

Role of Optimization and Forecasting for planning and operation of Energy Storage Systems

Gurobi Days
October 2023



**Customized
Energy Solutions**

ANALYZE. SIMPLIFY. IMPLEMENT.

CES-LTD.COM

Key Points

Cost benefit analysis of Renewables + Energy Storage assets in regions across the world

Enumerate savings and revenue potential for these assets

Analyze impact of siting on the asset: Behind-The-Meter, In-Front-Of-Meter, Aggregation

Help make right investment decisions

Help respond to Renewable and/or storage RFPs with right size and fitting economics

Help set the right hedging strategies on assets for market volatilities

Capture the real-world assets and scenarios in mathematical models

Use forecasted data and other financial parameters as inputs (this is a separate larger exercise in itself)

Evaluate the technical and commercial performance of the models

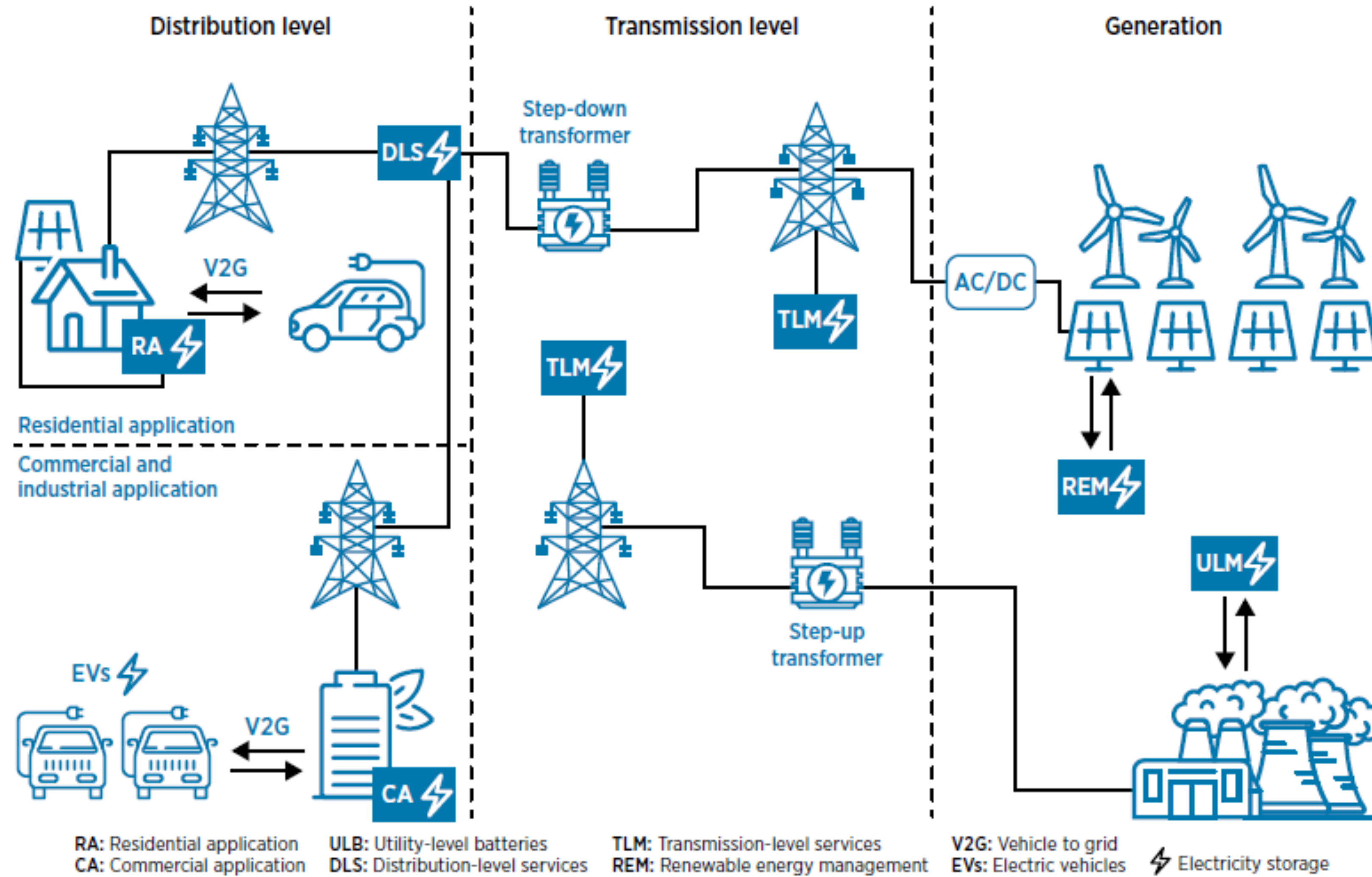
Arrive at the right qualitative and quantitative conclusions

Use models to help with trading strategies for assets under management

Help scale up analytical capabilities



Applications of Energy Storage



Reference: IRENA, Electricity Storage Valuation Framework 2020

Optimal Decision Making



SYSTEM LEVEL PLANNING

- Supply and demand
- Economic Dispatch
- Capacity Expansion

- Policy design
- Incentives planning



INVESTMENT ANALYSIS

- Long term contracts
- Optimal dispatch
- Merchant revenues

- Project finance
- Investment metrics

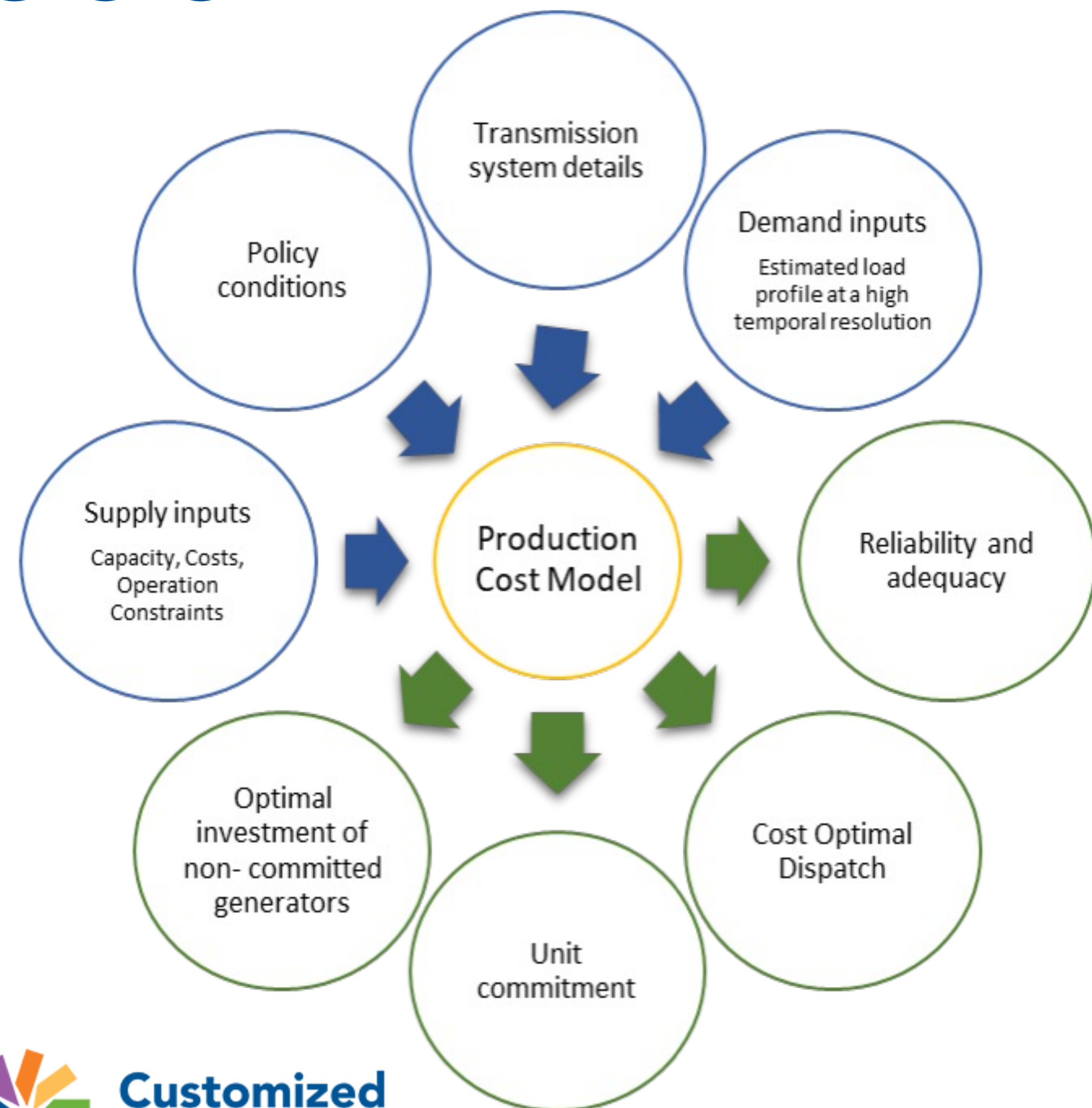


OPTIMAL OPERATIONS

- Short-term forecasts
- Learning models
- Risk management

- Optimal bids and offers
- Performance metrics

Planning with Production Cost Model



Production cost models

- are **Constrained Optimization models**
- **capture** various **costs** incurred during system operation
- both **fixed and variable** costs are considered
- adhere to **operational constraints**
- can operate at **high** temporal and spatial **resolution**
- output economic dispatch
- extends to security constrained unit commitment, capacity expansion or economic dispatch model

Invest or Not to Invest

Behind-The-Meter (BTM)

Demand Charges

From month	To month	Monthly Max	Peak	Mid Peak	Off Peak	Super Off Peak
Jun	Sep	\$ 10.00	\$ 5.00	\$ -	\$ -	\$ -
Oct	May	\$ 10.00	\$ -	\$ -	\$ -	\$ -

Energy Charges

From month	To month	Peak	Mid peak	Off peak	Super off peak
Jun	Sep	\$ 0.23	\$ 0.22	\$ 0.21	\$ 0.20
Oct	May	\$ 0.13	\$ 0.12	\$ 0.11	\$ 0.10

TOU definition:

Jun – Sept

Peak : 4pm to 8pm on weekdays

Mid Peak: 12pm to 4pm and 8pm to 10pm on weekdays
12pm to 10pm weekends

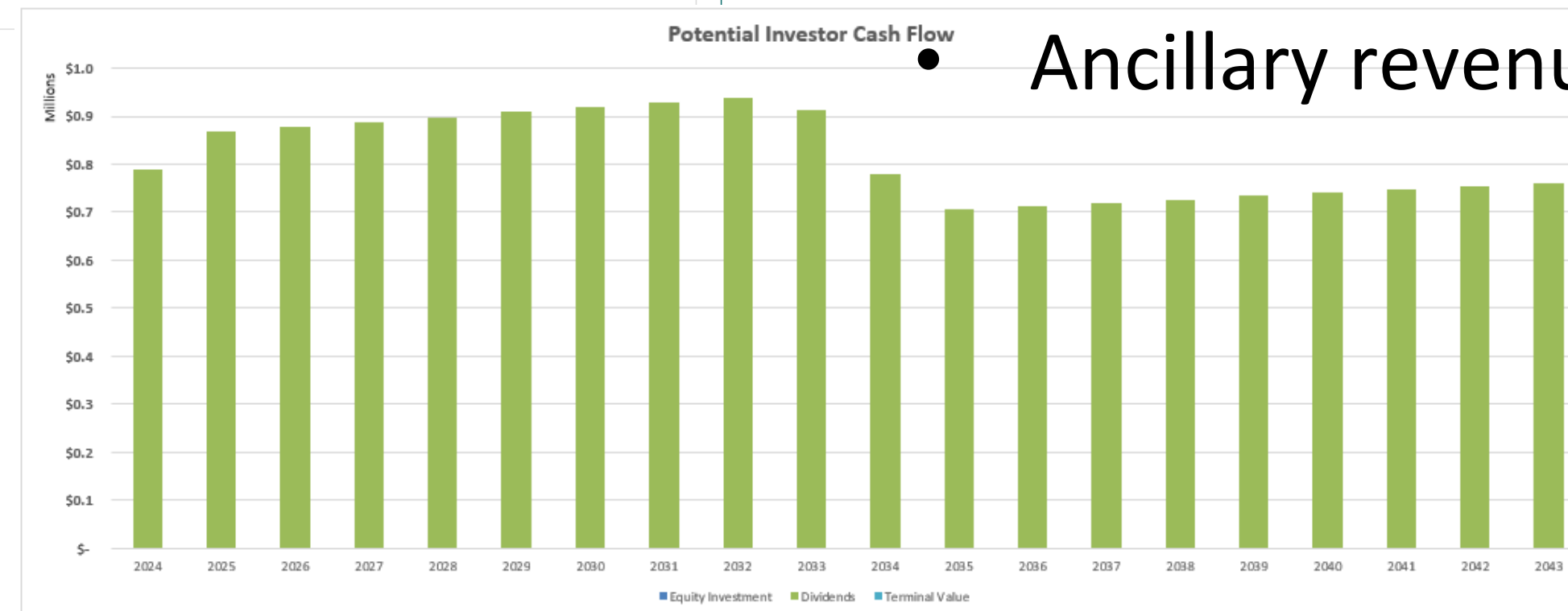
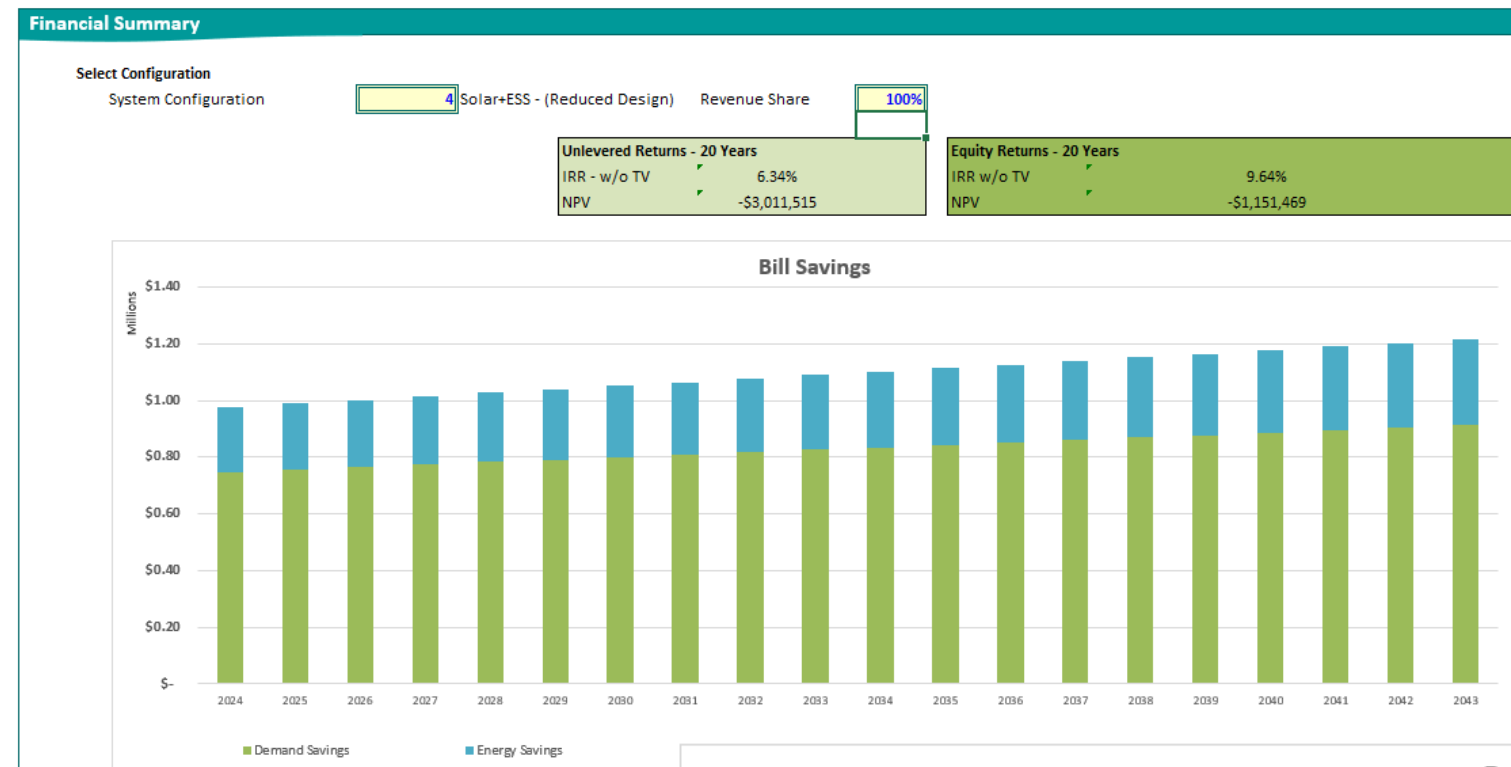
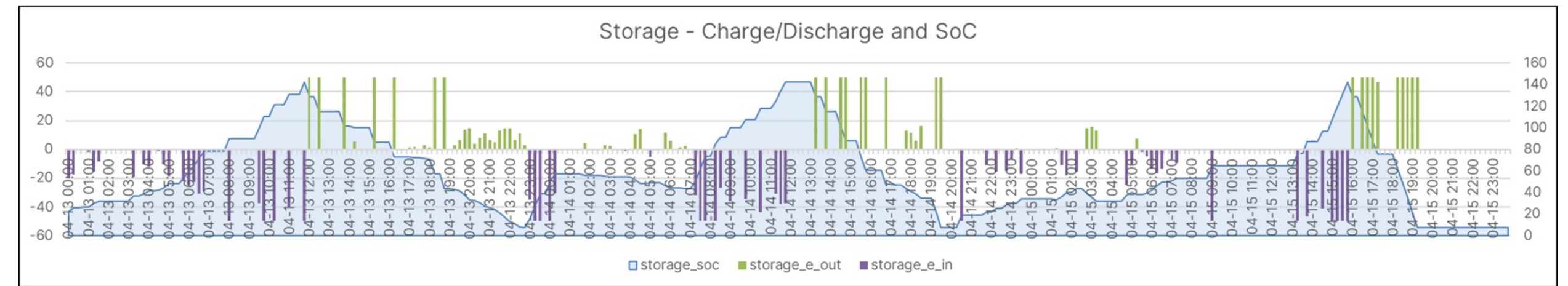
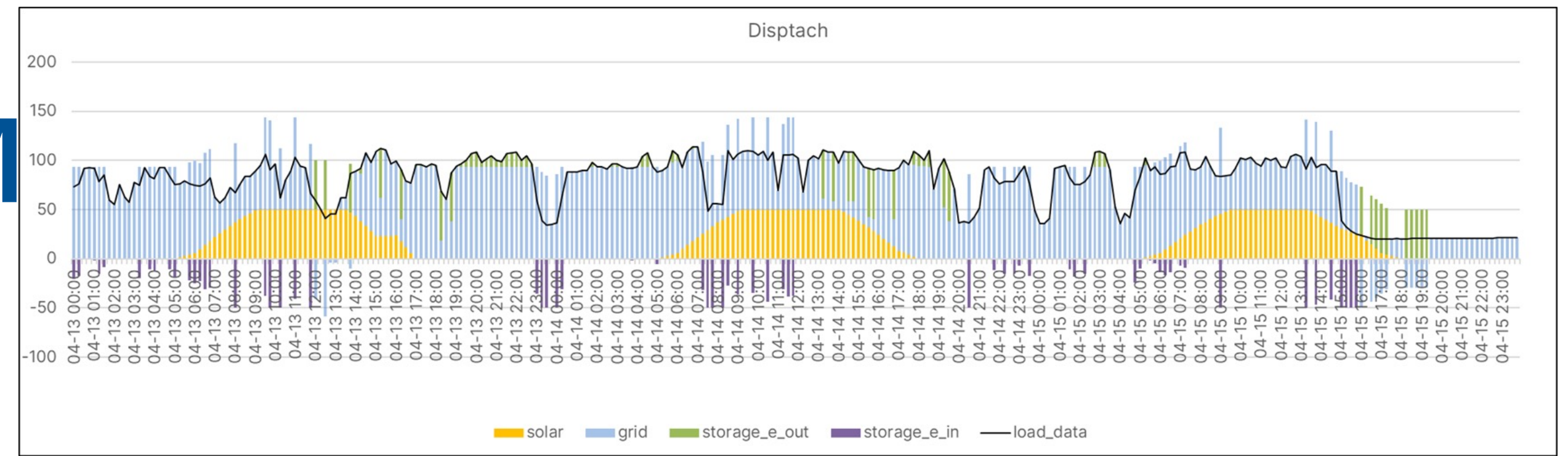
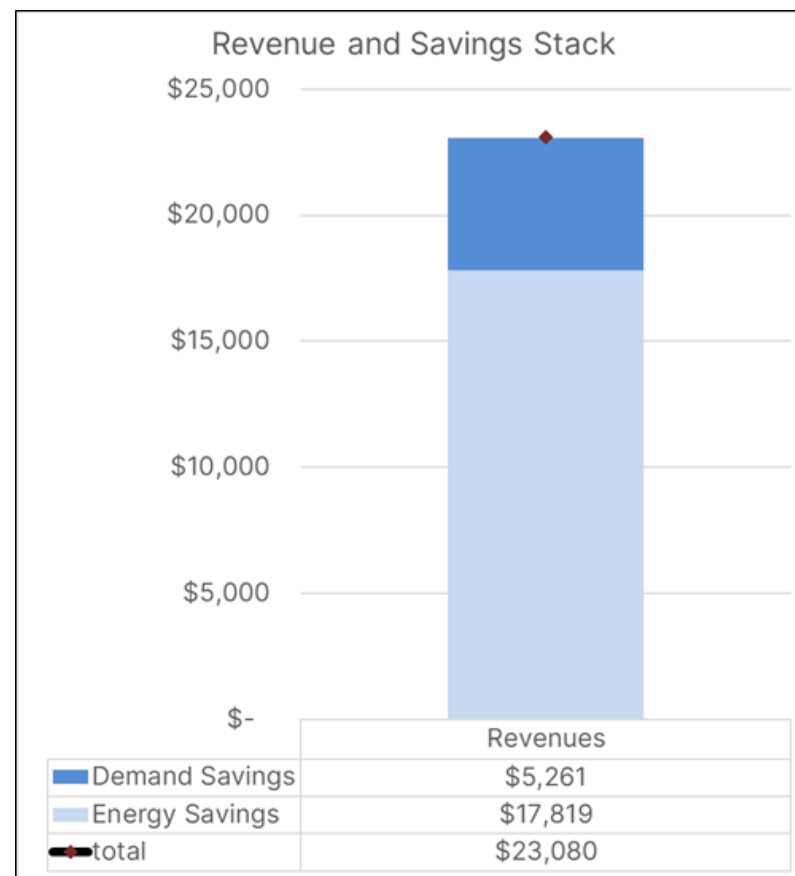
Off Peak: All other hours

Oct – May

Mid Peak: 4pm to 8pm on weekdays

Super Off Peak: 12pm to 8pm on weekends

Off Peak: All other hours



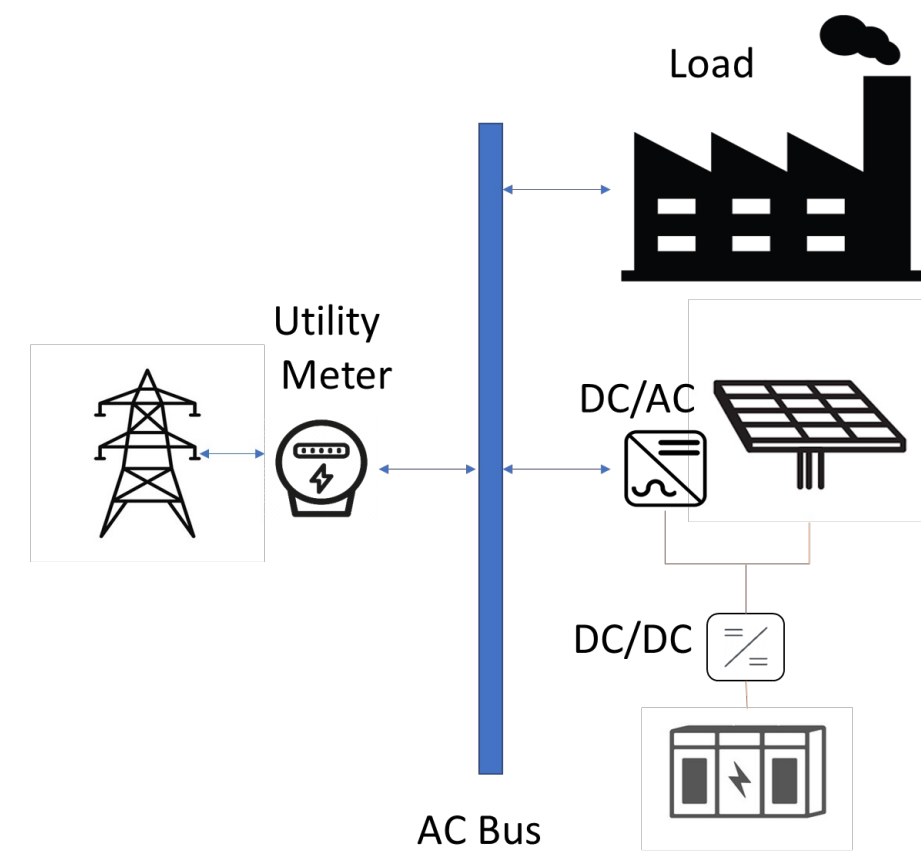
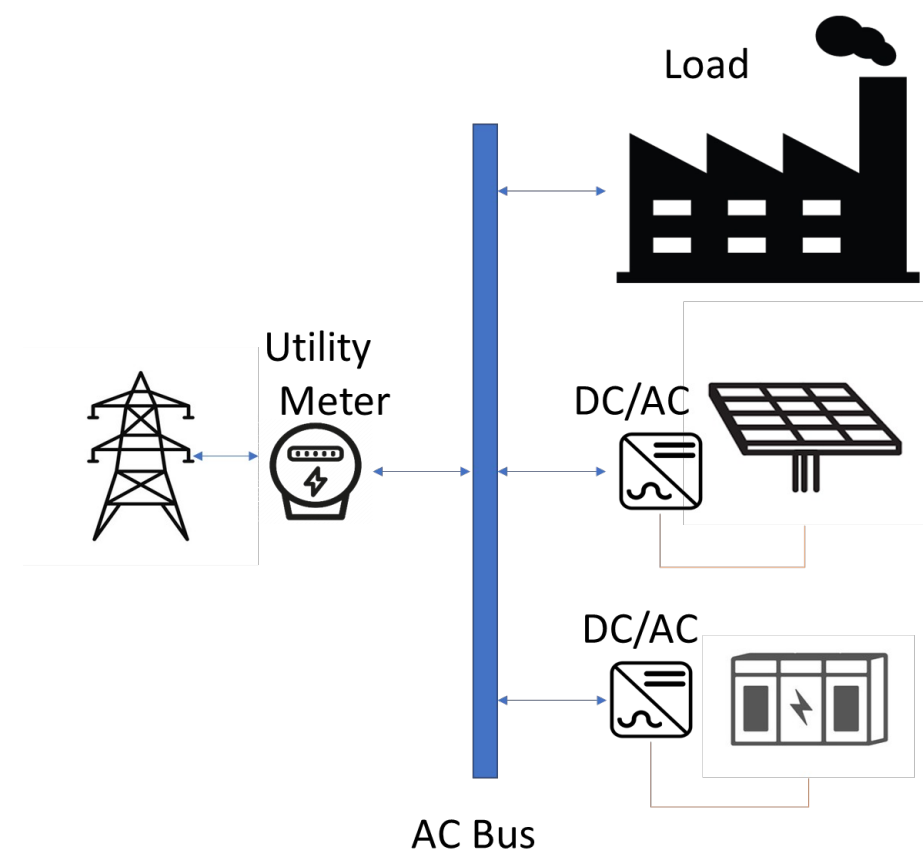
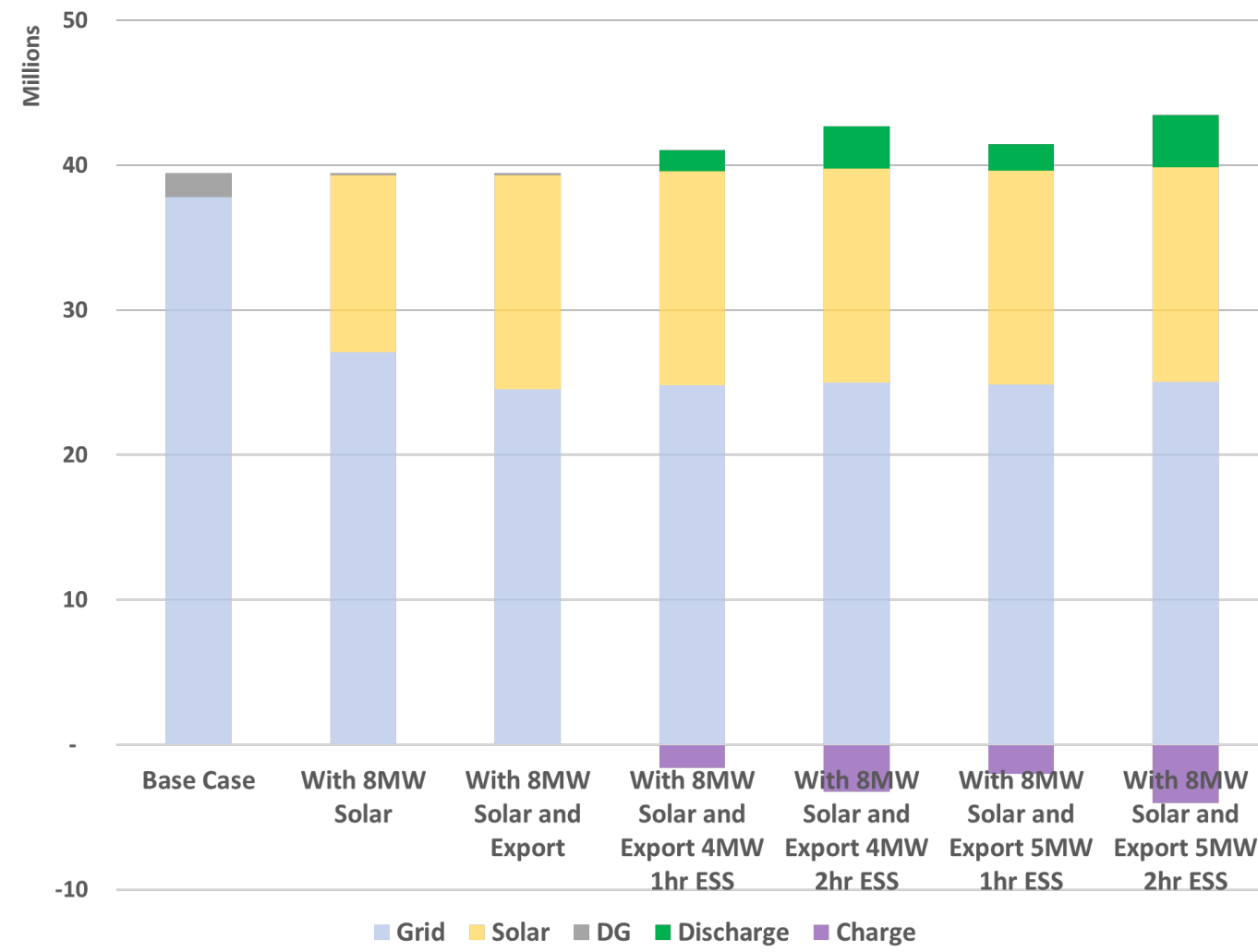
Value streams captured

- Demand Savings
- Energy Savings
- DR Revenue
- Incentive programs (CPEC, Connected solutions)
- Ancillary revenue



Microgrids

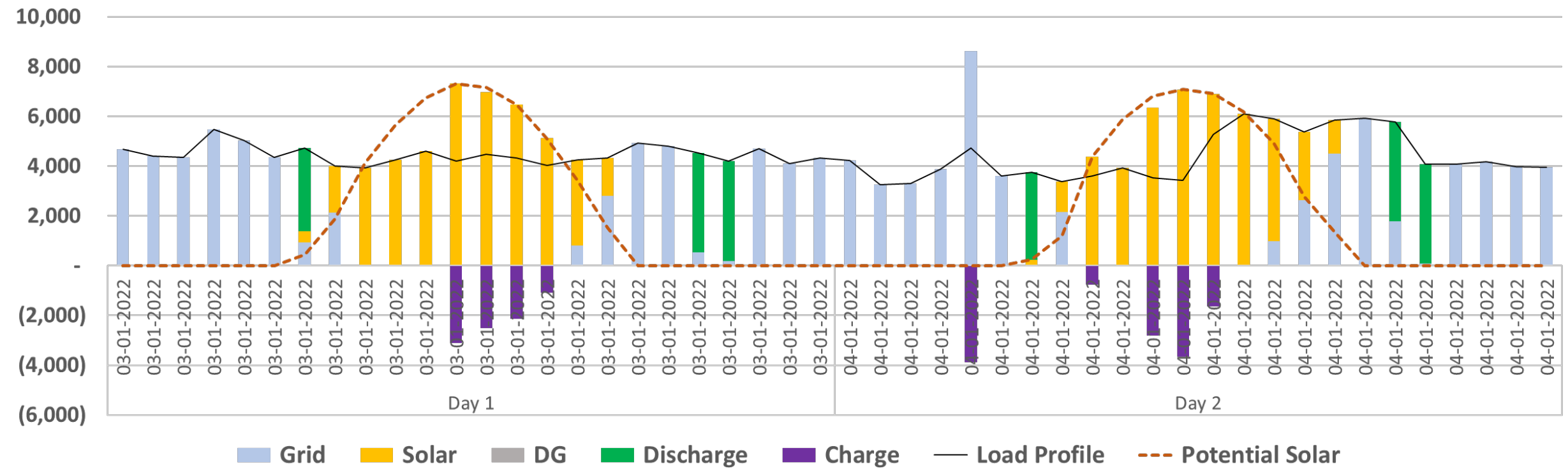
Units per annum



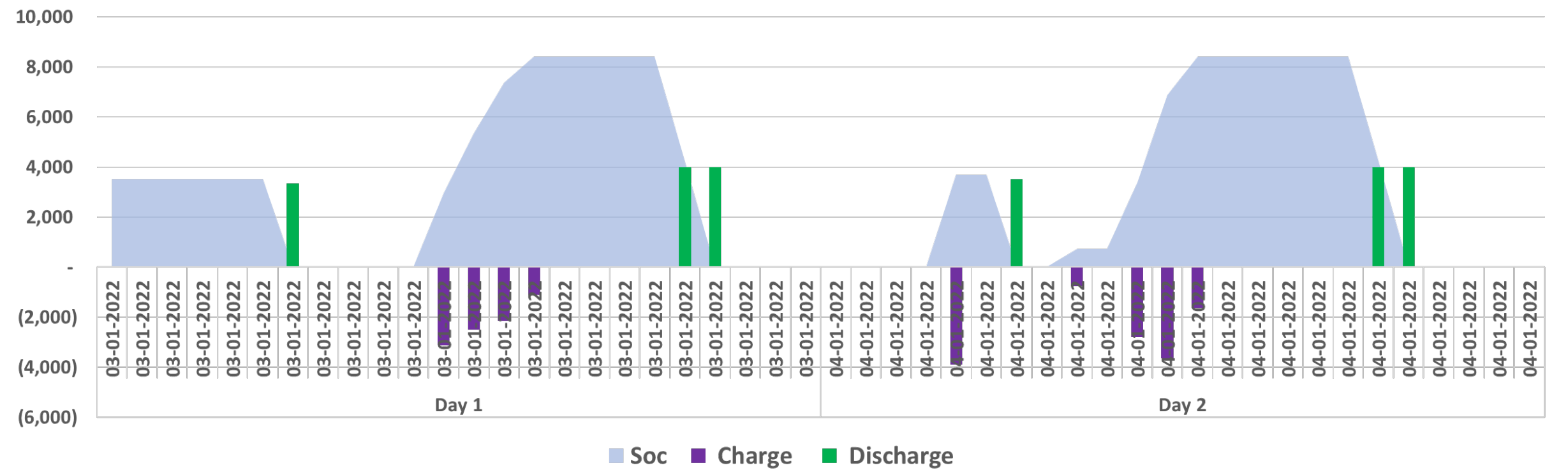
AC Coupled Solar + Storage System

DC Coupled Solar + Storage System

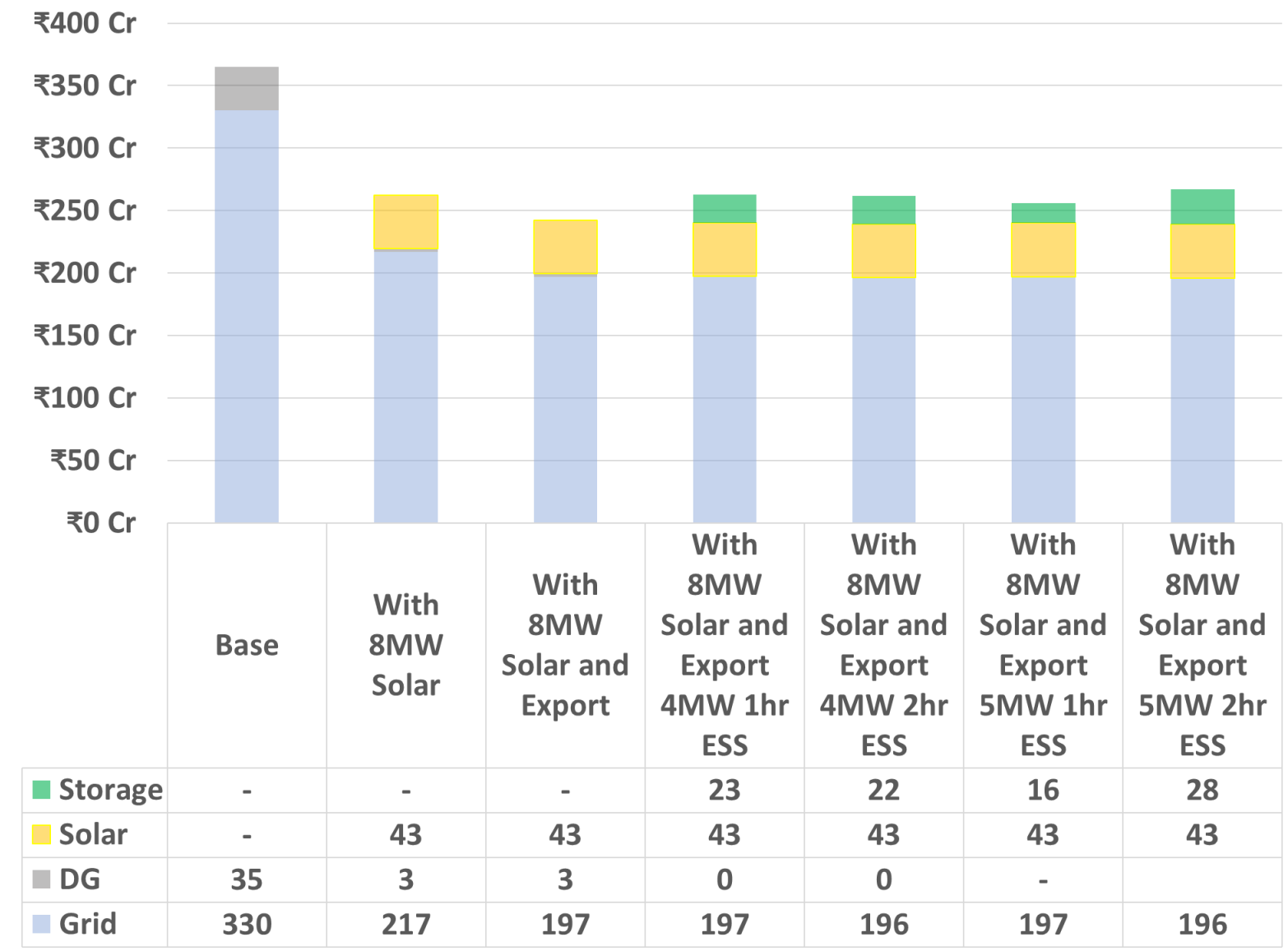
8MW Solar with 4MW 2hr ESS



ESS Dispatch



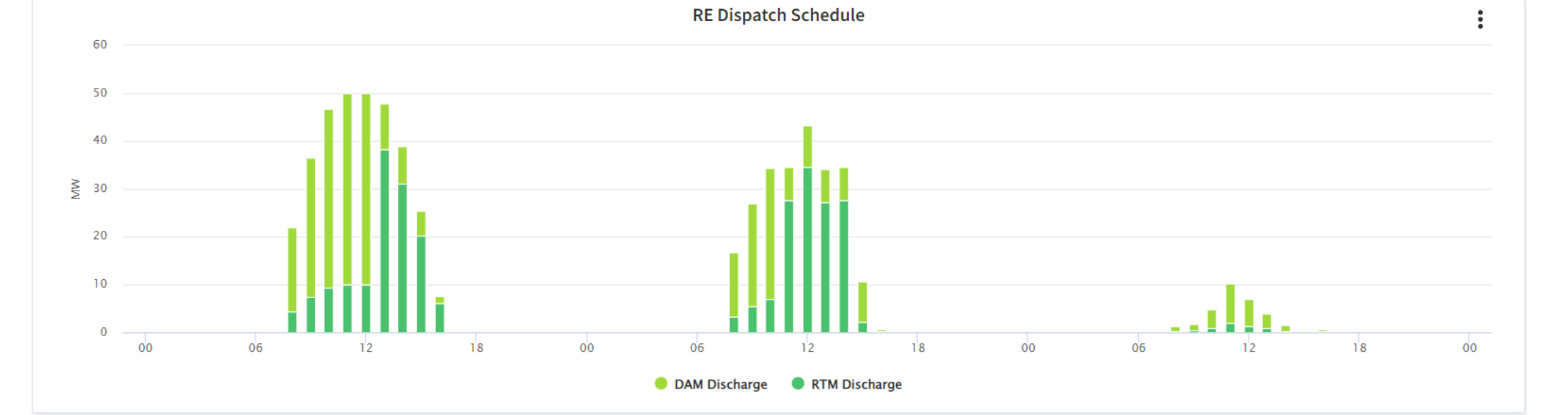
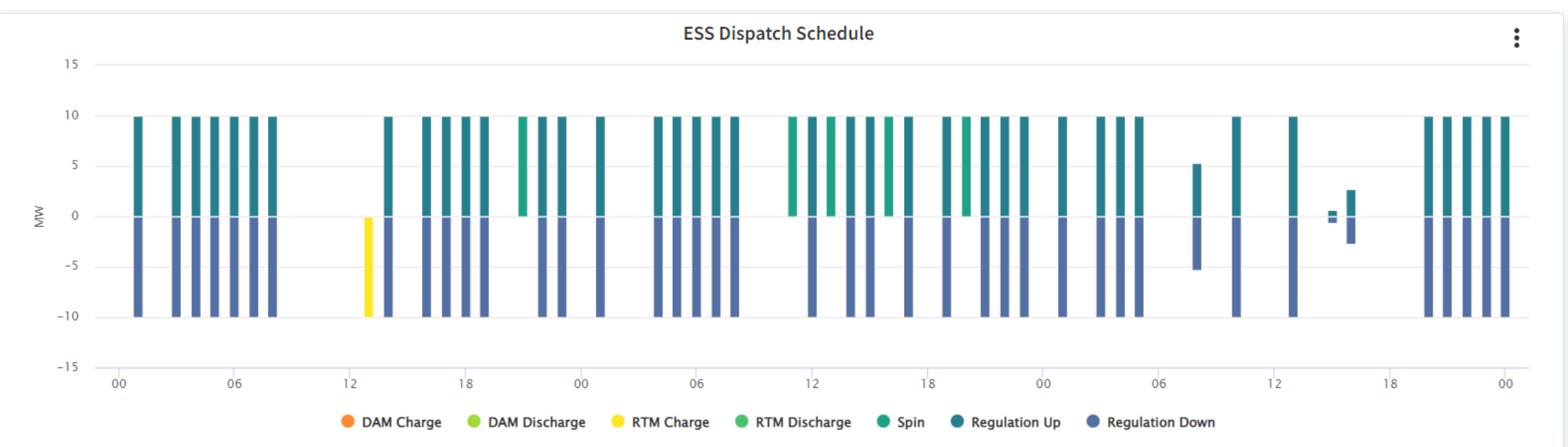
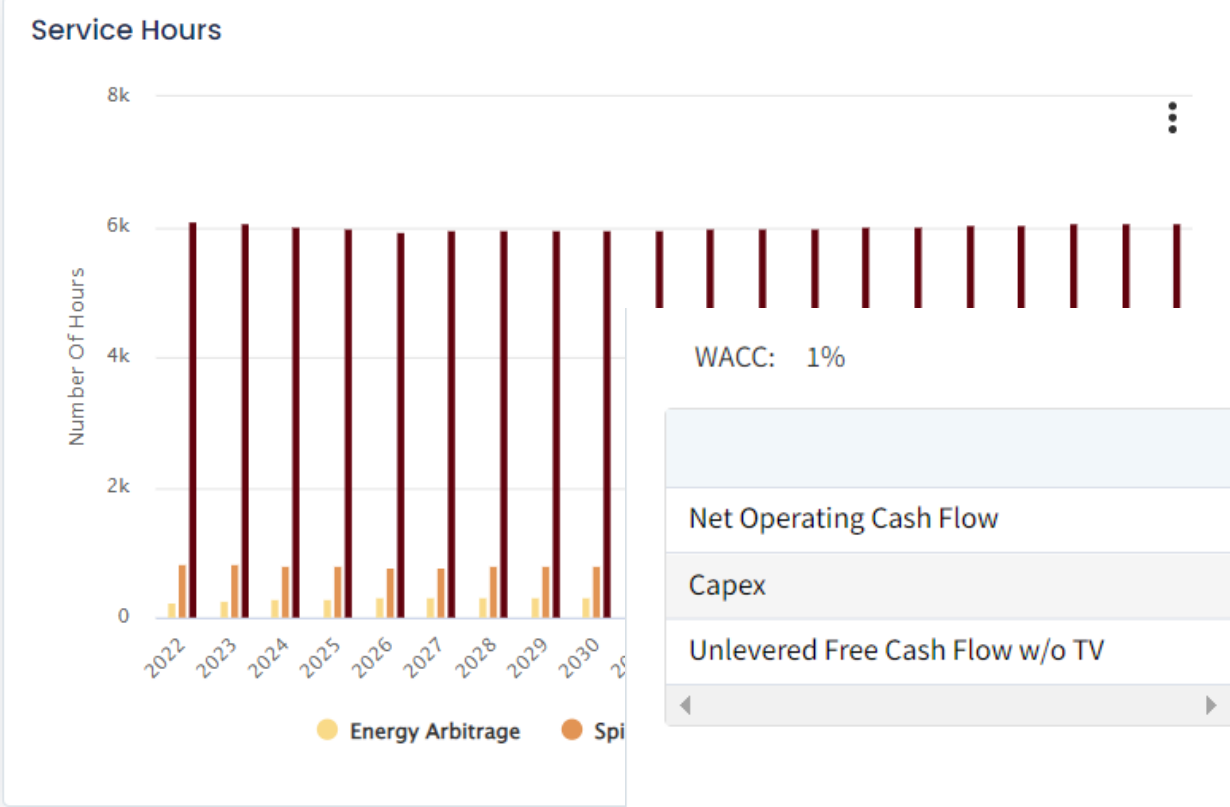
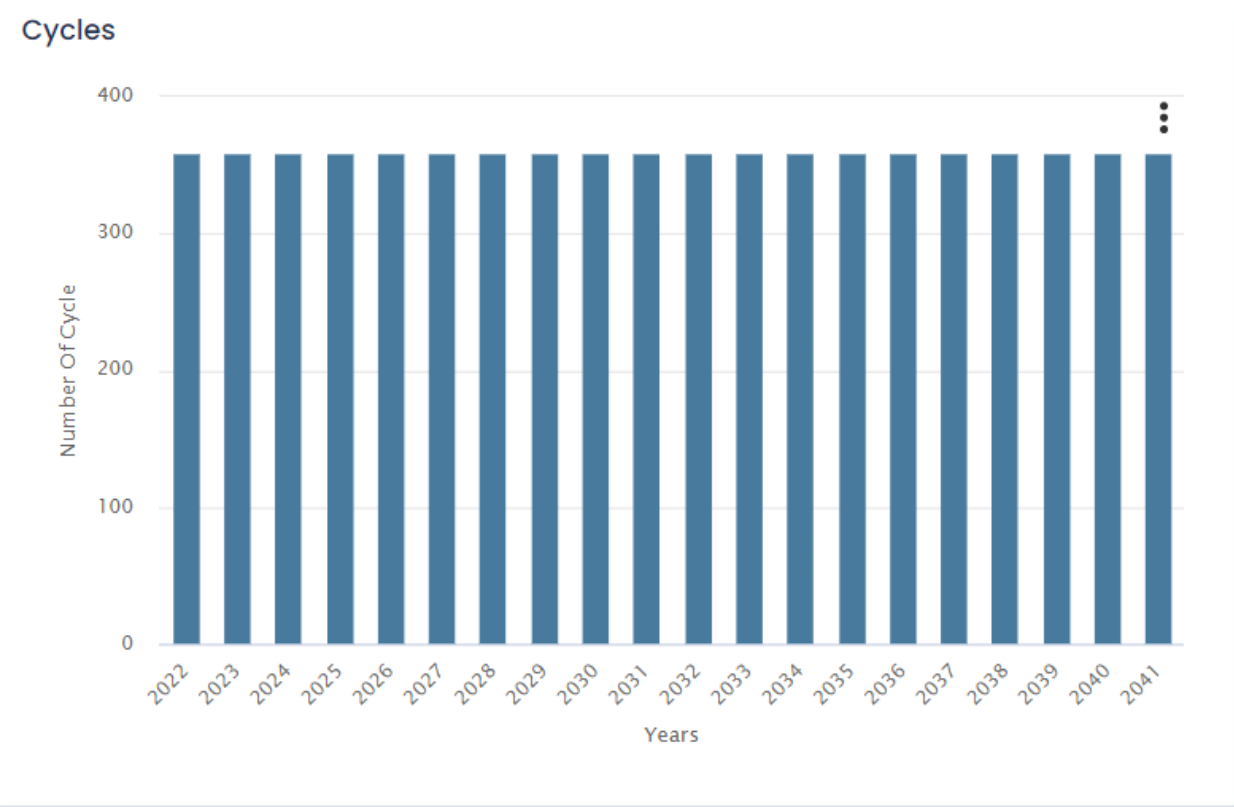
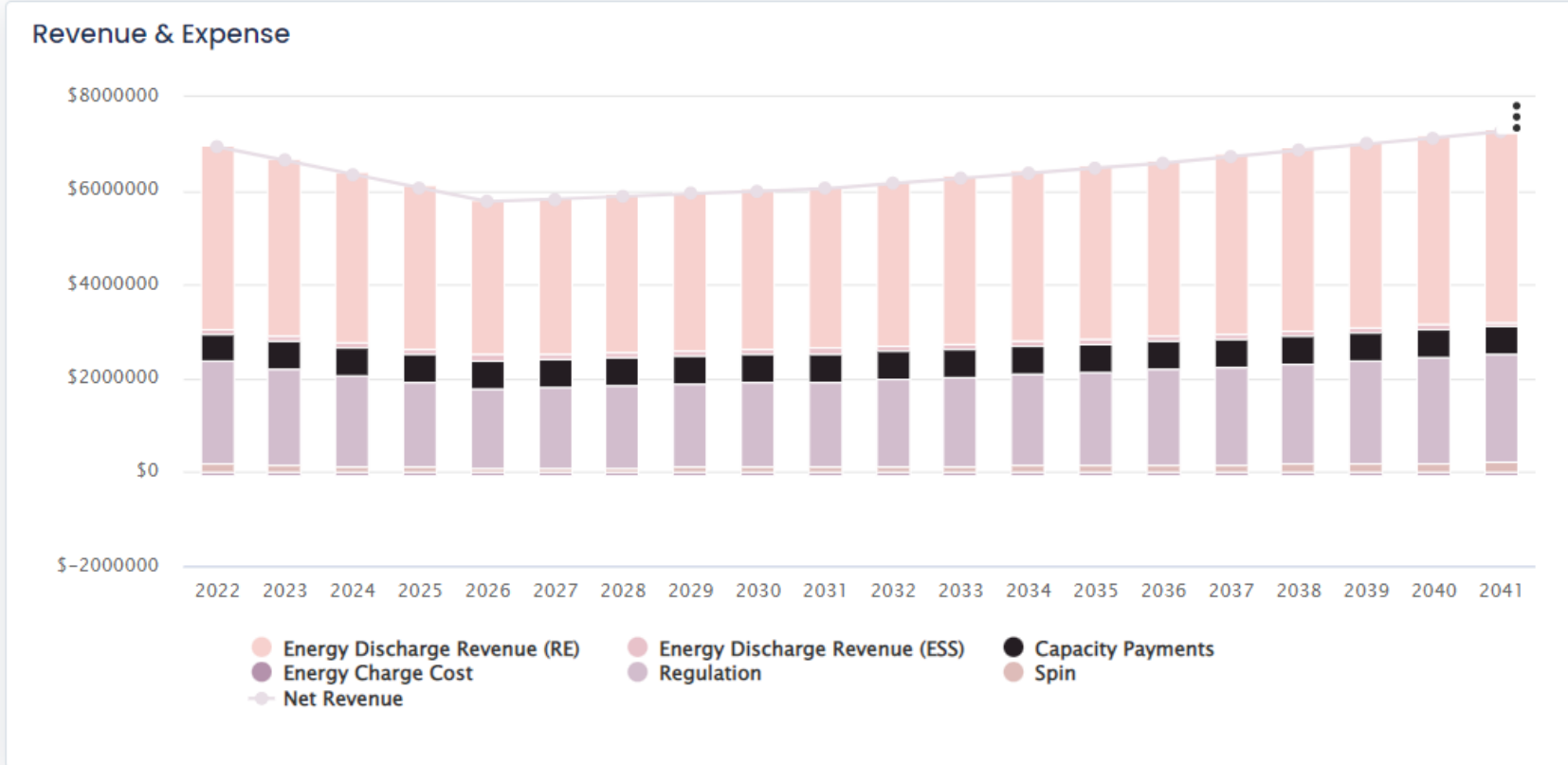
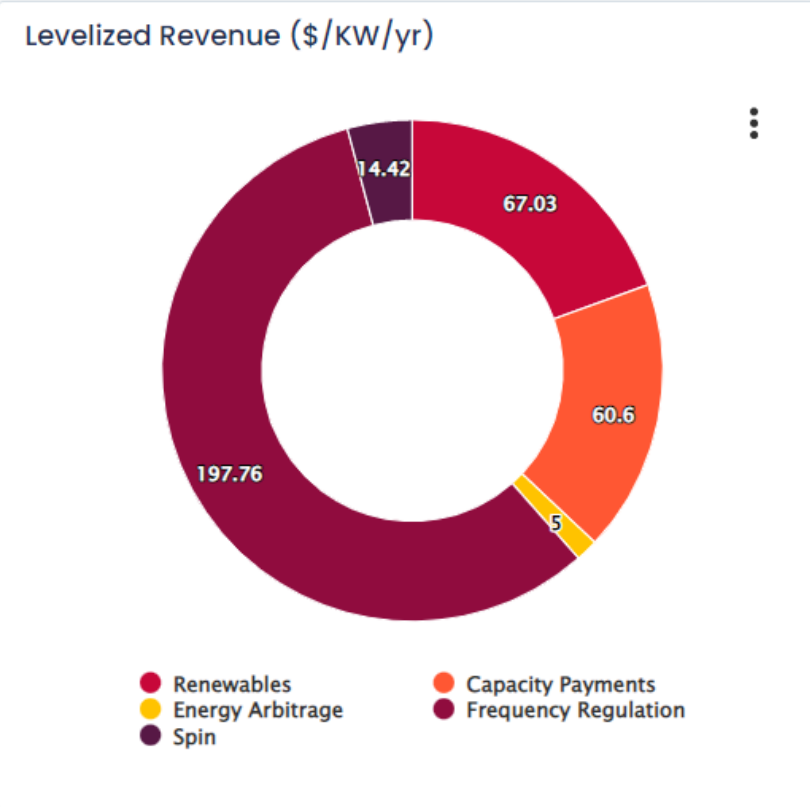
NPV of costs over life of project



In-Front-Of-Meter (Outputs)

Summary

Last updated: 14:30:26 [Switch To Table View](#) [Generate Report](#)



WACC: 1%

	2020-01-01	2021-07-01	2022-07-01	2023-07-01	2024-07-01	2025-07-01	2026-07-01	2027-07-01
Net Operating Cash Flow	-	-	\$5,534,155	\$6,520,378	\$6,158,543	\$5,844,742	\$5,535,214	\$5,540,000
Capex	-\$24,640,000	-\$24,640,000	-	-	-	-	-	-
Unlevered Free Cash Flow w/o TV	-\$24,640,000	-\$24,640,000	\$5,534,155	\$6,520,378	\$6,158,543	\$5,844,742	\$5,535,214	\$5,540,000

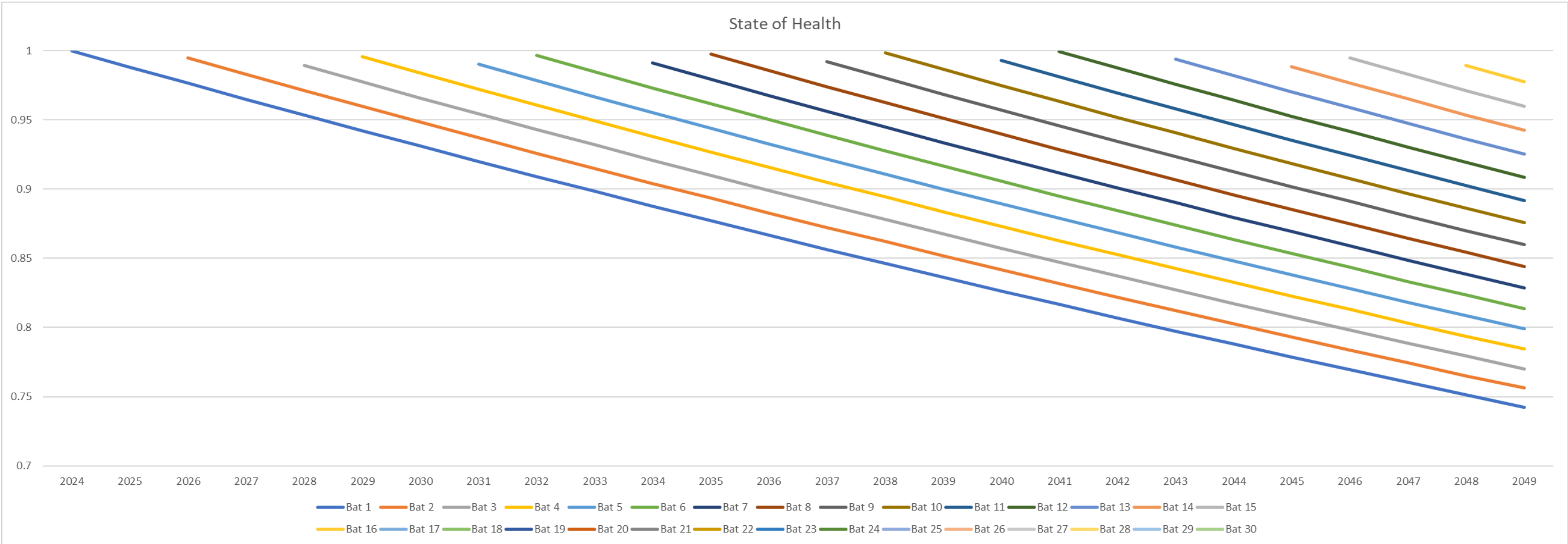
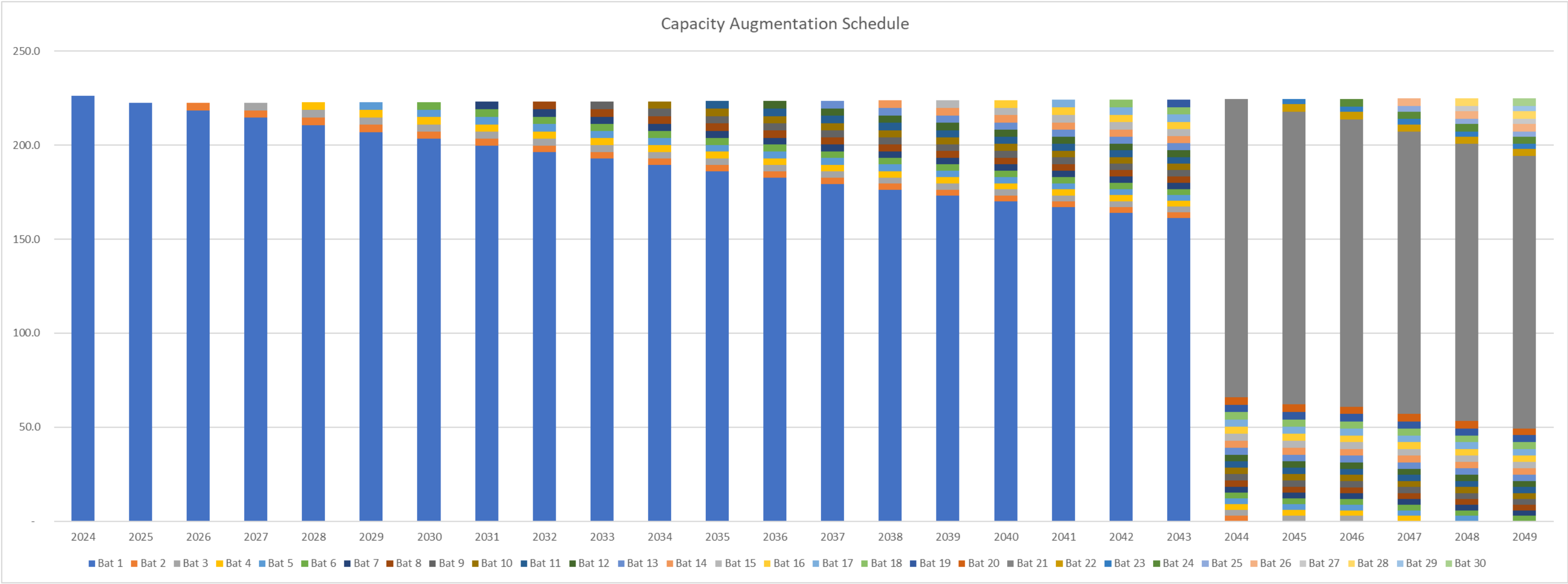
	2020-01-01	2021-07-01	2022-07-01	2023-07-01	2024-07-01	2025-07-01	2026-07-01	2027-07-01
Equity Investment	-\$24,640,000	-\$24,640,000	-	-	-	-	-	-
Dividends	-	-	\$5,534,155	\$6,520,378	\$6,158,543	\$5,844,742	\$5,535,214	\$5,540,000
Terminal Value	-	-	-	-	-	-	-	-
Investment Tax Credits	-	-	\$588,000	\$588,000	\$588,000	\$588,000	\$588,000	-
Returns with TV & ITC	-\$24,640,000	-\$24,640,000	\$6,122,155	\$7,108,378	\$6,746,543	\$6,432,742	\$6,123,214	\$5,540,000



Storage Capacity Augmentation and Replacement

Required energy 200 MWh

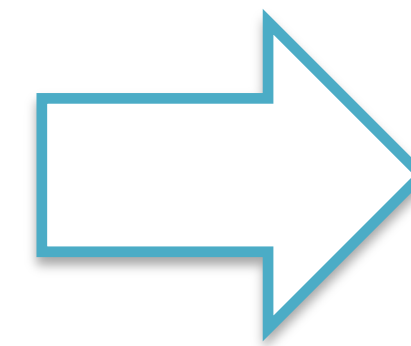
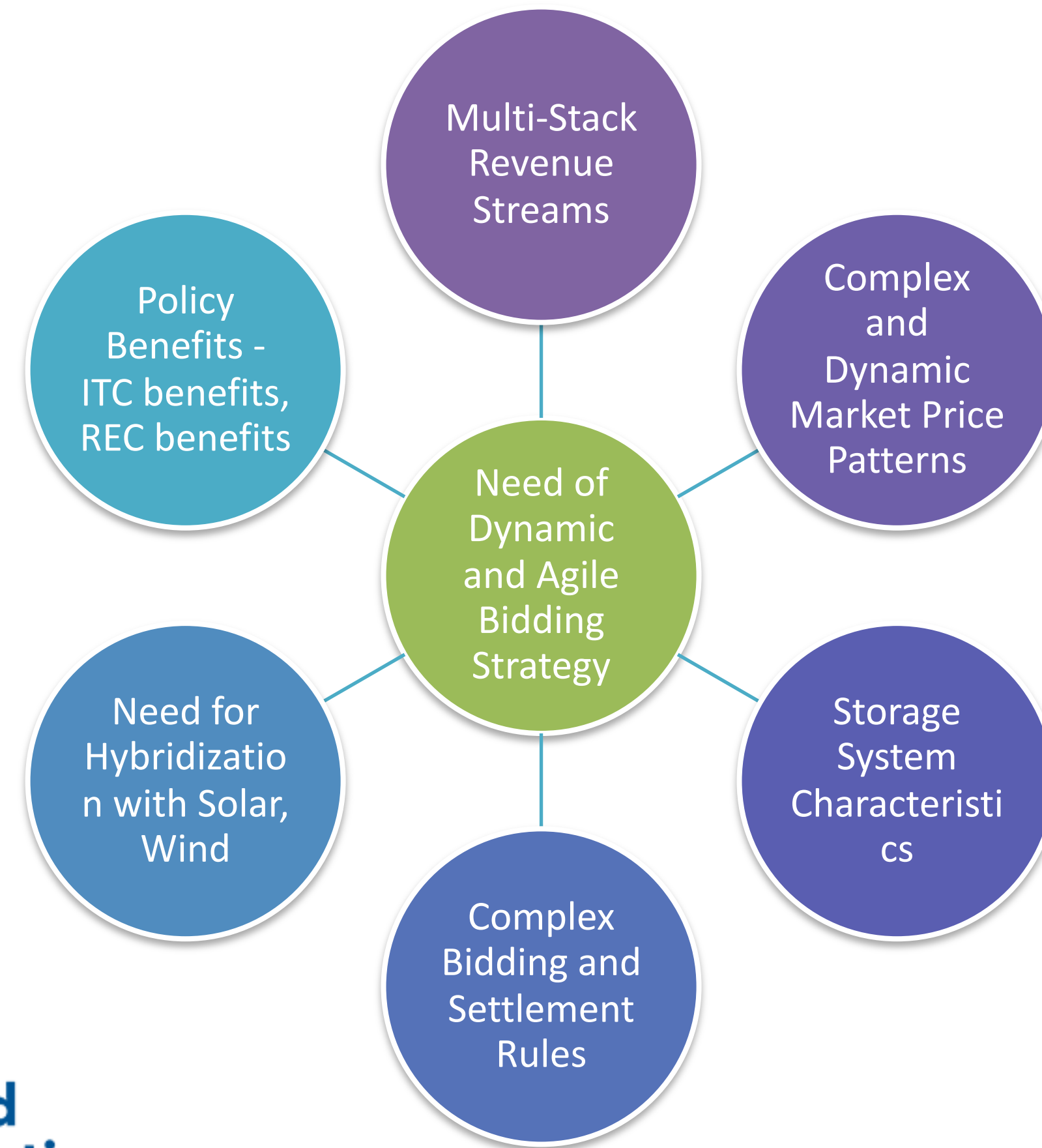
350 cycles / year



Market Operations

Why Optimize BESS Operations?

Optimization is used to get an hourly optimal bid-offer set of storage, for each market product in the wholesale electricity market

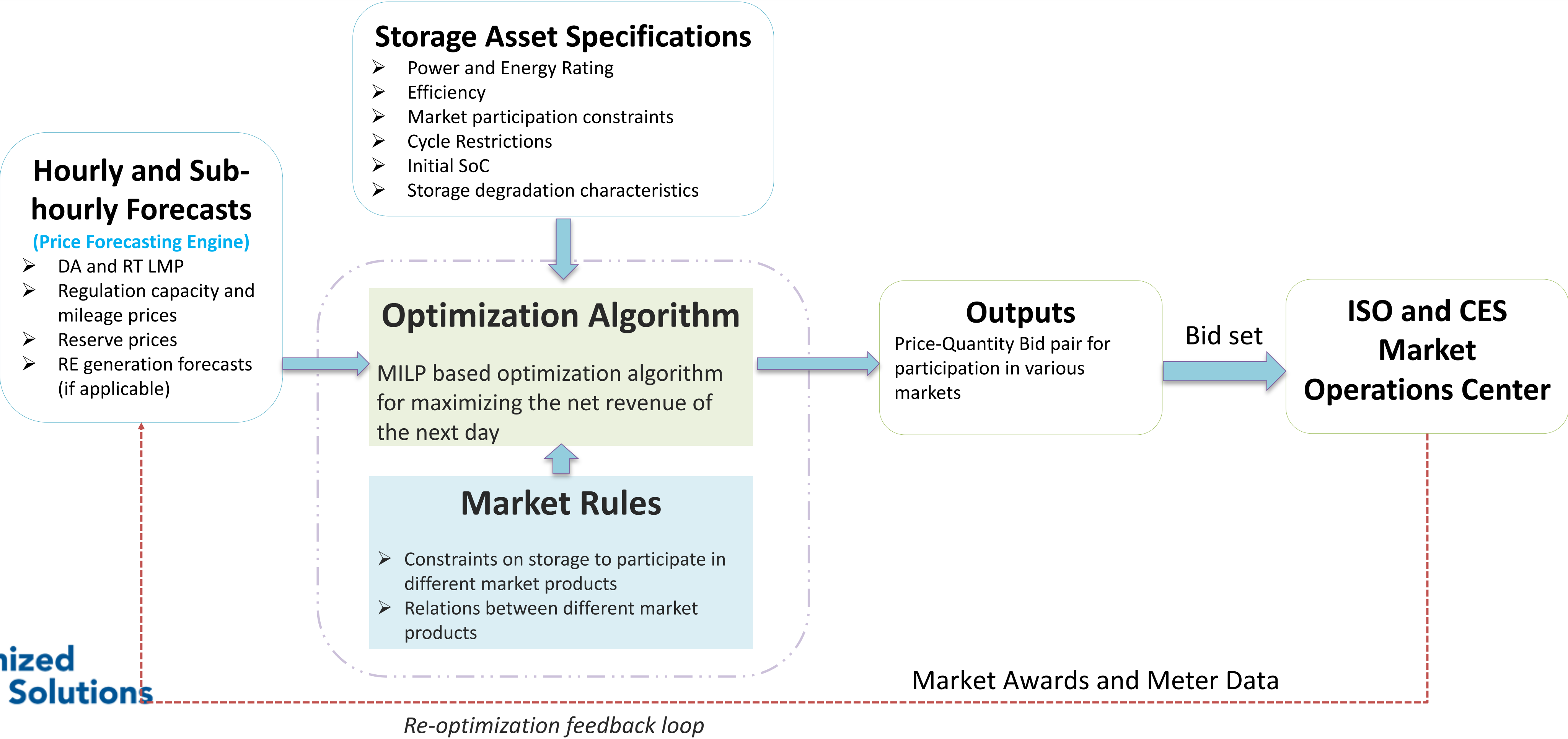


HOW TO MAXIMIZE THE DAILY REVENUE OF THE BESS, GIVEN TECHNICAL AND MARKET CONSTRAINTS?

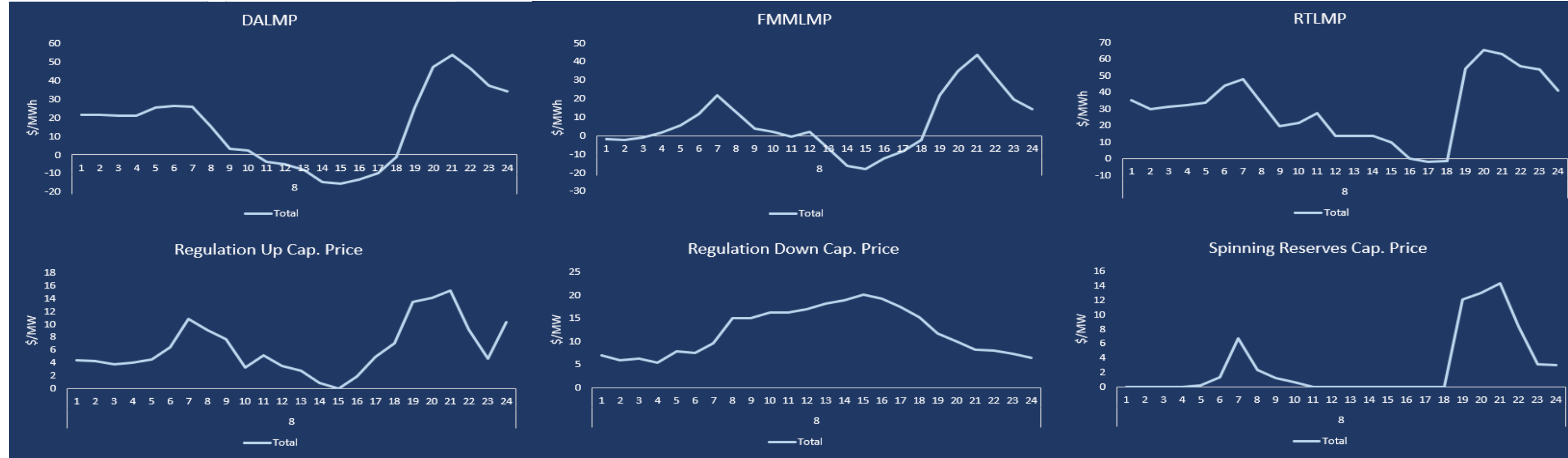
Bid Offer Optimization Process in GridBOOST

CES GridBOOST is a dedicated platform to optimize the operation of energy storage assets using optimal bidding in the electricity markets.

Price forecasting engine and optimization engine are run on Day-Ahead and hourly basis to generate the optimized bid offer sets.



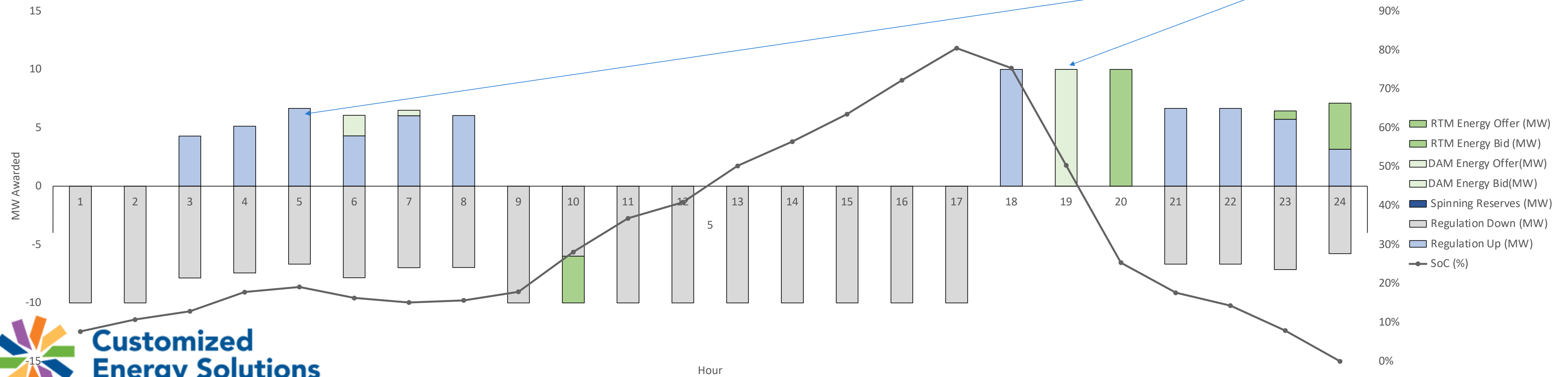
Optimized Dispatch of Standalone Storage for a Day in CAISO



Storage Config.-10MW and 40MWh with 90% RTE

Dispatch in DAM and RTM energy markets to capture the benefit of high LMPs in the morning and the evening solar ramp hours.

STORAGE OPTIMAL DISPATCH

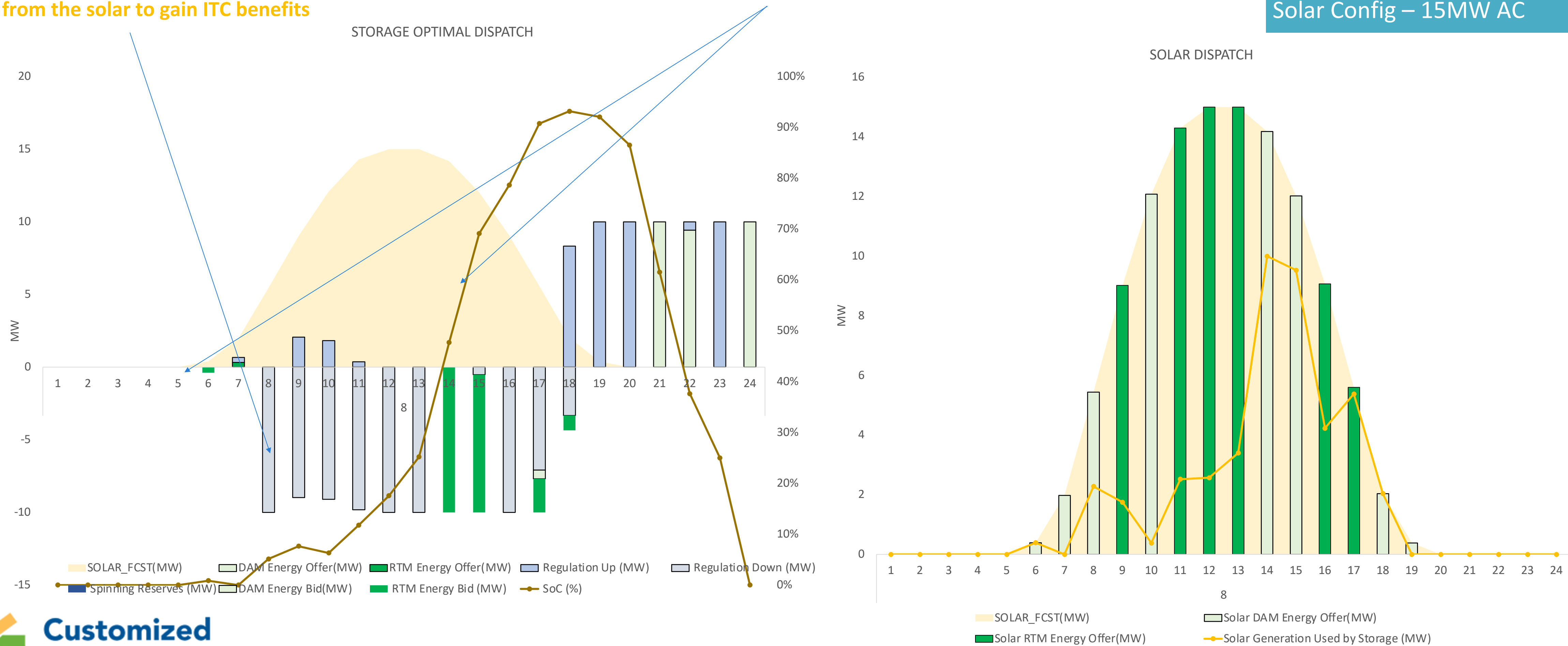


Optimized Dispatch of Co-located Solar + Storage for a day in CAISO

Storage charges only in the solar generation hours through the energy market bids and regulation down because of CONSTRAINT - 100% charging should be done from the solar to gain ITC benefits

Storage regulation offers and the energy discharge offers are limited by the POI limit of 15MW in the solar generation hours.

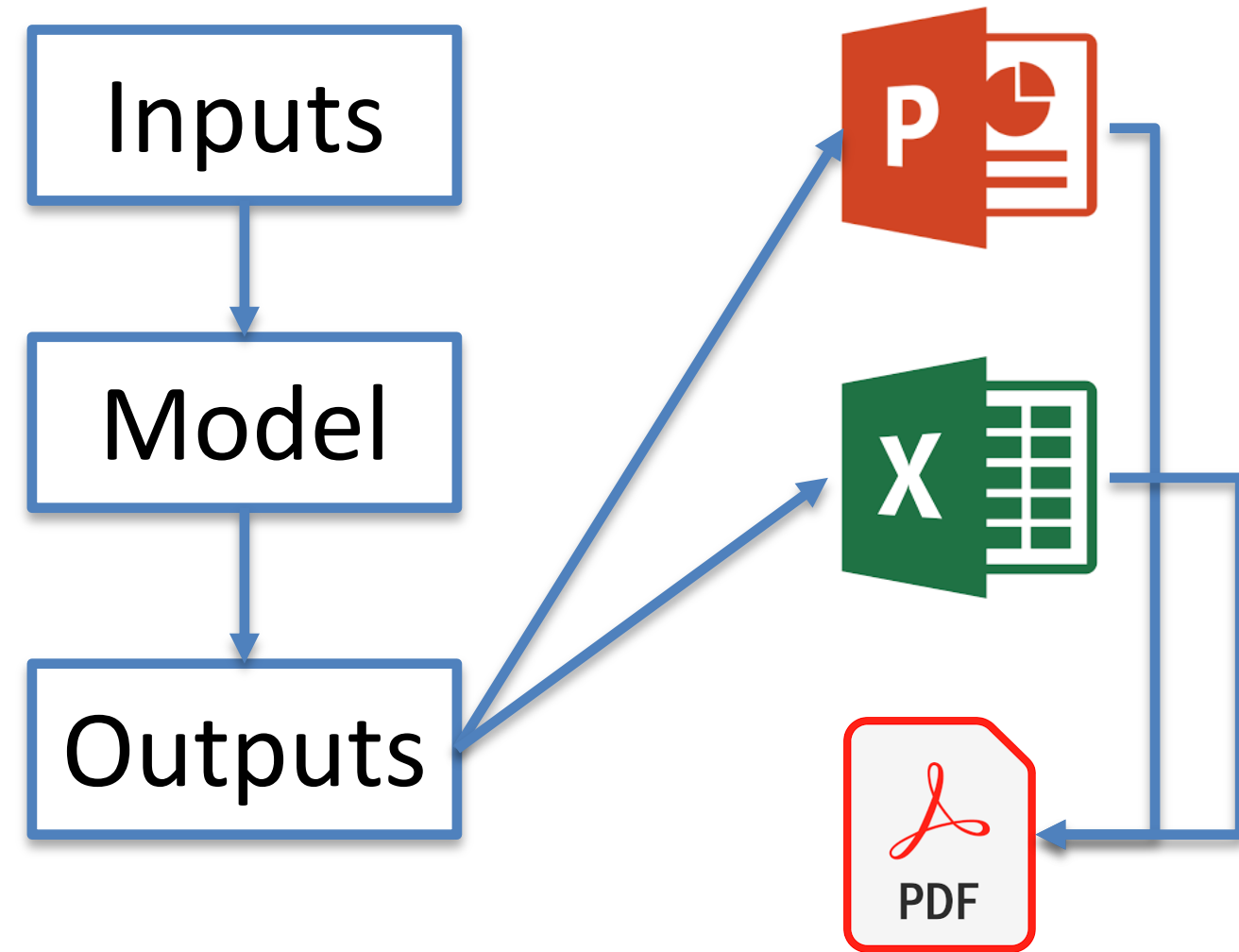
Storage Config. -10MW and 40MWh with 90% RTE
Solar Config – 15MW AC



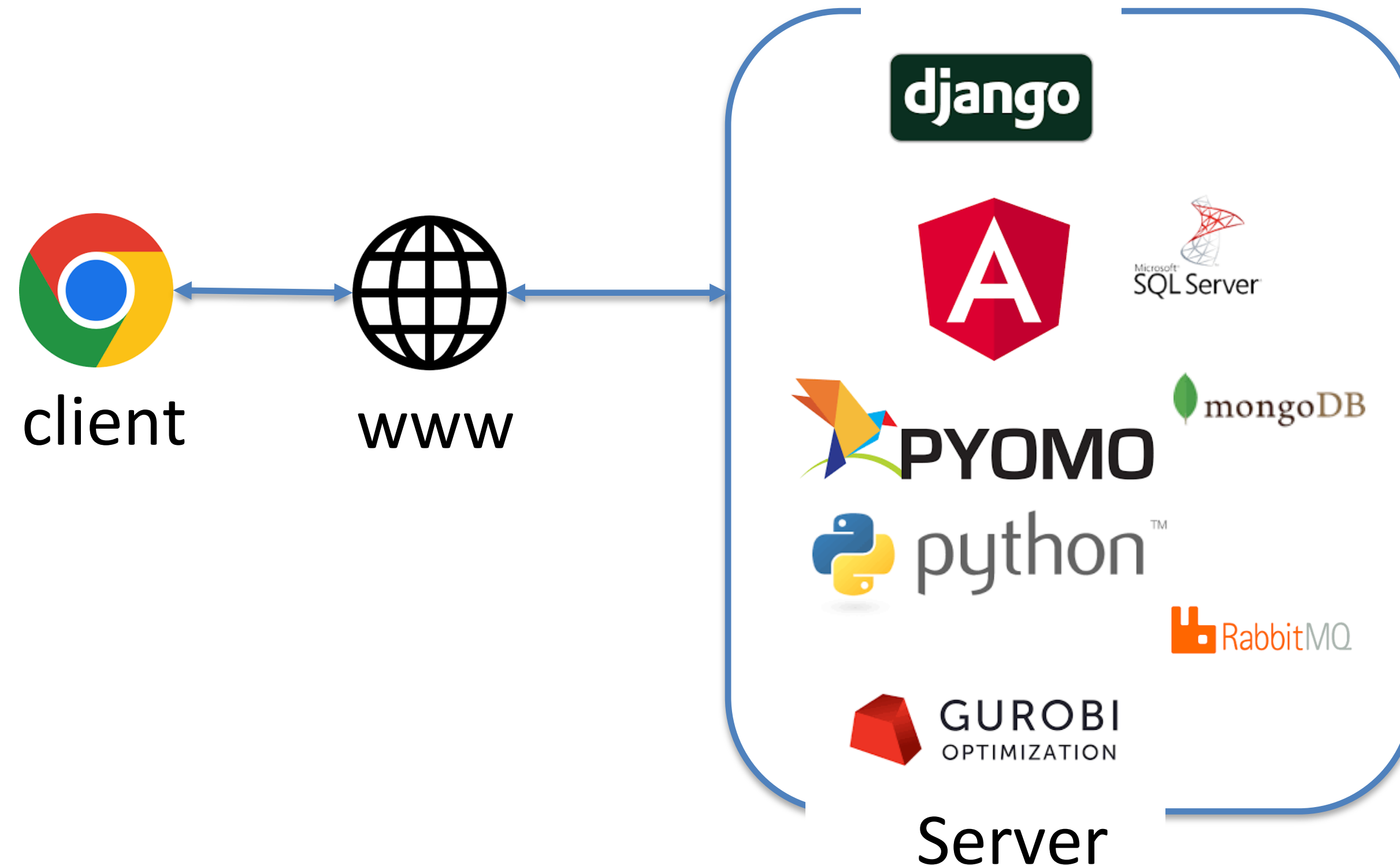
How we use Gurobi



Offline models (Majority delivery channel)



Online models



About CES

Customized Energy Solutions is a leading energy advisory and service company headquartered in Philadelphia. Established in 1998, CES's consulting services enable market participants, project developers, investors, technology providers, marketers, utilities and customers to prosper through change, by turning information into actionable intelligence

CES has steadily expanded its best-in-class hosted market operations platforms and services portfolio globally and is now serving more than 500+ customers operating in the United States, Canada, India, Japan, and Mexico.

500+ Global Clients	24x7 Market Operations	18+ GW Assets Managed
300+ Associates	Advanced Software Platforms	700+ MW Energy Storage Managed



Customized Across the Globe



CES is proud to have been recognized 11 times in Inc. 5000 as one of the most successful companies in the United States

CES Business Lines

MARKET INTELLIGENCE

CES MarketIQ keeps you ahead of the game on ISO rules changes, freeing you from the labor-intensive process of attending multiple meetings and analyzing ISO trends and activities

WHOLESALE SERVICES

Our 24-hour Market Operations Center (“MOC”) and Operations Control Center (“OCC”) provides options to customers that need a full-service scheduling coordinator or a more specific asset monitoring service

RETAIL SERVICES

CES offers a series of hosted platforms specializing in competitive energy market entry and operations, state and regional grid registration, renewable compliance and market intelligence

FUTURE GRID

CES serves customers in a variety of areas in the DER space including demand response, EV charging, peak load management, and management of bidding for energy and capacity in major ISOs/RTOs in North America

EMERGING TECHNOLOGIES

CES provides a wide spectrum to consulting services to help clients understand complex rules, identify key drivers and opportunities for energy storage, e-mobility, hydrogen projects, forecast project revenues and optimize investments

CES Emerging Technologies

CES has developed an integrated ecosystem spanning market intelligence, policy expertise, modeling and optimization software platforms, technical capabilities and market operations to support our clients in three key focus areas

ENERGY STORAGE

GREEN HYDROGEN

E-MOBILITY



Market Advisory

Overviews and detailed intelligence from across all North American ISO/RTO regions to help clients navigate through competitive markets



Revenue Forecasts

Powered by CES CoMETS, our revenue modeling services help clients make the right investment decisions with their projects



Financial Services

Financial Modeling, Project Valuation, Due Diligence and Bid support services to help clients compete in solicitations



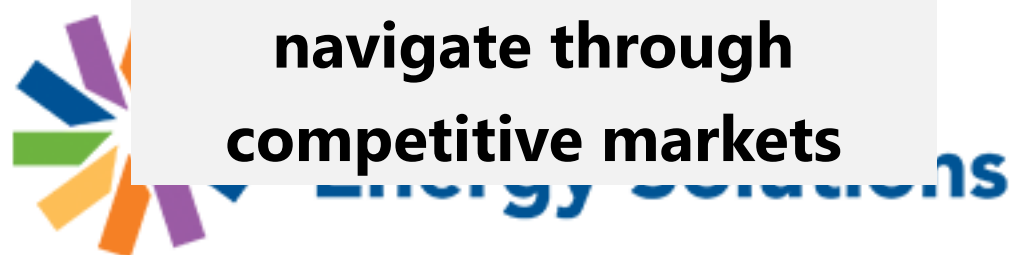
Strategy Consulting

Advisory services for new market entry, investments, partner search, development of strategic vision and corporate implementation plans



Technical Services

Technical Due Diligence, Testing, Performance Validation, Expert Recommendations for battery cells, packs and associated systems



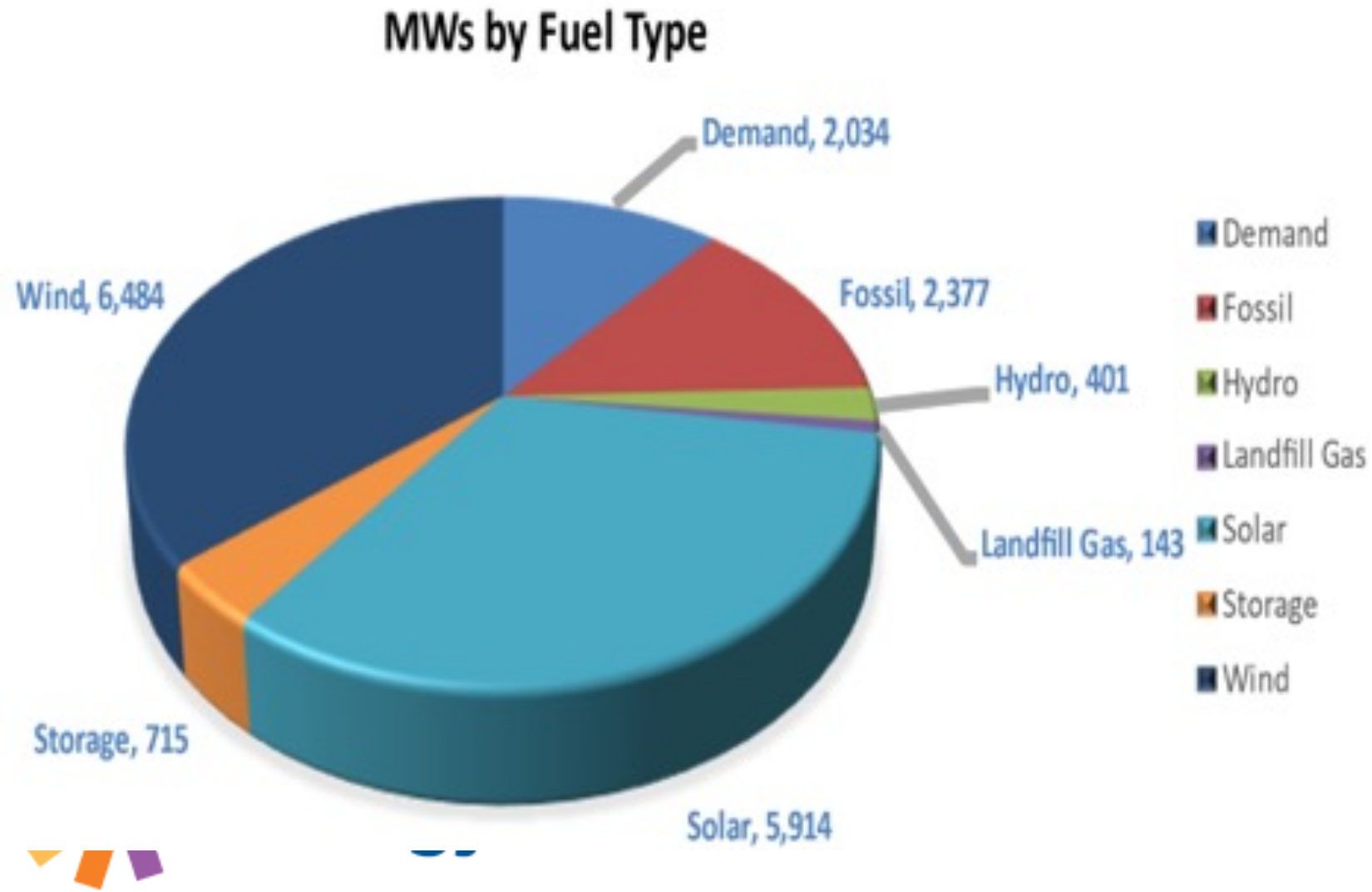
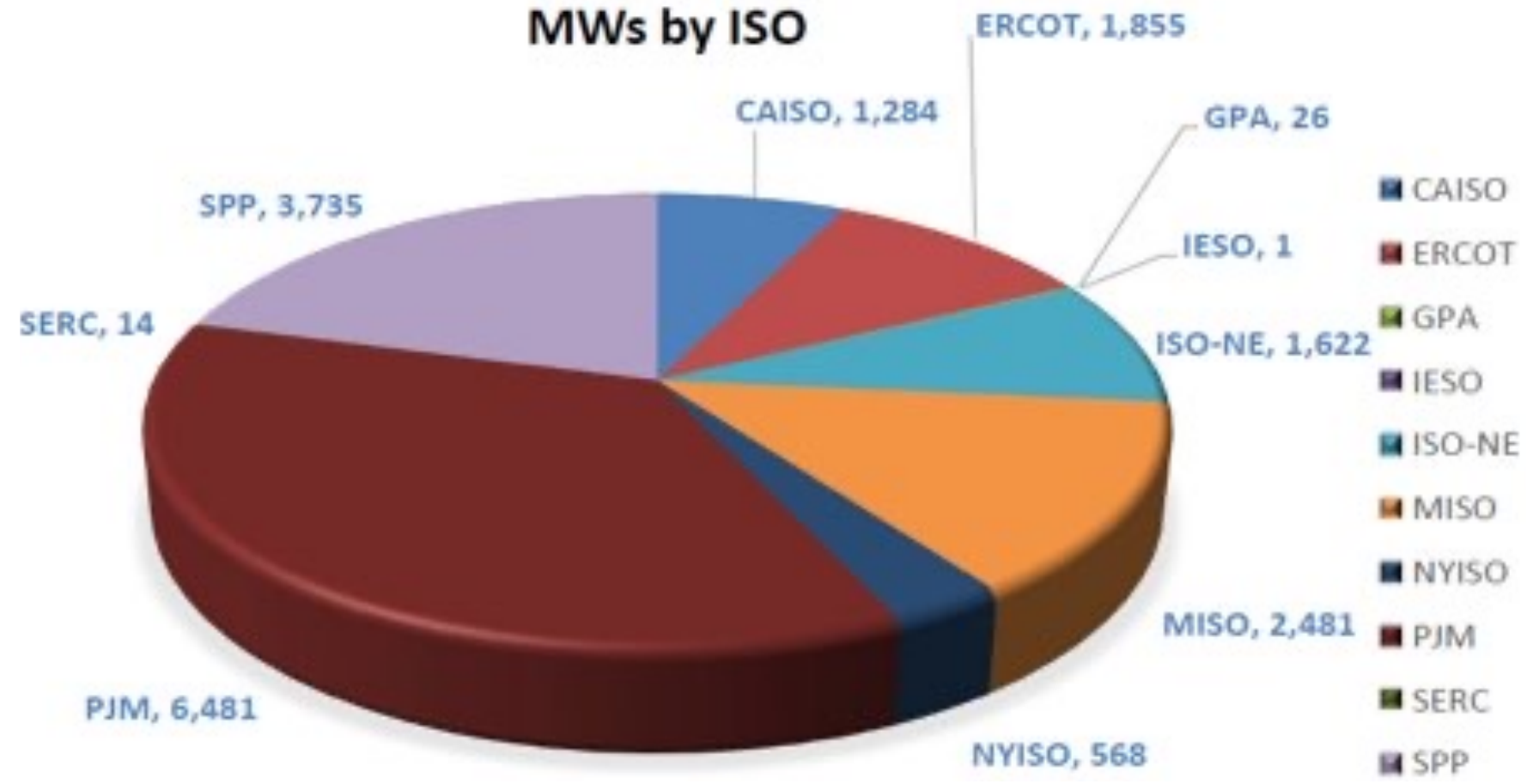
CES Operational Experience

CES MOC Assets under Management

18,000+ MW

350+ Resources

700+ MW ESS



Thank You.

Pranao Walekar

Product Manager (CoMETS), pwalekar@ces-ltd.com

Jatin Sarode

Senior Analyst (Future Grid), jsarode@ces-ltd.com

USA

CORPORATE HEADQUARTERS
1528 Walnut Street, 22nd Floor
Philadelphia, PA 19102

INDIA

HEADQUARTERS
A-501, G-O Square
Aundh-Hinjewadi Link Road
Wakad, Pune 411057, India

JAPAN

〒150-0036
16-28 Nanpeidaicho, Shibuya-ku,
Tokyo
Daiwa Shibuya Square 6th floor

VIETNAM

11 Bis Phan Ngu Street, Da Kao
Ward, District 1
Ho Chi Minh, Vietnam