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Distributed Energy & Microgrids

Technology Options, Market Trends, and Incentives

Topics

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- Overview
- Russelectric Background
- Definitions
- Microgrid Controllers
- Sample Projects
- Market & Technology Trends
- Market Targeting
- TN Solar Market
- Sample Project Economics

Overview

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- Microgrids Aren’t New
- What Is New Is
  - Solar PV & Energy Storage Are Increasingly Viable Options
  - More Business, Policy, & Financial Drivers for
    - Microgrids
    - Sustainability
    - Resiliency
- More Tech Options & Drivers = More Opportunities

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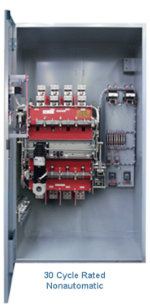
- 50 Years, Thousands of Installations
- Behind-the-Meter, Mid-To-Large Commercial & Industrial
- Mission Critical
  - Hospitals, Data Centers, Airports, Financial, Gov't, etc.

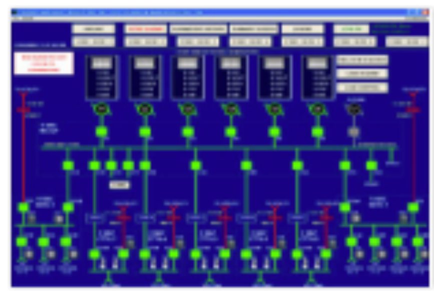
ATS



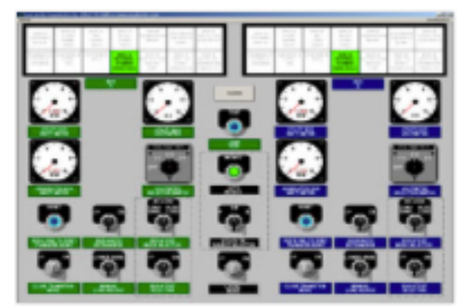
Switchgear

Power Control Systems

SCADA



Simulators



Trusted By Critical Facilities

American Express, amazon, Boeing, CAT, Cisco, Cigna, E*TRADE, ESPN, Fidelity Investments, FedEx, ExxonMobil, GE, HBO, IBM, UPS, Kaiser Permanente, NASA, Johns Hopkins University, P&G, Walmart, Hyundai, AT&T, Bank of America, BellSouth, Carolinas HealthCare System

Definition - Microgrid

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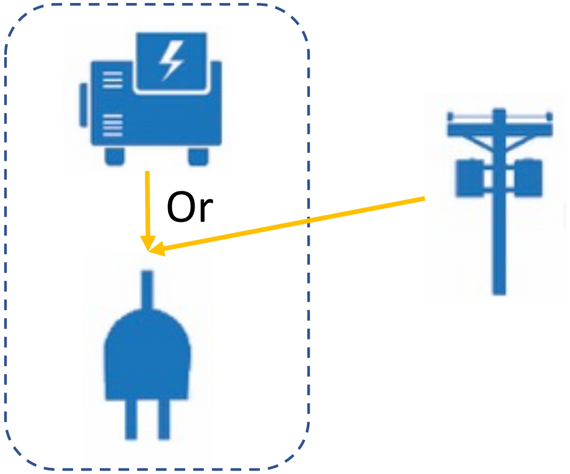
US DOE

- Group of interconnected loads & Distributed Energy Resources (DER)
- Within defined electrical boundaries that
- Acts as a single controllable entity &
- Can connect / disconnect from the grid to operate
  - grid-connected or
  - island-mode.



Definition DER, Microgrids, Hybrid

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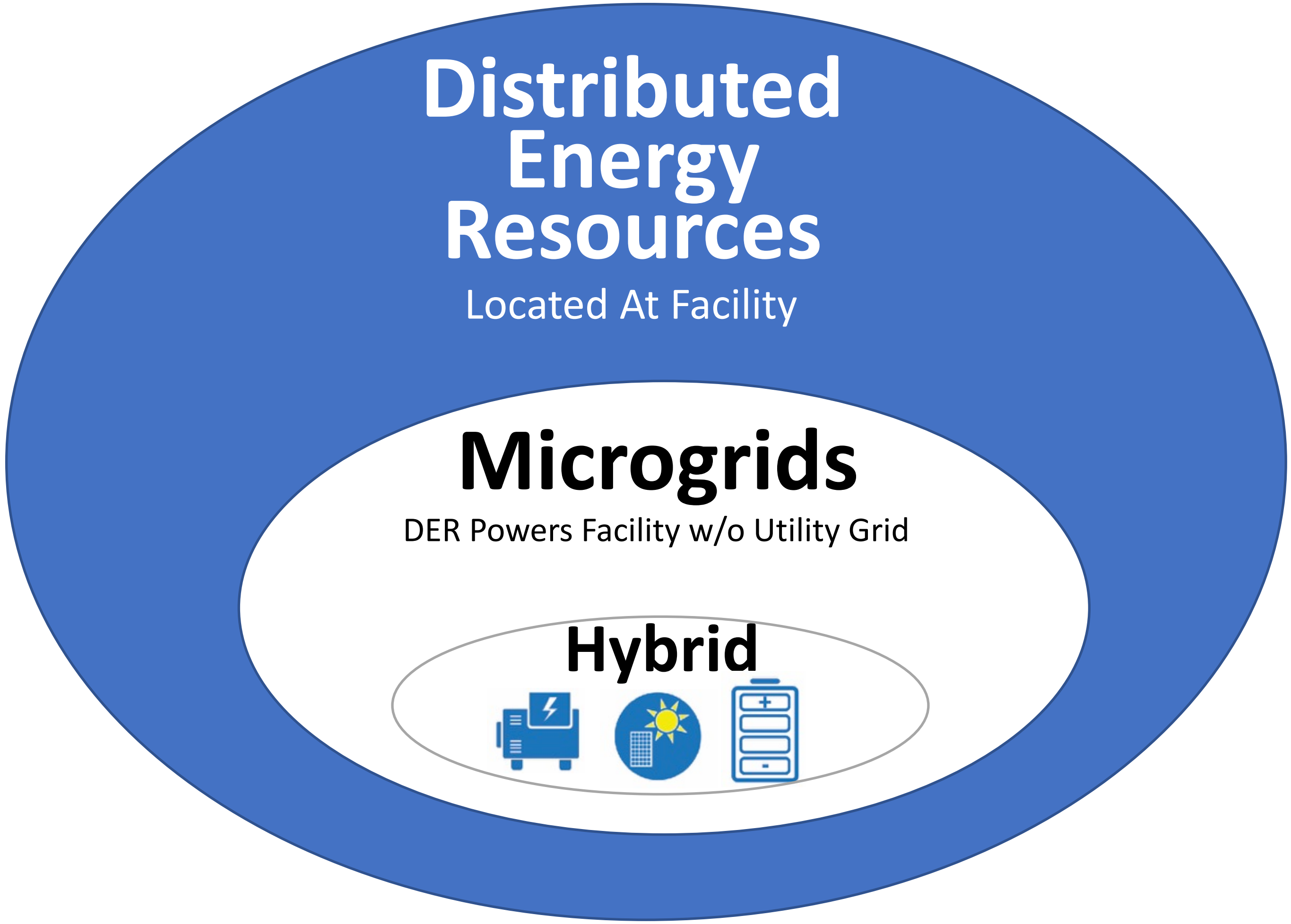

Example DER vs Microgrid

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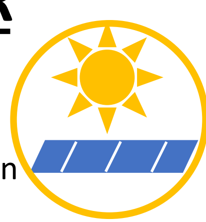
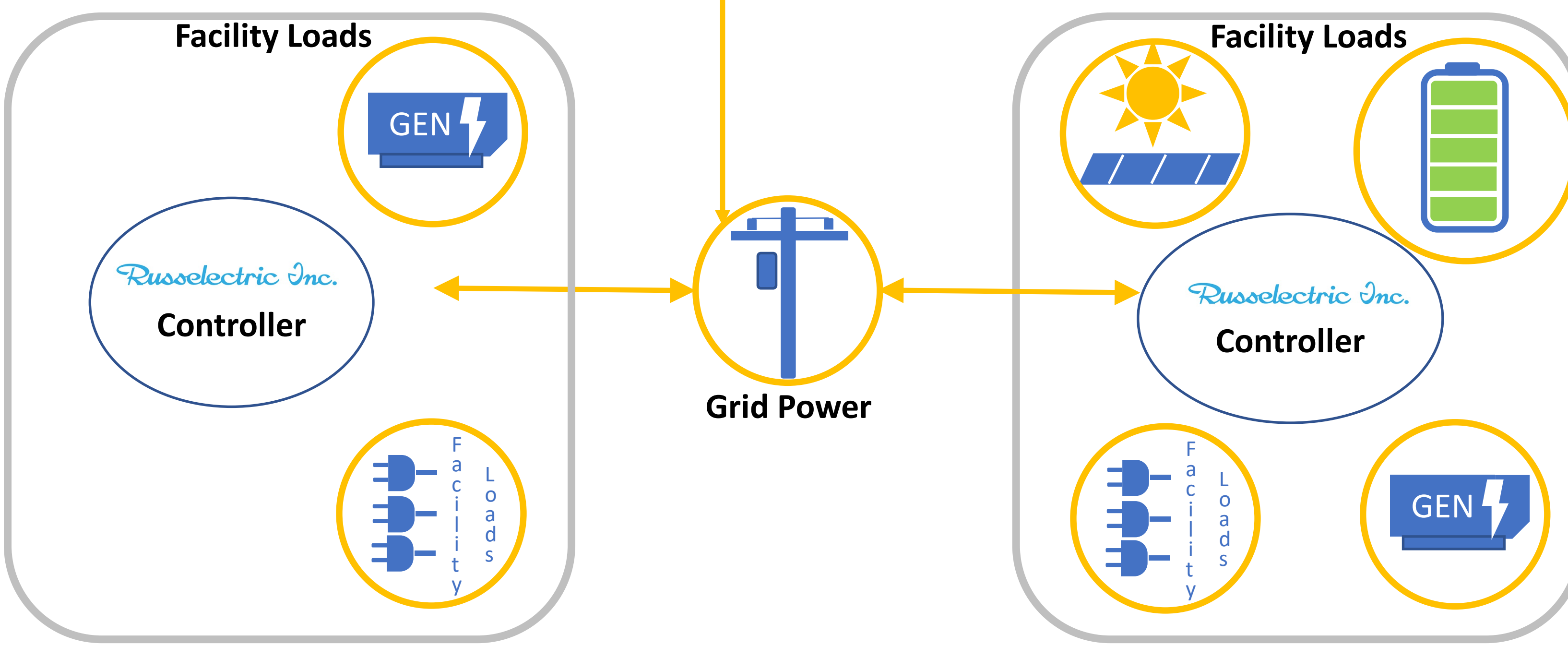
PV As DER

- Not Facility Integrated
- Shuts Down If Grid Down



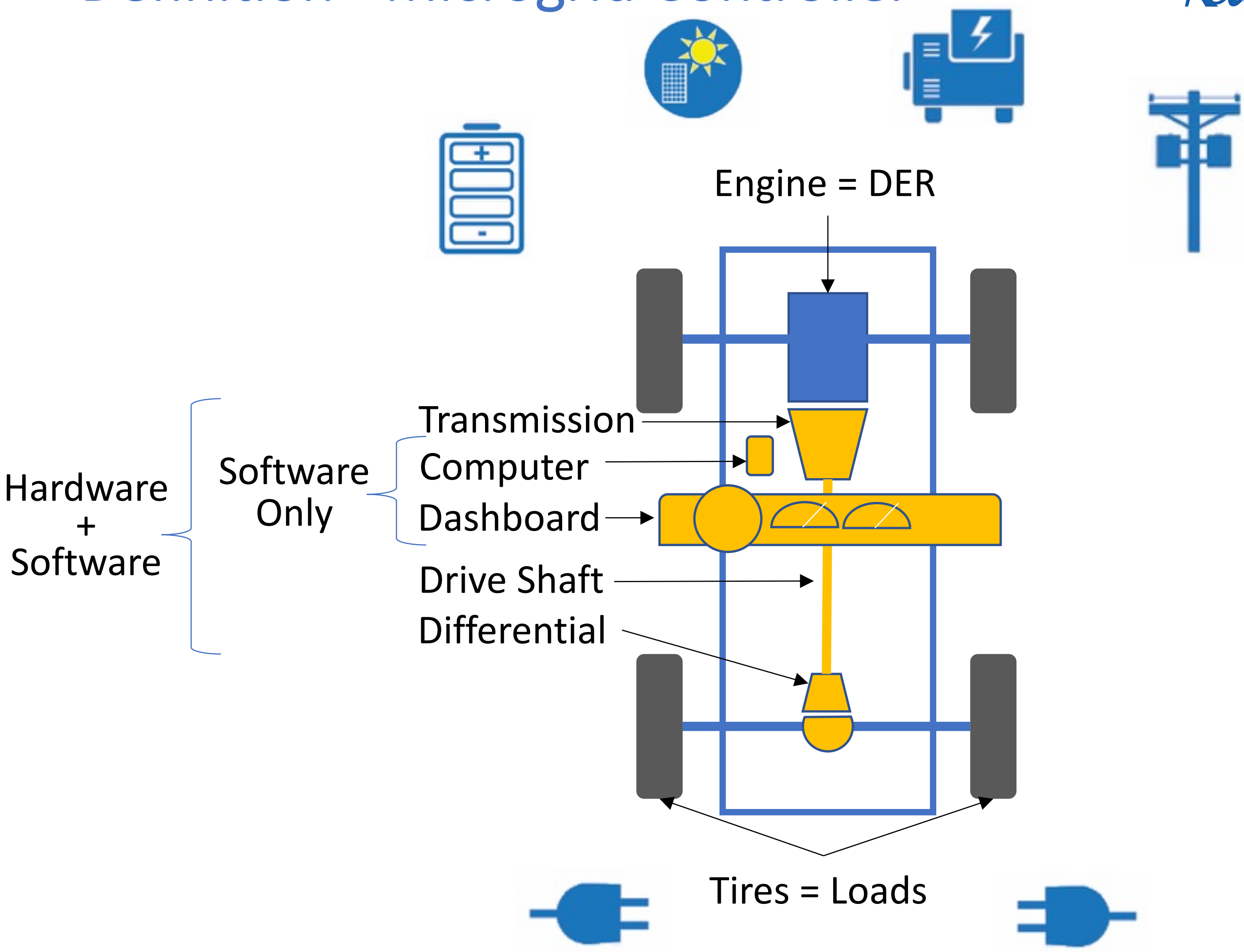
PV As Microgrid DER

- Coupled W Storage & Controls
- Can Be Integrated To Facility Loads
- Improve Continuity, Cost, & Carbon



Most PV Installed To-Date = DER. Large Retrofit / Upgrade Opportunity.

Definition - Microgrid Controller



Definition 2 - Controller = Orchestra Conductor

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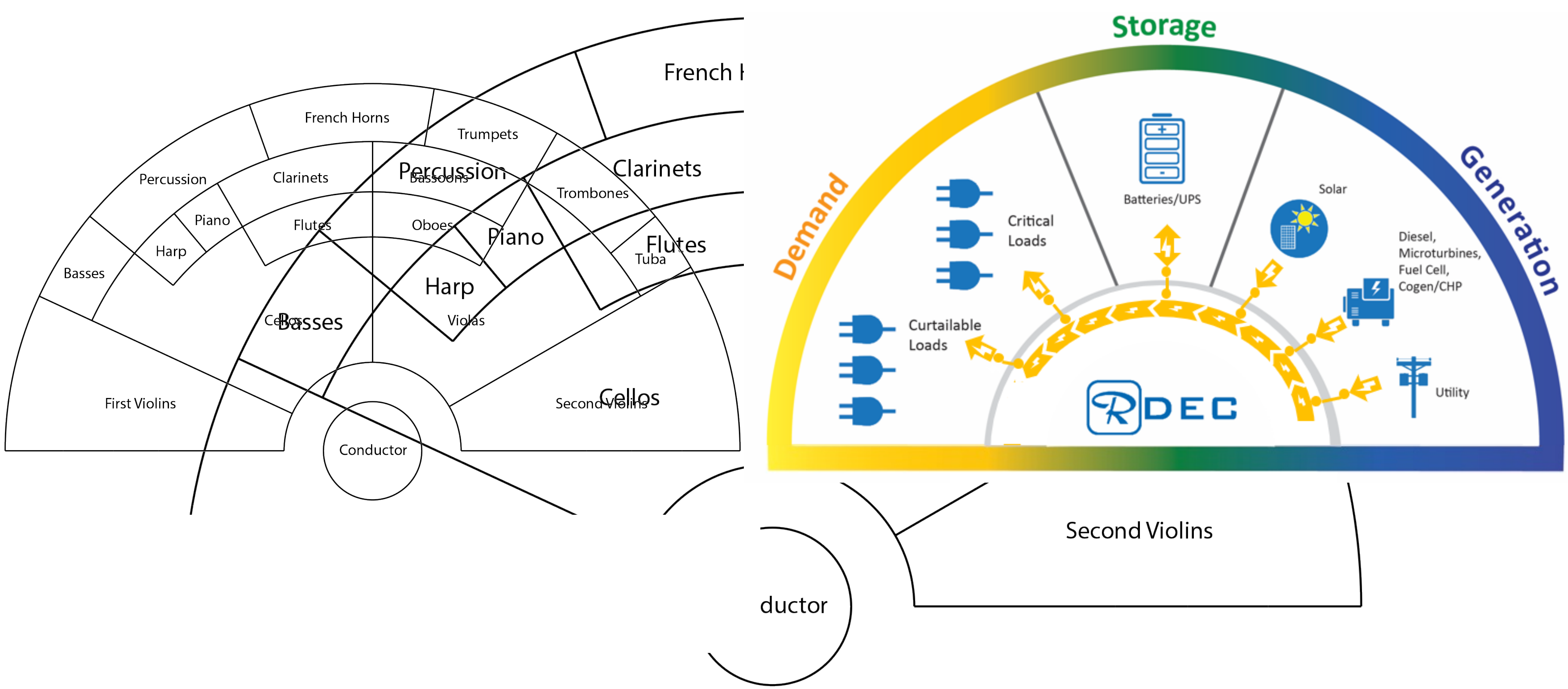
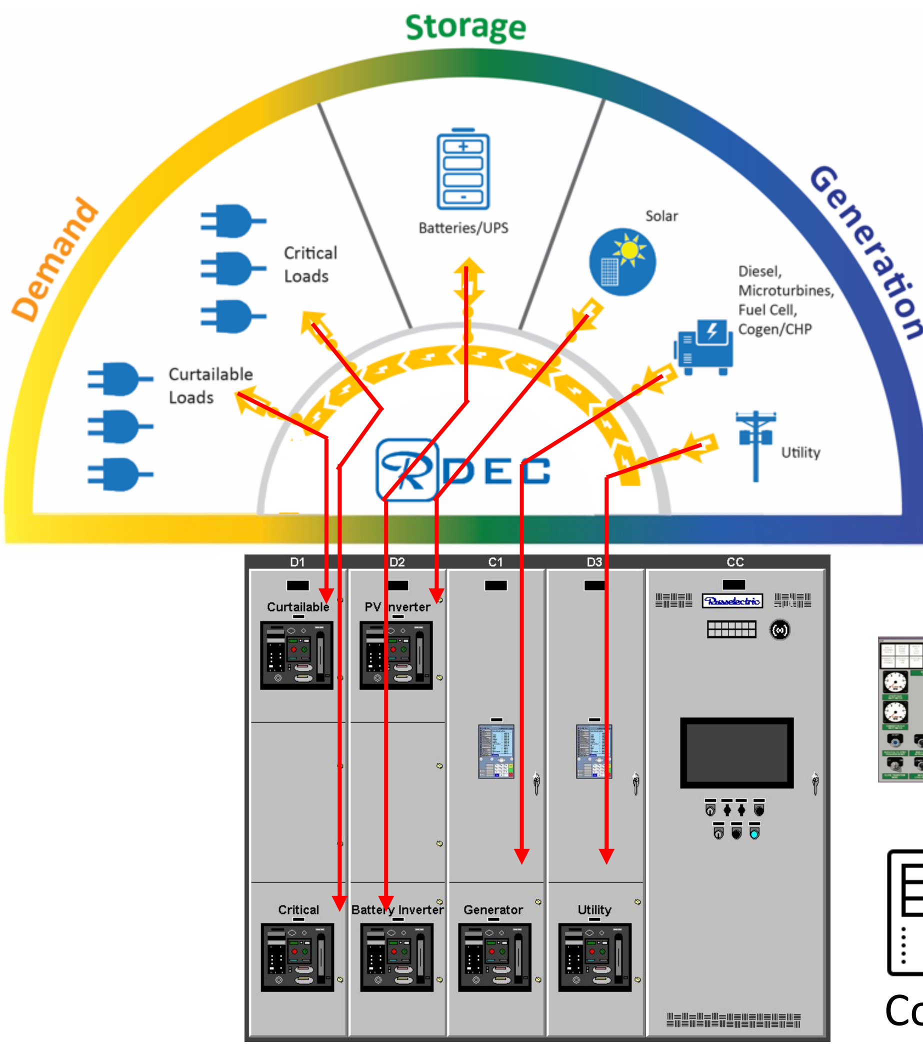
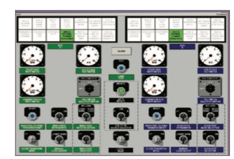
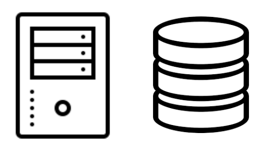


Distributed Energy Controller - Components





User Interface



Database

Computer / PLC

Power Control, Transfer Switches, Breakers

Definition – "DERMS"

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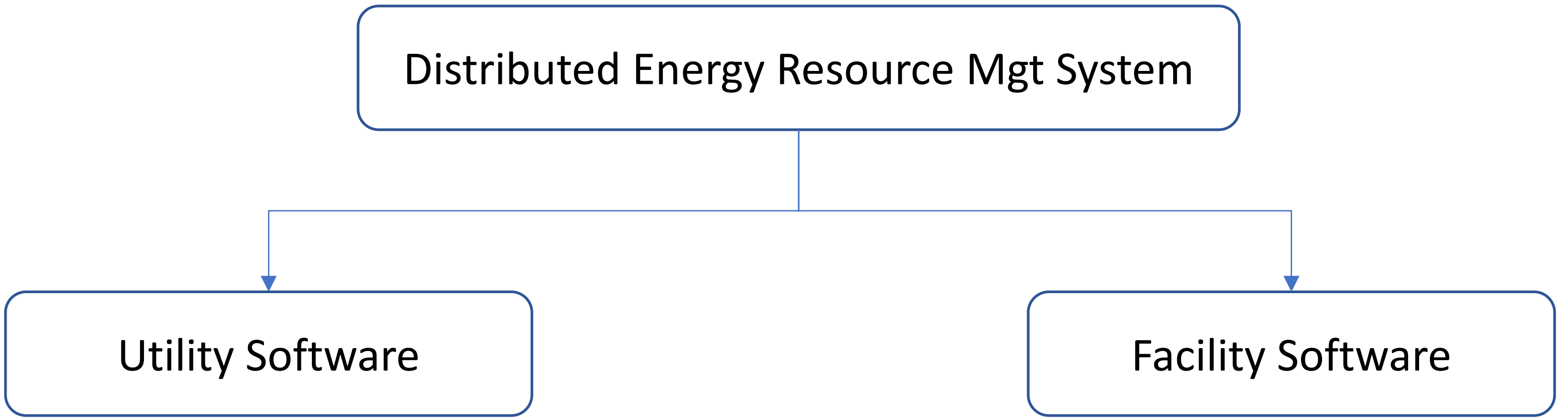

- Manage Fleets of DER's in Utility's Service Territory

- Manage Onsite DER Market Transactions, Forecasting
- Some Overlap with Controller

Controller vs DERMS Functionality Ladder

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External Markets

Energy Market Transactions & Optimization

DER Management System (DERMS)

- Optimize demand & generation based on forward weather, fuel, loads, emissions permits, electric rates, external market opportunities, e.g. ISO markets.

Internal (Site)

Site Controller

Utility Rate Optimization	Optimize onsite resources & utility rates, e.g. For Days of Week & TOU Periods, Enter Energy & Demand Rates, Target Demands. Optimize.
Peak Management	Specify target utility peak demand, prioritize generation & loads to achieve target.
Generation & Demand Prioritization	Specify Generation & Demand "Waterfall" or Prioritization.
Generation & Load Data & Control	Single, integrated data and control platform, all generation, loads, devices. Macro & drill down views.
Electrical Synchronization & Optimization	Achieve & maintain optimal electrical & power quality performance attributes.
Physical Integration & Control	Physically connect, switch, transfer loads & generation.

Sample Projects & PV + Storage + Generator Use Cases

Sample Project

QUINNIPIAC UNIVERSITY

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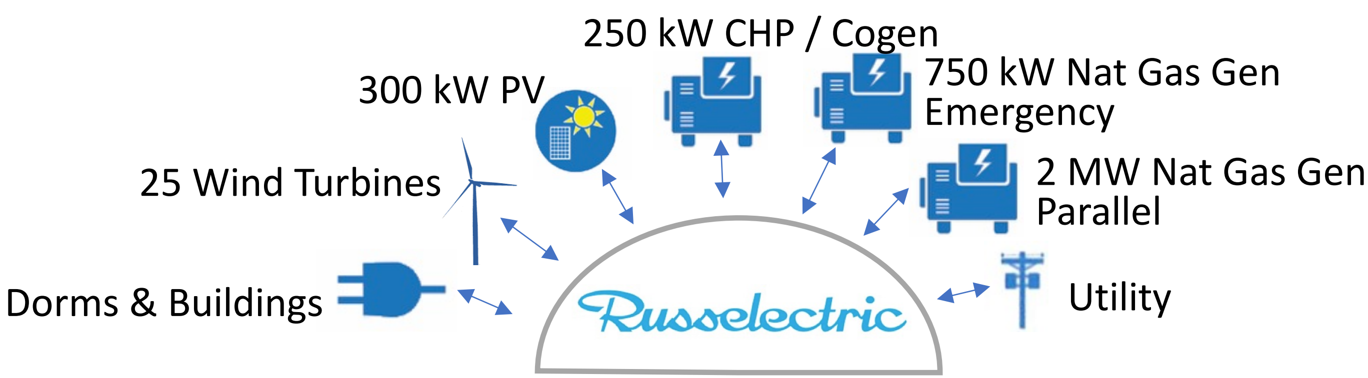
- Drivers
  - Resiliency
  - Cost Reduction
  - Sustainability
- New Campus
  - Wind & PV
  - Nat Gas Gen & CHP
  - 15+ Buildings



Sample Project – MA Casino

Encore BOSTON HARBOR

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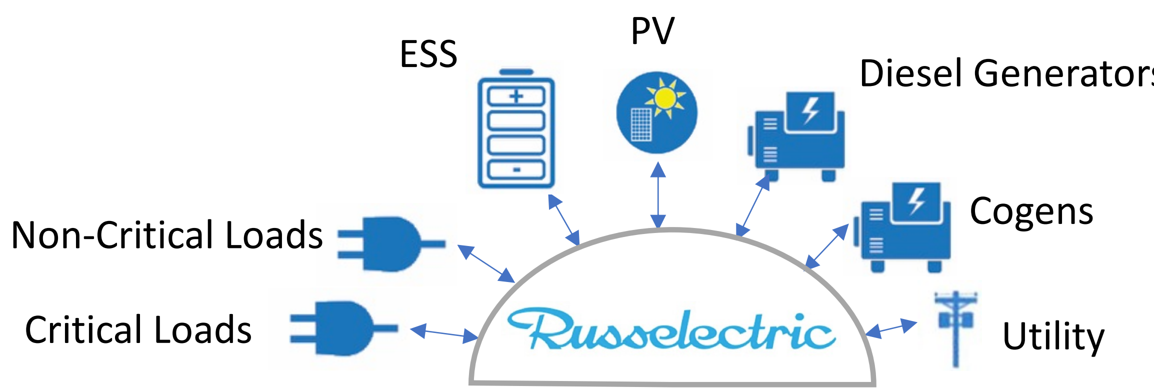
- Drivers
  - Resiliency
  - Cost Reduction
  - Sustainability
- New Casino – 5 – 10 MW
  - Utility Power
  - PV & ESS
  - Diesel & CHP



Possible Project – Southwest Data Center

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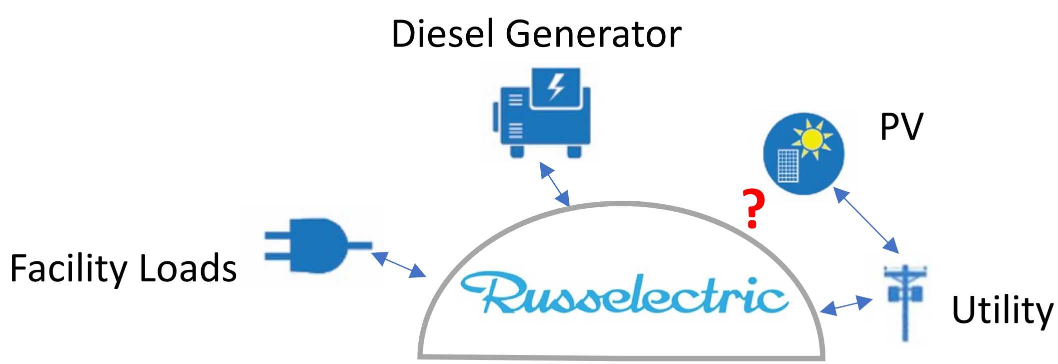
- Drivers
  - Cost Reduction
  - Resiliency

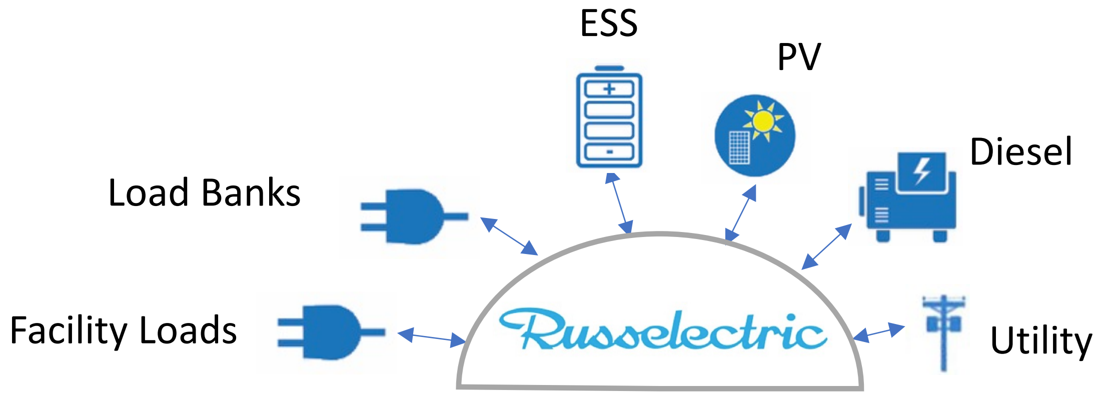
- Storm Destroyed Customer Owned Utility Transformer
- On Emergency Generator Power for Weeks
  - High Energy Cost
  - Emissions Penalties
- Diesel Based Microgrid Worked As Designed
- 2-3 MW Rooftop PV System
  - Not Part of Microgrid
  - Shut Down As Designed During Outage



Sample Project - Russelectric

Add PV + ESS To Traditional Diesel Microgrid

- Drivers
  - Cost Reduction
  - Sustainability
  - Product Development
  - Customer Demos / Use Cases



Hybrid Systems – 3 Use Cases

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- PV + Generator – No Storage
- PV AC Coupled to Storage + Generator
- PV DC Coupled to Storage + Generator

Hybrid Systems – PV + Generator

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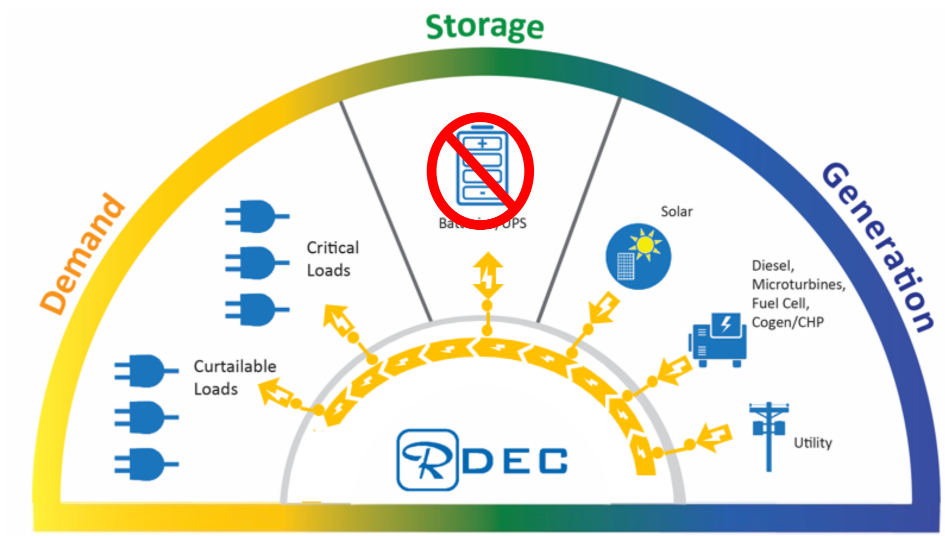
- No Storage
- PV
  - AC Coupled
  - Grid Outage Likely Trigger Disconnect / Reset
- Generator
  - Forms Grid
  - Must Balance Changes in
    - Load
    - PV Generation
  - Risk
    - Wet Stacking
    - Back Feeding



Hybrid Systems – PV + Storage + Generator

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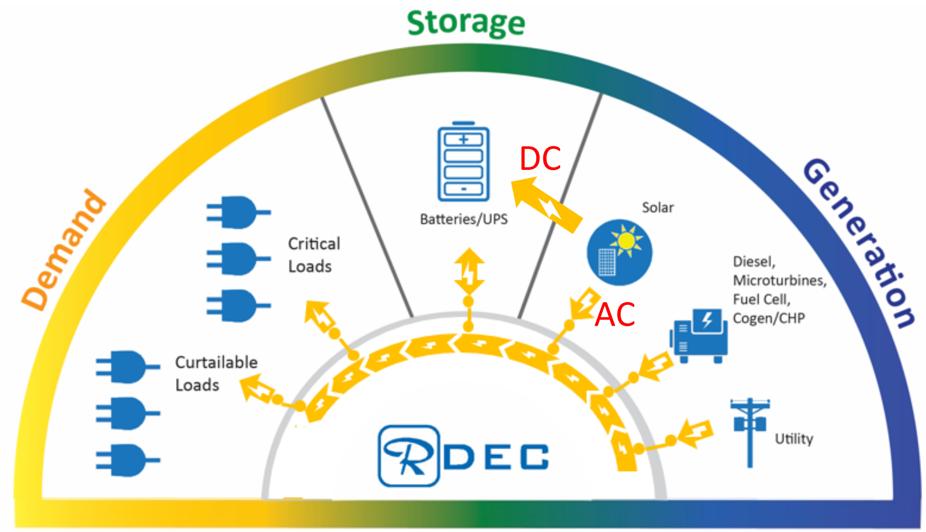
- Storage, Depending on Size
  - Balances Changes in
    - Load
    - PV Generation
  - Allows Generator to Operate More Consistently, Efficiently
  - Could Delay Use of Generator
  - Or, Rely on Storage for Primary Backup Power, Turning on Generator Only to Re-Charge Battery
- CA (Maybe Other States)
  - Restrictions on DC Coupled PV for Systems > 10 kW



AC	DC
Higher Cost	Lower Cost
Higher Conversion Losses	Lower Conversion Losses
Trip During Outage	Ride Thru Outage
Easier to Integrate Storage with Existing PV	Harder to Integrate Storage with Existing PV
More Flexibility & Control	Less Flexibility & Control
	Restrictions on Large PV
	If PV kW > Battery kW

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Market & Technology Trends

Microgrid Drivers

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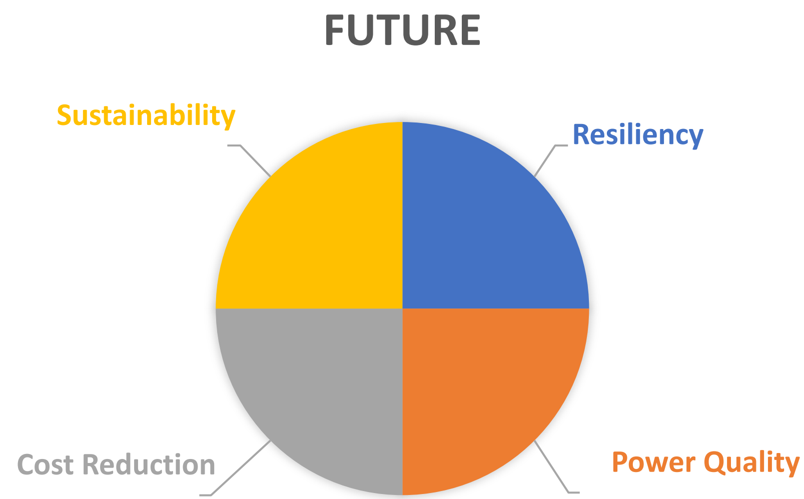
- Resiliency
- Cost Reduction
- Sustainability
- Power Quality



Value Streams & Technology Options

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↑Continuity	↑Quality	↓Carbon	↓Cost	Value Streams
✓				Outage Risk / Backup Mandates
	✓		✓	Power Quality Penalties
✓	✓		✓	PQ Internal Sensitivity
			✓	Rising Electric Rates
			✓	Energy Price Volatility
			✓	Time Of Use Rates
			✓	Smooth Load Shape Discount
			✓	Peak Demand Charges
			✓	Demand Control Incentives
			✓	ISO Markets
✓		✓	✓	Renewables - Incentives
✓		✓	✓	Renewables - Cost Reductions
✓	✓	✓	✓	Storage - Incentives
✓	✓	✓	✓	Storage - Cost Reductions
			✓	Storage - ISO Markets

Facility
DER / Microgrid
System

Tech Options	Continuity ↑	Quality ↑	Carbon ↓	Cost ↓
Diesel	✓			
CHP / Cogen	✓	✓		✓
Microturbines	✓	✓		✓
Fuel Cells	✓	✓	✓	✓
Wind	✓		✓	✓
Solar	✓		✓	✓
Storage	✓	✓	✓	✓
Curtailable	✓		✓	✓
Critical				

Generation

Demand

More { **Tech Options**
Value Streams
Complexity = More Opportunity }

Traditional Mission Critical Market
PV Market
New / Emerging Technologies & Market Drivers

Solar & Storage Cost Declines

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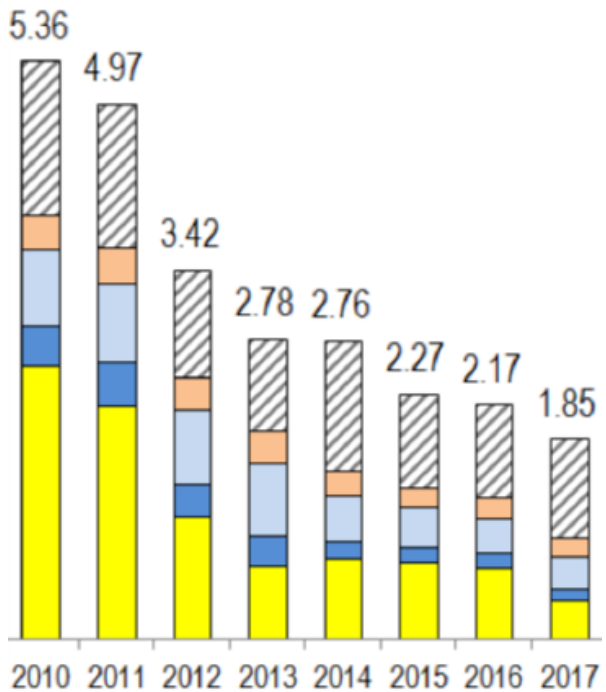
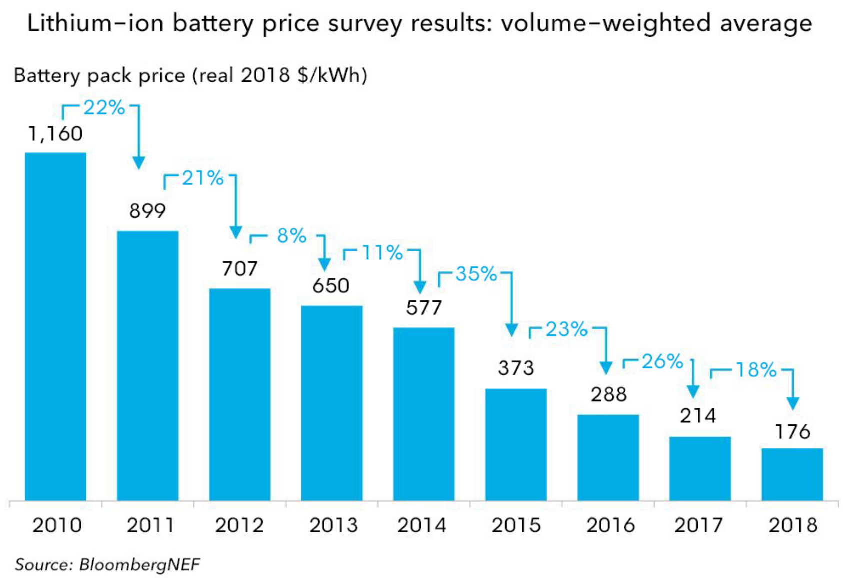
Solar PV $/Watt



Storage $/kWh



PV Maturing Tech - Incentives ↓

https://www.nrel.gov/docs/fy17osti/68925.pdf

Storage Emerging Tech - Incentives ↑

https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/

Solar PV & Diesel Generators

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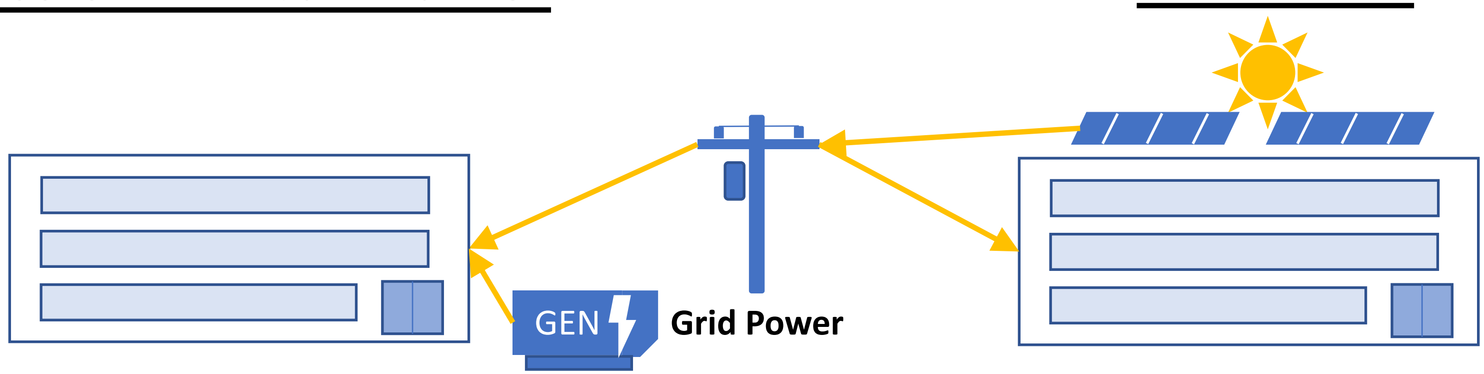
Mission Critical Market

PV Market



- 50+ Years
- Onsite Generation
  - Integrated Into Facility Loads
  - Operates During Grid outage
  - Grid Forming, Dispatchable
  - Limited Fuel Supply
  - Driver = Continuity
  - Low Capital Cost
  - High Energy Cost

- 10+ Years
- Onsite Generation
  - Connected to Grid (In The Past)
  - Designed to Shut Down During Outage
  - Non-Grid Forming, Intermittent
  - Unlimited, But Unpredictable Fuel
  - Driver = Cost Reduction & Sustainability
  - High Capital Cost
  - Zero Energy Cost

Solar PV & Energy Storage

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- Investment Tax Credit Eligible	↔	- ITC Eligible IF 75+% Charged by PV
- Shuts Down During Outage	↔	- Rides Through Outage
- Non Grid Forming, Intermittent	↔	- Grid Forming, Dispatchable
- Driver = Cost & Sustainability	↔	- Driver = Cost, Resiliency, Power Quality
- High Capital Cost	↔	- High Capital Cost
- Low Operating Cost	↔	- Low Operating Cost

Energy Storage Systems (ESS)

- Multiple Capabilities
- Multiple Value Streams

ESS – Multiple Value Streams &Value Stacking

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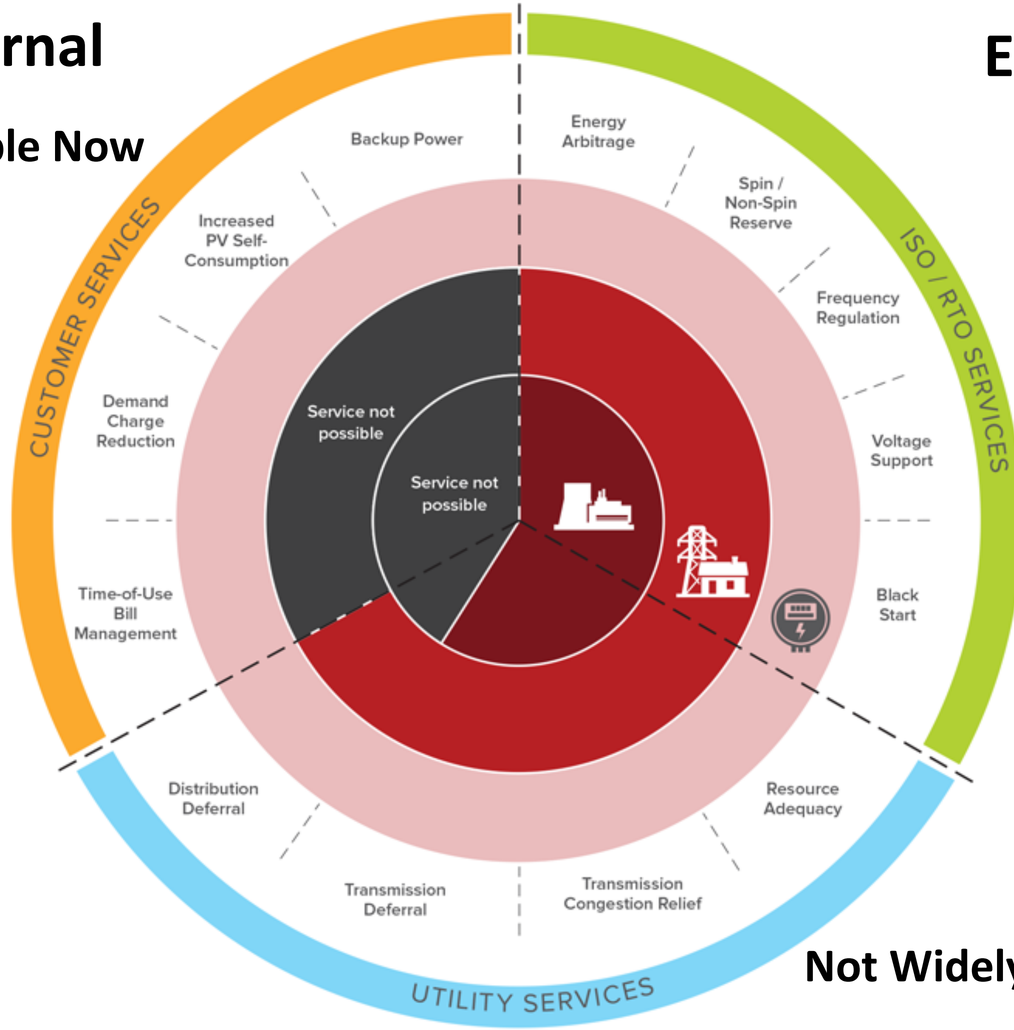
Internal

Available Now

External



FERC Order 745

- ESS Eligible for DR

FERC Order 841

- ESS Eligible for Power Markets
- 2020
- $100 - $200B Markets

Not Widely Available – Only NY Now

Utility Benefits

https://rmi.org/insight/economics-battery-energy-storage/

Energy Storage - New Cash Flows

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- Storage Incentives – CA, NY, & MA
  - 200 – 400 $/kWh
- FERC Order 745
  - ESS Eligible for Demand Response Programs
- FERC Order 841
  - Opens $100 - $200B ISO Power Markets to ESS
  - ESS >= 100 kW
  - Begins 2020

PV Inverters

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Cost	Controllability	
Lo	Lo	Central Inverters – Entire Array
Med	Med	String Inverters – Groups of Panels
Hi	Hi	Micro-Inverters & Power Optimizers – Individual Panels

CA Smart Inverters
Rule 21, UL 1741, IEEE 1547

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- Enacted 2014, Phased In 2017 - 2019
  - *describes the interconnection, operating and metering requirements for generation facilities to be connected to a utility's distribution system, over which the California Public Utilities Commission (CPUC) has jurisdiction*
- UL 1741 Tests
  - Anti-islanding
  - Low/High Voltage Ride Through
  - Low/High-Frequency Ride Through
  - Must Trip Test
  - Ramp Rate (Normal & Soft-Start)
  - Specified Power Factor
  - Volt/Var Mode
  - Frequency Watt
  - Volt Watt
- Intended to supplement & be used in conjunction with IEEE 1547 (Standard for Interconnecting Distributed Resources with Electric Power Systems) and IEEE 1547.1 (Standard for Conformance Test Procedures) in accordance with NEC
- make PV systems & grid more resilient during normal & abnormal operating conditions
- require reactive power priority (RPP) setting to be activated as default Volt/Var function
- enhance anti-island testing to ensure PV systems disconnect when required
- voltage and frequency ride through and ramp rate control testing ensure PV systems act in a predictable fashion as the grid experiences fluctuations to its operational thresholds
- ramp rate control allows grid operators the ability to balance thermal generation output against PV output while maintaining grid stability

https://www.civicsolar.com/article/ul-1741-rule-21-advanced-inverter-tests
https://www.renvu.com/Learn/Rule-21-Update-CA-Inverter-RPP-Requiremen
http://media3.ev-tv.me/UL-1741-Supplement-A_Webinar.pdft

Sustainability Driver

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"Walmart on Track to Reduce 1 Billion Metric Tons of Emission from Global Supply Chains by 2030"(Press Release 5/8/19)

- Project Gigaton – Avoid 1 Billion Metric Tons of Emissions by 2030, with Suppliers
- 2025 Target 50% Renewable Energy. Currently at 28%

"Walmart Enters into 46 Power Purchase Agreements to Supply (Solar) Power to Stores in 5 States" (5/14/19)

"Why Walmart and Other Companies Are Sticking with the Paris Climate Accord" (NYT, 11/6/19)

New Financial Markets

"Microgrid" = Little Utility. So, What Do Utilities Do?

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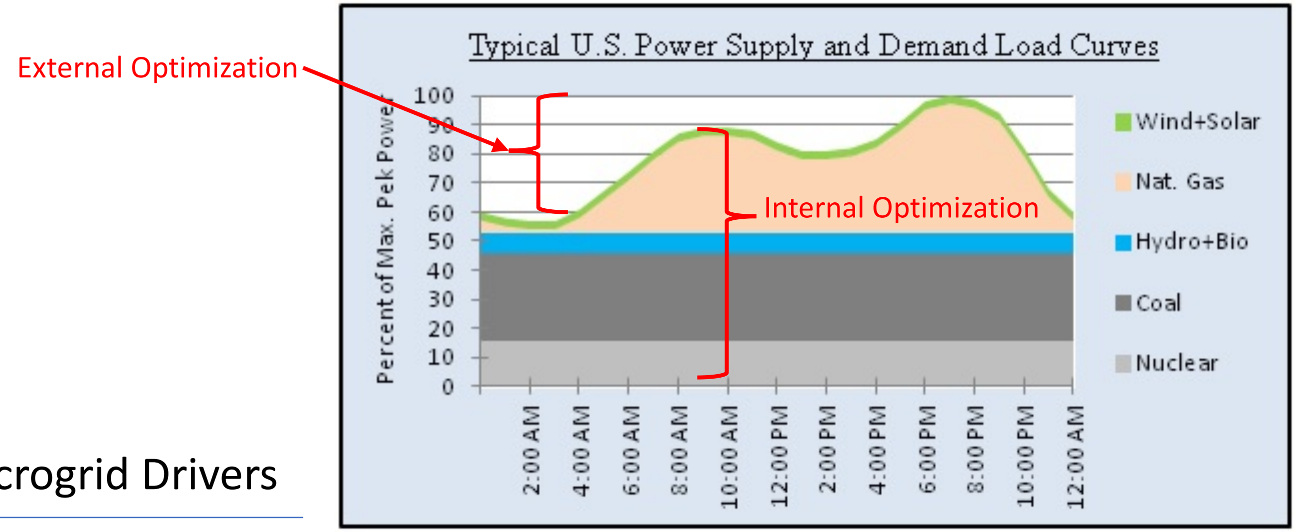

Microgrid Drivers

↑ Continuity
↑ Power Quality
↓GHG
↓ Energy Costs

+ Parallel
+ Island
+ Re-Synchronize

- "Obligation To Serve" = Match Supply to Demand
- Deliver Power Compliant w US Voltage / Frequency Standards
- Power Portfolio Compliance = Renewable Portfolio Standard
- Least Cost Power = Integrated Resource Planning
  - Internal / "Domestic" Financial Optimization
    - Deploy Least Cost Generation Sources to Meet Service Territory Demand
  - External / "International Trade" Financial Optimization
    - Buy / Sell / Trade Generation Assets to Other Utilities / Power Marketers

Example - Internal (Site) vs External Markets

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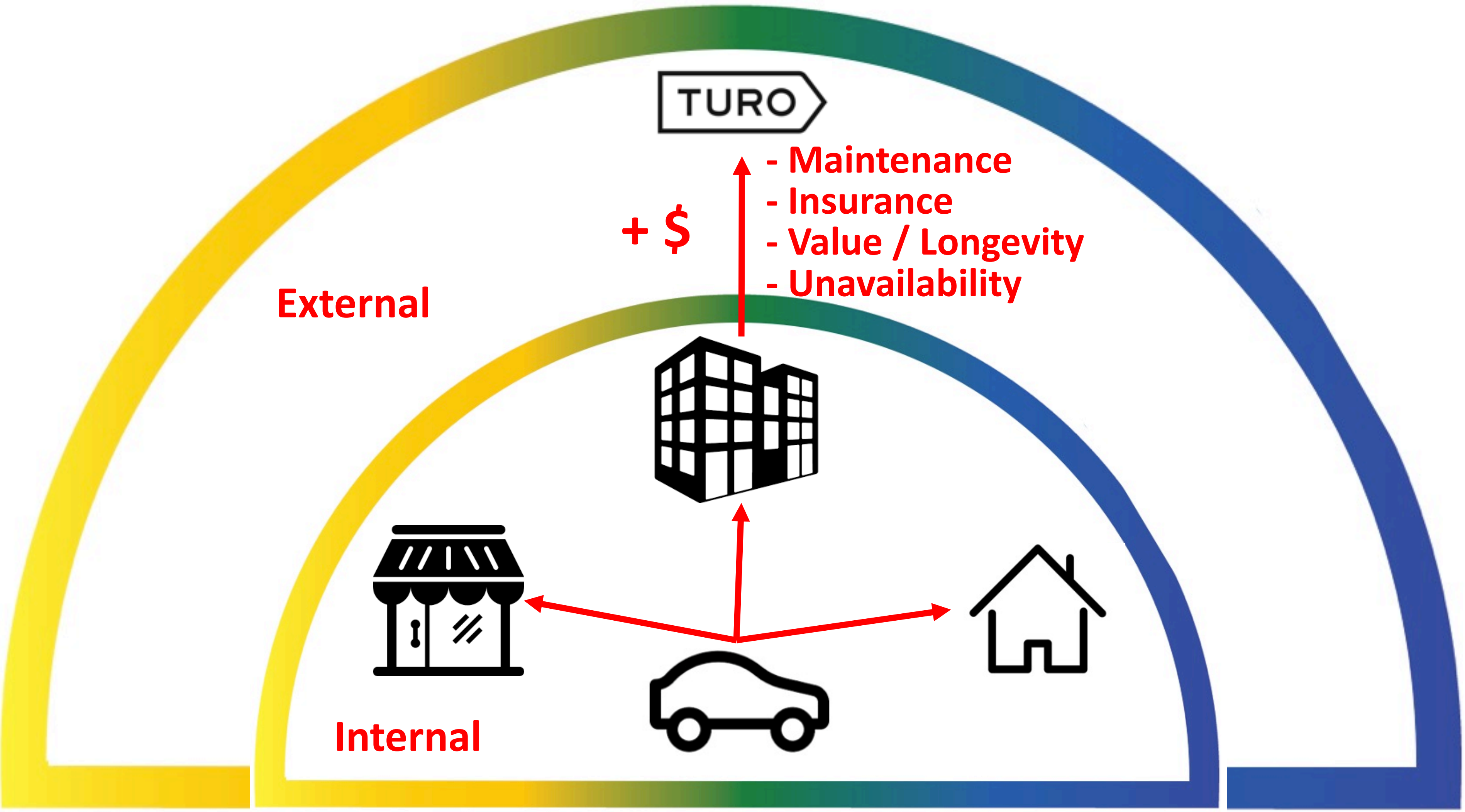

Independent System Operator Markets

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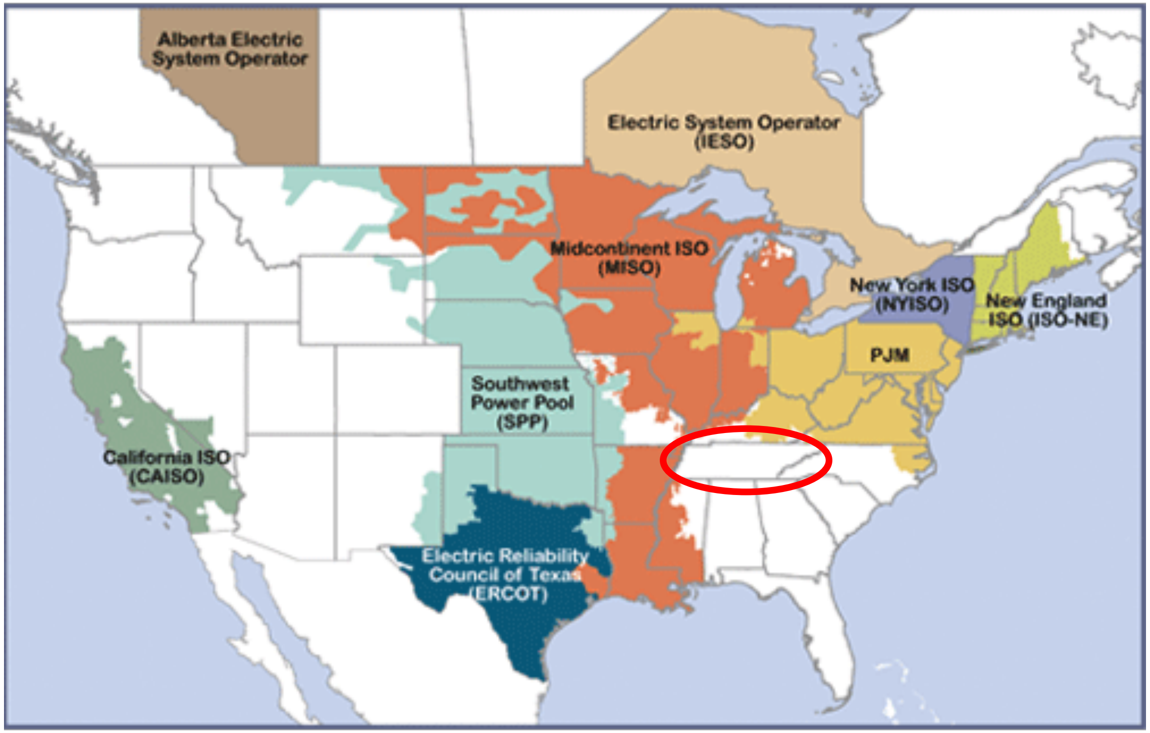
- $100-200 B Markets
- Energy
- Capacity
- Demand Response
- Ancillary Services
  - Reserves
  - Frequency Response
  - …



https://www.ferc.gov/industries/electric/indus-act/rto.asp

"External" Markets - What Does An ISO Do?

- Independent System Operator
  - Regional Electric Grid "Air Traffic Controller"
  - Mandate To Ensure
    - Overall Grid Reliability
    - Electric Generation Meets Electric Demand, Near & Long Term
    - Operates Day Ahead, Real Time, & Long Term Market Auctions
      - Energy
      - Demand / ICAP
      - Demand Response
      - Ancillary Services
        - Regulation
        - Voltage Support
        - Black Start
  - FERC Order 841 Opens All of These Markets to Storage
    - Effective 2020

Market Transactions - Sample

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- Day 1 (Day Ahead Market)
  - Facility Has 1 MW / 2 MWh Battery
  - Next Day, 2, Power Market Price Spike, 1000 $/MWh, Instead of 50 $/MWh
  - Facility Bids / Commits to Supply Market 2 MWh at 1:00 pm Day 2
- Day 2 Spot Market (Option 1)
  - Facility Has Outage at noon. Drains Battery. Can't Deliver at 1:00
  - ISO Buys Replacement Power on Spot Market at $2000 / MWh
  - ISO "Settles" With Facility, Charging $2000 - $1000 = $1000 / MWh
- Day 2 Spot Market (Option 2)
  - No Outage at Facility Before 1:00 pm
  - Facility Delivers Power & Receives $1000 / MWh * 2 MWh = $2,000
- Day 2 Spot Market (Option 3)
  - Facility Delivers Power to Market, Receives $2,000
  - Facility Has Outage at 2:00 PM, Battery Is Drained. Cost?

Geographic Markets

Regional Attractiveness Solar, Storage, & Hybrid Microgrids

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Regional Market Drivers

Drivers
↑ PV Installed Base
↑ PV New Installations
↑ Solar Irradiance
↑ Policy : PV & Storage
↑ Sustainability Driven
↑ Electric Rates
↑ Demand Charges
↑ TOU Rates & On / Off Peak Spread
↑ Nat Disaster Continuity Risk
↑ ISO Market Access
↓ Power Quality

Solar PV Installed Capacity by State Q2 2019

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60% (ranks 1–5)
78% (ranks 1–10)

Rank	State	MW	%
1	CA	25,773	37.0%
2	NC	5,601	8.0%
3	AZ	3,873	5.6%
4	NV	3,502	5.0%
5	FL	3,337	4.8%
6	TX	3,029	4.3%
7	NJ	2,911	4.2%
8	MA	2,567	3.7%
9	NY	1,775	2.5%
10	UT	1,671	2.4%
11	GA	1,571	2.3%
12	CO	1,268	1.8%
13	MN	1,206	1.7%
14	MD	1,174	1.7%
15	HI	999	1.4%
16	ME	999	1.4%
17	SC	831	1.2%
18	NM	818	1.2%
19	VA	803	1.2%
20	OR	612	0.9%
21	CT	606	0.9%
22	ID	488	0.7%
23	PA	452	0.6%
24	TN	429	0.6%
25	IN	355	0.5%

Rank	State	MW	%
26	VT	304	0.4%
27	AL	283	0.4%
28	MS	235	0.3%
29	OH	231	0.3%
30	MO	230	0.3%
31	WA	197	0.3%
32	RI	175	0.3%
33	MI	160	0.2%
34	AR	144	0.2%
35	IL	139	0.2%
36	DE	132	0.2%
37	WY	108	0.2%
38	LA	107	0.2%
39	NH	95	0.1%
40	IA	94	0.1%
41	WI	93	0.1%
42	DC	77	0.1%
43	MT	57	0.1%
44	NE	45	0.1%
45	KY	44	0.1%
46	OK	36	0.1%
47	KS	29	0.0%
48	WV	9	0.0%
49	AK	4	0.0%
50	SD	2	0.0%
51	ND	0	0.0%
	Total	69,683	100.0%

https://seia.org/states-map

Solar PV – Irradiance Map

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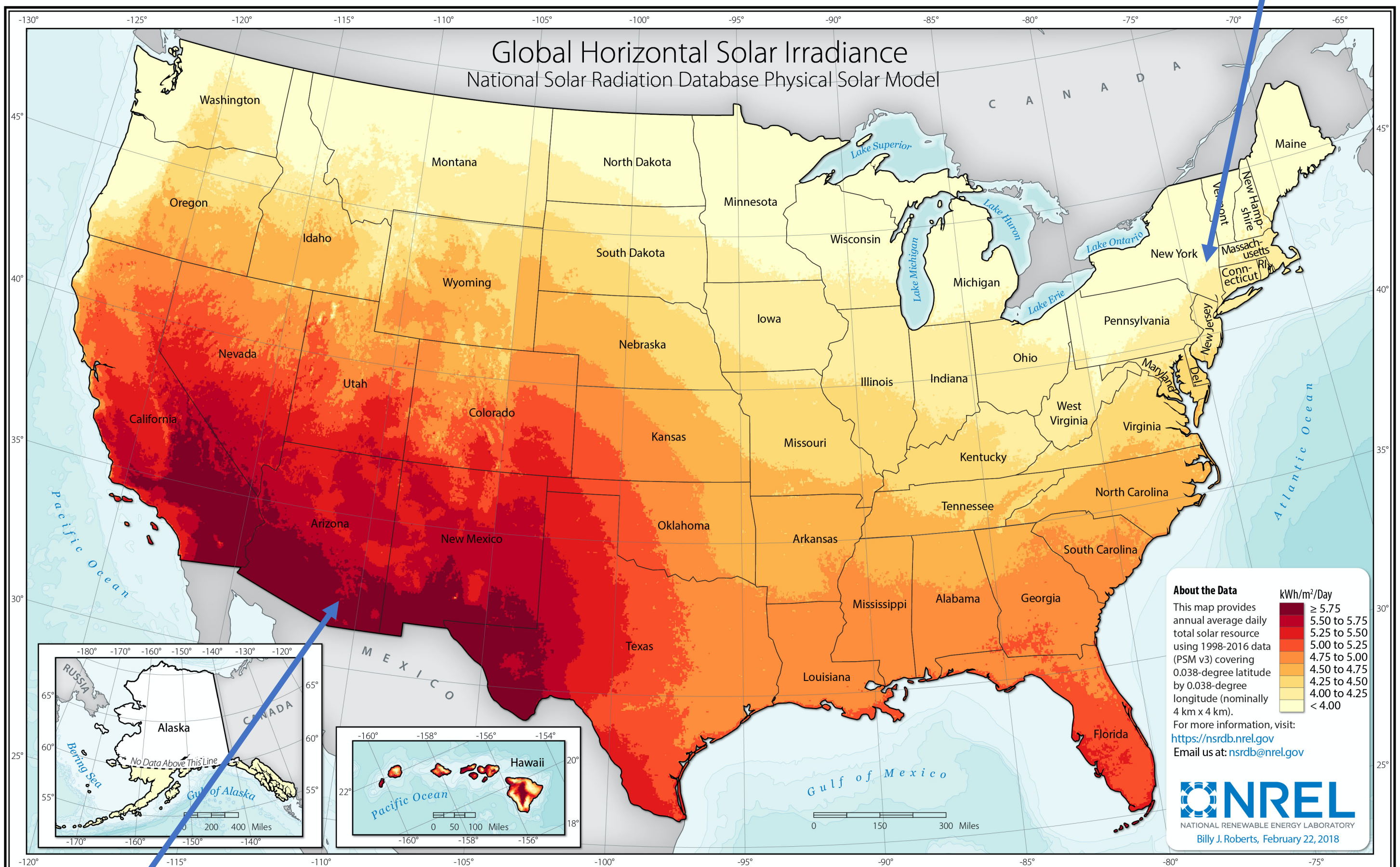
Albany
1237 MWh/kW



Tucson
1757 MWh/kW

42% More Than Albany

https://www.nrel.gov/gis/images/solar/solar_ghi_2018_usa_scale_01.jpg

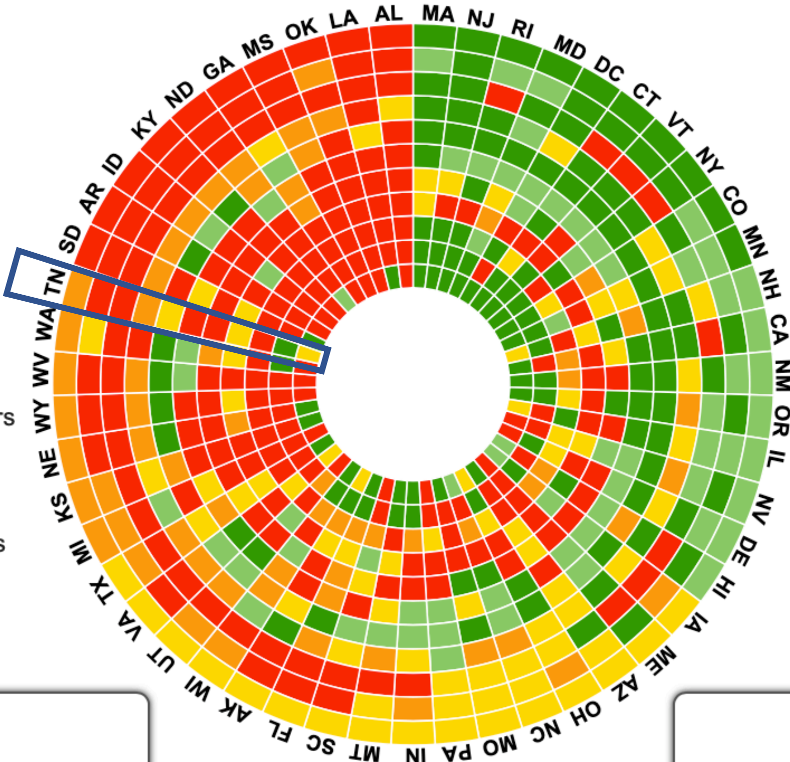
2019 State Solar Power Rankings Report

How to read the report:

This chart ranks the 50 states and the District of Columbia, from best (green) to worst (red), based on their solar-friendliness. For example, Massachusetts receives the best score, while Alabama receives the worst.

The outermost ring (closest to each state label) shows the overall grades awarded the states. The inner rings represent factors contributing to the grades.

Instructions: Roll over or tap on any segment of the chart to populate the boxes below with the state's grades and 2019 solar outlook.



Factors:

1) Overall Grade
2) Renewable Portfolio Standard (RPS)
3) Solar Carve Out
4) Electricity Price
5) Net Metering
6) Interconnection
7) Solar Rebates
8) State Solar Tax Credits
9) Performance Payments
10) Sales Tax Exemption
11) Property Tax Exemption

Tennessee

2018 SOLAR REPORT CARD

Overall Grade: D

Policy		Incentives	
F	RPS Law	F	Solar Rebates
F	Solar Carve Out	C	State Solar Tax Credits
D	Electricity Price	F	Performance Payments
C	Net Metering	A	Sales Tax Exemption
F	Interconnection	C	Property Tax Exemption

Avg. Payback: 14 Years **IRR:** 6.4%

Grading Scale

A	B	C	D	F

Toggle Colorblind Mode

Tennessee

41st place

Trend: ▲ 1

Tennessee's TVA used to offer a decent deal for homeowners who installed solar panels. The Green Power Providers Program used to pay a tiny premium for every kWh of solar added to the grid, and used to offer a modest $1,000 rebate for any solar installation. All those 'used tos' don't add up to anything but a big fat 'nope' for *current* homeowners who want to add solar systems to their roofs.

https://www.solarpowerrocks.com/state-solar-power-rankings/

Storage - Market Size & Potential

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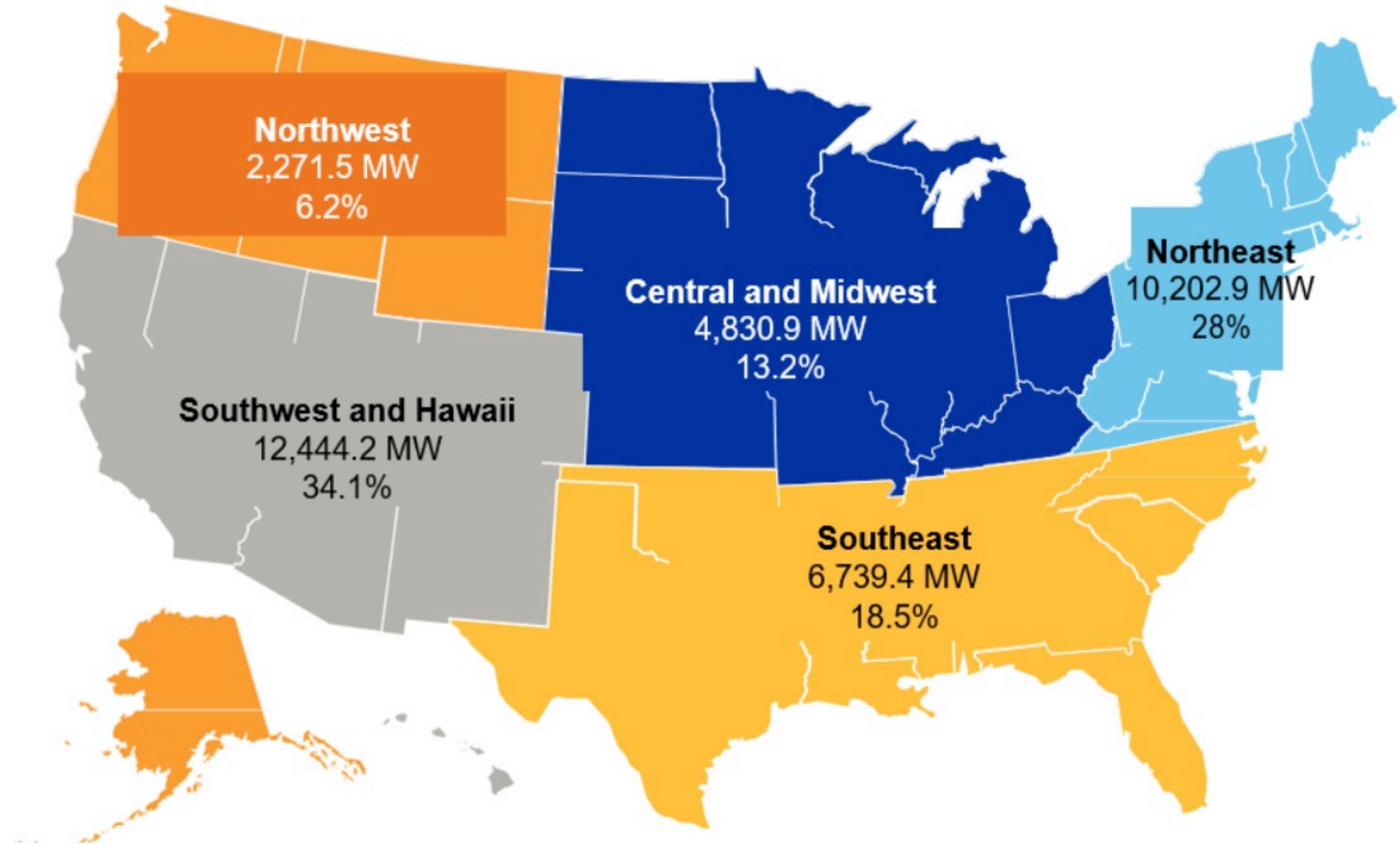
Projected Capacity Additions by Region (2017-2025)



Southwest & Northeast are each projected to install nearly as much as NW, Central, and SE combined.

http://eesat.sandia.gov/wp-content/uploads/2017/12/Roberts-2017-EESAT-Slides_web.pdf

Commercial & Industrial Electric Rates 2018

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Rank	State	Cents / kWh
1	HI	27.9
2	AK	18.4
3	MA	16.3
4	RI	16.3
5	CT	16.2
6	CA	15.5
7	NH	15.0
8	VT	13.3
9	NY	12.9
10	DC	11.9
11	NJ	11.9
12	ME	11.0
13	MD	10.2
14	MI	9.5
15	AZ	9.4
16	WI	9.3
17	KS	9.2
18	MN	9.2
19	FL	9.1
20	DE	9.0
21	SD	8.9
22	CO	8.9
23	TN	8.8
24	ND	8.7
25	MO	8.6

Rank	State	Cents / kWh
26	IN	8.3
27	OH	8.3
28	NE	8.2
29	AL	8.2
30	GA	8.1
31	MS	8.1
32	NM	8.1
33	VA	8.0
34	SC	8.0
35	IL	7.9
36	NC	7.8
37	MT	7.8
38	PA	7.8
39	OR	7.8
40	IA	7.7
41	WY	7.5
42	WV	7.5
43	UT	7.3
44	KY	7.2
45	ID	7.1
46	TX	7.0
47	NV	7.0
48	WA	6.9
49	LA	6.7
50	OK	6.6
51	AR	6.4

Maximum Demand Rates By Region

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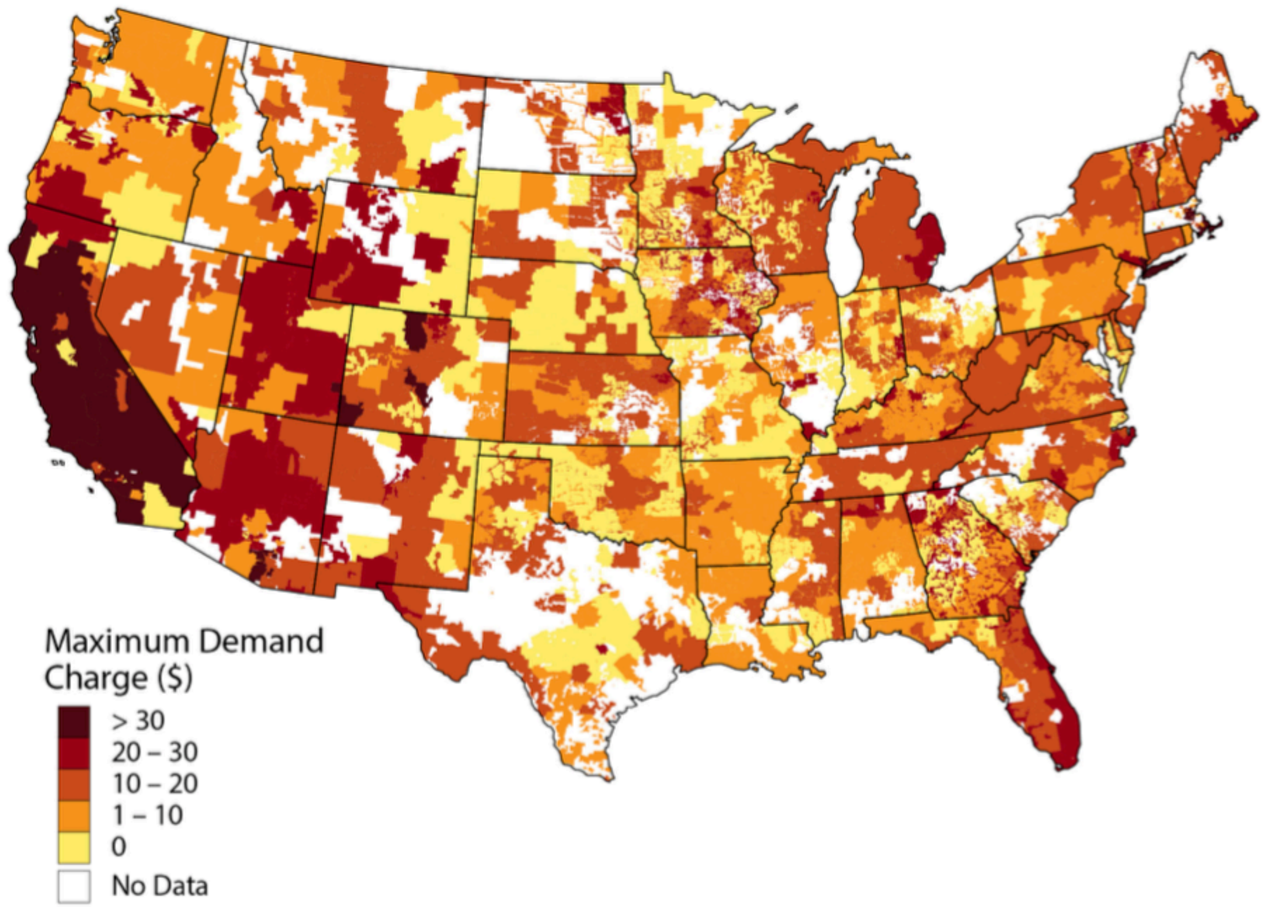

https://www.nrel.gov/solar/assets/pdfs/2017-us-demand-charges-webinar.pdf

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Key Markets – Microgrids / DER

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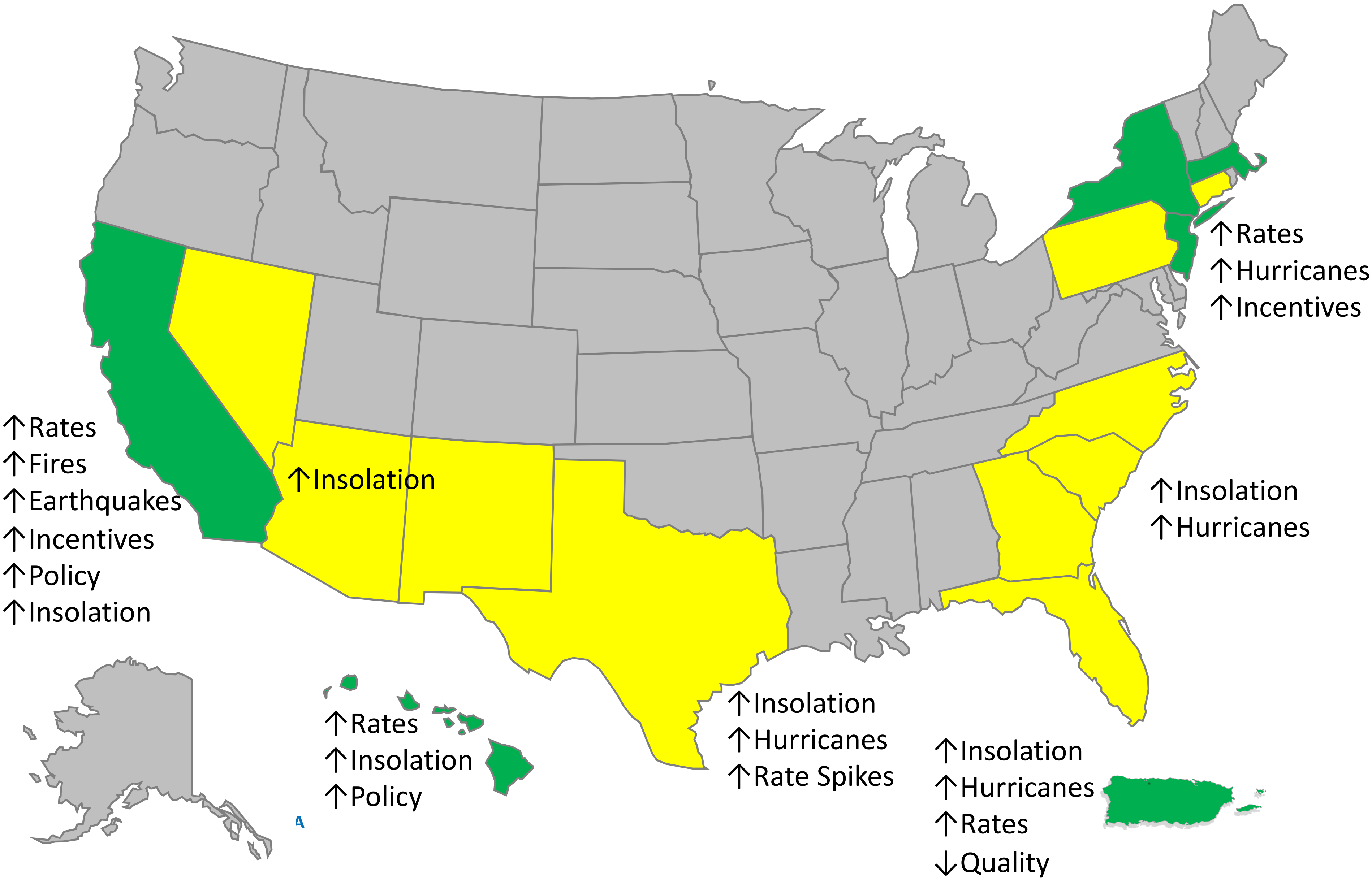

Hybrid Microgrid Market Attractiveness
Sample States

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Driver	NY	NJ	MA	FL	TN	TX	CA
↑ PV Installed Base	✓	✓	✓	~	X	✓	✓
↑ PV New Installations	✓	✓	✓	~	~	✓	✓
↑ Solar Irradiance	X	X	X	✓	~	✓	✓
↑ Policy : PV & Storage	✓	✓	✓	~	X	X	✓
↑ Sustainability Driven	✓	✓	✓	?	?	?	✓
↑ Electric Rates	✓	✓	✓	✓	~	~	✓
↑ Demand Charges	✓	✓	✓	?	✓	X	✓
↑ TOU Rates & On / Off Peak Spread	?	?	?	?	✓	✓	✓
↑ Nat Disaster Continuity Risk	✓	✓	✓	✓	X	✓	✓
↑ ISO Market Access	✓	✓	✓	X	X	✓	✓
↓ Power Quality	?	?	?	?	?	?	?

Tennessee

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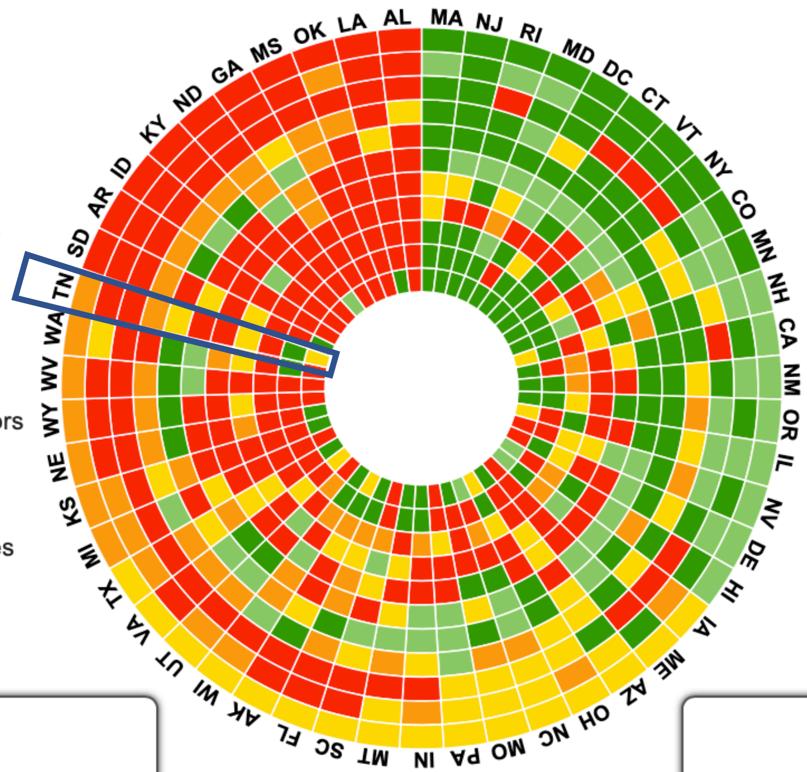

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https://www.solarpowerrocks.com/state-solar-power-rankings/

TN – Solar PV

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Solar Spotlight – Tennessee

SEIA Solar Energy Industries Association®

At A Glance

- **Solar Installed:** 429.4 MW (120.4 MW installed in 2018)[i]
- **National Ranking:** 23rd (17th in 2018)
- **Enough Solar Installed to Power:** 45,000 homes
- **Percentage of State's Electricity from Solar:** 0.40%[ii]
- **Solar Jobs and Ranking:** 4,690 (14th in 2018)[iii]
- **Solar Companies in State:** 165 companies total; 43 Manufacturers, 74 Installers, 48 Others[iv]
- **Total Solar Investment in State:** $734.29 million ($123.58 million in 2018)
- **Price Declines:** 32% in the last 5 years
- **Growth Projections and Ranking:** 752 MW over the next 5 years (ranks 28th)

https://www.seia.org/sites/default/files/2019-10/Factsheet_Tennessee.pdf

TN Notable Solar PV Projects

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- Providence Solar project has the capacity to generate 16.0 MW of electricity -- enough to power over 1,549 Tennessee homes.[v]
- IKEA and Volkswagen have both gone solar in Tennessee. VW has installed a 9 MW project at its location in Chattanooga.[vi]
- At 24 MW, Selmer 1 and 2 are among the largest solar installations in Tennessee. Completed in 2016, these photovoltaic projects have enough electric capacity to power more than 2,323 homes.[vii]

TN - Solar PV Historic Installations

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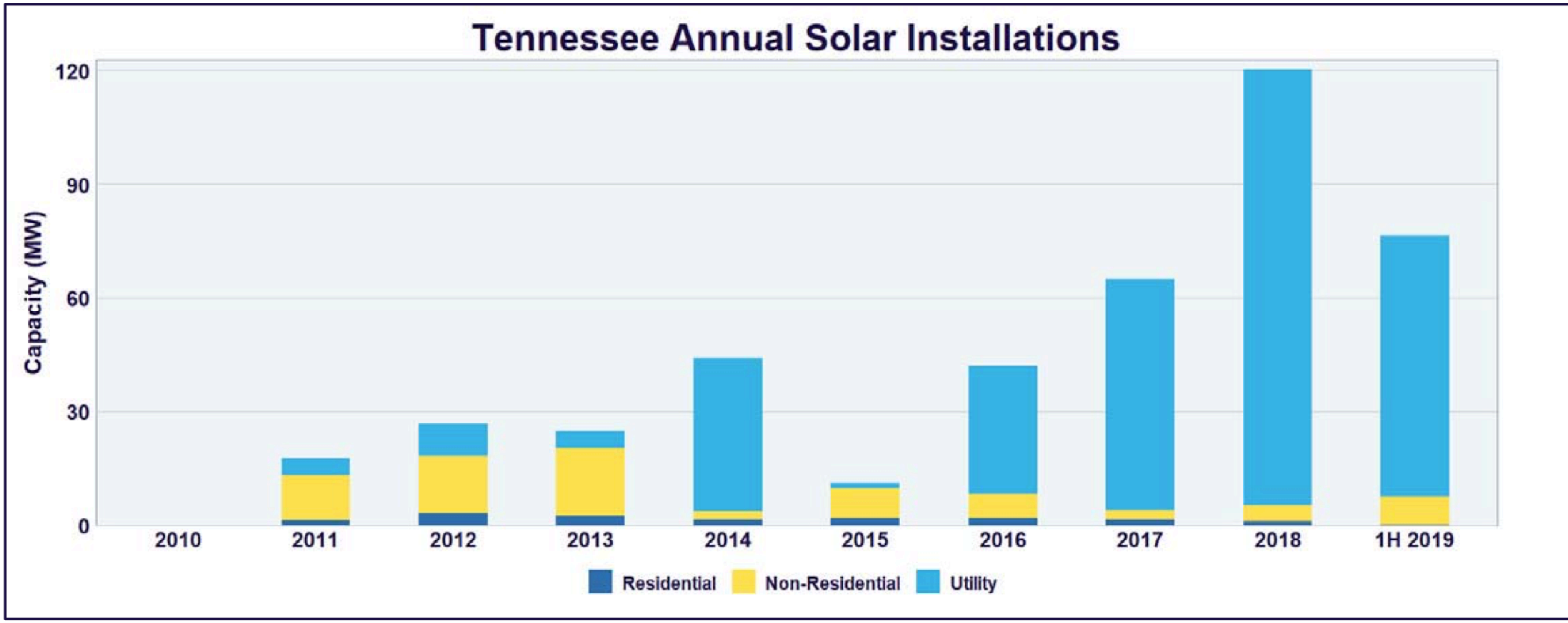

TN NES C&I Rates

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- GSA 2
  - Demand < 50 kW, Monthly Energy < 15K kWh
    - Demand = 5 $/kW-Mo
    - Energy = 9 – 10 c/kWh
  - 50 < Demand < 1000 kW, Energy > 15 K kWh
    - Demand = 5 $/kW-Mo, 1st 50 kW, 19 $/kW-Mo Above
    - Energy = 10 c/kW 1st 15K kWh, 6 c/kWh Above
  - 1000 < Demand
    - Demand = 19 $/kW-Mo
    - Energy = 6 c/kWh
- LGS 2 5000 kW < Demand <= 15,000
  - Demand
    - On Peak 10 $/kW-Mo, Max 5 $/kW-Mo
  - Energy
    - On Peak 7-8 c/kWh, Off Peak 2 c/kWh

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Decision Makers & Opportunities

Equipment Decision Makers

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Past / Present
Facility Owner Driver DER

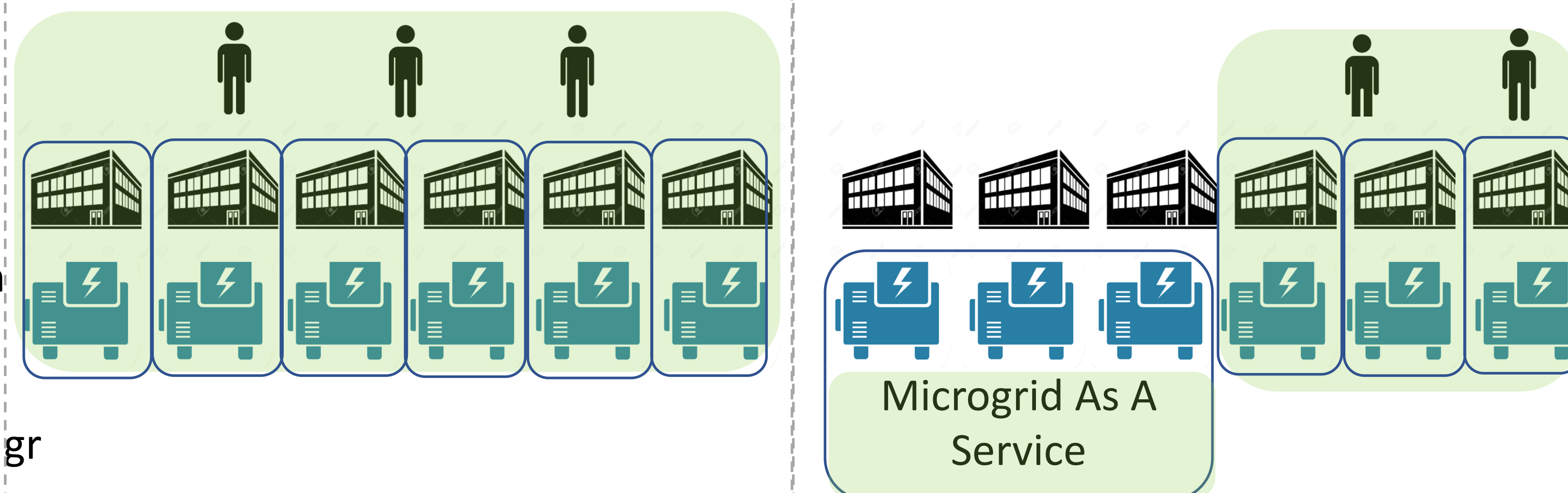
Future
More DER Fleet Owners

Consulting Engineers

Facility Owners

Generation Equipment

DER Asset Owner / Mgr



- Facility Owners Own DER Systems
- Facility, Engrs, & Gen Suppliers Spec Equip
- Value : Quality / Reliability / Price

- New Entities Own / Operate DER Fleets
- Their Engr's Will Spec Equipment
- Value : Price / Quality / Reliability +

  Repeat-ability / Scalability / Plug & Play
  Standardization / Secure Communications

Equipment Decision Maker

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PV & Storage Sample Economics

Solar PV – Levelized Cost of Energy

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Year	0	1	2	3	4	5	…	21	22	23	24	25
$000												
Operating Expenses		$ 15.0	$ 15.3	$ 15.5	$ 15.8	$ 16.1	…	$ 21.3	$ 21.7	$ 22.1	$ 22.5	$ 22.9
Capital Expense	$ 1,400.0											
Investment Tax Credit		$ (364.0)										
Total Expenses	$ 1,400.0	$ (349.0)	$ 15.3	$ 15.5	$ 15.8	$ 16.1	…	$ 21.3	$ 21.7	$ 22.1	$ 22.5	$ 22.9
Generation (MWh)		1,350	1,343	1,337	1,330	1,323	…	1,221	1,215	1,209	1,203	1,197

Total Expenses ($000)	$ 1,502.4	
Total Generation	31,801	MWh
LCOE	$ 47.2	$/MWh
Generation Yr 25 / 1	89%	

Assumptions:

- 1 MW Fixed Mount Rooftop System
- Capital Cost = 1.4 $/Watt
- Operating Expenses 15 $/kW, 2% Escalation
- ITC = 26%
- kWh / kW = 1350, 0.5% Annual Degradation

Solar PV Sample Economics

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						No Debt		With Debt	
				Rate			Payback		Payback
State	**City**	**kWh / kW / Yr**	**$/Watt**	**$/MWh**	**Incentive**	**IRR**	**Yrs**	**IRR**	**Yrs**
MA	Worcester	1288	1.6	150.0	Firm Rate	16%	5.1	34%	< 1
NY	Albany	1238	1.6	106.0	0.2 $/Watt	18%	4.3	44%	< 1
NJ	Freehold	1325	1.6	73.0	200 $/MWh	32%	2.4	72%	< 1
FL	Orlando	1525	1.4	62.5		8%	9	12%	4.7
TN	Nashville	1350	1.4	80.0		10%	7.8	18%	1.8
TX	Dallas	1506	1.4	70.0		10%	8.2	16%	2
CA	Las Angeles	1661	1.6	98.5		15%	5.6	31%	< 1

Assumptions:
- 1 MW Fixed Mount Rooftop System
- Capital Cost = 1.4 – 1.6 $/Watt
- Operating Expenses 15 $/kW, 2% Escalation
- Debt Scenario = 50% of Capital Cost, 6%, 15 Yrs

Storage – Sample Economics – Peak Clipping

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Avoided Demand $/kw-Mo	No Debt IRR	No Debt Payback Yrs	With Debt IRR	With Debt Payback Yrs
$ 10.0	10%	7.8	16%	4.1
$ 15.0	17%	6.6	30%	2.3
$ 20.0	22%	3.9	41%	1.7

Financial Benefit Reflects Only Peak Clipping. Does Not Reflect

- Time of Use Energy Arbitrage
- KVAR Discount
- Avoid Solar PV Excess Power
- Resiliency Value

Assumptions:

- 1 MW / 2 MWh System @ 600 $/kWh Capital Cost
- 26% 2020 Investment Tax Credit for Solar Applies
- Clip Peak 75% of Storage Capacity, i.e. 750 kW
- Operating Expenses 20 $/kW
- Replace Batteries Yr 12 at 80 $/kWh
- Debt Scenario = 50% of Capital Cost, 6%, 15 Yrs

Storage – Sample Economics
Peak Clipping & TOU Arbitrage

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No Debt		With Debt	
IRR	Payback Yrs	IRR	Payback Yrs
19%	4.8	30%	3

Financial Benefit Reflects Only Peak Clipping. Does Not Reflect

- Clip Peak 75% of Storage Capacity, i.e. 750 kW @ 10 $/kW-Mo
- TOU Energy Arbitrage
  - Charge Battery Off Peak at 2 c/kWh
  - Discharge On Peak at 7 c/kWh

Does Not Reflect

- KVAR Discount
- Avoid Solar PV Excess Power
- Resiliency Value

Assumptions:

- 1 MW / 2 MWh System @ 600 $/kWh Capital Cost
- No Investment Tax Credit. No Solar Charging.
- Operating Expenses 15 $/kW
- Replace Batteries Yr 12 at 80 $/kWh
- Debt Scenario = 50% of Capital Cost, 6%, 15 Yrs

PV + Storage – Sample Economics
Peak Clipping

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No Debt		With Debt	
IRR	Payback Yrs	IRR	Payback Yrs
10%	7.8	16%	4.1

Financial Benefit Reflects Only
- PV Energy Avoids 8 c/kWh On Peak Energy
- Clip Peak 75% of Storage Capacity, i.e. 750 kW @ 10 $/kW-Mo
- TOU Energy Arbitrage – Not Applicable

Does Not Reflect
- KVAR Discount
- Avoid Solar PV Excess Power
- Resiliency Value

Assumptions:
- 1 MW / 4 MWh System @ 600 $/kWh Capital Cost
- No Investment Tax Credit. No Solar Charging.
- Operating Expenses 20 $/kW
- Replace Batteries Yr 12 at 80 $/kWh
- Debt Scenario = 50% of Capital Cost, 6%, 15 Yrs

TX - Storage Economics – Energy Arbitrage

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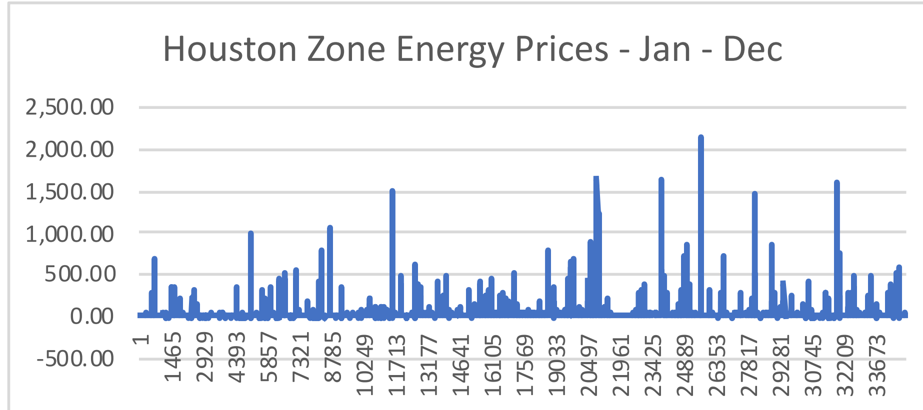
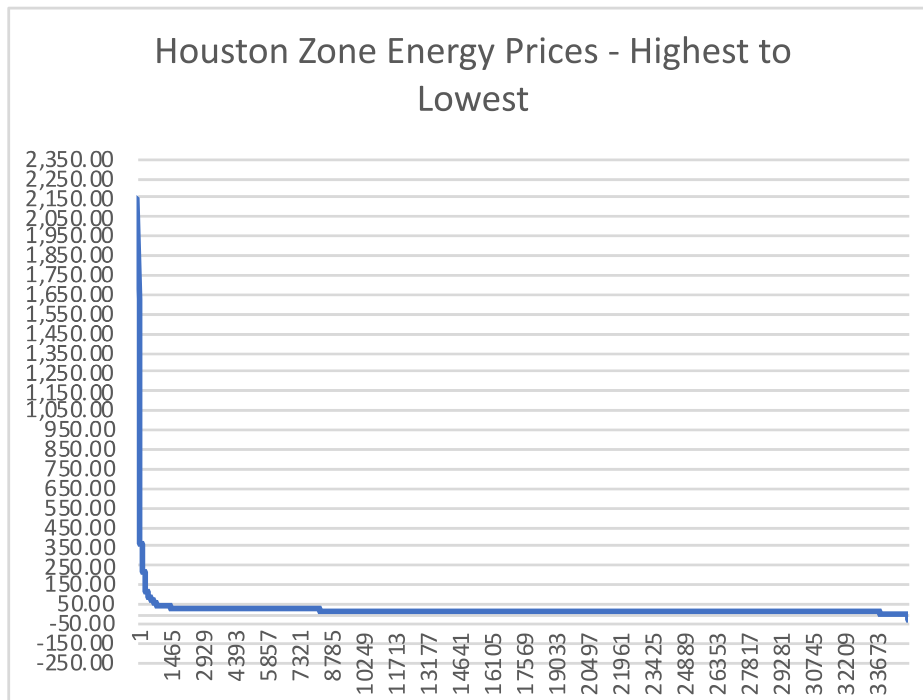
2016 Data

- Prices Spike to 2000+ $/MWh
- Most Prices Below 50 $/MWh
- Prices Above 60 $/MWh 185 Hrs





TX - Storage Economics – TOU Arbitrage 2019

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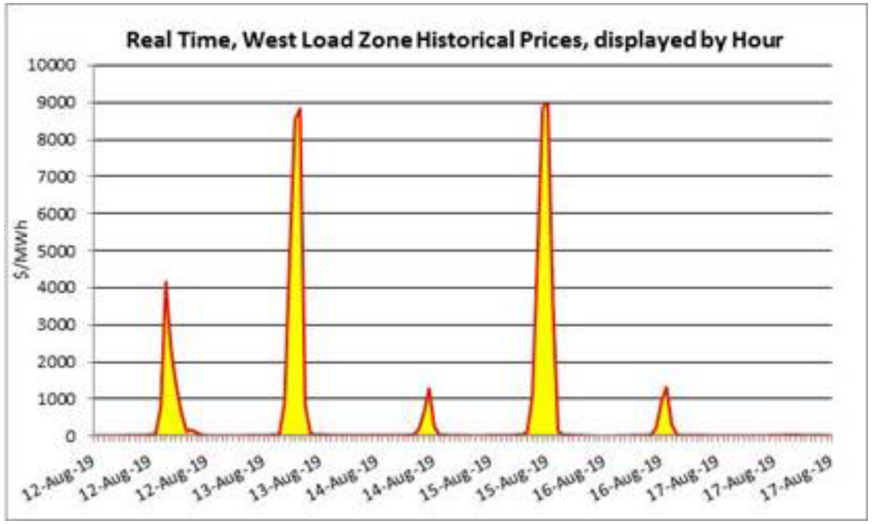
ELECTRIC POWER — 12 Aug 2019 | 22:20 UTC — Houston

ERCOT sets peakload record; real-time prices top $6,000/MWh

COMMODITIES AUGUST 14, 2019 / 10:20 AM / 2 MONTHS AGO

Texas power prices briefly soar to $9,000/MWh as heat wave bakes state



https://www.energycentral.com/c/pip/ercot-price-volatility-deeper-dive-causes-and-potential-effects

TX - Storage – Sample Project Economics

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Energy Price Scenario	0% Debt		50% Debt	
	IRR	Payback (Yrs)	IRR	Payback (Yrs)
Houston 2016	10%	8.7	14%	6.8
X 2	12%	7.3	20%	4.6
X 3	16%	5.9	27%	3.0

Key Assumptions

- $500 / kWh Capital Cost
- Investment Tax Credit = 30%
- 20 Yr Project Life
- Debt = 15 yrs @ 5.00%

Key Notes

- Includes
  - Avoid Above Normal Energy Price Spikes
  - Avoid 7 $/kW Demand Charge for 75% of ESS kW
  - Participate in Ancillary Services Market
    - 26 wks / yr, 5 days / wk, 4 hr / day, 50% of kW, @ 5 $/MWh
- Does Not Include
  - Resiliency Value
  - Power Quality Improvement
  - Demand Control Power Discount
  - Index Power Discount

Questions / Follow-Up

Russelectric®
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