U.S. DEPARTMENT OF ENERGY
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

HydroWIRES
U.S. DEPARTMENT OF ENERGY

Valuation Guidance and Techno-Economic Studies for PSH

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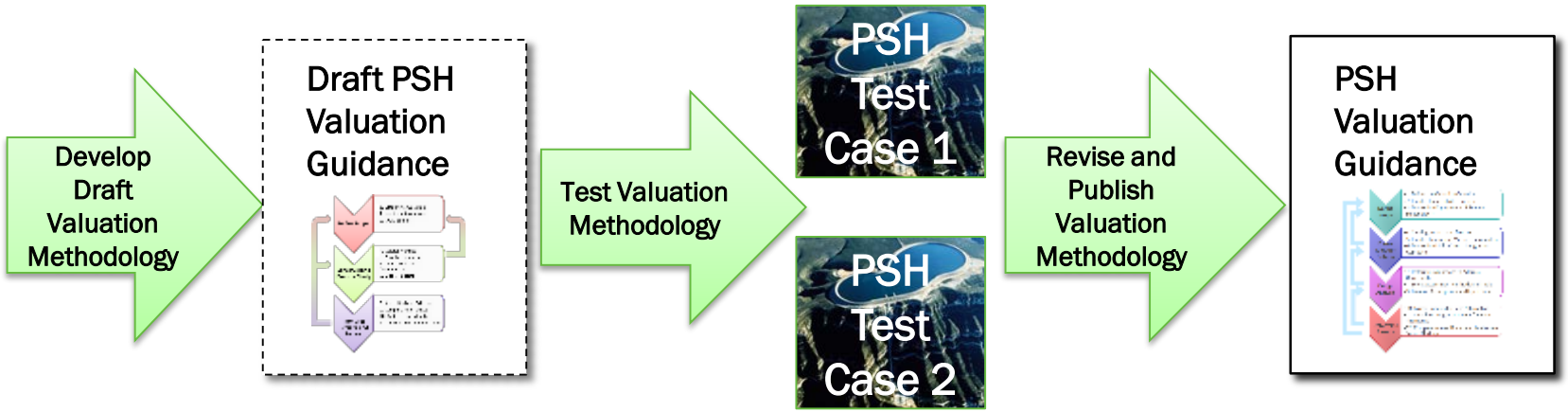
Project Goals and Objectives

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

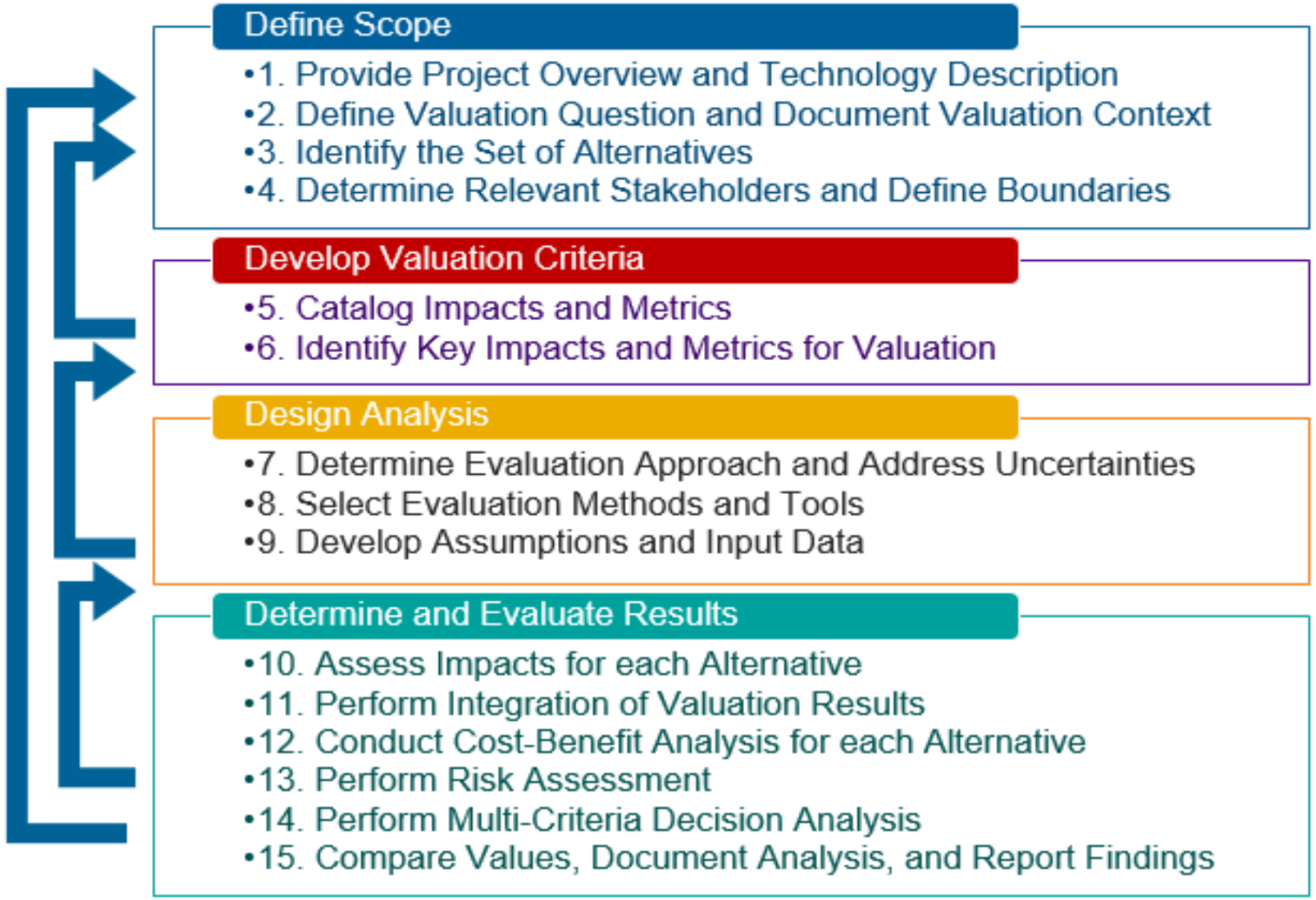
Specific goals:

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



Proposed PSH Valuation Process

A Cost-Benefit and Decision Analysis Valuation Framework



PSH Valuation Guidance Development Goals

- **Objective** and **comprehensive** methodology
- **Consistent** and **repeatable** valuation approach
- **Transparent** valuation process and results
- Can be applied to **different types and sizes** of PSH plants
- Accounts for **various services and contributions** that PSH plants provide to the grid
- Considers PSH **benefits and costs over time**
- Applies to both **traditional and restructured market environments**
- Can be used by **stakeholders with different perspectives**
- **Publicly available** for use by hydropower industry and stakeholders

The Project Team is Collaborating with Two Industry Partners

Absaroka Energy

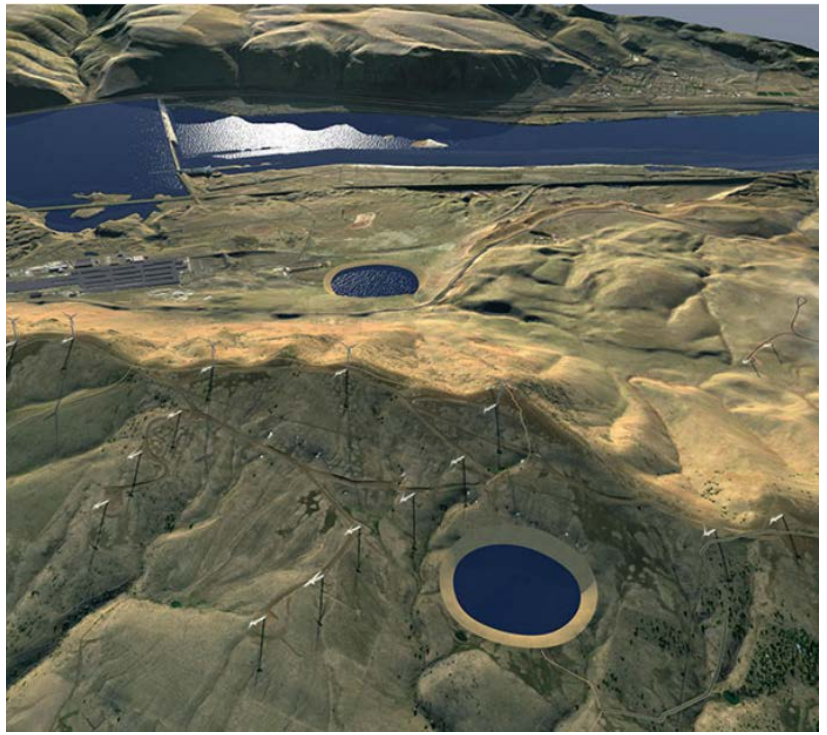
Banner Mountain PSH

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

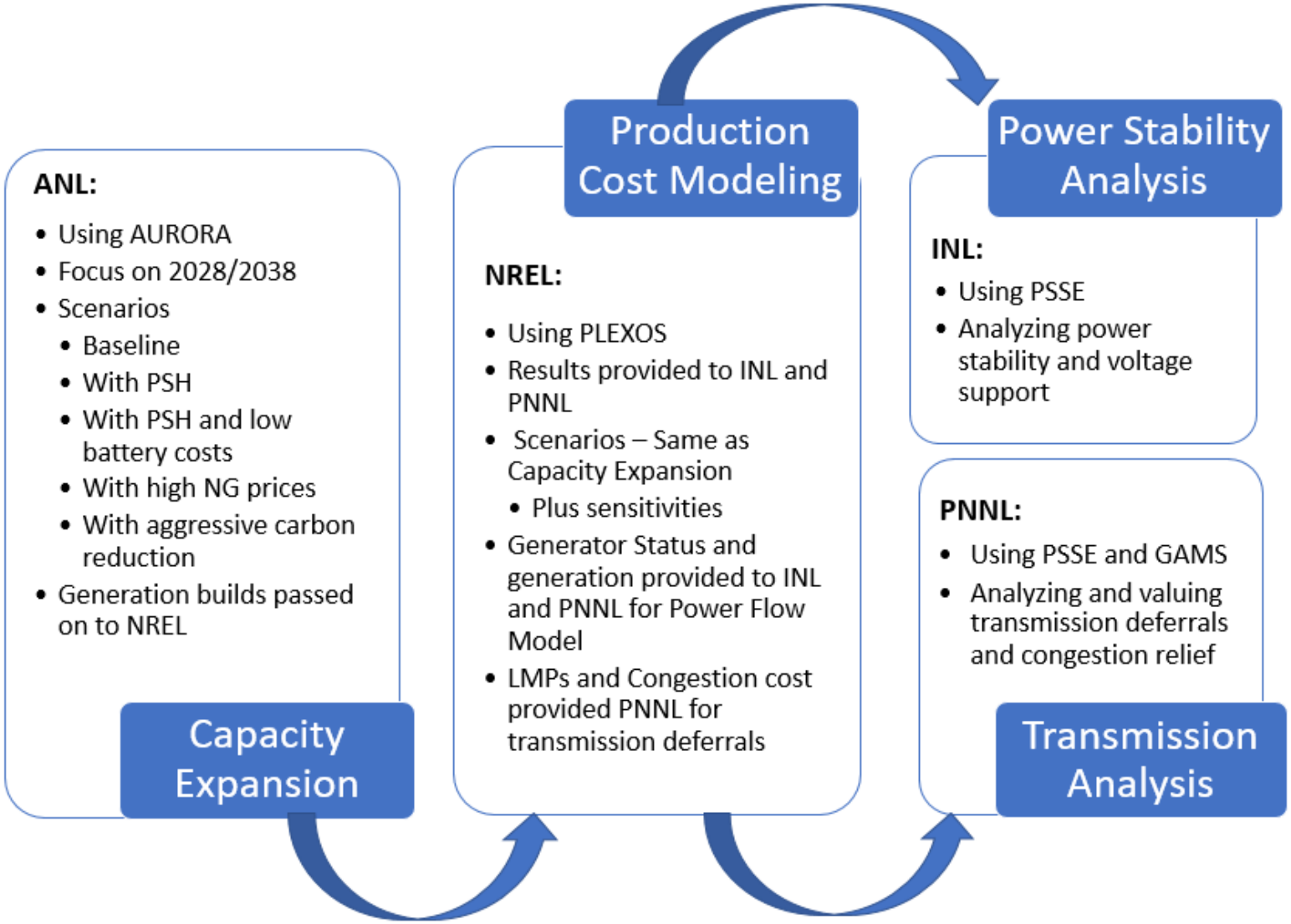
National Grid & Rye Development

Goldendale Energy Storage Project

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



TES Modeling Flow for Banner Mountain and Goldendale



Techno-Economic Studies for Banner Mountain and Goldendale

A variety of analyses are carried out to assess the costs and benefits of various PSH services and contributions to the grid

- ANL: Capacity valuation using AURORA model
- ANL: Historical electricity market analysis (PMAT)
- ANL: Black start service valuation (developing own model)
- NREL: Value of PSH ancillary services: regulation service, contingency reserves, and flexibility reserves (PLEXOS)
- INL: Power system stability services: inertial response, governor response (primary frequency control), transient and small signal stability, voltage support (PSSE)
- NREL: PSH impacts on power system cycling and ramping costs (PLEXOS)
- ORNL: Potential cost and performance impacts of increased PSH cycling and ramping operations (e.g., increased wear and tear of PSH units)
- NREL: Other system-wide effects of PSH operations (e.g., PSH impacts on system production costs, integration of variable energy resources, power system emissions) (PLEXOS)
- PNNL: PSH transmission benefits (congestion relief, transmission investments deferral) (PSSE)
- ORNL: PSH non-energy services (e.g., water management, socioeconomic benefits, and env. impacts)

Techno-Economic Analysis Example – Capacity Valuation

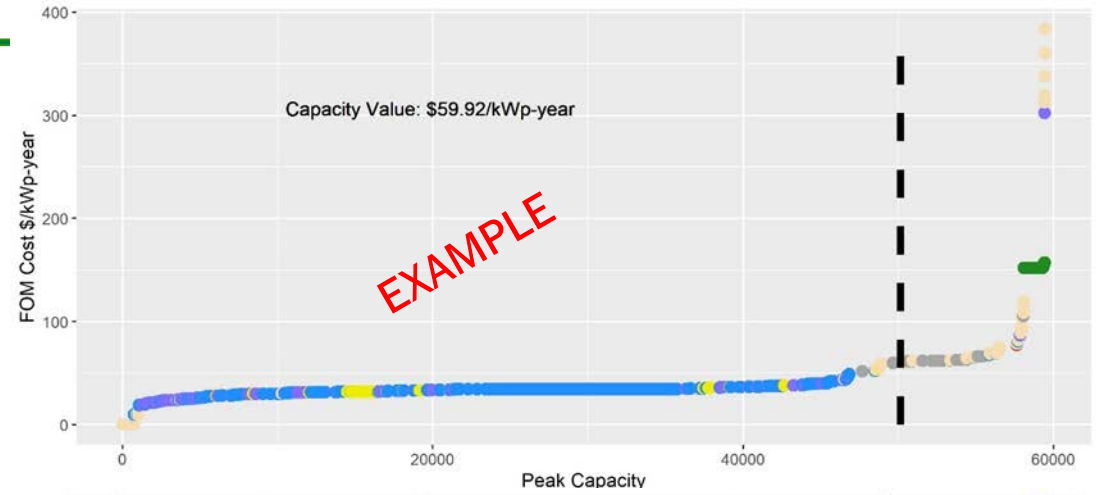
- Goal is to determine long-term system value of PSH capacity
- Capacity expansion analysis for the WECC region using AURORA model
- Baseline expansion plan 2019-2043 (~30 hours run time)
- Alternative plans with Banner Mountain and Goldendale PSH
- Sensitivities considered: natural gas price, load growth, technology costs, retirements, etc.

Sample capacity value results:

Capacity Valuation

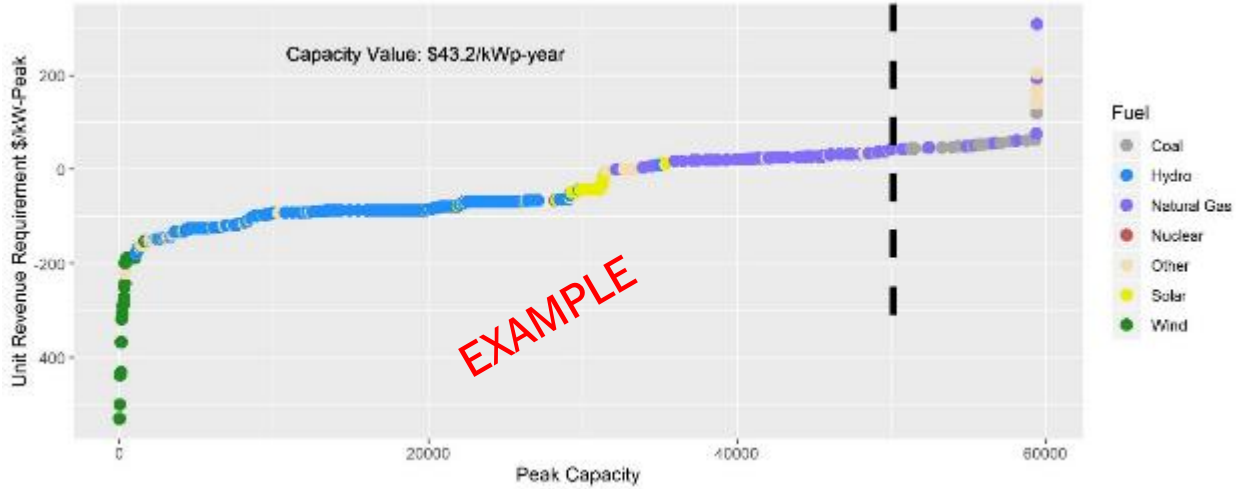
Unit Cost Approach

- **Order units based on fixed cost per unit of firm capacity**
  - With and without capital costs
  - Intersection of supply curve and PRM sets the capacity value



Unit Revenue Approach

- **Order units based on revenue requirement per unit of firm capacity**
  - Revenue required for unit to obtain zero profit in a given year
  - Intersection of supply curve and PRM sets the capacity value

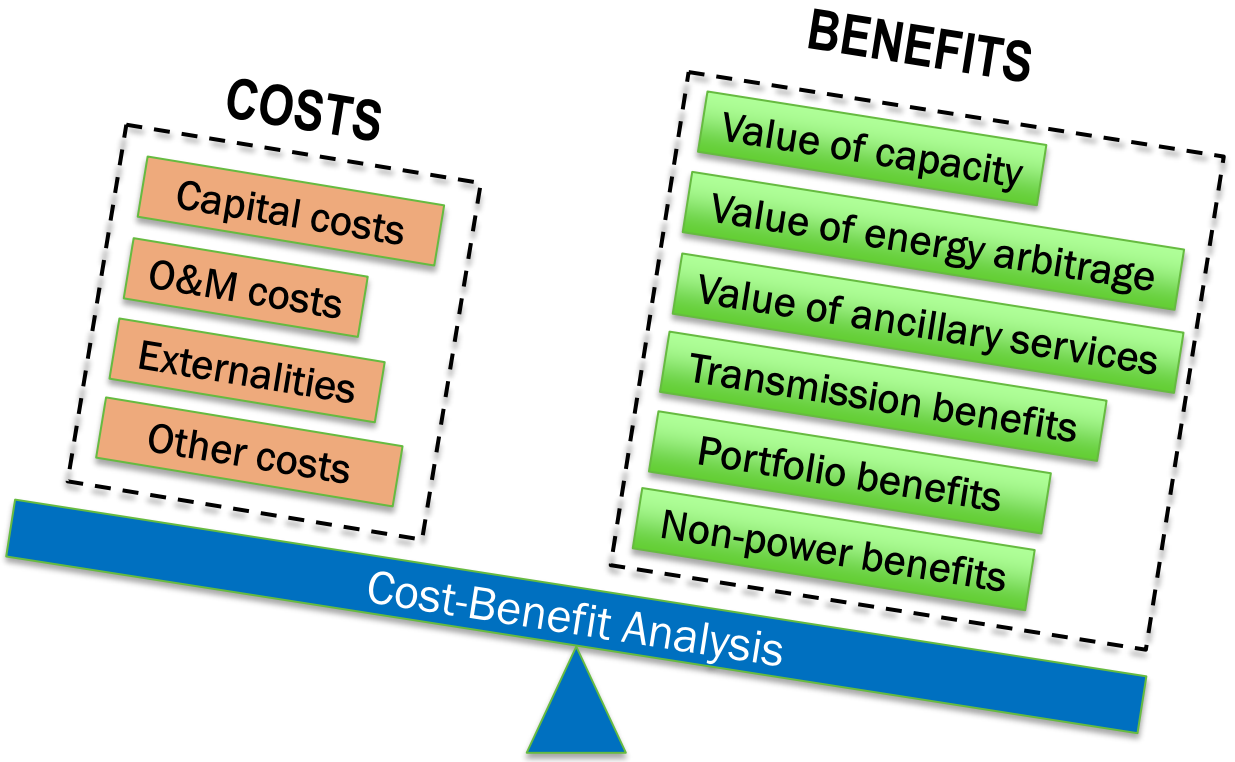


System Cost Approach

- **Determine system cost in a reference scenario and also with each PSH project**
  - Capacity valuation is difference between the system cost with and without the PSH project
  - Does not consider capital costs
  - Therefore, a capacity value that exceeds annualized capital costs may support project development from a neutral perspective

PSH Valuation Framework – Cost-Benefit Analysis

The results of various techno-economic studies will provide inputs for Cost-Benefit Analysis (CBA)

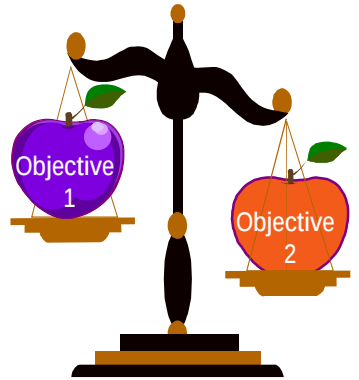


CBA will be used to calculate the net-present value (NPV), benefit-cost (B/C) ratio, etc.

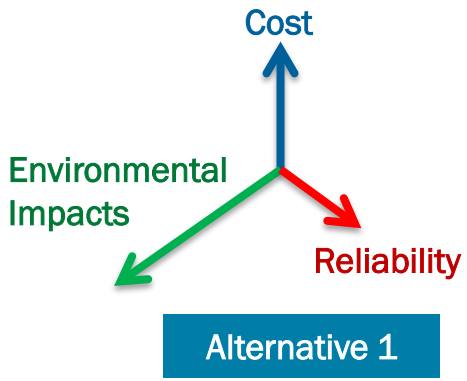
PSH Valuation Framework – Multi-Criteria Decision Analysis

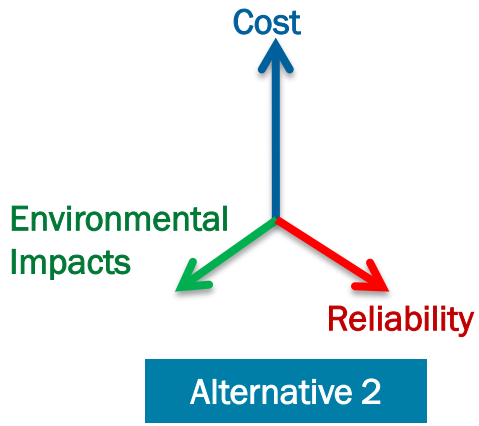
Choosing among different alternatives with multiple attributes

- Many PSH impacts are not easily monetized and have to be expressed in physical units or qualitatively
- How to compare different alternatives that are described by both monetized and non-monetized impacts?
- A decision-support system can help decision-makers choose among different alternatives defined by multiple attributes



Tradeoffs Among Objectives



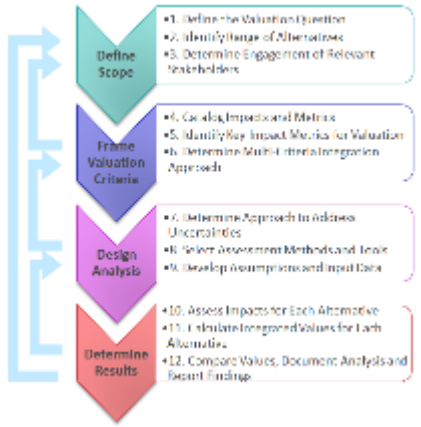


Which alternative is better?

Final Product of the Study: A Guidebook for Valuation of PSH Projects

- Draft PSH Valuation Guidebook will be revised and improved based on the experience gained during the two test case studies
- The revised final PSH Valuation Guidebook will be published and disseminated to hydropower industry and stakeholders
- A PSH Valuation Tool will be developed in a companion project

PSH Valuation Guidebook



Future Work

Develop PSH Valuation Tool

Year 1

- Review valuation models and identify key attributes in successful models
- Define basic model structure
- Acquire stakeholder input through TAG participation, discussion at HydroVision, and through follow-on interviews
- Issue final report with model recommendations.

Year 2

- Model development
- Model testing and review
- Stakeholder engagement
- Final model with User's Guide

Collaboration with Technical Advisory Group (TAG) and NARUC

Technical Advisory Group:

Denis Bergeron	Maine PUC
Norman Bishop	Knight Piesold
Brent Buffington	SCE – Southern California Edison
Wei Dang	PSE – Puget Sound Energy
Peter Donalek	Stantec
Christine Ericson	Illinois Commerce Commission
Don Erpenbeck	Stantec
Robert Fick	LADWP
Scott Flake	Scott Flake Consulting
Levi Gilbert	PG&E – Pacific Gas & Electric

Edward Hansen	PG&E – Pacific Gas & Electric
Elaine Hart	PGE – Portland General Electric
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Jay Mearns	PG&E – Pacific Gas & Electric
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Aidan Tuohy	EPRI
Bruno Trouille	Mott McDonald
Robert Williams	PSE – Puget Sound Energy

NARUC (National Association of Regulatory Utility Commissioners) is assisting the Project Team in coordinating TAG activities and in industry outreach.

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- Kerry Worthington
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Questions?

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