



Pacific  
Northwest  
NATIONAL LABORATORY

# Environmentally Sustainable Hydropower in the United States

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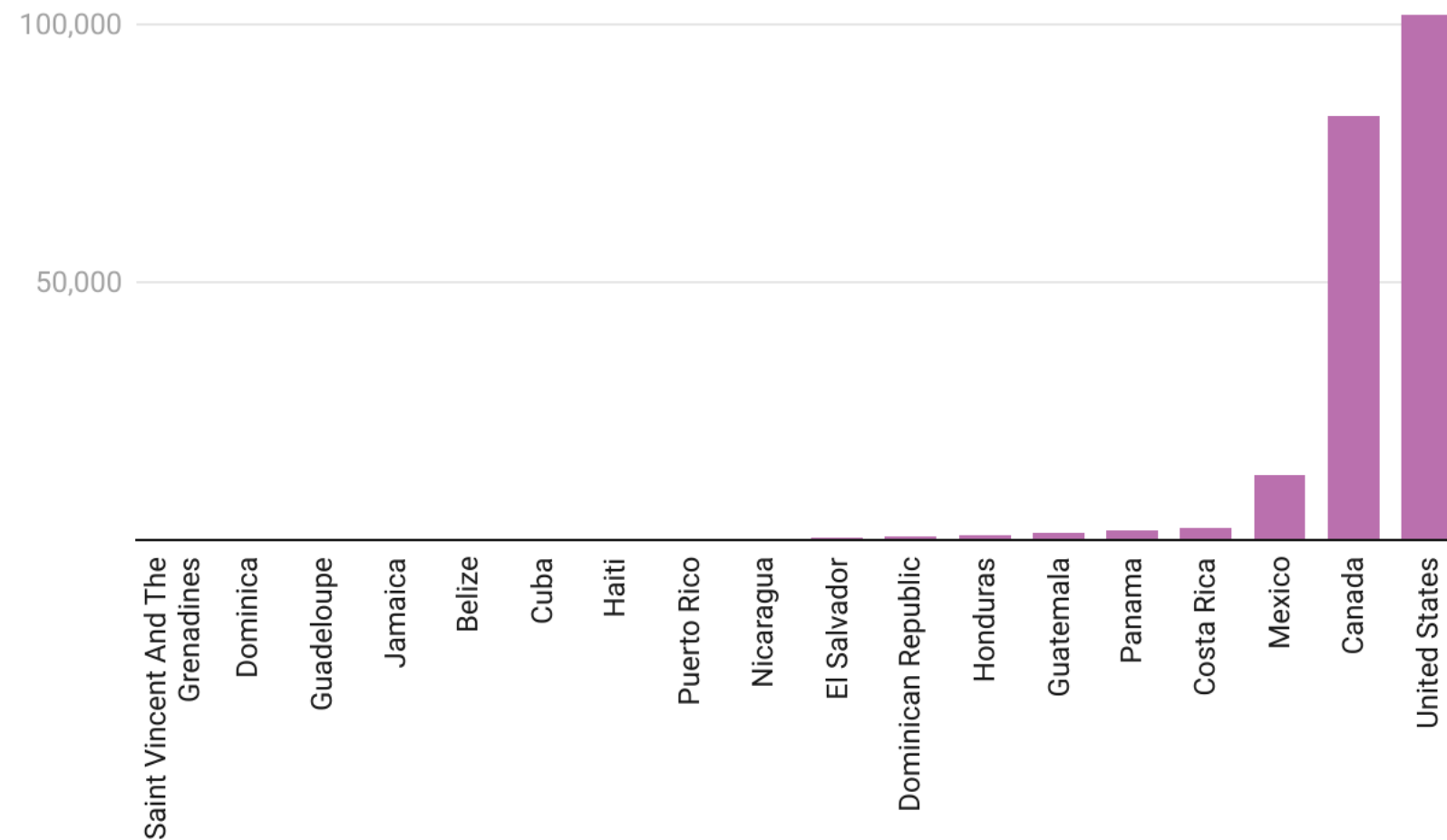
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# Hydropower in North America

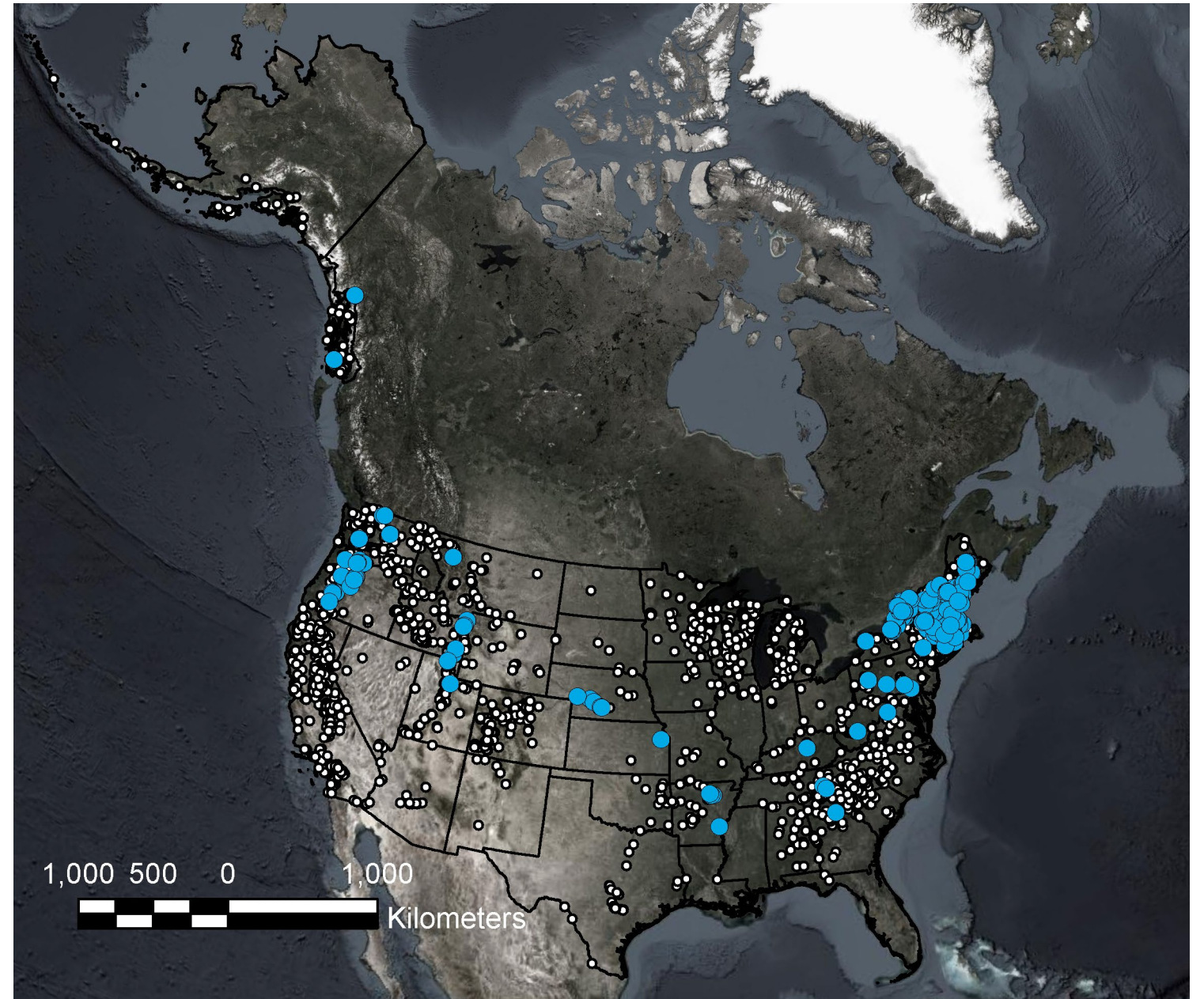
North and Central America: 2021 Hydropower installed capacity (MW) by country



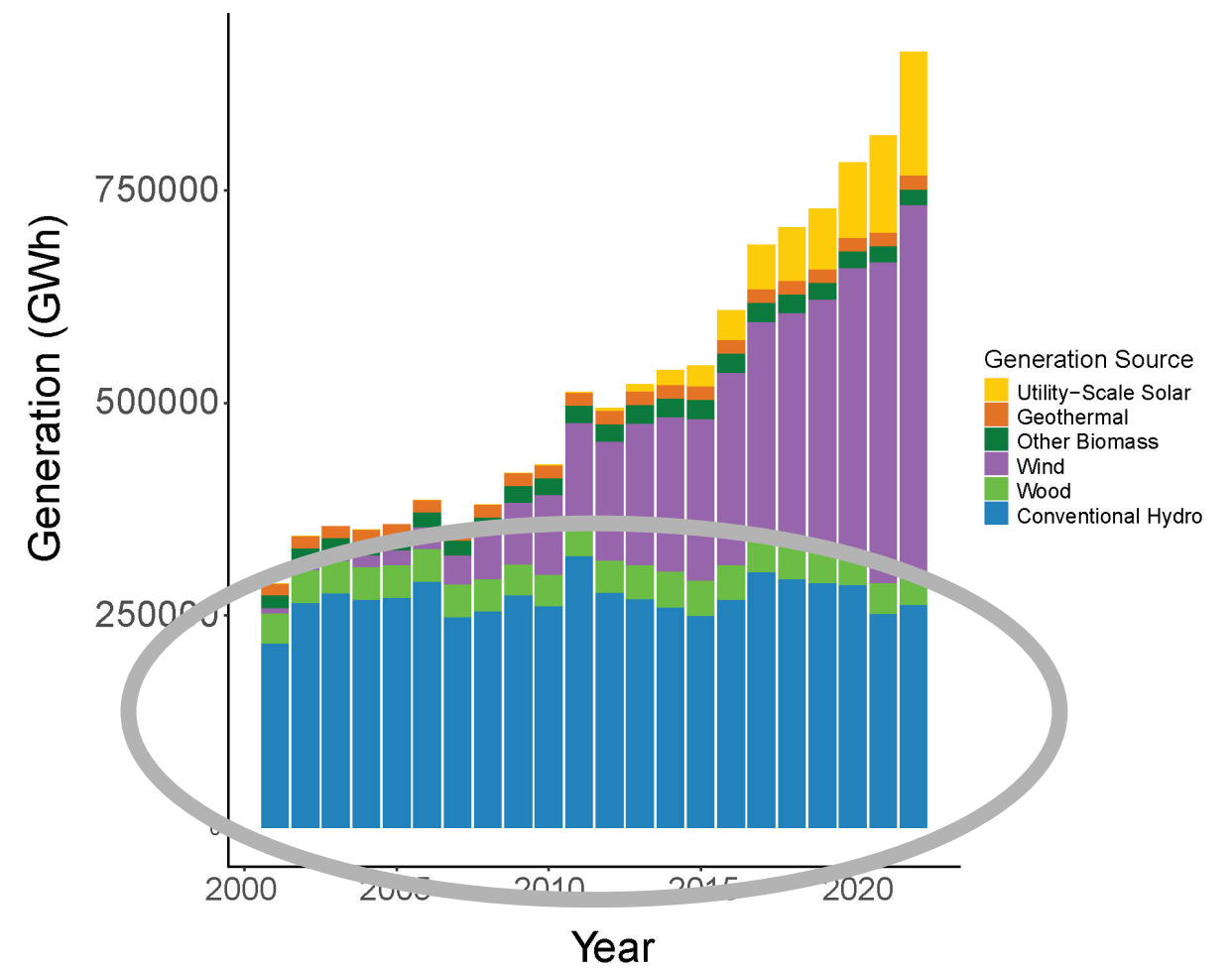
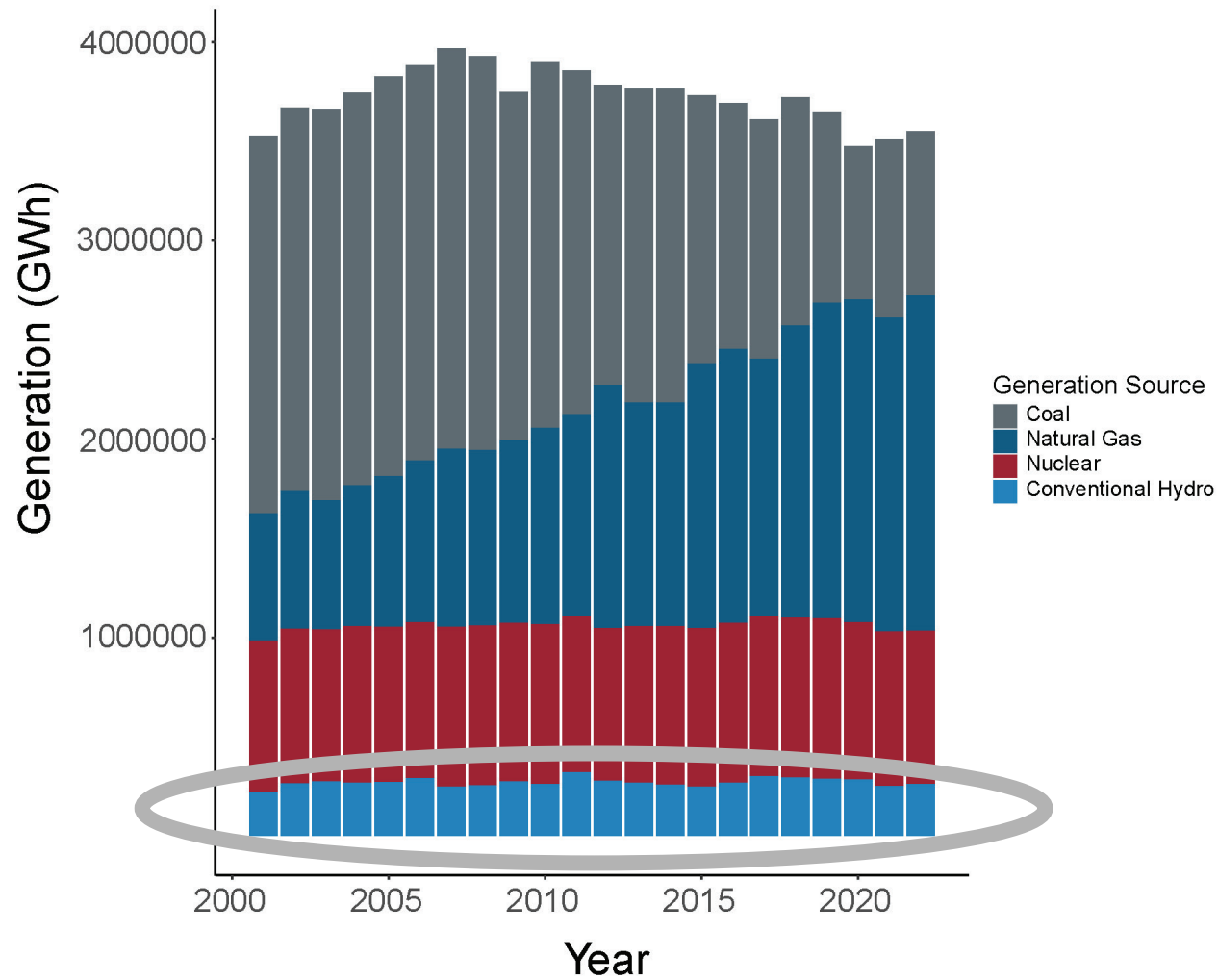
Third highest capacity globally

# Hydropower in the US

- 102 GW installed capacity
  - 80 GW conventional
  - 22 GW pumped storage
  - 3977 MW Low Impact Certified
- Hydropower 6% US generation
  - 29% renewable generation



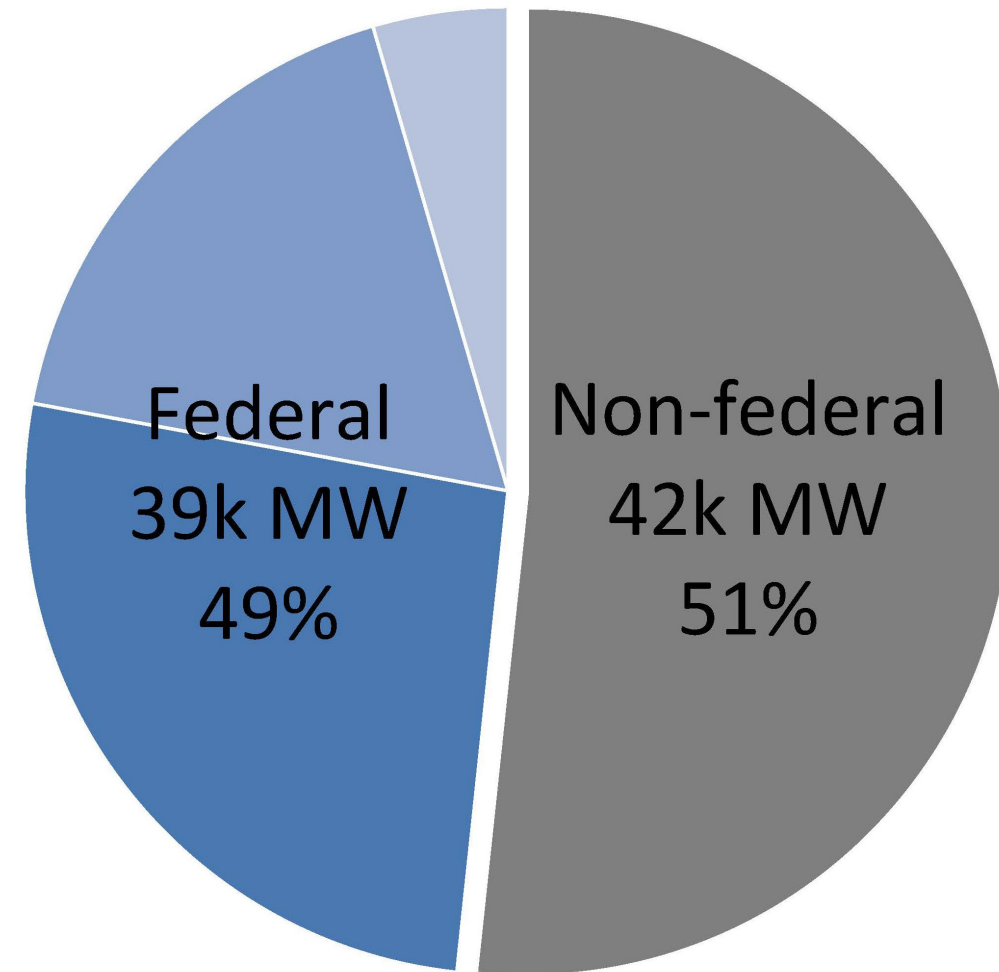
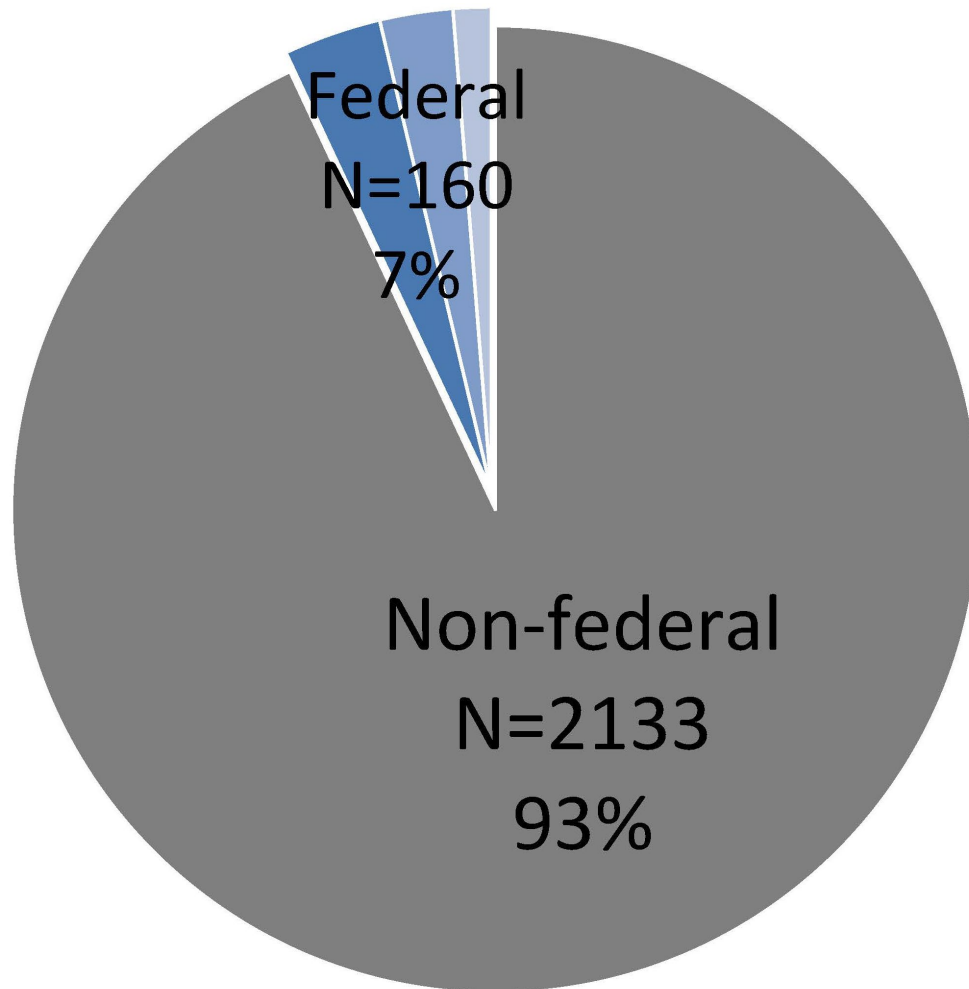
# Electricity Generation in the US



# Environmental sustainability in US hydropower

- Sustainability can be addressed through
  - Federal regulatory requirements for impact assessment and mitigation
  - Low Impact Hydropower Institute certification
  - Mitigations for federally-owned facilities
- Federal Energy Regulatory Commission (FERC) requires assessing resource impacts and appropriate protection, mitigation, and enhancement measures
- Low Impact Hydropower Institute (LIHI) provides a voluntary low impact certification program
- **EU Taxonomy** sets out climate and environmental objectives that must be met along with overarching conditions

# Non-federal hydro more numerous, but federal hydro produces more electricity



Data source: [ORNL Existing Hydropower Assets Database](#)

# Environmental sustainability in US hydropower

- Federal Energy Regulatory Commission (FERC) process requires extensive understanding of environmental characteristics at a facility
- Hydropower regulatory process addresses some environmental sustainability
  - Licensing requirements revisited every 30-50 years and takes ~7 years
  - All hydropower must comply with National Environmental Policy Act (NEPA)
    - ✓ Must assess resource impacts and potential mitigations
    - ✓ For non-federal hydropower, mitigations requirements determined at a later step
- Non-federal hydropower regulation is a participant-driven process
  - ✓ Tribal, state, federal, local governments, industry and environmental groups, and more
  - ✓ Participants negotiate impacts and mitigations
  - ✓ Fish passage usually constructed only when required by regulators
  - ✓ If there are specific targets for flows, biota, etc., they are negotiated by participants

# US Regulation and EU Taxonomy

## FERC

- Aquatic Resources
- Geological & Soil Resources
- Terrestrial Resources
- T&E Species
- Cultural & Historic Resources
- Land Use & Visual Resources
- Recreation Resources
- Socioeconomic Resources

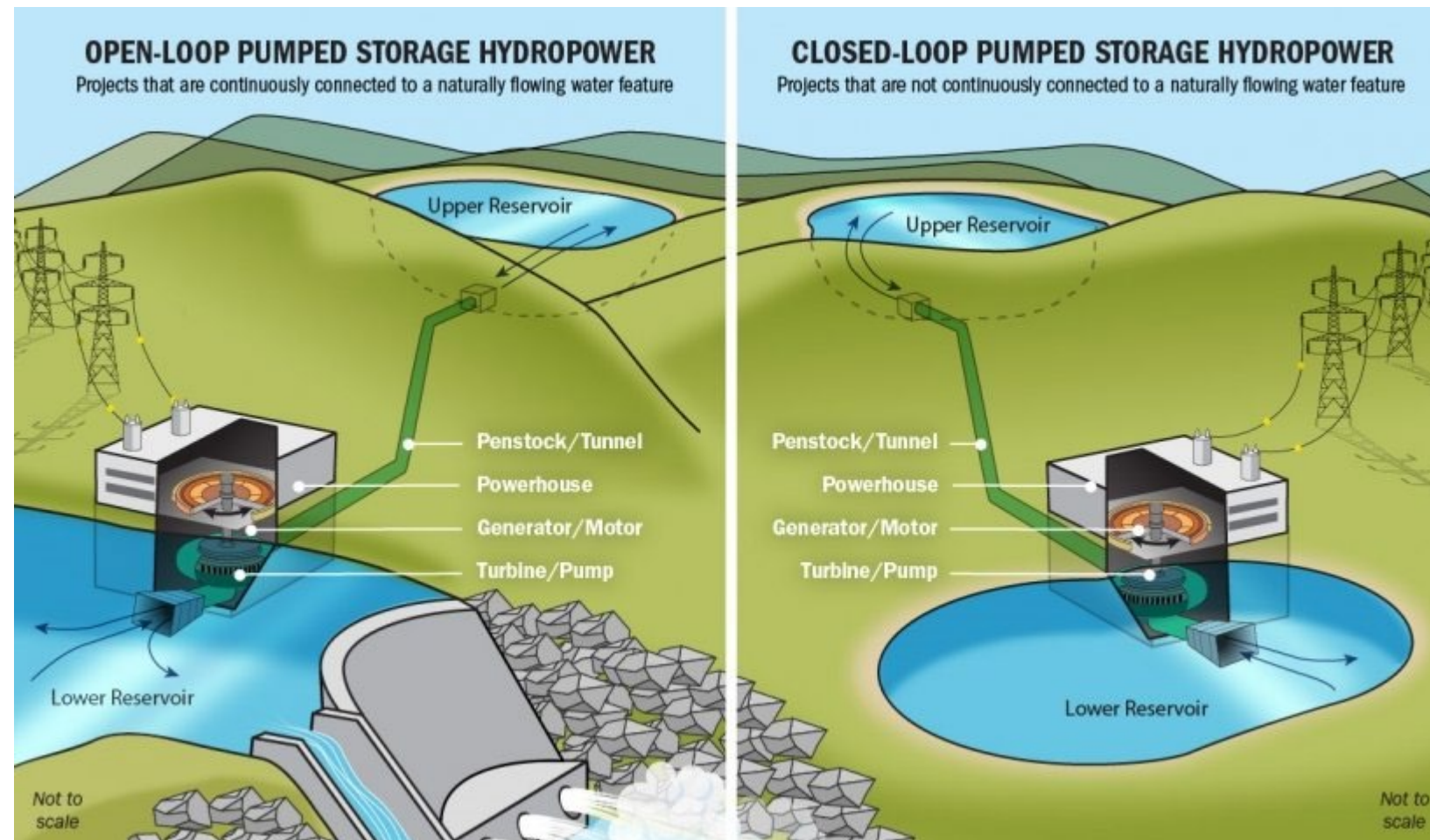
## EU Taxonomy

- Climate change mitigation \*
- Climate change adaptation
- Sustainable use & protection of aquatic resources \*
- Transition to circular economy \*
- Pollution prevention and control \*
- Protection & restoration of biodiversity & ecosystems \*



# A note about pumped storage hydropower

- Also require a FERC hydropower license
- FERC resource categories broad and can apply to pumped storage



# Environmental sustainability in US hydropower

- Low Impact Hydropower Institute (LIHI) provides a voluntary low impact certification program
- Largely based on information needed for FERC licensing
  - Only certain types of facilities eligible for certification and include
    - ✓ Facilities that did not involve construction of a new dam or diversion after August 1998
    - ✓ Retrofitting non-powered dams with turbines may be eligible
    - ✓ New facilities constructed within an existing diversion
  - Facilities not eligible include
    - ✓ Those at dams recommended for removal by a resource agency
    - ✓ Pumped storage hydropower
    - ✓ Hydropower located outside of the US
    - ✓ Facilities in marine environments or using hydrokinetic hydropower technologies
  - Hydropower facilities meeting requirements are issued a LIHI certificate that *may* be required to sell electricity on renewable energy markets in some places

## LIHI

Ecologically Supportive  
Flow Regimes

Water Quality  
Protection

Upstream Fish Passage

Downstream Fish  
Passage & Protection

Shoreline & Watershed  
Protection

Threatened & Endangered  
Species Protection

Cultural & Historic  
Resource Protection

Recreation Resources

## EU Taxonomy

Climate change  
mitigation \*

Climate change  
adaptation

Sustainable use &  
protection of aquatic  
resources \*

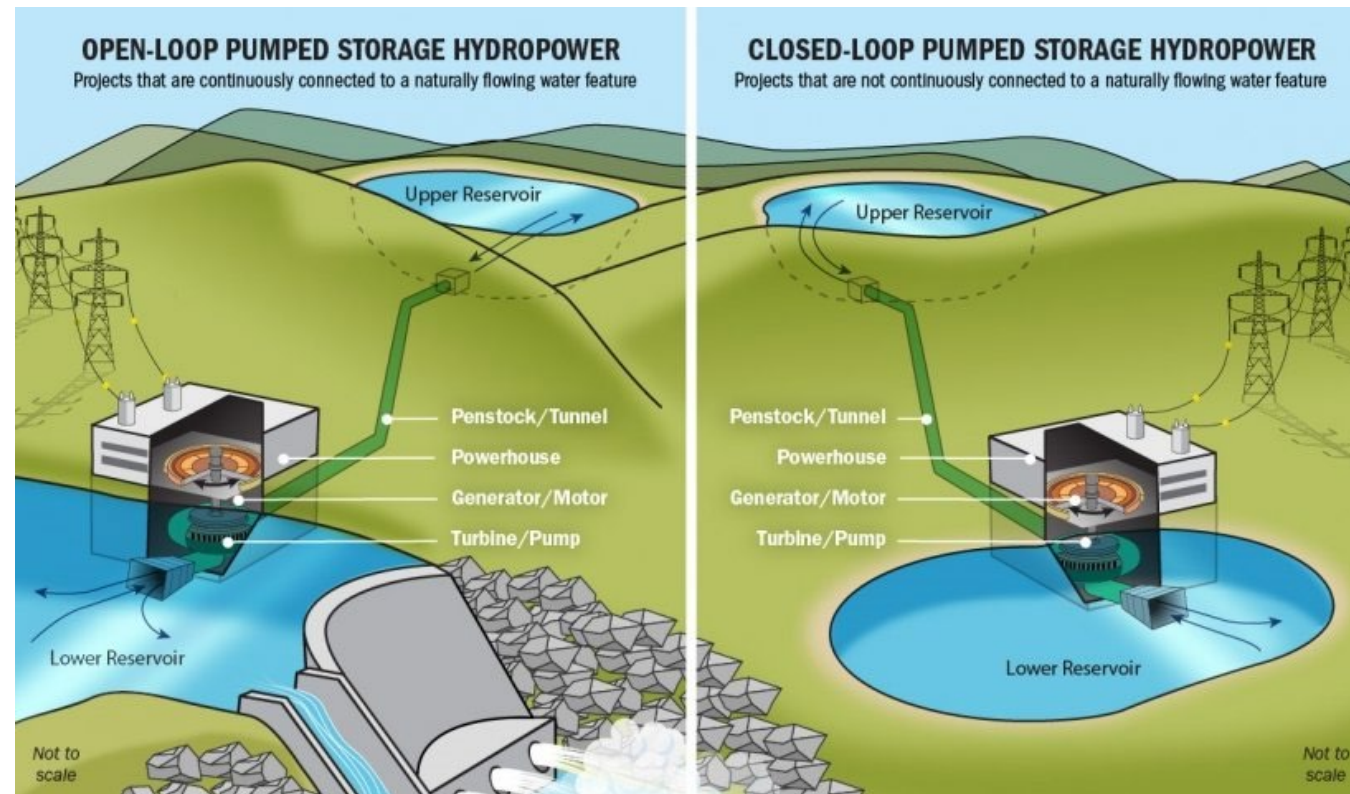
Transition to circular  
economy \*

Pollution prevention and  
control \*

Protection & restoration of  
biodiversity & ecosystems \*

## A note about pumped storage hydropower

- Pumped storage not eligible now but emerging as renewable energy solution
- LIHI categories based on in-channel dam
- If pumped storage certified in the future, new standard must be developed

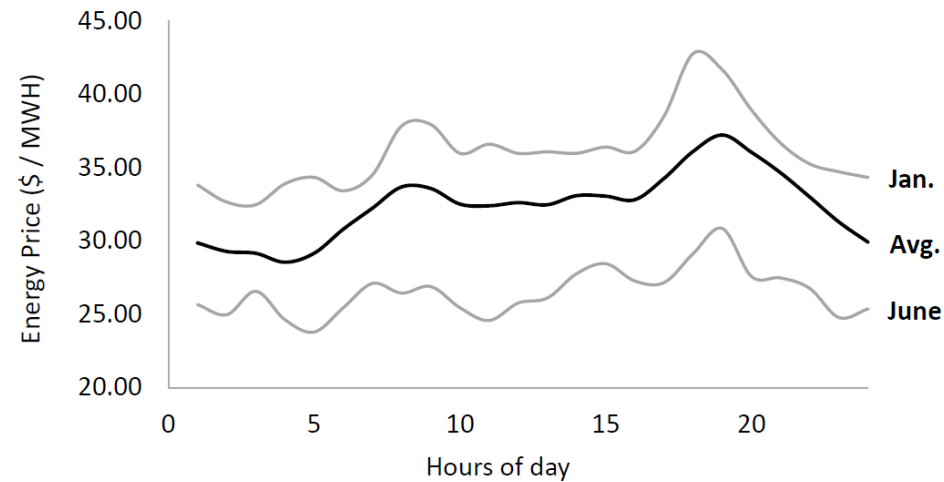


# LIHI goal, standard, and criteria structure

- Each criteria has a goal statement to define purpose/objective
- Tiers of standards for each criteria
  1. Not applicable or de minimis effect
  2. Agency recommendation
  3. Best practice/best available
  4. Acceptable mitigation
  5. Plus

# Case study examples

# Innovation in environmental flows



- Limits to “flexible” operations
  - Seasonal energy value
  - Critical times for biota
- Optimized solution
  - 95% Inflow=Outflow
  - 5% peaking
- **Retains 99% annual revenue**

Simulated dam discharge, current versus new operations  
Wilder Dam

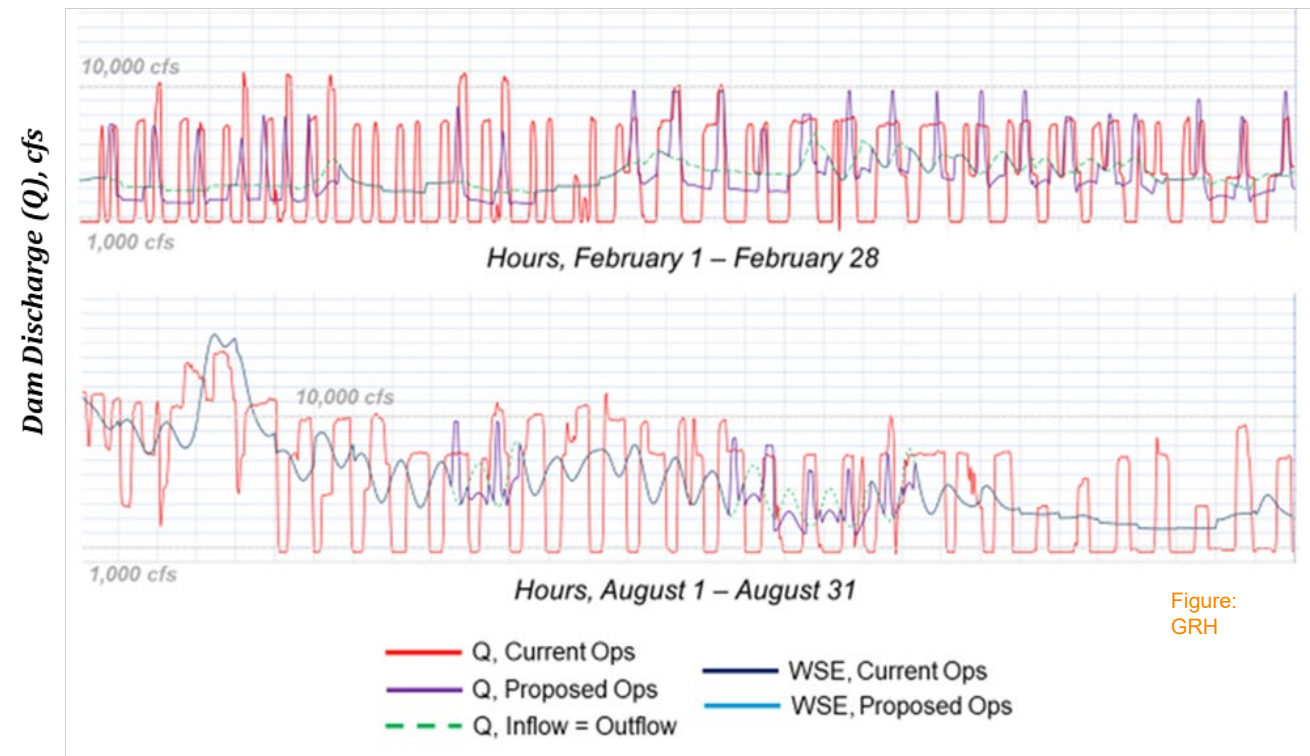


Figure:  
GRH

Pfeifle, S. L. (2020). A Framework for Meeting Economic and Ecological Objectives in Hydropower Operations. MS Thesis. U. Mass. Amherst.

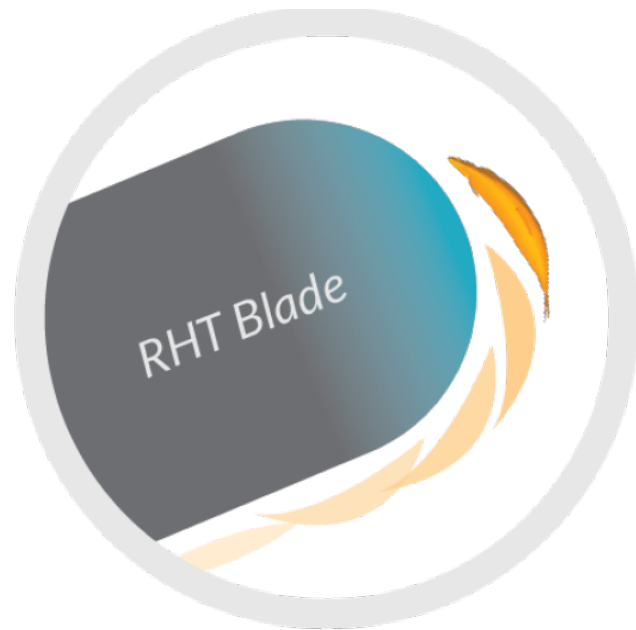
# Innovation in fish protection & low impact siting

- Monroe Drop facility (LIHI Certified)
- Sited in irrigation canal
  - Already impacted site
- Restoration Hydro Turbine
  - Can pass even large salmonids ( $\leq 53$  cm) safely
  - ... and pretty much everything else too!

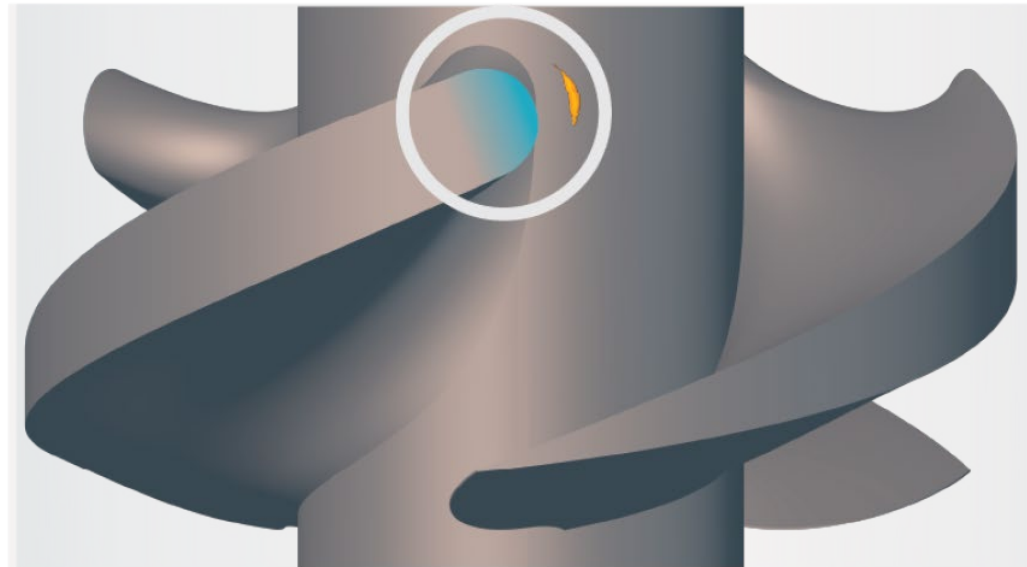




# Restoration Hydro Turbine



Curved blade  
deflects fish



Fish safe  
runner



Slanted tip

## Summary

- Hydropower among largest sources of renewable energy in US
- Environmental sustainability targets built into regulatory processes
  - Water quality and other standards must be met
  - Impacts must be mitigated
- Low Impact Hydropower Institute has voluntary certification standard
  - May allow access to renewable energy markets in some states
  - Some companies incentivized by corporate sustainability goals
- Continued innovation needed to meet forthcoming challenges of market needs
  - Increased rigor environmental standards
  - Climate change regulations
  - Flexibility



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**Thank you**



## LHI tiered criteria: Ecological flow regimes

- Goal: The flow regimes in riverine reaches that are affected by the facility support habitat and other conditions suitable for healthy fish and wildlife resources'
- Intro to standards: The applicant shall define all river reaches where stream flows are altered by the facility - for example, impoundments, tailwater or downstream reach below a powerhouse, bypassed reaches between a dam and tailrace confluence, and in riverine reaches immediately above the facility where flows are linked to facility operation such as in regulated upstream reaches subject to enforceable agreements with upstream facilities. In all locations, appropriate flow management should apply an ecosystem-based approach that supports fish and wildlife resources by considering base flows, daily, seasonal, and inter-annual variability, high-flow pulses, and short-term rates of change.

## LHI tiered criteria: Ecological flow regimes cont.

- STANDARD A-1. Not Applicable/De Minimis Effect: The facility operates in a true run-of-river operational mode and there are no bypassed reaches or water diversions associated with the applicable Zone of Effect; or the facility is located within an existing water conduit that does not discharge into natural waterways; or
- STANDARD A-2. Agency Recommendation: The flow regime at the facility was developed in accordance with a science-based resource agency recommendation; or
- STANDARD A-3. Limited Storage: In the absence of applicable agency recommendations and for facilities with limited storage capacity, the flow regime complies with a well-documented, regionally accepted instream flow policy or methodology (sometimes referred to as a standard-setting or desktop technique); or
- STANDARD A-4. Site-Specific Studies: In the absence of an applicable agency recommendation, the flow regime at the facility was developed on a site-specific basis, using a well-documented science-based habitat evaluation technique or a flow-ecology model.
- STANDARD A-PLUS: In addition to satisfying one or more of the standards above, the facility is operating an adaptive management program to regularly evaluate and adjust facility operations with respect to flows and habitat conditions; or has implemented significant, non-flow habitat enhancements (for example, structural improvements leading to river restoration) with demonstrated net benefits to fish and wildlife resources affected by the facility.