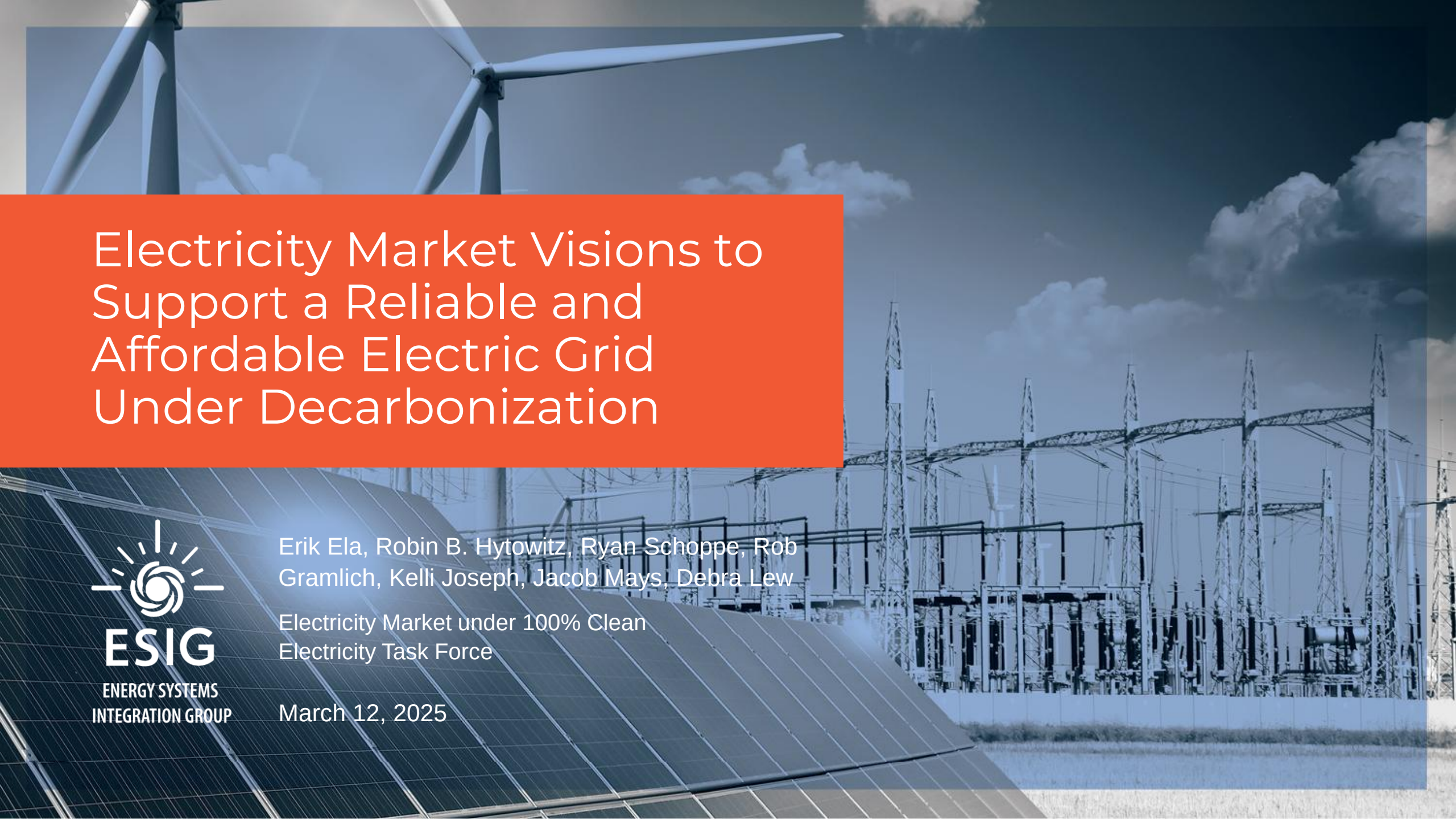

Electricity Market Visions to Support a Reliable and Affordable Electric Grid Under Decarbonization

Erik Ela, Robin B. Hytowitz, Ryan Schoppe, Rob Gramlich, Kelli Joseph, Jacob Mays, Debra Lew

Electricity Market under 100% Clean Electricity Task Force

March 12, 2025

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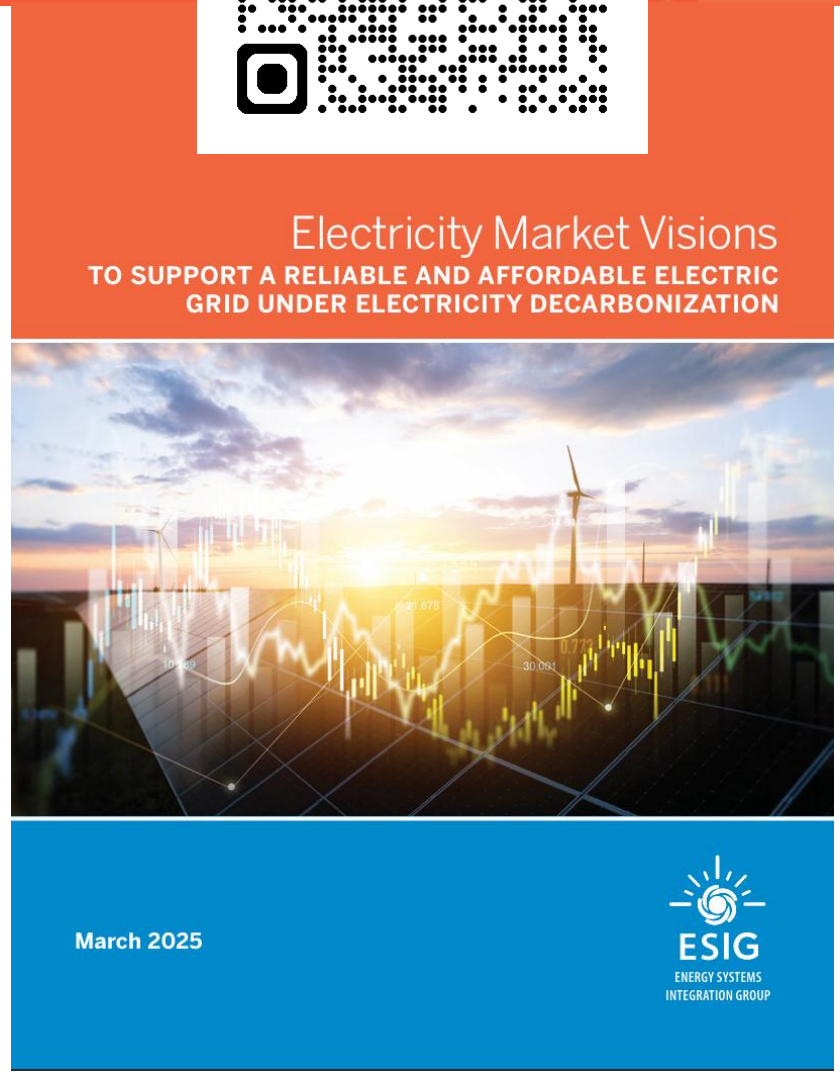
ESIG Electricity Markets Task Force

- Task Force made up of 55 individuals from different organizational types
- Task Force calls held primarily through 2024 with different themes presented
- 1st Workshop held in February 2023
  - Focused on key market elements and laying out potential challenges
- 2nd Workshop held in October 2024
  - Lead author vision proposals and discussion on metrics, next steps
- Final report released last week: March 2025



Presentation Agenda

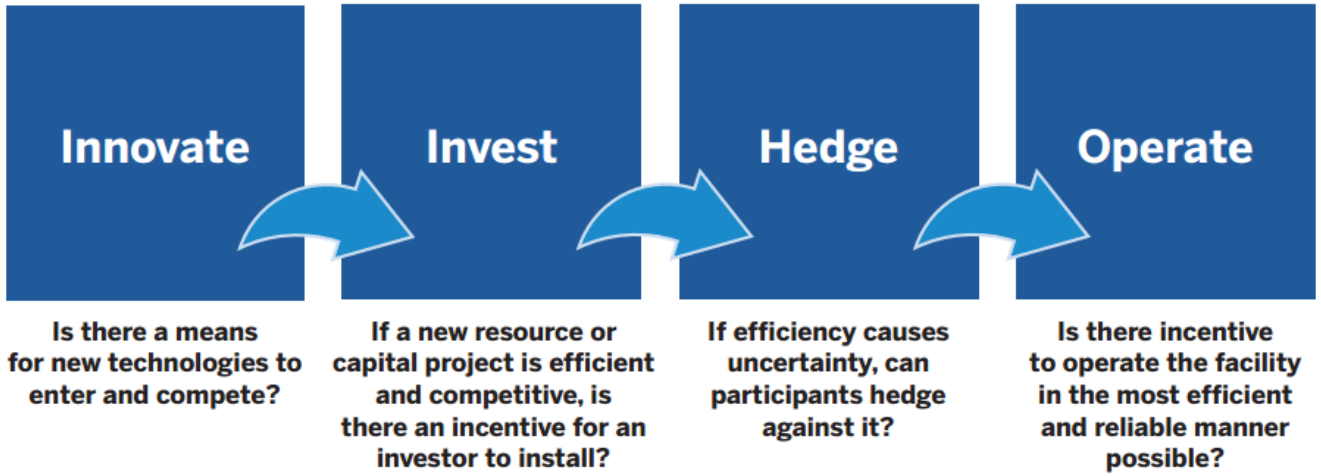
- Scope and Market Design Principles
- Review of Other Proposals by Researchers and Industry
- Assumptions about the future 100% clean electricity system
- Vision: Existing energy markets and transmission policy
- Vision: Full strength pricing and mandatory contracts
- Vision: Framework for policy and regional coordination
- Paper Vision Elements: Summary
- Recommendations
- Q&A

Vision Paper Outline

- Introduction to Paper and to Task Force
- 100% Clean Electric System: Assumptions and Potential Challenges
- Market Design Vision
- Possible Next Steps and Metrics for Evaluation
- Looking Forward

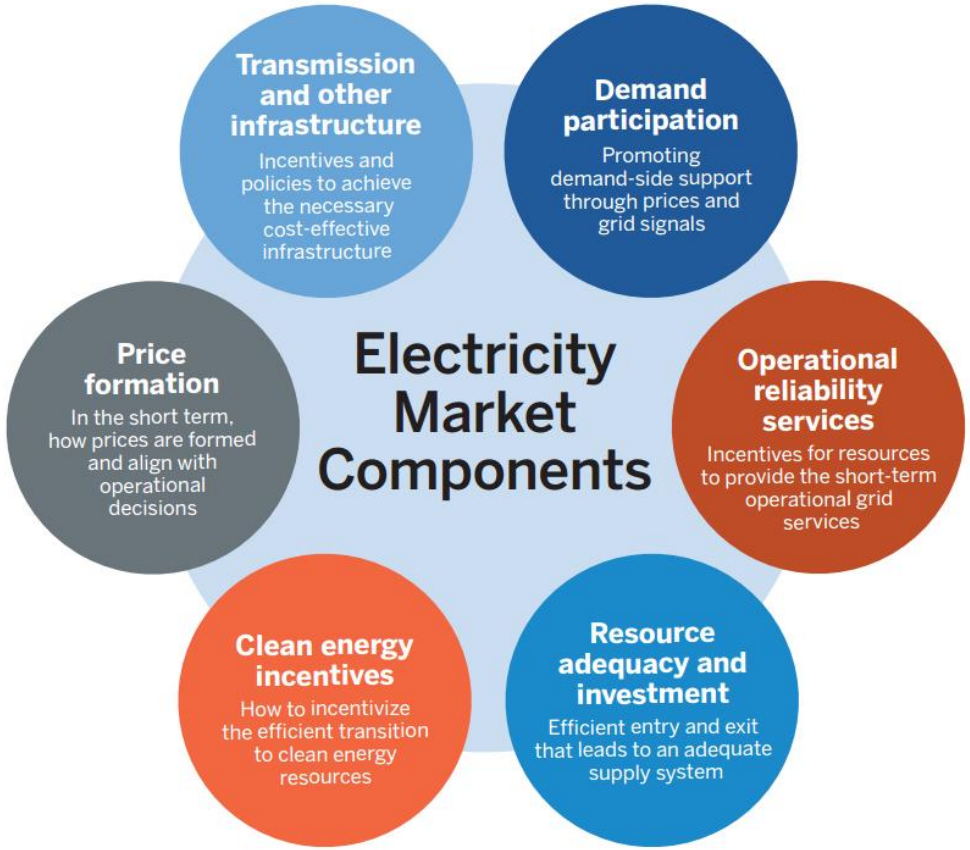
Scope of Market Design and Principles

FIGURE 2
Four Key Principles That Markets Aim to Accomplish

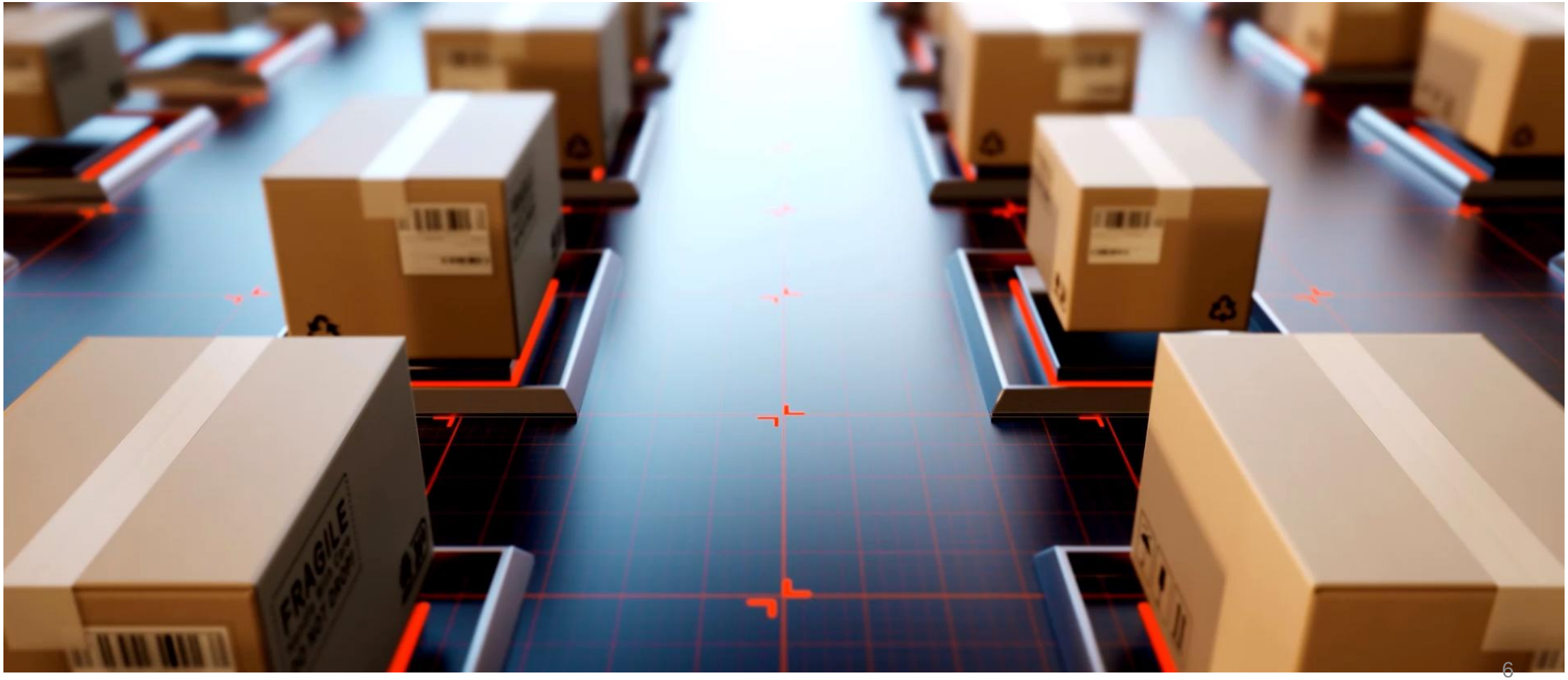


Successful markets must incentivize innovation, investment in capital, hedging against risk, and behavior to operate in ways that lead to reliable and economically efficient outcomes.

FIGURE 1
Categories of Change for Future Market Design Vision



A Review of Recent Proposals by Researchers and Industry: Full spectrum of possible market designs



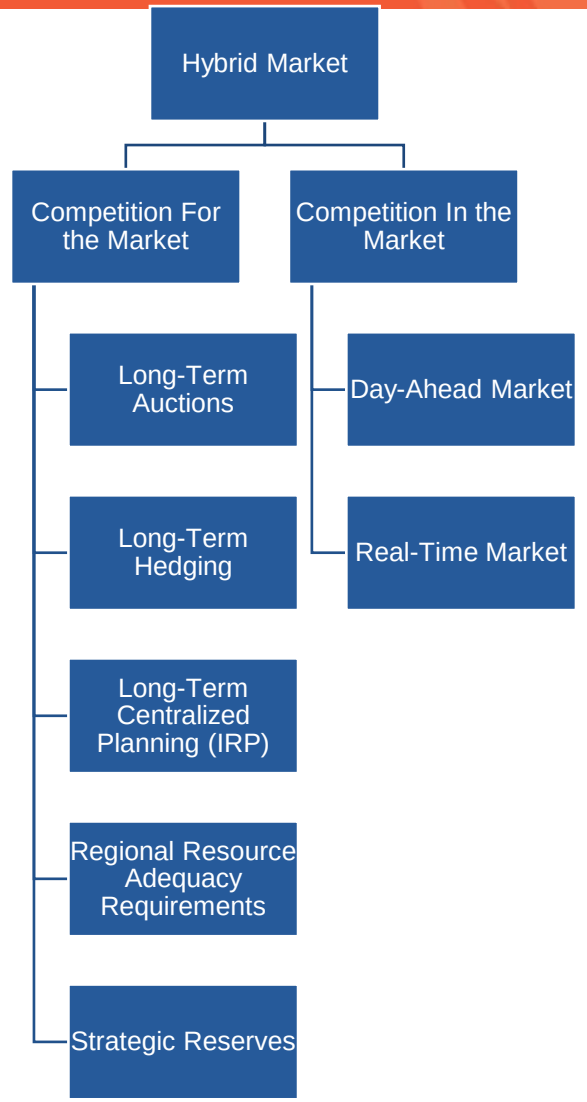
Energy-Only Markets

- The General Idea
  - The wholesale day-ahead and real-time markets alone should be enough to cover resource adequacy, short-term reliability, and policy objectives
  - Scarcity Pricing + Price Responsive Demand + Carbon Pricing would be necessary for reliability and meeting emissions goals
  - Voluntary long-term contracts can be made to hedge against high price spikes and reliability

- Challenges
  - May not provide sufficient incentive for moving the grid to a future that is both reliable and decarbonized without some big policy changes
  - Could lead to very high price volatility when renewables shift between being plentiful and scarce, impacting ability to invest
  - Some have suggested possible workarounds (e.g., extended ORDC, long-term marginal costs)

Hybrid Markets

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



Example Hybrid Market Proposals

Sub-Method	Summary	Advocates/Users
Centralized Capacity Auctions	The ISO runs a centralized auction that sells capacity as a product that uses a uniform clearing price and Resource Accreditation to normalize reliability contribution	• ISO-NE, PJM, NYISO, MISO
Regional Resource Adequacy Requirements	The ISO/planner determines resource adequacy requirements and LSEs are allocated a share and must ensure they bring a certain amount of generation to the table. Creates a bilateral market.	• CAISO • SPP
Long-Term Clean Energy 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.	• Steve Corneli • Brendan Pierpont • Spees/Brattle/ISO-NE proposal
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.	• Frank Wolak • Jacob Mays
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.	• Ballouz, Sean Meyn
Strategic Reserves	The state procures contracts with resources that would normally not participate in the markets (as well as firm energy agreements w/ neighbors) but could be called online during times of need.	California Department of Water Resources

**All of these maintain the short-term wholesale day-ahead and real-time markets

Proposal Taxonomy & Insight Summary

- No shortage of ideas for how to best design markets necessary for grid operations
  - Some advocate for adjustments to the existing markets without the addition of a secondary mechanism
  - Others support a hybrid structure where a secondary market helps incentivize adequate investment/adequacy and hedging
  - Still others have advocated for a major departure from existing market design
- This ESIG TF has converged toward the hybrid approach, but without consensus on the long-term mechanism

TABLE 2
Future Market Design Proposals

Potential Ways of Categorizing Future Market Design Proposals	
Energy Only Markets	• Long-term marginal cost • Price adders • Energy with operating reserve demand curve (ORDC)
Hybrid Markets	• Capacity markets • Mandatory bilateral capacity transactions • Strategic reserves • Coordinated planning • Integrated clean capacity market • Configuration market
Complete Redesign	• Cost-of-service regulation • Swing contracts • Capacity only auction

Assumptions about and Characteristics of 100% Clean Electricity Systems

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Assumptions and Impacts

- [x] Variable Renewables (Wind, Solar)
- [x] Fast & flexible resources, with limits (storage)

Transmission to deliver energy to load

Distributed Energy Resources

Zero-emission firm resources (Hydrogen, CCS, etc.)

Grid Responsive Demand

Reliability due to variability and uncertainty

Resource adequacy due to availability and energy limitations

Volatile energy prices, more prices at zero and at scarcity

Lack of emission incentive within market clearing

Transmission needs for large-scale generators

Control and visibility, coordination for DERs

Each region may have a completely different scenario

Market Design Vision: Regional bid-based security constrained economic dispatch with locational marginal pricing + economically sound transmission planning

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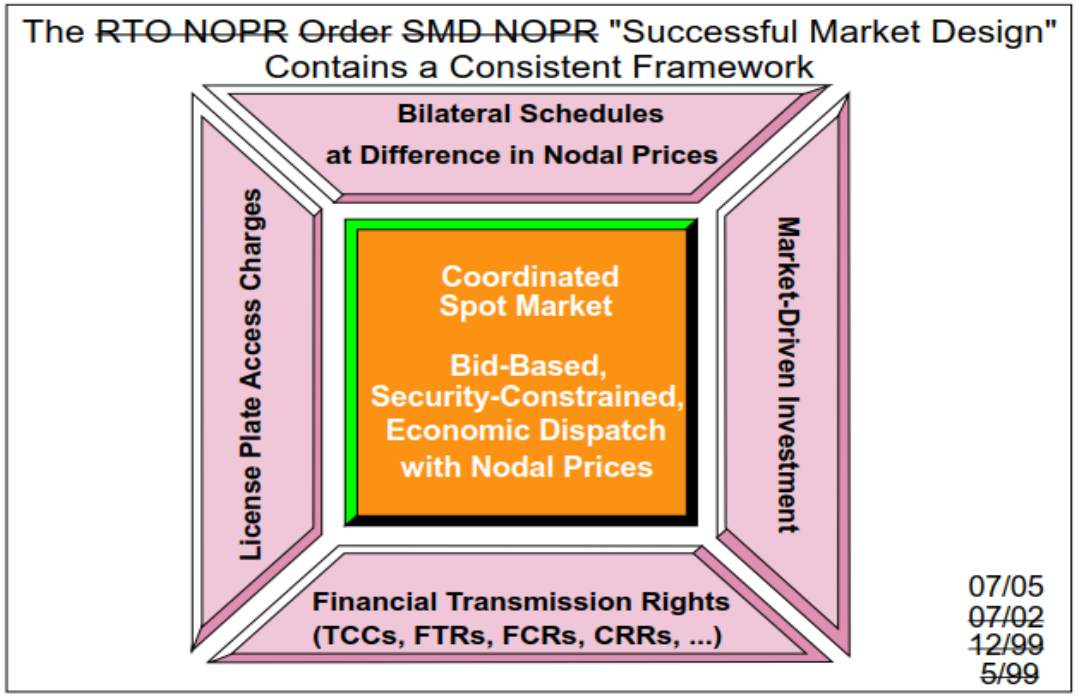
Energy Markets: Preferred Market Design

- 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 (or shorter) locational marginal price (LMP)
- Reliability Services—technology-neutral
  - Operating reserves, exact needs vary
  - 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

Efficient central spot markets attract flexibility while accommodating long-term bilateral contracting

- Geographically broad bid-based, security constrained economic dispatch with locational marginal prices, and financial transmission rights has become accepted in the US as best practice market design. Fast dispatch intervals (eg 5 minutes) enable rapid reaction to changes in supply or load, which enables reliable, efficient operation with high levels of variable energy sources.
- Should include both supply and demand-side bids.
- Multiple day ahead forward markets (eg, 1-3 days ahead) can help incorporate best renewable forecasts and other changes in supply and demand to commit and dispatch units efficiently.
- Bilateral contracts between load-serving entities and generators can occur in a compatible way, not administered by the RTO/ISO, to help hedge consumers' risk, and help finance generation.

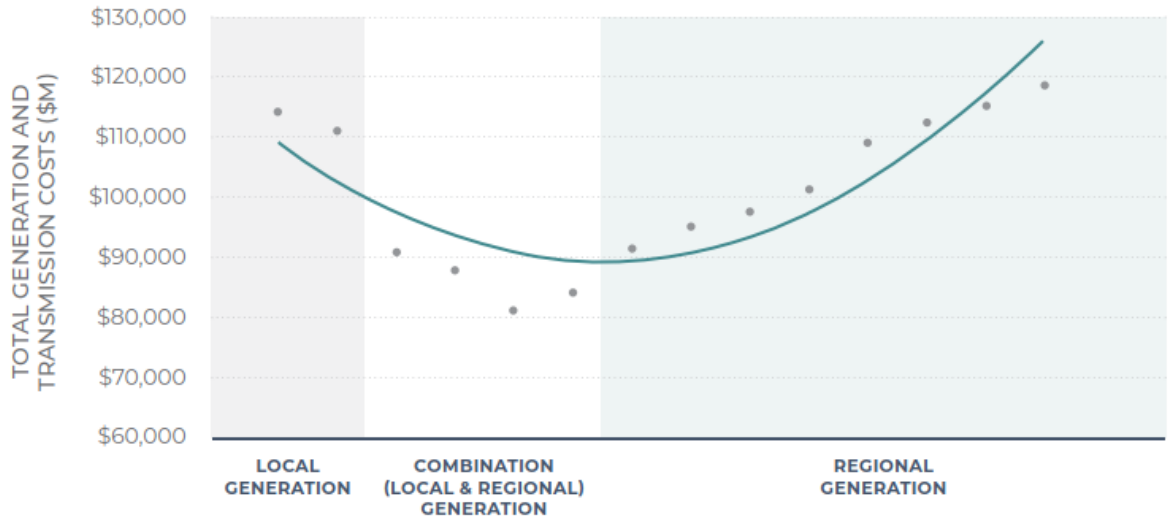
Transmission planning and expansion

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

Economically sound transmission planning

- "Just and reasonable" has to mean <u>maximize net benefits</u>
  - 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

Market Design Vision: Full-strength spot pricing and mandatory contracting

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Element 1: Full-strength Spot Prices

- Spot prices in U.S. markets are typically insufficient to support resource adequacy
- Insufficient revenue implies **poor incentives for investment**
- Weak pricing during scarcity leads to inconsistency between resource adequacy targets and operations, i.e., **poor incentives for operation**
- Mismatch becomes more important as energy-limited resources grow
- Full-strength prices enable demand-side and distribution-level resources to monetize value without administrative accreditation, i.e., **incentives to innovate**

Weak price formation leads to reliability issues and need for out-of-market interventions

Element 2: Mandatory Contracting

- Clearest issue with full-strength prices is the volatility of electricity markets
- Three big issues:
  - Consumer protection and political economy
  - Market power concerns
  - Under-investment due to frictions in contracting/hedging/insurance
- Capacity markets are one form of mandatory contract, but full-strength spot prices can support wide range of contracts

Mandatory contracts can address the clearest downsides of energy-only markets and capacity markets

Element 3: Proactive Transmission Planning

- Very long-lived assets with long lead time, economies of scale, and network externalities
- Cost of transmission still a relatively small component of overall costs at the wholesale level
- Issues in spot price formation and contracting are exacerbated with underinvestment in transmission
  - Market power, unpriced voltage/system strength issues, frictions to entry

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

Market Design Vision: Coordinated planning to achieve the right resource mix

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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.

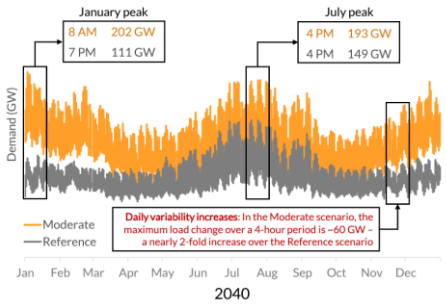
Bulk Electric System Reliability

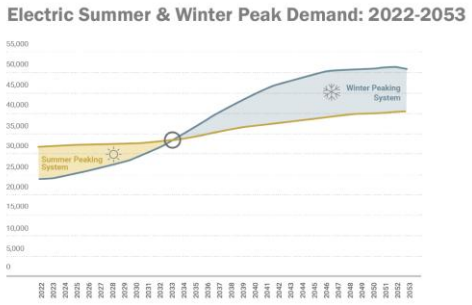
Resource Adequacy	+	Operating Reliability	+	Energy Adequacy
LOLP Risk Assessments		*Withstand Sudden Disturbances*		*Produce When Dispatched*

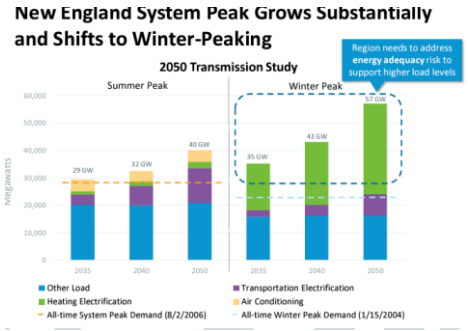
“Essential Reliability Services”/”Grid Attributes”/”Ancillary Services”

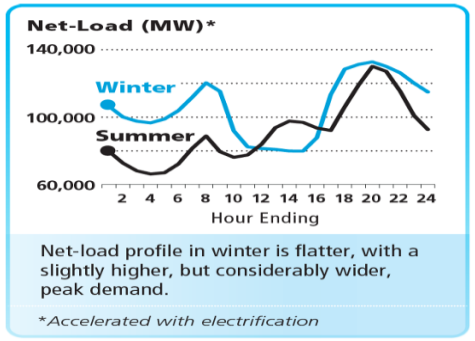
- Meeting mandatory and enforceable reliability standards
- Managing to contingencies
- Respond to changes in grid frequency or voltage stability
- Supply/Demand Balance
- Maintain transmission lines within rated limits
- Provided By Quick-Start/Fast-Ramping Resources

Gas-Electric Interdependency









Systems become winter peaking…with significant ramping needs

- Natural Gas = 40% today (EIA)
- Increasingly used to provide balancing energy (NERC 2023) critical for operating reliability
- 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

Economic Theory ….

- **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)

Relying on an LMP alone has never been a sufficient investment signal to meet reliability targets.

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

Batteries + Gas with sufficient fuel available

Addressing Gas/Electric Interdependency Challenges

2) Targeted incentives for the kinds of resources that can replace the operating reliability services gas assets provide. (**FUTURE**)

That provide specific grid services

Incentivizing new technologies

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

A Policy and Regional 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.
Reliability Coordinator *In some regions this is the Regional Transmission Organization (RTO) or Independent System Operator (ISO). In other regions, coordination with Balancing Authorities is 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 is 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 Consider Regional System Planning and the Need for Public Investment in Critical Infrastructure

- **Hybrid Markets**
  - Competition “for” 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?

- **Strategic Reserves** (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

- **Regional IRP for specific asset types** (a form of hybrid market)
  - Could still have competitive solicitation…which could enable new assets types that can fully replace fossil when commercially available

Market Design Vision: Summary of All Vision Elements

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Vision Elements Summary

Price Formation

- **Incentivize to Operate**: Continue bid-based, regional markets with economic dispatch and locational marginal cost pricing
- **Incentivize to Operate and Invest**: Prices that reflect scarcity and sloped demand curves
- **Incentivize to Operate**: Incremental enhancements to improve sector coordination, seams management, scheduling tool enhancements, and exploration of more granular pricing
- **Incentivize to Innovate and Operate**: Participation Models that are preemptive, prioritized for reliability, that do not prevent or stall new competitive technologies from participation

Vision Elements Summary

Demand Participation

- **Incentivize to Operate and Innovate**: Enable greater levels of demand participation through various means including providing access to more granular prices, while protecting customer classes

Operational Reliability

- **Incentivize to Operate and Innovate:** Continuous evaluation of whether new reliability products are necessary and if competitive auctions for those products provide value that outweigh administrative cost
- **Incentiize to Operate and Invest**: Determine whether ancillary service prices derived primarily from opportunity costs are sufficient for reliability resources to invest in technologies that provide those services adequately

Vision Elements Summary

Resource Adequacy

- **Incentivize to Invest and to Hedge**: Consider additional workable mechanisms beyond energy markets through a hybrid market paradigm to allow for efficient investment
- **Incentivize to Invest and to Hedge**: Interventions may be needed for resource adequacy and certain reliability attributes

Infrastructure

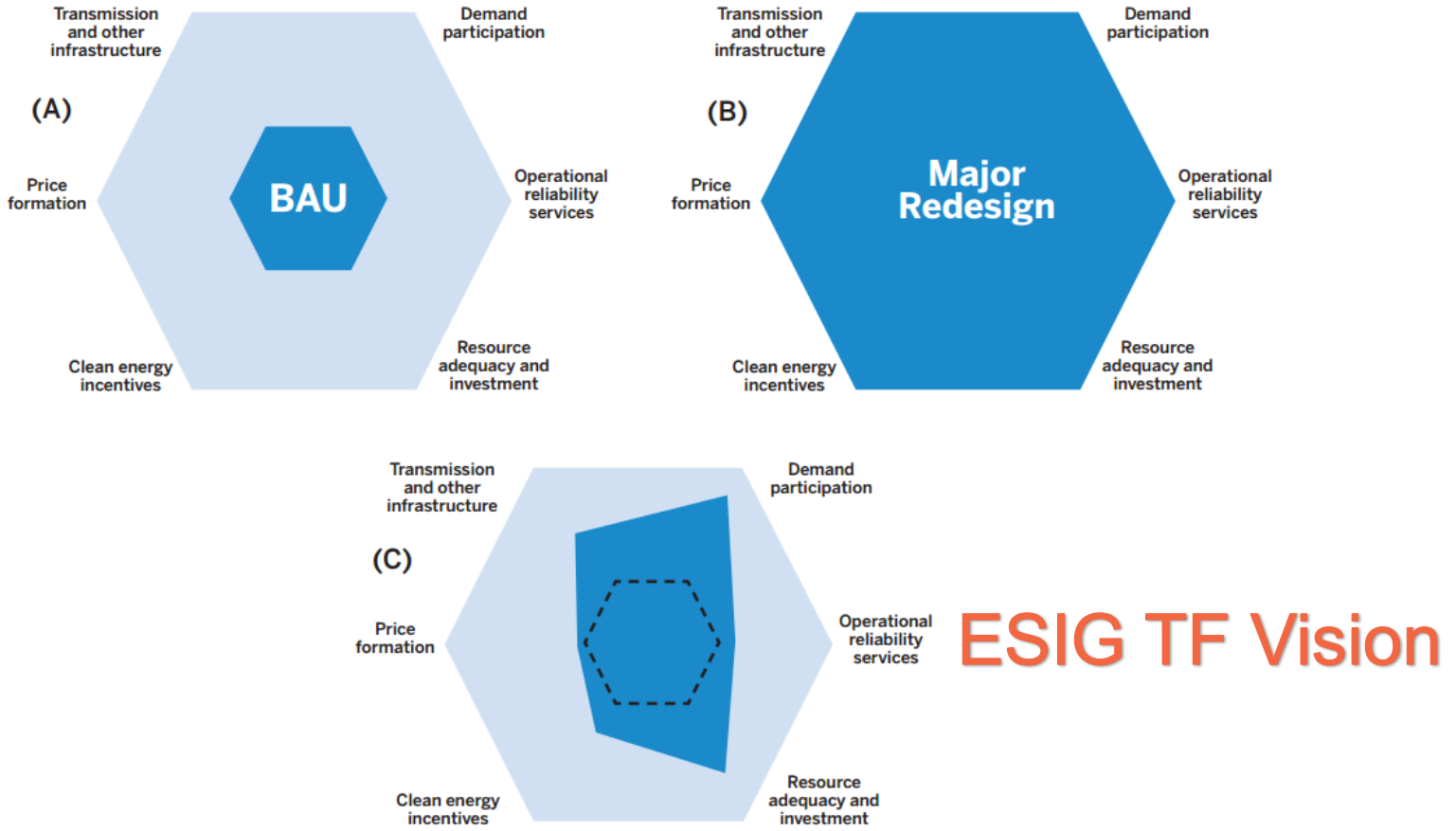
- **Incentivize to Invest and to Innovate**: Consider workable policy that could incentivize innovation and efficient investment in infrastructure

Clean Energy Incentives

- **Incentivize to Invest and Innovate:** Allow markets to facilitate efficient trading of energy with efficiently designed clean energy policies accommodated through constraints or pricing
- **Incentiize to Operate and Invest**: Consider whether loads could input their willingness to purchase clean energy as a market design element for improved transparency

ESIG Market Vision: Business as Usual or Major Redesign?

Viewing the Scale of Change of Market Design Futures by Category



ESIG TF Vision

Recommendations

- Further work on parts of the vision where differing solutions were presented
  - Particularly around long-term contracting and level of coordination
- Evaluation of Metrics that can help assess the performance of future market designs, which include combined use of quantitative and qualitative metrics
- Consider market pilots for complex design changes either through limited participation or limited scope
- Look for highlighting consensus from technical experts where it exists, to support policymakers
- Global collaboration, sharing lessons including failures and successes

Q&A
Please use Slido

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THANK YOU

For correspondence, questions, and future ideas, contact Erik Ela

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