OLD HICKORY HRAR

Dan Patla,
Mark Parrish
Hydroelectric Design Center
9 Oct, 2019

US Army Corps of Engineers®

OUTLINE

1) Background

2) Old Hickory HRAR Comments Received

3) Results

4) Recommendations

5) Old Hickory HRAR Schedule

BACKGROUND

The Hydropower Rehabilitation Analysis Report (HRAR) for Old Hickory began in 2014. The intent of the HRAR was to focus analysis from a MRER to be hydropower specific in order to determine the appropriate rehabilitation alternative.

HDC developed a model (SCE-TOM) to be able to address some of the complex questions surrounding various alternatives and the benefits they could provide

The first HRAR report was delivered in 2016. A revised report was provided in 2018.

OLD HICKORY HRAR COMMENTS RECEIVED

1. Scope Certainty – Several items were needed prior to beginning Plans and Specifications: a shaft study and powertrain analysis required to achieve the recommended alternative

A Shaft Study was completed, clearing the path for reuse of shafting at uprated conditions (2018). Moreover, a Powertrain Analysis was completed to understand the scope of the remaining Powertrain (2019)

2. Cost Certainty – As more analysis was necessary to confirm the scope, the costs carried some uncertainty as well

Cost input was refined to include appropriate costs from Unit 4 Refurbishment efforts. In addition, scope refinement improved cost certainty on shafting and powertrain. Cost estimates are in line with Level III cost estimates per ASTM E2516. Finally, more detail was included.

OLD HICKORY HRAR COMMENTS RECEIVED

3. A lesser uprate (38.5 MVA) was not evaluated

ES Table 3– Estimated Cost and Schedule

Alternative	Design, Manufacturing, and Rehabilitation Dates	Design & Manufacturing Duration (Years)	Outage Duration (Years)	Total Studied Cost	Total Burden Cost
ALT 1	2022-2029	5	6	$124,853,000	$151,964,000
ALT 2	2022-2029	5	6	$125,061,000	$152,497,000
ALT 3	2022-2029	5	6	$124,834,000	$152,270,000
ALT 4	2022-2029	5	6	$122,038,000	$149,474,000
ALT 5	2022-2029	5	6	$125,061,000	$152,497,000

Alternative	Description	Studied Generator Rating (MVA) [1]	Studied Generator Rating at Rated Power Factor (MW) [2]	Studied Rated Plant Capacity (MW) [3]
Status Quo	Current Turbine/Generators	35.9	28.7	143.6
Alternative 1	Adjust Kaplans for peak efficiency	35.9	28.7	143.6
Alternative 2	Adjust Kaplan turbines for peak efficiency and uprate Kaplan turbines	45	40.5	180
Alternative 3	Uprate three Kaplan turbines by adjustment and uprate one low head fixed blade turbine by reducing the size of the hub and enlarging blades for more capacity	45	40.5	180
Alternative 4	Uprate two Kaplan turbines by adjustment and uprate two low head fixed blade turbines by reducing the size of the hub and enlarging blades for more capacity	45	40.5	180
Alternative 5	Adjust Kaplan turbines for peak efficiency and uprate Kaplan turbines	38.5	34.65	154

OLD HICKORY HRAR COMMENTS RECEIVED

4. The Baseline (Do Nothing (2016), Replace after Failure (2018)) was not considered to be an appropriate baseline, opting rather for a Repair after Failure

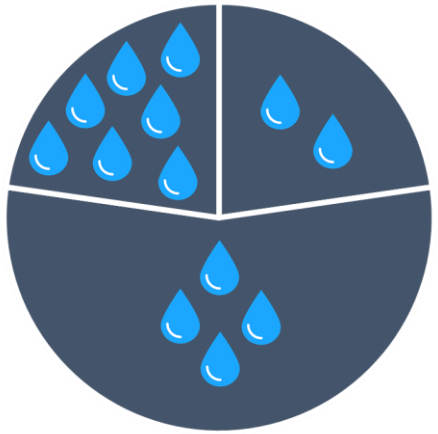
Old Method-Deterministic

- Assumed run to failure and then abandon baseline
- Computed energy benefits and reliability benefits separately
- Calculated average annual benefits assuming a single price signal averaged over 15 years of hydrological records.
- Calculated a single-point BCR

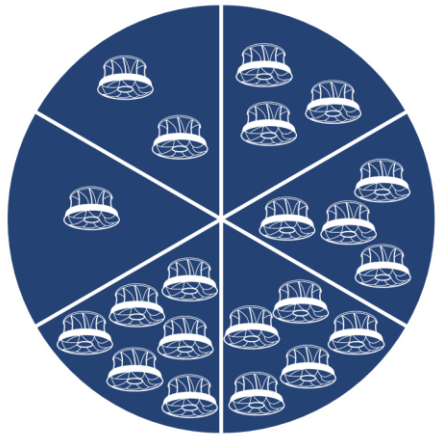
New Method-Stochastic

- Assumes run to failure and then repair
- Computed energy benefits and lifecycle costs
- Performs a complete Monte Carlo Simulation of hydrology, energy price , and unit availability
- Calculates a probability distribution of BCRs

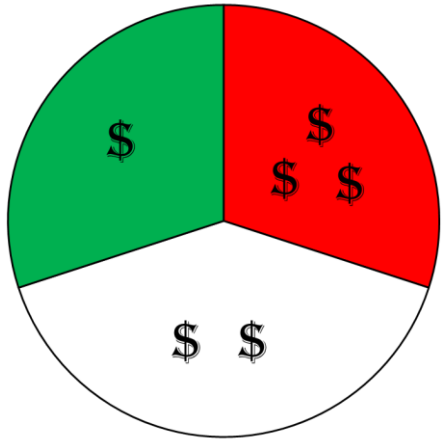
HYDROPOWER INVESTMENT UNCERTAINTY



Hydrology

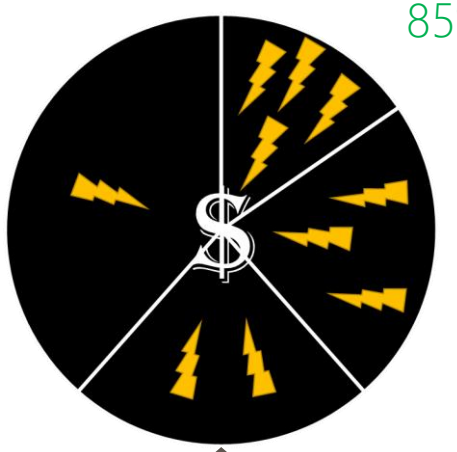


Unit Availability



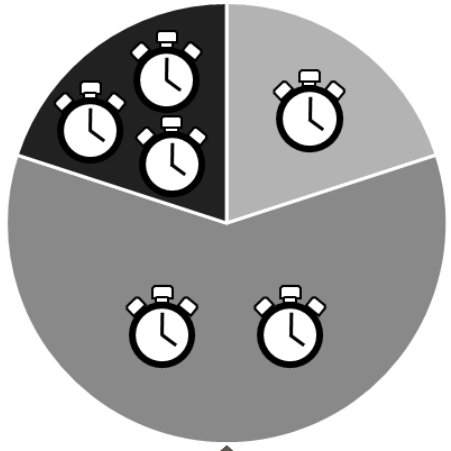
Direct Cost

85% Probability that NPV > 0



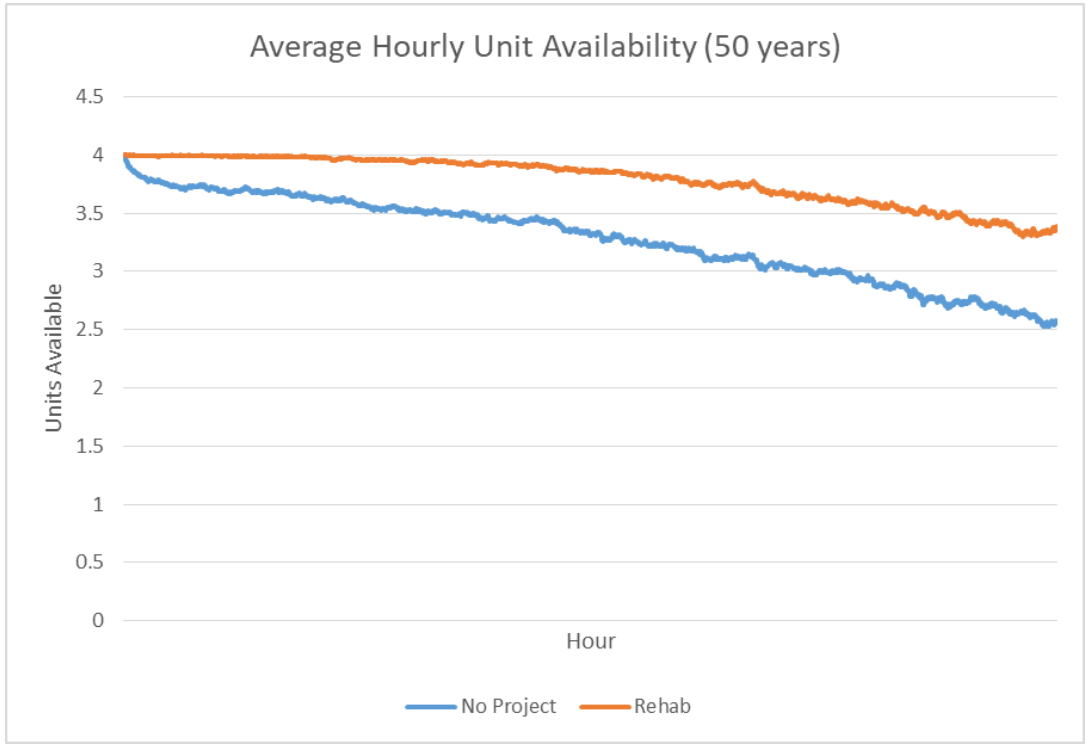
Energy Prices

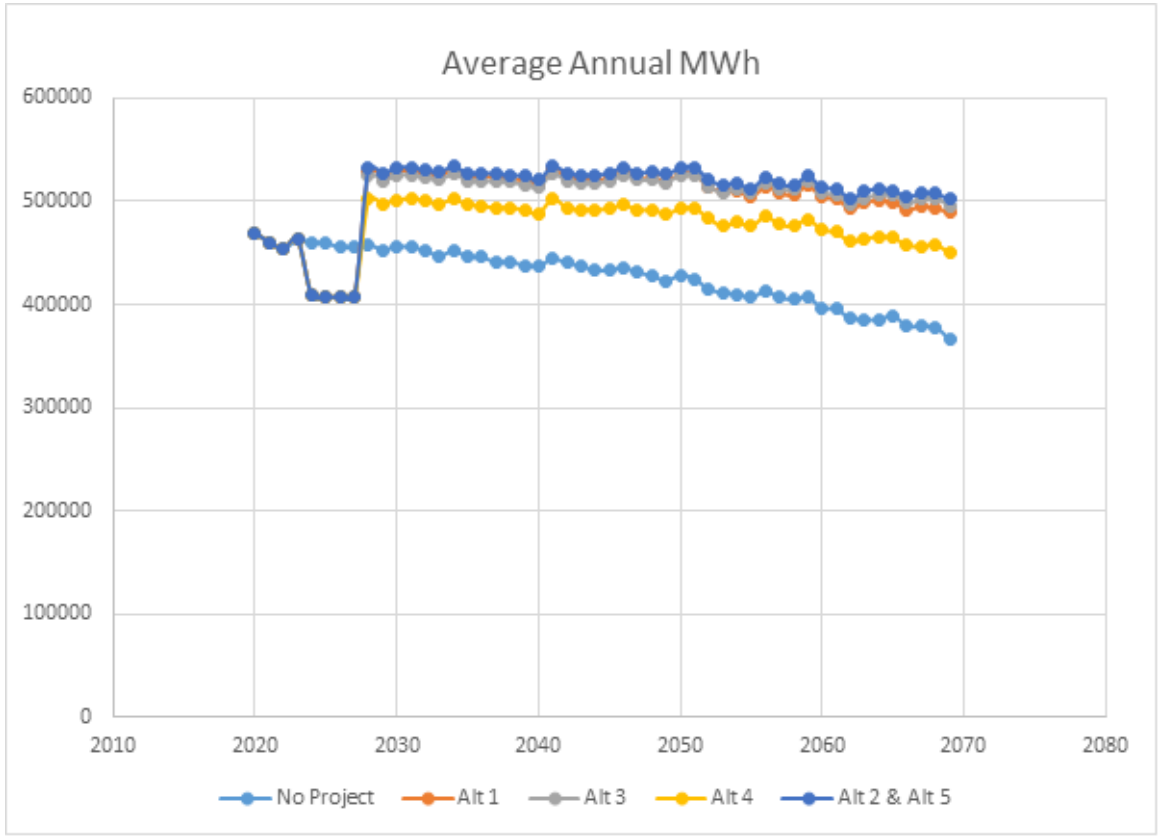
NPV= -$15 mil



Outage/Project Duration

HIGH LEVEL RESULTS:





BENEFITS CONSIDERED

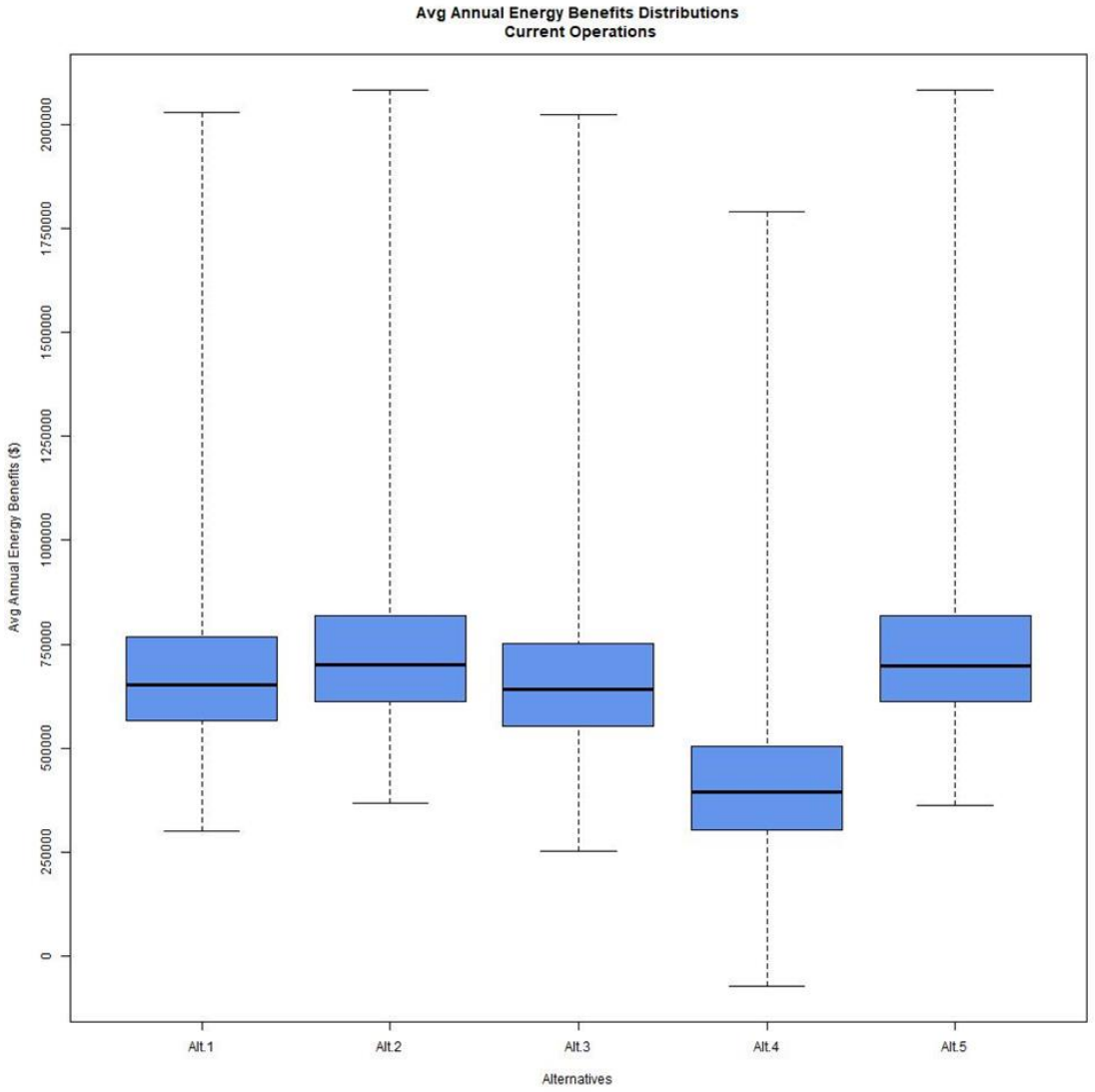
CAPACITY: Capacity benefits are measured as the increase in capability (MW) of the plant to meet regional peak demand. This benefit is computed only for critical months (July and August). The value of increased capacity is determined by the avoided capital investment of new or additional thermal generating resources

ENERGY: Energy benefits are calculated from an increase in generation (MWh) throughout the year. The value of this increase follows the seasonal variation in availability and demand reflected in regional energy prices.

RELIABILITY: Reliability benefits are defined as the reduction in generation due to unplanned forced outages.

ENERGY BENEFITS:

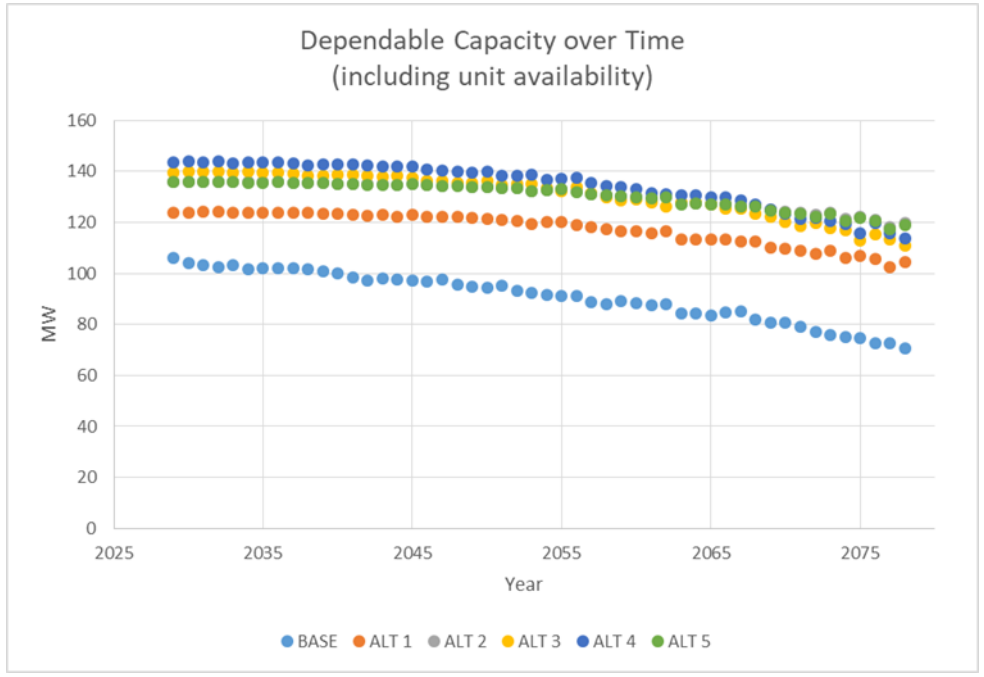
Alternative	Generation Benefit	
	Optimal Power	Current Operations
ALT 1	$705,172	$683,900
ALT 2	$763,146	$733,500
ALT 3	$726,132	$672,300
ALT 4	$570,667	$421,000
ALT 5	$755,391	$732,200

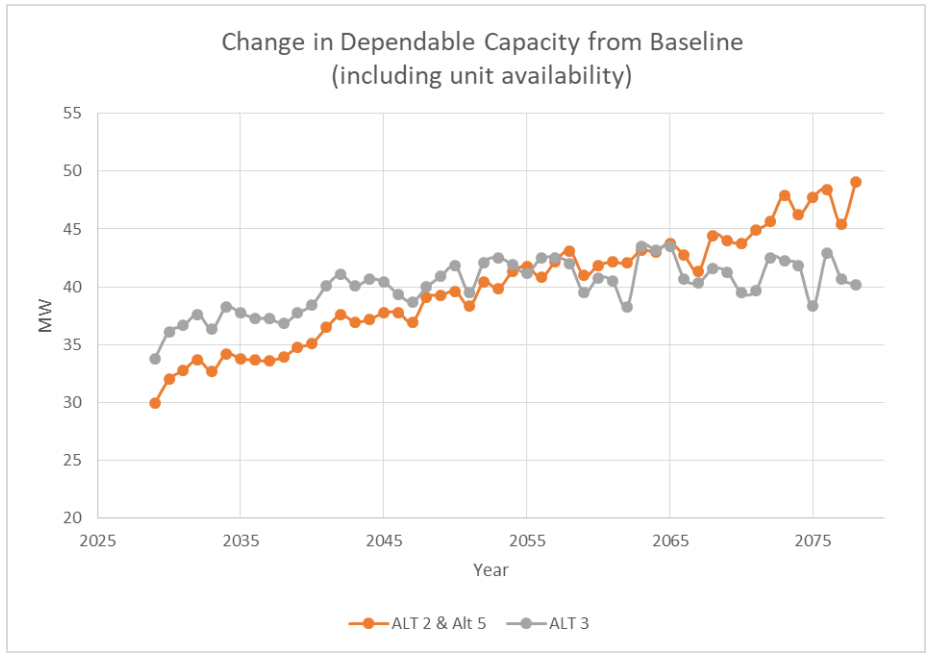


CAPACITY BENEFITS:

Alternative	Change in Dependable Capacity compared to Current Conditions (MW)	Dependable Capacity Benefit
ALT 1	14.07	$1,298,942
ALT 2	25.92	$2,392,934
ALT 3	29.98	$2,767,753
ALT 4	31.49	$2,907,156
ALT 5	24.44	$2,256,300

Typically Capacity benefits are not calculated as a function of reliability, however when comparing alternatives with Fixed blade turbines a stochastic benefit may need to be considered.

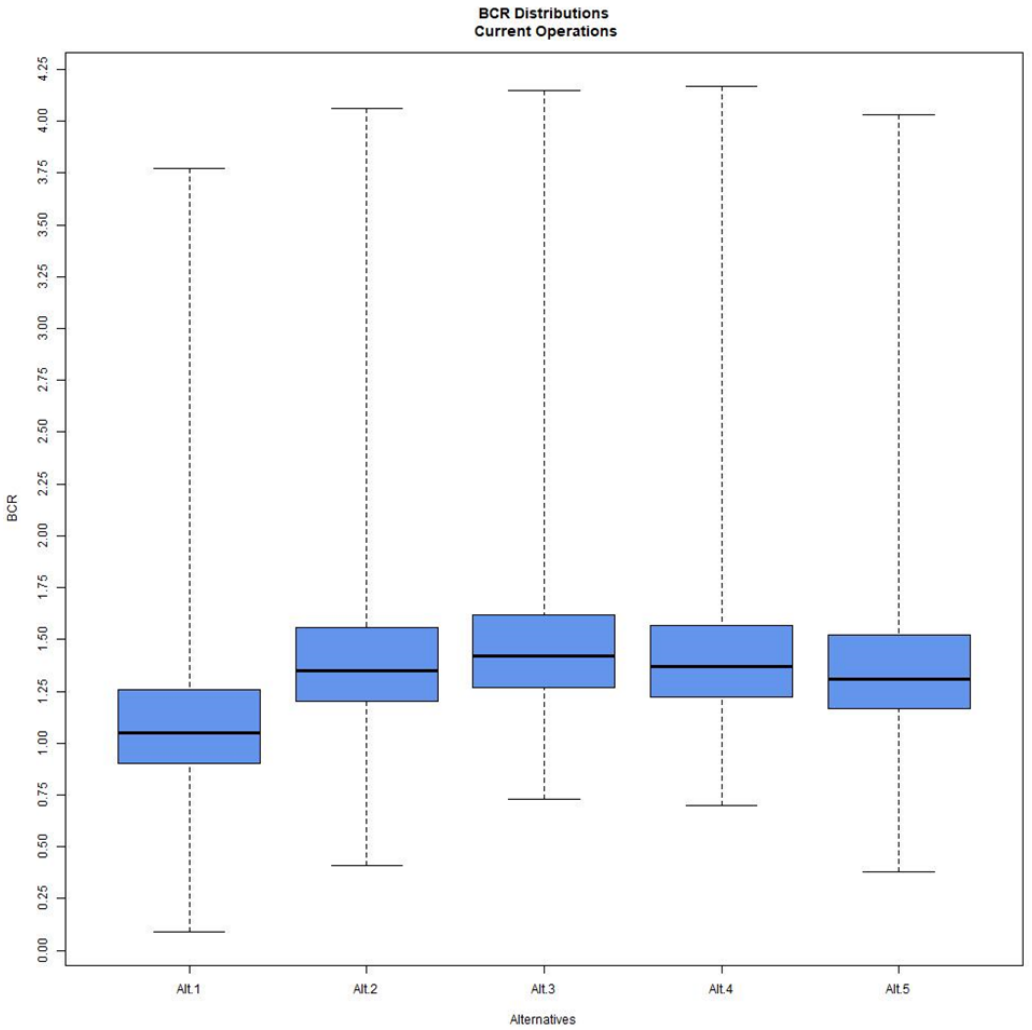




BENEFIT COST RATIOS

Alternative	Construction Cost (Including S&A)	PV Cost	PV Benefits	BCR
ALT 1	$124,853,063	$106,602,669	$121,707,102	1.14
ALT 2	$125,061,063	$106,775,874	$153,842,051	1.44
ALT 3	$124,834,032	$106,762,694	$161,611,857	1.51
ALT 4	$122,038,202	$104,322,284	$152,829,755	1.46
ALT 5	$125,061,063	$106,775,875	$150,076,647	1.41

	percent time BCR <1
Alt 1	38.5
Alt 2	1.8
Alt 3	0.9
Alt 4	2
Alt 5	1.9



CONSIDERATIONS

Alternatives 2 and 5 Considerations:

- Operation of a new family of turbines that is only Kaplans will be similar to the current operation
- The most flexibility is provided under Alternative 2 with the increase in operating range.
- Alternative 2 provided the most energy benefits.
- Alternatives 2 and 5 would not have multiple families, reducing the range of maintenance concerns
- Alternatives 2 and 5 may have larger capacity benefits overtime with the additional analysis incorporating unit availability

Alternatives 3 and 4 Considerations:

- Alternative 3 and 4 have the highest BCR
- Alternative 3 and Alternative 4 both have better capacity benefits
- Alt 3 and Alt 4 are much more sensitive to unit outages:
  - Long term forecast of less capacity
  - Higher range of uncertainty in Generation benefits

RECOMMENDATIONS

Alternative 3 and Alternative 4 provide more benefits, but also carry more risk and increase the range of maintenance concerns, which were considered in the AWB simulation.

The difference between fixed blade and Kaplan alternatives is a matter of the difference between energy and capacity benefits, and the difference in energy benefits relates to a decrease in flexibility when units are out of service.

Alternative 2 is recommended as it provides a similar level of benefits, reduced risk, and increased flexibility in operating range compared to Alternatives 3 and 4.

OLD HICKORY HRAR SCHEDULE

Draft Final Revision Delivered to Team Cumberland – 2 October 2019

Presentation of Results to Team Cumberland – 9 October 2019

Team Cumberland Comments Received – 25 October 2019

Final Report Delivered to Team Cumberland – 12 November 2019

Approval of Old Hickory HRAR – 31 December 2019

QUESTIONS?