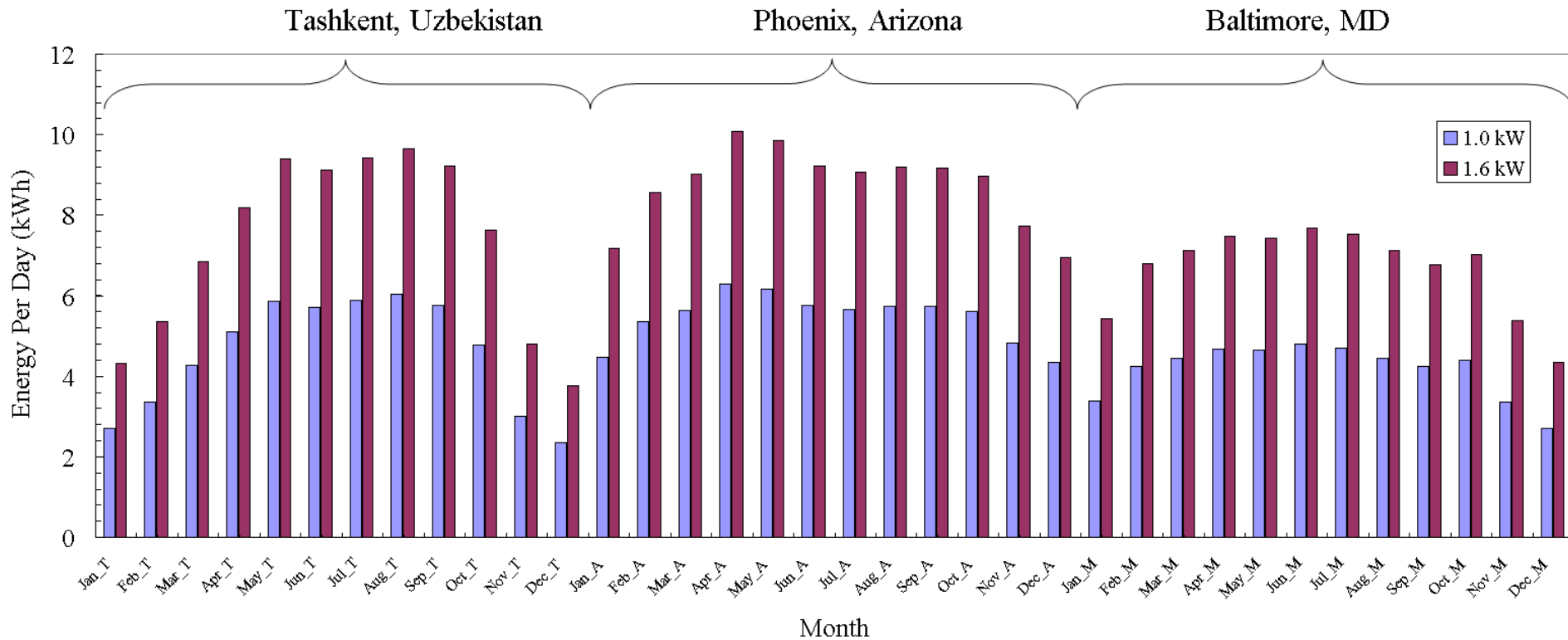
- Provides 300W continuous, 600W peak from a renewable source
  - 7.2kWh per day
  - 4.8kWh of energy storage
- Consists of individual packages weighing less than 80lbs
- Provides 24VDC and 120VAC output (true sine wave)
- Is capable of being setup in under 20 minutes by 4 Marines
- Weighs under 1000 lbs
- Is rugged enough for transport and usage
- Operates between -20°C and 55°C
- Is scalable to optimize the power supply based on a given mission

# Solar vs. Wind

- It was determined at the outset that solar would be selected to best meet the requirements laid out by Marine Corps Systems Command
  - Rapid deployment
  - Deployable in nearly every location
  - Minimal required training
  - Reduced signature (No required guyed tower, no noise or EMI concerns)

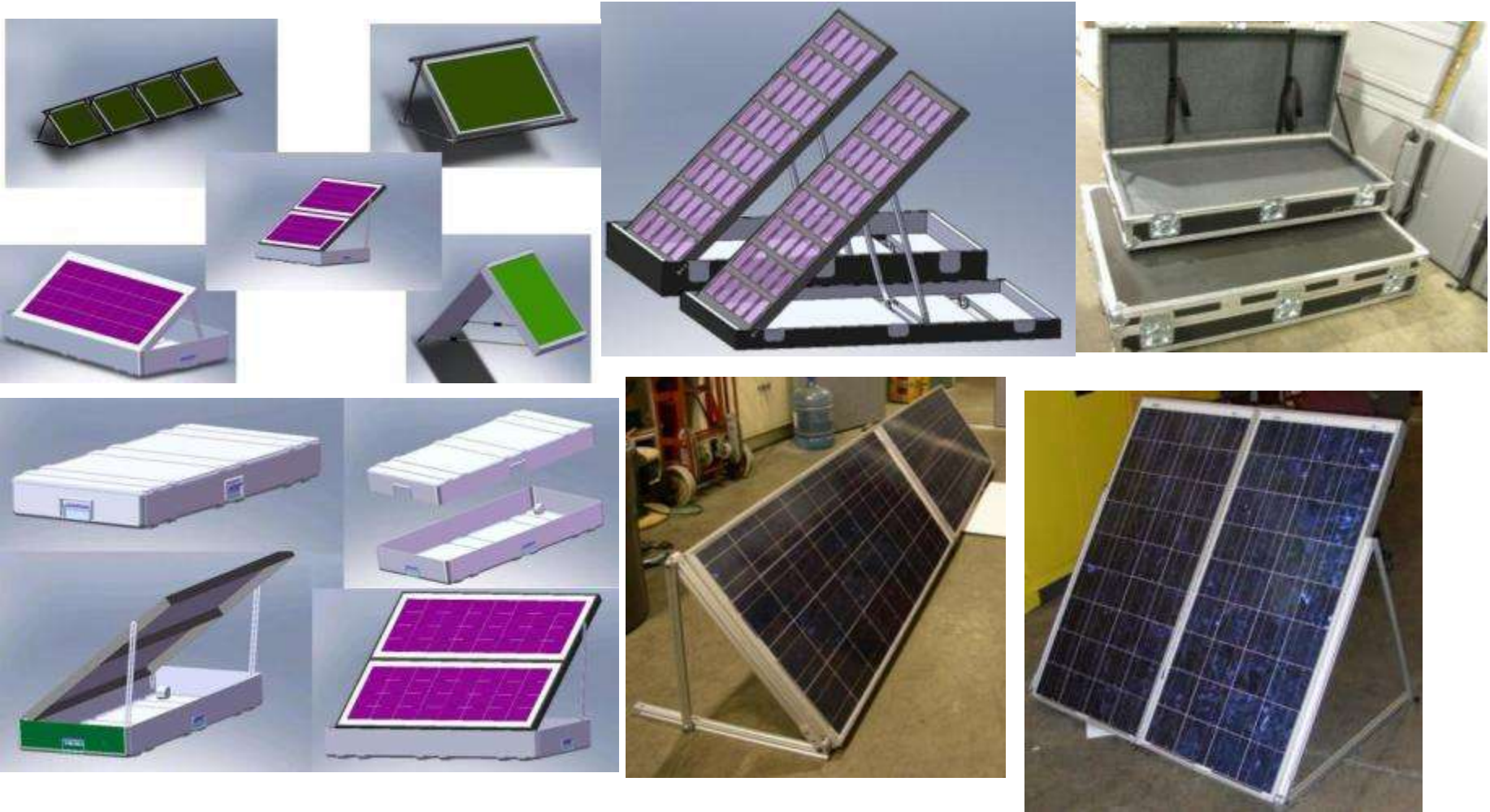
# Solar Power Characteristics

- Location, time of year, and deployment angle all play critical roles in determining solar energy production



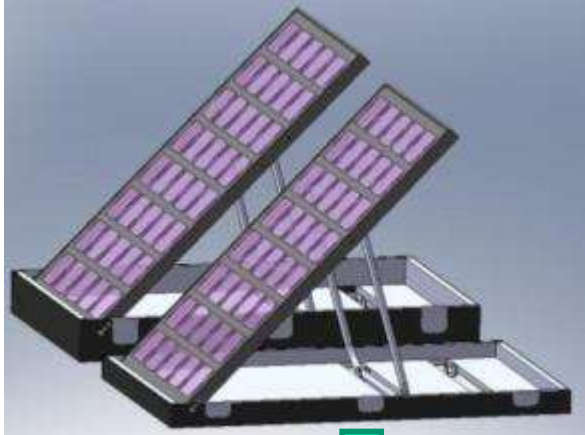
\*Data taken from NREL's PVWatts calculator  
<http://www.nrel.gov/rredc/pvwatts/>

# GREENS Deployment Concept Development





# Deployment Concept Selection



# Prototype Evaluation of GREENS: NAWS China Lake



## Objectives:

- To demonstrate the prototype GREENS system capable of delivering 300W continuously
- To study the effect of temperature and the harsh environment of the Mojave Desert on the overall performance of the system.

# Summary of Energy Generation

Design Goal  
300W Continuous

**7.2 kWh**



Rain all day  
Carderock, MD  
February 50 F

Cloudy all day  
Carderock, MD  
February 45 F

Partially cloudy  
Carderock, MD  
March 60 F

Clear day  
China Lake, CA  
July 110 F

Crystal clear day  
Carderock, MD  
March 65 F

**1.6 kWh**

**4.0 kWh**

**6.3 kWh**

**7.1 kWh**

**8.2 kWh**

300W for 5 hr

300W for 13 hr

300W for 21 hr

300W for 24 hr

500W for 17 hr

# Control Box Development

March 09



May 10



March 10



June 10



May 3-5 2011

Joint Service Power Expo

12

# Development Timeline

GREENS Tech. demonstrator  
NAWS China Lake, CA



GREENS Tech. Demonstrator  
Ex-FOB Phase II Quantico, VA



May 3-5 2011

GREENS Prototype Camp Pendleton, CA



GREENS Prototypes Twentynine Palms, CA



Joint Service Power Expo

# India Co. 3/5 Deploys With 7 Systems



From project start to a limited fielding in 23 months!

# Need For Production Level System

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- EPS worked concurrently during the GREENS development to identify vendors to build the production level system
- Lessons learned and performance metrics from the Prototype systems were used in the performance specification definition
- UEC and HDT were chosen to build prototypes of the production level system
- Testing of those systems is ongoing

# Production Version Improvements

	<b>Prototype System</b>	<b>Production System</b>
Continuous Power	300W	300W
Peak Power	600W	<b>1000W</b>
Total Weight	1200lbs	<b>900lbs</b>
Setup time (4 marines)	10 minutes	10 minutes
Operation Range	0F-140F	0F-140F
Output	120VAC/24VDC	<b>120VAC/24VDC regulated</b>
Battery Technology	Lead Acid	<b>Li-Ion</b>
Autostart Capability	No	<b>Yes</b>
Battery State of Charge Indicators	No	<b>Yes</b>
DC Charging	No	<b>Yes</b>
AC Charging	No	<b>Yes</b>



# Why Use Renewables?

Renewables are heavy and expensive but...

- No need to re-fuel the system (Reduced logistics burden).  
System can be self-sustaining in remote areas
- Short-term weight reduction benefit
- Lifecycle cost benefit
- **Silent operation**
- No mandatory MOS (Operated by the Incidental Operator)
- Reduction in maintenance (no oil/oil filter changes)
- Long lifetime (panels last 25 years)

# Conclusions

- Renewable energy systems will never be able to replace conventional power sources for power levels greater than 100kW
- When selected for the appropriate use scenario, rugged renewable systems can be developed and deployed to reduce fuel consumption and benefit the warfighter
- A detailed cost benefit analysis would have to be undertaken to determine under what scenarios GREENS could provide cost savings

# Acknowledgements

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## Sponsors

- Michele Anderson - Office of Naval Research
- Michael Gallagher - PM Expeditionary Power Systems, Marine Corps Systems Command

## Team

- Justin Govar, Matt Huffman, Evan Rule, Alex Askari, Calvin Peters, Anthony Suggs, Erick Satchell, Dave Meldrum

# Questions?

# Rugged Battery Case Design

- Lead Acid batteries previously connected manually with no packaging
- Prototype design packaged in a 24V configuration in cases

## Tech. Demonstrator Battery



Die Hard Marine Deep Cycle Lead Acid

- 100Ah
- 75lbs

## Prototype Battery Design

Optima Deep Cycle Lead Acid

- 55Ah (2 per pack)
- 110 lbs
- 60A Breaker

