U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Technoeconomic Studies for the Goldendale, WA and Banner Mountain, WY Pumped Storage Hydro Plants

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Presentation at the 2024 Pacific Northwest Regional Economic Conference

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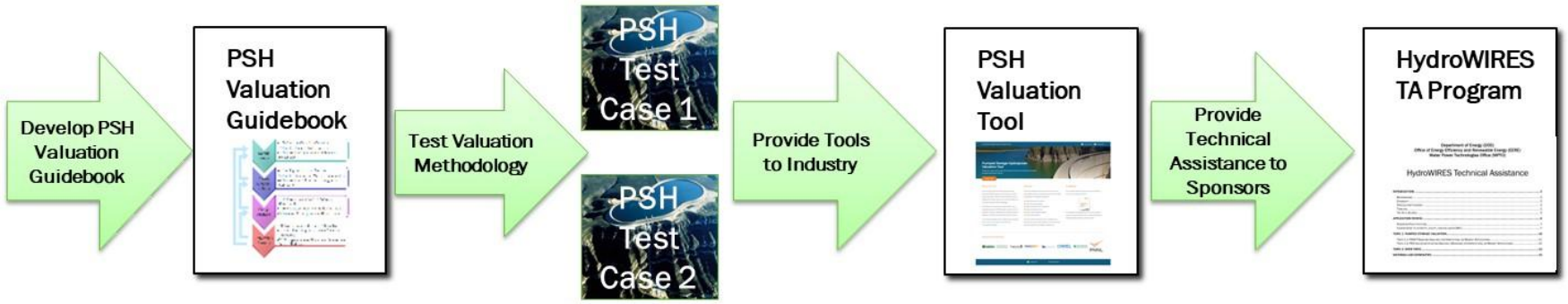
HydroWIRES PSH Valuation Program Goals and Objectives

Objective: Advance the state of the art in the assessment of value of PSH plants and their role and contributions to the power system

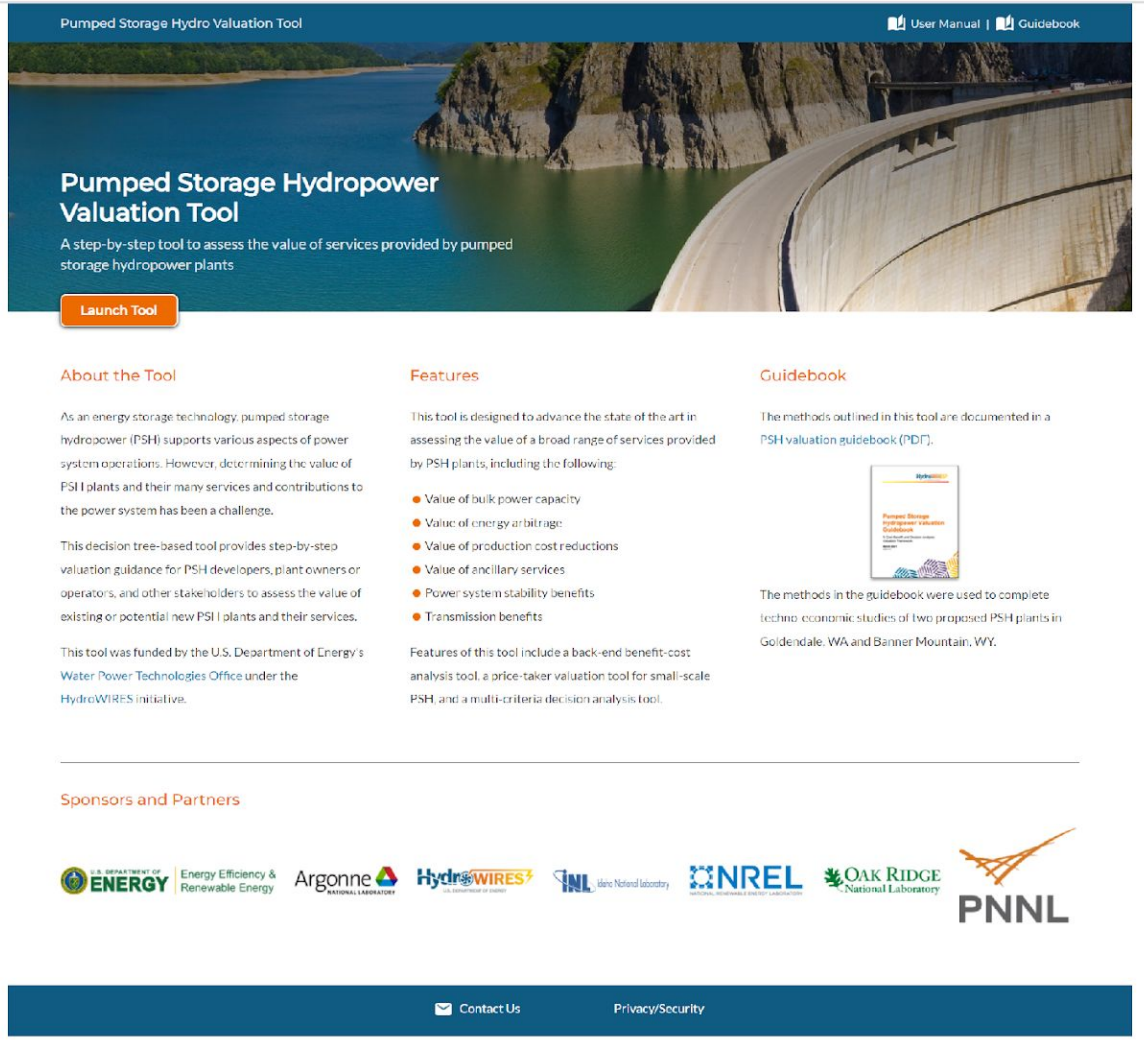
Specific goals:

1. Develop a comprehensive and transparent valuation guidance that will allow for consistent valuation assessments and comparisons of PSH projects
2. Test the PSH valuation methodology by applying it to two selected PSH projects
3. Transfer and disseminate the PSH valuation guidance to the hydropower industry, PSH developers, and other stakeholders
4. Provid



PSH Valuation Tool

- PSH valuation tool provides step-by-step valuation guidance for PSH developers, plant owners or operators, and other stakeholders
- PSH tool advances the state of the art in evaluating a broad set of use cases from three perspectives: owner/operator, system, and society
- PSH tool has several advanced features:
  - Embedded price-taker model
  - Multi-criteria decision analysis (MCDA) tool
  - Embedded financial worksheets and benefit-cost analysis (BCA) model
  - Embedded price-influencer model
- The PSHVT can be accessed at https://pshvt.egs.anl.gov/.



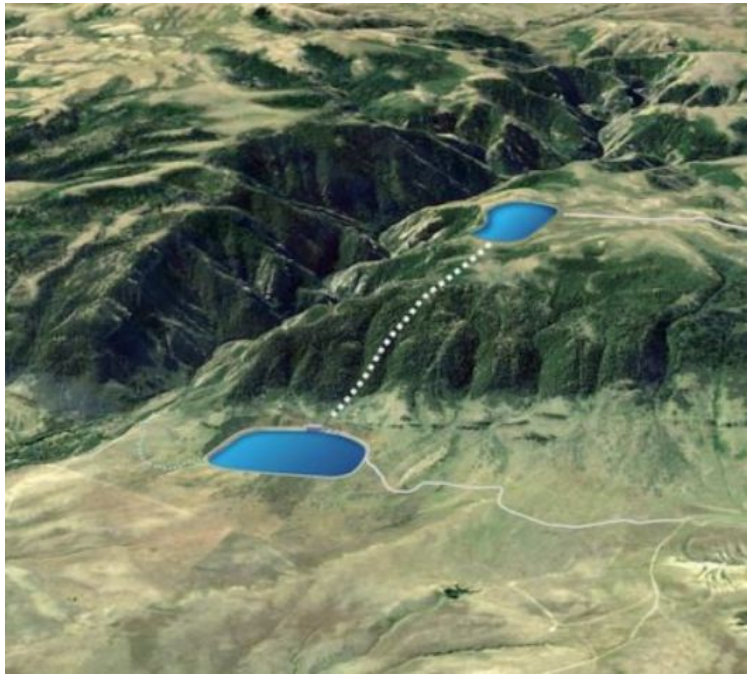
PSH Valuation Tool Home Page

The Project Team Collaborated with Two Industry Partners

Absaroka Energy

Banner Mountain PSH

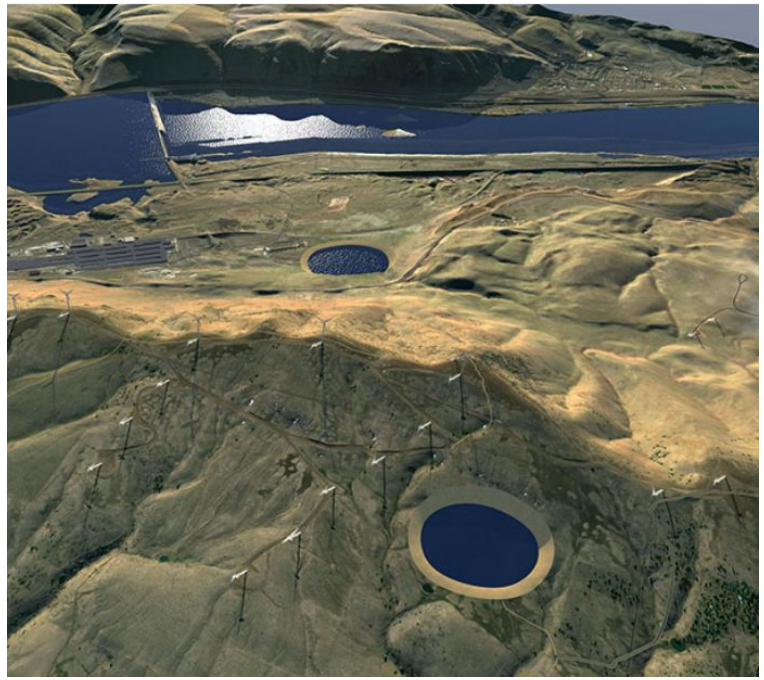
- 400 MW, quaternary technology
- Closed loop
- Site near Casper, WY



CIP & Rye Development

Goldendale Energy Storage Project

- 1,200 MW, adjustable speed technology
- Closed loop
- Site just north of OR/WA border



CIP = Copenhagen Infrastructure Partners

Capacity (Goldendale)

- Capacity value is set equal to the revenue requirement of the marginal resource in the planning pool
  - Order all resources by revenue requirement (negative profit)
  - Find first one needed to satisfy the planning reserve margin (PRM) constraint
- Determined for each WECC planning pool in 2028 and 2038
  - Based on full 8760 (8784) hourly operational runs for those years
- Replicates a competitive capacity market clearing where:
  - Planning pool has a vertical demand curve
  - Each resource offers capacity at its true revenue requirements
- Conceptually applicable in non-market regions as well
  - Implicit in a central planning process with guaranteed cost recovery
- *Integration: AURORA capacity expansion results integrated into PLEXOS model.*

Energy Generation Cost and Ancillary Services (Goldendale)

- PLEXOS production cost model (PCM) run with and without PSH to determine value in terms of reduced fuel and startup costs to system.
- PCM runs considered base and high renewable cases under day-ahead (DA) and real-time (RT) market scenarios.
- *Integration: Use cases co-optimized with capacity through AURORA capacity expansion and PLEXOS PCM, energy and ancillary services (AS) take highest priority in optimization.*

Scenario	Time Resolution		Production Costs ($M)	Production Cost Delta ($)
Base	Day Ahead	No Goldendale	10,782	
		With Goldendale	10,762	20
	Real Time	No Goldendale	11,428	
		With Goldendale	11,401	27
High Renewable	Day Ahead	No Goldendale	9,188	
		With Goldendale	9,141	47
	Real Time	No Goldendale	9,999	
		With Goldendale	9,944	55

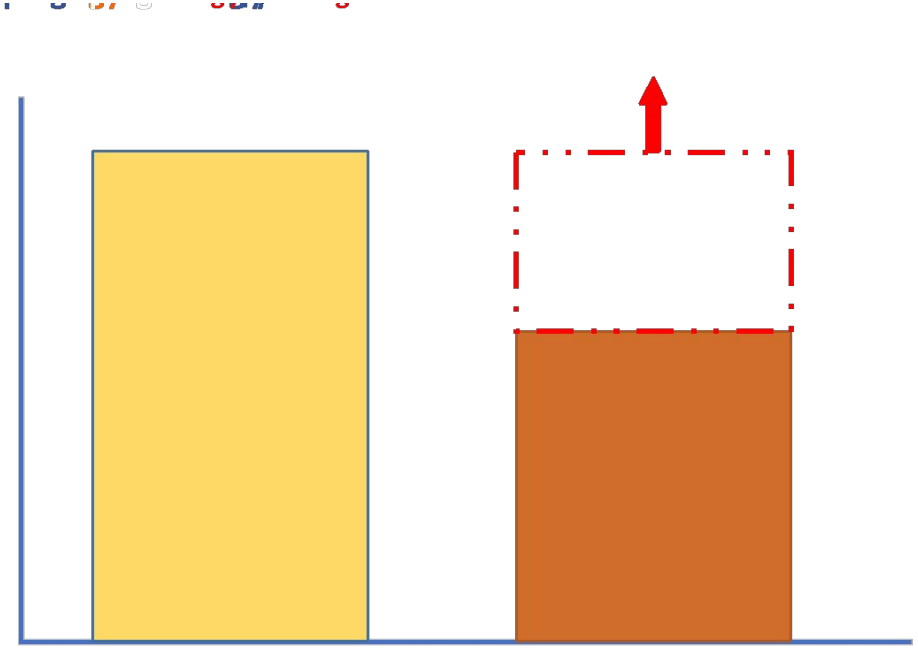
Production costs for the runs with and without Goldendale in $M.

	Ancillary Service Type	Interval	Provision (MWh)	Model Average Price ($)	Theoretical Real-World Price ($)	Theoretical Real-World Ancillary Revenue ($)
Base Case	CA_CISO Reg	DA	50,913	0	10	509,133
	RSG1_BPA+_Spin	DA	81,367	0	5	406,838
	CA_CISO Reg	RT	1,008	0	10	10,080
	CA_CISO_Spin	RT	124	0	5	621
High Renewable	CA_CISO Reg	DA	60,998	0	10	609,985
	RSG1_BPA+_Spin	DA	90,027	0	5	450,137
	CA_CISO Reg	RT	512	0	10	5,126
	RSG1_BPA+_Spin	RT	4	0	5	24

Ancillary service values.

Energy Arbitrage (Goldendale)

- Asset owner benefit: energy arbitrage profit
  - Assess the value of energy arbitrage from the perspective of asset owners based on the difference between the value of PSH electricity generation and cost of energy used for pumping.
  - Market revenue calculated using pumping/generating schedules and the locational marginal prices (LMPs) from PLEXOS.
- Values estimated for DA, RT market under baseline and high renewable cases.
- *Integration: Use case co-optimized with capacity and ancillary services through PLEXOS optimization and is the highest priority use case for the owner-operator*

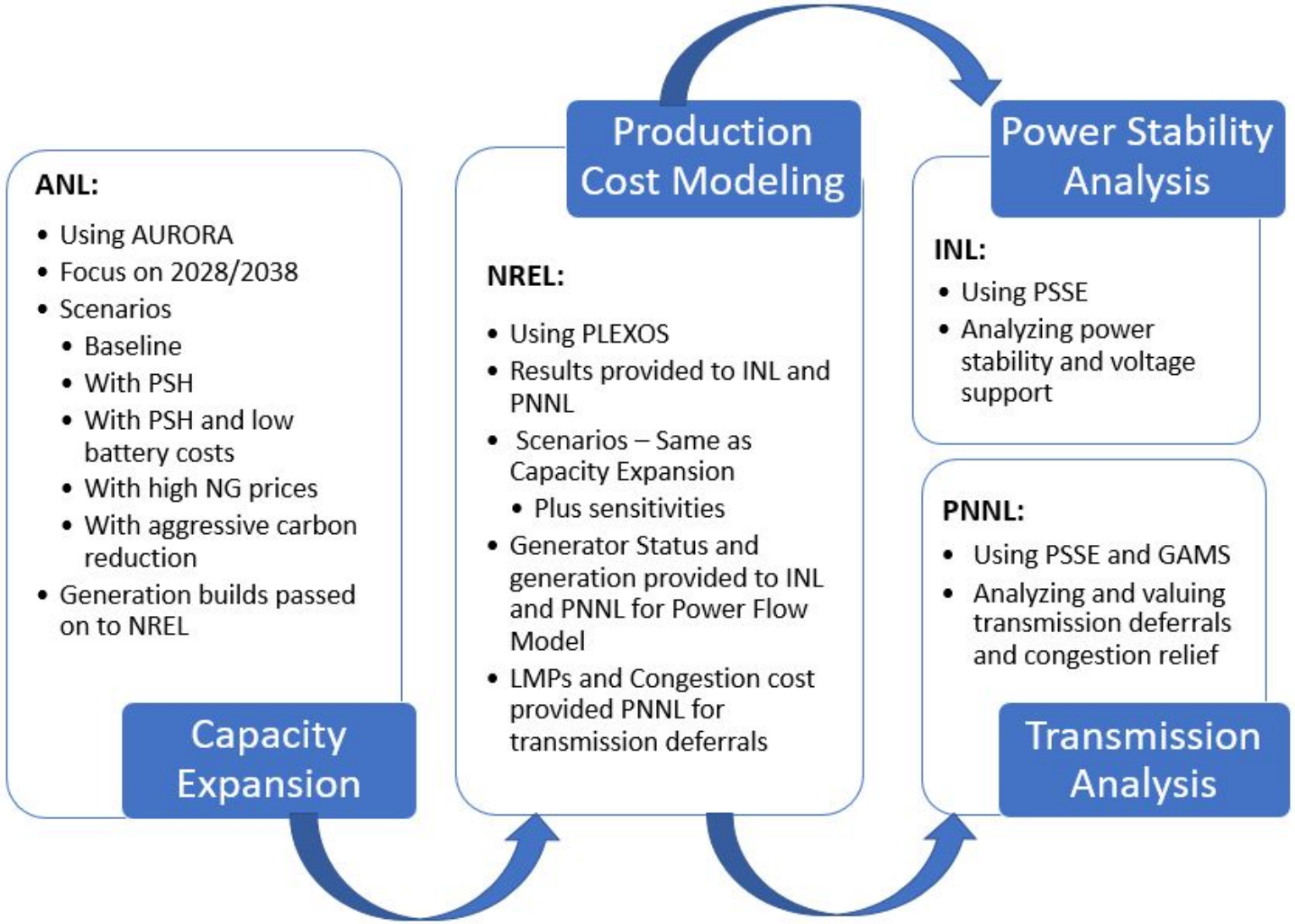


Assigning energy arbitrage value.

Other Value Streams (Goldendale)

Use Case	Basis of Value	Integration
Black Start	Baseline net cost of new entrant (CONE) plus 8 hours of training	Evaluation of exceedance curves demonstrates that 3.74 GWh of firm storage is available for black start service
Transmission Congestion Relief	PLEXOS runs establish dispatch and alternating current optimal power flow (ACOPF) model determines reduction in congestion component of LMPs	PLEXOS dispatch schedule used rather than optimal AC power flows
Transmission Deferral	AC optimal power flow (ACOPF) program used to alleviate congestion along targeted lines	PLEXOS dispatch schedule used rather than optimal AC power flows
Primary Frequency Response	BPA-CAISO contract at $44.40 per kW-year	Analysis performed by Idaho National Labs found up to 5% of Goldendale capacity can be committed to primary frequency response without conflicts with primary services
Voltage Support	CAISO does not provide direct compensation; other ISOs used to establish value	35 MVAR capacity available throughout year

Technoeconomic Study (TES) Coordination and Modeling Flow



Key Financial Parameters

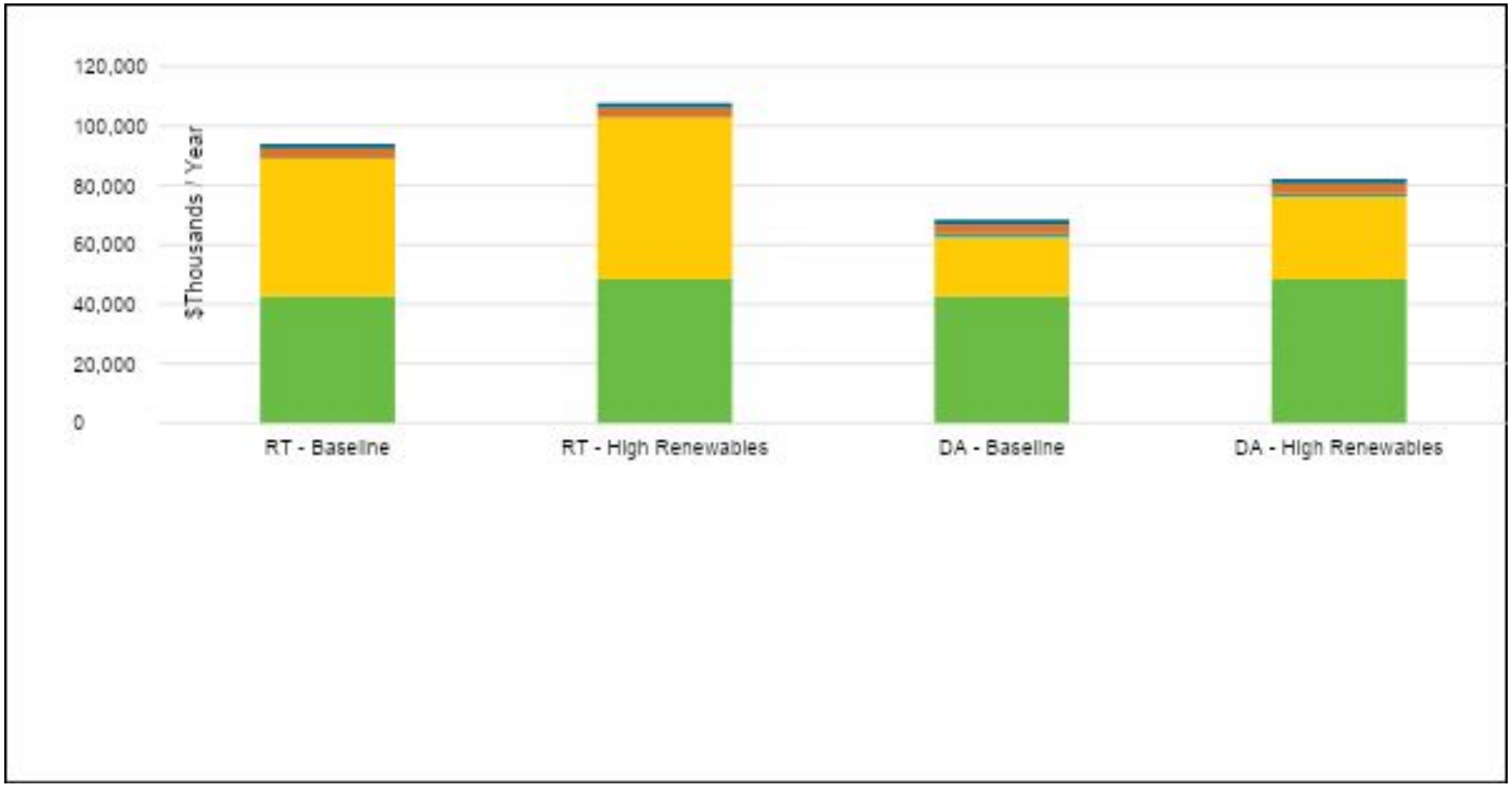
Key Financial Data Requirements	Goldendale	Banner Mountain
Project development period (years)	5	10
CBA period (years)	50	50
Plant economic life (years)	100	50
Total cost	$2.8 billion	$1.12 billion
Amount financed	70%	70%
Year of financial closure on loans (when funds are available and interest starts to accrue)	As required.	As required.
Repayment period (years)	30	30
Interest rate on debt financing (%)	3.25%	4%
Type of payment schedules	Even payments.	Even payments.
Weighted average cost of capital for sponsor - discount rate for owner-operator (%)	6.98%	6.98%
Federal tax rate (%)	21%	21%
State public utility tax rate (%)	3.8734%	0%
Recurring capital investment	$0	$100 million in Year 30
Annual O&M costs	$15 million	$6 million
Escalation rate for value of service and capital/O&M (%)	2%	2%
Insurance cost (annual as % of capital investment) (%)	0.10%	0.20%
Property tax and other cost rates (%)	.75%	0.01%
Expenditure pattern during construction period	8%, 31%, 31%, 25%, 5%	$0.5, $2, $2, $5, $5, $465, $180, $180, $180, $100.5 (Millions)
Non-depreciable investment costs	$75 million	$11.5 million

BCA Calculator & Financial Worksheets

- BCA calculator runs the user through a series of data input fields
- Model enables the user to define alternative scenarios, evaluate many use cases, and consider alternative debt structures, alternative depreciation methods, tax implications, salvage value, all capital and operations and maintenance costs, and refurbishment costs
- BCA calculator defines benefit-cost ratio, discounted payback period, net present value, and internal rate of return for each case

Goldendale Results for System Analysis

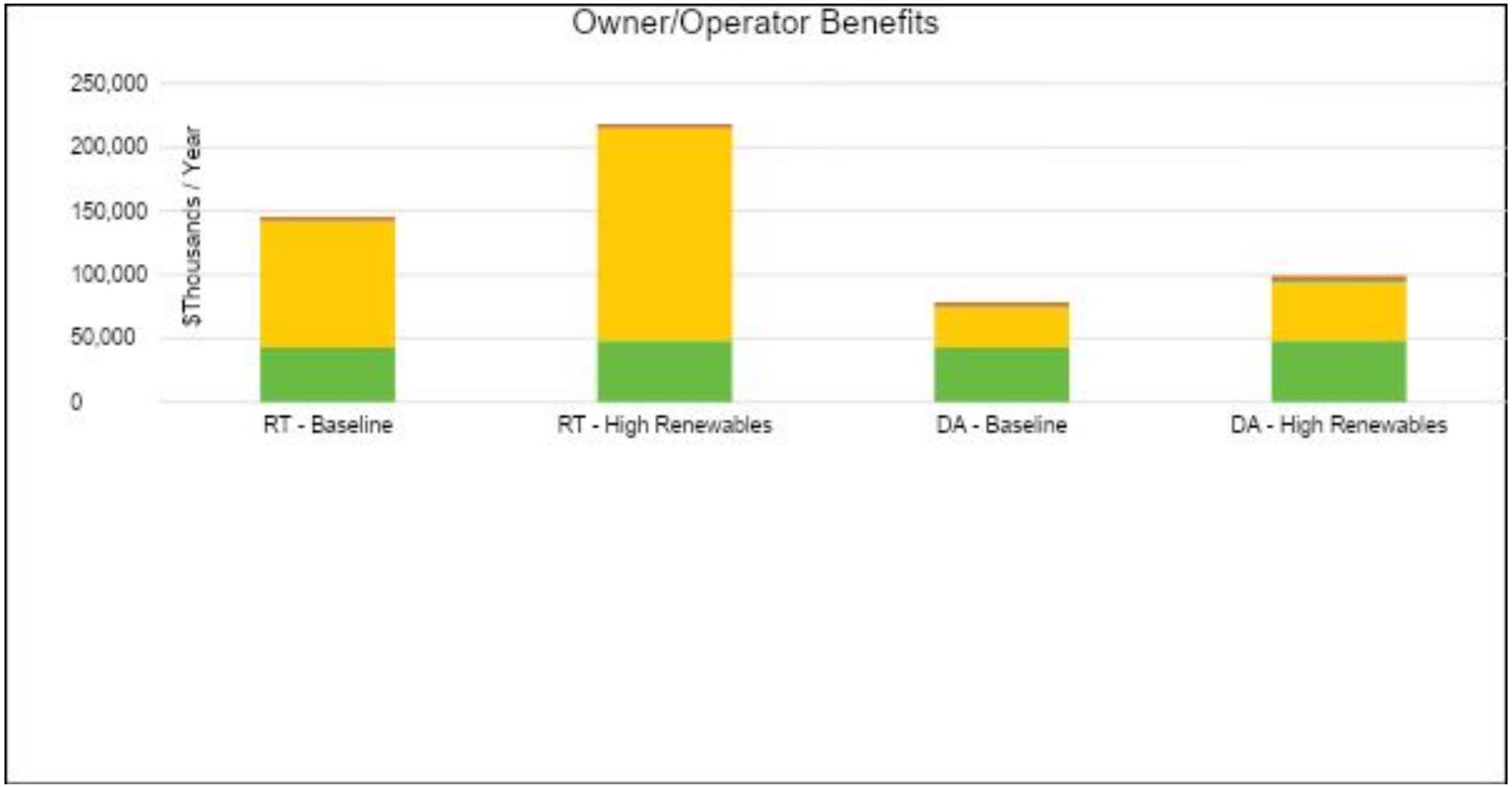
- Annual value to system ranges from $68.4 million (DA-baseline) or $57/kW-year to $107.8 million (RT-high renewables) or $89.82/kW-year
- Vast majority of value tied to capacity and energy (95% of base case)
- Unserved energy and other societal benefits excluded
- RT and high renewable cases drive benefits upward
- Transmission deferral value eliminated in co-optimization process



Annual system value of services provided by Goldendale PSH.

Goldendale Results for Owner-Operator Analysis

- Annual estimated revenue ranges from $78.5 million (DA-baseline) or $65/kW-year to $218.4 million (RT-high renewables) or $181.98/kW-year
- Vast majority of revenue tied to capacity and energy (98% of base case)
- Unserved energy and other societal benefits excluded
- RT and high renewable cases drive benefits upward
- Transmission deferral, transmission congestion relief, and voltage support value eliminated



Annual revenue to owner-operator for Goldendale PSH.

Goldendale BCA Results

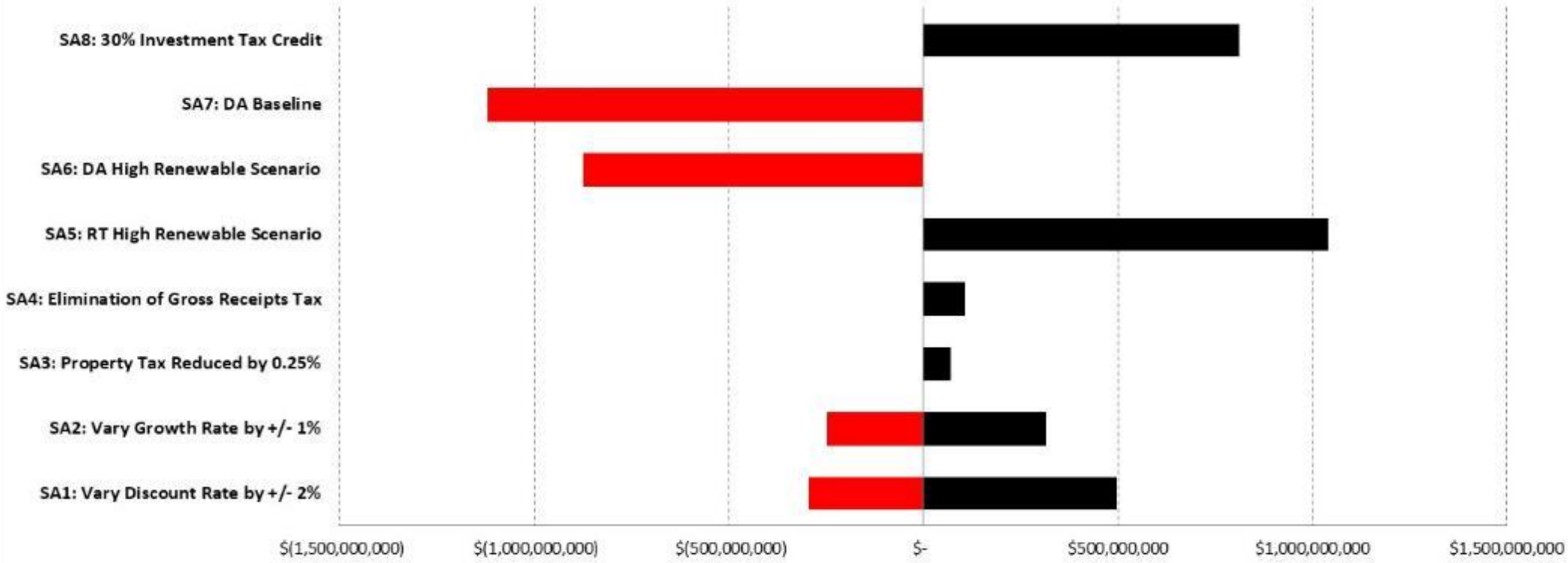
System Analysis Results

Key Financial Metrics	RT Baseline	RT-High Renewables	DA-Baseline	DA-High Renewables
NPV (end-of-the-year-method)	$ (1,364,191,189)	$ (1,145,171,592)	$ (1,783,814,840)	$ (1,555,082,889)
NPV (mid-year method)	$ (1,410,998,451)	$ (1,184,463,993)	$ (1,845,019,962)	$ (1,608,439,906)
Benefit-cost Ratio	0.56	0.63	0.41	0.49
Internal Rate of Return	1.2%	2.2%	-1.1%	0.2%
Discounted Payback Period (years)	N/A	N/A	N/A	N/A

Owner Operator Results

Key Financial Metrics	RT Baseline	RT-High Renewables	DA-Baseline	DA-High Renewables
NPV (end-of-the-year-method)	$ (581,873,921)	$423,812,734	$ (1,616,622,768)	$ (1,283,861,649)
NPV (mid-year method)	$ (601,838,809)	$438,354,328	$ (1,672,091,302)	$ (1,327,912,695)
Benefit-cost Ratio	0.82	1.12	0.47	0.58
Internal Rate of Return	4.7%	8.5%	-0.1%	1.6%
Discounted Payback Period (years)	N/A	32	N/A	N/A

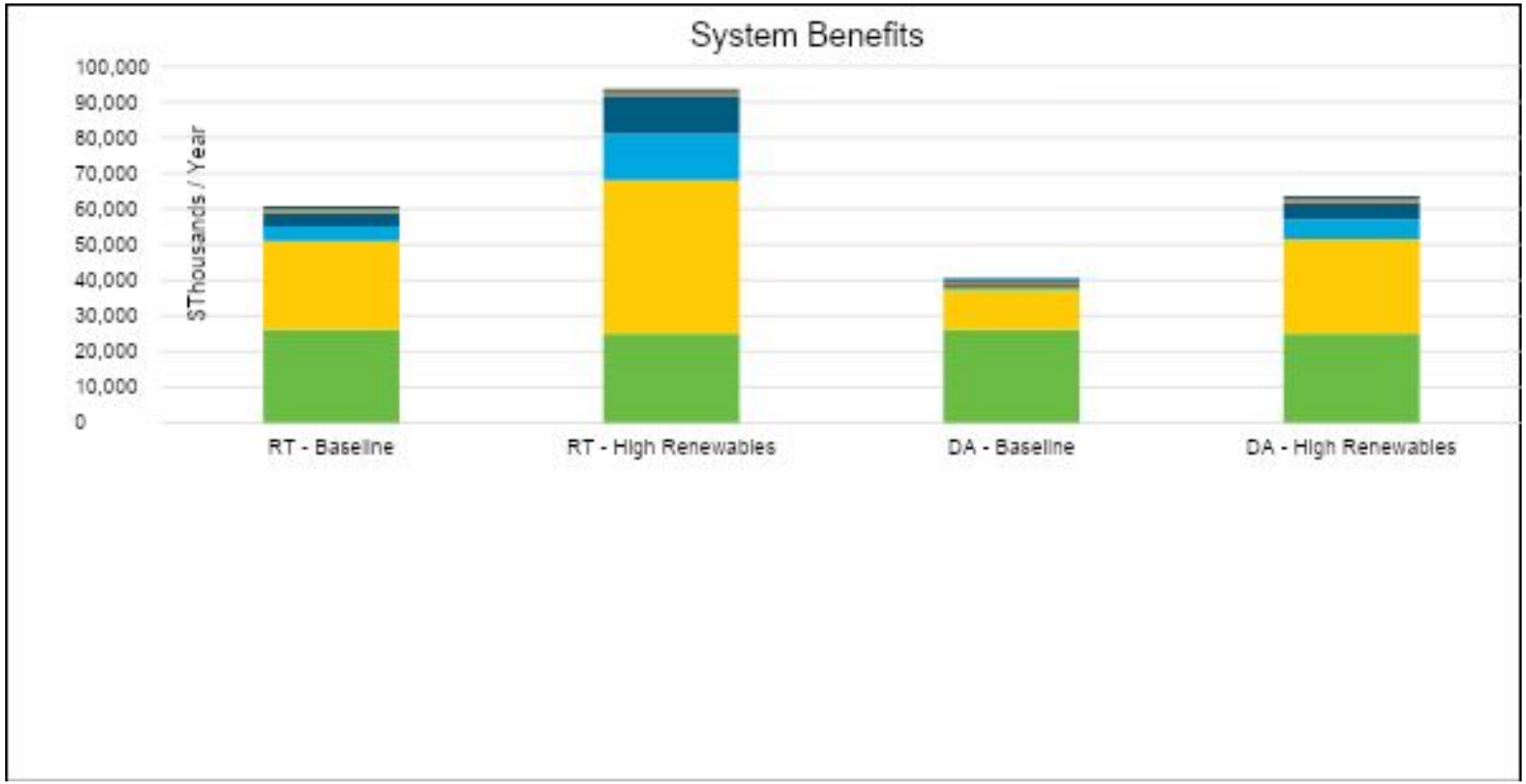
Goldendale Sensitivity Analysis Results – Owner/Operator



	SA1: Vary Discount Rate by +/- 2%	SA2: Vary Growth Rate by +/- 1%	SA3: Property Tax Reduced by 0.25%	SA4: Elimination of Gross Receipts Tax	SA5: RT High Renewable Scenario	SA6: DA High Renewable Scenario	SA7: DA Baseline	SA8: 30% Investment Tax Credit
Low	$(293,452,309)	$(247,614,389)	-	-	-	$(873,373,168)	$(1,119,577,988)	
High	$495,622,536	$314,906,004	$71,663,199	$106,070,087	$1,040,193,137	-	-	$812,134,555

Banner Mountain Results for System Analysis

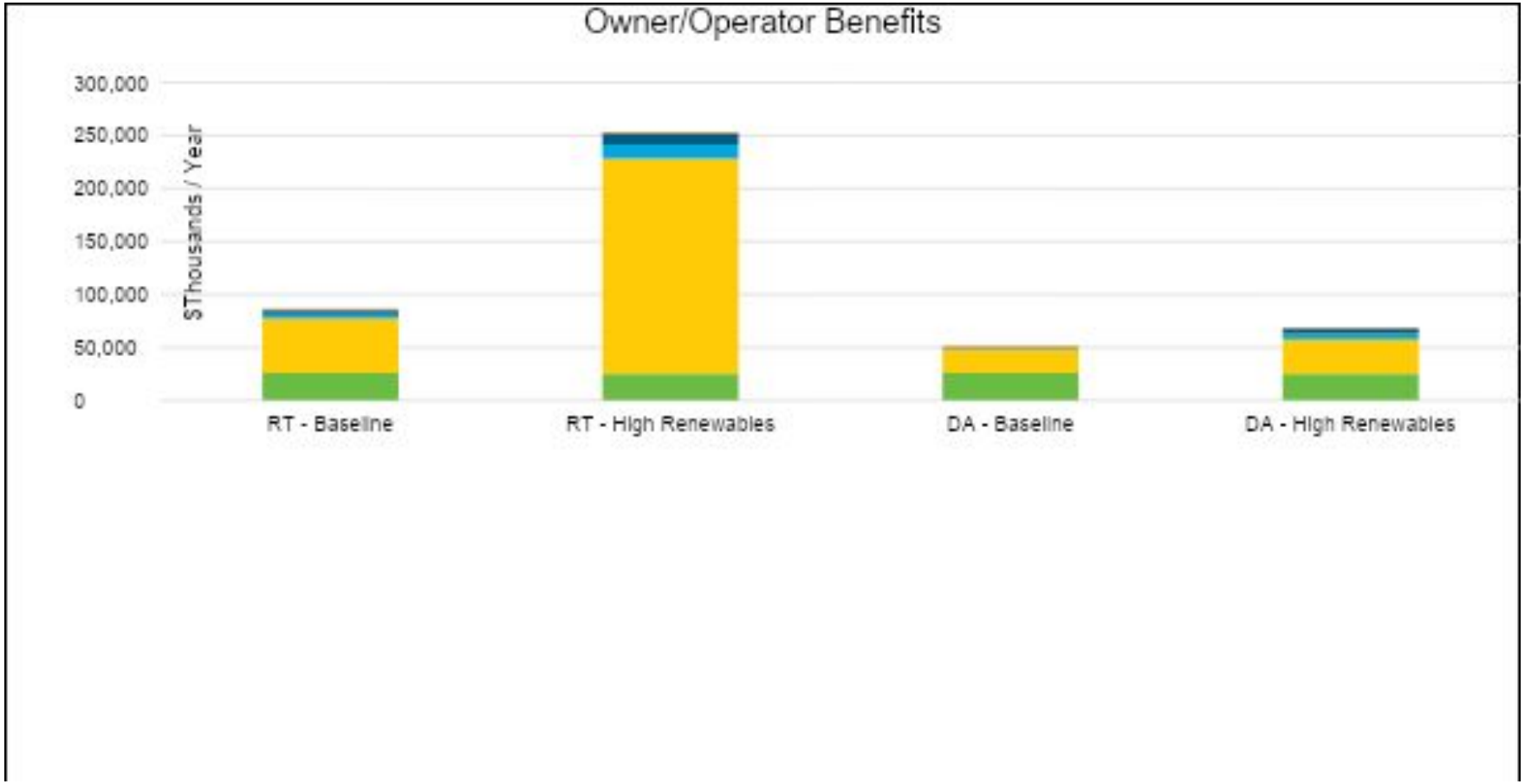
- Annual value to system ranges from $40.5 million (DA-baseline) or $101/kW-year to $93.7 million (RT-high renewables) or $234/kW-year
- Vast majority of revenue tied to capacity and energy (84% of base case)
- Unserved energy and other societal benefits excluded
- RT and high renewable cases drive benefits upward
- Transmission deferral value eliminated in co-optimization process



Annual system value of services for Banner Mountain PSH.

Banner Mountain Results for Owner-Operator Analysis

- Annual estimated revenue ranges from $50.9 million (DA-baseline) or $127/kW-year to $253.3 million (RT-high renewables) or $633/kW-year
- Vast majority of revenue tied to capacity and energy (90% of base case)
- Unserved energy and other societal benefits excluded
- RT and high renewable cases drive benefits upward
- Transmission deferral, transmission congestion relief, and voltage support value eliminated



Annual revenue to owner-operator for Banner Mountain PSH.

Banner Mountain BCA Results

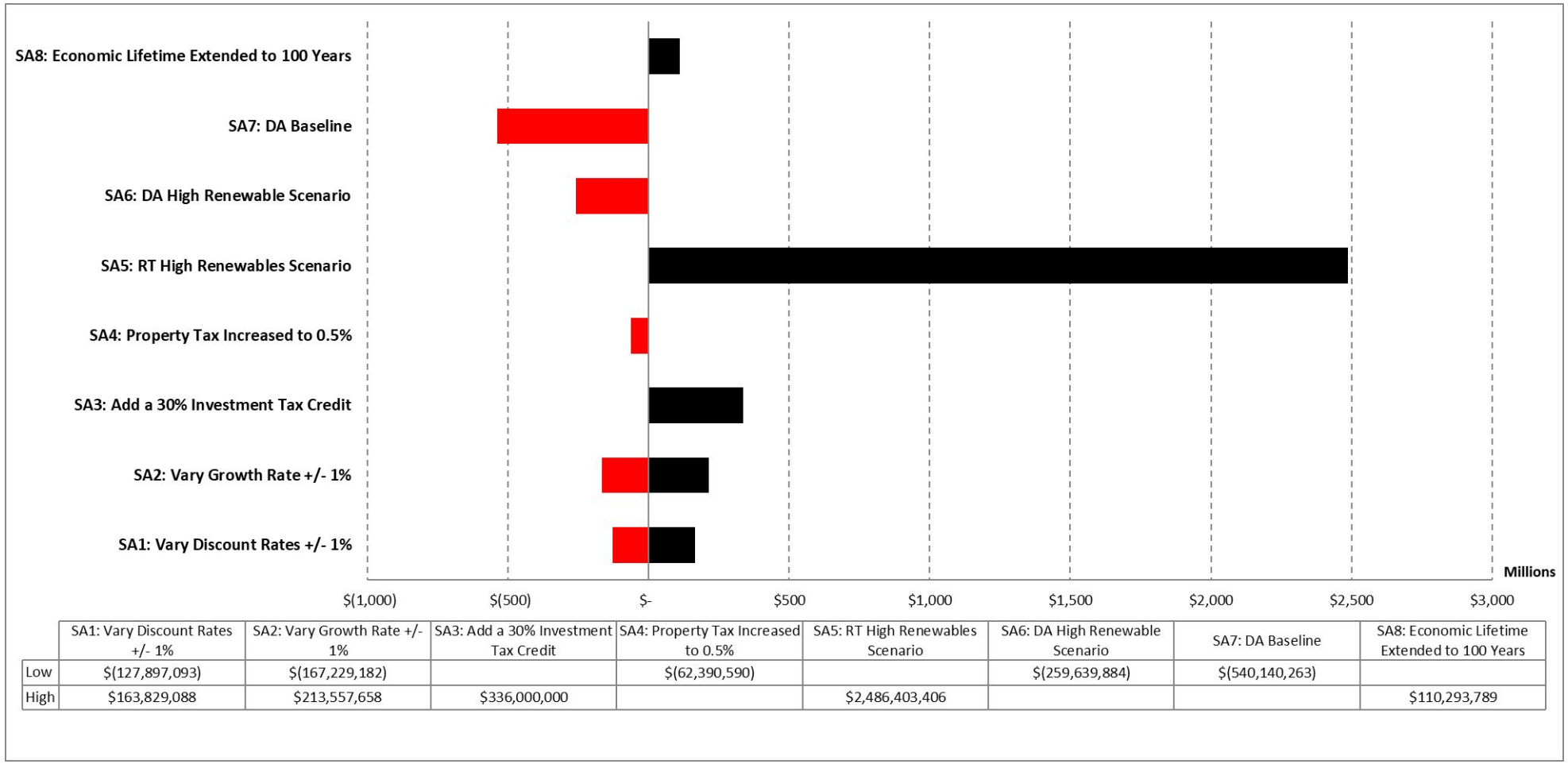
System Analysis Results

Key Financial Metrics	RT Baseline	RT-High Renewables	DA-Baseline	DA-High Renewables
NPV (end-of-the-year-method)	$(184,661,570)	$290,733,699	$(505,794,685)	$(143,993,215)
NPV (mid-year method)	$(190,997,560)	$300,709,169	$(523,149,191)	$(148,933,819)
Benefit-cost Ratio	0.76	1.38	0.33	0.81
Internal Rate of Return	5.2%	9.4%	1.9%	5.6%
Discounted Payback Period (years)	N/A	23	N/A	N/A

Owner-Operator Results

Key Financial Metrics	RT Baseline	RT-High Renewables	DA-Baseline	DA-High Renewables
NPV (end-of-the-year-method)	$184,934,365	$2,588,855,940	$(337,287,745)	$(66,092,447)
NPV (mid-year method)	$191,279,715	$2,677,683,121	$(348,860,548)	$68,360,169)
Benefit-cost Ratio	1.24	4.41	0.56	0.91
Internal Rate of Return	8.6%	22.4%	3.7%	6.4%
Discounted Payback Period (years)	31	11	N/A	N/A

Banner Mountain Sensitivity Analysis Results – Owner/Operator



	SA1: Vary Discount Rates +/- 1%	SA2: Vary Growth Rate +/- 1%	SA3: Add a 30% Investment Tax Credit	SA4: Property Tax Increased to 0.5%	SA5: RT High Renewables Scenario	SA6: DA High Renewable Scenario	SA7: DA Baseline	SA8: Economic Lifetime Extended to 100 Years
Low	$(127,897,093)	$(167,229,182)		$(62,390,590)		$(259,639,884)	$(540,140,263)	
High	$163,829,088	$213,557,658	$336,000,000		$2,486,403,406			$110,293,789

Study Limitations

There are a variety of complexities that affect the ability of the approach to yield realistic results for future operations.

- PCMs evaluate system benefits using perfect foreknowledge of grid conditions while allowing the region's full asset portfolio to address grid needs, thus minimizing disturbances and large swings in prices that yield additional value/revenue to PSH.
- The approach relies on multiple grid models to evaluate different value streams, thus presenting co-optimization challenges.
- The approach doesn't account for the presence of power purchase agreements signed between asset owners and potential off-takers.
- The studies were completed prior to the passage of the Inflation Reduction Act (IRA), and the capacity expansion results don't account for the investment and production tax credits in the IRA.
- It is extremely difficult to predict future climate, market, policy, and VRE penetration effects on grid operations and the associated value proposition for PSH.

Thank you! Questions?

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