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Scale of Energy Storage – Applications and Value of Hybrid Energy Storage on Grid Operations

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Technology - Drivers – Research Interdynamics

Storage technology

- Electrochemical storage
- Hydrogen storage
- Thermal storage
- Compressed air
- Supercapacitor
- Pumped hydro

Drivers

- Storage costs
- Energy markets evolution
- Energy rate structures
- Policy and regulations
- Variable renewable resources
- Resilience

Research

- Grid integration challenges
- Storage response time
- Storage characterization
- Storage sizing
- Battery life
- Storage asset evaluation

Scale of energy storage

Mobility

kWh scale
Lithium ion based

Residential

kWh scale
Lithium-ion
Lead-acid

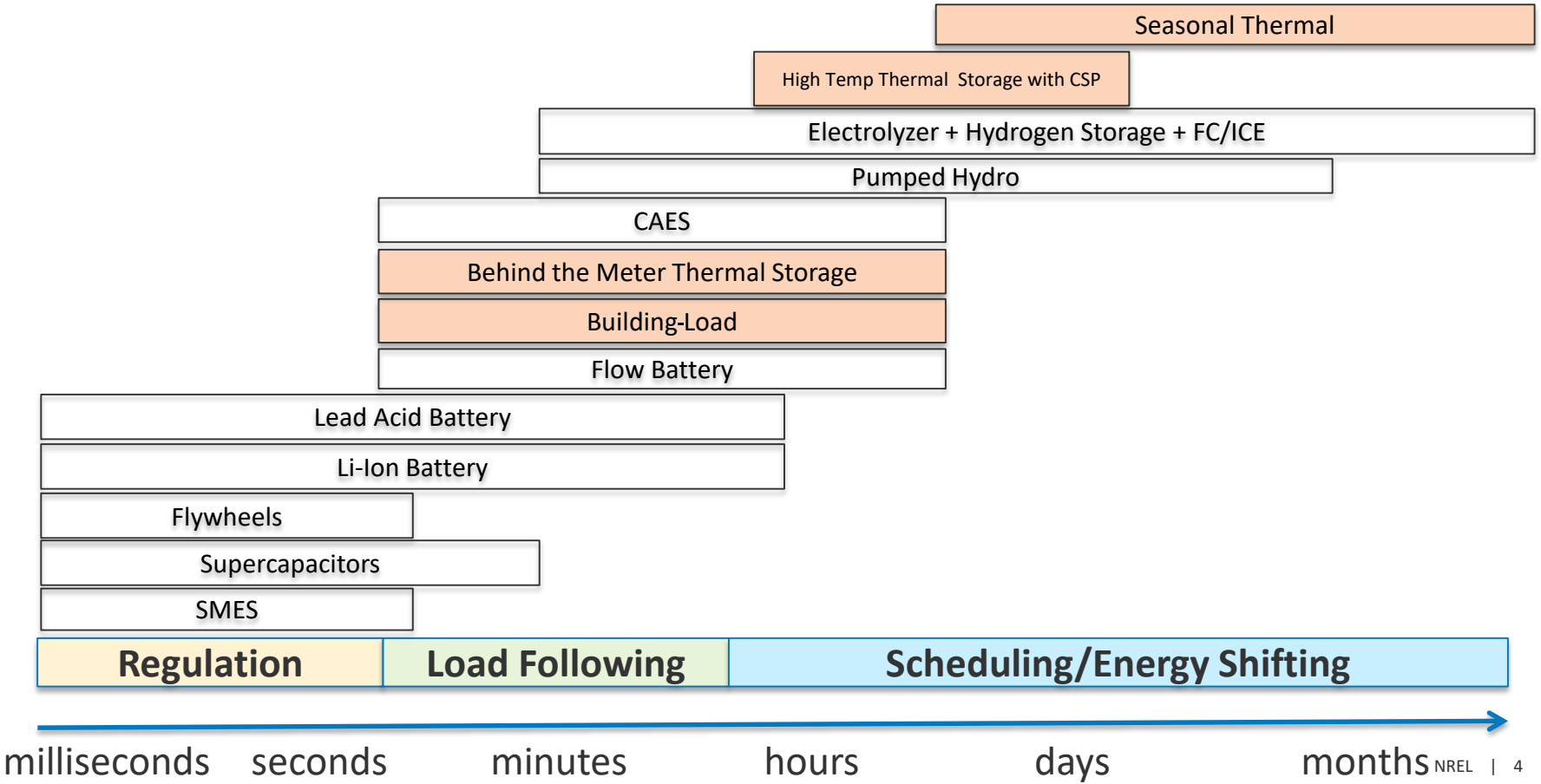
Utility-scale

MWh scale
Lithium-ion
Flow technology
Thermal storage

Bulk-grid

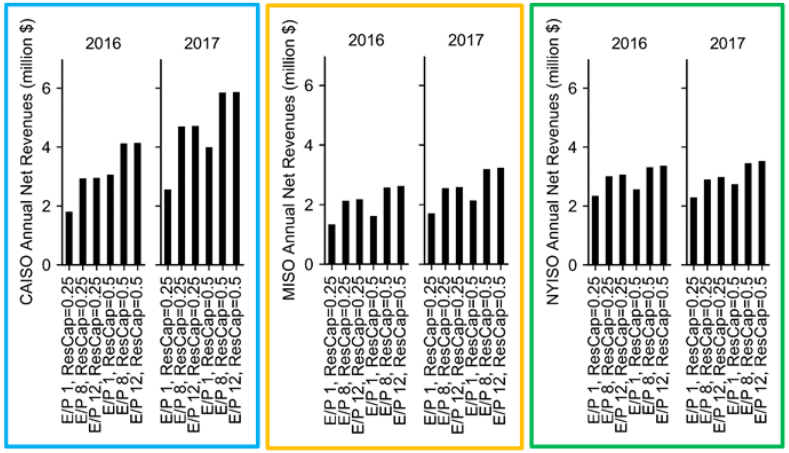
Multi MWh scale
Concentrated solar
Flow technology
Hydrogen storage
Thermal storage
Pumped hydro

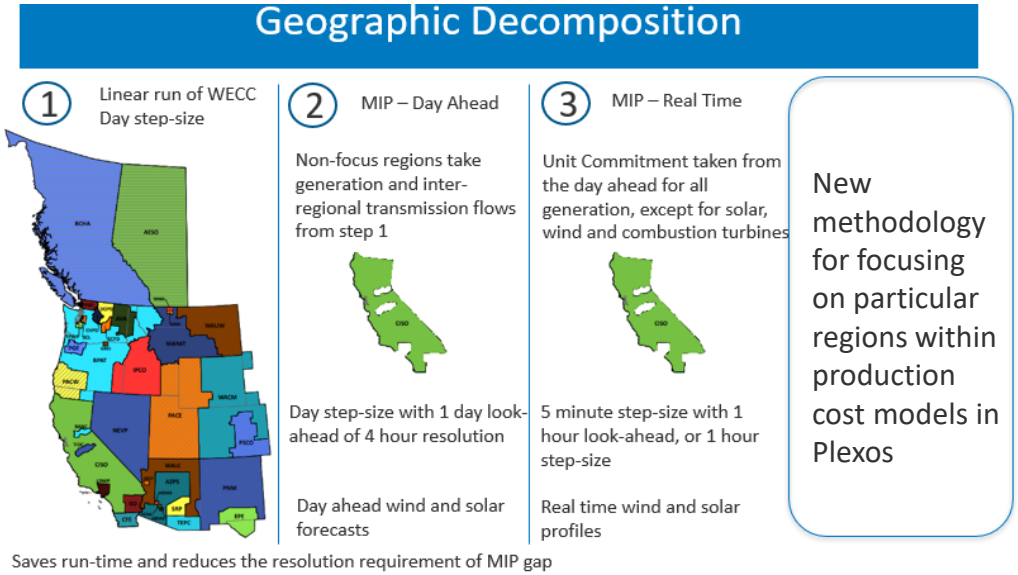
Types of stationary storage across timescales



Bulk grid storage

Pumped hydro





Pumped hydro research

- New methodology using co-optimization of price-taker model and production cost model to value hydropower pumped storage from an owner's perspective
- Working with two industry partners, both creating different turbine technologies
- Multiple areas in USA analyzed

Front of the meter
Utility-scale storage

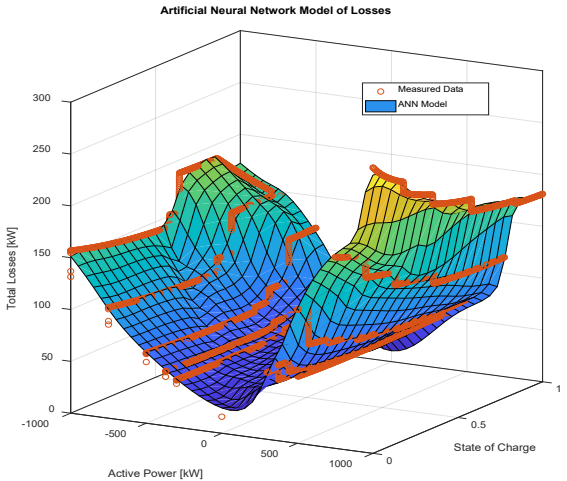
Distribution feeder choice and battery chemistry

2MW/4 hour Redox Flow Battery system

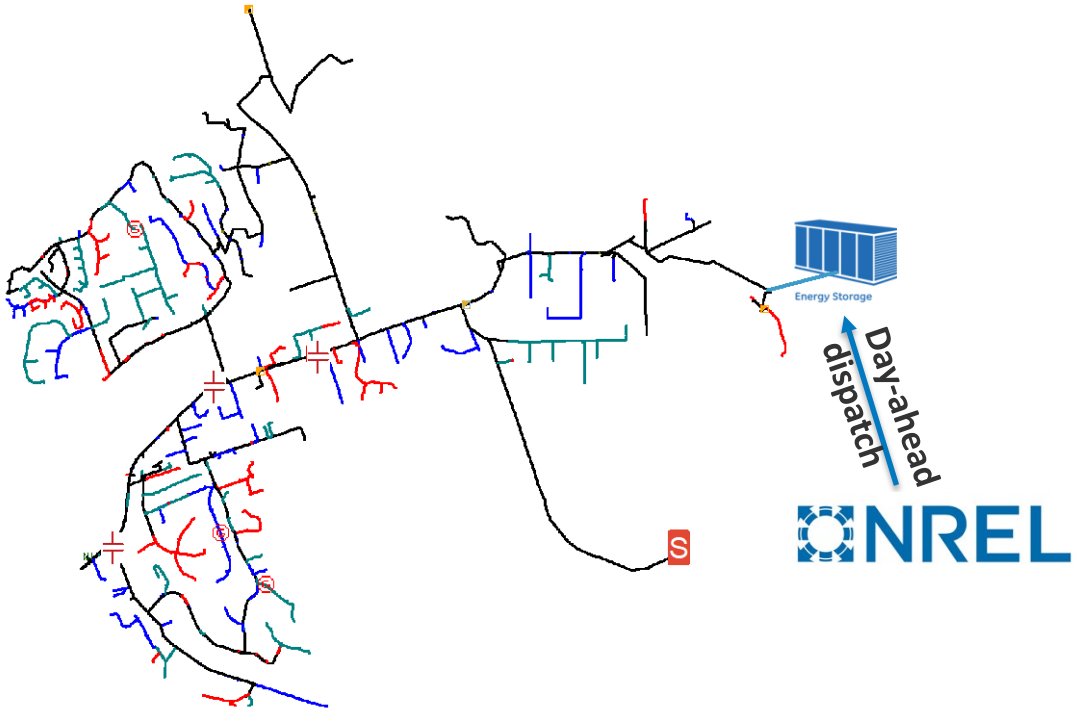
3MVA inverter capacity

6MW peak load and 3MW PV generation

Characterize battery chemistry

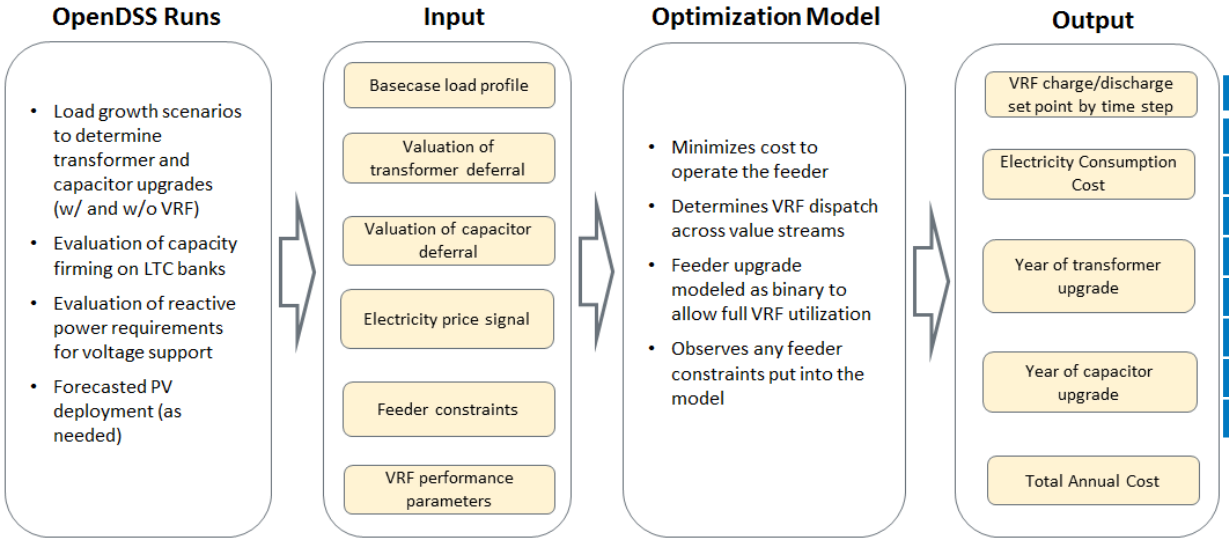


Model distribution feeder



Value streams from distribution feeder support

Value stream analysis



Economic Parameters and Costs	Assumption
Analysis period	25 years
Discount rate	6%
General inflation	0.1%
Electricity escalation rate	1.5%
Annual load growth	3%
Line upgrade cost	$670,000
Transformer upgrade cost	$1,497,000
New capacitor bank cost	$56,054

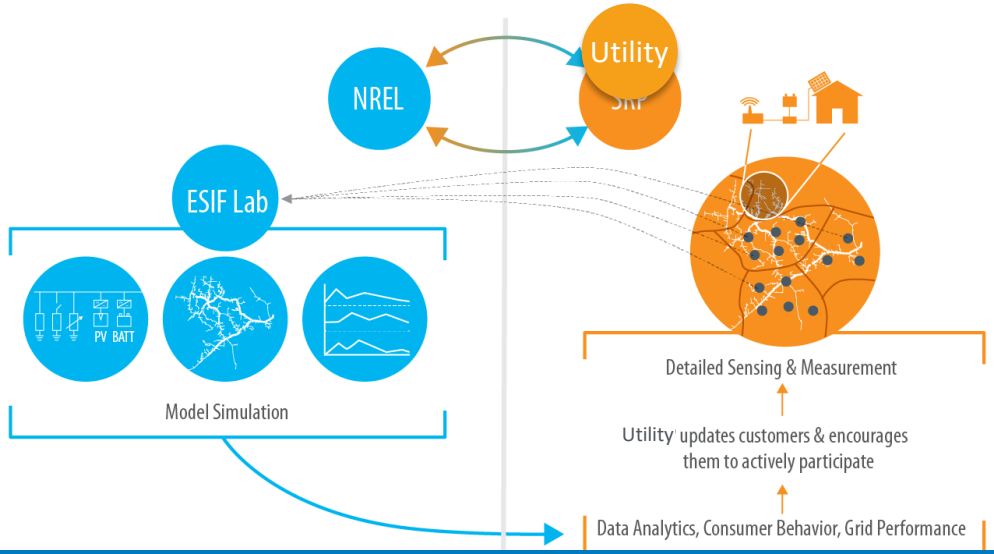
Jenkins, John D. 2014. "Capital Workpapers to Prepared Direct Testimony of John D. Jenkins on Behalf of San Diego Gas & Electric Company." November 2014. https://www.sdge.com/sites/default/files/SDGE-09-CWP_EDIST.pdf.

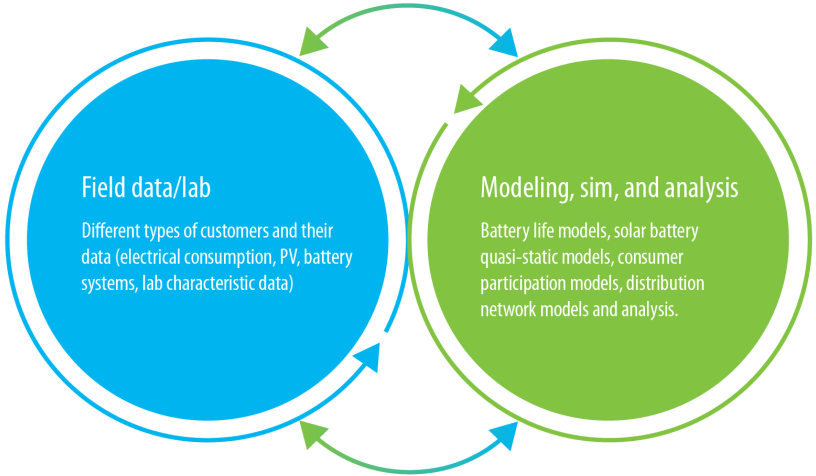
Value Stream	Monetization Mechanism	Year 1 Savings	Life-Cycle Savings
Peak shaving	Transformer upgrade deferral	–	$121,135
Capacity firming	Operation and maintenance savings from reduced LTC operations	–	–
Voltage support	New capacitor bank deferral	–	$7,463
Energy arbitrage	Time-shifting energy purchases on the LMP market	$56,069	$837,115
Total			$965,713

Jenkins, John D. 2014. "Capital Workpapers to Prepared Direct Testimony of John D. Jenkins on Behalf of San Diego Gas & Electric Company." November 2014. https://www.sdge.com/sites/default/files/SDGE-09-CWP_EDIST.pdf.

Value streams from local distribution grid support

Behind-the meter
Residential storage





Residential: Rate structures on battery use

- Develop battery models with consciousness of battery life, customer end-use and grid support
- Support utility customers to encourage customers understand value from BTM battery
- Analyze consumer behavior and grid operation analytics

Commercial customer battery storage reserach

Hybrid Battery Storage System Design

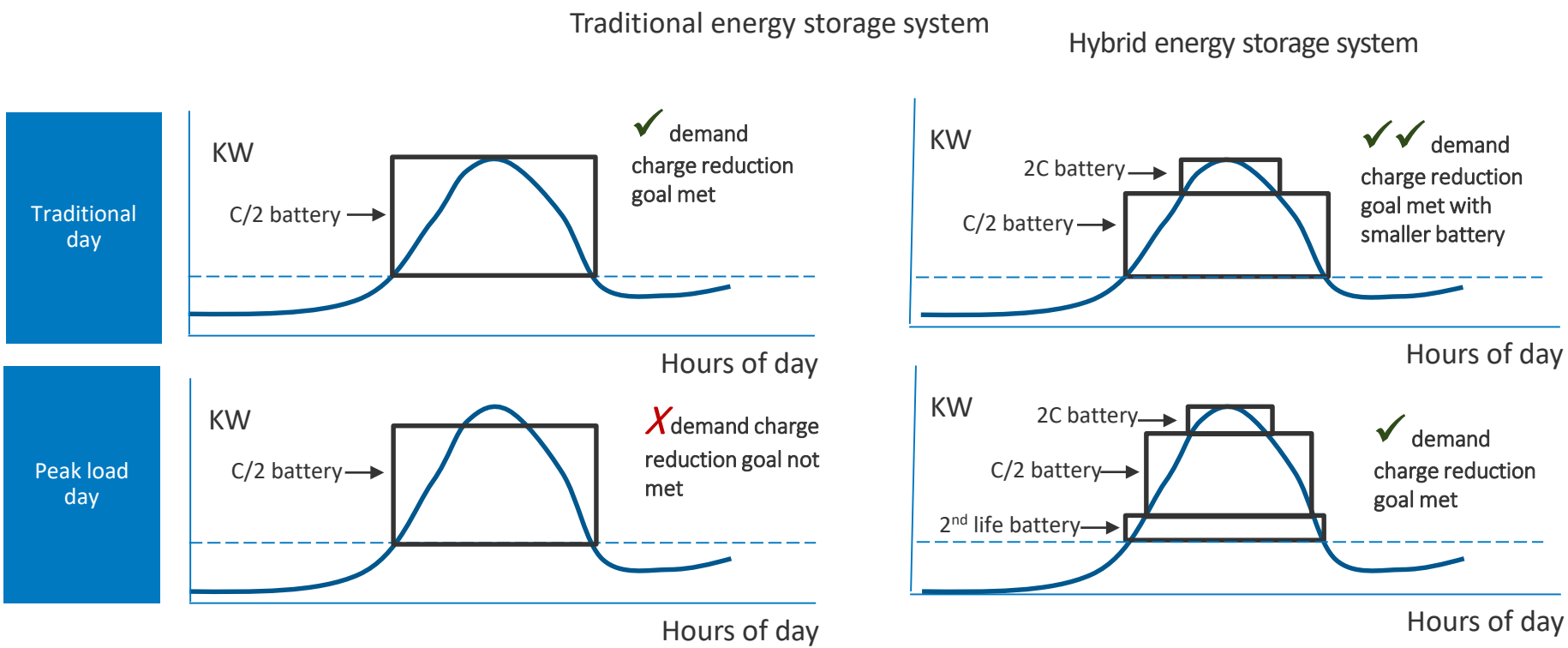
For applications in:

- EV Charging
- PV Storage
- Resiliency and Energy Efficiency

Design-for-purpose process:

1. Identify chemistry
2. Perform device design
3. Develop controls
4. Test integration of devices in ESIF

Can a hybrid system offer lower LCOE vs traditional Li-ion systems?



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Thank you

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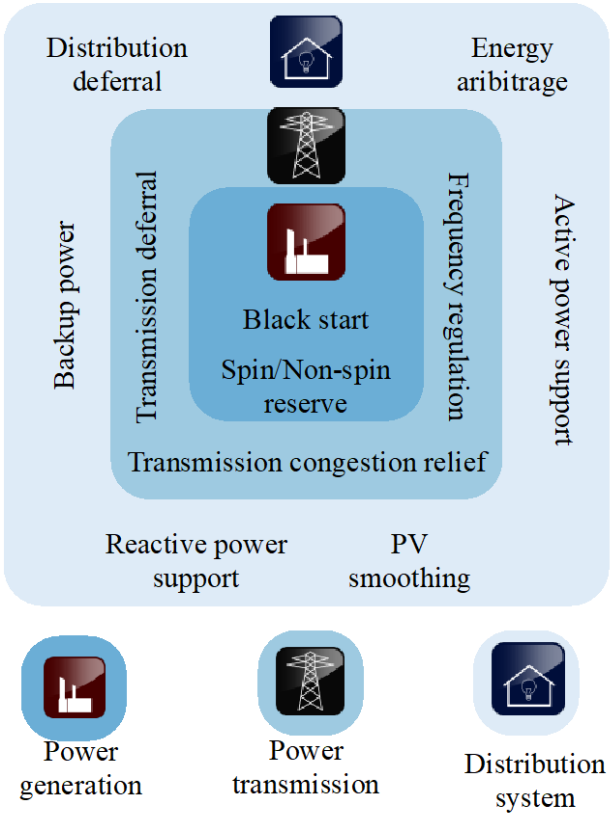
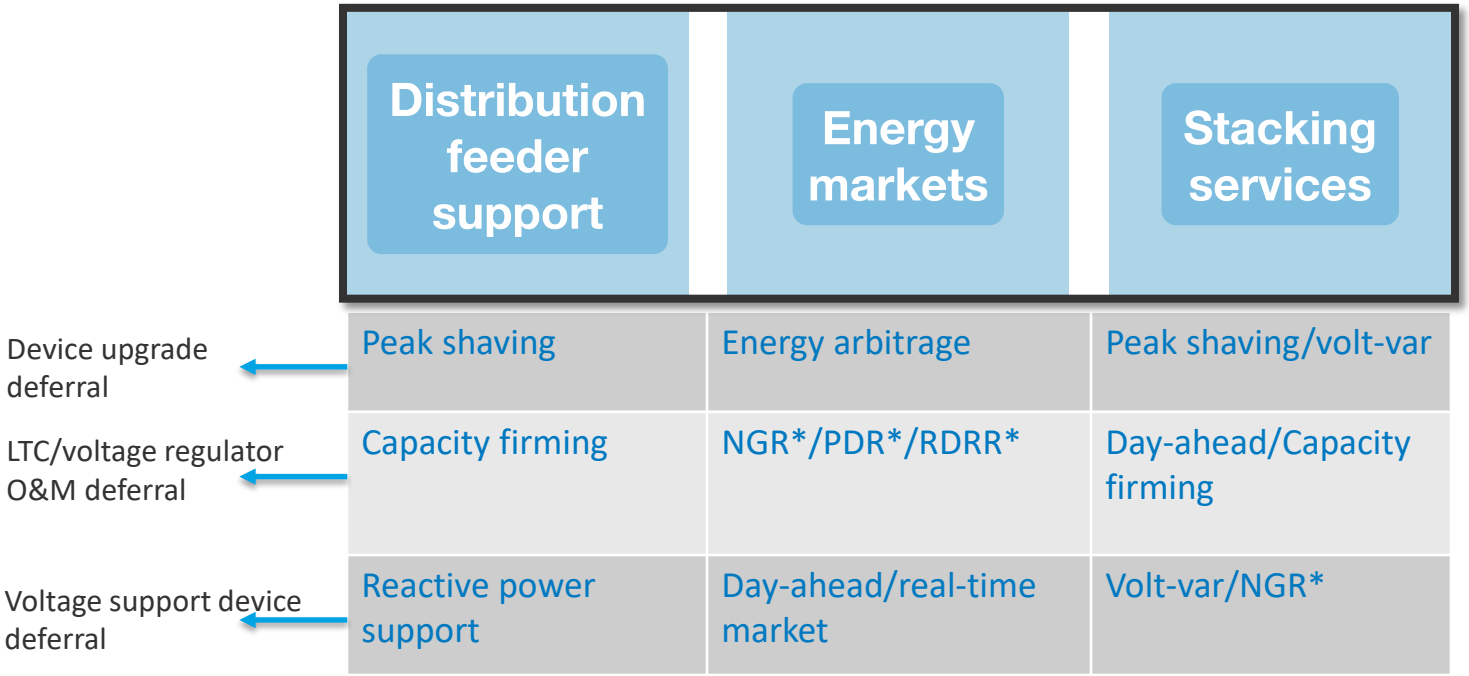
Storage Application in power grid



	Bulk Energy Services
market ←	Electric Energy Time-Shift (Arbitrage)
	Electric Supply Capacity
	Ancillary Services
market	Regulation
market	Spinning, Non-Spinning and Supplemental Reserves
	Voltage Support
	Black Start
	Other Related Uses
	Transmission Infrastructure Services
	Transmission Upgrade Deferral
	Transmission Congestion Relief
	Distribution Infrastructure Services
	Distribution Upgrade Deferral
	Voltage Support
	Customer Energy Management Services
	Power Quality
	Power Reliability
	Retail Electric Energy Time-Shift
	Demand Charge Management

Utilization of energy storage systems

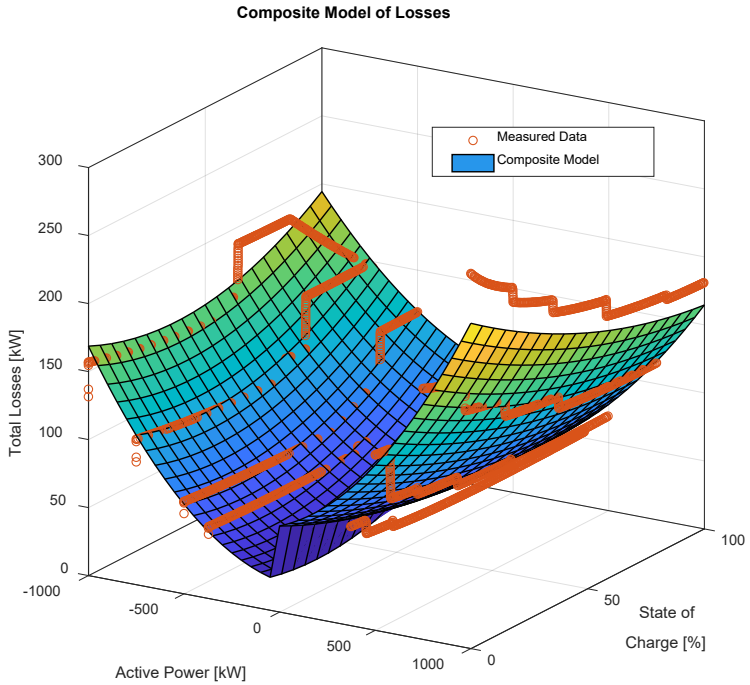


NGR: Non-Generator Resource
PDR: Proxy Demand Resource
RDRR: Reliability Demand Response Resource

Dynamic Battery Model – Composite Model

- Built Composite Loss Model into OpenDSS

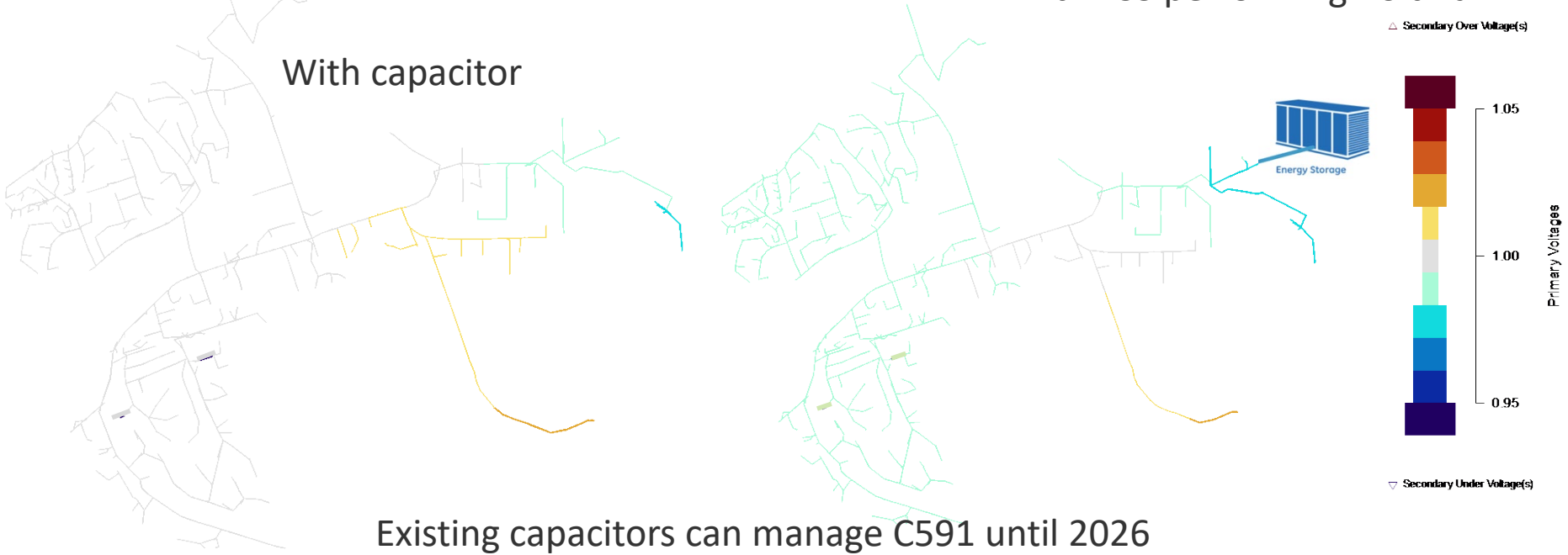
Total Losses= $(L_{PCS} + L_{Internal} + L_{Parasitic})$



Capacitor operation avoidance and deferral

With capacitor

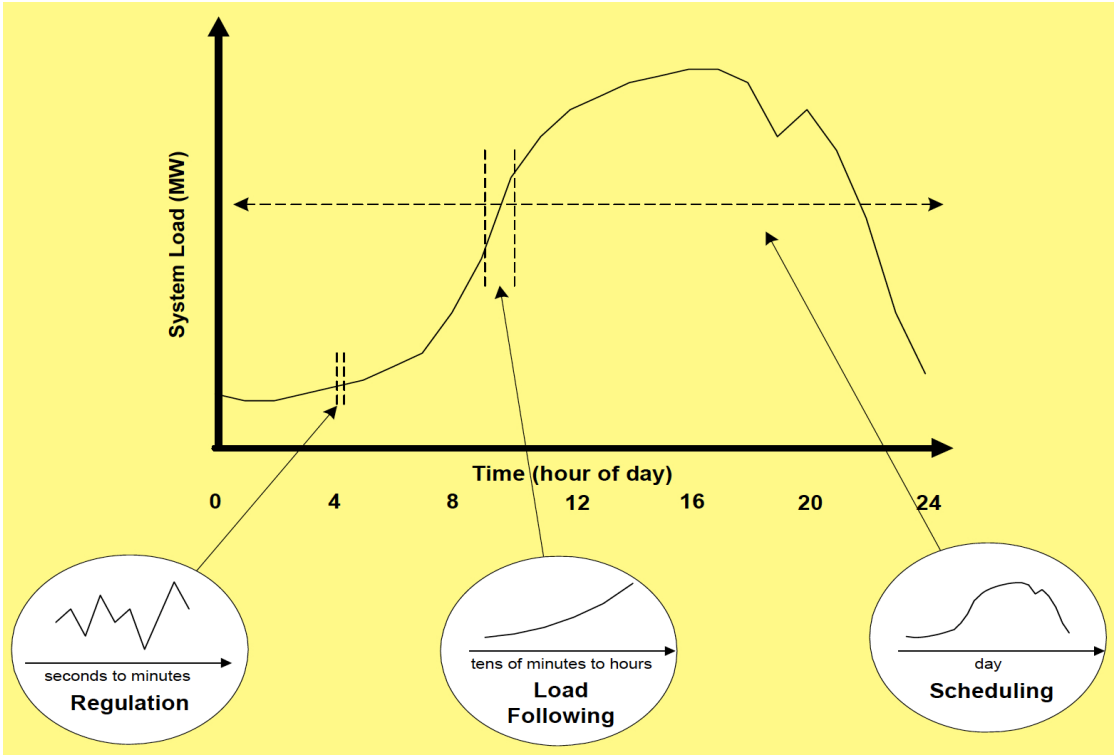
With ESS performing Volt-var



Existing capacitors can manage C591 until 2026

Energy storage performing volt-var can defer capacitor upgrade until 2031

Why to we need energy storage in power grid?



B. Parsons et al.(2006) Grid Impacts of wind power variability: recent assessments from a variety of utilities in the United States. National Renewable Energy Laboratory (NREL), Golden https://www.nrel.gov/docs/fy06osti/39955.pdf

Needed for balancing load and generation on the electricity grid match at a variety of timescales

- milliseconds to seconds
- seconds to minutes
- minutes to hours
- days

Storage provides ways to shift energy – helps to move variable generation to meet demand