Microgrids and Energy Storage for Emergency Grid Resilience Webinar Series

Session 1: Introduction to Microgrids & Energy Storage	
10:00 - 10:20	**Introductory Remarks** **Dr. Imre Gyuk**, Director, DOE Office of Electricity Energy Storage (ES) Program
10:20 - 10:40	**Introduction to Microgrids** **Dr. Kevin Schneider**, Pacific Northwest National Laboratory
10:40 - 11:00	**Introduction to Microgrids & Energy Storage Policy** **William McNamara**, Sandia National Laboratories
11:00 - 11:10	**Discussion/Q&A**
11:10 - 11:30	**Introduction to the Economics and Resilience Benefits of Microgrids** **Patrick Balducci**, Argonne National Laboratory
11:30 - 11:50	**Microgrids & Energy Storage for Energy Equity, Resilience, and Underserved Communities** **Dr. Summer Ferreira**, Sandia National Laboratories
11:50 - 12:00	**Discussion/Q&A**

Presented by:

Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

IOWA STATE UNIVERSITY
Electric Power Research Center

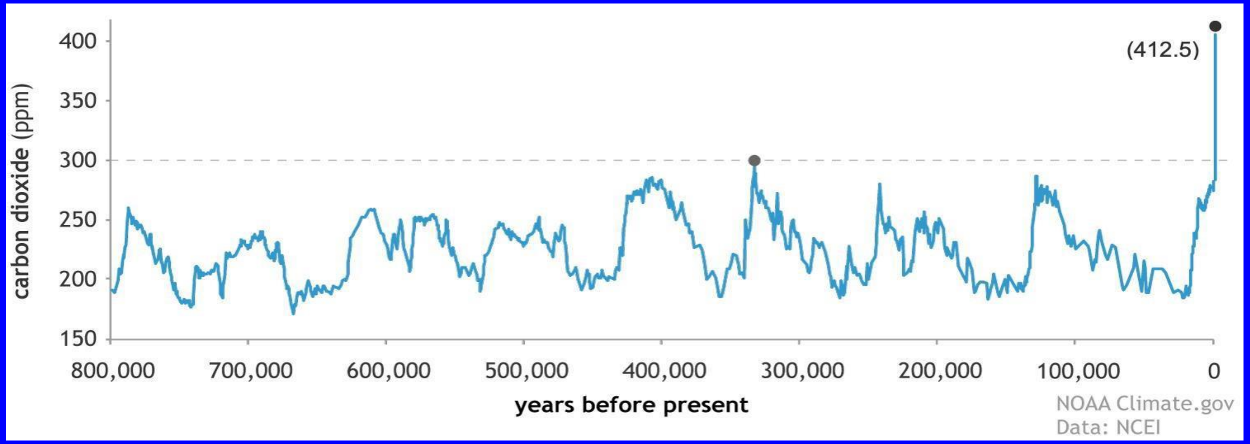
Energy Storage
And Micrograds

IMRE GYUK, DIRECTOR, ENERGY STORAGE RESEARCH, DOE-OE

Global Warming is Real!

NY, Hurricane Ida, Aug. 2021

West Coast: 400 year Drought



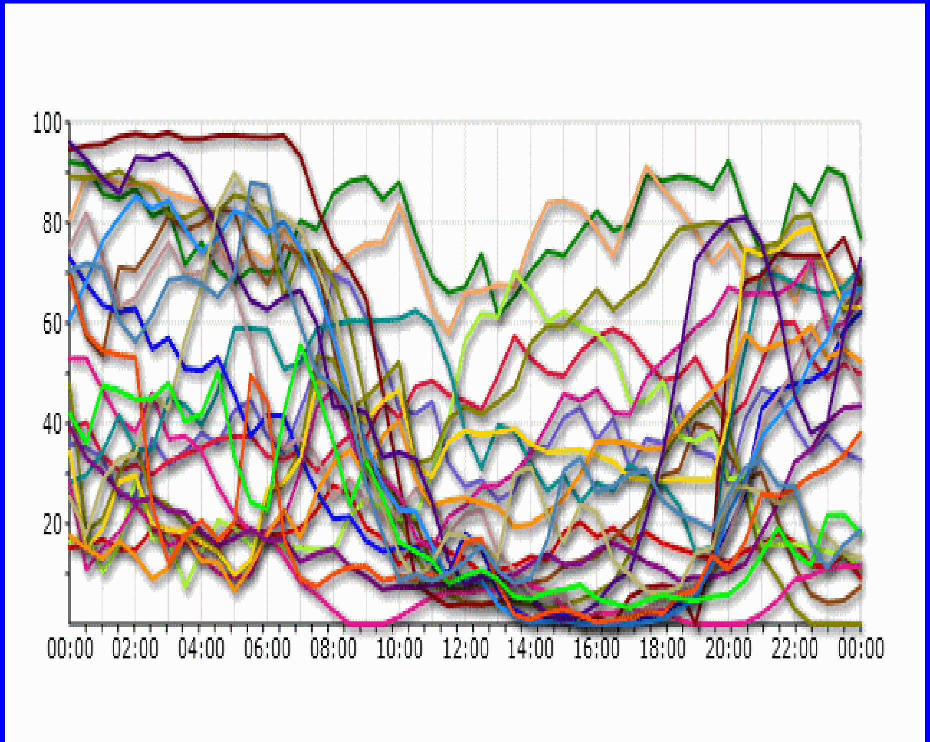
800,000 years Atmospheric Carbon Dioxide

Floods and Droughts,
but also
Sea Level Rise, Coastal Erosion,
Reduced Crop Yield, and Health
Impacts

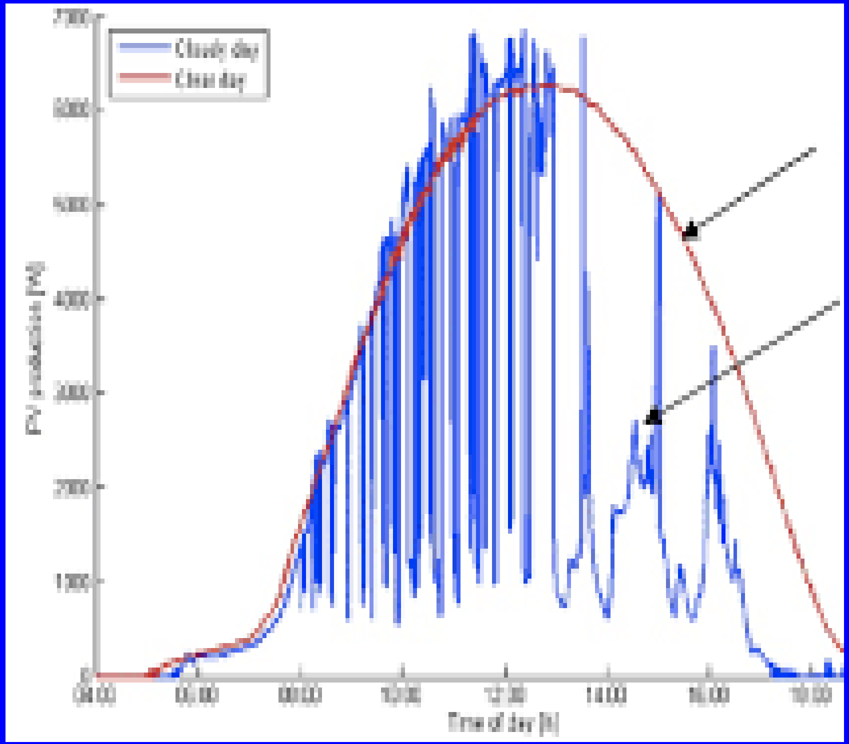
Global Warming has Emerged
as a Paramount Issue - World Wide!

We must Decarbonize,
we must change
to Renewable Energy!

And we have to do it soon!

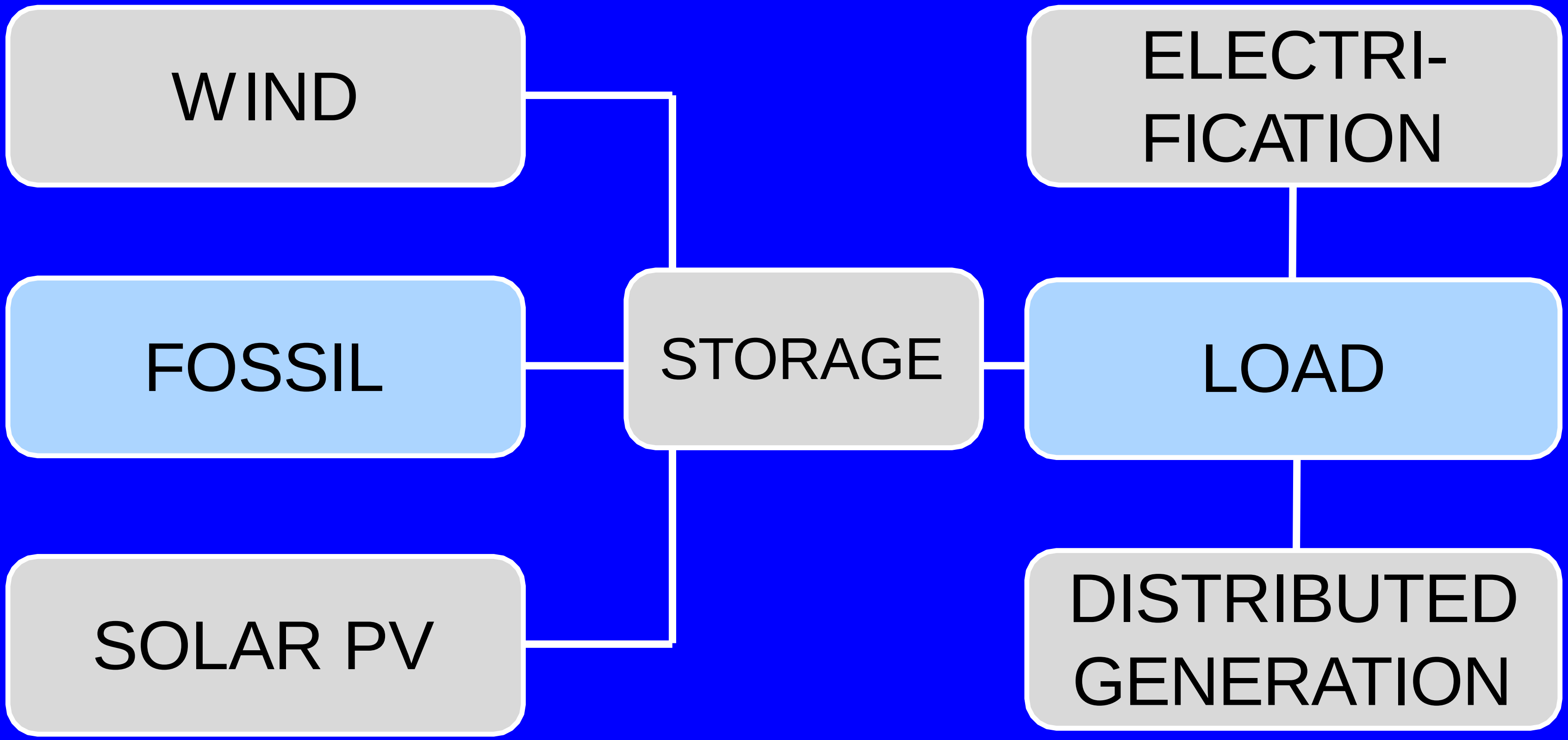


24 hours of wind –
“the wind blows where it wishes”



Day and night –
Clouds drifting by

Variable Generation - Variable Load



Energy Storage provides Energy

when it is needed

just as Transmission provides Energy

where it is needed

Storage Technologies:

Pumped Hydro
Compressed Air
Sodium Sulphur
Lead Acid
Flow Batteries:
- Vanadium, ZnBr, FeCr

MnO2 (Duracell)
NiMHyd
Li-Ion
Flywheels
Super-Capacitors

Energy

Power

A Developing Urgency!

30 states, Washington, D.C., and 3 territories
have adopted Renewable Portfolio Standards,
while 7 states and 1 territory
have set Renewable Energy Goals.

100% by 2050 or earlier!

Storage Facilities
have become bigger
but not longer in Duration

15 min -- 1hr – 4hrs

e.g. 2020 Q3: 476 MW / 764MWh
1 ½ hours!

To reach 100% Decarbonization

by 2050 we will need

to overbuild Renewable Power

and use Large Amounts of

Long Duration Energy Storage

to Balance Load and Generation.

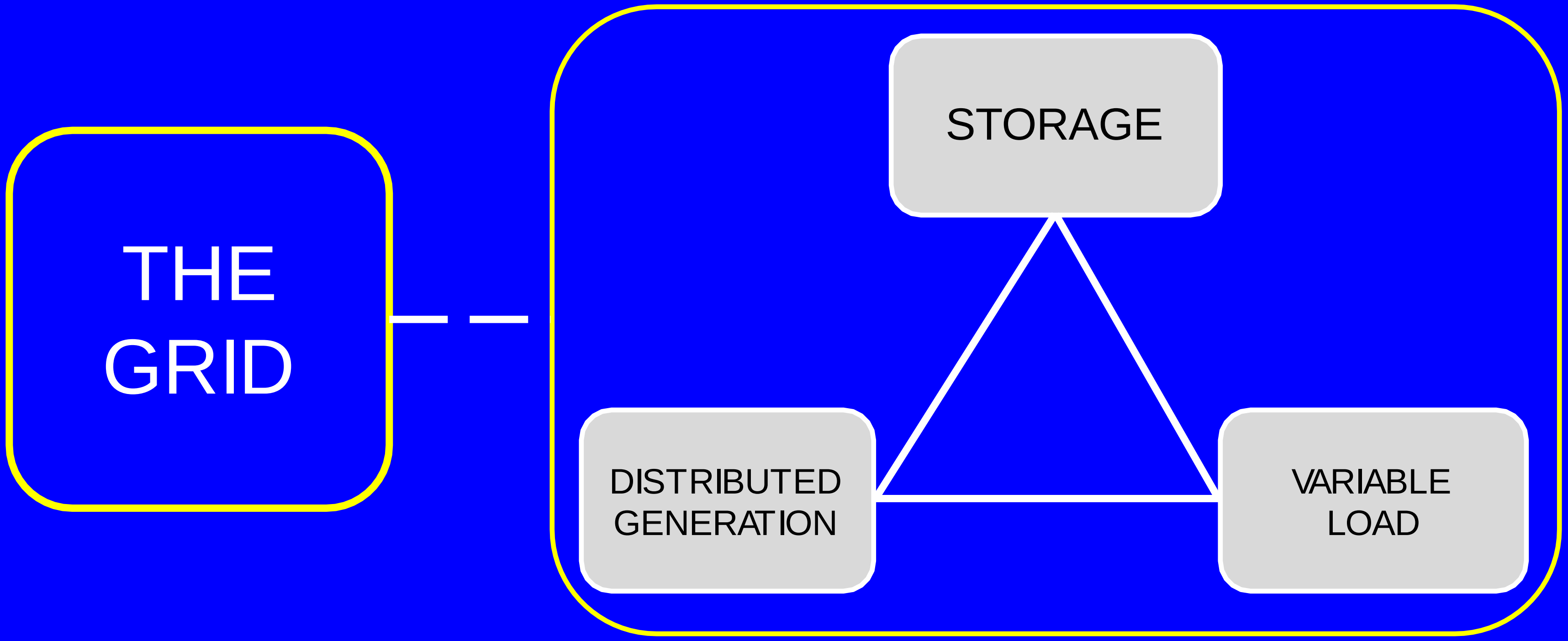
In the meantime
it is important to realize that
Catastrophic Climate Based Events
will continue to escalate.

Energy Storage will be required
for both pre-emptive
and ameliorating Measures

Leaving behind Wreckage and Misery

Electrical Infrastructure
is particularly vulnerable!

An Autonomous Micro-Grid



Developing Business Cases:

The **Cost** of a Storage System depends on the Storage Device, the Power Electronics, and the Balance of Plant

- Power Electronics 20-25%
- Energy Storage Device 25-50%
- Facility 20-25%

The **Value** of a Storage System depends on Multiple Benefit Streams, both monetized and <u>unmonetized</u>

- Arbitrage
- Frequ. Reg.
- Dem. Charges month, year
- Resiliency

Metrics will depend on locality!
And on Regulatory Structure

Sterling, MA: Microgrid/Storage Project

$1.5M Grant from MA. Additional DOE-OE Funding, Sandia Analytics

Sterling, MA,
Oct. 2016, NEC, Li-Ion

2016 Dec. till 2017 Nov.
Actual Savings:

- Arbitrage $11,731
- Monthly Peaks $143,447
- Annual Peak $240,660
- Total $395,839

Sean Hamilton

Dec. 2016, 2MW/2hr
Storage, 3MW PC
Capital Cost: $2.7M

Carina Kaainoa

April 2019: 1 million $ Avoided Cost!

Visitors: Germany, Switzerland, Denmark, Sweden, England, Ireland, Australia, Japan, Malaysia, Taiwan, Brazil, Chile, …. Thailand

Cordova, Alaska, Municipal System

Cordoba, Grid Isolated

6MW Run of RiverHydro Power

Total Capacity: 7.25MW Hydro; 2x 1MW Diesel

0.5MW Deflected as Spinning Reserve

Hydro: $0.06/kW; Diesel: $0.60/kW

1MW/1hour Battery, Commissioned June 7, 2019

Bad River Band of Lake Superior Chippewa in Wisconsin (DOE Indian Energy)

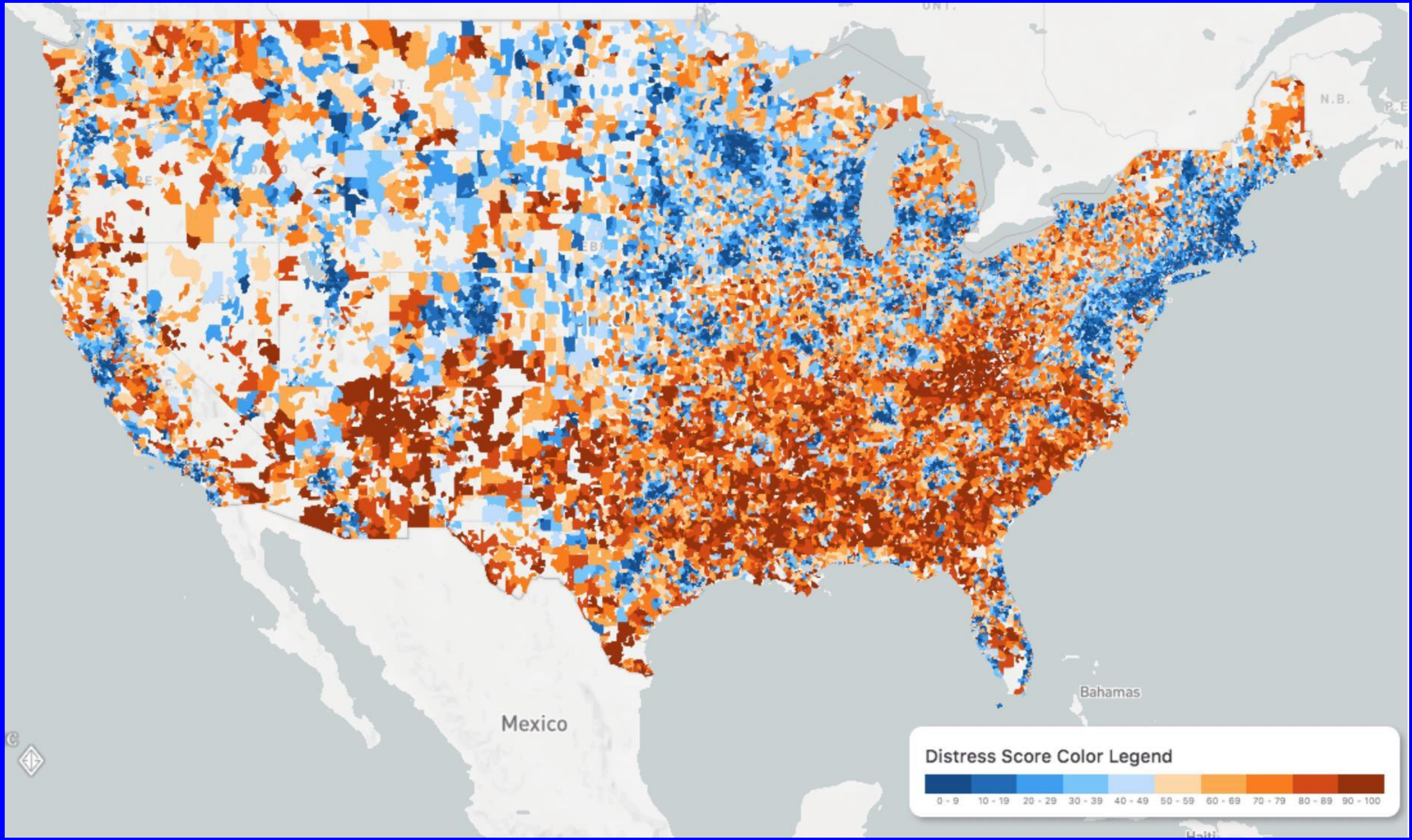
July 2016 Flood caused
Multiday Power Outage

Energy Sovereignty: $2M Microgrid

- Admin. Building
- Wastewater Treatment Plant
- Health & Wellness Center

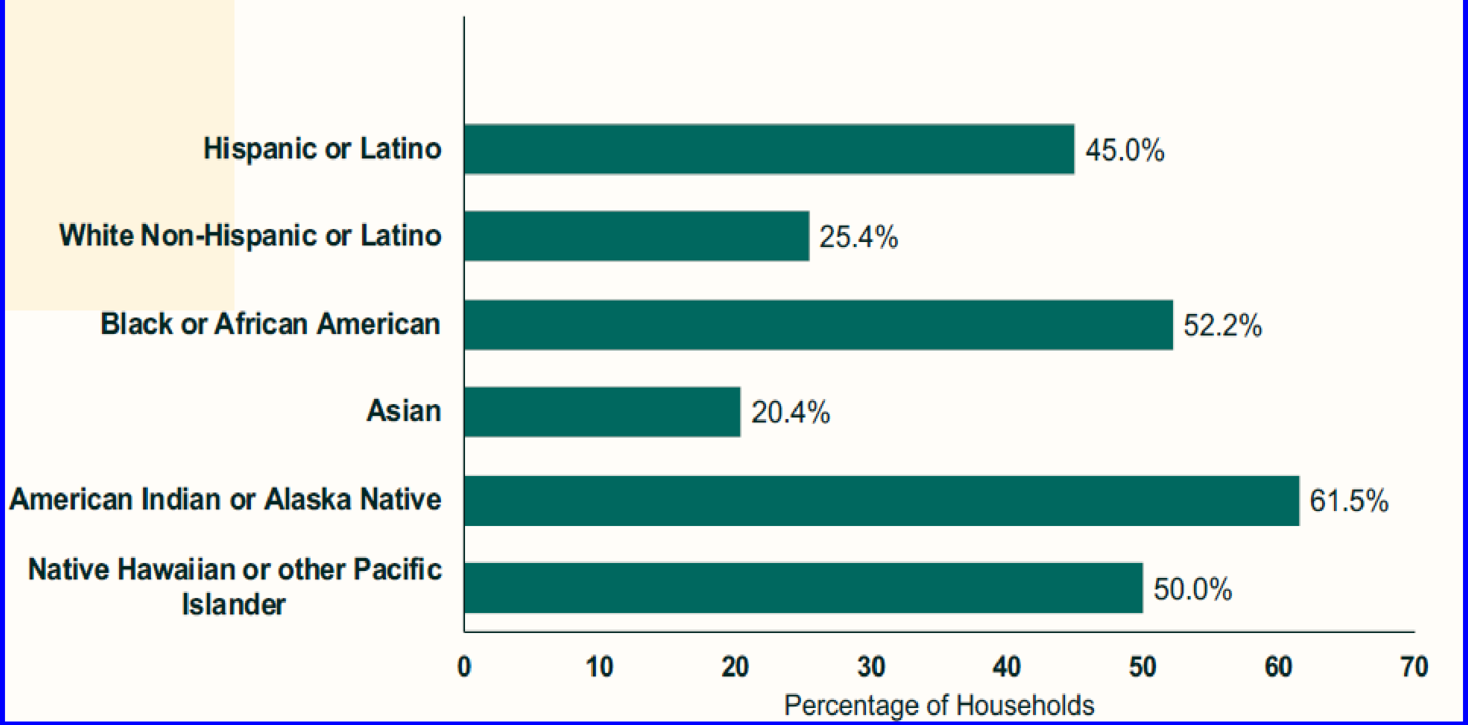
May 2021: 500 kW Solar
500kW/1 MWh Storage

Resiliency, Sustainability, Predictable Budget



Distressed Communities can be found throughout the U.S.

Households Experiencing Energy Insecurity from Electricity Prices and Outages



Lower income households are disproportionally non-white

Energy Storage offers itself
as a tool to alleviate
many of these problems

e.g. Storage to replace
Fossil Fuel Peakers

Microgrids with Storage
for outage mitigation

Solar + Storage for
Remote Tribal communities …..

Being prepared for Climate Disasters
Everywhere and
Assuring Energy Equity
for Urban, Rural, and Tribal
Disadvantaged Communities
should be High Priorities for the U.S.

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Introduction to Microgrids

November 5th, 2021

Kevin Schneider

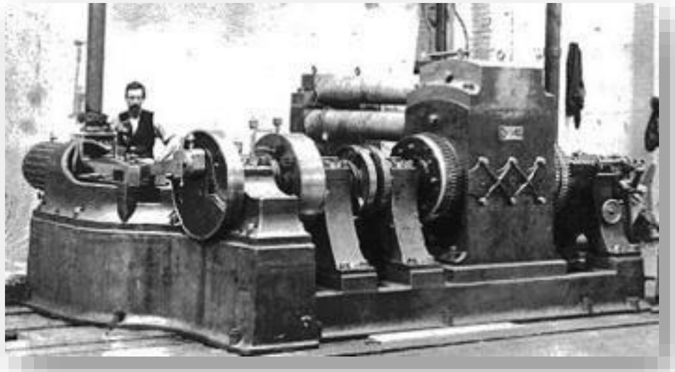
U.S. DEPARTMENT OF ENERGY BATTELLE

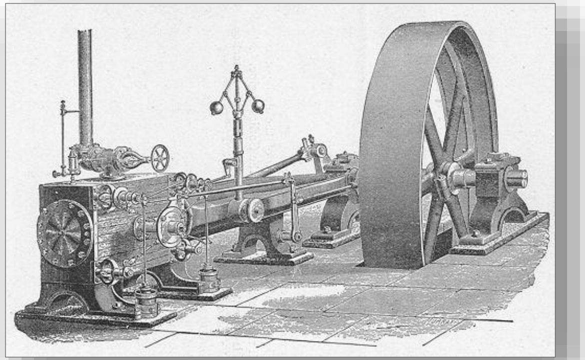
PNNL is operated by Battelle for the U.S. Department of Energy

Presentation Overview

- Part 1: History of Microgrids
- Part 2: Modern Microgrids

Part 1: History of Microgrids





History of Electric Power Systems

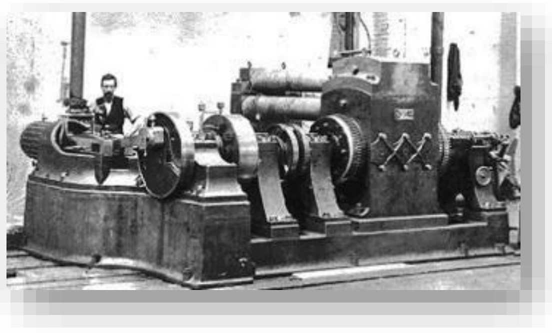
- While many industrialized nations rely on bulk power systems, the earliest electric power systems were effectively microgrids.

- These systems were initially direct current, with alternating current becoming a competitor.

- Edison’s Pearl Street Station in New York was the first commercial facility.
    - Direct current underground
    - A dingle dynamo (DC generator)
    - 110V service
    - 400 lamps primarily in banks and financial offices

- Due to the technology at the time, these small systems gave rise to modern bulk power systems.
    - Improved generation technology
    - Economies of scale
    - High voltage AC systems

- However, due to the advanced in technology, microgrids are once again a viable options for a range of operational problems.



150,000 Watts

805,000,000 Watts

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What is a Microgrid?

- There are many definitions of microgrids, some more inclusive than others.

- At its core, a microgrid typically has the following three key functions;
  - Generation sources
  - End-use loads
  - Controls

- With these three functions included, there are a wide range of what could be considered a microgrid, including, but not limited to:
  - Campus or military base that is connected to the local distribution utility
  - Utility owned resources that are coordinated for reliability/resiliency
  - Third-party controls that aggregate distributed resources
  - Remote island and/or mining facility with no connection to a bulk power system
  - Ships that can, or cannot, connect to shore power
  - Space craft that operates extra terrestrially

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Part 2: Modern Microgrids

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Variations in Modern Microgrids

- While microgrids were once the most common form of electrical power system, for many utilities microgrids are currently considered an “emerging technology”.

- Because of the variations in how they are deployed, it is often said that “every microgrid is different”.

- While the implementation of a microgrid may be unique, all microgrids must accomplish the same fundamental operational goals.
  - Maintain a stable voltage and frequency (if an AC system)
  - Balance load and generation
  - Be able to reconfigure and/or interconnect to meet operational needs

- Electrical Sources: Needed by every microgrid to produce electricity.
  - Rotating machines (diesel and natural gas engines)
  - Grid-following inverters (most solar PV)
  - Grid-forming inverters (battery energy storage)

- Controls: Exist in various forms to maintain a stable system. These may or may not require a communications system.
  - Centralized: everything controlled from a centralized unit (i.e., through a DMS/DERMS)
  - Distributed: all controls are remote (i.e., CERTS type microgrids)
  - Hierarchical: a combination of centralized and distributed control

How Microgrids are Interconnected

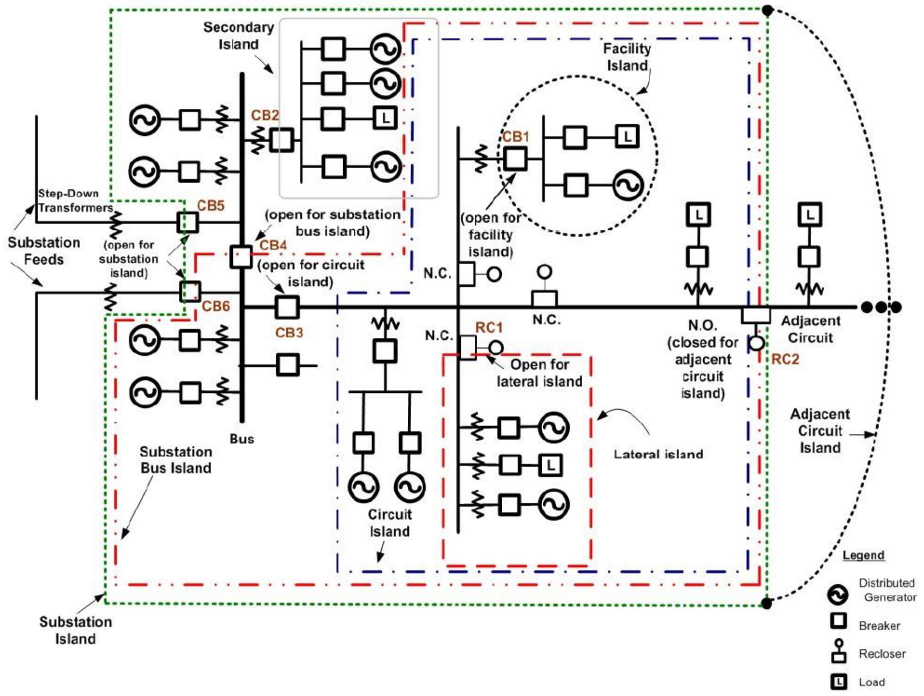
- ➢The interconnection of a microgrid to the local distribution system can be achieved through several different topological structures, as outlined in IEEE std. 1547.4.

- ➢Because of the complexity of microgrids there are numerous variations on the listed structures.

- ➢Regardless of the configuration, the formation and reconnection of a microgrid must be carefully coordinated with the local distribution system operator.

- ➢IEEE 1547.4 only considered a single microgrid, but the coordinated operation of multiple microgrids in the form of networked microgrids is being examined.

- ➢With networked microgrids, there exists the ability to interact/support bulk power system operations.



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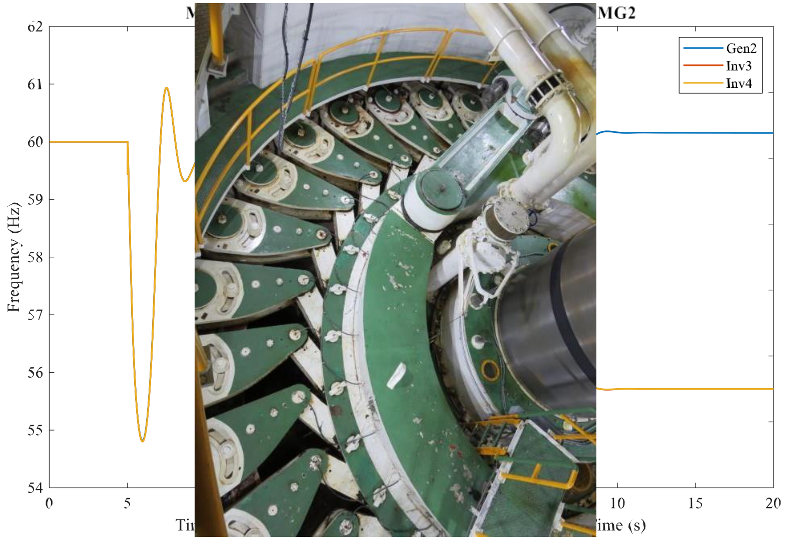
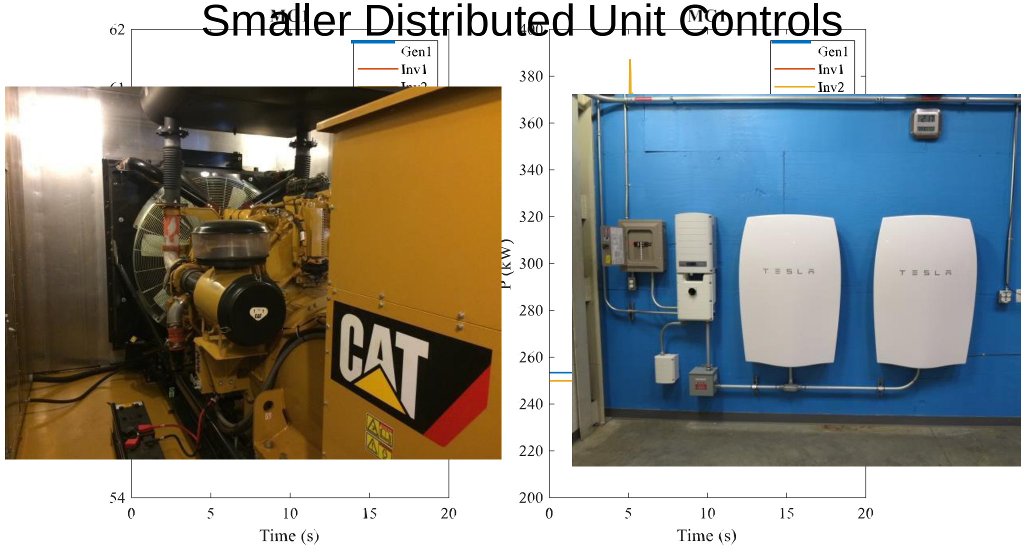
Microgrid Operations

- Microgrids follow the same physical principles as bulk power systems, but their characteristics are different.
- The time-scales of transients for microgrids are much smaller than bulk power systems.
    - Smaller physical control systems
    - Higher speed local controls
- Lower inertia systems with grid-following inverter can experience larger transients due to smaller system inertia.
- However, lower system inertia can be overcome with grid-forming inverters. These system can have smaller transients compared to systems with a large inertia.
- Microgrid operations present the opportunity for increased system flexibility, but they will also increase complexity.



Low Inertia with Grid-forming
Smaller Distributed Unit Controls



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Thank you

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Microgrids & Energy Storage for Resilience: Policy Issues

Prepared for the
ISUE Electric Power Research Center

WEBINAR SERIES

Will McNamara

November 5, 2021

Sandia National Laboratories

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

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The research included in this presentation has been funded by the Department of Energy, Office of Electricity, under the sponsorship of Dr. Imre Gyuk.

The focus of this presentation is policy issues for Microgrids & Energy Storage.

- I will be covering the following topics:
  - ➢ Defining characteristics of Microgrids
  - ➢ How these characteristics trigger policy considerations
  - ➢ Key policy issues for Microgrids—federal and state
  - ➢ Regulatory "best practices" by state example
  - ➢ High-level summary of Energy Storage policy issues
  - ➢ Policy correlations between Microgrids & Energy Storage
  - ➢ Q&A session

Defining Characteristics of Microgrids

Setting the stage for Microgrids' (future) prominent role.

- Costs for fossil fuels remain volatile and costs for renewable energy technologies are falling.

- Regulatory policies now promote clean energy & renewable energy, and frequently preclude the development or expansion of natural gas or coal-fired generating plants.

- Decarbonization by definition includes a comprehensive move away from fossil fuels and toward renewables and clean energy.

- As a result, the industry is transitioning away from a centralized model, and toward one that relies more heavily on distributed energy resources (DERs).

- Resilience and reliability concerns are also driving a need for localized power supply.

What is a Microgrid?

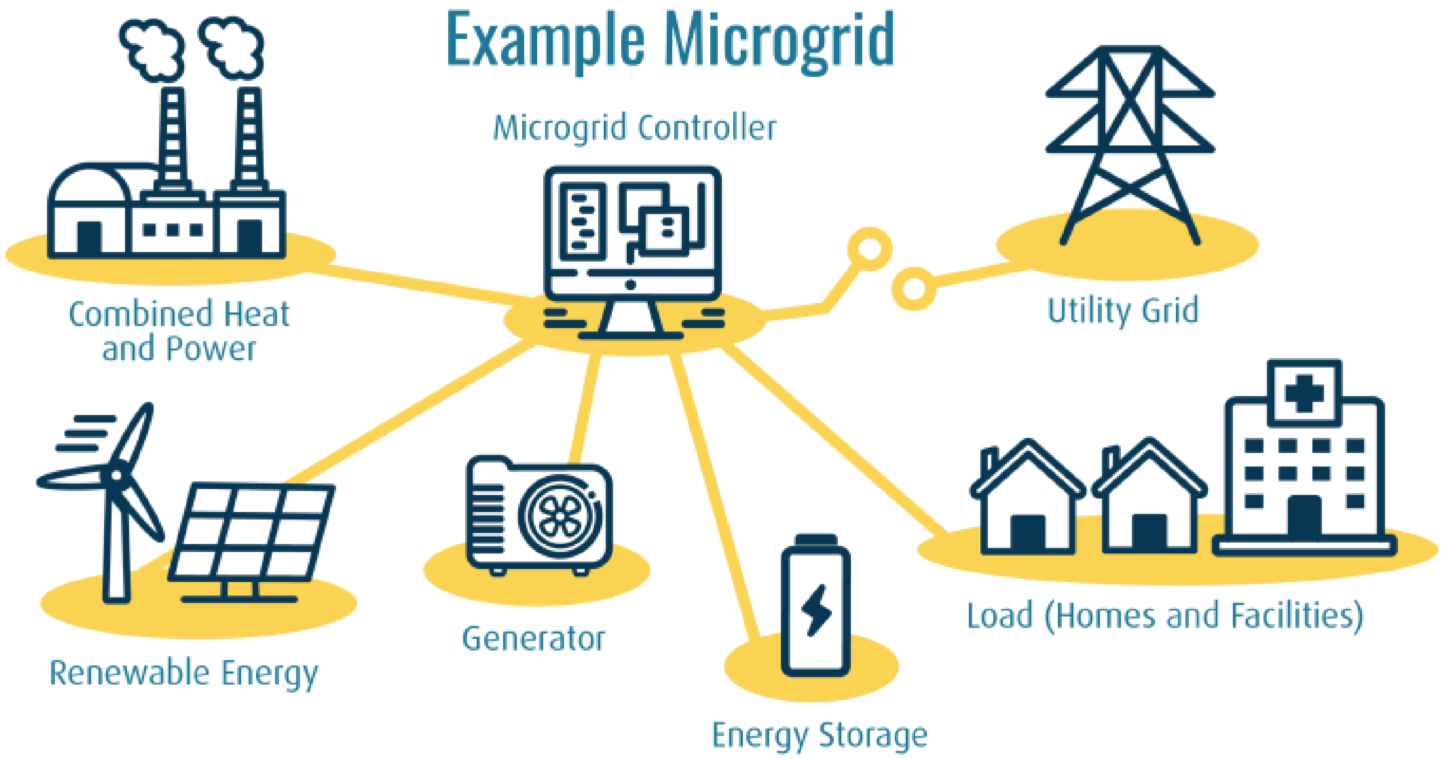
The Department of Energy's official definition:

"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."

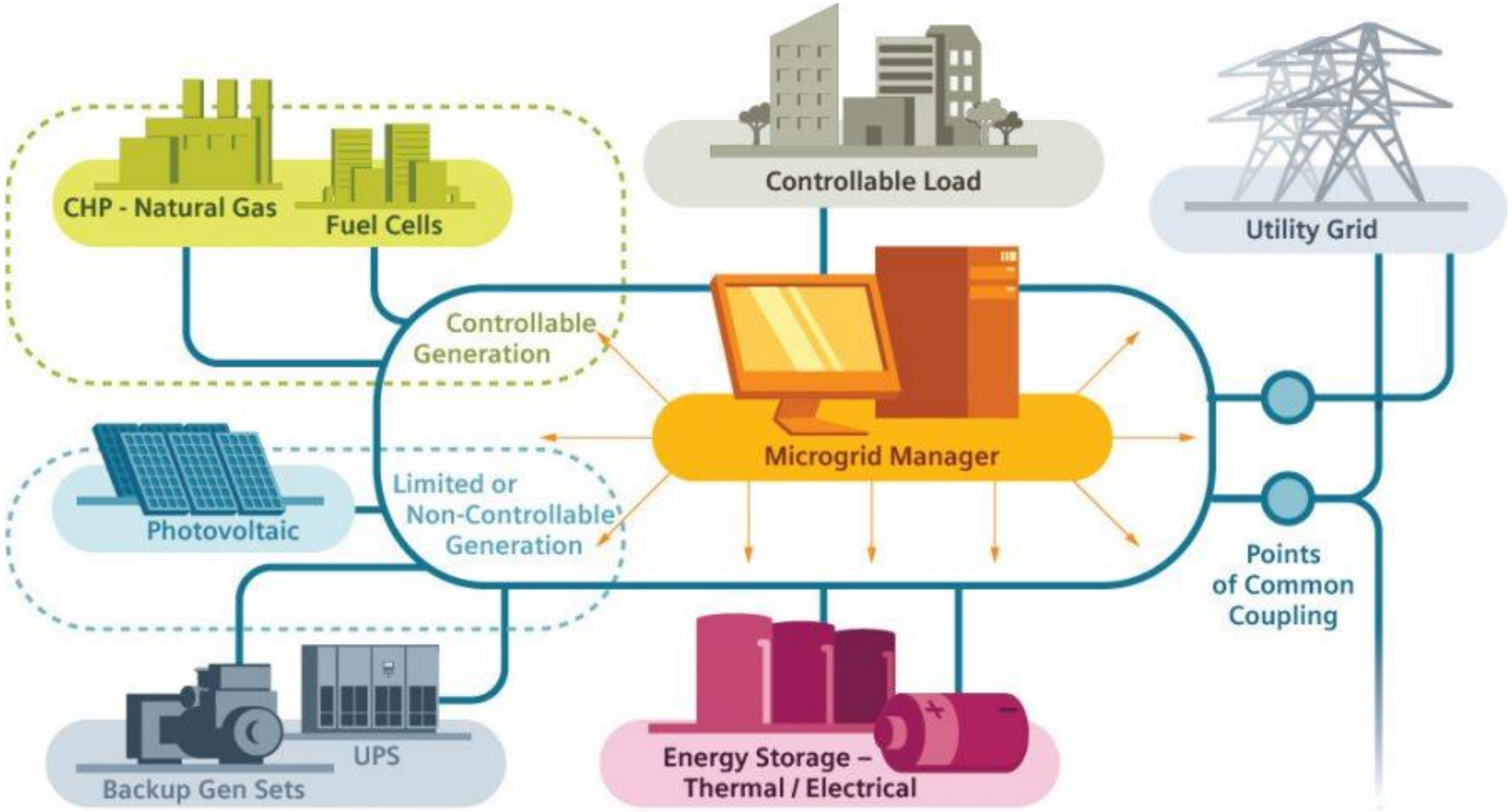
A Microgrid is defined by the services it is capable of providing (e.g., back up power) rather than the resources on which it operates.

What is a Microgrid?



Source: Department of Energy

What is a Microgrid?



Source: Department of Energy

“Real-world” examples of Microgrids

Borrego Springs Microgrid—
San Diego Gas & Electric
$4.5 million federally funded grant; 100 percent clean energy (mostly solar) with battery storage.

U.S. Marine Corp Parris Island, SC Microgrid: Natural gas and Solar PV; 5.5 MW of solar photovoltaic (PV) array, and a 4 MW battery-based energy storage system, together with an integrated control system capable of islanding and fast load shedding.

Source: Department of Energy

What is a Microgrid?

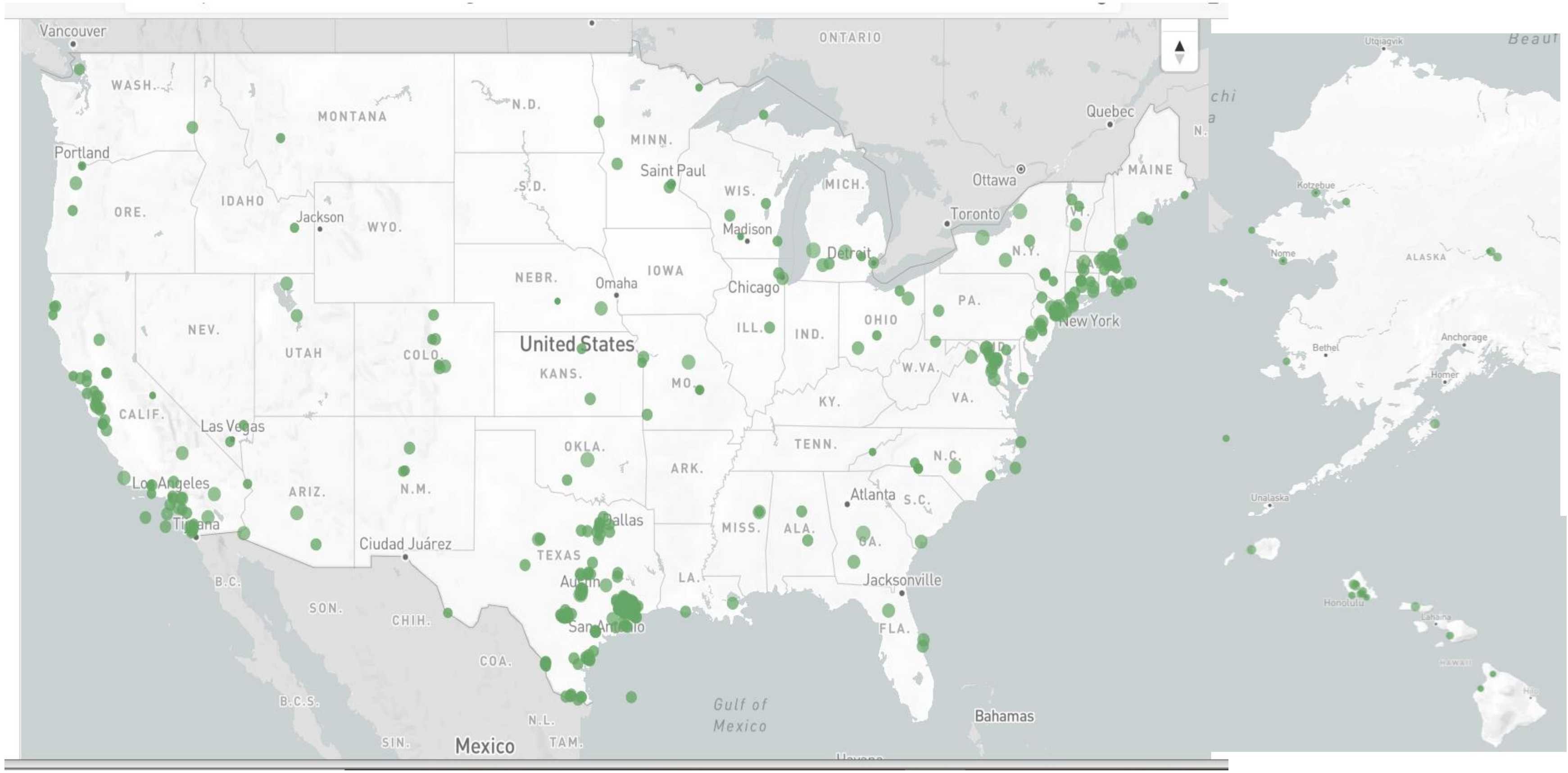
- By definition, most Microgrids can operate independently or connected to the grid. The ability to operate in both scenarios represents a key value of Microgrids.

- Whether or the Microgrid operates independently ("islanded") or is connected to the grid is the key determinant of regulatory oversight.

- Microgrids can be located in both vertically integrated and restructured states….and retail markets and wholesale markets, triggering either state or federal policy factors, respectively.

Where are Microgrids located?

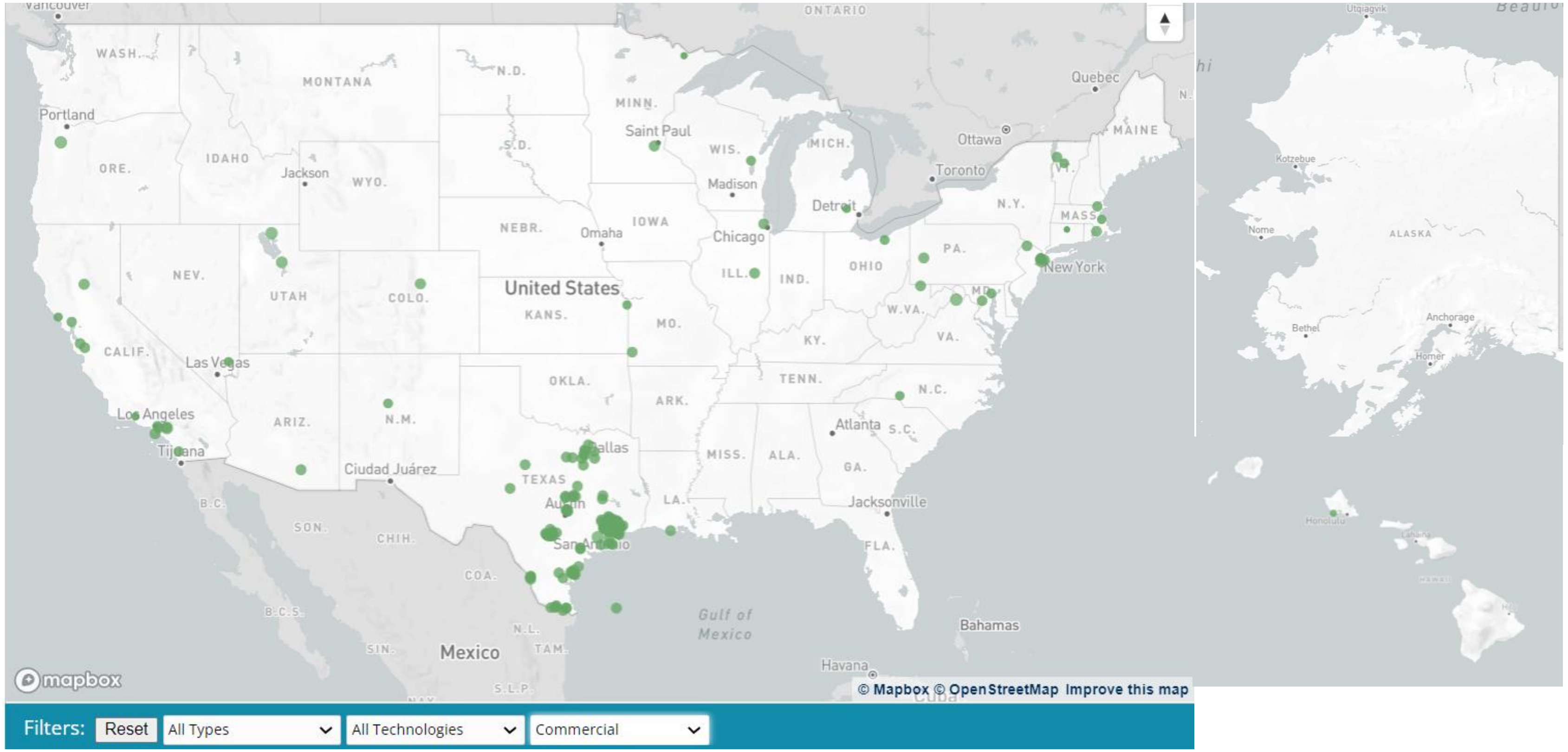
There are 461 operational microgrids in the U.S. that provide a total of 3.1 GW of electricity. Most are concentrated in seven states: AK, CA, GA, MD, NY, OK, and TX. The vast majority are used for onsite reliability needs (i.e., they do not participate in markets), although this is changing, as policies evolve.



Source: https://doe.icfwebservices.com/microgrid

Most of the 461 Microgrids are located in 1) C&U facilities; 2) military bases; and 3) universities.

Microgrid locations of ***C&I facilities*** in the U.S.



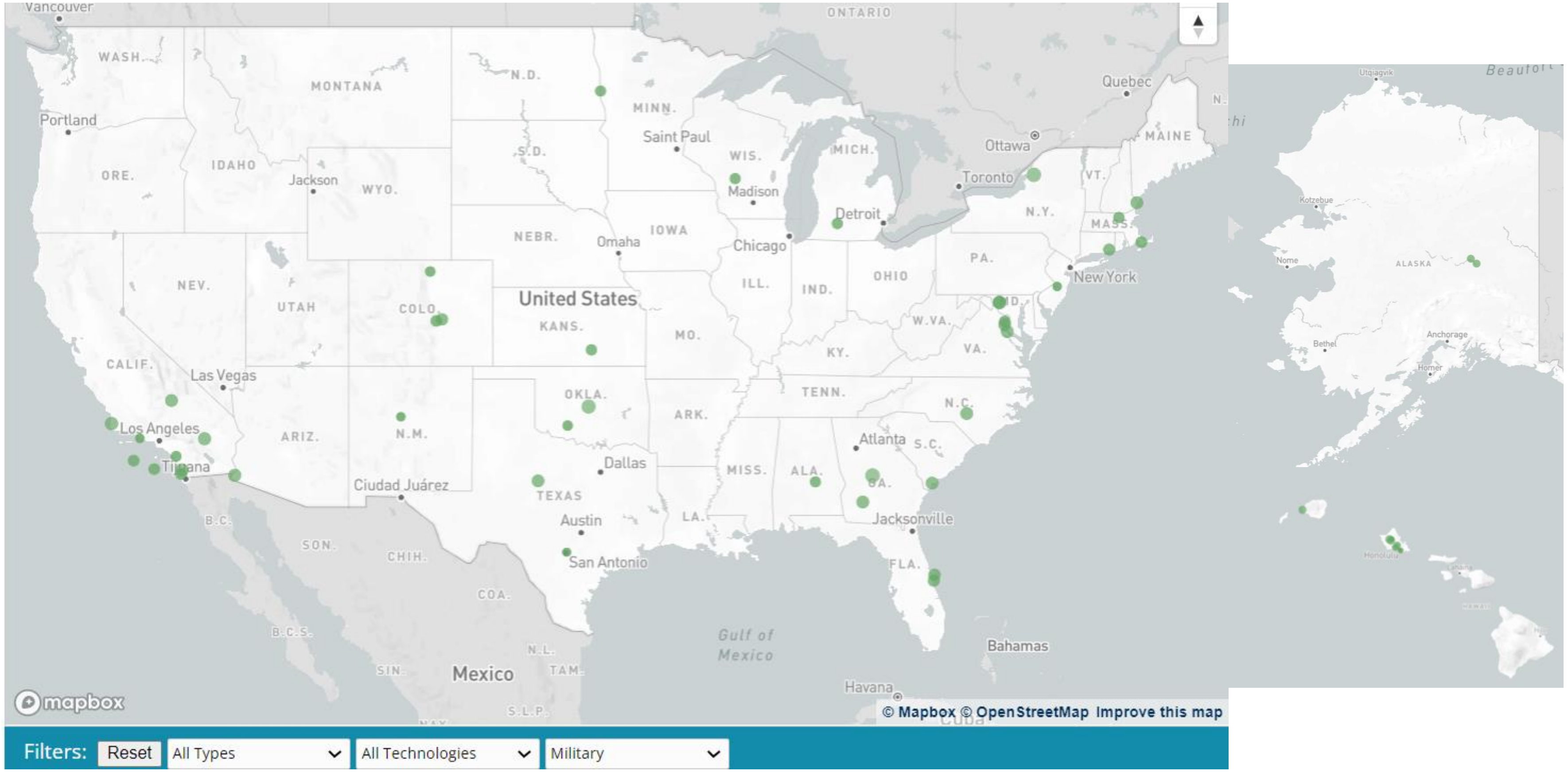
[0]

[1]

Source: https://doe.icfwebservices.com/microgrid

Most of the 461 Microgrids are located primarily in C&I, and military, sites.

Military site locations of Microgrids in the U.S.



[2]

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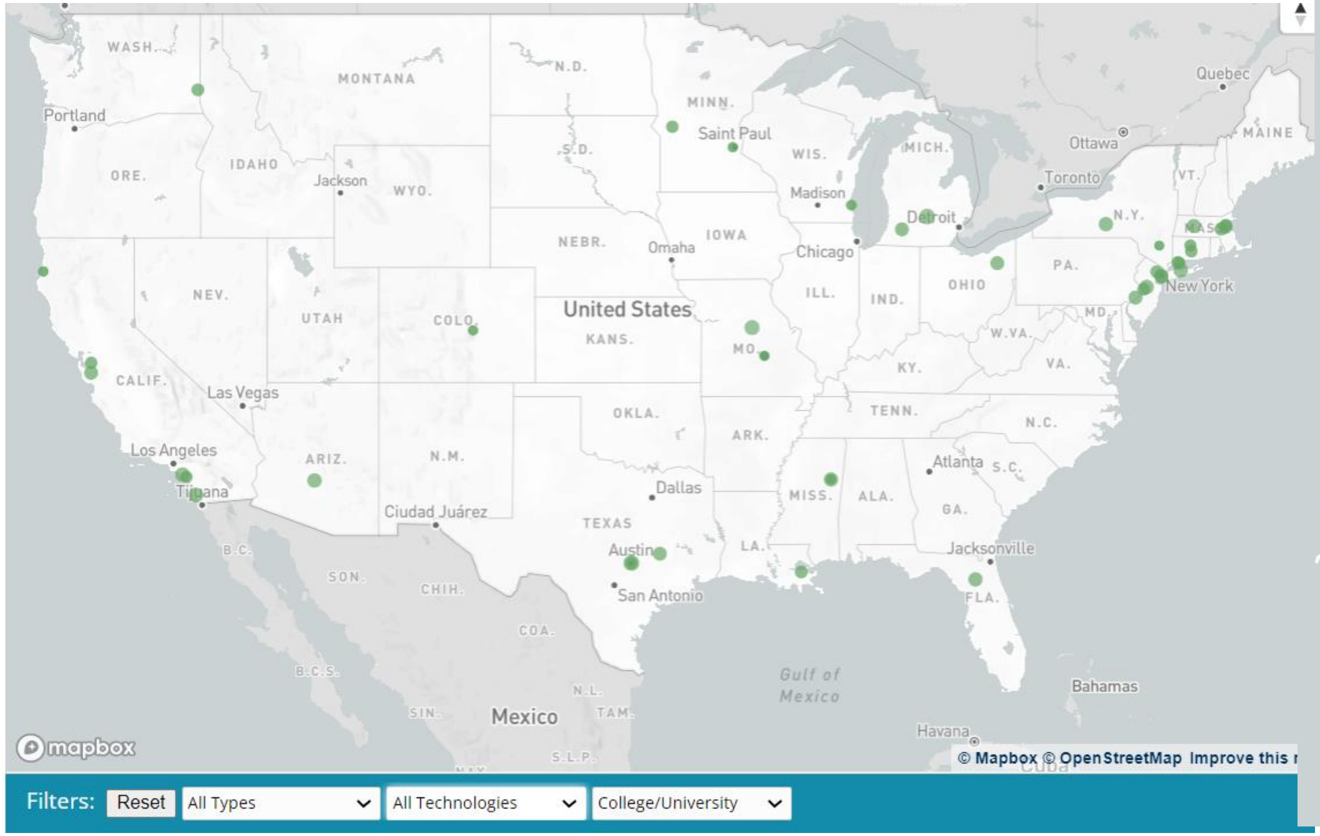
Source: https://doe.icfwebservices.com/microgrid

Most of the 461 Microgrids are located primarily in C&I, and military, sites.

Microgrid locations at U.S. **universities**.



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Source: https://doe.icfwebservices.com/microgrid

Fuel source in the 461 Microgrids varies.

DOE data indicate that the fuel sources primarily used in the nation's Microgrids are, in descending order: Solar, natural gas, diesel, wind and fuel cells

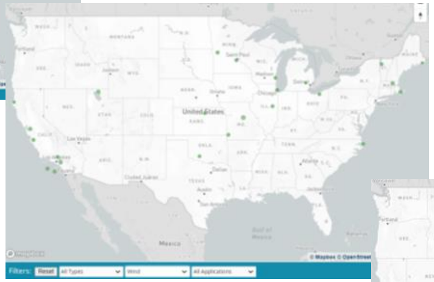
Largest Microgrid in U.S. is at the University of Texas at Austin (135-MW, natural gas)

Many Microgrids are quite small (<100 kW)

Solar

Natural Gas

Diesel



Wind

Fuel Cells

Source: https://doe.icfwebservices.com/microgrid

Which technologies are best suited for Microgrids?

- Flywheels, liquid or compressed air, pumped hydro and hydrogen do not easily scale down for Microgrids, although they could be appropriate for utility-scale applications.

- For batteries, flow batteries can scale to Microgrid needs across a wide range. Lithium-ion batteries may still struggle to compete on cost with other resources….but nevertheless most of the Microgrids now being deployed are using Li-ion.

- There is market interest in Zinc-air, but at this time it's only interest…there are no demonstrated Zinc-air systems that offer reliability performance data (i.e., not a single commissioned project using Zinc air right now)

- Going forward, Li-ion batteries will likely be the preferred chemistry for Microgrids.

Key Policy Issues for Microgrids—Federal & State

State policy & regulatory oversight can enable or restrict Microgrid development.

- As previously mentioned, Microgrids by definition can operate independently or be connected to the grid.
- If they are connected to the grid, this is triggers regulatory oversight at the state level, particularly regarding interconnection and cost allocation.
- State policies are not uniform.
- Compliance with state policies has been a primary focus for Microgrid developers, but federal policies are becoming equally important.
- Thus, both state-level and federal-level regulations impact the opportunities for Microgrids. Inconsistencies between state and federal policies are common.

Restrictive / obsolete policies in states create barriers for Microgrid development.

- No legal definition for Microgrids: Most states have yet to define Microgrids in law – indeed, the industry as a whole grapples with its definition.

- Vertically integrated states still protect the franchises of monopoly utilities.

- If Microgrids are defined as a “utility” they may be barred from developing in competition with the incumbent utility.

- Connecticut is the only state that has defined the term to resolve barriers associated with a “utility” designation. CA, MA, MD, NY are reportedly have pending decisions.

Ownership policies also create challenges at the state level.

- Classifications are closely tied to ownership policies.

- Is it a generation resource? Is it a DER? The answer triggers many implications.

Ownership Models (can vary by state)

Utility-Owned	Landlord	Customer-Generator	Re-Seller	Co-Op
Incumbent, regulated utility owns and operates the Microgrid	A single “landlord” single landlord owns and operates the Microgrid and sells power to end-users.	A single firm owns and manages the system, serving the electric and/or heating needs of itself and its neighbors	A third-party owns and manages the Microgrid and sells power and heat to multiple customers	Multiple parties own and operate the Microgrid for their collective power & heating needs

Ownership designation triggers other requirements.

- Primary issue is how the Microgrid is classified and whether it is legally recognized.
- Most state policies to date have favored the Utility and Landlord models.
- Most Microgrids will also need to seek Qualifying Facility (QF) status, a designation created by 1978's PURPA legislation as utilities are required to purchase power from QFs at avoided costs/ wholesale value.
- QF designation also allows a Microgrid to bypass being classified as a "utility."
- However, QF designation also has constraints that confound developers: restrictions on the number of customers that can be served by the Microgrid, and limitations on the geographical scope of loads served (often a mile or less).

Net metering policies also create challenges for Microgrids.

- Net metering, which vary by state, define the price at which power from a DERS sold to the grid will be compensated (typically at the retail rate).
- Net metering can become a reason why an incumbent utility may seek to block interconnections from DERs, or eliminate net metering programs entirely (e.g., Hawaii)
- What replaces the net metering program may not be much better for Microgrid developers: In a number of states, utilities have authority to set new tariffs for DERs that may render them to be uneconomical.

Key takeaway:

There is no one regulatory framework for Microgrids at the state level; state-level policy frameworks for Microgrids are heterogeneous in nature across the 50 states.

Standardization across states is a goal but not yet a reality.

NARUC and NASEO have formed the Microgrids State Working Group to share public- and private-sector best practices to advance beneficial microgrid development.

At the federal level, FERC's Order 2222 is directly relevant.

- Issued in September 2020, and directs RTOS & ISOS to revise their tariffs to allow energy from DERs including Microgrids to be sold into wholesale regional energy markets.

- The order removed an "opt-out" provision that had allowed grid operators to blocks offers from aggregated demand response providers in states where the practice is not allowed

- This federal rule is expected to unlock new revenue streams for Microgrids., because it will allow Microgrids primarily intended for isolated DR to aggregate with other DERs and participate in wholesale markets.

The order also benefits energy storage, electric vehicles, & energy efficiency technologies that often work in tandem with Microgrids.

The “bottom line” on Order 2222.

- It creates the marketplace in which it will be much easier to realize benefits of assets like Microgrids.
- It will help Microgrid developers and project financers to create solutions to meet market needs, rather than design solutions simply to meet a patchwork of disparate state rules.
- Order 2222 is not just a federal issue—RTOs and ISOs will need visibility into what’s happening at the distribution level — and vice versa.
- Thus state regulations need to be in sync with federal regulations.

<u>State issues:</u>
Ownership, interconnection, cost allocation, reliability, and safety issues

“Best Practices” for Microgrid Policymaking— State Examples

California—Policy Framework

- ***Legislation:*** SB 1339 (2018), which directed the CPUC, CA-ISO and CEC to jointly craft a microgrid policy framework.

- SB 1339 also specifically called out that ensure that the benefits of Microgrids should not extend only to wealthy customers or large corporations that can afford to pursue them.

- *Specific provisions included:*
  - Develop Microgrid service standards that meet state and local permitting requirements;
  - Reduce barriers for microgrid deployment without shifting costs among ratepayers;
  - Develop rates and tariffs to support Microgrids,; and
  - Streamline the interconnection process and lower interconnection costs for direct current microgrid applications.

California—Policy Framework

- ***Regulation:*** CPUC R.19-09-009 (2019) that initiated an evaluation whether and how Microgrids will reduce greenhouse gas emissions, protect California ratepayers, and advance California's progressive environmental goals.

- *Key provisions included:*
    - Prioritize and streamlining interconnection applications to deliver resiliency services at key sites and locations;
    - Modify existing tariffs to maximize resiliency benefits;
    - Evaluate IOU proposals for ownership

Connecticut—Policy Framework

- ***Legislation:*** Public Act 13-298:
  - Allows Microgrids to be owned by municipalities and to cross public rights-of-way.
  - Establishes that community choice aggregation programs could allow Microgrids to operate without being subject to the same regulations as electric utilities,.
  - Microgrids can use the incumbent utility's infrastructure (under strict conditions), and develop sub-rates that apply to their customers.
  - Regulatory environments that are friendlier to networked microgrids could emerge from these efforts to reform existing regulations.

Policymaking in other states also provide good points of reference.

Hawaii	New York	Rhode Island
Legislation required PUC to establish a microgrid services tariff. Legislation required steps be taken to streamline interconnection processes for Microgrids.	The state has earmarked $11 million to be awarded for Microgrid development through competitive applications	Regulatory commission has established Microgrids as a key component of its energy transformation. It may set microgrid development requirements, similar to procurement requirements for energy storage seen elsewhere.

Technology issues have policy implications.

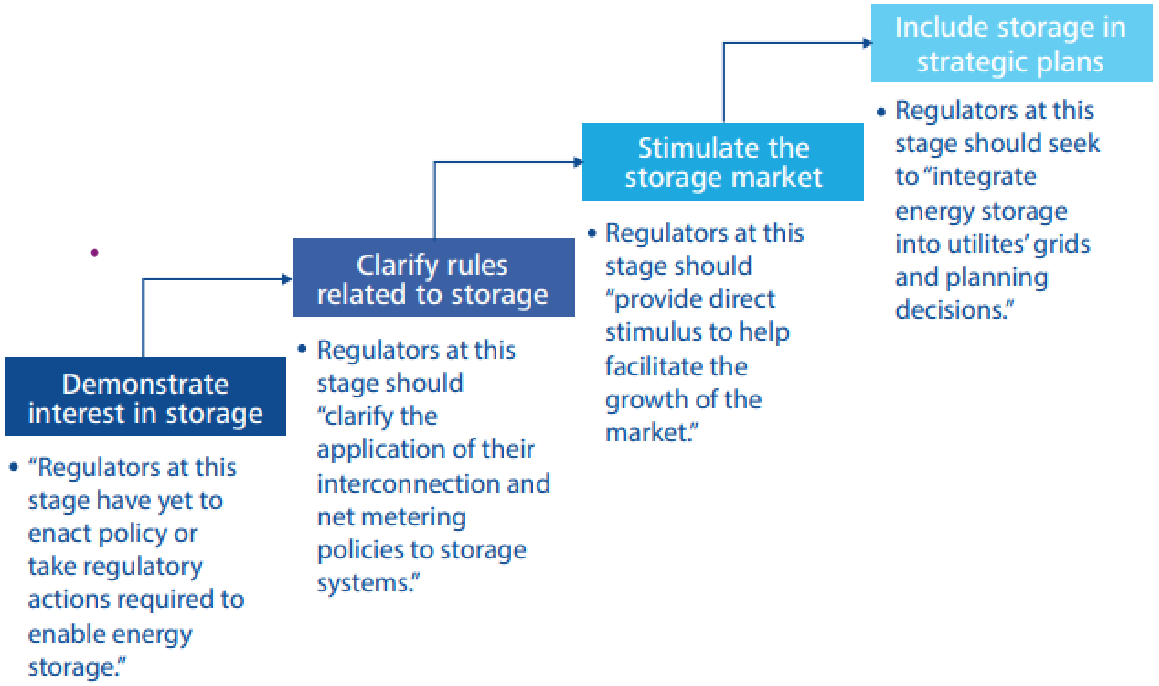
- There are number of technology issues that arise with Microgrid deployment that may need to be addressed through Policy:
  - Start-ups of Microgrids in “island mode” can cause a sudden intake of current which can affect the frequency of the system and voltages.
  - Microgrid balancing of generation and load in island mode needs to be constantly maintained or sudden or large change in loads can introduce instability into the island system.
  - Feeder design: Traditional generation feeders were not generally designed with Microgrids in mind. As microgrids are gaining popularity there seems to be lack of availability in suitable feeders that go with current microgrid designs.

Where Does Energy Storage Policy “Fit In”?

The potential value streams for Microgrids run in parallel with those for Energy Storage Systems.

Resiliency	Reliability and Power Quality	Power System	Environmental	Economic
• Security and Safety • Improved energy situational awareness	• Reduced power interruptions • Critical load reliability • Elective load service • Congestion relief	• Voltage support • Loss reductions (T&D) • Black Start support • Generator efficiency	• Reduction in emissions • Renewable integration	• Savings in electric costs • Revenue generation

State-level policymaking specific to ES is still quite nascent.



Source: Interstate Renewable Energy Council

- The majority of U.S. states are still at the far left of this trajectory, and may not have even taken the first step yet.
- This becomes even more the case when LDES/SES policymaking is in question.
- Arguably less than a handful of states have reached the top level (CA, NY, HI)

Key Energy Storage Policy Issues—States

Each of the 50 U.S. states (plus territories) will need to develop policy on many energy storage issues:

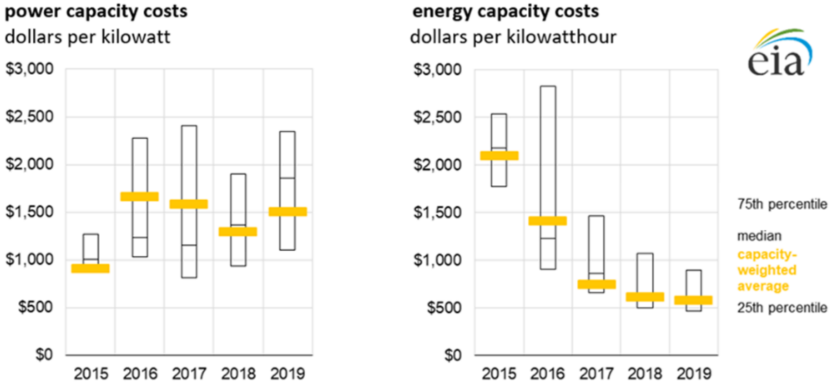
1. Procurement mandates
2. Utility ownership
3. Changes to RPS mandates
4. Benefit/cost analysis
5. Distribution system modeling
6. Updates to interconnection standards
7. Multiple use applications
8. Incentives / tax credits
9. Including in utility IRPs
10. Changes to net metering programs

Energy storage policy barriers can circumvent market development.

- The #1 barrier facing energy storage development is **Cost**, which is exacerbated by the lack of policy remedies to mitigate cost impacts.
- It is true that the cost for ES technologies has fallen dramatically, (now averaging about $625/kWh), but that does not tell the full story.

- *Costs vary greatly by region and application.*
- *ESSs remain expensive and the significant upfront investment required can be difficult to overcome.*
- *Policy levers at the federal and state level can help ease the burden of these costs with subsidies, low-cost financing, etc.*
- *But the reality is that these levers are few and far between , which is a barrier that may cause many ES developments to stagnate.*

Figure ES2. Total installed cost of large-scale battery storage systems by year



Source: U.S. Energy Information Administration, 2019 Form EIA-860, *Annual Electric Generator Report*

The following states have adopted clean energy / renewable goals.

Sandia National Laboratories

These are state-level initiatives.
Utility specific initiatives are not included here.

STATE	DEADLINE	GOAL	CLEAR ROLE FOR ES & MICROGRIDS?
AZ	2070	100% carbon-free electricity	NO
CA	2045	100% carbon-free electricity by	Somewhat
CT	2040	100% carbon-free electricity by	NO
HI	2045	100% renewable energy	Somewhat
LA	2050	Net zero greenhouse gas emissions	NO
ME	2050	100% clean energy	NO
MA	2050	Net-zero greenhouse gas emissions	NO
MI	2050	Economy-wide carbon neutrality	NO
NV	2050	100% carbon-free electricity	Somewhat
NJ	2050	100% carbon-free electricity	NO

The following states have adopted clean energy / renewable goals.

These are state-level initiatives.
Utility specific initiatives are not included here.

STATE	DEADLINE	GOAL	CLEAR ROLE FOR ES & MICROGRIDS?
NM	2045	100% carbon-free electricity	NO
NY	2040	100% carbon-free electricity	Somewhat
OR	2040	Greenhouse gas emissions reduced 100 percent below baseline emissions	Somewhat
RI	2030	100% renewable energy	NO
VA	2045	100% carbon-free electricity	NO
WA	2045	100% zero-emissions electricity	Somewhat
WI	2050	100% carbon-free electricity	NO

State Activities—The Current Status

- Only about 15 U.S. states have developed substantive energy storage policy as of 3Q 2021.
- At this time, these states represent "best practices" for state-level energy storage policies.

PM	I/TC	IRPs	NEM	RPS	C/B A	DSM	IC
CA	MD	CO	CA	CA	MN	CA	AZ
MA		IN	CO	HI		NY	
NJ		NJ	HI	NJ			
NY		NM		NY			
OR				OR			
VA				VT			

The energy storage policy landscape continues to evolve.

Sandia National Labs monitors and analyzes activity at the federal and state levels and publishes information in the Global Energy Storage Database, available at this link:

https://www.sandia.gov/ess-ssl/global-energy-storage-database/

Q&A Session

Thank you!

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Argonne NATIONAL LABORATORY

INTRODUCTION TO THE ECONOMIC AND RESILIENCE BENEFITS OF MICROGRIDS

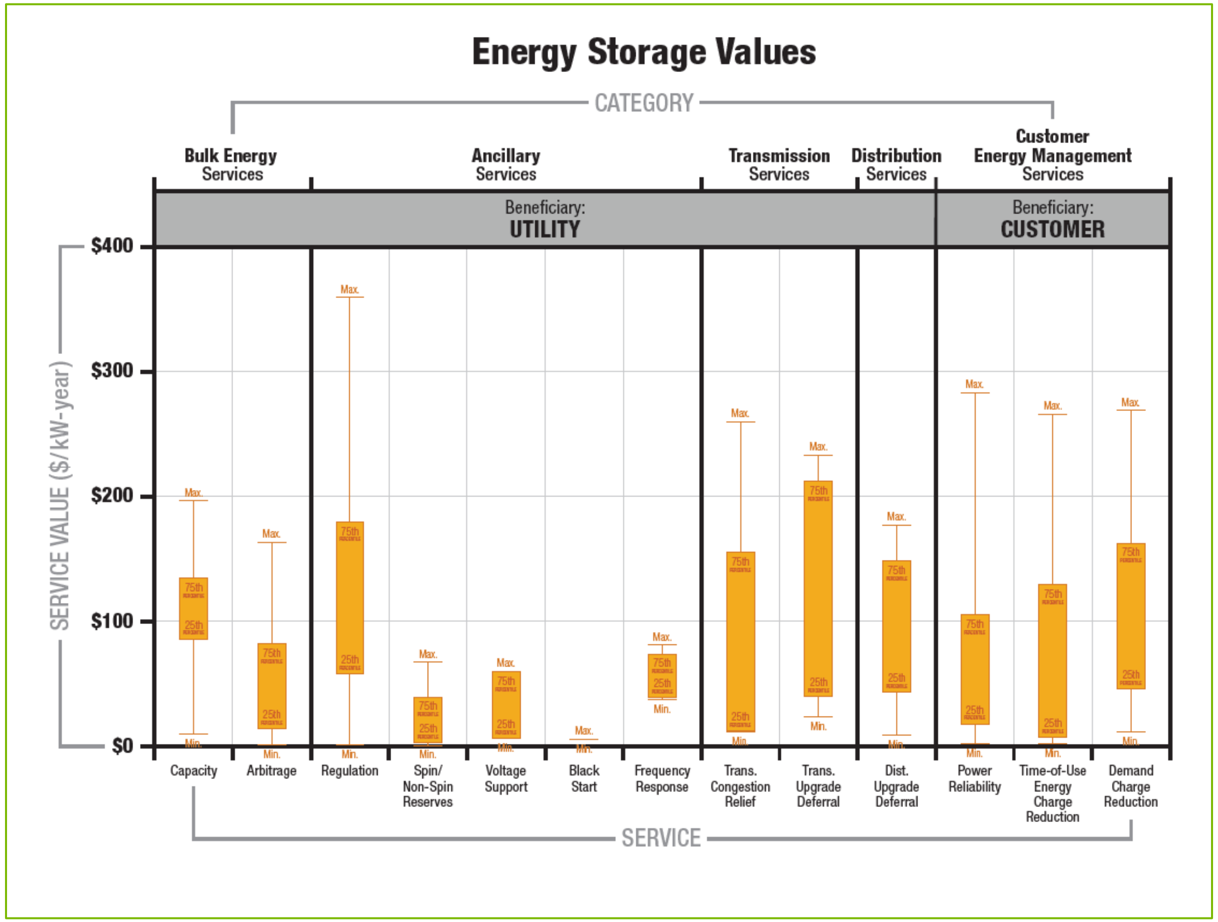
PATRICK BALDUCCI

Argonne National Laboratory

MICROGRIDS AND ENERGY STORAGE FOR EMERGENCY GRID RESILIENCE

NOV 5, 2021

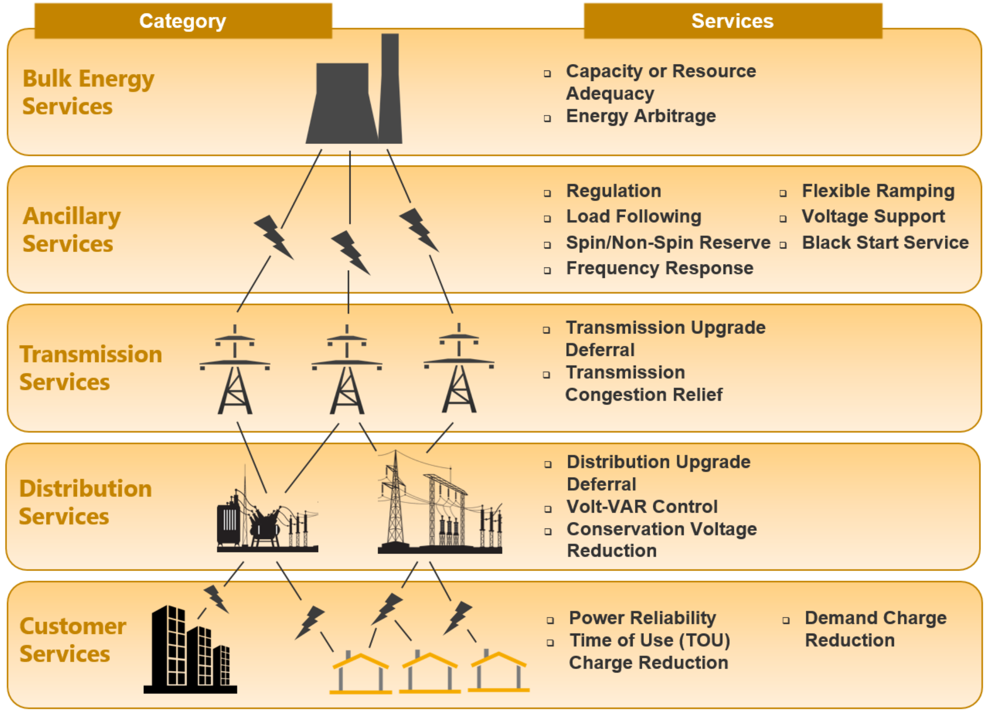
ENERGY STORAGE HOLDS TREMENDOUS VALUE

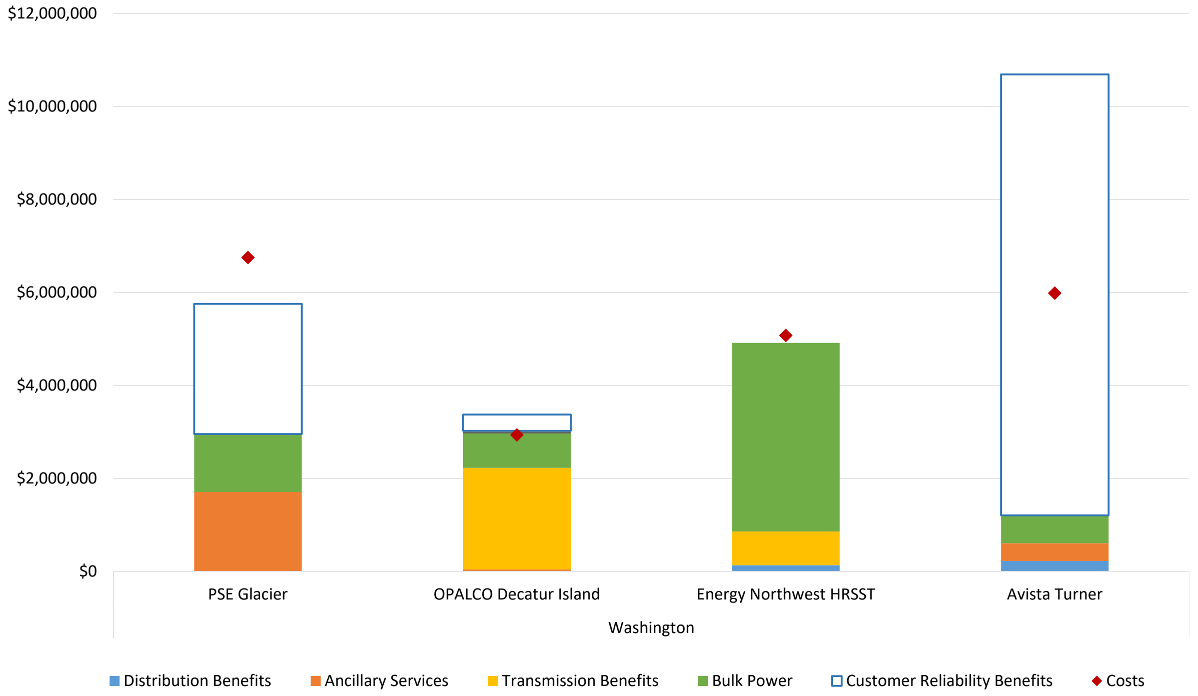


Key Lesson: The value of distributed energy resources (DERs) accrues at multiple levels of the electric grid, and there are no existing tools with all the required features to fully capture these values.

Source: Balducci, P., J. Alam, T. Hardy, and D. Wu. 2018. Assigning Value to Energy Storage Systems at Multiple Points in an Electrical Grid. Energy Environ. Sci., 2018, Advance Article. DOI: 10.1039/C8EE00569A. Available online at http://pubs.rsc.org/en/content/articlelanding/2018/ee/c8ee00569a#!divAbstract.

DEFINING AND MONETIZING THE VALUE OF ENERGY STORAGE AND DISTRIBUTED ENERGY RESOURCES

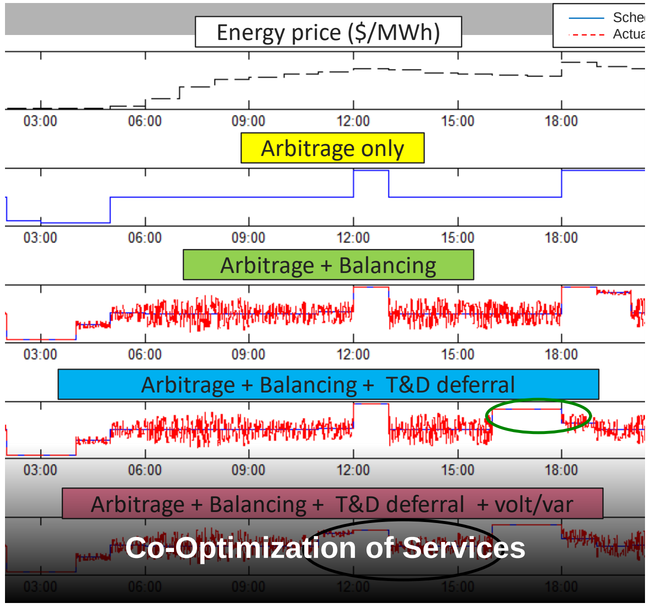




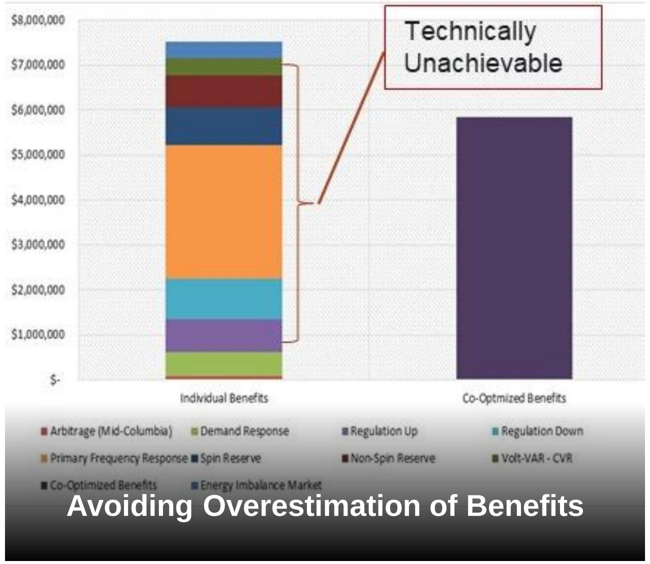
- A broad taxonomy and modeling approach for defining the value of storage is required to accurately assign value
- Economic value is highly dependent on siting and scaling of energy storage resources; many benefits accrue directly to customers

CHALLENGES TO ACCURATELY ESTIMATING ECONOMIC BENEFITS

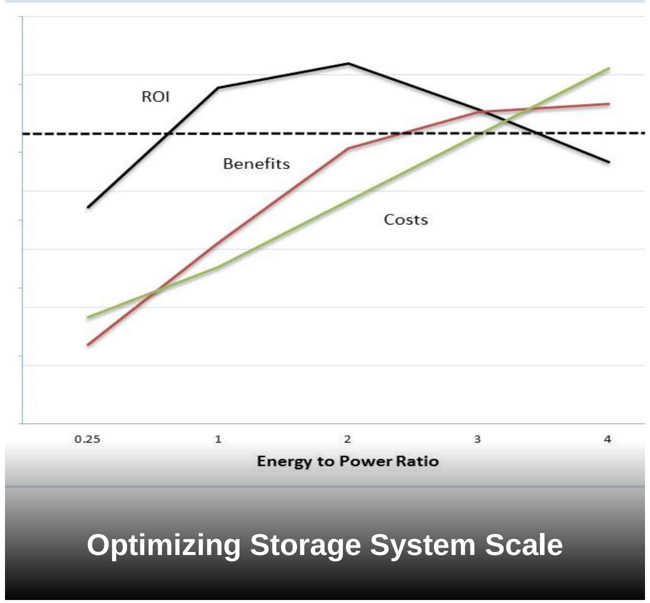
- Multidimensional competition for energy – not all services can be provided simultaneously and there exists intertemporal competition for energy
- Economic results are sensitive to sizing of energy storage system in terms of power and energy capacities
- Markets are complex and common practices of assuming perfect foresight into prices, price-taker position, and consistent performance lead to overestimation
- Battery performance is dynamic and there are challenges in capturing real-time value
- Battery degradation is an important consideration
- Storage valuation tools are required



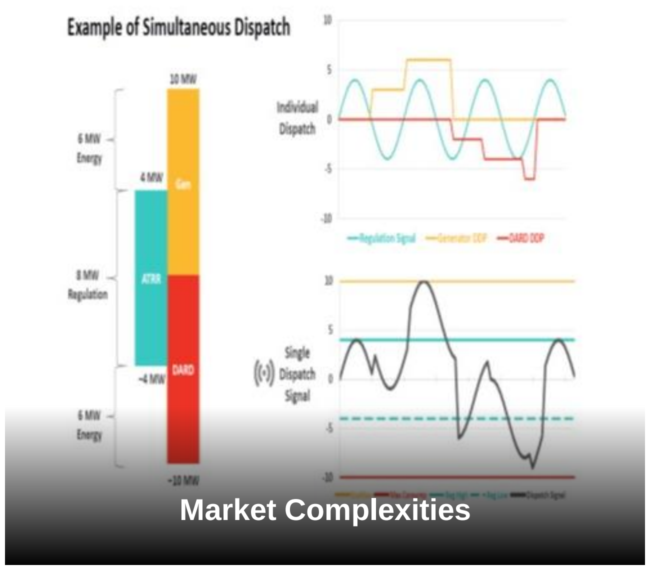
Co-Optimization of Services



Avoiding Overestimation of Benefits



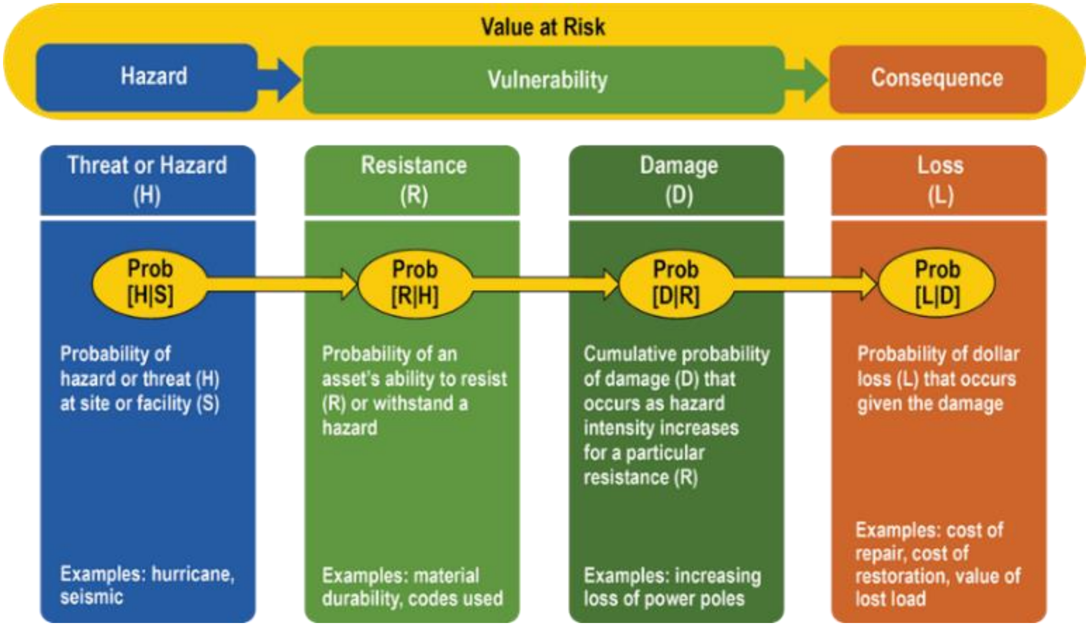
Optimizing Storage System Scale



Market Complexities

VALUING RESILIENCE

- Energy storage has demonstrated the capacity to enhance grid resilience
- Resilience benefits are poorly defined and generally ignored in energy storage valuation studies
- Resilience benefits are typically evaluated using customer damage functions and interruption cost studies, sometimes evaluated using willingness to pay studies (e.g., contingent valuation method) and input-output analysis
- Resilience value can be embedded in other value streams, including transmission deferral, voltage sag compensation, and outage mitigation
- Multi-hazard risk analysis that relies on expected value calculations based on probabilistic analysis, while addressing a broad range of hazards and values tied to lost economic productivity, infrastructure damage, and injuries/fatalities is required – annual risk premium approach
- More research is needed to properly value resilience

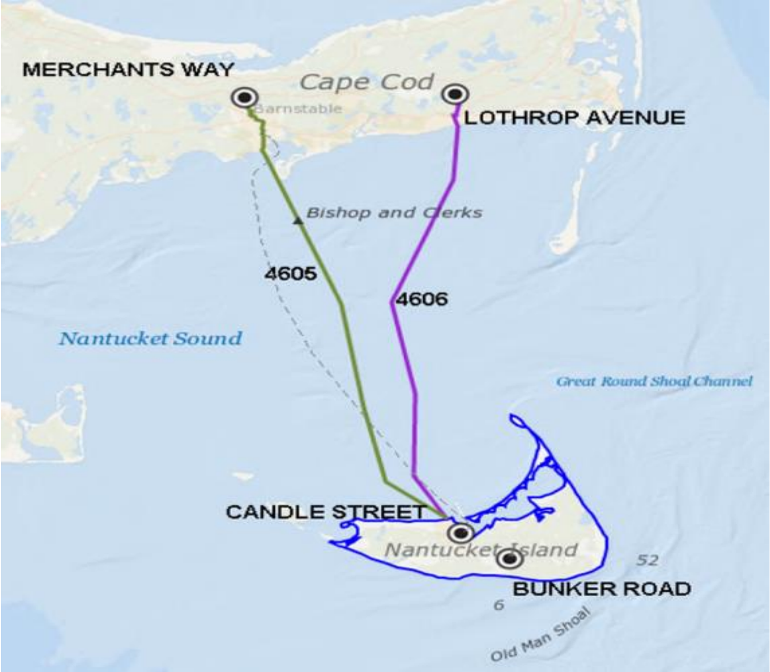


Pictorial Approach to Value Risk Assessment and Resilience Valuation

Source: Balducci, Patrick, Mongird, Kendall, and Weimar, Mark. Understanding the Value of Energy Storage for Power System Reliability and Resilience Applications. Germany: N. p., 2021. Web. https://doi.org/10.1007/s40518-021-00183-7.

NANTUCKET ISLAND ENERGY STORAGE SYSTEM

- Nantucket Island located off the coast of Massachusetts
  - Small resident population of 11,000; population swells to over 50,000 in summer
  - Nantucket's electricity supplied by two cables with a combined capacity of 71 MW and two small on-island combustion turbine generators (CTGs) with a combined capacity of 6 MW
  - Rather than deploying 3rd cable, National Grid is replacing two CTGs with a single, large (16 MW) combustion turbine generator (CTG) and a 6 MW / 48 MWh Tesla Li-ion battery energy storage system (BESS.)
- Use cases evaluated
  - Non-market operations
    - ✓ Transmission deferral
    - ✓ Outage mitigation
    - ✓ Conservation voltage reduction
    - ✓ Volt-VAR optimization
  - Market operations
    - ✓ Forward capacity market
    - ✓ Arbitrage
    - ✓ Regulation
    - ✓ Spinning reserves

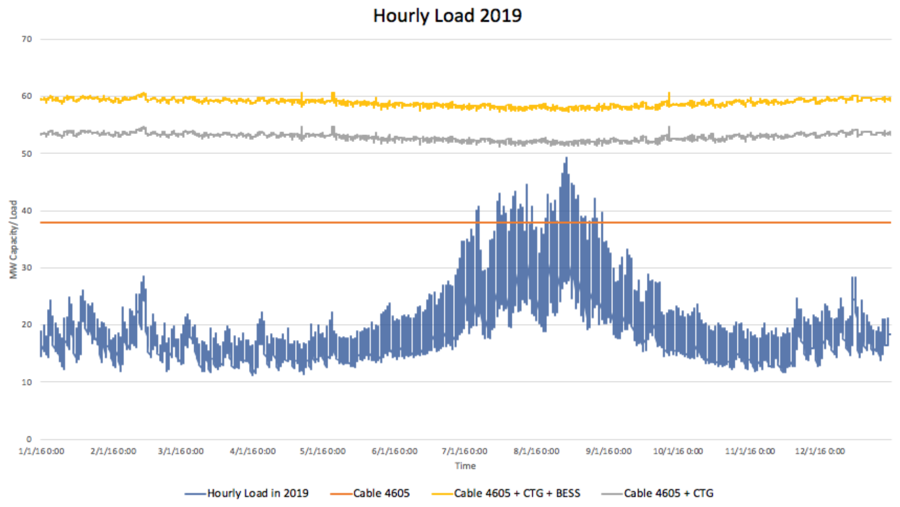


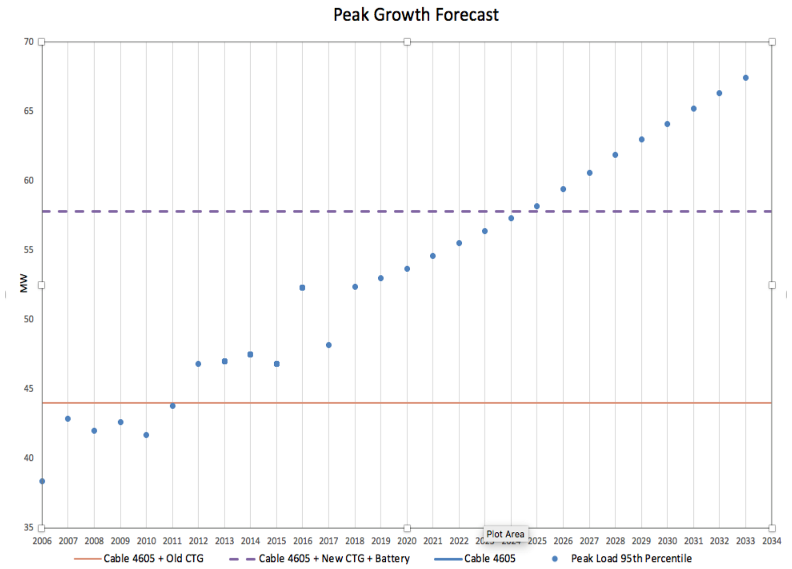
Nantucket Supply Cables

Source: Balducci, Patrick J., Alam, Md Jan E., McDermott, Thomas E., Fotedar, Vanshika, Ma, Xu, Wu, Di, Bhatti, Bilal Ahmad, Mongird, Kendall, Bhattarai, Bishnu P., Crawford, Aladsair J., and Ganguli, Sumitrra. Nantucket Island Energy Storage System Assessment. United States: N. p., 2019. Web. doi:10.2172/1564262.

BENEFITS OF LOCAL OPERATIONS

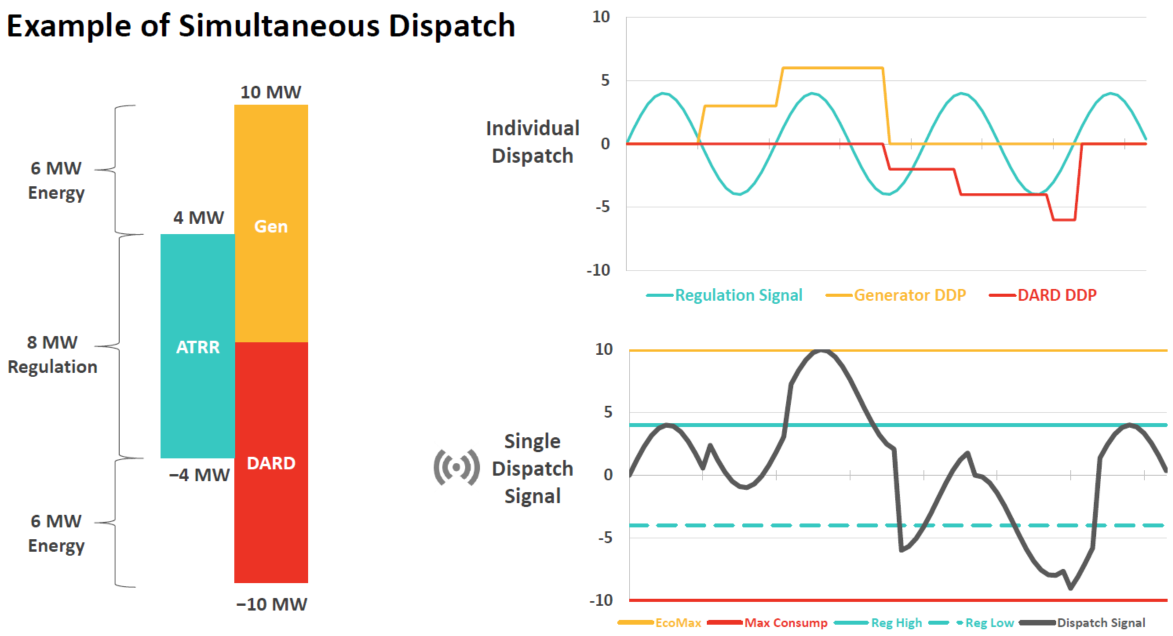
- The research team performed an extensive load analysis in order to define the n-1 contingency window and estimate the number of deferral years at 13
- Outage mitigation evaluated using historic outages and distribution system model
- Value of local operations ($122 million) exceeds the $93.3 million in revenue requirements for the systems, yielding an ROI ratio of 1.30





BENEFITS OF MARKET OPERATIONS

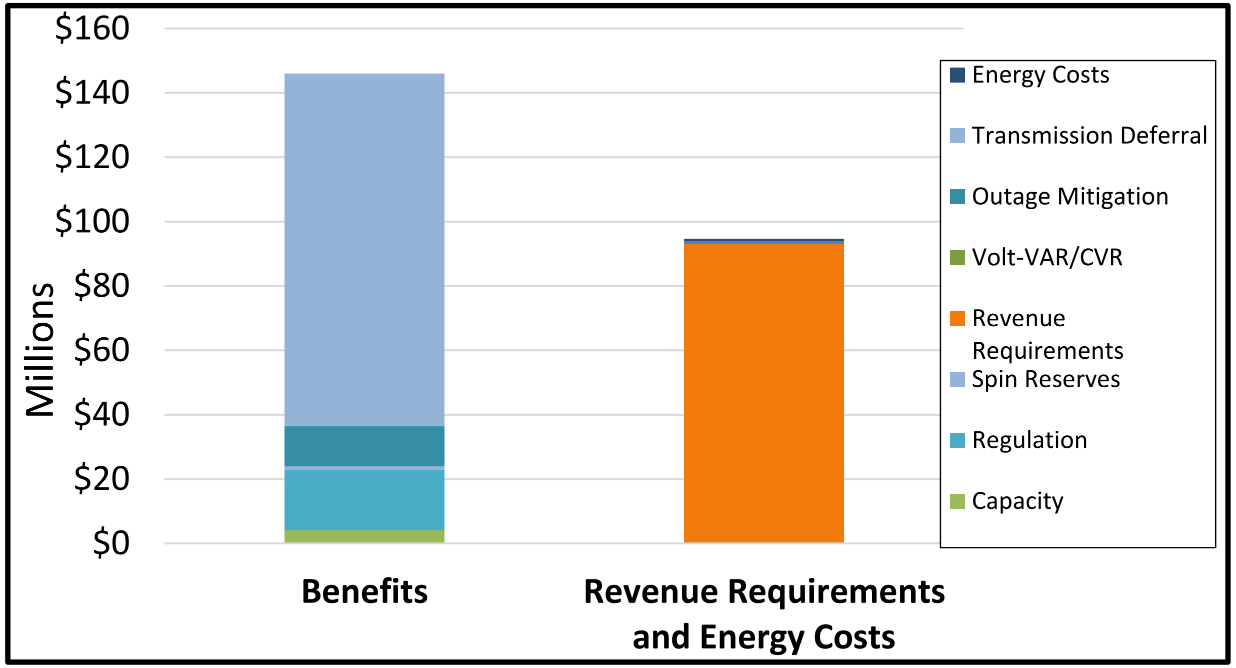
- Nantucket BESS modeled as a continuous storage facility
- BESS bid into markets using predicted prices – i.e., imperfect foresight
- Regulation follows energy neutral AGC signal with a performance score of 95%
- Market benefits estimated at $24.0 million over life of BESS
  - Regulation provides $18.8 million (78%) of market benefits
  - Capacity - $4.1 million (17%)
  - Spin reserves - $1.2 million (5%)



Simultaneous Dispatch of Continuous Storage Facility

NANTUCKET ISLAND CONCLUSIONS

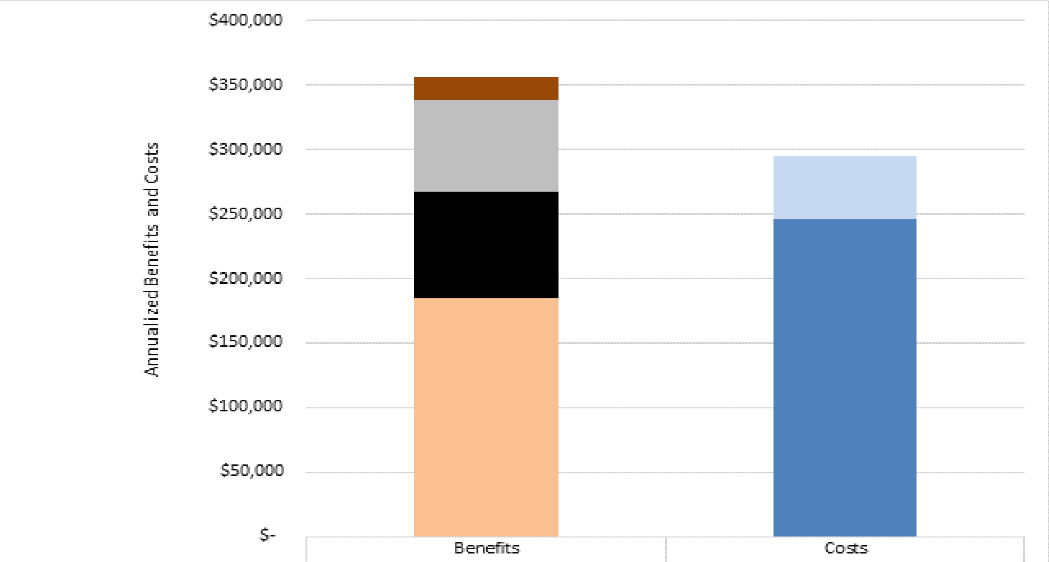
- Total 20-year present value benefits of BESS and CTG operations at $145.9 million exceed revenue requirements and energy costs at $93.9 million with an ROI ratio of 1.55
- Benefits largely driven by the transmission deferral use case, $109 million (75%) in present value terms.
- Regulation services - $18.8 million, 13% of total benefits
- Regulation service dominates the application hours, 7,900 hours each year



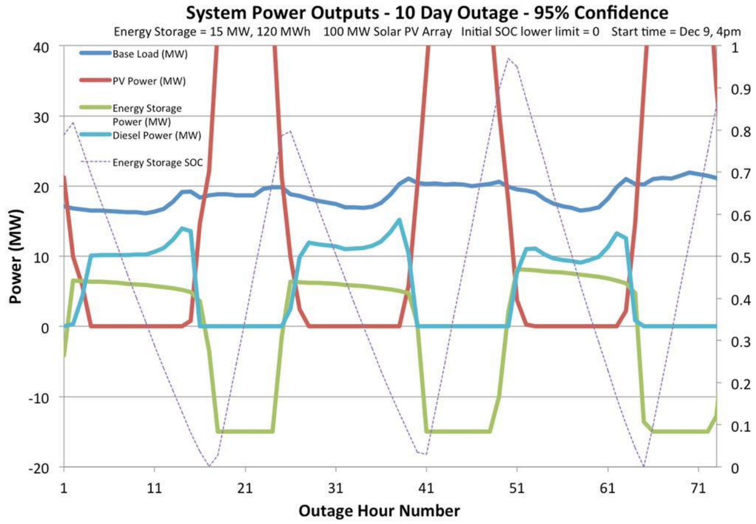
Benefits of Local and Market Operations (Base Case) vs. Revenue Requirements

JOINT FORCES TRAINING BASE LOS ALAMITOS

- JFTB Los Alamitos Microgrid Assessment
  - Resiliency goal – 90% survivability rate for a two-week outage
  - Energy assets – Photovoltaics, diesel gen sets, energy storage
  - Charge to analysts – Meet resiliency goal and maximize economic benefits given fixed budget



	Benefits	Costs
Mid-peak demand charge red.	$17,500	
On-peak demand charge red.	$71,400	
Facility demand charge red.	$81,900	
Energy charge red.	$185,100	
O&M costs		$49,030
Capital Costs		$245,751

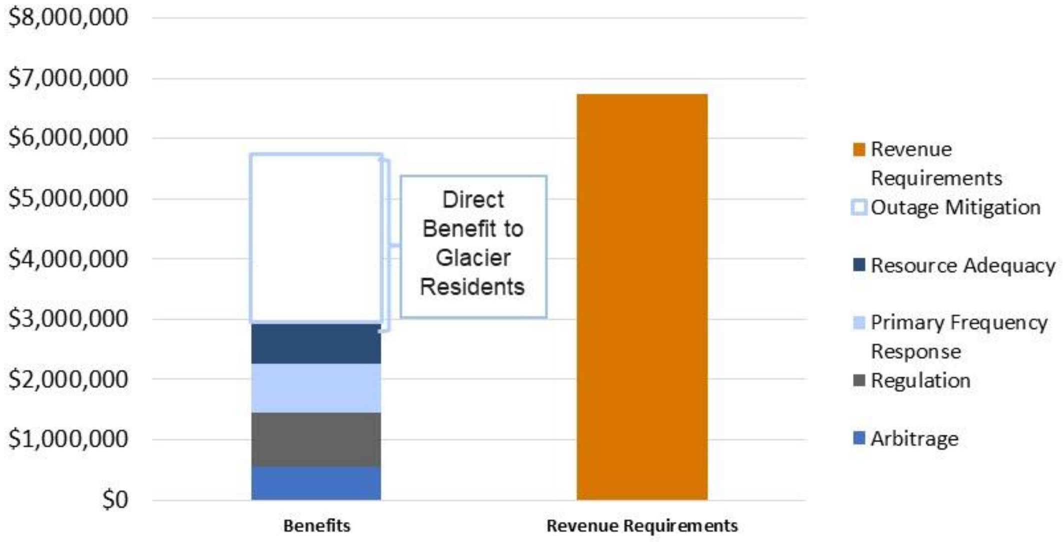


Optimal Microgrid Scale Required to Achieve *Energy Security* and *Operational Goals:*
Gen Set – 1,150 kW
Photovoltaics – 1,224 kW
Energy storage – 408 kW / 510 kWh

PUGET SOUND ENERGY GLACIER

- Outage Data
  - 27 hours of outages average annually
  - All outages (4 on average per year at approximately 6.5 hours each) can be mitigated with the BESS
  - PSE has islanded the downtown core of Glacier

- Customer information
  - Number and type of customers affected by outages determined (38 residential and 20 small commercial and industrial)
  - Annual benefit of roughly $310k to ratepayers

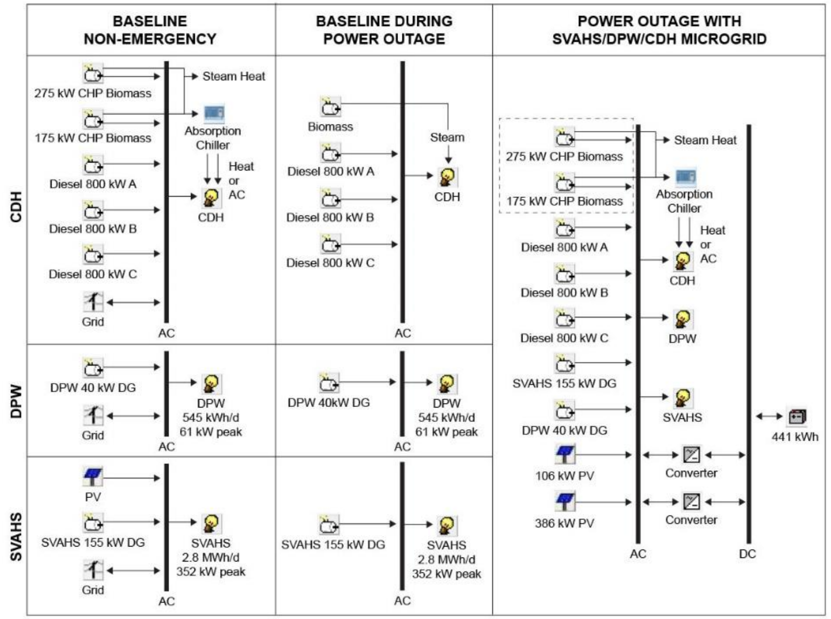


Element	Benefits	Revenue Requirements
Arbitrage	$ 550,816	
Regulation	$ 902,976	
Primary Frequency Response	$ 803,649	
Resource Adequacy	$ 695,292	
Outage Mitigation	$ 2,799,227	
Revenue Requirements		**$ 6,748,775**
	$ 5,260,262	

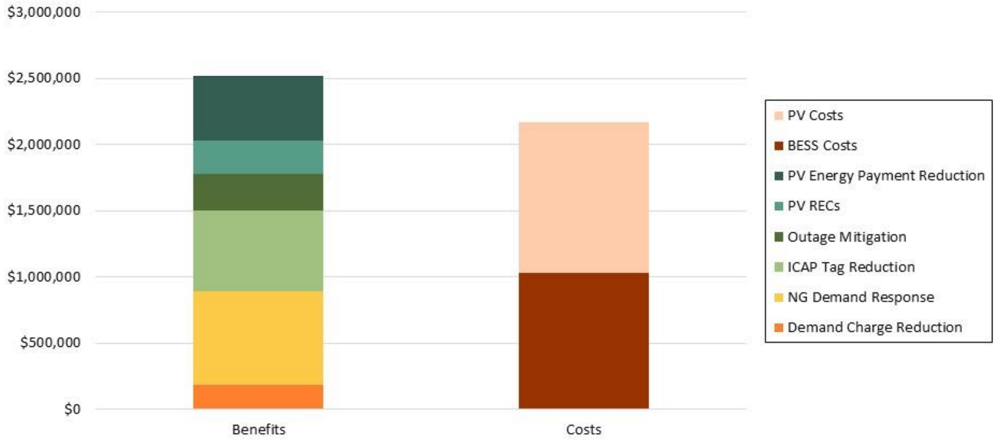
Source: Balducci, Patrick J., Mongird, Kendall, Alam, Jan E., Wu, Di, Fotedar, Vanshika, Viswanathan, Vilayanur V., Crawford, Aladsair J., Yuan, Yong, Labove, Garett, Richards, Shane, Shane, Xin, and Wallace, Kelly. Washington Clean Energy Fund Grid Modernization Projects: Economic Analysis (Final Report). United States: N. p., 2020. Web. doi:10.2172/1772558.

NORTHAMPTON MICROGRID

- Economic Benefits
  - BESS and the 386 kW solar array are estimated to generate a benefit-cost ratio of 1.16 with $0.3 million in net benefits.
- Resilience Benefits
  - When there is a full microgrid and full sharing between microgrid members, all facilities are able to withstand 100% of outages up to seven days in both summer and winter. If no microgrid exists, the survivability of Smith Vocational Area High School and the Department of Public Works during a seven-day outage assuming no DG failure drops to 41.24% and 88.95%, respectively.
  - When 14-day outages are considered, survivability drops significantly due to fuel shortages.



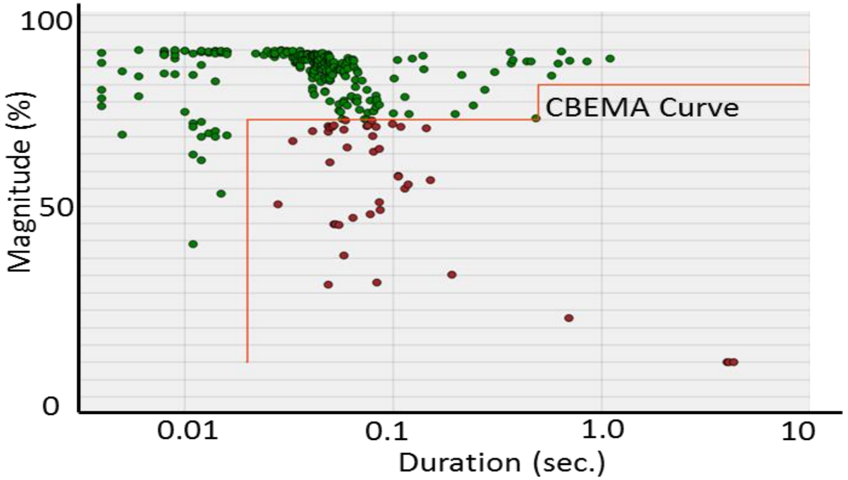
Existing and Planned Power Components of the Northampton Microgrid Project



Twenty-year Benefits and Costs for the Northampton Microgrid

Source: Balducci, Patrick, Mongird, Kendall, Wu, Di, Wang, Dexin, Fotedar, Vanshika, and Dahowski, Robert. An Evaluation of the Economic and Resilience Benefits of a Microgrid in Northampton, Massachusetts. Switzerland: N. p., 2020. Web. https://doi.org/10.3390/en13184802

TURNER ENERGY STORAGE PROJECT – VOLTAGE SAG COMPENSATION



- Sustained voltage sags lead to production disruptions
- PNNL evaluated voltage data from 2014-2017 provided by Schweitzer Engineering Labs
- Applying the Computer Business Equipment Manufacturers (CBEMA) defined power quality curve, over 40 voltage sag events (<70% in magnitude, >20 milliseconds in duration) identified
- On average, two events per year identified as capable of causing disruptions
- In addition, outages of over 5 minutes were experienced three times between 2011 and 2016
- Each outage causes a minimum of three hours of downtime at a cost of $150,000 per hour

Source: Balducci, Patrick J., Mongird, Kendall, Alam, Jan E., Wu, Di, Fotedar, Vanshika, Viswanathan, Vilayanur V., Crawford, Aladsair J., Yuan, Yong, Labove, Garett, Richards, Shane, Shane, Xin, and Wallace, Kelly. Washington Clean Energy Fund Grid Modernization Projects: Economic Analysis (Final Report). United States: N. p., 2020. Web. doi:10.2172/1772558.

CONCLUSIONS – KEY CONSIDERATIONS

Siting/Sizing Energy Storage	Siting/sizing of microgrid assets by capturing/measuring location-specific benefits is key prior to microgrid development
Broad Set of Use Cases	While most microgrid benefits are tied to demand charge reduction, time-of-use charge reduction and outage mitigation, additional benefits may accrue
Regional Variation	Differentiate benefits by region, market structures/rules
Utility Structure	Define benefits for different types of utility tariff structures
Battery Characteristics	Accurately characterize battery performance, including round trip efficiency rates across varying SOCs and battery degradation caused by cycling

ACKNOWLEDGMENTS

Dr. Imre Gyuk, DOE – Office of Electricity, Energy Storage Program

Bob Kirchmeier, Clean Energy Fund Grid Modernization Program, Washington State Energy Office

U.S. DEPARTMENT OF ENERGY

Mission – to ensure a resilient, reliable, and flexible electricity system through research, partnerships, facilitation, modeling and analytics, and emergency preparedness.

https://www.energy.gov/oe/activities/technology-development/energy-storage

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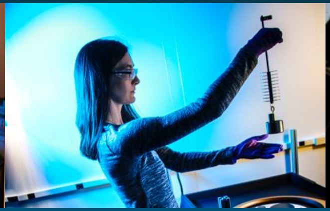
Microgrids and Energy Storage for Resilience and Social Equity



PRESENTED BY

Summer Ferreira, Bobby Jeffers

Nov 05, 2021

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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RESILIENT — Society withstands and recovers from acute shocks, even ones never before experienced.

EFFICIENT — Society performs well day-to-day in the near-term future.

SUSTAINABLE — Society performs well over very long periods of time.

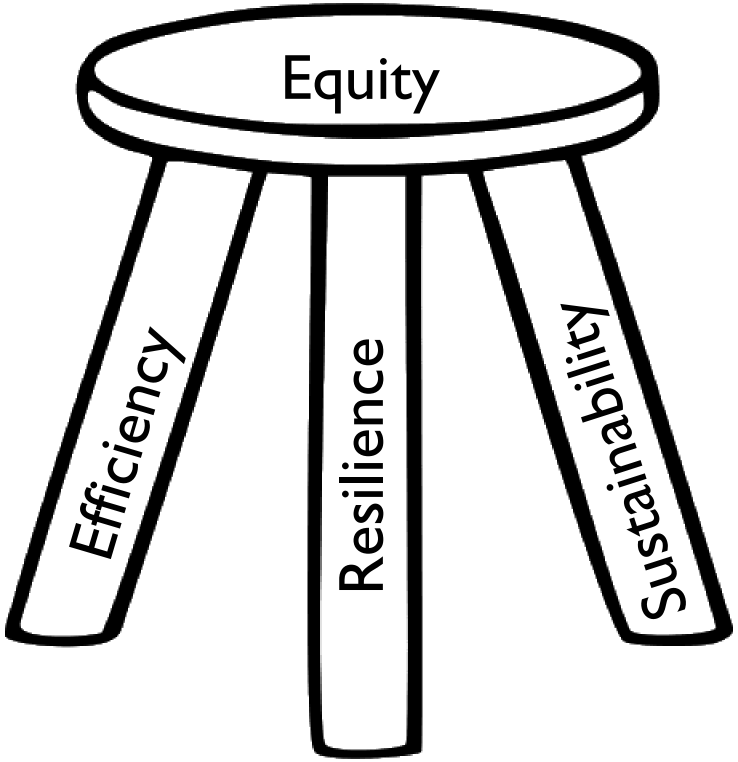
At all scales (T, D, Buildings), there are very real tradeoffs between performance in these dimensions.

Resilience is a component of Equity

Acute Social Burden

Energy Burden,
Equitable access to clean energy solutions,
…

Chronic environmental injustices,
…



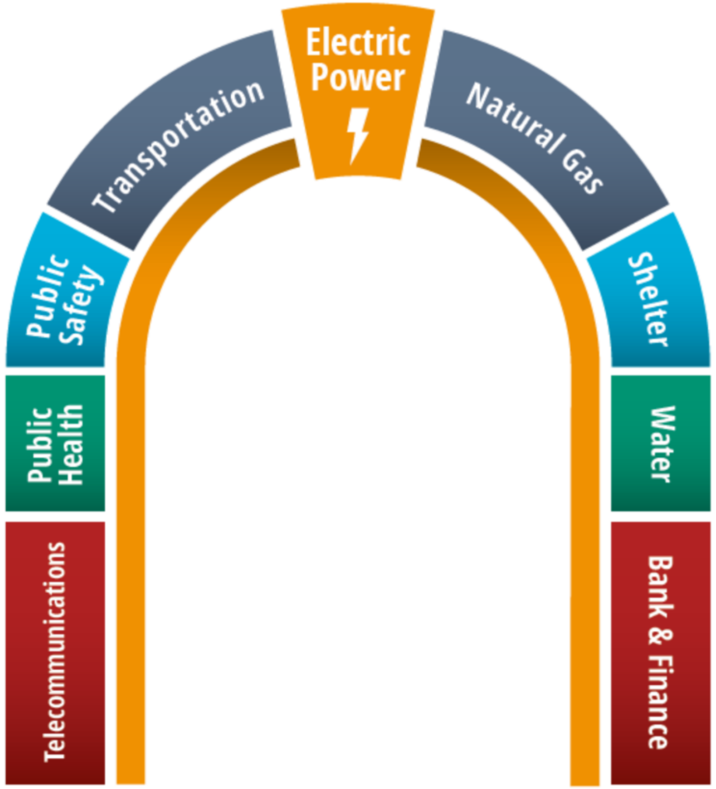
Cost of Service,
Customer Bills
…

GHG Emissions,
Land Use
…

Loss of Load Expectation
MWh not served
…

Convergence of Grid Resilience and Equity

- The grid is the keystone infrastructure – central to the web of interconnected systems that support life as we know it.
- During extreme events, prices do not reflect the value of all the services (food, water, shelter, etc.) that electricity provides
  - Consequence-focused **resilience is an externality** in power markets
  - The performance of the economy, military, and **society as a whole** are all important consequences



9 months after Hurricane Maria, thousands of Puerto Ricans still don't have power

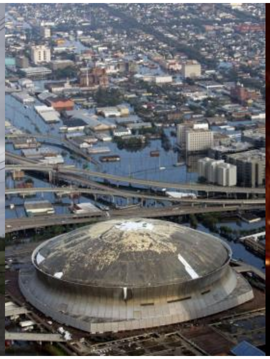
The grid is in worse shape than it was before Hurricane Maria.

By Umair Irfan | Updated Jun 20, 2018, 8:06am EDT

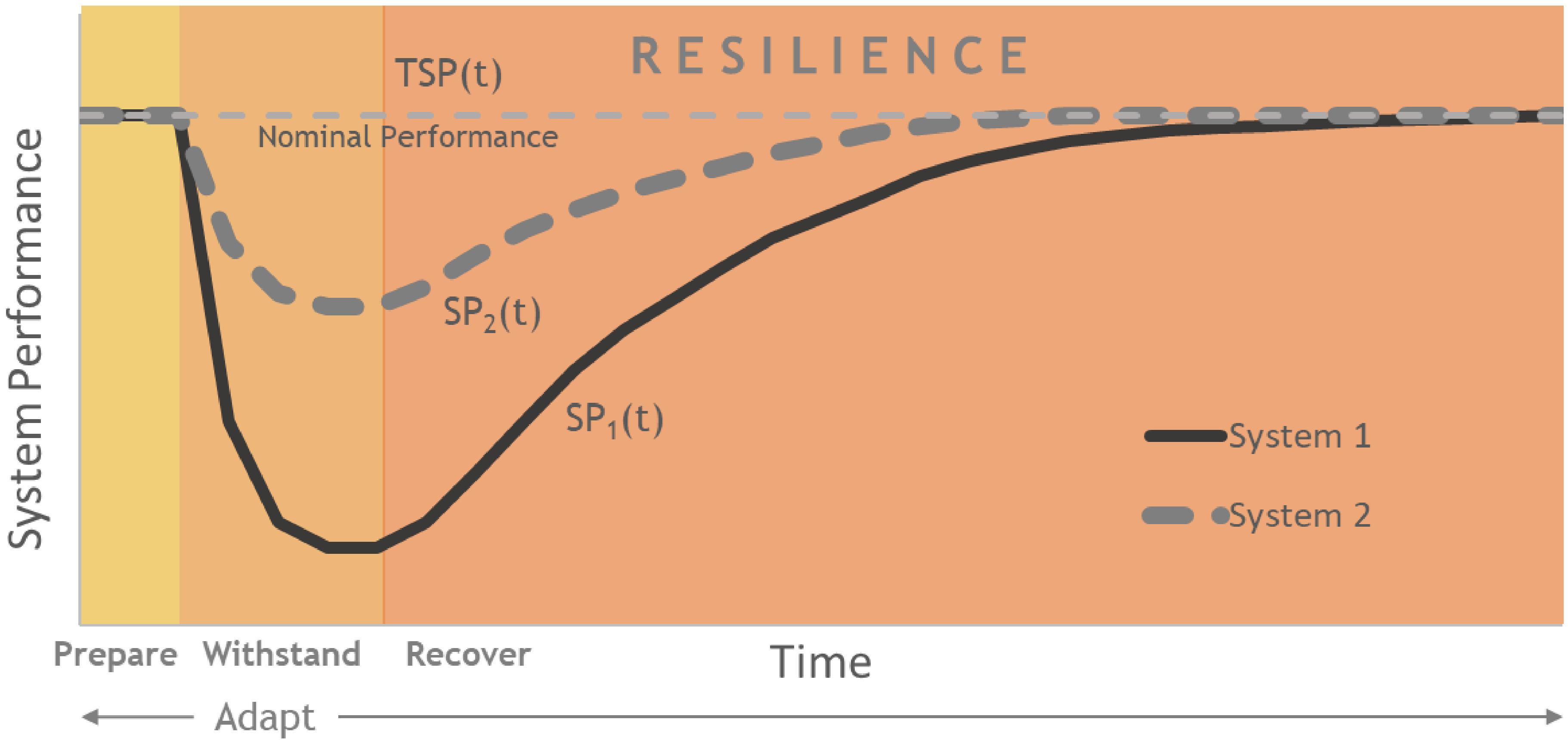
"It took Cardona 11 days to find a working phone and a cellular signal to let her mother in Florida know that she was okay. In the weeks following the storm, she woke up at 2 am to get in line for diesel fuel to run the generator at her father's home in Sabana Grande on the southwest coast of the island. After waiting for 13 hours, she went home empty-handed. She stood in lines that stretched blocks to get cash, since no electricity meant credit card readers weren't running."

Image credit: Wikimedia Commons user "Mdf"





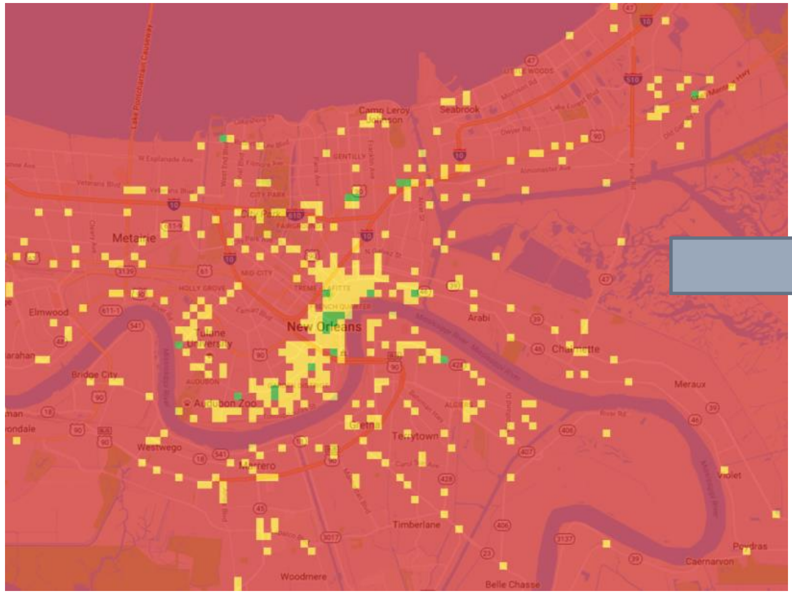
Measuring and forecasting resilience



Resilience metrics should:

- Convey the wide variance among outages in terms of size, duration, and impact on customers
- Capture the context of the threat environment
- Translate system performance into consequence, where the severity of consequences can change nonlinearly over time

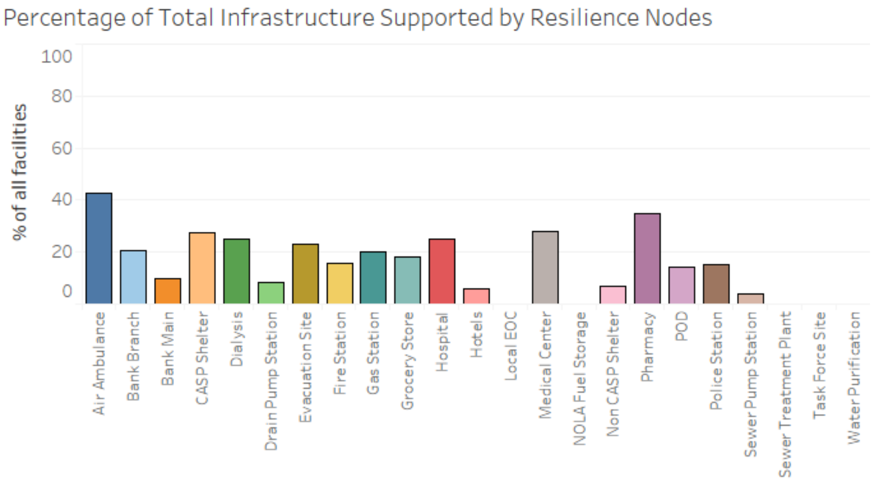
Outcome of GMLC New Orleans 2016



We have moved from “worst case” to “worst consequence” planning.

We need a metric for social resilience. Simply serving “critical” load is misleading.

The needs of multiple offices within local and state government are not adequately represented within power system planning.



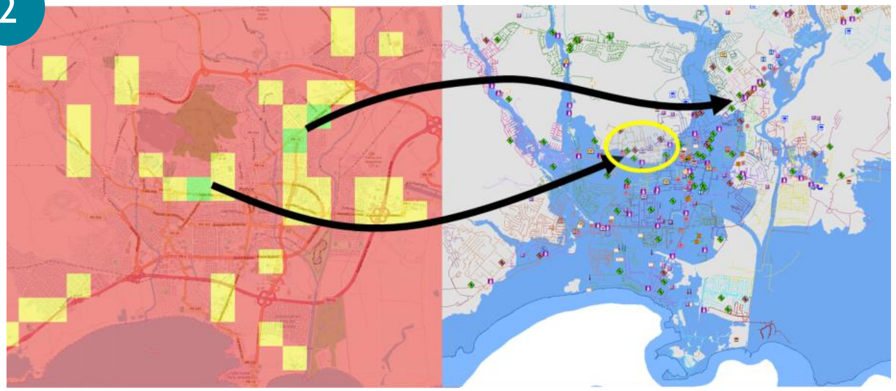
PR Recovery 2018

- During the **phase 1 PR recovery effort** in 2018, Sandia developed and demonstrated a process for siting and roughly sizing/costing microgrids with a focus on **social burden**.

- The phase 1 work furthered development of and utilized **ReNCAT 1.2** – an open-use tool that suggests clusters of assets that provides these services.

- Through utilization of ReNCAT and evaluation of microgrid resilience impacts using Social Burden, efficient portfolios (subsets) of 159 potential microgrids were identified

2



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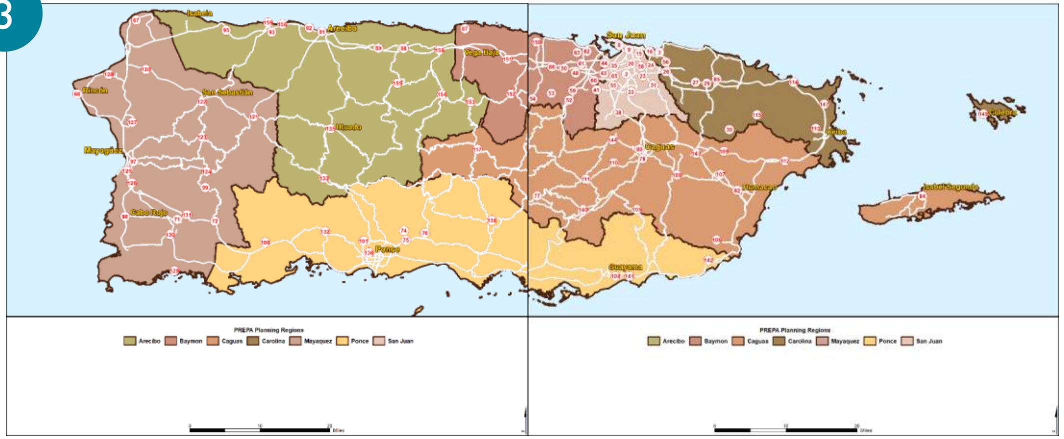

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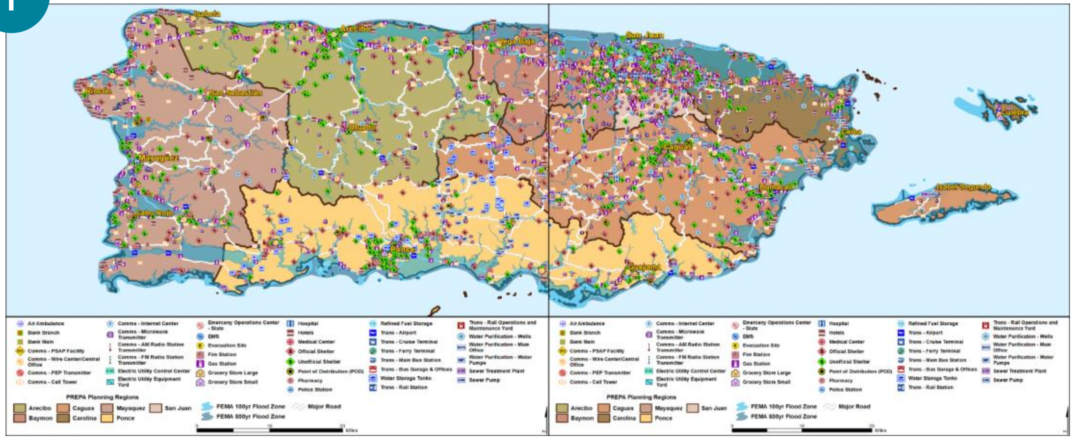
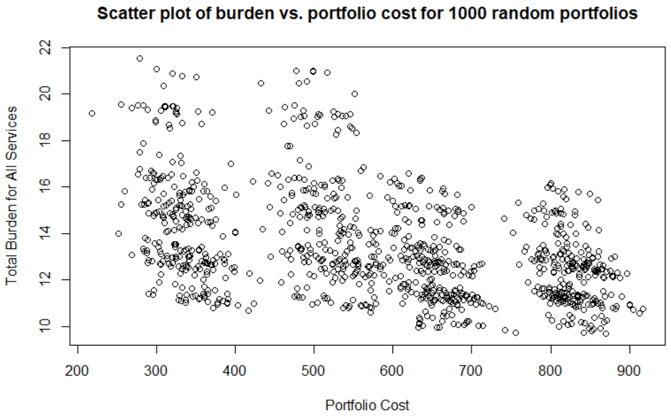


4

Social Burden

$$B_C = \sum_{inf} \sum_{pop} \frac{E_{inf,pop}}{A_{pop}}$$

inf = infrastructure service categories
pop = population groupings (census block groups)



Jeffers et al. (2018) Analysis of Microgrid Locations Benefitting Community Resilience for Puerto Rico. SAND2018-11145

Quantifying Social Resilience

Capabilities framework, based on Sen and Nussbaum, applied to energy by Day et al.

University at Buffalo
The State University of New York

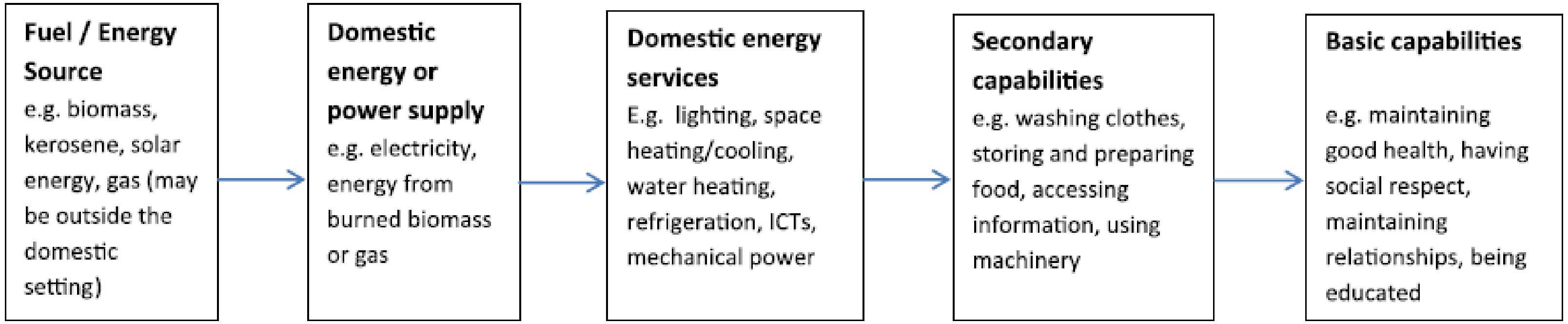


Fig. 1. Conceptualising the relationship between energy, services and outcomes.

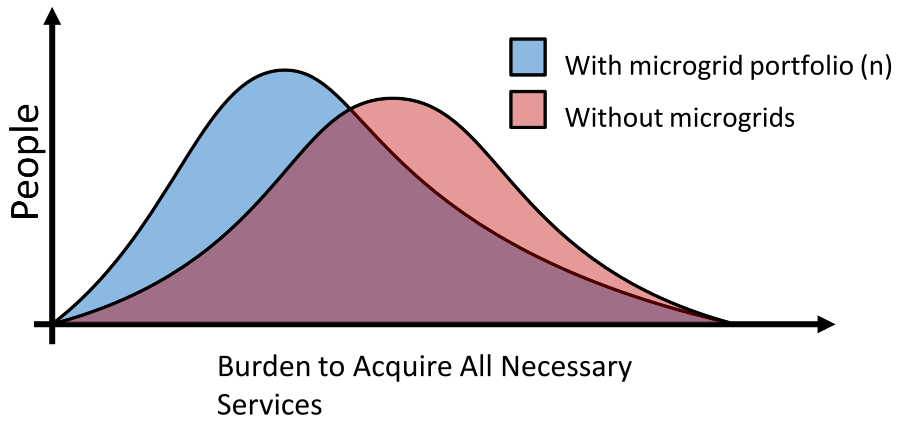
We are utilizing this theory, but advancing/extending in two ways:

- Chronic vs. Acute: we are applying the capabilities framework to acute, post disaster scenarios, whereas previous literature focuses on chronic "blue sky" capabilities
- Rigorous Quantification: we are the first to apply a mathematical formulation to the theory

Nussbaum, Capabilities as fundamental entitlements: Sen and social justice. 2003; Sen, Human Rights and Capabilities. 2005;
Day, R., Walker, G., Simocck, N. Conceptualising energy use and energy poverty using a capabilities framework. Energy Policy. 2016.

Performance Based Metric: Social Burden

The **social burden metric** calculates how hard society is working to achieve their basic human needs.



Effort

Time + money spent to achieve basic level of human needs

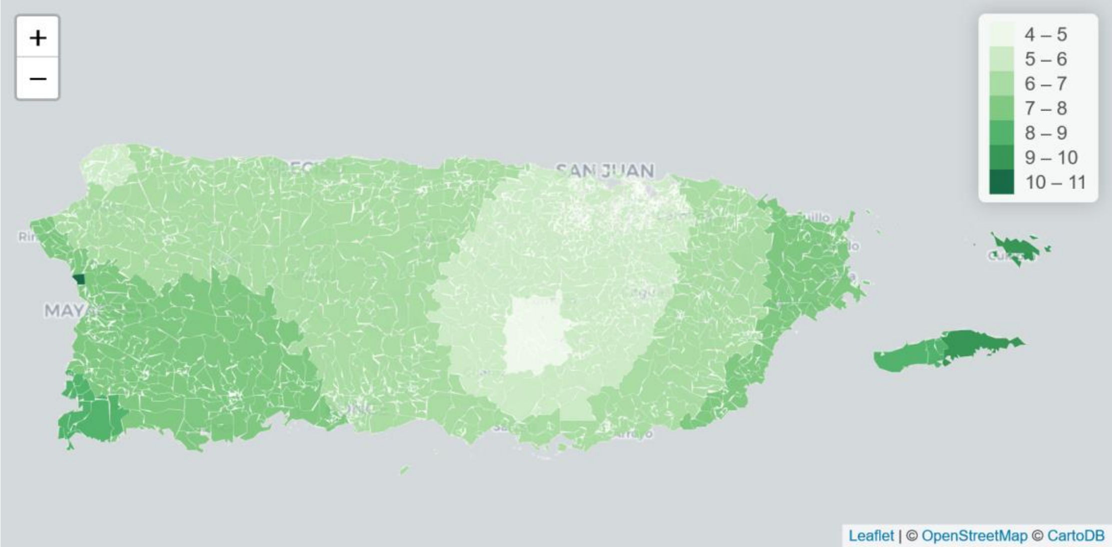
Ability

Median household income
Additional predictors

Burden

$$B_C = \sum_{inf} \sum_{pop} \frac{E_{inf,pop}}{A_{pop}}$$

Effort for a portfolio of 80 microgrids

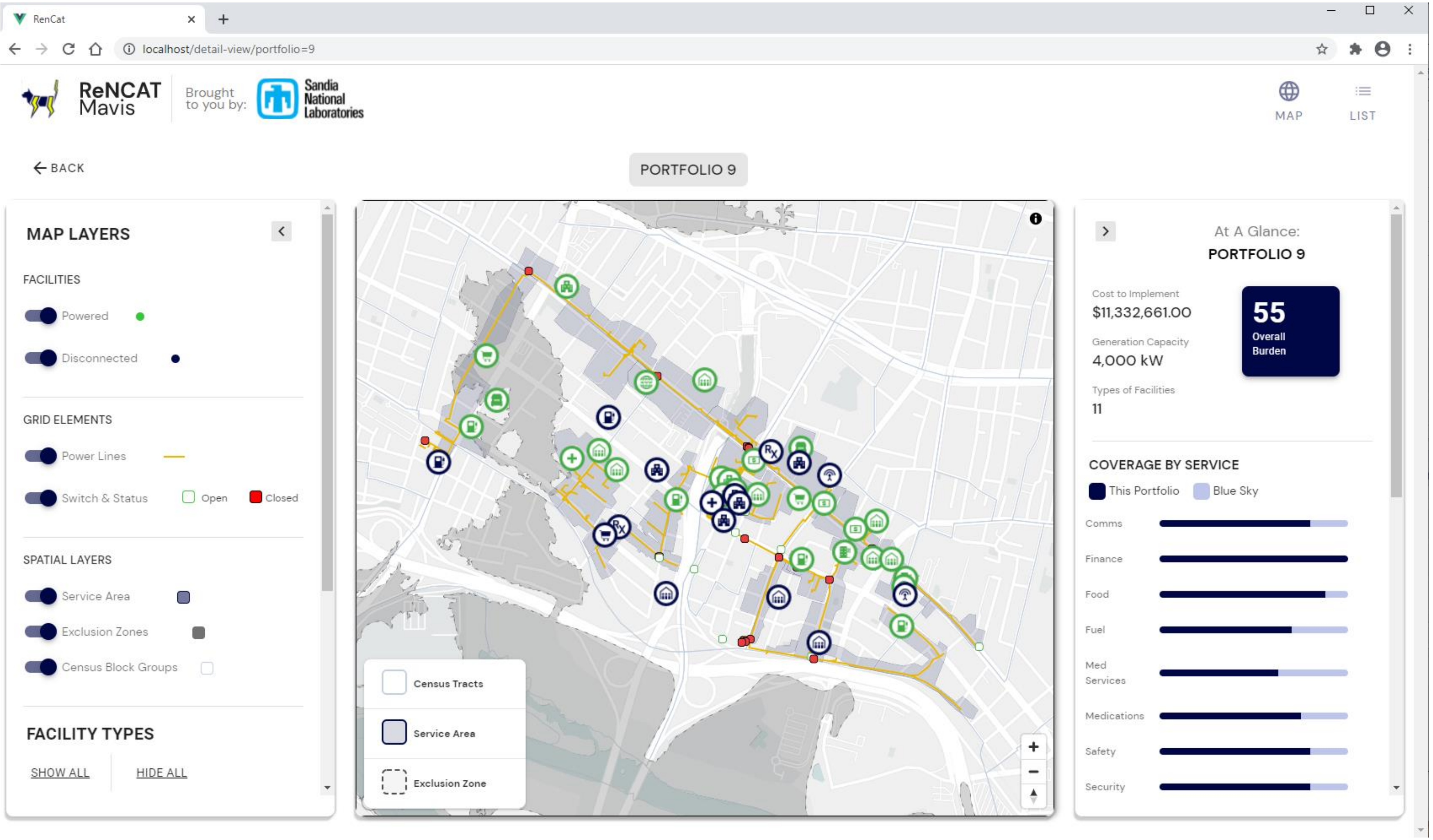


Social Burden for the same portfolio

Social Burden Applied to Grid Planning

Resilience Node Cluster Analysis Tool (ReNCAT)

- Uses genetic algorithm to site and size resilience solutions across a broad landscape
- Creates portfolios of resilience solutions that optimize for social burden vs. cost
- Grid and other critical infrastructure are explicitly modeled



Validating, Applying, Socializing

Validate

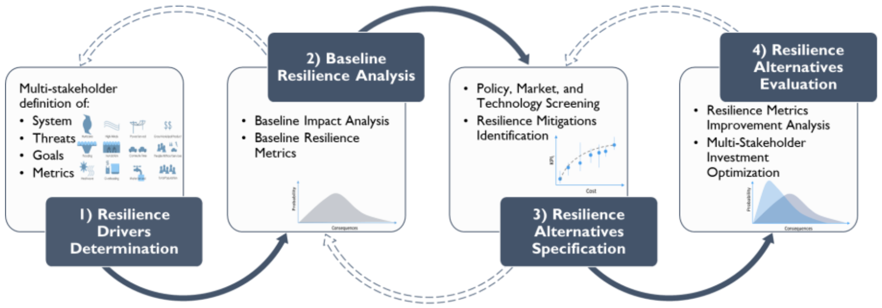
SAFEGRAPH

University at Buffalo
The State University of New York

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

1. **Data**: Do we have the data to calculate social burden ex post?
2. **Surveying**: What data can we receive directly from those impacted?
3. **Mod/Sim**: Improve connection between theory and calculation

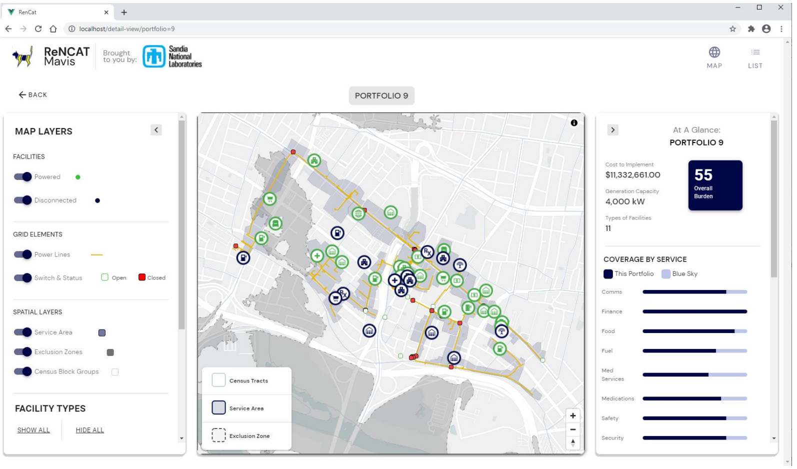
Socialize



DRC Stakeholder Advisory Group:

- New York + ConEd
- Los Angeles + LADWP
- Norfolk + Dominion Energy
- Boston + Eversource
- Honolulu + HECO
- San Antonio + CPS Energy
- National Association of Utility Regulatory Commissioners (NARUC)

Apply



Current:
Puerto Rico (3 x)
San Antonio
Colorado Springs

Remaining gaps

State Public Utility Commissions do not have a standardized planning and valuation process for resilience
- Standardization of metrics and approaches
- Desire to integrate across goals (decarbonization, equity, affordability, etc.)

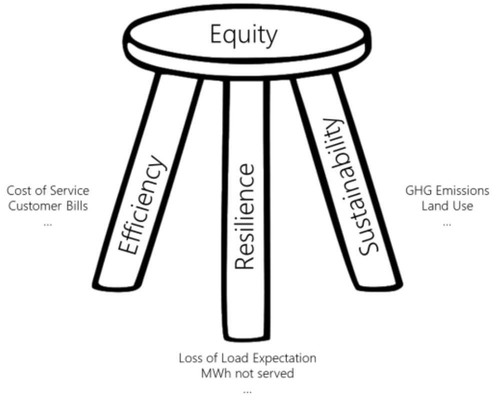
Equity and Environmental Justice are inherently multi-dimensional
- Be specific about which dimension of EEEJ is being improved or internalized

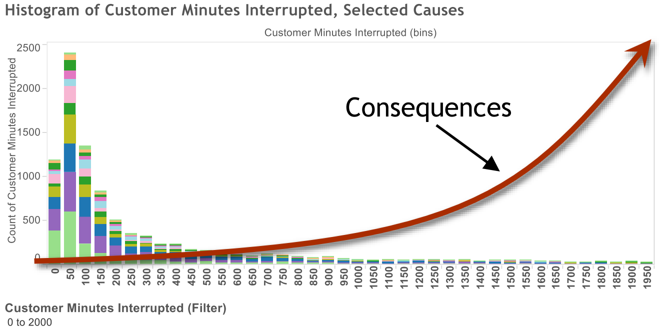
Within the Equity space, qualitative approaches remain valuable
- A complement to quantitative approaches
- What improves wellbeing?

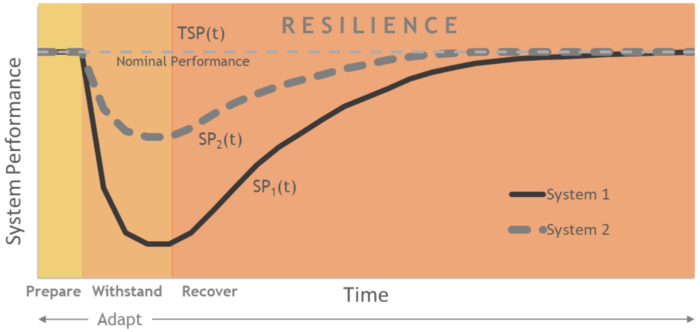
For public goods such as equity / resilience, who pays?
- Depending on the benefits, a combination of private ventures, ratepayers, taxpayers
- The question is what proportion and through what mechanisms

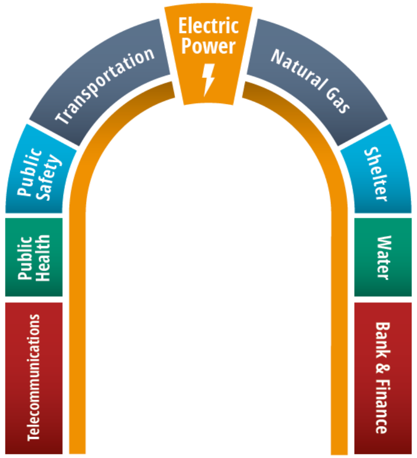
Thank You!

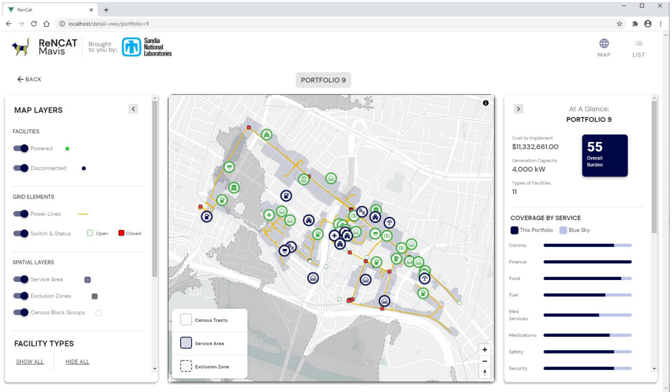
rfjeffe@sandia.gov



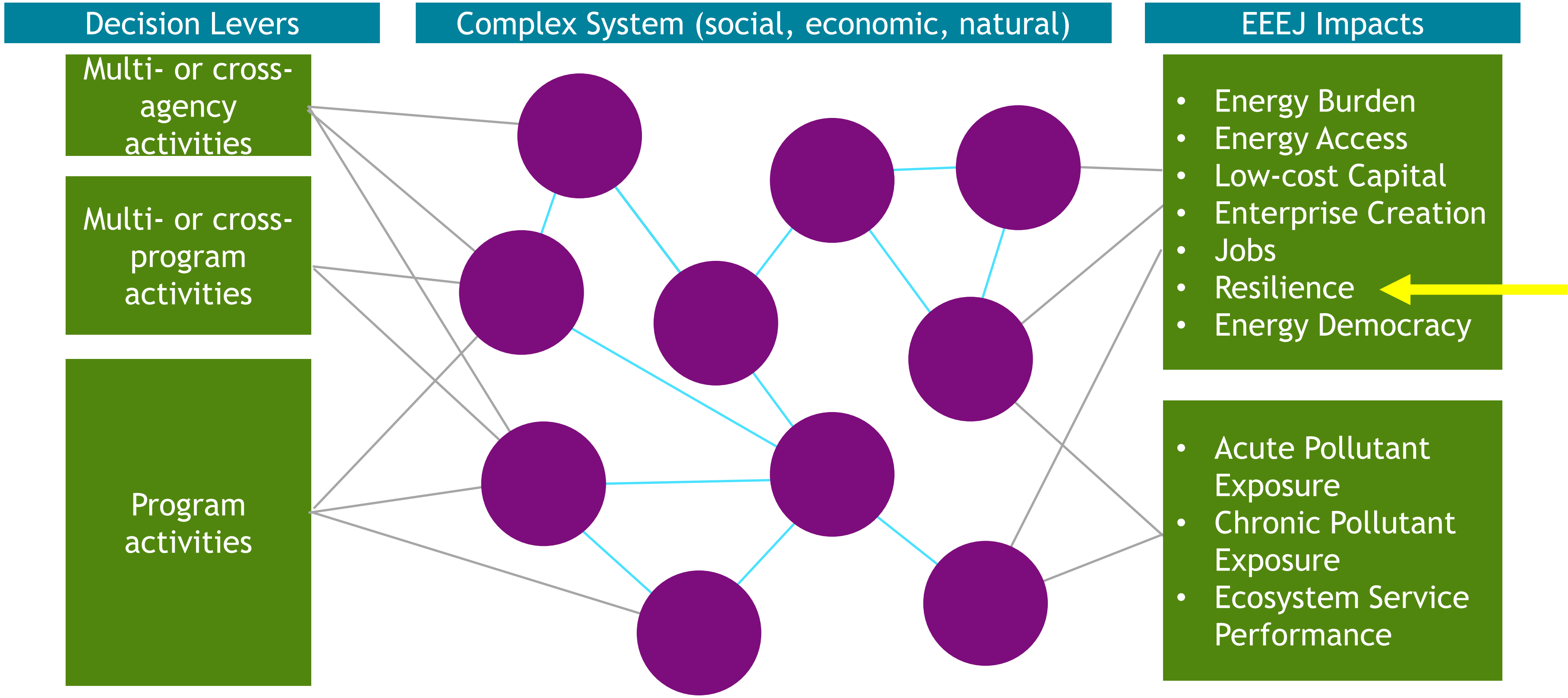








Equity is inherently multi-dimensional



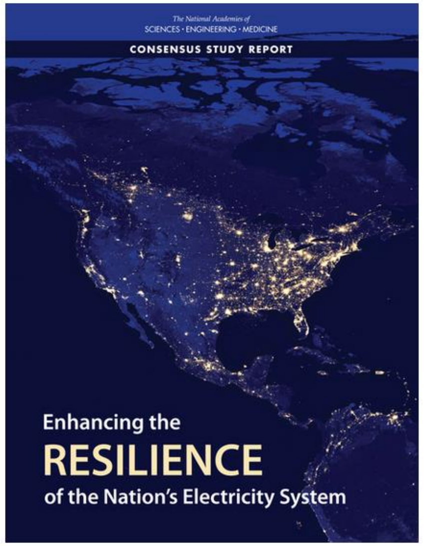
What are potential high-leverage activities (existing and potential) across the Energy Equity and Environmental Justice (EEEJ) impact categories?

Resilience Metrics

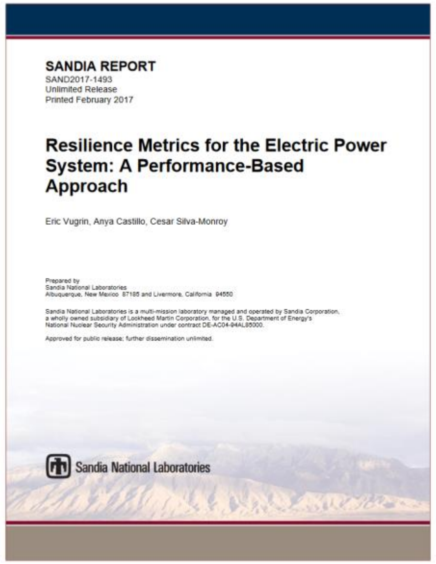
Attribute-based:
- What makes the system more/less resilient?
- Things you can count now (on a blue-sky day)
- Often grouped into categories that describe some aspect of resilience
  - Robustness, adaptivity, recoverability, etc.
- Often populated via surveys or checklists
  - Relatively simple to populate

Performance-based:
- How resilient is/was the system?
- Things you can measure only during disruption
- Often uses data from an event or a model of an event
  - Can be difficult to populate for planning
- Useful to weigh resilience against other goals
  - (e.g. within benefit cost analysis)

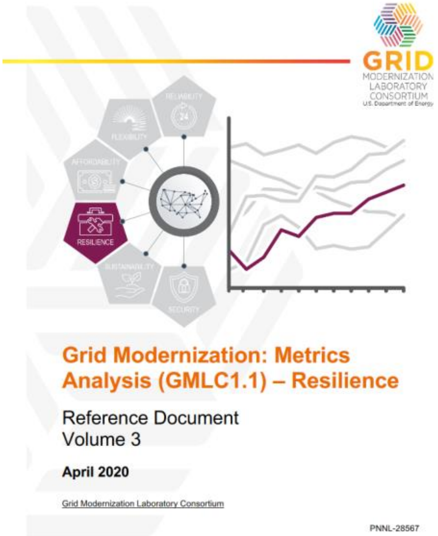
Either approach can be:
- Retrospective or forward-looking
- Power-focused or consequence-focused
- Threat-informed or threat-agnostic



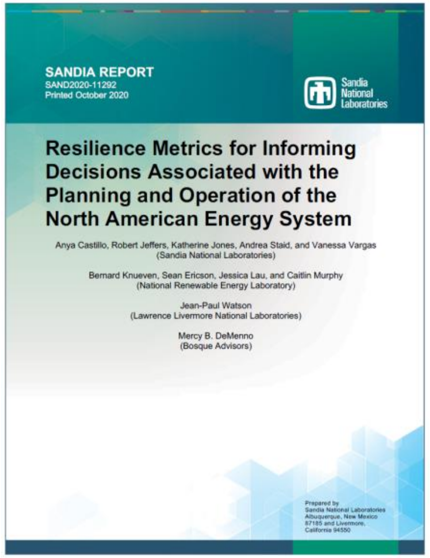
National Academies (2017), Recommendation #1 to DOE: "Improve understanding of customer and societal value associated with increased resilience and review and operationalize metrics for resilience…"



Vugrin et al. (2017) under GMLC 1.1 Foundational Metrics: First power-focused discussion of attribute-based and performance-based resilience metrics.

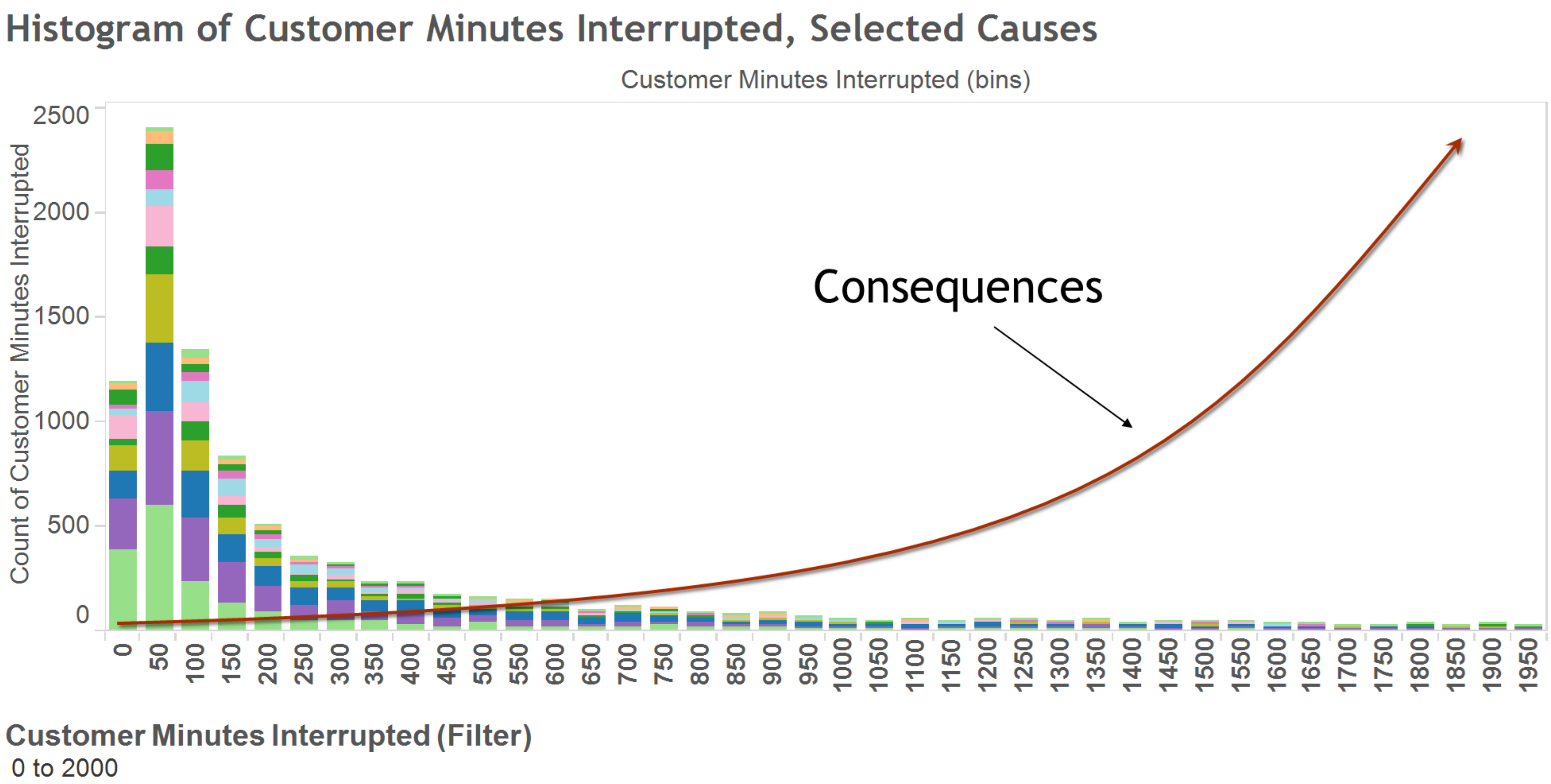


GMLC 1.1 Final Report (2020): Begins to clarify how attribute and performance-based approaches can complement.



NAERM Metrics Report (2020): Describes consequence dimensions and metric formulation

Beyond infrastructure performance – to consequence



Social Burden Explained

Service Layer $[\tilde{f}]$

Transportation Layer $[\tilde{J}]$

Social Layer $[\tilde{S}]$

Social Burden $_{Food}$

$= f(\tilde{f}, \tilde{J}, \tilde{S})$

$$Social\ Burden_{S,f} = \int_{t0}^{tf} \frac{1 \Big/ \sum_{inf} Svc_{inf} \Big/ E_{inf}}{Ability}$$

Units:
Hours of effort per dollar of ability