Power for DOD Installations:
Can We Have it All?

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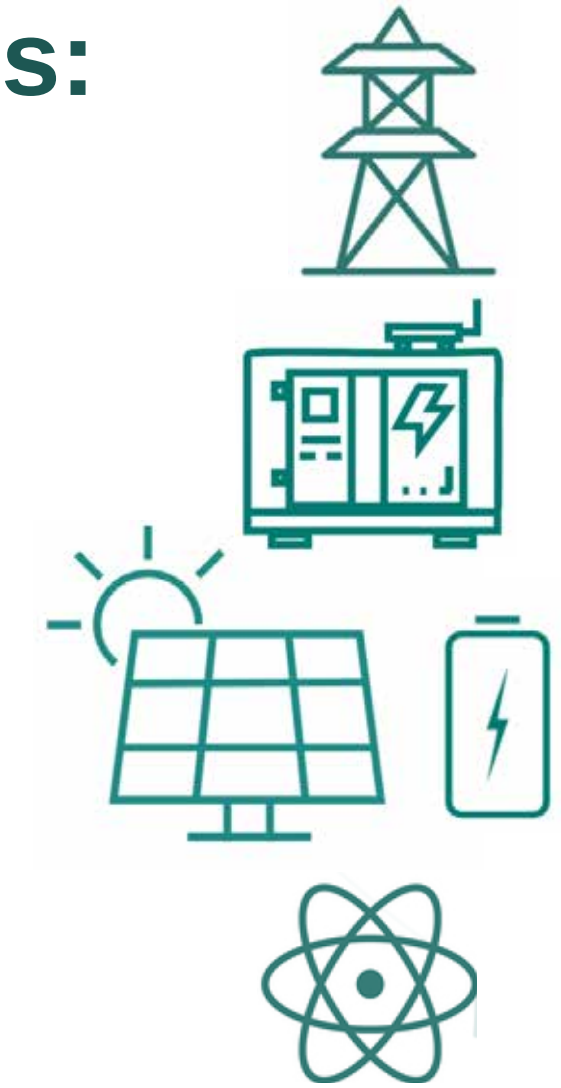

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Learning Objectives

1. Clarify the actual requirements for site power (resilient, renewable, carbon-free) and when they must be met.

2. Understand which generating technologies are ready for immediate deployment and which still need proving.

3. Learn what makes energy projects so expensive and how to control these factors.

4. Leverage generating assets and site distribution to lower operational costs even when there’s not an emergency.

DOD Federal Requirements

- **Energy Resilience**:
  - **Duration**: Critical Missions must have 14 days of on-site storage of energy and water[1]

  - **Uptime**: The annual percent of time power is available
    Range: 99.9% - 99.9999% BASED ON MISSION
    Corresponds to 8.5 hrs/yr (3-nines) to <1 min/yr (6-nines)

1. OSD Metrics and Standards for Resilience at Military Installations 20 May 2021

Federal Clean Energy Drivers

- **Energy Policy Act of 2005**
  - Renewable Energy Targets
- **Executive Orders[1] to DoD**
  - **Carbon Pollution Free Energy**
  - 100 percent **carbon pollution-free electricity** on a net annual basis by 2030, including **50 percent 24/7** carbon pollution-free electricity
- Flow-downs to DOD policies

NOTE: Back-up generation does not need to be carbon free.

- But could be a missed opportunity

Quick Note on Electrification

- *IS* possible for most climates, but relies on newer heat pump technology.
- More incentives/marketing for cold-climate heat pumps required.
- AVOID steam for heating. Period.
- Limit Steam for industrial uses.
- For transportation, the grid beats ICE engines. Always.

Generation Technologies

1. Combustion Generators
2. Fuel Cells

⟩ **FOSSIL FUELS OR GREEN/GREEN HYDROGEN**

3. Solar Photovoltaic (PV) + BESS
4. Wind

⟩ **RENEWABLE**

5. Biomass - **RENEWABLE (SOMETIMES)**
6. Nuclear - **NOT TECHNICALLY RENEWABLE, BUT “CLEAN” and “CARBON FREE”**
7. Geothermal - **RENEWABLE (VERY LOCATION DEPENDENT)**

Fuel-Based Generation

1. Combustion Generators
   - Reciprocating Engines
   - Combustion Turbines
2. Fuel Cells
   - PEM
   - Solid Oxide
   - Molten Carbonate

Fuels used

- Diesel
- Nat. Gas
- Hydrogen

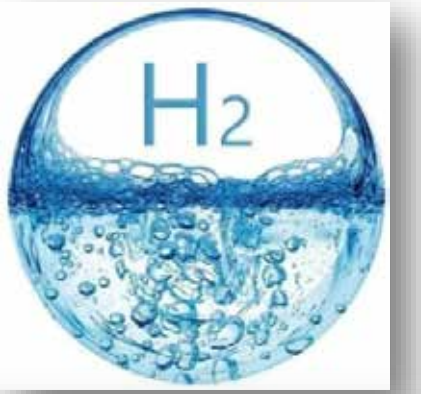
Must consider:

Fuel availability during and after catastrophic events

What About Hydrogen?

Hydrogen is a perfect fuel, BUT…

- Most hydrogen is made using fossil fuels (typically nat. gas)
- “Green” production currently has lower round-trip efficiency than Battery Storage
- Difficult and expensive to transport and store
- Limited continuous availability
- Makes sense when combustion and/or very high temps are needed. (Generally, not for HVAC)



Renewable Generation

1. Solar PV (Ground, Parking, Roof)
   - Relatively cheap, minimal O&M,
   - NOT CONTINUOUS
2. Wind
   - Low cost (utility scale); higher utilization than PV
   - Highly location dependent
   - Can interfere with aviation
3. Geothermal
   - Highly location dependent
   - Requires large-scale commitment, long delivery time

Renewables - Solar PV

- Relatively cheap; Low maintenance
- Rooftop; Parking Canopies; Ground Mounted; Floating
  - Bigger is generally better
  - Rooftop is least desirable for large energy projects, but it should be considered for all new buildings.
- NOT CONTINUOUS

Anatomy of BESS

MODULAR CONTAINER WITH EXTERIOR ACCESS

Battery Energy Storage Systems (BESS)

1. Can be integrated into any power architecture
    - Can save utility expenses
    - Can increase use of renewable energy (esp. PV)
2. Mature technology and benefitting from commodity pricing
    - Lithium iron phosphate (LFP) most common
    - Storage media can change but rest of system can be re-used.
    - Relatively large area required for stand-off distance
    - Country or origin concerns. More BAA-compliant options are coming.

Small-Scale Nuclear

- Proven designs; some are passive cooling
- Micro (<5 MW) and Mini (<100MW)
- Modular configurations (SMR)
- Carbon-free energy
- Continuous generation
- *Still generate nuclear waste*

Small-Scale Nuclear

Seems like the perfect solution, but very difficult to permit and plan.

Opinion: Without multiple example installations very unlikely to be viable for generation/microgrid projects within 10 years.

	Climate Change	Predictable Electrical Output	Inverter Based System	Standby Power	Black Start (Dispatchable)	Primary Power	Base Load Power	Load Following	Power Quality Correcting
SMALL-SCALE NUCLEAR	✓	✓	⊘	✓	✓	✓	✓	✓	✓

From UFC 3-550-04

Generation Comparison

	Climate Change	Predictable Electrical Output	Inverter Based System	Standby Power	Black Start (Dispatchable)	Primary Power	Base Load Power	Load Following	Power Quality Correcting
Turbine or Engine-Driven (Low Speed)	⊘	✓	⊘	✓	✓	✓	✓	⊘	△
Engine-Driven and RICE (High Speed)	⊘	✓	⊘	✓	✓	✓	✓	✓	△
Facility Level, Stand-alone Engine-drive[8]	⊘	✓	⊘	✓	✓	△[5]	△	✓	△
(Natural) Gas-Fired	✓	✓	⊘	✓	✓	✓	✓	△[4]	△
PV	✓	⊘	✓	△[1]	⊘[1]	△[1]	△[1]	⊘	△
Wind Turbine	✓	⊘	⊘	△[2]	⊘	△[2]	△[2]	⊘	△
Fuel Cell (High Temp)	✓	✓	✓	✓	△[3]	⊘[7]	✓	⊘	△
Fuel Cell (Low Temp)	✓	△	✓	△	△[3]	⊘[7]	△[3]	⊘	△
BESS/UPS	✓	✓	✓	✓[6]	△[3]	⊘[7]	△[3]	✓	✓
Flywheel (FESS)	✓	✓	⊘	✓[6]	△[3]	⊘[7]	⊘	✓	✓
Symbol Key		✓ = Yes, ideal		△ = Possible, with caution		⊘ = No			

[1] subject to availability allowed by weather conditions
[2] subject to wind conditions; min speed must be met & max (lockout) speed not exceeded
[3] battery storage must be charged
[4] only for microturbines
[5] facility-level dedicated generators are typically permitted for backup only
[6] instant backup power – rapid ride-through
[7] energy storage must first be charged by another resource, but can still serve significant loads
[8] UFC 3-540-01

What Makes Power/Resilience Projects so Expensive?

- Controls: Generators and control of switching
  - Typically, “black-boxes”
  - Much more competition now
- Lots of Equipment
  - Generators, switchgear, transformers, controls, distribution
- No ability to recoup costs
  - Most generator projects provide benefits only in emergency situations
- Artificially-Low Electrical Rates

How Can Power/Resilience Projects be Less Expensive?

- **Don’t overbuild. Use metered data. (Planning)**
- Use generating assets to save money during non-emergency times
- Battery Energy Storage Systems (BESS), when carefully applied, can limit number of generators
- Examine multiple architectures and consider all federal goals
- Consider lifecycle costs. Mix pots of money.

Takeaways

- There is no perfect solution (Hydrogen pipelines are still a long way off. SMRs may be even longer)
- Bigger projects are often cheaper
- **Look for solutions that can help with normal operation**
- Consider combined heat and power
- Don’t let the perfect be the enemy of the good. Mix of renewables and fuel
- Get utility involvement

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