Electric Power Grid of the Future

CIGRE Next Generation Network
March 4, 2020

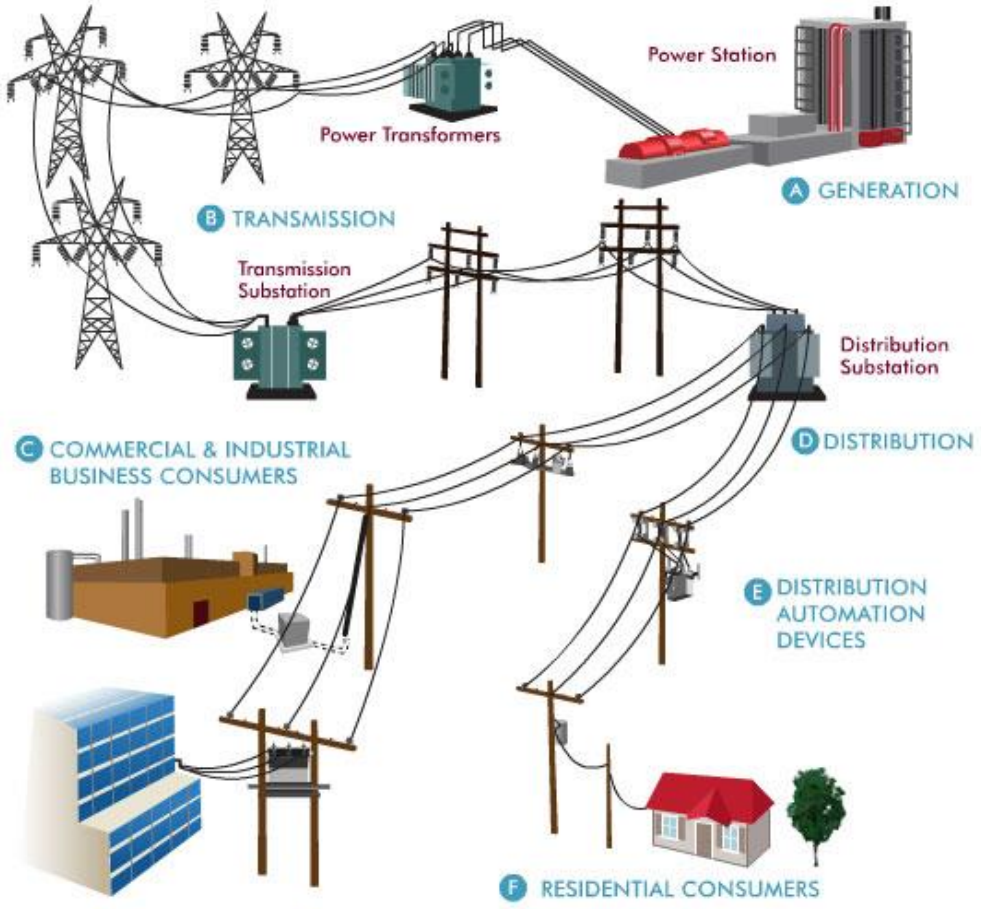
Rob Gramlich

www.gridstrategiesllc.com

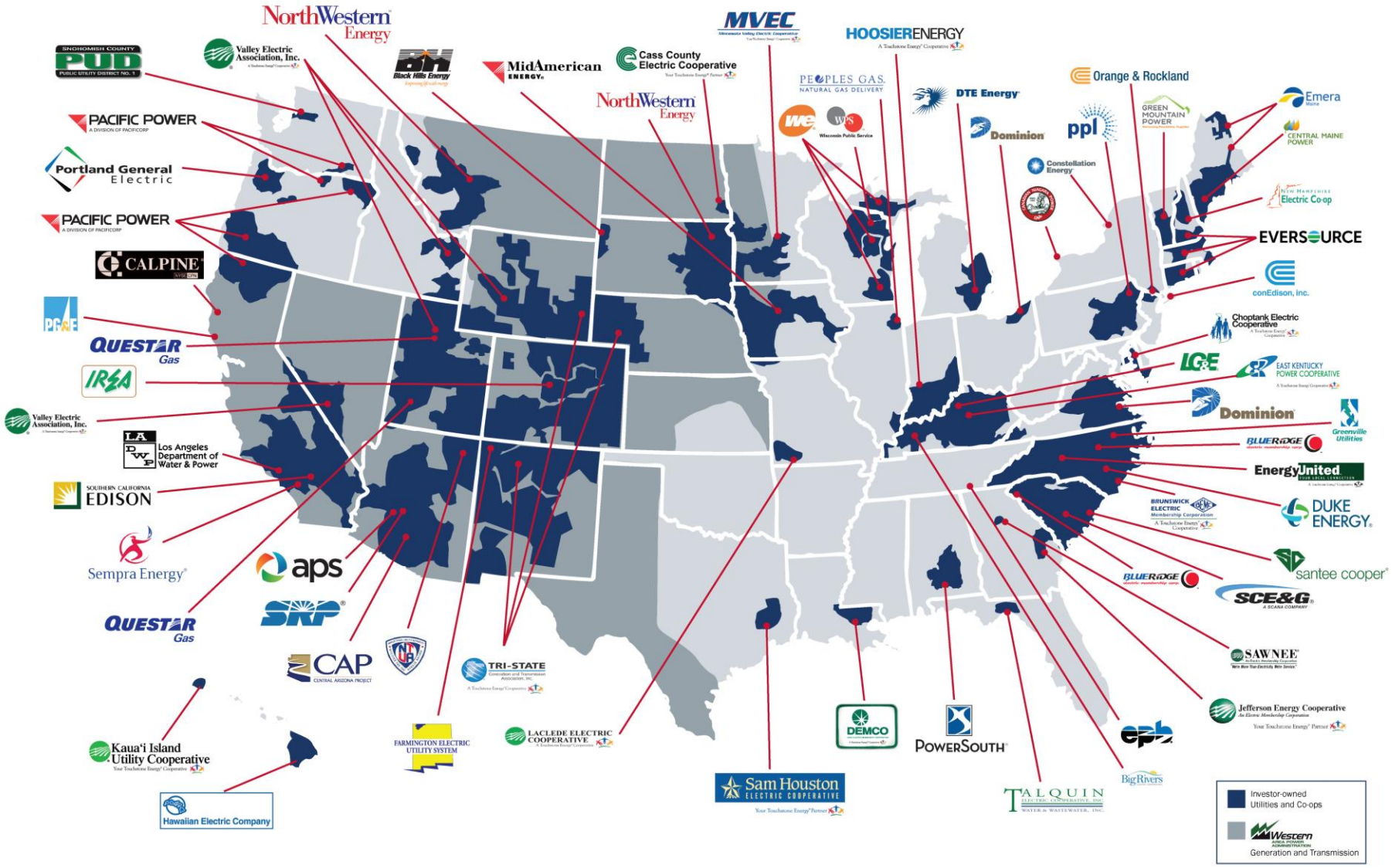
Grid History and Future
with high penetration renewables

1. Traditional vertical industry structure
2. Need for regionalization
3. Need for a robust macro grid
4. Need for efficient transmission utilization
5. Need for large regional power markets
6. Reliability considerations
7. Hybrid resources

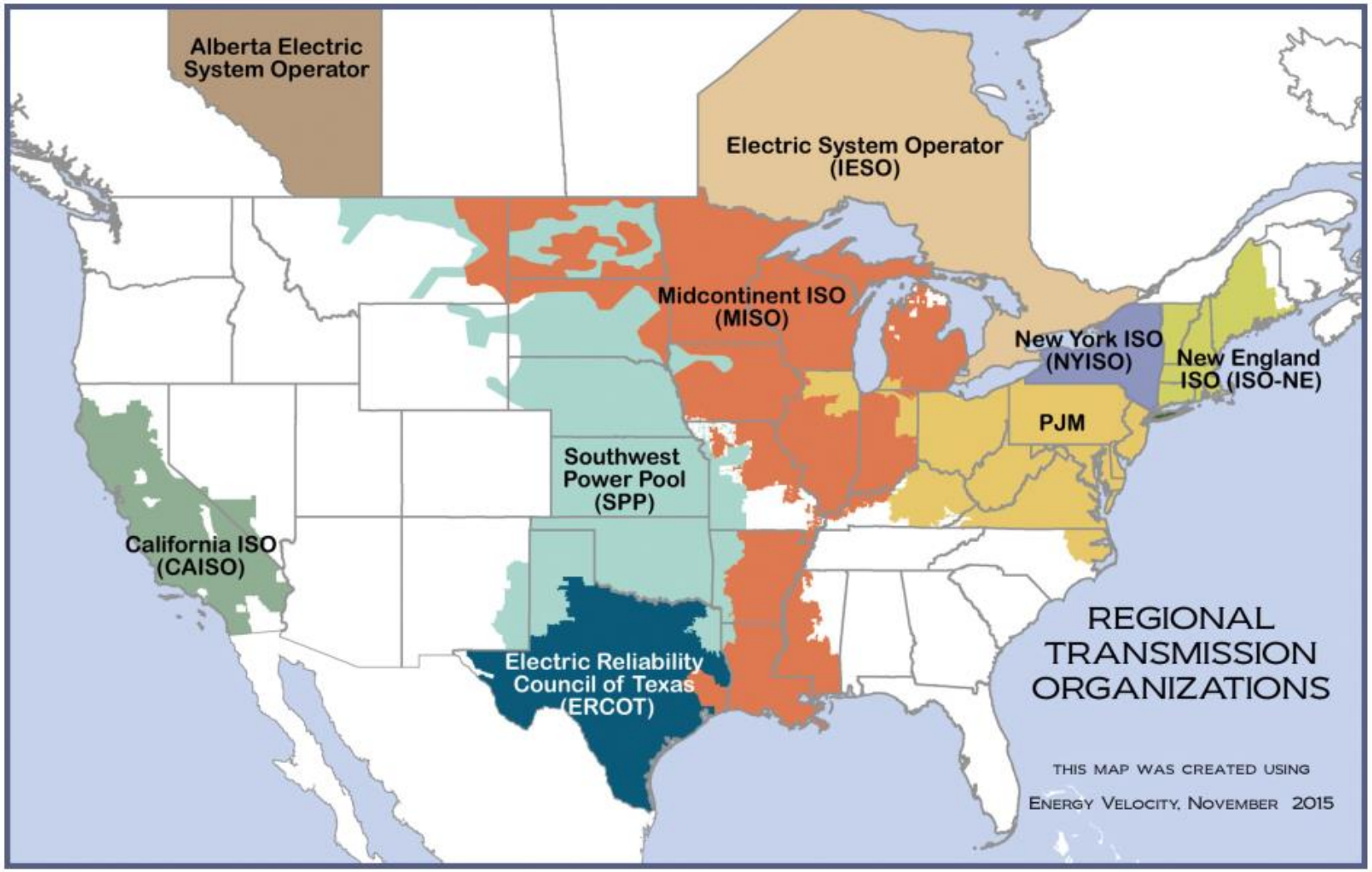
Traditional vertically integrated utility structure



Traditional vertical utilities



Regionalization with RTOs and ISOs



RTO Characteristics and Functions

(FERC Order 2000) (1999)

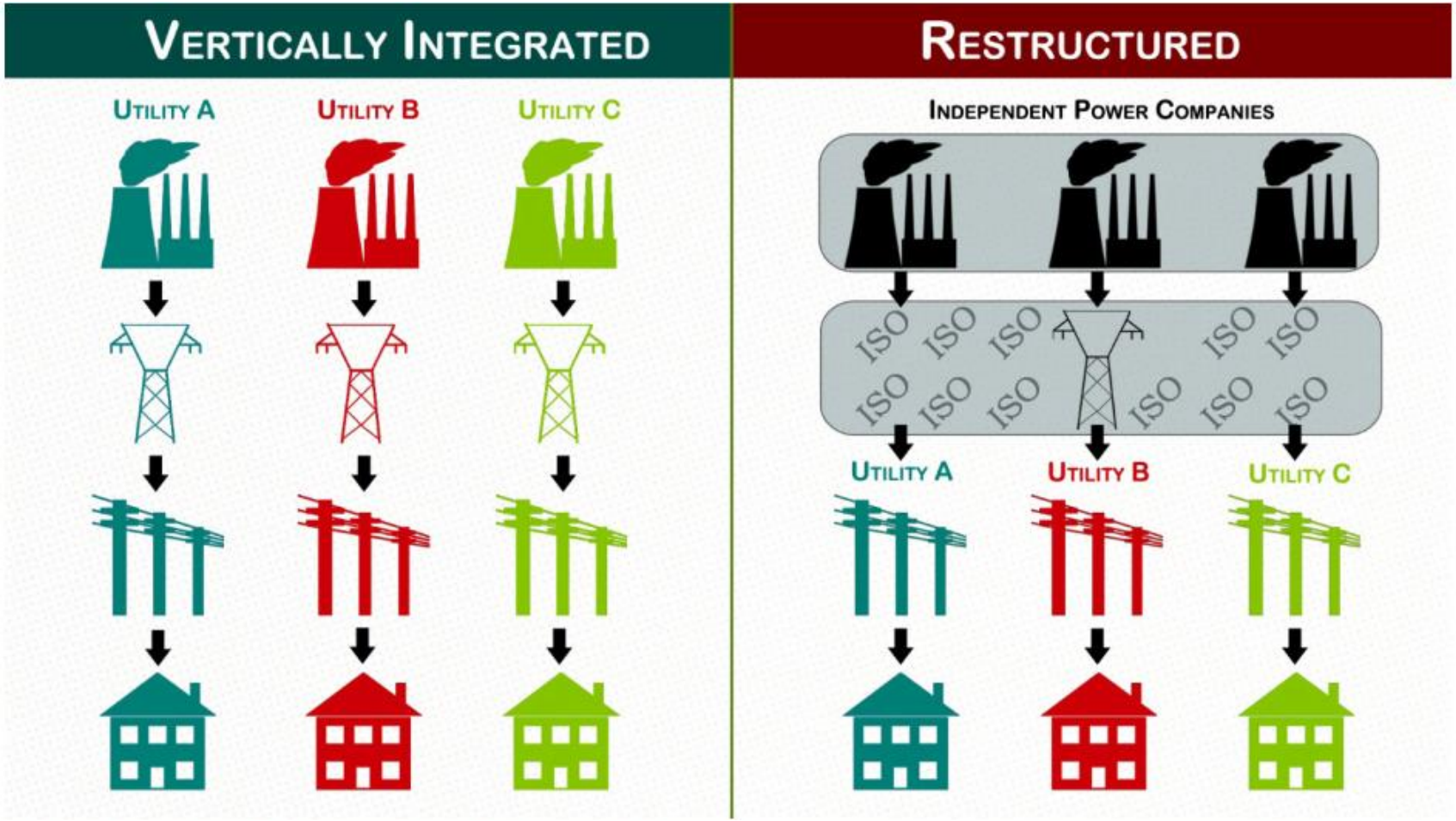
Characteristics:

1. Independence
2. Scope and regional configuration
3. Operational authority
4. Responsibility for short-term reliability.

Functions:

1. Administer and design tariffs
2. Manage congestion
3. Solve the parallel path flow problem
4. Manage and provide ancillary services
5. Maintain OASIS and post the transmission capability
6. Perform market monitoring
7. Plan and manage transmission system expansion
8. Handle interregional coordination.

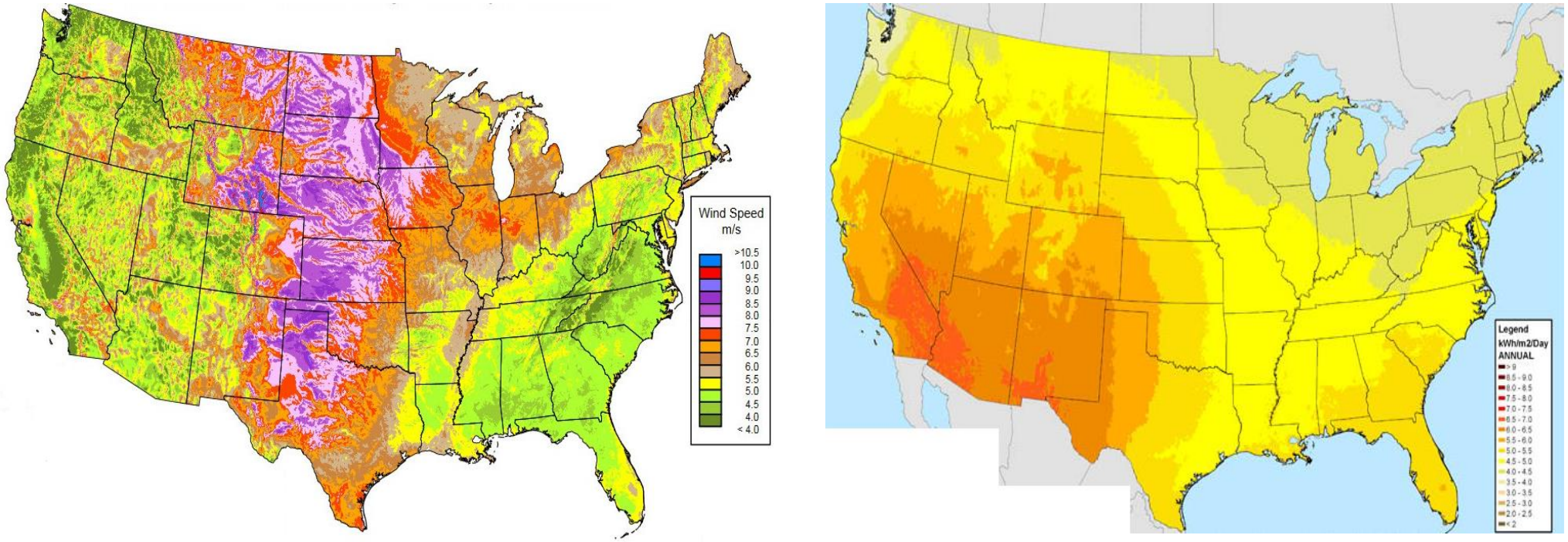
Wholesale Competition Structure



-Devin Harman https://www.rstreet.org/wp-content/uploads/2016/08/67.pdf

Transmission and Renewable Energy

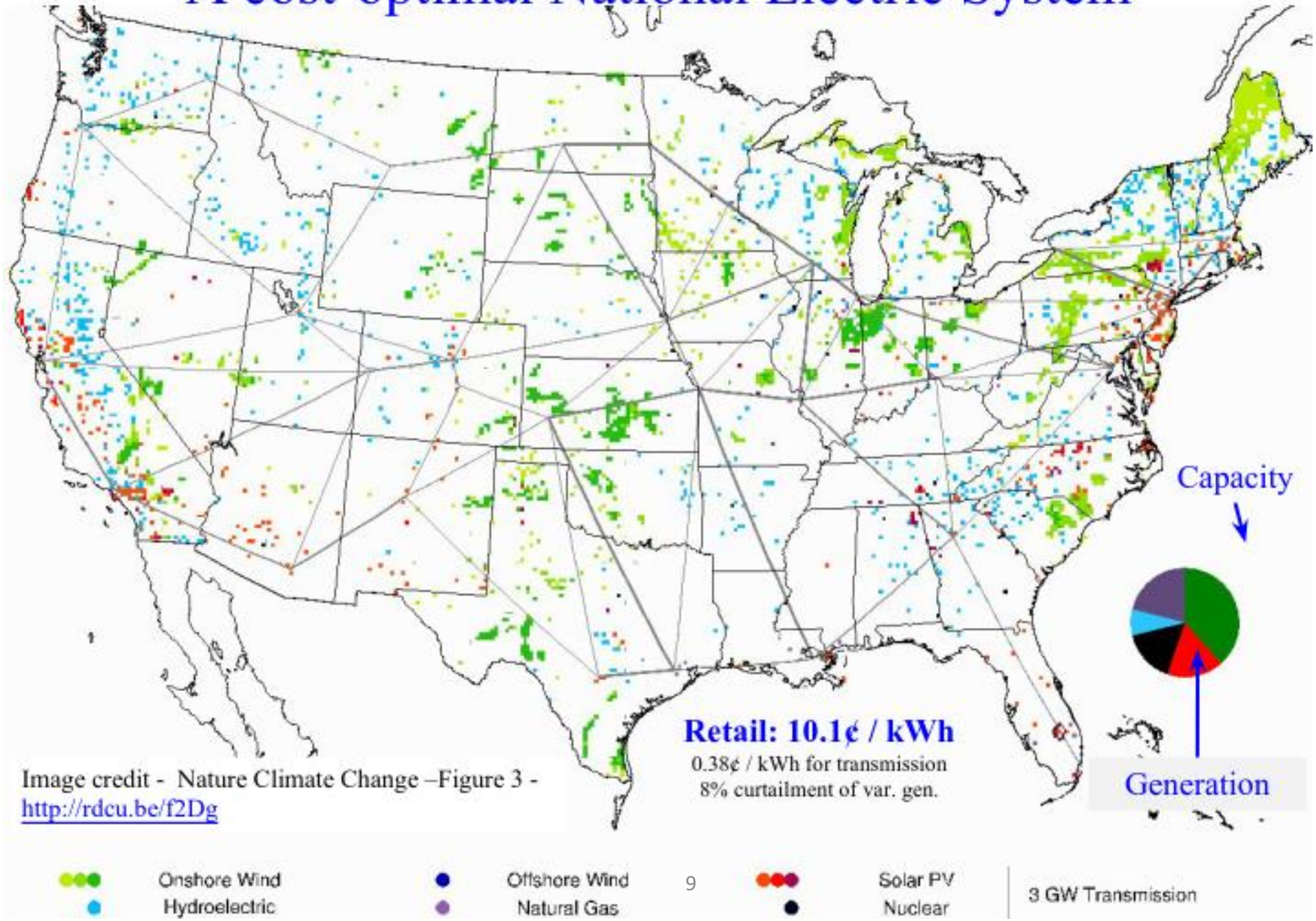
- Best wind and solar far from load



NREL Wind (left) and Solar (right) Resource Maps

https://windexchange.energy.gov/maps-data/319 , https://www.nrel.gov/gis/images/map_pv_us_annual10km_dec2008.jpg

A cost-optimal National Electric System



Dr. Christopher Clack
VCE

Transmission in other countries: China case

Europe Renewables and Transmission

https://globalchange.mit.edu/sites/default/files/MITJPSPGC_Reprint_16-9.pdf

US Transmission Congestion Costs Rising (Again)

Transmission Congestion Costs ($ millions) for RTOs from 2016-2018

RTO	2016	2017	2018
ERCOT	497	976	1,260
ISO-NE	38.9	41.4	64.5
MISO	1,400	1,500	1,400
NYISO	529	481	596
PJM	1,023.7	697.6	1,310
SPP	273.7	405.3	380.9
Total	**3,762.3**	**4,101.3**	**5,011.3**

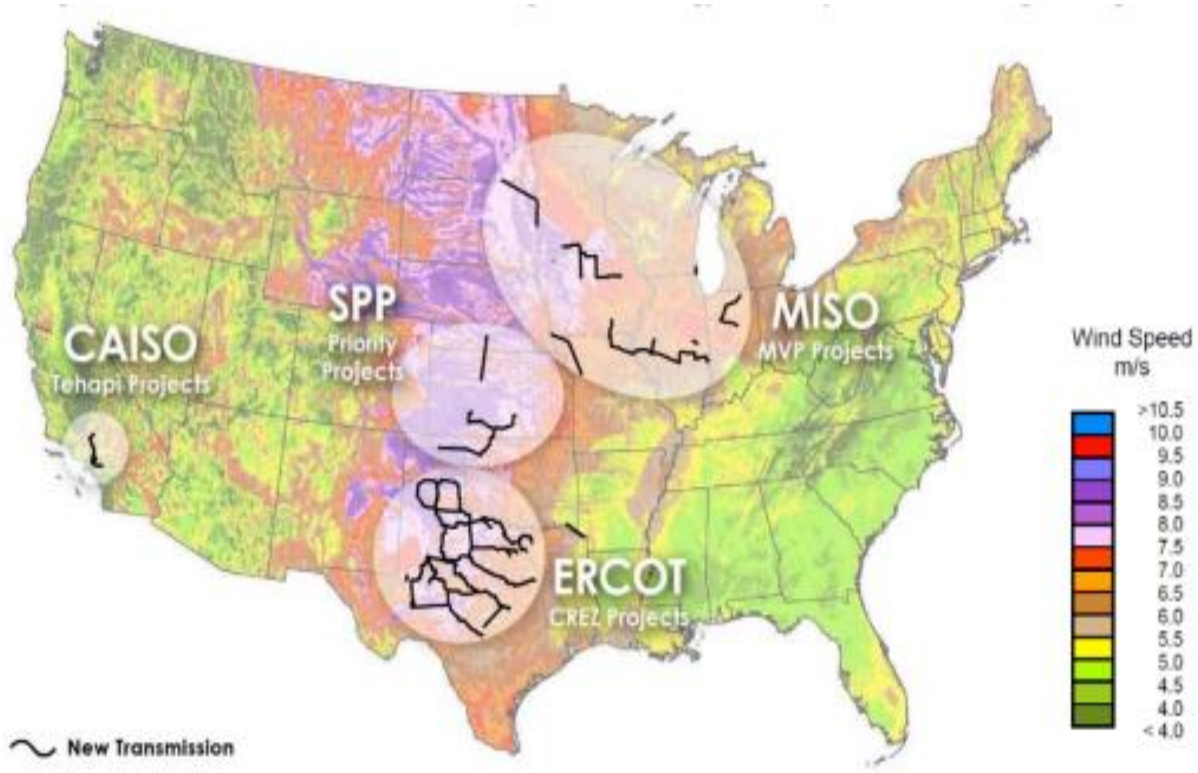
First, Use the Existing Grid More Efficiently

- **Power Flow Control**
  - Push and pull power, modular, scalable, movable
- **Dynamic Line Ratings**
  - Adjust path rating based on ambient conditions, allows capacity forecasting
- **Topology Optimization**
  - Software to optimize transmission assets, eg circuit breakers
- **Storage as Transmission**

➔ **Re-set incentives on transmission owners**

Recent Large-Scale Expansions

- MISO MVP, SPP priority projects, ERCOT CREZ
- 3:1 Benefit-Cost ratios
- Winning formula:
  - Pro-active multi-benefit planning
  - Broad, beneficiary pays allocation



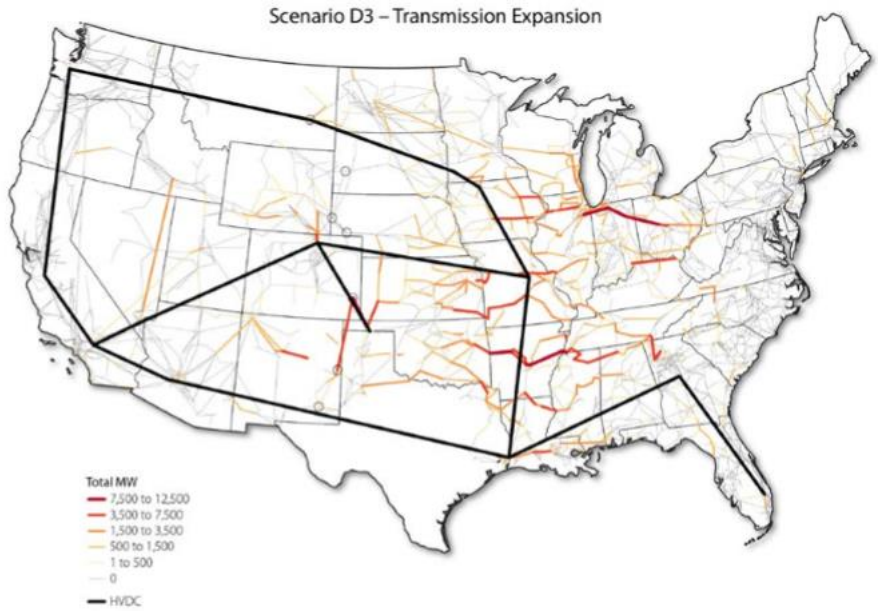
Transmission Enabled ½ of US Wind Capacity

~105 GW installed in US

Transmission plan	Wind Capacity Enabled (GW)
Tehachapi	4.5
Texas CREZ	14.5
MISO MVP	14
SPP Priority Projects, Balanced Portfolio	6
CO+ME+NV+PAC+BPA	10
Total	49

Transmission Barrier 1: Permitting

- State by state review
- States impacting other states, national interest not being considered



Transmission Barrier 2: Narrow planning

- Almost no inter-regional plans have been produced
- Planning by RTOs has been ground-up rather than comprehensive
- Planning has not been pro-active to consider known generation development in resource areas
- Planning benefits have been compartmentalized: economic/reliability/resilience/generator interconnection

➔ Broad regional and inter-regional multi-purpose planning

Transmission Barrier 3: Funding

- FERC generator interconnection policy allowed “participant funding”
  - Even when many generators are connecting in the same area
- Not all benefits considered

➔ Broad cost allocation
  - Consider all benefits
  - As they may change over time
  - FERC assign costs to all beneficiaries

➔ Investment Tax Credit

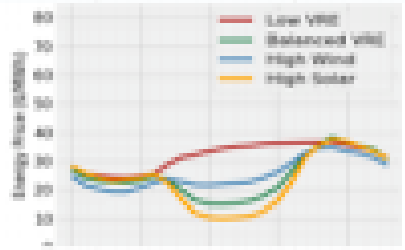
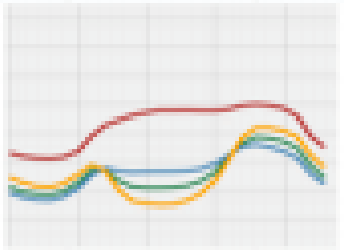
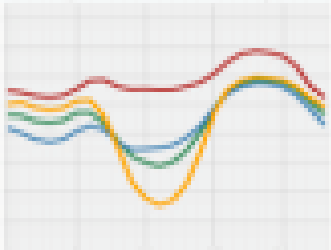
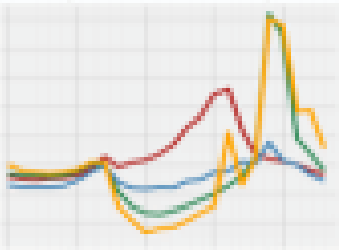
Market Design for an Evolving Resource Mix

- Flexible
  - Fast (eg, 5 minute) dispatch, price based on value
  - Close to real time commitments and dispatch
- Fair
  - Technology neutral—pay for DELIVERED SERVICES, not ATTRIBUTES
  - Small building blocks
- Far
  - Large geographic areas with seamless trading
- Free
  - Bilateral contracts uninhibited
  - Full demand side participation, all flavors

See https://windsolaralliance.org/wp-content/uploads/2018/11/WSA_Market_Reform_report_online.pdf

Wholesale Price Effects of 40-50% Wind & Solar

(Wind: 30% wind & 10+% solar | Balanced: 20% wind & 20% solar | Solar: 30% solar & 10+% wind)

Impacts in 2030 relative to baseline with 2016 wind & solar shares	Southwest Power Pool (2016: 18% wind & 0% solar)			NYISO (New York) (2016: 8% wind & 1% solar)			CAISO (California) (2016: 7% wind & 14% solar)			ERCOT (Texas) (2016: 16% wind & 1% solar)		
	Wind	Balanced	Solar	Wind	Balanced	Solar	Wind	Balanced	Solar	Wind	Balanced	Solar
Lower Average Prices [$/MWh]	-19%	-21%	-27%	-37%	-38%	-39%	-25%	-23%	-27%	-25%	-17%	-15%
More Hours <$5/MWh In baseline: 0% of all hours	6%	8%	13%	2%	7%	11%	6%	7%	11%	6%	11%	19%
Changes in Diurnal Price Profile red baseline shows 2016 wind & solar shares												
More Price Variability	1.8x	2.1x	2.5x	2.1x	2.3x	2.5x	3.0x	2.9x	3.4x	1x	4.7x	6.6x
Higher AS Prices Regulation Down	5x	6x	9x	2x	2x	3x	3x	3x	3x	2x	3x	4x
Change in Timing of Top Net-Load Hours	Shift from 4pm to 7pm			Shift from 3pm to 5-7pm			No further shift 7pm			Shift from 3pm to 6-8pm		

Source: LBNL

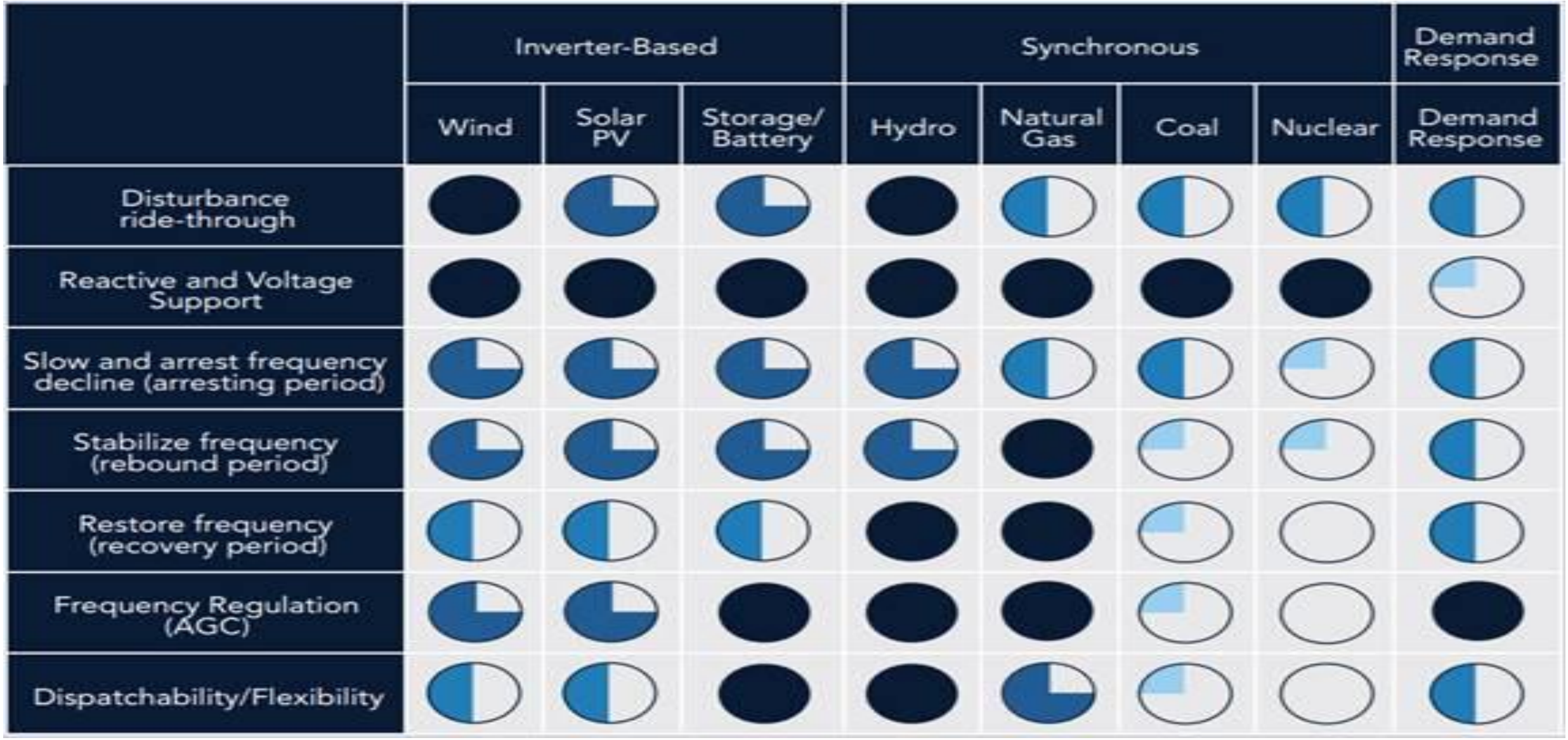
Best Market Structure for Low Cost De-Carbonization

- Environmental regulators internalize externalities
- RTO/ISO balances power system and administers short term spot markets
  - Procures energy and reliability services based on engineering definitions
  - Also plans transmission infrastructure for reliability and efficiency given future resource mix, recovers cost in regional tariff
- Retail suppliers competitively procure power (hedge) with PPAs to serve load
- State PUCs oversee hedging for some or all customers
  - ensure retail suppliers are credit-worthy buyers of wholesale power
  - Level playing field between retailers and provider of last resort
- Utilities build, own, and operate monopoly T&D (not G) with regulated rates
- Independent Power Producers build and own generation to sell electricity products to retail suppliers/wholesale buyers
- Financial participants provide risk management products

Reliability Efforts with Generation
being considered by NERC and RTOs

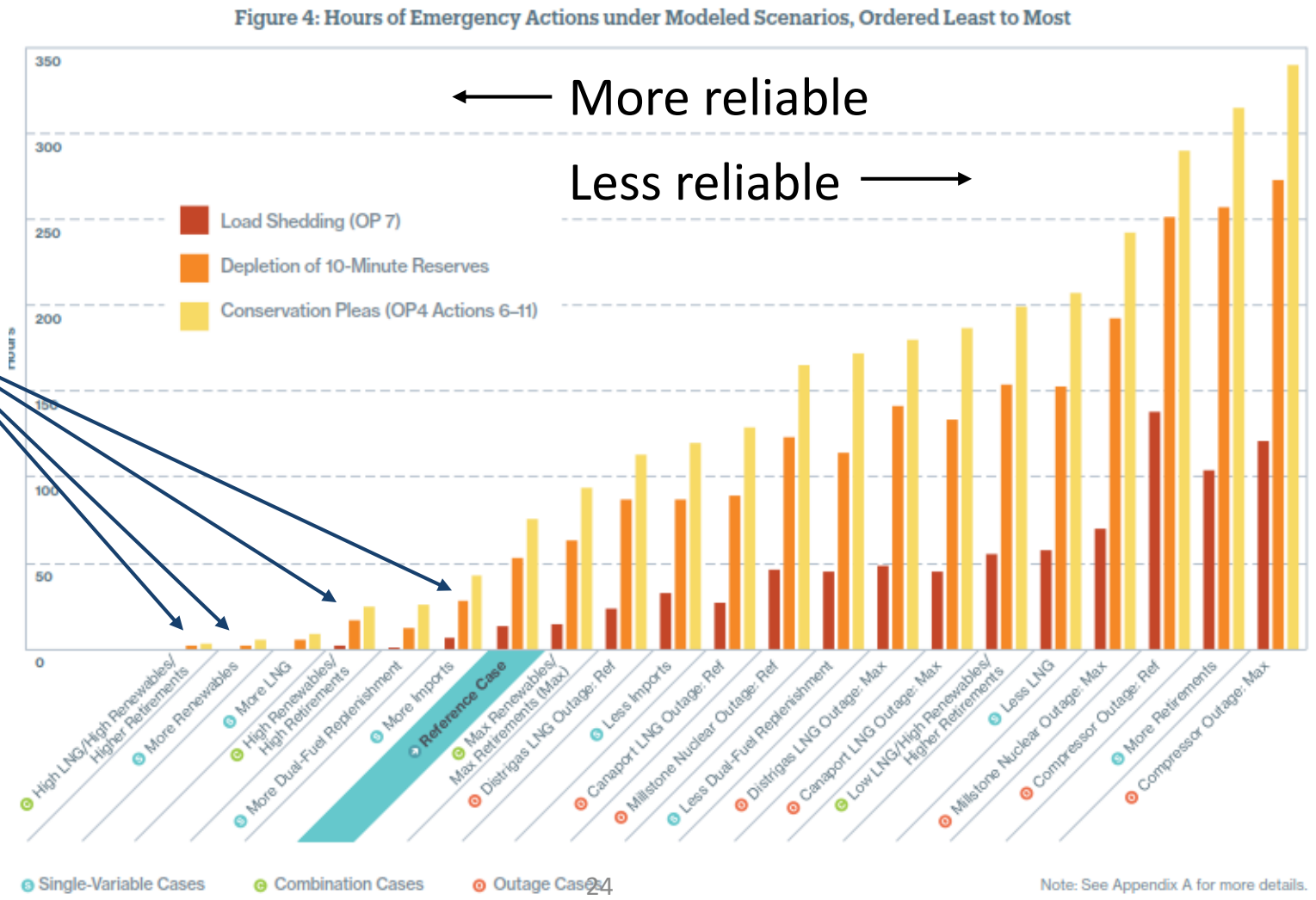
- Common mode failures affecting multiple generators that are getting credit for having uncorrelated outages
- Peak energy supply in Northeast/Midwest winter Polar Vortices
  - If gas and transmission import constraints
- Ride-through capability and settings on inverter-based technologies
- Stability in weak areas of the grid
- Inertia/Fast Frequency Response adequacy with declining amounts of synchronous generation

Reliability Services of Generation Sources



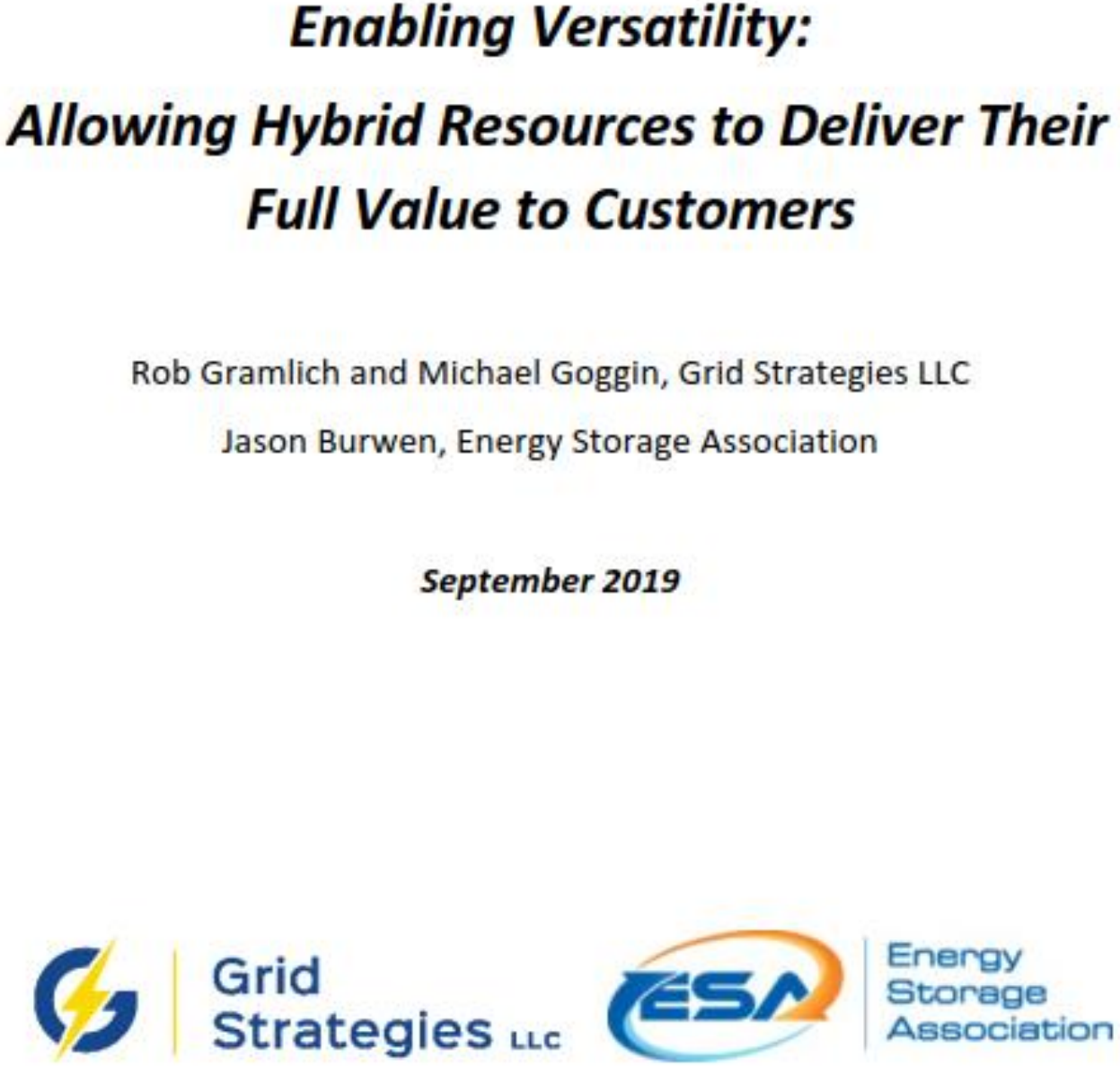
Physical Balancing With High Renewables:
Fuel Security in ISO-NE

High Renewable Scenarios



New Development: Hybrid Resources

- Interconnection
- Operational protocols
- Capacity value



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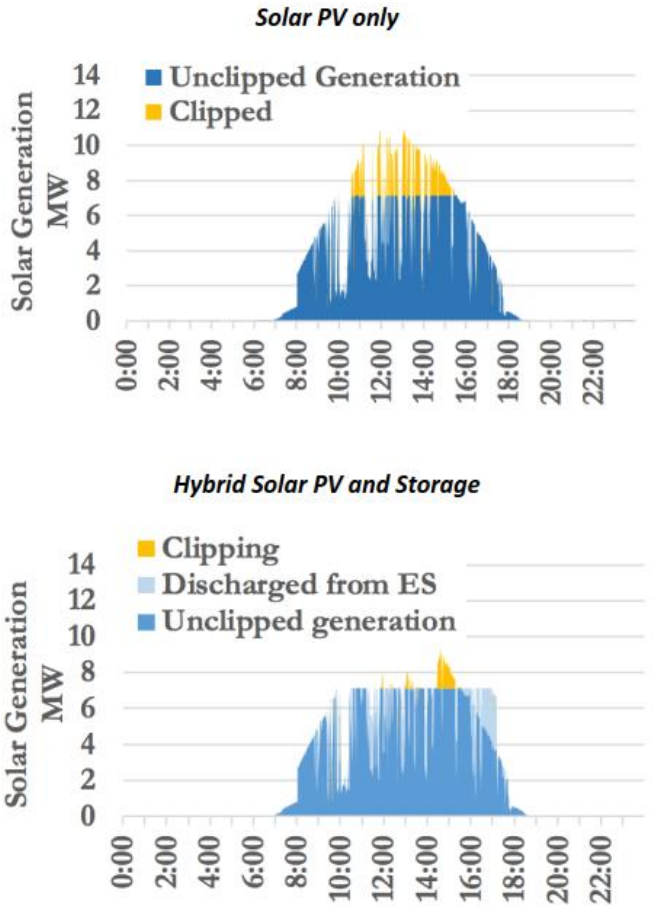
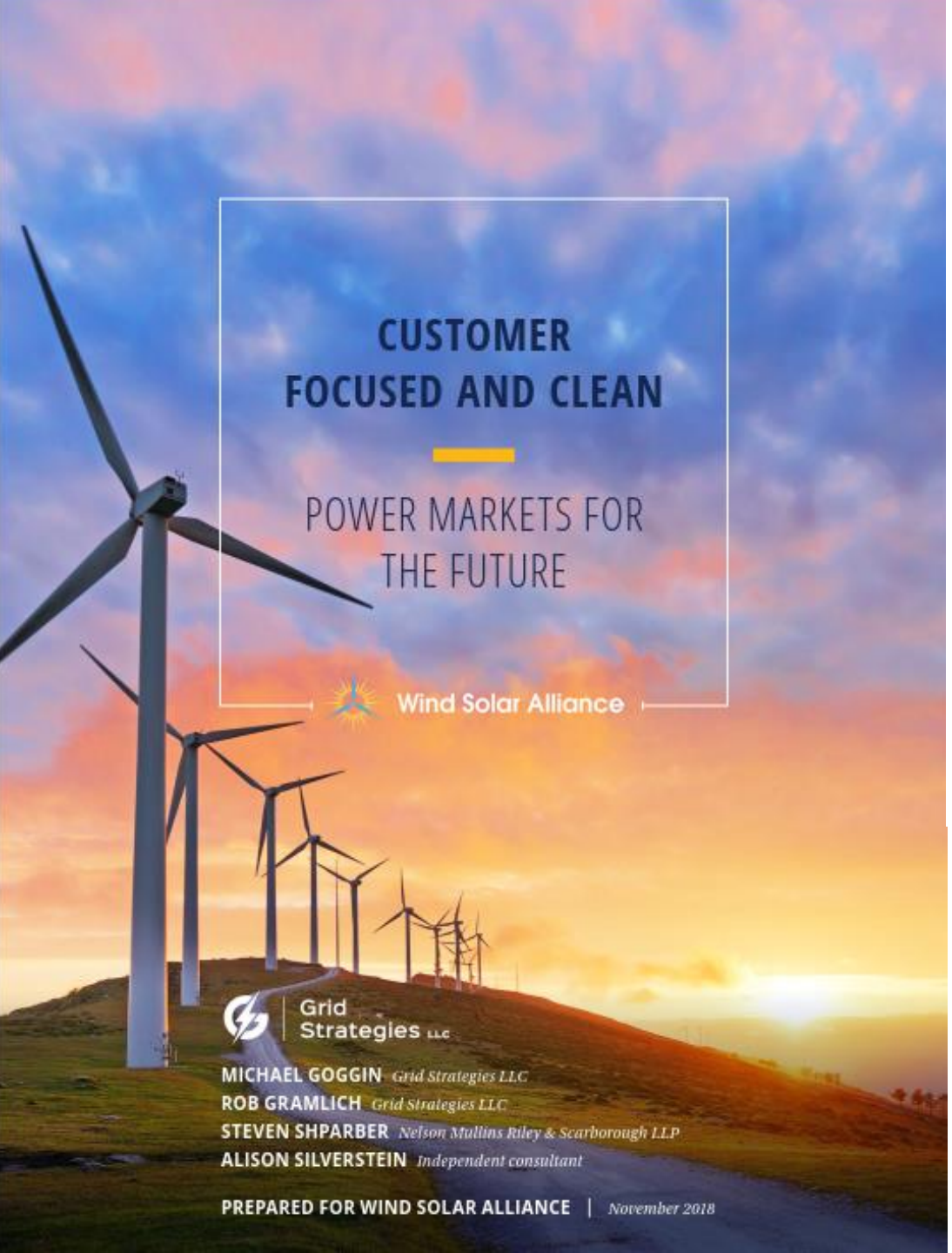
ESA Energy Storage Association

Hybrid Resource Efficiencies

- Solar PV clipping with and without storage





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www.energyinnovation.org
98 Battery Street, Suite 202
San Francisco, CA 94111
power@energyinnovation.org

WHOLESALE ELECTRICITY MARKET DESIGN FOR RAPID DECARBONIZATION: A DECENTRALIZED MARKETS APPROACH

BY ROB GRAMLICH[1] AND MICHAEL HOGAN[2] ● JUNE 2019

"What wholesale market design would provide the best framework for integrating reliably and at least cost the new, clean resources that will be needed to de-carbonize the power system?"

This common question includes what model best provides clean sources with fair access, what model best drives timely retirement of the fossil generation these clean resources are meant to replace, and what role the wholesale market should play in enabling new "smart" resources at the distribution/retail level. The question also includes both market structure (which entities perform which functions) and market design (what are the trading, bidding, and price-setting rules).[3] The pace and scale of new investment in clean resources will be determined in part exogenously, by environmental legislation or regulations. Such public policy instruments, including zero-carbon portfolio standards or carbon cap-and-trade, should be designed to address the market externalities of greenhouse gas emissions in a way that complements rather than substitutes for the role of the market in driving investment.

The question above is often motivated by three concerns regarding the standard spot electricity market design that shaped most current organized wholesale energy markets:

TABLE OF CONTENTS

[1] Grid Strategies LLC https://gridstrategiesllc.com/
[2] Regulatory Assistance Project https://www.raponline.org/
[3] The question does not address the substantial transmission infrastructure needs for a de-carbonized grid; this is a more difficult challenge that also must be addressed and involves a significant role for traditional planning.

A Customer-focused Framework for Electric System Resilience

ALISON SILVERSTEIN | ALISON SILVERSTEIN CONSULTING
ROB GRAMLICH | GRID STRATEGIES LLC
MICHAEL GOGGIN | GRID STRATEGIES LLC

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May 2018

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