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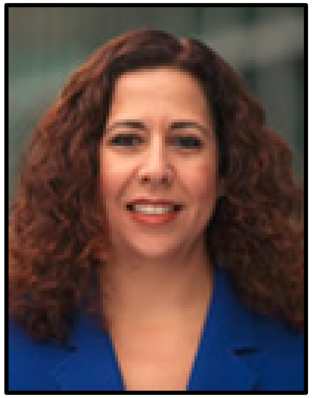
Battery Storage Resiliency Results from Installation Microgrid Simulations and Opportunities for Field Demonstration

February 6, 2020

Welcome and Introductions

Rula A. Deeb, Ph.D.
Webinar Coordinator



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Webinar Agenda

- **Webinar Logistics** (5 minutes)
  Dr. Rula Deeb, Geosyntec Consultants

- **Overview of SERDP and ESTCP** (5 minutes)
  Mr. Tim Tetreault, SERDP and ESTCP

- **Battery Storage Resiliency Results from Installation Microgrid Simulations and Opportunities for Field Demonstration** (55 minutes + Q&A)
  Dr. Jeffrey Marqusee, National Renewable Energy Laboratory
  Mr. Craig Schultz, ICF

- **Final Q&A session**

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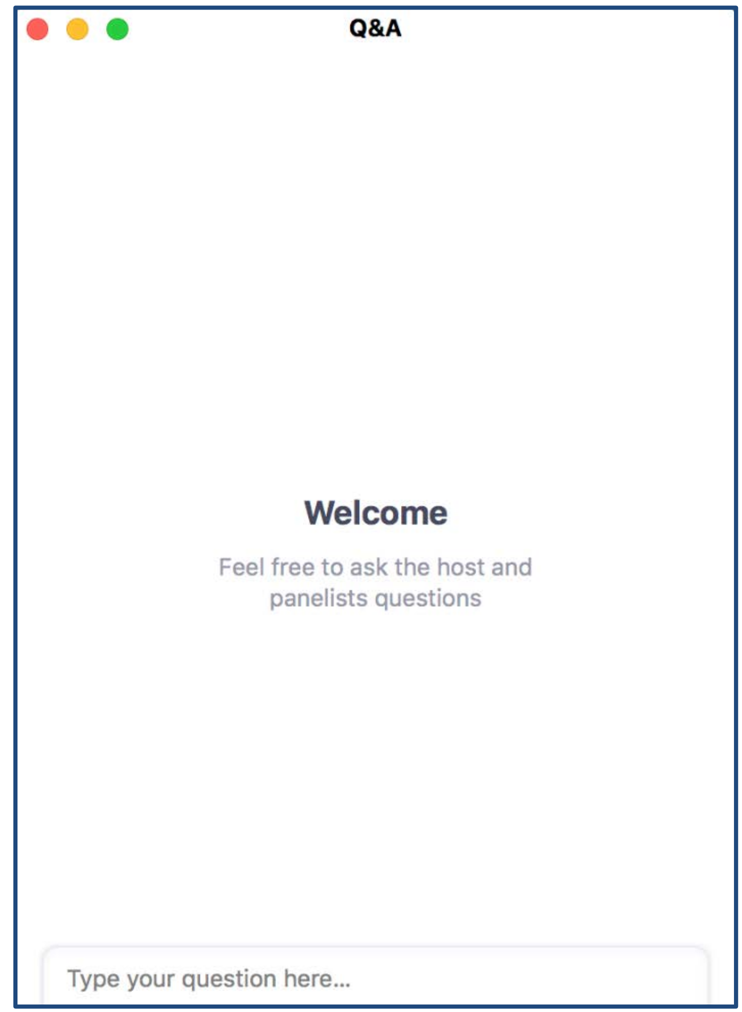


SERDP and ESTCP Overview

Timothy Tetreault
SERDP and ESTCP

SERDP

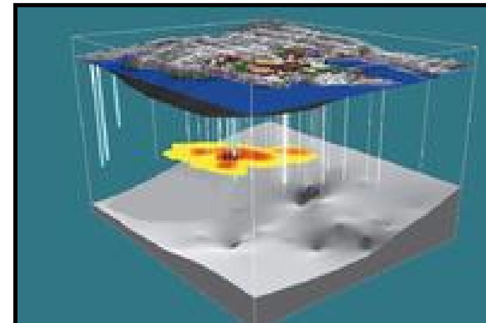
- Strategic Environmental Research and Development Program
- Established by Congress in FY 1991
  - DoD, DOE and EPA partnership
- SERDP is a requirements driven program which identifies high-priority environmental science and technology investment opportunities that address DoD requirements
  - Advanced technology development to address near term needs
  - Fundamental research to impact real world environmental management

ESTCP

- Environmental Security Technology Certification Program
- Demonstrate innovative cost-effective environmental and energy technologies
  - Capitalize on past investments
  - Transition technology out of the lab
- Promote implementation
  - Facilitate regulatory acceptance

Program Areas

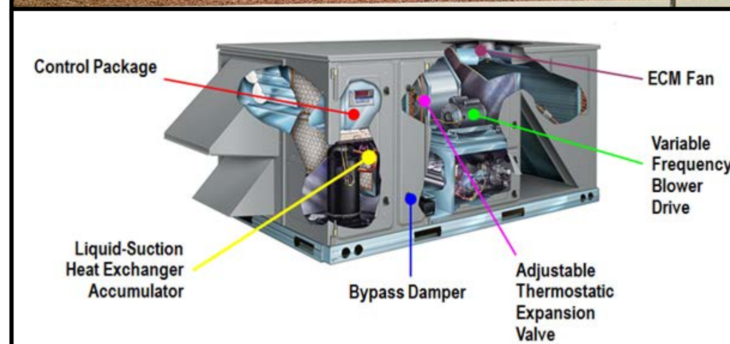
- Environmental Restoration
- Installation Energy and Water
- Munitions Response
- Resource Conservation and Resiliency
- Weapons Systems and Platforms





Installation Energy and Water

- Smart and secure installation energy management
  - Microgrids
  - Energy storage
  - Ancillary service markets
- Efficient integrated buildings and components
  - Design, retrofit, operate
  - Enterprise optimized investment
  - Advanced components
  - Intelligent building management
  - Non-invasive energy audits
- Distributed generation
  - Cost effective
  - On-site
  - Emphasis on renewables



SERDP and ESTCP Webinar Series

Date	Topic
February 27, 2020	Advances in the Development of Environmentally Friendly Pyrotechnic and Propellant Formulations
March 12, 2020	Applying Compound-Specific Isotope Analysis to Document Contaminant Degradation and Distinguish Sources
March 26, 2020	Long-Term Ecological Studies: Evaluating Responses to Ecosystem Restoration and Optimizing Recovery of Plant Communities
April 9, 2020	Ecological Risk Assessment Approaches at PFAS-Impacted Sites

For upcoming webinars, please visit

http://serdp-estcp.org/Tools-and-Training/Webinar-Series

Battery Storage Resiliency Results from Installation Microgrid Simulations and Opportunities for Field Demonstration

Jeffrey Marqusee, Ph.D.
National Renewable Energy Laboratory

Craig Schultz
ICF

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ESTCP Objective and Program Structure, and Reliability Performance Baseline

Jeffrey Marqusee, Ph.D.
National Renewable Energy Laboratory

Agenda

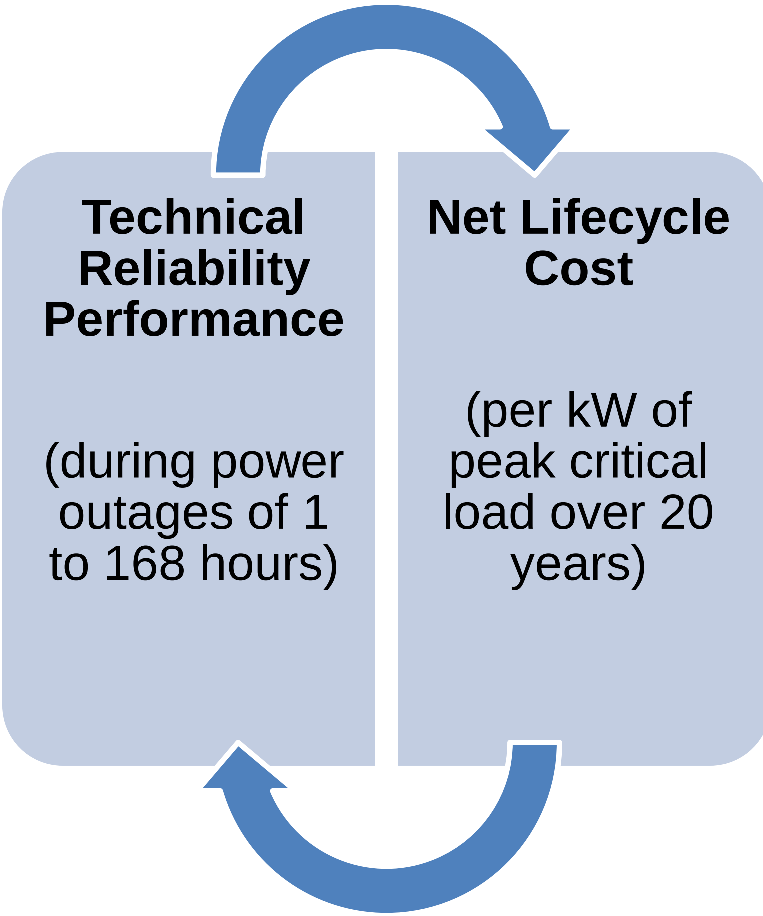
- ESTCP objective and program structure
- Reliability performance baseline
- Economic performance baseline
- Highlights of storage results
- Future plans

ESTCP Objective

- Quantify, demonstrate, and validate the value of energy storage in a microgrid
  - Reliability
  - Life cycle costs

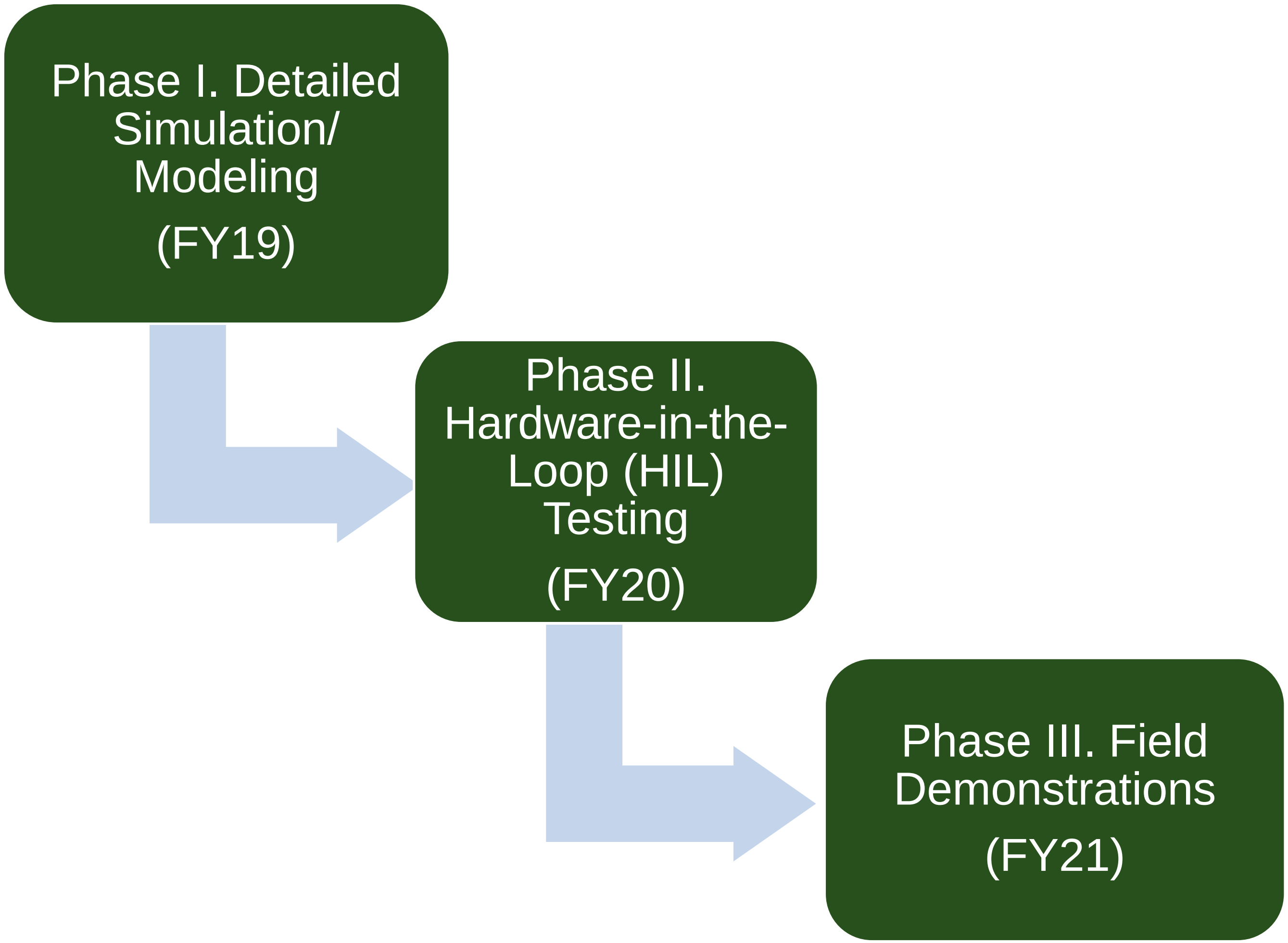
Compared to a Baseline Microgrid with Emergency Diesel Generators, PV, and UPS

Objective Metrics for Isolating Energy Storage Contributions in a Microgrid



Compared to Modeled Baseline Microgrid at each Installation with no Storage, N+1 Back-Up Diesel Generators, solar PV, and UPS

Phased R&D Program



Phase I Conditions

Four Types of Variables			
Military Installation Conditions - Critical Load - Solar Assets - Electric Rate Structure	Energy Markets - Rules - Prices (multiple scenarios)	Energy Storage Technologies - Lithium-Ion - Flow - Other	Technology Configuration and Operational/ Approaches

RELIABILITY PERFORMANCE BASELINE

Critical Loads and Energy Assets for Installation Baselines

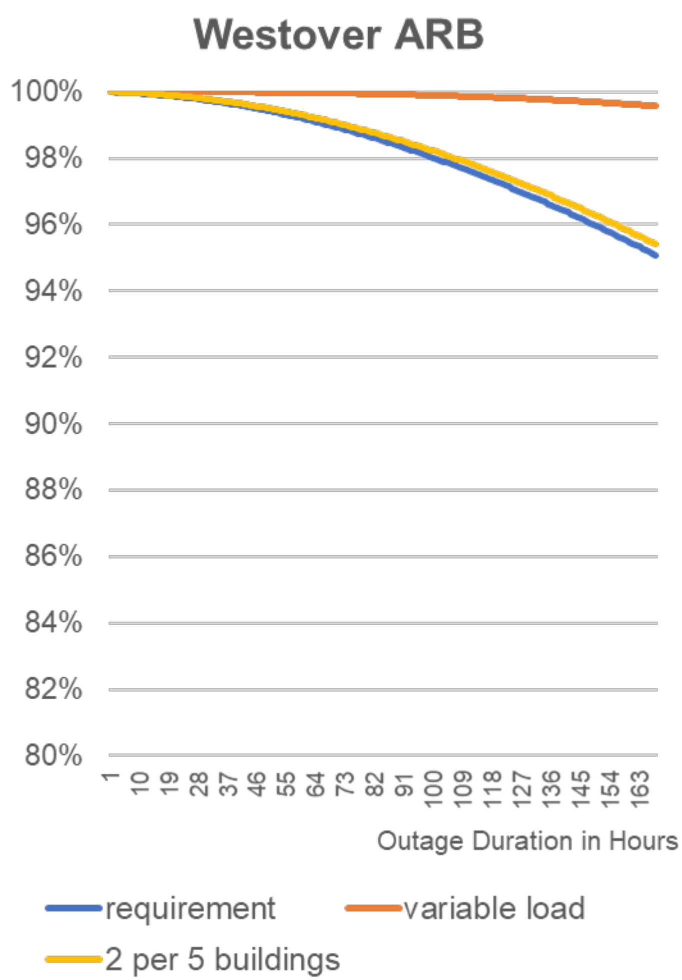
Installation	Peak Critical Load (kW)	PV Size (kW-AC)	EDG* Size (kW)	# EDG	UPS Size	# UPS
Holloman AFB	5,996	5,000	750	9	250 kVA 63 kWh	13
March ARB	600	400	250	4	250 kVA 63 kWh	3
Westover ARB	1,707	2,000	750	4	250 kVA 63 kWh	5
NAS Corpus Christi	4,410	1,200	750	7	250 kVA 63 kWh	9
NAS Patuxent River	8,014	2,000	750	12	250 kVA 63 kWh	17
Naval Base Ventura County	4,003	830	750	7	250 kVA 63 kWh	9
Fort Bliss	12,507	6,200	2,000	8	2,000 kVA 500 kWh	4

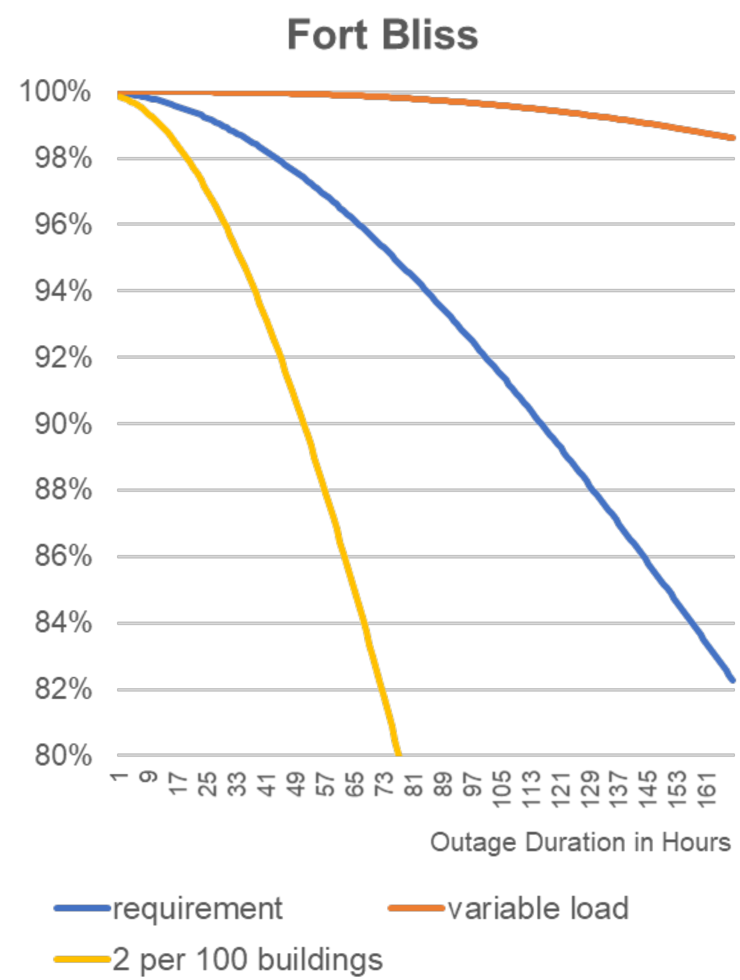
**EDG – emergency diesel generator*

Baseline Reliability Performance: Definitions

- Probability all critical loads will be supported as function of outage duration
  - Failure to carry load due to EDG failure
- Well-maintained EDG reliability metrics
  - Availability = 99.9%
  - Failure to start = 0.2%
  - Mean time to failure (MTTF) = 1,700 hours
- Requirement set by EDG microgrid for a fixed load equal to peak critical load
  - Reliability under 8760-hour variable load is higher
  - “2 per # buildings” scenario assumes 2 EDGs tied to each building with critical loads

Baseline Reliability for Microgrid: Results





Economic Performance Baseline, and Highlights of Energy Storage Results

Craig Schultz
ICF

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ECONOMIC PERFORMANCE BASELINE

Baseline Microgrid Economics

Installation	Baseline Microgrid 20-Year NPV of Electricity Costs + Energy Security Assets	Pre-Microgrid 20-Year NPV of Electricity Costs for Installation	Annual Net Cost of Protecting each Kilowatt of Peak Critical Load ($/kW)
Holloman AFB	$95.3 MM	$83.5 MM	**$98**
March ARB	$65.8 MM	$60.8 MM	**$416**
Westover ARB	$26.2 MM	$20.5 MM	**$166**
NAS Corpus Christi	$106.8 MM	$98.9 MM	**$89**
NAS Patuxent River	$257.7 MM	$241.9 MM	**$98**
Naval Base Ventura County	$110.7 MM	$99.9 MM	**$135**
Fort Bliss	$312.0 MM	$291.3 MM	**$83**

NPV = Net Present Value

Net Cost Calculations for Baseline Microgrid

Installation	*Peak Critical Load (kW)*	Diesel Generators (A)	UPS (B)	Microgrid (C)	Demand Response & Peak Shaving Savings (D)	Annual Net Cost of Protecting each Kilowatt of Peak Critical Load (E)
Holloman AFB	*5,996*	$49	$22	$36	($10)	**$98**
March ARB	*600*	$121	$52	$243	($0)	**$416**
Westover ARB	*1,707*	$77	$31	$85	($27)	**$166**
NAS Corpus Christi	*4,410*	$52	$21	$49	($34)	**$89**
NAS Patuxent River	*8,014*	$49	$22	$36	($10)	**$98**
Naval Base Ventura County	*4,003*	$57	$23	$54	($0)	**$135**
Fort Bliss	*12,507*	$47	$18	$18	($0)	**$83**

Expressed in annual $/kW of peak critical load
Formula for table: A + B + C + D = E
Rounding causes $1/kW differences in totals in some cases

HIGHLIGHTS OF ENERGY STORAGE RESULTS

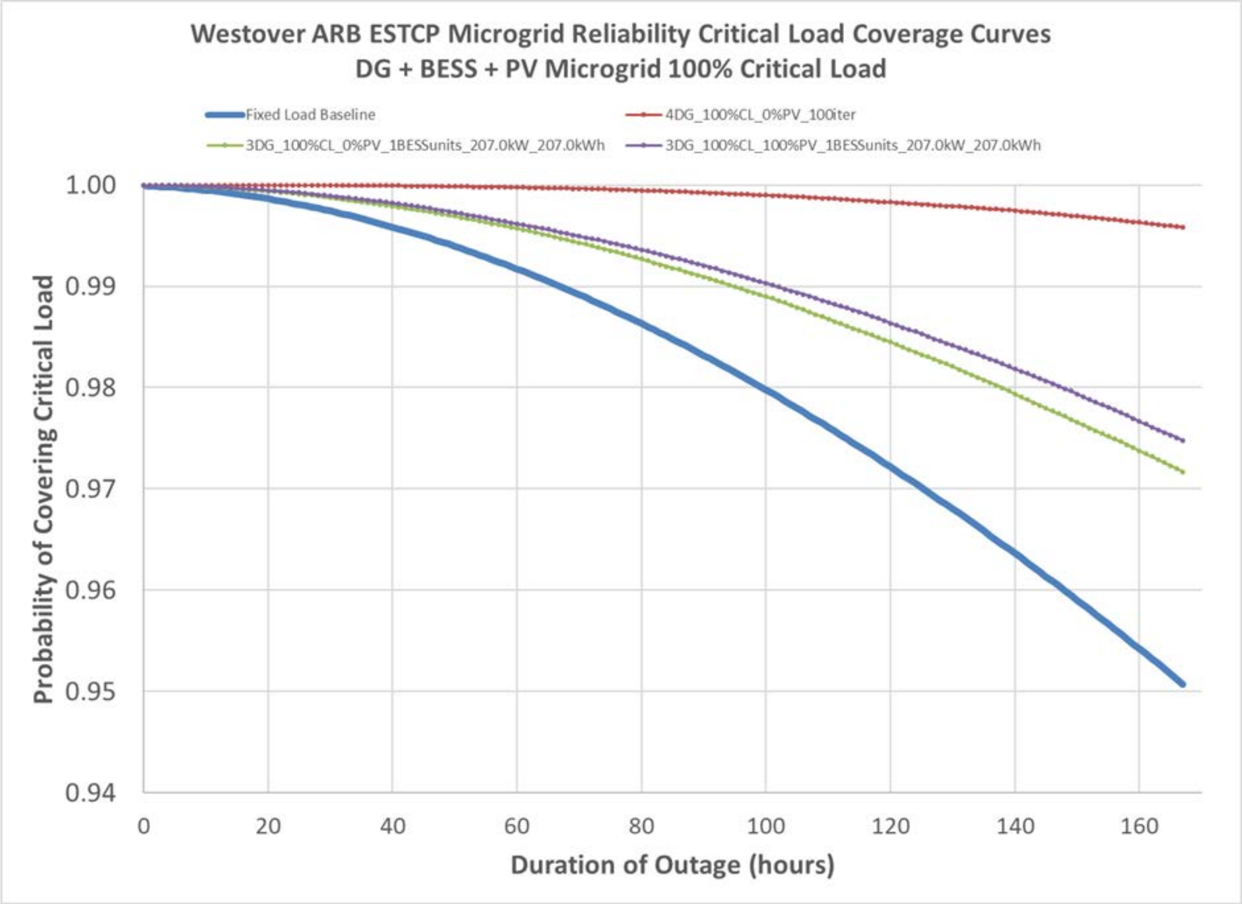
Sources of Results

Lead Organization Name	Phase I Project Name
Accord EI	*Modeling of a High-Efficiency, Resilient, Dual-Battery Microgrid Combined with Diesel GenSet and Solar PV*
Ameresco	*Demonstrating the Benefits of Long-Duration, Low-Cost Flow Battery Storage in a Renewable Microgrid*
Arizona State University/Southern Research Institute (SRI)	*Design, Modeling, and Control of Hybrid Energy Storage System for Defense Installation Microgrids*
Electric Power Research Institute (EPRI)	*Energy Security for Military Installations through Optimized Integration of Large-Scale Energy Storage into Microgrids*
Raytheon Integrated Defense Systems	*Advanced Phasor-based Control of Energy Storage Microgrids*
Siemens Corporation	*CMES: Comprehensive Microgrid Energy Storage Designs with Guaranteed Optimality*

Reliability Highlights (Preliminary)

Covering 100% of Critical Load

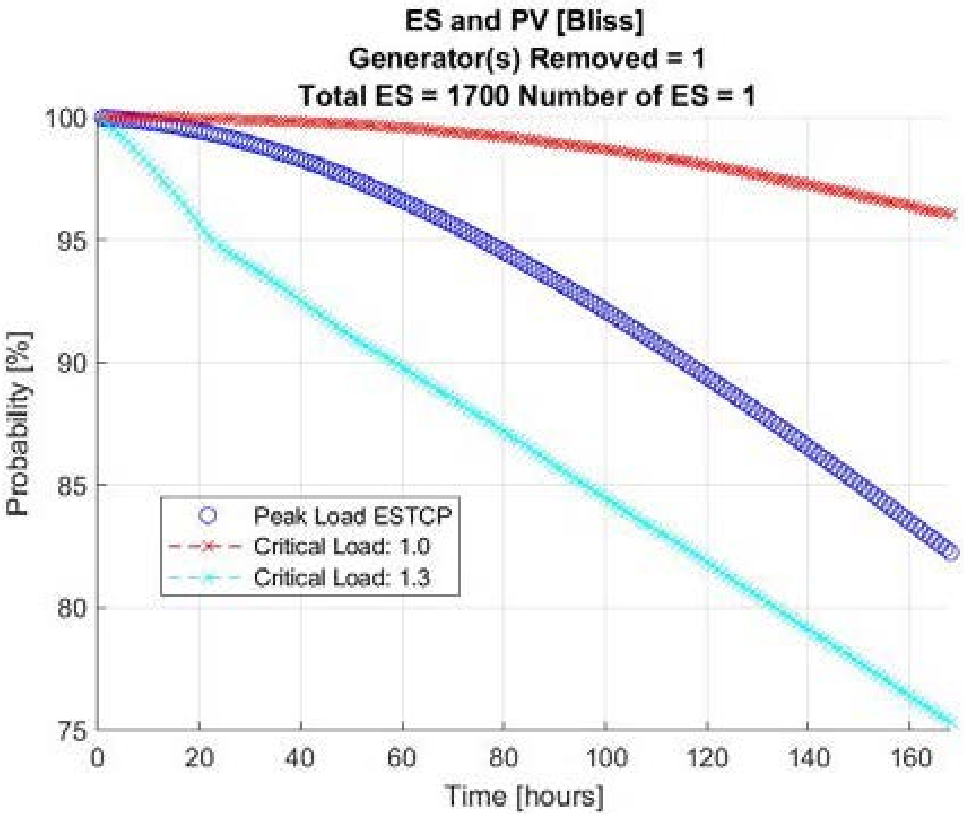
- Outages of 1 to 168 hours (starting any hour)
  - Storage (BESS)-enabled microgrid performance typically met or exceeded baseline requirement
    - Example at right



Reliability Highlights (Preliminary)

Growing Load and No Remaining Fuel

- During outages
  - How microgrid served 130% of historic peak critical load
    - o Example at right
  - How microgrid performed after fuel supply is exhausted
    - o Highly-dependent on ratio of PV to peak critical load



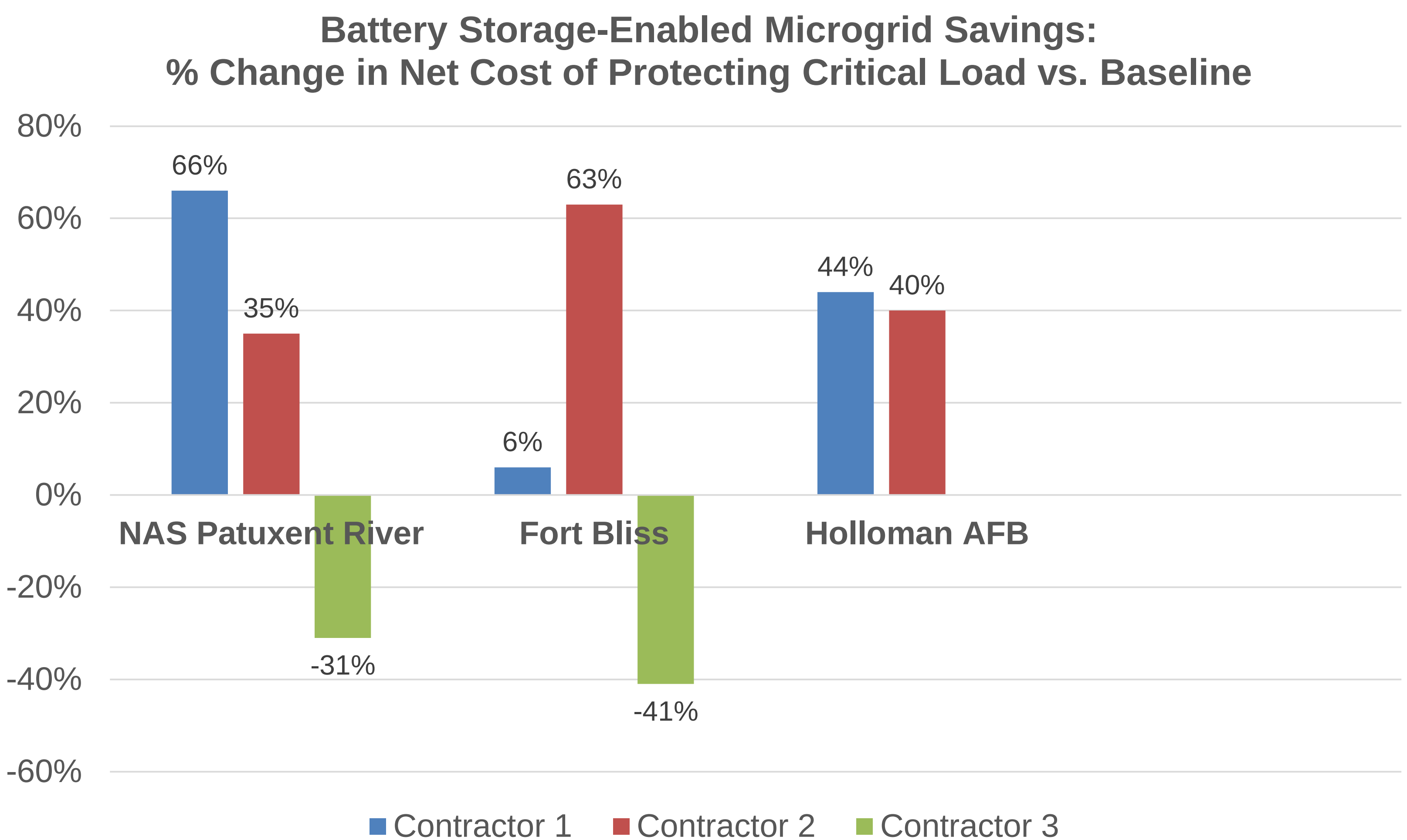
Economic Highlights (Preliminary)

Sources of Savings

- Wide variation in levels and sources of savings between installations due to:
  - Available electricity wholesale market options and pricing
  - Retail electric bill structure and allowable activities
    - Peak shaving and time-of-use shifting
  - Battery chemistry, sizing, and dispatch choices
    - In addition to affecting wholesale and retail market operations, these choices affect how many EDGs can be safely eliminated and whether UPS can be eliminated at all

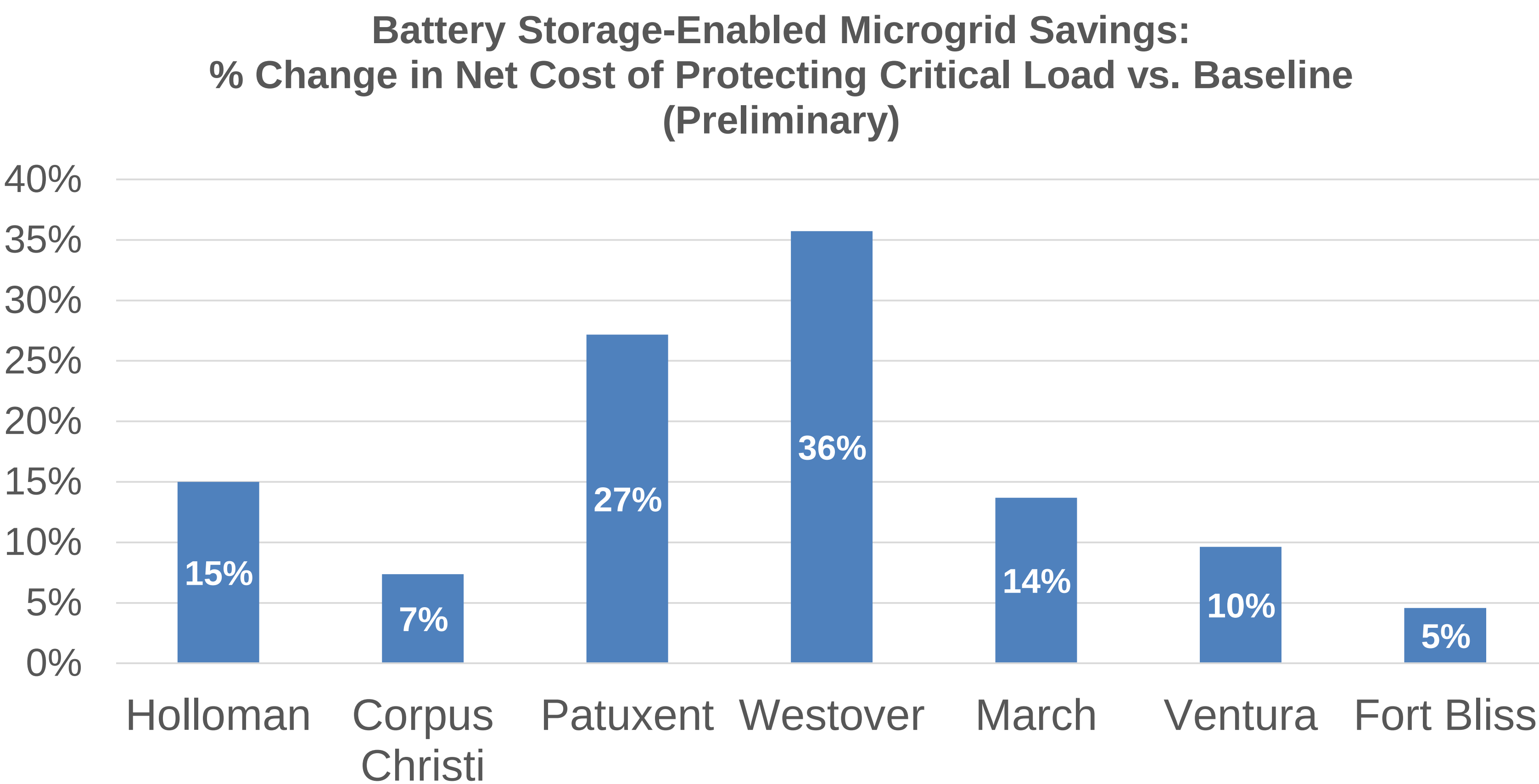
Economic Highlights (Preliminary)

Overall Savings on Key Metric



Notes: Negative savings were from an emerging battery technology. Contractor 3 did not select Holloman AFB for modeling

NREL Also Conducted Storage Modeling as Basis for Comparison

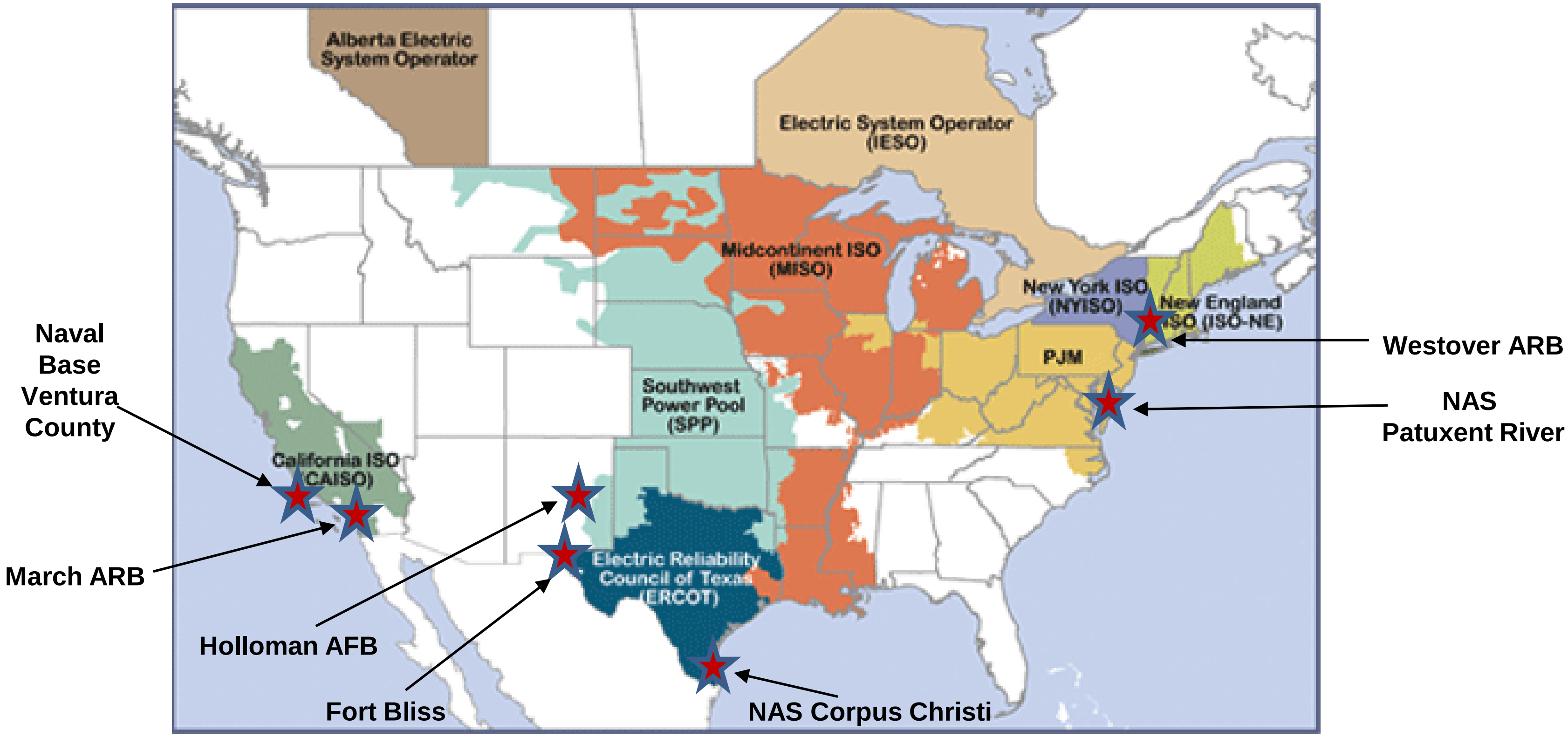


Drill-down of NREL Preliminary Storage Economic Modeling Results

Units are Net Costs of Energy Security (in annual $/kW peak critical load) unless noted	March ARB	NAS Patuxent River
Baseline microgrid cost (with no storage)	**~ $419**	**~ $94**
Optimal battery size (MW/MWh)	*0.6/1.7*	*2.4/3.0*
Battery cost (capital cost & operating expenses)	$96	$19
Battery retail bill savings	($109)	($26)
Battery demand response & wholesale revenue	($14)	($15)
Reduction of diesel generator & UPS costs	($30)	($4)
Storage-enabled microgrid cost	**$361**	**$68**
Storage-enabled savings compared to baseline, with same reliability	14%	27%

NREL-calculated baselines differ slightly from earlier values

One Driver of Economic Results: Energy Market Diversity of Installations



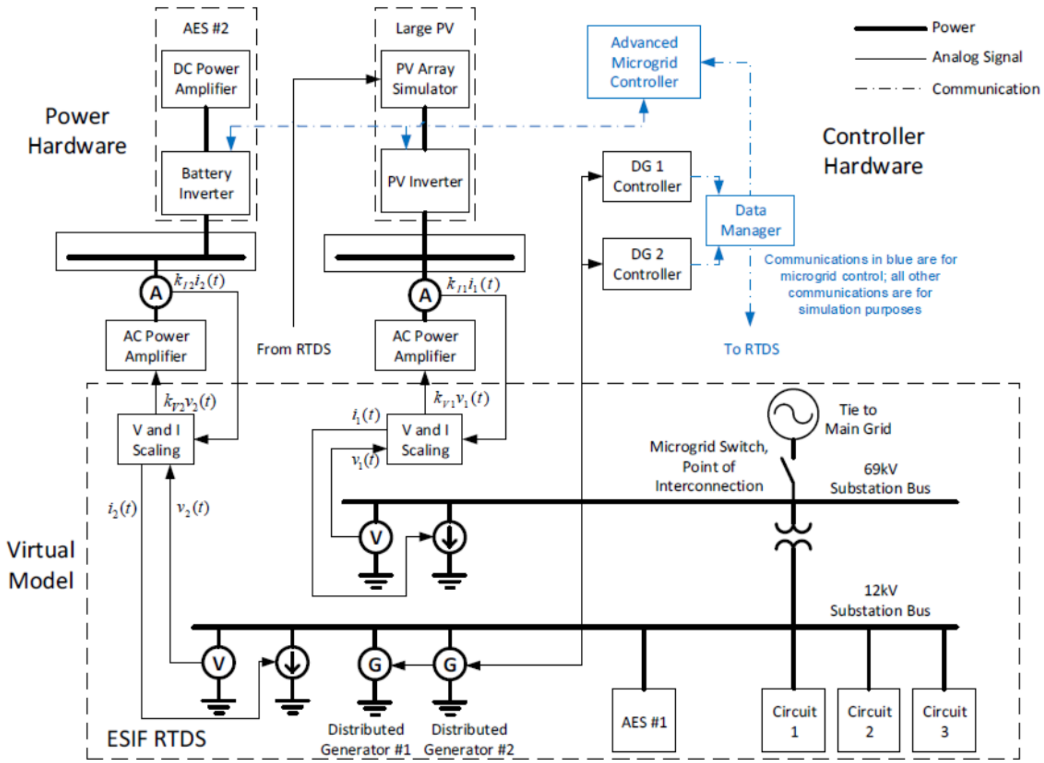
Future Plans

Jeffrey Marqusee, Ph.D.
National Renewable Energy Laboratory

Phase II: HIL Testing

Hardware-in-the-Loop

Figure 32: Borrego Springs ESIF local CHIL/PHIL setup



- Functional testing of three designs
  - Ameresco
  - Arizona State Univ./SRI
  - Raytheon
- Scenarios
  - Operating while grid tied
  - Disconnecting
  - Operating while islanded
  - Reconnecting

Phase III: Field Demos

- Installation demonstrations
  - FY21
- Identifying potential sites now
  - Existing or under construction PV required
- Decisions dependent on Phase II results

Conclusions

- Storage-enabled microgrids can provide enhanced resiliency
  - Lower life cycle costs and equal to higher reliability
- Phase I results to be released soon
  - Project reports and synthesis report
- HIL tests in FY20 seek to validate functional performance and further define and de-risk field demos
- Encourage demonstration sites for FY21
  - Interested in increasing resiliency through storage in microgrids

For additional information, please visit https://www.serdp-estcp.org/Program-Areas/Installation-Energy-and-Water

Speaker Contact Information
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Q&A Session

The next webinar is on February 27, 2020

Advances in the Development of Environmentally Friendly Pyrotechnic and Propellant Formulations

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