Energy+Environmental Economics

E3 Market Price Forecasting Service

Q3 2020

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Contents

About E3

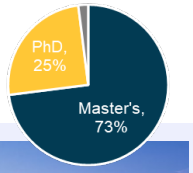
Who is E3?

Thought Leadership, Fact Based, Trusted.

Technical & Strategic Consulting for the Clean Energy Transition

70 full-time consultants

Deep expertise in engineering, economics, mathematics, public policy…



San Francisco

New York

Boston

250 projects per year for our diverse client base

Advisory and bid evaluation services to the State of South Carolina for the potential sale of Santee Cooper (~$9 billion valuation)

Integrated Resource Planning for the CA Public Utilities Commission (CPUC) to achieve state clean energy targets (SB100)

Evaluation of gas peaker replacement and/or hybridization with energy storage in New York City and Long Island

Price and revenue projections and due diligence for GIP acquisition of NRG renewables portfolio (~$1.4 billion)

Multiple studies on costs and feasibility of high renewables integration and low-carbon transition pathways from 2020-2050

Reliability analysis of closing coastal gas-fired power plants and assessment of alternatives (transmission, storage, etc.)

E3's expertise across our 5 practice areas gives us a unique perspective on the energy industry

+ **E3's project scope and breadth is unmatched for a firm of its size. We complete over 250 projects a year across the energy sector, emphasizing electricity**
+ **E3's 30-year track record and extensive expertise across our 5 practice areas has informed the creation of the market price forecasting tool**

Asset Valuation & Strategy

Determines asset values and strategies from multiple perspectives

Uses proprietary in-house models and in-depth knowledge of public policy, regulation and market institutions

E3 has five working groups which foster continual innovation in cutting-edge projects and best practices across the firm

Clean Energy

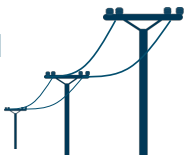
Provides market and policy analysis on clean energy technologies and climate change issues

Includes comprehensive and long-term GHG analysis

DERs & Rates

Analyzes distributed energy resources, emphasizing their costs and benefits now and in the future

Supports rate design and distribution system planning



Resource Planning

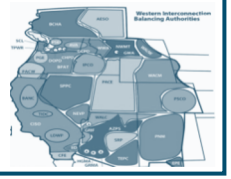
Develops and deploys proprietary tools to aid resource planners

Informs longer-term system planning and forecasting

Market Analysis

Models wholesale energy markets both in isolation and as part of broader, more regional markets

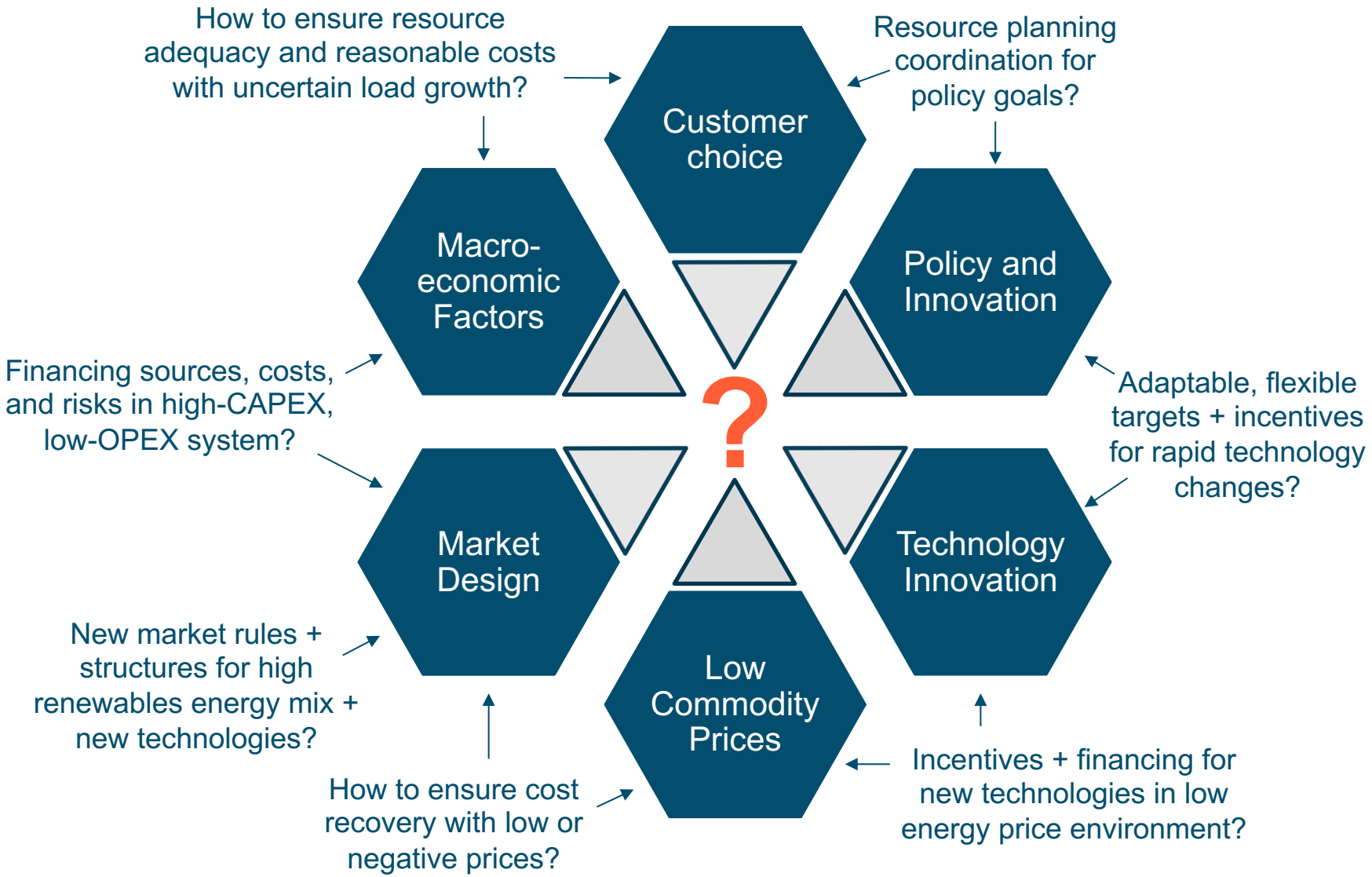
Key insights to inform system operators and market participants



Energy+Environmental Economics

Industry Trends: Uncertainty + Transformational Change

Key trends are changing the U.S. electricity sector, with uncertain results



The future electric system will be defined by widespread deployment of low-cost renewables

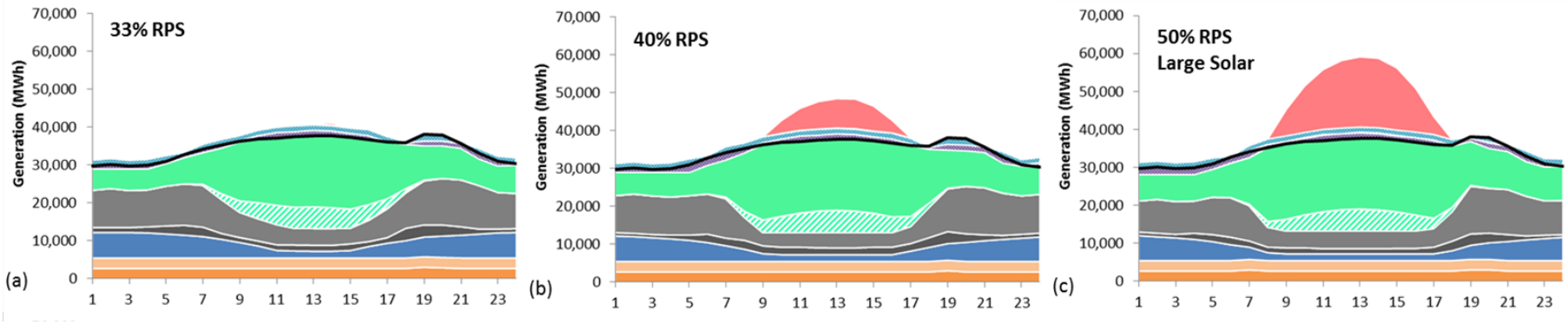
+ **Widespread deployment of variable renewable resources requires fundamental shifts in system planning and operations. System operators must answer two critical questions:**

How many MW of dispatchable resources are needed to (a) meet load and (b) meet flexibility requirements at various time scales

What is the optimal mix of new resources (renewables, storage, thermal) to (a) achieve policy goals and (b) meet reliability requirements at least cost?

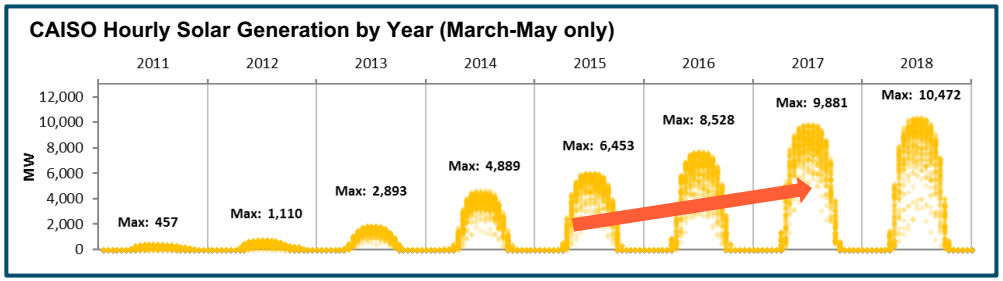
+ **However, this will create challenges at high penetrations due to**
  - Renewable oversupply during low load periods
  - Inflexible conventional generation such as must-run resources; technical constraints on ramping, stable levels, up and down time; and high costs associated with frequent cycling
  - Small balancing areas or constrained interactions with neighboring regions

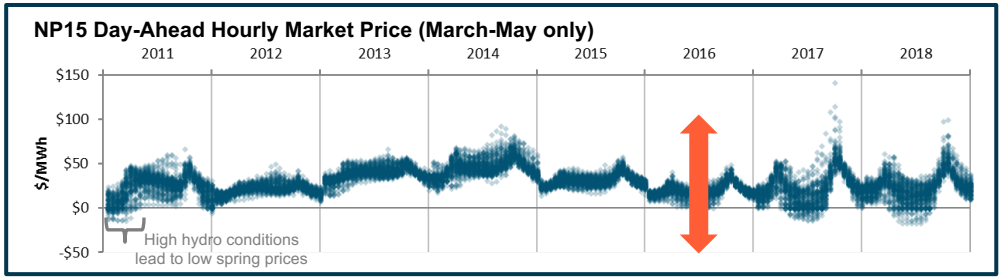
+ **Research and industry attention has shifted to focus on grid integration solutions such as storage, flexible loads, and more interconnected markets**

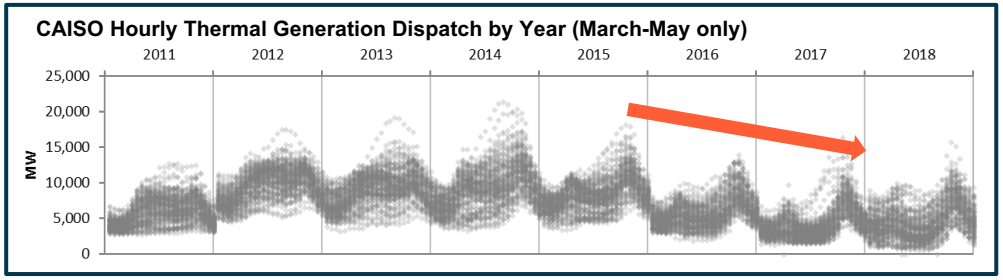


We have seen California's markets begin this evolution in the last 7 years

+ **The impact of lower gas prices and renewables build out in recent years has already resulted in negative prices**







Increasing solar and renewables penetration creates mid-day over-generation and curtailment, leading to $0 or negative prices during many daytime hours in recent years

This increases the spread of energy prices and calls for generation with fast-ramping capability

Thermal generation has been falling, pointing to the importance of capacity payments for many existing resources

Source: CAISO, E3 Analysis; note that solar generation does not include rooftop solar

The world looks different in 2050 relative to today's markets

- **Market prices that are zero or negative are not outliers, but a daily occurrence in most seasons**
  - Different **generator classes have different economic propositions** and incentives
- **Electricity system costs are dominated by fixed costs; resources are likely to recover costs outside of energy markets**
  - Capacity payments, **especially for emissions intensive reliability resources**, become more important
- **The rules around regional interactions may completely change what market prices look like**
  - **What do prices look like in linked markets with different policy mechanisms** in place? How does price formation occur with Washington's CES, CA SB100 + carbon price and Oregon TBD policy?
- **The disconnect between wholesale market prices and current retail rate regimes may become starker**
  - How can **DER and wholesale resources be co-optimized**?

Energy+Environmental Economics

Our Approach to Building Better Price Forecasts

For Today's Unprecedented Market Uncertainty…

We Believe in Unrivaled Transparency and Flexibility.

Transformational change across North America's electricity markets is making traditional forecasts increasingly irrelevant.

Traditional Forecasting Paradigm

+ Gas prices are primary driver

+ "Black Box" Forecasting:
  - Multi-variate regressions force short-term relationships to predict long-term trends
  - No clear narrative or predictability for systemic step-changes in grid operations and prices from high renewable integration

+ Static Predictions:
  - Focus on commodity trends and near-term market impacts

E3 Methodology

+ **Policies are the primary driver of investments, loads, and future prices**

+ **Transparent Forecasting:**
  - All inputs/outputs available on as granular basis as necessary, i.e. hourly or sub-hourly, pre/post E3 processing steps, etc.
  - Fundamentals-based production cost modeling connects the dots between policies, retirements, builds, and prices → ***clear narrative of causes + effects***

+ **Flexible Scenarios:**
  - Integrated policy + market scenarios capture interrelated dynamics of policy attainment or failures

Forecasts Built from 30 Years of 360° Experience

E3 has been creating customized electricity price forecasts for clients for many years…

We now offer a standalone market outlook and price forecast built on:

+ **30-year track record**
+ **360° industry view**
+ **Deep knowledge and leading insights from all E3 practices:**
  - Asset Valuation
  - Resource Planning
  - Climate Pathways
  - Markets + Regulation
  - Distributed Energy Resources

Four Key Factors Set Our Forecasts Apart

+ **Based on E3's vast internal expertise and industry-leading IP**
  - E3's market price forecasting tools were developed in-house and lean on our expertise in the electricity industry, such as highly renewable energy systems, market design, electrification, storage and DERs.
+ **Used by a wide variety of clients across the industry for many different uses**
  - E3 market price forecasts have been used by some of the biggest players in the industry for things as diverse as renewables purchasing strategy to asset valuation.
+ **Built with transparency at the core**
  - E3 does not believe in the "black box" mentality and we are transparent and open when it comes to explaining our analyses. We are happy to provide inside-the-box explanations of drivers and results and work with you to answer your questions and explain our process.
+ **Are the only price forecasts that are policy-driven**
  - U.S. electricity markets currently exhibit a historically high degree of uncertainty, driven by fundamental policy and technology changes that are rapidly evolving and hold the potential to transform price formation and push the limits of existing market constructs.
  - E3 is the only one to take this into account by building policy scenarios as the cornerstone of our price forecasts.

Policy-driven Scenarios Capture Different Trajectories for Systemic Change

+ **US electric markets currently have a historically high degree of uncertainty, with fundamental policy and technology factors that are rapidly evolving and interacting in ways that affect prices**
+ **E3 is the only one to offer market price forecasts that are policy-driven**
+ **E3's approach combines**
  - E3's market insight from detailed analysis of long-term fundamentals and cutting-edge research
  - Scenario-based approach that is essential for understanding the impact of these uncertainties.
+ **Scenario-driven analysis allows for rapid testing of price sensitivity to a range of futures**

	Low Policy Achievement	Base Policies	High Policy Achievement
Policy	Intermediate policy targets are met, but decarbonization and RPS deployment does not achieve long-term goals on schedule.	Existing intermediate and long-term policy targets are met on schedule.	Higher RPS or GHG-reduction policies are implemented with greater regional coordination.
Load Growth	Load growth is driven only by existing trends.	Loads reflect economically realistic levels of energy efficiency and electrification given policy.	Loads reflect more ambitious levels of energy efficiency and electrification given decarbonization policies.
Regional Alignment	Jurisdictions pursue policies independently without much coordination.	Similar jurisdictions align carbon policy (e.g. coordinated carbon policy for CA, WA and OR).	Similar jurisdictions align carbon policy (e.g. coordinated carbon policy for CA, WA and OR).

+ **Sensitivities can be constructed from each core scenario by changing gas and carbon price trajectories, technology cost and capacity credit assumptions, or policy enforcement mechanisms (RPS vs. GHG)**

Scenario-based Production Cost Simulation for Hourly Day-Ahead Energy Prices

Key Scenario Variables

1. **Scenario-specific load forecasts** (including electrification load)
2. **Scenario-specific policy assumptions**
3. **Regional coordination** (transmission and policy alignment)
4. **Other Major Drivers:**
   - Costs of new resources
   - Gas prices
   - Carbon prices

AURORA Model Outputs

Long-Term Capacity Expansion

Resource Buildout

- Snapshot year resource builds
- Interpolation for interim years

Hourly Production Simulation

Energy Market Price Forecasts

- Hourly day-ahead energy prices by scenario and by zone
- Dispatch, renewable curtailment, and transmission flows

E3 Derived Outputs

Market Product	Geographic Granularity	Temporal Granularity
Energy (Day-Ahead and Real-Time, adjusted for REC and scarcity)	Zonal	Hourly
Capacity (low, medium, high forecasts)	System / Local	Annual
Ancillary Services (Reg, Spin, Non-Spin)	ISO	Hourly
ELCC Curves	Regional	Annual
REC	State / ISO	Annual
System Operations	System / Local	Hourly / Monthly

RECs, Capacity Prices, AS Prices, and RT Prices are all generated using DA energy prices as an input to ensure alignment with fundamentals.

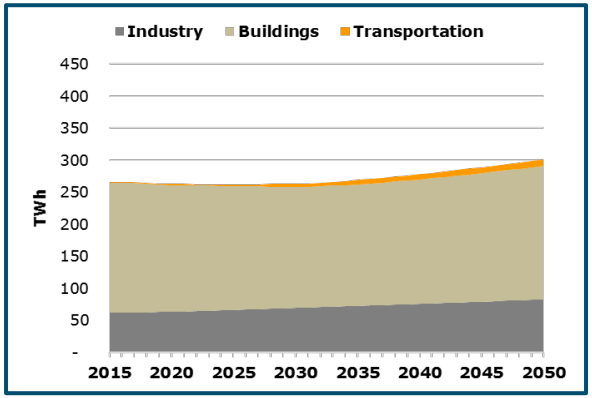
In-House Electrification Load Modeling Using E3's Proprietary RESHAPE Tool

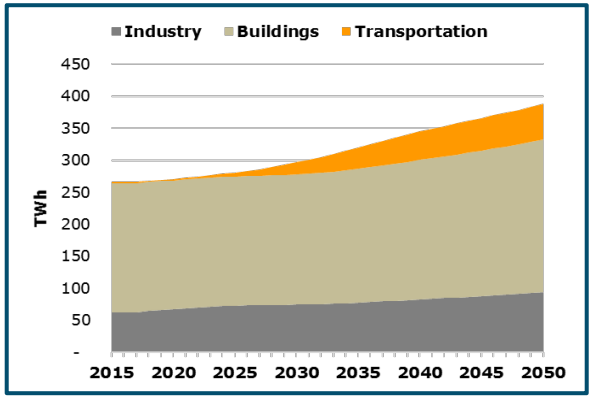
- **Load growth is driven by electrification of buildings and vehicles and varies by scenario**
- **Building loads based on**
  - Building profiles
  - Weather
  - Growth and efficiency
  - Heat pump attributes and adoption rates
- **EV load models flexible and inflexible EV charging load in all scenarios**
  - Heavy and medium-duty vehicles (HDV and MDV) modeled as inflexible throughout the run horizon
  - Light-duty vehicles (LDV) charging flexibility grows over time with technology and EV penetration

Policy Scenario

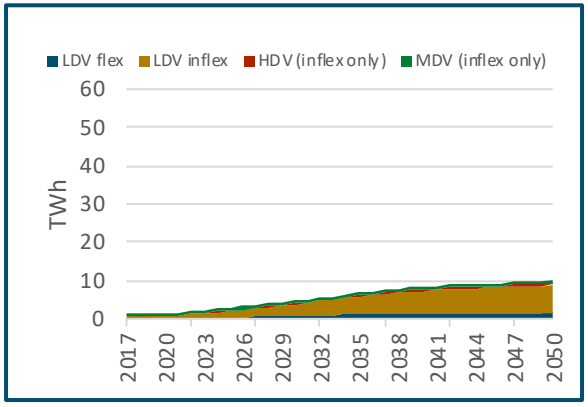
Renewables Scenarios

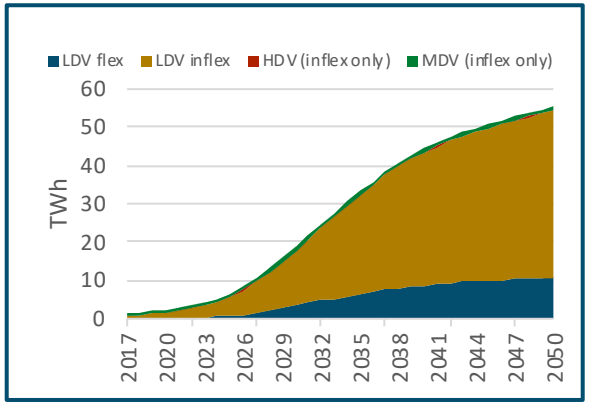
Load growth (TWh)





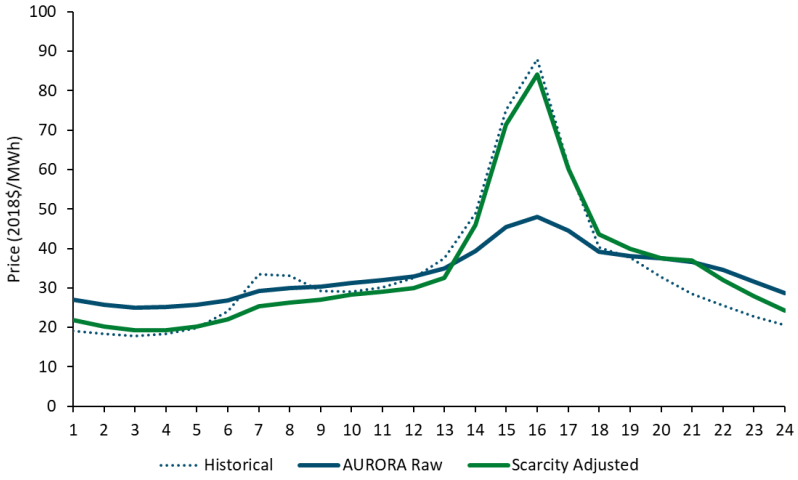
Load flexibility (TWh)





E3 Post Processing

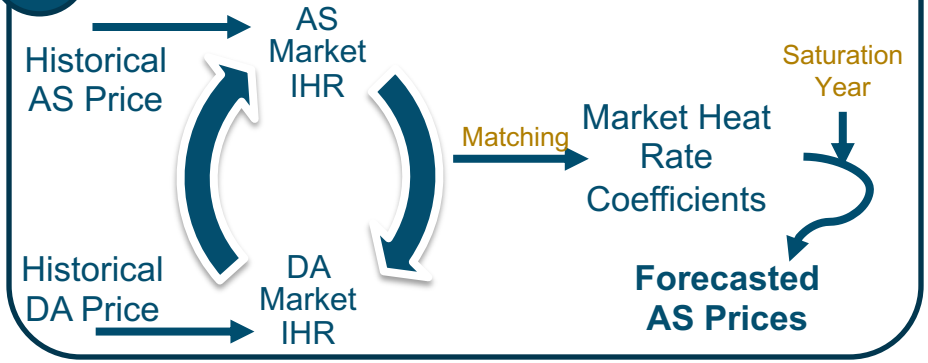
1 Scarcity Adjusted DA Prices



+ **AURORA's dispatch is generally "over-optimized," i.e. it does not capture unplanned outages, import flexibility constraints, gas price volatility, or certain bidding behavior**

2 RT Prices

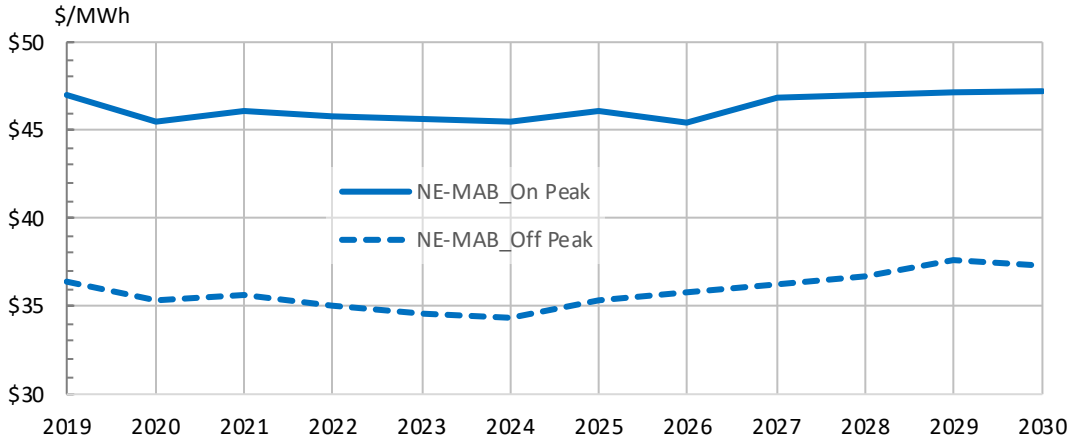
3 AS Prices



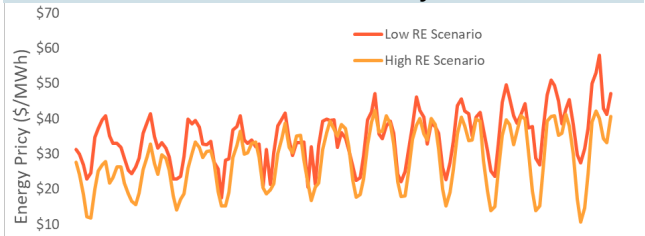
Our Forecasts vs. Competitors (Illustrative)

- **Comparing against other market forecasts, divergence is apparent**
  - Many other forecasts projects higher energy prices with similar historical patterns
  - E3's higher renewable scenarios shows potential for significantly lower average prices which could be offset with higher electrification loads and other fundamental system changes
  - Even if averages converge, daily and hourly shapes are very different where volatility increases with increasing renewables

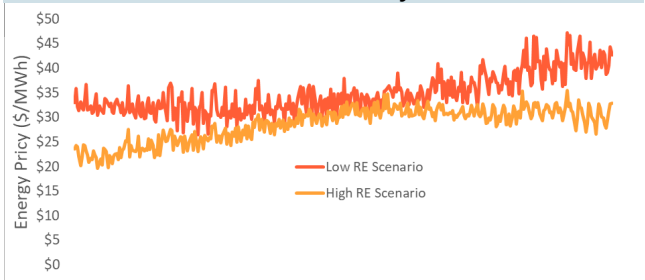
Competitor Energy Price Forecast, 2019-2030 ($/MWh)



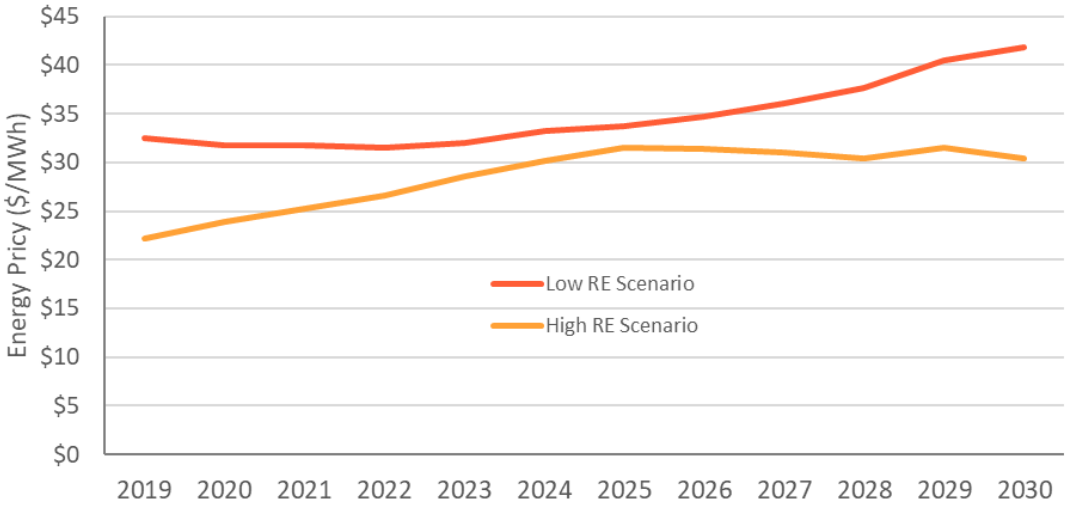
E3 Forecast with Monthly Variation



E3 Forecast with Daily Variation



E3 Energy Price Forecast, 2019-2030 ($/MWh)



Our Partnership with cQuant.io

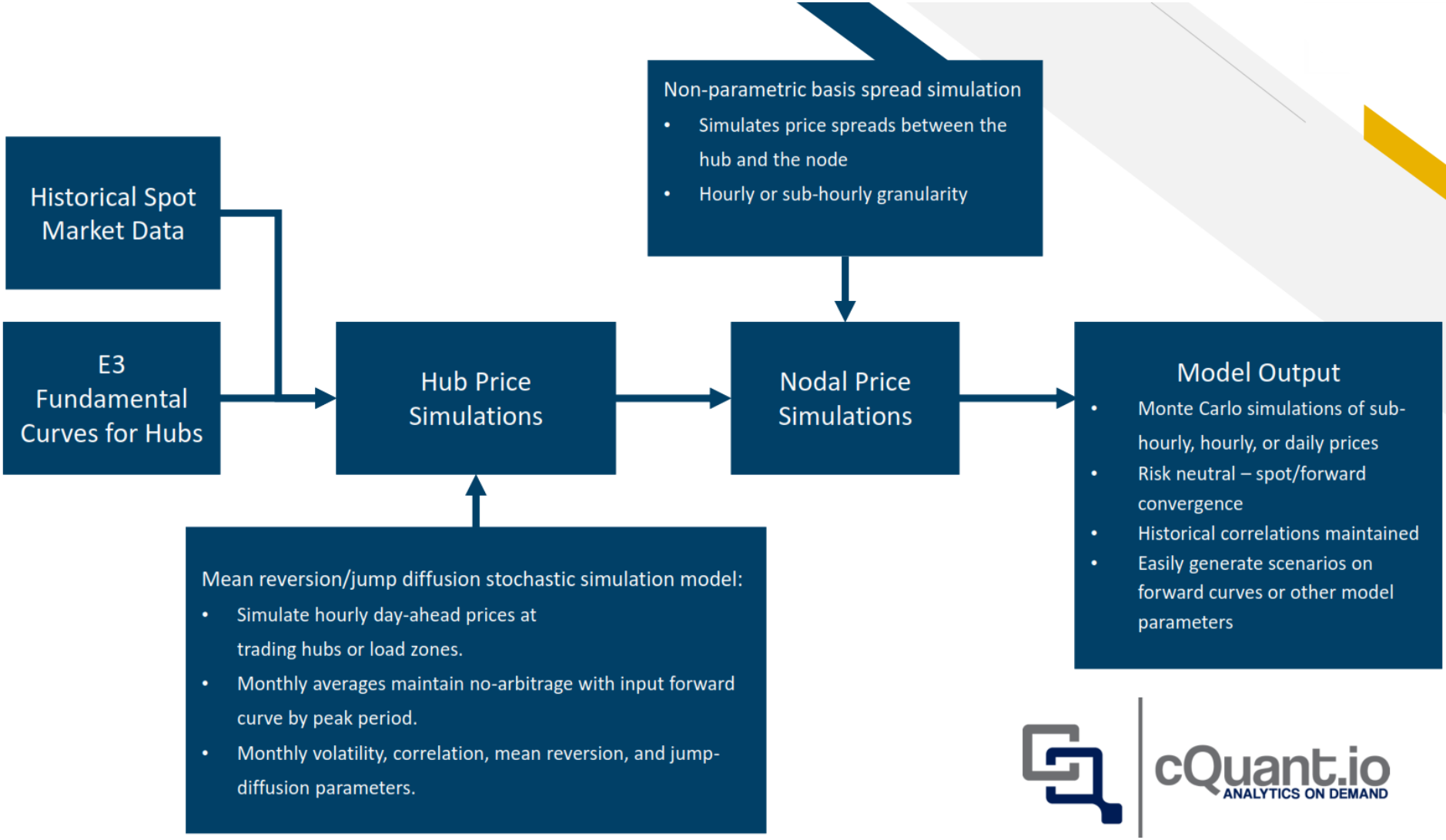
Industry-leading market fundamentals

- Production cost modeling reflects systemic changes in generation mix
- Integrated policy scenarios include RPS/GHG trajectories, distributed resources, electrification, and EVs
- Energy, AS, and capacity forecasts reflect evolving market rules and price formation dynamics

Best-in-class stochastic modeling and simulation

- Advanced, layered modeling approach captures real-world, non-standard distributions in intra-day, monthly, and seasonal dynamics
- Cloud-based platform provides easy, flexible access to models and results

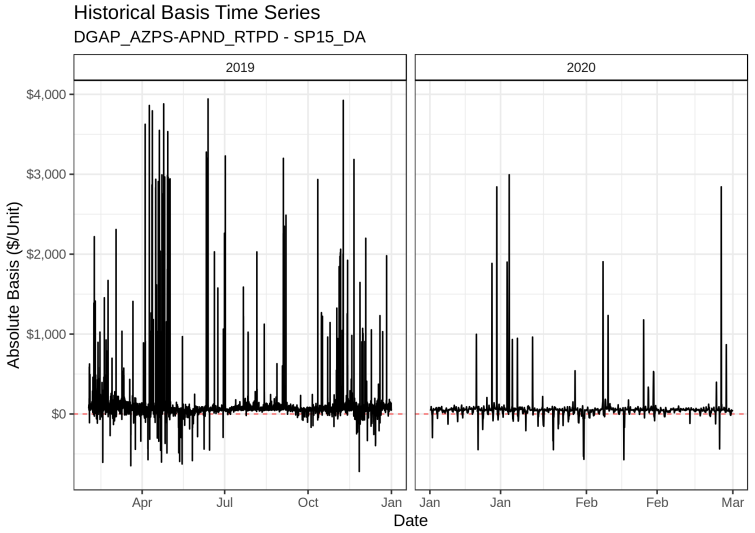
cQuant Nodal Price Simulations

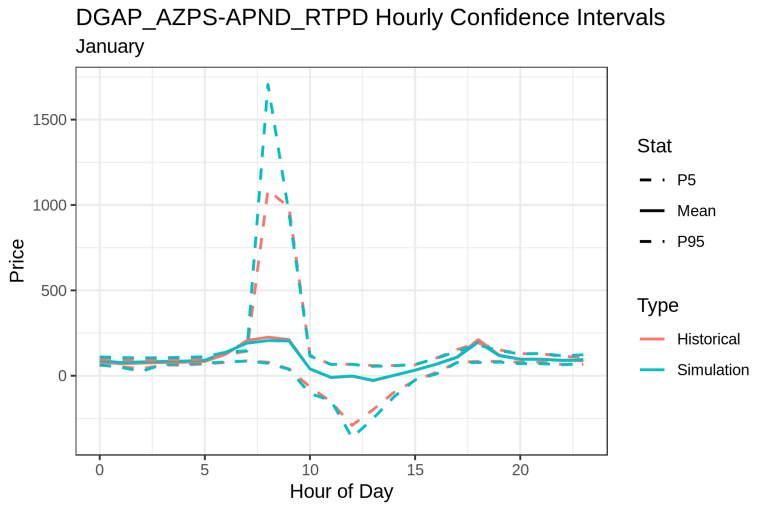


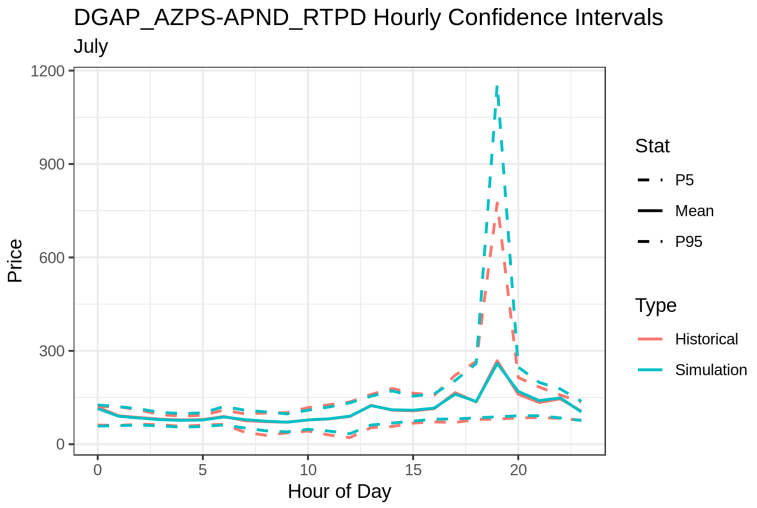
cQuant.io
ANALYTICS ON DEMAND

cQuant Simulation Results

- Capture seasonal, hourly, and sub-hourly trends in expected price and uncertainty.
- Account for hub-to-node basis spreads.
- Accurately reflect negative price dynamics.
- Expected price by month and peak period with sub-monthly spot price dynamics.
- Probability-weighted scenarios to support distributions of value and risk.







Energy+Environmental Economics

Our Offerings: Market Forecasts + Support Services

Our Market Forecast Offerings

E3 offers the following as part of the market price forecasting service:

Outputs for three core scenarios (2020-2050)	•Day Ahead energy prices •Real-time energy prices •Ancillary services prices	•Capacity / RA prices (includes resource specific ELCC curves) •Hourly zonal curtailment
Sensitivities	•Gas, carbon, and load growth scenarios •Resource costs and performance, transmission or model topology	•Other custom sensitivities available on demand
Market Report	•Detailed assumptions and modeling approach •Analysis and commentary on long-term trends and market dynamics	
Optional Support	•Expert support from our senior staff to defend forecasts •General analysis, consulting and engagement support •Revenue forecasting on an individual asset or portfolio level	
Bi-Annual Updates	•Comprehensive global refresh in January •Semi-annual update in June/July	

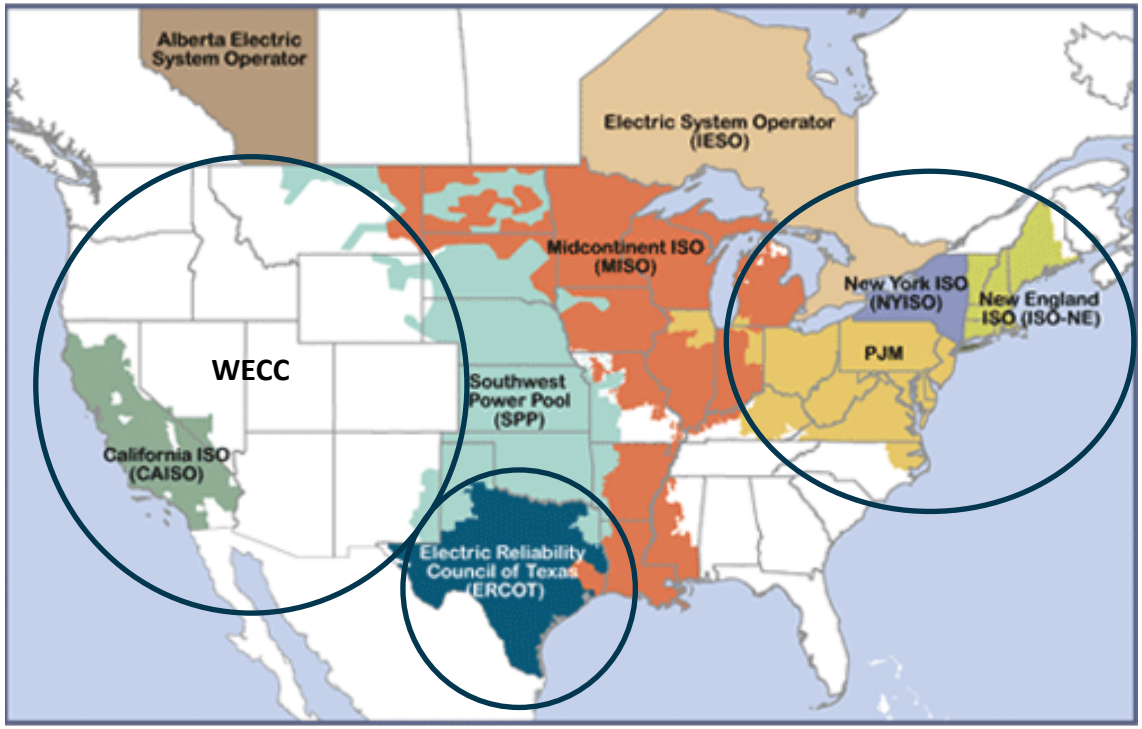
National Coverage, from West to East

Now Available:

+ **WECC**
  - CAISO
  - Pacific NW
  - AZ, NV, CO, NM, UT, WY
+ **ERCOT**
  - All four zones (Houston, North, South, West)

Coming Fall 2020:

+ **PJM, NYISO, ISO-NE**



Source: FERC

For other markets (SPP, MISO, AESO, IESO) and vertically integrated regions such as TVA and Florida, we provide customized forecasts upon request

Additional Services

Strategy

- Market Entry + Go-to-Market
- Investment Strategy
- M&A, Partnerships, and Corporate Strategy
- Business Case / Competition Landscape
- Regulatory Strategy

Project Development

- Project Screening
- Site Selection
- Design + Technology Selection
- Offtake / Contracting
- RFP / Bid Support

Asset Value

- Asset operations
- Revenue projections
- Terminal value assessment
- Policy and regulatory analysis
- Contracting analysis
- Curtailment analysis
- Risk analysis

Expert support,

from Big Picture to Bottom Line.

Energy+Environmental Economics

Forecast packages starting at $20k.
Please contact us for details.

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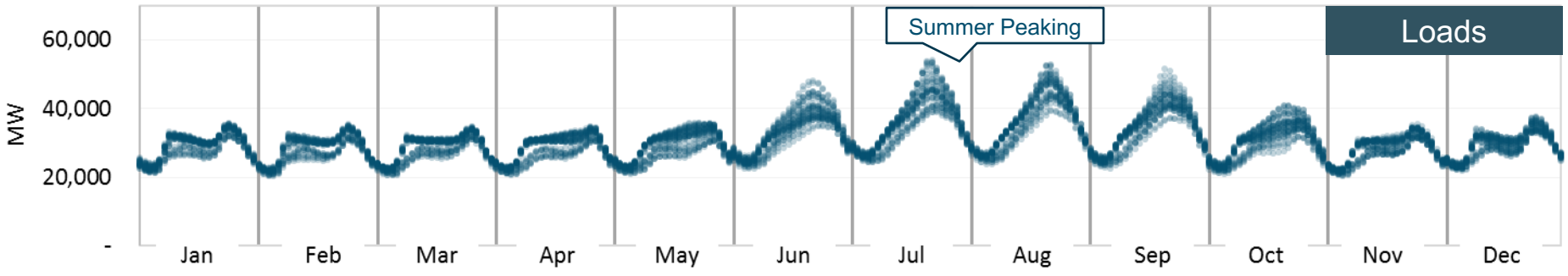
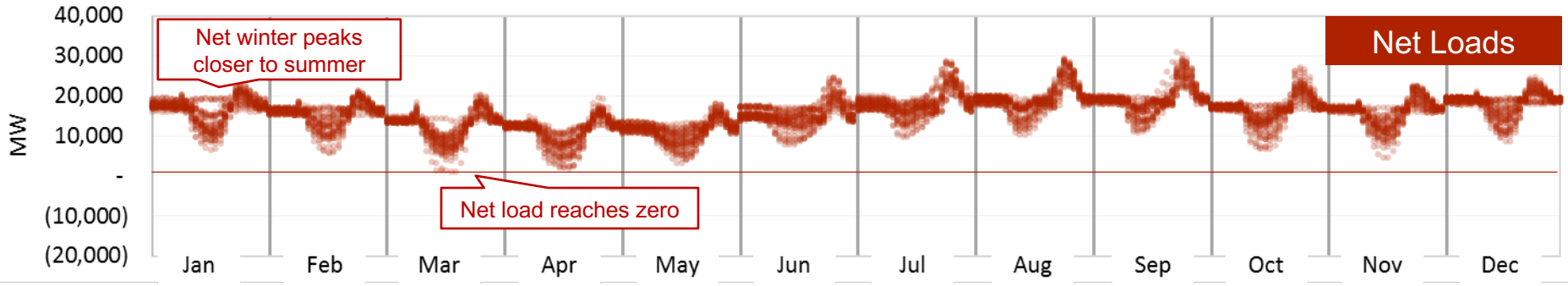
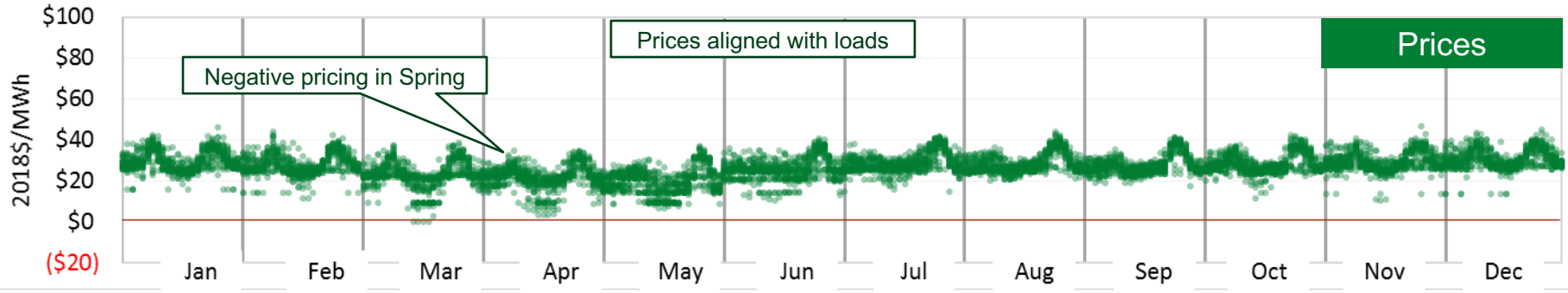
Appendix: Illustrative Outputs

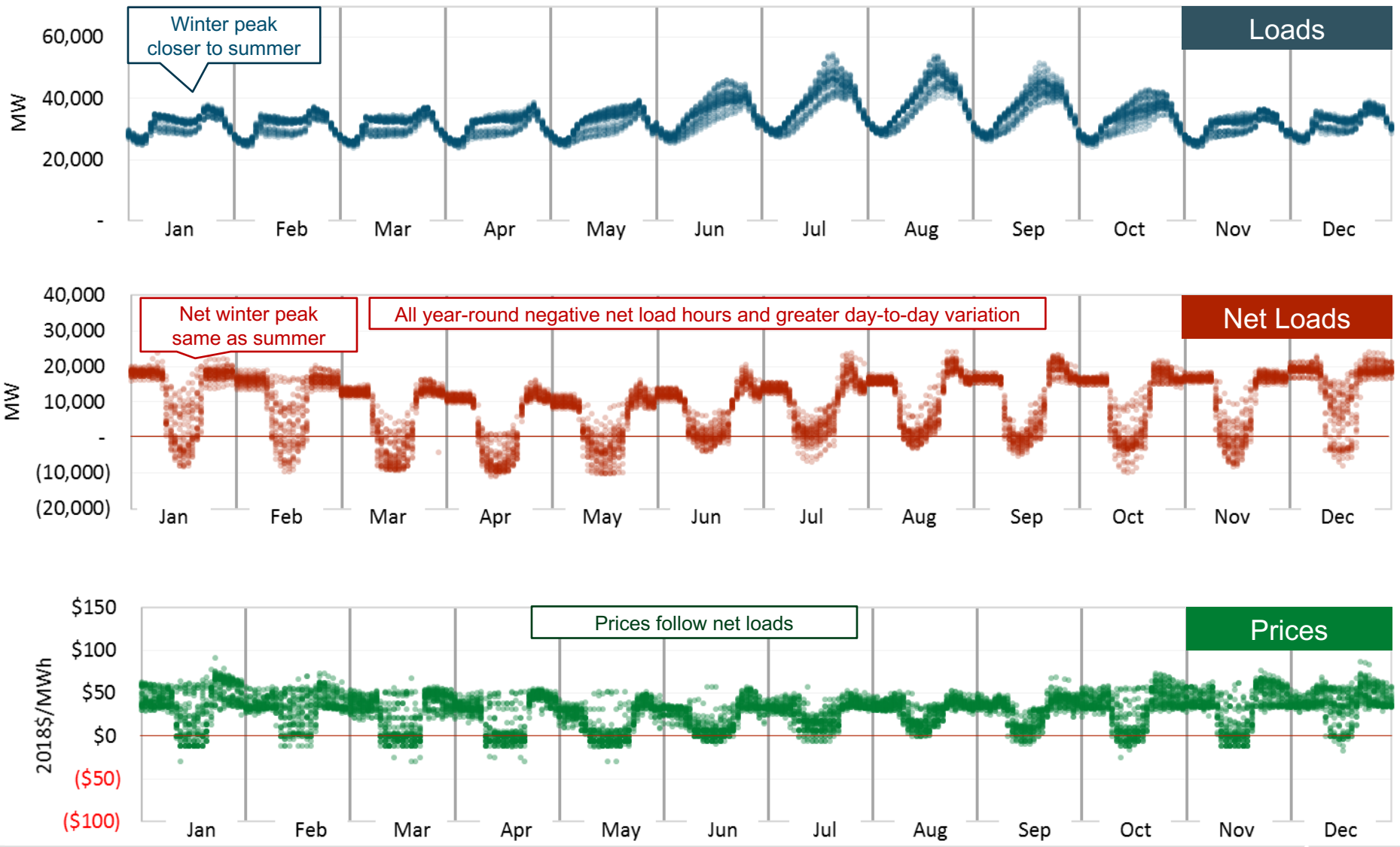
Illustrative Near-Term California Prices



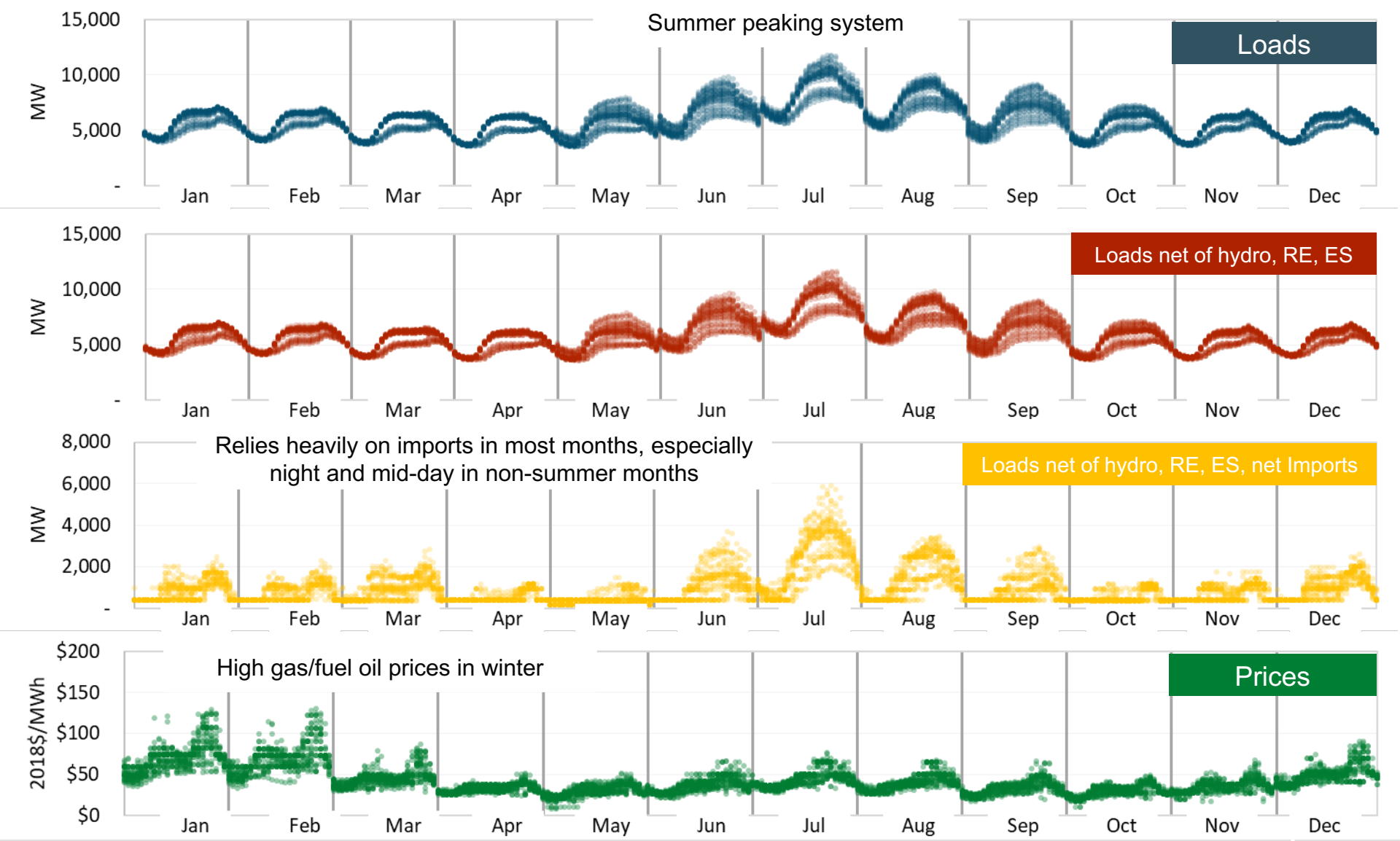




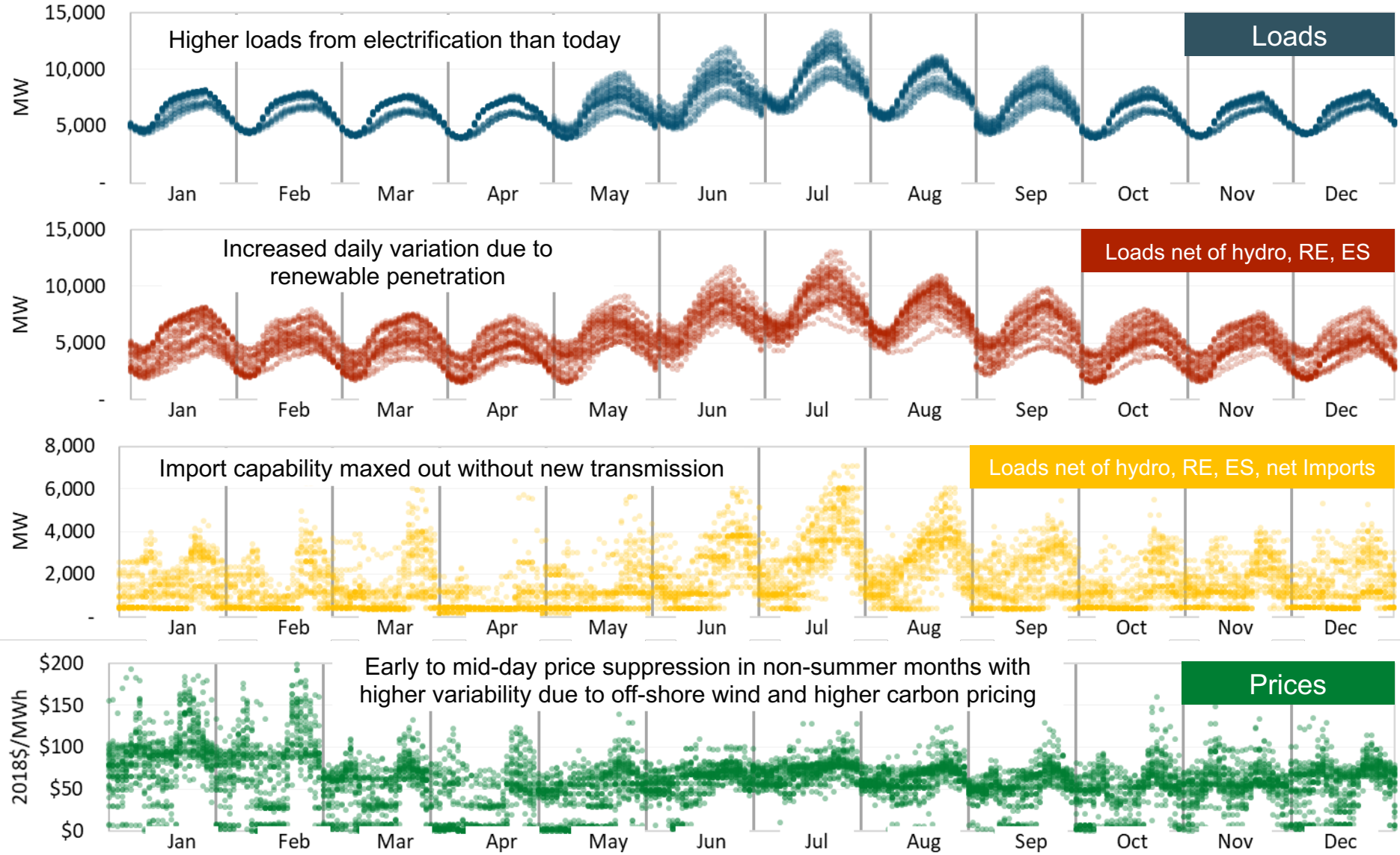
Fast forward to 20XX in California



Illustrative Near-Term New York City Prices



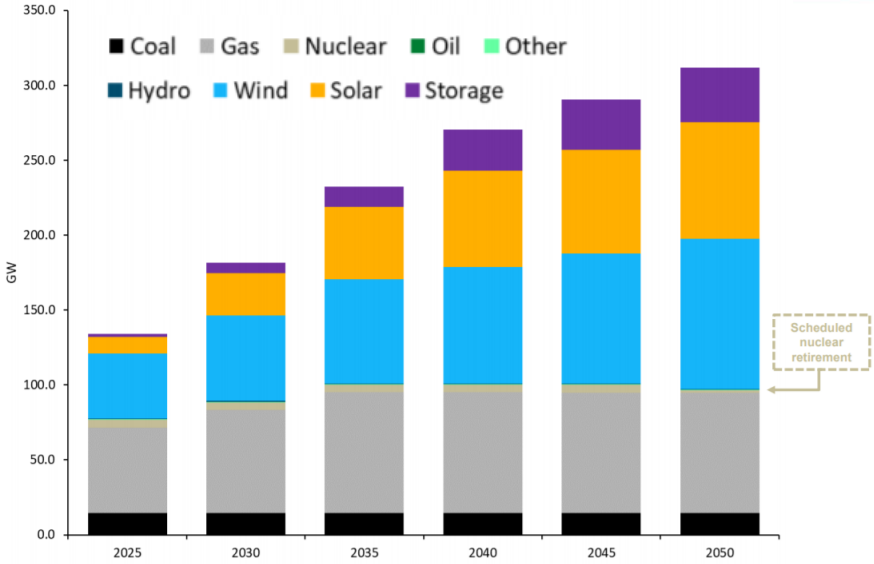
Fast forward to 20XX in New York City



Changing Resource Mix in Texas

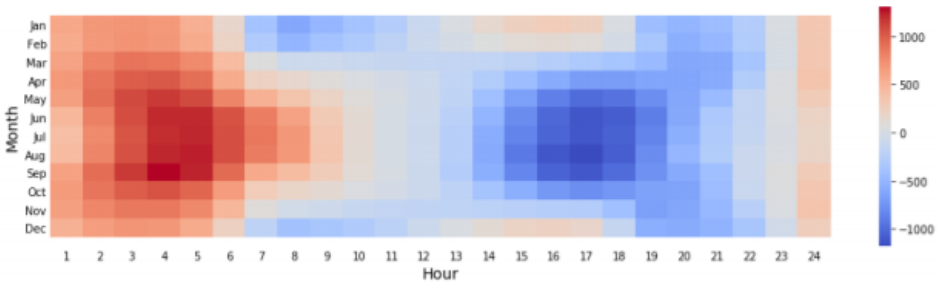
- As solar economics drive increasing penetration, storage additions will likely follow
- Storage economics will be driven by opportunity to charge during lower-priced midday hours and discharge to meet evening peaks

ERCOT Nameplate Capacity, 2025-2050
Illustrative E3 Scenario

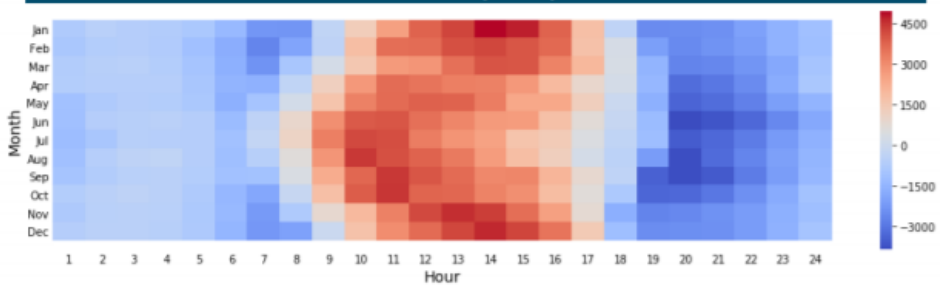


Modeled Storage Charge-Discharge Patterns in ERCOT

2025 (MW)



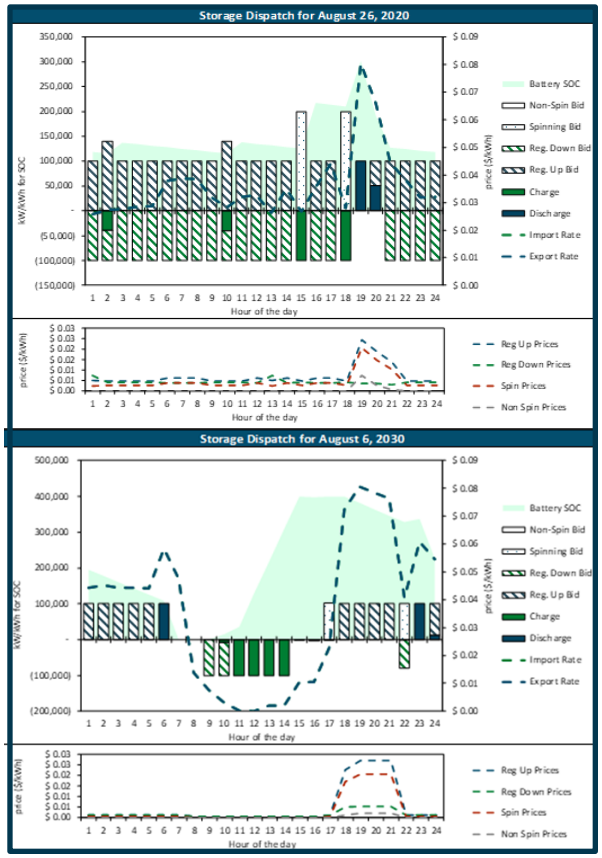
2030 (MW)



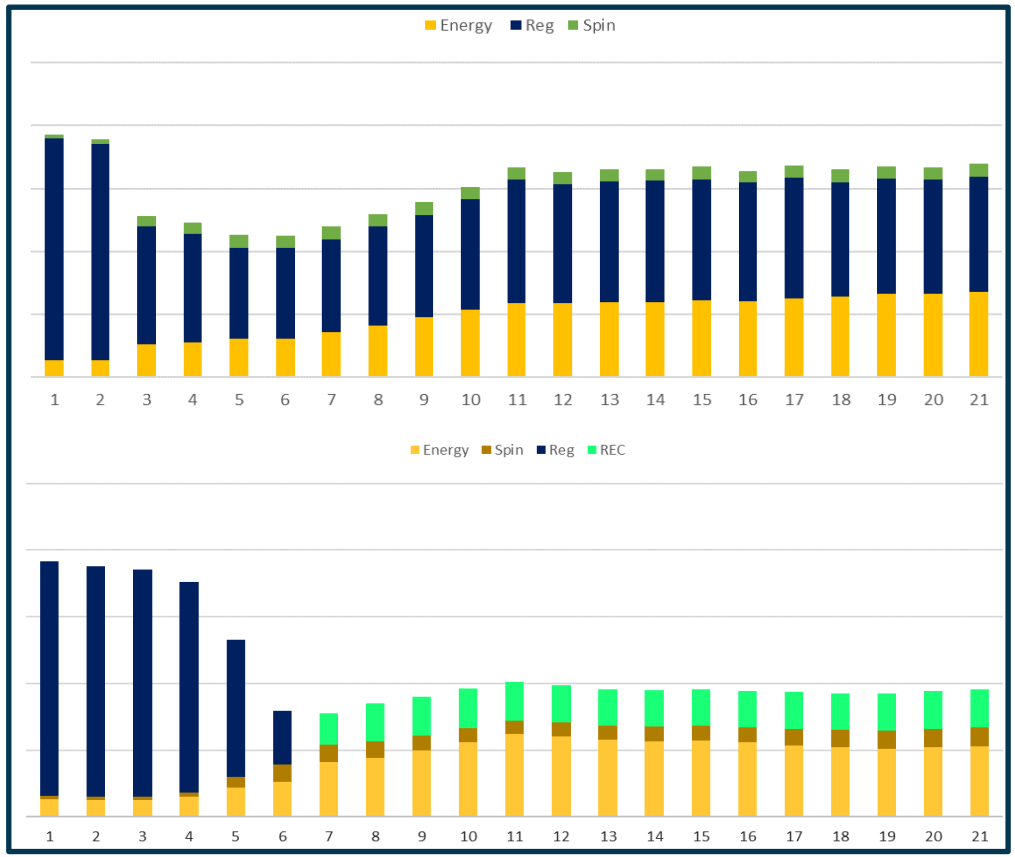
Illustrative Storage Revenues in CAISO

- Revenue trajectories can vary significantly based on policies, prices, operating profile, siting, and market dynamics
- We create detailed revenue scenarios to present the envelope of value based on asset-specific inputs under a range of outcomes

Example Battery Operations



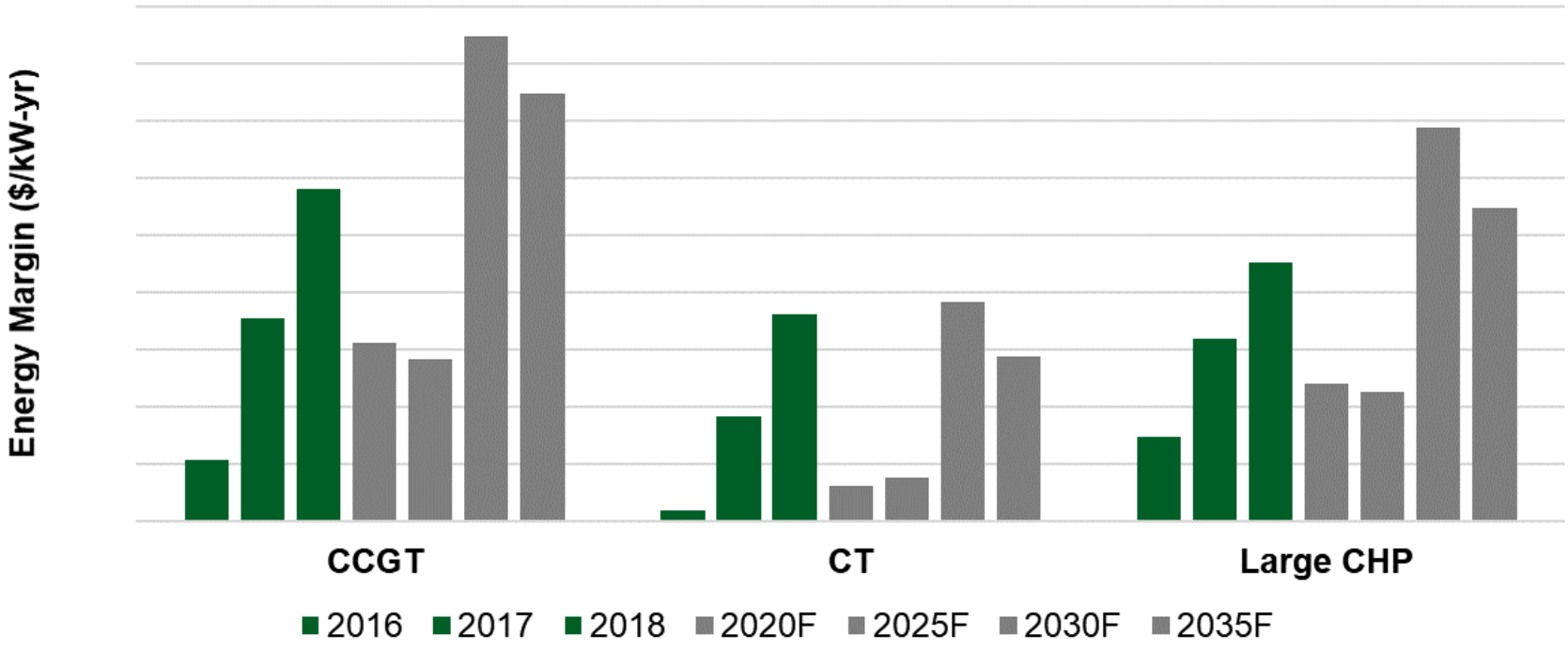
Example Revenue Trajectories



Illustrative Natural Gas Generation Revenue Analysis

+ Example projected annual revenue for CCGTs, CTs, and large CHPs based on E3 market price forecasts and its in-house generation asset dispatch model

Average Energy Margins by Plant Technology: E3 Modeled Backcast and Forecast
$/kW-yr



Illustrative solar- and wind-weighted price outputs and REC price implications

- **Solar value changes rapidly in future, increasing/declining from $XX/MWh today to $XX/MWh in the 20XX-20XX timeframe**
  - Future value driven increasingly by generation in xxx hours and seasonally in the xxx months
- **Wind value increases/declines from $XX/MWh today to $XX/MWh in the 20XX-20XX timeframe**
  - Load growth and large baseload thermal retirements changes wind's value over time along with carbon pricing (if applicable)

Solar-Weighted Energy Value vs. LCOE

	2018	2025	2030	2035
Solar LCOE (34% CF)	$27.75	$27.83	$25.34	$24.41
Solar-weighted energy value	$XX.XX	$XX.XX	$XX.XX	$XX.XX
Residual cost	$XX.XX	$XX.XX	$XX.XX	$XX.XX

Wind-Weighted Energy Value vs. LCOE

	2018	2025	2030	2035
Wind LCOE (38% CF)	$27.38	$37.98	$35.57	$34.57
Wind-weighted energy value	$XX.XX	$XX.XX	$XX.XX	$XX.XX
Residual cost	$XX.XX	$XX.XX	$XX.XX	$XX.XX