Osher Lifelong Learning Institute at CMU
Economics of Battery Energy Storage

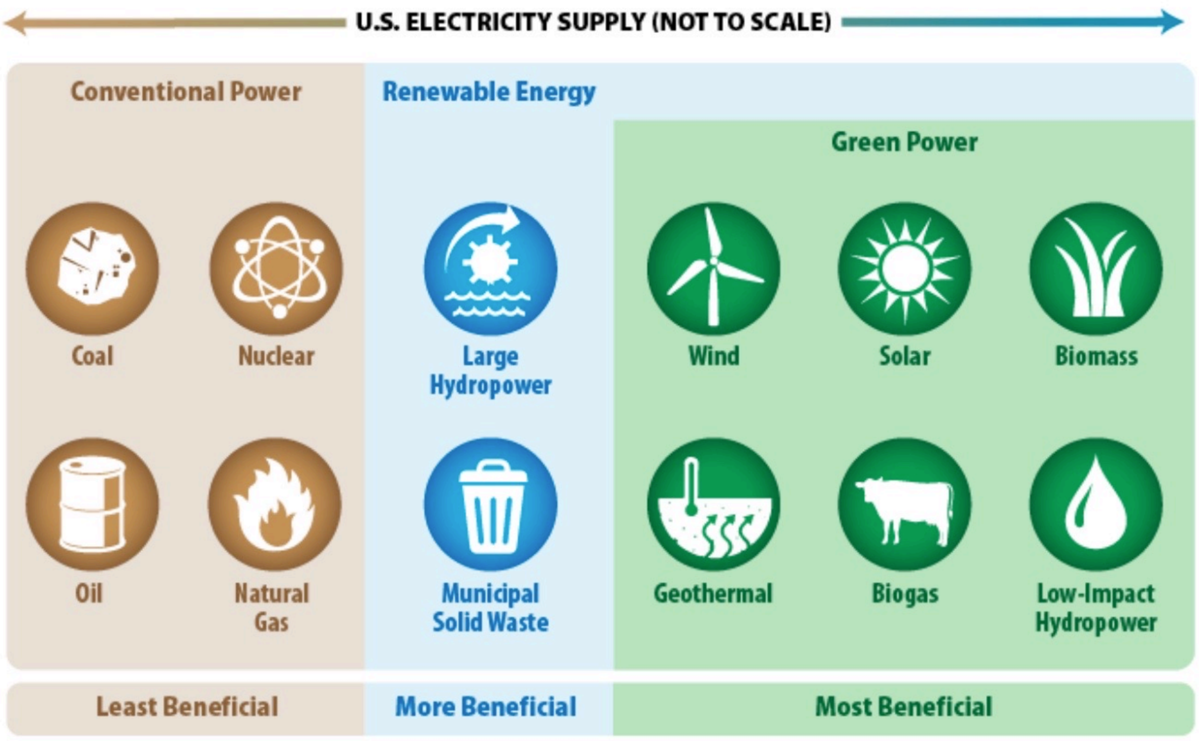
GL “Pat” Ervin

Spring 2024

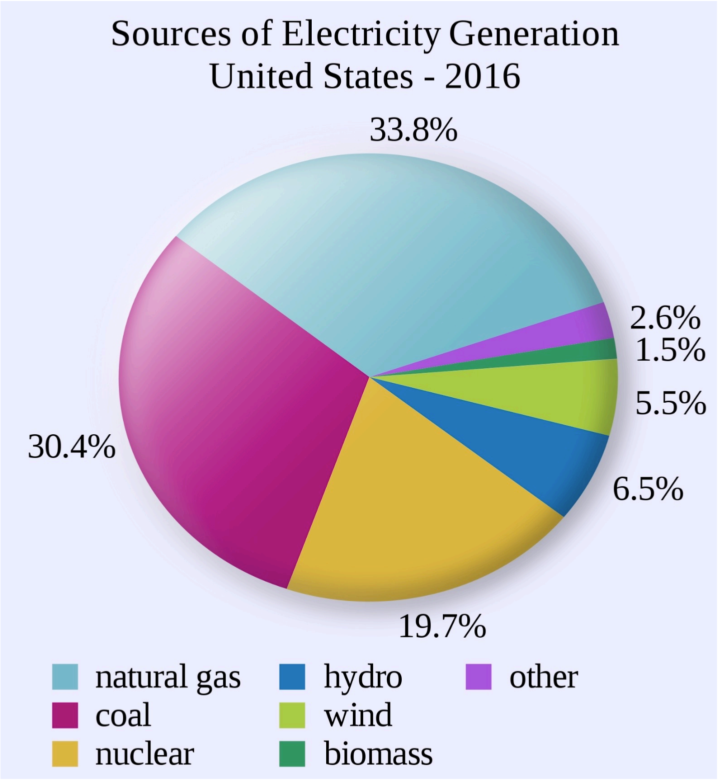
Course Description:

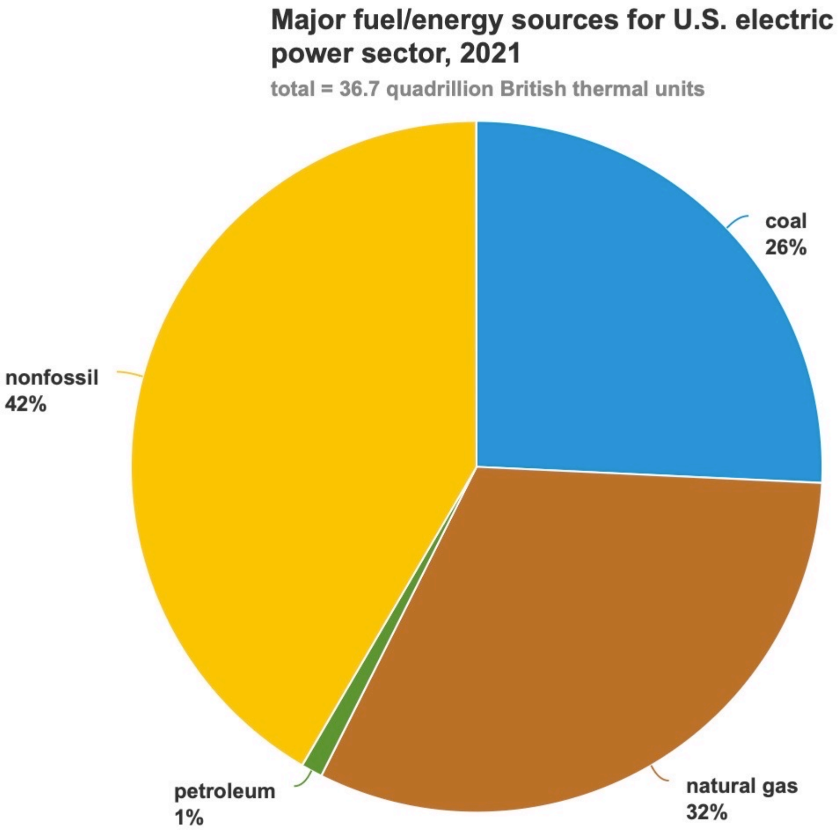
Participate in developing the economics for a potential green energy project. An in-depth knowledge of economics or engineering is NOT required for this course. This course will review the Rocky Mountain Institute paper "The Economics of Battery Energy Storage" and develop a cost benefit analysis for a potential campus battery energy storage system. A battery energy storage system can generate financial benefits from regional transmission operator market services, utility services, and savings on electric rates. A battery energy storage system built into a future campus building addition or modification will enable a future campus microgrid. The initial module will review the project concept, battery energy storage technology, and the regional, local, & campus power grids. Additional modules will explore ways a battery energy storage system can save money on campus utility bills and generate income from participation in regional transmission & utility services markets.

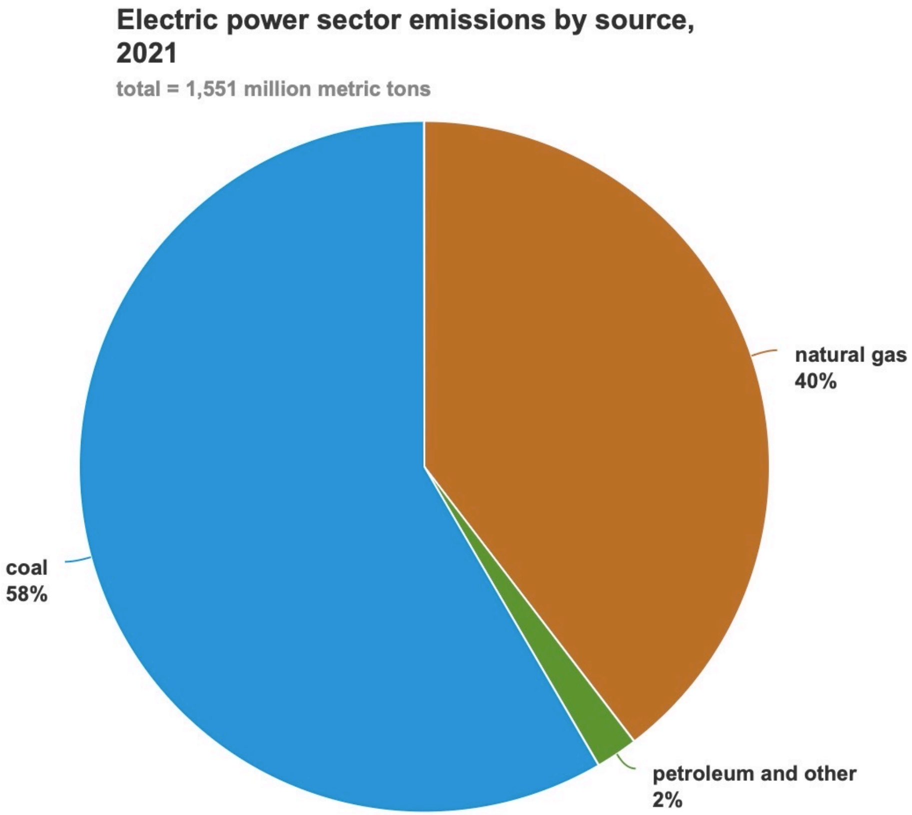
What is green energy?



[US Environmental Protection Agency (EPA)]





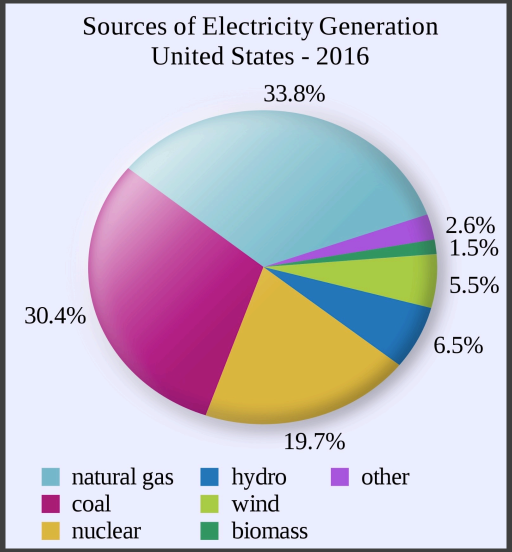


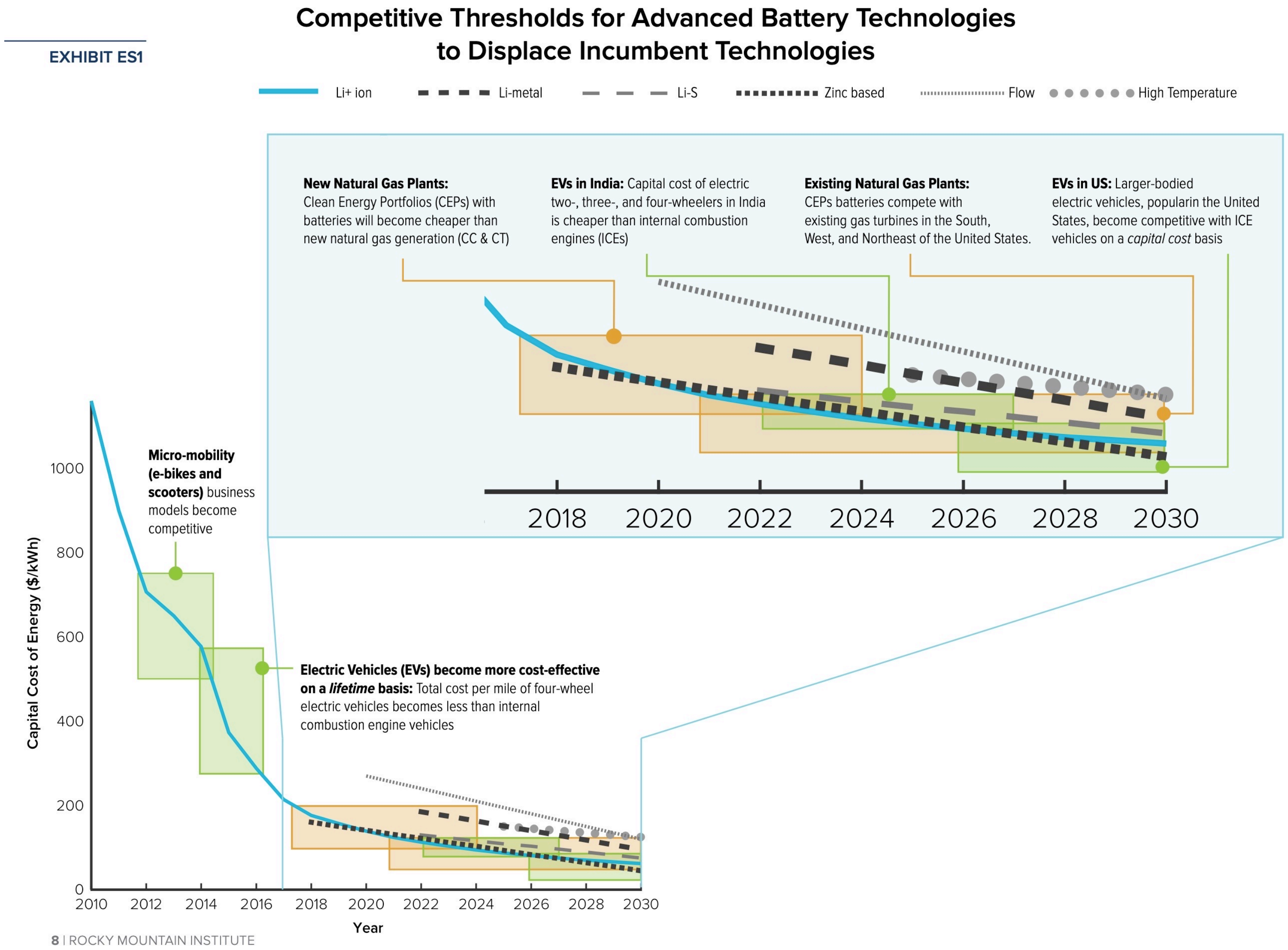
[US Energy Information Agency (EIA)]

CO2 emissions to produce a Tesla Model 3 battery: 2-16 metric tons. A gas-powered car emits 1 metric ton per 2500 miles.

An electric vehicle running on electricity generated by coal runs cleaner or about the same as as a gas- powered vehicle so the dirtiest electric vehicle looks like our best gasoline vehicles today

[MIT Climate Portal]





[“Break Through Batteries Powering the Era of Clean Electrification"]

Wattage

100 Watts (W)= light bulb 

1000 Watts (W) or 1 kiloWatts (kW)= hair dryer 

10,000 Watts (W) or 10 kiloWatts (kW)= 2000 sq ft house (5 Watts/sq ft) 

100,000 Watts (W) or 100 kiloWatts (kW)= 20,000 sq ft campus building (5 Watts/sq ft) 

10,000,000 Watts (W) or 10,000 kiloWatts (kW) or 10 MegaWatts (MW)= portion of college campus

A battery energy storage system (BESS) consists of pre-engineered, preassembled, and pretested battery, inverter, transformer, and control modules connected to the power grid.

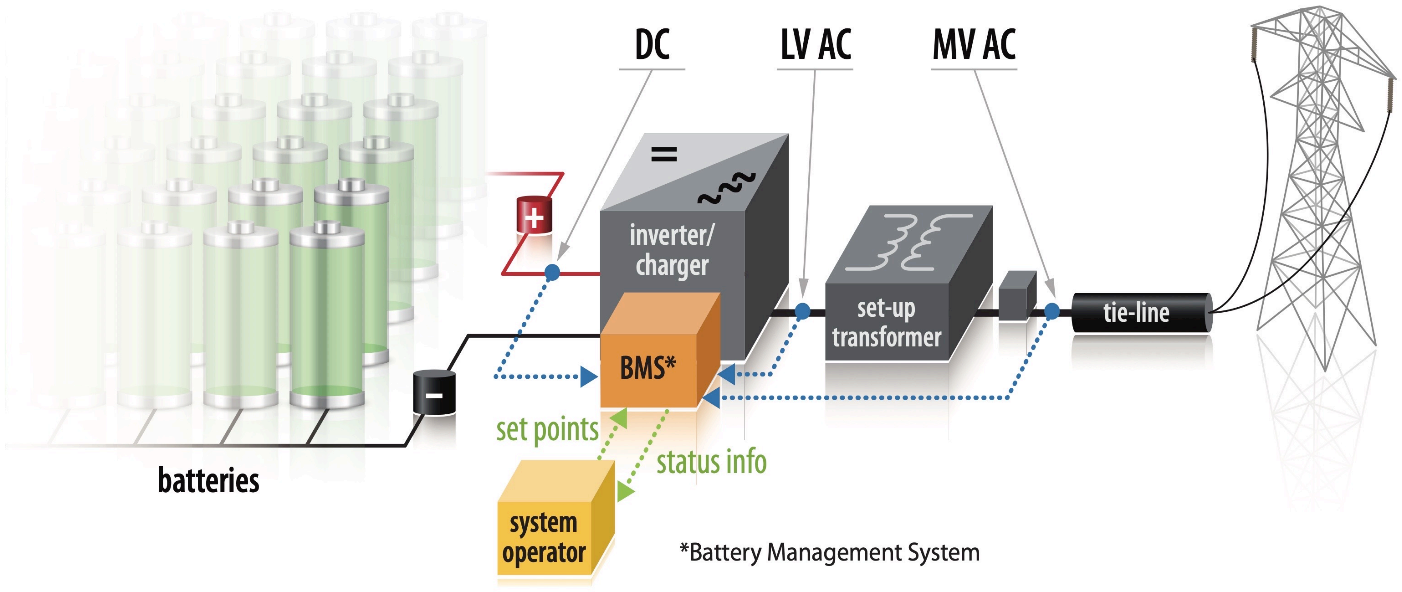
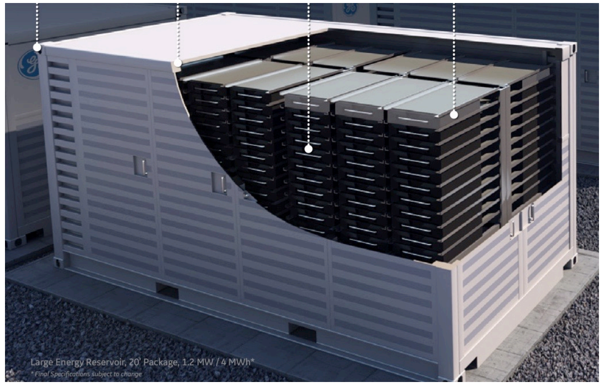
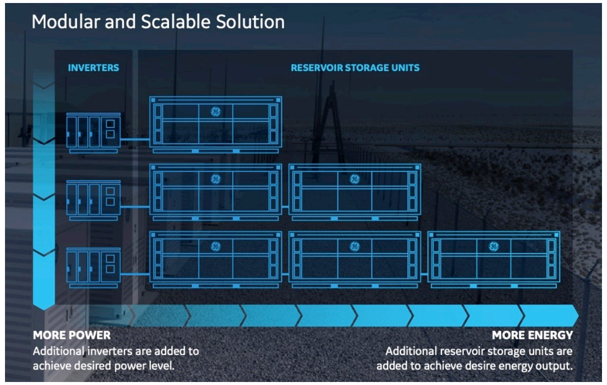


Figure 3: Key components of BESS interconnected at the transmission substation level. LV AC represents a low-voltage AC connection, while MV AC represents a medium-voltage AC connection.[4] *Source: Denholm (2019)*

US National Renewable Energy Lab





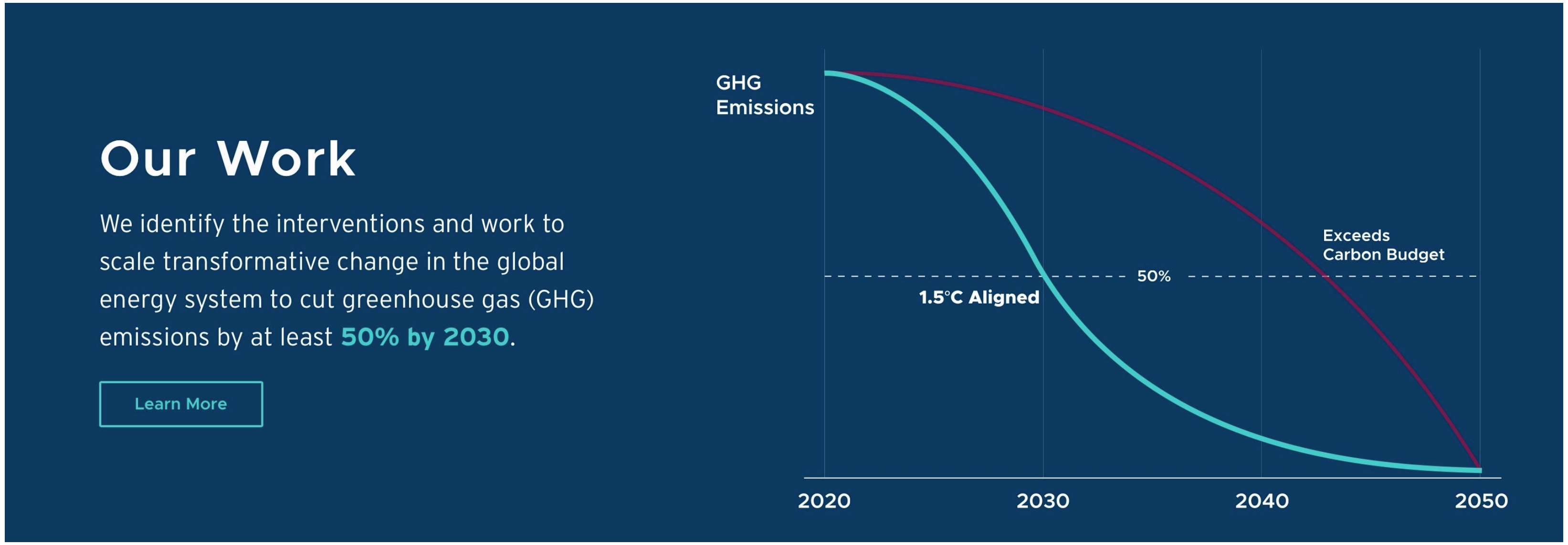
GE BESS Brochure

PRODUCT DATA	UNITS	ENERGY STORAGE UNIT RSU-4000
Nameplate Energy Capacity	kWh_{DC}	4184
Maximum Power	kW_{DC}	1300

[GE BESS 4184 kWh Data Sheet]

Total Installed Cost of $500/kWh x 4184kWh= $2 million

Rocky Mountain Institute Institute (RMI)



[Rocky Mountain Institute (RMI)]

["Economics of Battery Energy Storage"]

RMI is tackling the climate crisis by focusing on its main contributor: energy production and use, which represents 70% of global greenhouse gas emissions.

Carbon-Free Electricity

Accelerating the transition to clean electricity around the world.

Learn More

Carbon-Free Buildings

Carbon-Free Mobility

Climate-Aligned Industries

Breakthrough Technologies

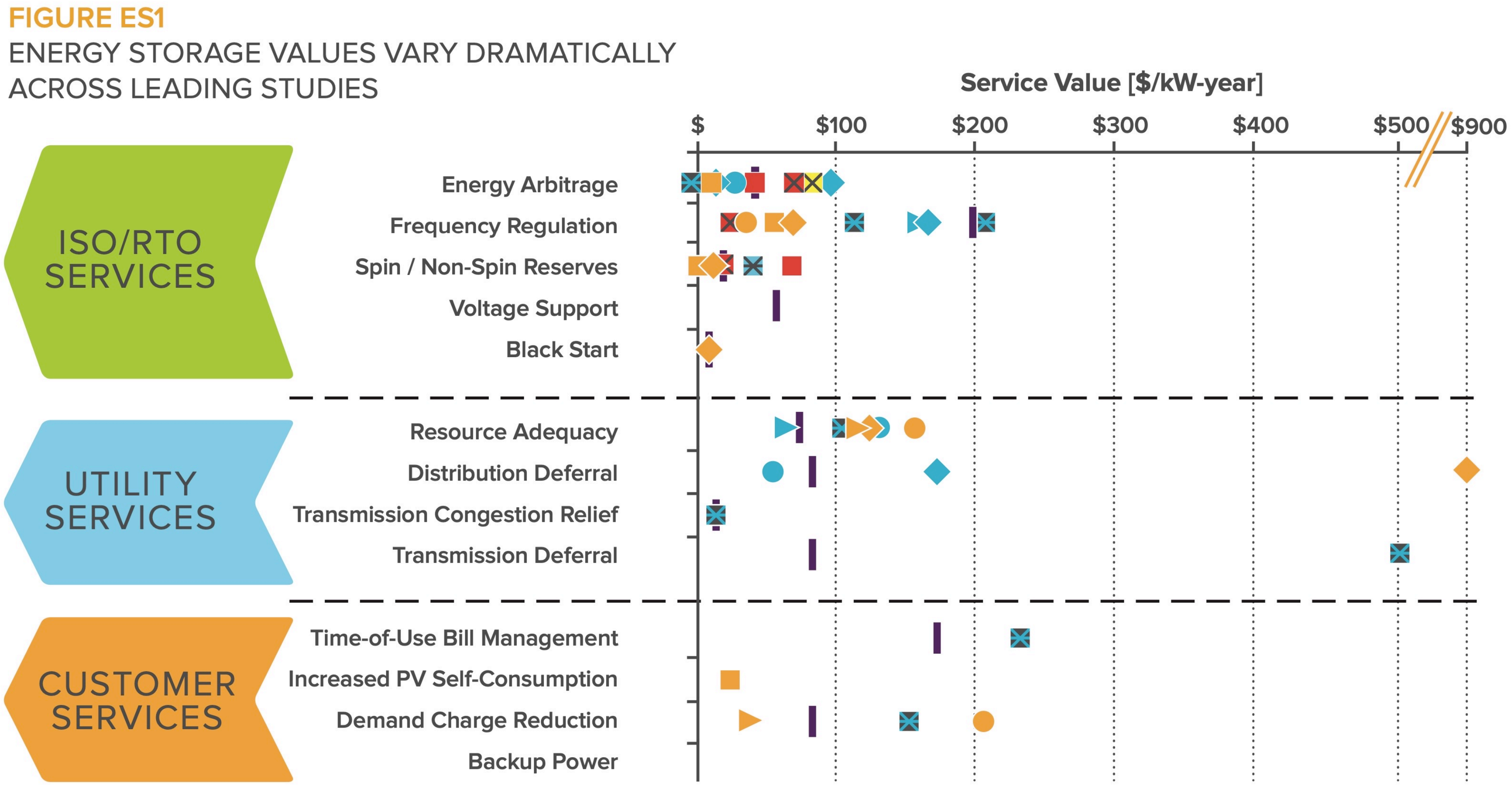
Scaling climate tech and opening new markets for innovation

Learn More

Climate Intelligence

Urban Transformation

Strategic Analysis & Engagement Group

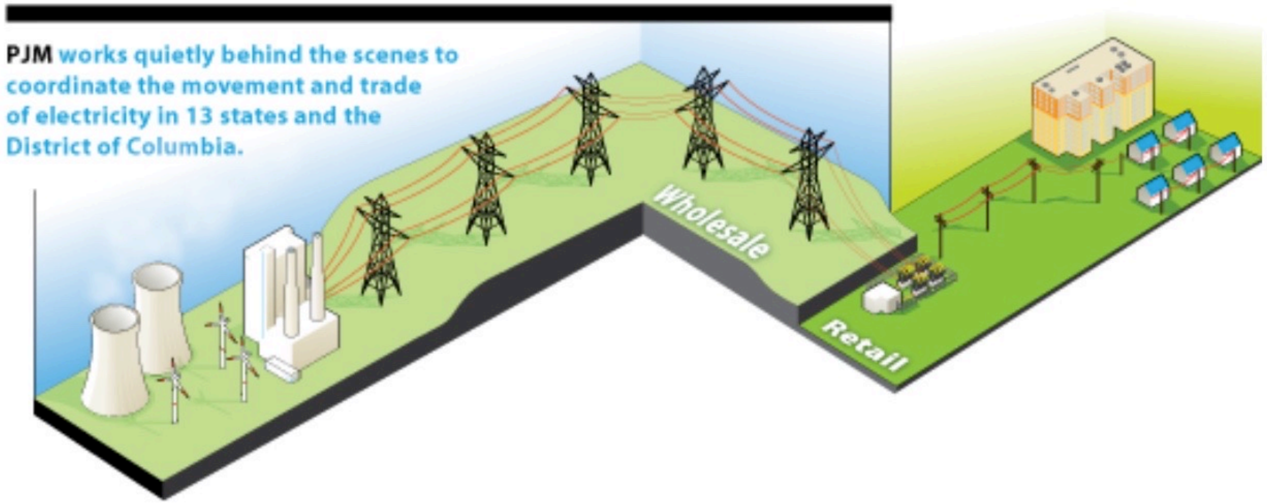


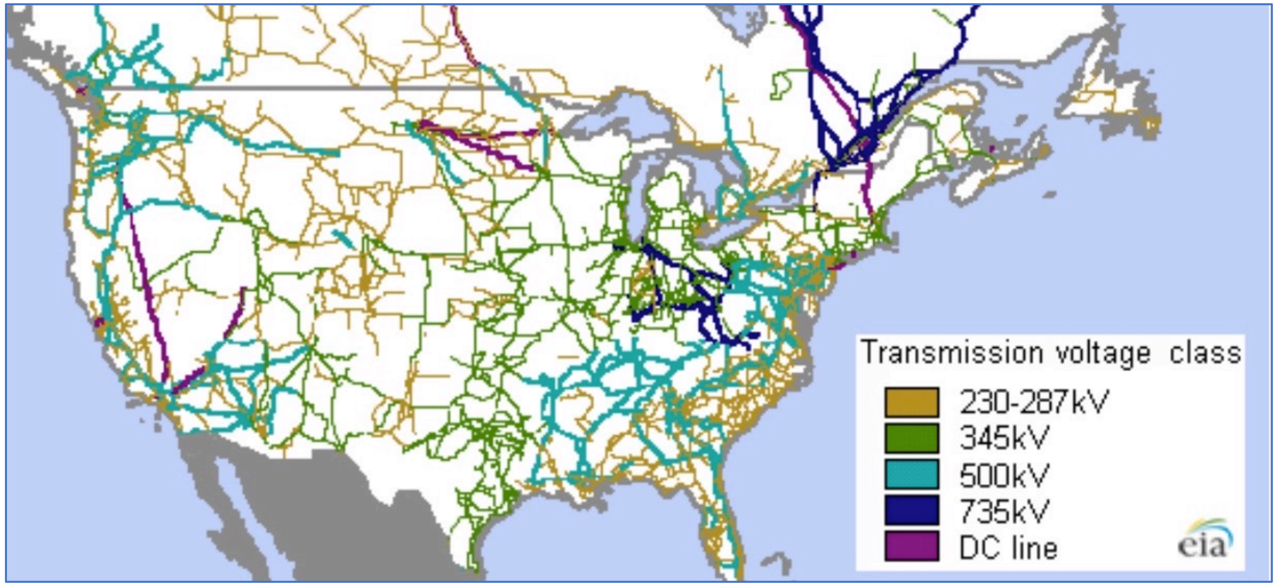
Rocky Mountain Institute "The Economics of Battery Energy Storage"

US National Renewable Energy Lab

Table 1: Applications of Utility-Scale Energy Storage			
Application	**Description**	**Duration of Service Provision**	**Typically Valued in U.S. Electricity Markets?**
Arbitrage	Purchasing low-cost off-peak energy and selling it during periods of high prices.	Hours	Yes
Firm Capacity	Provide reliable capacity to meet peak system demand.	4+ hours	Yes, via scarcity pricing and capacity markets, or through resource adequacy payments.
Operating Reserves			
• Primary Frequency Response	Very fast response to unpredictable variations in demand and generation.	Seconds	Yes, but only in a limited number of markets.
• Regulation	Fast response to random, unpredictable variations in demand and generation.	15 minutes to 1 hour	Yes
• Contingency Spinning	Fast response to a contingency such as a generator failure.	30 minutes to 2 hours	Yes
• Replacement/ Supplemental	Units brought online to replace spinning units.	Hours	Yes, but values are very low.
• Ramping/Load Following	Follow longer-term (hourly) changes in electricity demand.	30 minutes to hours	Yes, but only in a limited number of markets.
Transmission and Distribution Replacement and Deferral	Reduce loading on T&D system during peak times.	Hours	Only partially, via congestion prices.
Black-Start	Units brought online to start system after a system-wide failure (blackout).	Hours	No, typically compensated through cost-of-service mechanisms.

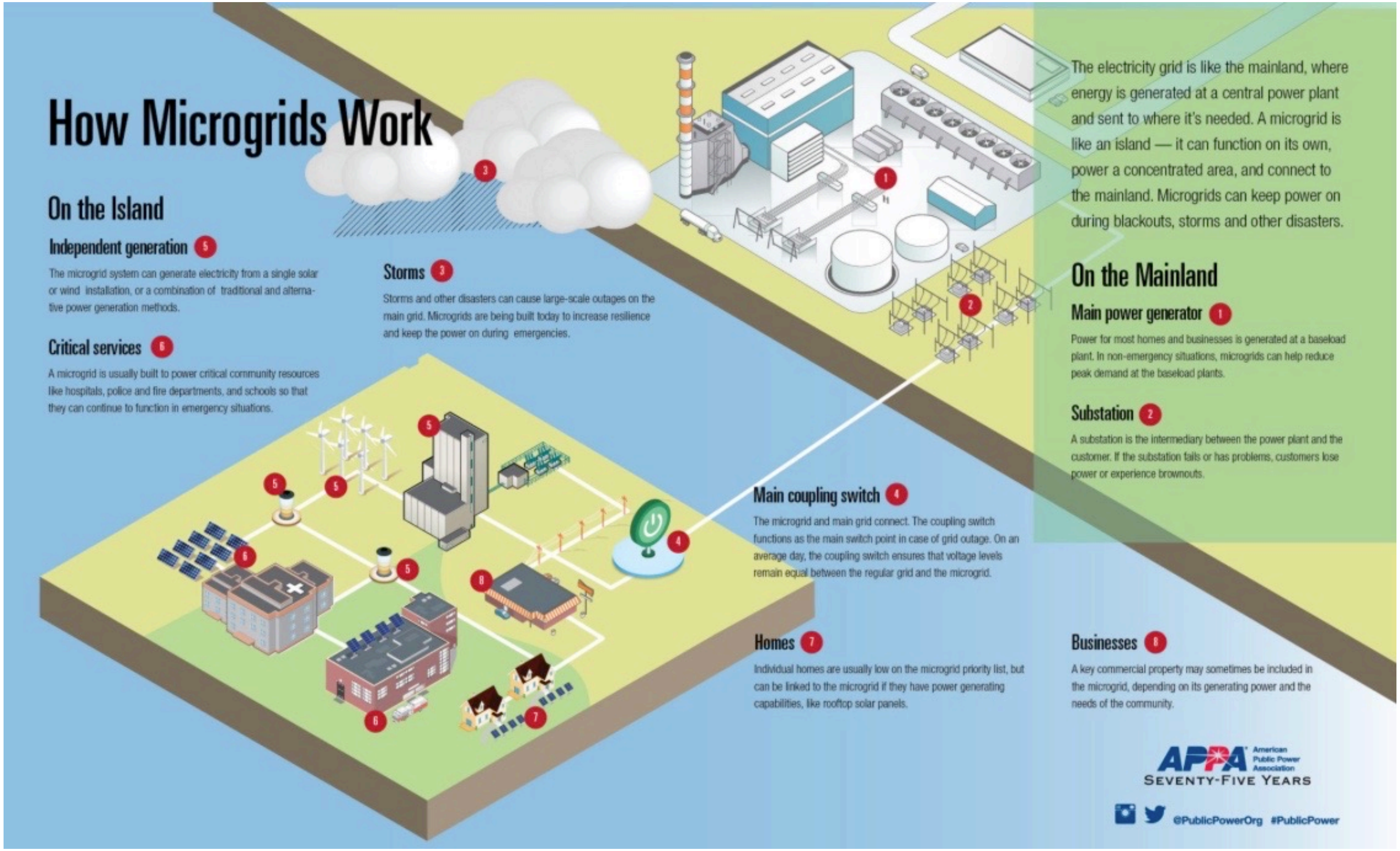
Grid Overview





Transmission Grid (High Voltage)

Distribution Grid (Medium Voltage)

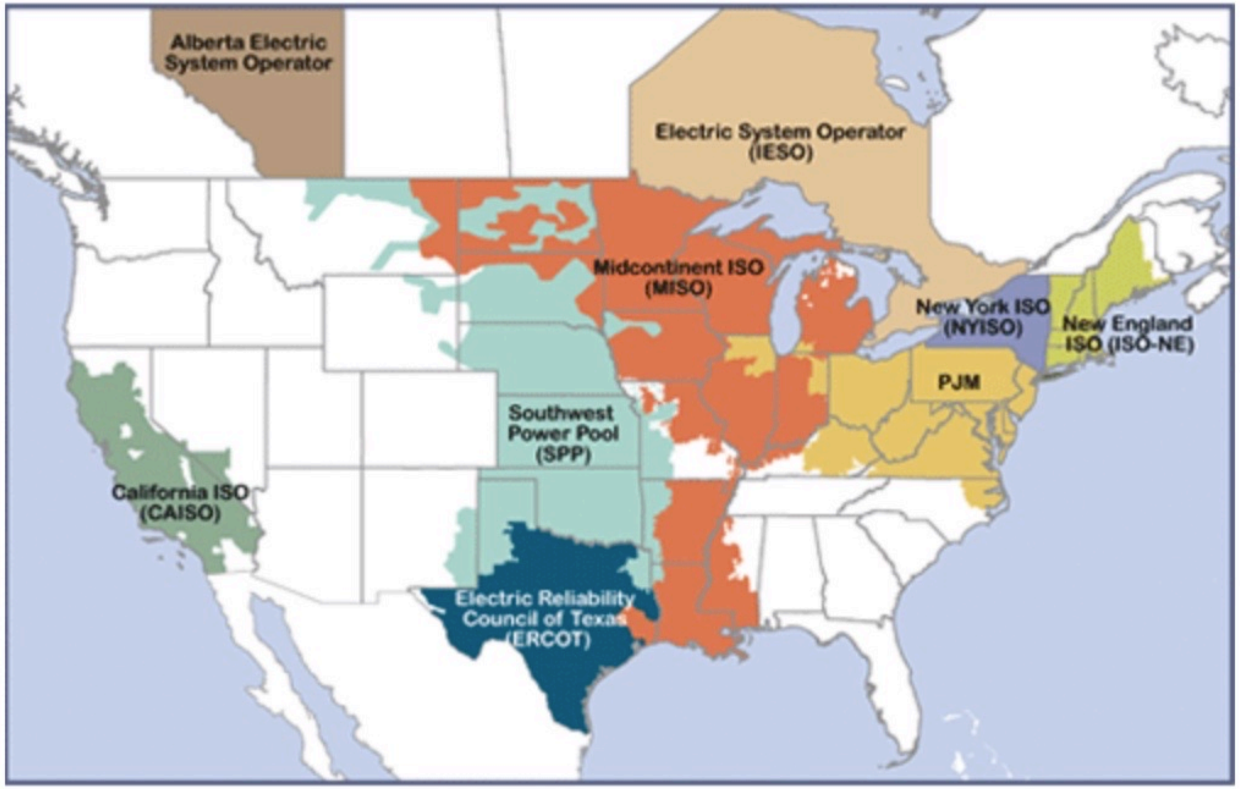


How Microgrids Work
On the Island
Independent generation 5
The microgrid system can generate electricity from a single solar or wind installation, or a combination of traditional and alternative power generation methods.
Critical services 6
A microgrid is usually built to power critical community resources like hospitals, police and fire departments, and schools so that they can continue to function in emergency situations.
Storms 3
Storms and other disasters can cause large-scale outages on the main grid. Microgrids are being built today to increase resilience and keep the power on during emergencies.
The electricity grid is like the mainland, where energy is generated at a central power plant and sent to where it's needed. A microgrid is like an island — it can function on its own, power a concentrated area, and connect to the mainland. Microgrids can keep power on during blackouts, storms and other disasters.
On the Mainland
Main power generator 1
Power for most homes and businesses is generated at a baseload plant. In non-emergency situations, microgrids can help reduce peak demand at the baseload plants.
Substation 2
A substation is the intermediary between the power plant and the customer. If the substation fails or has problems, customers lose power or experience brownouts.
Main coupling switch 4
The microgrid and main grid connect. The coupling switch functions as the main switch point in case of grid outage. On an average day, the coupling switch ensures that voltage levels remain equal between the regular grid and the microgrid.
Homes 7
Individual homes are usually low on the microgrid priority list, but can be linked to the microgrid if they have power generating capabilities, like rooftop solar panels.
Businesses 8
A key commercial property may sometimes be included in the microgrid, depending on its generating power and the needs of the community.
APPA American Public Power Association
SEVENTY-FIVE YEARS
@PublicPowerOrg #PublicPower

[Public Utilities Regulatory Act (PURPA)](#) PURPA is a federal law enacted in 1978 in reaction to the mid 1970s energy crisis and implemented by state public service commissions for rate-regulated electric utilities. PURPA's goals are to encourage competition, conservation, reliability and efficiency in generating and delivering electricity.

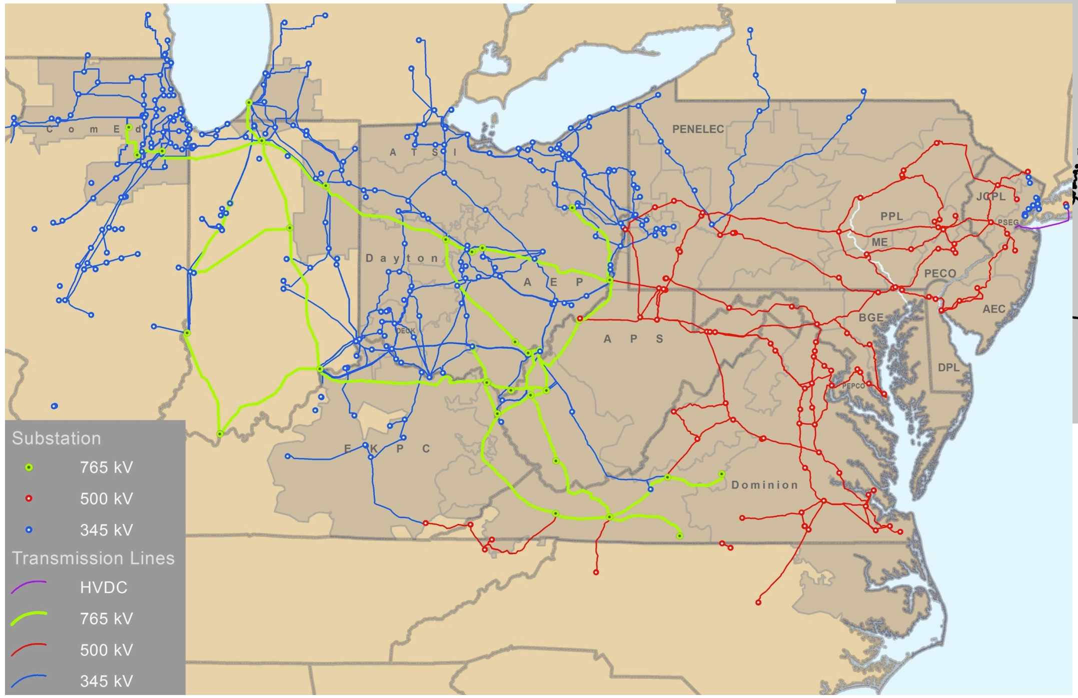
[Federal Energy Regulatory Commision (FERC)](#) created by the Federal Power Act in 1920 is an independent agency that regulates the interstate transmission of electricity, natural gas, and oil. FERC also reviews proposals to build liquefied natural gas (LNG) terminals and interstate natural gas pipelines as well as licensing hydropower projects.

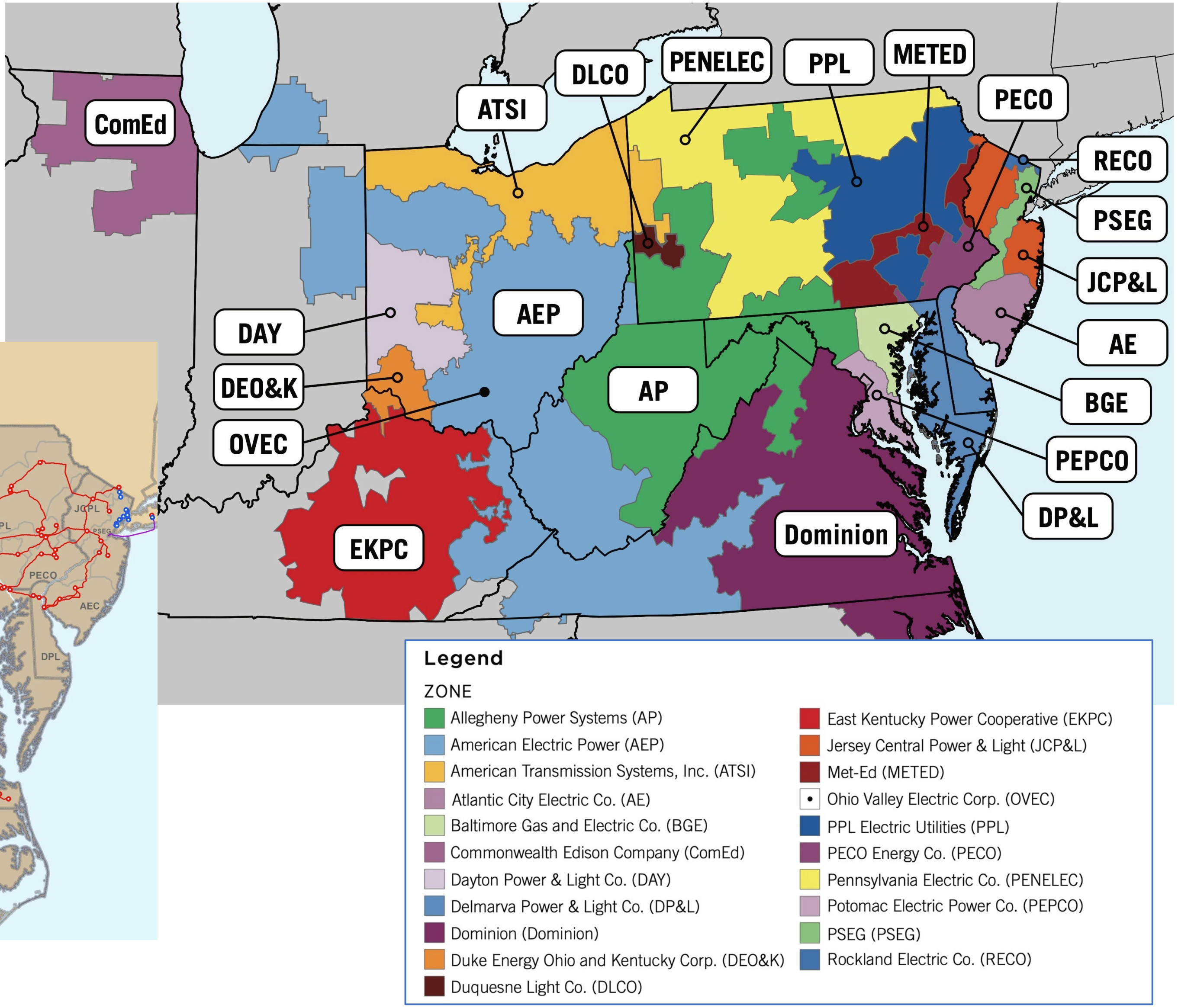
[FERC Order 888](#) in 1996 suggested the concept of an Independent System Operator as one way for existing power pools to satisfy the requirement of providing non-discriminatory access to transmission. Several years later [FERC Order 2000](#) encouraged the voluntary formation of Regional Transmission Operators.



[Regional Transmission Organizations (RTOs) & Independent System Operators (ISOs)](#)

PJM Territory and Members





PJM is authorized by FERC to oversee the grid in its region, bringing independence to operating and planning infrastructure that is built , owned, and maintained by transmission owners. The North American Energy Regulatory Corporation (NERC) oversees cyber & physical security.

PJM was founded in 1927 as a power pool of three utilities serving customers in Pennsylvania and New Jersey. In 1956, with the addition of two Maryland utilities, it became the Pennsylvania-New Jersey-Maryland Interconnection, or PJM.

The PJM Interconnection operates a competitive wholesale electricity market and manages the reliability of its transmission grid.

PJM provides open access to the transmission and performs long-term planning. In managing the grid, PJM centrally dispatches generation and coordinates the movement of wholesale electricity in all or part of 13 states.

PJM's markets include energy (day-ahead and real-time), capacity and ancillary services.

PJM became a fully functioning ISO in 1996 and, in 1997, it introduced markets with bid-based pricing and locational market pricing (LMP). PJM was designated an RTO in 2001.

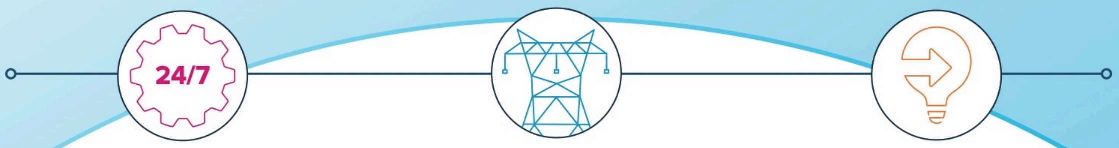
Membership costs $5000 annually for participation in the PJM wholesale market.

PJM 2MW Energy Storage Demonstration Project

PJM has gained experience with storage technology on its campus. A 2-megawatt array of lithium-ion batteries (owned and operated by a subsidiary of The AES Corp., a PJM member) was stationed at PJM for years and demonstrated how it could change its output or electricity consumption in less than 1 second to help PJM quickly balance short-term variations in electricity use.

This battery project allowed PJM and the storage industry to better understand the operational and market nuances of this new technology. As a result of this initial work more than 300 MW of battery energy storage systems have been developed across the PJM footprint.

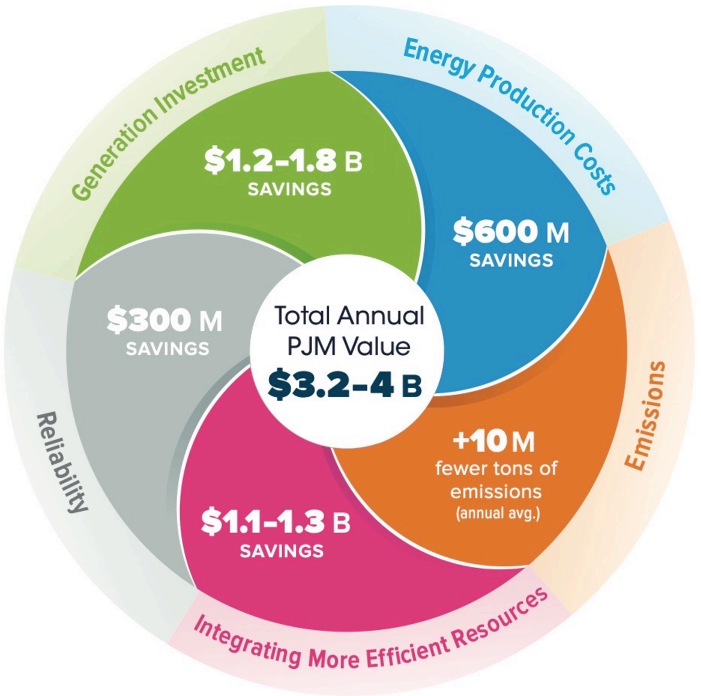
PJM operations, markets and planning result in annual savings of $3.2 – 4 billion. These savings represent the vital functions that PJM provides and that lead to less cost to consumers:



- Ensuring reliable power 24 hours a day, 7 days a week
- Providing capacity for the future and reserves for emergencies

- Managing generation and other resources in real time to meet consumer demand
- Procuring specialized services that protect the stability of the grid

- Lowering emissions by encouraging generator efficiency
- Offering additional benefits including training, compliance audits and knowledge sharing



PJM Value Proposition

PJM Energy Markets

Energy Market: The largest of the PJM markets is the Energy Market, making up the majority of wholesale electricity costs (62% in 2021). The Energy Market operates much like a stock exchange. PJM matches the demand for electricity with offers to provide it. As the market operator, PJM's role is to balance the needs of buyers, sellers and other market participants while monitoring market activities to ensure open, fair and equitable access.

The Energy Market is divided into the Day-Ahead and Real-Time markets. Both markets match offers from power suppliers with bids from power consumers to ensure that suppliers are ready to deliver at the right time and place.

Capacity Market: While the Energy Market addresses near-term electricity needs, the Capacity Market prepares for future demand. PJM's capacity market secures enough power supplies, three-years ahead, to ensure sufficient supply for peak demand.

Each year, PJM holds a competitive auction to obtain these future power supplies at the lowest reasonable price. Capacity is the commitment by resources to deliver electricity or to lower consumption when needed, particularly in an emergency.

The capacity market thus ensures reliable power in the future for the PJM region. In return, the capacity market provides a dependable flow of income to power resources. In all, the capacity market helps generators maintain existing capability, attracts investment in new resources, and encourages companies to develop new technologies and sources of electric power.

PJM Energy Markets (continued)

Ancillary Services Markets

Because electricity must be produced and consumed the instant it is needed, PJM dispatchers must continuously match the electricity flowing on the grid with customers' demand for it.

Key elements of this delicate balancing act are regulation resources and reserves, which are called ancillary services – a small but vital part of the electricity markets.

Regulation is a reliability product that corrects short-term, unforeseen fluctuations in electricity use and supply that could affect the stability of the power system. Regulation providers are resources that have the ability to adjust output or consumption in response to an automated signal.

Reserves are generation resources that can come online (or end-use consumers that can reduce consumption) within 10 or 30 minutes in the event of an unexpected loss in generation. These operating reserves also help balance the system in emergency situations.

FERC Order 841 (February 2018) mandated all ISOs and RTOs create a market-participation model in which energy storage resources can provide all the market services that they are technically capable of offering.

FERC Order 2222 (September 2020) will help usher in the electric grid of the future and promote competition in electric markets by removing the barriers preventing distributed energy resources (DERs) from competing on a level playing field in the organized capacity, energy and ancillary services markets run by regional grid operators.

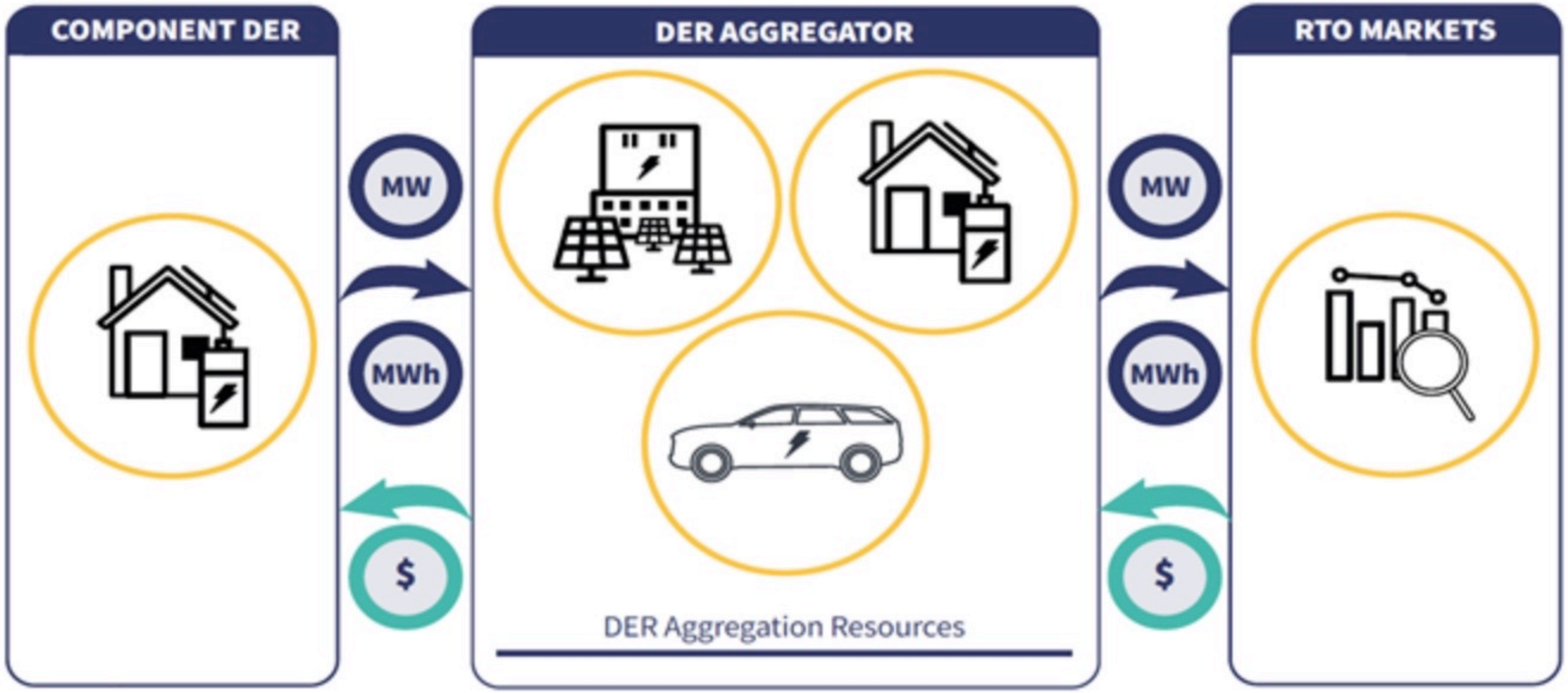
What are distributed energy resources?

DERs are small-scale power generation or storage technologies (typically from 1 kW to 10,000 kW) that can provide an alternative to or an enhancement of the traditional electric power system. These can be located on an electric utility's distribution system, a subsystem of the utility's distribution system or behind a customer meter. They may include electric storage, intermittent generation, distributed generation, demand response, energy efficiency, thermal storage or electric vehicles and their charging equipment.

What does Order No. 2222 do?

This rule enables DERs to participate alongside traditional resources in the regional organized wholesale markets through aggregations, opening U.S. organized wholesale markets to new sources of energy and grid services. It will help provide a variety of benefits including: lower costs for consumers through enhanced competition, more grid flexibility and resilience, and more innovation within the electric power industry.

This rule allows several sources of distributed electricity to aggregate in order to satisfy minimum size and performance requirements that each may not be able to meet individually.



[FERC 2222 Explainer]

ISO / RTO SERVICES	SERVICE NAME	DEFINITION
	Energy Arbitrage	The purchase of wholesale electricity while the locational marginal price (LMP) of energy is low (typically during nighttime hours) and sale of electricity back to the wholesale market when LMPs are highest. Load following, which manages the difference between day-ahead scheduled generator output, actual generator output, and actual demand, is treated as a subset of energy arbitrage in this report.
	Frequency Regulation	Frequency regulation is the immediate and automatic response of power to a change in locally sensed system frequency, either from a system or from elements of the system.[1] Regulation is required to ensure that system-wide generation is perfectly matched with system-level load on a moment-by-moment basis to avoid system-level frequency spikes or dips, which create grid instability.
	Spin/Non-Spin Reserves	Spinning reserve is the generation capacity that is online and able to serve load immediately in response to an unexpected contingency event, such as an unplanned generation outage. Non-spinning reserve is generation capacity that can respond to contingency events within a short period, typically less than ten minutes, but is not instantaneously available.
	Voltage Support	Voltage regulation ensures reliable and continuous electricity flow across the power grid. Voltage on the transmission and distribution system must be maintained within an acceptable range to ensure that both real and reactive power production are matched with demand.
	Black Start	In the event of a grid outage, black start generation assets are needed to restore operation to larger power stations in order to bring the regional grid back online. In some cases, large power stations are themselves black start capable.

Electric Utility: a corporation, person, agency, authority, or other legal entity or instrumentally aligned with distribution facilities for delivery of electric energy for use primarily by the public. Included are investor-owned electric utilities, municipal and State utilities, Federal electric utilities, and rural electric cooperatives. A few entities that are tariff based and cooperatively align with companies that own distribution facilities are also included.

Pennsylvania Public Utilities Commission (PA PUC) the mission of the Pennsylvania Public Utilities Commission is to balance the needs of consumers and utilities; ensure safe and reliable utility service at reasonable rates; protect the public interest; educate consumers to make independent and informed utility choices; further economic development; and foster new technologies and competitive markets in an environmentally sound manner.

Duquesne Light Company (DLC) is a leader in the transmission and distribution of electric energy in the Pittsburgh region and has been for more than 140 years. We consistently rank among the most reliable utilities in the state and part of that reliability is our commitment to upgrading our infrastructure. That includes nearly $2 billion in investments between 2022-2026. Our employees are dedicated to ensuring equal access to safe, resilient, reliable and affordable energy while also enabling our region's clean energy future. DLC Tariffs (Rates)

- [DLC Riazzi 138kV Transmission Substation]

	SERVICE NAME	DEFINITION
UTILITY SERVICES	Resource Adequacy	Instead of investing in new natural gas combustion turbines to meet generation requirements during peak electricity-consumption hours, grid operators and utilities can pay for other assets, including energy storage, to incrementally defer or reduce the need for new generation capacity and minimize the risk of overinvestment in that area.
	Distribution Deferral	Delaying, reducing the size of, or entirely avoiding utility investments in distribution system upgrades necessary to meet projected load growth on specific regions of the grid.
	Transmission Congestion Relief	ISOs charge utilities to use congested transmission corridors during certain times of the day. Assets including energy storage can be deployed downstream of congested transmission corridors to discharge during congested periods and minimize congestion in the transmission system.
	Transmission Deferral	Delaying, reducing the size of, or entirely avoiding utility investments in transmission system upgrades necessary to meet projected load growth on specific regions of the grid.

Rocky Mountain Institute “The Economics of Battery Energy Storage”

	SERVICE NAME	DEFINITION
CUSTOMER SERVICES	Time-of-Use Bill Management	By minimizing electricity purchases during peak electricity-consumption hours when time-of-use (TOU) rates are highest and shifting these purchase to periods of lower rates, behind-the-meter customers can use energy storage systems to reduce their bill.
	Increased PV Self-Consumption	Minimizing export of electricity generated by behind-the-meter photovoltaic (PV) systems to maximize the financial benefit of solar PV in areas with utility rate structures that are unfavorable to distributed PV (e.g., non-export tariffs).
	Demand Charge Reduction	In the event of grid failure, energy storage paired with a local generator can provide backup power at multiple scales, ranging from second-to-second power quality maintenance for industrial operations to daily backup for residential customers.
	Backup Power	In the event of grid failure, energy storage paired with a local generator can provide backup power at multiple scales, ranging from second-to-second power quality maintenance for industrial operations to daily backup for residential customers.

Rocky Mountain Institute "The Economics of Battery Energy Storage"

DLC rates CMU currently pays

MONTHLY RATE

SUPPLY

Customers who elect to purchase their electric supply requirements from the Company may do so under the provisions of Rider No. 9 – Day-Ahead Hourly Price Service and will be billed in accordance with the terms contained therein.

DISTRIBUTION

DEMAND CHARGES

Service Voltage Less than 138 kV:

First 5,000 kilowatts or less of Demand	$39,174.00
Additional kilowatts of Demand	$15.68 per kW

ELECTRIC CHARGES

The Company will provide and charge for Transmission service consistent with the PJM Open Access Transmission Tariff approved or accepted by the Federal Energy Regulatory Commission for customers who receive Default Service from the Company. The Transmission Service Charges are included, for informational purposes, in Appendix A of this Tariff.

Rider Titles:

Rider No. 1 — Retail Market Enhancement Surcharge
Rider No. 2 — Untransformed Service
Rider No. 3 — School and Government Service Discount Period
Rider No. 4 — Intentionally Left Blank
Rider No. 5 — Universal Service Charge
Rider No. 6 — Temporary Service
Rider No. 7 — Intentionally Left Blank
Rider No. 8 — Default Service Supply
Rider No. 9 — Day-Ahead Hourly Price Service
Rider No. 10 — State Tax Adjustment
Rider No. 11 — Street Railway Service
Rider No. 12 — Billing Option – Volunteer Fire Companies and Nonprofit Senior Citizen Centers
Rider No. 13 — General Service Separately Metered Electric Space Heating Service
Rider No. 14 — Residential Service Separately Metered Electric Space and Water Heating
Rider No. 15 — Intentionally Left Blank
Rider No. 15A — Phase IV Energy Efficiency and Conservation Surcharge
Rider No. 16 — Service to Non-Utility Generating Facilities
Rider No. 17 — Emergency Energy Conservation
Rider No. 18 — Rates for Purchase of Electric Energy from Customer-Owned Renewable Resources Generating Facilities
Rider No. 19 — Community Development for New Load
Rider No. 20 — Smart Meter Charge
Rider No. 21 — Net Metering Service
Rider No. 22 — Distribution System Improvement Charge (“DSIC”)
Appendix A — Transmission Service Charges

RIDER MATRIX

	RS	RH	RA	GS/GM	GMH	GL	GLH	L	HVPS	AL	SE	SM	SH	UMS	PAL
Rider No. 1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Rider No. 2				X	X	X	X								
Rider No. 3				X	X	X	X	X							
Rider No. 4															
Rider No. 5	X	X	X												
Rider No. 6				X											
Rider No. 7															
Rider No. 8	X	X	X	X	X					X	X	X	X	X	X
Rider No. 9				X	X	X	X	X	X						
Rider No. 10	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Rider No. 11				X		X									
Rider No. 12				X	X										
Rider No. 13				X											
Rider No. 14	X														
Rider No. 15															
Rider No. 15A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Rider No. 16				X	X	X	X	X							
Rider No. 17						X	X	X	X						
Rider No. 18	X	X	X	X	X	X	X								
Rider No. 19				X		X		X							
Rider No. 20	X	X	X	X	X	X	X	X	X	X					
Rider No. 21	X	X	X	X	X	X									
Rider No. 22	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Appendix A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

STANDARD CONTRACT RIDERS - (Continued)

RIDER NO. 16 - SERVICE TO NON-UTILITY GENERATING FACILITIES - (Continued)

(Applicable to Rates GM < 25, GM ≥ 25, GMH, GL, GLH and L)

DISTRIBUTION

A distribution charge of $3.09 per kW shall be applied to the Back-Up Service Maintenance Demand Billing Determinants.

The Maintenance Contract Demand distribution charges will be applied in each month based on the customer's Maintenance Contract Demand without regard to actual usage.

An additional distribution charge of $6.79 per kW shall be applied to the Back-Up Service As-Used Contract Demand Billing Determinants. The As-Used Contract Demand distribution charge will be applied in each month based on the customer's As-Used Contract Demand if the customer calls upon Back-Up service during the Peak Period.

Overage charges will also apply if the customer exceeds their Maintenance Contract Demand by 10% or more. The Maintenance Overage Charge of $9.88 per kW shall be applied to the difference in actual maximum billing demand during the billing period and the customer's combined Supplementary and Maintenance Contract Demands. No additional charges will apply to the As-Used Contract Demand Charge.

If actual usage of Back-Up Service exceeds zero for more than 15% of the hours in any Base Period, then those hours above the 15% threshold will be counted toward the billing on the customer's applicable general service rates, including all ratchets applicable.

DUQUESNE LIGHT CO.

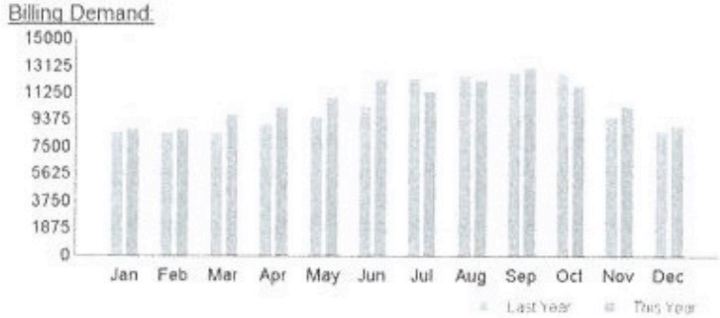
CARNEGIE MELLON UNIVERSITY - MAIN ACCT
PO BOX 2631
Account # 2187-820-000

Due Date	Amount Due
01/06/2023	$425,721.99

Usage and Demand

Period	Total kWh Usage	Avg Daily kWh Usage	# of Days	Avg Daily Temp (F)
Current Month	5574973	174218	32	36
Last Month	5513970	190137	29	51
Same Month Last Year	4921807	164060	30	41

Average Monthly Usage for the last 12 months: 5880105 kWh
Total Annual Usage for the last 12 months: 70561259 kWh



Bill Summary

Bill ID: 218981453865 **Date Prepared: 12/21/2022**

Previous Account Balance	$430,271.06
Payment(s) Received as of 12/20/2022	-$430,271.06
Balance Forward	**$0.00**
DLC Charges	$111,131.99
Supply Charges - GDF SUEZ ENERGY RESOURCES N	$314,590.00
AMOUNT DUE BY 01/06/2023	**$425,721.99**

Message Center

Energy costs are on the rise. Learn what you can do to save money at **DuquesneLight.com/PTC**.

Signing up for our e-Bill program is fast and easy! Enroll today at **DuquesneLight.com/ebill** and you'll receive an email each month when your bill is available.

Duquesne Light Company partners with Dollar Energy Fund to provide assistance to customers who struggle to pay their electric bill. If you would like to support the Dollar Energy Fund and your neighbors in need, make a tax deductible monthly pledge at **DuquesneLight.com/dollar**.

DOLLAR ENERGY FUND

CARNEGIE MELLON UNIVERSITY - MAIN ACCT **Account #** 2187-820-000 Page 3 of 4

Account Detail

5000 FORBES AVE **Supplier Agreement ID: 2187820652**

Meter Reading Usage Information

Meter Number		G09837034
Voltage		2.4/4.16KV
Meter Readings - kWh		
Present	12/18/2022 Act	218.2406
Prior	11/16/2022 Act	9,736.2308
Difference		482.0098
Your Meter Multiplier		4800
Total kWh Used		2,313,647.0400
Meter Readings - kVARh		
Present	12/18/2022 Act	5,642.8177
Prior	11/16/2022 Act	5,469.0887
Difference		173.7290
Your Meter Multiplier		4800
kVARh		833,899.2000

Meter Number		G09837082
Voltage		2.4/4.16KV
Meter Readings - kWh		
Present	12/18/2022 Act	3,936.1844
Prior	11/16/2022 Act	3,603.5247
Difference		332.6597
Your Meter Multiplier		4800
Total kWh Used		1,596,766.5600
Meter Readings - kVARh		
Present	12/18/2022 Act	4,667.4330
Prior	11/16/2022 Act	4,577.1400
Difference		90.2930
Your Meter Multiplier		4800
kVARh		433,406.4000

Meter Number		G02770897
Voltage		2.4/4.16KV
Meter Readings - kWh		
Present	12/18/2022 Act	4,333.9630
Prior	11/16/2022 Act	3,813.7881
Difference		520.1749
Your Meter Multiplier		3200
Total kWh Used		1,664,559.6800
Meter Readings - kVARh		
Present	12/18/2022 Act	3,699.0138
Prior	11/16/2022 Act	3,489.4000
Difference		209.6138
Your Meter Multiplier		3200
kVARh		670,764.1600

Current Bill Details

DLC Rate	L-Large Commercial		
DLC Charges			**$111,131.99**
Demand Distribution	5000.0000 kW@ $7.834800	$39,174.00	
Demand Distribution	4202.3050 kW@ $15.680000	$65,892.14	
PA EEA Fixed		$395.29	
PA EEA Variable	12569.3715 kW@ $0.330000	$4,147.89	
Smart Meter Charge Thre	MTR@ $0.040000	$0.04	
Smart Meter Charge Thre	MTR@ $0.040000	$0.04	
Smart Meter Charge Thre	MTR@ $0.040000	$0.04	
DSIC Surcharge	-0.09%	-$98.65	
Pennsylvania Tax Adjustment		-$12.92	
Late Payment Charge		$1,634.12	
Supply Charges - GDF SUEZ ENERGY RESOURCES NA			**$314,590.00**
Fixed Price @ 5574973.2805 KWH @ $ 0.036		$202,650.28	
Unforced Capacity 14926.9488 KW @ $ 1.60		$23,906.36	
Trans Charge 12001.4093 KW @ $ 5.33472		$64,024.16	
TEC Adj 12001.4093 KW @ $ 0.16040		$1,925.03	
Gross Receipts Tax		$18,339.90	
Late Payment Charge		$3,744.27	

Active Totalization

Voltage	Prior	Present	On-Peak	Off-Peak	PFM	AdjKW
2.4/4.16KV	11/16/2022	12/18/2022	9,123.8400	8,997.1200	1.0086	9,202.3050
Total Billed Demand						**9,202.3050**

Total kWh Used **5,574,973.2800** **Service Charges** **$425,721.99**

Current Bill Details

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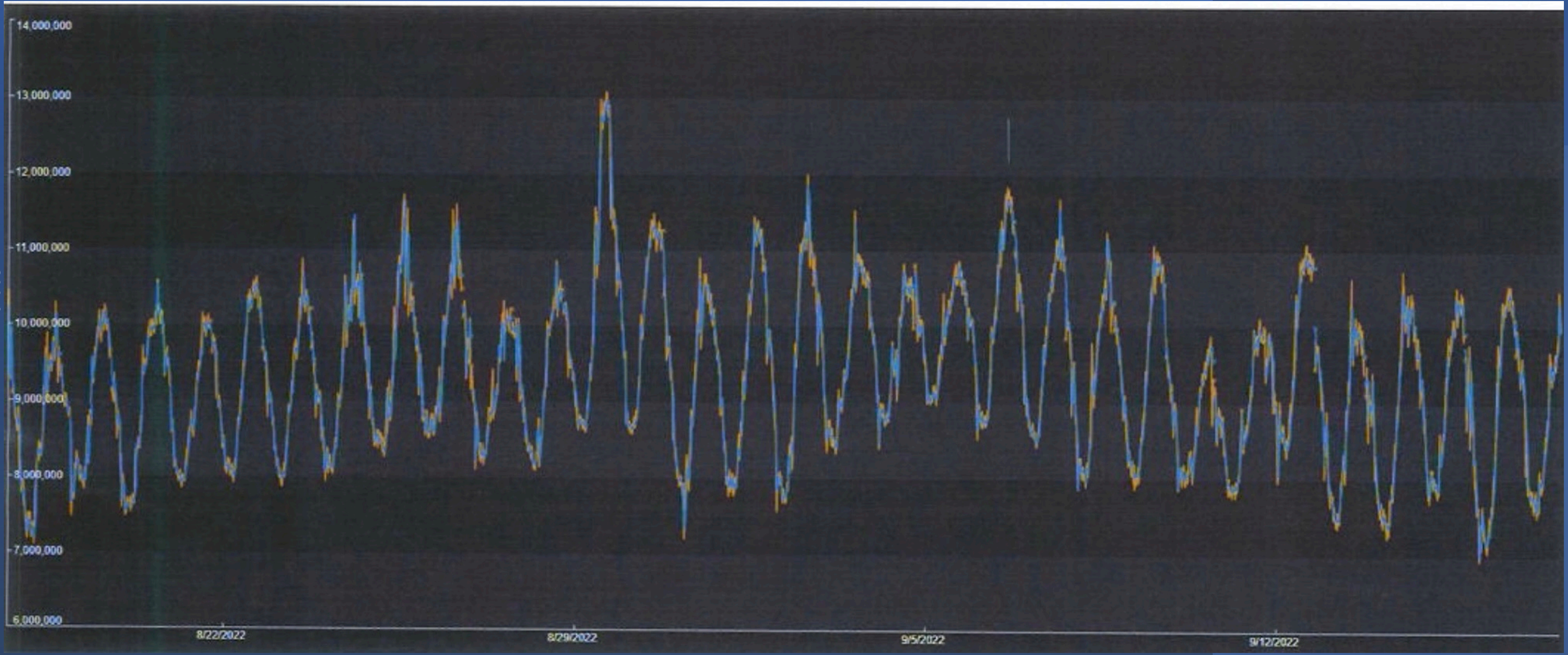
CMU Demand Curve



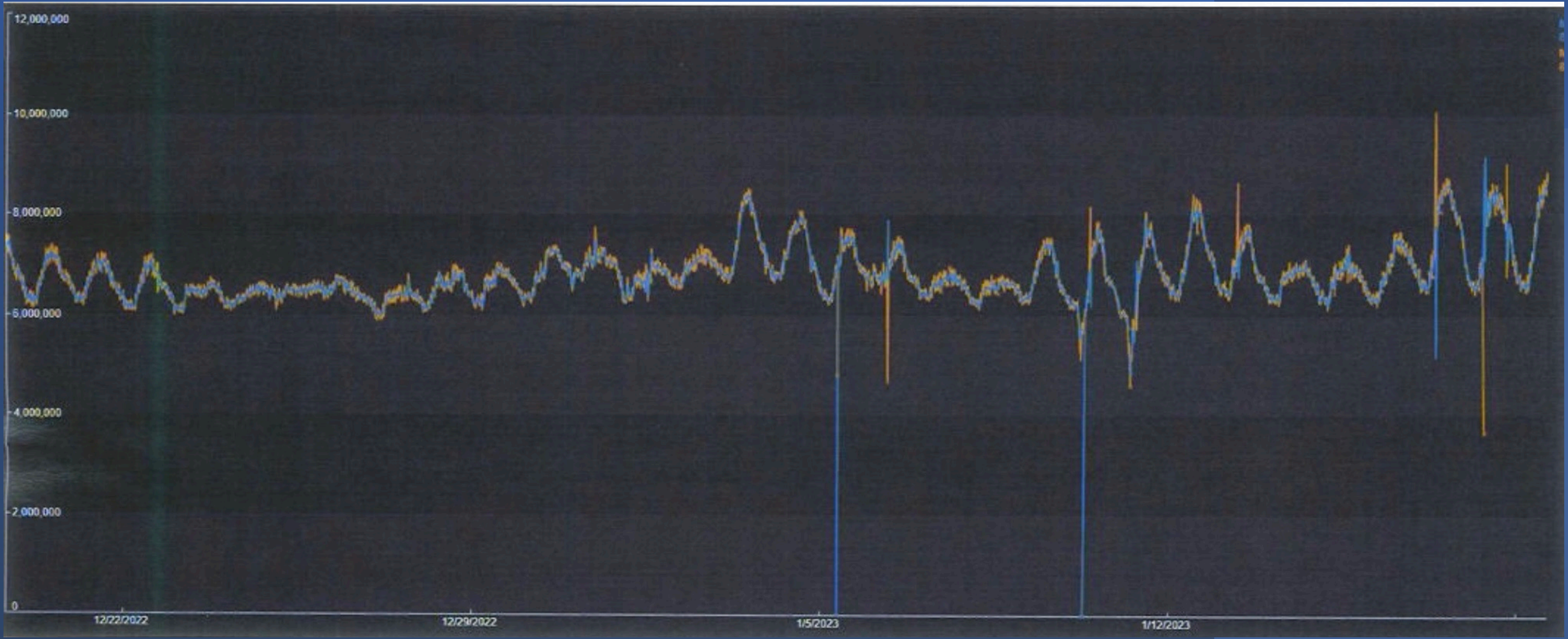
Watts

Hours

GE Energy Storage Unit RSU-4000 is rated 1,300,000 Watts/ 4,184,000 Watt-hours

CMU Demand Curve

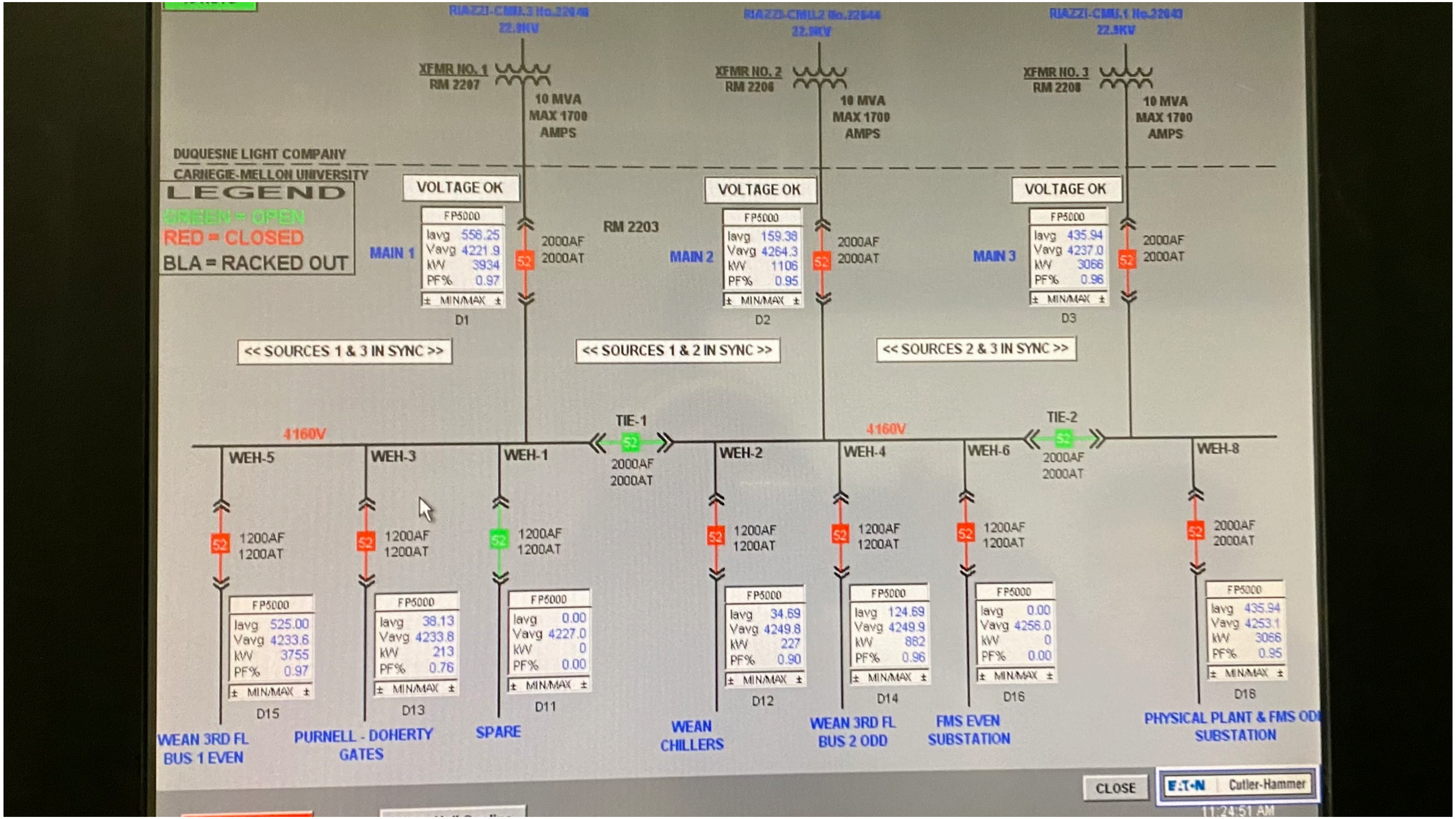
Watts



Hours

GE Energy Storage Unit RSU-4000 is rated 1,300,000 Watts/ 4,184,000 Watt-hours

CMU 4160 Volt Point of Connection (POC)



CMU Battery Energy Storage System (BESS) Cost Benefit Analysis as of 20FEB23

Point of Connection (POC) CMU 4160 Volt Grid

BESS Maximum Power (kW)	1300
BESS Energy Capacity (kWh)	4184
BESS Total Installed Cost per RMI ($/kWh)	500
Number of charges & discharges per day	1
CMU Contracted Supply Charge ($/kWh)	0.036
Demand Charges ($/kW)	
DLC Tier 2	15.68
DLC PA EEA	0.33
Supply Charge Unforced Capacity	1.6
Supplier Transmission	5.33
Supplier TEC	0.16
DLC Standby Charge ($/kW)	3.09
DLC Interconnection Cost ($)	TBD
PJM Interconnection Cost ($)	0
Annual O&M Cost ($/kW)	20

PJM Services Benefit		**$/year**
Energy Arbitrage		TBD
Frequency Regulation		TBD
Spin/Non SpinReserves		TBD
Voltage Support		TBD
Black Start		TBD
Duquesne Light Services Benefit		
Resource Adequacy		0
Distribution Deferral		0
Transmission Congestion Relief		0
Transmission Deferral		0
CMU Benefits		
Time of Use Bill Management		0
Increased PV Self Consumption		0
Demand Reduction		312,156
Back UP Power		0
	Sub Total	**312,156**
Annual O&M Cost		**20**
	Total	**312,136**

Project Costs		**$**
BESS Total Installed Cost (RMI)		2,092,000
	Total	**2,092,000**
Grant/endowment		**2,092,000**