U.S. DEPARTMENT OF ENERGY
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Designing and Managing Data Centers for Resilience: Demand Response and Microgrids

FEMP
Federal Energy Management Program

Webinar Logistics

- This webinar is being recorded. The Q&A portion will not be made publicly available.
- Your phone will be muted throughout the webinar.
- Enter any questions in the Question Box throughout the webinar.
- Instructions to take the quiz will be provided at the end of webinar.
- Slides will be sent out afterwards to those who attend the entire webinar

Presenters

Rachel Shepherd
DOE-FEMP
Data Center Program Lead

Dale Sartor, P.E.
Lawrence Berkeley Laboratory
Staff Scientist/Engineer

Rish Ghatikar
Electric Power Research Institute
Project Lead, Senior Program Manager

Bruce Myatt, P.E.
ARUP
Data Center Business Lead

Mukesh Khattar
Electric Power Research Institute
Technical Executive, Data Centers

Russell Carr, P.E.
ARUP
Technical Lead

Agenda

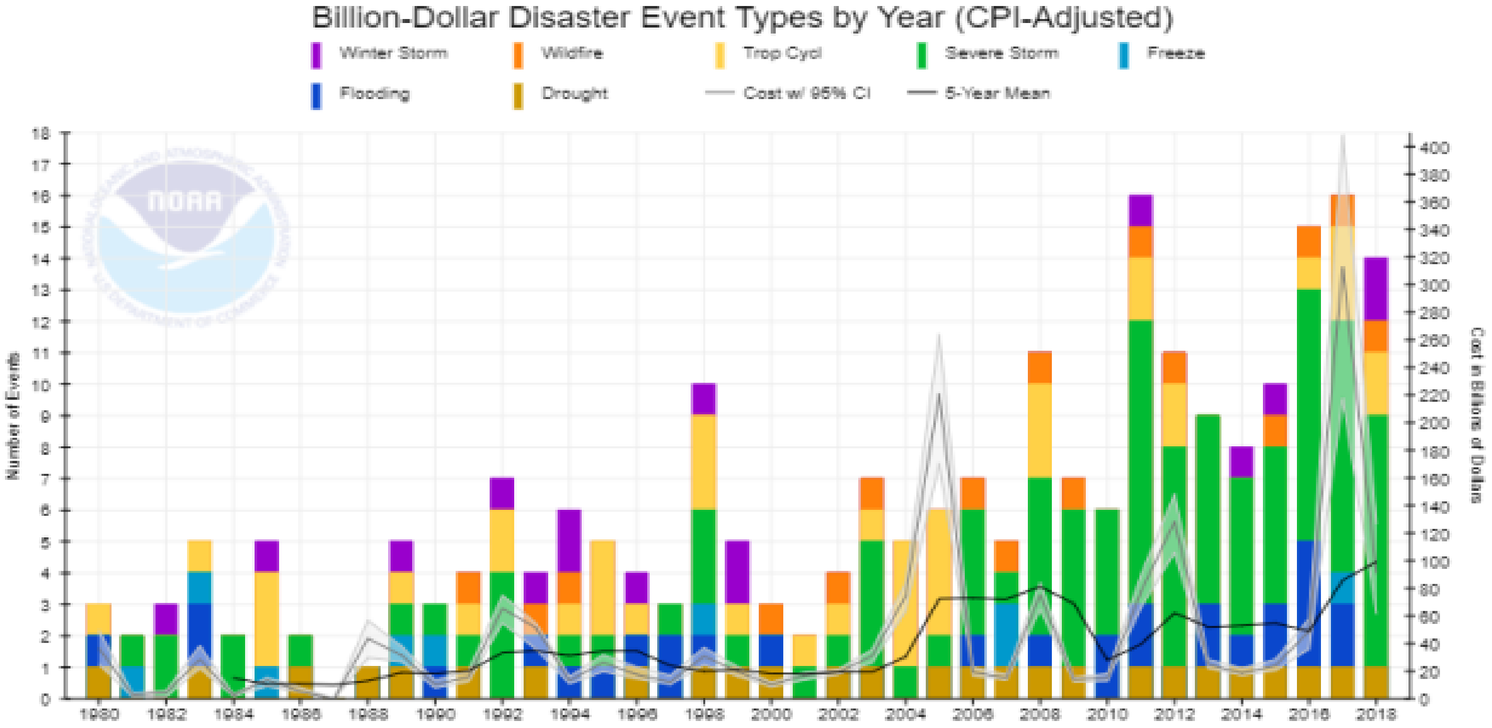
- Introduction
- What does resilience mean for data centers?
- Resilience and efficiency
- Intro to advanced strategies for data center resilience
- Data center demand response (DR)
- Data center microgrids
- Next steps toward a resilience strategy
- Summary
- Resources
- Q&A

Resilience – What is it?

*The ability to prepare for and adapt to changing conditions and <u>withstand and recover rapidly from disruptions</u>. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents.**

- **Very large-scale events (VLSEs) with potentially catastrophic impacts pose increasing risk.***
  - Can be **man-made** (cyber, electromagnetic pulse) or **natural** (hurricanes, wildfires)
- **Frequency and severity of VLSEs may continue to increase with "malicious intent" and "climate risks."**

* Presidential Policy Directives PPD 8 & 21 2013; Grid Modernization Laboratory Consortium 2017; FERC 2018



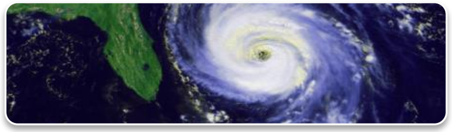
The number bars, left axis, type colors, and annual cost right vertical axis of U.S. billion-dollar disasters from 1980-2018
Source: NOAA

Challenges to Electric System Resilience

Natural Hazards

High-Magnitude Earthquake

Geomagnetic Disturbance (GMD) - Severe Space Weather



Hurricanes, Wildfires, Other Severe Weather Events

Manmade Hazards

Electromagnetic Pulse (EMP), Nuclear/Chem/Bio

Cyber Terrorism

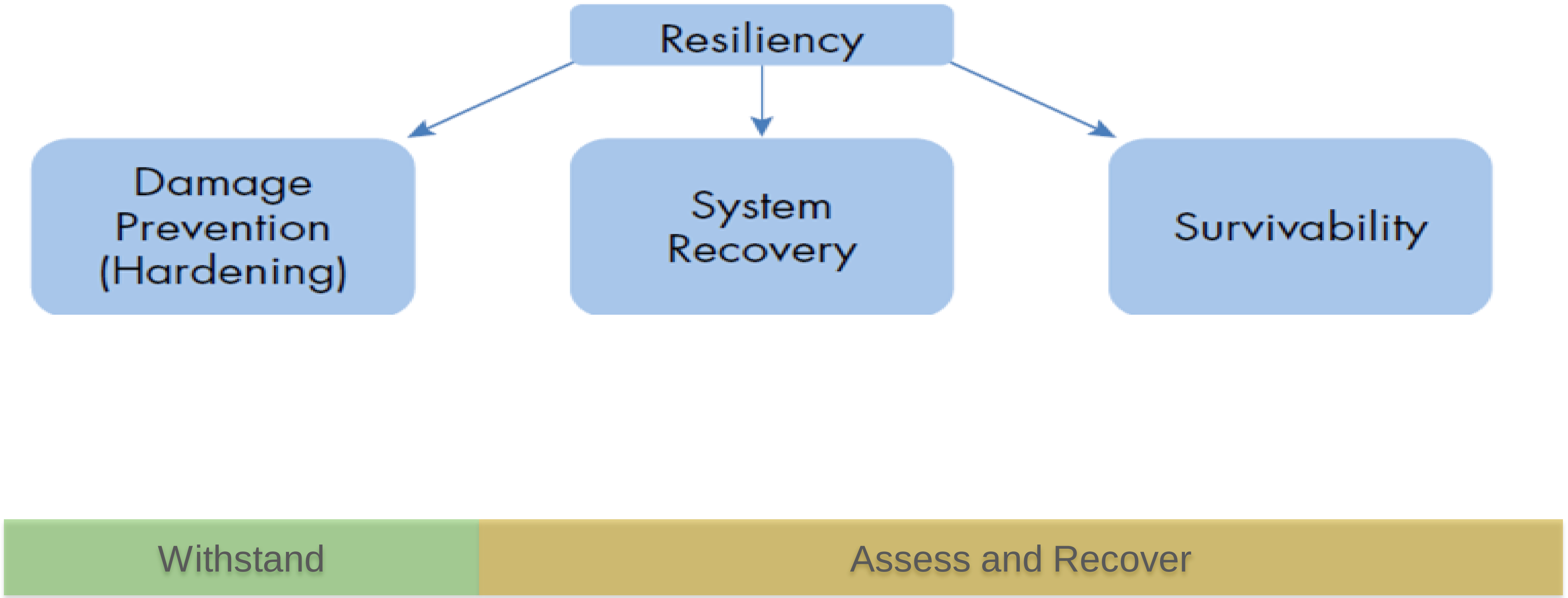
Coordinated Physical Assault

Other Interruptions

Accidents, Fuel Supply Unavailability, Public Safety Power Shutoff

Source: Electric Power Research Institute

Three Complementary Pathways to Improving Resilience



Source: Electric Power Research Institute

What is Data Center Resilience?

Reliability

- How often a component or system suffers an outage or fails, e.g., MTBF

Availability

- How much time power and cooling is available for IT operations

Resilience

- Above plus ability to withstand extreme, system-wide events with managed recovery
  - **Reaches beyond the data center**, e.g., ensures a durable upstream fuel supply chain
  - **Sustains delivery of the most critical end services**

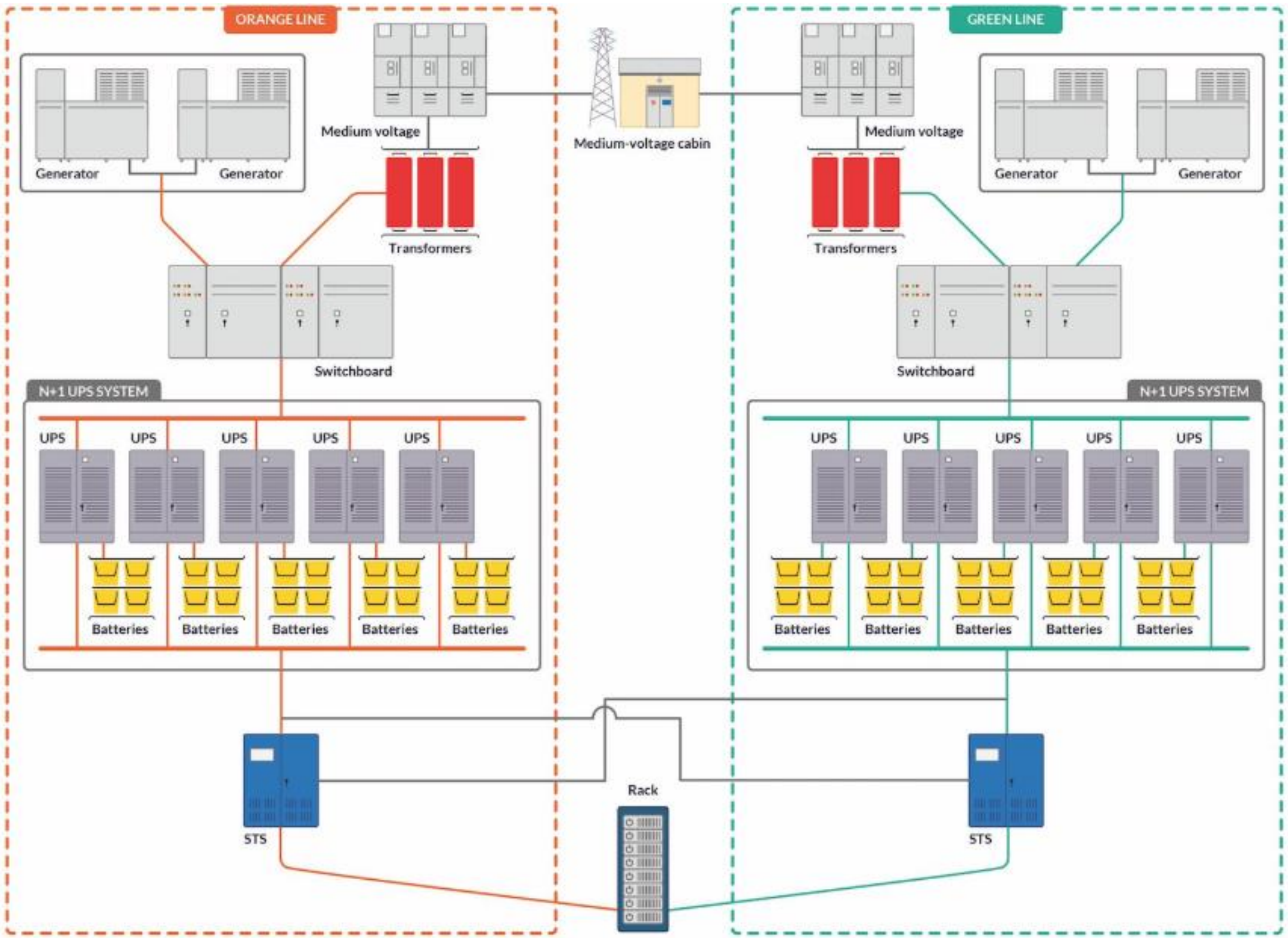
Critical Missions Demand High Resilience

- **Data centers are already sited, designed and operated for high reliability.**

- **High availability of power, cooling, networks & applications**

- **Utility & Grid Independence**
  - Uninterruptible power supplies (**UPS**), on-site generation, e.g., **diesel generators** and **thermal storage** are commonly used.

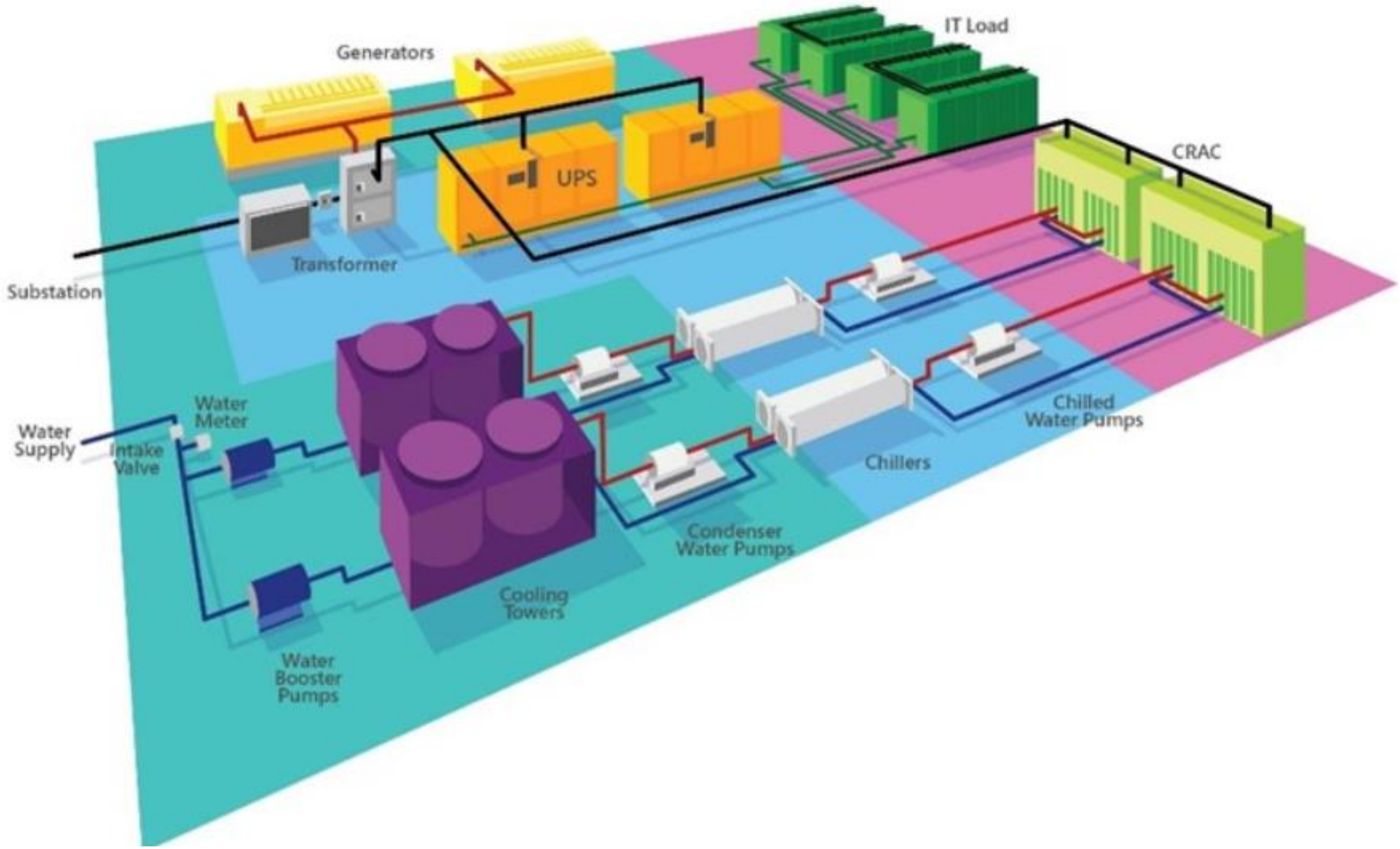
Mission Critical Power Availability



- Redundant electrical system, e.g., 2N
- Dual Path Power – Grid and UPS/Generator

Image Source: Aruba S.p.A

Mission Critical Cooling Availability



- Redundant chilled water system
- May have redundant water supply

Data Center Availability: Tier Classifications

- Tier 1 = Non-redundant capacity components, single uplink and servers
- Tier 2 = Tier 1 + redundant capacity components
- Tier 3 = Tier 2 + dual-powered equipment and multiple uplinks
- Tier 4 = Tier 3 + all components are fully fault-tolerant and dual-powered, including uplinks, availability storage, chillers, HVAC systems, servers, etc.

What Tier Is Best?

- **Carefully evaluate applications: What is really needed?**
  – Not all data center applications are critical, especially for a short interruption.
- **Higher tiers add cost, complexity**
  – Higher energy cost due to redundant systems operating in parallel at low load
- **Tiers don't guarantee availability**
  – Can still have fuel contamination, broken fuel or water pumps, etc.
  – Slow breaker can turn brief outage into a data center crash
- **Many examples of data centers without redundant systems, UPS, generation and even compressor-based cooling**
  – National lab HPCs

Resilience strategies can be different

  – Data centers can have low-tier availability but still be resilient – e.g., if they can "fail over" or transfer IT load to another facility unaffected by large-scale events.
  – More diversity in location and power/fuel supply = greater resilience.

Beyond Tiers: Mission Critical Network & Application Availability

Reliability is often not about a single facility.

- Networking and failover among multiple data centers can be very cost effective
- “Availability zones” feature one or more data centers linked in a given geographic region to allow replication of applications and data across physically separate data centers. Failure of any one data center leaves up-to-date copies or “instances” of those services available at other data centers.

  - Parallel data processing
  - IT/data failover from one DC to another
  - Other forms of networked redundancy (asynchronous, cloud)

Image Source: Amazon Web Services

Can Resilience Be Synergistic With Efficiency?

- **Efficiency is a resilience strategy, but EE and resilience can sometimes be in tension.**
- **Strategies that boost efficiency can support resilience:**
  - Smart air management - optimizing fan and cooling energy while improving reliability
  - Back-up cooling and generation can be minimized, given lower demand
  - Wider environmental envelopes (w/more robust IT equipment) allow for greater efficiency and continued operation under compromised conditions, e.g., failure of compressor cooling.
  - Data Center Infrastructure Management (DCIM) can detect faults and provide early warning of potential problems. Can also help segregate loads by mission criticality.
- **Simple systems (e.g., no compressor cooling) are generally more efficient and can be more reliable by reducing chances of human error.**

Beyond Redundancy: Two Advanced Resilience Strategies

Demand Response (DR)

- Controlled changes in electric usage:
  - Lower electricity use at times of high prices or when system reliability is jeopardized.
  - Increase electricity use when prices are low (e.g., batch loads).
- Multiple choices of mode, timing and magnitude of load change
- Especially effective in conjunction with microgrids and variable supply resources.

Microgrids

- A bounded, local energy system capable of operating in isolation of the grid (e.g., control and balancing of loads, gen and storage).
- Many components already deployed in data centers.
- Allows "arbitrage" among multiple resources
- Given the high value of redundancy and availability, data centers are a good target for microgrids.

Demand Response as a Strategy for Resilience in Federal Data Centers

Rish Ghatikar and Mukesh Khattar, Electric Power Research Institute (EPRI)

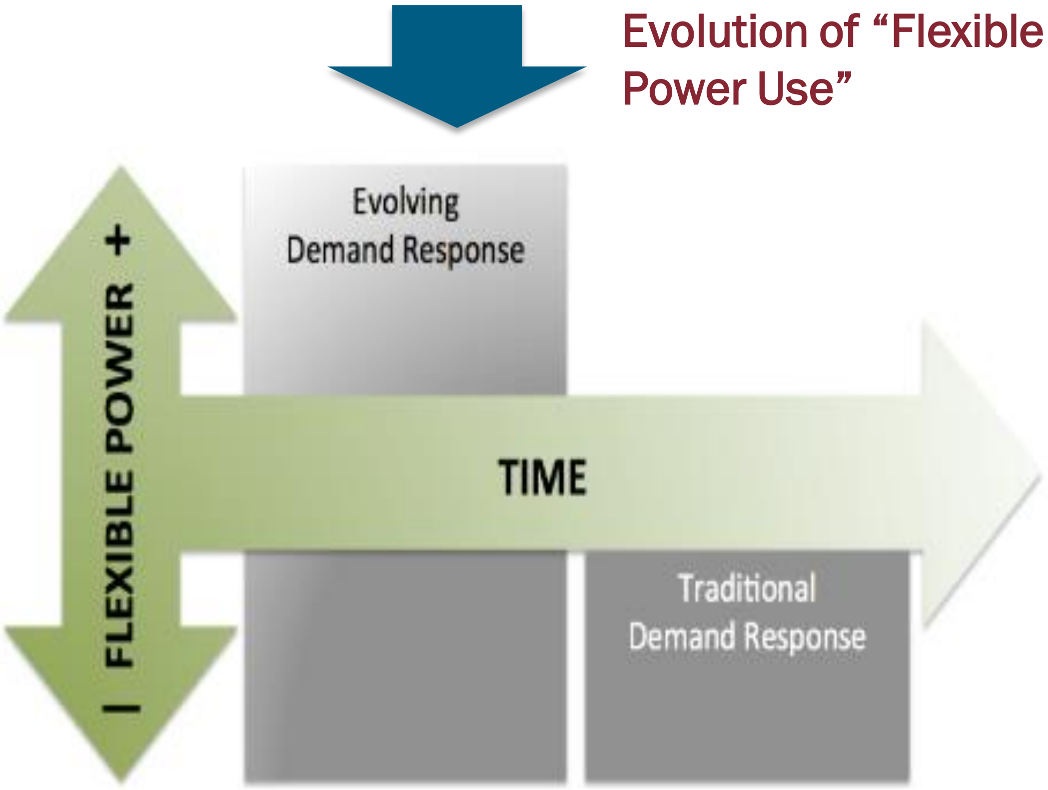



Context and Problem Statement: Demand Response (DR)

*Changes in electric usage by demand-side resources from their normal consumption patterns in response to changes in electricity price, incentives to lower electricity use at times of high wholesale market prices or when system reliability is jeopardized.**

1. **Traditional DR has focused on managing peak electricity usage.**
2. **Increasing proliferation of variable renewable generation and advanced communications and control technologies are enabling fast-responding DR resources.**
3. **Large energy consuming customers (e.g., industrial facilities) commonly contract with system operators for interruptible electricity in exchange for lower electricity rates.**

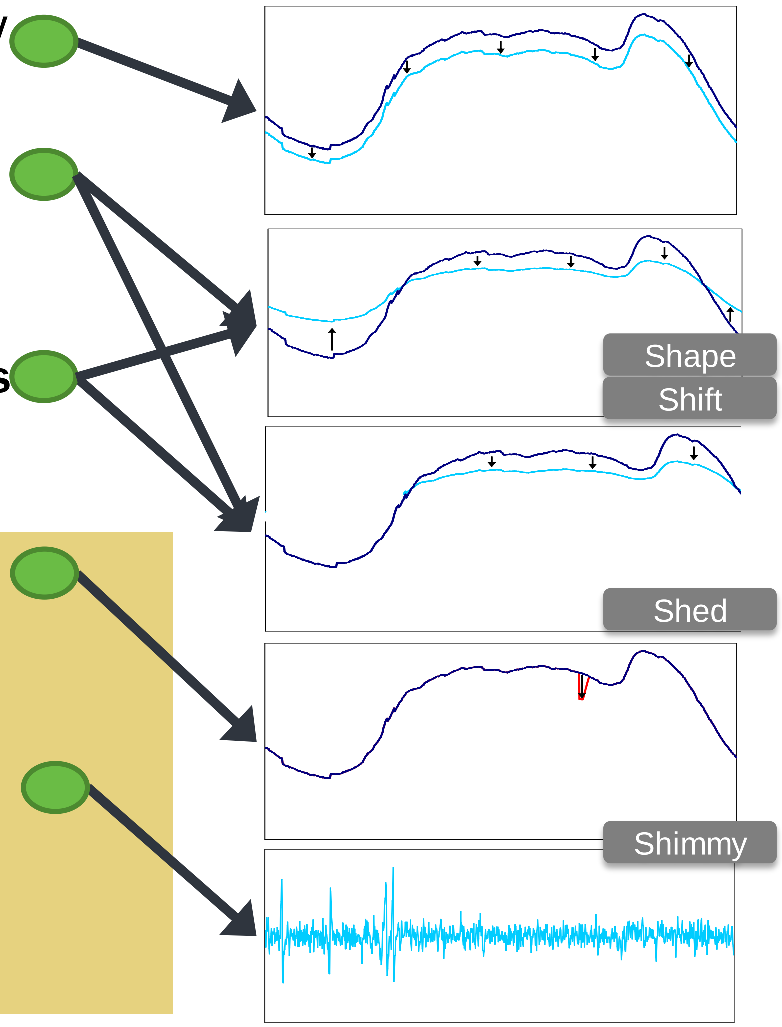
Evolution of "Flexible Power Use"



** Federal Energy Regulatory Commission (FERC)*

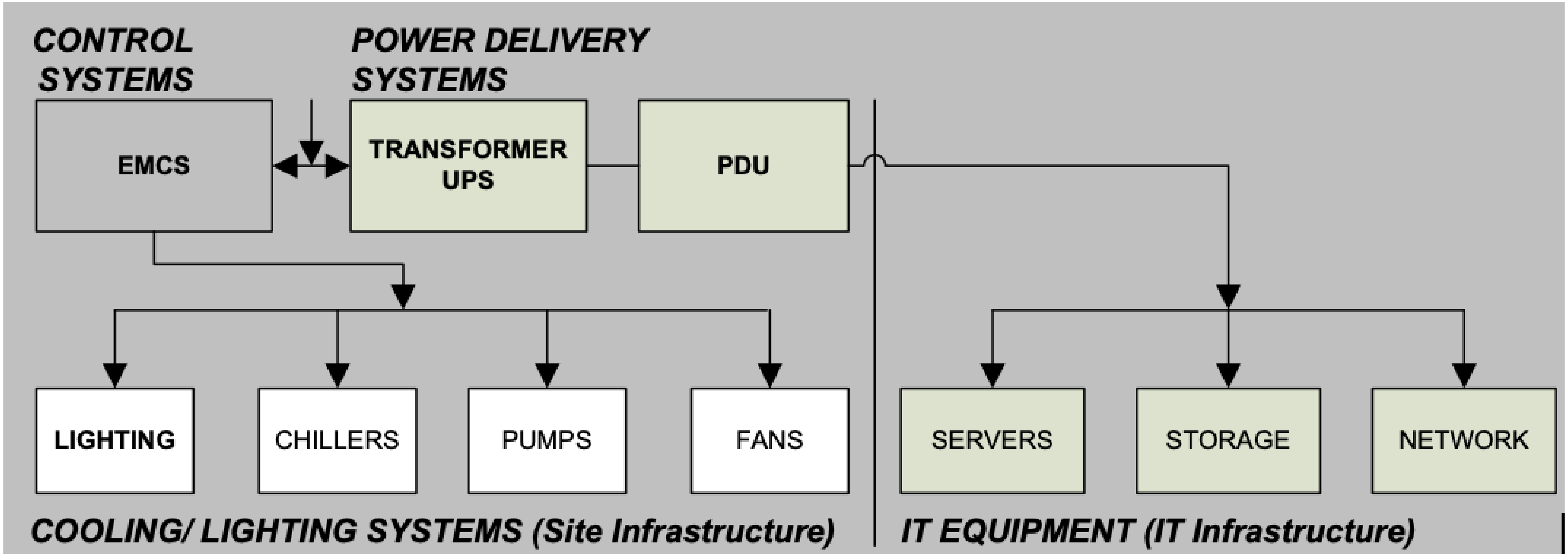
Expanding Demand-Side Management Objectives

1. **Energy Efficiency** programs reduce overall electricity consumption, generally also at times of peak demand.
2. **Price Response** programs move consumption from times of high prices to times of lower prices (real time pricing or time of use) – can address transmission distribution congestion management.
3. **Peak Shaving** programs require more response during peak hours and focus on reducing peaks on high-system load days – can address transmission & distribution congestion management.
4. **Reliability Response** (contingency response) requires the fastest, shortest duration response. Response is only required during power system "events." This is new and slowly developing.
5. **Regulation Response** continuously follows minute-to-minute commands (sub-minute telemetry) from the grid in order to balance the aggregate system load and generation. This is also very new and appears to be very promising for certain loads.



Adapted from: Demand Response Spinning Reserve Demonstration Project, Consortium for Electric Reliability Technology, LBNL, Joseph Eto presentation October 19, 2009 (http://certs.lbl.gov/certs-loadkey-drsrdp.html).

Demand Response (DR) Context for Data Centers



Data Center DR opportunities: ***Facility infrastructure and IT infrastructure***

Demand Response (DR) Context for Data Centers

- **Data centers sparingly participate in DR programs**
  - Perceived risks (e.g., to availability) often given more weight than the value from participation
  - Most participation is from cooling loads, which in some private-sector data centers are declining with increased use of direct/indirect evaporative cooling of outside air without mechanical cooling and thus increased efficiency (PUE)*

$$\mathbf{PUE} = \frac{\mathbf{Total\ Facility\ Energy}}{\mathbf{IT\ Equipment\ Energy}}$$

- **Data center participation is often focused on managing cooling loads**
  - Example: Raise temperature set-points during the DR event.
- **Leveraging IT equipment load is critical for long-term DR engagement efficacy.****
  - Computing power-capping technology developed by the industry.
  - Reducing computing load has synergistic effects on cooling loads

* For example, a PUE 2.0 data center with 2 MW demand, uses 1 MW for non-IT load.

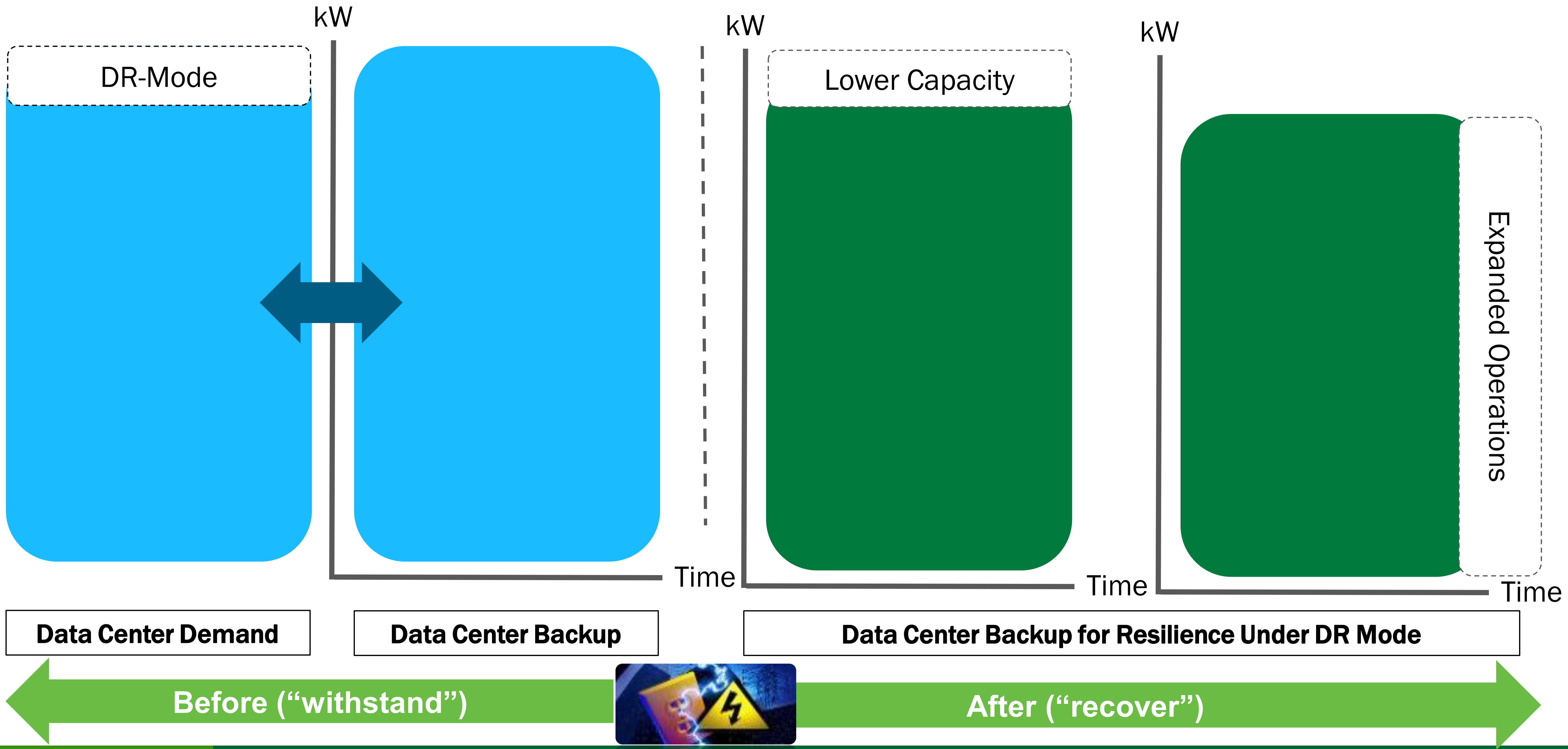
** Ghatikar G., V. Ganti, N. Matson, & M. A. Piette, Demand Response Opportunities and Enabling Technologies for Data Centers: Findings from Field Studies, Aug. 2012. LBNL-5763E.

DR Improves Resilience of Electric System and Data Center Site

- **Data centers can effectively integrate DR best practices**
  - Power capping reduces clock speeds during peak demand periods and so can improve resilience and lower electricity costs.
- **DR is used now to improve electricity <u>system resilience</u>**
  - Adaptation to increased over- and under-generation supply
    - Raising or lowering temperature set-points and/or variable fan speeds
  - Can be even more important within a microgrid
- **DR can also be effective in improving <u>local resilience</u>:**
  - Enable lowering of the infrastructure requirements, e.g., cooling system size
    - Lower back-up capacity and costs due to lower demand
  - Extending the timespan of local resilience
    - Extends duration of islanded operation

Slow-responding DR resources: Can support "withstand."
Fast-responding DR resources: Can support "withstand, survive, & recover."

Expanding DR to Support Local Resilience



Data Center DR Strategies: IT Infrastructure

Equipment, Function Type	DR Operational Strategy
IT Load	**Power capping** • Limit clock speeds or otherwise slow process for less or non-essential loads.
	Load shifting or queuing IT jobs • Use job scheduling techniques to reduce (or increase) load as desired.
	Use built-in server power management capabilities for more aggressive load reduction.
	Use virtualization or techniques such as software-based power management to manage loads and power utilization (temporarily manage the available buffer)
	Use virtualization and migration technologies to move load to another facility on a lower stressed grid
	Implement more **aggressive network power management**

Data Center DR Strategies: Facility Infrastructure

<table>
<tr><th>Equipment, Function Type</th><th>DR Strategy</th></tr>
<tr><td rowspan="5">Facility Infrastructure</td><td>Increase temperature set points (e.g., from recommended to allowable range)
• Decreases load, and increases cooling efficiency including greater use of economizers</td></tr>
<tr><td>Cycle off or reduce power (e.g., speed control) to chillers, CRACs, fans, lights, UPS (e.g., put in “eco” mode), transformers, etc.
• Modern UPS technologies and batteries provide additional value to support DR while maintaining back-up availability/reliability</td></tr>
<tr><td>Intelligent linking of controls to respond to IT load reductions (rapid multiplier effect).</td></tr>
<tr><td>Energy storage (also can increase availability)
• Thermal Storage
• Electric Storage (including short duration strategic use of UPS to help utility balance loads and frequency)</td></tr>
<tr><td>Strategic use of emergency fossil-based generation
• When allowed by local air quality or environmental rules
• Run required testing when DR desired</td></tr>
</table>

Data Center DR Case Studies: Net Apps, Berkeley Lab, UC-Berkeley & San Diego Supercomputing Center

Data Center	DR IT, Facility Infrastructure and Network Migration Operational Strategies
NetApp	Shift/Queue data backups to storage
	Temperature set point adjustment
LBNL 50B	Server and CRAC units shutdown
	Data Center Shutdown
SDSC, UCB and LBNL 50B	Load migration - Homogeneous – Idling
	Load migration - Homogeneous – Shutdown
	Load migration – Heterogeneous - Decay

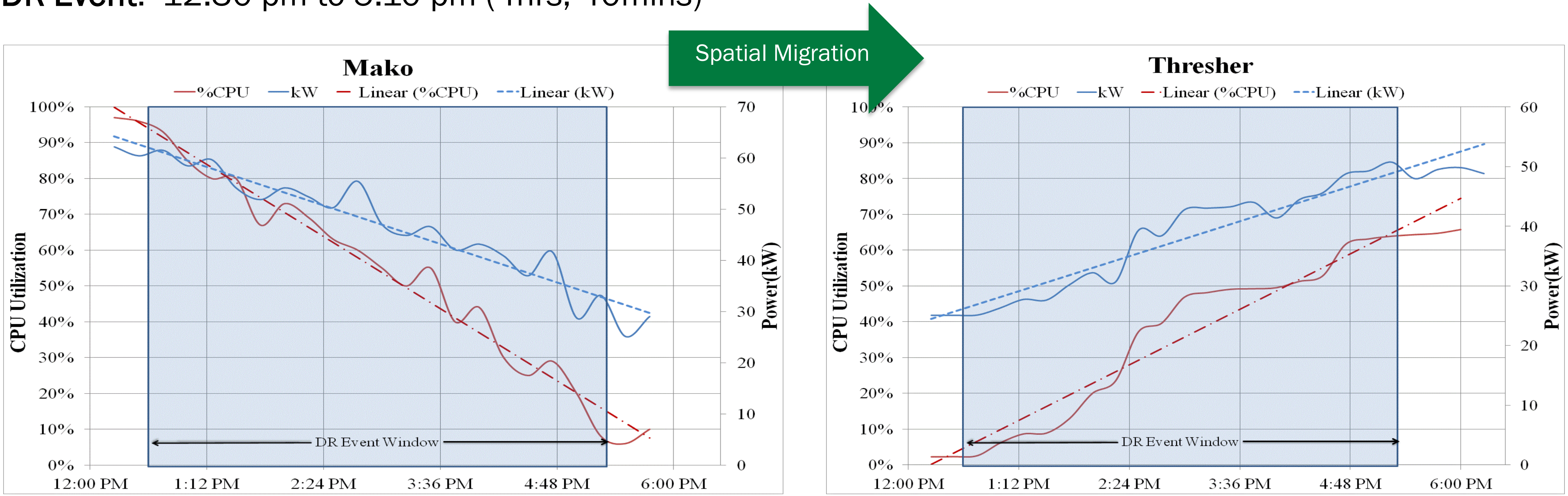
Key Lessons

- DR effectiveness proven for many infrastructure and IT loads*
- No negative impacts (e.g., when recovering/recovered)
- High value to the grid and low operational impact on DC

Ghatikar G., V. Ganti, N. Matson, & M. A. Piette, Demand Response Opportunities and Enabling Technologies for Data Centers: Findings from Field Studies, Aug. 2012. LBNL-5763E.

Field Test Results | Correlation of CPU Utilization and Power

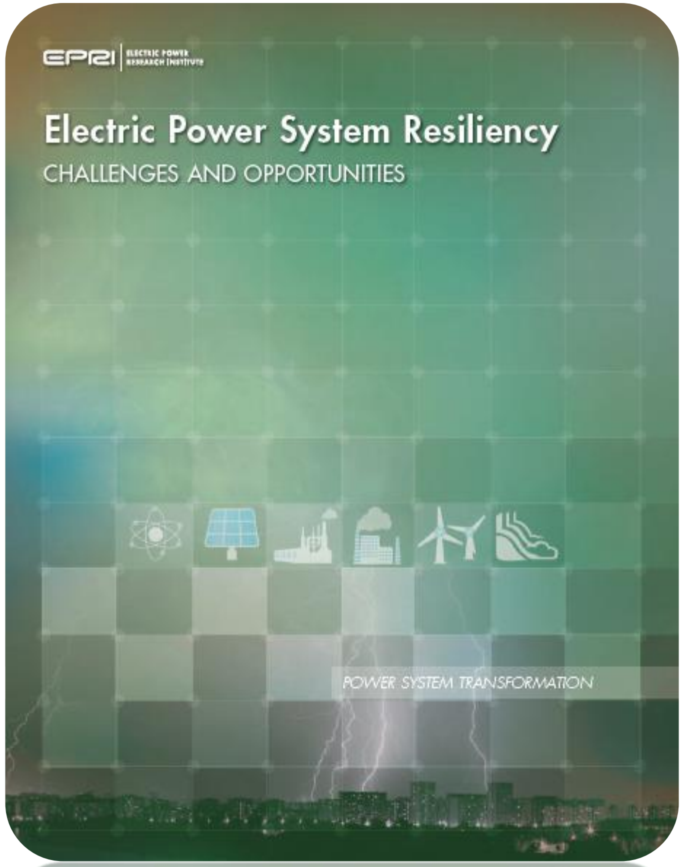
UC Berkeley (Mako) >> SDSC (Thresher) Load Migration Strategy
DR Event: 12.30 pm to 5.10 pm (4hrs, 40mins)

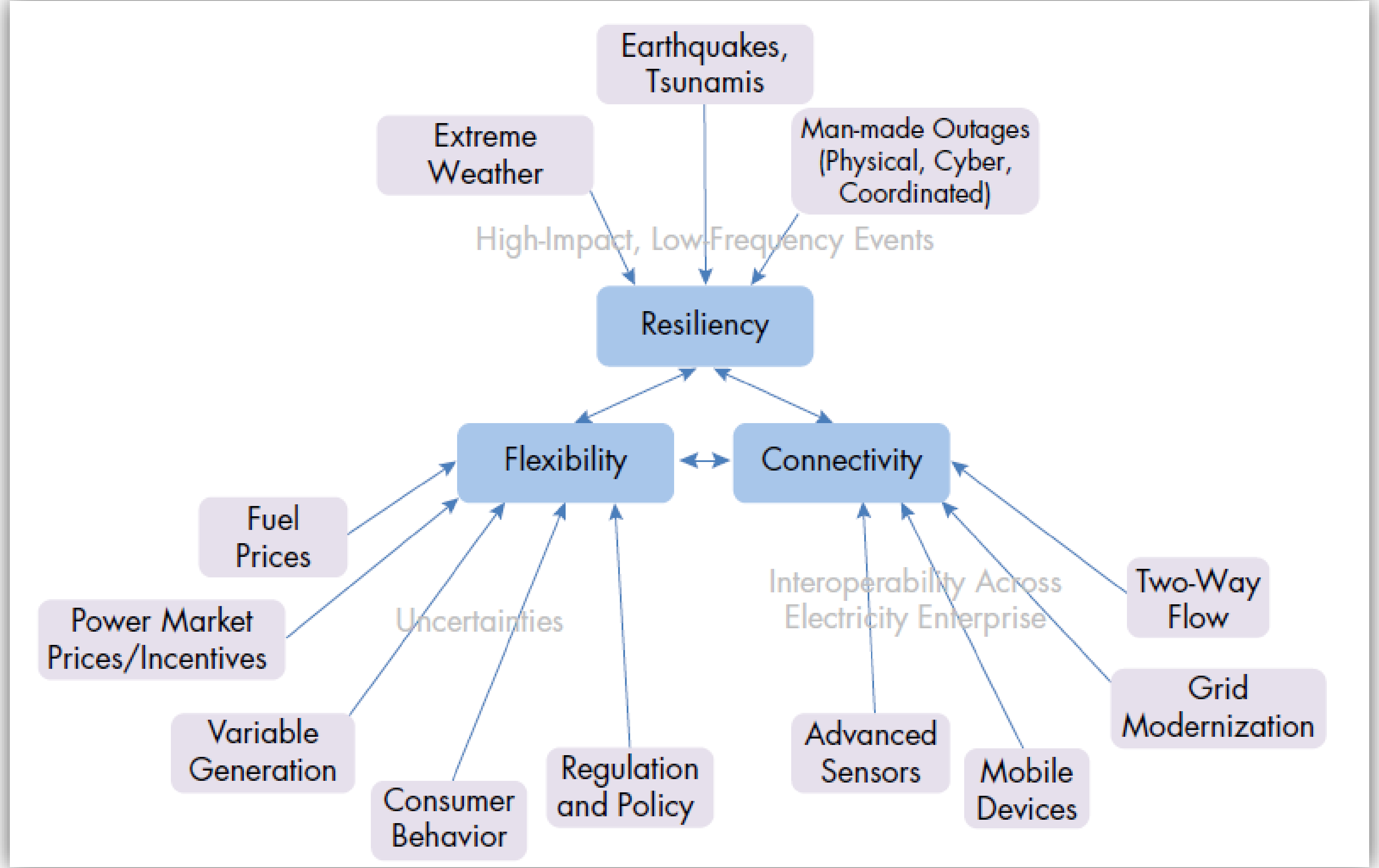


Results show a <u>linear correlation between CPU utilization rate and power draw</u> for dynamic increase or decrease in CPU capacity reservation.

Ghatikar G., V. Ganti, N. Matson, & M. A. Piette, Demand Response Opportunities and Enabling Technologies for Data Centers: Findings from Field Studies, Aug. 2012. LBNL-5763E.

Resilience Enabling Technologies: DR Flexibility & Connectivity



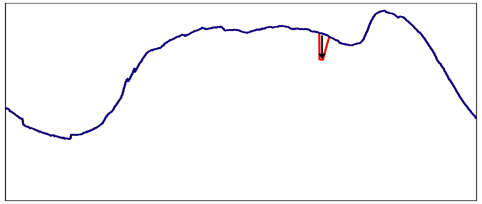


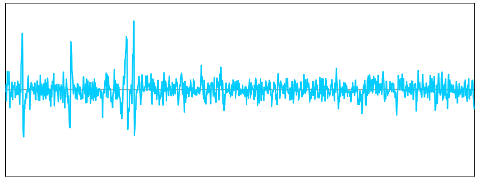
Three Attributes of the Power System in a "No-Regrets" Strategy

Source: EPRI Report ID 3002007376, February 2016

Advanced Technologies for Fast-Responding Energy Resources

1. Reliability Response
2. Regulation Response





- **Faster responding DR resources (e.g., reliability and regulation response) are well-suited for shorter-notification resilience events (e.g., flash floods).**
- **Advanced technologies (internal and external) play a key role in supporting resilience objectives.**
  - Secure external communication systems to grid operators on emergency conditions.
  - Secure internal communications and control operational strategies to manage demand.
  - Interoperable communication technologies with electric grid (e.g., utilities, system operators) and internal systems (e.g., cooling and IT systems)
- **Advanced technologies require supporting markets for electric system resilience (e.g., prevent a blackout from undergeneration)**

Data Center Strategies for Local Resilience

Data Center Local Resilience

Overarching Connectivity Resilience

Strategy

- Enhanced cybersecurity
- Strategies for robust and reliable network & communications
- Strategic digital & analog capabilities

During Resilience Event (Withstand)

Strategy

- DR: Reduce non-critical demand.
- Fuel supply assurance.
- Equipment and service hardening, and disaster recovery planning

Post Resilience Event (Recover)

Strategy

- DR: Aggressive reduction of non-critical demand.
- Local & network redundancy
- Local supply: DER and microgrids

Adapted from EPRI Reference Framework for Grid Resiliency.

Open Questions: DR Programs to Resilience

- While benefits can be fairly quantified for local resilience, the same are not well-quantified for electric system resilience.
  - How do we value resilience for the system?
  - What are the cost and benefits of resilience?
- How do we show DR business value and test-cases during- and post-resilience periods?
  - When is N+1 or 2N+1 a better design choice?
  - Is network redundancy a better alternative for certain resilience triggers?
  - What metrics can we use for DR to provide resilience value?
- **How do we value resilience for data centers since there is no one-size-fits-all resilience metric?**
  - **Attribute-based metrics:** Measure components or properties of an asset or system that increase its resilience
  - **Performance-based metrics:** Assess how an asset or system performs during a disruption.
- **Can we answer some or all of these questions working with federal data centers owners and operators. and field tests?**

Demand Response Summary

- **Proven for a range of loads, purposes, and business-cases in data centers**
- **More important with increasing variable generation capacity**
  - Especially for microgrids with limited supply options/resources
  - Can withstand and adapt to over- and under-generation supply conditions onsite and on the grid
- **Continue to operate mission critical infrastructure originating from resilience triggers by activating DR operational strategies.**
- **DR Operational strategies can also be effective in:**
  - Lowering the infrastructure need for local resilience
  - Increasing the timespan of power and cooling availability

Advanced Microgrids as a Resiliency Strategy for Federal Data Centers

Bruce Myatt, PE, and Russell Carr, PE, Arup North America

From Mission Critical Facilities to Resilient Service Delivery

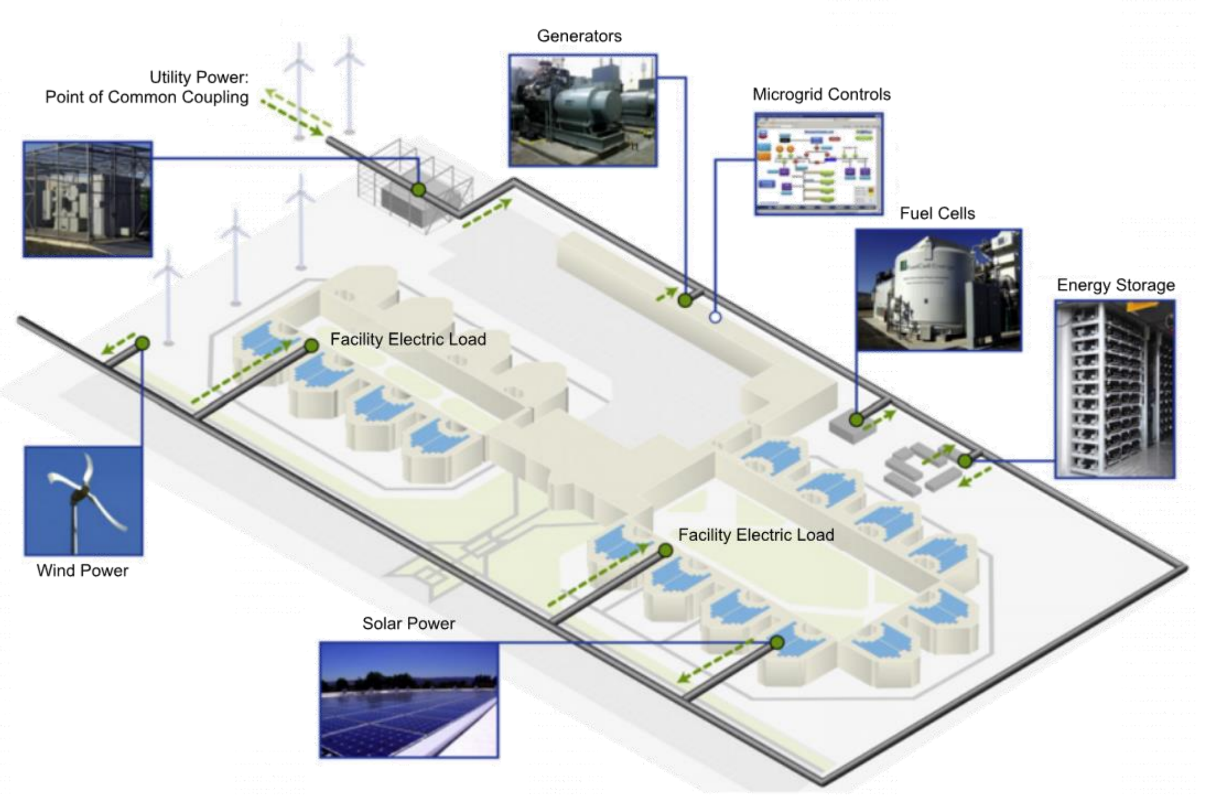
- Hazards mitigation and preventative measures
  - Accelerating changes in global weather patterns
  - Flood plain map changes from human & natural reasons
- Survival strategies for aggressive & frequent cyber attacks
- Single site vs multi-site regional perspective
  - “Shared Fate” of multiple nearby facilities can make network fail-over ineffective
  - PRA analysis, FMEA data & engineered solutions for selective hardening
- Long term operations and recovery after an event
  - Historical building performance and utility recovery timeline after event
- Microgrids
  - Distributed Energy
  - Grid Interdependence

What is a Microgrid? - Distributed Energy & Grid Interdependence

U.S. Department of Energy Microgrid Exchange Group:

- A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid.
- A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode.

DERs can involve onsite conventional and clean generation (e.g. renewables, fuel cells, CCHP), as well as demand management and storage (thermal and electric).

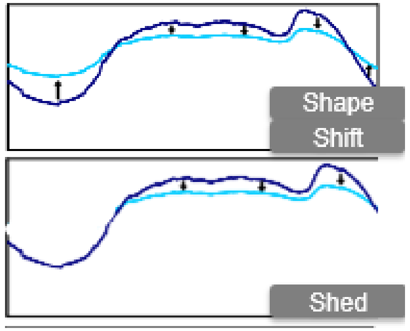


Ton, D. and Smith, M. (2012). The U.S. Department of Energy's Microgrid Initiative. *The Electricity Journal*, 25(8), pp.84-94.

Moving From Back-Up Power to Resilient Microgrid

- **Multiple generation sources (on-site and grid)**
  - Multiple sources of continuously synchronized power, inc. onsite primary generation & energy storage

- **Advanced communication networks and controllers**
  - Onsite centralized SCADA or distributed independent controls
  - Real-time algorithms to access the most available and lowest cost supply



- **Optimized operations for resiliency, efficiency and sustainability**
  - Balance and sequence multiple loads and energy sources in real time
  - Shape load with electric storage and/or shifting IT loads
  - Shed non-critical loads or migrate to another data center

- **Potential for full Direct Current (DC) power**
  - DC generators to DC-powered servers, HVAC (VSDs) and LEDs
  - Simpler, more robust system - more reliable switching, fewer inverters, less conversion losses
  - Energy and cost savings

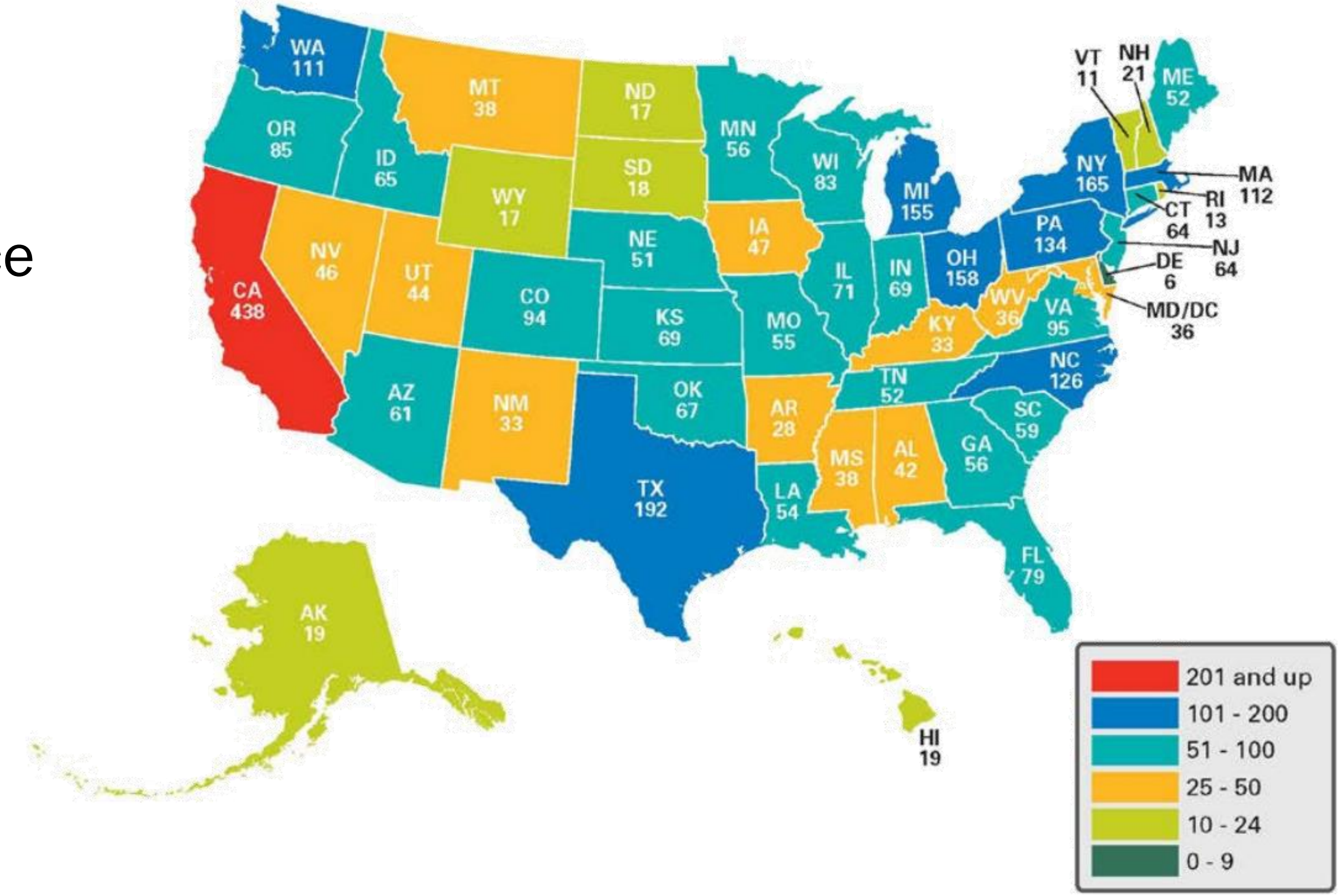
Efficient, Sustainable and Resilient Microgrids

AREA	WITHOUT MICROGRID	WITH MICROGRID
Improved power reliability / resilience	• Typically standby power is provided by diesel generators only • Limited fuel supply; site is vulnerable if system fails or fuel is exhausted	• Multiple power sources providing power – if one source fails, can load shed and use other source, e.g., fuel cells.
Cost risk reduction (outages)	• Typical utility outages are 0-4 hours in length and fuel storage is usually acceptable	• Extreme events – wildfire, earthquakes, hurricanes – longer outage durations • Multiple power sources including renewables, may operate indefinitely
Improved sustainability	• Offset energy use with renewables • Still rely on diesel as back-up	• Onsite renewables - no large transmission losses • In island mode, reduces diesel consumption

Savings, e.g., demand response and total cost of ownership	• Less flexibility for load shifting	• Many load-shifting mechanisms available
		    • UPS system as a resource
		    • Demand response of non-critical loads
		    • Generation assets when power is expensive via gen and storage dispatch.

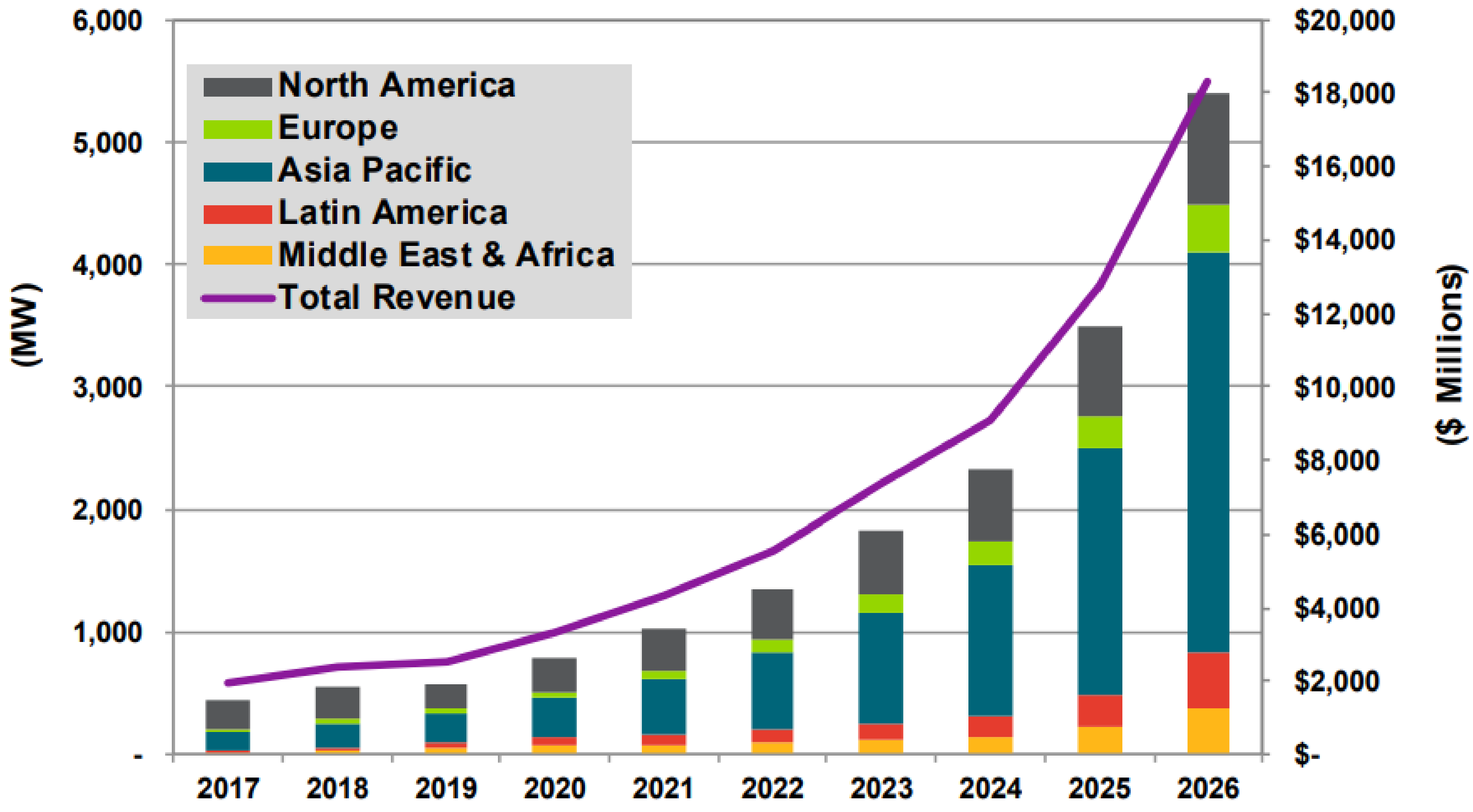
Why Microgrids Today?

- Improved power availability & resiliency
- Cost risk reduction (fewer service outages)
- Improved sustainability
- Operating cost savings
  - Energy efficiency
  - demand response
  - total cost of ownership



Power outages by state - Eaton Blackout Tracker (2018).
https://switchon.eaton.com/blackout-tracker - Outages from 2008 - 2017

Microgrids Growth Curve – Today & Tomorrow

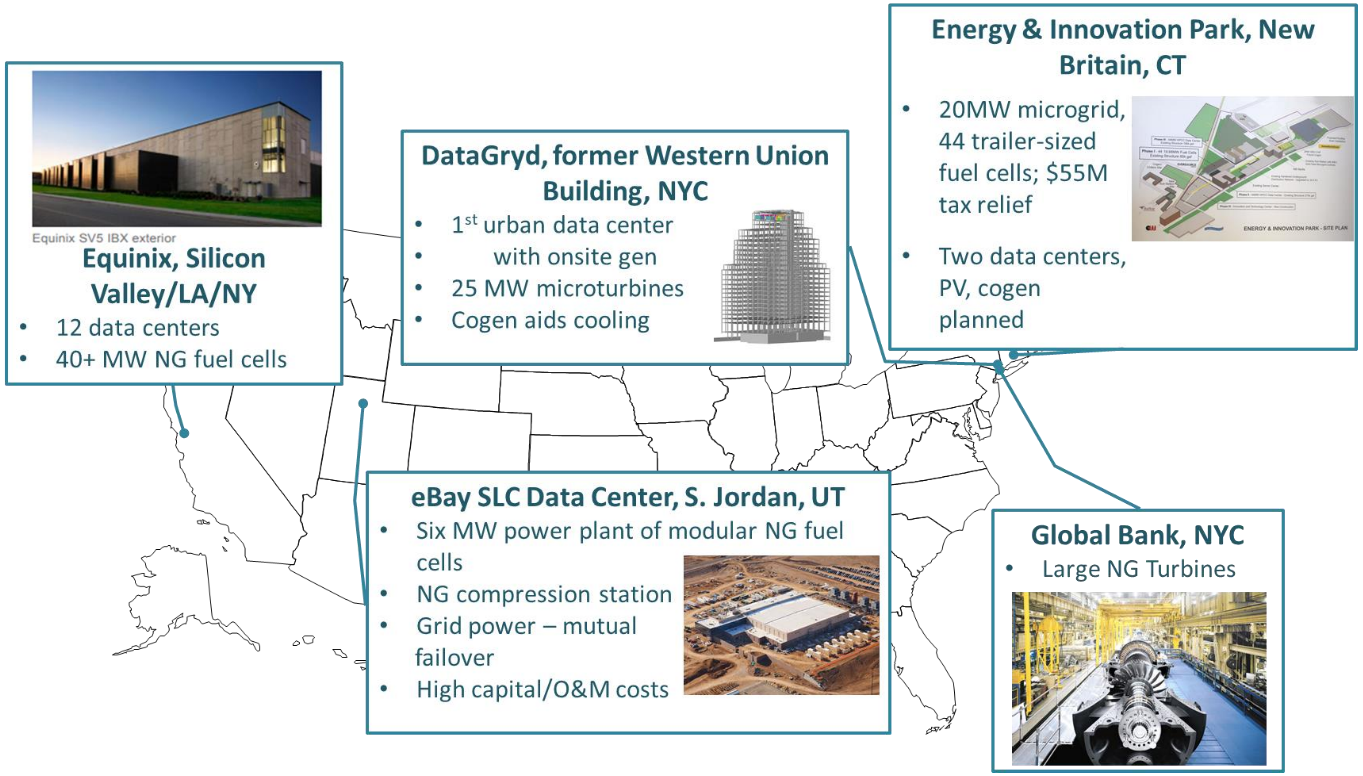


- Exponential growth
- Driven by C&I customers
- Technology is being tried and proven true
- Mission critical applications

Source: Navigant Research

Business Case Studies – Onsite Gen for Advanced Data Center Microgrids

- FUEL CELLS – Ebay & Equinix
- NATURAL GAS ENGINES – NetApp
- MICRO-TURBINES – DataGryd
- BIO GAS FUEL CELLS – Microsoft
- SOLAR & WIND POWER – Apple
- NATURAL GAS TURBINES & CCHP – Qualcomm



Alternative Energy – Primary On-Site Power

Proposed $1 Billion Connecticut Data Center Site

- Fuel cell microgrid receives $55.2m tax break
- Energy Innovation Park, LLC (EIP) and Thunderbird CHP

20MW Fuel Cell-Powered Microgrid

- Data center coming later
- 44 trailer-sized fuel cells in a 45,000 square foot factory

Strong Business Case Support

- CT Department of Energy and Environmental Protection approved the fuel cell-powered facility in July of 2018
- Site expected to bring 3,000 jobs, $200 million in state tax revenue and $45 million in local tax revenue over 20 years
- $8 million of that tax revenue would come from the fuel cell project alone.

Source: Data Center Dynamics, https://www.datacenterdynamics.com/news/proposed-1-billion-connecticut-data-center-fuel-cell-microgrid-receives-552m-tax-break/?mkt_tok=eyJpIjoiT0RFM016UmhORGhqTnpRMyIsInQiOiIrTCtnNWowWWJHRGh0aGk5bEoyZU9NcGhVVVVYRDJmcGhoczJzKzd3UWhoSGk5a0JRZURxQ3JkZnhGN2dVeElrTFJDRkR5WkZJbjB1WnN2YmVQQmxPdVlIOGE2STJZYmttS1wvcVdGWnhkemZGQk1JM1lXMUtobFp5Z1wvMmVNRHYrIn0%3D

Renewable Energy - PPA or IPP

Solar Farms Adjacent to Data Centers

- Apple announced a joint venture with Nevada Energy (NV Energy)
  - Builds out 200MW of PV solar to power its data center in Reno, Nevada
  - Apple's largest solar project to date and live in 2019
- NV Energy PPA price is 3.099¢/kWh with 2% annual escalator
  - Very inexpensive energy
  - Two other solar farm PPA’s
  - Lowest overall price for US solar power
  - 3.24¢/kWh and 3.42¢/kWh for 25-year terms

Source: https://www.computerworld.com/article/3161732/apple-to-build-200mw-solar-farm-to-power-data-center.html

- Apple built a 50MW solar power plant
  - 300 acres in Florence, Arizona
  - Powering its Mesa data center

Natural Gas Turbines – Combined Cooling, Heat & Power

NATURAL GAS TURBINES – QUALCOMM

- Proven technology globally with efficiencies approaching 50%
- Excellent for full CCHP (combined cooling, heat and power) tri-generation with high temperature waste heat opportunities like power, steam and hot & chilled water with 70-80% efficiencies
- Turbine "back-up" fuel options include jet fuel, which is easier to store on site than natural gas
- Historically slower to respond to power outages than diesels, as backup (newer systems are faster)
- <u>Excellent as primary source of power and cooling, and best with an off-taker for steam & water by-product for CCHP</u>

GE Natural Gas Turbines from 11 MW to 340 MW
Heavy Duty, High Efficiency Turbines

Distributed Generation & Loads Management

A microgrid is a local energy system that incorporates three key components: Generation, Storage and Demand, all within a bounded and controlled network. It may or may not be connected to the grid.

- A microgrid is a distributed level energy system which includes all the necessary components to operate in isolation of the grid.
- When operating independently of the grid in ''island'' mode, a microgrid is a self-sustaining independent energy system.
- Demand is modulated through the microgrid control systems, incorporating demand response.

- Generation may be from a range of variable distributed energy resources
- Storage may include battery arrays, electric vehicles and liquid air, among others.

- Microgrids are predominantly electrically based, but they can also incorporate a thermal energy component.
- They operate as AC, DC, high-frequency AC or a combination.

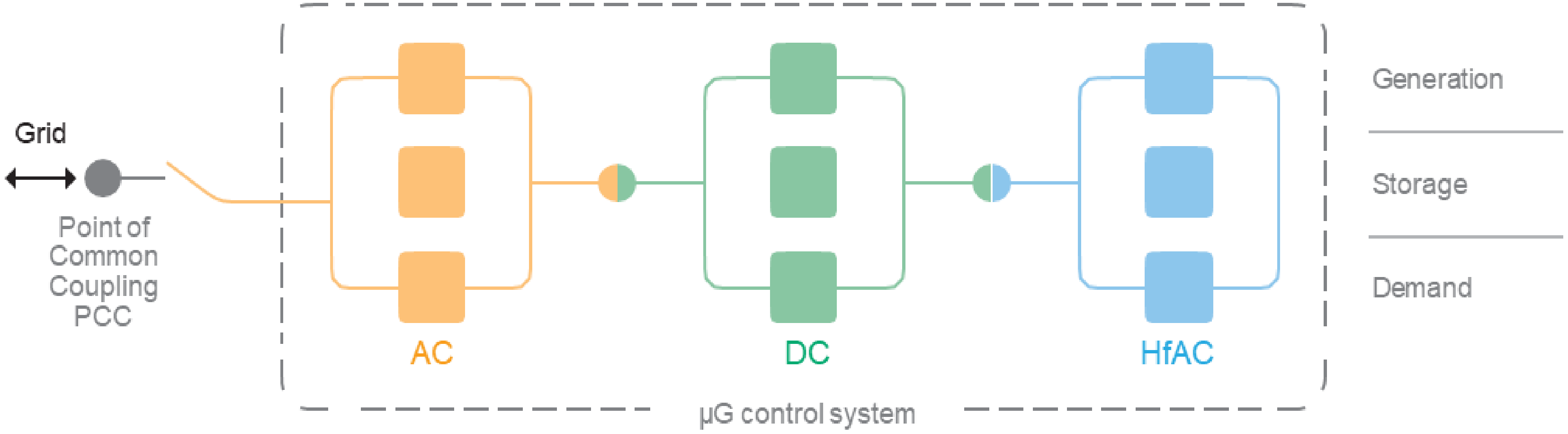


Image Source: Arup

Controlled Balance of Supply & Demand

Microgrids can balance available supply and desirable load through a careful marriage of supply and demand, combined with intelligent control of any imbalance.

- Microgrid energy supply
  - Diverse sources ranging from readily controlled to intermittent and less controllable
- Microgrid energy storage
  - Critical supply fall-back as well as a means to "time-shift" own generation to match load demands.
- Microgrid energy load
  - Range of controllability characteristics ranging from critical loads such as data systems to adjustable loads such as lighting or grid dispatch.

Each type of supply, demand and storage can be categorised on the basis of its controllability and dependability in the microgrid context:

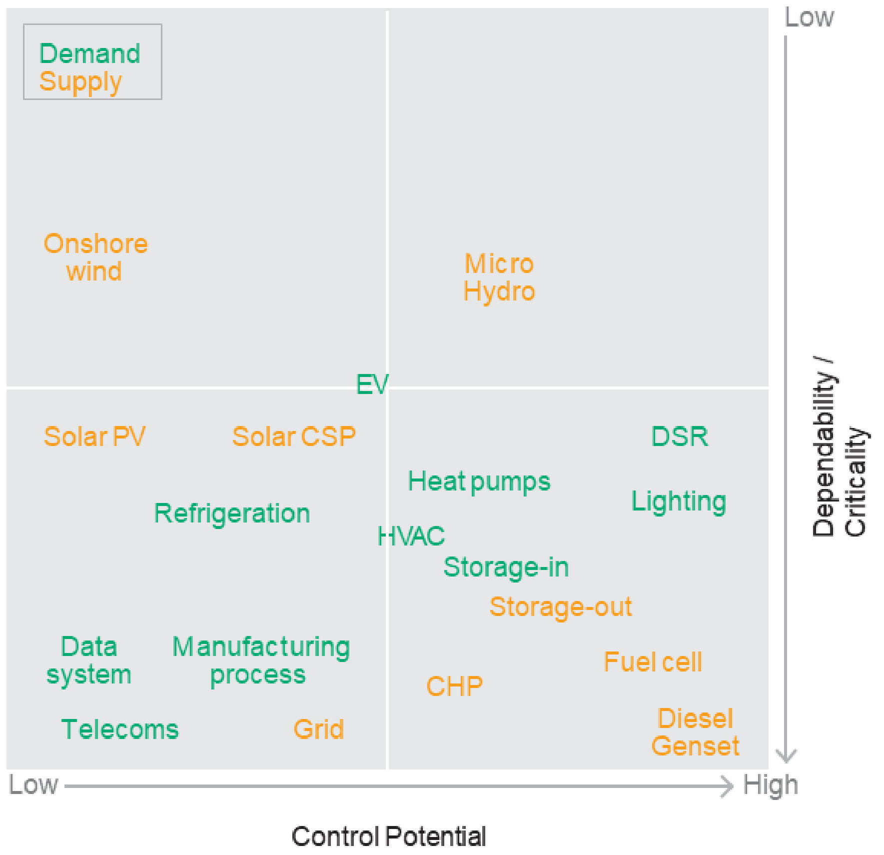
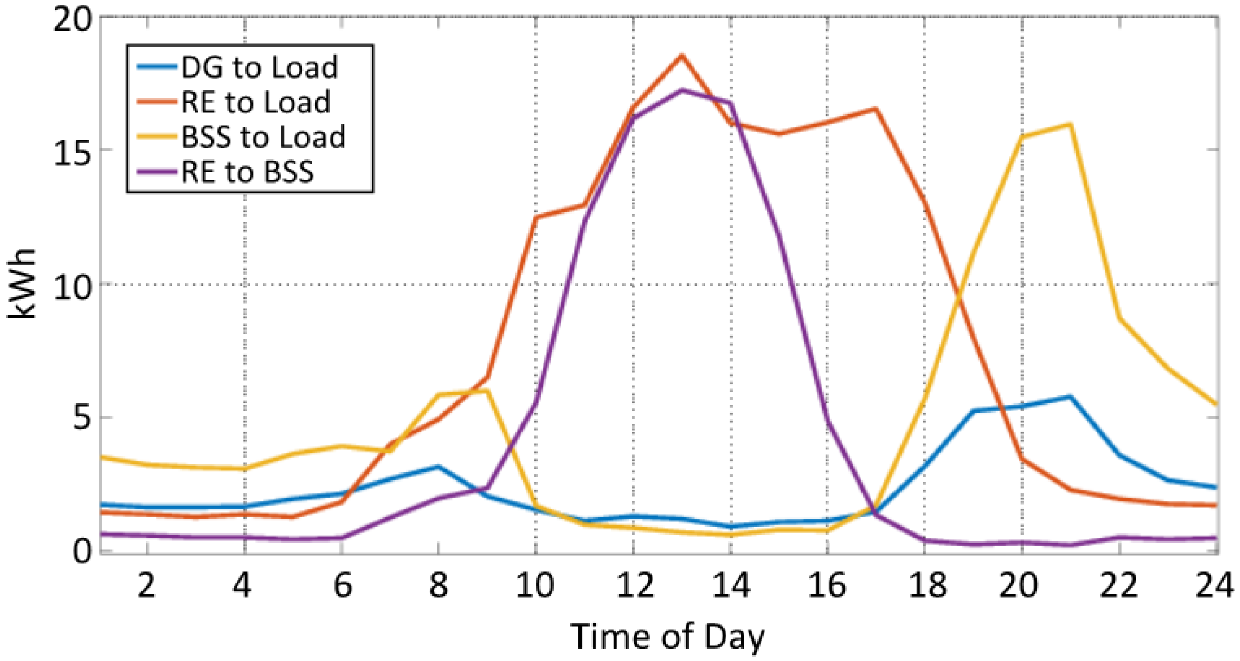


Image Source: Arup

"Advanced" Microgrids for the Data Center

- Interdependent grid operations
  - Improved resilience of local grid
- Demand management
  - Dynamic dispatch algorithms
  - Predictive energy management
- Load growth
- Lower costs of outages
- Technology readiness
- Cleaner cloud
- Improved cybersecurity
- Resource sharing with community



Aldaouab, I. and Daniels, M.C. (2018). Model predictive control energy dispatch to optimize renewable penetration for a microgrid with battery and thermal storage. 2018 IEEE Texas Power and Energy Conference (TPEC), 1-6.

Navigant Research, IDC

Why Advanced Microgrids for Data Centers?

- Build on existing infrastructure and share community resources
- Prioritize and shape demand and supply based upon load criticality and availability/cost
- Manage data center energy systems to withstand, survive, and recover operations after unexpected events
- Improve overall resiliency including continuation during extended VLSE outages
- Cleaner and renewable power generation

Source: Schneider Electric

47

Data Center Applications – One Size Does Not Fit All

Data Center Type	Suitable DR and Microgrid Applications
Hyperscale	Onsite primary power generation (e.g. natural gas fuel cells or combustion generators, and occasionally renewables) and storage that facilitates grid independence, energy efficiency and controlled shut down.
Edge	Possible energy resource sharing with local community, campus, or base to prioritize and deliver grid and onsite power capacities, waste heat recovery and use for district heating, chilled water (possibly via CCHP) for cooling, and data and communications as a commodity.
Colocation and Enterprise	**Large-scale** & stand alone - similar to Hyperscale but with a greater need for back-up/resilient power (high availability). **Small-scale** & building mixed use (e.g. embedded with shared resources like cooling plant) – similar to Edge with variations based on mission criticality/SLAs.
HPC	Similar to Hyperscale and Edge (depending on size), often with less of a need for back-up power resources (e.g. scientific computing), a lower power priority for compute resources, and higher potential to capture and reuse heat.

The Microgrid Value Chain

To receive maximum value/benefits and ROI, stack as many value propositions as possible.

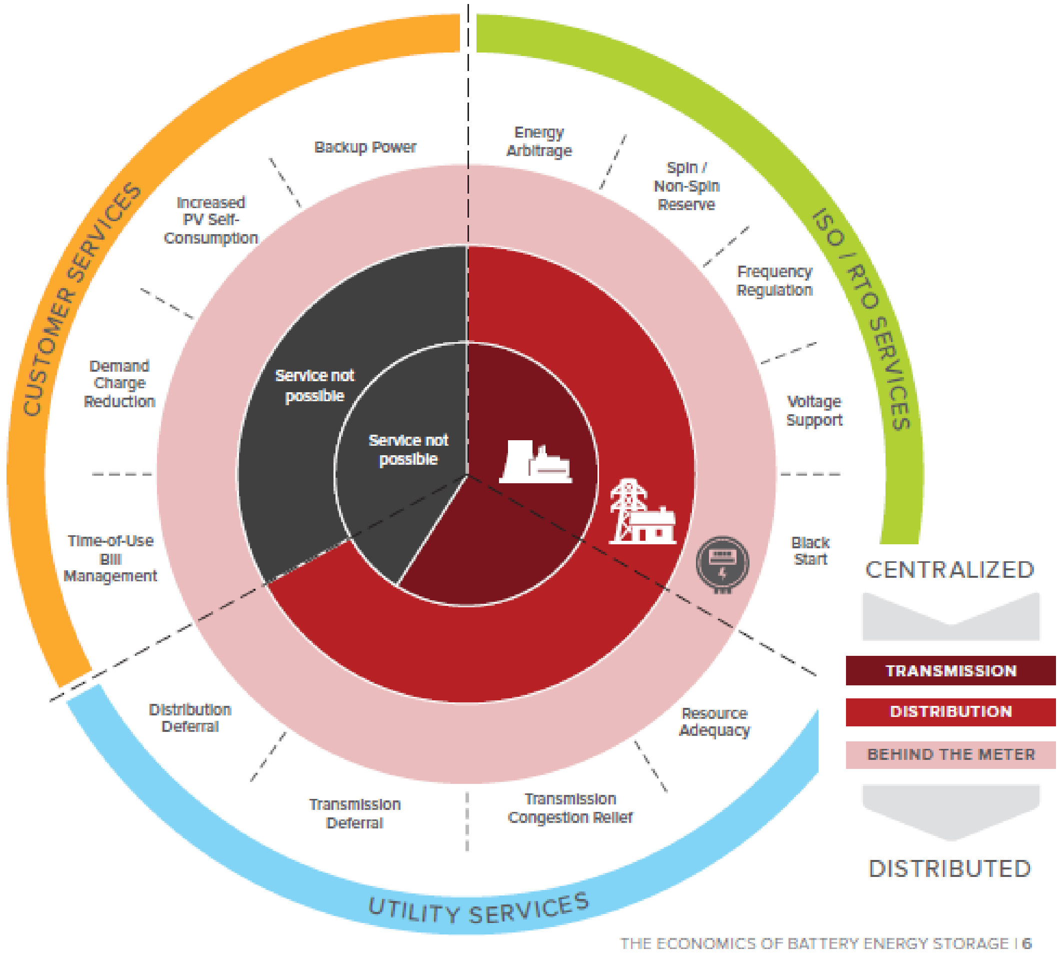
Some benefit the user while others benefit the grid

Utilities and electric grid managers can—and do--- provide financial incentives and payments for many types of services.

Common business justifications for microgrids include event management, black-start capabilities, storm hardening and financial optimization.

Microgrids can be:

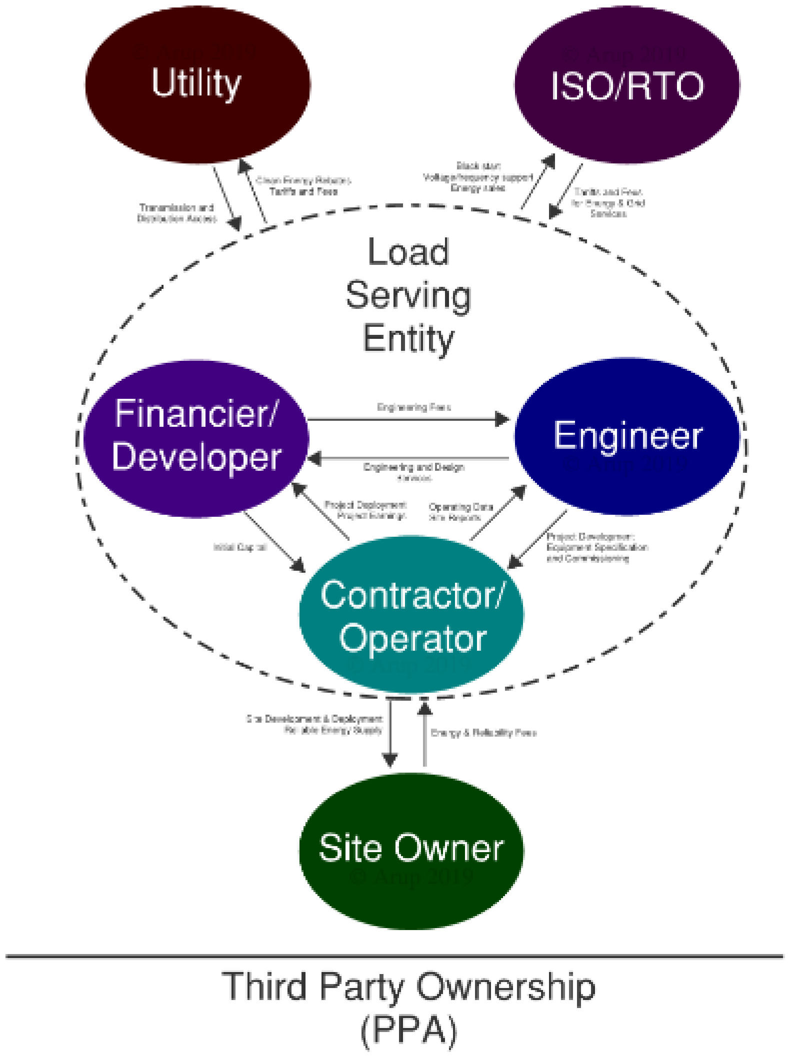
- Optimized for Resiliency
- Optimized for Economics
- Optimized for Sustainability
- All of the Above



Source: The Economics of Battery Energy Storage 2015 | By Garrett Fitzgerald James Mandel Jesse Morris Hervé Touati

Business Models: Microgrid Ownership Models

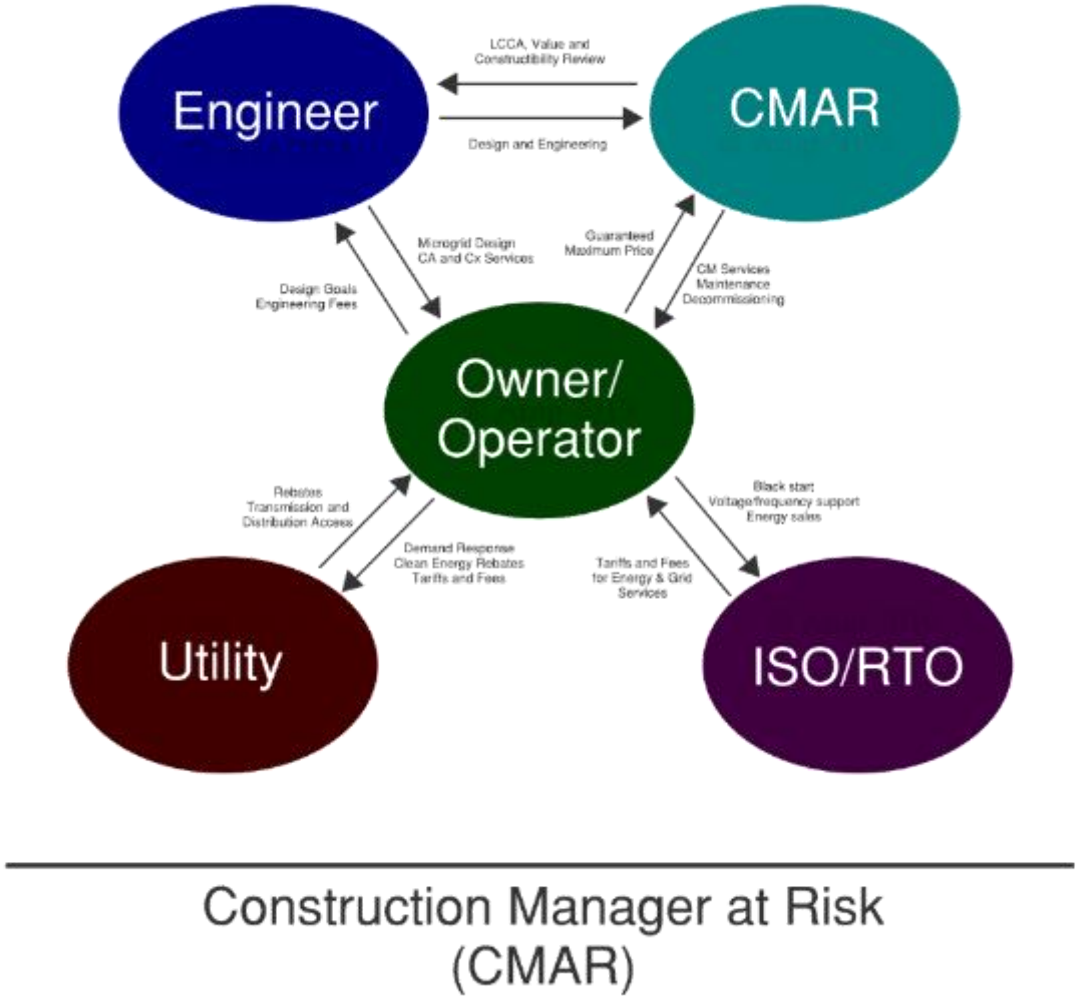
- Single-party owner
- Shared ownership
- Third-party owner
- Utility ownership
- Community ownership



Examples of capital and service exchanges in a third party ownership model – Arup 2019

Microgrid Delivery Models

- Design-bid-build (DBB)
- Design-build-finance (DBF)
- Integrated project delivery (IPD)
- Public-private partnership (P3)
- Construction manager at risk (CMAR)



Examples of capital and service exchanges using CMAR project delivery – Arup 2019

Advanced Microgrids - New Build vs. Retrofit

NEW BUILD

- Planned from the outset
- Common integrated platform can be developed
- Equipment is all of the same vintage
- Commissioning can be undertaken in an empty building
- Can be cheaper than retrofit

RETROFIT

- Varying vintages of equipment in a building
- Not all equipment will be able to be controlled with retrofit
- Severe disruption when commissioning
- Upgrade equipment to “microgrid ready” during asset replacement to fully build out as replacement happens

Source: Schneider Electric

Project Development: Commissioning & Operations

- Commissioning
- Integrated Systems Testing
- Verification & Validation
- Retro-commissioning
- Ongoing O&M Procedures

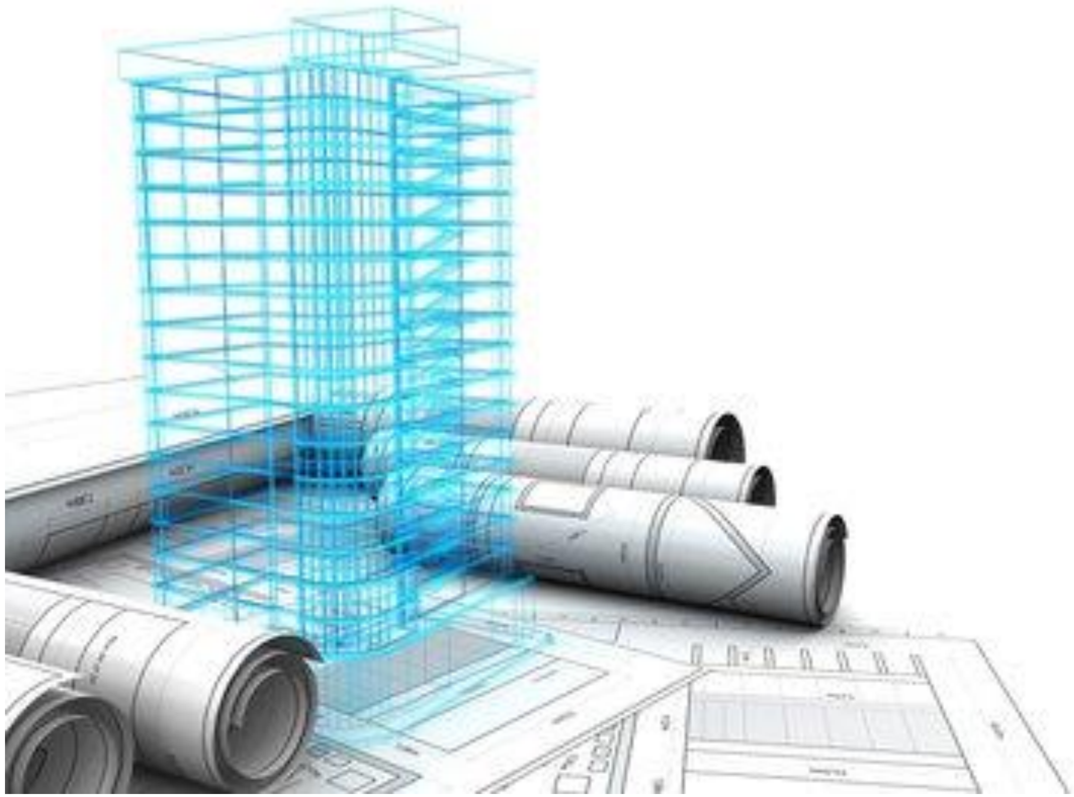


Image Source: Data Center Dynamics

Conclusions – The Data Center Advanced Microgrid

- Advanced microgrids deliver intelligent, flexible orchestration of loads and power supplies
- Open new paths to higher availability and resilience:
  - On-site primary generation
  - Demand response
  - Added energy storage
- Improved data center uptime:
  - Overcoming short-term outages with resources other than redundant generators
  - Idle diesel generators can be replaced with alternative sources of on-site primary power, coupled with quick-start diesel generators for black start and life-safety power.
- Owner gets improved control of energy costs and quality
- Microgrid also enables sustainability, efficiency and grid independence/inter-dependence.
  - Mutually beneficial operations with utility, grid and local community

Next Steps - Microgrids

- **Update energy & risk management plans for your data center(s)**
  - Regional planning for natural hazards events and mitigations
  - Impact of microgrids on disaster recovery & business continuity plans
- **Measure the total cost & benefit of today's new microgrid strategies**
  - Renewable/alternative on-site primary power generation and storage
  - Community benefits of energy resource sharing for multiple buildings & loads
  - Intelligent controls for energy sourcing, distribution and utilization
- **Identify and measure opportunities for your existing facilities**
  - Energy costs and uptime improvements
  - Current DER and grid connectivity
  - Edge and distributed computing demand

DR and Microgrids as Two Overlapping Strategies for Federal Data Center Resilience

Next Steps: Weighing Resilience Needs, Choosing a Strategy

- **Explore and develop resilience plans for a single building or multiple sites with FEMP's Technical Resilience Navigator (https://femp.energy.gov/resilience/)**
  - Identify mission-critical assets and functions
  - Identify threats and vulnerabilities
  - Develop solutions
- **Other considerations unique to data centers include:**
  - Resilience investments can offset redundancy and its costs
  - Demand response can bolster the grid and reduce costs (e.g., DR incentives, lower demand charges)
  - Costs of disaster recovery, lost business continuity often underestimated for data centers
  - New build vs. retrofit, own vs. energy service
- **For more in-depth resources on data center efficiency, see the DOE Center for Expertise in Energy Efficiency in Data Centers at LBNL https://datacenters.lbl.gov**

Summary

- Data centers typically are built for high degrees of resilience.
- Demand response and microgrids are advanced strategies that can enhance resilience and offset some redundancy.

Demand Response

- **Proven for a range of loads and purposes in data centers**
- **More important with increasing variable generation capacity**
  - Can help data centers ride out over-/under-generation conditions onsite and on the grid
  - Both enabled by and complementary to microgrids
- **Can also be effective in:**
  - Lowering infrastructure needs, including redundancy and demand charges
  - Increasing the timespan of power and cooling availability

Microgrids

- **Microgrids orchestrate loads and supply to enable continuity of service**
  - Provide a natural extension of existing data center infrastructure
  - Enable islanding
  - Integrate multiple primary onsite generators with the shaping and sequencing of loads
  - One size does not fit all – not every data center or commercial site needs a microgrid, e.g., lab HPCs

58

Technical Advisory Group

- Peter Asmus, Navigant Consulting LLC
- Peter Gross, PMG Associates (formerly Bloom Energy)
- Aloke Gupta, California Public Utilities Commission
- Suresh Pichai, Equinix
- Alex Portilla, Pacific Gas & Electric

Contacts

- Rachel Shepherd, Data Center Program Lead, Federal Energy Management Program, rachel.shepherd@ee.doe.gov
- Dale Sartor, Staff Scientist and Director of the DOE Center of Expertise on Energy Efficiency in Data Centers, Lawrence Berkeley National Laboratory, dasartor@lbl.gov
- Rish Ghatikar, Senior Program Manager, Electric Power Research Institute, gghatikar@epri.com
- Bruce Myatt, Data Center Business Lead, Arup North America, Bruce.Myatt@arup.com

SLIDE REFERENCES

https://www.energy.gov/sites/prod/files/2019/05/f62/femp-resilience.pdf

https://femp.energy.gov/resilience/about-technical-resilience-navigator

https://journal.uptimeinstitute.com/application-resiliency-vs-infrastructure-resiliency/

Ghatikar G, M.A. Piette, S. Fujita, A. McKane, J.H. Dudley, A. Radspieler, K.C. Mares, D. Shroyer; Demand Response and Open Automated Demand Response Opportunities for Data Centers. January 2010. LBNL-3047E. DOI 10.2172/981725

Data Centers and Advanced Microgrids Meeting Resiliency, Efficiency, and Sustainability Goals Through Smart and Cleaner Power Infrastructure Published 4Q 2017 Commissioned by Schneider Electric

Ton, D. and Smith, M. (2012). The U.S. Department of Energy's Microgrid Initiative. The Electricity Journal, 25(8), pp.84-94.

https://www.navigantresearch.com/news-and-views/navigant-research-identifies-2258-microgrid-projects-representing-nearly-20-gw-of-capacity

Aldaouab, I. and Daniels, M.C. (2018). Model predictive control energy dispatch to optimize renewable penetration for a microgrid with battery and thermal storage. 2018 IEEE Texas Power and Energy Conference (TPEC), 1-6.

https://www.scientificamerican.com/article/how-big-batteries-at-data-centers-could-replace-power-plants/

The Economics of Battery Energy Storage

2015| By Garrett Fitzgerald James Mandel Jesse Morris Hervé Touati

https://www.bloomenergy.com/newsroom/press-releases/equinix-install-largest-deployment-fuel-cells-colocation-data-center

https://www.datacenterknowledge.com/the-facebook-data-center-faq-newest-page

IACET Credit for Webinar

The National Institute of Building Sciences' (NIBS) Whole Building Design Guide (WBDG) hosts the FEMP training program's learning management system (LMS).

The WBDG LMS:

- Allows for taking multiple trainings from multiple organizations through one platform.
- Houses the assessments and evaluations for all accredited courses.
- Allows you to:
  - Track all of your trainings in one place.
  - Download your training certificates of completion.
- Eases the CEU-achievement process.

Visit the WBDG at www.wbdg.org to view courses and create an account

WBDG WHOLE BUILDING DESIGN GUIDE a program of the National Institute of Building Sciences

ACCREDITED IACET PROVIDER

IACET Credit for Webinar

To receive IACET-Certified CEUs, attendees must:

- Attend the training in full (no exceptions).
  - If you are sharing a web connection during the training, you must send an e-mail to Elena Meehan (elena.meehan@ee.doe.gov) and indicate who was on the connection and who showed as connected (will reflect in the WebEx roster).
- Complete an assessment demonstrating knowledge of course learning objectives and an evaluation **within six weeks of the training**. A minimum of 80% correct answers are required for the assessment.

To access the webinar assessment and evaluation, visit:

https://www.wbdg.org/continuing-education/femp-courses/femplw12032019

If you have a WBDG account and enrolled previously, simply log in and click the *Continuing Education* tab on the user account page. Click *Proceed to Course* next to the course title.