National Laboratory of the Rockies

Pumped Storage Hydropower Operation & Maintenance Cost Estimation

Components, Sources, and Screening-Level Estimates

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September 2, 2026

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1. Overview

The five-component operations and maintenance cost framework

1. Introduction

- The National Laboratory of the Rockies (NLR) develops a bottom-up cost model for pumped storage hydropower (PSH), available online as a downloadable spreadsheet and an interactive web tool.
- The cost model was initially created to characterize capital costs only.
- This slide deck describes methodology to expand the NLR PSH cost model to include itemized operations and maintenance (O&M) costs, using a variety of literature sources and approaches.

1. Overview

This approach separates O&M into five components

- Direct Costs
  - Routine direct O&M
  - Major overhauls.
- Indirect Costs
  - Administrative and general (A&G) expenses
  - Operating insurance
  - Property taxes and regulatory fees.
- Each component is addressed separately because source literature treats them differently, and data quality varies across them.
- No single publication provides a complete estimate, which includes all five components for newly developed U.S. PSH.
- Figures herein are assembled from a mix of empirical operating data, parametric equations, and standard regulatory percentages.

1. Components and Sources

Each of the five components has its own source basis.

Component	Description	Sources of Estimates
Routine direct O&M	Plant-site operations and maintenance labor, materials, parts, routine on-site contractor support	EPRI GS-6669 [1]; EPRI 1023140 [2]; Oladosu and Sasthav [4]; 2023 U.S. Hydropower Market Report [5]
Major overhauls	Periodic refurbishment and replacement of major equipment (in 10–60-year intervals)	Mongird et al. [6]; EPRI GS-7325 [8]
Administrative and general (A&G)	Project allocated corporate overhead—management, accounting, human resources, information technology, legal	FERC Hydropower Evaluation Manual [7], as cited in EPRI GS-6669 [1]; EPRI 1023140 [2]
Operating insurance	Property, liability, and business-interruption coverage	FERC Hydropower Evaluation Manual [7], as cited in EPRI GS-6669 (1990) [1]
Property taxes and regulatory fees	Local property taxes on the plant and land; Federal Energy Regulatory Commission (FERC) annual charges under Part I of the Federal Power Act	Property tax: no universal published default. FERC annual charges: 18 CFR Part 11, Fiscal Year (FY) 2025 schedule [9]

2. Routine Direct O&M

Recurring plant-site operating costs and screening-level basis

2. Routine Direct O&M

Scope and fixed vs. variable structure

- Covers all recurring day-to-day operating costs at the plant site: operations labor, maintenance labor, consumable materials and spare parts, and routine contractor support for inspections, minor repairs, and environmental monitoring.
- Costs are typically expensed (not capitalized) under the FERC Uniform System of Accounts. These are incurred every year of the plant's life.
- Major overhauls are explicitly excluded and treated as a separate cost component.
- Fixed component costs (staff wages and benefits, scheduled inspections, periodic servicing, routine spares) dominate; staffing is roughly half of direct O&M in plant-survey data from EPRI GS-7325.
- Screening-level analyses reports routine direct O&M as a single $/kW-yr figure rather than a fixed-plus-variable cost, which is assumed appropriate at a screening level but obscures operational considerations such as pump-generation cycles and capacity factor.

2. Routine Direct O&M (continued)

Screening-level equation for Routine Direct O&M (from EPRI GS-6669 in 1987$s):

EPRI/HDR equation (primary basis)

- EPRI GS-6669 [1] developed a power-law equation regressed against 1980–1984 FERC Form 1 data for eight operating U.S. PSH plants. EPRI 1023140 [2] updated escalation factors (a 2.5X factor from 1987 to 2010 dollars) and confirmed that the structure remained appropriate for screening use.

FERC Form 1 empirical cross-check

- Oladosu and Sasthav [4] / 2023 U.S. Hydropower Market Report [5]: “Very Large” plant category (>500 MW) averaged ~$16/kW-yr in 2020$. Six of seven plants in that category are PSH.
- Cross-check tests temporal stability rather than independent agreement—EPRI/HDR was itself regressed using 1980–1984 Form 1 data.

$$\text{O\&M Costs (1987\$/yr)} = 34{,}730 \times C^{0.32} \times E^{0.33}$$

Where: C = Plant Capacity (MW); E = Annual Gross Energy Output (GWh).

Then multiply by an escalation factor for the necessary dollar year, e.g., 2.5 for 2010

3. Major Overhauls

Periodic refurbishment and replacement of major equipment

3. Major Overhauls

Scope

Covers periodic refurbishment and replacement of major rotating and hydraulic equipment at 10- to 60-year intervals: pump-turbine runners, generator rewinds and rotor-pole refurbishment, generator circuit breakers, spherical (inlet) valves, governors, powerhouse cranes, and end-of-life runner and generator core restack.

Project Element	Typical Frequency
generator circuit breaker and phase reversal switch rebuild	1,000 starts
Spherical valve seal maintenance	10 years
Pump-turbine overhaul	20 years
Powerhouse crane major refurbishment	20 years
Governor replacement	20 years
Generator-motor rewind/rotor pole refurbishment	30 years
Generator circuit breaker replacement	30 years
Spherical valve refurbishment	30 years
Runner impeller replacement	60 years
Generator-motor core restack/rotor pole refurbishment	60 years

These costs are typically capitalized or tracked as funded reserves in project finance structures rather than expensed annually. They must be annualized and included in the O&M cost stack for complete life cycle cost analysis.

3. Major Overhauls

Source Basis

Mongird et al. [6]—primary screening-level default

- 2020 Grid Energy Storage Technology Cost and Performance Assessment (PNNL) provides an annualized refurbishment cost for PSH of $9.0/kW-yr in 2018$, ~$12.0/kW-yr in 2025$.
- This estimate is intended for technology cost comparison rather than project-level life cycle planning. The cost basis is not fully documented and should be reviewed before being used as a final value for a specific project.

EPRI GS-7325 [8]—contextual support

- Field visits to over 30 U.S. PSH plants during 1985–1988. Routine annual maintenance: 800–1,200 man-hours/unit/yr (up to 4,000 for large units). Major overhaul labor: 6,700–36,000 man-hours; planning benchmark 15,000 for 10-year overhaul.

Major Overhauls ~$12/kW per year

4. Indirect Costs

A&G expenses, operating insurance, property taxes and FERC fees

4.1 Administrative and General Expenses

Allocated corporate overhead beyond plant-site operations

- Covers corporate overhead allocated to the plant from utility or corporate headquarters: executive and general management, accounting and finance, human resources, information technology, legal and regulatory affairs, and other shared services.
- In the FERC Uniform System of Accounts for investor-owned utilities, A&G is captured in Accounts 920–935 and reported at the utility level rather than allocated to individual plants in public filings. That is why it is not captured in the FERC Form 1 plant-level cross-check.

FERC Hydropower Evaluation Manual [7], as cited in EPRI GS-6669 [1]

- Establishes an A&G surcharge of 35% of direct O&M cost as a default for hydropower cost evaluation. This implementation of the factor is used throughout the PSH O&M literature.

EPRI GS-6669 [1] and EPRI 1023140 [2]

- 1990 EPRI Guide and 2011 HDR update both carry the 35% A&G factor forward without structural change or independent re-derivation, endorsing it as an appropriate screening-level assumption for PSH. No more recent published sources were identified that update or replace this factor for large PSH applications.

A&G ~ 35% of direct O&M

4.2 Operating Insurance

Property, liability, and business-interruption coverage

- Covers the annual premium for property damage coverage on the physical plant, public liability coverage, and business-interruption coverage for lost revenue during an unplanned outage.
- For a facility with a dam, property insurance typically includes dam-failure liability coverage, subject to underwriting requirements that may vary by insurer.
- Excludes construction-phase insurance (builder's risk, contractor's liability)—this is considered a capital cost rather than O&M.
- Excludes worker's compensation and employer liability—this is included in direct O&M labor costs.

FERC Hydropower Evaluation Manual [7], as cited in EPRI GS-6669 [1]

- Default annual rate of 0.1% of plant investment cost is attributed to the August 1978 FERC manual via EPRI GS-6669 [1].

Operating Insurance ~ 0.1% of Plant Investment (assumed total direct+indirect)

4.3 Property Taxes and Annual FERC Charges

Two distinct sub-items: local property taxes and FERC fees

- Property taxes are typically levied by local jurisdictions on the physical plant, equipment, and land—the amount depends on state law, local mill rates, and assessment methodology.
- FERC annual charges are fees assessed against licensed hydropower capacity under Part I of the Federal Power Act, distinct from one-time licensing fees. Income taxes are excluded (these are included in project finance models, not operating cost estimates).

Property taxes—no universal default source

- Inherently site-specific; cannot be derived from a single published default. No published PSH-specific property tax benchmark was identified.

FERC annual charges—18 CFR Part 11, FY2025 schedule [9]

Set under three subsections: § 11.1 (administrative charges), § 11.2 (use of federal lands), § 11.4 (use of federal dams for PSH). For a typical greenfield closed-loop PSH project on private land, only § 11.1 applies.

- Under § 11.1(c)(3)(ii), administrative annual charge = installed capacity (kW) × Unit Charge Factor (UCF). FY2025 UCF for private licensees: $2.775556 per charge-factor unit = ~$ 2.78/kW-yr for a 1,000 MW plant. Well below the 2% maximum cap of FERC's total adjusted hydropower program administration costs for the year per § 11.1(f).
- Under §11.2 annual charges for the use of federal lands are assessed at per-acre rates set by county and updated each fiscal year by FERC; for six currently proposed projects, FY2026 rates range from approximately $7/acre (Carbon County, WY) to $47/acre (Knox County, KY), reflecting the low agricultural land values typical of rural western and Appalachian counties where PSH development is most likely to occur.
- Under §11.4 Annual charges for the use of federal dams by pumped storage projects are determined by FERC on a case-by-case basis under Section 10(e) of the Federal Power Act and cannot be estimated at the screening level; they must be established through the licensing process for projects that propose to use a federal dam or other federal structure.

5. Summary

Components, scope, and screening-level estimates at 1,000 MW

5. Summary: Assumed 1,000 MW plant

Component	Method / Equation	Assumed Inputs (representative plant)	Result (2025$)
Routine direct O&M	EPRI GS-6669 [1] / HDR [2] equation; escalated 2.5× (1987→2010) × CCT 558/338 [3]	C = 1,000 MW; E = 3,500 GWh/yr CCT* (2025) = 558; CCT (2010) = 338	**~$19/kW-yr** (cross-check: ~$21/kW-yr from FERC Form 1)
Major overhauls	Mongird et al. [6] annualized refurbishment cost; escalated CCT 558/409 [3]	$9/kW-yr in 2018$ (Table 34, [6]) Not a function of plant size per Mongird CCT (2025) = 558; CCT (2018) = 409	**~$12/kW-yr**
A&G expenses	35% surcharge on routine direct O&M (FERC 1978 [7]/ EPRI GS-6669 [1])	Routine direct O&M = ~$19/kW-yr (from EPRI/HDR equation above)	**~$7/kW-yr**
Operating insurance	0.1% of plant investment (FERC 1978 [7]/ EPRI GS-6669 [1])	Plant investment = ~$3,000/kW (2025$)	**~$3/kW-yr**
Property taxes and FERC fees	FERC §11.1 [9]: capacity × UCF. Property tax: site-specific, no published default.	FY2025 UCF = $2.775556/charge-factor unit (18 CFR §11.1) §11.2 federal land charges: site-specific per-acre rate (FY2026 schedule) §11.4 federal dam charges: case-by-case, not estimable at screening level	**FERC §11.1: ~$2.78/kW-yr** Property tax, federal dam and land charges: site-specific
Total O&M Cost**			**$43.78/kW-yr**

* CCT = construction cost trends composite index from the U.S. Bureau of Reclamation [3]
** Not including site-specific federal land and dam charges

5. Conclusions

A five-component framework covers the full O&M cost stack for new PSH

- No single published source provides a complete O&M estimate for newly developed U.S. PSH. The five-component method assembles direct costs (routine O&M and major overhauls) and indirect costs (A&G, operating insurance, property taxes and FERC fees) from separate source literature, each with its own data basis and uncertainty.

The EPRI/HDR equation is appropriate for screening-level routine O&M estimation

- The EPRI GS-6669 power-law equation, escalated using the USBR CCT Composite O&M index, produces estimates of ~$19/kW-yr (1,000 MW) in 2025 dollars. This is consistent with FERC Form 1 empirical averages for the Very Large plant category, confirming temporal stability of the equation structure over four decades.

The method is scalable and transparent

- Each component can be calculated from a small number of site-specific inputs (capacity, energy throughput, plant investment cost) and applied to any prospective PSH facility, including closed-loop sites in the NLR PSH supply curves. Estimates are appropriate for AACE Class 5 screening use; project-level analysis requires site-specific cost studies.

Key data gaps remain

- No publicly available plant-level indirect O&M data exists for merchant PSH operators. Property taxes and federal land and dam use charges are inherently site-specific with no published PSH default.

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Thank You

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NLR/PR-6A40-101207

This work was authored in part by the National Laboratory of the Rockies for the U.S. Department of Energy (DOE), operated under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Critical Minerals and Energy Innovation Hydropower and Hydrokinetic Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

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