Clean Coalition

Affordability through **Energy Tetris**:
Implementing Integrated Grid Planning in California

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Mission

To accelerate the transition to renewable energy and a modern grid through technical, policy, and project development expertise.

Renewable Energy End-Game

100% renewable energy; 25% local, interconnected within the distribution grid and ensuring resilience without dependence on the transmission grid; and 75% remote, fully dependent on the transmission grid for serving loads.

Three grid dimensions need constant balancing

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Service	Key to Delivering Service
Energy Balancing	Capacity of real power (W)
Voltage Balancing	Location of reactive power (VAr)
Frequency Balancing	Speed of sourcing or sinking real power (W)

The Duck Chart only addresses Energy Balancing, but Inverter-Based Distributed Energy Resources (IBDER) can provide unparalleled balancing of all three dimensions.

San Onofre Nuclear Generating Station (SONGS) replacement case study:
261 MVAr needed for Voltage Balancing in 2012

or

290 MVars of synchronous condensers in Huntington Beach (minus line losses = **261 MVar**)

570 MW of local solar alone with grid-forming inverters, oversized by 10% set at 0.9 Power Factor = **261 MVAr**

- **Transmission Access Charges (TAC):** These are volumetric ($/kWh) charges assessed to customers to recover costs of <u>historical and present</u> investments in transmission infrastructure.
  - The chart below shows that the average TAC rate in the IOU service territories has more than tripled over the last 11 years.
  - Since 2008, the IOU's base annual Transmission Revenue Requirement (TRR) has increased from $4.6 billion to $21 billion.
- **Future Transmission:** CAISO estimates that $30 billion in transmission capex will be needed over the next 20 years (for the high-voltage system only, not including low-voltage).
- The upfront capital cost of a transmission project is only 10% the full cost in nominal dollars shouldered by the ratepayers when considering profit and O&M over 50-year transmission depreciation schedules.

Nominal costs

Asset value capital cost ($100 base)	$100
Return	$197
O&M	$631
Total nominal ratepayer cost per $100 investment (50 years)	**$928**

Real costs, discounted for inflation

Discount rate	2.19%
Asset value capital cost ($100 base)	$100
Return, discounted	$140
O&M, discounted	$296
Total discounted (real) ratepayer cost per $100 investment (50 years)	**$536**

In nominal dollars, total lifetime ratepayer cost is nearly 10x the initial capital cost; O&M accounts for 68% of this because it increases much faster than inflation. In real dollars (constant value dollars, accounting for inflation), the total lifetime cost is 5x the initial capital cost, and O&M accounts for 55% of this.

2025 TAC (wholesale rates)

PG&E	$0.037/kWh
SCE	$0.0153/kWh
SDG&E	$0.066/kWh

California Statewide Energy Planning Processes – High Level Overview
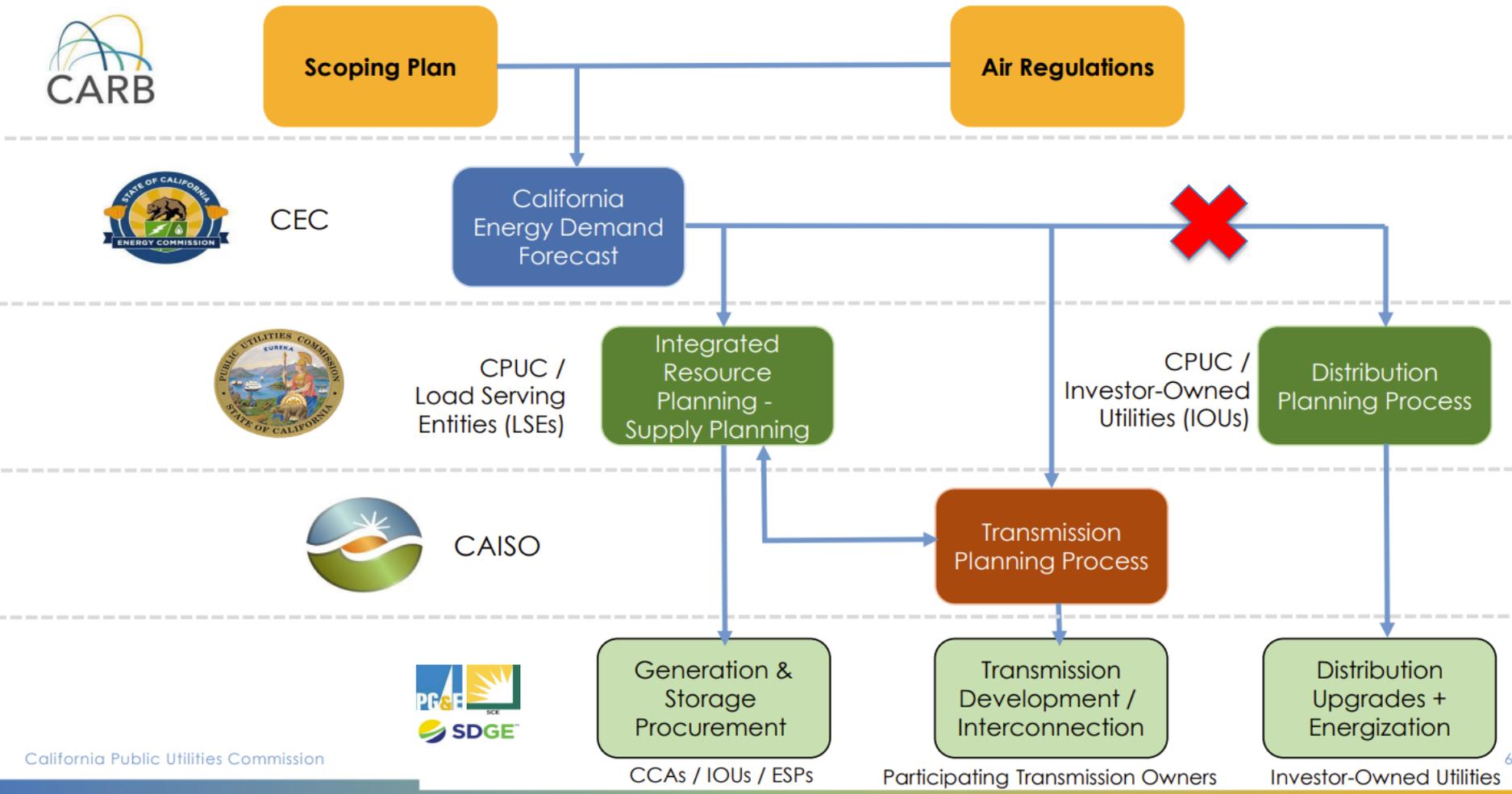
CAISO Demand Curve

August 20, 2025 Net Demand Trend

Meeting Total Demand with Baseload Power

August 20, 2025 Net Demand Trend
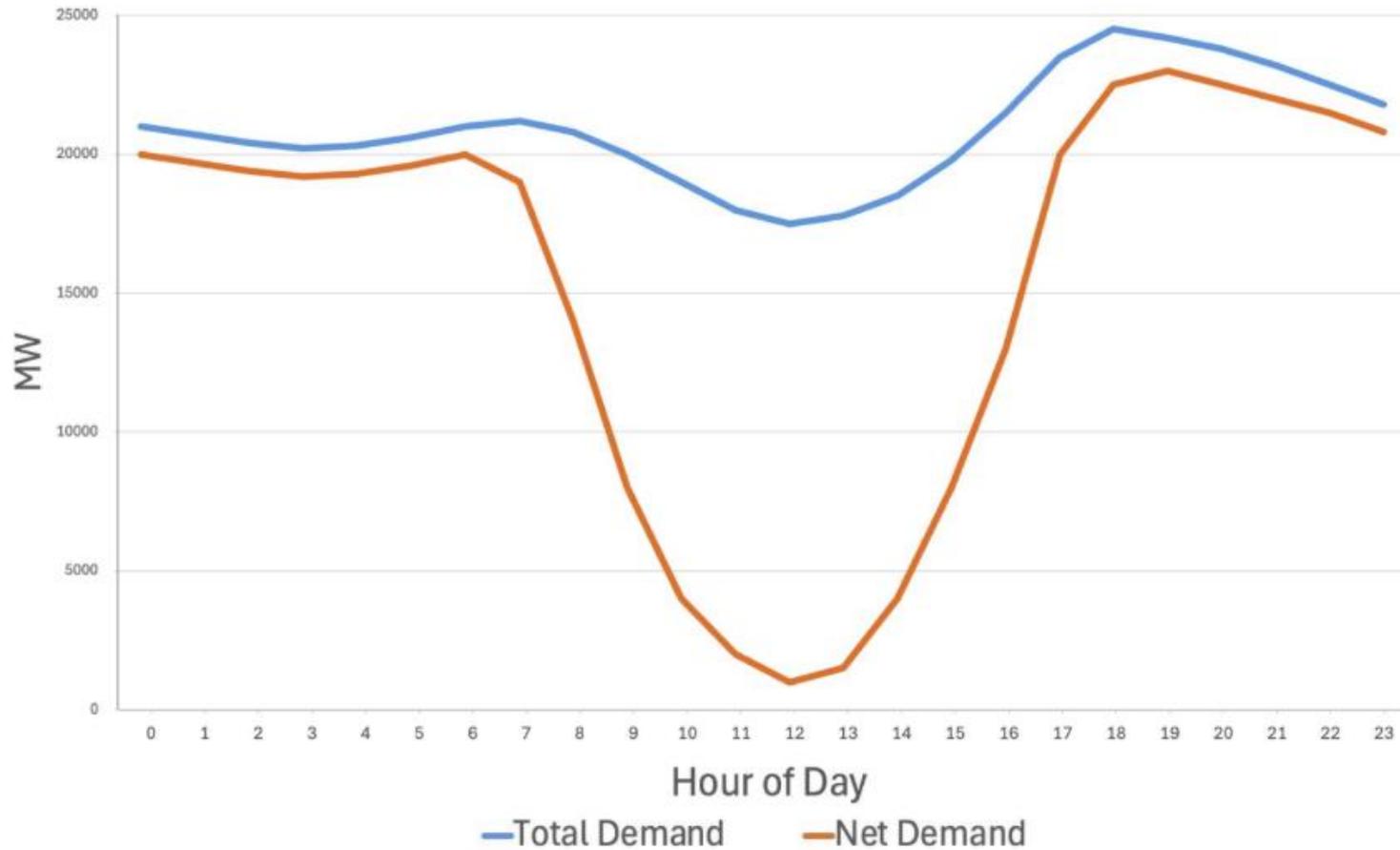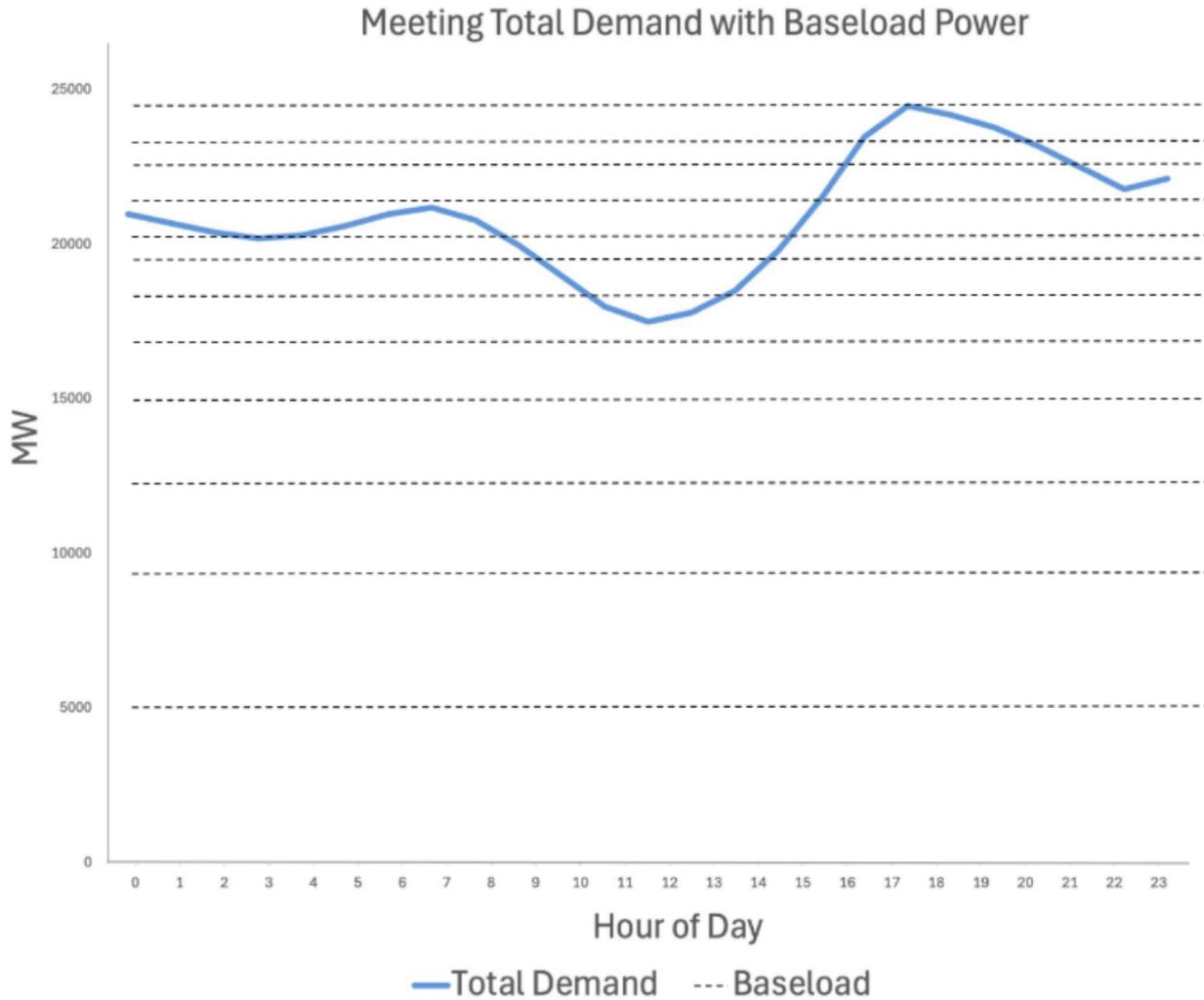
CA Electricity Supplies on the 2024 Peak Load Day
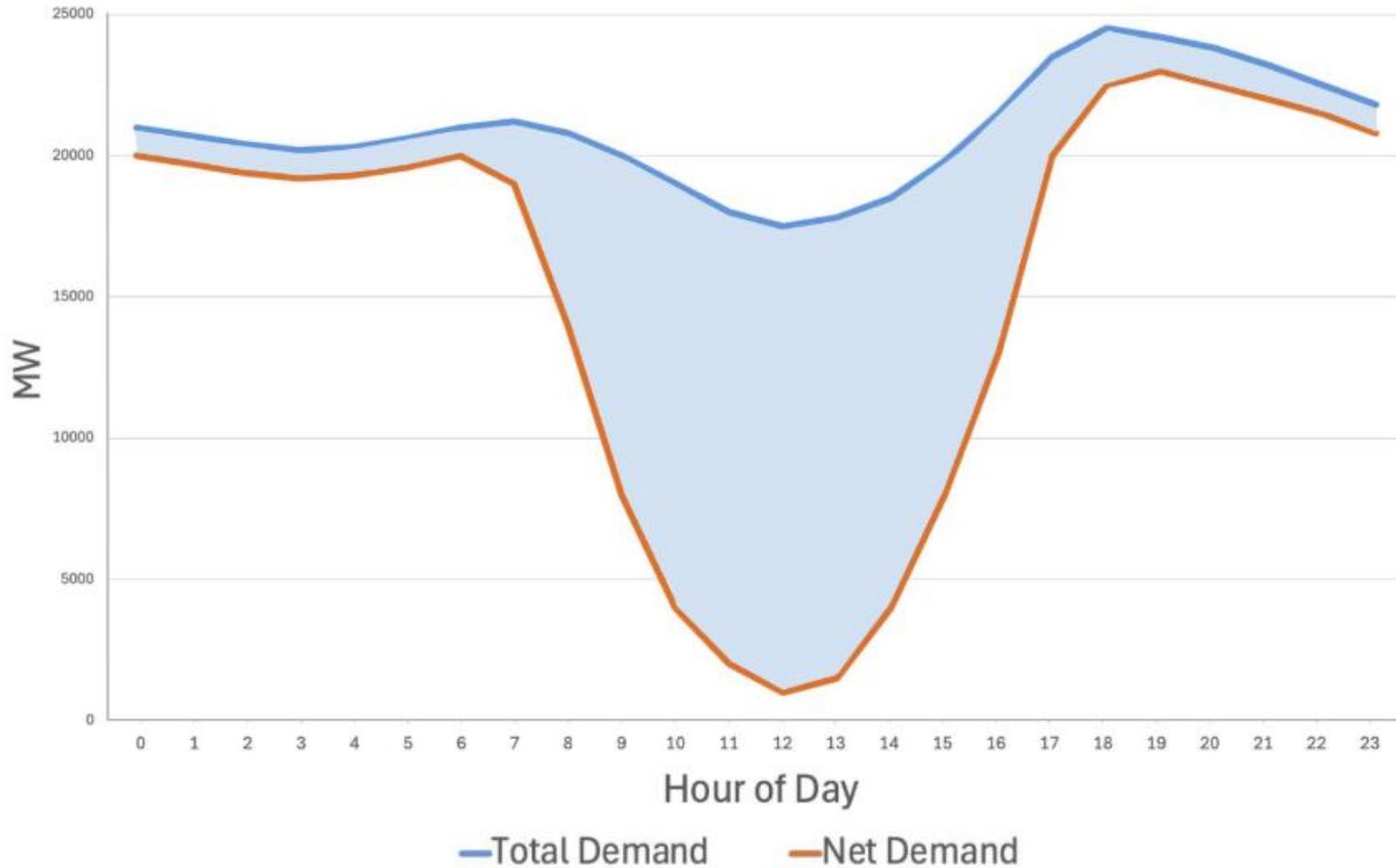
NEM Customers Serve Nearly 20% of Peak Demand

Customers' site load peak

CAISO metered peak

Legend:
- Customer Batte...
- Rooftop Solar
- Large Scale Bat...
- Large Scale Sol...
- Wind
- Small hydro
- Biogas
- Biomass
- Geothermal
- Natural gas
- Imports
- Large hydro
- Nuclear
- Gross Demand
- Grid Demand
- Net Demand

Y-axis: Megawatt Demand (60,000 / 50,000 / 40,000 / 30,000 / 20,000 / 10,000)

X-axis: Hour of the Day (1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24)

Source: CAISO website; California Distributed Generation Statistics; PV Watts

POLICY ANALYSIS FOR THE PUBLIC AND PRIVATE SECTORS
M.CUBED

California's Loading Order (& other policy goals)

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|	
1. Energy Efficiency & Conservation (always first)	• Building efficiency • Appliance standards • Industrial process efficiency • Conservation and behavior-based programs • Demand avoidance (e.g., weatherization)
2. Demand Response, Load Flexibility & Distributed Energy Resources	• Traditional DR programs • Automated load shifting and flexible demand • Behind-the-meter solar, storage, EV charging control • Virtual Power Plants & Aggregated DERs • Community Microgrids & Energy management systems
3. Renewable Energy	• Solar PV (utility-scale) • Wind (onshore & offshore) • Geothermal • Biomass/biogas • Small hydro • Eligible RPS resources
4. Grid Enhancements & Upgrades	• Distribution system upgrades • Transmission upgrades • Interconnection improvements • Hosting capacity increases • Advanced inverters & voltage support • Non-wires alternatives • Dynamic operating envelopes
5. Clean & Efficient Fossil Generation (always last)	• High-efficiency gas turbines • Combined-cycle natural gas • Reliability-must-run (RMR) units • CHP that meets FERC/CEC efficiency thresholds

2030 Energy Goals:

- **7 GW of load flexibility,** double what is currently deployed *(SB 846)*
- **Double energy efficiency savings** *(SB 350)*
- **Deploy 2-5 GW of offshore wind** (AB 525)
- **Install 6 million heat pumps** *(California Building Energy Action Plan)*
- Expected need for **1 million public/shared EV chargers**.
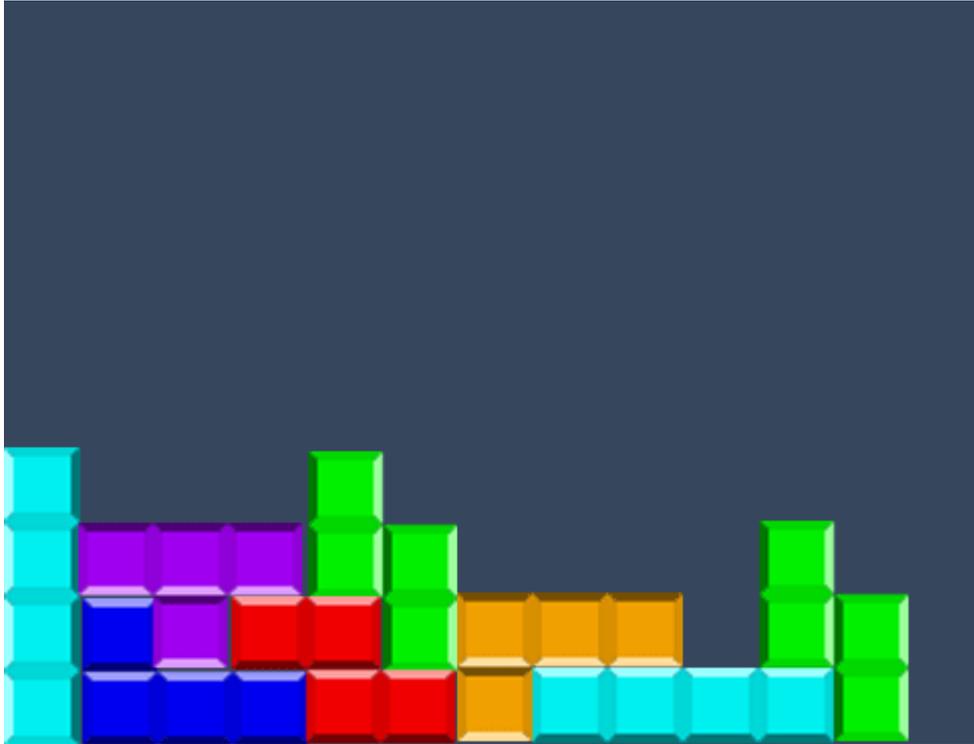
California is attempting to meet it energy goals and balance the grid by playing Tetris without using half of the available pieces. The affordability crisis is a clear sign that things need to change

- Opportunities for distributed supply & demand side management are consistently missed.
- DER are excluded from core energy portfolio planning, suggesting that the state has not yet fully accepted the reality of a rapidly modernizing grid.
- On average, it takes 8-10 years to complete a new transmission project in California.
- Local solar alone lowers peak transmission usage by roughly 50% of its installed capacity, translating into billions of dollars in avoided transmission investments.
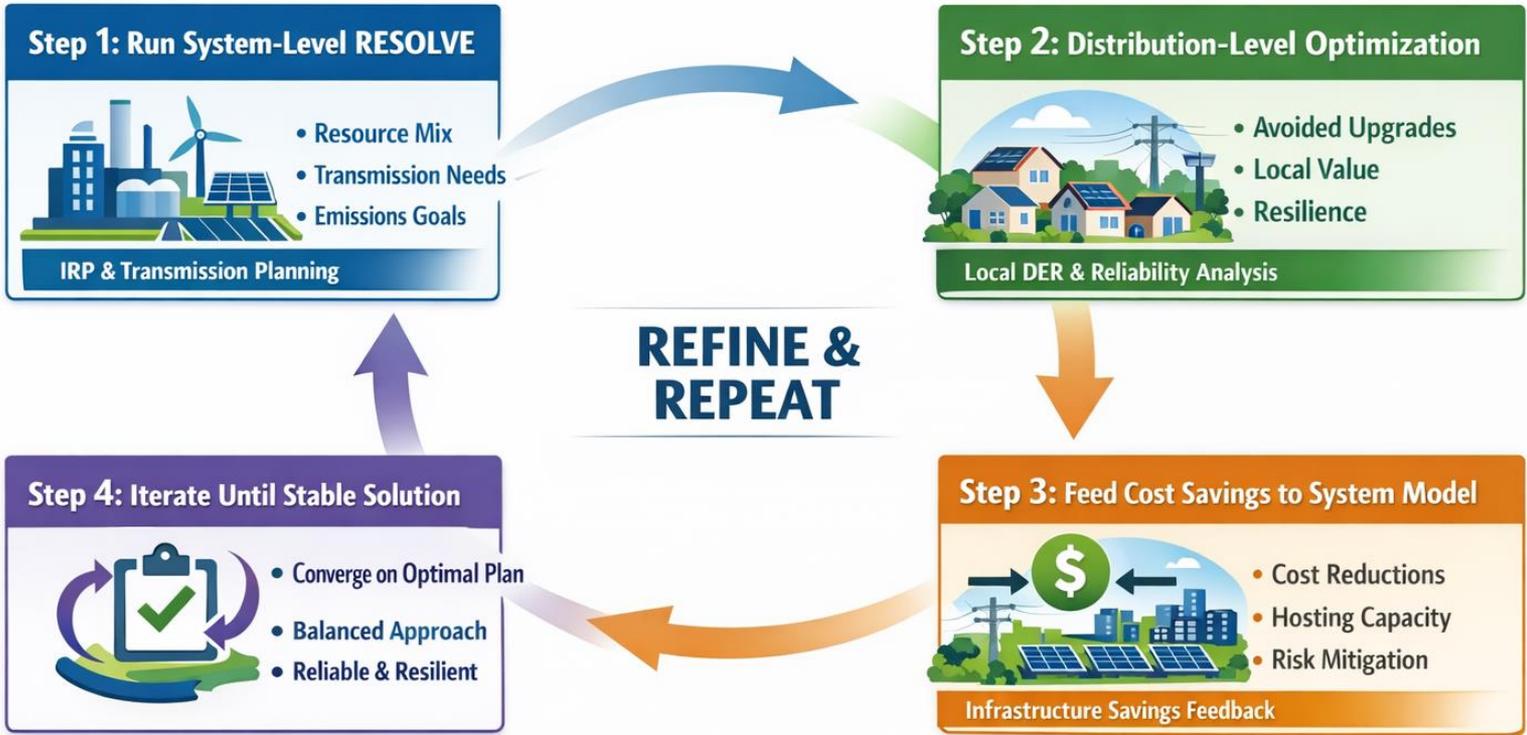
Transitioning to an integrated grid planning process that embraces Energy Tetris at the distribution level will promote an energy future that is affordable, cleaner, and more resilient.
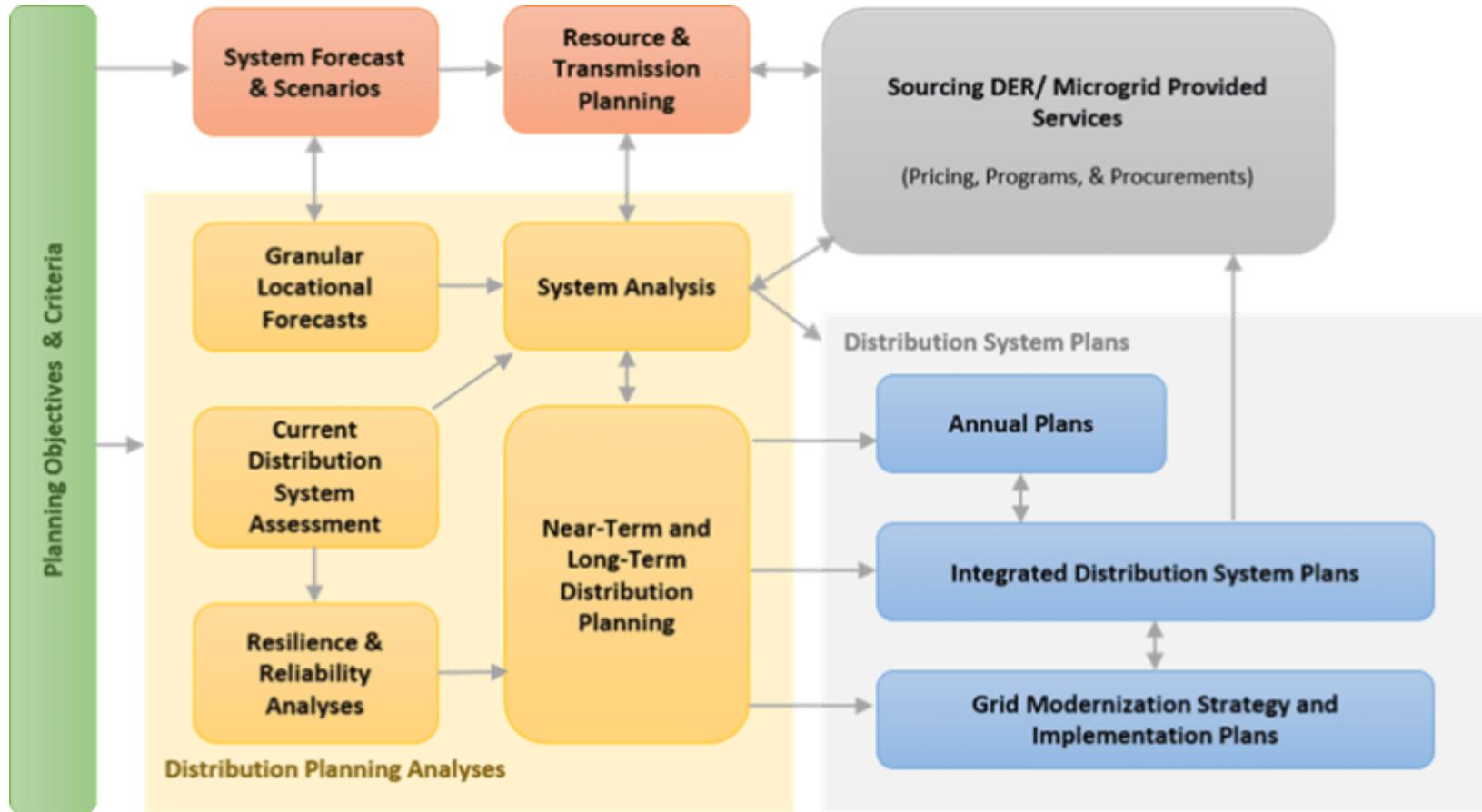
Levelized cost of energy (LCOE) should be replaced by a metric that considers the **total system benefit (TSB)** for the ratepayers based multiple criteria, not just the cost of generation.

Integrated Grid Planning requires a co-optimized loop that evaluates generation, transmission, and distribution investments simultaneously while internalizing infrastructure costs within portfolio decisions and allowing distributed resources to compete directly with wires solutions.

Iterative Co-Optimization Framework

Step 1: Run System-Level RESOLVE
- Resource Mix
- Transmission Needs
- Emissions Goals

IRP & Transmission Planning

Step 2: Distribution-Level Optimization
- Avoided Upgrades
- Local Value
- Resilience

Local DER & Reliability Analysis

REFINE & REPEAT

Step 4: Iterate Until Stable Solution
- Converge on Optimal Plan
- Balanced Approach
- Reliable & Resilient

Step 3: Feed Cost Savings to System Model
- Cost Reductions
- Hosting Capacity
- Risk Mitigation

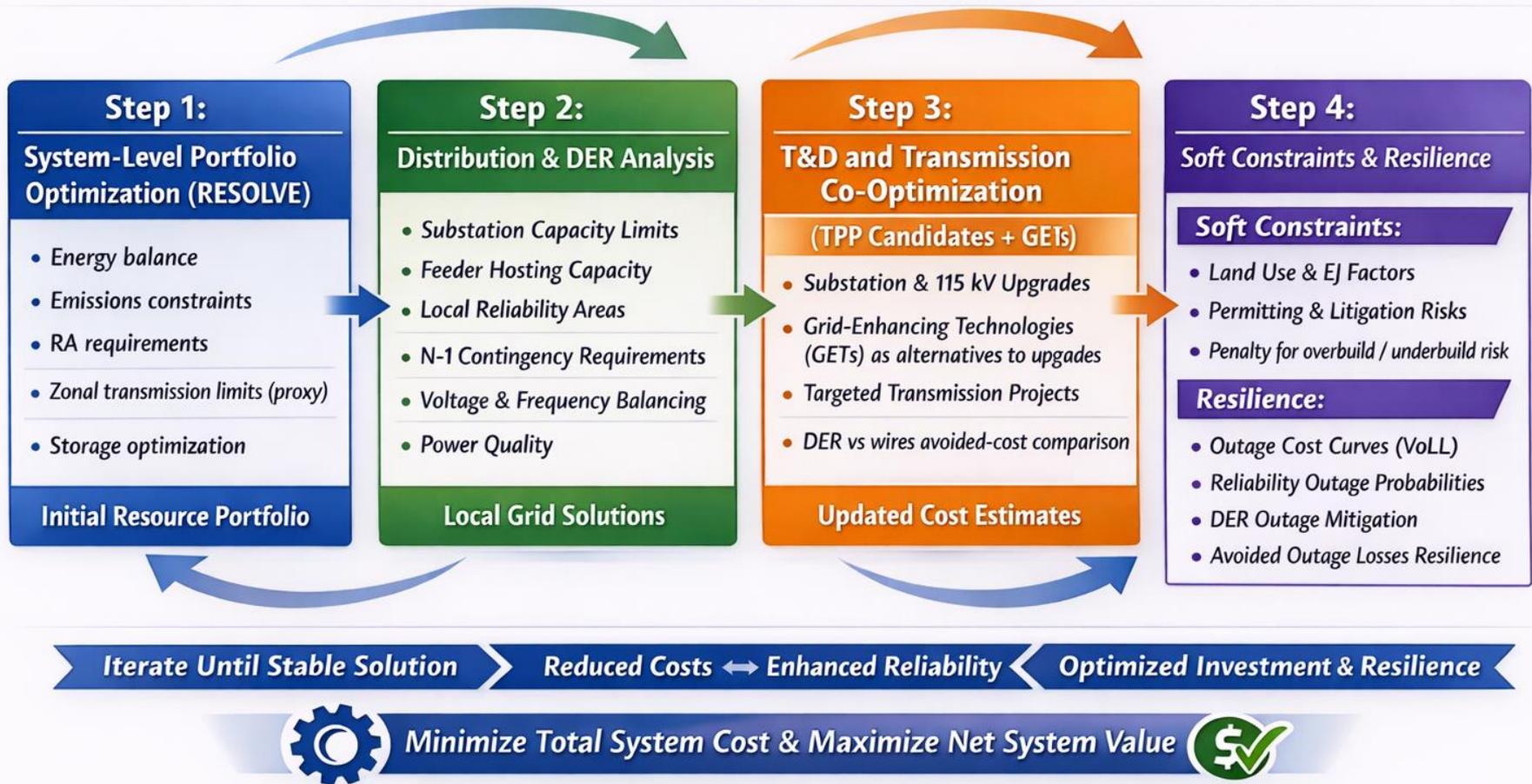Infrastructure Savings Feedback

BENEFITS: Increased Reliability, Resilience & Cost Savings

Iterative Co-Optimization Framework

Step-by-Step Process to Achieve a Stable Solution

Step 1:
System-Level Portfolio Optimization (RESOLVE)

- Energy balance
- Emissions constraints
- RA requirements
- Zonal transmission limits (proxy)
- Storage optimization

Initial Resource Portfolio

Step 2:
Distribution & DER Analysis

- Substation Capacity Limits
- Feeder Hosting Capacity
- Local Reliability Areas
- N-1 Contingency Requirements
- Voltage & Frequency Balancing
- Power Quality

Local Grid Solutions

Step 3:
T&D and Transmission Co-Optimization
(TPP Candidates + GETs)

- Substation & 115 kV Upgrades
- Grid-Enhancing Technologies (GETs) as alternatives to upgades
- Targeted Transmission Projects
- DER vs wires avoided-cost comparison

Updated Cost Estimates

Step 4:
Soft Constraints & Resilience

Soft Constraints:
- Land Use & EJ Factors
- Permitting & Litigation Risks
- Penalty for overbuild / underbuild risk

Resilience:
- Outage Cost Curves (VoLL)
- Reliability Outage Probabilities
- DER Outage Mitigation
- Avoided Outage Losses Resilience

Iterate Until Stable Solution → **Reduced Costs ⟷ Enhanced Reliability** ← **Optimized Investment & Resilience**

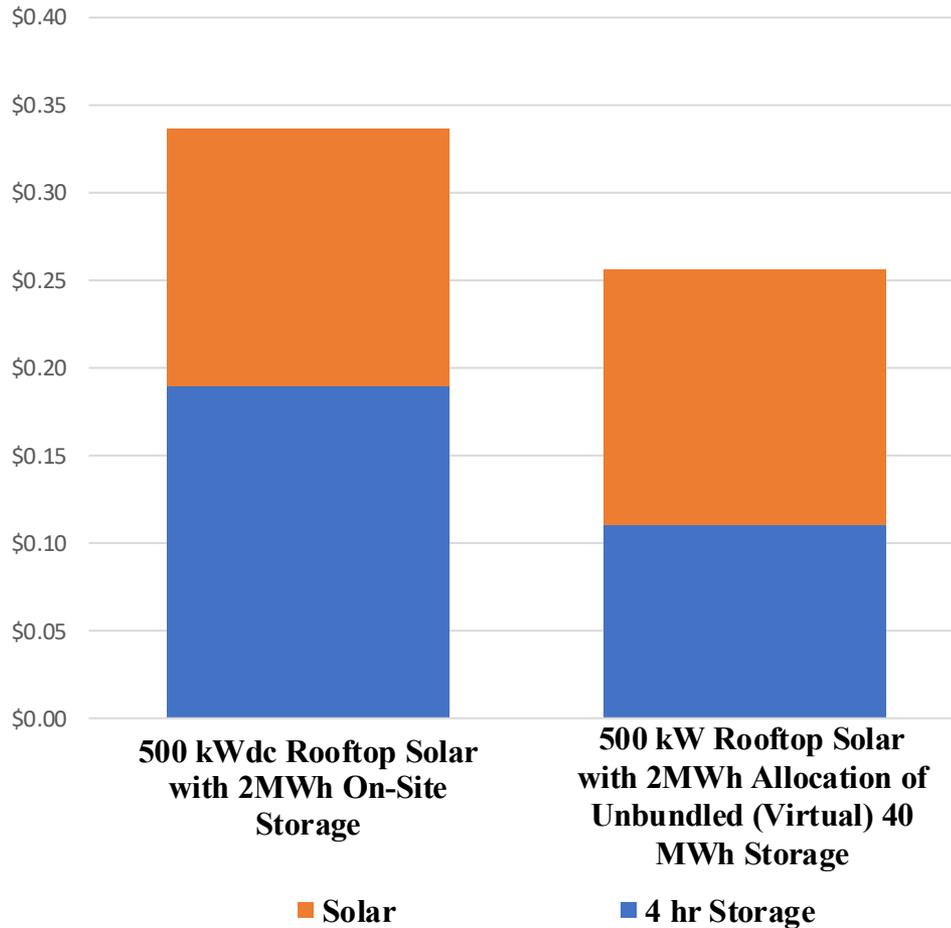**Minimize Total System Cost & Maximize Net System Value**

Meeting Total Demand in California with Energy Tetris
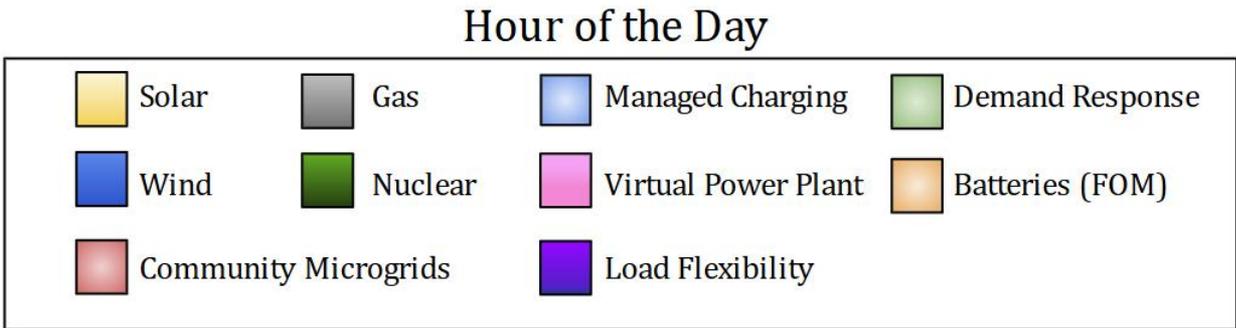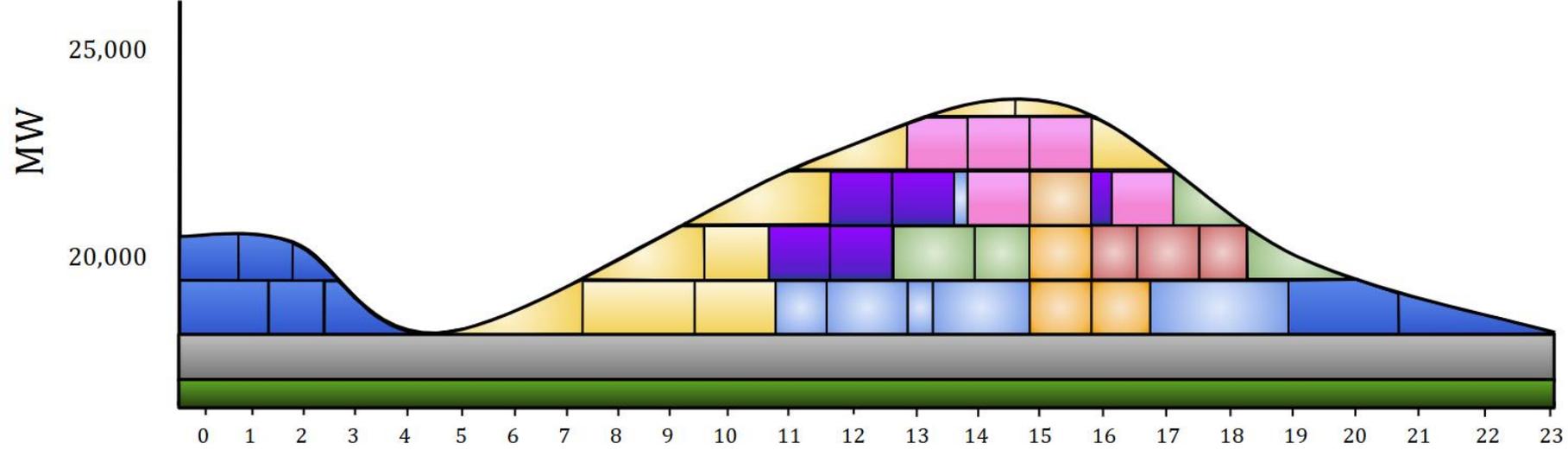
Relying on a more diverse mix of resources will help California meet demand in the most efficient manner possible, preventing a costly overbuild of grid infrastructure. Utilizing IBDER to reduce demand and support the distribution grid will allow utilities to balance all dimensions of the grid – energy, frequency, & voltage – at a granular level.

Cost Comparison: On-Site Solar+Storage & Solar + Virtual Storage

Chart y-axis: $0.00 to $0.40

Category 1: **500 kWdc Rooftop Solar with 2MWh On-Site Storage**

Category 2: **500 kW Rooftop Solar with 2MWh Allocation of Unbundled (Virtual) 40 MWh Storage**

Legend: ■ Solar   ■ 4 hr Storage

- Standalone storage can achieve lower per-unit costs than distributed paired systems due to economies of scale and optimized interconnection.
- The Community Solar cost comparison shows a 25% lower storage cost with a virtual allocation of standalone storage.
- Strategically sited storage near substations can defer or avoid T&D upgrades.
- FOM storage provides energy shifting, capacity value, voltage support, and frequency response.
- Properly sized FOM storage reduces peak demand and improves overall grid reliability.

Example: Distribution-sited storage

CPUC Energy Storage Procurement Study: Executive Summary

Project group or cluster:
- **Transmission-connected**
- **Distribution-connected (3rd-party)**
- **Distribution-connected (utility)**
- **Customer-sited non-SGIP**
- **SGIP non-residential (7clusters)**

High local capacity value; versatile to local & community needs
But barriers to reaching market potential at scale

High system-wide value to the bulk grid
Successfully scalable to a large portfolio

Barriers to energy and capacity value to the grid
Successfully scalable to meet site-specific needs

High efficiency and market-participating
Versatile to local & community needs
But barriers to reaching market potential at scale

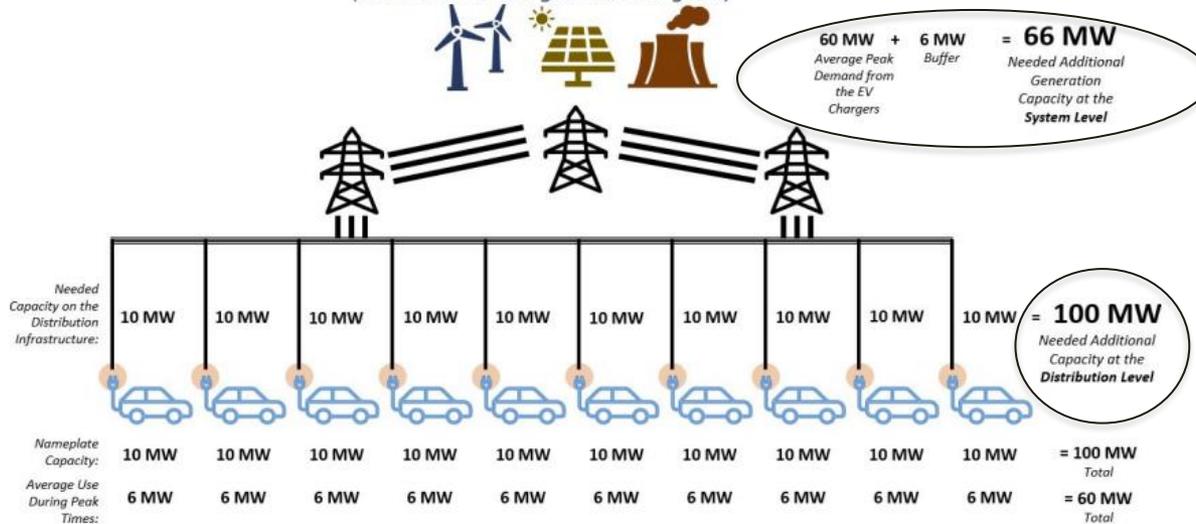*Figure 1: Summary of ratepayer benefit/cost ratio results.*

Distributed Capacity Procurement in Minnesota:
- Xcel proposed deploying 200 MW of utility-owned front-of-meter distributed storage.
- "Xcel presents the program as a pragmatic, low-risk way to deploy distributed storage, gain operational experience and deliver system benefits to customers."
- _The underlying premise is that these assets are cost-effective._

Barry's presentation will demonstrate how data centers can increase the benefits from behind the meter energy storage.

Example: Managed Charging

Figure 3-5: Example of the Difference Between System Level and Distribution Level Need (when Ten EV Chargers are Energized)

60 MW + 6 MW = 66 MW
Average Peak Demand from the EV Chargers / Buffer / Needed Additional Generation Capacity at the **System Level**

Needed Capacity on the Distribution Infrastructure: 10 MW | 10 MW | 10 MW | 10 MW | 10 MW | 10 MW | 10 MW | 10 MW | 10 MW | 10 MW = **100 MW** Needed Additional Capacity at the **Distribution Level**

Nameplate Capacity: 10 MW | 10 MW | 10 MW | 10 MW | 10 MW | 10 MW | 10 MW | 10 MW | 10 MW | 10 MW = 100 MW Total

Average Use During Peak Times: 6 MW | 6 MW | 6 MW | 6 MW | 6 MW | 6 MW | 6 MW | 6 MW | 6 MW | 6 MW = 60 MW Total

figure 2. An aggregate EV charging load on a single transformer with no management. kVA: kilovolt-amperes. (Source: WeaveGrid.)
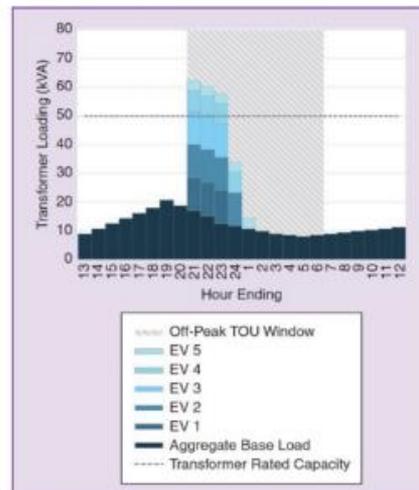
figure 3. An aggregate EV charging load on a single transformer when optimized solely for bulk system benefits. (Source: WeaveGrid.)
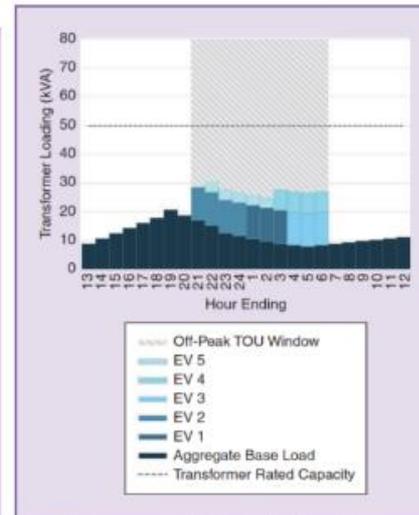
figure 6. An aggregate EV charging load optimization on a single transformer when considering distribution constraints. (Source: WeaveGrid.)

- Grid upgrades are conducted based on the assumption that grid energy will be needed to serve 100% of loads during peak periods.
- Managed charging responds to signals from the grid to charge during periods when the grid is less congested, minimizing the hosting capacity impact and avoiding T&D grid upgrades.
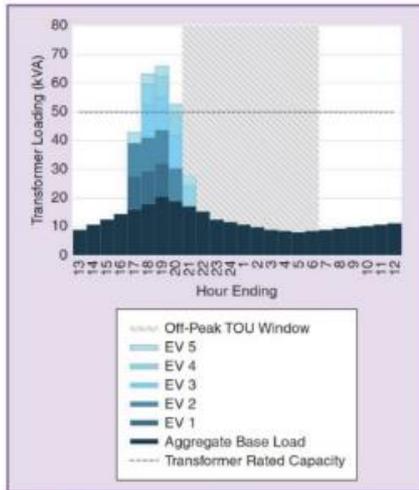- A dynamic rates pilot delivered 98% of EV charging loads during off-peak periods (MCE & SVCE).

Results of Effective Policy Design

Dynamic Approach Delivers Maximum Energy Off-Peak

% Energy Delivered Off-Peak

Time of Use	TOU + Managed	Dynamic Pricing + Managed
70	90	98

ev. energy