Design and Operation of U.S. Power Markets

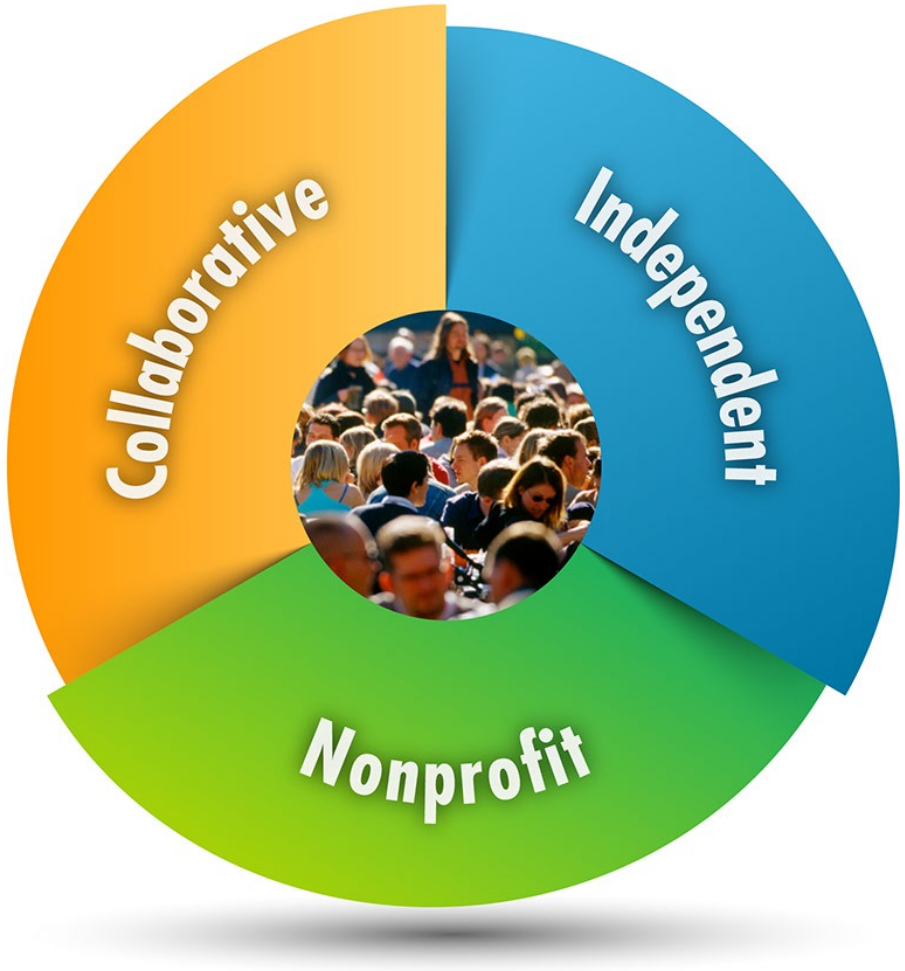
Toward Zero-Carbon Power Markets

Erik Ela

June 7, 2023

ANL SINTEF Virtual Workshop on Zero-Carbon Power Markets

EPRI Mission



Nonprofit

Chartered to serve the public benefit

Collaborative

Bring together scientists, engineers, academic researchers, and industry experts

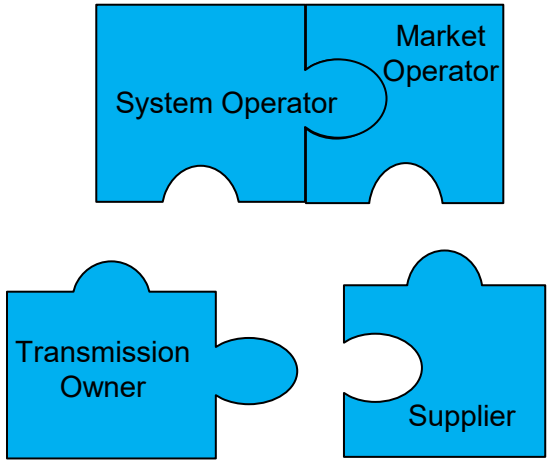
Independent

Objective, impartial, scientifically based results to address reliability, efficiency, affordability, health, safety, and the environment

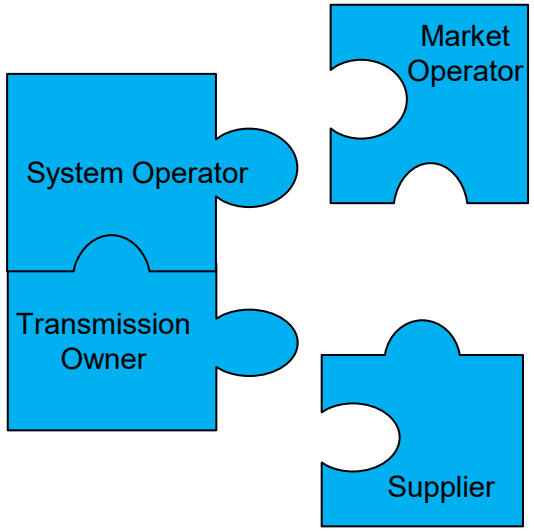
EPRI Electricity Markets and Grid Integration Research Areas collaborate with U.S. ISOs/RTOs, utilities within U.S. ISOs/RTOs, utilities participating in exchange and imbalance markets, international system/market operators, and other stakeholders involved in these challenges around the world

Market Structure and Responsibility Makeup

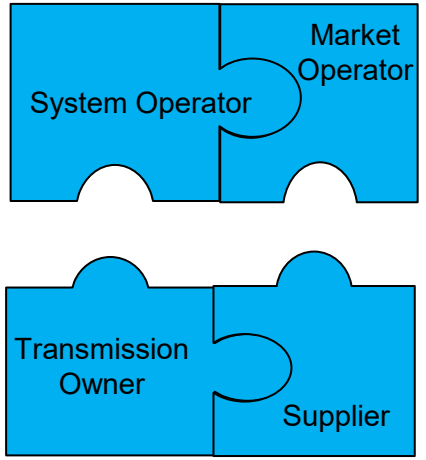
U.S. Market Regions (NY, NE, PJM)



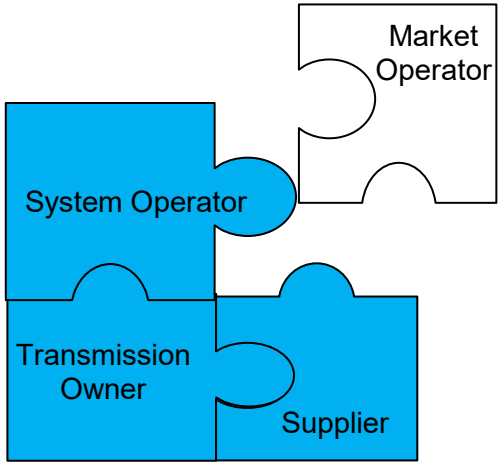
EU Market Regions



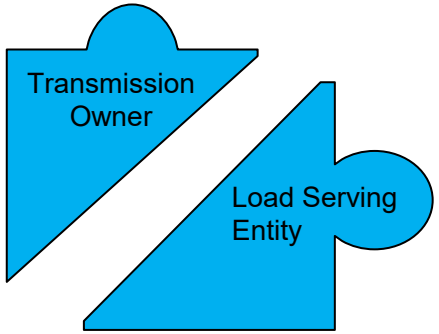
U.S. Market Regions (SPP, MISO)



U.S. non-market regions (SE)



Retail Choice Areas



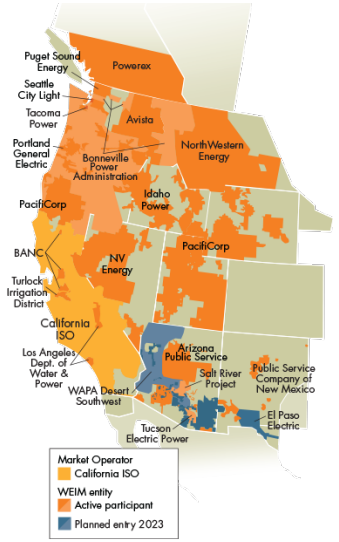
NY: New York Independent System Operator
NE: Independent System Operator of New England
PJM: Mid-Atlantic Regional Transmission Organization
SPP: Southwest Power Pool
MISO: Midcontinent Independent System Operator
SE: Southeast United States Vertically Integrated region

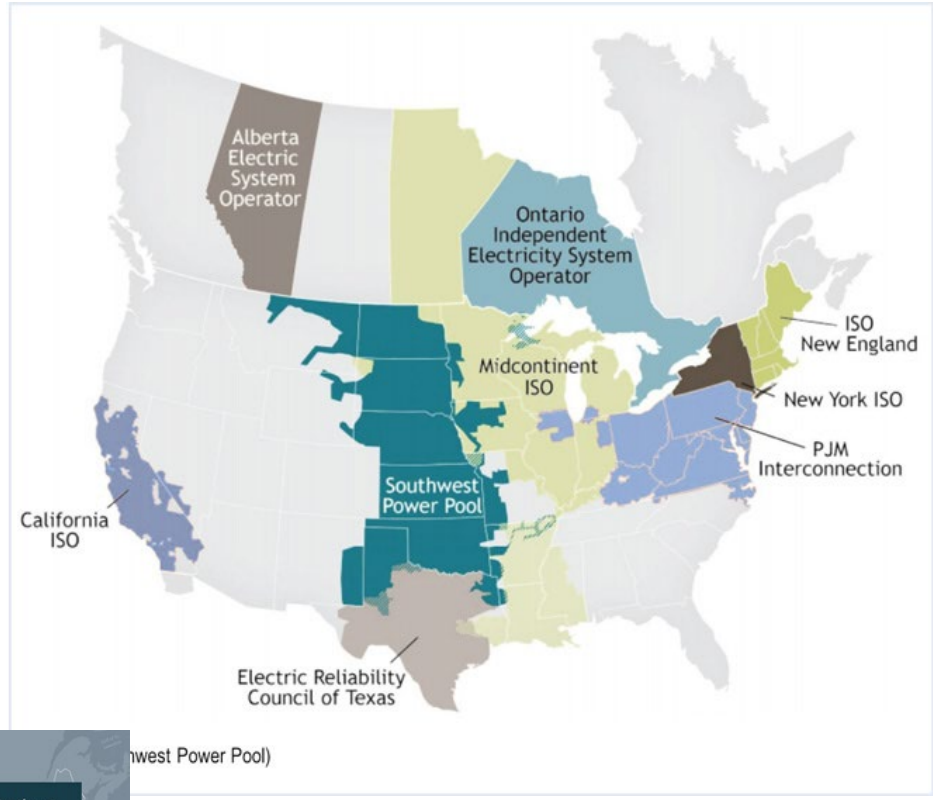
Electricity Market Organizations

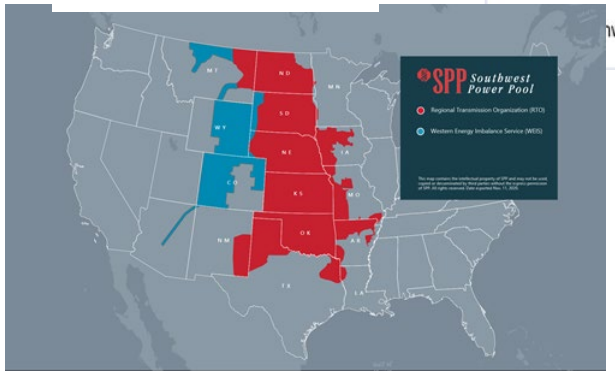
	European Union	United States
Real-time balancing	Transmission System Operator (TSO)	Independent System Operator (ISO) or Regional Transmission Organization (RTO)
Day-ahead market	Power Exchange (PX)	Independent System Operator (ISO) or Regional Transmission Organization (RTO)
Governmental body	European Commission DG Energy	U.S. Department of Energy
Regulatory wholesale electric body	Agency for the Cooperation of Energy Regulators (ACER)	Federal Energy Regulatory Commission (FERC)
Coordinated body of regional regulators	Council of European Energy Regulators (CEER)	National Association of Regulatory Utility Commissions (NARUC)
Regional regulators	National Regulatory Authorities	Individual State Public Utility Commissions (PUC)
Regional government bodies	National Government Departments	State Energy Commissions and State Legislatures
Reliability regulatory body	European Network of Transmission System Operators (ENTSO-E)	North American Electric Reliability Corporation (NERC)

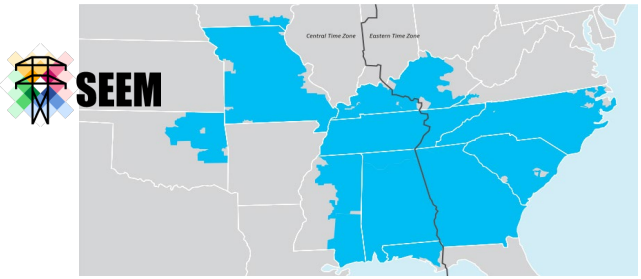
RTO/ISO Wholesale Markets in North America

- Most RTO/ISOs formed out of tight utility power pools
- Initiated late 1990s, early 2000s
- Northeast markets relatively unchanged
- Expansions
  - MISO South
  - SPP North
  - Western EIM (CAISO)
  - Western EIS (SPP)
  - Southeast Energy Exchange

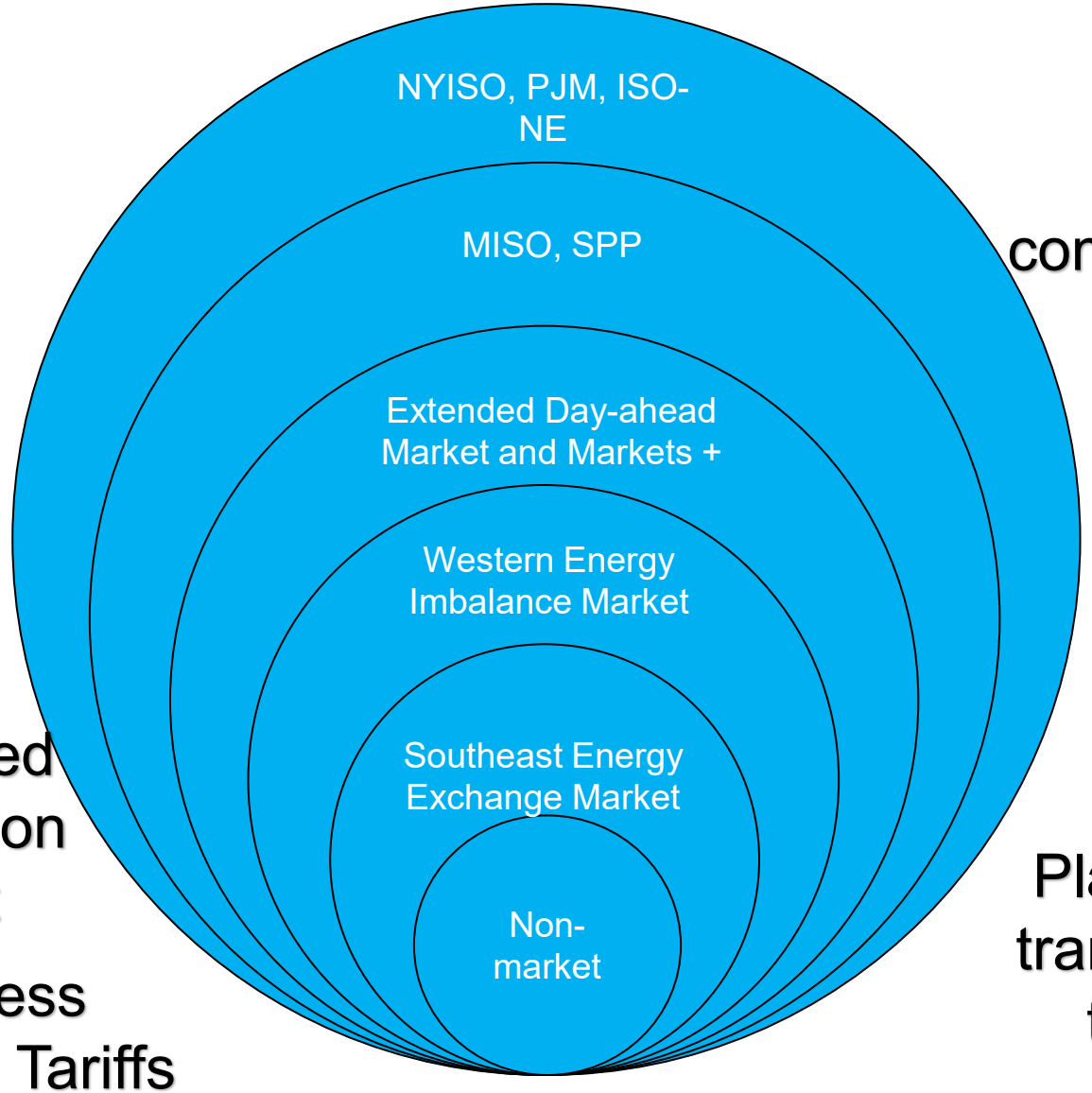








Complex properties of U.S. electricity markets



Restructure, divest generation and transmission, retail competition and centralized supply procurement

Consolidate balancing area, co-optimize energy and grid services, RTO

Greater volume of transactions, transmission system enabling

Efficiently formed prices, congestion management

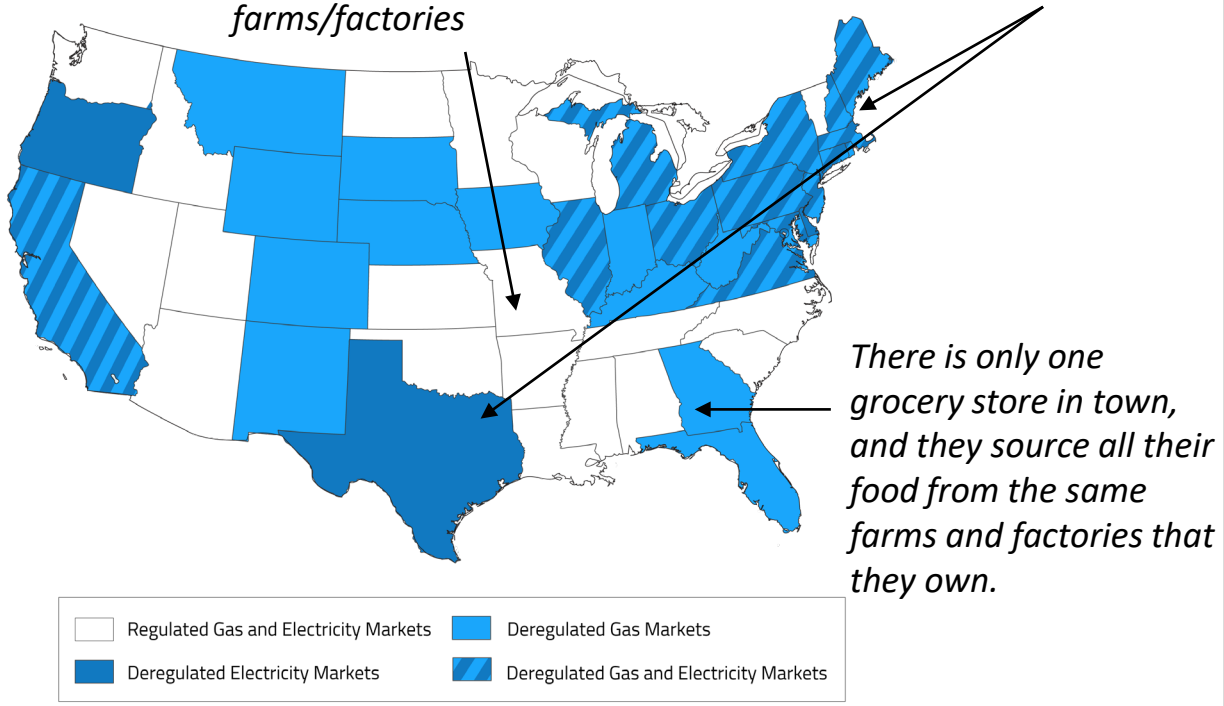
Open Access Transmission Tariffs

Platform to make transactions, price transparency

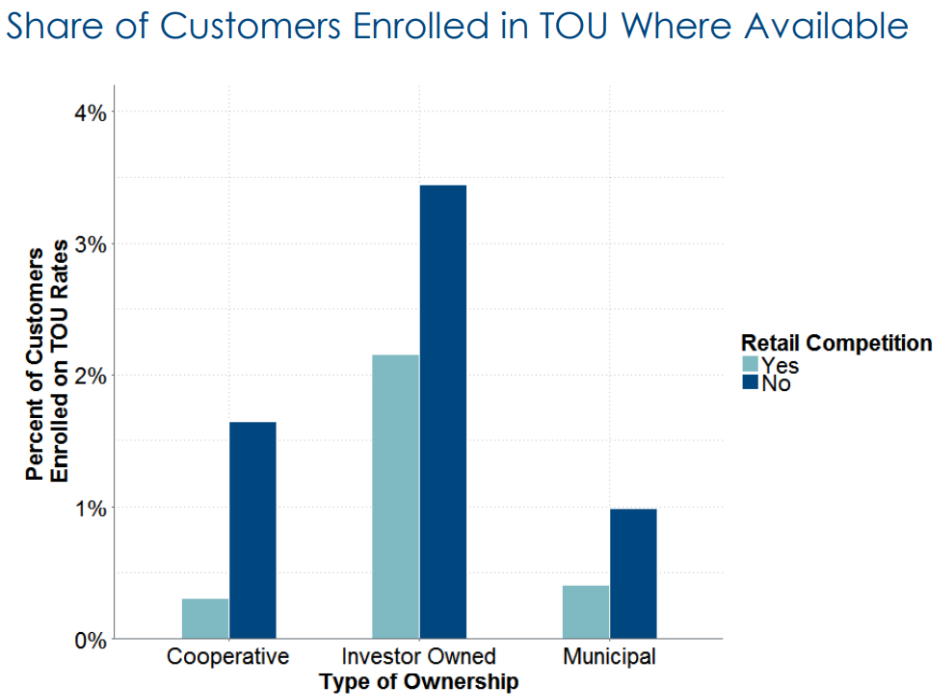
U.S. Retail Electricity Markets

There is only one grocery store in town, but they continuously find tastier, cheaper, and healthier food from different farms/factories

I can go to any grocery store I want, and the grocery stores will have products from different farms/factories



There is only one grocery store in town, and they source all their food from the same farms and factories that they own.



https://www.brattle.com/wp-content/uploads/2021/05/17904_a_survey_of_residential_time-of-use_tou_rates.pdf

Retail rates are regulated by **state** utility commissions or other local retail regulatory authorities

Province of Ontario: 90% enrolled
California: Time of Use Default Rate
Michigan: Time of Use Required

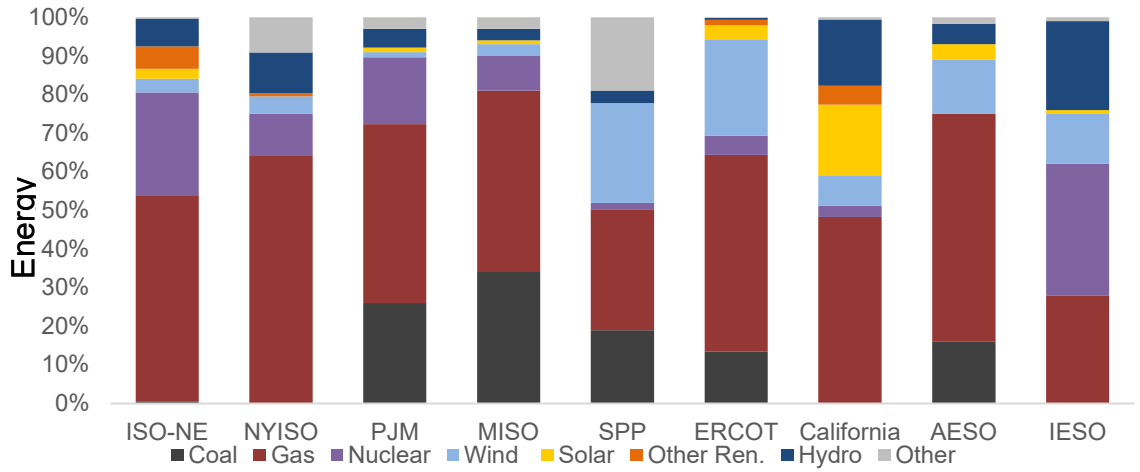
North American ISO and RTO Characteristics

	Total Market Volume ($B)	All-in-Price ($/MWh)	Energy ($B)	Ancillary Services Markets ($M)	Uplift ($M)	Financial Transmission Rights ($M)	Capacity Market ($M)
AESO (CAD$)	20.4	162.46	19.9	501	4.57	N/A	N/A
CAISO	13.04	56	12.6	165	158	115	N/A
ERCOT without Uri)	17.4	46.7	16	212	356	832	N/A
ERCOT (with Uri)		167.88	65.9	3,200	2,100		
IESO (CAD$)	20.0	28.5	3.92	58.96	260.96	58.9	N/A
ISO-NE	8.41	45.38	6.1	54	35	25.9	2,200
MISO	29.5	41	28.1	87.3	225	873	177
NYISO	9.98	55	6.4	198	54	252	3,076
PJM	70.6	40.87	62.4	844	289.9	812.6	6,252
SPP	16.59	25.96	14.6	127	191	1,671	N/A

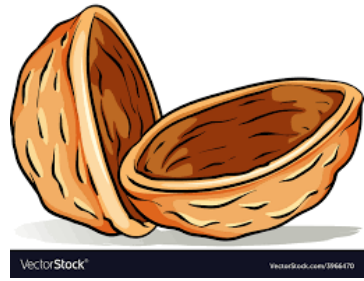
Wholesale Electricity Market Design in North America: 2022 Review. EPRI, Palo Alto, CA: 2023. 3002024553.

Older, public version: https://www.epri.com/#/pages/product/000000003002009273/?lang=en

	PJM	ISO-NE	NYISO	MISO	SPP	ERCOT	CAISO	AESO	IESO
Wholesale Market Regulator	FERC	FERC	FERC	FERC	FERC	TX PUC	FERC	AUC	OEB, CA NEB
Resource Adequacy	FERC	FERC	NYSRC, FERC	FERC/ states	FERC/ States		CPUC, FERC		OEB
Organization representing state interests	OPSI	NESCOE	NY PSC	OMS	SPP RSC		CPUC		



U.S. electricity market design



Independent Market Operators do not own transmission

Nodal pricing for suppliers

Security-constrained centralized commitment and **5-minute** centralized dispatch

Day-ahead and real-time markets for energy and ancillary services

Three-part offers, partially convexified prices

Technology-specific participation models

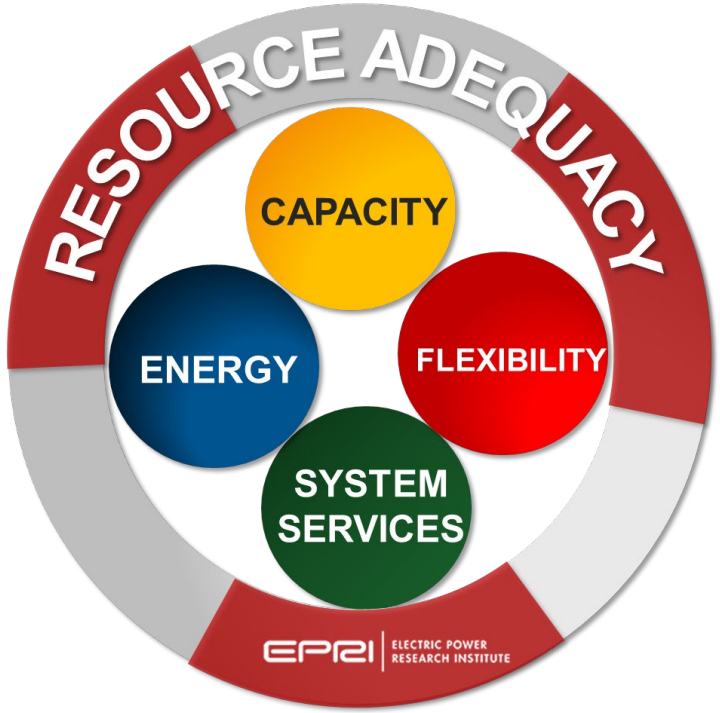
Co-optimized active power short-term ancillary service markets

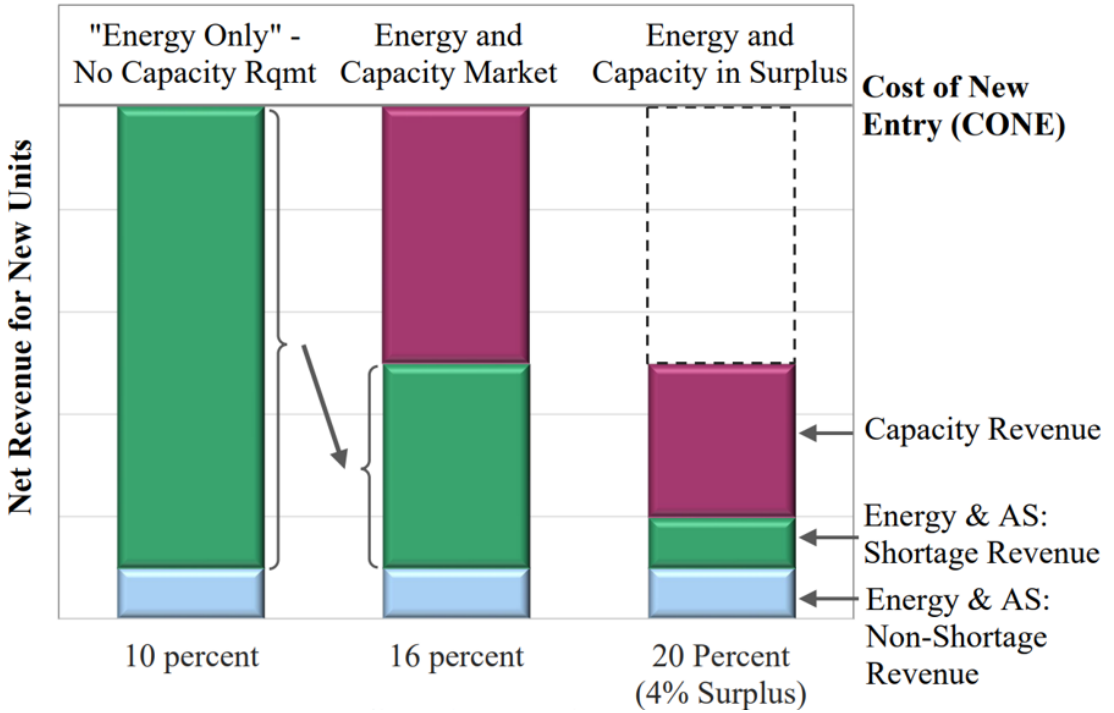
Certain financial markets run by ISO (locational hedging and day-ahead convergence)

Reserve shortage pricing key to capital cost recovery

Electricity Markets in the U.S.: Future Outlook

Resource Adequacy and Market design





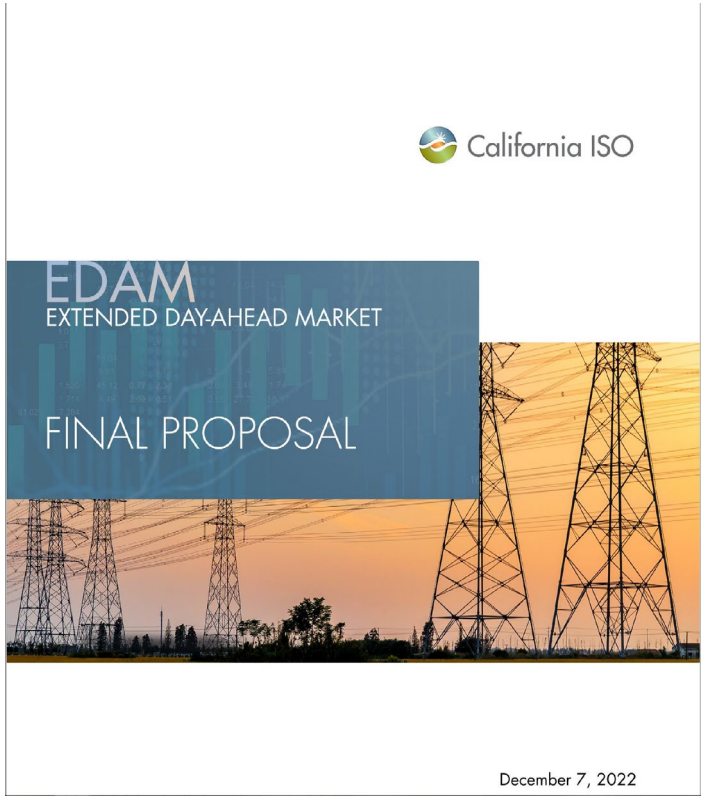
Electricity Markets in the U.S.: Future Outlook

Transmission Policy

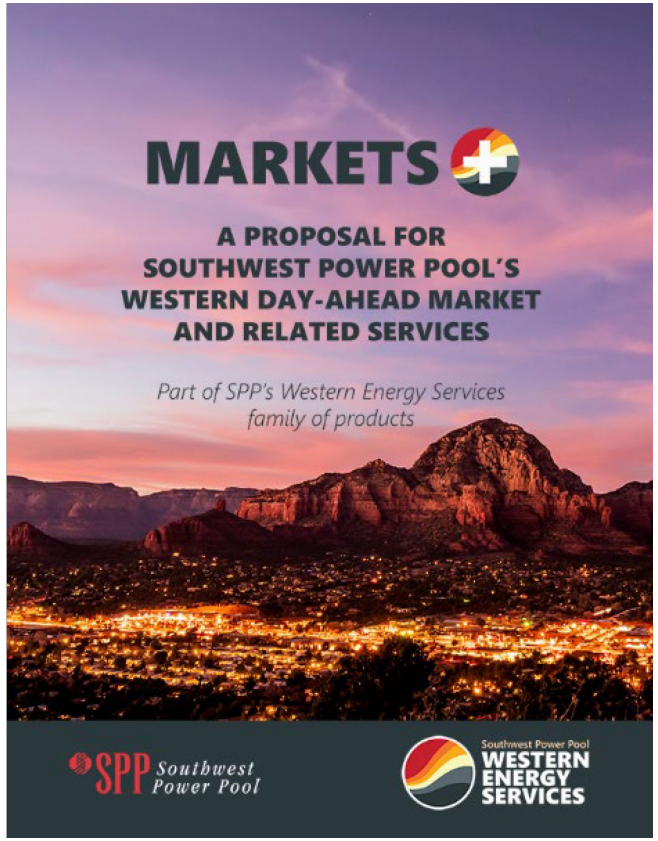
Electricity Markets in the U.S.: Future Outlook

Market Expansion

EDAM
EXTENDED DAY-AHEAD MARKET



MARKETS+



SEEM

Delivering more economic and clean energy to our customers.

SEEM is a unique and thoroughly new approach to enhancing the existing bilateral market. The SEEM platform facilitates sub-hourly, bilateral trading, allowing participants to buy and sell power close to the time the energy is consumed, utilizing available unreserved transmission. Participation in SEEM is open to other entities that meet the appropriate requirements.

SEEM is a 21st century solution designed for the incredible pace of change resulting from the electricity sector growing toward an ever-greener future. Southeastern electricity customers will see cost and environmental benefits as a result of the platform.

SEEM members include Associated Electric Cooperative, Dalton Utilities, Dominion Energy South Carolina, Duke Energy Carolinas, Duke Energy Florida, Duke Energy Progress, Georgia System Operations Corporation, Georgia Transmission Corporation, JEA, LG&E and KU Energy, MEAG Power, N.C. Municipal Power Agency No. 1, NCEMC, Oglethorpe Power Corp., PowerSouth, Santee Cooper, Seminole Electric Corporation, Southern Company, Tampa Electric Company and TVA.

SEEM members represent nearly 23 entities in parts of 12 states with more than 180,000 MWs (summer capacity; winter capacity is nearly 200,000 MWs) across two time zones. These companies serve the energy needs of more than 36 million retail customers (nearly 60 million people).

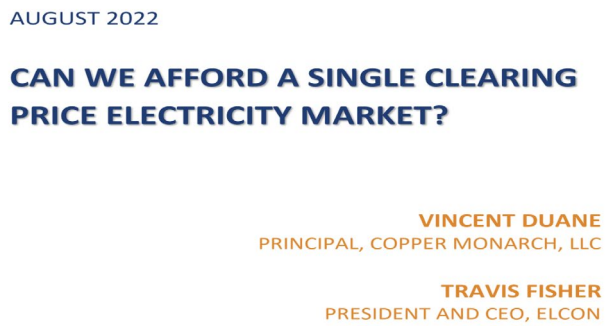
Electricity Markets in the U.S.: Future Outlook

Wholesale & Retail Alignment

Grid Need	Can load provide?	Signal on supply	Signal on wholesale demand	Signal on retail demand
Energy/shaping	✓	Locational marginal prices, dispatch, make whole payment	Locational marginal prices	TOU, VPP, RTP
Capacity (defer generation)	✓	Capacity price or scarcity price, contract	Capacity price / scarcity price	Demand charge
Distribution upgrade deferral	✓	Agreed-upon contract	Agreed-upon payment	Demand charge
Transmission upgrade deferral	✓	Congestion prices, agreed-upon contract	Congestion prices, agreed-upon payment, 4CP (Ex)	Demand charge
Ramping reserve	✓	Ancillary service price	Load-ratio allocation	N/A
Spinning reserve	✓	Ancillary price, operator call	Load-ratio allocation	N/A
Regulation reserve	✓	Ancillary price, AGC signal	Load-ratio allocation	N/A
Frequency response / inertia	✓	No incentive, autonomous control	N/A	N/A
Voltage regulation	~	Cost recovery, automated or manual dispatch	None	N/A
Black start	X	Cost recovery, operator call	N/A	N/A
Short circuit contribution	~	N/A, autonomous	N/A	N/A
Resilience	✓	Standards	Having power	Having power

On the horizon

Price Formation

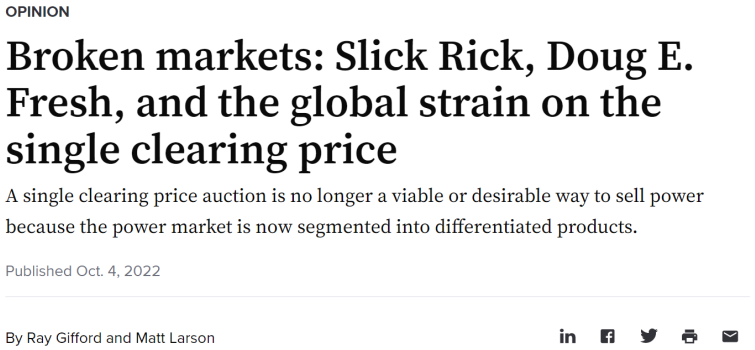

AUGUST 2022

CAN WE AFFORD A SINGLE CLEARING PRICE ELECTRICITY MARKET?

VINCENT DUANE
PRINCIPAL, COPPER MONARCH, LLC

TRAVIS FISHER
PRESIDENT AND CEO, ELCON

"For example, I think it is time to put the all-important question of the continued use of locational marginal pricing (LMP) in these market constructs on the table for serious scrutiny and discussion."
– Cmmsr Mark Christie in concurrence with FERC Docket AD21-10 *Modernizing Wholesale Electricity Market Design*


OPINION

Broken markets: Slick Rick, Doug E. Fresh, and the global strain on the single clearing price

A single clearing price auction is no longer a viable or desirable way to sell power because the power market is now segmented into differentiated products.

Published Oct. 4, 2022

By Ray Gifford and Matt Larson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MARKETS | HEARD ON THE STREET

Your Utility Bill Is Going to Hurt, but the Market Might Benefit

Lingering high electricity prices should spark conversations about optimal electricity-market design.

Market Design under deep decarbonization

- How will markets enable the transition?
- Will average prices decline or be more volatile? What will they look like?
- The demand side will be a crucial piece – how does it fit?
- Will substantial changes to the design and structure of electricity markets be necessary? Are the existing market designs functional for this scenario?
- If the price is set by the marginal cost, and there are no fuel costs, what sets the price?

ESIG 100% Workshop

Ela, Mills, Gimon, Hogan, Bouchez, Giacomoni, Ng, Gonzalez, DeSocio, "Electricity Market of the Future: Potential North American Designs Without Fuel Costs," IEEE Power and Energy Magazine, Vol. 19, no. 1, Jan/Feb. 2021. Available: https://nxt-staging-books.s3.amazonaws.com/nxtbooks/pes/powerenergy_010221/src/pes_powerenergy_010221.pdf.

Wholesale Electricity Market Design for Rapid Decarbonization - Energy Innovation: Policy and Technology

U.S. electricity market design (not consistent)

Spot or forward capacity markets	Demand Response participation (and retail rules)	Short-term flexibility products
Extended sloping operating reserve demand curves	Mitigation Procedures	Subsidies (due to state regulation)
Flexible capacity procurement	Individual Resource or Scheduling coordinators	Real-time market horizon