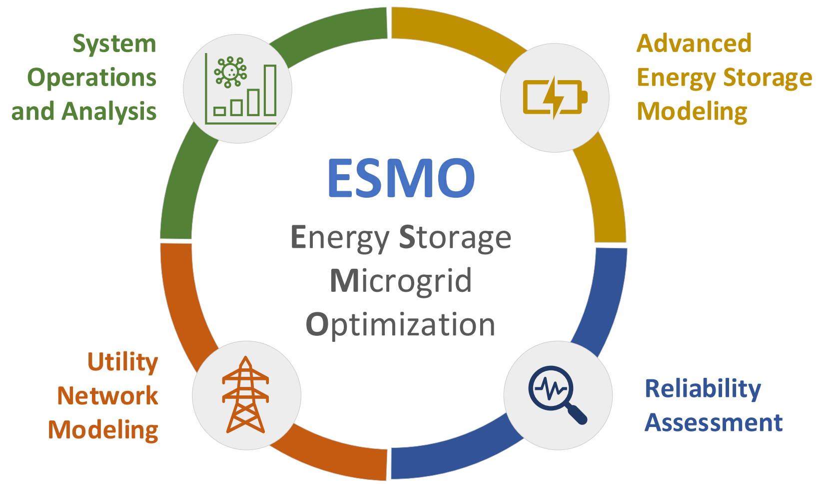
DOE Office of Electricity Peer Review
Oct 26, 2023

ADVANCED ANALYTICS TO SUPPORT TECHNOECONOMIC STUDIES OF STORAGE INVESTMENTS



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Argonne National Laboratory

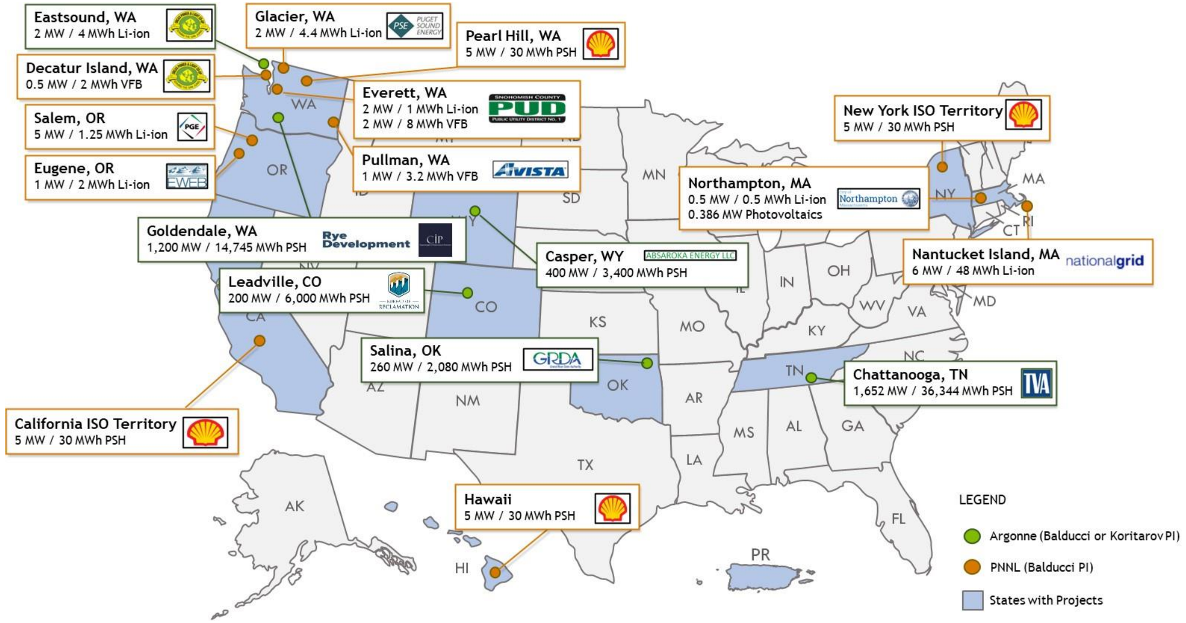
Presentation ID # 906

OVERVIEW

PROJECT SYNOPSIS AND ACCOMPLISHMENTS

Funded by DOE Office of Electricity (OE), DOE Water Power Technologies Office (WPTO), Washington State Clean Energy Fund, Utility Partners, and others

- Studies evaluated Li-ion, flow batteries, small- and large-scale pumped storage hydro (PSH), and hydrogen-based facilities
- FY 23 projects – Mt. Elbert PSH and Orcas Power and Light Co-op (OPALCO) Microgrid
- FY 23 Goals
  - Evaluate storage projects with novel use cases
  - Build new tools/models and approaches, evaluate new use cases
  - Share lessons learned



Energy Storage Technoeconomic Assessments Led by Patrick Balducci or Vladimir Koritarov of Argonne

3,754 MW 62,763 MWh at 18 Sites

*Note that all projects highlighted in orange were led by Patrick Balducci during his tenure at Pacific Northwest National Laboratory.

MT. ELBERT

OVERVIEW OF MT. ELBERT STUDY

- Study objective – Develop a plan highlighting areas of focus to **increase the value of the Mt. Elbert (ME) PSH** to the Bureau of Reclamation and its power customers
- Mt. Elbert power plant
  - Located outside of Leadville, Colorado above 9,000' of elevation at the headwaters of the Fryingpan-Arkansas Project
  - Receives conduit water inflows controlled by Reclamation
  - Plant is reaching end of useful life and upgrades are necessary
- Broad study and modeling design can be applied to other Reclamation facilities to maximize their value

Mt. Elbert Powerplant

Funding
- DOE OE - $150k
- DOE WPTO - $300k
- Reclamation - $157k

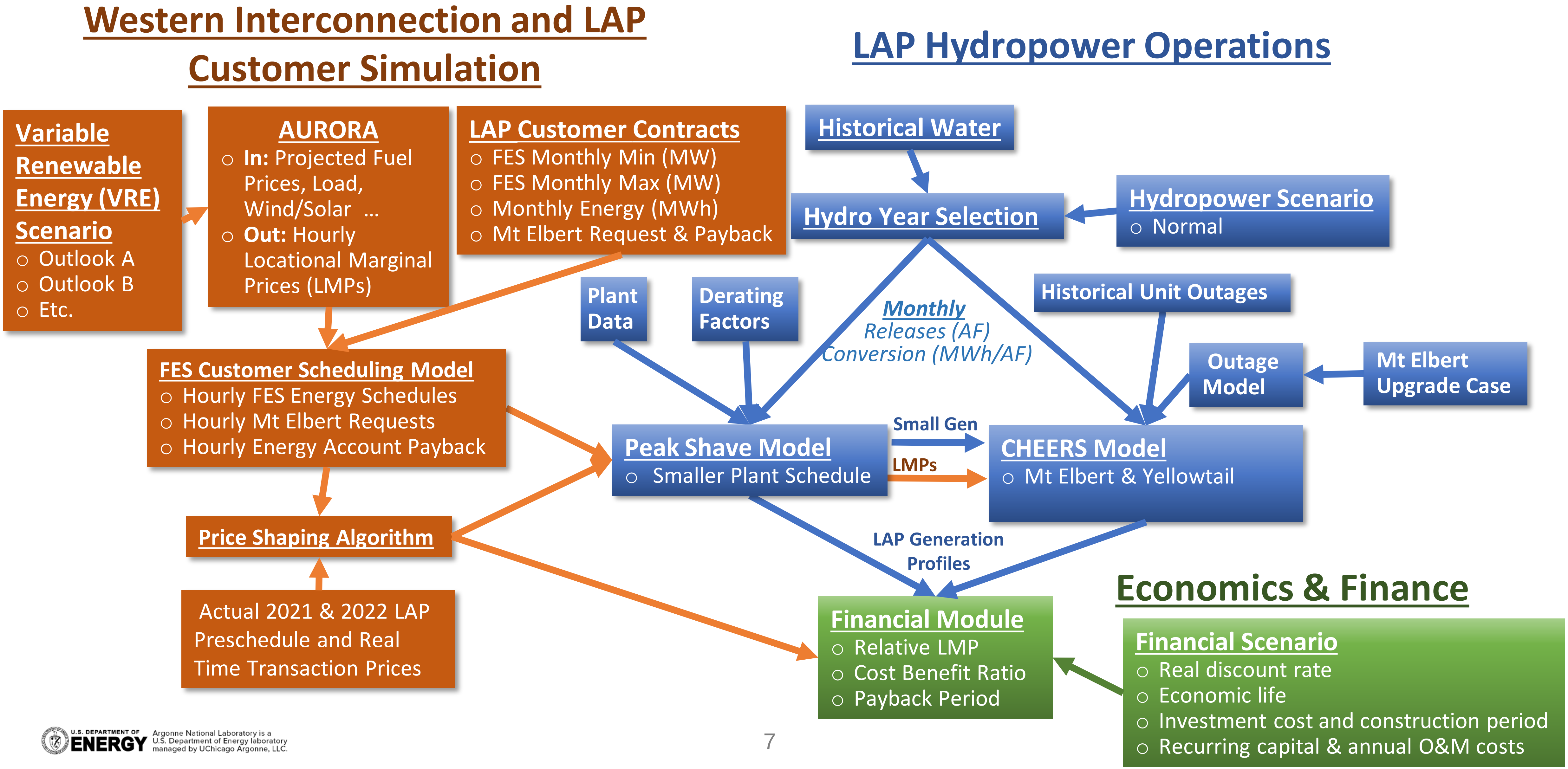
MT. ELBERT STUDY SYNOPSIS

Task 1: Study Planning and Literature Review
Task 2: Mt. Elbert Systems Study
Task 3: Systems Study without Mt. Elbert
Task 4: Analysis of Transmission Contracts and Constraints
Task 5: Mt. Elbert O&M Evaluation
Task 6: Market Factors Analysis
Task 7: Evaluation of Alternative Technologies
Task 8: Final Reporting

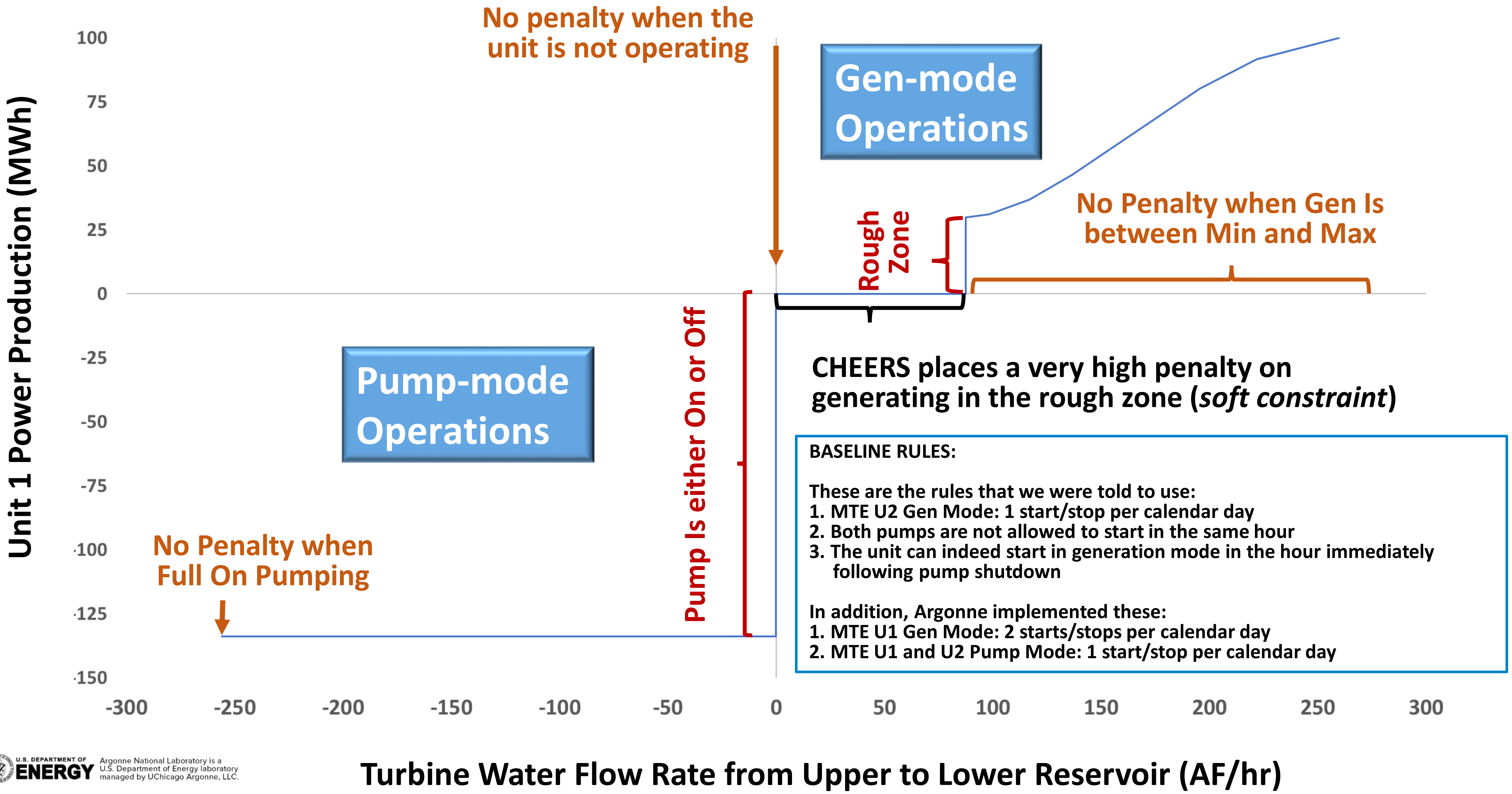
- The main work product produced under each task 1-8 will be a set of CHEERS model results; AURORA used to model future prices and simulate FES customer energy requests and energy payback under Loveland Area Projects (LAP) long term firm (LTF) contracts
- Under each of the various tasks, CHEERS and the Peak Saving Algorithm optimize the operation of:
  - The Mt. Elbert PSH power plant,
  - Energy market balancing transactions, and
  - Operation of other hydropower facilities in the LAP system such as Yellowtail (YT)
- The highest priorities in the modeling system is to serve Firm Electric Service (FES) customer loads with LAP hydropower resources and to optimize market transactions
- The optimization can be performed for multiple technology alternatives and operational scenarios

MT ELBERT ANALYSIS/MODELING STRUCTURE

Loveland Area Project (LAP) Customers, Hydropower Operations, & Financial Viability



MT ELBERT REPRESENTATION IN CHEERS



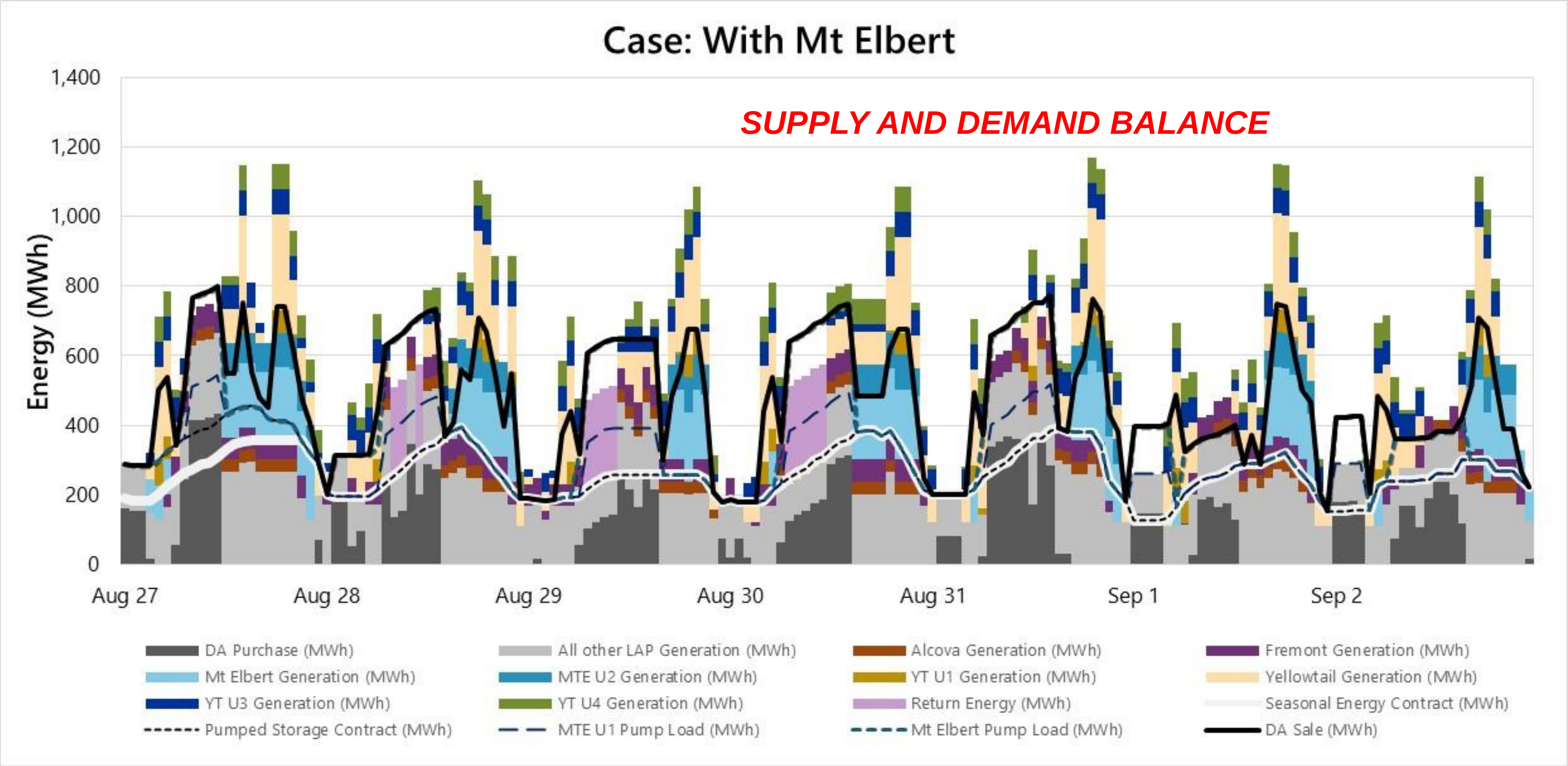
BASELINE RULES:

These are the rules that we were told to use:
1. **MTE U2 Gen Mode: 1 start/stop per calendar day**
2. **Both pumps are not allowed to start in the same hour**
3. **The unit can indeed start in generation mode in the hour immediately following pump shutdown**

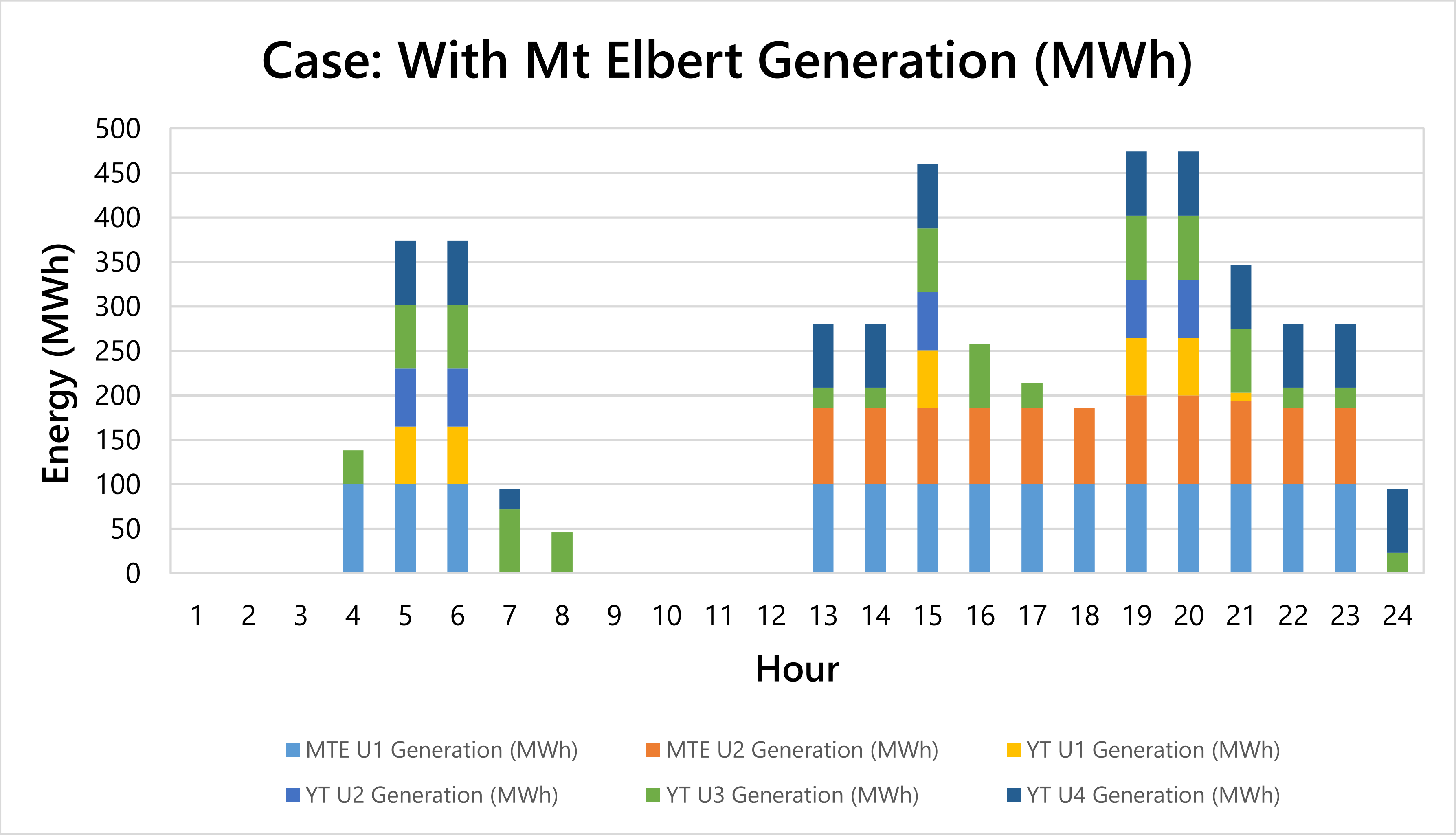
In addition, Argonne implemented these:
1. **MTE U1 Gen Mode: 2 starts/stops per calendar day**
2. **MTE U1 and U2 Pump Mode: 1 start/stop per calendar day**

CHEERS: SYSTEM DISPATCH INCLUDES ALL LAP HYDROPOWER RESOURCES

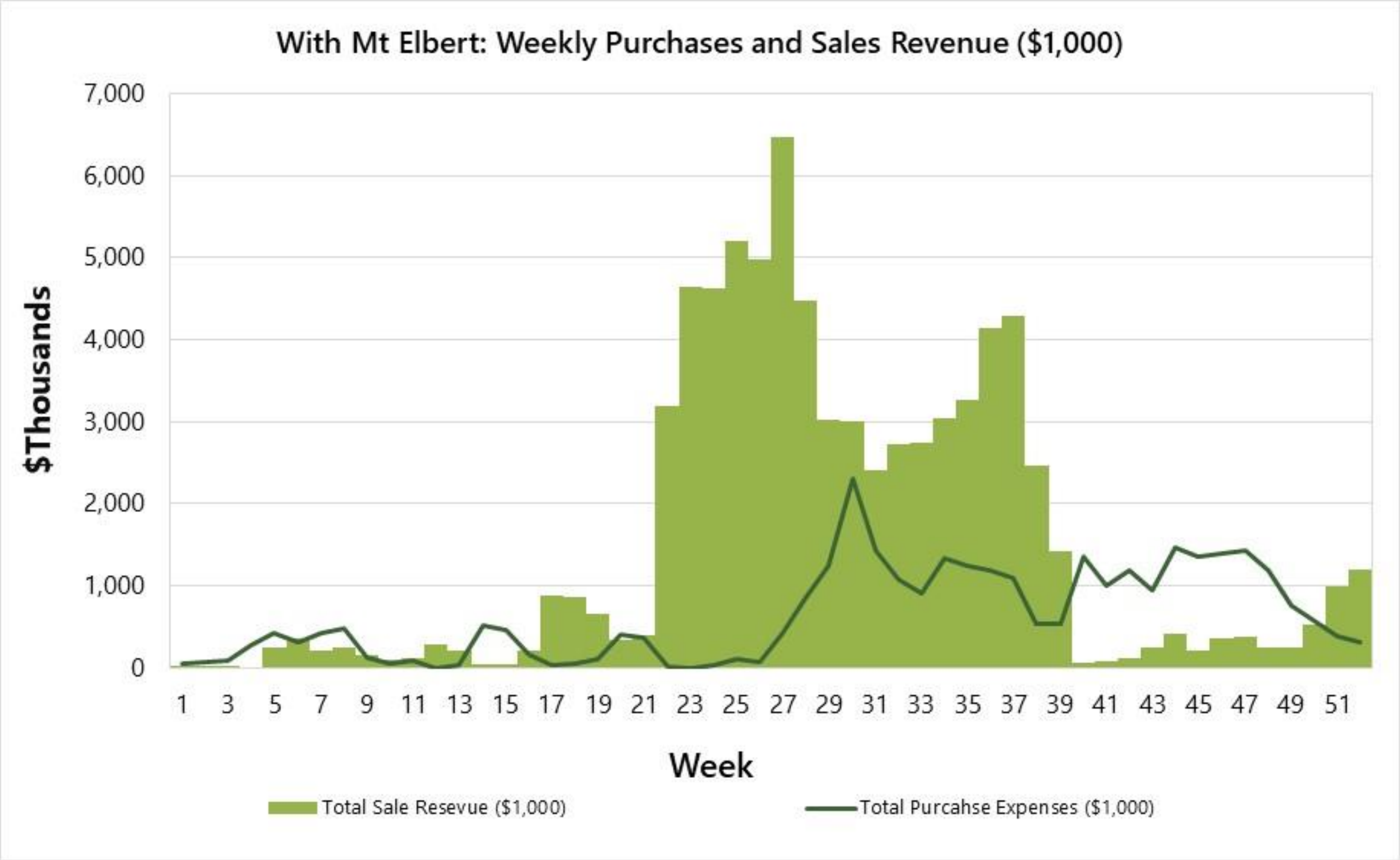
Key Model Decision Variables Include Purchase and Sales Transactions



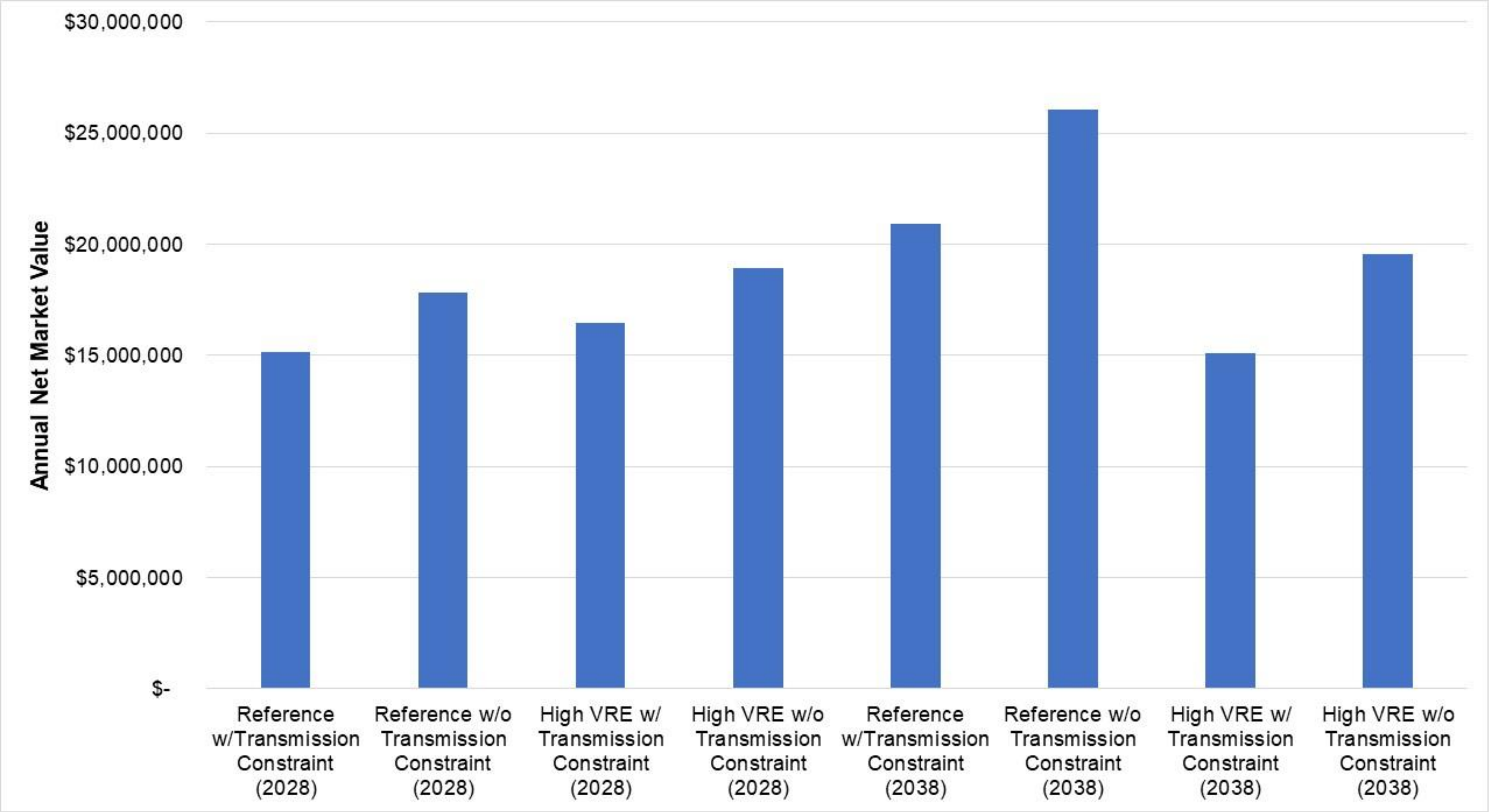
MT ELBERT AND YELLOWTAIL OPERATIONS



ENERGY MARKET TRANSACTIONS INCUR PURCHASE COSTS WHEN ENERGY IS SHORT BUT YIELD REVENUE WHEN ENERGY IS LONG

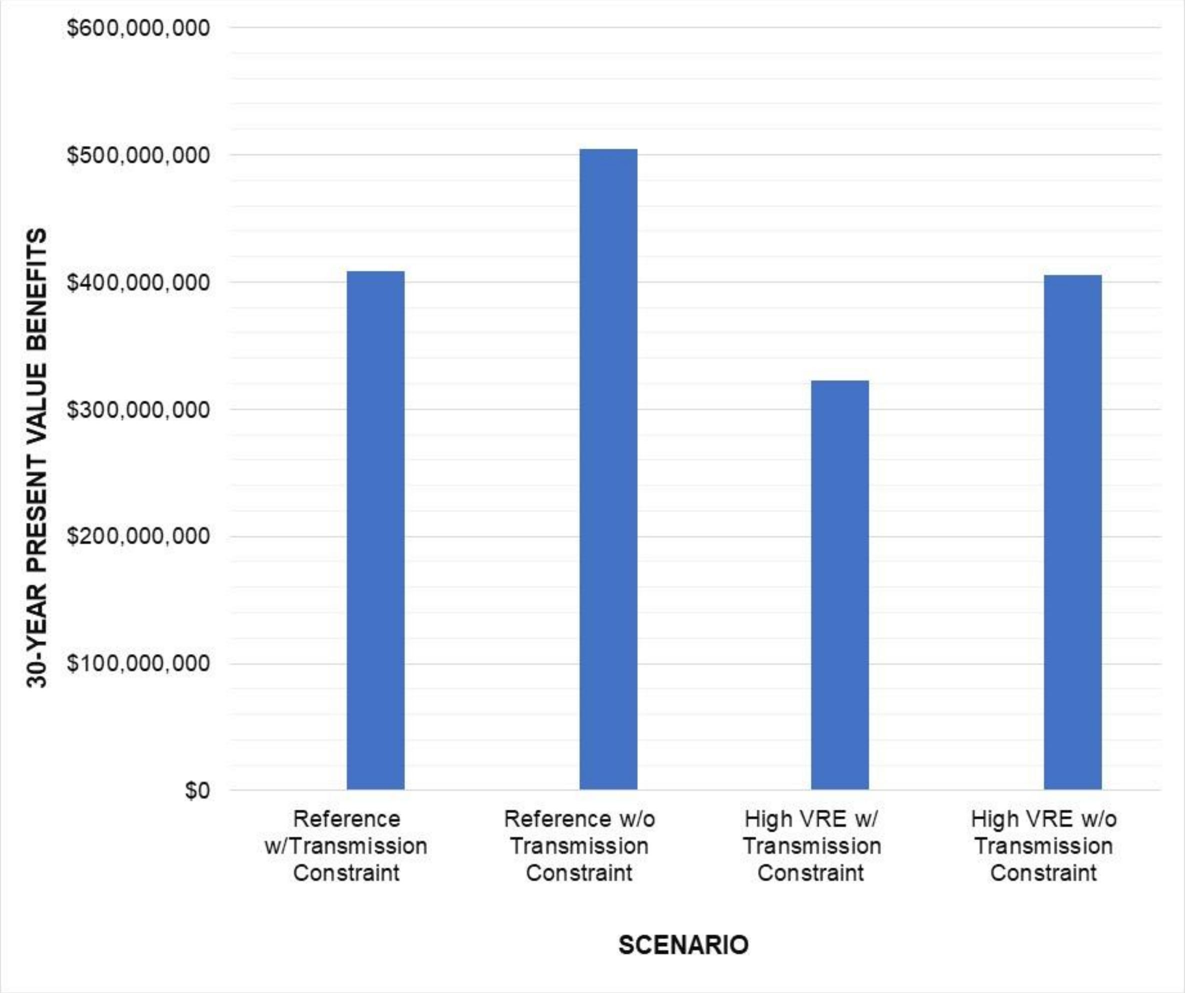


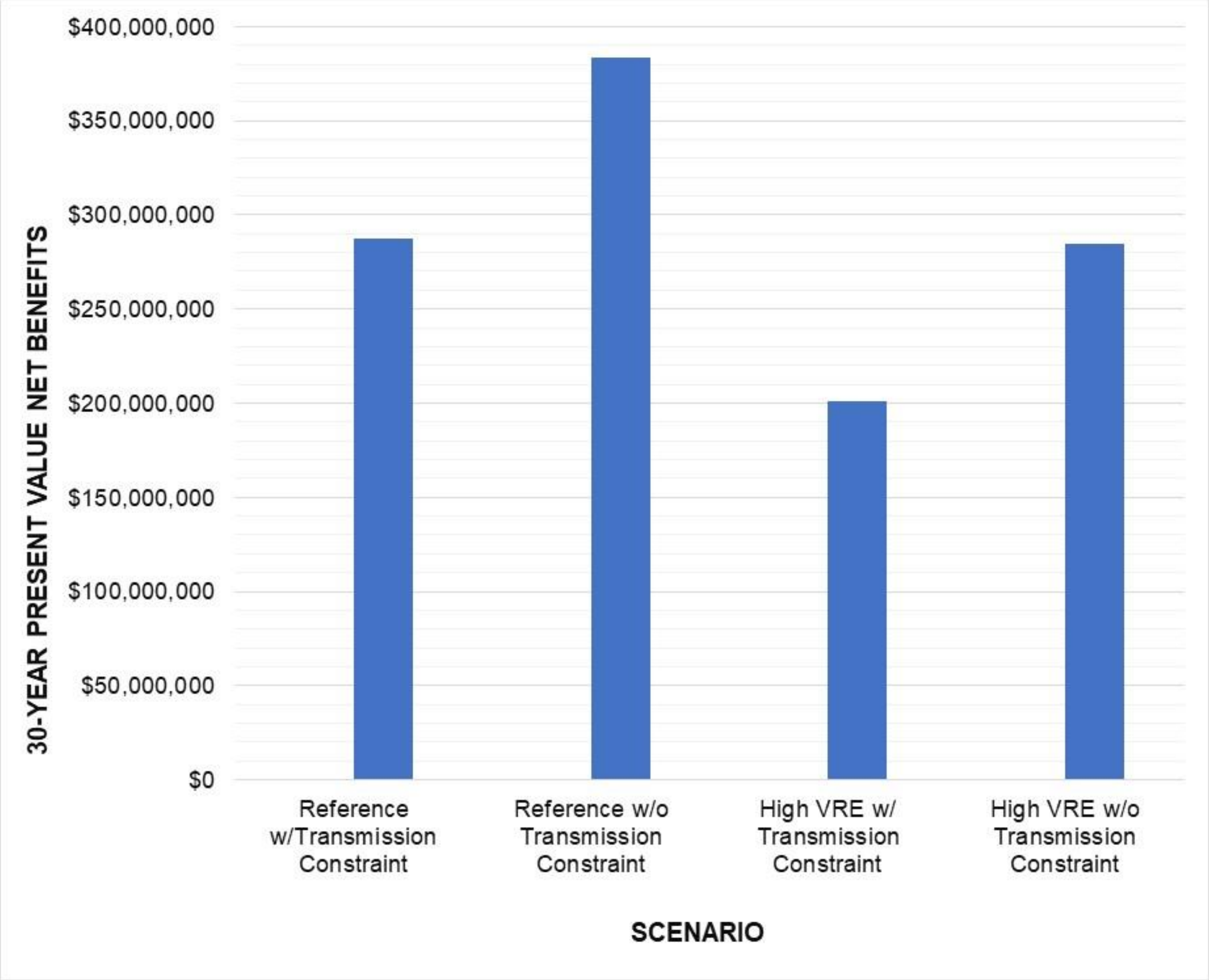
ANNUAL NET MARKET VALUE OF MT. ELBERT UNDER EACH SCENARIO



- Enabling an additional cycle per day improves financial performance by $1.2 million annually
- Mt. Elbert benefits (energy plus avoided system balancing costs) between $75.39 and $130.40-kW-year

30-YEAR PRESENT VALUE BENEFITS OF MT. ELBERT OPERATIONS





LESSONS LEARNED AND NEXT STEPS

- Lessons Learned
  - Mt. Elbert offers significant value (net benefits of \$15-\$26 million annually) to LAP customers through energy and system balancing services, which reduces risk exposure to customers through market transactions, but several benefits have not yet been evaluated
  - The vast majority of the value accrues from weeks 21 through 39 due to higher price spreads, higher customer loads, and favorable hydrological conditions
  - The presence of outages, rough zones, and high O&M costs due to poor plant conditions are costly
  - Relaxing transmission and cycling constraints would benefit LAP customers, yielding \$3-5 million and \$1.5 million in annual benefits, respectively
- Next Steps
  - Mt. Elbert O&M Evaluation. Recommend approaches to enhancing the efficiency of O&M operations
  - Market Factors Analysis. Evaluate full bulk energy and ancillary service benefits of operations in the Southwest Power Pool
  - Evaluation of Alternative Technologies. Evaluate the benefits and costs of a range of potential investments for both Unit 1 and Unit 2
  - Prepare final report
  - Model values in LAP system more broadly

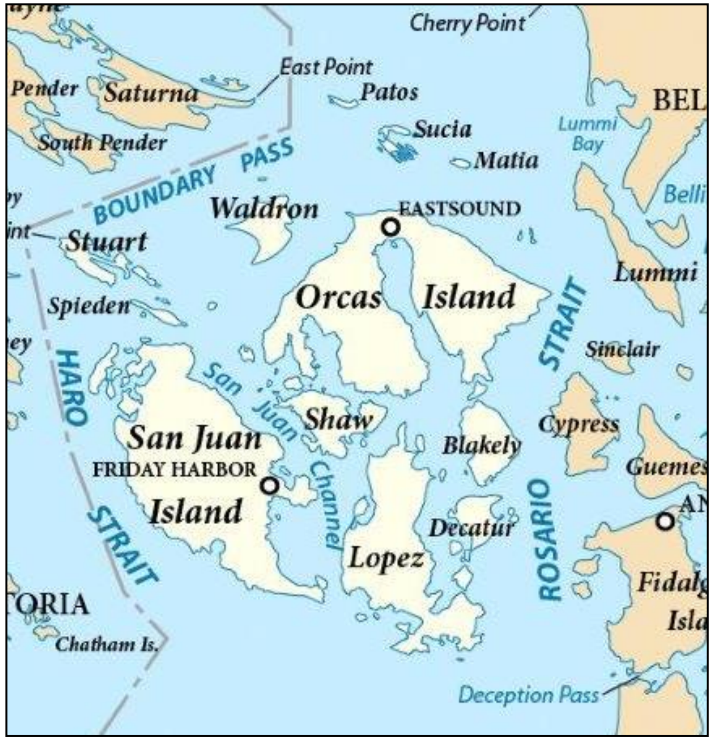
ORCAS POWER AND LIGHT COOPERATIVE MICROGRID

OPALCO MICROGRID STUDY PROJECT SYNOPSIS

Task 1:	Develop Methodology and Data Requirements for Evaluating the Financial Benefits of the Tidal Power, Solar, and Battery Energy Storage Systems (BESSs)
Task 2:	Perform Financial Evaluation
Task 3:	Consider Alternative Scenarios
Task 4:	Produce Final Report

Funding
- DOE OE - $150k
- OPALCO - $75k

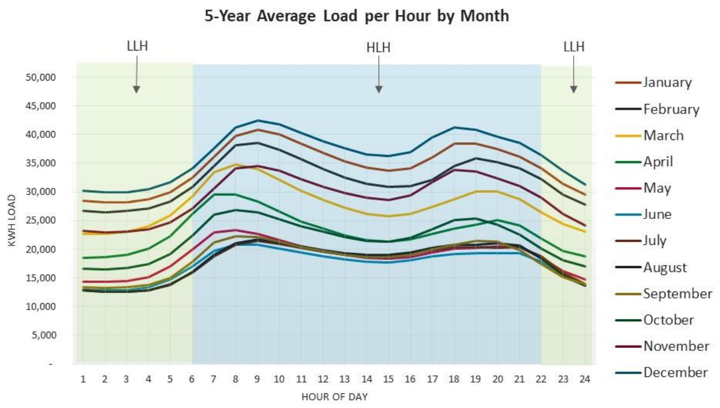
- To assess the technical and economic feasibility of tidal power in the OPALCO network, Argonne National Laboratory (Argonne) employed an optimization model to evaluate several economic benefits associated with:
  - 2.4-9.6 megawatts (MW) of tidal power deployed in Rosario Strait
  - 1.0 MW / 2 MWh Li-ion BESS on Decatur Island
  - Additional BESS on Orcas Island
  - 504 kW LG Community Solar (photovoltaic or PV) Array from Puget Sound Solar
- Scenarios
  - Tidal power in isolation,
  - Tidal power plus local storage, and
  - Tidal power and local storage plus PV and coordinated use of the Decatur Island BESS.



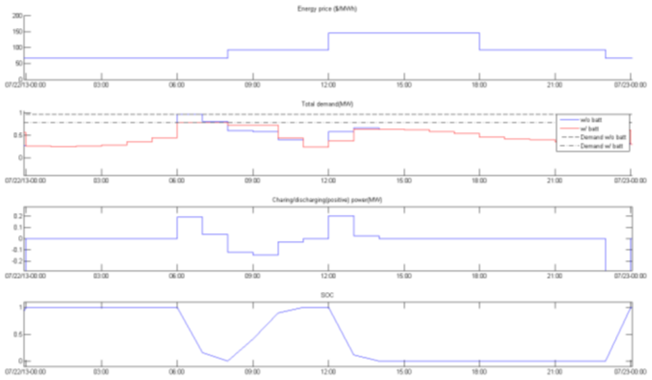
Map of San Juan Islands, WA

LOAD SHAPING AND DEMAND CHARGE REDUCTION

- Load Shaping Charge
  - Monthly charge/credit determined by taking deviation between expected load (kWh) for both Heavy Load Hours (HLH) and Light Load Hours (HLH)
  - Value obtained by charging battery during lower-rate LLHs and discharging during higher-rate HLHs, also through tidal power and PV production
- Demand Charge
  - Monthly charge determined based on deviation between OPALCO's highest energy load (kWh) and average load during heavy load hours in a given month
  - Value obtained by discharging energy to shave peak loads and also charging during non-peak HLH hours



Load Shape

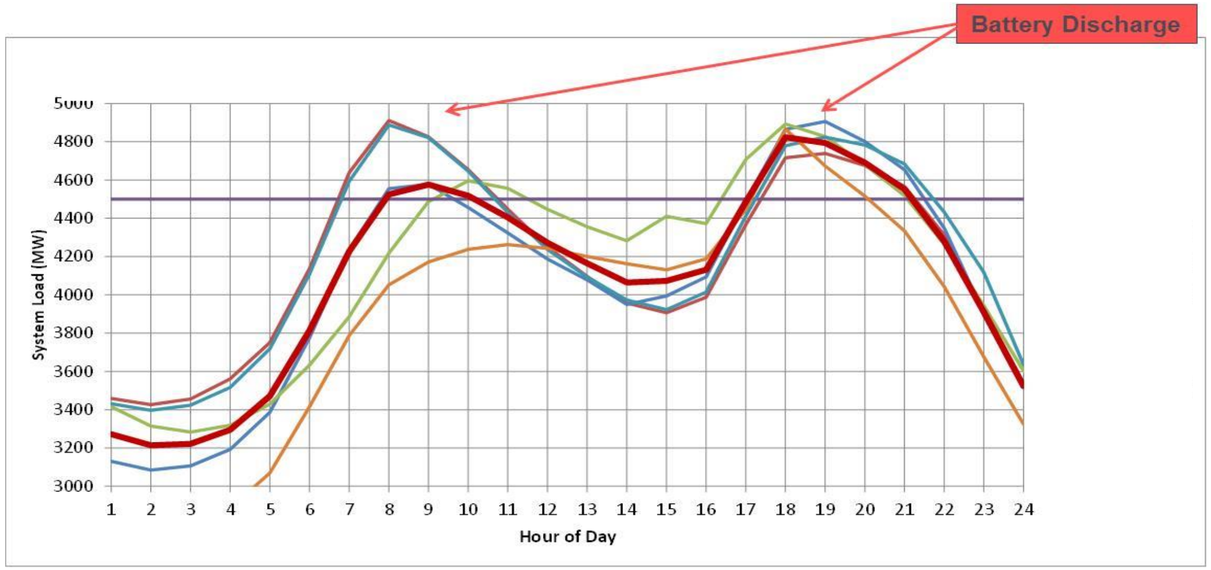


Energy Shifting to Reduce Demand Charges

Source: Balducci, P., V. Viswanathan, J. Alam, A. Crawford, K. Mongird, Y. Yuan, D. Wu, T. Hardy, J. Mietzner, T. Neal, R. Guerry, and J. Kimball. 2018. PNNL-SA-131674. "Washington Clean Energy Fund (CEF) II –OPALCO Community Solar and Energy Storage on Decatur Island presented Jan 18, 2018 to OPALCO".

TRANSMISSION, BASIC SERVICE CHARGE, AND OTHER CHARGES

- Transmission Charge
  - Monthly charge determined by OPALCO's total energy purchases (kWh) during Bonneville Power Administration's (BPA) peak transmission load hour – transmission charge is $2.10 per kW-month
  - BPA does not recognize local load served by distributed energy resources during transmission system peaks; Argonne encouraged to participate in next rate case to address this barrier
- Basic Service or Energy Charge
  - Set annually based on tier one cost allocation or TOCA; set at 2.7 cents/kWh – value obtained through PV and tidal energy production
- Miscellaneous charges based on annual load

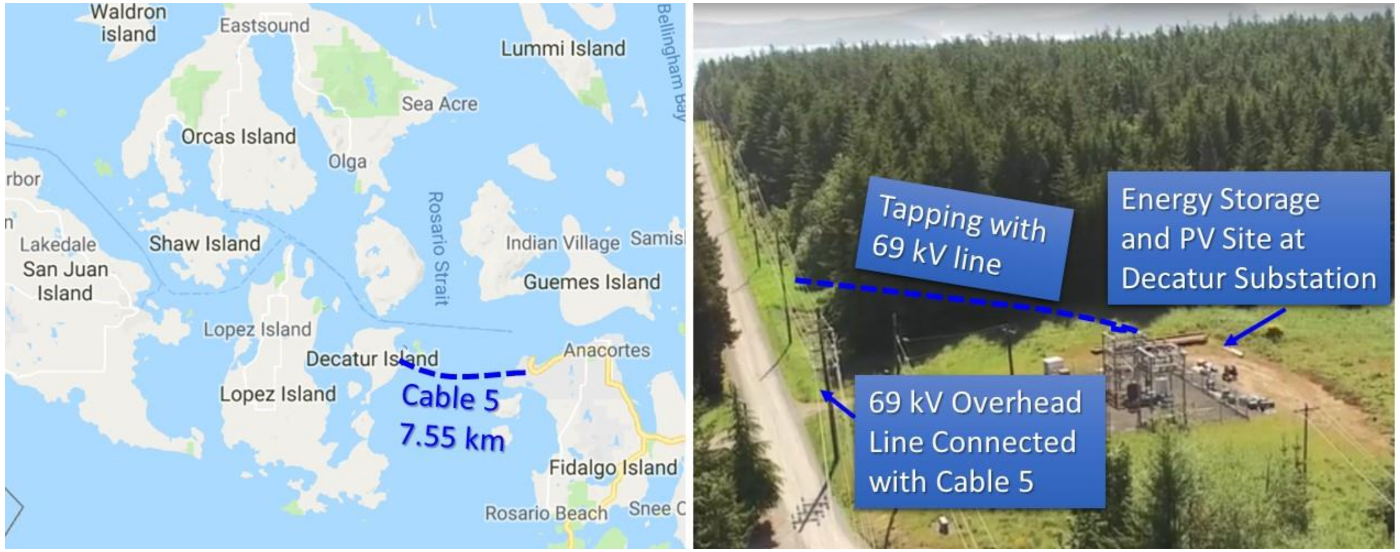


Illustrative Shaving of Peak Demand

Source: Balducci, P., V. Viswanathan, J. Alam, A. Crawford, K. Mongird, Y. Yuan, D. Wu, T. Hardy, J. Mietzner, T. Neal, R. Guerry, and J. Kimball. 2018. PNNL-SA-131674. "Washington Clean Energy Fund (CEF) II –OPALCO Community Solar and Energy Storage on Decatur Island presented Jan 18, 2018 to OPALCO".

TRANSMISSION SUBMARINE CABLE REPLACEMENT DEFERRAL

- BPA-owned submarine transmission cable from Anacortes to Decatur & Lopez Islands, approximate 40-year lifespan – OPALCO may be required to pay for replacement cable
- Value obtained by reducing heating on the cable and acting as a reactor that compensates for the submarine cable's large capacitance, extending the length of its usable life and deferring costly new cable investment. All future cable expenditures will be deferred but only two rounds included in assessment due to risk/uncertainty

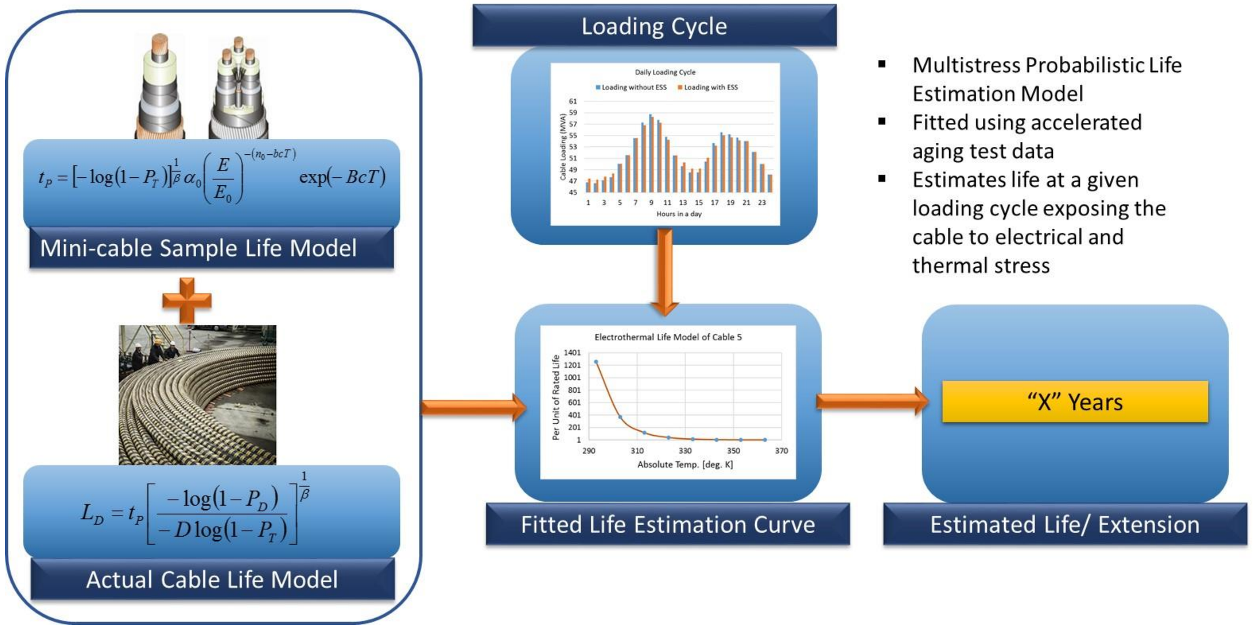


Cable 5 Location

Source: Balducci, P., V. Viswanathan, J. Alam, A. Crawford, K. Mongird, Y. Yuan, D. Wu, T. Hardy, J. Mietzner, T. Neal, R. Guerry, and J. Kimball. 2018. PNNL-SA-131674. "Washington Clean Energy Fund (CEF) II –OPALCO Community Solar and Energy Storage on Decatur Island presented Jan 18, 2018 to OPALCO".

POTENTIAL LIFE EXTENSION BENEFIT OF ESS AND TIDAL POWER

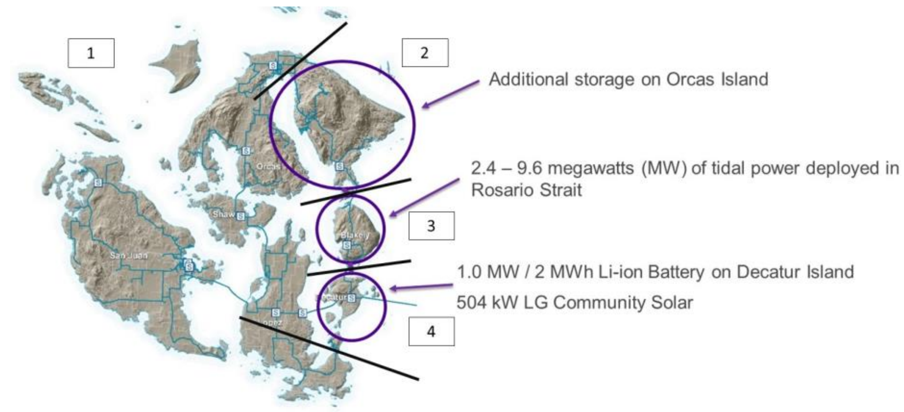
- Hourly data transformed into a 2-week representative data set, which was used to construct cable loading cycle
- Using the fitted model and the selected load cycle, potential life extension estimated
- A detailed pro-forma for the transmission cable was developed and used as the basis of calculating reductions in present value costs achieved through deferral
- Future load growth incorporated into life extension estimates



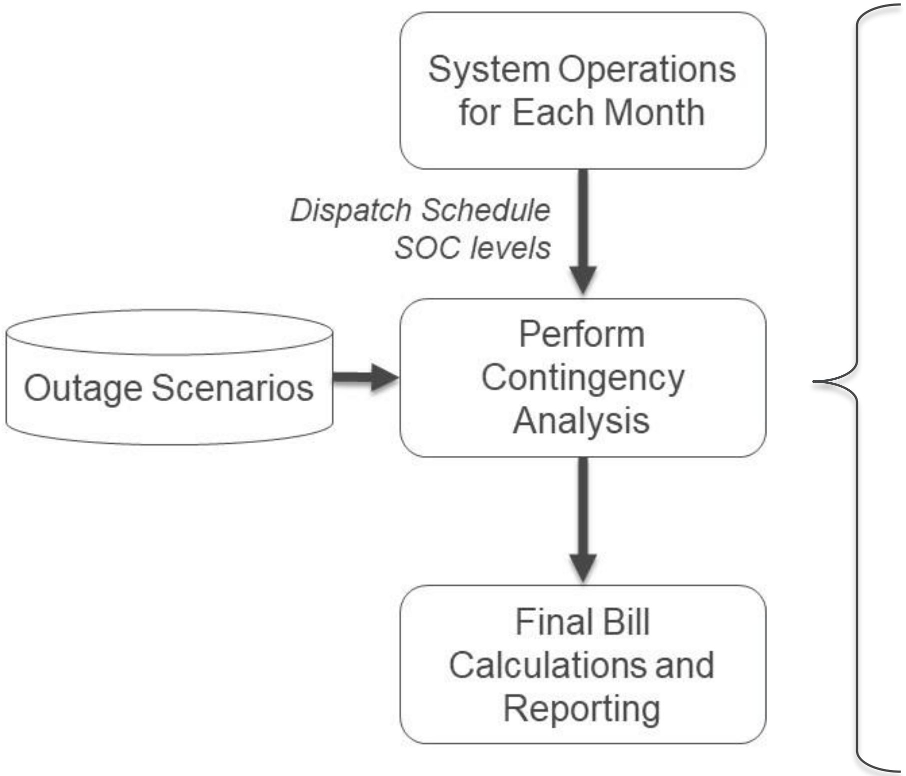
Life Estimation Approach

Source: Balducci, P., V. Viswanathan, J. Alam, A. Crawford, K. Mongird, Y. Yuan, D. Wu, T. Hardy, J. Mietzner, T. Neal, R. Guerry, and J. Kimball. 2018. PNNL-SA-131674. "Washington Clean Energy Fund (CEF) II –OPALCO Community Solar and Energy Storage on Decatur Island presented Jan 18, 2018 to OPALCO".

OUTAGE MITIGATION



Outage Mitigation Zones and Assets



- **Goal**: Minimizing Interruption Costs
  - Reduce financial impact and inconvenience caused by power interruptions
  - Account for interruption costs for every customer class in each zone

Source: https://icecalculator.com/

Sector	Cost Per Event (2016$)	Cost Per Average kW (2016$)	Cost Per Unserved kWh (2016$)
Medium and Large C&I	$7,816.8	$52.7	$52.7
Small C&I	$799.3	$189.2	$189.2
Residential	$6.2	$4.1	$4.1

- **Method**: Optimizing Resource Utilization
  - Optimal utilization of available resources during outage periods
  - Respect operating conditions of energy storage resources in steady-state simulations
    - The available energy at the start of an outage is derived from monthly system operating results

ENERGY STORAGE MICROGRID OPTIMIZATION MODEL

System Operations and Analysis

- Optimal scheduling of energy resources
- Flexible configuration options for temporal resolutions
- Modeling of emerging technologies (e.g., Tidal power)

Advanced Energy Storage Modeling

- Comprehensive modeling capabilities for diverse energy storage technologies
- State-of-charge management (hourly, multiple consecutive days)
- Energy throughput constraints

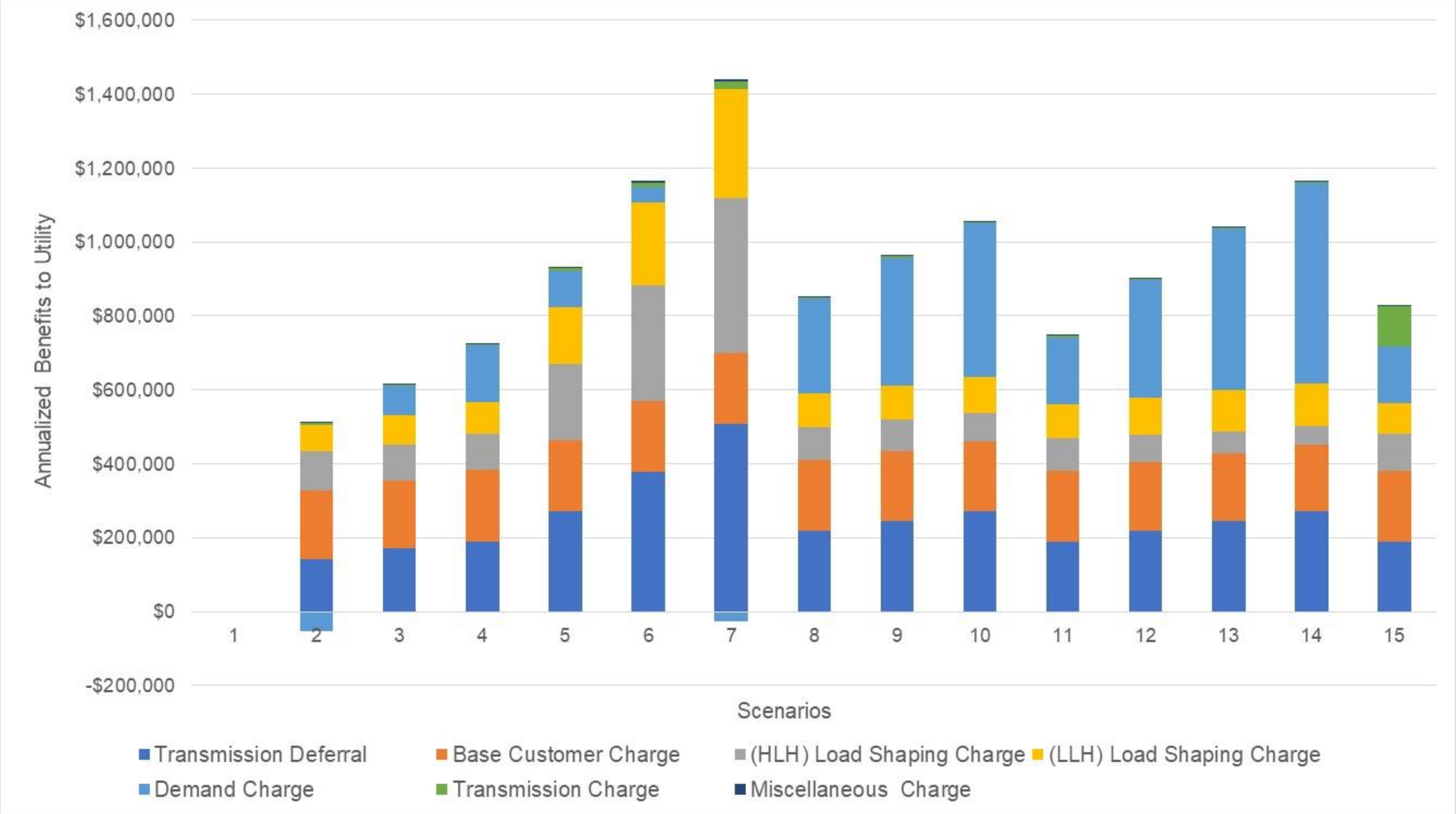
Utility Network Modeling

- Detailed zonal or nodal representation of utility networks
- Customized modeling of utility-specific rate structures
- Modeling of energy import and export

Reliability Assessment

- Advanced analysis tools to evaluate system behavior and reliability under pre-determined outage conditions
- Determine the value of energy storage in supporting post-contingency conditions

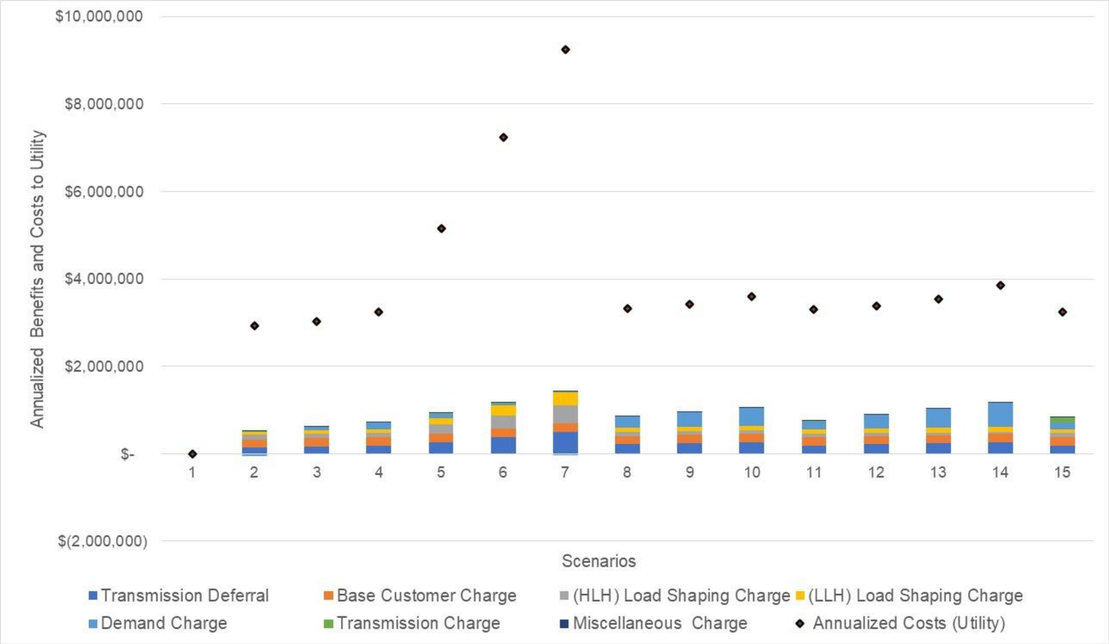
RESULTS - UTILITY PERSPECTIVE



Scenario
1. no DERs
2. Tidal power in isolation
3 .Tidal power plus local storage on Orcas Island
4. Add in Decatur solar and the Decatur BESS to Scenario 3
5. Use Scenario 4; 2X tidal power
6. Use Scenario 4; 3X tidal power
7. Use Scenario 4; 4X tidal power
8. Use Scenario 4; 2x Orcas ES Cap
9. Use Scenario 4; 3x Orcas ES Cap
10. Use Scenario 4; 4x Orcas ES Cap
11. Use Scenario 4; 1x Orcas ES Cap, 4 hr
12. Use Scenario 4; 2x Orcas ES Cap, 4 hr
13. Use Scenario 4; 3x Orcas ES Cap, 4 hr
14. Use Scenario 4; 4x Orcas ES Cap, 4 hr
15. Use Scenario 4 but no assets are DSRs

- Scenarios yield $458k to $1.4 million annually
  - Demand and transmission charge reductions of up to $542k and $111k, respectively, largely driven by BESS operations
  - Transmission deferral ($143k-$507k), fixed customer charges ($185-$194k), and load shaping charges ($167-$715k), largely driven by tidal energy production

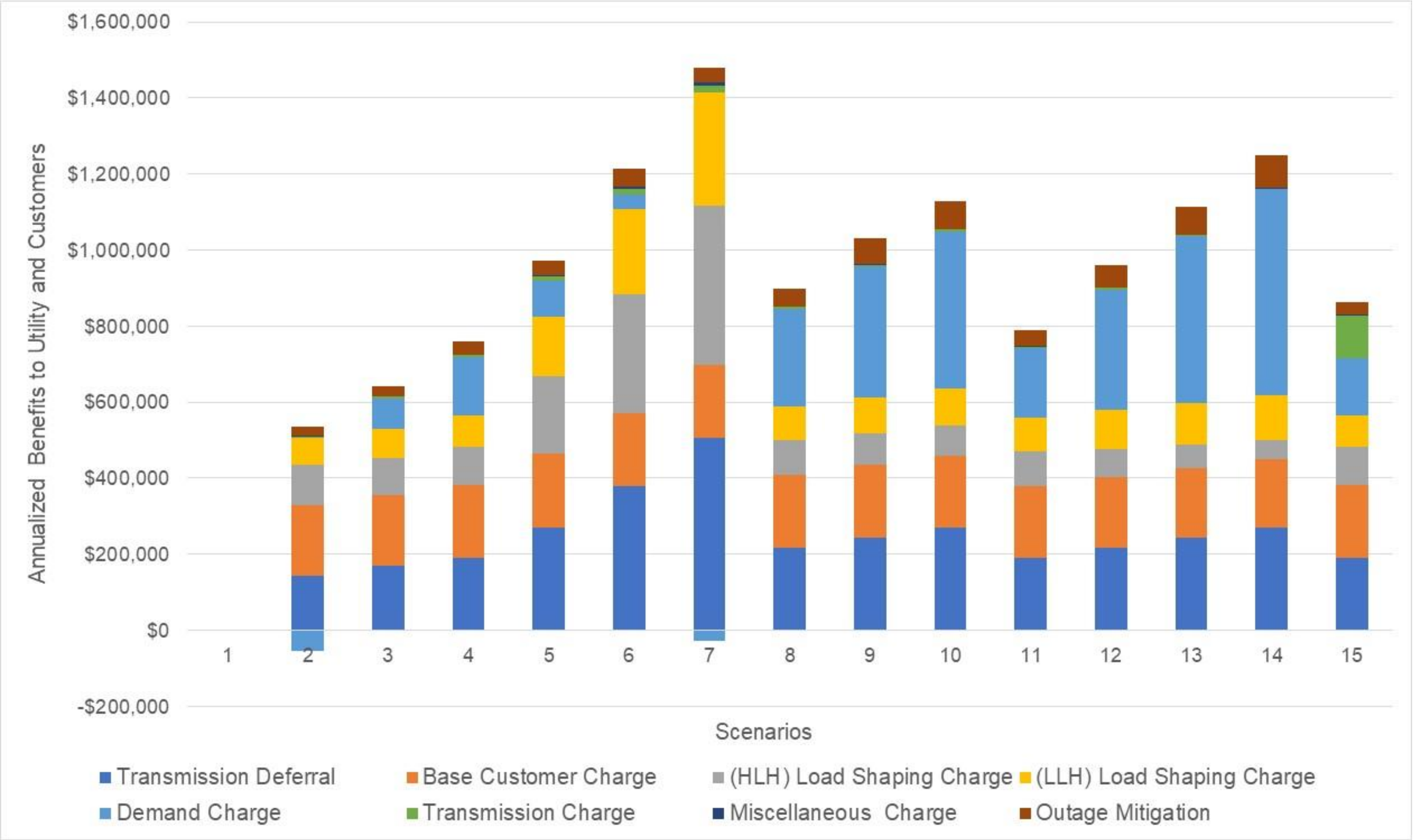
RESULTS UTILITY PERSPECTIVE



Scenario	Scenario Description	BCR	Net Benefits
1	no DERs	-	$-
2	Tidal power in isolation	0.25	$(38,928,858)
3	Tidal power plus local storage on Orcas Island	0.33	$(36,005,736)
4	Scenario 3 plus Decatur PV and BESS	0.36	$(36,721,945)
5	Scenario 4 with 2X tidal power	0.29	$(64,838,966)
6	Scenario 4 with 3X tidal power	0.26	$(95,111,142)
7	Scenario 4 with 4X tidal power	0.25	$(123,589,131)
8	Scenario 4 with 2x Orcas storage capacity	0.41	$(34,679,214)
9	Scenario 4 with 3x Orcas storage capacity	0.45	$(33,099,590)
10	Scenario 4 with 4x Orcas storage capacity	0.47	$(33,674,358)
11	Scenario 4 with 1x Orcas storage capacity @ 4 hr.	0.36	$(37,187,749)
12	Scenario 4 with 2x Orcas storage capacity @ 4 hr.	0.43	$(34,373,644)
13	Scenario 4 with 3x Orcas storage capacity @ 4 hr.	0.47	$(33,105,594)
14	Scenario 4 with 4x Orcas storage capacity @ 4 hr.	0.49	$(35,081,812)
15	Scenario 4 but no assets are DNRs	0.41	$(33,755,712)

- Benefit-cost ratios (BCRs) vary from 0.25 - 0.49; lifetime net benefits range from -$123.6M to -$33.1M
- Analysis defines grant required for tidal power to break even at $38.9M
- Microgrid assets serve as hedge against energy price inflation; sensitivity analysis found a breakeven point at 7.2% annual price inflation
- Battery storage on Orcas Island yields positive net benefits of $3M

RESULTS FROM UTILITY / CUSTOMER COMBINED PERSPECTIVE



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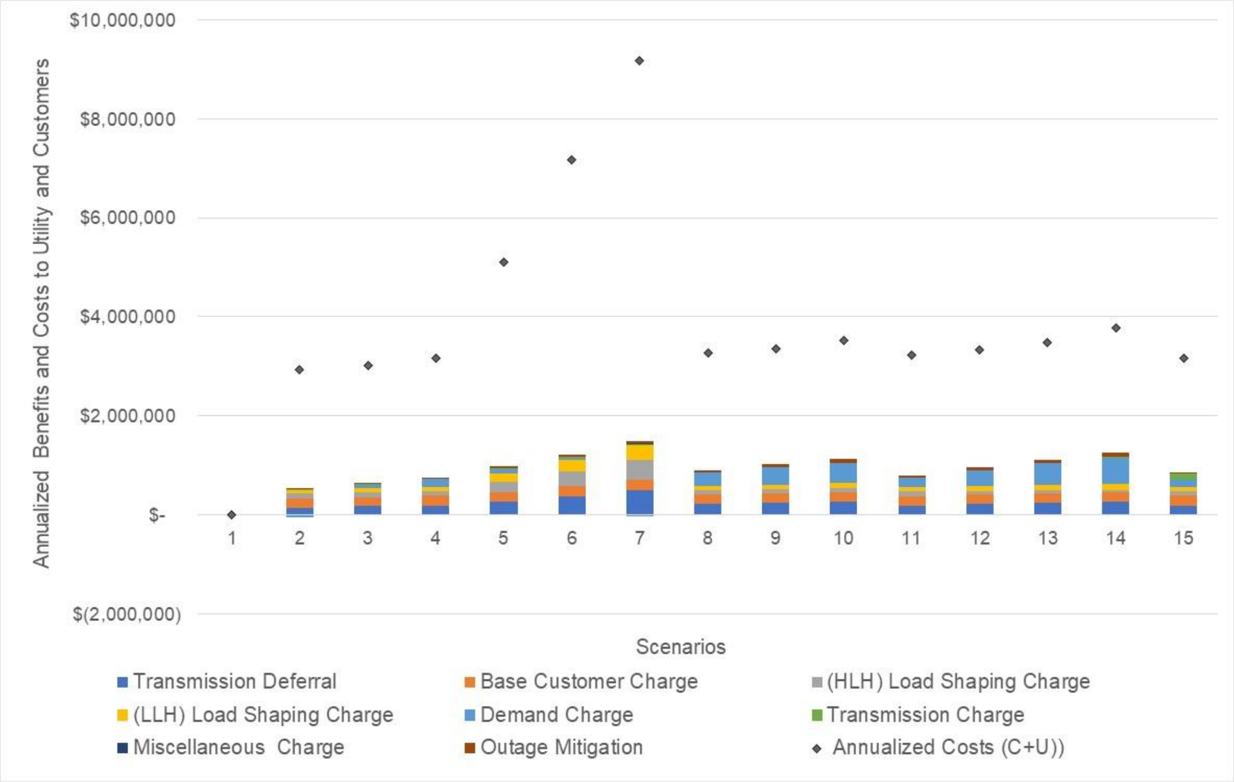
12. Use Scenario 4; 2x Orcas ES Cap, 4 hr
13. Use Scenario 4; 3x Orcas ES Cap, 4 hr
14. Use Scenario 4; 4x Orcas ES Cap, 4 hr
15. Use Scenario 4 but no assets are DSRs

- Scenarios yield $483k to $1.5M annually
  - Outage mitigation benefits are $35k annually in base case but reach as high as $86k per year in Scenario 14
  - The utility plus customer combined case also benefits from removal of OPALCO losses tied to community solar project

RESULTS UTILITY /CUSTOMER COMBINED PERSPECTIVE



Scenario	Scenario Description	BCR	Net Benefits
1	no DERs	-	-
2	Tidal power in isolation	0.26	(38,224,659.03)
3	Tidal power plus local storage on Orcas Island	0.34	(35,270,472.30)
4	Scenario 3 plus Decatur PV and BESS	0.39	(34,569,500.89)
5	Scenario 4 with 2X tidal power	0.31	(62,552,353.68)
6	Scenario 4 with 3X tidal power	0.27	(92,577,700.89)
7	Scenario 4 with 4X tidal power	0.25	(121,314,112.55)
8	Scenario 4 with 2x Orcas storage capacity	0.44	(32,223,433.20)
9	Scenario 4 with 3x Orcas storage capacity	0.49	(30,005,805.37)
10	Scenario 4 with 4x Orcas storage capacity	0.51	(30,422,457.91)
11	Scenario 4 with 1x Orcas storage capacity @ 4 hr.	0.39	(34,821,506.74)
12	Scenario 4 with 2x Orcas storage capacity @ 4 hr.	0.46	(31,580,146.21)
13	Scenario 4 with 3x Orcas storage capacity @ 4 hr.	0.52	(29,825,421.70)
14	Scenario 4 with 4x Orcas storage capacity @ 4 hr.	0.53	(31,467,237.68)
15	Scenario 4 but no assets are DNRs	0.44	(31,603,315.67)

- BCRs vary from 0.26 – 0.53; net benefits range from -$121.3M to $-29.8M and no scenarios have BCRs that exceed 1.0
- BESS investments drive positive outcomes through enhanced outage mitigation

ACCOMPLISHMENTS AND FUTURE CONSIDERATIONS

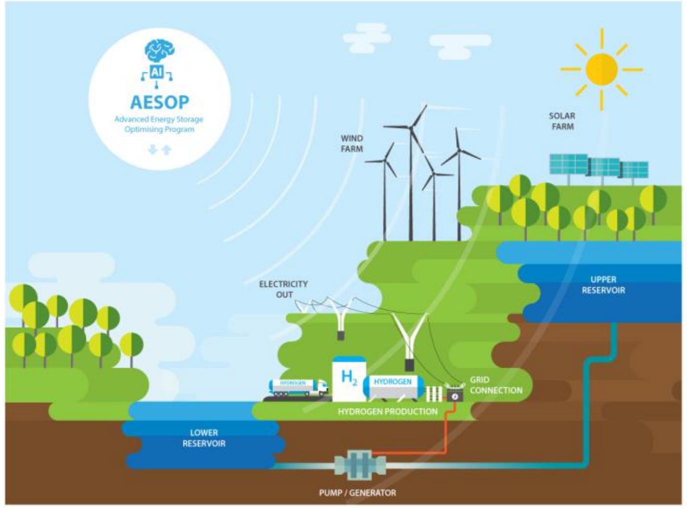
ACCOMPLISHMENTS AND FUTURE DIRECTIONS

Accomplishments

- Energy Storage Microgrid Optimization (ESMO) tool
- Customized Aurora, CHEERS, and price-scaling models
- Extensive modeling approach for PSH in larger hydro systems
- 2 invited presentations and one technical report so far

Future Directions

- Mt. Elbert
  - Complete Phase 2 of project - O&M evaluation, market factors analysis, evaluation of alternative technologies, and final reporting
- Sunshine Hydro
  - Hydrogen, renewables, and storage hybrid
- Storage as a dual-use transmission asset
- Publish OPALCO results, continue model development and pursue innovative projects



Sunshine Hydro

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CONTACT INFORMATION

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