Modeling Optimized Energy Project Structure under California's Resource Adequacy Slice-of-day Framework

BUSINESS PROBLEM

Renewable project development in California has become increasingly costly and time-consuming due to limited land availability, rising interconnection costs, and lengthy permitting processes. With energy demand projected to increase for the first time in decades, utilities and other load serving entities require large amounts of low-cost power. As California's grid transitions toward renewable energy, the daytime solar surplus of solar energy must be stored and shifted to serve nightly loads, creating a growing mismatch between supply and demand that 4-hour batteries cannot adequately bridge. Additionally, new slice-of-day RA regulations must be understood and incorporated into the development process for new energy projects in California.

DATA SOURCES

1. CPUC Report on Resource Adequacy - detailed description of slice-of-day accounting rules

2. RA Showing Template - Excel tool to calculate LSE RA showings, includes the resource database

3. CPUC Master Resource Database (MRD) - contains information about CAISO generation projects and generation profiles

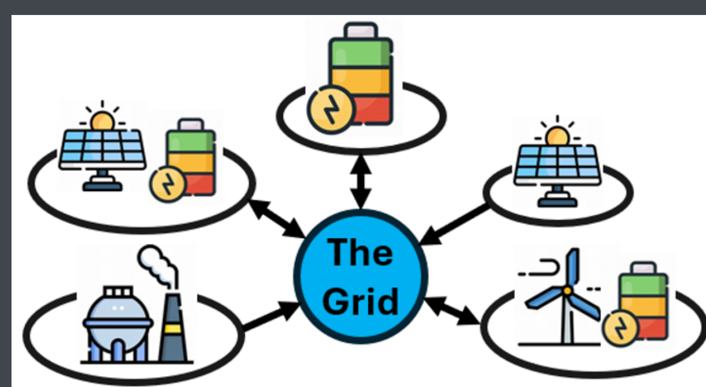
4. CEC Demand Forecasts - hourly power demand curves from 2025 through 2040.

Data Types and Format

Numeric, Structured

APPROACH

An optimization model was constructed to determine project formats responsive to the regulations in CAISO's new resource adequacy (RA) slice-of-day framework. The copperplate, capacity expansion model was developed in Python using the Gurobi optimizer. This model minimizes the cost of new construction required to meet CPUC-mandated RA demand requirements incorporating round-trip efficiency losses, battery capital costs, solar exceedance values, and deliverability status while ensuring new charging sufficiency requirements are met year-round.



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IMPACT

The analysis demonstrates that solar overbuild and longer duration battery construction are economically viable given nominal assumptions for demand growth. Results also indicate the optimal DC:AC ratios for construction of solar, storage and interconnection. Without new natural gas plant construction, nuclear power emerges as a potential carbon-free generator in California. For developers like NextEra, the model provides a replicable framework to identify optimal project designs that decrease the cost per MWh, provide RA credit, and increase resource firmness.

DRIVERS	California's SB 100 mandate requires 100% renewable resources for all retail electricity by 2045. This has resulted in a rapid transition toward renewable energy and an effective prohibition on new natural gas plant construction. Simultaneously, energy demand in California is increasing for the first time in decades.
BARRIERS	An 8760 model with over 1, 000 existing CAISO projects required solving millions of decision variables and utilizing significant memory. The treatment of longer-duration storage under the new RA regulations also remains insufficiently defined.
ENABLERS	Access to comprehensive public datasets from the CPUC and CEC, including the Master Resource Database and the RA Showing Template, provided the detailed generator-level parameters necessary. Subject matter experts at NextEra Energy provided insight regarding the practical constraints that would shape the model design.
ACTIONS	Research began with an exploratory analysis of the Master Resource Database to validate that its data could reproduce published CAISO resource adequacy figures, confirming data integrity before model construction. Three optimization models were then sequentially developed: a base capacity expansion model, an RA buffer maximization variant, and a full-year, 8760 model. RA demand curves were extrapolated from CPUC-provided peak-day data.
INNOVATION	The RA buffer metric provides a novel proxy for grid reliability reliant on the slice-of-day framework. The core of this work was the construction of the first known optimization model explicitly designed around the CAISO RA slice-of-day framework. By modeling all 8, 760 hours of the year rather than only peak days, the model ensures that charging sufficiency constraints are binding year-round, not just during the highest-load days.
IMPROVEMENT	Implementation of the proposed adjustments to project sizing are estimated to reduce capital requirements by roughly 10% and reduce interconnection costs by almost two thirds. This would result in faster deployment of capital and shorter construction timelines.
BEST PRACTICES	An object-oriented model clarified the separation between system-level and project-level parameters. When scaling the model to 8, 760 hours, computational load was reduced by merging plants with common parameters. Finally, construct test scenarios with known outputs to validate the model.
OTHER APPLICATIONS	The optimization framework developed in this thesis is directly applicable to any load serving entity operating under the CAISO RA slice-of-day framework seeking to evaluate generation mix decisions or the adoption of longer-duration storage. The capacity expansion model could also be extended to evaluate the economics of storage and energy arbitra