Enabling Smarter Investment Decisions for Distributed Energy Resources

BUSINESS PROBLEM

Large commercial buildings in deregulated U.S. electricity markets face escalating costs due to volatile wholesale prices and punitive peak-demand tariffs. Traditional planning tools rely on smoothed averages that miss the sub-hourly price spikes dictating Distributed Energy Resources (DER) profitability, while short-term operational models cannot evaluate multi-year capital investments. Large enterprises need a rigorous, data-driven framework to confidently size and deploy behind-the-meter DER portfolios (solar, battery storage, and fuel cells) that minimize total cost of ownership under stochastic market conditions.

DATA SOURCES

Metered Load – 15-min grid import kW (24 months, Company)
Wholesale Prices – 5-min RT & hourly DA LMPs for PJM, CAISO, ERCOT
Solar Irradiance – 15-min GHI (NSRDB/NASA)
Weather – Daily max temp (Meteostat API) Occupancy – Daily headcount (Company)
Retail Tariffs – JCP&L utility & Constellation supply rates
Henry Hub – Daily gas spot price (EIA)

DATA TYPES AND FORMAT

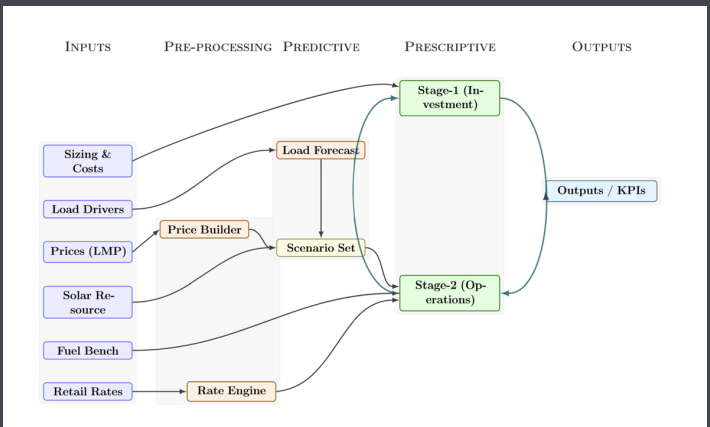
Categorical (nominal), Count (integer), Numeric, Spatial, Static, Structured, Time series (Dynamic)

APPROACH

A two-phase predictive-prescriptive framework:

Phase 1 (Predictive): A 168-model Random Forest ensemble with a conditional generative noise model synthesizes 15-min stochastic building load scenarios. A price-builder engine constructs forward-adjusted wholesale daily prices via temperature-bucketed pairing.

Phase 2 (Prescriptive): A two-stage stochastic Mixed-Integer Linear Program co-optimizes DER portfolio sizing (solar, BESS, fuel cell) and sub-hourly operational dispatch across thousands of scenarios, with a custom rate-calculator engine replicating actual retail tariff billing logic.



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IMPACT

The co-optimized DER portfolio (750 kW / 3, 000 kWh battery, 1, 000 solar panels, 1 fuel cell) reduces the pilot building's annual utility costs by 58% versus the do-nothing baseline (from ~$2.03M/yr to ~$0.84M/yr). This translates to ~$1.18M in annual operational savings against a $16.8M one-time CAPEX investment, yielding a 6.8% ROI with a 14.7-year payback.

Key quantified results:
- 58% reduction in annual electricity operating costs
- Peak monthly grid demand cut by 40-60% through coordinated battery dispatch and fuel cell baseload offset
- Co-optimized portfolio outperforms best standalone technology by 17% in annual savings ($1.18M vs $1.01M for fuel cell alone)
- Rate engine validated to within ±5% of actual historical utility bills
- Simulated load distribution statistically matches historical out-of-sample data
- Portfolio remains robust across market regimes: 15.1% savings under PJM, 19.0% under CAISO, 19.3% under ERCOT pricing
Framework is modular and scalable: can be deployed across diverse real estate portfolios by swapping site-specific metered data, tariffs, and building constraints. It is building-specific.

DRIVERS

PJM capacity auction prices surged 833% from 2024/25 to 2025/26, making peak demand a dominant cost driver. Corporate net-zero mandates require transitioning from passive consumers to active grid participants. Traditional tools cannot capture sub-hourly tariff volatility, creating a clear need for data-driven DER investment frameworks.

BARRIERS

Integrating heterogeneous data sources at 15-min resolution; modeling complex, site-specific retail tariff structures with proprietary formulas; preserving realistic tail -event volatility in long-horizon synthetic scenarios; and managing computational cost of evaluating thousands of portfolios across stochastic scenario ensembles.

ENABLERS

Access to 24 months of granular 15-minute metered building data from the company; wholesale market data from PJM, CAISO, and ERCOT; Gurobi optimization solver for the MILP; strong sponsorship from the energy management team; and academic guidance from MIT advisors in stochastic optimization and electrical engineering.

ACTIONS

Integrated 10+ datasets into a unified 15-min analytical base. Built a rate-calculator engine replicating utility billing, validated to ±5%. Developed a 168-model RF ensemble with conditional generative noise for load simulation. Constructed forward-adjusted price scenarios via temperature- bucketed pairing. Implemented a two-stage stochastic MILP with parallelized search. Stress-tested the portfolio across three U.S. market regimes.

IMPROVEMENT

58% reduction in annual utility costs ($2.03M to $0.84M). Co-optimized portfolio delivers 17% more savings than best standalone tech. Peak grid demand reduced 40-60% monthly. Robust across markets: 15-19% savings under PJM/CAISO/ ERCOT. Rate engine achieves 1.7% error vs. actual bills.
First quantitative foundation for confident DER capital allocation across a large real estate portfolio.

BEST PRACTICES

Design the data pipeline robustly before the optimization model. Validate supporting engines (rate calculator, solar simulator) against ground truth. Co-optimize technologies jointly (synergies compound significantly vs. silo evaluation). Use scenario-based stochastic inputs rather than smoothed averages to capture tail risk driving peak costs.

OTHER APPLICATIONS

The framework is market-agnostic: extensible to any restructured grid (e.g. CAISO, ERCOT) by swapping tariff inputs. Applicable to any large commercial portfolio (data centers, hospitals, campuses, manufacturing). The engine also supports short-term operational dispatch and demand response evaluation. This requires 15-min building load data.