Self-Sufficient, High Reliable Microgrids

Microgrid Conference 2017
Nov 5, 2017

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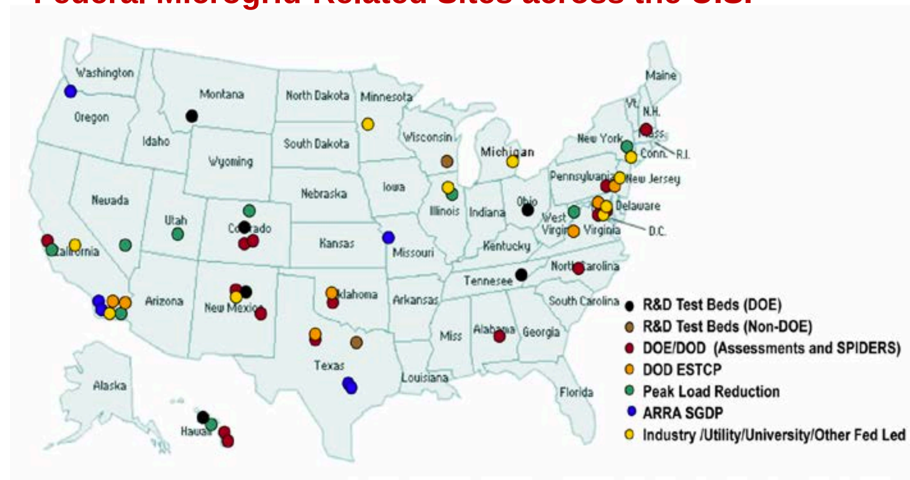
Introduction

- **Interest in Microgrids has taken off in the past 10 years**
- **The Federal Government has made a major push to support Microgrid research and development**
- **Reasons for Microgrid interest include:**
  - Economic Benefits
  - Environmental Benefits
  - Resiliency Benefits
- **Resiliency benefits of microgrids have focused on addressing Electric Grid outages**
  - In the U.S. these outages are typically infrequent and of short duration
- **This talk will explore using microgrids to address more severe types outages**
- **Such extended outages will require microgrids that can be self-sustaining and highly reliable**

Federal Microgrid-Related Sites across the U.S.



https://www.energy.gov/oe/services/technology-development/smart-grid/role-microgrids-helping-advance-nation-s-energy-syst-0

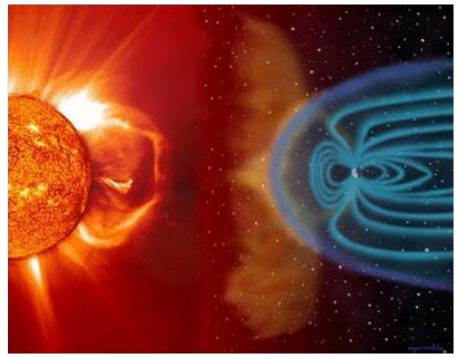
Utility Name	State	Number of Customers (meters)	SAIDI with major events (minutes)	SAIFI with major events (# events)
Pacific Gas & Electric Co	CA	5,446,629	147.200	1.052
Southern California Edison Co	CA	5,033,330	114.827	0.916
Florida Power & Light Co	FL	4,796,829	65.080	0.820
Commonwealth Edison Co	IL	3,853,843	109.000	0.970
Consolidated Edison Co Inc*	NY	3,385,176	21.100	0.112
Oncor Electric Delivery Co LLC	TX	3,321,366	267.300	1.880
Virginia Electric & Power Co*	VA	2,420,939	183.103	1.381
CenterPoint Energy	TX	2,394,231	258.840	1.980
Georgia Power Co	GA	2,366,621	175.100	1.500
Public Service Elec & Gas Co	NJ	2,278,286	81.330	0.687
DTE Electric Company	MI	2,167,276	277.000	1.000
Duke Energy Carolinas, LLC	NC	1,914,496	213.000	1.170
Consumers Energy Co	MI	1,797,075	440.700	1.180
Duke Energy Florida, Inc	FL	1,724,120	97.000	1.210
PECO Energy Co	PA	1,722,629	227.000	0.940

Table data source: U.S. Energy Information Administration Form EIA-861 *Not IEEE standard (these utilities define SAIDI and SAIFI outside of the established IEEE Standard 1366 definitions).

High Impact Electric Grid Vulnerabilities

The Federal Government has identified 6 threat classes that have the potential to produce long duration outages to large portions of the U.S. electric grid

Severe Weather



Geomagnetically Induced Currents

Cyber Attacks

Physical Attacks

Directed Energy Attacks

EMP Attack

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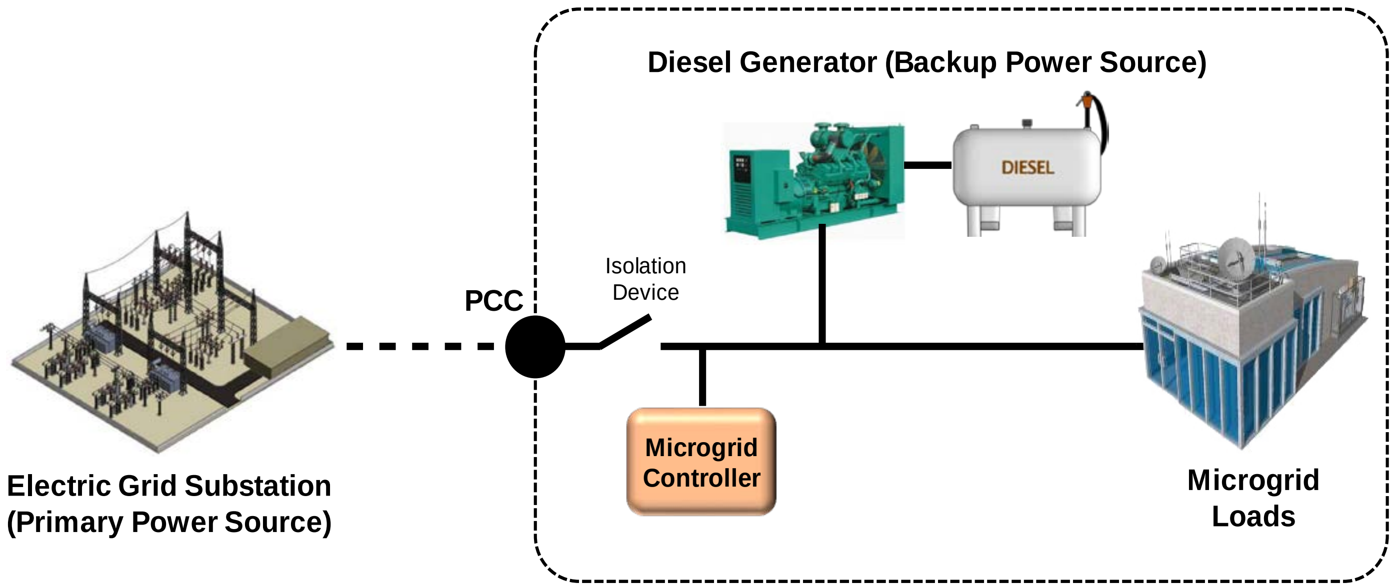
Today's Approach to Resiliency: Diesel-Based Microgrids



POSITIVES

- Proven Technology
- Readily Available
- Reasonable Cost

NEGATIVES

- High Carbon Footprint
- Continual Fuel Replenishment
- Inefficient unless operating at near full load
- Unreliable if not used frequently (10%-15% failure rates)
- Noisy

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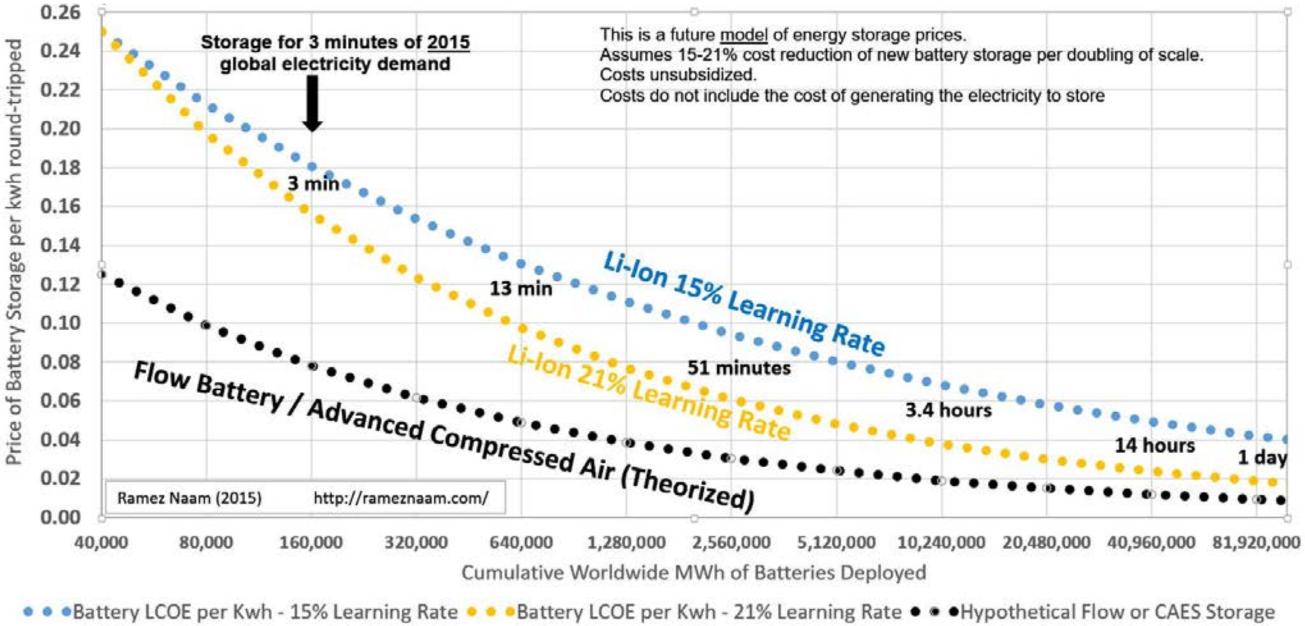
The Game Changer: Long-duration, low cost Energy Storage

- **Energy Storage costs have been the biggest obstacle to migrating from Diesel to Renewable based Microgrids**

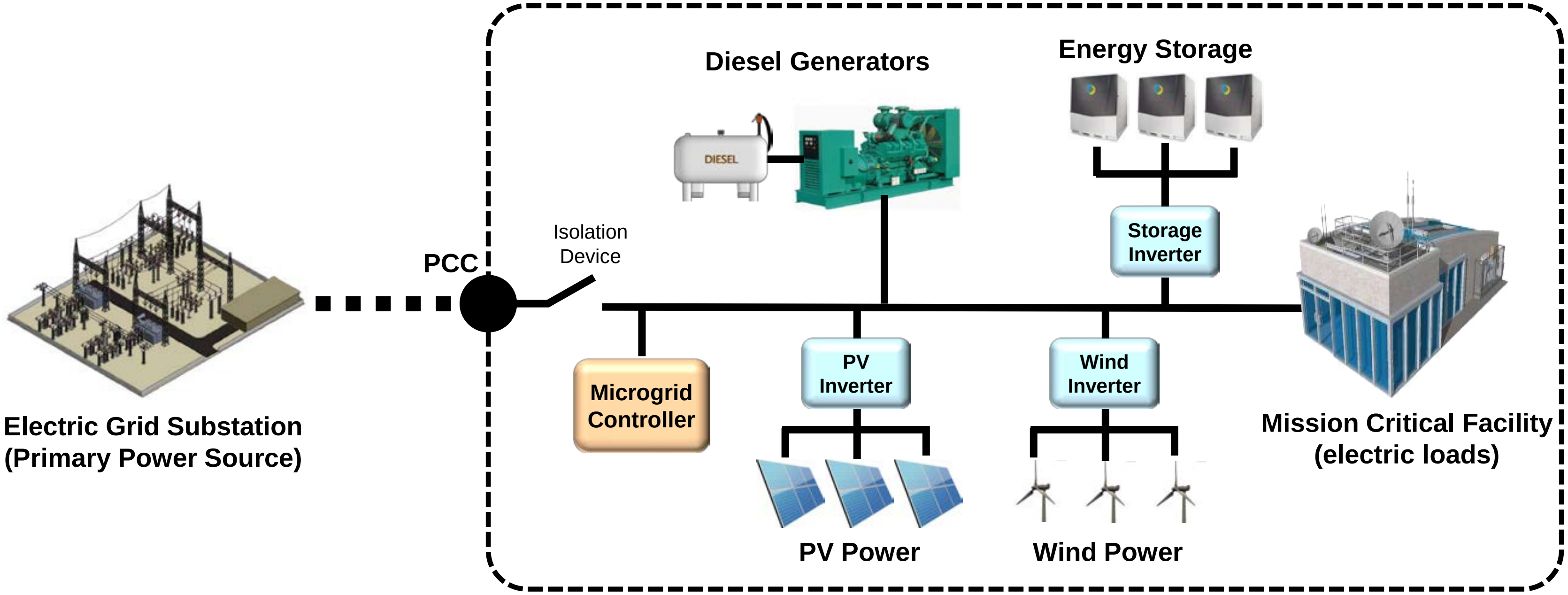
- **But recent advancements are driving down Energy Storage costs to the point where non-diesel solutions are becoming practical**

- **As Energy Storage production takes off, it will see cost reductions curves that are similar to those of PV and Wind**



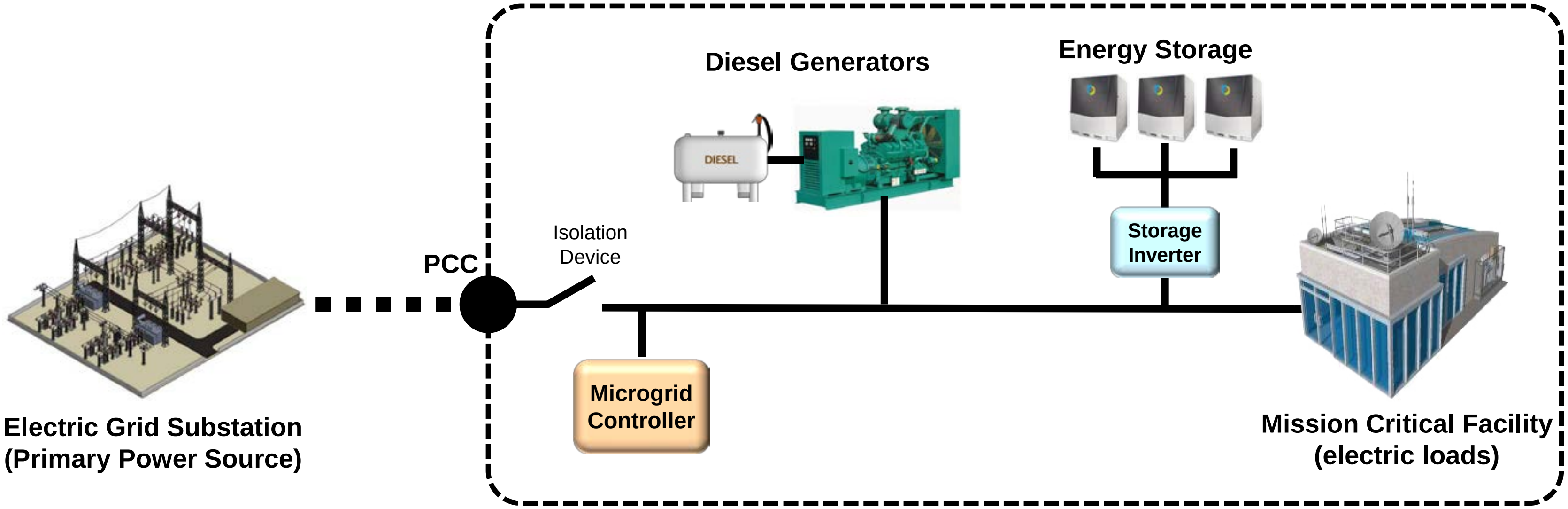
Self-Sufficient, High Resilience Microgrids

- **Self-Sufficient, High Resilience Microgrids:**
  - A microgrid that uses combination of renewable energy and long-duration, low cost energy storage to enable a facility to operated in the face of long duration electric grid outages



Use Case #1: Enhance Diesel using Storage

- **Use Energy Storage to enhance resiliency by:**
  - Providing power during cut over from grid to diesel generators
  - Providing power when a diesel generator is offline for repairs
  - Allowing diesel generators to run at full power
  - Diesel is still main power source



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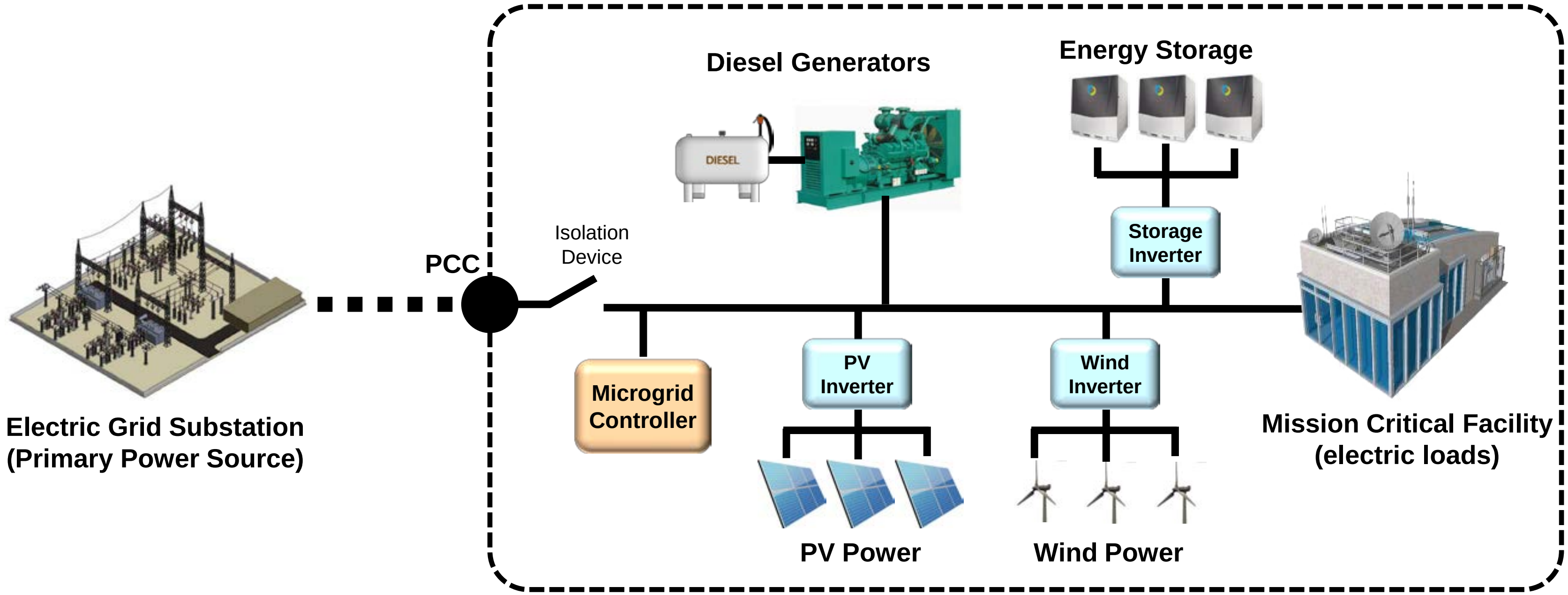
Use Case #2: Enhance Diesel with Storage + Renewable

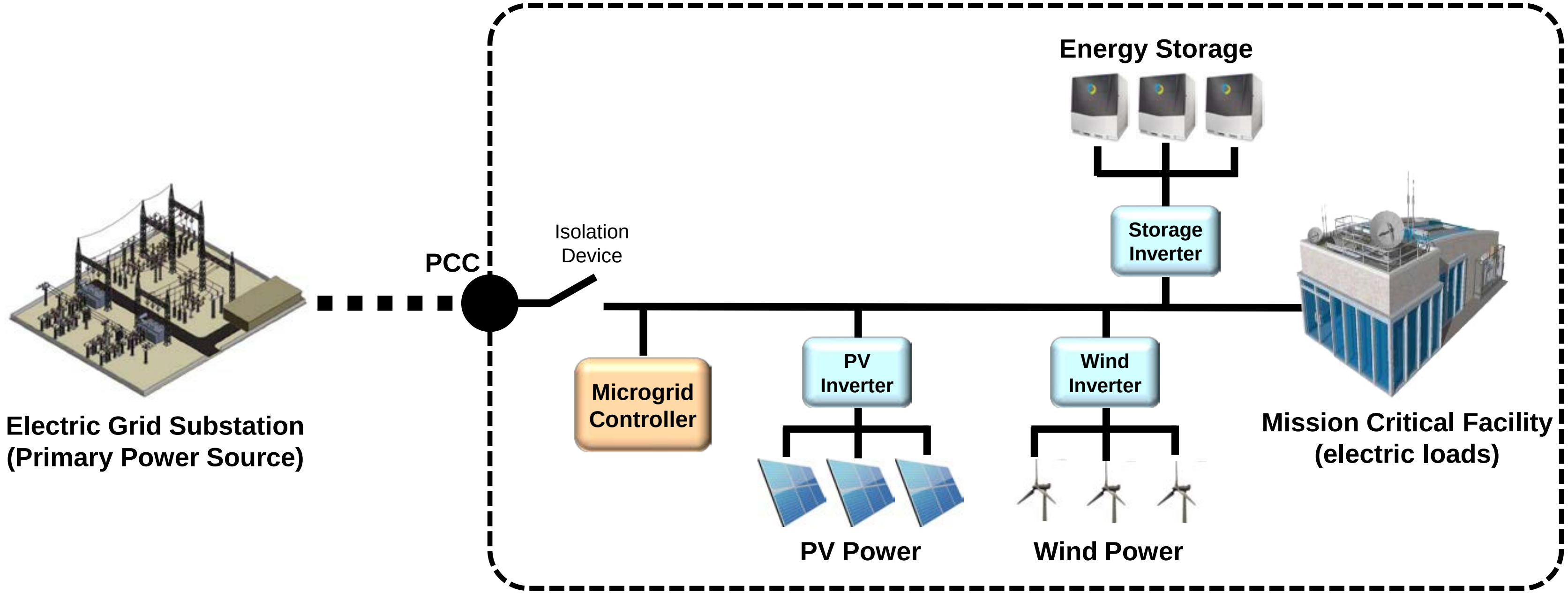
- **Use Renewable + Energy Storage to enhance resiliency by:**
  - Providing the same benefits of Use Case #1
  - Using Energy Storage to cache renewable power for use at night (PV) or no wind conditions
  - Reducing the use of diesel (proportional to the amount of Storage/Renewables)
  - Extending the time that diesel fuel will last



- **Range of operating conditions from**
  - Diesel = main power, Renewables augment diesel and acts as additional back up
  - Diesel/Renewables approximately 50/50
  - Renewables = main power, Diesel augments Renewables and acts as additional back up

Use Case #3: Replace Diesel with Storage + Renewable

- **Use Renewable + Energy Storage to enhance resiliency by:**
  - Eliminating need for Diesel Generators
  - Eliminating need to truck in diesel fuel on an ongoing basis
  - Total power comes from Renewable sources
  - Energy Storage enables caching of renewable power for use at night (PV) or no wind conditions



- **Near-Term the economics of Use Case #3 are currently not practical**
  - Amount of storage must be 3-5 time larger than nominal to account for 3 sigma events (e.g. multiple days of no sun or no wind)
  - Long-term this will change as cost of Storage continues to drop

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Recent Primus Self-Sustaining/High Reliability Microgrid Projects

Customer	Piloting Activity
US Marine Corps Air Station at Miramar	Primus Power integrated a 1 MWh EnergyPod system to an existing 280 kW solar PV array. Raytheon provided the control system. The system enabled the critical facilities at building 6311 to operate when disconnected from the main power grid. This effort received the 2016 ESTCP project of the year and the 2017 Federal Energy and Water Management Award.
Microsoft-Redmond Campus	Primus Power installed and tested an EnergyPod at a Microsoft data center that demonstrated the ability to support the data center completely from stored energy
Samruk Energy – Kapchagay solar farm	Samruk-Energy used an EnergyPod at a remote, 2 MW solar PV facility and successfully demonstrated the ability of batteries to enhance the resiliency of the power provided by the solar PV.

A high-resilience microgrid implemented at the Marine Corps Air Station at Miramar that employs a Primus Power 1 MWh battery system to firm solar power.

Long Term Challenges

- **Establishing a strong engineering foundation for Resiliency in microgrids**
  - Metrics for microgrid resiliency
  - Standardized analytic methods for characterizing the Resiliency of microgrids
  - Achieving community consensus on the above
- **Getting Customers to understand (and be willing to pay for) Resiliency**
- **Hardening microgrid solutions to be resilient to long duration threats**
  - Microgrids are vulnerable to many of the same threats that put the main electric grid at risk
- **Investing in Energy Storage to increase production and drive down unit costs**
  - Same challenge that PV/Wind had to overcome
- **Impacts on current Utility Business models**

Summary

- **The high reliability of the national electric grid can no longer be taken for granted**
- **Mission Critical facilities must address emerging long duration threats to the national electric grid**
- **Microgrids have an important role in improving electric power resiliency**
- **Energy Storage costs are reaching the price point where more powerful microgrid resiliency solutions can be achieved**
  - Initially augment existing Diesel solutions
  - Eventually replace existing Diesel solutions