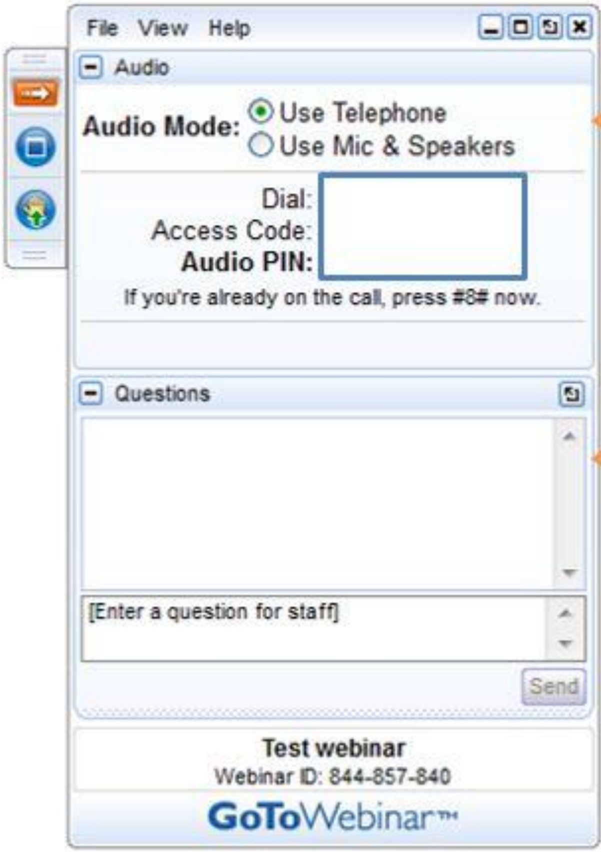
Energy Storage Technology Advancement Partnership (ESTAP) Webinar:

Microgrid Technologies: A Guide to CHP, Energy Storage, PV and Fuel Cells

April 4, 2014

Housekeeping



All participants are in "Listen-Only" mode. Select "Use Mic & Speakers" to avoid toll charges and use your computer's VOIP capabilities. Or select "Use Telephone" and enter your PIN onto your phone key pad.

Submit your questions at any time by typing in the Question Box and hitting Send.

This webinar is being recorded.

You will find a recording of this webinar, as well as all previous CESA webcasts, archived on the CESA website at

http://www.cleanenergystates.org/webinars/

State & Federal Energy Storage Technology Advancement Partnership (ESTAP)

Todd Olinsky-Paul

Project Director

Clean Energy States Alliance

Thank You:

Dr. Imre Gyuk
U.S. Department of Energy,
Office of Electricity Delivery and
Energy Reliability

Dan Borneo
Sandia National Laboratories

CleanEnergy States Alliance

Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

ESTAP is a project of CESA

Clean Energy States Alliance (CESA) is a non-profit organization providing a forum for states to work together to implement effective clean energy policies & programs:

- Information Exchange
- Partnership Development
- Joint Projects (National RPS Collaborative, Interstate Turbine Advisory Council)
- Clean Energy Program Design & Evaluations
- Analysis and Reports

CESA is supported by a coalition of states and public utilities representing the leading U.S. public clean energy programs.

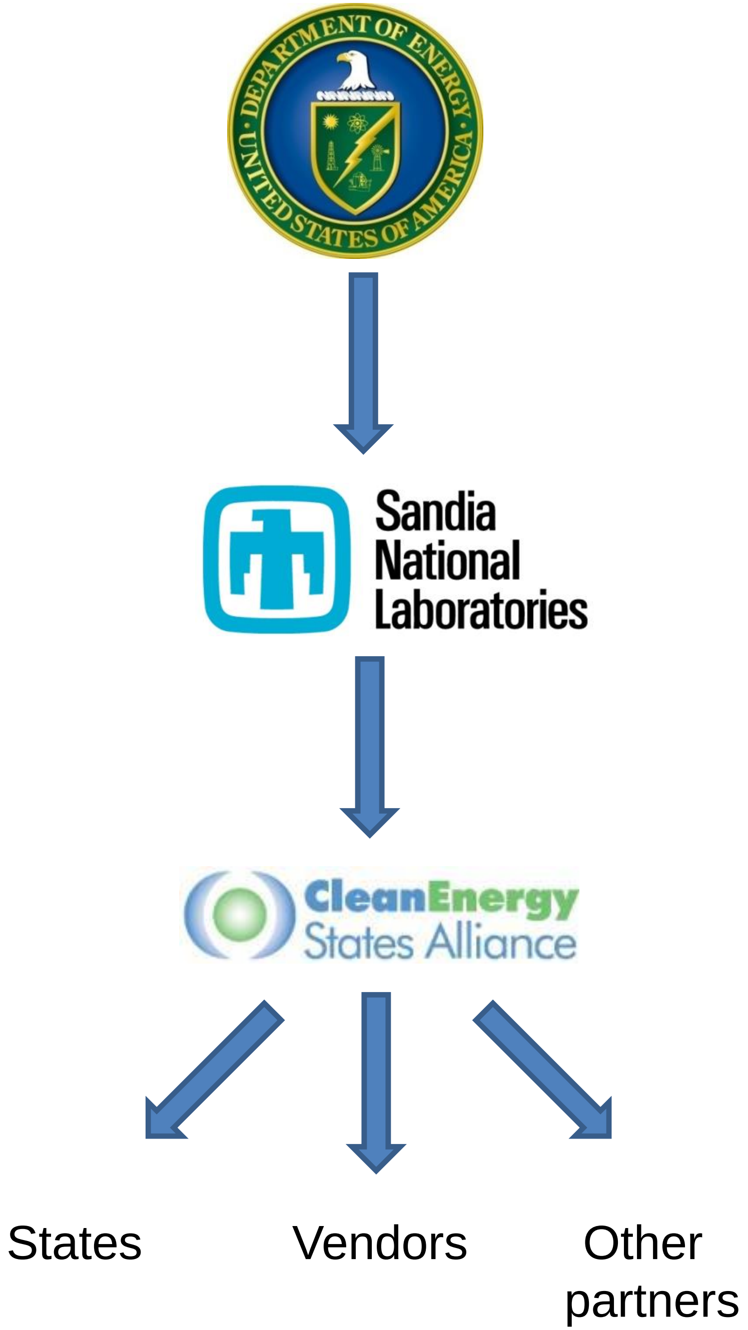
Clean Energy States Alliance   Sandia National Laboratories   U.S. DEPARTMENT OF ENERGY

ESTAP* Overview

Purpose: Create new DOE-state energy storage partnerships and advance energy storage, with technical assistance from Sandia National Laboratories

Focus: Distributed electrical energy storage technologies

Outcome: Near-term and ongoing project deployments across the U.S. with co-funding from states, project partners, and DOE



* (Energy Storage Technology Advancement Partnership)

ESTAP Key Activities

1. Disseminate information to stakeholders

    - ESTAP listserv >500 members
    - Webinars, conferences, information updates, surveys

2. Facilitate public/private partnerships at state level to support energy storage demonstration project development

    - Match bench-tested energy storage technologies with state hosts for demonstration project deployment
    - DOE/Sandia provide $ for generic engineering, monitoring and assessment
    - Cost share $ from states, utilities, foundations, other stakeholders

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ESTAP Webinars

Policy Webinars:

- Introduction to the Energy Storage Guidebook for State Utility Regulators
- Briefing on Sandia's Maui Energy Storage Study
- The Business Case for Fuel Cells 2012
- State Electricity Storage Policies
- Highlights of the DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA

Technology Webinars:

- Smart Grid, Grid Integration, Storage and Renewable Energy
- East Penn and Ecoult Battery Installation Case Study
- Energy Storage Solutions for Microgrids
- Applications for Redox Flow Batteries
- Introduction to Fuel Cell Applications for Microgrids and Critical Facilities
- UCSD Microgrid

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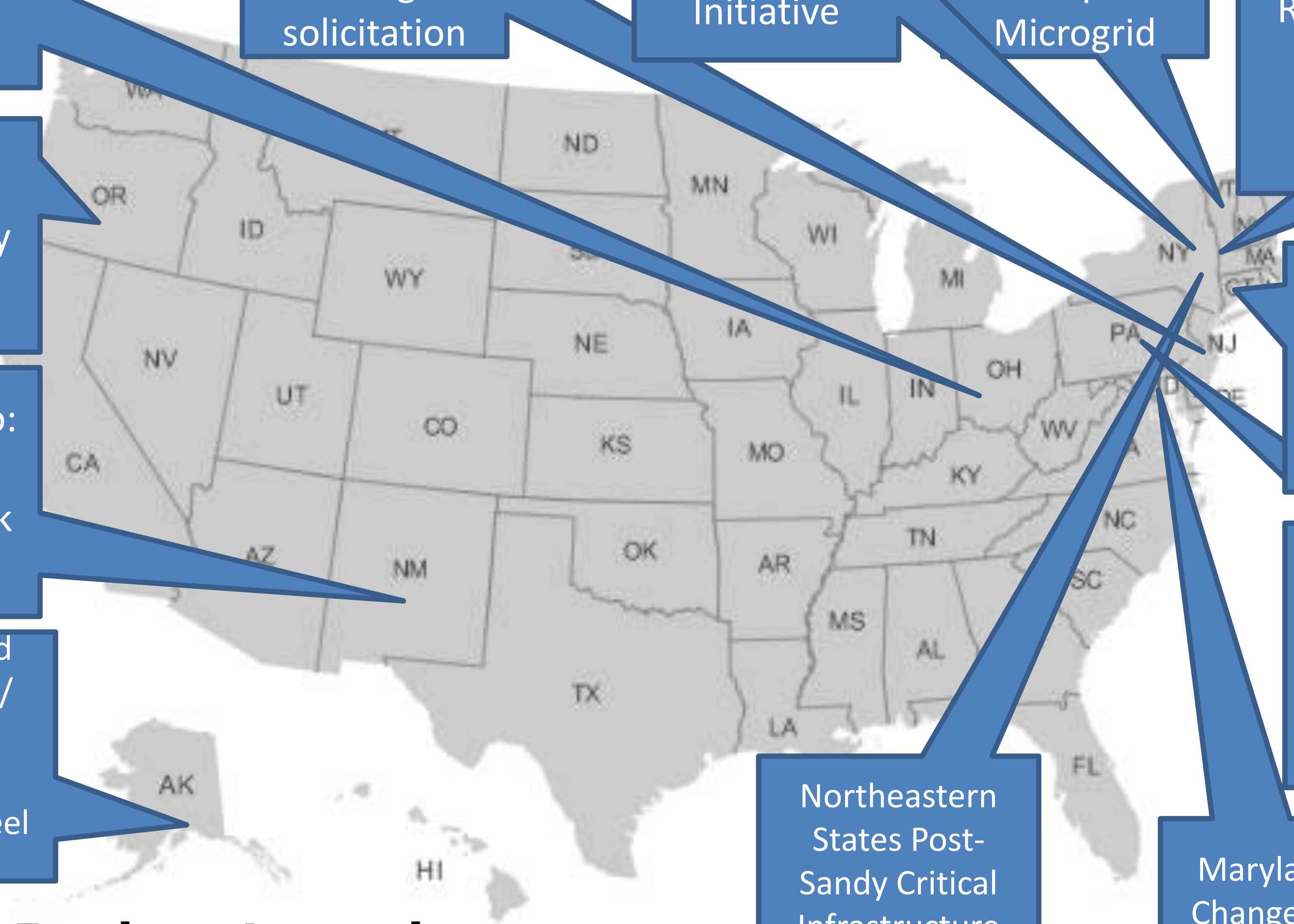

Ohio: Potential project

New Jersey: 4-year energy storage solicitation

New York $40 Million Microgrids Initiative

Vermont: PV/energy storage RFP & Airport Microgrid

Massachusetts: $40 Million Resilient Power Solicitation

Oregon: Initiating state energy storage effort

Connecticut Microgrids Initiative Rounds 1 & 2

New Mexico: Energy Storage Task Force

Pennsylvania battery demonstration project

Kodiak Island Wind/Hydro/ Battery & Cordova Hydro/flywheel projects

Northeastern States Post-Sandy Critical Infrastructure Resiliency Project

Maryland Game Changer Awards: Solar/EV/Battery

ESTAP Project Locations

Clean Energy States Alliance

Sandia National Laboratories

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Today's Guest Speakers

Veronica Szczerkowski, Microgrid Program Coordinator, Connecticut Department of Energy and Environmental Protection

Paul Michaud, Attorney, Murtha Cullina LLP

Dan Borneo, Engineering Project Manager, Sandia National Laboratories

Tom Bourgeois, Acting Executive Director**,** Pace Energy and Climate Center

ESTAP Contact Information

CESA Project Director:

Todd Olinsky-Paul (Todd@cleanegroup.org)

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Dan Borneo (drborne@sandia.gov)

Webinar Archive: www.cleanenergystates.org/webinars

ESTAP Website: http://www.cleanenergystates.org/projects/energy-storage-technology-advancement-partnership/

ESTAP Newsletter: http://www.cleanenergystates.org/projects/energy-storage-technology-advancement-partnership/energy-storage-listserv-signup/

Today's Guest Speakers

Tom Bourgeois, Acting Executive Director**,** Pace Energy and Climate Center, tbourgeois@law.pace.edu

Dan Borneo, Engineering Project Manager, Sandia National Laboratories, drborne@sandia.gov

Paul Michaud, Attorney, Murtha Cullina LLP, pmichaud@murthalaw.com

Veronica Szczerkowski, Microgrid Program Coordinator, Connecticut Department of Energy and Environmental Protection, veronica.szczerkowski@ct.gov

Getting Ahead of the Curve:

Connecticut's First-in-the-Nation Statewide Microgrid Program

Connecticut Department of
ENERGY & ENVIRONMENTAL PROTECTION

Getting Ahead of the Curve: Connecticut's First-in-the-Nation Statewide Microgrid Program

Round 2 Educational Webinar Series

Toward Cheaper, Cleaner, More Reliable Energy

Microgrid Program – Educational Webinar Series

- Educational webinar series
  - – • Overview of project financing options– March 25, 2014 from 1:00-2:00pm EDT
  - – • Technical aspects of microgrids –April 2, 2014 from 10:00-11:30am EDT
  - – • Other microgrid assistance (legal, process, etc.) – April 3, 2014 from 10:00-11:00am EDT
  - – • Clean generation, renewable generation, storage – April 4, 2014 time 11:00-12:30pm EDT
    - **Representatives from REEBA, PACE Law School, the Clean Energy States Alliance and Sandia National Laboratory will discuss how clean and renewable generation resources as well as storage can be incorporated into a microgrid.**

Microgrid Program – Questions

- What if you still have questions?
  - Ask them today
  - Put them in writing to DEEP – DEEP.EnergyBureau@ct.gov
    - Must be received by April 18, 2014
    - Replies will be posted by May 1, 2014

Thanks for listening

Contact Information:

DEEP Microgrid Program Team

Connecticut Department of Energy and Environmental Protection

DEEP.Energybureau@ct.gov

Link to Microgrid Program information:

http://goo.gl/pbr9FT

Renewable Energy and Efficiency Business Association, Inc.

Webinar:
Microgrid Technologies – A guide to PV, Wind and Fuel Cells for Connecticut Municipalities and Other Interested Parties

Paul R. Michaud, Esq.
Founder & Executive Director

April 4, 2014

What is REEBA?

With over 70 members, REEBA is an active business organization that promotes the sustainable deployment of renewable energy, demand-side management and energy efficiency in Connecticut.

Member Benefits:

- Advocacy
- Networking
- Information Sharing

CT Class I Renewable Generation For Microgrids

- Photovoltaic
- Wind
- Fuel Cells

Photovoltaic & Wind

- To be counted toward microgrid capacity, PV and Wind systems must be paired with Energy Storage (e.g. batteries)
- Energy Storage must allow the power produced by the PV or Wind resource to be utilized 24/7 when islanded

Photovoltaic & Wind - *continued*

- PV or Wind may still be a useful subset of a microgrid generation system
- Current technology may allow PV or Wind to tie into the microgrid distributed generation output when the grid is down via a reference voltage such as a fuel cell

Fuel Cells for Microgrids

- Ultra-clean
  - Class 1 Renewable Energy Source in Connecticut
- High Efficiency
  - Electric-only: 42% - 50% LHV
  - System efficiencies for CHP fuel cells: 55% - 90% LHV
- Relatively Low operating costs

Fuel Cells - *continued*

- Reliability/Capacity Factor (80-95%)
- Availability (over 90%)
- Continuous operation with or without the grid
  - Creates a viable economic model for majority of operating time
- Load following (select fuel cell technologies)

Fuel Cells - *continued*

- Preventative Maintenance: May be done while fuel cell is running base load (select fuel cell technologies)
- Competitive Life Cycle Cost vs. CHP
- Cleaner than non-renewable CHP
- Exempt from air permitting requirements

Emissions Reductions and Energy Savings

- Fuel cell generation facilities can substantially reduce emissions, greenhouse gases, and energy use

Potential Average Annual Emissions Reduction and Energy Savings Associated with the Displacement of 1 MW of Conventional Fossil Fuel Generation			
Air Emissions		Energy Savings	
NO_X	5.6 tons	Btu	35 – 40 Million
SO_2	4.7 tons	No. 2 Oil Equivalent	250,000 – 300,000 Gallons
CO_2	3,609 tons		

Source: Connecticut Center for Advanced Technology, Inc.

Selected Fuel Cell Installations in CT

- Pepperidge Farms Bakery – Bloomfield, CT
- Middletown High School – Middletown, CT
- Cabelas – East Hartford, CT
- New Haven Water Pollution Control Authority – New Haven, CT
- St. Francis Hospital – Hartford, CT
- Yale University – New Haven, CT
- Connecticut Science Museum – Hartford, CT
- Whole Foods Market – Glastonbury, CT
- Mohegan Sun – Uncasville, CT

Fuel Cells - Enablers

- Fuel cells meet DEEP's generation requirement for microgrid funding
  - Avg. availability across all technologies ~90%
- Financial flexibility
  - PPA
  - Lease-to-buy
  - Energy service agreement (lease-only)
  - LREC Auction Program
  - CEFIA programs (CPACE)

Fuel Cells - Enablers

- Supportive regulatory framework in Connecticut
  - Retail rate net metering
  - Virtual net metering (State. Muni, & Ag.)
  - Standby charge waiver ≤ 1MW
  - Natural gas rebate (T&D charges waived for Class 1 and Class III technologies)
  - Demand ratchet waiver (reduced from 12 mos. to 1 mo.)

Potential Obstacles/Opportunities

- Interconnection into microgrid
- Who owns/operates the fuel cell?
- Who operates the fuel cell?
- How do microgrid customers of the fuel cell pay for the power?
- Siting

Thank You!

pmichaud@murthalaw.com

Sandia National Laboratories

Exceptional service in the national interest

Electrical Energy Storage for Microgrids

Daniel Borneo, P.E.

Presentation for

Connecticut DEEP

April 2014

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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SAND Doc # **5334539**

AGENDA –

Presentation Outline

- A Brief Look at Energy Storage in a microgrid and What to Do, Know and Watch out for
  - Applications and benefits of Energy Storage (ES) in a microgrid
  - Project considerations
    - Project design
    - Project team
    - Testing and commissioning
  - ES technologies/systems that might be best suited

Stimulate more questions than will answer

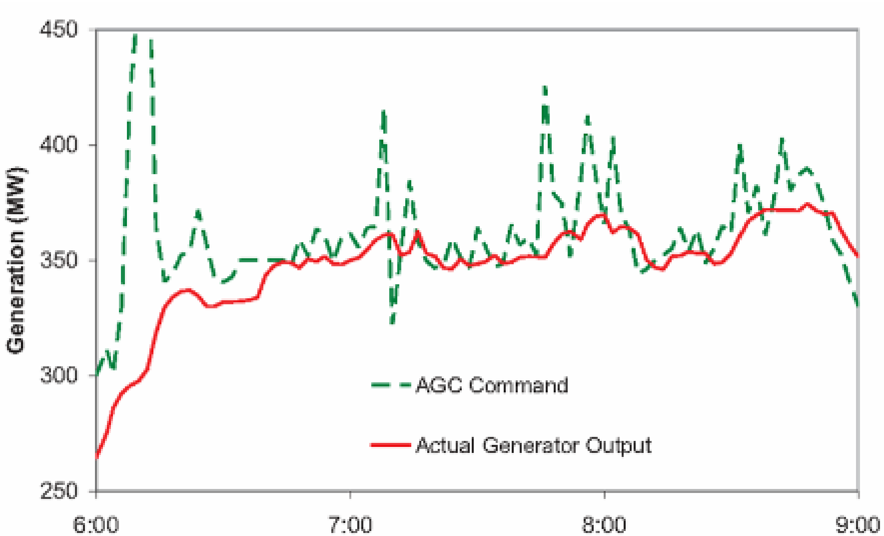
Applications and Benefits of Energy Storage in a Microgrid?

Application and Benefits of ES in a Microgrid

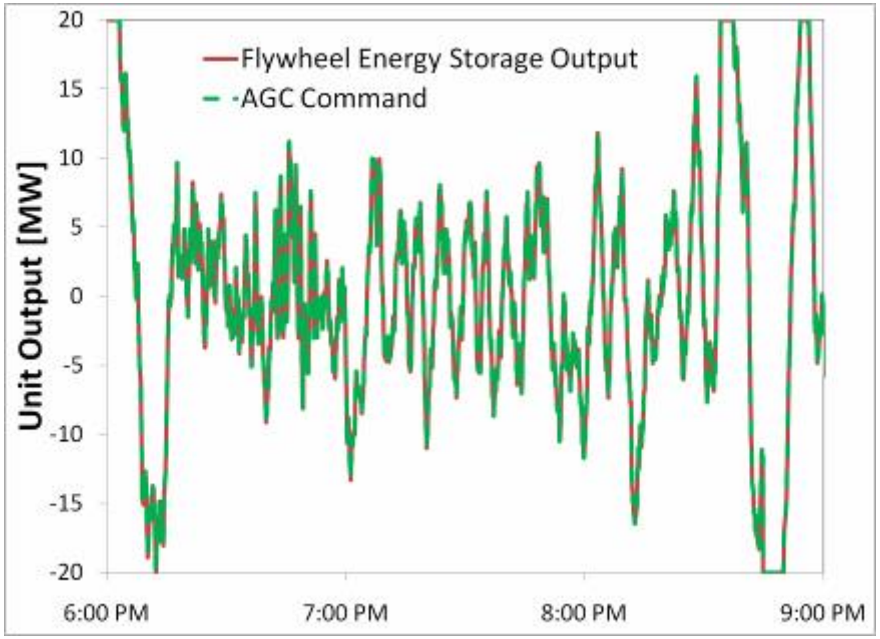
- Power Quality/ Reliability/UPS: Can provide instantaneous ride through during power glitches or momentary interruptions.
- Demand Reduction: Can be utilized to decrease peaking load on the grid, which may eliminate need for upgrade to distribution equipment.
- Renewable Energy and Distributed Energy support: Can provide steady source of energy during any variability caused by Renewables or other Distributed Energy Resources (DER).
- Generator Support: Can provide generator load to increase generator efficiency and if matched to load, ES can be used to reduce generator run time.

ES SERVING MULTIPLE APPLICATIONS IS THE MOST COST EFFECTIVE.

Fast Response: Speed Matters



Significance of ES Contribution

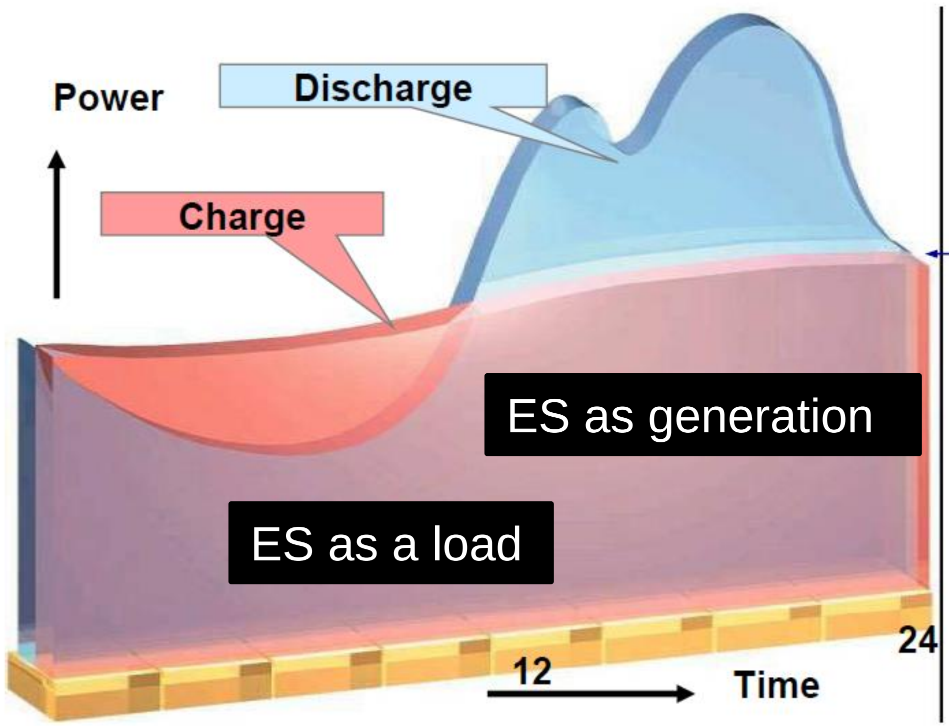


ES Attributes

- Storage has a near instantaneous response
- Provides Power Quality and ride through
- Helps firm variable generation like wind & solar

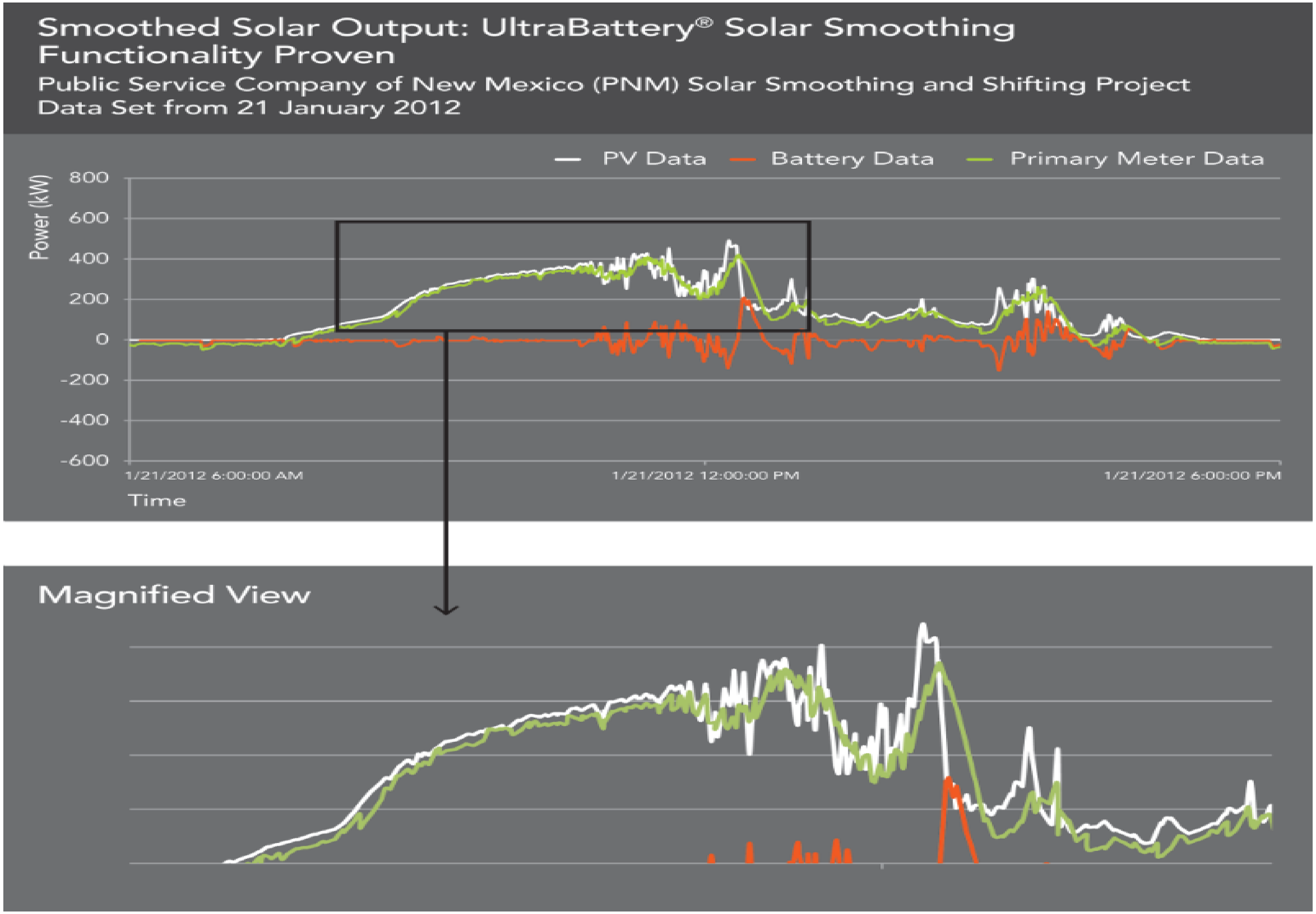
Storage for Load/Power balancing is new state of the art

Storage Applications – Demand Reduction



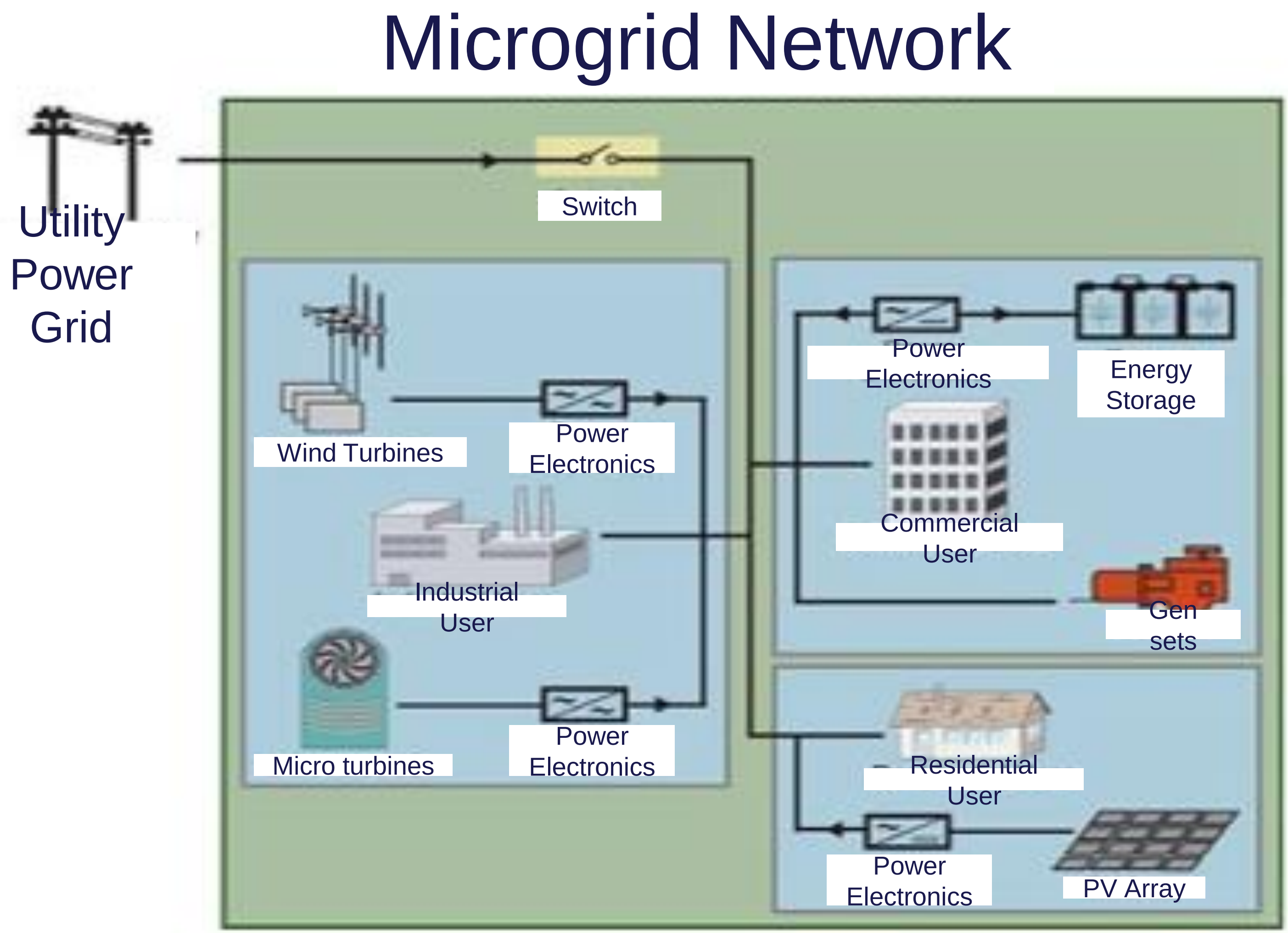
- Energy Shifting
  - Gen run-time reduction
  - DER Support
  - Arbitrage

PV-intermittency

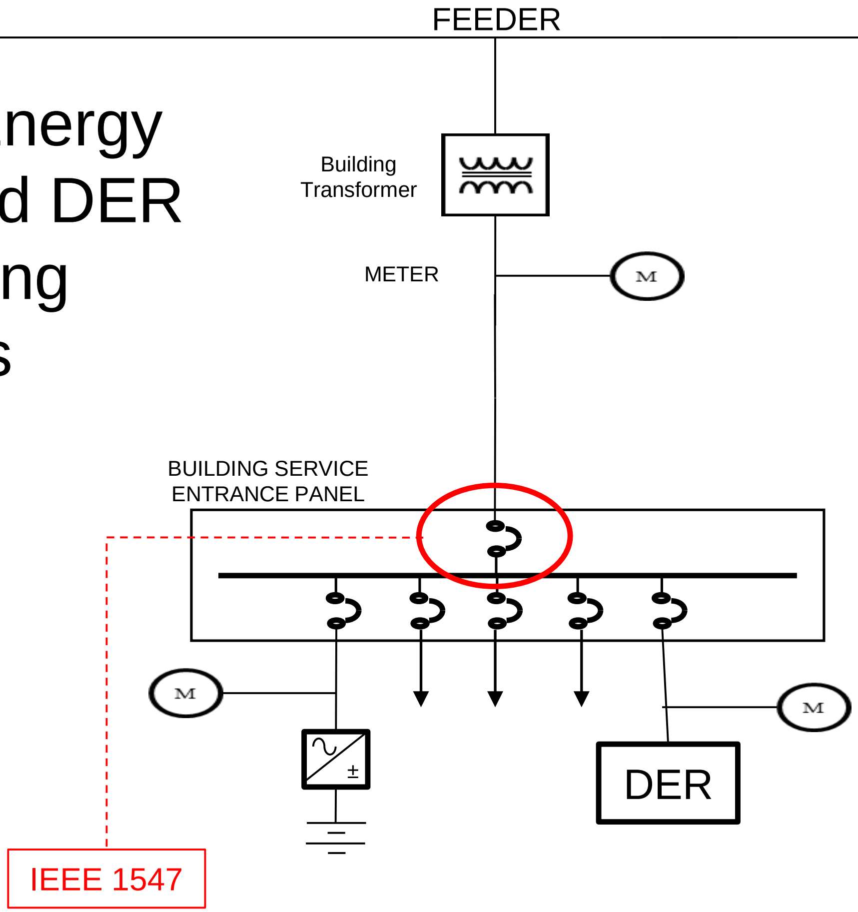


Project considerations
Design

Microgrid Applications –
i.e. Disconnected Distribution Line



Electrical Energy Storage and DER with Islanding Capabilities



Project considerations - Energy Storage Design

- Understand the applications and design ES Appropriately
  - Optimize the KW and KWH
  - Some technologies better suited for long durations rather than short
- Design the control to perform the various applications and integrate with DER
  - One master controller to control all components
  - Utilize ES to offset any fueled generation
- Does system have necessary certifications
  - UL listed - If not need to get buy-in from AHJ
- What codes and standards are required to install ES
  - Local and National (See Appendix)
- What inspections are required
  - AHJ
  - Interconnection
- Detailed construction and installation design package
- Detailed ES Specification

Project considerations – Project Team

- Project team should consist of the following (minimum)
  - System Integrator – YOU NEED ONE… Preferably one of the Equipment vendors. **ONE OWNER FOR OVERALL SYSTEM OPERATION.**
  - Engineering Design team – Develop construction drawings and specifications
  - Energy Storage (ES) and Distributed Energy Resources system vendor – Provide system, start-up and warranty
  - Authority Having Jurisdiction (AHJ) – Adding ES to the project adds a new component that may be unfamiliar with the local AHJ.
  - First Responders (Fire) and Insurers – Fireman need to understand Battery systems, your insurance underwriter
  - Liaison from the local power company to resolve potential interconnection issues

Project considerations – Testing and commissioning

- Full commissioning should be done on integrated system as well as individual components.
- A detailed commissioning plan should be developed and implemented and should include the following sections:
  - Factory acceptance testing
    - Should be conducted on system and include third part independent testing and verification.
  - Design Verification and construction complete
    - Was system installed as designed?
    - Does it meet all code, standards, and regulation requirements?
    - All safeties in place

Project considerations – Testing and commissioning

- Commissioning plan sections (continued).
  - Operational Acceptance Test (OAT)
    - Do all the individual components operate as required?
  - Functional Acceptance Test (FAT)
    - Does system operate in unison with other microgrid components?
    - Does system respond to external control as required?
    - Doe system perform the application(s) for which it was designed?
  - Shake Down
    - Do the System safeties work in the event of an anomaly

ES Technologies/Systems that might be best Suited for Microgrids.

Electro Chemical Options

Type	Storage Mechanism	Common Duration	Cycles
Lead Acid and Advanced Lead Acid	Electro-chemical	Seconds to Hours	100's – 1000's
Li-ion	Electro-chemical	Seconds to hours	1000's plus
Zinc Flow	Zinc Plating	Hours	1000's plus
Vanadium Flow	Ion Exchange	Hours	1000's plus

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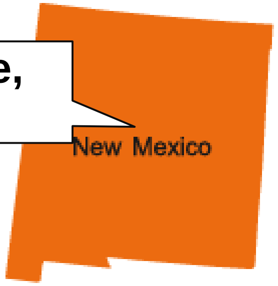
GS Battery Energy Storage
(An Example for Microgrids)

HES RESCU
HYBRID ENERGY SYSTEM RUGGED ENERGY STORAGE CONTAINMENT UNIT

Albuquerque, NM



60kW / 106kWh Compact Energy Storage System

DC: 106.3kWh VRLA storage (@20hr)

- Valve-regulated lead acid storage batteries
- 432Vdc nominal bus voltage (36 batteries, series connected)
- 246Ahr total
- Estimated Runtimes @100% DOD:
  - @30kW AC output: 2.5 HRS
  - @60kW AC output: 1.1 HRS

AC: 60kW liquid cooled power converter

ZBB Energy

ZBB EnerSystem™ transforms & integrates multiple power generation / power flows into economical, clean and reliable power systems

- Modular electronics and storage enable factory architected solution to any customer power problem
- *Expandable* and versatile to interface with various grid conditions and storage types
- Patented technology enables intelligent harvesting of all available "value streams" for fast ROI
- Reduces energy costs and increases energy reliability
- On-grid or off-grid operation

125kw 2.4 hour system supporting a 30kw PV.

- Easy to permit
- Kw to Multi MW capability

Grid-Connected, Long Duration Energy Storage

EnerVault - Fe-Cr Redox Flow Battery 1 MW-hr_{AC}

- Began commissioning January 2014
- Co-located with a PV solar system driving water pumping at an almond farm in Turlock, CA

Largest Iron-Chromium Redox Flow Battery Installed Globally

- EnerVault - 250 kW_{AC}, 4-hour Iron Chrome
- Inherently safe system design based on NASA science
- Grid-scale EnerVault systems advertised to meet DOE cost targets and deliver 4-12 hrs of energy

EaglePicher A/GES Technologies

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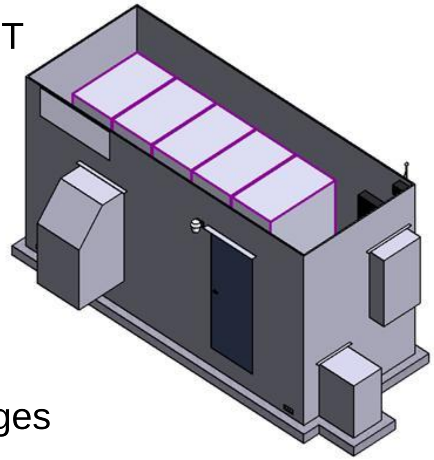
Energy Storage Simulator

Software simulates a grid-tied energy storage system to calculate business case analysis/estimated ROI

Load Profile
+
Tariff Definition → Operation Strategy = Modified Utility Costs
+
Storage Definition

Na-Beta Battery Project

- U.S. DOE ARPAe & EPT funded effort
- Planar Sodium Nickel Chloride
- + 30% Energy Density
- 10X Cost Reduction
- 30% Temp Reduction
- Transformational Changes



PowerPyramid™

Energy Storage Options

Electrochemical Solutions
- Lithium-ion
- Lead Acid
- Sodium Sulfur
- Sodium Nickel Chloride
- Redox Flow Batteries
- Nickel Cadmium
- Electrochemical Capacitors

Mechanical Solutions
- Flywheels
- Compressed Air Energy Storage (CAES)
- Superconducting Magnetic Energy Storage

Benefits of Hybrid Approach
- Optimize Cost
- Leverages Existing Technologies
- Adaptable to Technology Improvement
- Balances Variability with Variable Power Sources
- Smoothes/Levels Supply to Grid
- Represents "Spinning" Capacity

RAPIDS

- Mobile energy generation and storage station
- Provide regulated prioritized load shedding power to balance energy supply and demand
- Accepts power from multiple sources
  - Solar
  - Wind
  - Generator set
- Designed using EPT Patented Power Pyramid ™ Technology

ES Cost Considerations

Capital Costs

- Design/permitting/Studies
- Site and infrastructure prep
- ES System - $/kw and/or $/KWh
- Balance of Plant
- Installation

Operating Costs

- Efficiency factors
- Cycle life/replacement
- Operations
- Maintenance
- Debt Service

Cost metric must include a variety of important elements.

Summary

- ES is needed for renewables to be counted toward generations
- Need to understand application of ES in a microgrid
- Need to optimize the KW and KWH rating of ES
  - DNV-GL – Evaluation Tool richard.fioravanti@dnvgl.com
- ES installation may require additional oversight:
  - Insurance, codes and standards
  - Utility Interconnection, AHJ, First Responders
- Need to have a robust commissioning plan
  - Independent third party testing and/or verification

Thank You and a mention of our SNL Sponsor – DOE/OE - Grid Energy Storage program managed by Dr. Gyuk

Questions?

Further Questions should be handled through the RFP Process

Contact Information:

Dan Borneo - drborne@sandia.gov

Resources

- www.cleanenergystates.org/projects/energy-storage-technology-advancement-partnership/

- www.eelectricitystorage.org
- DOE?EPRI 2013 Electricity Storage Handbook…
  - http://www.sandia.gov/ess/publications/SAND2013-5131.pdf

Additional Information

Safety & Reliability Resource In Development:

Battery and System Testing Website

For more information, visit the website at:
www.sandia.gov/battery testing

2014 Call:
January 16 - July 15, 2014.

The database will be open for *FAST-Track* Proposals. These should be limited in scope and have strong justification for expedited processing.

Contact: Summer Ferreira
srferre@sandia.gov
or David Rose
dmrose@sandia.gov

Overview of Current Standards

Courtesy of Laurie Florence -UL

Document No.	Title
ANSI UL 1973	Batteries for Use in Light Electric Rail (LER) and Stationary Applications
UL Subject 9540	Safety for Energy Storage Systems and Equipment (under development)
IEEE 3575	Guide for the Protection of Stationary Battery Systems
IEEE 1679	Recommended Practice for the Characterization and Evaluation of Emerging Energy Storage Technologies in Stationary Applications
IEC 62485-2	Safety requirements for secondary batteries and battery installations – Part 2: Stationary batteries
IEC CD 62619	Secondary cells and batteries containing alkaline or other non-acid electrolytes. - Safety requirements for secondary lithium cells and batteries, for use in industrial applications (under development)
IEC NP 62897	Stationary Energy Storage Systems with Lithium Batteries – Safety Requirements (under development)

Energy Storage Applications

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	POWER (<15min)		ENERGY (>1hr)
LOAD	PQ, Reliability, UPS	Spinning Reserve/ Load Following, UPS	Demand Reduction, Load Shifting
GRID	Voltage Support, Transients, Regulation	Dispatchability for Renewable Energy Resources	T&D Congestion Mitigation, Time of Use Arbitrage, Upgrade Deferral
	seconds	minutes	hours

Storage Varieties

Type	Storage Mechanism	Common Duration	Cycles
Capacitor	Electrical charge	Seconds (minutes)	100,000's
Flywheel	Kinetic energy	Seconds / Minutes	1000's - 100,000's
Battery	Electro-chemical	Minutes (hours)	100's-1000's
Thermal	Ice, Molten Salts	Hours	1000's

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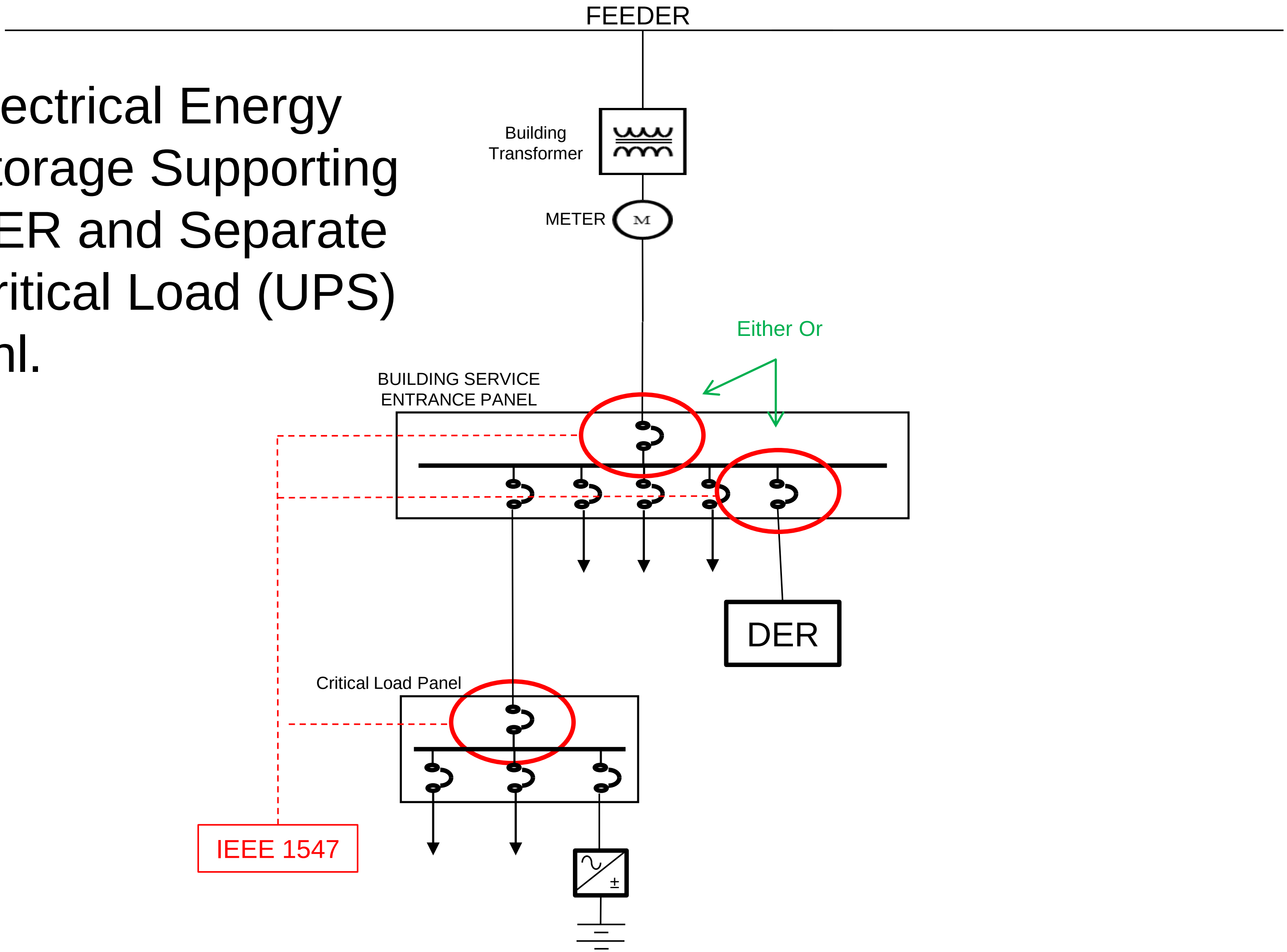
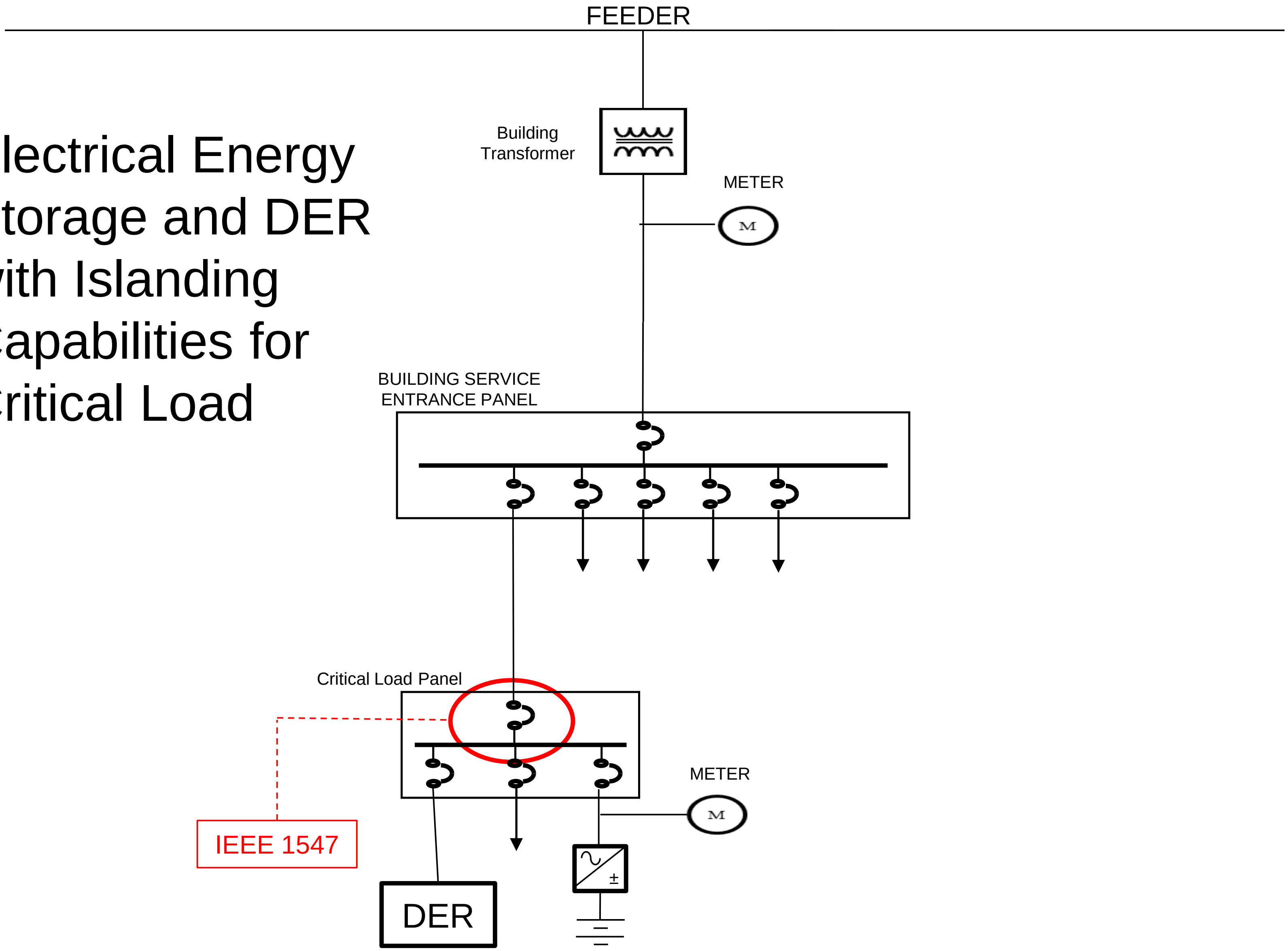
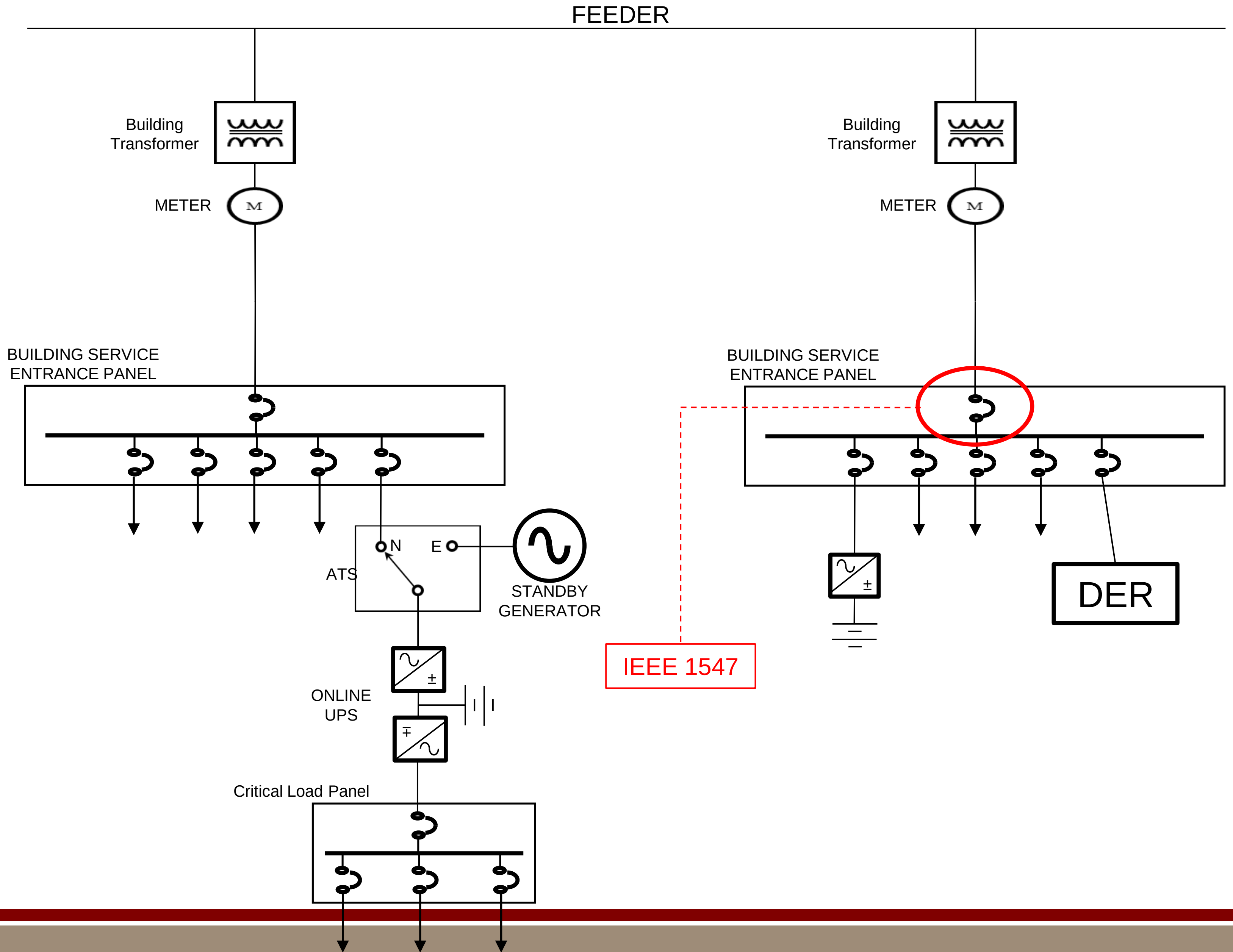
Electrical Energy Storage Supporting DER and Separate Critical Load (UPS) Pnl.



Electrical Energy Storage and DER with Islanding Capabilities for Critical Load

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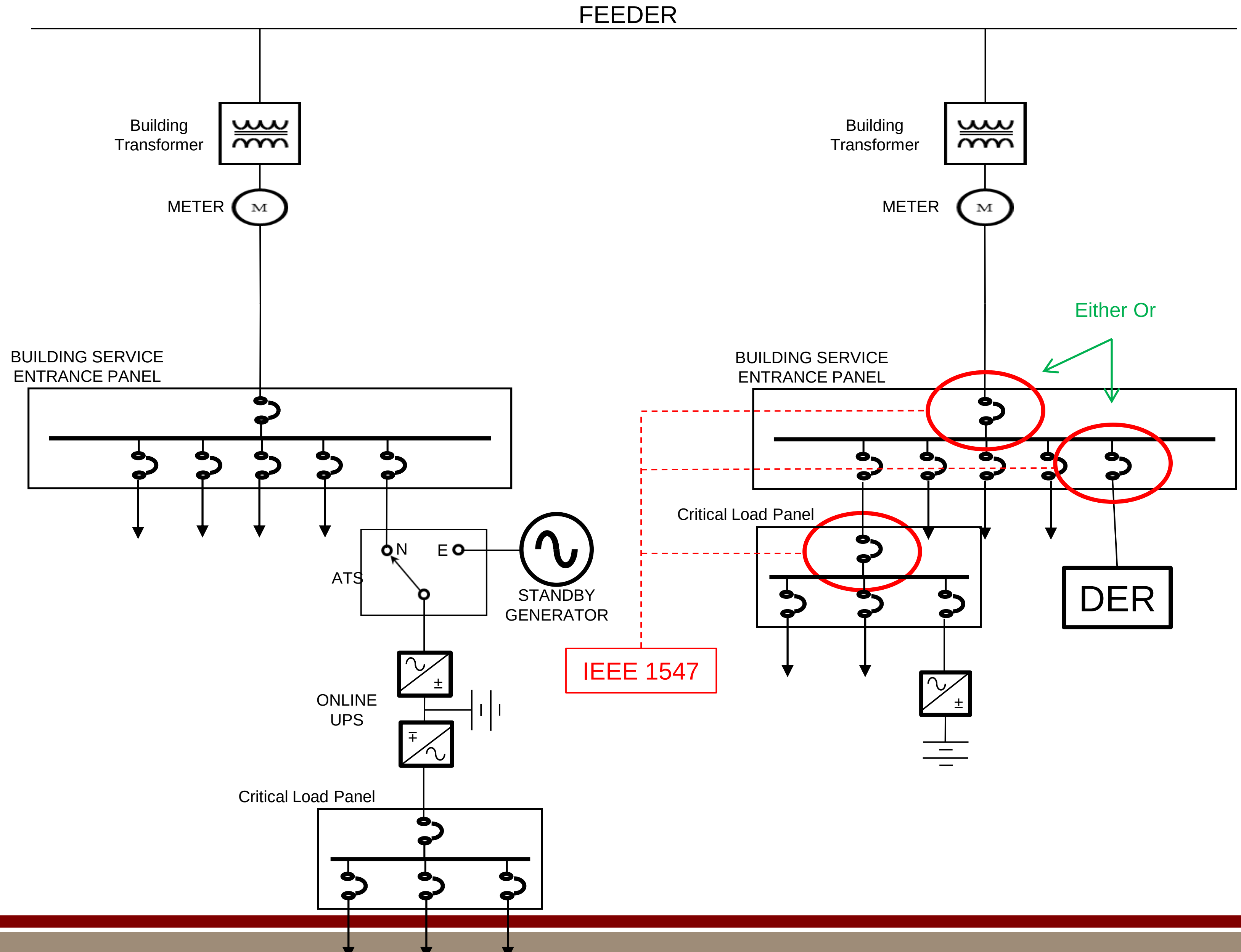
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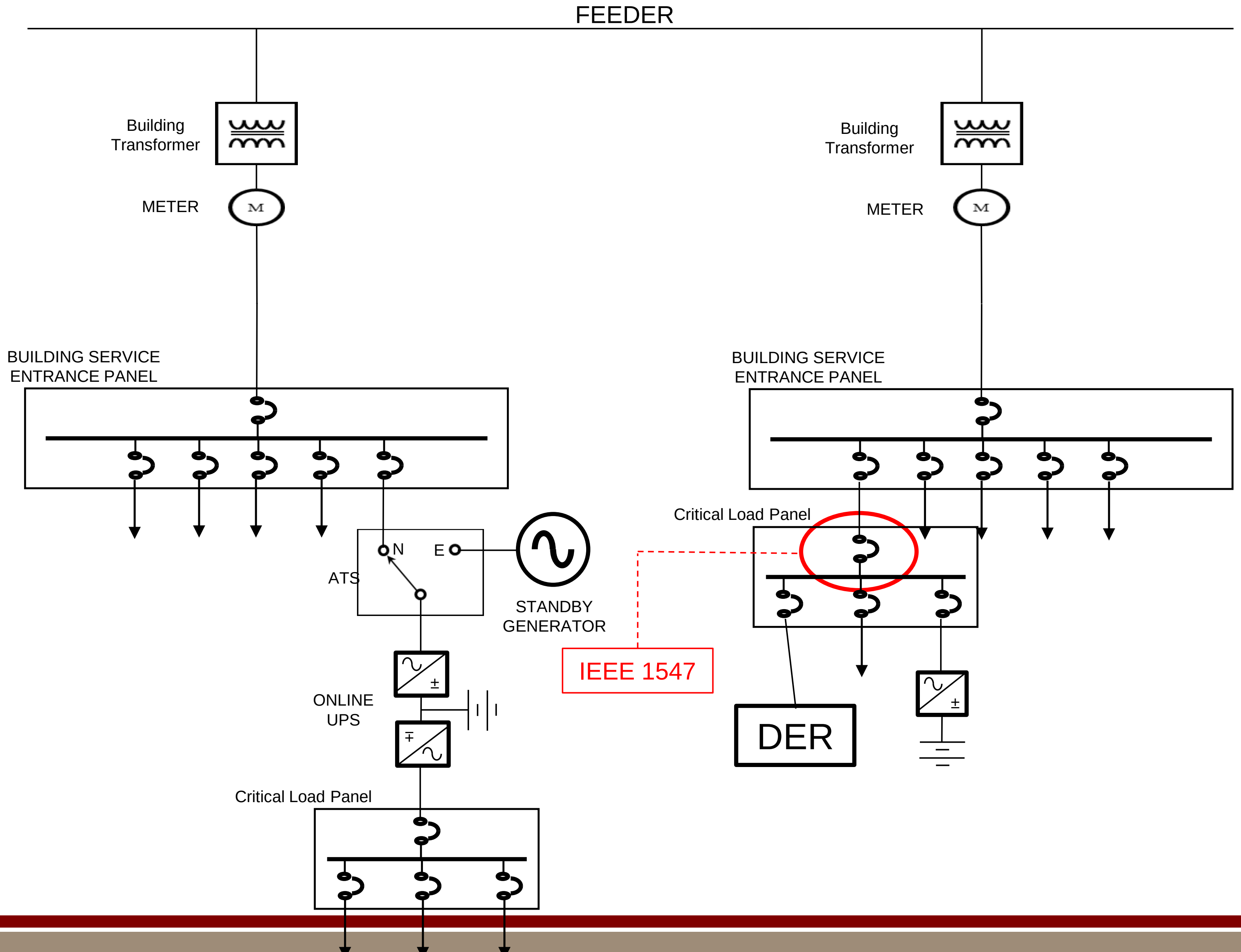
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Building Transformer
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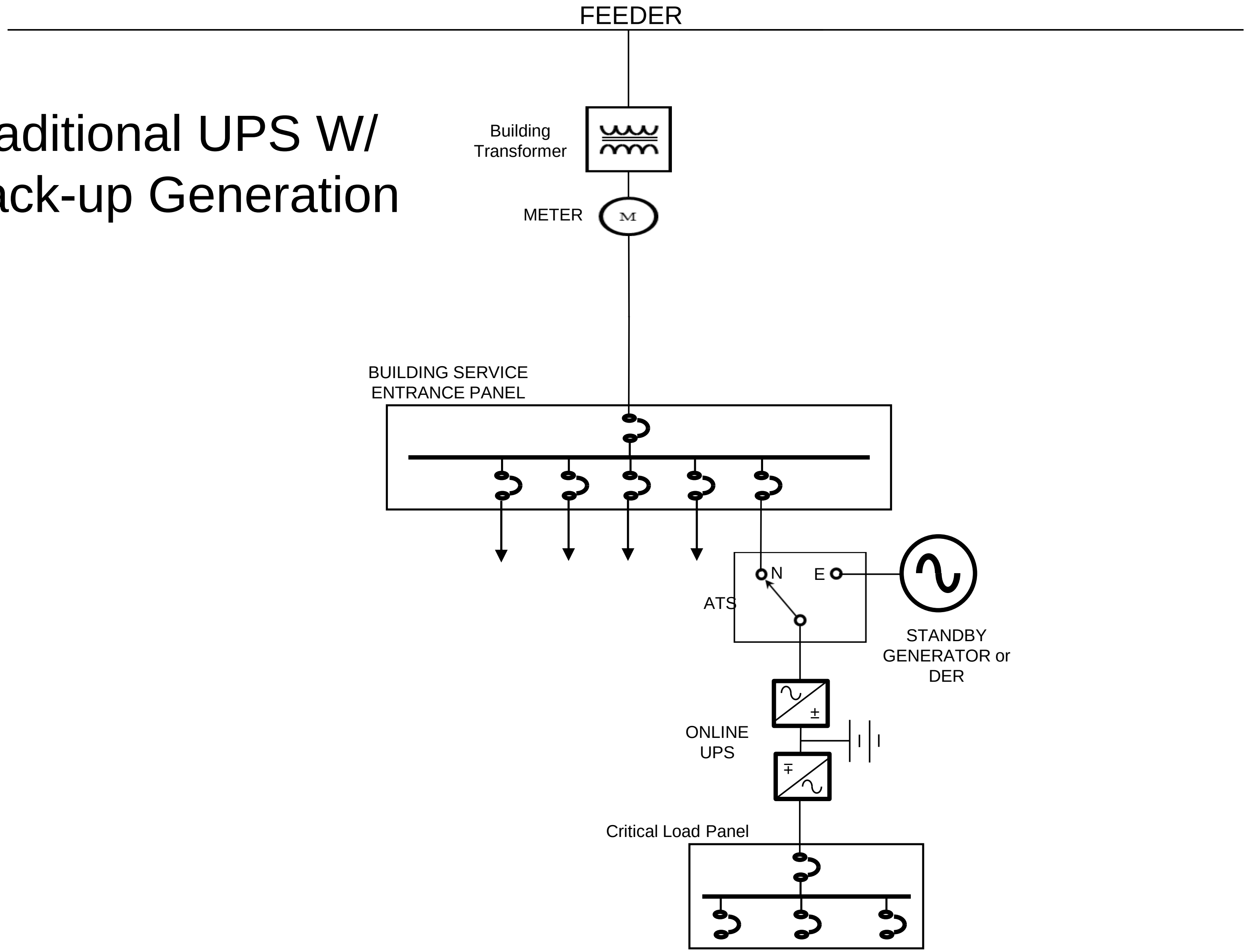
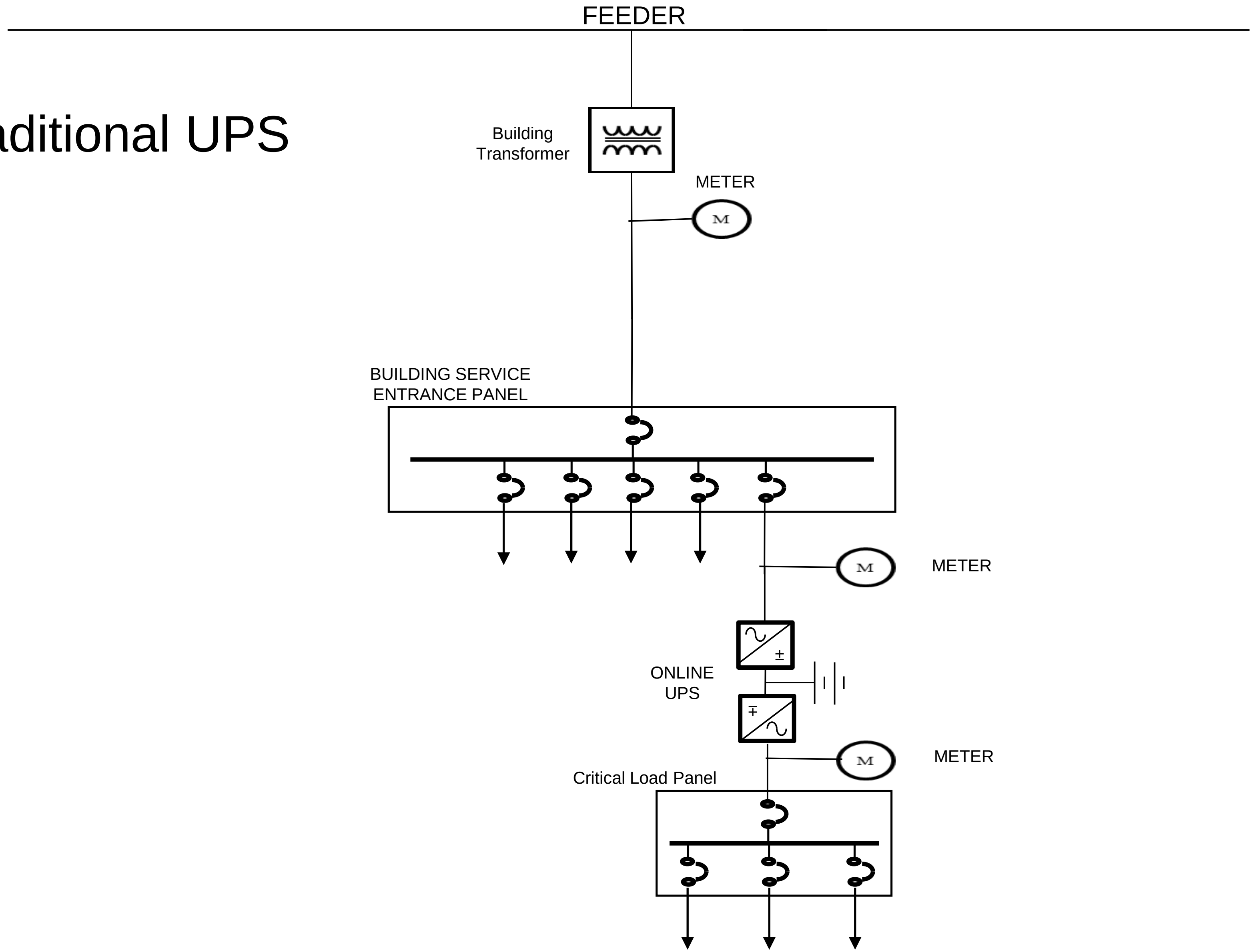
M
BUILDING SERVICE ENTRANCE PANEL
Critical Load Panel
IEEE 1547
DER

Traditional UPS W/ Back-up Generation



Traditional UPS



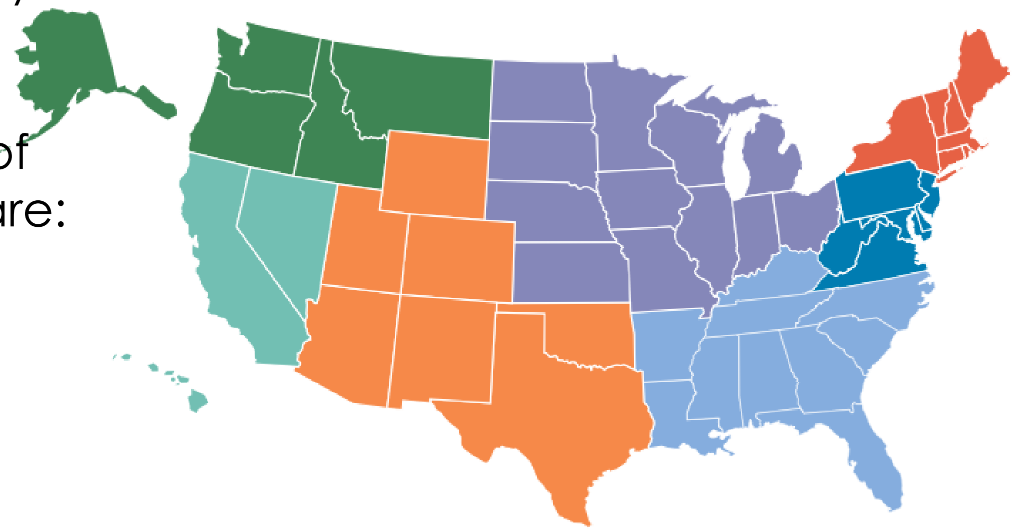
Why CHP for Microgrids?

Thomas Bourgeois

U.S. DOE Northeast CHP Technical Assistance Partnership

CHP Technical Assistance Partnerships

The President's Executive Order 13624 set the goal of 40GW of *new* CHP by 2020 in the United States.



CHP TAPs are critical components of achieving the goal because they are:

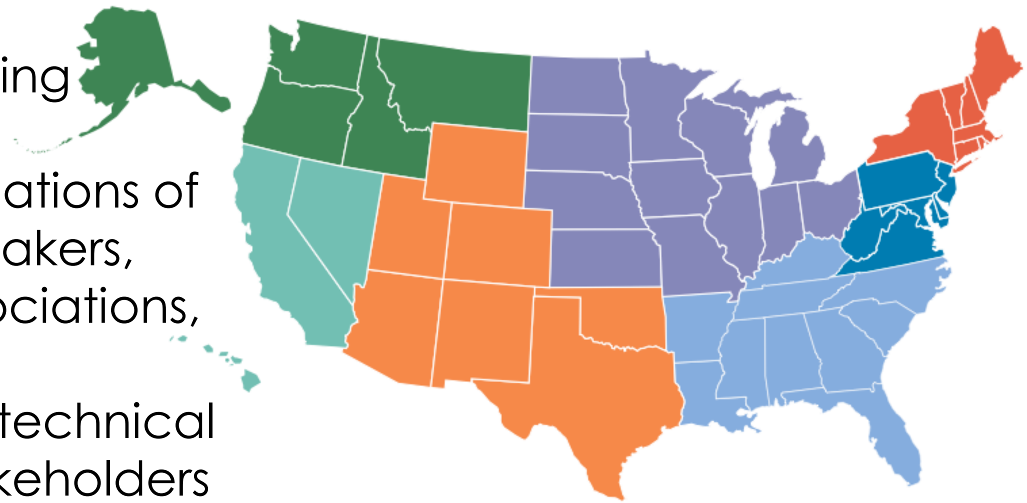
- Regional CHP experts
- Provide fact-based, un-biased information on CHP
    - Technologies
    - Project development
    - Project financing
    - Local electric and natural gas interfaces
    - State best practice policies
- Vendor, fuel, and technology neutral

http://eere.energy.gov/manufacturing/distributedenergy/chptaps.html

CHP Technical Assistance Partnerships

Key Activities:

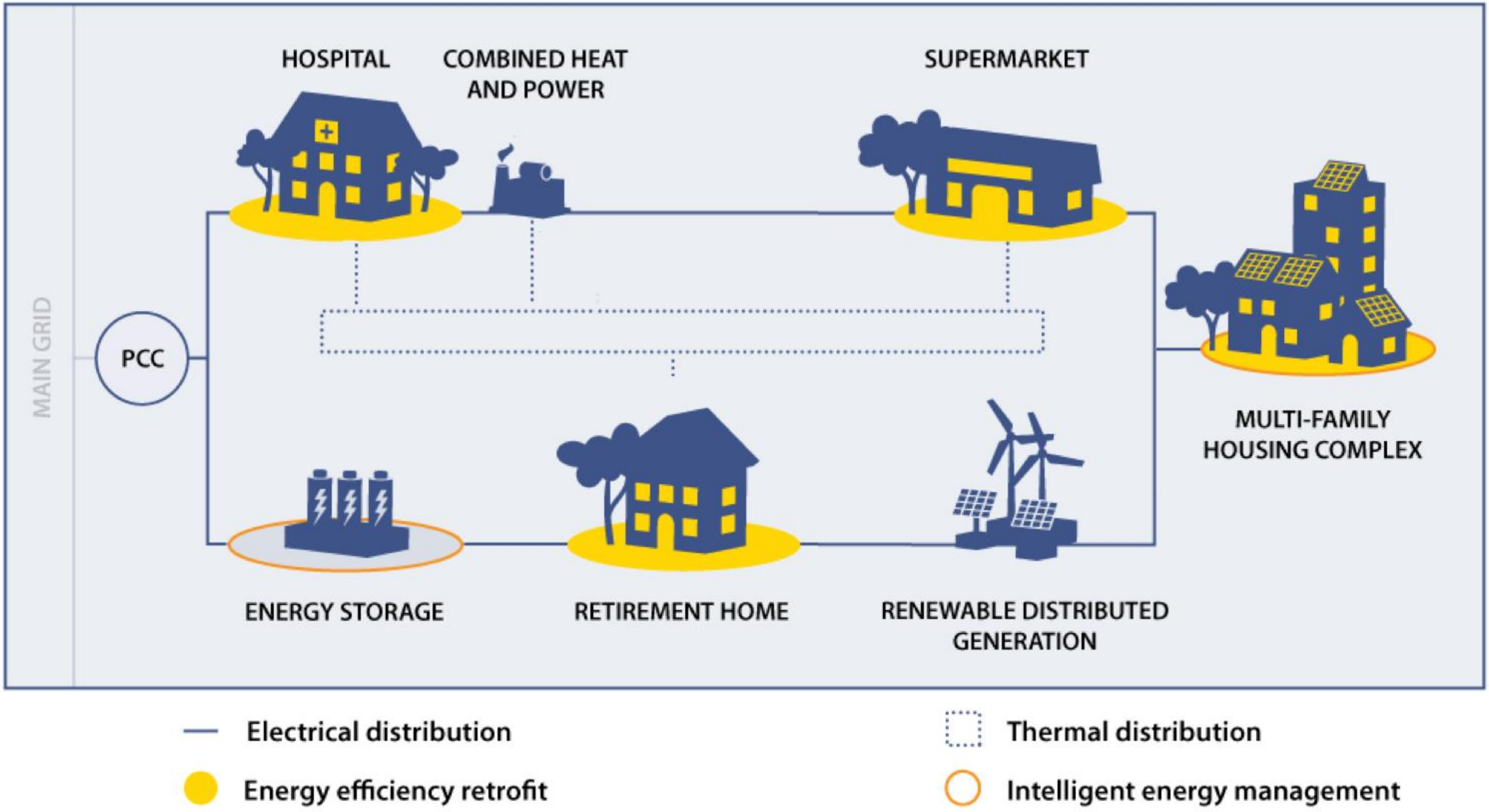
- **Market Opportunity Analysis.** Supporting analyses of CHP market opportunities in diverse markets including industrial, federal, institutional, and commercial sectors.
- **Education and Outreach.** Providing information on the energy and non-energy benefits and applications of CHP to state and local policy makers, regulators, end users, trade associations, and others.
- **Technical Assistance.** Providing technical assistance to end-users and stakeholders to help them consider CHP, waste heat to power, and/or district energy with CHP in their facility and to help them through the development process from initial CHP screening to installation.



http://eere.energy.gov/manufacturing/distributedenergy/chptaps.html

CHP Can Be The Centerpiece of a Community Microgrid

Source: Pace Energy and Climate Center, “Community Microgrids: Smarter, Cleaner, Greener.”

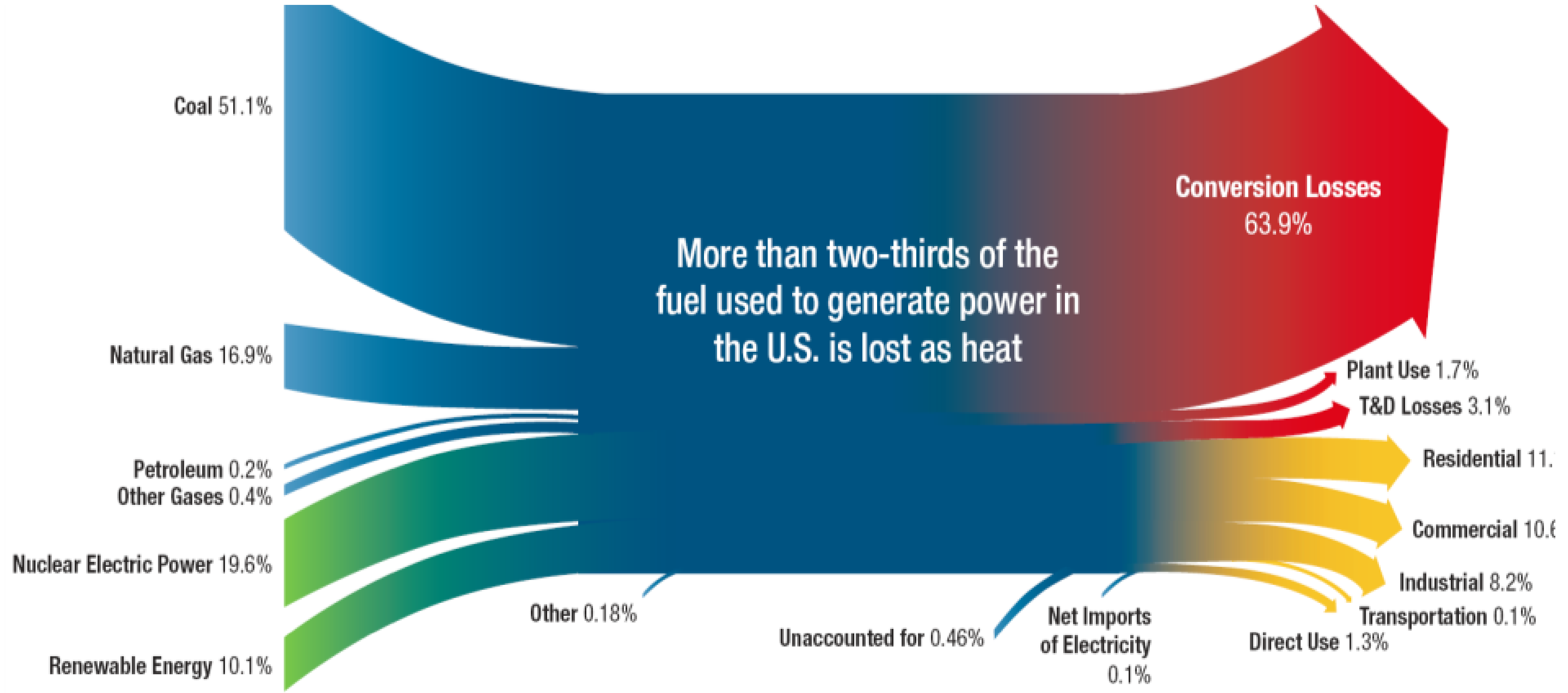


What Is Combined Heat and Power?

CHP is an *integrated energy system* that:

- Is located at or near a factory or building
- Generates electrical and/or mechanical power
- Recovers waste heat for
  - heating,
  - cooling or
  - dehumidification
- Can utilize a variety of technologies and fuels

Fuel Utilization by U.S. Utility Sector



Source: http://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_report_12-08.pdf

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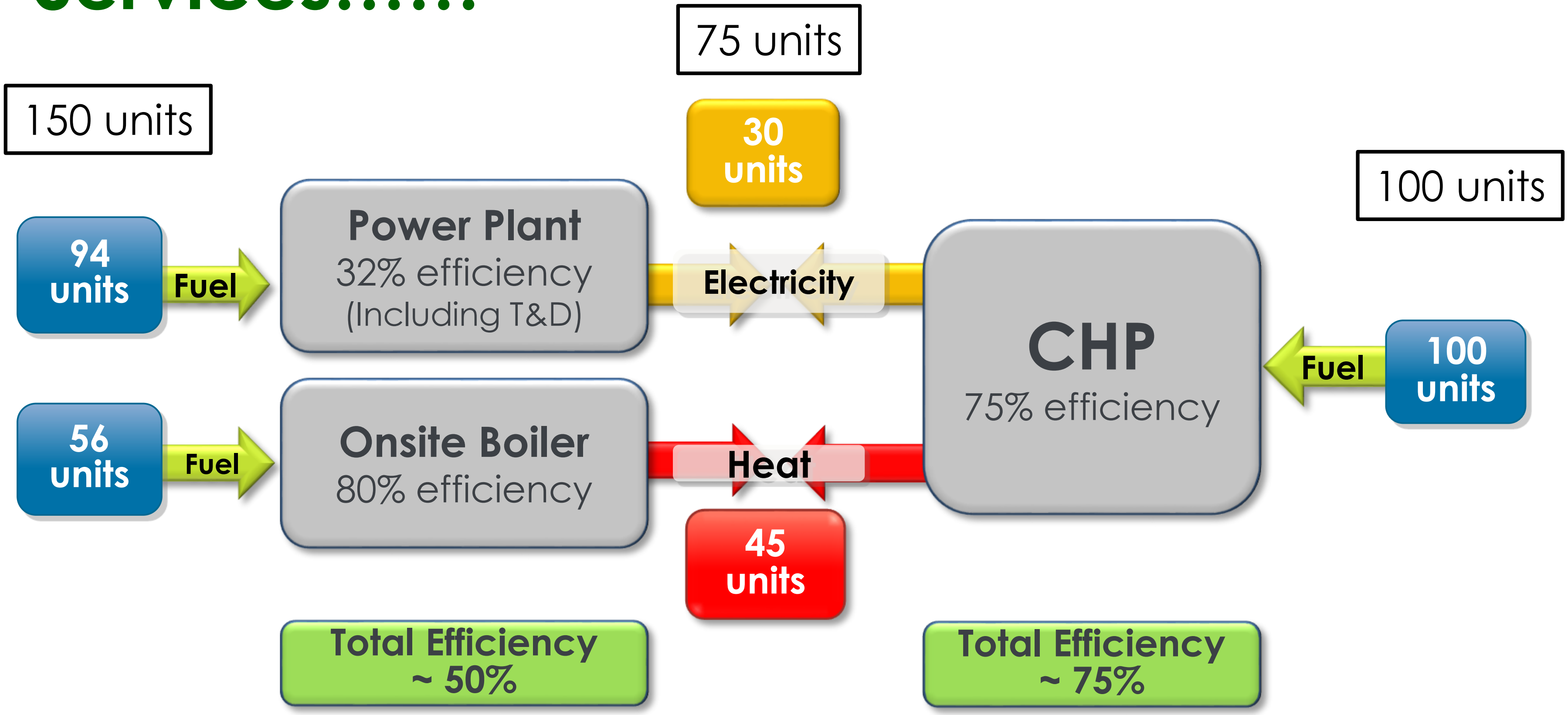
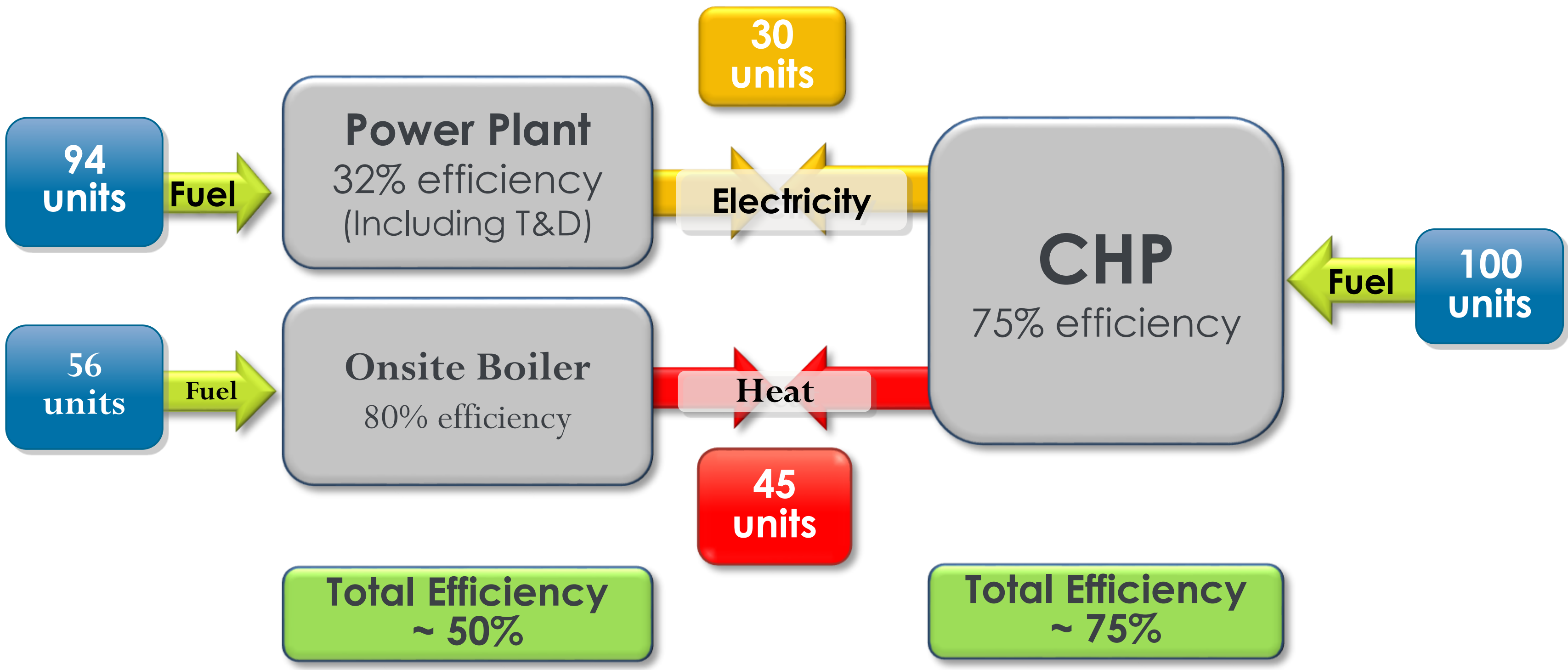
CHP Recaptures Much of that Heat, Increasing Overall Efficiency of Energy Services……



.....and Reducing Greenhouse Gas Emissions



30 to 55% less greenhouse gas emissions

CHP's Higher Efficiency Results in Energy and Emissions Savings

Category	10 MW CHP	10 MW PV	10 MW Wind	10 MW NGCC
Annual Capacity Factor	85%	22%	34%	70%
Annual Electricity	74,446 MWh	19,272 MWh	29,784 MWh	61,320 MWh
Annual Useful Heat Provided	103,417 MWh_t	None	None	None
Footprint Required	6,000 sq ft	1,740,000 sq ft	76,000 sq ft	N/A
Capital Cost	$20 million	$60.5 million	$24.4 million	$10 million
Annual Energy Savings, MMBtu	308,100	196,462	303,623	154,649
Annual CO_2 Savings, Tons	42,751	17,887	27,644	28,172
Annual NOx Savings	59.9	16.2	24.9	39.3

Source: Combined Heat and Power A Clean Energy Solution: August 2012: DOE and EPA

What Are CHP Technologies?

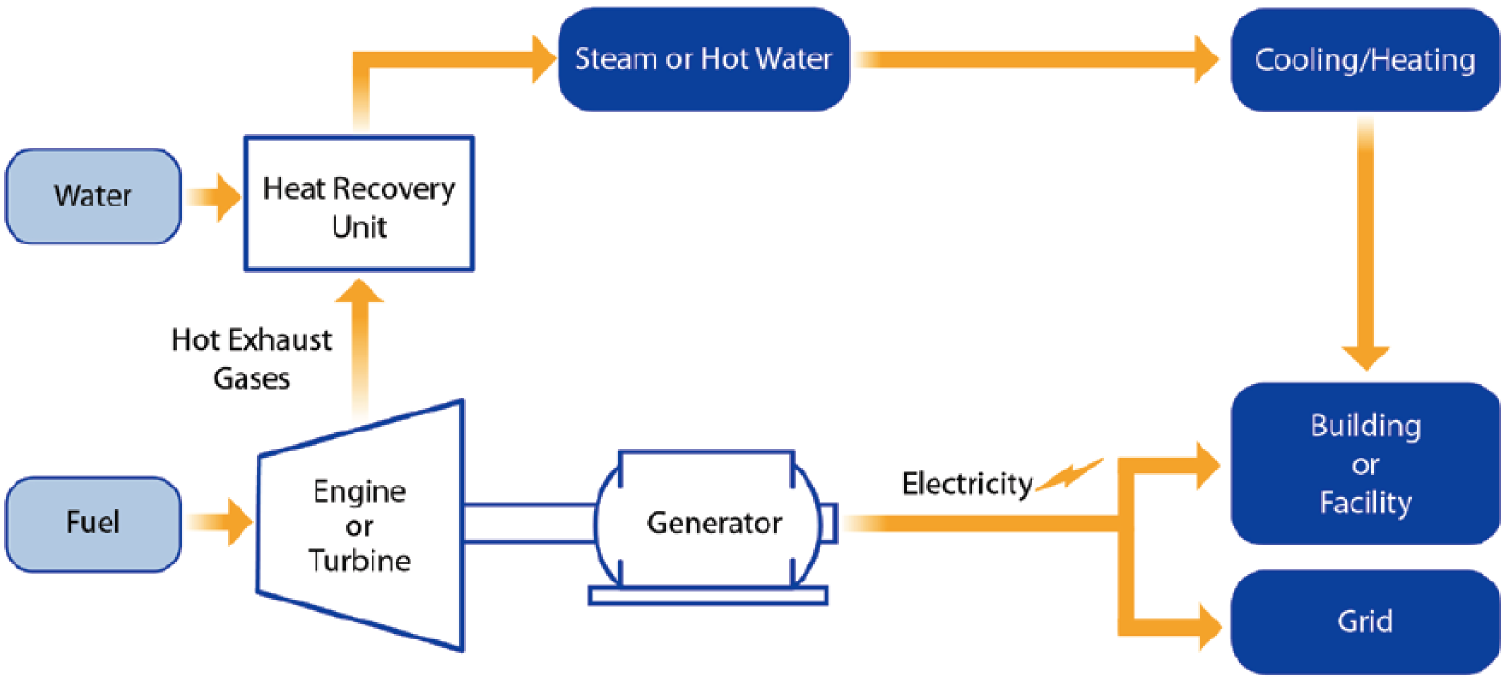
- Electric Generation Equipment
  - Reciprocating Engines
  - Turbines / Microturbines
  - Steam Turbines
  - Fuel Cells
- Heat Recovery Systems Create
  - Hot Water
  - Steam
- Thermally Activated Technologies
  - Absorption Chillers
  - Desiccant Dehumidification
  - Thermal Storage

Defining Combined Heat & Power (CHP)

The on-site simultaneous generation of two forms of energy (heat and electricity) from a single fuel/energy source

Conventional CHP

(also referred to as Topping Cycle CHP or Direct Fired CHP)



Separate Energy Delivery:

- Electric generation – 33%
- Thermal generation - 80%
- Combined efficiency – 45% to 55%

CHP Energy Efficiency (combined heat and power) 70% to 85%

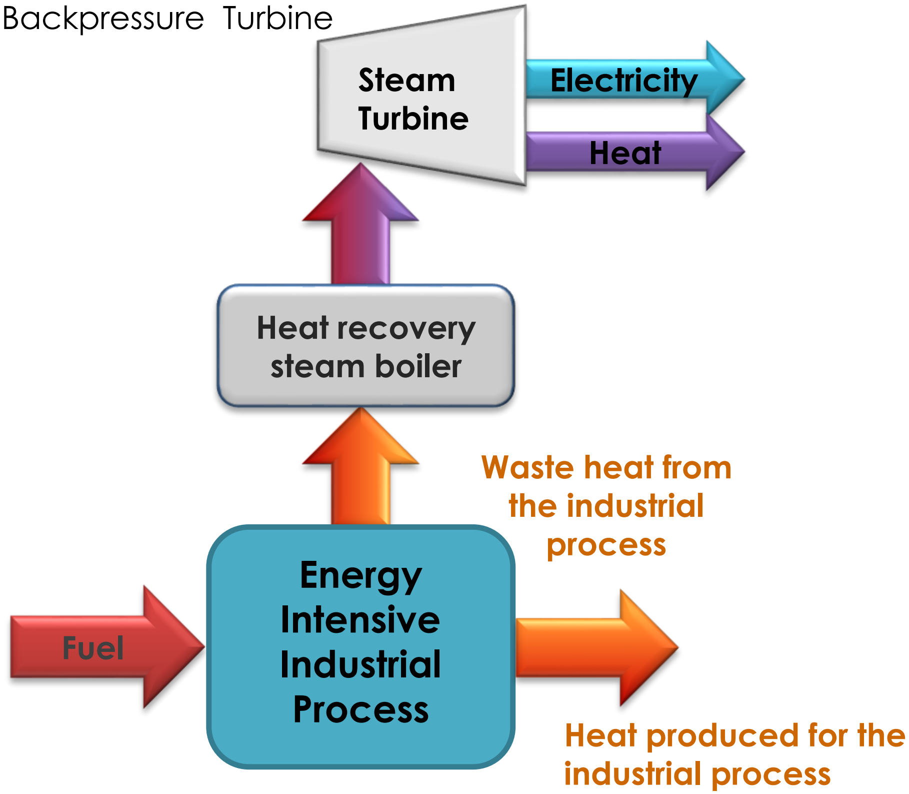
Defining Combined Heat & Power (CHP)

The on-site simultaneous generation of two forms of energy (heat and electricity) from a single fuel/energy source

Waste Heat to Power CHP

(also referred to as Bottoming Cycle CHP or Indirect Fired CHP)

HRSG/Steam Turbine
Organic Rankine Cycle
Backpressure Turbine



- Fuel first applied to produce useful thermal energy for the process
- Waste heat is utilized to produce electricity and possibly additional thermal energy for the process
- Simultaneous generation of heat and electricity
- No additional fossil fuel combustion *(no incremental emissions)*
- Normally produces larger amounts electric generation *(often exports electricity to the grid; base load electric power)*

Attractive CHP Markets

Industrial
- Chemical manufacturing
- Ethanol
- Food processing
- Natural gas pipelines
- Petrochemicals
- Pharmaceuticals
- Pulp and paper
- Refining
- Rubber and plastics

Commercial
- Data centers
- Hotels and casinos
- Multi-family housing
- Laundries
- Apartments
- Office buildings
- Refrigerated warehouses
- Restaurants
- Supermarkets
- Green buildings

Institutional
- Hospitals
- Schools (K – 12)
- Universities & colleges
- Wastewater treatment
- Residential confinement

Agricultural
- Concentrated animal feeding operations
- Dairies
- Wood waste (biomass)

CHP Is Used at the Point of Demand

4,200 CHP Sites (2012)

82,400 MW – installed capacity

Saves 1.8 quads of fuel each year

Avoids 241 M metric tons of CO_2 each year

87% of capacity – industrial

71% of capacity – natural gas fired

Source: ICF International

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Why Does CHP Make Sense for Microgrids?

- Continuously operates 24/7.
- Efficiently provides electrical and thermal energy.
- Reduces GHG emissions.
- Provides resilient power through storms, blackouts, and other emergencies when designed to do so.
- Microgrids can be used to improve municipal economics by providing a cost effective alternative to the existing aging grid, and the high cost of electricity.

New CHP Installations (number of sites), 2007 - 2011	
State	Installations
CA	95
NY	92
CT	**64**
MA	44

Source: ICF/CHP database

CHP Versus Backup Generation

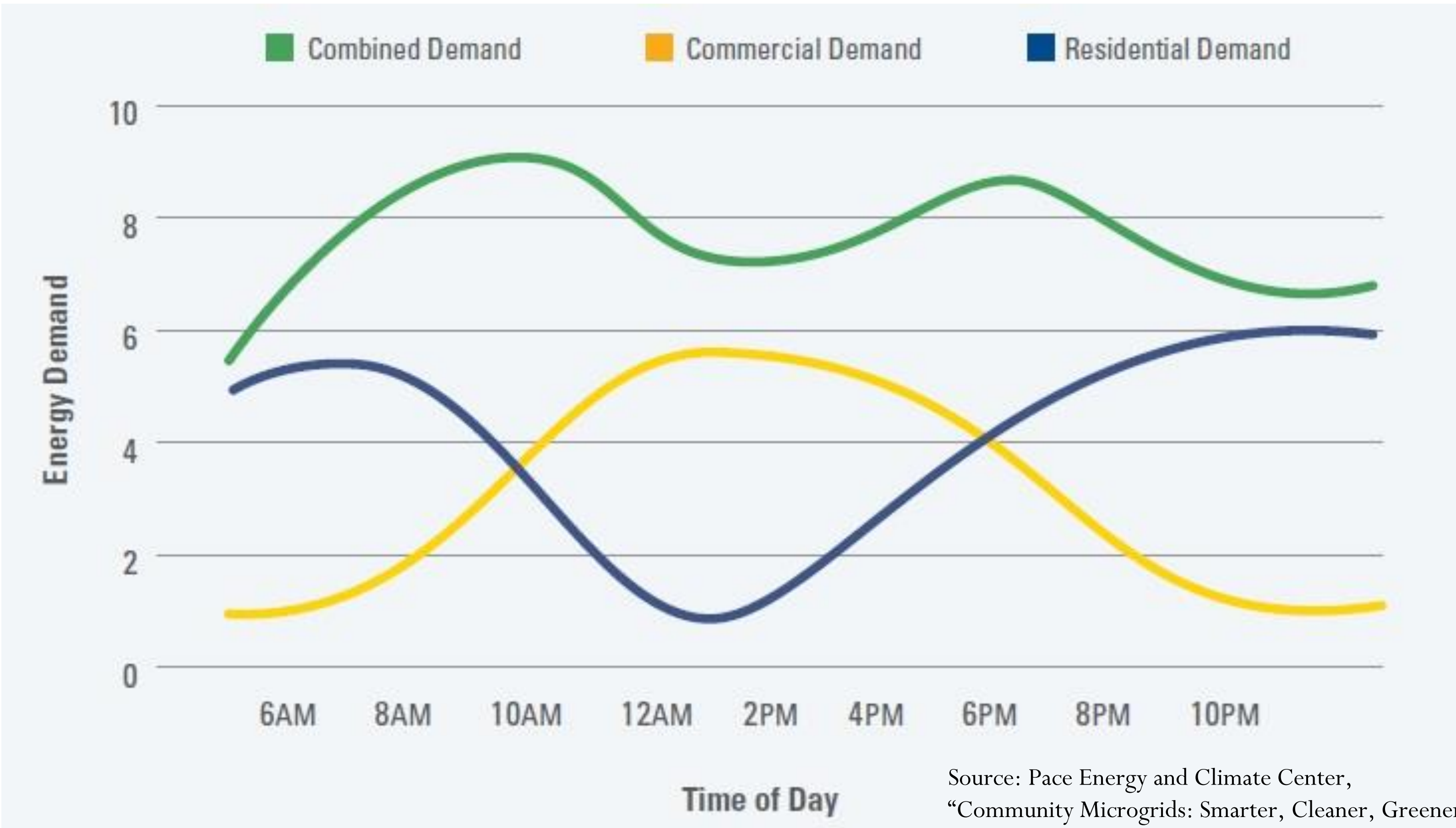
	CHP	Backup Generation
System Performance	• Designed and maintained to run continuously • Improved performance reliability	• Only used during emergencies
Fuel Supply	• Natural gas infrastructure typically not impacted by severe weather	• Limited by on-site storage
Transition from Grid Power	• May be configured for "flicker-free" transfer from grid connection to "island mode"	• Lag time may impact critical system performance
Energy Supply	• Electricity • Thermal (heating, cooling, hot/chilled water)	• Electricity
Emissions	• Typically natural gas fueled • Achieve greater system efficiencies (80%) • Lower emissions	• Commonly burn diesel fuel

CHP Benefits: Lower Energy Costs

- Burrstone microgrid's college, nursing home and hospital: utilize 4 natural gas recip engines with CHP. Each customer saves $300,000 - $500,000 annually, or 15-20%, of total energy costs, creating a 10 year payback period on project.
- Cornell University microgrid : utilizes 30.7 MW of CHP combustion gas turbines, and realizes an 8-10% return on investment through energy savings.
- South Oaks Hospital CHP system saves nearly $540,000 annually on $1.467 million energy bill.
- NY Presbyterian: by purchasing 10% more fuel (natural gas), they avoid purchasing 80% of electricity requirements.

Lowering Costs by Maximizing System Efficiency

Complementary Users Combine to Form a Levelized Load, Meaning Microgrid Generators are Less Likely to Sit Idle or Run Inefficiently



Source: Pace Energy and Climate Center, "Community Microgrids: Smarter, Cleaner, Greener."

CHP Benefits: Improved Resiliency

- Fairfield, University (CT) – 4.6 MW CHP
  - 98% of the Town of Fairfield lost power, university only lost power for a brief period at Sandy's peak.
  - University buildings served as area of refuge for off-campus students.
- Danbury Hospital (Danbury, CT) – 4.5 MW CHP
  - Supplied 371 bed hospital with power and steam to heat buildings, sterilize hospital instruments & produce chilled water for AC during Hurricane Sandy.
- UMass Medical Center system ran through Oct. 2011 storm, permits the Campus to operate with virtually no supplemental grid power.
- NY Presbyterian Hospital system provides 100% redundancy to entire inpatient areas, accounts for 100% of baseload and 2/3 of peak requirements.

Resilient Infrastructure: South Oaks Hospital - Amityville, NY

- Hospital & Nursing Home campus with natural gas-powered CHP system
  - System consists of five 250 kW IntelliGen engines
- When macrogrid went down during Sandy, South Oaks transitioned to "island mode" - no interruption of power
- CHP System provided 100% of the facility's electricity, thermal and hot water demands for 15 days
- In addition to meeting the hospital's needs, South Oaks admitted evacuated patients from nearby healthcare facilities, refrigerated medications, and housed hospital staff who had lost power

Well designed CHP is highly efficient

- UMass Medical Center's new 16.5 MW system operates at 86% total system efficiency
- NY Presbyterian 7.5 MW system reports operating at 85% efficiency
- At full load, South Oaks hospital's CHP system operates at 88% efficiency (32% electrical, 56% thermal/mechanical)

Community Microgrids with CHP: Co-Op City - Bronx, NY

- One of the largest cooperative housing units in the world.
  - 35 residential buildings
  - over 55,000 residents
- 38 MW CHP
- Utility savings estimated $15,000,000 per year.
- CHP facility provided full power to Co-Op City before, during, and after Superstorm Sandy.

Favorable Characteristics for CHP Applications

- Concern about energy costs
- Concern about power reliability
- Concern about sustainability and environmental impacts
- Long hours of operation
- Existing thermal loads
- Central heating and cooling plant
- Future central plant replacement and/or upgrades
- Future facility expansion or new construction projects
- EE measures already implemented
- Access to nearby renewable fuels
- Facility energy champion

CHP TAP Tools & Resources

Providing resources to interested communities including:

- Assessing economic viability
- Addressing interconnection issues
- Navigating legal and regulatory matters
- Understanding tariffs and standby charges
- First Order District Energy Screening Tool
- CHP Qualification Screenings & Technical Assessments

First Order District Energy/CHP Screening Tool

Main Features

- **Data –** Regional Load Profiles, Energy Prices, Labor Rates, Financial rates, Pipe Cost,
- **Project Definition -** District Composition, Phasing
- **Options appraisal – LIFE CYCLE COST** Comparison of Costs of Options vs Baseline (Building Boilers and Chillers and Purchased Power)
- NOT *Proforma*

What to do Next?

Screening Tool Parameters

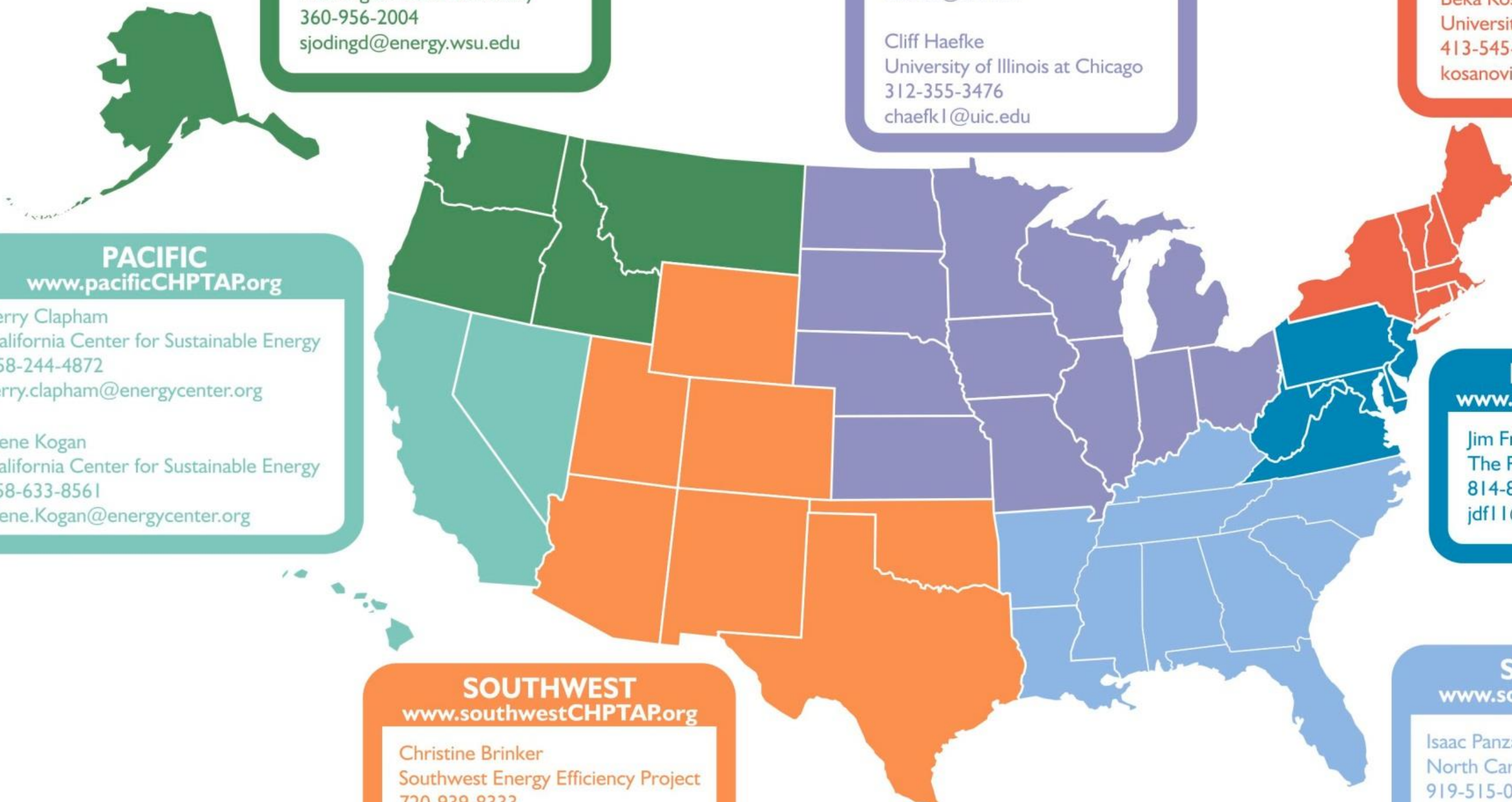
Operating Expense	Capital Expense	Economic Considerations

• Energy Costs
• Labor Costs
• Maintenance Costs (LTSA)
• Consumables
	• Unit Cost estimates by system type
	  • Boilers
	  • Chillers
	  • Electric gear
	  • CHP equipment
	  • Distribution Piping
	  • Building SF Costs
	• Debt Service
		• Discount Rate
		• Escalation Rates
		  • Electricity
		  • Natural Gas
		  • General Inflation
		• Loan Terms

Next Steps

- Contact the Northeast CHP TAP for assistance in getting your project off the ground!

DOE CHP Technical Assistance Partnerships (CHP TAPs)



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Thank You!

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