Electricity Markets Under Deep Decarbonization

SECOND WORKSHOP OF THE TASK FORCE ON MARKETS UNDER 100% CLEAN ELECTRICITY

Workshop Organizers
Robin Hytowitz (NextEra Analytics)
Erik Ela (EPRI)

October 24, 2024

ESIG

About ESIG

The Energy Systems Integration Group is a nonprofit organization that marshals the expertise of the electricity industry's technical community to support grid transformation and energy systems integration and operation. More information is available at https://www.esig.energy.

ESIG Publications Available Online

This workshop summary is available at https://www.esig.energy/100-clean-electricity-task-force/. All ESIG publications can be found at https://www.esig.energy/reports-briefs.

Get in Touch

To learn more about the topics discussed in this report or for more information about the Energy Systems Integration Group, please send an email to info@esig.energy.

Acknowledgment

The Energy Systems Integration Group gratefully acknowledges the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy for supporting this workshop.

The Energy Systems Integration Group held the second workshop of the Task Force on Markets Under 100% Clean Electricity on October 24, 2024, in Providence, Rhode Island. It was attended by 50 participants, and the workshop agenda can be found in **Appendix A**.

Introductory Presentations by the Task Force Chair and the Working Group Chair

Robin Hytowitz, of NextEra Analytics and chair of the Markets for 100% Clean Electricity Task Force, acknowledged Department of Energy support for this task force and presented an overview of the group's goal: to investigate visions and options for wholesale market designs and structures that can support 100% clean electricity futures. In particular, she described how the task force had been discussing how to accommodate high levels of variable, zero-fuel-cost, and inverter-based resources; high levels of limited-duration resources; and a dynamic distribution system with price-responsive or dispatchable demand-side assets. She noted that several authors were commissioned to articulate visions for wholesale market designs and structures that can support 100% clean electricity futures, and they would present on their work in the afternoon session. The goal of this workshop was to discuss metrics that can be used to evaluate these visions as well as other market designs, summarize these visions, and receive feedback from the workshop participants. Robin Hytowitz's presentation can be found in **Appendix B**.

Erik Ela of EPRI and the chair of ESIG's Systems Operation and Market Design Working Group, presented context for this markets work based on ESIG's 2019 work on key research needs for 100% renewable energy pathways and a February 2023 Workshop on Markets under Deep Decarbonization.[1] Erik Ela's presentation can be found in **Appendix C**.

Break-out Session on Evaluation Tools and Metrics for Performance of Future Market Designs

Five break-out groups explored evaluation tools and metrics to assess the performance of different market designs. In the first break-out session, there was discussion of maximizing market surplus versus minimizing costs as a goal. There was a great deal of discussion about the need for adaptability for a market design, with participants noting that, while existing market designs might hold up to very high levels of clean electricity, but something else might be needed for 100% clean electricity systems. Some discussed how markets have always needed "fixes," such as capacity markets and operating reserve demand curves, and adapting wholesale markets to 100% clean electricity can be seen as the next step in that evolution.

There was a lot of discussion about equity, including that equity is not an economic/market concept but rather exists at the interface between markets and policy. Similarly, there was discussion of power system reliability as a public good. There is a need for very competent regulators, who understand that prices are supposed to be signals, as opposed to politicians who may have other priorities.

[1] https://www.esig.energy/wp-content/uploads/2020/06/Toward-100-Renewable-Energy-Pathways-Key-Research-Needs.pdf and https://www.esig.energy/market-evolution-for-100-percent-clean-electricity/.

The second break-out session focused on the interdependence of the various markets; the need for long-term investments to support a short-run market; and the prioritization of metrics. Metrics for today may be different from metrics needed for the transition to 100% clean electricity. Some participants noted that metrics should focus on the behavior of market participants, e.g., demand response incentives for crypto-miners, and if behavior is undesirable, then market changes need to be made.

There was discussion of roles and responsibilities of different actors and an overreliance on "the Market" to solve all problems. Some participants believed that locational marginal prices cannot solve all policy problems, and there are situations today where entities feel that market structures are not doing what they need to be doing.

Specifically:

1. The first break-out group was a diverse group and discussed what makes an efficient market. Some metrics considered were affordability, reliability, practicality, fairness, capacity, price convergence between day-ahead and real-time price, liquidity and trading in the market, speed of implementing changes, rational behavior inside the region and at the seams, and squeezing everything you can out of existing resources. Key metrics were affordability and reliability.
2. The second group was also diverse. Participants discussed production cost to serve load, investment costs, affordability at the retail level, perceived reliability, comparison of long-term contracts and short-term markets, observed costs vs. modeled counterfactuals, the volatility of retail rates, simplicity, transmission, and the use of reliability-must-run contracts.
3. The third group was economist-heavy and discussed a framework focused on maximizing social welfare, aligning price outcomes with different time scales, adaptability across different system conditions to ensure that markets meet their goals, equity (which may be outside the market), price-responsive demand and alignments between the wholesale and retail markets, political and social acceptance, and extreme events. They discussed how evaluation should be performance-based and resource/technology-agnostic, with grid services defined by capability.
4. The fourth group was more philosophical. They discussed where we are today with the least-cost framework that has worked reasonably well thus far but may not be useful to achieve a decarbonized system. "Optimal" makes less sense when you have objectives that are hard to monetize. Traditionally, reliability has been most important. For example, during emergency events, costs are de-emphasized and we may not be pricing reliability appropriately. Participants discussed metrics such as environmental goals and equity/fairness.
5. The fifth group said that if the problem statement is to maximize social welfare, the key metrics are reliability and consumer cost. Getting new resources built quickly is important, as is coordination between transmission and distribution systems and coordination between resource adequacy and the interconnection queue. Efficient prices are needed but also need hedging.

Market Visions

Each of the market vision authors presented their vision to the workshop participants for discussion.

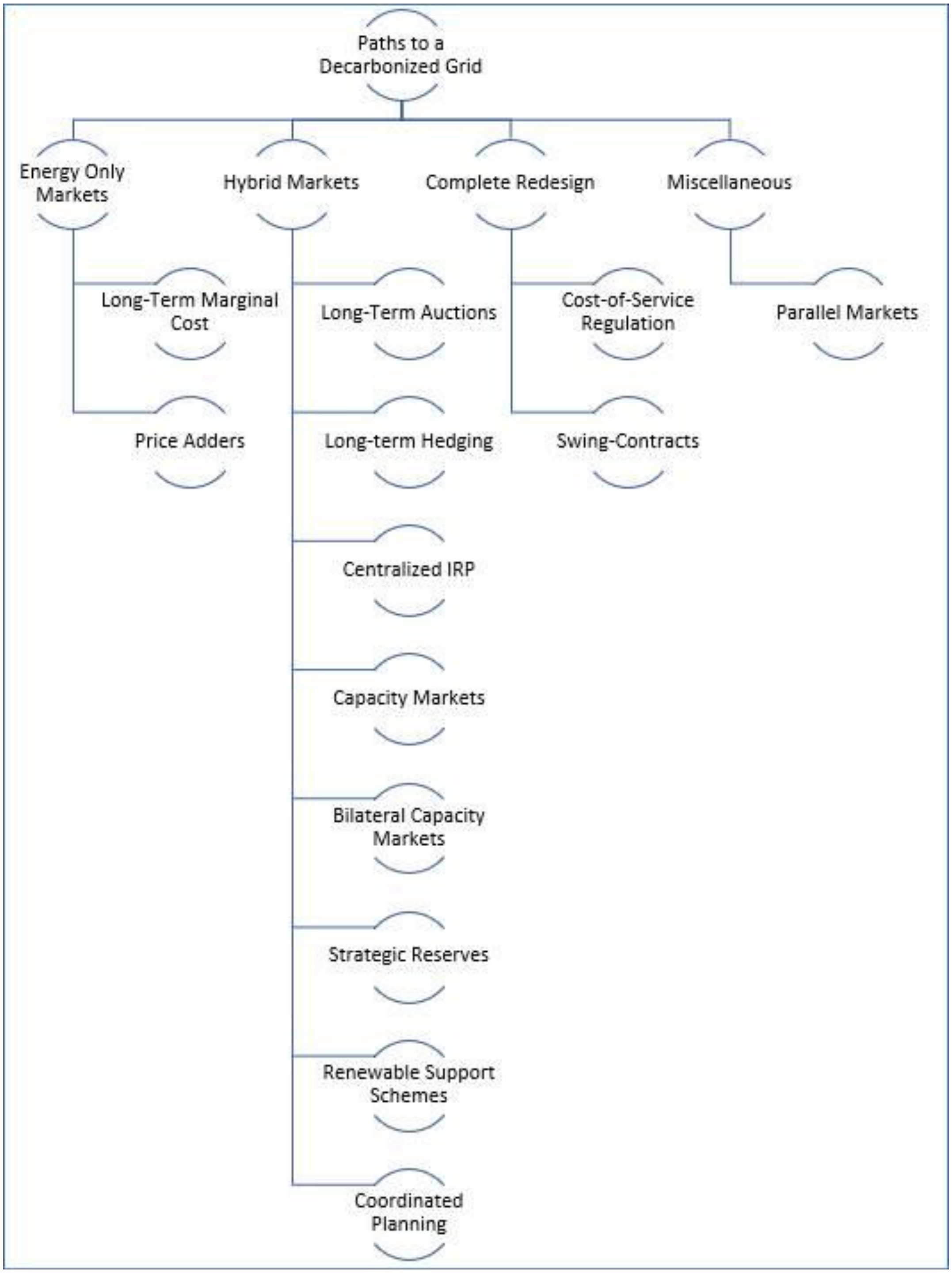
Rob Gramlich of Grid Strategies discussed a vision for markets that have zero-cost resources and periods of zero locational marginal prices (see **Appendix D**). There will be short- and long-duration storage that has opportunity costs that will drive non-zero prices in this future. Long-term contracts will still be important, and the system will still be centrally dispatched. Storage can be used as a replacement for transmission or for arbitrage, essentially optimizing over time and space. This is competition for the market. Day to day, this is similar to a vertically integrated utility with competitive procurement on a long-term basis. There are likely lessons from hydro-dominant systems here, such as Brazil or Nordpool.

Kelli Joseph of the University of Pennsylvania discussed the limits to existing market constructs and the need for a coordinated planning solution (see **Appendix E**). If the policymakers are setting sustainability targets, the policymakers need to be at the table in helping to construct the solutions to maintaining grid reliability. Currently many of these state-level decisionmakers do not have responsibilities for reliability, and locational marginal pricing alone is not enough to drive the investments needed.

Jacob Mays of Cornell discussed his vision of full-strength spot prices with mandatory contracting (see **Appendix F**). He showed an example from the California Independent System Operator in which spot prices hit price caps around 1:00 pm on two hot summer days, triggering storage to discharge prematurely, as the limited-duration storage resources were needed for the evening net-load peak. Lifting price caps could reduce this type of issue and allow storage resources headroom to differentiate themselves and when they are dispatched. Jacob suggested that everything at a time scale of 5 minutes and longer should be a market choice and a design choice, whereas attributes of reliability services, such as everything sub-5-minutes (like frequency and voltage regulation that are not priced typically today), are not solved through market changes. He also expressed concern that we should not overly prescribe how essential reliability services are procured, because the resource mix will change over time.

Jessica Greenberg of Enel discussed the need to keep markets adaptable and reduce regulatory uncertainty (see **Appendix G**). From a developer's perspective, it would be useful to have a market for reliability services, essentially providing more revenue streams for generators.

Ryan Schoppe of EPRI presented several other market designs and a taxonomy to categorize market designs (shown below) (see also **Appendix H**) .


Paths to a Decarbonized Grid
Energy Only Markets
Hybrid Markets
Complete Redesign
Miscellaneous
Long-Term Marginal Cost
Price Adders
Long-Term Auctions
Long-term Hedging
Centralized IRP
Capacity Markets
Bilateral Capacity Markets
Strategic Reserves
Renewable Support Schemes
Coordinated Planning
Cost-of-Service Regulation
Swing-Contracts
Parallel Markets

One participant proposed a new vision that included competitive procurement for physical assets or contracts from generation and storage; centralized dispatch of all resources in operations (no transparent prices, no bids, no prices), and storage as a substitute for transmission and providing arbitrage and being optimized by the central system operator.

There was general agreement among the visions that the following market design, based on the widely prevalent market design used in most independent system operators and regional transmission organizations, is very helpful even if we do not have fossil units with different marginal operating costs as we did when this design was developed:

- Bid-based security-constrained economic dispatch with a single market-clearing price for energy at each hour and node (locational marginal price) and financial transmission rights
- Competitive hourly or short-term procurement of physically defined technology-neutral ancillary services with a single price for each service. Increasingly, energy-limited resources like storage of various durations and demand-side resources will set the price
- Scarcity pricing
- Hedging/long-term contracting by load-serving entities
- Regional transmission planning to determine a plan that maximizes net benefits and allocates costs to beneficiaries

Summary of Forward-Looking Actions to Enable Visions

Existing markets work relatively well today for efficiency, competition, and low costs, but it is clear that they are becoming less well suited for the future. In order to assess the efficiency of a market, some form of baselining is needed, some concept of ideal efficiency across all objectives. But even this definition of optimal becomes subjective, and it is not clear that optimal is a realistic stick against which to measure.

Traditionally, reliability has been the priority metric, with cost as secondary in some sense—when there is a reliability event, cost becomes secondary. This implies that reliability may not be priced appropriately and that the least-cost framework has broken down. Other key metrics are sustainability, equity or fairness, and stability. There was a lot of discussion on what is or is not "fair," but no concrete metrics or clarity was gained around how fairness fits into economics.

To summarize, electricity markets are fundamentally feasible, but the devil is in the details, and different details will lead to different efficiency outcomes. We can use competitive markets in different ways than we are doing now. We need to be realistic, truthful, and not too stuck on theoretically optimal outcomes. Delineating roles and responsibilities is critical. There is a problem with relying so heavily on the "the Market," as everything becomes "the Market's" responsibility but no one agrees on who those specific entities are. We need to operate with information asymmetry, because we do not have all the information needed to design and operate an "efficient market, and it may not be possible or practical to get it. And this problem gets bigger as we move to 100% clean electricity. Finally, changing markets are important and inevitable. Change is not an admission of failure; rather, it is critical to adapt to the needs of the evolving system. The big question is how to assess what changes are needed, especially as metrics and objectives become more subjective.

Appendix A:

Workshop Agenda

Electricity Markets under Deep Decarbonization

Second Workshop of the ESIG Electricity Markets under 100% Clean Electricity Market Task Force

October 24, 2024

Omni Providence Hotel

THURSDAY, OCTOBER 24, 2024		
TIME	**TOPIC**	**PRESENTER/LEAD**
7:30 – 8:00	**Breakfast**	
8:00 – 8:45	**Welcome and Introduction** **Recap of 2023 Workshop** **Challenges associated with markets where supply is 100% clean energy**	*Robing Hytowitz, NextEra Analytics, Debra Lew, ESIG* *Erik Ela, EPRI*
9:00 – 10:00	**What evaluation tools and metrics can help us understand the potential performance of future market designs? Breakout Session 1**	*Breakout Leads:* • *Conleigh Byers* • *Jim Gonzalez* • *Todd Levin* • *Bethany Frew* • *Francisco Munoz*
10:00 - 10:30	**Break**	
10:30-11:15	**What evaluation tools and metrics can help us understand the potential performance of future market designs? Breakout Session 2**	*Breakout Leads from above*
11:15-12:00	**Breakout report back**	*Breakout Leads*
12:00 – 1:00	**Lunch**	
1:00 – 3:00	**Paper and Visions Review**	*Leads* • *Rob Gramlich, Grid Strategies* • *Kelli Joseph, WRI* • *Jacob Mays, Cornell University* • *Jessica Greenberg, ENEL* • *Ryan Schoppe, EPRI*
3:00 – 3:30	**Break**	
3:30 – 4:15	**Breakout: What is missing, what other possible challenges are left unaddressed?**	*Breakout Leads (same as above)*
4:15 – 4:50	**Forward Looking Actions to Enable Visions**	*Lead:* • *Rob Gramlich, Kelli Joseph, Jacob Mays, Jessica Greenberg, Ryan Schoppe*
4:50-5:00	**Close out**	*Robin Hytowitz, NextEra Analytics*
TBD	**Networking Reception**	

Breakouts

Groups of no more than 8 lead by breakout leads but leads are also encouraged to participate

Morning Breakout 1

9:00 – 9:15 Intro and break into groups

9:15 – 10:00 Leads discuss first questions

Questions

What evaluation tools and metrics can help us understand the potential performance of future market designs?

- List metrics you would use to evaluate electricity markets. They can be qualitative or quantitative, encompass many aspects of market design or just a few.
- (after discussing) How many of these were included? Are these worthwhile?
    - Maximizes market surplus
    - Complexity
    - Transparency
    - Openness
    - Competition
    - Market structure (creating new vs maintaining existing structures)
    - Reliability
    - Resilience
    - Affordability
    - Equity
    - Scalability
    - Market manipulation/power potential
    - External policy goals (e.g., GHG markets)
    - Revenue sufficiency
    - Two-sided market (encourages demand-side participation)
    - Long-term vs. short-term goals
    - Practicality
- Can they be ranked? Are some more important than others?
- Are there regional metrics or should they apply at a national level? Global?

Morning Breakout 2

10:30 – 11:15 Remaining questions

Questions

- How important is the **interdependence** of markets? Do visions for the future need to address energy, ancillary, transmission and capacity?
- How should we weigh the importance of **long-term investments** and **transmission** investments in a short-run market?
- How do these metrics apply to **DERs and local markets**? How much interaction should wholesale market metrics have on distribution utilities or retail rate design?
- Should we evaluate different metrics during the **transition** to 100% clean energy?
- **Who** should be evaluating these markets? What role do different entities play (state, PUC, federal, ISO, BA, etc.)?

11:15 – 12:00 **Report back**

- Key points on the questions (or other topics discussed)
- Was there consensus on any questions?
- Where were the biggest disagreements?
- Where are the gaps?

Afternoon Breakout

3:30 – 3:40 Break into groups

3:40 – 4:15 Discuss questions

Questions (*What is missing, what other possible challenges are left unaddressed?*)

- What do you think about these ideas?
- What visions are we missing?
- What are the gaps that we need to fill?
- Are there voices we haven't heard?
- How do we practically get to these visions?

Appendix B:

Robin Hytowitz Presentation

Markets for 100% Clean Electricity

ESIG
ENERGY SYSTEMS INTEGRATION GROUP

ESIG Task Force Meeting

October 24, 2024

1

Workshop Agenda

ESIG

TIME	TOPIC	PRESENTER/LEAD
8:00 – 8:45	Welcome and Introduction Recap of 2023 Workshop	Robing Hytowitz, NextEra Analytics, Debra Lew, ESIG Erik Ela, EPRI
9:00 – 10:00	What evaluation tools and metrics can help us understand the potential performance of future market designs? Breakout Session 1	Breakout Leads: Conleigh Byers, Jim Gonzalez, Todd Levin,Bethany Frew, Francisco Munoz
10:00 - 10:30	Break	
10:30-11:15	What evaluation tools and metrics can help us understand the potential performance of future market designs? Breakout Session 2	Breakout Leads from above
11:15-12:00	Breakout report back	Breakout Leads
12:00 – 1:00	Lunch	
1:00 – 3:00	Paper and Visions Review	Leads Rob Gramlich, Kelli Joseph, Jacob Mays, Jessica Greenberg, Ryan Schoppe
3:00 – 3:30	Break	
3:30 – 4:15	Breakout: What is missing, what other possible challenges are left unaddressed?	Breakout Leads (same as above)
4:15 – 4:50	Forward Looking Actions to Enable Visions	Lead: ● Rob, Kelli, Jacob, Jessica, Ryan
4:50-5:00	Close out	Robin Hytowitz, NextEra Analytics
TBD	Networking Reception	

2

2

Task Force Goals

ESIG

- Questions we hope to address
  1. What different visions and options for wholesale market designs and structures can support 100% clean electricity futures?
  2. How to accommodate high levels of variable, zero-fuel cost, and inverter-based resources, high levels of limited duration resources, and a dynamic distribution system with price responsive demand-side assets?
- Objective
  - Discussion and debate
  - Develop a paper containing several visions for wholesale market pathways

    to support instantaneous penetration of 100% clean as well as ensure reliability through periods of low renewables outputs and provide sufficient investment signals for future capacity needs.

3

3

Paper Outline

ESIG

- Introduction and Visions Overview
  - What are visions? *In the context of this paper, visions are market designs and structures that modify current practice to accommodate 100% clean energy. Modification can be slight or drastic, or starting over completely.*
  - What is defined as "clean" electricity (fuels included)? How much do we need to focus on the transition? What are the major gaps we need to address?
- Visions
  - Physical structures, institutional roles, and designs needed for achieving a reliable and affordable carbon-free grid
  - Mandatory Contracting Around Full-Strength Spot Prices
  - Coordinated Planning for the Energy Transition
  - Assessing price adders for lost load, capacity, flexibility, and carbon displacement
  - Additional visions: Hybrid markets, un-restructuring, energy-only
- Metrics to evaluate markets
- Conclusions and next steps

4

4

Goals for Today's Workshop

ESIG

- Brainstorm and discuss metrics to evaluate future (or current) markets
  - How should we evaluate future markets?
  - Is there a single metric (qualitative or quantitative) that captures market efficiency?
- Summarize visions and get feedback
  - Paper lead authors will discuss their visions
  - Are there missing future visions?
- Please speak up!

5

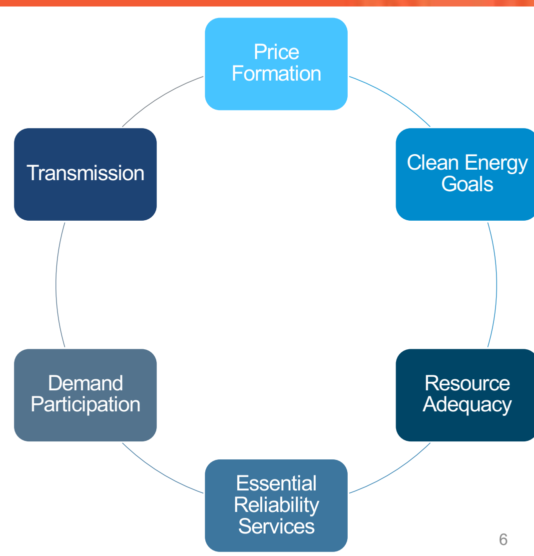
5

Future Visions: Framework

ESIG

Three major visions:

- Status quo / incremental changes
  - Can we make sufficient changes within the current market structures to accommodate changing resource mix and other technological advances?
- Large scale changes
  - Do we need to make fundamental changes to our markets? Are there designs or structures that are unique to the old resource mix?
- Blank slate / Cost of service
  - Should we dissolve the ISOs/RTOs and move to full cost-of-service regulation?



6

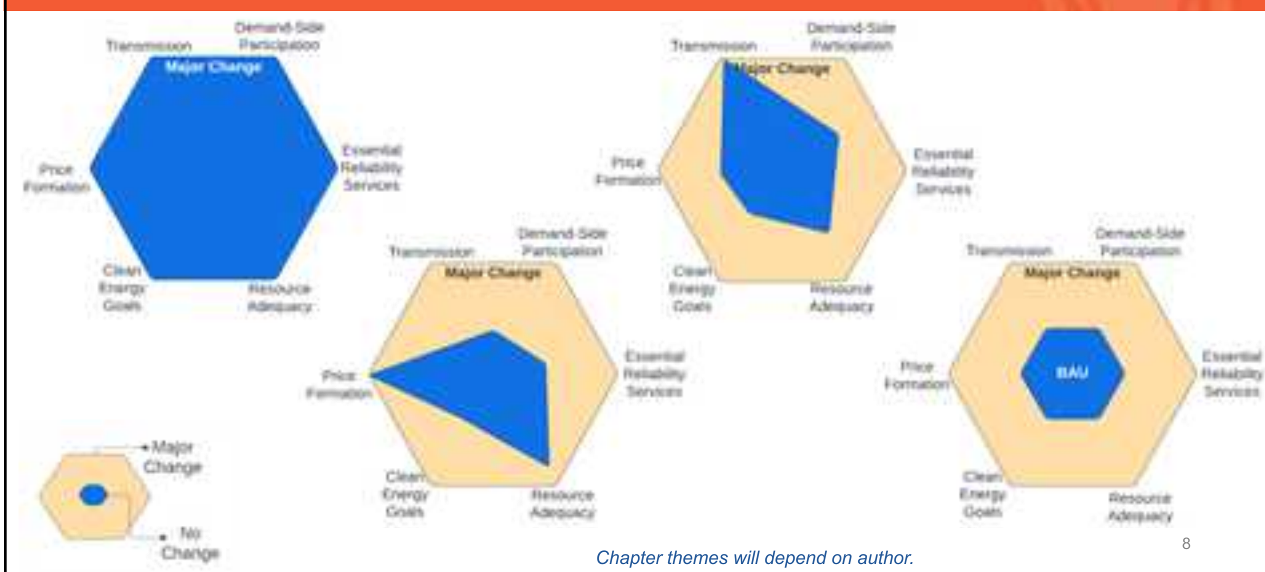
6

THANK YOU

7

Future Visions: Potential Visualization

ESIG



Chapter themes will depend on author.

8

8

Appendix C:

Erik Ela Presentation

ESIG 100% and Markets Activities

Erik Ela
2nd Workshop on Markets for 100% Clean Energy
10/24/2024
Providence, Rhode Island

www.epri.com

1

What will Electricity Markets look like?

2

2

ESIG: Toward 100% Renewable Energy Pathways

Lots of Building Blocks:
- Nuclear
- Carbon Capture
- Renewables/Storage
- Demand Participation
- Electrification

source: ideas.lego.com

Meeting Materials

Report

Topic(s)	Notes
Electrification & Demand Participation	• Heavily electrified future economy; demand going up; demand profiles changing • More integrated electric system will be needed; Digitalization of society will lead to demand side participation • Getting to 80% penetration w/ existing tech is possible; 100% will require new tech/approaches
Storage	• Dramatic cost declines; Thermal storage becoming an option for the future
Decentralization	• Having energy production close to consumption may lead to changes to the centralized paradigm
Adequacy	• Adequacy metrics need to be updated to properly reflect the needs of society (i.e. LOLP is arbitrary) • Classical adequacy may be replaced by a cost-minimization problem (i.e. investment vs. reducing/shifting demand) • Transmission & distribution/storage resources should be modeled in adequacy studies
Operations & Flexibility	• Visibility and control at sufficient levels of detail needed; Adequacy/Flex considered simultaneously
Markets	• Unsure whether current market structures will lead to the investments needed to reach net-zero
Voltage & Frequency	• Will be challenging to design an AC system w/ little or no synchronous generation (need grid-forming converters)

Pathways will be regional, but renewables/storage, electrification, and responsive demand will be "global"

3

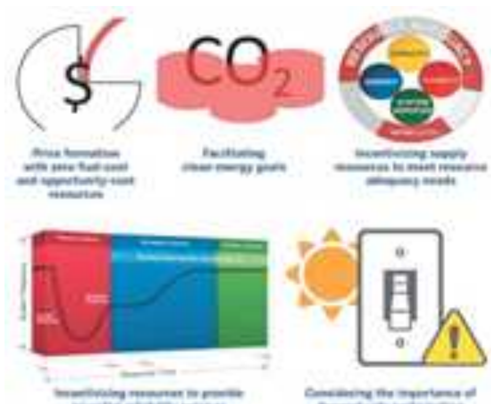
3

Markets under Deep Decarbonization:

ESIG Workshop 1

Meeting Notes

- Generally, a consensus on the use of marginal cost pricing in the future, but:
  - How will storage and demand impact those prices
  - What will market power look like?
- What is the role of ISOs w/ Clean Energy Targets: prescriptive, facilitating, accommodating.
- Do GHG wholesale market integration design (GHG pricing, GHG constraints) make sense with other large-scale policies?
- Who makes the RA decisions? States, ISOs?
- What other attributes belong in the RA decision-making process
- How do you know when you need a new grid service market product? When a product vs. grid code?
- Is consumer demand participation a wholesale participation or a retail participation? How connected should the two be?
- Are markets for Operations only, or driving procurements too?



Which of these gaps have we gotten closer to addressing in last 18 months?

4

4

ESIG Markets Next Steps

- Should the Task Force continue in a broad way, or should it become more granular with specific gaps?
- What other stakeholders need to be involved?
- What activities are helpful:
  - Education: for who?
  - Research: What types?
  - Pilots: What kinds?

Think about this throughout today and we will discuss at the end of the workshop

5

5

6

6

Appendix D:

Rob Gramlich Presentation

Changes needed to reliably and affordably achieve very high renewable penetration

Rob Gramlich, President
Michael Goggin, Vice President

1

Work in these main areas is needed to reach very high renewable penetration

1. Energy markets/seamless regional dispatch
2. Transmission planning/expansion
3. Resource adequacy
4. Power system stability with high inverter-based resource penetration
5. Generation procurement
6. Clean energy policy
7. Integrate DR and DERs with wholesale markets
8. Transmission operational efficiency

2

2

1. Energy markets: Preferred Market Structure

- RTO/ISOs balance power system and administer short term spot markets
  - Procures energy and reliability services based on engineering definitions
  - Also plan 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. Might be monopoly or competitive retail suppliers (up to the state).
- 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

GridStrategies

3

3

1b. Energy markets: Preferred Market Design

- Flow-based, no physical capacity reservations
- Spot market with bilateral contracts
  - Expect most payments and revenue in long term PPAs, priced at average cost of competitive new unit
  - Spot market for residuals and re-balancing
- Bid-based security constrained economic dispatch
- Energy at each time and location
  - Hourly locational marginal pricing (LMP)
- Reliability Services--technology-neutral
  - Operating reserves, exact needs vary by region
  - Reactive support—non-market compensation
- Scarcity pricing
  - prevents free-riding, encourages contracting,
  - attracts flexible resources
  - Most load hedged, and doesn't pay it.

Source: Bill Hogan, Harvard University

GridStrategies

4

4

2. Transmission planning/expansion

Address the '3Ps'

- Planning
  - Proactive, all electricity system benefits, probabilistic/scenario based, portfolio of network upgrades, all technology options, community engagement
- Permitting
  - Demonstration of benefits with credible regional authorities leads to high batting average
- Paying
  - Broad beneficiary pays cost allocation

GridStrategies

5

5

Incorporate all benefits of transmission

Capacity value

Greater ability to supply when power is scarce with regionally diverse portfolio.

Wind/hydro/geothermal/solar/storage complementarity

Congestion

Production cost modeling always under-forecasts congestion, by a lot.

Reliability/resilience

50% of value in 5% of hours (LBNL)

Flows in both directions (winter storms Elliot, Uri, etc)

LBNL

GridStrategies

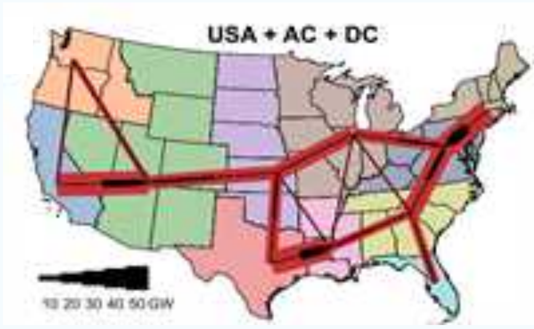
6

6

Transmission Vision—Full Macro Grid

10s of GWs of power transfer back and forth across and between regions
Benefit > cost with 2-3x increase in national transmission capacity

MIT Value of Interregional Transmission Study



Brown (MIT), https://www.cell.com/joule/fulltext/S2542-4351(20)30557-2

NREL Seams Study (updated by Jim McCalley)

Bloom (NREL), https://cleanenergygrid.org/wp-content/uploads/2020/11/Macro-Grids-in-the-Mainstream-1.pdf

GridStrategies

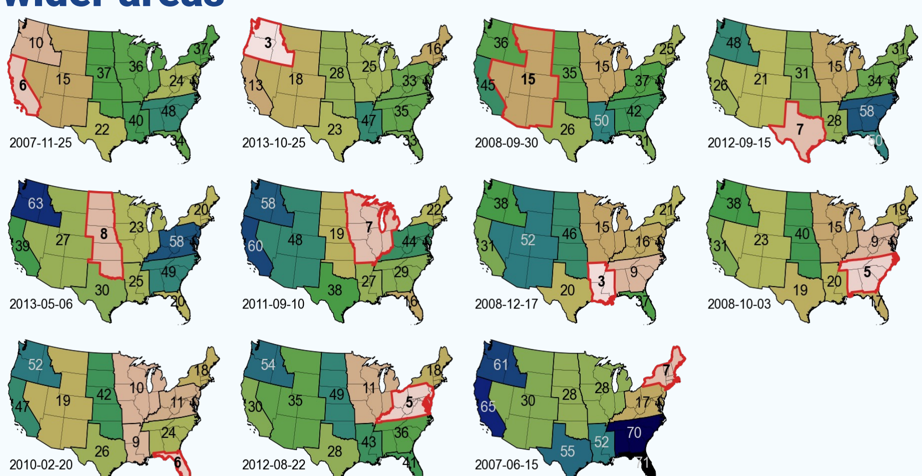
Renewables can contribute to resource adequacy and reduce costly generation reserve margins. Output is steady across wider areas

Take the least-windy day in each planning area from 2007–2013.

How windy are each of the other planning areas on that day?

Single-day wind capacity factor [%] at top quintile of sites

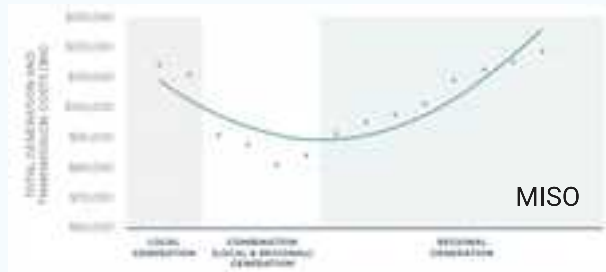
(Patrick Brown, MIT, NREL)



GridStrategies

Economically sound transmission planning

- "Just and reasonable" has to mean maximize net benefits
  - Any other decision rule raises costs to consumers
  - Not least cost of transmission but least cost of delivered energy (generation + transmission)
  - Not benefit/cost ratio
- Dr. William Hogan: "A forward-looking cost-benefit analysis provides the gold standard for ensuring that transmission investments are efficient."
- Overcome generator protectionism with strong independent planning



- Co-optimize transmission and generation

GridStrategies

9

9

Transmission Infrastructure expansion—why is it so hard?

- The electric industry grew up as ~3000 separate utilities focused on their own small areas.
- Utilities and the regulatory structure were not designed to plan, permit or pay for interstate highway-type lines.
- Linear infrastructure is always hard because it must string together contiguous pieces of land, each of which is important to someone.

GridStrategies

10

10

High-Performance Conductors: modern conductor technologies which have greater performance characteristics when compared to traditional conductors

Carbon and composite core conductors are overhead, bare conductors that use a trapezoid shaped wire of annealed aluminum to carry electrical current and use a carbon or composite core for support, reducing sag and increasing power-flow capacity.

Superconductors use a class of metallic compounds that exhibit negligible resistive losses when cooled using liquid nitrogen, enabling very low losses and very high power-flow capacities.

Capacity Expansion with High-Performance Conductors

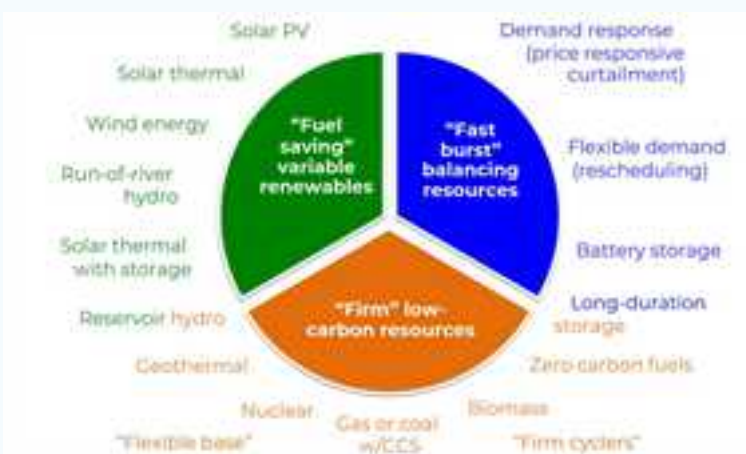
Reconductoring with high-performance conductors replaces existing transmission lines with high-performance conductors using the original tower and right-of-way. In some cases, upgrades to terminal equipment may be required.

For rebuilds, transmission towers along with the conductor are replaced, either due to age or to accommodate larger conductors within an existing right-of-way.

Reconductoring generally takes 1-3 years and can 2x the capacity of a corridor at approximately half the cost of a new transmission line, while rebuild options can add significantly more capacity.

GridStrategies

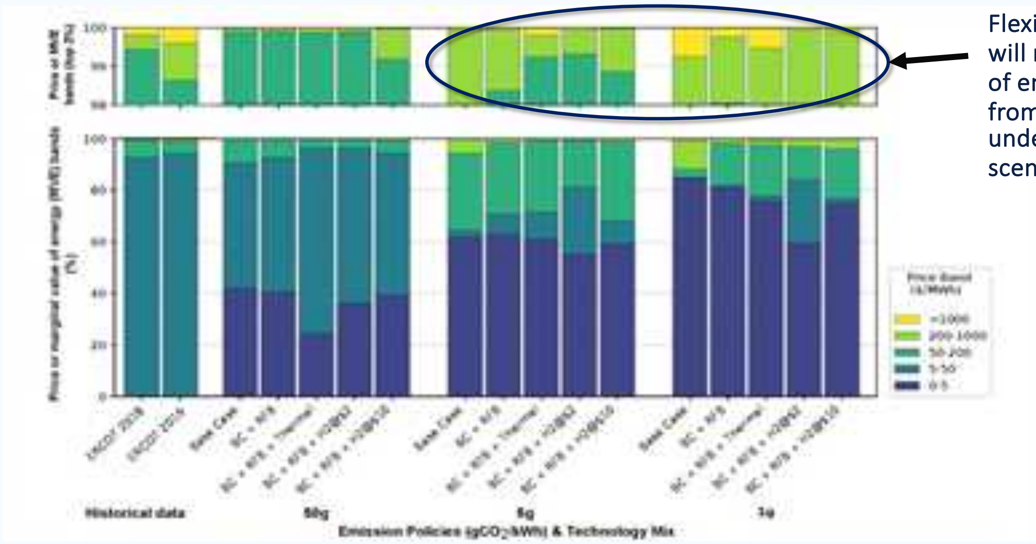
3. Resource adequacy: Reliable Carbon-Free Electricity Portfolios



Sepulveda, N., Jenkins, J.D., et al. (2018), "The role of firm low-carbon resources in deep decarbonization of electric power systems," Joule 2(11).

GridStrategies

Dispatchable/capacity resources will run less and be paid in a small number of hours, or paid a reservation fee

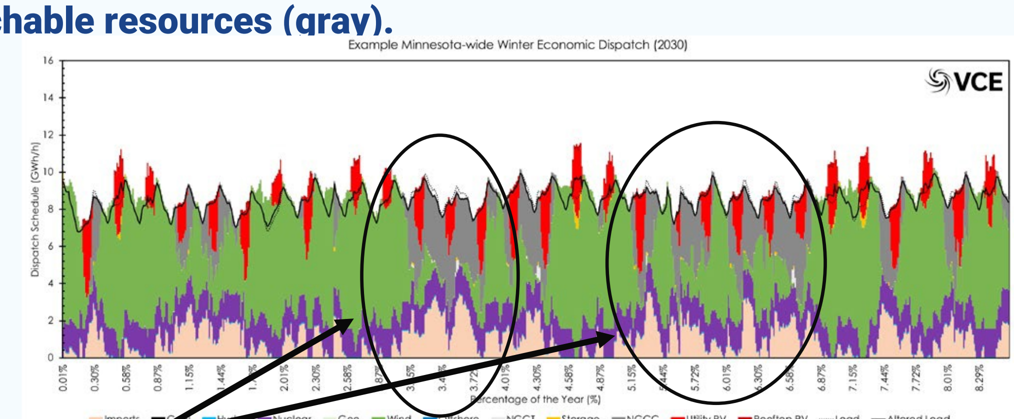


Flexible generators will make majority of energy revenue from 2% of hours under low-emission scenarios

GridStrategies Source: Mallapragada, Jung, Wang, Pfeifenberger, Joskow, and Schmalensee, Electricity Pricing Problems in Future Renewables-Dominant Power, MIT CEEPR

13

Resource Adequacy Challenge:
60-80 percent renewable systems require other resources for multi-day periods with low renewable output such as imports (beige) and firm dispatchable resources (gray).



Multi-Day periods of low wind+solar, usually winter.

Source: Clack, VCE, Minnesota/Eastern Interconnection study. See also E3, EFI, Telos, Brattle, Jenkins, MIT EI, Princeton NZA, Gridlab/UC Berkeley, NREL, LBNL, IEA, ESIG, other studies

GridStrategies 14

14

4. Power System Stability with high IBR penetration

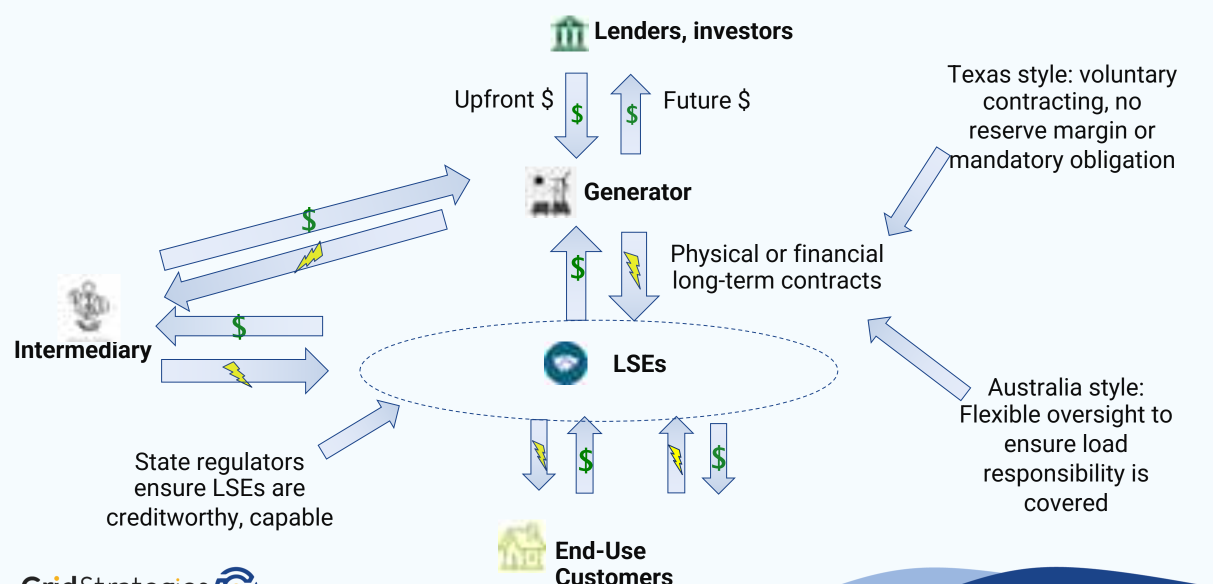
- **Frequency Stability, Voltage and Angular Stability**
- **Solutions**
  - Grid-forming inverters—industry and government leadership to solve the chicken and egg problem.
  - Transmission
  - Synchronous condensers
  - IBR standards
  - IBR control tuning
- **Join ESIG!**

GridStrategies

15

15

5. Generation procurement: Load-Serving Entities' key role



GridStrategies

16

6. Clean energy policy

- Lawmakers and environmental regulators internalize externalities through incentives and requirements.
- Carbon tax is most efficient
- Renewable requirements and incentives also beneficial

GridStrategies

17

17

7. Integrate DR and DERs with wholesale markets

- More ground-up system planning with resources close to load
- Learn from Bryan Hannegan/Holy Cross, and other utilities doing this!
- Remove barriers to on-site and community-based resources

GridStrategies

18

18

8. Transmission operational efficiency

Advanced Power Flow Control	Topology Optimization	Dynamic Line Ratings
2022 UK: Unlocked 1.7 GW network capacity in UK, saving ratepayers $500M	**2016 PJM analysis:** could reduce day-ahead energy costs by $145m/year	**2022 Pennsylvania:** DLR increases line capacity by 25% on average.
2023 New York: Unlocked capacity for 185 MW of generation, with $10M+ savings over legacy tech	**2022 SPP ex-post:** could resolve 98% of overloads in utility's territory	**2012 Belgium:** DLR increases capacity by 20%+ over 90% of the time

GridStrategies

19

19

Appendix E:

Kelli Joseph Presentation

Coordinated Planning for the Energy Transition

Kelli Joseph, PhD

ESIG October 2024

100% Clean Electricity Markets Task Force Workshop

Highlights

- United States Electricity Policy Reality
- What is Reliability?
- Gas and Electric Interdependency
- The Challenges with Relying on Market Prices Alone for the Energy Transition
- A Planning and Policy Coordination Solution for an Orderly and Reliable Transition
- Markets within a Planning Framework

The U.S. Electricity Policy Reality

K Joseph, PhD

Two Challenges for the U.S Energy Transition

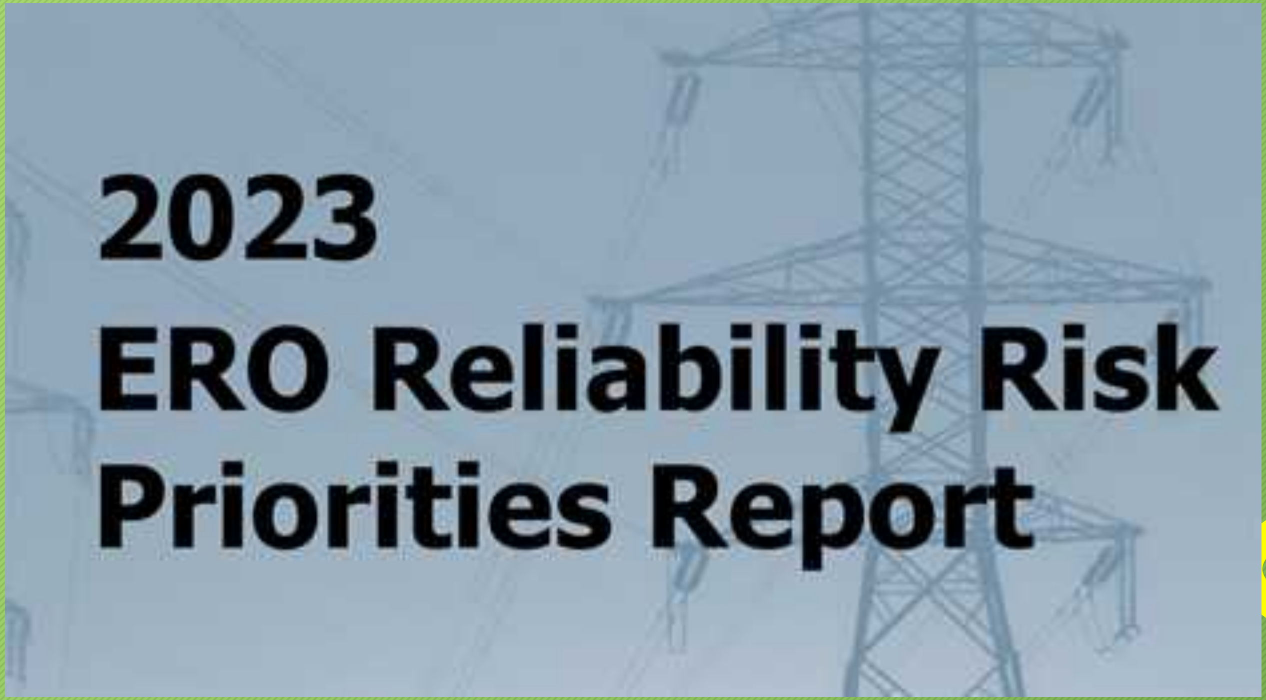
- Lack of coordinated policy (federal/state and cross-sector) creates reliability and investment risk.

- In organized markets: Prices are great for managing efficient short-term dispatch, but there are limitations to relying on prices (an "LMP") *alone* for the energy transition.

Policy Gaps in Electricity

Policy	**Gap**
State/Federal Decarbonization Target Setting	No one setting targets at state/federal level also has grid reliability responsibilities
IRA Technology-Neutral Incentives	A *specific* technical mix of resources is needed for reliable grid operations
EPA carbon pollution standards require meaningful community engagement in state compliance plans, including "reaching out to reliability authorities"	There is no coordinated, regional planning process for this kind of meaningful engagement with reliability authorities

Policy Gaps Create Reliability Risk



K Joseph, PhD

Reliability Impacts of Energy Policy

Policy as a Reliability Risk Factor

Energy Policy can drive changes in the planning and operation of the BPS. Accordingly, policy can affect BPS reliability and resilience and could present risks to its reliable operation. Ensuring reliability during and after policy driven transitions should be a key consideration in setting Energy Policy. The implementation of policy decisions can significantly affect the reliability and resilience of the BPS. Decarbonization, decentralization, and electrification have been active policy areas. Implementation of policies in these areas is accelerating, and, with changes in the resource mix, extreme weather events, and physical and cyber security challenges, reliability implications are emerging. Demonstrated risks, such as energy sufficiency as well as natural gas and electric interdependency, are becoming increasingly critical. Emerging potential risks, such as aggregate DERs, are increasingly concerning. Due to the interdependency of critical infrastructures (i.e., electricity, natural gas, water, transportation, and communications), potential reliability risks are magnified when cross industry segments and agencies act independently to create or implement policy. Development of reliability standards and processes recognizes and respects the jurisdictional authorities setting and implementing policy decisions. It will take strong collaboration and partnerships across a multitude of boundaries to mitigate the emerging risks we face today – state, federal, provincial and private – ensuring reliability of the grid is a prioritized tenet of critical infrastructure.

Policy Gaps Make it Hard to Focus Investment

Scaling Dispatchable Clean Technologies

Batteries, geothermal, advanced nuclear, long duration storage, hydrogen, bioenergy, or abatement technologies

- Technology-neutral incentives need to be focused and directed.
- Not all of technologies are possible in all geological locations
- Some require investment in additional infrastructure to scale and enable their use in electricity
  - Pipelines for CCS or Hydrogen
  - Storage for spent fuel rods

K Joseph, PhD

What is Grid Reliability?

K Joseph, PhD

Bulk Electric System Reliability (NERC definition)

(1) **Resource Adequacy** (2) **Operating Reliability**

+

LOLP Risk Assessments Withstand sudden disturbances

(3) **Energy Adequacy**

Resources that produce when dispatched

K Joseph, PhD

Operating Reliability: Real-Time Power System Operations

- Meeting mandatory and enforceable reliability standards
- Managing to contingencies
- Respond to changes in grid frequency or voltage stability
- Supply/Demand Balance
- Maintain transmission lines within rated limits

“Essential Reliability Services”/”Grid Attributes”/”Ancillary Services”

Challenges as the Resource Mix Changes

- Resources that can produce at all times
- Meeting “Net” Load
- Flexible, Dispatchable Resources that are Quick-Start and Fast-Ramping

Growing sources of uncertainty

- Generation output (Renewable, Energy-Limited Storage, Fuel-Limited Gas)
- Electrification Targets (heating + transportation)
- Changing and extreme weather
- Customer-sited generation (not visible to bulk grid operators)

K Joseph, PhD

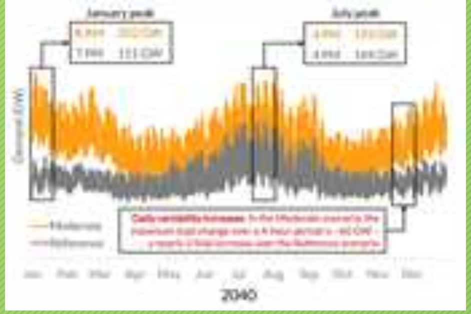
Reliable Grid Operations ("Grid Attributes")

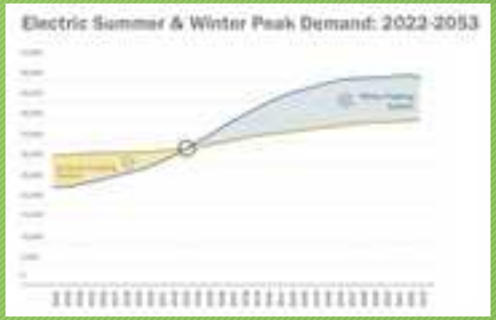
- **Balancing Energy**
  - Flexible Generation Resources
  - Fast-Start
  - Quick-Ramping
- **Operating Reserves**
  - Produce within 10 min/30 min
  - Once deployed, must be replaced within 60-90 min

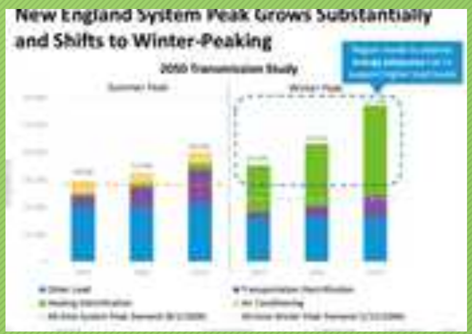
Today provided by batteries and gas generators…

And both are limited

Gas-Electric Interdependency







Systems become winter peaking…with significant ramping needs

- Natural Gas = 40% today (EIA)
- Increasingly used to provide balancing energy (NERC 2023)
- Challenge in the U.S.:
  - Bring on clean, flexible resources while ensuring the natural gas system is capable of supporting electric system needs throughout the transition *(see FERC 2023; NAESB 2023; RTO Blueprint 2024)*
  - May require strategic gas storage reserves/pipelines *(NAESB 2023)*
  - States set heating decarbonization targets without considering bulk electric system reliability needs *(Joseph 2024)*

Challenges with Relying on Market Prices *Alone* for the Energy Transition

Economic Theory for the Deregulation Paradigm

- **Prices coordinate resource investment**
  - The LMP that enables short-term market operation efficiency would also be the only entry/exit signal.
- **Scarcity pricing especially important**
  - Symbiotic investment: Generators and Consumers
- **Electricity is a commodity**
  - Markets for electricity are about hedging delivery and price risk
  - Resources are fungible: It doesn't matter which resource delivers energy, only that energy is delivered (Hogan and Harvey 2022)

The reality…
Scarcity Price/LMP Alone Challenges

Missing Money	Missing Markets
Price Caps/Market Power	Insufficient markets for risk
Operator Actions	Insufficient incentives for hedging
Inelastic Demand and "can't target deficient LSEs" (Also raises serious equity concerns)	Always have default/bankruptcy option
Non-Convexity	Hard to forecast scarcity/discount these hours
Reliability Standards > CBA Economic Investment	

Scarcity pricing has never been a sufficient investment signal to meet reliability targets.

An LMP is important, helpful, useful, and necessary for efficient ST operations, but relying on an LMP alone for sufficient investment in the resources that enable reliable system operations has always been a challenge.

K Joseph, PhD

Investment Risks for Clean, Dispatchable (“Clean Firm”/”DEFR”) Resources

- Significant price volatility expected
- How forecast revenues?
  Uncertainty in policy = uncertainty in the resource mix
- How ensure revenue sufficiency?
  For assets that may run less over time, but provide critical reliability services when they do.
- How ensure associated infrastructure that can enable innovative technologies to deploy and scale?

K Joseph, PhD

A Moonshot Mission to Decarbonize the Electricity Sector

- Markets are always incomplete and imperfect. Instead of the constant focus on how to fix market gaps, we should ask: "What needs to be done?" (Mazzucato)

- We need reliability-informed policy and markets that meet changing reliability needs throughout the transition.

A Planning and Policy Coordination Solution

K Joseph, PhD

Policy should focus on two timelines

1) Need resources that meet operating reliability needs in all hours and all seasons as more renewable resources come online. (**TODAY**)

That provide specific grid services

Natural Gas with sufficient fuel available + Batteries

2) Targeted incentives for the kinds of resources that can replace fossil assets. (**FUTURE**)

That provide specific grid services

Examples: Geothermal, Advanced Nuclear, Hydrogen, Bioenergy, Long-Duration (Multi-day) storage, Fossil with Carbon Removal ("abated")

K Joseph, PhD

A Policy and Planning Coordination Framework

Entity	Role	Activities
States	Provide study assumptions	Study assumptions based on integrated Resource Plans (IRPs), state policy targets, and/or federal policy requirements and state plans (e.g., the EPA.)
Reliability Coordinator *In some regions this is the Regional Transmission Organization (RTO) or Independent System Operator (ISO). In other regions, coordination with Balancing Authorities may be needed.*	Consensus Building	Regional system planning study (with agreed-upon scenarios) based on state and federal policy (e.g., types of generation, timing, locations, electrification targets, EPA regulations, etc.)
Reliability Coordinator *In some regions this is the Regional Transmission Organization (RTO) or Independent System Operator (ISO). In other regions, coordination with Balancing Authorities may be needed.*	Provide regional reliability assessments. These studies would identify reliability needs (resource adequacy and operating reliability) over a defined period.	Provide assessments over defined timelines: Short-term (1-5 years) Medium-term (5-10 years) Longer-term (10-20 years)
States	Consider studies and scenarios for reliability-informed policy planning.	Targeted incentives for technology types that meet policy and system reliability needs.
States	Coordinated regional planning for generation and infrastructure that meet identified reliability needs.	Could include mechanisms to consider regional planning and coordinated procurement of needed resources and infrastructure.

Market Design Solutions

That recognize the importance of **SYSTEM PLANNING**

K Joseph, PhD

Market design solutions

- <u>Hybrid Markets</u>
  - Competition “for” the market instead of “in” the market. Replace voluntary with mandatory contracting.
  - Recognizing policy as driver of new entry. Informed by system planning.
  - Auction designs that avoid lock-in when resources are no longer needed?
- <u>Strategic Reserves</u> (a form of hybrid market)
  - All pay the cost of resources needed to maintain reliable grid operations
  - Could still have competitive solicitation…which could enable new assets types that can fully replace fossil when commercially available
- <u>Regional IRP for specific asset types</u> (a form of hybrid market)
  - Could still have competitive solicitation…which could enable new assets types that can fully replace fossil when commercially available

Concluding Thoughts

K Joseph, PhD

Bulk Electric System Reliability is a Public Good

- RTOs = The **supplier of last resort** for the **essential reliability services** needed to maintain reliability and prevent network system collapse. (Order 2000)

- What grid operators do to prevent network collapse is both non-exclusive and non-rivalrous. (Report to Congress on Electricity Market Competition 2007)

K Joseph, PhD

Electricity is too important, too critical, too essential

- Reliability throughout the transition depends on having a **SPECIFIC TECHNICAL MIX** of resources that meet:
  - Policy targets + Balancing needs (load following, ramping, quick-start) + Operating reserve requirements.

- The transition must be orderly **AND** reliable
  - Gas system must be capable of responding to rapidly changing electricity needs
  - Transitioning away from natural gas requires focused and coordinated policy and planning.

K Joseph, PhD

QUESTIONS? LET’S DISCUSS!

K Joseph, PhD

Appendix F:

Jacob Mays Presentation

Electricity Markets under Deep Decarbonization

Jacob Mays

ESIG Fall Technical Workshop

October 24, 2024

Three elements of the “vision”

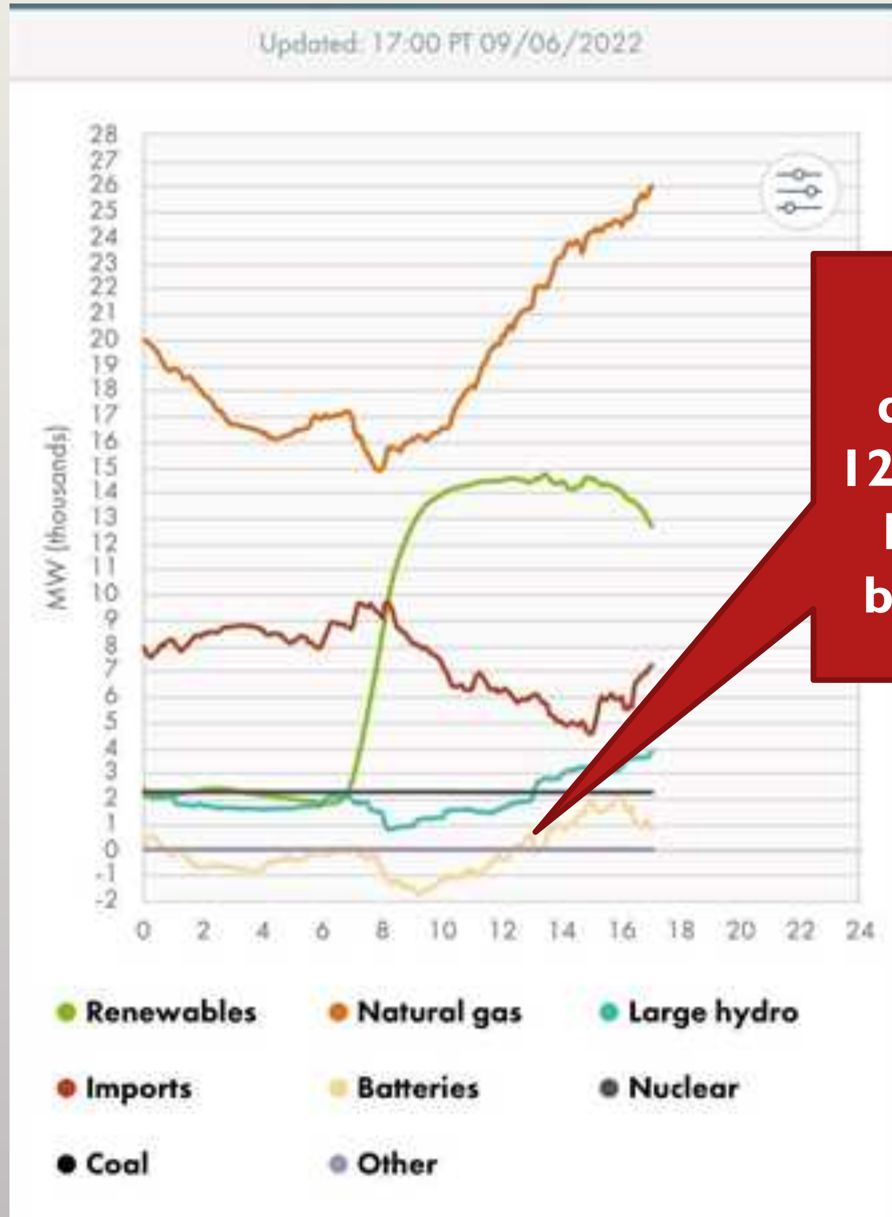
1. Full-strength spot prices
2. Mandatory contracting
3. Proactive transmission planning

Three elements of the “vision”

1. **Full-strength spot prices**
2. Mandatory contracting
3. Proactive transmission planning

Near-miss in California: Part 1

Near-miss in California: Part 2



Batteries start discharging around 12-1pm, positioning to be fully discharged before critical hours

CornellEngineering

Near-miss in California: Part 3

Price cap causing poor incentives for operation

Near-miss in California: Part 4

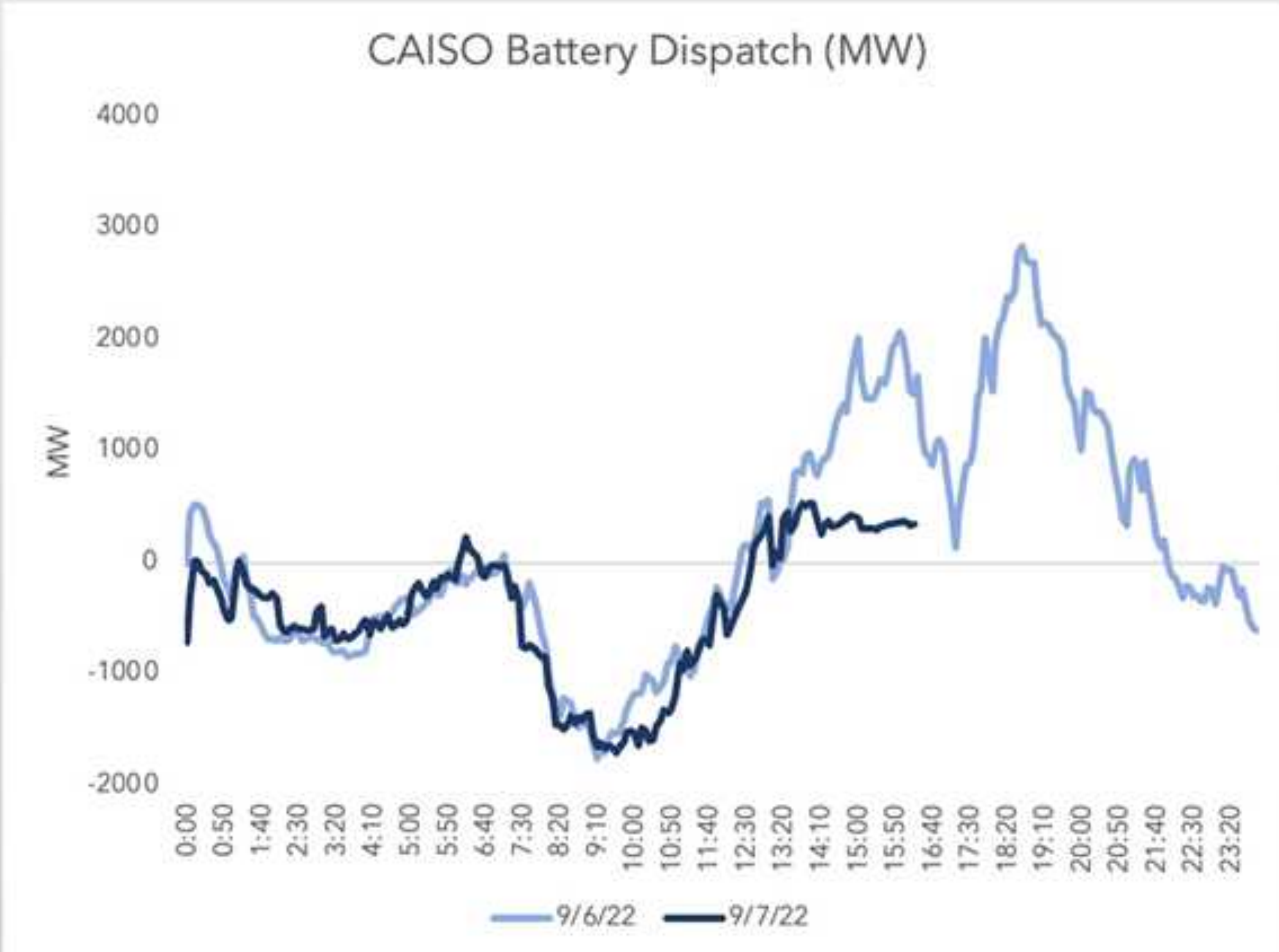
California ISO
@California_ISO

#ISO declares an Energy Emergency Alert 3 with rotating #power outages very possible. Please reduce your energy use.

Pricing problems can become reliability problems

Near-miss in California: Part 5

Near-miss in California: Part 6



Near-miss in California: Part 7

Cody Hill
@cody_a_hill

Replying to @brendanpierpont

CAISO operators have been using Exceptional Dispatch, forcing batteries to sit back and wait for the absolute peak. Clearly reacting to yesterday's too-close call.

7:56 PM · Sep 7, 2022 · Twitter Web App

- **Pricing problems create need to override the market**

Element 1: full-strength spot prices

- **Want consistency between resource adequacy targets and operational expectations**
- **Mismatch becoming more important as energy-limited resources grow (also relevant for gas)**
- **Also enables demand-side and distribution-level resources to monetize value without administrative accreditation**

Failure to produce full-strength prices for energy and ancillary services leads to reliability issues and need for out-of-market interventions

Three elements of the "vision"

1. Full-strength spot prices
2. **Mandatory contracting**
3. Proactive transmission planning

CornellEngineering

Political economy

Contracts shift exposure to high spot prices from load to generation and could contribute to a more durable market design

Winter Storm Uri	Winter Storm Elliott
• Significant political backlash to high prices despite most retail customers being hedged • Substantial market design changes in ERCOT without sound basis	• Significant complaints about non-performance penalties within industry, but no major political response • Sound reforms to accreditation implemented in PJM

CornellEngineering

Market power

THE SACRAMENTO BEE

California power prices have skyrocketed. Is this normal — or more Enron-style 'manipulation'?

- **Contracted generators have little incentive to exercise market power in spot market**
- **While market power concerns persist in longer-term markets, contracting can be part of an overall mitigation strategy**

Financial risk, demand side

REUTERS®

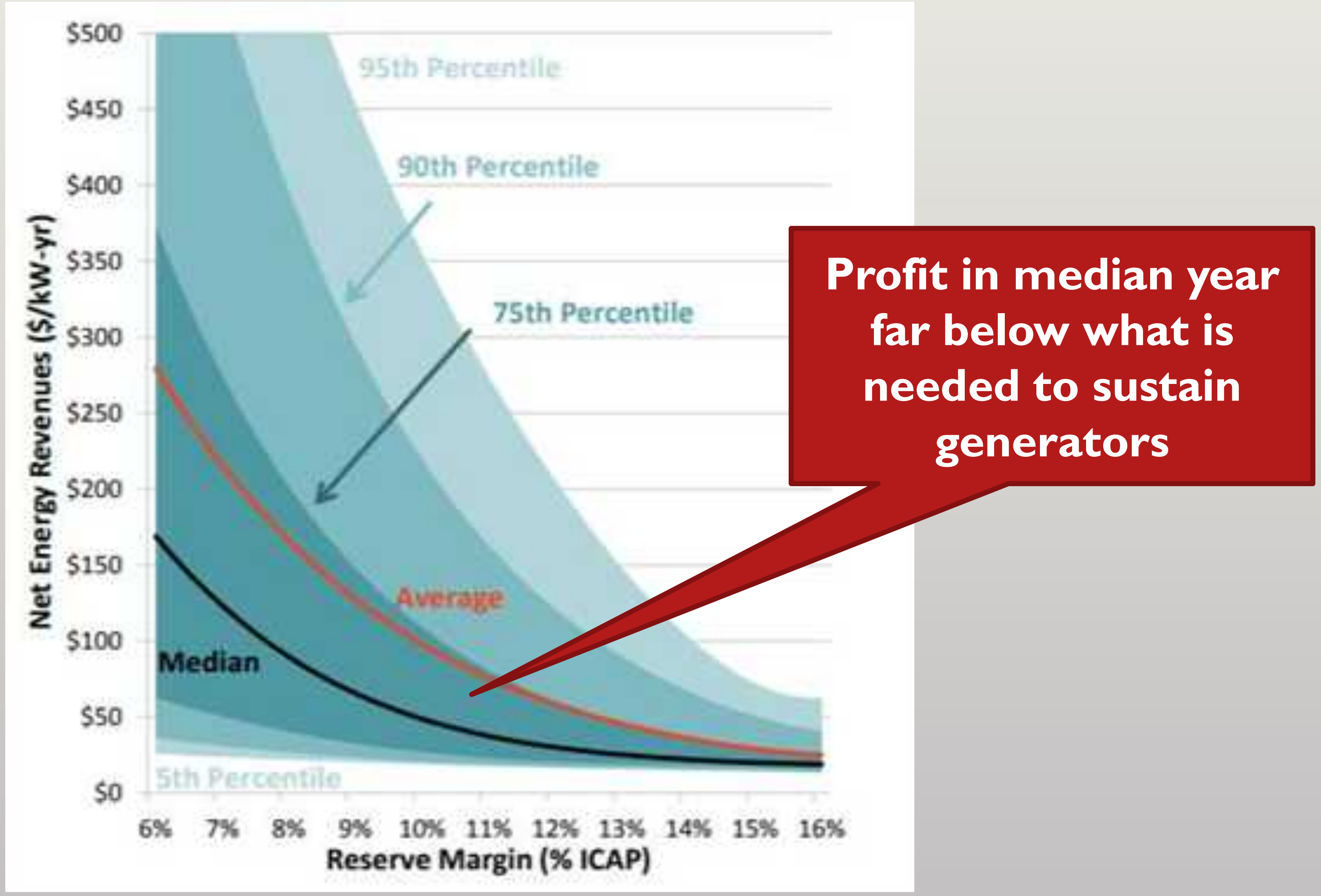
Britain faces 'massacre' of 20 more bust energy suppliers, Scottish Power says

- **Volatility creates significant risk for retailers and users of electricity**

CornellEngineering

Financial risk, supply side

Distribution of operating profits in ERCOT



Source: Estimation of the Market Equilibrium and Economically Optimal Reserve Margins for the ERCOT Region (The Brattle Group)

Preconditioning risk

Two routes for policymakers, regulators, and market operators to manage risk

1. **Suppress volatility in spot prices**

2. **Mandate contracts**

My opinion: avoid the former, pursue the latter

Element 2: mandatory contracting

Can require that load serving entities contract with suppliers, with several high-level design choices:

- **Full-strength spot prices?**
- **State, market operator, or combination?**
- **Centralized or bilateral?**
- **What contractual form?**
- **Financial or physical?**

Workable configuration likely dependent on market structure and existing mechanisms

Three elements of the "vision"

1. Full-strength spot prices
2. Mandatory contracting
3. **Proactive transmission planning**

CornellEngineering

Planning and economic issues

- **Very long-lived assets**
- **Long lead times for construction**
  - **~3x that of generation**
  - **~10x that of load**
- **Economies of scale (=> non-convex cost functions)**
- **Complex physics (=> network externalities)**

These features militate toward a centralized solution for transmission

Paying and cost allocation

Challenge is determining "how proactive" to be:

- **Significant uncertainty**
- **Different beliefs and risk preferences**
- **Potential to "crowd out" less expensive solutions from generation, demand, storage**
- **Difficult to converge on mutually agreeable scenarios and benefit estimates**

In principle planning models can be used to assess who beneficiaries are likely to be, including the effect of different policies in different jurisdictions

Element 3: proactive transmission

- Cost of transmission a relatively small component of overall system costs at the wholesale level
- Issues with spot price formation and contracting exacerbated with transmission underinvestment
  - Market power
  - Effect of (unpriced) voltage and system strength issues
  - Frictions to market entry in interconnection
  - Partially unhedgeable basis risk

➤ Transmission best viewed as a platform on which efficient price formation and contracting can occur

Three elements of the "vision"

1. Full-strength spot prices
2. Mandatory contracting
3. Proactive transmission planning

Addendum: what about policy?

- **ISO/RTO market design subordinate to policy**
  - **Avoid subsidies "within" the market design**
  - **Do not try to "correct" subsidies coming from outside the market**
- **Policy threat to reliability?**
  - **Business case for "clean firm" dependent on strong, consistent carbon policy**
  - **Business case for "conventional firm" dependent on lack of carbon policy**
  - **Uncertainty in policy can lead to underinvestment in both**

Three elements of the “vision”

1. Full-strength spot prices
2. Mandatory contracting
3. Proactive transmission planning

Appendix G:

Jessica Greenberg Presentation

A Developer's Vision for Clean Energy Markets

Jessica Greenberg
Senior Manager, Growth Strategy and Power Markets
Enel North America

1

INTERNAL

Agenda

01. What are growth strategy considerations?

02. What are remuneration options?

03. Energy Prices 101

04. What are our challenges in 100% Clean Markets?

05. Why is price formation important?

06. Wishful thinking?

2

2

INTERNAL

What are growth strategy considerations?

Policy
- Policy support
- Tax incentives
- Clean energy targets (state, utility, consumer, etc.)

Load Growth
- Data centers
- Electrification

Resource
- Strong wind/solar energy
- Pipelines
- Geologic carbon sequestration
- Nuclear fuel supply and storage

Development
- Permitting/Environmental Challenges
- Land Availability
- NIMBY

Transmission
- Siting
- Congestion
- Interconnection costs
- Queue timelines
- Regional transmission plans
- GETs deployment

Markets
- Tariff Variations
- Presence of an RTO/ISO
- Revenue source – Energy, Capacity, Ancillary, RECs, etc.
- Market size

3

3

INTERNAL

What are remuneration options?

Market Revenues
- Energy
- Capacity
- Renewable Energy Credits (RECs)
- Ancillary Services

Other Revenue Opportunities
- Utilities Power Purchase Agreements (PPAs)
- Commercial & Industrial PPAs
- Tax credits

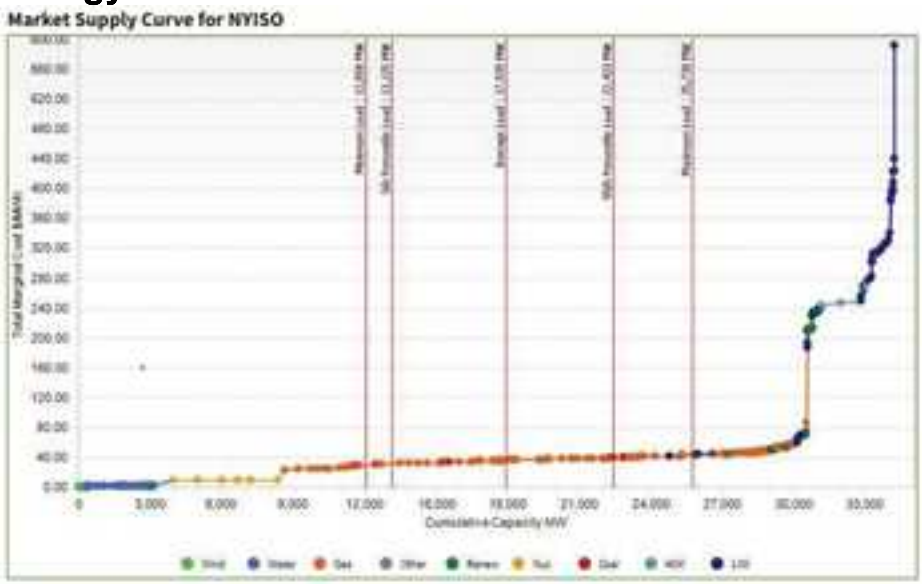
4

4

INTERNAL

Energy Prices 101

enel



https://www.ferc.gov/sites/default/files/2020-06/energy-primer-2020_0.pdf

5

5

INTERNAL

What are our challenges in 100% Clean Markets?

enel

Remuneration

Transmission availability?

Interconnection Queues?

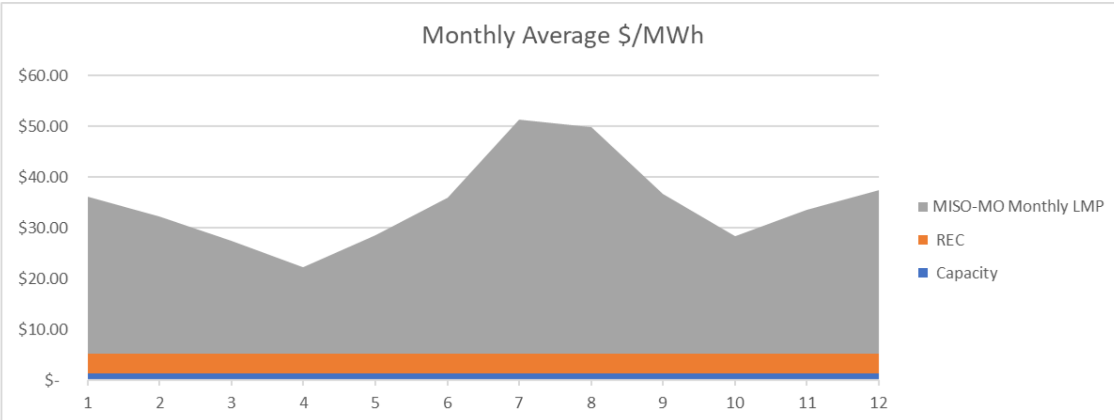
Siting?

6

6

INTERNAL

Why is price formation important?



7

7

INTERNAL

Why is price formation important?

Price Adder Options

- Value of Loss of Load
  - Scarcity Pricing
- Value of Capacity
  - Capacity Markets
- Value of Flexibility
  - Responsive to Fluctuating Load and Weather Dependent Generation Patterns
- Value of Carbon Displacement
  - Measuring the Displacement of Carbon and Other Pollutants

8

8

INTERNAL

Wishful Thinking?

If energy price is truly intended to help cover fixed costs in the long run, a more holistic view of price formation needs to be taken, which may result in a more complicated outcome

9

9

Appendix H:

Ryan Schoppe Presentation

2024 ESIG Fall Technical Workshop

Markets for 100% Clean Electricity Workshop

Overview of Decarbonized Grid Methodologies

Ryan Schoppe, P.E.
EPRI

10/24/2024

www.epri.com

1

Background

- Currently putting together a “Visions” paper that includes work from several contributors:
- ***Rob Gramlich*** → Fully decarbonized markets will require large amounts of transmission investment, fast/flexible renewables, load flexibility, carbon pricing, and clean/firm resources
- ***Kelli Joseph*** → Energy transition will require a large coordinated effort from institutions with important roles like states doing IRP and ISOs running coordination studies
- ***Jacob Mays*** → A hybrid market view w/ full-strength spot prices, mandatory contracting, & proactive transmission planning
- ***Ryan Schoppe*** → Provides an aggregate summary of various proposed solutions along with a taxonomy

2

Overall Taxonomy

3

Hybrid Markets

- A market design that includes a short-term day-ahead/real-time market coupled with an additional long-term mechanism for investment
- Acknowledges shortcomings in the energy-only design in incentivizing adequate investment for reliability and large-scale buildouts of renewable generation
- “Competition for the market” and “Competition within the market” is the mantra
- A significant amount of proposals tend to fall under this design where an additional long-term mechanism is proposed to supplement the short-term wholesale market

4

Competition both "For" and "In" the Market

**Fabien Roques (2021). Market Design for Financing Capital Intensive Low Carbon Technologies

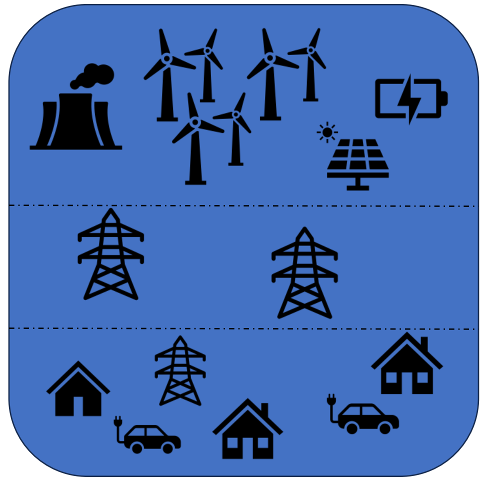
5

Hybrid Proposal	Description	Advocates or Users
Long-Term Auctions	Some form of long-term market is run (perhaps several years in advance) to determine which resources are chosen to accomplish the goals of the auction. For example, a new storage or renewable facility might receive a fixed contract to build out the facility and in return give up the market revenue. The idea is similar to capacity markets, but may be more tailored to clearing clean energy resources.	Steve Corneli, Brendan Pierpont
Long-Term Hedging	Renewable resources and demand both are required to obtain contracts to hedge their risk and reduce concerns of short-term price volatility. Some specify a certain low percentage (e.g. 0% 48 months ahead) of energy must be cleared in the long-term and the percentage increases until reaching 100% in DA	Frank Wolak, Jacob Mays, Cramton
Long-Term Centralized Planning	The ISO or a new entity would take on the integrated resource planning (IRP) responsibilities on behalf of the states/participants and determine an optimal resource/transmission mix based on the goals of reliability, affordability, and limiting emissions.	Hala Ballouz, Sean Meyn
Regional Resource Adequacy Requirements	The ISO determines resource adequacy requirements (e.g. a planning reserve margin) and the states are given a certain share of the requirements and must ensure they bring a certain amount of generation to the table. The participants are free to figure this out on their own (e.g. PPA w/ a developer) or build their own generation. These are sometimes referred to as "bilateral capacity markets".	SPP, CAISO
Strategic Reserves	The state procures contracts with resources that would normally not participate in the markets. Firm energy agreements are also made with neighbors. These reserves are called online during times of need.	CAISO, Germany
Capacity Markets	The longer-term reliability of the grid is ensured by "procuring an amount of power supply resources needed to meet predicted energy demand" for some time period in the future. Resources must be available during system emergencies or pay a large non-performance payment (PJM).	PJM, France, Italy
Renewable Support Schemes	Methods that help support the development of renewable energy resources such as feed-in tariffs, production tax credits, investment tax credits, R&D, and renewable auctions.	Ireland, USA…etc
Coordinated Planning	Similar to the Long-Term Centralized Planning concept, but the ISO or a new entity doesn't do the IRP. Instead, the state does the IRP as is traditional and there is tight coordination between the ISO, state, regulators…etc, such as the ISOs running regional reliability studies using the state's IRP results	Kelli Joseph

6

Cost of Service Regulation

- This model would resemble the fully vertically integrated utilities still common in the West and Southeast
- These entities would handle their own planning of which resources, transmission, and demand response programs they need and include the overall costs in their rate base
- Centralization has some benefits as state level goals involving reliability, affordability, and emissions can all be planned for in a manner that meets stakeholder approval
- This could limit innovation and lead to cost overrun concerns, but the utilities could still use competitive procurement processes
- This model has backing from some former FERC staff (e.g. Christie, McNamee)



7

Linked Swing Contracts

- Proposed by Dr. Leigh Tesfatsion as a solution to what she claims are conceptually problematic issues with ISO markets
  - Does not believe grid-delivered energy meets the necessary requirements to be a commodity, so marginal cost pricing is not appropriate
  - ISO markets are complex with hundreds of pages of rules
- The RTO/ISO would run a series of auctions (i.e. long-term, mid-term, short-term) for contracts that reflect the avoidable fixed costs and variable costs and clear/dispatch the contracts accordingly
  - This design handles both long-term investment and short-term operations
  - Process is run multiple years in advance and then closer to the operating day and on the operating day….each time it clears certain contracts and puts them on the ISO's book of contracts
- The design is still new though and Leigh is continuing work on expanding the design

8

Parallel/Adjacent Markets

- Parallel/adjacent markets is a term used to point out proposals that advocate for demand and generation not part of the utility's grid
- Examples
  - Data center co-located with nuclear plant
  - Industrial facility or Industrial clusters with on-site generation
- Lots of different examples of this being discussed right now:
  - Upcoming FERC Technical Conference on Co-Location of Large-Load Customers w/ Generating Facilities
  - Various EPRI work
  - Kiesling blog posts
  - …etc
- This does not address existing concerns with how to transition the wider grid
  - This is more of an incremental development to keep and eye on

9

Price Adders

- Contribution from Jessica Greenberg (ENEL)
- Points out the importance of energy prices for renewables in comparison to other markets (e.g. RECs)
- Asks about investment signals in the long-term with decarbonized markets when everyone has a zero short-run marginal cost
  - How do you plug the gap from the missing energy prices?
  - How do you recover your capital investment costs?
- The industry assumes that the addition of price-responsive demand will come to the rescue, but will that be the case?
- Is there a need for some kind of price adder?

10

Summary

- We cannot predict the future under an industry that is evolving so fast
  - However...we can make some assumptions based on going through all the different proposals
- There seems to be a fair amount of agreement regarding the role of hybrid markets in facilitating an energy transition that meets both environmental and reliability goals
  - There are many different forms of market hybridization and we will likely see many of these in-use in the future
  - Incremental evolution may seem more likely than rapid revolution, but this has to be balanced against aggressive decarbonization goals

11

Electricity Markets Under Deep Decarbonization

Second Workshop of the Task Force on Markets Under 100% Clean Electricity

This workshop summary is available at https://www.esig.energy/100-clean-electricity-task-force/.

To learn more about our work in this area, please send an email to info@esig.energy.

ESIG