

PJM Market Price Forecast E3 Core Case

2023 edition



Energy+Environmental Economics

marketprices@ethree.com



Disclaimer

E3 created the following forecasts and analyses using the best available public information and our expertise and knowledge of the relevant markets, along with commercially available 3rd party software models and proprietary in-house energy market price forecasting tools. However, the future is uncertain, and these forecasts (along with underlying market expectations) may change due to many factors, including unforeseen events, new technology adoption or inventions, new market structures, regulatory actions, and changes in both state and federal government policies. E3 makes no guarantees related to these forecasts or the information presented herein and should not be held liable for any economic damages associated with independent investment decisions.



Contents

- + Executive Summary
- + PJM Market Overview
- + E3 Forecasting Approach
- + E3 Modeling Assumptions
- + E3 Forecast Results: 2024-2050



Energy+Environmental Economics

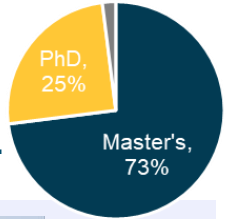
Executive Summary



Who is E3?

Thought Leadership, Fact Based, Trusted.

110+ full-time consultants | 30 years of deep expertise | Engineering, Economics, Mathematics, Public Policy...



San Francisco



New York



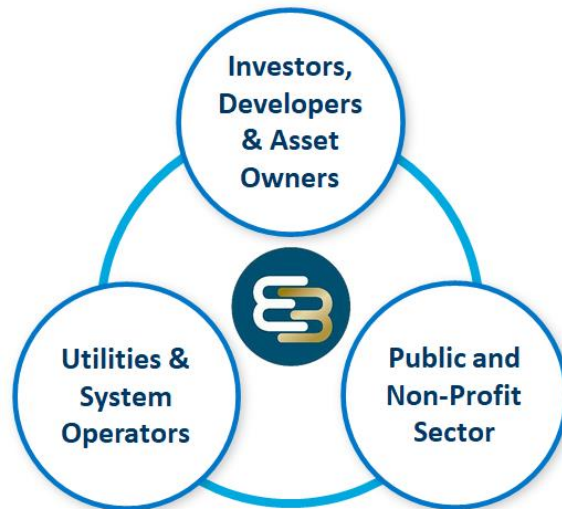
Boston



Calgary

E3 Clients

350+ projects per year across our diverse client base



Recent Examples of Relevant E3 Projects

Buy-side diligence support on several successful investments in **electric utilities** (~\$15B in total)

Supporting investment in several **stand-alone energy storage** platforms and individual assets across North America (15+ GW | ~\$5B)

Acquisition support for several portfolios and individual **gas-fired and renewable generation assets** (20+ GW | ~\$5B)

Acquisition support of several **electric vehicle infrastructure companies** (~\$500M)

Strategic advisory support for a SPAC offering of a **distributed energy resource aggregation software company** (~\$1.3B)

Supporting an investment into an **electric vehicle V2G software company** (~\$750M)

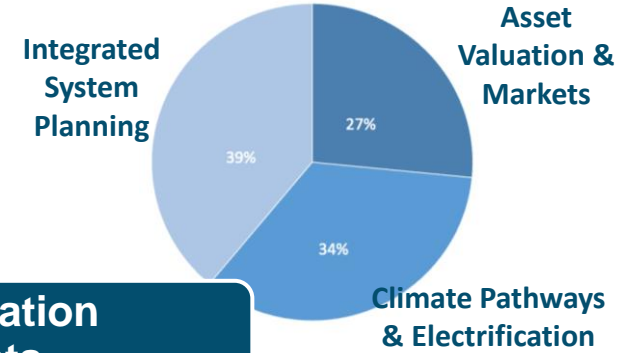
Buy-side diligence support to acquire several **residential and C&I solar portfolios** (~1+ GW | 200,000+ customers)

Supporting investment in over 5+ GW of **community solar and distributed energy resource projects**



E3's 3 Practice Areas

+ E3 has organized itself across three main practice areas to maximize its impact through the diversity of clients, project work, and technical innovation to support the energy transition across North America in a holistic, transparent, and intellectually honest manner



Climate Pathways & Electrification

- Climate pathways studies
- Future of gas
- Low carbon fuels
- Building electrification
- Transportation electrification
- Load forecasting



Integrated System Planning

- Integrated system planning for electricity: G, T, & D & non-wires alternatives
- Utility procurement
- Rate design
- Grid modernization
- Avoided costs
- Distributed resource planning



Asset Valuation & Markets

- Asset valuation and due diligence
- Strategic advisory for commercial clients
- Energy market price forecasting
- Market design & analysis
- DER dispatch & asset optimization

Policy

Integrated Energy Planning

Commercial Interests



E3 Work in PJM

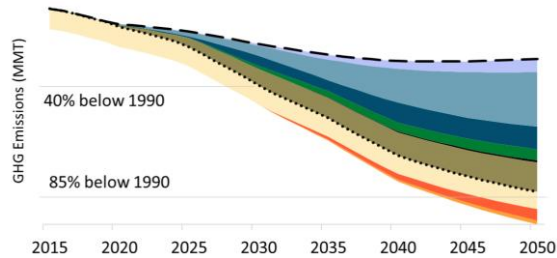
- + E3's experience with such a broad range of industry participants in PJM gives us an unparalleled understanding of policies, regulations, stakeholder interests, market dynamics, contract structures, and the competitive landscape**
- + E3's work in PJM has covered a wide range of topics and clients such that we not only understand the current market but have thought extensively how the market may change over the short-, medium-, and long-term from a holistic, transparent, and intellectually honest perspective**
- + Previous versions of this forecast has been used by a wide range of market participants and stakeholders to support market strategy, project development, and major capital investment decisions across a diverse set of energy asset classes and mandates**
- + Examples of work with participants and stakeholders in the region:**
 - Worked with an asset owner client to explore options for adapting current peaking generators to utilize battery storage resources to reduce emissions and to meet state policy requirements
 - Worked with a large utility client to develop scenarios to meet state decarbonization requirements
 - Worked with PJM technical staff to advance the design and modification of the capacity market towards the use of an ELCC metric for capacity accreditation



E3's Comprehensive and Best-in-Class Modeling Toolkit

PATHWAYS

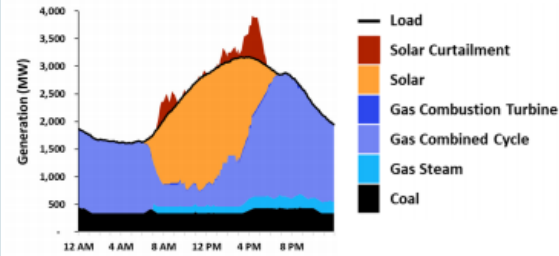
Economy-wide accounting of energy supplies and demands under deep decarbonization scenarios



Production Simulation

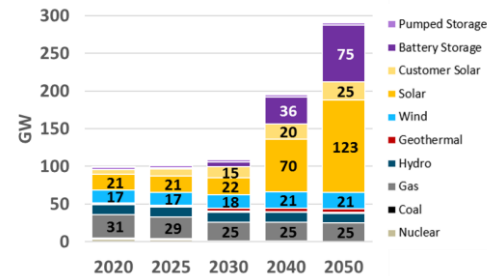
(AuroraXMP and PLEXOS)

Detailed operational simulations of system dispatch and flexibility needs



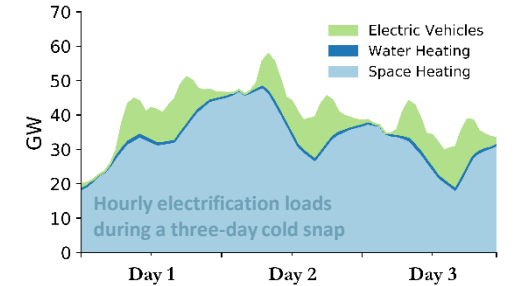
RESOLVE

Optimal capacity expansion model for electric systems



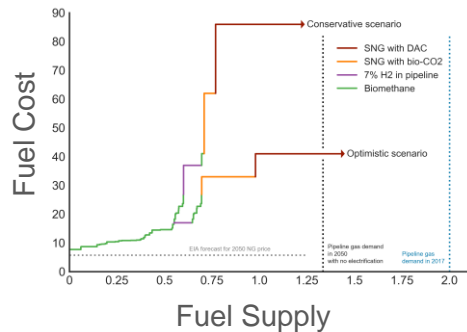
RESHAPE & EVGrid

Hourly simulations of electric loads for specific end uses



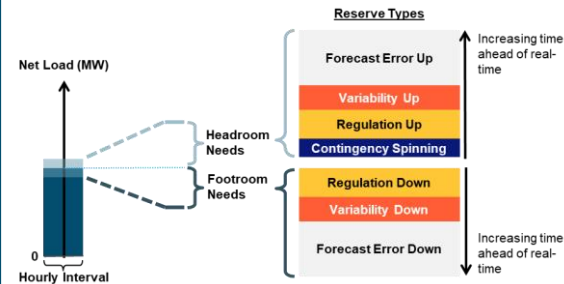
Low-Carbon Fuels and Future of Gas

Role of fuels in deep decarbonization



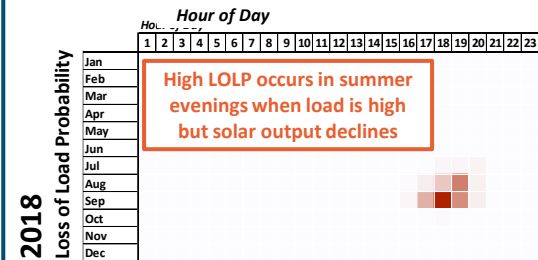
RESERVE

Dynamic operating reserves for renewable integration



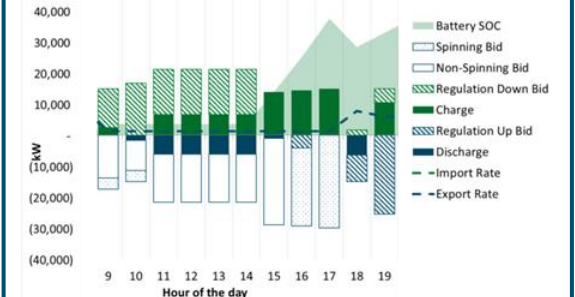
RECAP

Loss of load probability simulation to measure resource adequacy



RESTORE & IDSM

DER Toolkit for optimizing DER value stacking opportunities and adoption



Economy-wide energy systems

Bulk grid power systems

Grid edge & behind-the-meter



Asset Valuation and Strategy Practice Area

- + The Asset Valuation and Strategy practice area works primarily with project developers, asset owners, and investors
- + Insights informed by work being done across the firm that provides a unique 360-degree perspective of rapidly evolving markets
 - Clean Energy Policy → how will policy change the playing field for different resources?
 - Planning → what resources will power the grid in 2020? 2030? 2050?
 - Market Analysis → how will market prices evolve in the grid of the future?
- + The E3 Asset Valuation and Strategy team provides a variety of analytical support tailored to client needs.

+ Typical services include:

- Transaction support and due diligence on both the buy side and sell side
- Strategy formulation and market entry
- Board-level reports on market outlook and asset performance
- Customized forward-market price projections incorporating impacts of policy and technology changes
- Revenue stream/benefits analysis, either on an individual asset or portfolio basis
- Production simulation cost modeling using in-house proprietary tools or customized commercial software
- Project site evaluation
- Off-taker assessments
- Basis spread assessment
- Wholesale market rules and bidding strategies



Asset Valuation / Strategy

- Analyze asset value from multiple perspectives in vertical, bilateral, and wholesale markets
- Strategic support for project development, acquisition, and operation, including market entry
- Proprietary in-house models and in-depth knowledge of public policy, regulation and markets



E3 Model Ecosystem for Market Price Forecasts: Built on Decades of Experience and 360° Analysis

E3 Model Toolkit

Input Models

E3 PATHWAYS

Least-cost decarbonization pathways across sectors to meet GHG targets

E3 RESHAPE

Load simulation for building electrification & EVs

E3 Pro Forma Model

Levelized costs of new resources including financing and tax incentives

E3 RECAP

Stochastic reliability modeling for ELCCs of renewables and storage

Output Models

E3 RESTORE

Optimized battery operations and revenues

E3 Scarcity + RT Price Model

Forecasts scarcity and real-time energy prices with regression analysis

E3 Nodal Price Model

Node-zone basis forecast for nodal prices

E3 Ancillary Services Model

Forecasts AS prices with regression analysis and market saturation

E3 Capacity Market Models

Capacity price formation by market, aligned with unique market dynamics

E3 REC Market Models

Renewable Energy Credit prices aligned with unique market dynamics

Market Price Forecasting Approach

Key Scenario Variables

- 1 **Load Forecasts**
Regional load growth, energy efficiency, building electrification, and EVs
- 2 **Policies**
RPS, CES, GHG, other mandates
- 3 **Regional Coordination**
Transmission, Trading, and policy alignment
- 4 **Costs:**
 - New resource costs
 - Gas prices
 - Carbon prices

AURORA Model Outputs

- 5 **Long-Term Capacity Expansion (Annual)**
New Resource Additions
 - Economics
 - Policies and mandates (RPS, CES, GHGs)
 - System reliability needs
 - Retirements
- 6 **Production Cost Simulation (Hourly)**
Energy Market Forecasts
 - Hourly day-ahead energy prices by zone
 - Dispatch, renewable curtailment, and transmission flows

E3 Forecasts

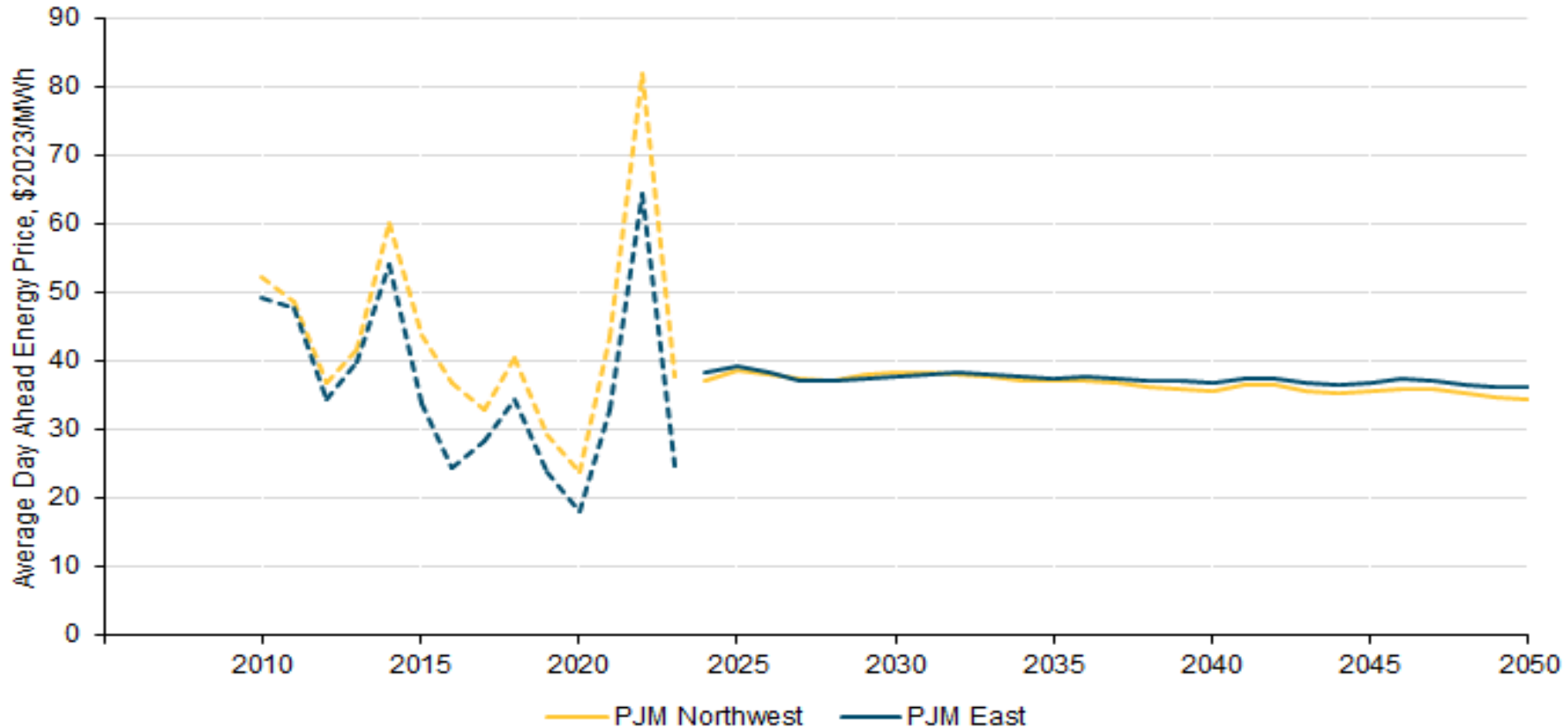
| Market Product | Geographic Granularity | Temporal Granularity |
|----------------------------------------------------|------------------------|----------------------|
| Energy (Day-Ahead and Real-Time) | Zonal | Hourly |
| Capacity (low, medium, high forecasts) | System / Local | Annual |
| Ancillary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

Fundamentals-based market modeling built on day-ahead energy prices



PJM East and PJM Northwest Annual Average Prices

- + Annual average prices expected to stabilize after volatility over historical period and decline in last 2 years as higher gas and power prices increase energy margins
- + Longer term, prices remain stable as wind and solar builds meet load growth and retiring thermal capacity



* Average annual prices for the historical years are pulled from ABB's Velocity Suite through October 2023, and are shown in nominal unadjusted numbers



Energy+Environmental Economics

PJM Market Overview



Energy+Environmental Economics

E3 Forecasting Approach



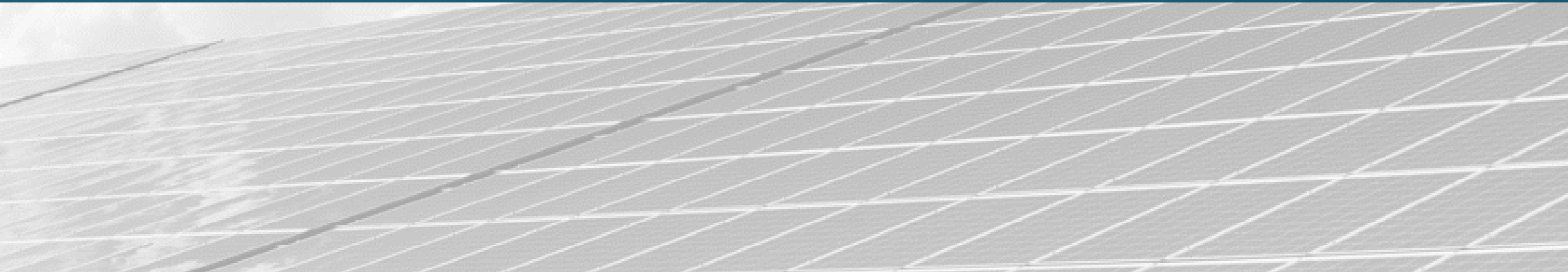
Energy+Environmental Economics

E3 Modeling Assumptions



Energy+Environmental Economics

E3 Forecast Results: 2024-2050





Energy+Environmental Economics

Appendix: Inflation Reduction Act (IRA)