

U.S. DEPARTMENT OF  
**ENERGY**

Office of  
**ENERGY EFFICIENCY &  
RENEWABLE ENERGY**

SECTION

# Hydropower Program

Technology R&D for Low-Impact Hydropower Growth  
Modernization, Upgrades, and Security  
Grid Reliability, Resilience, and Storage  
Environmental R&D and Hydrologic Systems Science  
Big-Data Access and Management



# HYDROPOWER PROGRAM OVERVIEW

Hydropower is America’s oldest renewable and currently makes up nearly 7% of U.S. generation. Hydropower has long remained the largest source of renewable electricity generation, accounting for roughly 40% of U.S. renewable electricity generation in 2018; pumped storage hydropower (PSH) remains the largest contributor to U.S. energy storage, with an installed capacity of 21.6 GW or roughly 95% of all commercial storage capacity in the United States.

## Vision

A U.S. hydropower and pumped storage industry that is fully utilized to support grid reliability and the integration of other energy resources; capitalizes on new, low-impact opportunities for growth; maintains and optimizes existing assets; and continues to improve the environmental sustainability of hydropower systems.

## Mission

To conduct early-stage R&D and applied science to further the development of transformative, cost-effective, reliable, and environmentally sustainable hydropower and pumped storage technologies; to better understand and capitalize on opportunities for hydropower and pumped storage to support a rapidly evolving grid; and to support the use of hydro to improve U.S. energy-water infrastructure and water security.

To achieve the mission and realize the vision of the Hydropower Program, WPTO has identified five core research and development (R&D) activity areas:

1. Technology R&D for Low-Impact Hydropower Growth
2. R&D to Support Modernization, Upgrades, and Security for Existing Hydropower Fleet
3. Grid Reliability, Resilience, and Storage
4. Environmental R&D and Hydrologic Systems Science
5. Big-Data Access and Management.

The Hydropower Program plans to launch a public Request for Information to solicit feedback from stakeholders on its revised programmatic strategy in fiscal year (FY) 2020. Through the revised hydropower strategy, WPTO aims to clearly communicate the rationale for and organization of possible DOE-supported hydropower R&D from now to 2030. The tables below summarize the foundation of the revised strategy—WPTO’s description of U.S. hydropower’s challenges and the Hydropower Program’s approaches to address such challenges.

## Challenges for Hydropower and Pumped Storage in the U.S.

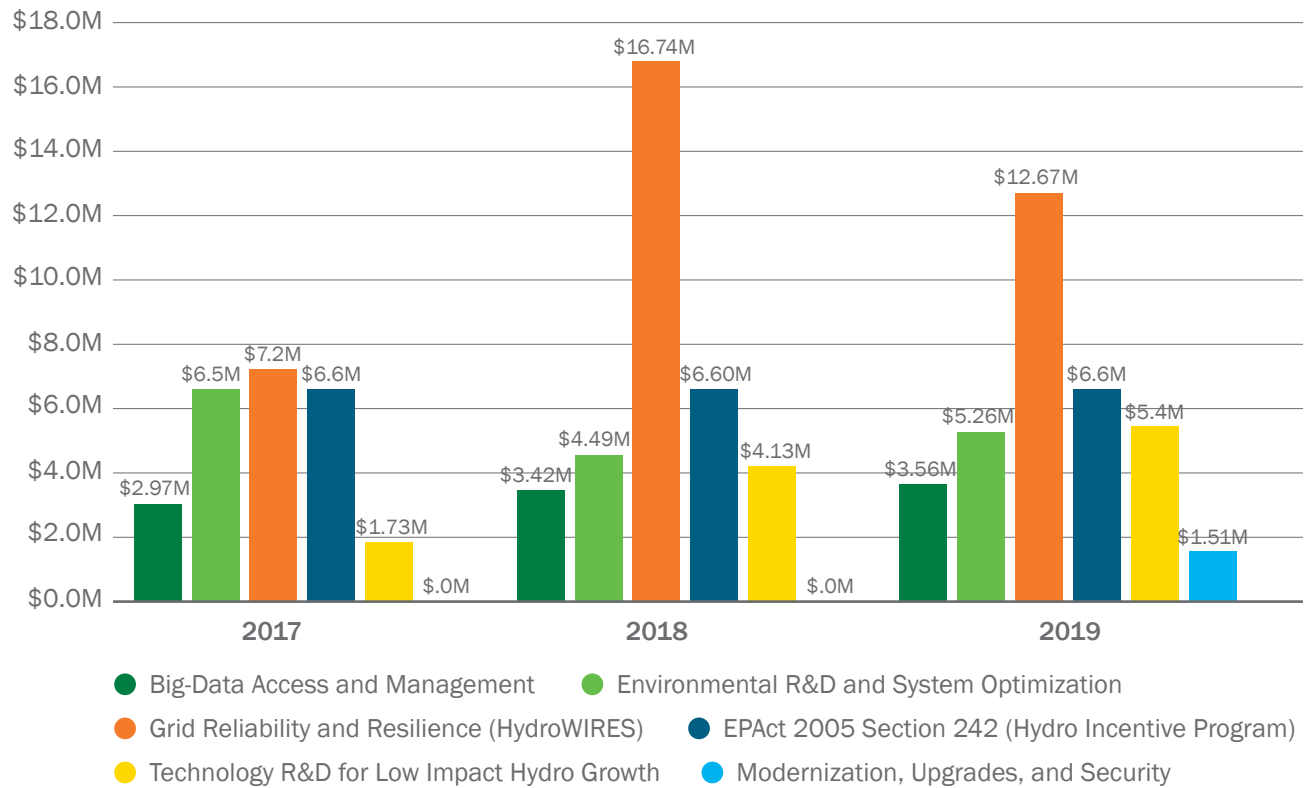
Untapped Potential for Hydro & PSH to Better Support Grid Reliability & Integration of Other Energy Resources	Limited Opportunities for New, Affordable Generation Growth Given Existing Hydro Technologies	Maintaining Cost-Competitiveness and Security of Existing Hydropower Assets Given Fleet Age	Addressing Environmental Impacts and Balancing Multiple Uses for Water	Lack of Access to Information Necessary to Support Decision-Making
<ul style="list-style-type: none"> <li>• The electric system is changing rapidly, and existing hydropower and PSH systems were originally optimized to operate under very different conditions.</li> <li>• Significant gaps in information about the costs to hydro and PSH in providing grid reliability and resiliency services.</li> <li>• Hydropower flexibility is constrained by a range of variables including licensing requirements and other water uses.</li> <li>• There has been relatively little attention or research into these areas, especially on the development of new PSH systems.</li> </ul>	<ul style="list-style-type: none"> <li>• Remaining new hydro resources (including non-powered dams and new stream-reaches) are smaller, lower-head, more diverse and distributed, and require new technologies to be cost-competitive.</li> <li>• There can be significant environmental impacts with existing hydro designs/systems; it has been difficult to develop more hydro using existing technologies and meet ecological objectives.</li> <li>• There is a lack of infrastructure and capabilities to test and validate new technologies and designs.</li> </ul>	<ul style="list-style-type: none"> <li>• Introduction of new technologies and upgrades of the existing fleet occur over long time periods given longevity of assets.</li> <li>• Hydropower facilities are extremely different from one another, with wide ranges of operational and physical characteristics and limited information availability.</li> <li>• Hydropower and PSH plants are increasingly connected to information technology systems which heighten cybersecurity risks.</li> <li>• Effective application of digitization requires a heretofore unestablished “right sized” focus on information and analytics.</li> </ul>	<ul style="list-style-type: none"> <li>• The many uses of/for water itself make development and operation of hydropower complicated, with many different variables and sensitivities to be considered.</li> <li>• There are analytical challenges in evaluating tradeoffs, and management objectives (environmental recreational, irrigation, etc.) that are changing, and sometimes unclear and difficult to reconcile.</li> <li>• Hydropower plants and the environments they are deployed in are both extremely diverse.</li> <li>• There are remaining scientific knowledge gaps around biology, behavior and interaction of many species with hydropower facilities (including limitations in instrumentation and monitoring technologies).</li> </ul>	<ul style="list-style-type: none"> <li>• Information on technologies, available resources, species distribution, markets, etc. is widely dispersed, of differing qualities, and difficult to identify and gain access to.</li> <li>• Regulatory processes are costly and time-intensive, and there is poor information and data available/accessibility on regulatory process outcomes and drivers.</li> </ul>

WPTO's Approaches to Address Challenges				
Understand, Enable, and Improve Hydropower's Contributions to Grid Reliability, Resilience, and Integration	Technology R&D for Low-Impact Hydropower Growth	R&D to Support Modernization, Upgrades and Security for Existing Hydropower Fleet	Environmental R&D and Hydrologic Systems Science	Big-Data Access and Management
<ul style="list-style-type: none"> <li>Understand the needs of the rapidly evolving grid and how they create opportunities for hydropower and PSH.</li> <li>Investigate the full range of hydropower's capabilities to provide grid services, as well as the machine, hydrologic, and institutional constraints to fully utilizing those capabilities to provide grid services.</li> <li>Invest in innovative technologies that improve hydropower capabilities to provide grid services.</li> </ul>	<ul style="list-style-type: none"> <li>Enable the development of new technologies for both existing water infrastructure and new stream-reach applications that incorporate ecological and social objectives.</li> <li>Leverage new advancements in manufacturing and materials to dramatically lower costs of components and systems designs.</li> <li>Support testing of new technologies, including development of necessary testing infrastructure.</li> </ul>	<ul style="list-style-type: none"> <li>Create mechanisms to classify hydropower plants by mechanical and cyber-physical systems, providing better characterization of the fleet and allowing identification of exemplary facilities or practices.</li> <li>Advanced technology solutions and data evolution to improve equipment longevity and condition-based repair.</li> <li>Creation of cybersecurity tools and studies which help enhance the security of critical dam infrastructure by articulating the cybersecurity target, risk and recovery landscape.</li> <li>Develop cross-cutting digitalization systems and advanced sensor suites to empower data driven decisions on O&amp;M and asset management.</li> </ul>	<ul style="list-style-type: none"> <li>Develop better monitoring technologies to evaluate environmental impacts.</li> <li>Develop technologies and strategies that avoid, minimize, to mitigate ecological impacts.</li> <li>Support development of metrics for better evaluating environmental sustainability for new hydropower developments.</li> <li>Assess potential impacts of long-term hydrologic variations to hydropower generation and flexibility.</li> <li>Improve abilities to assess potential methane emissions from reservoirs.</li> <li>Better identify opportunities and weigh potential trade-offs across multiple objectives at basin-scales.</li> </ul>	<ul style="list-style-type: none"> <li>Help industry to manage large, disparate and dissimilar datasets relevant for performance, operations, costs, maintenance, permitting, and environmental mitigation.</li> <li>Support comprehensive reviews of historical regulatory process drivers and outcomes.</li> <li>Identify information-sharing mechanisms that could increase coordination among permitting agencies.</li> <li>Develop effective methods of communicating process complexities to non-technical stakeholders.</li> </ul>

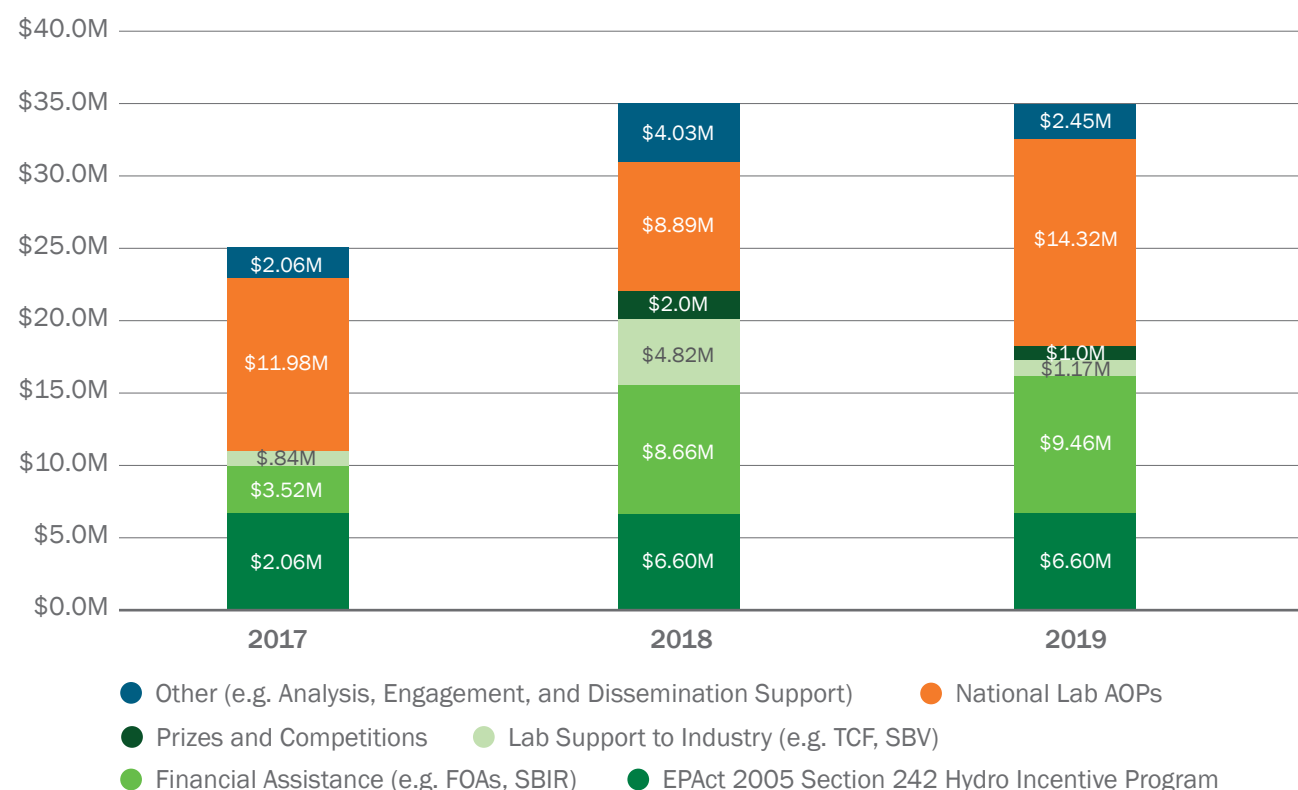
## Overview of the Hydropower Program during this Peer Review Period

Figure 6 shows the Hydropower Program's spending by activity area over recent years (FY 2017, 2018, and 2019). It should be noted that some of the projects reviewed during the 2019 WPTO Peer Review period were funded with prior year dollars (such as from FY 2016 or before). However, when viewed as a whole, the figure best represents current and recent program funding. Due to the multiyear nature of DOE R&D program planning, some aspects of the portfolio were more heavily emphasized in a particular year. For example, the spike in funding for grid reliability and resilience can be explained by the launch of the HydroWIRES initiative in FY 2018. Though the program had previously invested in this area of research, WPTO set forth new priorities and a targeted approach to an issue that is now more important than ever.

**Figure 6. Hydropower Program FY17–FY19 portfolio—total budget by activity area**



The Hydropower Program leverages a variety of funding mechanisms, and the distribution by funding mechanism for FY 2017–2019 can be seen in the chart below. For descriptions of each funding mechanism, please see [the Funding Mechanisms section of the WPTO Overview](#). Note that the Hydropower Incentive Program is a mandated program for which Congress specifies the exact funding level each year.

**Figure 7. Hydropower Program FY17–FY19 portfolio—total by budget by funding mechanism**

The 2019 Peer Review looked at the first three years of WPTO as an independent office, and there were several program developments during this time period:

- **A new grid research initiative:** During this peer review period, WPTO officially launched the HydroWIREs initiative—a new research initiative to understand, enable, and improve hydropower and PSH’s contributions to grid reliability, resilience, and integration in a rapidly evolving electricity system. Though the program had previously invested in this area of research, WPTO set forth new priorities and a targeted approach to an issue that is now more important than ever. The initiative leverages expertise from industry and DOE’s national laboratories to understand the value drivers for hydropower, to quantify its unique capabilities and constraints, to improve operations and planning for hydropower alongside other resources, and to invest in technology innovation to improve hydropower capabilities. Key efforts in FY 2019 included industry support for quantifying hydropower flexibility and national lab work to improve hydropower modeling capabilities.
- **Support to the Department’s Advanced Energy Storage Initiative:** Through the Advanced Energy Storage Initiative, DOE coordinates research from across all of its applied offices to drive advancements in bi-directional electrical storage, thermal storage, chemical storage, and flexible generation and loads. WPTO, with the HydroWIREs initiative and funding to PSH R&D, is an integral part of DOE’s work on innovations in energy storage and grid flexibility. The Hydropower Program supports the Advanced Energy Storage Initiative and continues its focus on hydropower and PSH’s roles in grid reliability and resiliency by continuing to support innovative PSH technologies and conducting new research to evaluate and improve the flexibility and grid services provided by hydropower and/or PSH.

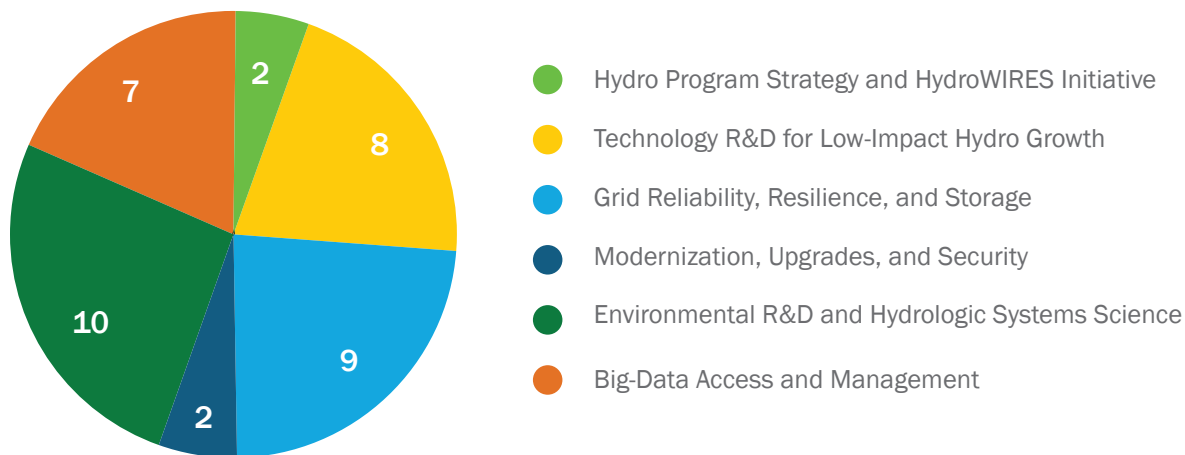
- **Increased efforts to leverage a variety of funding and partnering mechanisms:** For example, in FY 2019, the Hydropower Program launched its first prize competitions. One was in support of HydroWIRES, the FAST prize, which stands for “Furthering Advancements to Shorten Time.” Through FAST, WPTO gathered innovative ideas for technology solutions to cut down the time for commissioning pumped storage from 10 years to 5, all while reducing both cost and risk. Finalists participated in a pitch contest the day before peer review, and the winners received up to \$550,000 in national laboratory vouchers and cash prize. Also, in FY 2019, WPTO partnered with the Department of Interior’s Bureau of Reclamation and other federal agencies to launch a prize seeking innovative methods for excluding fish from water diversions and intakes, the Fish Protection Prize.
  - A Notice of Technical Assistance is another example of a novel partnering mechanism leveraged by the Hydropower Program. In FY 2018, WPTO issued a NOTA to perform techno-economic studies for two selected PSH projects. Project developers applied for the opportunity for the DOE national laboratories to evaluate the long-term value of their potential project. Two sites were selected, and the evaluation methodology applied will be tested and refined, after which, the guidance and valuation tools will be made publicly available for use by the hydropower industry.
- **New design concepts for Standard Modular Hydropower (SMH):** The program advanced new approaches to hydropower design and, in FY 2018, launched the first FOA to support industry to develop SMH components and site designs. SMH takes a completely new approach to designing hydropower facilities by shifting the design philosophy from custom designing each facility to extract the greatest amount of energy possible and then mitigating environmental impacts, to designing a system with a key goal of sustaining the existing environment. By focusing the design process on sustaining the important hydrologic, hydraulic, geomorphic, physiochemical, and ecologic processes that occur in streams and watersheds, SMH can deliver the benefits of hydropower at lower cost and with greater environmental benefits, while leveraging standardized and modular component designs that are more easily and cheaply manufactured.
- **Small hydropower valuation in alternative markets:** In FY 2019, the Hydropower Program began looking into new areas where hydropower could have major impact (e.g., in irrigation modernization). WPTO funded an initial case study that demonstrated that hydropower co-development can be a key enabler of irrigation modernization while also providing agricultural, economic, environmental, and resiliency benefits to communities across the United States. Thus, WPTO sees irrigation modernization as an example of a business case for developing small hydropower in which generation is not the sole driving factor, which is an alternative market for hydropower. Much like hydropower can unlock greater benefits for an irrigation district trying to improve its infrastructure, there are more markets in which hydropower can enable desired outcomes. WPTO intends to investigate some of these potential markets in FY 2020. Other examples of potential value streams that WPTO may study include water and wastewater treatment, ecosystem and river health, flood control, and historic preservation. Though this is a new area of research that was too new to be reviewed during the 2019 review, it may lead to new areas of work for WPTO in coming years and result in projects for review in a future WPTO peer review.

This bulleted list not only provides context for some of the newer approaches WPTO took during the years under review, but also what to expect from WPTO in future years and in the next WPTO peer review.

## Organization of Tracks and Review Panels

Both the Hydropower Program Strategy and individual projects were reviewed and scored during the 2019 WPTO Peer Review. Additionally, the reviewers scored and provided specific feedback on the future direction of HydroWIREs. Three panels of reviewers reviewed these program elements, as well as individual projects across all of the Hydropower Program's technology areas. Figure 8 depicts the total number of hydropower presentations reviewed by program and activity area.

**Figure 8. Hydropower Program Portfolio—number of presentations by activity area**



The following external experts served as reviewers for the Hydropower Program during the 2019 Peer Review.

**Table 5. Hydropower Reviewers**

Name	Organization	Review Panel
Greg Lewis*	Duke Energy	New Technology and Modernization
David Hanson	Retired	New Technology and Modernization
David Sinclair	Advanced Hydro Solutions	New Technology and Modernization
Steve Lewis	Sapere Consulting	New Technology and Modernization
Scott Flake**	Independent Consultant	Grid Reliability and Resilience
John Simonelli	Retired	Grid Reliability and Resilience
Charlton Clark	formerly DOE	Grid Reliability and Resilience
Tom Acker	Northern Arizona University	Grid Reliability and Resilience
Tim Brush**	Inter-Fluve	Environmental R&D and Data Management
Colleen McNally-Murphy	American Rivers	Environmental R&D and Data Management
Edith Zagona	University of Colorado-Boulder	Environmental R&D and Data Management
Juliusz Kirejczyk	Independent Consultant	Environmental R&D and Data Management

\* Program Review Chair

\*\* Review Panel Lead



## Organization of the Results

The quantitative and qualitative results are summarized at the program, activity area, and project level. Information in this section has been compiled based on the following sources and is organized as follows:

1. [\*Hydropower Program Evaluation Summary\*](#): A summary of all hydropower reviewers' comments that provides insight into the program's strengths and weaknesses or potential issues and specific recommendations. The Program Review Chair was responsible for drafting the program summary report in consultation with each Review Panel Lead and all hydropower reviewers.
2. [\*Hydropower Programmatic Response\*](#): The program's official response to the recommendations provided in the Review Chair's program evaluation summary.
3. [\*Hydropower Program Score Results\*](#): The results of the peer reviewers' scores, organized by the activity areas where individual projects were grouped for the 2019 Peer Review. Each subsection includes each activity area's score results, an evaluation summary prepared by the Review Panel Lead, and individual project evaluations.

# HYDROPOWER PROGRAM EVALUATION SUMMARY

*Prepared by Greg D. Lewis, Hydropower Program Chair*

## Key Takeaways

WPTO's Hydropower Program is conducting broad, complex, innovative R&D that enhances hydropower's attributes as an increasingly environmentally friendly, flexible, reliable, and sustainable renewable resource for our country's energy and water supply needs. In the spirit of continuous improvement, the fully transparent peer review process used input from experts in the hydropower community to objectively assess the R&D projects within the program's portfolio and provided recommendations for future program improvement. The program staff is dedicated and well qualified and did an excellent job coordinating the peer review. The Hydropower Program assembled a superb peer review panel with extensive knowledge and expertise to gather critical feedback and suggestions. This year's peer review process successfully offered assessments, guidance, and future recommendations that will continue to ensure high-level value and impact from WPTO-supported research.

## Feedback from the Review Chair to WPTO

Reviewers were supportive of the overall direction of the Hydropower Program and noted the program's adaptability to the ever-changing energy, environmental, and societal landscapes. The program is investigating some excellent areas of work that have the potential to become transformative, "game changing" innovations. However, as might be realistically expected, there were very wide-ranging project outcomes within this broad and complex portfolio. Reviewers observed some excellent project concepts, with solid project management and well-documented findings included in final reports, but there were also some poorly vetted project concepts, with weak project management and poor accomplishments in relation to the initial objectives. These general observations have led the reviewers to suggest several opportunities for improvement:

### 1. *Industry expertise and involvement*

While the reviewers acknowledge that some project failures are expected within any R&D portfolio, the reviewers agreed that several of the projects would have benefitted greatly from more engagement with industry stakeholders in the early stages of the project. Reviewers suggested that the program enlist peer reviewers and/or other industry experts, as well as potential end users, earlier and continuously throughout the project process to assist with design reviews and project management oversight, as well as to provide technical advisement. Stronger upfront scrutiny of concepts and designs, using industry and community expertise, would have significantly altered the direction on a few projects and greatly enhanced the stewardship of taxpayer funds as a result. Reviewers agreed that incorporating industry expertise continuously from the beginning to the end of a project could assist WPTO and the project team. Industry experts could support and inform the direction of the program by offering connections to industry partners for disseminating information. Incorporating additional industry expertise, advisement, and end user support earlier in the project process would be a relatively small cost that could significantly reduce project risks and ensure maximum impact of WPTO-supported research.

## *2. Additional project management emphasis*

Reviewers agreed that the project management skills exhibited by PIs varied widely. Some projects produced quality summaries for review, delivered extensive final reports, and adhered to a set schedule and budget. Conversely, other projects produced ineffective summaries for review, experienced significant delays in schedule, exceeded budgets, and failed to adequately convey accomplishments in comparison to initial objectives. Reviewers agreed that more attention to the go/no-go frameworks, the decisions that were made, and why they were made during a project's timeline would be helpful. A clearer explanation of expenditures during all previous years, as well as anticipated future budgets, would also be helpful for multi-year and ongoing projects. These observations highlight an opportunity for a stronger emphasis on project management principles and enforcing consistent expectations.

While not every project requires a full-time project manager, the reviewers thought that some PIs had a poor understanding of project management principles. An introductory webinar on project management and WPTO's expectations could help deliver more consistent results for the peer review. Solid project management should include:

- Clear objectives, well-defined scope, and deliverables
- Schedule outline, including critical path activities, milestones, and decision gates or hold points with clear go/no-go criteria
- Complete budget status, including cash flows and contingency amounts spent to date and remaining to be spent
- Regular communications, status meetings, and progress reports
- Risk assessments, performance metrics, and success criteria.

Developing more consistency in the project management approach would benefit the projects, as well as simplify DOE oversight and greatly reduce the unknowns included in the sometimes inconsistent and incomplete information being communicated to reviewers.

## *3. Clarify, emphasize, and monitor expectations of PIs*

Reviewers noted that some projects made lofty but unsubstantiated claims of anticipated initial cost reductions, efficiency improvements, or reduced levelized cost of energy (LCOE). Furthermore, there was often a complete lack of compelling evidence or calculation to support these assumptions and “hoped for” claims. A more detailed explanation of expectations upfront to the PIs may help reduce these assertions that appear unfounded. This could include a list of expectations to include final documentation of accomplishments as compared to initial objectives, expected deliverables in the form of presentation summaries and reports, and evidence supporting how their project will meet or has met objectives of lower LCOE, higher efficiency, and lower initial capital costs. Again, it is possible that WPTO may be communicating similar expectations and receiving some substantiating proof of these improved outcomes from the PIs. However, without continuity of reviewer involvement in earlier aspects of the process, reviewers can only judge the projects based on the information “snapshot” that is presented, and unfortunately, that information was often incomplete or lacking compelling evidence.

Several projects were considered monumental undertakings that require extensive amounts of data compilation and analysis. Reviewers acknowledge that there could be value in these tools if they are user friendly and completed successfully, but the volume, complexity, and long-term management of these databases present some concerns that need to be addressed. Large data intensive projects should require quality assurance/quality control (QA/QC) protocols for data, including sample selection and data validation



processes. Additionally, a plan and budget for future updating of the databases should be included as an expected budget cost for these projects. Also, these projects must be undertaken with a clear initial focus on engaging the end user to determine how these data tools can be useful to avoid getting mired in superfluous analyses of voluminous available data.

## Summary of all Reviewers' Comments

### Overall Impressions

There are some solid, innovative projects that can advance the state of the technology within the hydropower portfolio, including some well thought out, planned, managed, executed, and documented projects. Unfortunately, this high level of project performance was not consistently observed for all projects. Based on the limited snapshot of information available to reviewers, opportunities for improvement exist in consistently engaging industry and stakeholder expertise, providing stronger upfront scrutiny of concepts and designs, emphasizing typical project management principles, and more clearly outlining, monitoring, and requiring compliance with Program expectations. Also, including more representation from non-industry stakeholders was suggested as being important to gathering diverse perspectives in the peer review process.

### Program Strategy and Objectives

Reviewers agreed that the program did an excellent job of ensuring that all presenters described how their projects aligned with DOE objectives. The consistent introductory slides and generally consistent required summaries were helpful to reviewers. The program's vision and mission statements, as well as the mix of projects, demonstrate an excellent understanding of the near and long-term challenges within the hydropower community. The diverse selection of projects shows investment in early-stage research to accelerate the development of innovative water power technologies, while ensuring that long-term sustainability and environmental issues are addressed. Evidence of this innovation was observed in projects that could potentially deliver cost-effective, environmentally friendly advancements in new turbine technology. While there is always room for improvement in a few specific projects within a broad portfolio, reviewers generally agree, that on an overall basis, taxpayer funds have been invested wisely.

### Program Portfolio

Reviewers agreed that the projects in the hydropower portfolio contribute to meeting the program's strategy and objectives, though not all projects contributed equally. The diverse projects within this program portfolio are addressing key challenges and reducing barriers to advancing water power technologies, and they are appropriate for WPTO's role as a public R&D organization. As might be expected in a broad and complex portfolio, some projects could benefit from the suggested improvements outlined in the prior sections.

Reviewers were provided a 'snapshot' of information that attempted to capture project accomplishments from several years of investigation. For ongoing projects, a conclusive assessment of the impacts was not always possible since much work remains, so the end effectiveness could not be predicted. In addition, there may have been background information that reviewers did not see or have adequate time to review and digest. Given these circumstances, constructive comments were offered with these limitations in mind.

### Program Management Approach

Reviewers agreed that that the projects focused on priority research. In addition, the reviewers agreed that the program team is well qualified and generally effective at directing the activities needed to meet its objectives, but the team could be most effective with occasional support from the hydropower community. Similarly, the

program team demonstrates the professional and technical capabilities needed to identify, monitor, and guide its portfolio of projects, but they could benefit from greater industry and stakeholder input and expertise that could assist with additional project oversight and serve as supporting thought leaders to inform the direction of the program. Reviewers generally agreed that, based on the very narrow time window and limited resulting evidence that peer reviewers can observe, it would be presumptuous to say that the operations and oversight procedures were fully utilized and sufficient.

### **Stakeholder Engagement, Outreach, and Dissemination**

While the engagement, outreach, dissemination, and resulting effectiveness vary by project across the portfolio, reviewers generally agreed that the program transparently communicates how WPTO funds are being utilized and evaluates project impacts internally and externally using the peer review process. This year, the peer review cast a much broader net across the hydropower community and gathered feedback from within the industry and from stakeholders and NGOs in the larger hydropower community. Multiple feedback opportunities were offered in addition to the peer reviews, including the Town Hall feedback forum, suggestion boxes, and websites. All of these can be used to inform and improve WPTO projects and strategy.

Additionally, the early engagement of potential end users, as well as industry and stakeholder experts, could enable earlier, more widespread communication of work underway. These same end users and experts could also fill support roles as thought leaders to inform the direction of the program and offer additional connections to industry partners for disseminating information.

Effective dissemination of information is challenging because many recipients are already suffering from information overload. Sharing a high-level status of the Hydropower Program's various projects at key conferences such as HydroVision International, Waterpower Week, The Centre for Energy Advancement through Technological Innovation (CEATI), and Electric Power Research Institute (EPRI) events provides significant coverage and reaches many potential end users in the industry. Additional communication in Hydro Review Weekly, DOE newsletters and webinars, and other electronic media can also reach a high percentage of hydropower community stakeholders (if they take the time to read it). Other information sharing and gathering opportunities could include periodic engagement of an R&D focus group via meeting or webinar. It was noted that publication of results in journals that are relatively obscure to the hydropower industry will probably not be seen and will have little value to most end users.

# HYDROPOWER PROGRAMMATIC RESPONSE

*Prepared by Tim Welch, Hydropower Program Manager*

## Overview

The Hydropower Program would like to thank the reviewers for their time and effort to evaluate our program strategy and R&D portfolio. The program will continue to benefit from external feedback from the hydropower community regarding our strategic direction and the investment of taxpayer funds. The program thanks the reviewers for acknowledging that our mission and vision and diverse portfolio of projects demonstrates an understanding of the near- and long-term challenges facing the hydropower industry. Reviewers noted that the program did an excellent job of ensuring that projects were aligned with strategic objectives and remarked that some projects were “transformative” with “game changing” innovations. We appreciate the recognition of our program staff, whom reviewers described as “dedicated,” “well qualified,” and “supportive of the overall direction of the program.” Overall, reviewers recognized that they only received a limited snapshot of information on each project and outlined several opportunities for improvement in (1) consistently engaging industry and stakeholder expertise to provide stronger upfront scrutiny of concepts and designs, (2) emphasizing typical project management principles, and (3) more clearly outlining, monitoring, and requiring compliance with program expectations. The following sections outline the program’s official response to the recommendations provided in the review chair’s program evaluation summary, as well as responses to potential issues or specific recommendations noted by the review panel for each individual activity area.

### Recommendation 1: Industry expertise and involvement

The reviewers’ key recommendation to the program is to focus on increasing direct hydropower industry involvement in the program’s R&D portfolio. Reviewers recommended that projects would greatly benefit from continuous industry engagement throughout the life of the project, particularly in the technology R&D portfolio. Though all projects are subject to a comprehensive external merit review prior to funding, we agree that the program would benefit from ongoing involvement of experienced industry reviewers, especially in establishing performance metrics for go/no-go decisions. This ongoing industry engagement would provide necessary expertise to ensure that any technical difficulties encountered during a project could be overcome in a way that would increase the likelihood of success. However, the level of industry engagement should be proportionate to the type and scale of a project.

### Recommendation 2: Additional project management emphasis

Reviewers noted an opportunity for the program to improve project management by adding more technical rigor to the go/no-go decision process. We agree with this suggestion and will work to add more rigor to our required milestones and these reviews to focus on results rather than simply project progression. As mentioned above, we are interested in collaborating with the hydropower industry on the performance metrics to use at these go/no-go decision points. Additionally, the reviewers suggested WPTO and PIs provide more details on these milestones in future peer reviews, and noted that some project summaries did not include information on these milestones and failed to describe accomplishments with respect to objectives. Moreover, reviewers noted that some projects were over budget and behind schedule, which raised doubts that oversight procedures were fully utilized and sufficient. However, reviewers recognized that they only received a limited snapshot of information on each project but thought that more background information may have been needed in some cases. The program acknowledges that not all relevant milestones were included in the project summaries and presentations, which may not have given reviewers the necessary insight into the project management process.



The program recognizes the benefit in providing additional project details to reviewers and will work to adjust project templates and guidance and ensure rigorous internal review of materials in future peer reviews. We will work to ensure that PIs put greater emphasis on major project milestones, particularly go/no-go decisions, in project summaries and presentations to give peer reviewers a more complete picture of how the project was managed. In addition, the program is developing a standard framework for a logic model designed to help PIs clearly define and articulate project activities, outputs, outcomes, and impacts, as well as how these align with the program's strategy and approach. WPTO envisions this logic model to serve as both a project management and communication tool that can inform project plans and help better identify meaningful and appropriate data and metrics to monitor and measure. We will pilot the logic model with several project teams in FY 2021 and further encourage PIs to integrate impact-focused thinking into the project lifecycle. Finally, we concur with the recommendation that a training or webinar would be beneficial to lab PIs and new FOA awardees to outline the program's project management expectations.

### **Recommendation 3: Clarify, emphasize, and monitor expectations of PIs**

Reviewers suggested that the program provide more clarity on expectations for PIs, along with more external reviewer involvement. In the individual project evaluations, reviewer comments indicated that this recommendation was primarily focused on two low-scoring projects in the technology R&D portfolio. These projects were selected in 2015 as part of a funding opportunity announcement for research into small turbines for low-head hydropower. From the beginning, we recognized that both projects were high risk endeavors, with an objective focused on cost reductions and greater operational flexibility in low-head hydropower. These projects were carefully monitored throughout the process and ultimately moved forward through the go/no-go decision based to their potential to provide valuable information that could inform future R&D efforts. Though we did not succeed in the potential development/deployment of these new technologies, our research into small turbines for low-head hydropower provided important lessons learned, including:

- Use of advanced manufacturing and composite materials is possible to enable standardization of hydropower components, allowing most parts and tooling to be reused across all units.
- Multi-body dynamic models in a hydropower application can easily simulate and test virtual turbine prototypes of various mechanical designs in a fraction of the time and cost required for physical build and test.
- If a new low-head turbine technology cannot pass fish with near-zero mortality rates, inclusion of fish screens is likely cost prohibitive for standard modular hydropower.

We recognize that continuous industry expertise and involvement may help to manage expectations for future technology R&D projects. To ensure that project goals and objectives are clearly met, the program will work to more clearly develop and define project and program-level metrics to measure successes.

### **Technology R&D for Low-Impact Hydropower Growth**

Reviewers agreed that the program's technology R&D portfolio demonstrates an understanding of the challenges for small hydropower development. The program funds small hydropower R&D projects with an overall goal of lowering the capital costs and reducing the environmental impacts of new development. Across a few projects, reviewers expressed concern that the innovations achieved would be insufficient to ensure small hydropower could compete with current low-cost generation options. For low-impact hydropower growth to become a reality, the program acknowledges that transformational changes must be made in the way hydropower projects are conceived and built. This is the rationale behind the program's standardized, modular approach to hydropower design and development, which can reduce per unit costs and

also effectively incorporate ecological and social objectives for river systems earlier in the design process. In addition, hydropower can provide unique value propositions due to synergies with other renewables (e.g., complementary load profiles), system flexibility (for reservoir hydropower), and water system benefits. There is an opportunity to advance the small hydropower value proposition by investigating alternative markets in which non-energy drivers create opportunities for small-scale hydropower development. Moving beyond our program’s traditional focus, we will investigate other drivers and markets to illuminate co-benefits, business cases, and specialized markets in order to articulate other systems and environments that may increase the value proposition for small hydropower.

### Grid Reliability, Resilience, and Storage/HydroWIRES Initiative

Reviewers were very supportive of the HydroWIRES Initiative, stating that this highly valuable program will offer critical guidance for projects supporting the hydropower industry. One recommendation was for the program to consider reviewing any overlapping study areas among the portfolio to avoid duplication of research, such as overlapping bulk market studies. We acknowledge the concerns of the reviewers and note that part of our motivation for aggregating diverse projects into a unified HydroWIRES portfolio was to manage projects in a comprehensive way to avoid duplication of research. In fact, as a result of the diverse valuation approaches, we are comprehensively evaluating sixteen ongoing FOA projects under a valuation harmonization protocol to understand strengths, weaknesses, and applicability of each approach.

In addition, reviewers recommended that we focus more on end users through engagement with regional industry experts and regulatory experts. Specifically, reviewers recommended that we reach out to independent system operators (ISOs) and regional transmission organizations (RTOs) directly, rather than relying solely on data-based research. We wholeheartedly agree and plan to implement new protocols, such as the use of logic models across the portfolio, to ensure that every PI has a comprehensive and effective plan for disseminating project results to potential end users. In addition, we will work to develop a detailed HydroWIRES engagement strategy that includes a tiered structure of potential end users, including the communities they belong to, their specific organizations, and a targeted assessment of how the goals and objectives of our initiative aligns with their needs. Our HydroWIRES engagement strategy will reach beyond the traditional hydropower community (i.e. National Hydropower Association, (NHA) Northwest Hydroelectric Association, CEATI, utilities, and hydropower OEMs) to engage the broader power system or “grid” community (e.g. Energy Systems Integration Group, Electric Power Research Institute, CEATI Strategic Options for Integrating Emerging Technologies and Distributed Energy Interest Group, ISO/RTOs, National Association of Regulatory Utility Commissioners, etc.). We agree that direct engagement with ISOs is important for effective insight into the evolving U.S. grid; therefore, the HydroWIRES team will meet with a variety ISOs in the immediate future.

Regarding the Hydropower Value Study, reviewers expressed concerns with relying on public data for the value analyses. We understand this concern but recognize that analyzing public data allows the entire community to further investigate and analyze the same data, even if some of the community (e.g. ISOs) will already be aware of it. On the other hand, analyzing private data—when sharing agreements can be established—may unearth new insights but may not allow for deeper investigation by others across the community. We believe that both approaches are necessary for a clear understanding of hydropower value.

Finally, reviewers recommended that HydroWIRES examine the role of hydropower in distribution sector. We agree that a deeper examination into the roles for hydropower and PSH at the distribution scale is warranted, at least with respect to microgrids, and will consider ways to evaluate the most appropriate use

cases for hydropower and PSH as well as batteries. More generally, HydroWIREs and the broader DOE portfolio includes investigation of hydropower hybrid configurations (e.g. hydropower/PSH paired with batteries), which could include both microgrid and or residential applications.

### **Modernization, Upgrades, and Security**

Though only two projects were reviewed this year, the reviewers agreed that the modernization, upgrades, and security portfolio contributes to meeting the Hydropower Program's strategy and objectives. Reviewers overwhelmingly agreed that the Solid-State Processing project was a clear example of investing in early-stage research to accelerate the development of innovative water power technologies, and that this project was worthy of continued investment, considering its low-risk, high-reward potential. Reviewers thought that the Short Intake Flow Measurement Research project exemplified an attempt to overcome long-standing difficulties to validate unit performance and could be used to deliver efficiency gains for many small and medium sized hydro stations.

Reviewers praised the Solid-State Processing project for its breakthrough potential in increasing cavitation resistance of newly manufactured turbines, which is a key challenge that could dramatically lower maintenance costs and reduce outage durations in a high percentage of hydro stations. The program concurs with the reviewers' assessment that the results from this project are promising and represent a major step forward for protection of turbines from cavitation damage. Currently, we are seeking an industry partner to conduct field testing and demonstrate the value of this research.

Regarding the Short-Intake Flow Measurement project, reviewers were most concerned that achieved error levels will likely not lead to significant improvements in intake flow measurements. Reviewers thought that the project should better articulate how flow measurement accuracy will lead to improved hydropower performance, as well as create a process for transmittal of any significant results to the hydropower community. We share the reviewers concerns that the performance of the flow measurement techniques developed in this project do not achieve the stringent accuracy requirements of performance test standards for flow measurement. However, flow measurement in short converging intakes has been a long-standing problem within the industry, and this project presents an improvement to the status quo of existing flow measurement technologies, regarding both timing and measurement accuracy. The project results chart a pathway to reducing the deployment time and effort of flow measurement sensors, as well as enabling non-invasive continuous measurement, which cannot currently be done in short converging intakes. Finally, while we have worked extensively with the U.S. Army Corps of Engineers in field testing, we agree that more extensive and far reaching industry engagement would be valuable to test the higher resolution alternatives and ensure repeatability of the solution in the field.

### **Environmental R&D and Hydrologic Systems Science**

The Environmental R&D portfolio received the highest scores out of all the activity areas. Reviewers agreed that the portfolio of projects is well aligned with the program's objectives and needs of the industry. Reviewers commended our efforts to develop innovative technologies and tools, particularly fish tags. Though a reviewer noted a first-hand negative experience with commercialization of fish tags, that same reviewer also applauded the program for its improvements in this area. Finally, reviewers recognized that the projects included in the Environmental R&D portfolio are clearly addressing key challenges posed by the hydropower industry. With the power of current computers, reviewers stated that the modeling projects will produce very useful results and tools. Similarly, with the advances in materials science, battery miniaturization, and computational fluid dynamics (CFD) tools, reviewers recognized the program's large strides in addressing fish passage and monitoring issues.



## Big-Data Access and Management

Overall, reviewers expressed concern with the volume and complexity of our big data management efforts. Reviewers recommended that our data management protocols include QA/QC procedures, such as sample selection and data validation, a plan and budget for future updating, and an initial focus on end users to determine how these datasets can be useful to the hydropower community. We recognize the volume and complexity concerns in our efforts to homogenize and consolidate a diverse range of large hydropower datasets; however, the benefits of this endeavor will confer a wide range of benefits. We will continue to work with ORNL to revisit our data QA/QC practices, including validation, to ensure that we have a solid plan and budget for identifying aberrant data and revising in the future. Additionally, we are reassessing our data strategy overall, while working to strengthen our team's data science expertise. In the near term, we plan to develop a more formal outreach strategy to ensure that our data products meet the needs of end users, both currently and going forward.

Regarding the Hydropower Fleet Intelligence (HFI) project, reviewers expressed concerns about the quality of data and converting data to actionable information. Reviewers recommended additional engagement with the hydropower industry, in particular project operators, and identification and use of other sources of hydropower operational data. We recognize that several of the industry data sources for the HFI project, such as HydroAmp condition data, suffered from significant accuracy issues. We identified the QA/QC issues associated with HydroAmp data and provided recommendations to enable HydroAmp to become a viable source of hydropower condition data in the future. To ensure a reliable source of more current hydropower condition data, we have engaged directly with some major industry utilities for access to more reliable hydropower condition data. In addition, we would like to note our successful efforts with respect to other primary sources of data for reliability and cost (e.g. North American Electric Reliability Corporation's Generating Availability Data System and the Electric Utilities Cost Group) to identify means by which QA/QC procedures can be incorporated into these datasets, with the end goal of identifying aberrant data. Finally, we agree that additional industry engagement is needed for the HFI project to ensure that our results are germane to the needs of the industry with respect to improved O&M cost savings. As part of our future efforts, we will partner with the Hydropower Research Institute and its industry members—U.S. Army Corps of Engineers, Chelan County Public Utility District, and Southern Company—which will provide unprecedented access to reliable hydropower operational data.

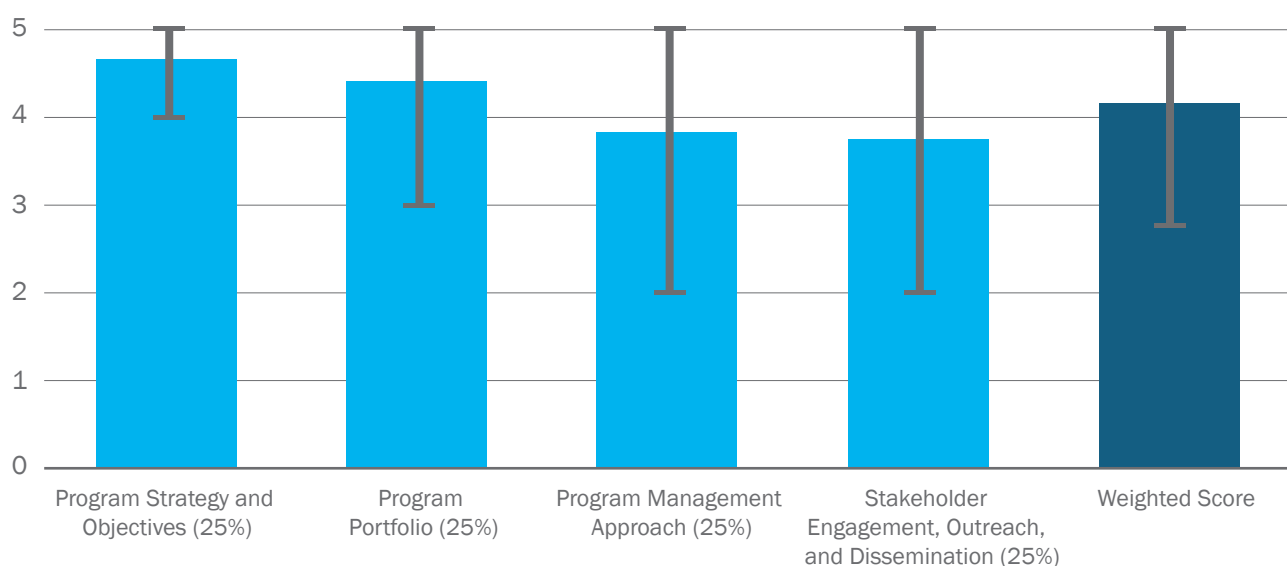
Another area of concern for reviewers was related to the objectives and proposed outcomes of the licensing project—An Examination of the Hydropower Licensing and Federal Authorization Process. This project collects both quantitative and qualitative data to identify the costs and uncertainties associated with the U.S. federal regulatory process for non-federal hydropower projects. The reviewers strongly felt that it is not enough just to understand the reasons for regulatory delays, but that the project should make definitive recommendations for how to improve the hydropower regulatory process. For years, delays in the federal hydropower authorization process have been cited as a chilling effect on the growth of hydropower in the U.S. However, the reasons for these delays have been based primarily on anecdotal information from a variety of divergent viewpoints (e.g. the hydropower industry, regulators, and environmental NGOs). To date, there has been no attempt at a science-based, objective, and quantitative analysis of the federal hydropower authorization process. Through our Stakeholder Working Group—a diverse group of hydropower stakeholders from across the hydropower community—we intend to develop a report that comprehensively and objectively examines the full spectrum of federal and state hydropower authorization processes. The report will not include recommendations for regulatory reform because it is not within DOE's mandate to make such recommendations; however, a comprehensive report of this nature provides objective, unbiased information that any parties can consider as part of any efforts to update regulatory processes.

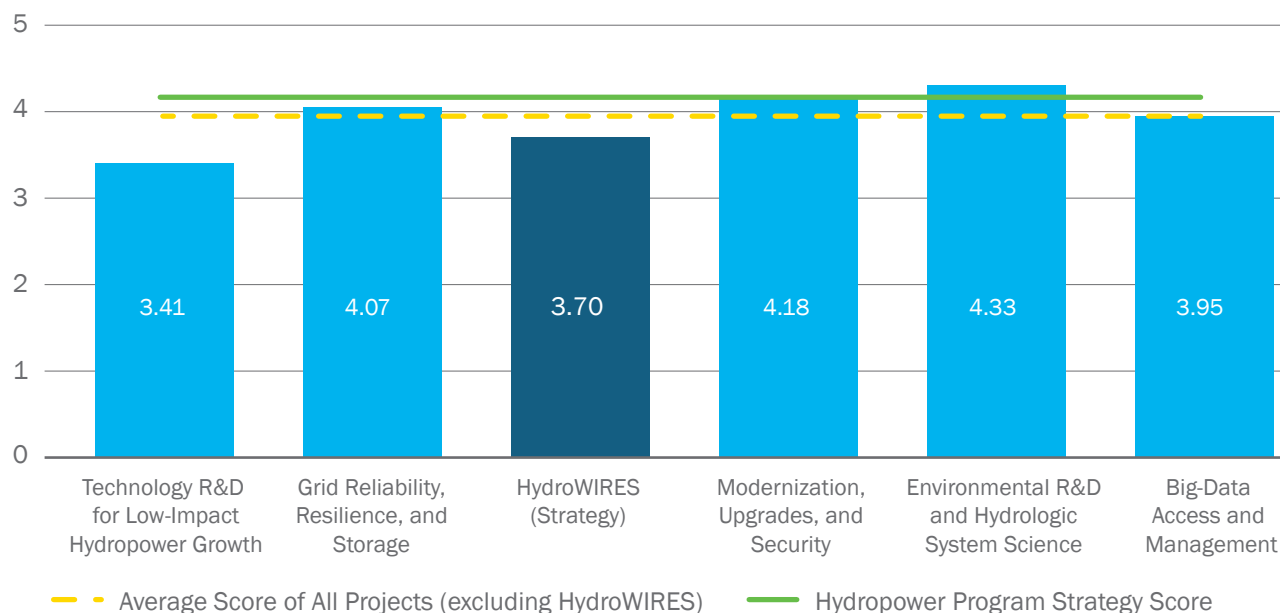
# HYDROPOWER PROGRAM SCORE RESULTS

This section provides an overview of the scoring for the Hydropower Program strategy, all projects within the Hydropower Program, and the HydroWIRES Initiative. Reviewers evaluated the Hydropower Program strategy and HydroWIRES on the following, equally weighted criteria: (1) program strategy and objectives; (2) program portfolio; (3) program management approach; and (4) stakeholder engagement, outreach, and dissemination. Reviewers provided scores on a scale of 1 (“unsatisfactory”) to 5 (“superior”) for each criterion and were also asked to answer unscored, supplemental questions for each program or strategic initiative, which are outlined in [Appendix B](#). A summary of the reviewers’ responses to the unscored, supplemental questions were incorporated into the Hydropower Program Evaluation Summary. Figure 9 summarizes the weighted score of the Hydropower Program strategy and average reviewer score according to each program evaluation criteria.

In addition, reviewers were asked to evaluate a set of WPTO’s projects, both numerically and with specific, concise comments to support each evaluation. Reviewers evaluated each project on the following specific criteria: (1) project objectives, impacts, and alignment with the program strategy; (2) end user engagement and dissemination strategy; (3) management and technical approach; (4) technical accomplishments and progress; and (5) future work. Project scoring involved weighting the evaluation criteria based upon each project’s category—sunsetting/completed, ongoing, or new—which was based on a project’s start and/or end date. Reviewers were asked to comment on the strengths and weaknesses behind their scoring and to provide recommendations that they felt that the office should consider. Figure 10 summarizes the average score of all projects within each activity area, the average score of all hydropower projects, the average HydroWIRES strategy score, and the average program strategy score.

**Figure 9. Average reviewer score of the Hydropower Program Strategy by program evaluation criteria**



**Figure 10. Average weighted score by Hydropower Program activity area**

Note: Of the 36 projects reviewed in the Hydropower portfolio, the number of projects reviewed per activity area include: Technology R&D—8 (22%); Grid Reliability—9 (25%); Modernization—2 (6%); Environmental R&D—10 (28%); Big-Data—7 (19%).

## Organization of Activity Area and Project Results

The 2019 Peer Review results are organized by the activity areas into which individual projects were grouped for the review. Each subsection (i.e., activity area) includes the following components:

1. *Activity Area Score Results*: This chart depicts the average weighted score for each project in each activity area.
2. *Activity Area Summary Report*: This consists of a summary of the review panel's comments that provides insight into each activity area's strengths and weaknesses or potential issues and specific recommendations. Review panel leads were responsible for drafting activity area evaluation summaries in consultation with the full review panel and program review chair. Consensus among the reviewers was not required, and reviewers were asked to include differences of opinion and dissenting views within the report.
3. *Project Evaluations*: These are individual project reports, which constitute 2–3-page reports summarizing the results of each project evaluated during the review process. Each report includes the following elements:
  - a. *Project Name and Work Breakdown Structure (WBS) Number or Award Agreement*: The full project name is listed as the heading, with the identifying code underneath in parentheses. Project evaluations for each activity area are ordered by WBS number, followed by award agreement number, from lowest to highest.
  - b. *Weighted Project Score*: Each project's average weighted score is stated numerically. A bar chart depicts the average scores for each evaluation criterion, as well as the range of scores given to the project by the individuals within the review panel. The chart also indicates the average value for each evaluation criterion across all projects within the activity area.



- c. *Summary Table*: Each report provides reference information about the project, including the recipient organization, PI name, project dates, project type, and funding values.
- i. *Recipient*: The recipient indicates the organization tasked with leading the project (this may include multiple organizations in situations where the project has more than one recipient).
  - ii. *Principal Investigator*: The PI is the individual affiliated with the recipient organization who is assigned to lead the project.
  - iii. *Project Category*: Each project is categorized as sunseting, ongoing, or new, based on its start/end date.
  - iv. *Project Type*: There are many types of projects within the WPTO portfolio, but this review focused primarily on two types of projects: (1) AOPs, which are core R&D projects performed by DOE's national laboratories, and (2) projects awarded through a FOA, which are indicated in this table by listing the FOA's name or number.
  - v. *Funding*: Each project includes total costed and total authorized. Total costed is the budget executed during the full peer review period (from FY17 through Q2 of FY19). Total authorized for AOPs is the sum of prior year (FY16) carryover and budget authorized during the full peer review period (from FY17 through Q2 of FY19). Total authorized for FOAs is the total DOE negotiated award amount, including amounts allocated to sub-recipients.
  - vi. *Project Descriptions*: Project descriptions are compiled from the project summaries that the PIs submitted for each project.
  - vii. *Summary of All Reviewers' Comments*: Reviewers were responsible for consolidating and summarizing all reviewer comments on their assigned projects, in consultation with the review panel leads and program chairs. These project evaluation summaries were edited only for grammar and clarity. In a limited number of cases, reviewer remarks deemed inappropriate or irrelevant were excluded from the final report.

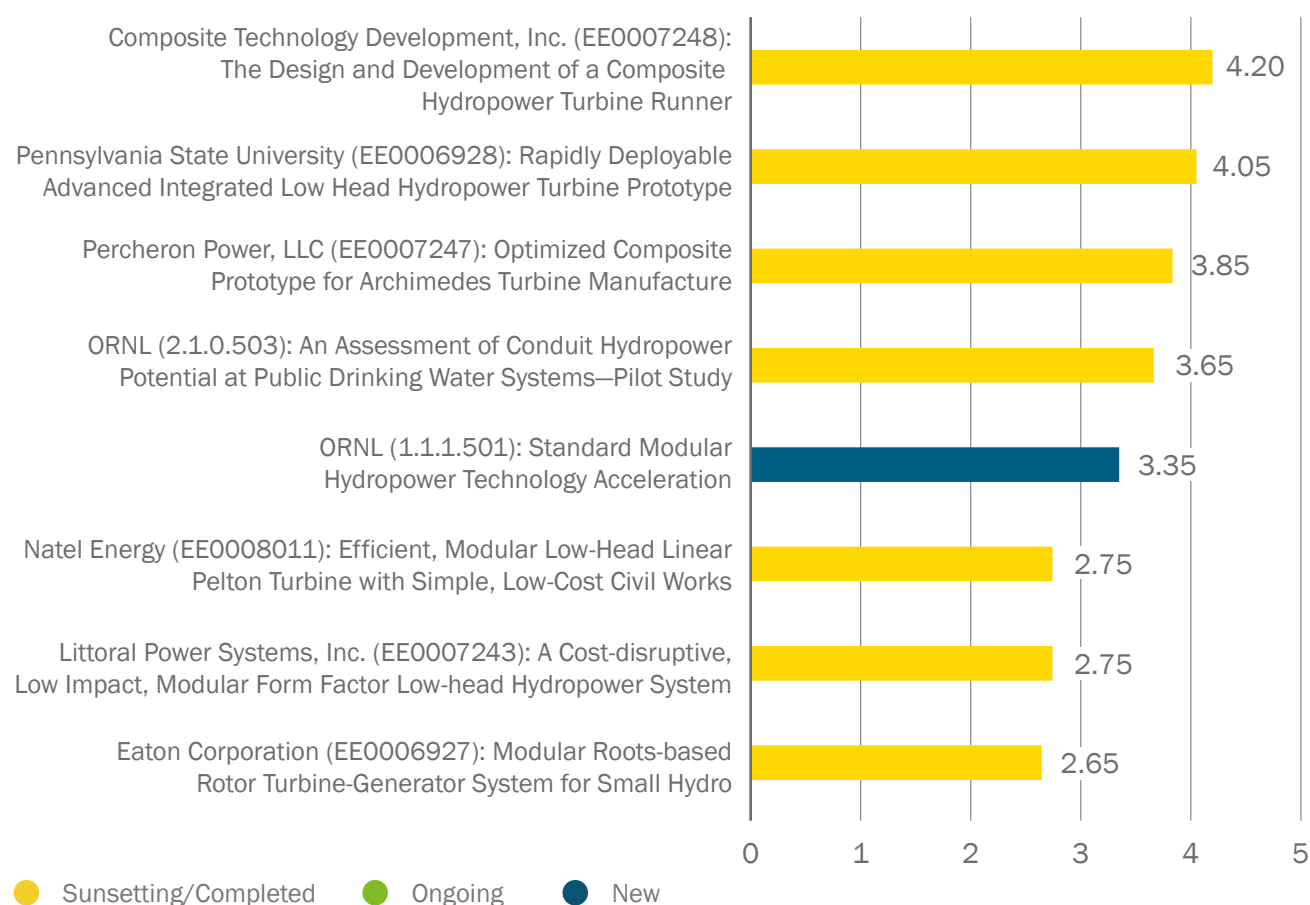
## Technology R&D for Low-Impact Hydropower Growth

This section provides an overview of the scoring for all projects within the Technology R&D for Low-Impact Hydropower Growth activity area (see Figure 11); the review panel lead's summary of reviewer comments in response to the evaluation criteria; and full evaluation results for individual projects.

### Activity Area Score Results

Name	Average Weighted Score of All Projects
Technology R&D for Low-Impact Hydropower Growth	3.41

**Figure 11. Technology R&D for Low-Impact Hydropower Growth activity area—average weighted score by project**



## **Activity Area Summary Report**

*Prepared by the Review Panel Lead*

### **Feedback from the Review Panel to WPTO**

There were very wide-ranging project outcomes in the Technology R&D for Low-Impact Hydropower Growth (Tech R&D) portfolio. Reviewers observed some excellent project concepts with solid project management and documented findings in final reports, but also some poorly vetted project concepts with weak project management and poor accomplishments in relation to the initial objectives.

### **Summary of all Reviewers' Comments**

#### **Overall Impressions**

There were some solid, innovative projects that can advance the state of the technology within the Tech R&D portfolio, including some well executed, managed, and documented projects. Unfortunately, this was not consistent from project to project. Opportunities for improvement exist in consistently engaging industry expertise, providing stronger upfront scrutiny of concepts and designs, emphasizing project management principles, and more clearly outlining, monitoring, and requiring compliance with expectations.

#### **Program Strategy and Objectives**

The reviewers generally agreed that the program did an excellent job of ensuring that all presenters described how their projects aligned with DOE objectives. The consistent introductory slides and generally consistent required summaries were helpful to reviewers. The mix of Tech R&D projects demonstrate an understanding of the near and long-term challenges facing industry and other stakeholders for low-impact hydro growth to have any chance to occur. A couple projects also displayed innovative potential that could possibly help some struggling existing locations through future use of more cost-effective, environmentally friendly technology advancements. The diverse selection of Tech R&D projects shows investment in early-stage research to accelerate the development of innovative water power technologies, while ensuring that long-term sustainability and environmental issues are addressed.

#### **Program Portfolio**

Reviewers generally agreed that, while not all projects contributed equally to the results within this program portfolio, overall, the projects contribute to meeting the program's strategy and objectives. The projects within this program portfolio are addressing key challenges and reducing barriers to advance water power technologies and are appropriate for WPTO's role as a public R&D organization, but could benefit by the improvements outlined in the "Feedback from the Review Panel to WPTO" section above.

#### **Program Management Approach**

Tech R&D reviewers generally agreed that the program team effectively manages and directs the activities needed to meet its objectives but could use a little help from industry to be most effective. Similarly, the program team demonstrates the professional and technical capabilities needed to identify, monitor, and guide its portfolio of projects, but they could benefit from greater input from industry experts, who could provide additional project oversight and serve as supporting thought leaders to inform the direction of the program. Reviewers agreed that, based on the very narrow time window and limited resulting evidence that peer reviewers can observe, it would be difficult to say that the operations and oversight procedures were fully utilized and sufficient. See suggested improvements above.

**Stakeholder Engagement, Outreach, and Dissemination**

While the engagement, outreach, dissemination, and resulting effectiveness vary by project in the Tech R&D portfolio, reviewers generally agreed that the program transparently communicates how WPTO funds are being utilized and evaluates project impacts internally and also externally using the peer review process. This year, the peer review meeting cast a much broader net across the hydro community and gathered feedback from within the industry and from stakeholders and NGOs in the larger hydro community. Multiple feedback opportunities were offered in addition to the peer reviews and included the Town Hall feedback forum, suggestion boxes, and websites. All of these can be used to inform and improve WPTO projects and strategy. Finally, the engagement of industry experts could also fill a support role as thought leaders to inform the direction of the program and offer connections to industry partners for disseminating information.



## Project Evaluations

# STANDARD MODULAR HYDROPOWER TECHNOLOGY ACCELERATION

(WBS #: 1.1.1.501)

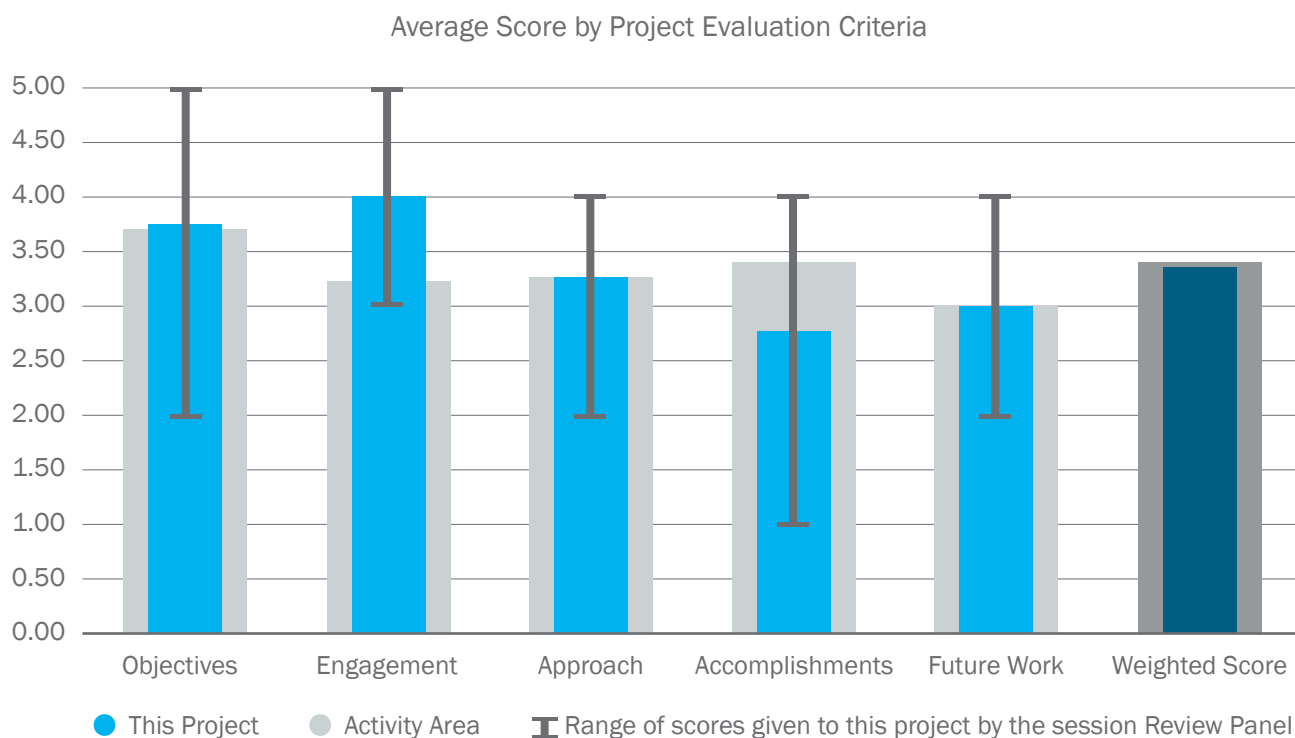
Recipient:	ORNL
Principal Investigator:	Brennan Smith
Project Type:	AOP
Project Category:	Ongoing Projects
Total Authorized:	\$3,260K
Total Costed:	\$2,679K

## Project Description

This project's objective is to explore new ways to site, design, develop, and operate small hydropower facilities in the United States at lower costs with greater environmental compatibility. SMH R&D focuses on three areas: (1) standardization of design, review, manufacturing, and other features to reduce site specificity and project costs; (2) modularity of a hydropower facility into discrete functional units, allowing scalability to deliver energy and environmental benefits at many different sites; and (3) priority design objectives for environmental compatibility to maintain stream functionality and ecosystem health.

## Weighted Project Score: 3.4

*Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.*



## Summary of all Reviewers' Comments

### Overall Impressions

This is a bold plan for the development of new stream reaches by starting with environmental and recreational improvements, then adding hydropower as an ancillary component, which reviewers found intriguing. The challenge will be two-fold: (1) seeking out funding sources for those primary elements, as the hydropower will not provide the economic driver, and (2) convincing non-governmental organizations (NGOs) and state agencies of the value of this approach.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The project aims to change how the United States approaches hydropower development to strip away some of the site-specific planning requirements, regulatory hurdles, and environmental impacts that hinder development in the increasingly competitive energy generation space. It is not clear how the project approach accomplishes the goals of enabling the design and development of new SMH or how it leverages new advancements. It seems like the project is simply a quasi-advertising process for small modular approaches. The summary provides little information regarding what the end products will include, such as models, design tools, testing facilities, and assessment protocols. Researchers must focus on stakeholder engagement and the effort to shift the paradigm.

### End User Engagement and Dissemination Strategy

The project presenter identified the primary end users of the new approach to be technology developers, environmental stakeholders, and hydropower project developers. The presenter's descriptions of how stakeholders have been engaged so far consist of U.S. Department of Energy (DOE)-funded projects involving manufacturing, facilitated stakeholder engagement, and a stakeholder review board. It is unclear if any plans are underway to demonstrate SMH at a site under development. Technical and academic resources have been utilized; however, industry manufacturers and developers have been less involved. The process of end user engagement was explained, but it is not clear if the end users who were targeted as part of the meetings and feedback from publications are the right audience.

Dissemination of progress is comprehensive—ranging from project website updates, publications in peer-reviewed journals, and conference presentations but underestimates the incredible task of convincing NGOs and state agencies of the value of SMH. Reviewer's comments suggested they generally agreed that a lot of unique work has been accomplished and information disseminated to those that have an interest in small hydropower development, and that information on [smh.ornl.gov](http://smh.ornl.gov) website is pretty extensive and useful.

### Management and Technical Approach

The project management approach primarily states that the work is fully orchestrated by Oak Ridge National Laboratory (ORNL), utilizing a wide variety of expertise from researchers and staff with hydropower backgrounds, as well as a host of subcontractors ranging from design engineers, sediment transport/geomorphology experts, and outside facilitation. The project is on schedule and under budget, but there is no supporting information.

The project has a conceptual goal but does not really have concrete success criteria or metrics in place. The stated areas of technical advancement do not appear to have results at this time. It is unclear whether standard project management practices are in place for the project, which will be important given the relatively large scope of the project. The basic premise that modularity reduces cost while increasing flexibility has not been proven, yet it is treated as a given in this project. Every stream and non-powered dam in the United States has

its own peculiarities, which no amount of standardization can address. Secondly, no matter how much one can standardize components, the cost of new stream development yields no adequate return on investment with today's wholesale electrical pricing.

### **Technical Accomplishments and Progress**

The technical progress and accomplishments made so far for this project are primarily a reiteration of the same material presented throughout the presentation, consisting of a list of publications issued for the SMH program. It is unclear what technical accomplishments have been made.

ORNL is engaging at several fronts: (1) partnering with other grant awardees related to new turbine designs and modular concepts and (2) supporting DOE in the formulation of funding opportunity announcements. This project is the hub of a concerted effort by DOE/ORNL to change the way small untapped hydropower opportunities are evaluated and implemented. However, feedback received from stakeholder engagement seems to be missing. It is unclear whether the environmental community has embraced this new paradigm for new hydropower development, and whether they expressed an interest in working with hydropower developers within the new paradigm to promote SMH.

The processes and framing have been developed, but the proof will be when SMH deployments start to happen. There are many challenges that are inherent in such a complex undertaking. While the goal of standardizing modular small hydropower deployments is admirable, it seems doubtful—given the variability of river and stream environments, as well as local interests—that standardization is a realistic goal.

### **Future Work**

Future work for this project is contingent on wider stakeholder engagement. Researchers should focus less on ideas for modules and more on describing the benefits of stream reach development to NGOs, local governments, and other stakeholders outside of hydro. Current turbine/generator programs have been unsuccessful and should not be included in this effort. Future work would benefit greatly from a process to ensure that (1) the project has a clear, succinct, and well-stated goal, and (2) the work supports the objectives of such goal.

As stated by the PI, the approach to the development of new hydropower facilities in the U.S. should be based on the concept of river functionality, which essentially means work with the river rather than tame the river. Convening stakeholder focus groups to help guide and inform the development of these new concepts is imperative, particularly from the environmental/recreational community that are key players in licensing new hydropower facilities. There are doubts whether one can remove the site-specificity of environmental issues, but on generic issues such as fish passage and sediment transport through the new facility, the approach may be successful.

## AN ASSESSMENT OF CONDUIT HYDROPOWER POTENTIAL AT PUBLIC DRINKING WATER SYSTEMS— PILOT STUDY

(WBS #: 2.1.0.503)

Recipient:	ORNL
Principal Investigator:	Shih-Chieh Kao
Project Type:	AOP
Project Category:	Completed and Sunsetting Projects
Total Authorized:	\$75K
Total Costed:	\$75K

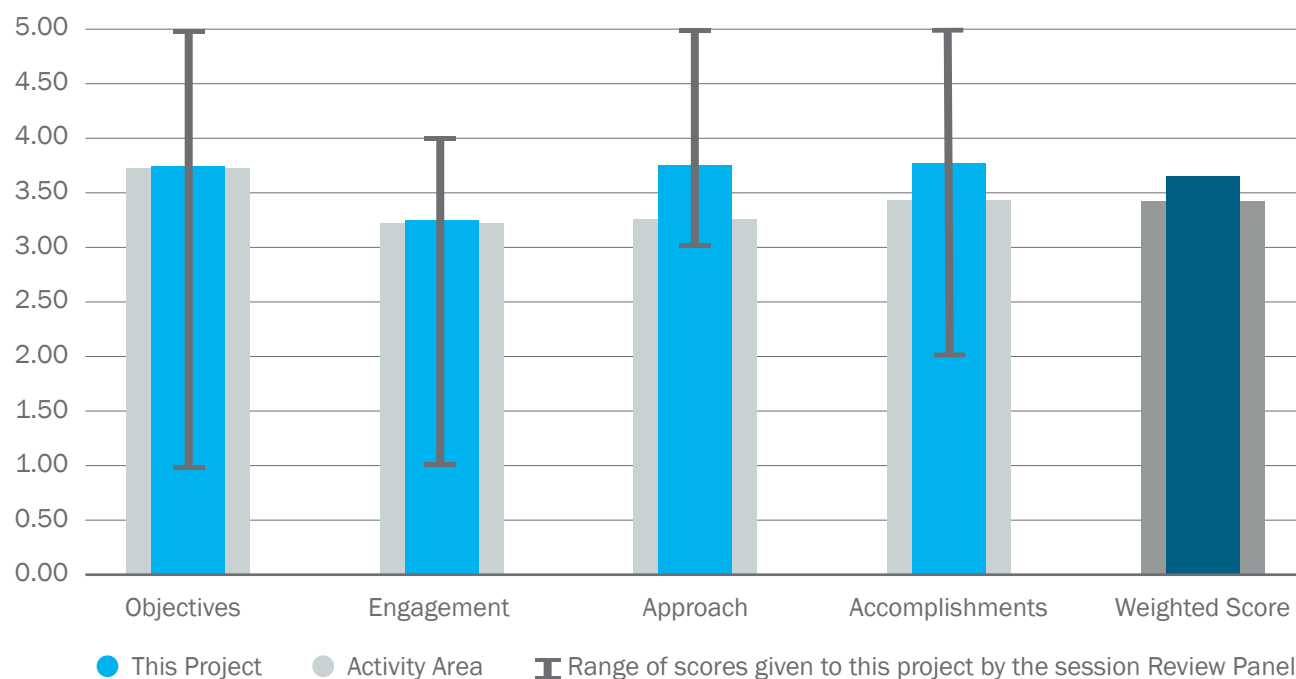
### Project Description

This project was awarded to Telluride Energy and ORNL by the DOE SBV Pilot Program in FY 2017. Under a cooperative research and development agreement, Telluride Energy and ORNL designed a geospatial assessment approach to estimate the total undeveloped conduit hydropower potential at public water systems, which might be retrofitted with hydropower to take advantage of the expedited permitting process through the Hydropower Regulatory Efficiency Act of 2013. The project team collected and analyzed multiple public and nonpublic datasets in this pilot study for the states of Oregon and Colorado. The assessment can be further expanded to quantify the national public water systems conduit hydropower potential and their interregional differences across the country.

### Weighted Project Score: 3.7

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%

Average Score by Project Evaluation Criteria





## Summary of all Reviewers' Comments

### Overall Impressions

This project represents a focused and well-executed pilot study that illuminates the potential for conduit hydropower in public drinking water supplies of two key states. Whether the investigation should be expanded to other states is uncertain given the relatively small amounts of energy predicted by the pilot study. As acknowledged by the PI, most water districts/agencies are well aware of the pressure-reducing valve opportunities for hydropower development in their systems, which suggests that enumerating the potential generation throughout the country may not significantly alter current DOE policy. The team should consider focusing future efforts on developing a user application package of benefits and analysis models, as well as promoting the value of undertaking these conversions, such as the addition of battery storage that could be integrated into their water supply operations.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The reviewers all agreed that the project was based on clearly stated objectives; potential benefits are straightforward; and the project is inexpensive. The project clearly lays out the value of exploring this area given the advent of legislation that eases licensing of conduit hydropower and the opportunities to gain economic benefit via net metering.

### End User Engagement and Dissemination Strategy

The end users are defined as water districts and water agencies. The primary engagement and dissemination of information described has been passive via SBV, which closely collaborates with national laboratories. This seems appropriate as this is a pilot project with little need for external input. If this effort expands to other states, it would be useful for ORNL researchers to examine the level of use of the ORNL website by water districts throughout the country and determine whether or not a more focused outreach strategy is needed.

### Management and Technical Approach

The reviewers agreed that the technical approach is sound and thorough, and many were surprised given the limited budget of this project. The technical approach demonstrates a clear algorithm for estimating generation potential, the sources of information that were gathered (including the need for non-disclosure agreements to garner data on intake locations), as well as a discussion of why pumped groundwater added to the conduit system was not used. The only improvement suggested by one reviewer was that the project could have identified specific sites to do more thorough engineering reviews as a test against the generalized approach to validate the capacity and energy potential for Oregon and Colorado.

### Technical Accomplishments and Progress

The reviewers generally agreed that the technical accomplishments of this project align with the original objectives of investigating: (1) the number of potential sites in Oregon and Colorado, (2) their cumulative capacity, and (3) their cumulative estimated annual energy production. These results are valuable as an initial reconnaissance-level evaluation of the potential hydropower generation at conduits operated by municipal water agencies and districts in two states with favorable topography, surface water resources, and population levels. Overall, progress appears to be very good, but the opportunity appears to be very small.

## MODULAR ROOTS-BASED ROTOR TURBINE-GENERATOR SYSTEM FOR SMALL HYDRO

(WBS #: EE0006927)

Recipient:	Eaton Corporation
Principal Investigator:	David Yee
Project Type:	FOA 1006: Water Power Manufacturing
Project Category:	Completed and Sunsetting Projects
Total Authorized:	\$2,549K
Total Costed:	\$1,549K

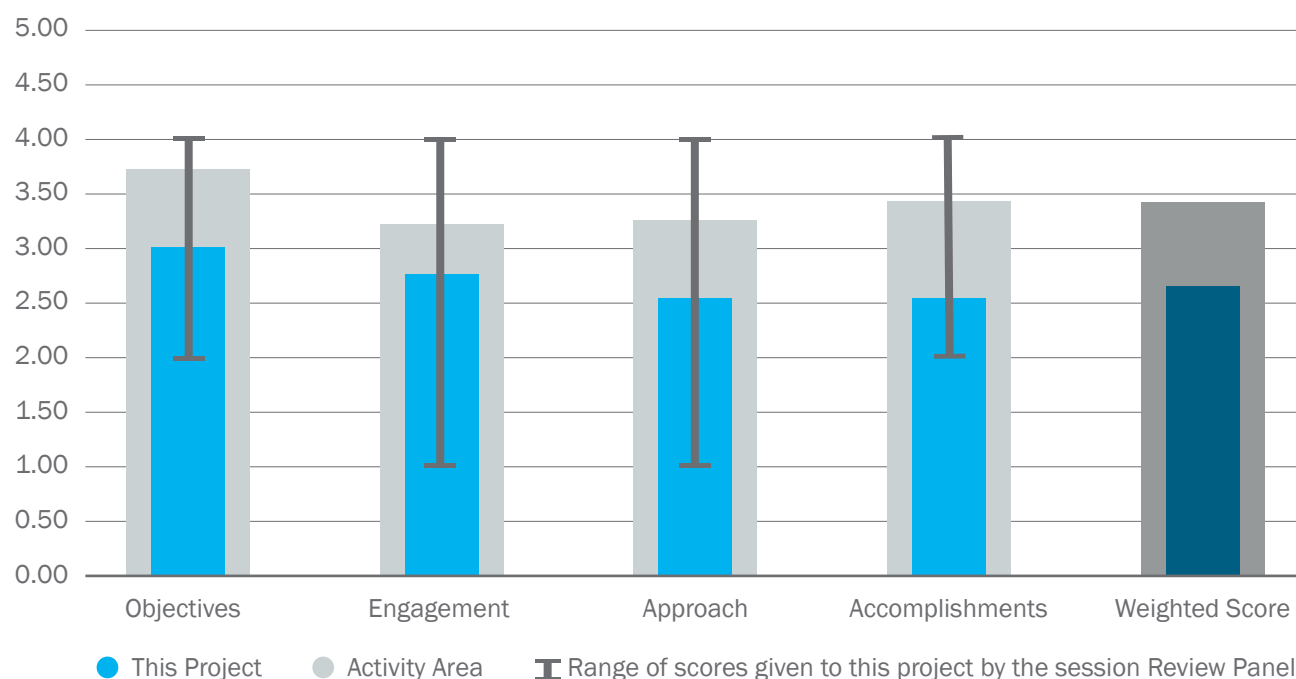
### Project Description

Approximately 50 GW of potential renewable power is residing in more than 25,000 U.S. non-powered dams having low head and flow. This resource remains untapped because it is not cost effective to scale-down and deploy traditional large hydro turbine systems into these applications. This project's objective is to develop and demonstrate a Roots-based turbine-generator system that can cost-effectively deliver power from these existing non-powered dams. The Roots device is uniquely qualified to meet the application needs because it has a broader efficiency window when compared to traditional turbine runners.

### Weighted Project Score: 2.7

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%.

Average Score by Project Evaluation Criteria



### Summary of all Reviewers' Comments

#### Overall Impressions

In general, the research at this stage does not provide a compelling case that modular turbine designs of the Roots-based turbine-generator can be installed at non-power dams at sufficient low cost and/or improved

efficiencies to achieve the LCOE values needed to make low-head, small hydropower competitive with solar and wind development. This project could have benefitted by a rigorous design review in the early stages with input from other industry experts. A design review would better guide the PI away from challenging hard spots and also better inform the DOE regarding the risks that need to be overcome prior to the go/no-go decision point. Providing additional industry expertise as part of the oversight team to follow along each project throughout its full lifecycle would have been money well spent to assist both the PI and DOE.

### **Project Objectives, Impacts, and Alignment with the Program Strategy**

The reviewers were in general agreement that the objectives were clearly stated as to how the project aligns itself with the DOE program objectives. However, the reviewers generally expressed concerns regarding unresolved challenges, including the need for a gearbox/variable speed system that would potentially double costs, close gaps between the rotors and body that would make the system unstable under conditions of high silt and debris.

### **End User Engagement and Dissemination Strategy**

The reviewers generally agreed that the end users of the research were well described as dam owners (utilities, water agencies, etc.); engineering, procurement, and construction firms; manufacturing companies; and ultimately, consumers benefiting from a lower LCOE value project. The reviewers also concluded that the researchers engaged a variety of entities in conversations to receive preliminary feedback on design elements of the project. However, reviewers generally felt that the project could have benefitted greatly by an industry advisory group (or design review) since the PI may not have been familiar with typical operational challenges in hydro waterways and relied on subcontractors that apparently did not raise appropriate risk concerns with the PI.

### **Management and Technical Approach**

There was general agreement among the reviewers regarding how well the project was planned, including a clear description of the roles and responsibilities of different members of the research program. However, the core team of the program does not appear to have specific expertise in turbine design or practical in-field operations and maintenance (O&M) issues. Project management has struggled to deliver a working device and has fallen behind schedule by a year or more. A good design review early on should have determined that the close clearances of this Roots-type device were not very compatible with real-world waterborne debris loading and fish turbine mortality issues that would be present in the majority of applications with this device. Additionally, debris removal systems, which would be necessary to eliminate all but the very small contaminants, would be extremely maintenance intensive in most waterways and would add significantly to the cost challenges of this system. As a result, this device would have limited opportunities for economically viable hydropower installations.

### **Technical Accomplishments and Progress**

With respect to the technical accomplishments, there were mixed comments among the reviewers. While reviewers thought the use of laminated rotors was creative and the Roots-type design was credible and well established, there were concerns raised regarding the technical accomplishments, including the concern that the turbine design package represented a poor choice for most small hydropower applications that have debris, silt, sand, leaves, and other waterborne contaminants. These operational and maintenance risks would likely outweigh any small efficiency gains, if any, over other existing tried and true turbine technologies.

## RAPIDLY DEPLOYABLE ADVANCED INTEGRATED LOW HEAD HYDROPOWER TURBINE PROTOTYPE

(WBS #: EE0006928)

<b>Recipient:</b>	Pennsylvania State University
<b>Principal Investigator:</b>	Arnold Fontaine
<b>Project Type:</b>	FOA 1006: Water Power Manufacturing
<b>Project Category:</b>	Completed and Sunsetting Projects
<b>Total Authorized:</b>	\$2,750K
<b>Total Costed:</b>	\$2,200K

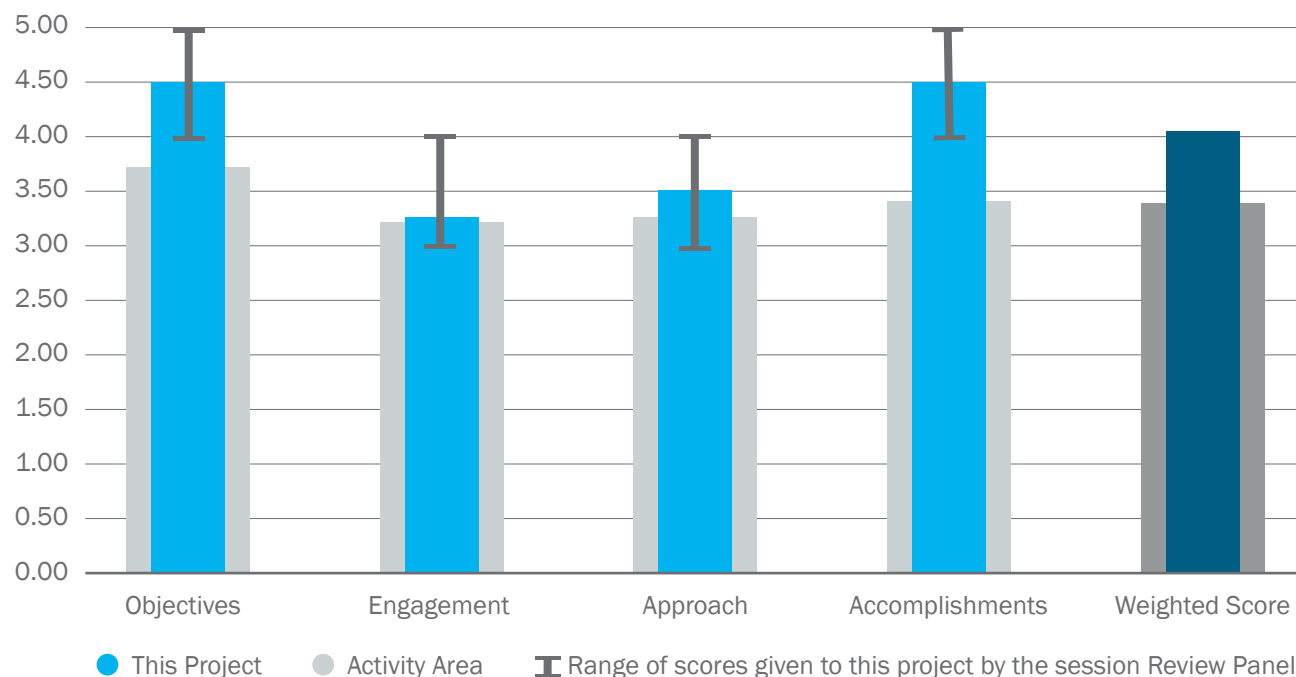
### Project Description

Develop and test a rapidly deployable advanced hydropower turbine-generator targeting low LCOE. The project includes the following innovative features: (1) modular, multi-blade row, hub-less (ecological friendly, self-cleaning, low maintenance) hydro turbine providing high-efficiency, low-head, variable-flow energy extraction; (2) design for advanced manufacturing; (3) condition-based health monitoring; and (4) direct-rim-drive, variable speed generator design, minimizing drivetrain and casing geometry enhancing modularity. The project team fabricated and performance-tested a 0.2-m prototype model in Pennsylvania State University's Applied Research Laboratory's 0.305-m diameter water tunnel facility under variable flow conditions. The project also had additive manufacturing capability and included a cost-assessment feasibility study, which featured a 0.9-m diameter scale inlet guide vane and rotor blade builds.

### Weighted Project Score: 4.1

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%

Average Score by Project Evaluation Criteria





## Summary of all Reviewers' Comments

### Overall Impressions

Overall, this project demonstrated an interesting and innovative turbine concept worthy of DOE funding. While the additive manufacturing of blades does not appear to be a promising avenue of further research, the program team is encouraged to work with a turbine manufacturer to create a larger machine that can be deployed in the field for evaluation. A practical application for such a device could be in pressure-reducing valve replacement at water treatment plants.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The reviewers agreed that the project objectives were clearly identified and aligned with DOE program strategy. They clearly describe an innovative approach to turbine-generator design using the rim drive concept, targeting the primary objective of lowering LCOE by reducing manufacturing costs, installation costs, and O&M costs, as well as designing an environmentally friendly turbine. The project summary aptly describes what they are working on and how the hub-less runner and direct-drive generator could lower LCOE and help drive development in low-head scenarios.

### End User Engagement and Dissemination Strategy

The reviewers were in general agreement that the project leaders did not pursue an aggressive program to engage potential end users in their project. The basic conclusion is that the success of the project will speak for itself and convince potential user groups to develop similar designs. Nevertheless, the work performed demonstrates a good pursuit and engagement of potential ultimate end users via ongoing discussions with Voith turbine manufacturing.

### Management and Technical Approach

The project contributors both coordinated with each other and led their individual aspects of the project successfully, which signifies a solid project management approach. However, reviewers stated that they would have appreciated more specific details regarding the decision gates and project management principles applied. The six-task technical approach, extending from initial turbine design to validation testing, demonstrated a sound and logical progression of steps. However, there is little discussion of critical success factors, such as how they know the turbine generator design will achieve the LCOE reduction goals they set out to accomplish.

### Technical Accomplishments and Progress

The reviewers agree that the project has been mostly successful, essentially meeting their objectives and demonstrating excellent progress on an innovative small-flow turbine concept. However, while it is clear a new turbine generator was successfully designed, built, and tested, the project does not provide sufficient evidence that lowering hydroelectric development LCOE has been accomplished. The self-cleaning nature of the hub-less design and its expected fish-passage friendly nature appears promising, but not proven or discussed with researchers familiar with fish-friendly turbines.

## A COST-DISRUPTIVE, LOW IMPACT, MODULAR FORM FACTOR LOW-HEAD HYDROPOWER SYSTEM

(WBS #: EE0007243)

<b>Recipient:</b>	Littoral Power Systems, Inc.
<b>Principal Investigator:</b>	David Duquette
<b>Project Type:</b>	FOA 1286: Innovative Technologies for Low Impact Hydropower Development
<b>Project Category:</b>	Completed and Sunsetting Projects
<b>Total Authorized:</b>	\$1,792K
<b>Total Costed:</b>	\$1,023K

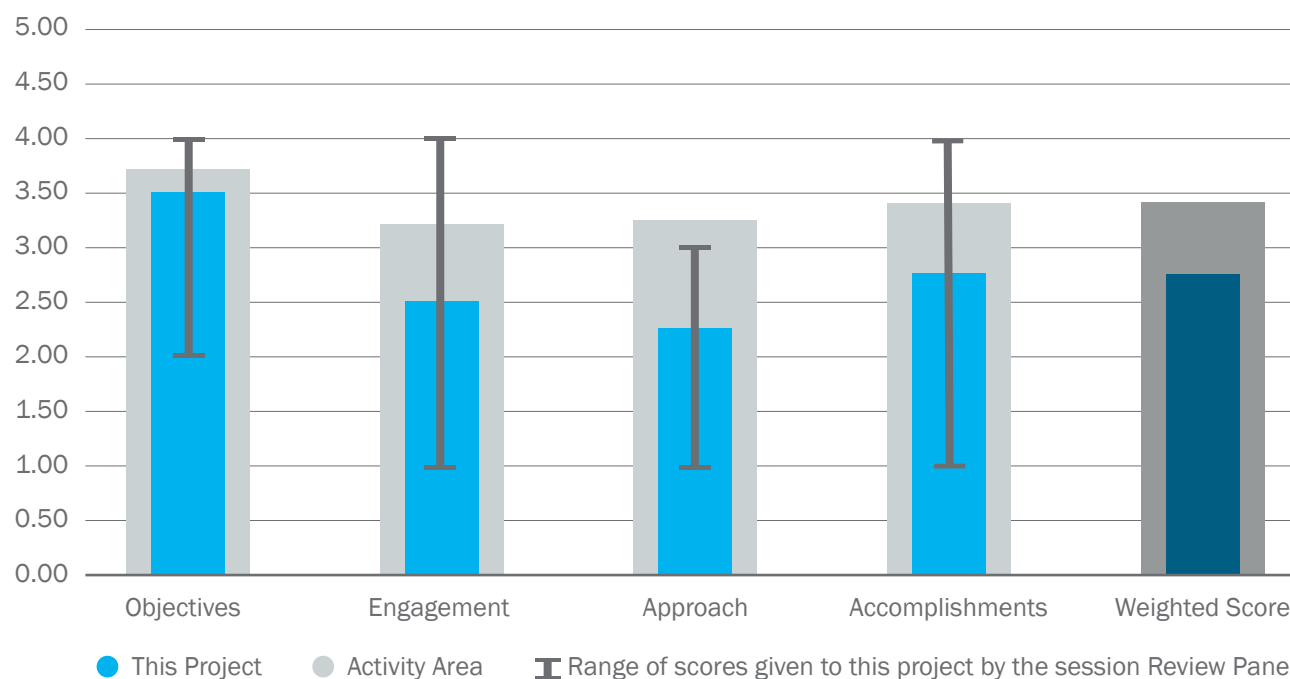
### Project Description

Small hydropower facilities—defined for this purpose as those of under 10 MW in installed capacity—have a relatively low impact on the environment as evidenced by favorable licensing regulations, particularly when configured as run-of-the-river plants. However, they face severe cost challenges. Addressing these cost challenges, Littoral Power Systems conceived a new type of hydropower equipment. It is a kit of standard, prefabricated modular parts based on the form factor of intermodal shipping containers. When assembled, the kit provides dam safety, power generation, spill control and other hydropower facility functions. The Littoral Power Systems system can be used to build and maintain a hydropower facility at substantially lower costs than traditional cast in place concrete, while optimizing generation. This project developed the module designs and analyzed the most critical dam safety functions to prove the feasibility of the system. The project exceeded the original goals and delivered designs beyond the proof-of concept stage backed up by thorough professional engineering analysis of stability, seepage, and structural integrity. Construction plans and professional engineering cost estimates indicated an LCOE half of the original LCOE goal.

### Weighted Project Score: 2.8

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%

Average Score by Project Evaluation Criteria



## Summary of all Reviewers' Comments

The project represents an innovative approach to advancing new hydropower projects that could have a significant impact on the development of new stream reach opportunities. It offers the potential to reduce civil construction costs with the modular design, but before this particular technology can move any further, it must overcome significant hurdles. Primary among these is the issue of site-specific geotechnical conditions. The underlying problem is that issues such as seepage and stability involve foundation characteristics that are site-specific and not amenable to modular construction. Ultimately, the most formidable hurdles associated with this technology will be cost related, as new modular hydropower development will need to be competitive with wind and solar LCOE values that are well below the targeted values for this technology.

### Project Objectives, Impacts, and Alignment with the Program Strategy

In general, the reviewers agreed that the objectives and success criteria of the project were clearly stated and align well with the Standard Modular Hydro program objective. This project is clearly an innovative approach for construction in new stream reaches and potentially at non-power dams, particularly in instances where there is an existing dam structure that is compatible with the addition of modular units. The researchers have explored a concept of modularity in construction with an eye on development in a real-world situation using defined industry and regulatory standards. The stated LCOE goal of the project is identified as \$0.18/kwh, which would not be competitive with solar and wind development.

### End User Engagement and Dissemination Strategy

Reviewers generally agreed that a broad spectrum of stakeholders were engaged as part of the project, and it appears their input was factored into the overall process. It is unclear what the dissemination strategy is on a go-forward basis as Littoral appears more inclined to pursue site licenses and construction. In that vein, much remains to be determined with acceptance by the Federal Energy Regulatory Commission (FERC) and U.S. Army Corps of Engineers' (USACE) from a dam safety perspective before a licensed project can proceed.

### Management and Technical Approach

The reviewers agreed that the project management plan was described in minimal detail and lacked a description of the team's organizational structure. It appeared from the presentation that the team did not follow appropriate project management practices throughout the project. Specific details regarding the project development were not explained, and it appears that the project team may have spent their time pursuing a FERC license application without adequately vetting the technical issues associated with the project. The project has already been through four substantial design changes, which has undoubtedly made this more likely to be successful than the initial design out of the gate. However, it also suggests an incomplete design process and underscores the need for additional oversight and concept vetting in the early stages of a research project.

### Technical Accomplishments and Progress

There was general agreement by the reviewers with regard to the uncertainty of the proven accomplishments of this project. Notwithstanding the ongoing licensing proceeding for the Scott's Dam Project on the James River, the reviewers expressed concern over the likelihood of this modular concept due to a variety of concerns such as (1) insufficient evidence that future capital development costs or O&M costs associated with these modules will be supportive of the \$0.11/kWh LCOE forecast; (2) no proven, acceptable means of anchoring the structure to river bedrock; and (3) no current design for upstream or downstream fish passage modules, as well as for sediment transport modules.

## OPTIMIZED COMPOSITE PROTOTYPE FOR ARCHIMEDES TURBINE MANUFACTURE

(WBS #: EE0007247)

<b>Recipient:</b>	Percheron Power, LLC
<b>Principal Investigator:</b>	Jerry Straalsund
<b>Project Type:</b>	FOA 1286: Innovative Technologies for Low Im-pact Hydropower Develop-ment
<b>Project Category:</b>	Completed and Sunsetting Projects
<b>Total Authorized:</b>	\$1,389K
<b>Total Costed:</b>	\$983K

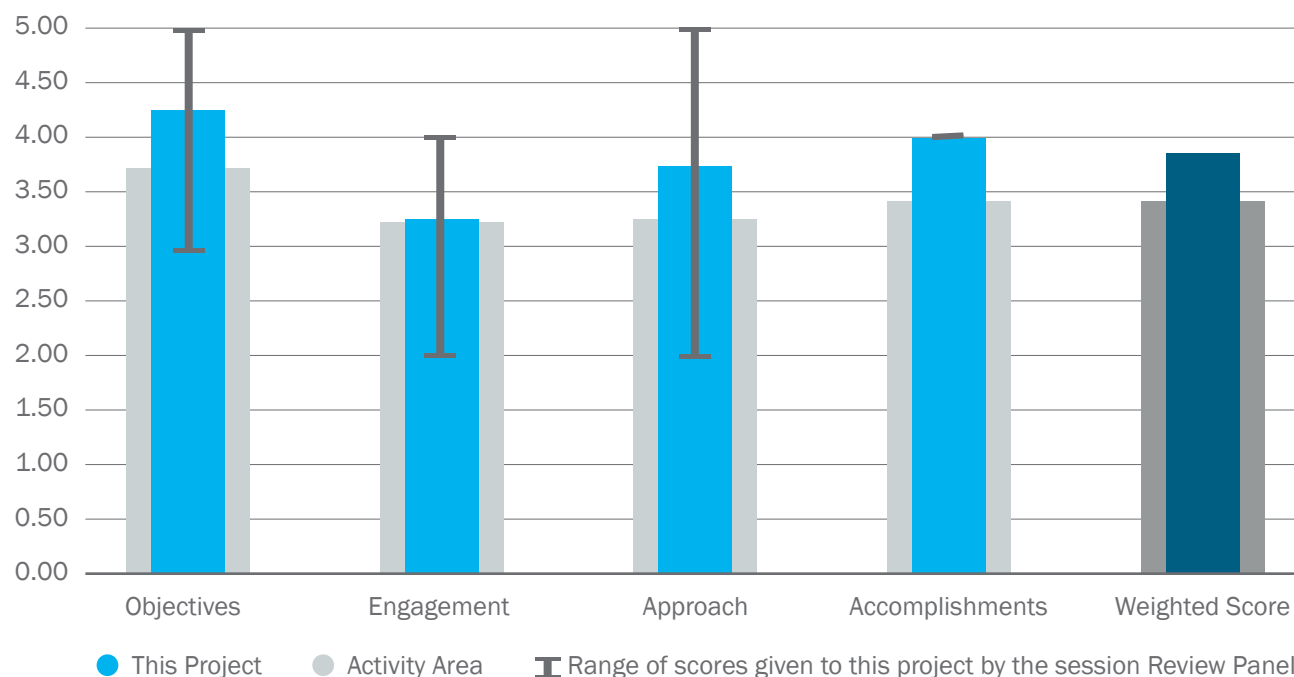
### Project Description

The goal of the Composite Archimedes Hydrodynamic Screw (CAHS) Project was to develop an optimized Archimedes Hydrodynamic Screw (AHS) turbine which is made of composite materials using advanced manufacturing methods. Conventional AHS turbines are made of steel and typically are shipped fully assembled from the factory. The turbines can be quite large, up to 16 feet in diameter and over 70 feet long, which requires oversize shipments and complicated and costly transportation logistics. The diameter of these turbines directly scales with the desired flow through the turbine, so the flow capacities per turbine also are currently restricted by the maximum transportable turbine diameter. The overall goals of this project were to reduce the LCOE for this relatively new low head hydropower technology, overcome the present barriers to steel AHS turbines, and demonstrate advanced U.S. manufacturing capability to produce the optimized turbine. Lowering the equipment and installation costs and producing the optimized turbines domestically should promote more rapid adoption of this promising low head technology across the U.S.

### Weighted Project Score: 3.9

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%

Average Score by Project Evaluation Criteria





## Summary of all Reviewers' Comments

### Overall Impressions

This project's progress demonstrates that is a promising area of research. Using composite materials to improve on a vintage hydropower design is creative and has potential beneficial ramifications in low-head and low-flow development opportunities. The potential to improve construction and maintenance costs are well understood, but the project team needs a better quantitative assessment of cost and value impacts, particularly as prevailing energy markets (driven by relatively cheap solar and wind projects) may form a significant barrier to the widespread adoption of composite Archimedes turbines. End user engagement could also be improved on this project. Addressing these concerns would improve upon a generally well-received and impressive project report and presentation.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The reviewers agreed that the potential benefit of the composite Archimedes design is well-defined in a qualitative sense and that the goals of the project align with those of the program. The benefits of reduced shipping, installation, and ongoing O&M costs are logical and benefit industry. It was also clear that the project was well-aligned with the program's desire to reduce costs in low-flow/low-head applications. Two of the reviewers did cite a lack of quantitative specificity around the project's objective of reducing cost.

### End User Engagement and Dissemination Strategy

The project seemed to have input from technical experts, but the reviewers felt that outreach to developers or water agencies/districts who may actually purchase and install the system was lacking. There was a sense that Percheron Power may intend the project for their own commercial development and the lack of broader end user engagement may protect that plan. There was also concern that improving the cost to build from the current status of fabricating and shipping turbines from Europe is not a sufficient competitive benchmark and that benchmarking against solar and wind LCOE would provide a better metric for the technology's viability.

### Management and Technical Approach

The management and technical approach were sufficient to support the accomplishments and progress to date, which have provided promising results. Two reviewers noted that the project management approach could be improved with clarity and details around project milestones and decision gates to guide continued work. As to the promising results, one reviewer noted that the 89% efficiency is remarkable for this device.

### Technical Accomplishments and Progress

The reviewers completely agreed that the technical accomplishments and progress are impressive. The prototype's efficiency is impressive, and the logic for reduced installation and maintenance costs are well-understood from a qualitative standpoint. Reviewers presented the following concerns for this project:

- There is no definition of design, nor application limits in size, flow, and head
- Reductions in transportation and construction costs are not quantified
- The durability and longevity of the composite screw are concerning
- There is a lack of understanding regarding how prevailing low energy markets will present a significant barrier to adoption.

Overall, though, this is a promising area of research for the hydroelectric industry.

## THE DESIGN AND DEVELOPMENT OF A COMPOSITE HYDROPOWER TURBINE RUNNER

(WBS #: EE0007248)

<b>Recipient:</b>	Composite Technology Development, Inc.
<b>Principal Investigator:</b>	Paul Fabian
<b>Project Type:</b>	FOA 1286: Innovative Technologies for Low Impact Hydropower Development
<b>Project Category:</b>	Completed and Sunsetting Projects
<b>Total Authorized:</b>	\$1,347K
<b>Total Costed:</b>	\$977K

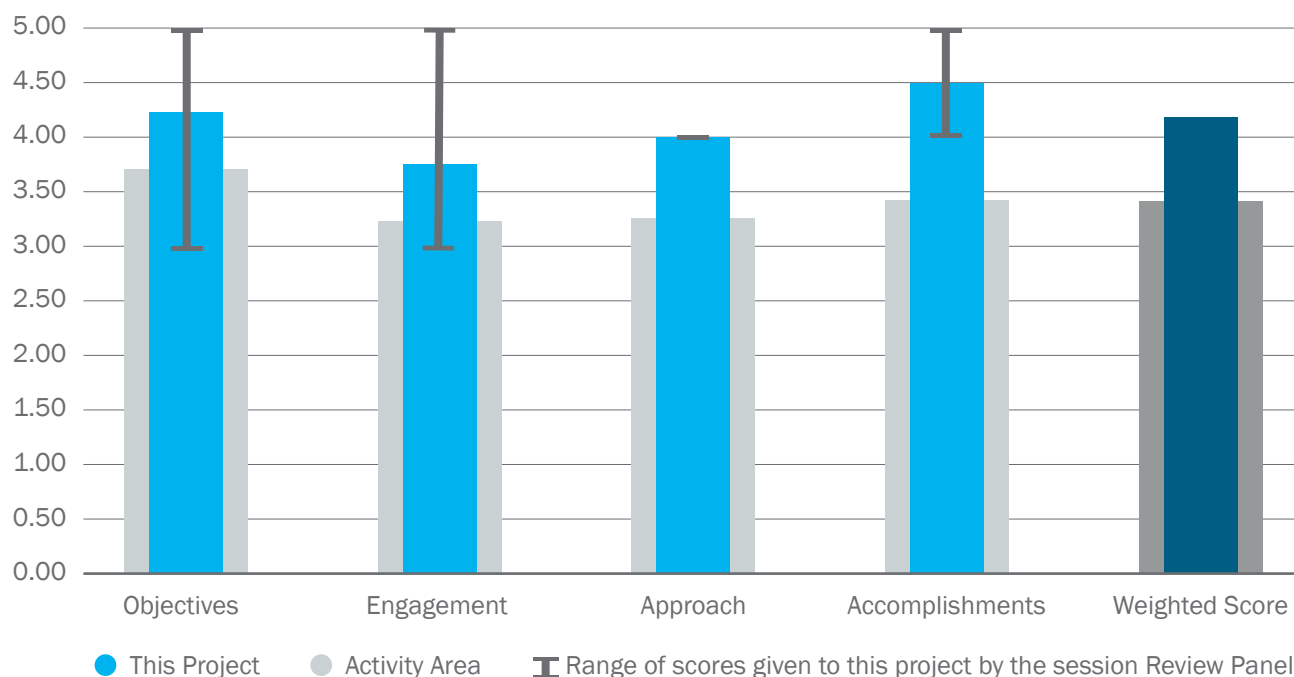
### Project Description

Through this project, Composite Technology Development, Inc. sought to design and laboratory test new and innovative conventional hydropower powertrain components, such as composite and replaceable blade technologies for turbine runners and/or materials and coatings for powertrain components. The overall goal of this project is to verify that composite materials are a reliable and economic alternative to traditional metallic runners and can provide designers with new design options to reduce operating costs and increase energy capture in a hydropower turbine system. The project objectives were to develop cavitation-resistant coatings and to prototype and test a composite runner system under real-world hydropower turbine operating conditions.

### Weighted Project Score: 4.2

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%

Average Score by Project Evaluation Criteria



## Summary of all Reviewers' Comments

### Overall Impressions

The research shows promise, and the development of successful composite runners could significantly reduce the cost of hydroelectric development, particularly for smaller-scale projects. There is much work to be done to demonstrate the viability of the technology, particularly as it relates to the use of soft coatings to reduce cavitation, as well as the durability and longevity of the application. The delay in prototype testing is unfortunate, as it may have addressed some of these concerns. Continued work in this area is warranted, as the results to date are promising, and the potential benefits to the industry could be substantial.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The goal stated by the project performer in developing composite runners is well-articulated, and the potential impact to the industry could be significant. These impacts align with program objectives, particularly as they relate to improving the potential development of low-flow/low-head hydroelectric sites. One reviewer requested additional specificity regarding the potential impacts that could result from the work. Another was concerned that improved environmental impact was a stated objective, but no results in this area were cited.

### End User Engagement and Dissemination Strategy

All reviewers responded positively to Voith's involvement as a project partner, stating that the company provided the project with an avenue to commercial development, as well as some real-world grounding. Two reviewers did note that outreach beyond Voith is desirable and that the project team needs to do a better job of engaging others in the industry, such as end users, hydropower operators, and developers. Additionally, the team should develop a plan to ensure the technology advancements are distributed throughout the industry.

### Management and Technical Approach

All reviewers agree that the project performers deployed sound approaches to managing the project, including well-defined milestones and decision gates, which has contributed to the project's success. The metrics and criteria related to the management process and the decision gates would have improved the project report and provided a better understanding of the potential benefits of the technology. Also, it was noted that the project is currently behind schedule, and the application of the management approach to the delays is not well-described.

### Technical Accomplishments and Progress

The accomplishments are clearly explained and understood, as were concerns about the commercial viability of the technology. The work related to the cavitation issue and the various soft coatings is also understood, although more detailed results in this area are desired. The progress being made toward prototype testing should help address concerns related to potential cavitation, as well as demonstrate the actual performance of the device in a simulated environment. Field testing of the technology ultimately will be needed but should not detract from the impressive accomplishments on this project to date.

## EFFICIENT, MODULAR LOW-HEAD LINEAR PELTON TURBINE WITH SIMPLE, LOW-COST CIVIL WORKS

(WBS #: EE0008011)

Recipient:	Natel Energy, Inc.
Principal Investigator:	Abe Schneider
Project Type:	FOA 1455: HydroNEXT: Innovative Technologies to Advance Non-Powered Dam and Pumped-Storage Hydropower Development
Project Category:	Completed and Sunsetting Projects
Total Authorized:	\$2,285K
Total Costed:	\$1,703K

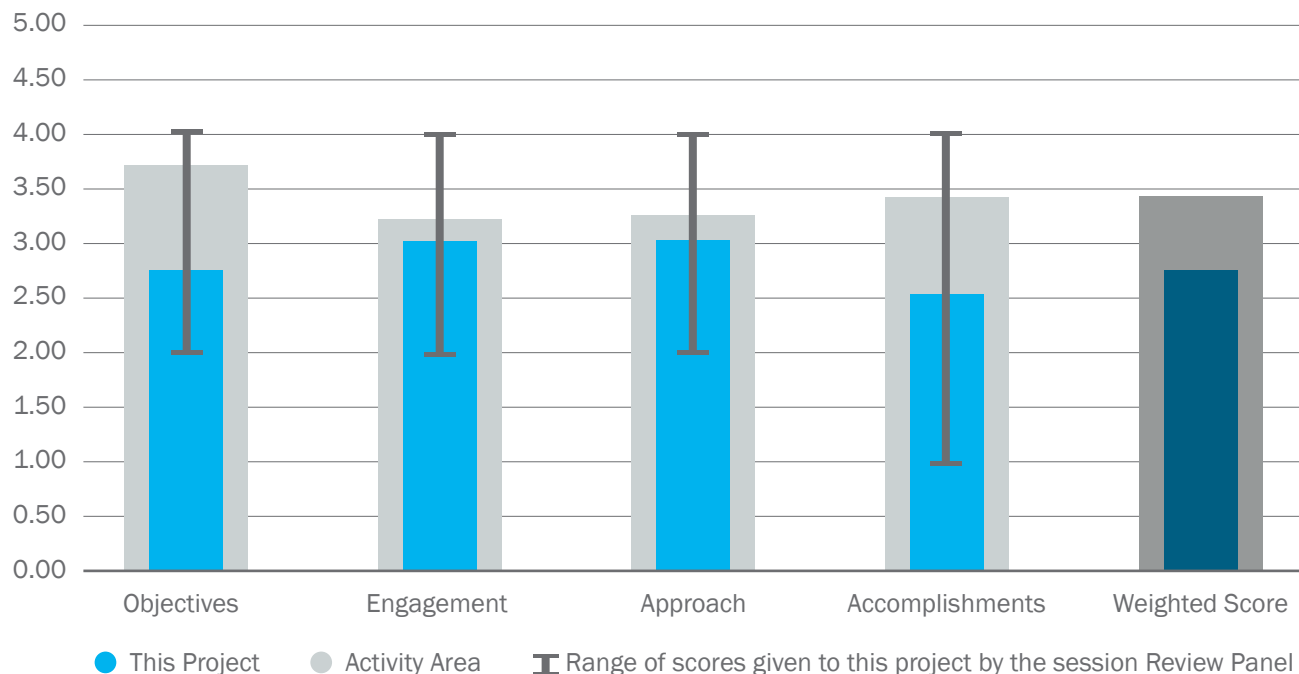
### Project Description

In this project, Natel Energy and its team developed a completely new hydraulic turbine, called the Linear Pelton (LP), from concept to functional, tested hydraulic scale model. Natel also developed plans for two alternative civil works implementations (stationary and floating powerhouses), enabling the assessment of potential cost reductions of hydropower development at non-powered dams. The LP is an impulse turbine, which achieves large specific speed and good efficiency at low head. Operating above tailwater, the turbine allows reduction of submerged civil works. The project focused on powertrain dynamics and fatigue (including modeling and testing), design for manufacture, scalability, and hydraulic performance.

### Weighted Project Score: 2.8

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%

Average Score by Project Evaluation Criteria



## Summary of all Reviewers' Comments

### Overall Impressions

While this project involved radically new and innovative approaches to low-head turbine design, there were multiple foreseeable difficulties and constructability challenges that should have been uncovered earlier in the project process. The research into the LP device and other low-head concepts should not have necessitated costly exploratory manufacturing of a prototype or detailed engineering from consultants to identify the overwhelming obstacles to feasibility. The lessons learned from this project highlight the benefits of engaging additional technical oversight from industry experts that could assist the PI and offer support to DOE project management by using a thorough design review prior to the first go/no-go decision point.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The reviewers generally agreed that the project objectives were clear and aligned with program strategy. However, the reviewers also agreed that project performers should have recognized earlier in the project process that the technical hurdles associated with these innovative concepts would be too difficult to overcome.

### End User Engagement and Dissemination Strategy

The reviewers generally agreed that the attempts to engage advisory groups were directionally correct, but the input from these selected in-house advisors did not result in the kind of objective, self-critiquing evaluations needed for a thorough, holistic design review and feasibility study. Hydro manufacturers and industry subject matter experts could have helped guide or change this project but did not appear to be engaged.

### Management and Technical Approach

Reviewers agreed that the project team put forth out-of-the-box thinking and enthusiastic efforts to develop a new low-head, first-of-a-kind, LP turbine. Unfortunately, the concept design appeared to be overly complex compared to existing low-head turbine technologies. Furthermore, the demonstrated manufacturing difficulties, materials development challenges, real-world maintenance concerns, and undetermined costs and efficiency losses were all of greater concern than with existing technologies. Thus, the initial technical approach appeared to be inadequately vetted to enable significant success in a real-world environment. On the positive side, the numerous emerging problems seemed to be openly identified, optimistically pursued, and generally managed appropriately. This project offers lessons learned for the PI, as well as opportunities for DOE to fortify their support and oversight of projects.

### Technical Accomplishments and Progress

Reviewers generally agreed that this became a series of subprojects to address the multitude of problems that the very complex overall concept presented. While some of the subprojects required new modeling techniques and areas of research that appeared to be handled well, the requirement for the total project to demonstrate and deliver benefits seemed to get lost in all the additional work scope. The result was that the project failed to deliver on its primary objective to produce a working 1-MW turbine within the time and funding available, and the team was unable to prove how this device would be more efficient, have lower LCOE, or possess any competitive advantage over existing turbines.



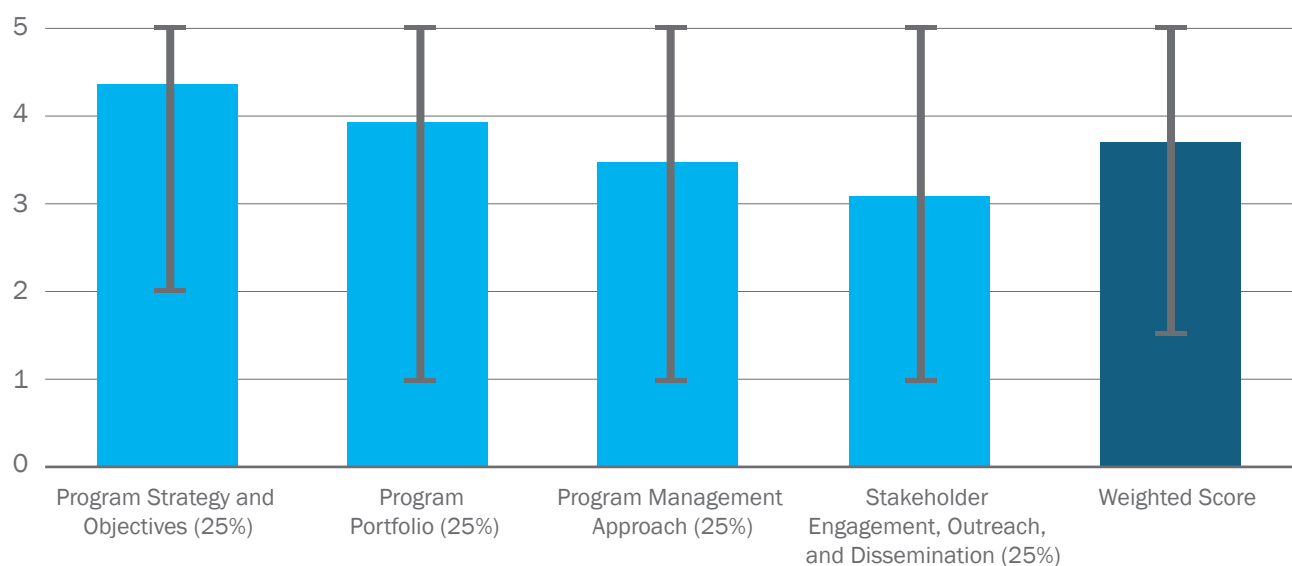
## HydroWIRES Initiative / Grid Reliability, Resilience, and Storage

This section provides full evaluation results for the HydroWIRES Initiative and strategy; an overview of the scoring for all projects within the Grid Reliability, Resilience, and Storage activity area; the review panel lead's summary of reviewer comments in response to the evaluation criteria; and full evaluation results for individual projects.

### Activity Area Score Results

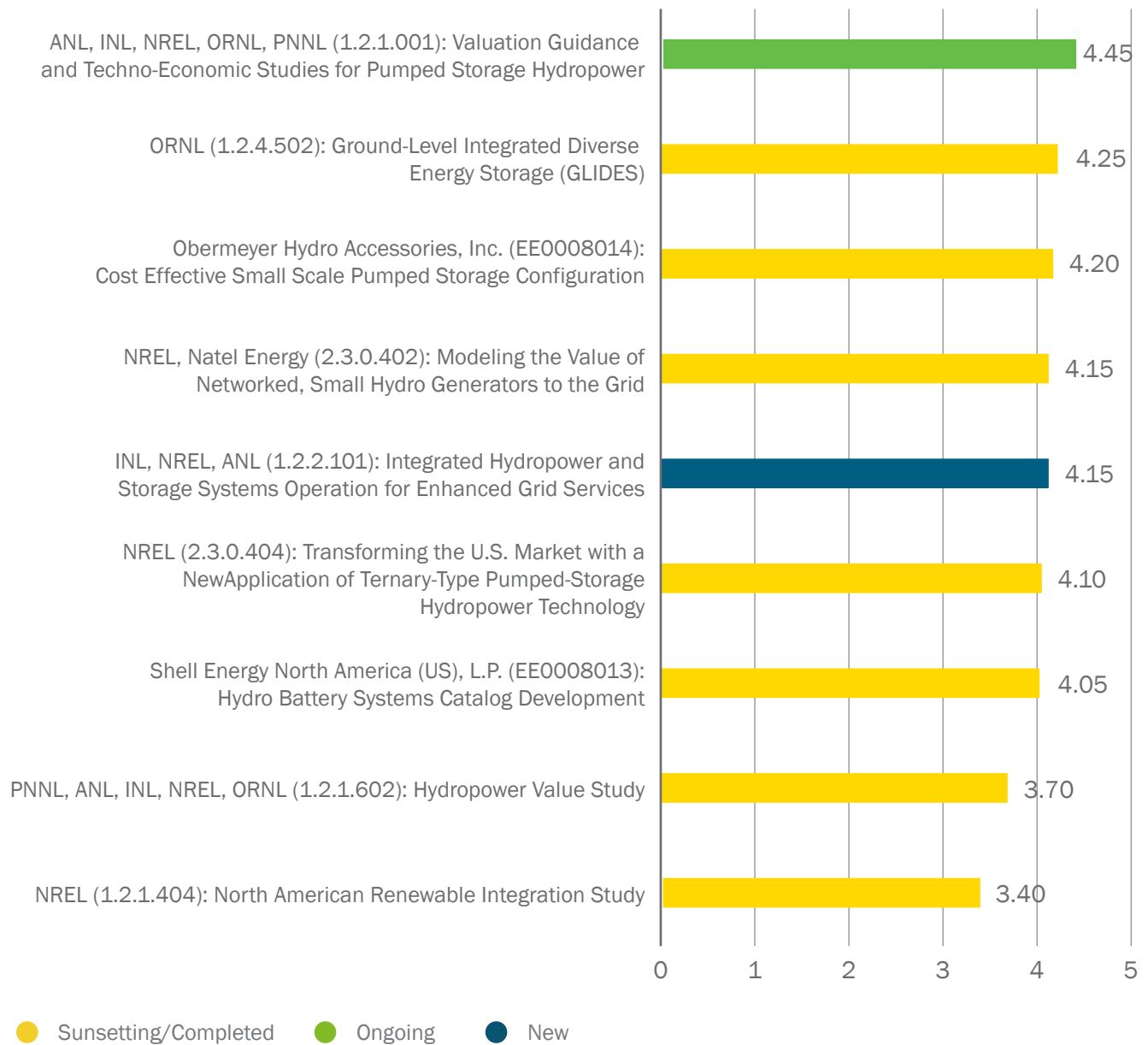
Figure 12 summarizes the weighted score of the HydroWIRES Initiative strategy and average reviewer score according to each program evaluation criterion. Figure 13 shows the average weighted score for each project in the Grid, Reliability, Resilience, and Storage activity area.

**Figure 12. Average reviewer score of the HydroWIRES Strategy by program evaluation criteria**



Name	Average Weighted Score of All Projects
Grid Reliability, Resilience, and Storage	4.07

**Figure 13. Grid Reliability, Resilience, and Storage activity area—average weighted score by project**



## Activity Area Summary Report

*Prepared by the Review Panel Lead*

*Feedback from the Review Panel to WPTO*

The HydroWIRES program was viewed by each reviewer as a highly valuable program that will offer critical guidance for projects supporting the hydropower industry. The four key questions and supporting strategies provide an overall structure for the program and provide important guidance to the projects that are supported by this program. Support for this type of overall programmatic structure, to guide future research, is critical and should be supported into the future. WPTO should consider reviewing any overlapping study areas among the project portfolio to avoid duplication of research such as, overlapping bulk market studies. Other areas to consider are the role of hydropower in the distribution sector and the ability to manage “behind the meter” renewable resources. Several projects in the portfolio appear well suited for operation in a distribution system. The program should also consider providing additional project management guidance to the projects to ensure scope, schedule, and budget are effectively managed.

*Summary of all Reviewers’ Comments*

### Overall Impressions

Overwhelmingly, the reviewers supported and appreciated this program and the approach it has developed to focus research and guidance for the hydropower project portfolio. The structure of the program provides flexibility to allow projects to address new technology and evolution of the energy marketplace. As the program matures, it will be important to support leading research to help hydropower penetrate larger markets, including distribution systems, and integrate other technologies, including paring hydro with non-hydro technology.

### Program Strategy and Objectives

The stated goal of the HydroWIRES program is to research untapped hydro resources to support a rapidly evolving grid. To do this, the HydroWIRES program has developed four research areas and strategic objectives. All of the reviewers appreciated this approach and the presentation of these strategies as part of each project overview. These four goals and research areas are important for a grid-focused knowledge base and are directly aligned with WPTO objectives for innovation, public good, access to affordable and reliable energy, wisely investing tax payers’ funds, seeking input from stakeholders, and transparency.

Comments for each strategic area are:

- In the area of exploring value under evolving system conditions, there was a focus on the wholesale markets and bulk electric transmission system. As the grid evolves, it may be wise to also include review of opportunities to incorporate hydro into the distribution system.
- In the area of capabilities and constraints, the focus was on flexibility, modeling, and forecasting. It may be helpful to go further than the raw data and discuss the data inputs with the organizations collecting the information, use renewable inputs rather than grid upsets in analysis, and explore longer term energy storage for PSH technology.
- For operations and planning, the focus was on bulk electric grid projects. Reaching out to the ISOs and RTOs directly and not relying solely on data-based research can strengthen these areas. Also consider expanding the focus into the distribution system.

- The technology innovation area explored several types of innovative technology and provided an excellent overview of innovation in hydropower. Comments in this area included exploring different ways to combine various technologies with hydro to determine how each can benefit from the technology's different strengths. An example is the ternary technology and comparing this technology to conventional hydro and battery technology to help integrate renewables.

### **Program Portfolio**

The HydroWIREs program has done a very good job organizing projects that align with WPTO's mission and vision statements. During the peer review, all of the projects presented aligned well with the HydroWIREs program objectives and with WPTO's mission statement. Specific recommendations for the HydroWIREs program going forward are to provide projects with guidance on expanded outreach and to reduce overlapping study objectives. Several reviewers noted that expanded outreach to ISOs would be helpful to better refine the objectives of the projects. WPTO should ensure that all projects provide transparency and accountability in publicly funded research.

A key challenge going forward for the program is to support "behind the meter" renewable integration and microgrids. To expand this research area, reviewers recommended that the program expand from wholesale markets and the bulk electric system to include the distribution system. Also, more direct involvement of the ISOs and RTOs could provide additional details to supplement the data-focused work presented during this peer review.

### **Program Management Approach**

Many of the projects under the HydroWIREs program could have used better guidance on overall project management, including schedule development and presentation, overall project budgets, milestones, and risk management. Several peer reviewers recommended providing management guidance to include project schedules, budget overview for the entire project, project milestones, and go/no-go gates for the HydroWIREs program.

WPTO relies heavily on the exceptional technical capabilities and tools of the various national labs; WPTO should make a conscious effort to involve other industry technical experts to help with some of this effort. There are areas where there is no practical alternative to real world experience in planning and operating the bulk power system, which can help WPTO achieve the HydroWIREs goals.

Coordinating the research priorities of the projects at the program level to avoid overlapping research was another suggestion from several, but not all, peer reviewers. An example of overlapping research was noted when several of the HydroWIREs projects conducted studies on wholesale markets. In the future, the HydroWIREs program should consider one study of the wholesale markets that can be shared with other projects.

### **Stakeholder Engagement, Outreach, and Dissemination**

The HydroWIREs presentation and material did not discuss a specific outreach objective or goal for this program. Most reviewers had a hard time assessing the effectiveness of the outreach program and of getting the word out about the program in general. During the peer review, many of the projects presented focused their outreach on typical industry conferences and publications. It would be helpful for the HydroWIREs program to provide guidance to the projects on outreach and how to expand the reach of the program beyond the usual industry conferences and publications.

While not specifically stated in the summary, it seems as if WPTO will rely on the national labs to handle the dissemination of information during the "hands-on" phase of the project. A more definitive dissemination plan to inform the industry of goals, milestones, and achievements would be beneficial.

## Project Evaluations

# VALUATION GUIDANCE AND TECHNO-ECONOMIC STUDIES FOR PUMPED STORAGE HYDROPOWER

(WBS #: 1.2.1.001)

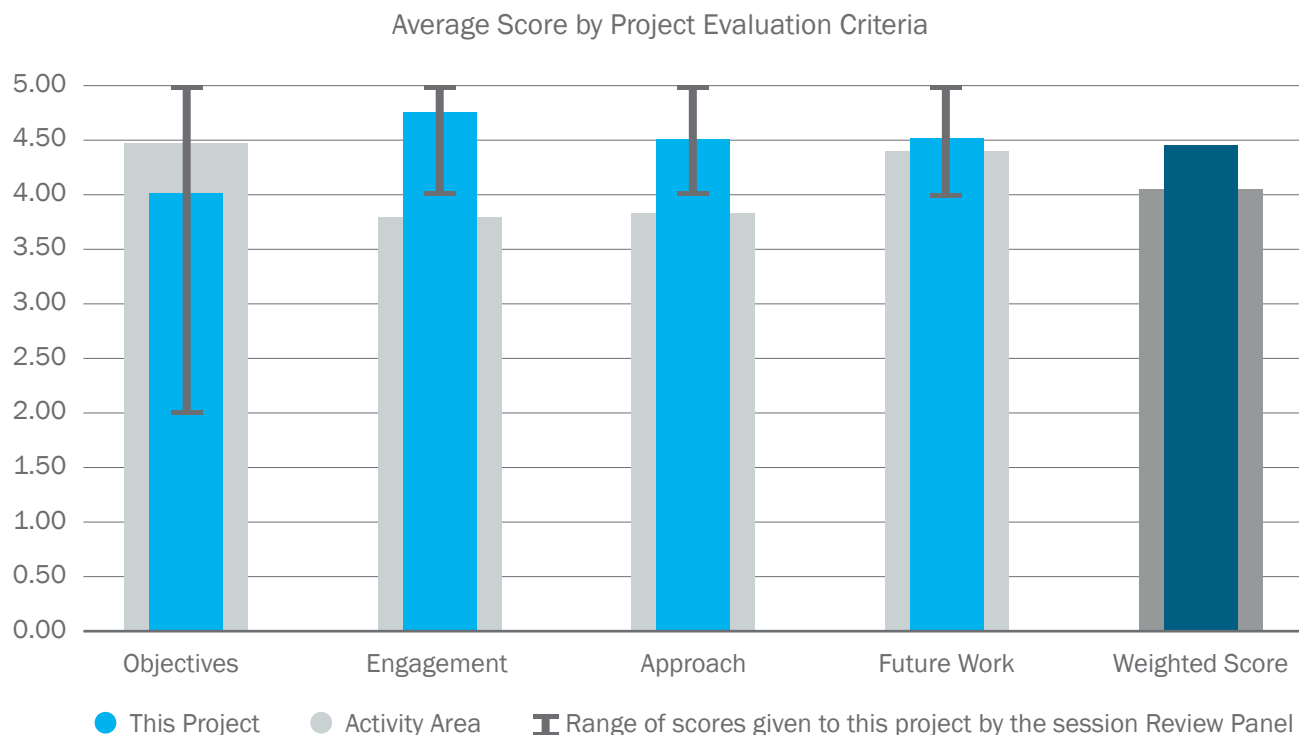
Recipient:	ANL, INL, NREL, ORNL, and PNNL
Principal Investigator:	Vladimir Koritarov
Project Type:	AOP
Project Category:	New Projects
Total Authorized:	\$1,767K
Total Costed:	\$1,193K

## Project Description

As an energy storage technology, PSH supports all aspects of power system operations. However, determining the value of PSH plants and their many services and contributions to the grid has been a challenge. The objective of this project is to advance the state of the art in assessing the value of PSH plants and their role and contributions to the power system. The specific goal is to develop detailed, step-by-step valuation guidance that can be used by PSH developers, plant owners or operators, and other stakeholders to assess the value of existing or potential new PSH plants. This valuation guidance will be applied to two competitively selected proposed PSH sites to assist the developers in understanding the value streams available from the project. This technical assistance effort will inform the development of the final, public step-by-step valuation guidance.

## Weighted Project Score: 4.5

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Future Work–40%.





## Summary of all Reviewers' Comments

### Overall Impressions

This is a highly relevant project that builds on past work to develop a useful guide, which will aid industry in valuing PSH via the development and dissemination of a clearly articulated methodology. The most important part of this project will be continuing support of the tool after the guidebook is fully developed to continue to sell the capabilities and ensure industry adoption. The information will need to be shared widely to industry and should be clearly focused on working with other related U.S. Department of Energy (DOE) activities.

### Project Objectives, Impacts, and Alignment with the Program Strategy

This project goal is to develop a guidebook describing how to value PSH projects, which clearly aligns with the Hydropower Program's overall strategy. The project articulated how the final guidebook will be used by the stakeholder community to better understand the economic benefits of PSH, which can be very impactful, especially when combined with similar DOE efforts across other technologies. The review panel expressed concern that the study may focus too narrowly on economic evaluation given industry's current knowledge of the operating capabilities of PSH; however, the hope is that clear valuation guidance will help open further PSH development going forward.

### End User Engagement and Dissemination Strategy

This project has a well-established engagement and dissemination strategy that reached all the vested stakeholders. The project performers have identified the project beneficiaries as electric utilities owning and operating PSH plants, PSH developers, grid and electricity market operators, public utility commissions and state energy offices, hydropower equipment manufacturers, engineering and consulting companies, as well as investment banks and other financial institutions. These end users will benefit from a better understanding of the actual value of PSH on the grid. By involving those currently looking to develop PSH facilities, state regulatory bodies, federal agencies, as well as other industry experts, the team has the technical know-how and access to multiple communication paths to disseminate critical information to those that need to know. The National Association of Regulatory Utility Commissioners is a uniquely positioned partner to contribute to the project via the Technical Advisory Group.

### Management and Technical Approach

The project performers have implemented a technically sound R&D approach to developing the PSH valuation guidebook and are working to demonstrate it in two case studies. The project management plan includes detailed tasks and a well-defined set of milestones. Project risks were not specifically addressed. The report described critical success factors, the challenges involved, and a rational plan to achieve success. The communication between the responsible parties and the dissemination of data back and forth is well documented. The team has put the technical values into seven cogent buckets, and within those particular buckets, they will look at parallel services, those provided at the same time, and individual services that can only be provided as singular values. This will allow them to attempt to quantify the value of each individual service. They will leverage the existing work of WPTO and the Electric Power Institute. This is a very organized and relevant approach to develop a methodology to quantify the value that PSH brings to the table.

### Technical Accomplishments and Progress

The project team lists the eight deliverables that will signify completion of the project. They further state that the project is on schedule and on budget. The most significant deliverable is going to be the PSH valuation guidebook. The project appears to be on schedule, having produced intermediate results consistent with the project team's management plan. While the specific project analysis is not innovative (similar work was

conducted by Argonne National Laboratory in past years), the development of a clear and concise valuation guidebook is a great step in clarifying how to create an apples-to-apples analysis methodology.

**Future Work**

It appears all future work is confined to two major efforts: (1) continued development of the software tool that will allow stakeholders to better utilize the valuation guidebook and (2) dealing with the economic evaluation relative to markets. It would have been beneficial to see more detail on exactly what the project proposed to do relative to the market value of PSH capabilities. The plan to develop a tool to aid in the final process is innovative and should be very useful. The key to ensuring the project's overall success will be in continuing support of the tool after project completion to continue to sell the capabilities and ensure industry adoption.

# NORTH AMERICAN RENEWABLE INTEGRATION STUDY

(WBS #: 1.2.1.404)

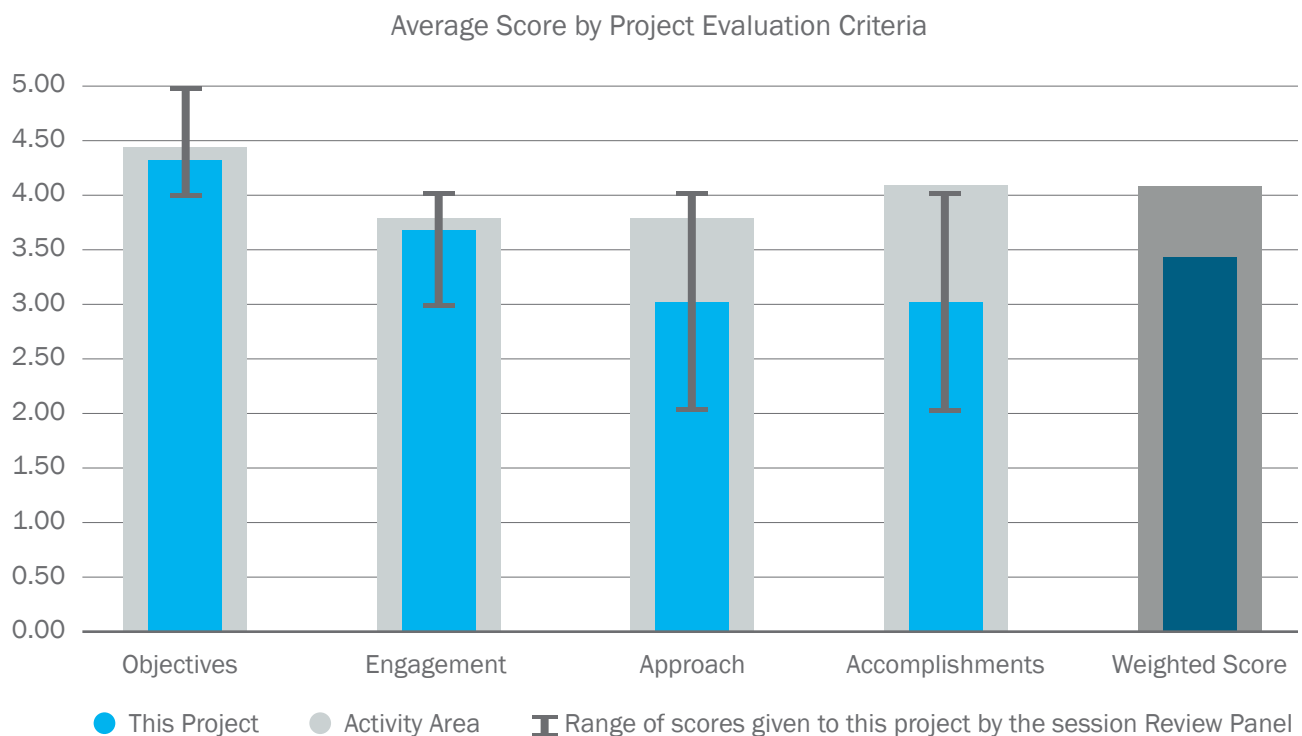
Recipient:	NREL
Principal Investigator:	Greg Brinkman
Project Type:	AOP
Project Category:	Completed and Sunsetting Projects
Total Authorized:	\$1,433K
Total Costed:	\$986K

## Project Description

The North American power system is evolving—how we generate and consume electricity is changing and becoming increasingly meteorologically dependent. A modern power system can take advantage of the diversity of resources and consumption to provide reliable, affordable, sustainable power to everyone. Opportunities will exist for new and existing grid technologies, including hydropower and PSH. The North American Renewable Integration Study will analyze the challenges and opportunities of transitioning to a modern power system in North America through the year 2050. It is a partnership between DOE, the Mexican Ministry of Energy, and Natural Resources Canada.

## Weighted Project Score: 3.4

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%



## Summary of all Reviewers' Comments

### Overall Impressions

This project is very large and complex, with many models employed. The report provided to the review committee did a good job of explaining the project's alignment with the Hydropower program objectives and strategies. Stakeholder engagement was good via the large and representative Technical Review Committee (TRC), with its semi-annual meetings for communications and feedback. It was evident that modern, cutting-edge modeling tools were both used and developed as part of this project; these tools required significant amounts of detailed future system data and assumptions. Based on the information presented in the project report, it was difficult to assess the technical soundness of the study. To do so would require an understanding of modeling details, validation activities, and TRC involvement. The project management plan was not clearly stated and did not show detailed objectives, milestones, and status in achieving the milestones and relevant go/no-go decision points. The dissemination plan was also not clearly presented. Overall, the committee was split on the usefulness of the project, with some of the members feeling it is essential to answer key questions that will allow development of a high renewables future, while others felt its conclusions are not surprising and could be expected by many in the industry.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The project report indicated how the work aligns with DOE's goal to "Understand, Enable, and Improve Hydropower's Contributions to Grid Reliability, Resilience, and Integration." The report showed that the project performers have considered the use/applications of their expected products and outputs, and they anticipate it will provide stakeholders with new methods, tools, and datasets to further their own understanding of planning and operations in a modern grid. Project relevance was described and is meritorious, including how successful completion of the project will advance the understanding of hydropower's impact and role in operations and reliability in the future, as well as the influence of wet and dry years.

### End User Engagement and Dissemination Strategy

The project report described how specific stakeholders and end users have been engaged through the TRC. The list of grid operators and planners and other organizations involved is long and very impressive. The TRC meets twice annually and appears to be engaged, providing thoughtful critique and input. However, the type of information exchange and input from the TRC was not articulated in the report or presentation, and this would be helpful in assessing the effectiveness of the TRC and ultimately the project. The report described a logical approach to stakeholder/end user engagement strategy and targets the electric grid planners, operators, and stakeholders with an interest in studying the future grid. The dissemination plan upon project completion of the project is not clear. Because there are no publicly available reports and few details in the review report, it was difficult to tell if the study will be effective in meeting its goals.

### Management and Technical Approach

The North American Renewable Integration Study is quite detailed and complex, with many datasets and assumptions necessary for its completion. Evaluating the project for its technical soundness would require a much more detailed description and/or presentation from the PI than what is available in the project report. From a high-level perspective, however, the project seems to be well set-up and using appropriate tools (ReEDS, dGEN, PLEXOS), as well as developing some useful new tools (PRAS and datasets). The project team is mainly using the capacity expansion model and the production cost model, both of which are appropriate for the study. However, without understanding the study set-up, assumptions, resolution, etc.,

along with the level of interaction and review of grid planners and operators, it is difficult to determine if the project results will be effective or not.

Within the brief report, the project management plan was described in general terms. The plan included a few high-level milestones but did not present detailed information about schedule and milestones. Thus, the reviewers could not determine if the management approach was well-designed or effective. Risks were not identified, though there were certainly many, such as the data exchange between countries, etc. There did not appear to be any go/no-go decision points in the project.

The report did not substantially address critical success factors or the challenges that must be overcome to achieve success.

### **Technical Accomplishments and Progress**

The project report described the questions that will be answered by the study and, in general terms, the new tools and datasets that will be made publicly available to support future studies. The summary highlighted some of the assumptions involved in running the study, such as meteorological, distributed energy resources, capacity expansion, outages (generation and transmission), extreme events, nodal production costing, etc., but it did not provide details on the data. Related to hydropower, the report did not provide any specific detail about how modeling hydropower in wet and dry years was conducted. Additionally, no description was provided about existing limitations in modeling hydropower in the tools/techniques used, nor how this study will overcome those limitations. The decision to “cloister” results from the project until its completion made it very problematic to assess the accomplishments. During the review presentation, the PI did present some interesting results and answered numerous questions, but to truly assess the technical accomplishments, a longer presentation focused on the project goals, milestones, and outcomes would have been necessary.

### **Future Work**

Future work was briefly mentioned in the report in terms of completing the remaining tasks. The review committee felt that stakeholders—especially those listed as beneficiaries of the work—should have a voice in identifying the direction of the other future work related to the North American Renewable Integration Study to ensure its usefulness.

## HYDROPOWER VALUE STUDY

(WBS #:1.2.1.602)

<b>Recipient:</b>	PNNL, ANL, INL, ORNL, and NREL
<b>Principal Investigator:</b>	Abhishek Somani
<b>Project Type:</b>	AOP
<b>Project Category:</b>	Completed and Sunsetting Projects
<b>Total Authorized:</b>	\$1,440K
<b>Total Costed:</b>	\$1,395K

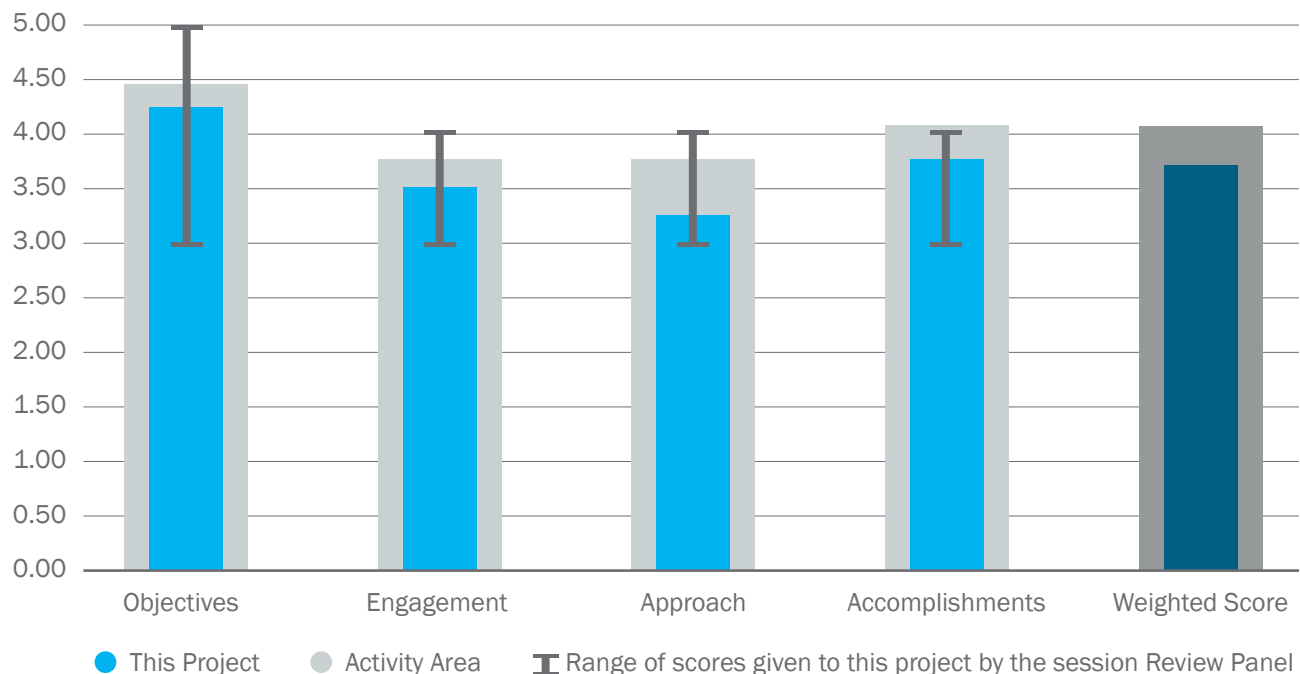
### Project Description

The primary purpose of this project was to comprehensively understand the current landscape of hydropower operations and the resulting value of resources in power markets across the country. The project was designed to lay out the foundation for future research that enables the comprehensive understanding of the value of hydropower resources in a variety of future grid states.

### Weighted Project Score: 3.7

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%

Average Score by Project Evaluation Criteria





## Summary of all Reviewers' Comments

### Overall Impressions

The project presented an interesting approach to understanding the potential hydropower has toward the reliability and resiliency of the grid based on past historical hydropower performance. However, as presented, producing large volumes of data based on historical information with the intent of doing some form of statistical trending may provide value to only a small subset of the overall general stakeholder body. The review team expressed some concerns about how the data would be used by the general stakeholder community and who would benefit.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The project team described how this effort will contribute to the Water Power Technologies Office's overall resiliency and reliability goals and identified potential industry beneficiaries. Project goals would be accomplished through trending of existing hydropower operational performance. The historical data collected was gleaned from publicly available sources like FERC.

### End User Engagement and Dissemination Strategy

The project team identified hydropower plant owners and operators, power system operators, marketing entities, and the ISO/RTO community as potential beneficiaries of this effort. These entities functioned in more of an advisory role because the operational data used in the analysis was primarily mined from public sources. While the report indicated results have been presented over time at various technical conferences, there were no details on what workshops and what feedback the project team received back at those workshops. Overall, the review team felt there were not enough details to determine exactly what the data entailed and how it was going to be used going forward.

### Management and Technical Approach

The review team felt the project had a technically sound research approach using publicly available data and national laboratory expertise. There was concern that use of publicly available historical data may not have provided as much insight as using more detailed data, which could be obtained from operating entities (i.e., the ISO/RTO community), would. The review team questioned why the ISO/RTO community, who has more detailed data at their disposal, would they benefit from having it reported back to them in a less granular format through this effort. The summary presented some historical hydropower performance on the Chelan facility, but there were no accompanying details on exactly how the plant was operating during that period. There also was a general lack of data specificity (e.g., how much of the total U.S. hydropower resources were included in reporting, were all hydropower types included, how was the data broken down, what specific operating timeframes were considered, etc.). The summary report did not contain a detailed project management summary with individual milestones, assigned national laboratory responsibilities, associated accomplishments, go/no-go decision points, and budget/project controls.

### Technical Accomplishments and Progress

The project team was able to present a limited subset of the results of their research. While the results did suggest some potentially insightful observations on various hydropower operations in certain areas of the United States, there appeared to be gaps in understanding exactly what data was used, how it was coordinated, and how representative of the overall hydropower industry it was. The review team recognized that there is a significant amount of data that has been collected; however, the difficult task is organizing that data so that significant and valuable trends can be obtained. The review team had concerns with the use of publicly

available data rather than actual detailed operating data to drive an analysis of the value of hydropower toward grid resiliency and reliability. The review team further questioned the overall value of this effort to the greater stakeholder community.

**Future Work**

The project team did propose 10 additional areas as candidates for future research. Careful consideration should be given before advancing them forward. The review team does not think all of them merit continued research without additional detail on goals, objectives, and methods for research. Any future work must include key stakeholders, and the project team should not be proposing their own future scope without outside engagement.

# INTEGRATED HYDROPOWER AND STORAGE SYSTEMS OPERATION FOR ENHANCED GRID SERVICES

(WBS #:1.2.2.101)

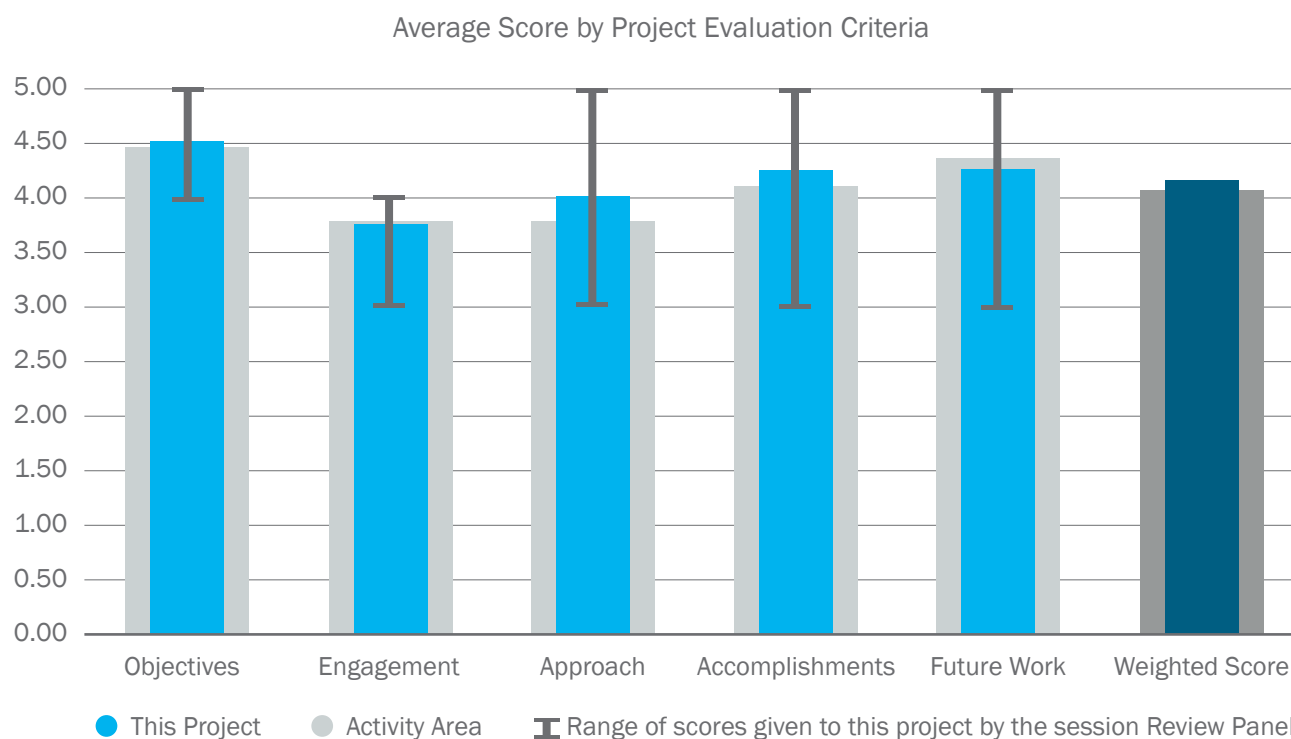
Recipient:	INL, NREL, and ANL
Principal Investigator:	Thomas Mosier
Project Type:	AOP
Project Category:	Ongoing Projects
Total Authorized:	\$2,488K
Total Costed:	\$2,217K

## Project Description

This project demonstrates the technical potential and economic benefit of co-locating and coordinating hydropower plants with energy storage devices to create “virtual reservoirs.” These virtual reservoirs enable the integrated system to contribute essential reliability services and participate in ancillary services markets. The approach is agnostic to the type of energy storage and, in some cases, may benefit from a combination of energy storage technologies. For example, digital simulations demonstrate that hybrid systems composed of batteries, supercapacitors, and flywheels can leverage the unique performance characteristics of each storage technology, leading to better performance than systems employing only one energy storage type. The approach is also applicable to multiple types of hydropower plant characteristics. As a starting point, the project focused on demonstrating that energy storage can enable a run-of-river hydropower plant to perform like a hydropower plant with reservoir storage. In partnership with Siemens, the project team developed a centralized control scheme, the Smart Energy Box, to coordinate the operation of energy storage devices and one or more hydropower plants. The project also includes cost-benefit analyses that consider the increased ancillary services’ market performance and capital and operational costs of the storage system.

## Weighted Project Score: 4.2

*Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work*



## Summary of all Reviewers' Comments

### Overall Impressions

This project was viewed as a highly valuable research area that can better optimize existing infrastructure and also have the ability to incorporate new technology within existing hydropower resources to better integrate renewables and provide grid services. The peer reviewers appreciated that the project team used existing models and leveraged previous research. Overall, the project would benefit from a broader dissemination strategy.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The project ties into the overall program goals very well by utilizing existing infrastructure and combining it with new technology to provide grid services and renewables integration. This is a good example of using existing infrastructure to meet new grid integration needs with technology. The panel thought that the project could be expanded beyond ancillary services and renewable integration to include energy storage and other services and technologies.

### End User Engagement and Dissemination Strategy

End user engagement in this project has come via partnership with Idaho Falls Power, Siemens, and American Governor. Working with a host utility provides value and real-time operational experience to the project team. This approach ties into the identified end users who are owners and operators of existing hydropower facilities. To date, the project team has made presentations at industry conferences with others underway. Since the target audience is hydropower owners and operators, making presentations at industry-focused conferences and submitting content to industry-focused publications makes sense. The project needs a better plan on disseminating results to a broader stakeholder audience. For example, the project team should consider additional outreach to ISOs and RTOs on how they can utilize this study and also to better understand how they would interact with the “Smart Box” instead of each unit.

### Management and Technical Approach

This project brings a wealth of technical background and knowledge to the table by coordinating three respected national labs, as well as practical hydropower plant operation and equipment by including Idaho Falls Power, Siemens and American Governor. This fits very well with the project objectives and target audience.

The technical approach for the project presentation included key project milestones and deliverables on an annual schedule, which was very helpful for an overview of the project. Additional detail on the project schedule and how the milestones are incorporated into a detailed project schedule would help reviewers understand how the project objectives would be achieved. Go/no-go gates were also provided for work that was completed.

The project's technical approach was well thought out, utilizing the virtual reservoir concept coupled with innovative control technology and existing infrastructure, including a cost-benefit analysis. The underlying premise of the “Smart Box” is its ability to optimize performance. The summary, however, did not explain what the optimization objective was, and optimization can mean many things (e.g., maximizing energy storage for future needs, maximizing reactive support, maximizing primary frequency response, etc.). At the presentation, it was clear that the optimization function would be user configurable, which is a desirable design capability. This approach took full advantage of the technical experience that was developed as part of the project's management approach.

## **Technical Accomplishments and Progress**

To date, the project has met its goals and is below budget. The project created virtual reservoirs by modeling existing systems; it then used existing model, CHEERS, to show how the system can be integrated into markets. Additionally, the summary claims of other advantages to the grid, specifically in the areas of frequency response and black start. While these may be a technical accomplishment, it is unclear exactly how they were accomplished, and additional details should be provided. The project report demonstrated that the team has made progress in reaching their objectives. No information was provided from previous peer reviews or industry feedback.

## **Future Work**

The project report did not clearly present the work plan that is remaining, beyond providing a couple bullets of upcoming work. From what was presented, future work includes expanding the services provided by the virtual reservoirs and performing a field demonstration of the capability to provide black start services in 2020. However, it was not clear if this future work will only focus on demonstrating black start or will also demonstrate in the field the results of their digital simulation of coordinating reservoirs to provide frequency regulation while enhancing revenues. The reviewers suggested that grid security and ISO outreach be included, and the project team should address grid cybersecurity or NERC standards review of the technology. Future work should include a go/no-go gate. Furthermore, the project would benefit from a clearer dissemination strategy that describes how the broader community will be informed about this project's successes and can potentially take advantage of them.

## GROUND-LEVEL INTEGRATED DIVERSE ENERGY STORAGE (GLIDES)

(WBS #:1.2.4.502)

Recipient:	ORNL
Principal Investigator:	Ayyoub Momen
Project Type:	AOP
Project Category:	Completed and Sunsetting Projects
Total Authorized:	\$1,100K
Total Costed:	\$830K

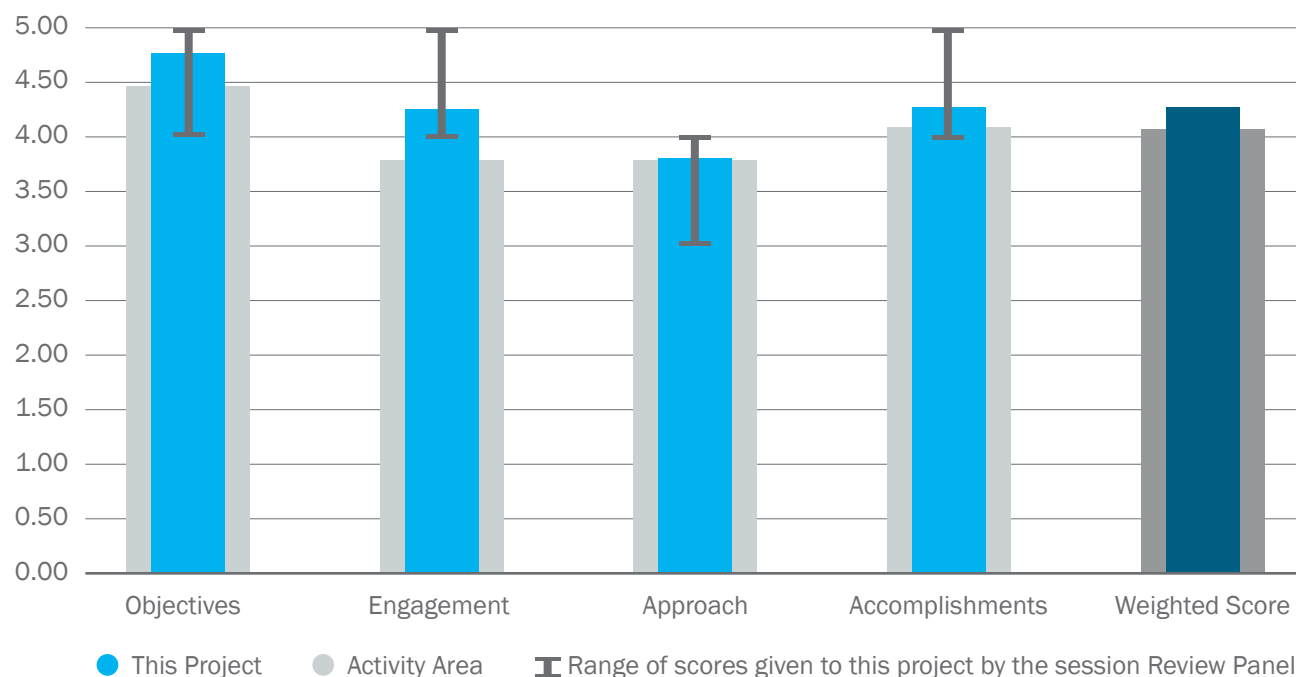
### Project Description

This project explores the value proposition of a modular PSH technology with the potential to fill the technology gap between small-scale battery technology and large grid-scale PSH. ORNL researchers invented the Ground-Level Integrated Diverse Energy Storage (GLIDES) technology, a cost-effective, scalable, flexible storage system that can provide a broad range of ancillary services. GLIDES's modularity, energy density, scalability, and environmental benignity position it well to mitigate many of the market and regulatory barriers faced by large PSH.

### Weighted Project Score: 4.3

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%

Average Score by Project Evaluation Criteria





## Summary of all Reviewers' Comments

### Overall Impressions

This is a well-organized and highly relevant project that is working to develop a modular PSH system based on the use of pressure vessels rather than large water reservoirs. While still in an initial prototype phase, the project has considered a number of potential applications. The market analysis associated with the project seems very promising, although reviewers encourage the team to look beyond transmission level and analyze behind-the-meter applications. The review panel hopes to see the Hydropower program continue the development of this technology.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The project clearly contributes to the program's strategy to understand, enable, and improve hydropower's contributions to grid reliability, resilience, and integration. The output of this project is to quantify the value proposition, identify cost reduction opportunities, and prioritize future research directions for the GLIDES modular PSH technology. This project is highly relevant and will advance the state of technology, as well as the viability of commercial applications by identifying and quantifying GLIDES's improvement over competing energy storage technologies. While the market analysis is a great addition to the project, the project team should consider distribution system market analysis rather than wholesale, as this is the more relevant market segment. GLIDES scalability allows it to be used at both grid and distributed scales, such as residential building applications.

### End User Engagement and Dissemination Strategy

The project involved a wide stakeholder group, including various DOE departments, Tennessee Valley Authority, University of Tennessee, and ORNL's Manufacturing Demonstration Facility. However, the project team did not engage outside of the governmental organizations listed. The project performers identified that the beneficiaries from this project will be electric utilities and the electric sectors, residential buildings, military applications, and commercial buildings. Because this technology can be utilized in industrial setting and on sub-transmission level distribution systems, it may be wise to expand the outreach to include other folks who might be able to benefit outside the traditional utility and industry audience. The overall dissemination plan was briefly mentioned but is quite limited. ORNL indicated that it is still working on prototype development and working to expand engagement though attempts to partner with an outside entity to commercialize the technology, which the review panel strongly supports. It would be useful if the project dissemination plan included a technical report that documents the experimental mock-up and performance, the cost model that was developed, and the results of applying the cost model.

### Management and Technical Approach

The reviewers agreed that the team had a strong overall approach to developing cost and performance modeling capability and implementing economic analysis, and, in general, a good management structure. The project was broken into three major efforts: (1) costing and designing the facility along with building a prototype; (2) determining the market value of having such storage resources available on the transmission and distribution systems; and (3) building a techno economic model that would allow for marketing the unit in various regions. Limited information was provided related to the specifics of the project management plan (i.e., specific milestones) or discussion of risks. The project should consider how this technology will operate in a distribution sub-transmission level system since this appears to be where the potential target customers are located. The reviewers believe performers showed a strong understanding of critical success factors.

### **Technical Accomplishments and Progress**

The project team has made progress in reaching their objectives based on their project management plan, as articulated in their list of technical accomplishments. In particular, the project seems to be yielding great benefits and is developing a good overall understanding of the cost reduction pathways for future development. The evaluation of a number of potential pressure vessels is a great way to broaden the horizon for potential future applications of the overall concept, concluding that this project is feasible for both small-scale systems, as well as large grid-scale systems. The research in wholesale markets shows that this type of system has the potential to create a positive revenue stream. It was noted that the revenue stream would be very dependent on what ancillary markets the storage resource would participate in and that was all relative to where it was in the pressure cycle. More work is needed to identify how this system might create value in the distribution system.

### **Future Work**

The program should continue to support the GLIDES concept. Potential application for commercial and residential building systems could be a game changer given the limited environmental impacts of GLIDES compared to lithium-ion battery technology. Furthermore, it would be beneficial to provide additional research for projects located at industrial and commercial sites served by the distribution system. This project will have a different economic evaluation and likely not participate directly in the organized wholesale markets. Evaluation of peak demand shaving, energy savings, and use of renewable energy, as well as distribution reliability services, would be helpful.

# MODELING THE VALUE OF NETWORKED, SMALL HYDRO GENERATORS TO THE GRID

(WBS #:2.3.0.402)

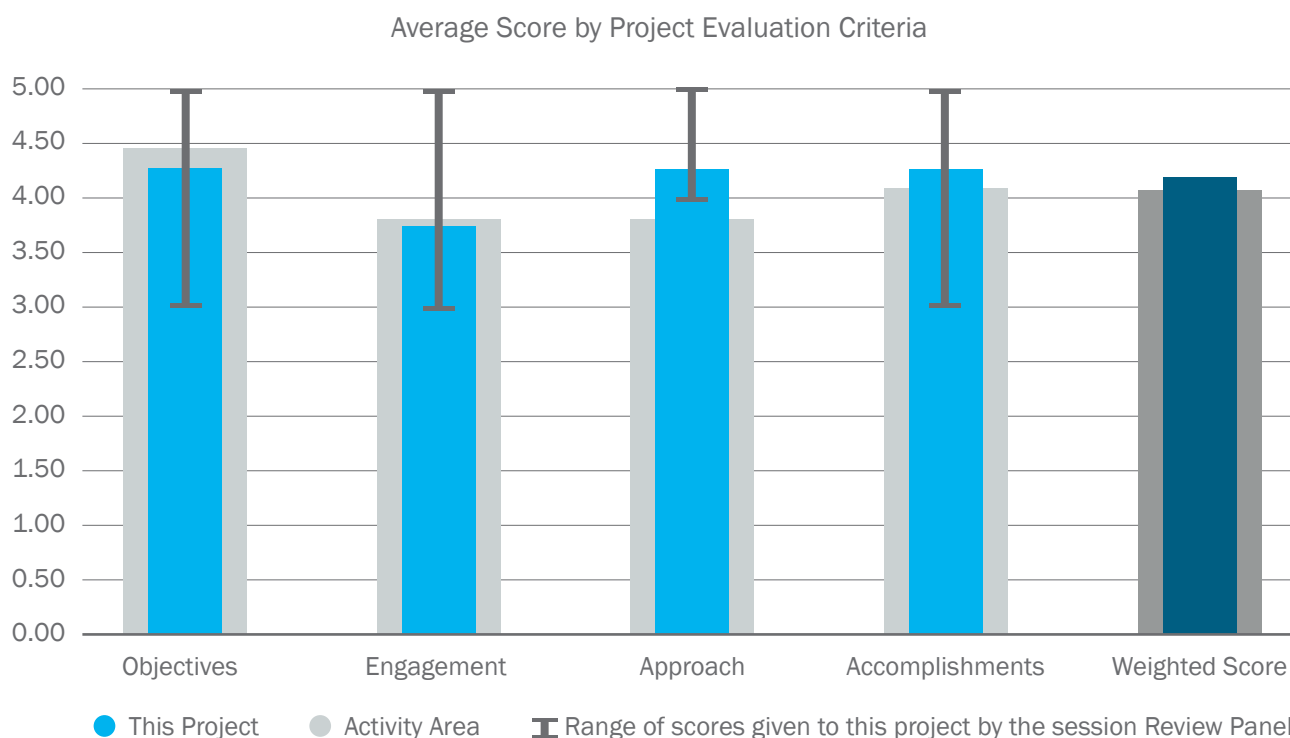
Recipient:	NREL and Natel
Principal Investigator:	Greg Stark
Project Type:	AOP
Project Category:	Completed and Sunsetting Projects
Total Authorized:	\$185K
Total Costed:	\$144K

## Project Description

DOE's SBV program provides U.S. small businesses access to DOE's national laboratories, helping them tap resources to overcome critical technology challenges for advanced energy products. Through this program, Natel utilized NREL's grid analysis capabilities to better understand the potential grid value of a cascading network of Natel's hydroEngine® turbines during dry, typical, and wet operating years. This project used operational optimization to quantify net revenue and the ability of the system to meet grid needs for varying hydrologic conditions. NREL also assessed operations under multiple operating cost scenarios, storage volumes, market types, and plant locations.

**Weighted Project Score: 4.2**

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%



## Summary of all Reviewers' Comments

### Overall Impressions

The project report effectively described how this project, which was a successful example of the SBV program, contributed to the Hydropower program's strategies and approaches. The beneficiaries and end user engagement strategy were well described in this low-impact hydropower project. The project was completed on time and on budget. The project accomplished what it set out to do, ultimately providing an ability to understand the value of networked low-head hydro, its impact on downstream flows, and the effect of flow constraints on revenue.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The project report effectively described how the SBV project contributes to the program's strategies and approaches. The report also described the use of the project outcomes, which included understanding the value of networked low-head hydro, its impact on downstream flows, and their relationship to revenue. The project report also addressed the relevance of the project and how it advances the state of technology for networked, low-head hydro, and demonstrated the viability of such a network in commercial applications. Another main tenant of the proposal was to demonstrate how optimized unit commitment of cascading hydropower can be used to respond to grid needs, which was not necessarily delineated in the summary.

### End User Engagement and Dissemination Strategy

Beneficiaries of the project have been identified as the SBV applicant (Natel), other similar companies, and irrigation districts with potential for low-head hydropower applications (such as the Imperial Irrigation District) or river systems (such as the Yuba River). The project explained stakeholder (i.e., project partner) engagement. Project results were published in a journal article and a conference paper; however, the audience was primarily manufacturers and those participating in the study. Limited information was provided on the dissemination plan and how results will be shared beyond the project awardee. With such a positive environmental result, it seems like results should also be made more widely to environmental groups, as well as through their conferences and meetings.

### Management and Technical Approach

The approach to perform the project analysis was technically sound. The management approach included researchers, modelers, utilities/end users, and the manufacturer. Additionally, the project accepted input from expert advisers. As a result, the project was able to overcome some technical difficulties and regroup using a different modeling approach, while staying on schedule and within budget. The modified analysis approach appears to have been appropriate given the inconsistencies encountered with the originally planned production cost model. This glitch required the team to use in-house software. From the way it is explained in the summary, that software did not allow some of the sensitivity testing that the group originally intended to do but did enable them to refine other aspects of the study such as environmental impact on river flow. The critical success factors were addressed, and a technically viable solution was achieved despite challenges.

### Technical Accomplishments and Progress

The project performers met their objectives and completed the project. The most important accomplishments were identified, as well as the most important challenge. The results revealed that the hydro generators could operate in a manner to achieve grid and financial objectives, while also providing a positive environmental result. While the technical accomplishments of this study clearly show multiple benefits to small hydropower facilities that are configured in a cascading manner on a common waterway, it did not clearly demonstrate any of the value to grid reliability and resiliency.

# TRANSFORMING THE U.S. MARKET WITH A NEW APPLICATION OF TERNARY-TYPE PUMPED-STORAGE HYDROPOWER TECHNOLOGY

(WBS #:2.3.0.404)

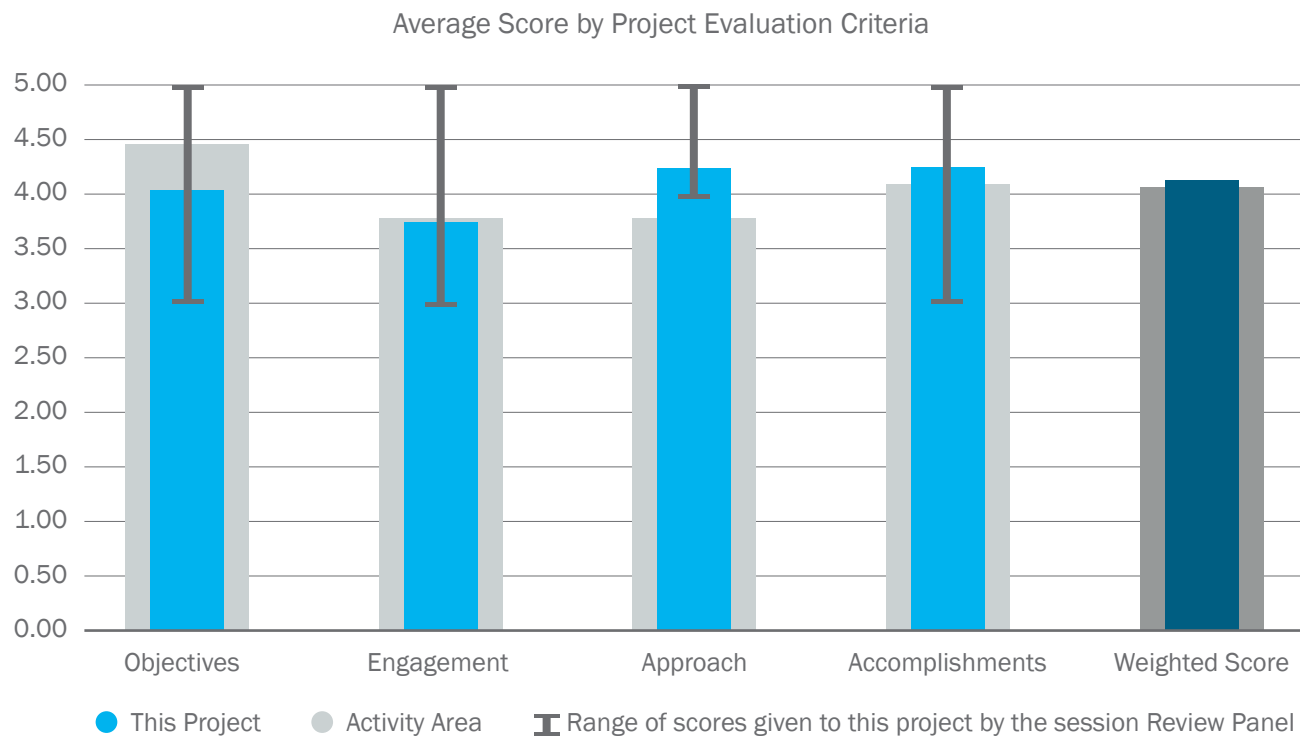
Recipient:	NREL
Principal Investigator:	Mark Jacobson
Project Type:	AOP
Project Category:	Completed and Sunsetting Projects
Total Authorized:	\$1,500K
Total Costed:	\$827K

## Project Description

The overarching goal of this project is to assess and quantify how innovative, fast-acting advanced PSH systems can solve the grid integration challenges facing U.S. renewables in the most cost-effective manner. This project focuses on ternary PSH technology, as well as quaternary PSH, and couples them with sophisticated transmission monitoring and control equipment (i.e., dynamic transmission) as a solution to the integration issues.

**Weighted Project Score: 4.1**

*Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%*



## Summary of all Reviewers' Comments

### Overall Impressions

The project team did a good job of modeling the ternary PSH technology and then adding the quaternary PSH technology midway through the project. The project presented a nice, detailed project management plan with many milestones enumerated. The project could have had more of a focus on, and explanation of, one of the primary project objectives, to determine how ternary PSH can aid in the integration of renewable energy into the grid rather than an analysis of response to grid disturbances.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The project identified four major goals: (1) how ternary PSH pairs with renewable energy and the services it can provide for grid stability, (2) R&D support for this technology, (3) R&D for closed-loop PSH, and (4) big data access and management using a reference plant in Montana.

The project goals align with overall program objectives of improving grid resilience and reliability by better integrating renewables on the grid. To accomplish this, the team studied ternary PSH system paired with a phasor measurement unit, flexible alternating current transmission system device, and renewables that looked at revenue stream, system stability, and ancillary services in the Northwest power pool and CAISO. It was not clear how this project would achieve this goal due to the addition of a different technology midway into the project. The ternary technology seemed to be superseded by the quaternary technology without changing the project goals or objectives. Furthermore, it was not entirely clear how the state of the art will be significantly advanced, or the eventual impact of successfully meeting the project goals.

### End User Engagement and Dissemination Strategy

The project team has already done considerable outreach with several journal articles and presentations at industry conferences. Additional outreach is planned after the scheduled completion of the project in September. In addition, the project has targeted utilities that have significant renewable generation on their system to get specific feedback from end users and offtakes. The project team also discussed the results with CAISO. Additional outreach to ISOs is recommended.

### Management and Technical Approach

The project management approach included several technical experts and engineers familiar with this technology. The narrative project summary included a project schedule and milestone activities with due dates; the project was well organized and clearly presented its goals, schedule, and milestones. Information about this project was disseminated at some conferences via technical journals. It is unclear if those technical journals were distributed only to the hydropower community or to the stakeholder community at large.

The technical approach included a full analysis of the cost and capacities of the technology and then modeling it in the market. Because of the very fast response from both the ternary and quaternary technology, the existing models did not fully capture the benefits. The project team did a very good job in adjusting to this new technology to fully capture the benefits of the project in the market. Project did not include evaluation of other technologies that can offer the same services (e.g., batteries).

Project risks were not specifically identified. Challenges were mentioned, but there was not enough detail on how they were overcome, or lessons learned.



### **Technical Accomplishments and Progress**

The project team presented seven technical accomplishments that support the project objectives. All of these milestones demonstrate the value-add of T-PSH. They had to overcome several technical and modeling obstacles, but they were able to complete the project on time and within the approved budget. A new project analysis was added to the project, but there was no justification or adjustment to overall project goals when the new technology was added. It is unclear how the original project would have turned out if the new technology had not been added.

### **Future Work**

The project is near completion. While the project demonstrated the value of adding T-PSH to the system, the summary lacked any specifics on exactly how the T-PSH can be integrated with a heavy penetration of renewables, dynamic transmission line ratings, and FACTS, which was alluded to in the earlier part of the paper. There should be more detailed reporting of details.

## HYDRO BATTERY SYSTEMS CATALOG DEVELOPMENT

(WBS #: EE0008013)

<b>Recipient:</b>	Shell Energy North America
<b>Principal Investigator:</b>	JT Steenkamp
<b>Project Type:</b>	FOA 1455: HydroNEXT: Innovative Technologies to Advance Non-Powered Dam and Pumped- Storage Hydropower Development
<b>Project Category:</b>	Completed and Sunsetting Projects
<b>Total Authorized:</b>	\$2,188K
<b>Total Costed:</b>	\$958K

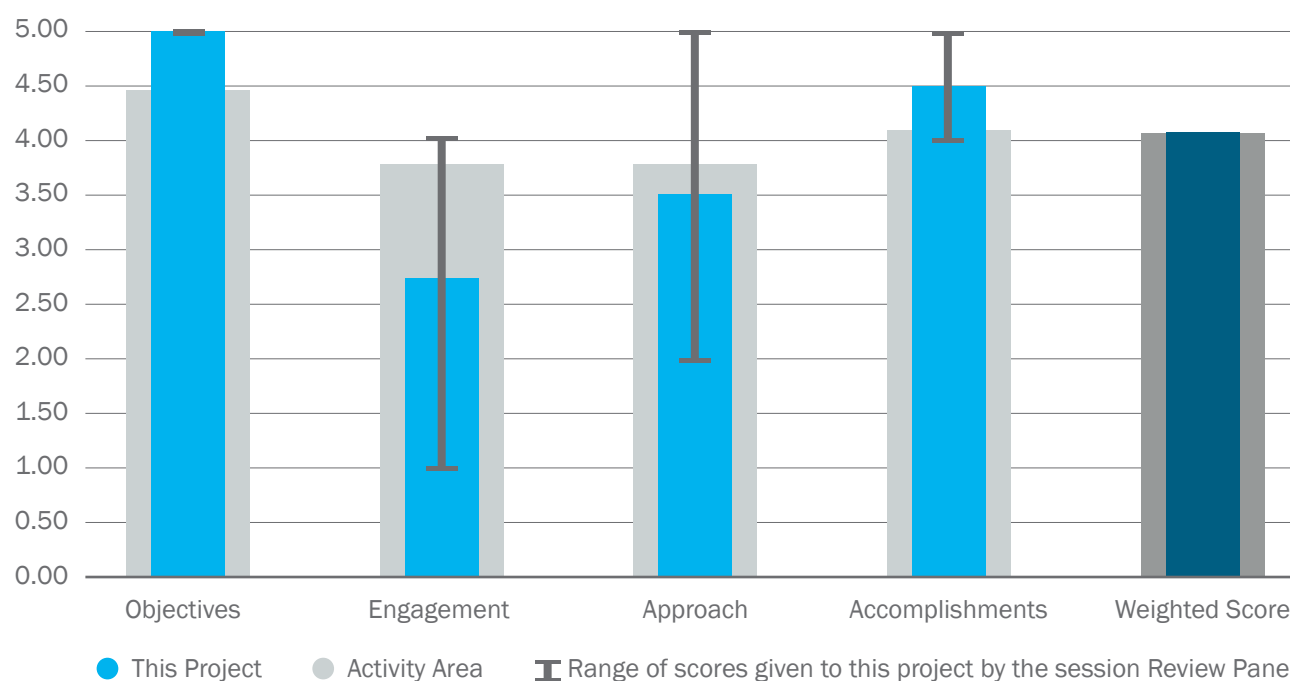
### Project Description

Shell Energy North America is developing an innovative, completely modular 5-MW PSH system in which a floating membrane and a water storage tank comprise each reservoir for a closed-loop configuration. One project goal is to enable additional replication and additional configuration opportunities. The project will have a relatively small footprint, as the civil earthwork will be reduced as much as possible. Through this award, Shell Energy North America is determining the feasibility of the floating reservoir through design, modeling, and testing of a full-scale prototype. Shell Energy North America will also deliver a detailed engineering design of the balance of systems using Pearl Hill, Washington, as a reference site. The design includes the tank reservoir, modular pump and turbine sets, penstock, modular electrical substation, and auxiliaries. Lastly, a market analysis is being conducted for the system in five market regions to identify value streams within the context of larger renewable energy portfolios.

### Weighted Project Score: 4.1

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%

Average Score by Project Evaluation Criteria



## Summary of all Reviewers' Comments

### Overall Impressions

The review team felt this project did bring forward some innovative approaches to improving the efficiencies and therefore the likelihood of small-scale PSH facilities being constructed. The ability to modularize the components and build them on this scale will be valuable especially in lieu of efforts to leverage existing oil and gas technologies. The review team did feel, however, that there was some degree of secrecy about certain aspects of the design components, innovation points, and potential information dissemination strategies in the project. There appeared to be some conflict between the developer who is looking to patent a product and go commercial and the engagement of the general stakeholder community. Overall, the reviewers had several questions about the viability and risks of the floating membrane component of the system that were not addressed in the summary.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The technical concepts and proposed advancements in this project align with WPTO goals, namely the development of an innovative, low-cost, modularized, PSH project that would provide a full range of grid services within existing markets. This project has identified several areas where it can contribute to the program's strategy and goals. The first is to better identify the services that a small modular PSH project can provide. These projects are unique in that they can connect in a more distributed manner rather than at grid scale, so they may offer different services. The project also proposed to identify a standard design to lower costs and a scalable solution for modular deployment. The use of commercially available industry membranes represents an interesting and innovative approach to building such facilities. By leveraging existing equipment and technology from the gas and oil industry, the project team simplified some aspects of the proposal and allowed them to effectively cost the project with a reasonable degree of certainty. This is a highly relevant project that could reduce huge cost and environmental concerns that have stalled the PSH industry.

### End User Engagement and Dissemination Strategy

The project team consisted primarily of Shell Energy North America and DOE, with some ancillary technical support from other entities. While the summary identified entities that the project team thought would benefit from the proposal, there appeared to be a lack of follow-up in disseminating information to the stakeholder community. While the project partners were all involved in detailed discussions throughout the effort, the project team did not feel the need to update the general stakeholder community.

### Management and Technical Approach

The project was broken down into four major tasks: (1) the floating membrane technology, (2) the balance of the PSH systems, (3) financial evaluation, and (4) lifecycle intensity assessment. Each task was assigned to a multidisciplinary team with expertise in technical design, modeling, and market analyses. Overall, the reviewers felt this was an innovative approach to small-scale, closed-loop PSH. The project has included a good check-and-balance type management approach, with a go/no-go gate between the two budget periods to mitigate project risks. While there was a clear approach to accomplishing the tasks in the project, there appeared to be a discrepancy between the actual budget and timeline. It was noted that the project had slipped with no accompanying explanation of why. More detailed milestones, timelines, go/no-go decision metrics, and accompanying budget updates would have made the review more thorough.

**Technical Accomplishments and Progress**

From a technical standpoint, the project demonstrated that the use of a prefabricated, corrugated metal, upper reservoir paired with a lower floating reservoir is a workable proposal for small-scale PSH. The project team did not address some valid project risks such as environmental impacts of the large storage facility at a high elevation, destructive impact risks to a floating membrane, and siting of penstocks. The review team felt the project team should have explored some of these project risks and commented on them in the summary. Also, from a strategic implementation standpoint, the review team felt this project is more appropriate for distribution systems rather than the transmission system. It did not appear that the project team considered this aspect.

**Future Work**

The review team would like to see this project continue with the development of a workable prototype. Future market analysis on similar sized technologies should consider distribution-scale market evaluations. Additional detail on project materials and testing should be part of any future project funding.

# COST EFFECTIVE SMALL-SCALE PUMPED STORAGE CONFIGURATION

(WBS #: EE0008014)

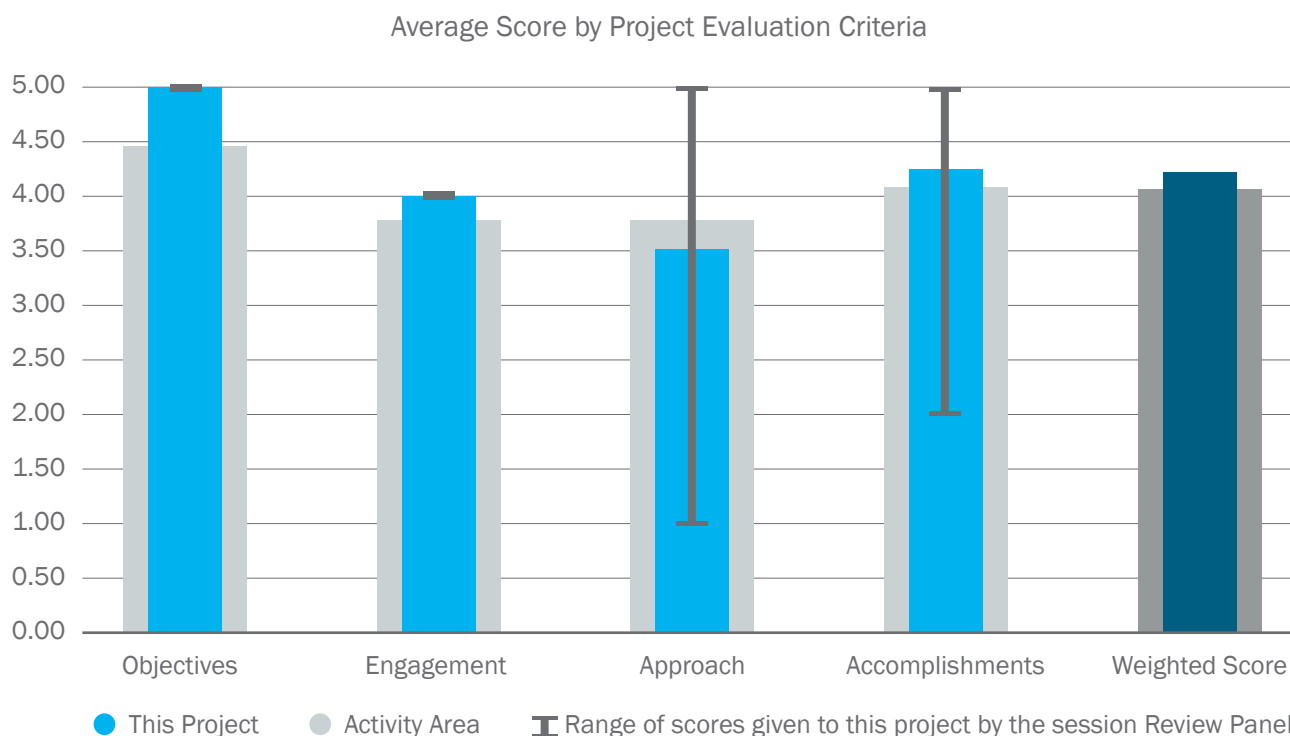
Recipient:	Obermeyer Hydro Accessories, Inc.
Principal Investigator:	Henry Obermeyer
Project Type:	FOA 1455: HydroNEXT: Innovative Technologies to Advance Non-Powered Dam and Pumped- Storage Hydropower Development
Project Category:	Completed and Sunsetting Projects
Total Authorized:	\$1,605K
Total Costed:	\$879K

## Project Description

The goal of this project is to design a cost-effective, small-scale, adjustable-speed PSH system optimized for the U.S. energy storage requirements. The technology is proven through concept design for exemplar sites, including estimated costs. The project demonstrates that the proposed technological innovation is commercially viable and that energy storage needs can be economically met with the proposed system. Using the developed project design, including cost estimates and ranges of application, the markets were analyzed to determine locations for installation opportunities.

## Weighted Project Score: 4.2

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%



## Summary of all Reviewers' Comments

### Overall Impressions

The reviewers generally had a very favorable impression of this project from a technical standpoint. The types of advancements in hydro turbine technology and design of the overall modularized storage facility has enormous industry potential. The review team did have some concerns about project management on this project. The concerns were not really related to the technical aspects of the project but more toward the lack of reporting about the budget, timelines, milestones, deliverables, and commercialization of the project.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The reviewers felt that this project fully aligned with the goals set by DOE. The proposal offered up some very innovative approaches to smaller scale PSH facilities. Turbine design proposals lead to an increase in efficiencies that may help justify building these facilities. Also, based on the vertical design, the reduced footprint may make these types of facilities more palatable for siting, as well as more palatable to the environmentalists. The reviewers believe the project should continue to be funded if future funding is available for this type of work.

### End User Engagement and Dissemination Strategy

The review team felt that this project has a good cross section of various subject matter experts in the hydropower field. The approach to the study addressed mechanical, hydrological, and electrical aspects of the PSH facility. There did seem to be little information regarding potential environmental impacts (e.g., the potential impact on fish population). As progress was made, the pertinent information was disseminated to various entities within the hydropower community both in North America and internationally via workshops and technical publications. The review team believes that the project team kept the appropriate parties informed on this project.

### Management and Technical Approach

The project brought in experts from Auburn University, Micro-tunneling, and Small Hydro Consulting to help with the technical work. NREL was brought in to evaluate some of the marketing and cost implications. There was no significant information about how this team was effectively managed nor was there concrete and detailed information on budgets, timelines, or milestones. It would have been more effective in reviewing this project if explicit milestones with progress summaries were included.

This collection of experts did bring the necessary knowledge to design, prototype, and evaluate this innovative approach to PSH. The team encountered some serious technical challenges with the concept of a vertically installed turbine/generator/pump configuration, which required very innovative solutions.

The review team also felt that there was an over emphasis on contributing to grid reliability. These facilities, because of their small size, may be more suited to interconnection on the distribution system rather than transmission system. The review team felt there may be more opportunities by considering the lower voltage distribution systems. The inclusion of project milestones and go/no-go gates would have aided in the review to better understand how the project was managed.

### Technical Accomplishments and Progress

The review team felt this project accomplished several technical innovations across several different fronts on PSH. The project clearly demonstrated that the vertical PSH concept is workable and cost competitive. It was apparent the project team made some significant mechanical turbine design changes to make the vertical



concept work; these were very innovative and proved very effective. Additionally, the technical advancements were not confined solely to turbine design; as an example, they developed an innovative approach for hoisting the turbine/generator/pump configuration up the shaft for maintenance. The project will continue to move forward and develop a 40-KW prototype, which the reviewers supported. Additional technical advancements may be forthcoming from validation of the prototype. There was mention in the summary of successfully pairing the facility with a solar photovoltaic plant, but there was no follow-up detail, which reviewers would have liked to see.

### **Future Work**

The review team feels there are other potential applications and advancements that can be realized if this technology can be coupled with other projects, like GLIDES, and other DOE initiatives.

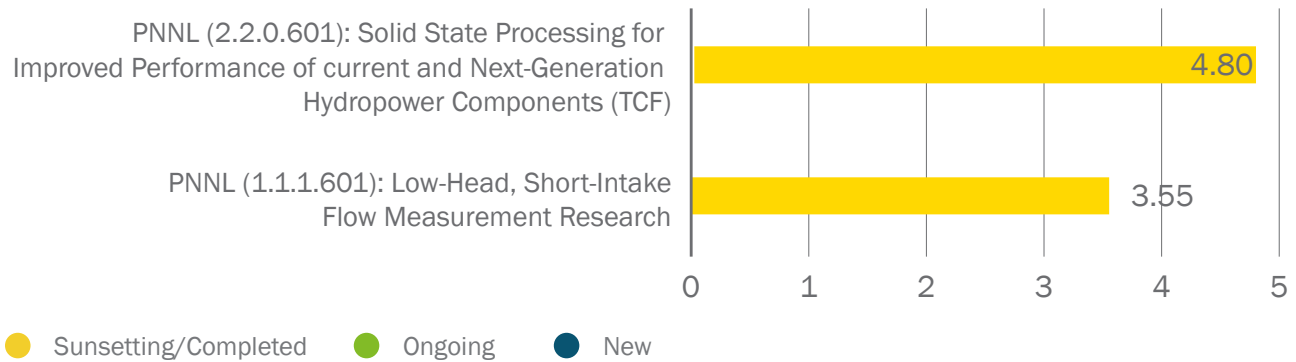
Modernization, Upgrades, and Security

This section provides an overview of the scoring for all projects within the Modernization, Upgrades, and Security (MUS) activity area (see Figure 14); the review panel lead’s summary of reviewer comments in response to the evaluation criteria; and full evaluation results for individual projects.

Activity Area Score Results

Name	Average Weighted Score of All Projects
Modernization, Upgrades, and Security	4.18

Figure 14. Modernization, Upgrades, and Security activity area—average weighted score by project



Activity Area Summary Report

Prepared by the Review Panel Lead

Feedback from the Review Panel to WPTO

There are only two projects in this year’s MUS portfolio; however, it is worth noting that the Solid-State Processing project by PNNL has breakthrough potential for the cavitation resistant manufacture and repair of hydro turbines. The reviewers were in full agreement that these efforts should continue at full speed and should explore combined use with robotic techniques, if (or when) the process is successfully demonstrated in field or manufacturing situations. This relatively low-risk investment but high potential payback was deemed as one of the best projects in the entire hydro portfolio. An excellent, model example of the potential benefits of R&D!

Summary of all Reviewers’ Comments

Overall Impressions

In general, reviewers were “wowed” by the incredible potential of Solid-State Processing project’s techniques for increasing the cavitation resistance of newly manufactured turbines and the potential for more cavitation resistant field repairs. The reviewers were less impressed with the results of the Short Intake Flow Measurement Research, which attempted to address a long-standing difficulty of getting cost-effective, yet accurate, flow measurements for short rectangular penstocks. The combined analytical and field-testing process required much less machine downtime for installing and completing flow testing, but unfortunately, the process fell short on the resulting final accuracy.

### **Program Strategy and Objectives**

The reviewers generally agreed that the projects aligned with the objectives of the program. The Solid-State Processing project was a clear example of investing in early-stage research to accelerate the development of innovative water power technologies. The Short Intake Flow Measurement Research project was a clear example of a project that attempts to overcome long-standing difficulties to validate unit performance and could be used to deliver efficiency gains for many small and medium sized hydro stations.

### **Program Portfolio**

While the sample size of projects in this category is very limited this year, reviewers agreed that these projects contribute to meeting the program's strategy and objectives. The Solid-State Processing project is focused on reducing the impacts of cavitation, which is a key challenge that could dramatically lower maintenance costs and reduce outage durations in a high percentage of hydro stations. This project has a low-risk, high-reward potential and is worthy of continued investment. Overall, the projects within this activity area are appropriate for WPTO's role as a public R&D organization.

### **Program Management Approach**

For the limited projects in this year's MUS portfolio, it did not appear that much additional program team oversight was required for these projects to be reasonably smoothly executed and meet the intent of the program objectives. While the technical capabilities needed to monitor and guide these MUS projects appeared to be sufficient in these instances, the reviewers generally agreed that, in other activity areas, there is a much greater need for additional industry expertise and field experience to support the PIs and assist with DOE project management and technical oversight.

### **Stakeholder Engagement, Outreach, and Dissemination**

While the engagement, outreach, dissemination, and resulting effectiveness vary by project in the MUS portfolio, reviewers generally agree that the program has demonstrated good stewardship of taxpayer funds by performing research on chronic barriers to improvement and high value, high potential impact areas. The reviewers also generally agreed that WPTO could be well served to engage peer reviewers and/or other industry experts earlier and continuously throughout the project process to assist with design reviews, project management oversight, and technical support. These experts could also fill a support role as thought leaders to inform the direction of the program and offer connections to industry partners for disseminating information. This would be a relatively small cost to insure maximum impact of WPTO-supported research.

## Project Evaluations

# LOW-HEAD, SHORT-INTAKE FLOW MEASUREMENT RESEARCH

(WBS #: 1.1.1.601)

Recipient:	PNNL
Principal Investigator:	Marshall Richmond
Project Type:	AOP
Project Category:	Completed and Sunsetting Projects
Total Authorized:	\$524K
Total Costed:	\$412K

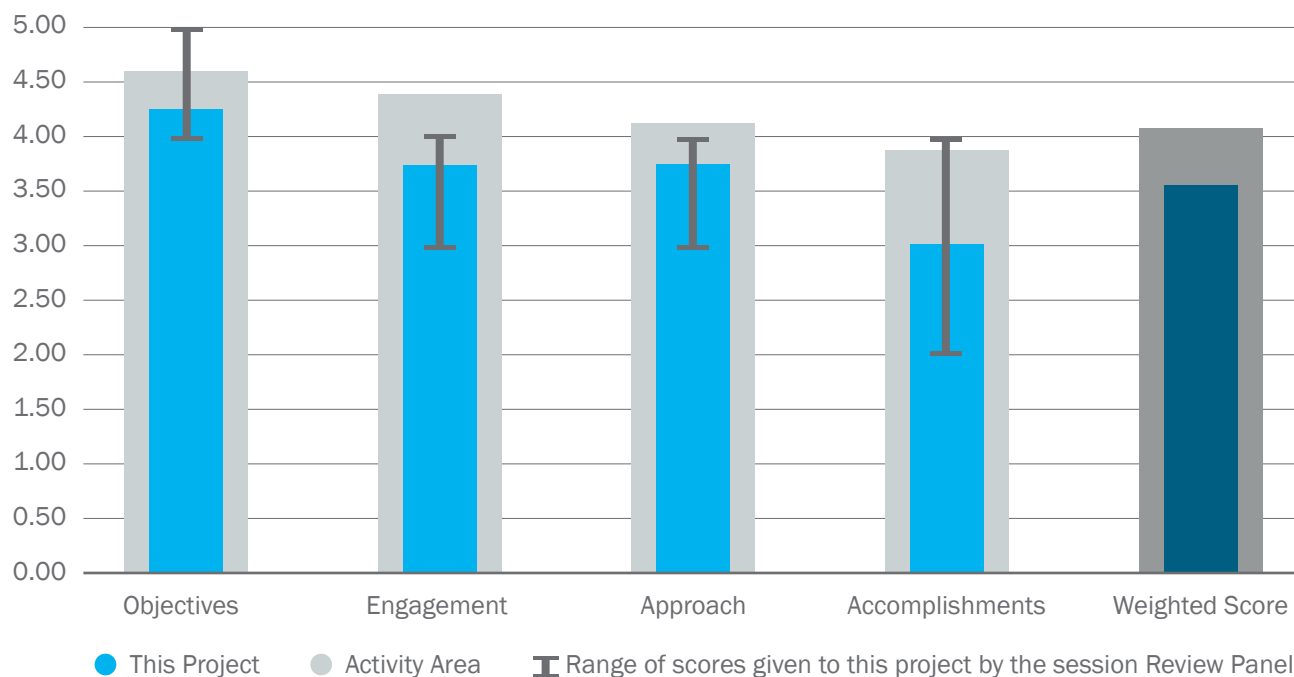
## Project Description

The overall objective of this project is to develop improved flow (discharge) measurement technology that will enable U.S. hydropower assets to produce more energy from available water. Achieving optimal generation, long-term water-use efficiency, asset monitoring, and sustainable water management objectives require active monitoring and control of hydropower unit operations. The availability of accurate flow-rate measurement technology is a primary factor in monitoring and controlling the instantaneous efficiency of hydropower energy production in the face of multiple constraints on hydropower asset operations. The ultimate outcome will be flow measurement technology and site-specific analysis methods that can be applied to a wide range of turbine types in the U.S. hydropower fleet that cannot be readily measured using existing technology.

## Weighted Project Score: 3.6

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%

Average Score by Project Evaluation Criteria



## Summary of all Reviewers' Comments

### Overall Impressions

This was an innovative attempt to improve absolute flow measurements for short rectangular penstocks using cost-effective methods. Unfortunately, the results of this method at this time do not provide sufficient accuracy ( $\pm 3\%$ ) to overcome this long-standing and difficult challenge.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The reviewers agreed that the explanation of project objectives was clear and aligned with DOE program objectives. The goal of this project was to reduce the cost and time required for absolute flow measurement in short rectangular penstocks, while delivering high accuracy. Cost-effective flow measurement is key to assessing true efficiency and performance but has been an insurmountable challenge in rectangular penstocks for many years.

### End User Engagement and Dissemination Strategy

Reviewers agreed that there are a number of end users and hydropower units having this rectangular intake geometry that would benefit from this project's successful completion and accurate flow measurement delivery. Engagement of the U.S. Army Corps of Engineers' Hydroelectric Design Center and Chief Joseph Hydro Station as a deployment site were very useful to the project. It is not completely clear how this information will be disseminated or what the expected value proposition is for the end user.

### Management and Technical Approach

The technical approach utilized a creative combination of analytical modeling and field test measurements to reduce the time for test set-up and to ultimately get accurate measurements more quickly. Reviewers generally agreed that the approach was innovative and reasonable, although the project management aspects (schedule, milestones, achievements, etc.) could have been more thoroughly described. Also, it was not completely clear how the analytical models from this initial effort could be used at other locations or if additional modeling would be needed for each site and what that cost and schedule might look like.

### Technical Accomplishments and Progress

Reviewers generally agreed that this approach was innovative in attempting to overcome a problem that has been a performance measurement challenge at many old hydro stations for many years. Unfortunately, the results from the method in this pilot do not provide sufficient accuracy ( $\pm 3\%$ ) to use for turbine performance acceptance guarantees and would require significant improvement to match the best available (but labor intensive) existing technologies ( $\pm 1\%$ ). Reviewers agreed that this method, in its current state of accuracy, would probably not see widespread application and would likely have limited potential, but it was seen as a valiant attempt at a very challenging problem.

## SOLID STATE PROCESSING FOR IMPROVED PERFORMANCE OF CURRENT AND NEXT-GENERATION HYDROPOWER COMPONENTS (TCF)

(WBS #: 2.2.0.601)

Recipient:	PNNL
Principal Investigator:	Ken Ross
Project Type:	AOP
Project Category:	Completed and Sunsetting Projects
Total Authorized:	\$200K
Total Costed:	\$195K

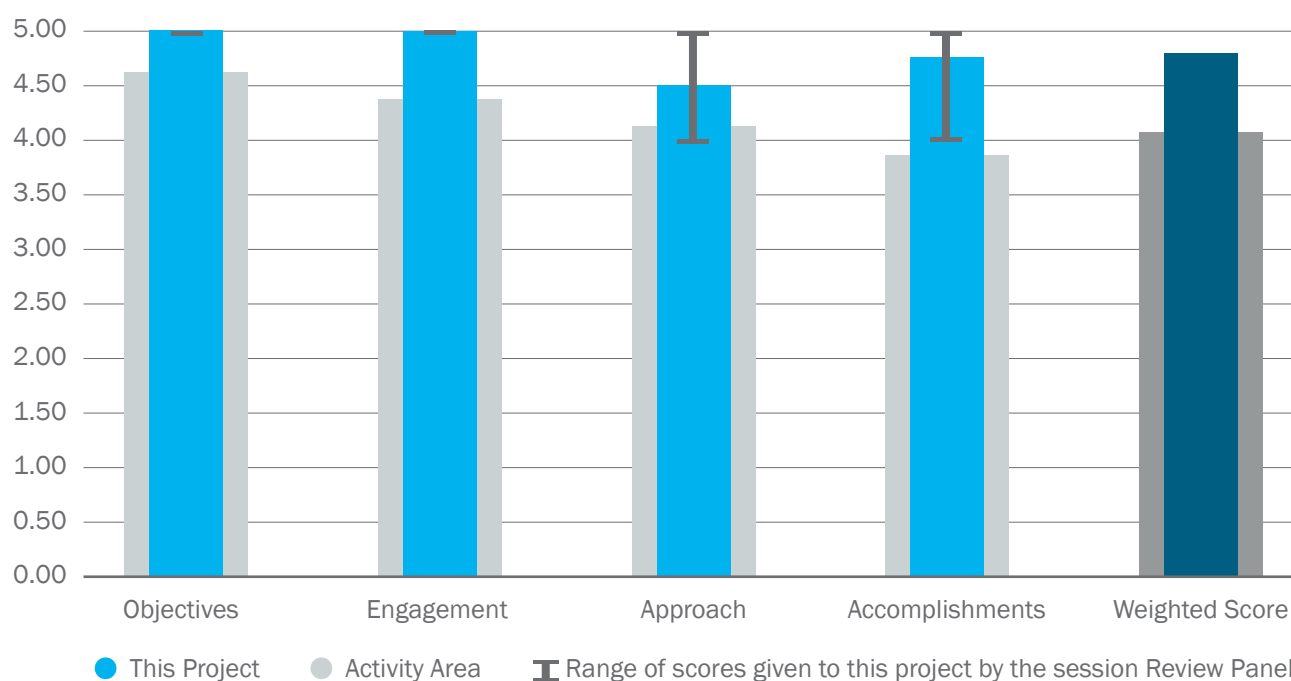
### Project Description

Component failures in hydraulic machinery, such as pumps, hydropower turbines, and propellers, are often caused by cavitation. In hydropower turbines, cavitation can also be harmful to fish passing, causing an increased fish mortality rate. To reduce the deleterious effect of cavitation, it is important to focus on mitigating material loss due to cavitation in the design and maintenance of hydraulic machines. The goal of this project was to demonstrate the feasibility of solid-state processing for cavitation repair of hydropower turbine runners, as well as to manufacture more cavitation resistant turbines. Solid-state processing is an emerging approach for producing a wide range of materials. It has the potential of delivering high-performing components with a low energy input. Solid-state processing produces controllable materials via high strain and plastic deformation. The specific solid-state processes investigated within the project duration are cold spray and friction stir welding. The project team evaluated the cavitation erosion resistance of sample plates, which they compared to unprocessed steel. Surface cavitation patterns and cavitation rates were characterized, and the mechanisms of material removal were discussed.

### Weighted Project Score: 4.8

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%

Average Score by Project Evaluation Criteria





## Summary of all Reviewers' Comments

### Overall Impressions

The project supports the hydropower fleet by targeting significant cost reductions to reduce and repair cavitation damage and shortening outage times, which improves system reliability. The project seems to be moving in a logical fashion through testing and is at a stage where field deployment and testing are warranted. The project performers should be commended for their accomplishments and for focusing on an important issue to the hydroelectric industry. While technically sound and with appropriate input from end users, the project could benefit from improvements in project management and clarity in communications.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The reviewers were in complete consensus that the project has the potential to provide significant benefits to the hydroelectric industry by delivering a new cost-effective approach to repair runner cavitation damage. This may become a bigger issue in the future as the hydroelectric system is increasingly used for flexibility purposes and units may experience increased cavitation. The project performers clearly described how the technology could be deployed commercially and advance the state of technology in the industry.

### End User Engagement and Dissemination Strategy

The reviewers were in consensus that the project appropriately engaged potential end users as evidenced by the relevance of their work to the industry and as provided in their project information. The beneficiaries of their work were identified as well. The inclusion of project owner/operators (e.g., Army Corps of Engineers, Bureau of Reclamation, Idaho Power), as well as the Bonneville Power Administration, as collaborators provided a commercial sense to the activities and should provide the project performers with opportunities to field test their technology at projects experiencing cavitation issues.

### Management and Technical Approach

The reviewers generally felt that the management and technical approach was appropriate for the work performed, which was demonstrating the properties of the different solid-state applications and the potential for improving cavitation repairs in a test environment before moving to field testing. Two of the reviewers cited minor shortcomings in the project summary related to this area—specifically that the project management approach could be improved and that the milestone descriptions were vague. Improved project management techniques may be warranted as the project moves to field testing in actual units. A better explanation of the technologies themselves (friction stir welding and cold spray applications) would have greatly improved the written summary.

### Technical Accomplishments and Progress

The technical accomplishments are impressive and warrant continued work and deployment. Three of the reviewers noted that the progress was poorly communicated and that future written materials will need to address this shortcoming. This may be particularly important as the project moves toward field testing where project owners/operators will need to be convinced to take a significant step in using new technologies on expensive operating equipment. The project presentation addressed some of the shortcomings in the summary. It was clear from the presentation that progress had been made relative to the objectives and that the accomplishments warrant continued work in this area. A successful aspect of this research is the fact that all these tests were conducted at a very reasonable budget, highlighting the fact that this initial research into increasing cavitation erosion has paid great dividends and should continue into future phase of development and dissemination.

## Future Work

The next step would be to implement these findings in the field and to evaluate the benefits for coating newly manufactured runners. Additionally, the team should explore the feasibility of combining solid-state processing methods with robotic repair and contouring techniques. If robotic repairs are possible, this would be even more valuable to the hydropower industry since confined space and poor accessibility pose significant problems for turbine repair workers. This is groundbreaking work of incredible importance to the industry.

agreed that the approach was innovative and reasonable, although the project management aspects (schedule, milestones, achievements, etc.) could have been more thoroughly described. Also, it was not completely clear how the analytical models from this initial effort could be used at other locations or if additional modeling would be needed for each site and what that cost and schedule might look like.

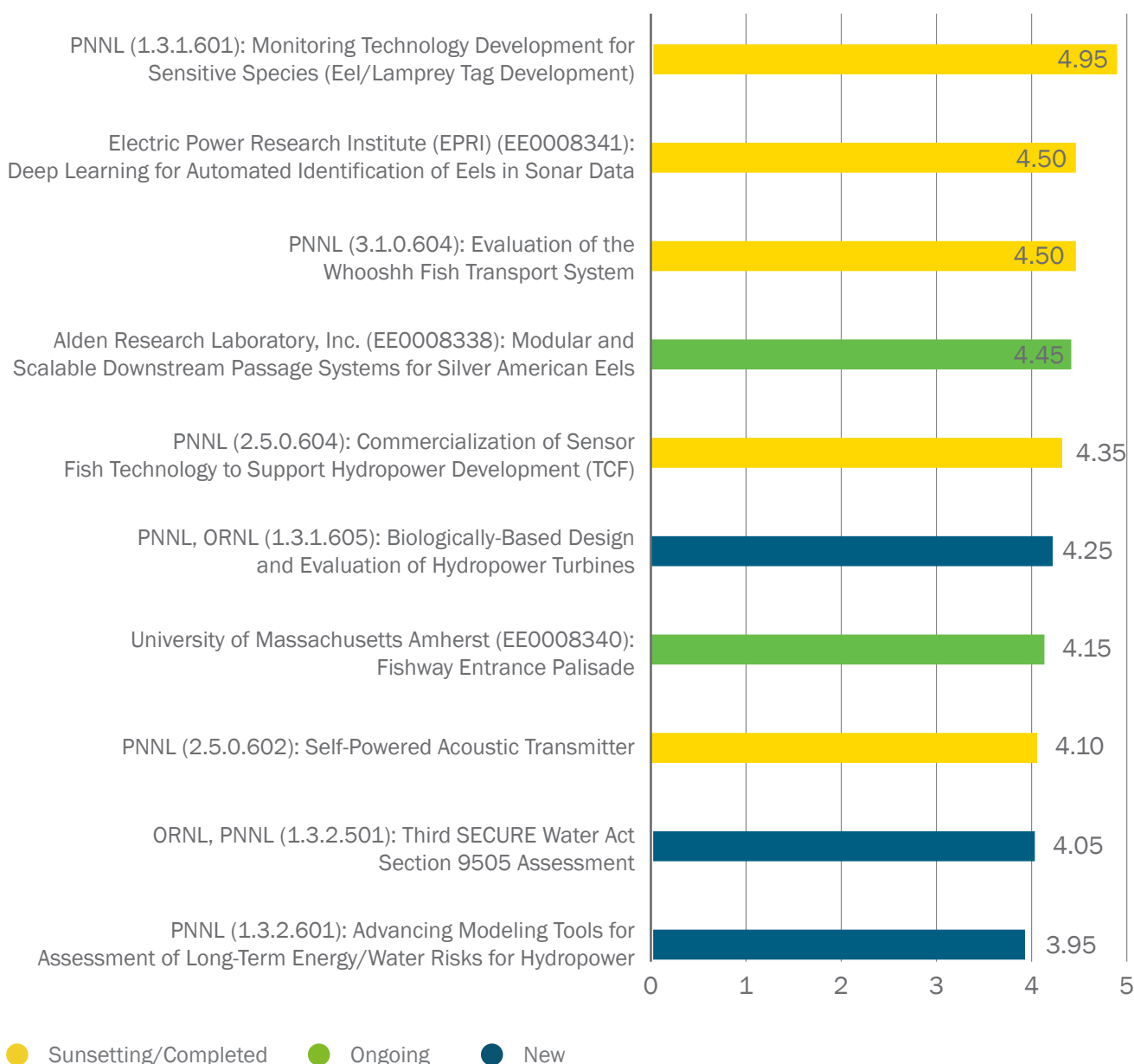
## Environmental R&D and Hydrologic Systems Science

This section provides an overview of the scoring for all projects within the Environmental R&D and Hydrologic Systems Science activity area (see Figure 15); the review panel lead's summary of reviewer comments in response to the evaluation criteria; and full evaluation results for individual projects.

### Activity Area Score Results

Name	Average Weighted Score of All Projects
Environmental R&D and Hydrologic Systems Science	4.33

**Figure 15. Environmental R&D and Hydrologic Systems Science activity area—average weighted score by project**



## Activity Area Summary Report

*Prepared by the Review Panel Lead*

### *Feedback from the Review Panel to WPTO*

Reviewers were strongly supportive of the projects in this program. There were a few suggestions for improvement and a few criticisms but, overall, there was strong support. The tools developed through this program should be very useful.

### *Summary of all Reviewers' Comments*

#### **Overall Impressions**

The projects were strongly supported by reviewers for their objectives. There were some comments on the lack of information related to budgets and go/no-go decision-making frameworks, which was more a symptom of the peer review process and execution than of the projects' performance.

#### **Program Strategy and Objectives**

The presenters did a fine job with the objectives of their projects. In hindsight, perhaps a 1–2-page summary by WPTO for each program area would be helpful as context for reviewers (e.g., an explanation of how the three modeling focused projects fit with the seven fish passage/monitoring focused projects). WPTO should consider sharing an outline of each program to include the genesis of it, point along the program timeline at the time of the peer review, previous projects within the program, anticipated opportunities/focus areas for upcoming projects, and budget information (e.g., allocation for each project and spent to date for each, anticipated future funding).

Reviewers agreed that all the projects appeared to align well with the program objectives and needs of the industry. It is evident that this program invests in early stage research and develops innovative technologies. One of the criticisms specific to this lead has been the time to commercialization for some tools (e.g., Sensor Fish, and Juvenile Salmon Acoustic Telemetry System). It appears that WPTO is increasingly focused on timely commercialization, and if so, this criticism will no longer be waged. All reviewers agreed that the tools being developed are/will be useful to the industry.

This area of the Hydropower Program is not particularly focused on grid reliability, but the research complements other areas of the program that do support grid reliability. Through the various labs and outside facilities, industry has good access to testing infrastructure. Anecdotally, one reviewer suggested that WPTO should think critically about intellectual property (IP) ownership requirements at the labs and how this affects outside organizations and partners. Again, while anecdotal, one reviewer did not think it was clear why a lab should benefit through ownership of IP created in partnership with outside parties.

No reviewers explicitly stated that taxpayer funds have not been invested wisely. There were comments on the lack of attention (even though prompted by the review topics) to go/no-go decision points or frameworks. Given that the projects under peer review are in various stages along their timeline, it can be difficult to judge whether wise investments have been made. More attention to the go/no-go frameworks and presentation of what decisions were made (and why) during a project's timeline would be helpful.

## **Program Portfolio**

All reviewers agreed that the projects presented contribute to the program's focus and objectives, and the projects included are addressing key challenges. With the power of current computers, the modeling projects will produce results and tools that will be very useful to the industry. Similarly, with the advances in materials science, battery miniaturization, and CFD tools, large strides in addressing fish passage and monitoring issues can be made.

The rationale for and organization of the funded projects and program approaches was adequately conveyed during the peer review. One aspect that would be helpful to reviewers is to have all materials (including slides) delivered as a single package well in advance of the presentations. Receiving slides the night after the first day of presentations was not helpful, as there was little time to review them. Complete budget information was not presented in many cases, and few effectively described those milestones in the timeline where go/no-go decisions were made and why.

In all cases, reviewers saw some or great merit in the projects, assuming they are completed in a cost-effective manner. With the 'snapshot' approach to this peer review process, it can be difficult to assess whether priorities and resources are appropriately allocated. One suggestion was to have a specific team of reviewers stay with a project (and perhaps program) from proposal to completion. There may be some difficulties in implementing such an approach, but reviewers offered it for consideration. It is evident from the strong support of reviewers that the projects in this program are appropriate for WPTO to support.

## **Program Management Approach**

In most cases, reviewers scored the management of projects with high scores. However, there were some questions about how project teams might accomplish various aspects of their projects (e.g., whether existing efforts by others might be sufficient to inform the model development in PNNL's project titled "Advancing Modeling Tools for Assessment of Long-Term Energy/Water Risks for Hydropower" (1.3.2.601); whether the self-powered tag will come to fruition as a useful tool, especially as a commercialized tool; was an abundance of existing information of fish passage survival utilized in development of the tools in PNNL's project "Biologically-Based Design and Evaluation of Hydropower Turbines" (1.3.1.605)?

It was apparent that all projects reviewed focused on priority research areas that create the greatest impact on new technology and industry advancement. In general, the program team effectively communicated priority research areas and the allocation of resources. However, reviewers agreed that presentation of budget and future work aspects would have been more useful if complete project budgets were included. Dissemination of the technical information seemed to be well done.

In all cases, the reviewers agreed that the Hydropower Program team demonstrated the professional and technical capabilities needed to identify, monitor, and guide its portfolio of projects and thought that the project teams were well qualified. However, it is hard to assess that with any rigor or detail with the limited amount of time to observe the team in action.

## **Stakeholder Engagement, Outreach, and Dissemination**

Regarding transparently communicating how WPTO funds are being utilized, reviewers agreed that more information on the budgets and their use would have appreciated. Some project presenters only presented budget used for the past two years and not the full project, so it was virtually impossible to assess whether funds were used efficiently over the course of the project.

In gathering feedback from stakeholders to inform and improve WPTO's projects and strategy, reviewers recommended continuing to consult with its current strong ties to the NHA, the Northwest Hydroelectric Association, and the Hydropower Foundation. The Hydropower Foundation is anxious to find the next program with WPTO to make a difference in the hydro industry. With Linda Ciocci as the new Executive Director, the organization is well positioned to tackle new initiatives. Reviewers recommended engaging in a series of regional meetings with high-level representatives of individual hydro, regulatory, consulting, and special interest groups. It is unclear whether such meetings would be more productive if you were to segregate or integrate groups based on their position along the hydro value spectrum, perhaps attempts at both would be informative. WPTO should pose questions and situations that test the representatives of each sector to justify their positions and broker meaningful conversations between articulate advocates for important issues/positions and policymakers.

Overall, reviewers thought that the dissemination of WPTO-supported research results was extensive. The panel lead questions the importance of focusing on primary literature publications in journals that are relatively obscure to the industry. Reviewers recommend that PIs should focus on better disseminating information to the end users.

Reviewers generally agreed that the program provides access to accurate and objective information and data that can help to accelerate industry development and inform decision makers. One caveat, as mentioned before, is the time to commercialization, but if time to commercialization is a focus of WPTO moving forward, it will be applauded.



## Project Evaluations

# MONITORING TECHNOLOGY DEVELOPMENT FOR SENSITIVE SPECIES (EEL/LAMPREY TAG DEVELOPMENT)

(WBS #: 1.3.1.601)

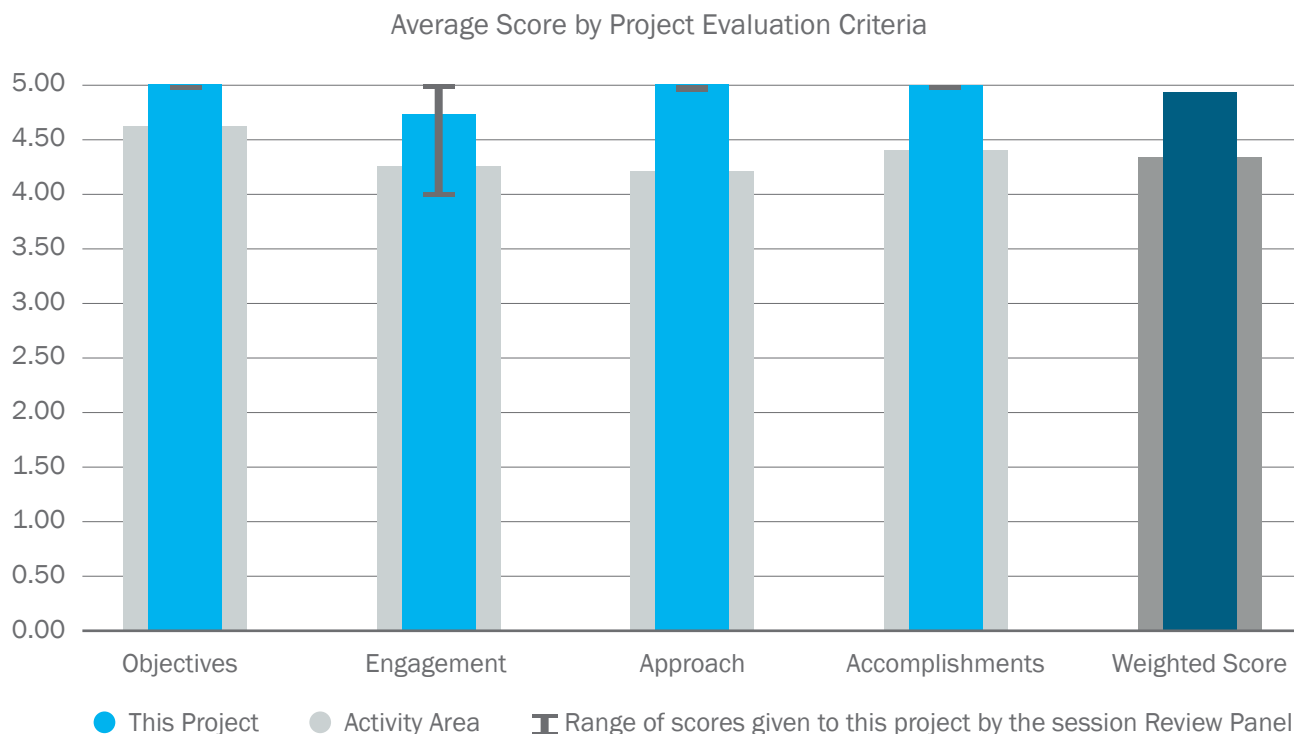
Recipient:	PNNL
Principal Investigator:	Daniel Deng
Project Type:	AOP
Project Category:	Completed and Sunsetting Projects
Total Authorized:	\$1,068K
Total Costed:	\$1,068K

## Project Description

The goals of this project were to design, prototype, and perform laboratory and field tests of an acoustic micro transmitter that can be used to study the behavior and survival of juvenile eel and lamprey. The ability to implant acoustic transmitters and track the movement of juvenile eels can help researchers better understand migration routes, habitat use, and hydropower dam survival rates to make more informed management decisions regarding new and existing hydroelectric facilities.

**Weighted Project Score: 5.0**

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%



## Summary of all Reviewers' Comments

### Overall Impressions

The project created a miniature monitoring device for implanting in juvenile eels and lampreys to better understand migration of these sensitive species through hydropower dams. The result is a remarkably small tag, capable to transmit data on a relatively long distance and tracking 3-D position of the fish in stream. All reviewers were impressed with this tag its potential application. It will likely be widely used to better understand fish movements and behavior.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The project objectives are to better understand behavior of eels to protect them and ultimately make better hydropower management decisions. Reviewers agreed that the explanation of project objectives was clear and aligned with DOE program objectives. All reviewers offered a score of 5 for this aspect.

### End User Engagement and Dissemination Strategy

Reviewers agreed that the project has successfully engaged end-users and has a substantial dissemination strategy with publications, presentations, media coverage, and more. A broad range of stakeholders might be interested in results of the proposed work. There was one reviewer question about the status of commercialization.

### Management and Technical Approach

All reviewers scored this section with a 5 due to the strong team and performance. The management approach required multi-disciplinary collaborations that the project team managed well. Reviewers thought that the technical approach was robust and multi-faceted. One reviewer suggested including a commercialization schedule in the report.

### Technical Accomplishments and Progress

Reviewers agreed that the technical accomplishments were substantial and that the acoustic micro-transmitter is a remarkable success. For its size, reviewers thought that it has excellent longevity and offers potential of being widely used not only for targeted fish species, but in a much broader range of applications. This tag should be a very useful tool for better understanding fish movements and behavior. One reviewer suggested that the project team include more details on tag power and detection range.

# BIOLOGICALLY-BASED DESIGN AND EVALUATION OF HYDROPOWER TURBINES

(WBS #: 1.3.1.605)

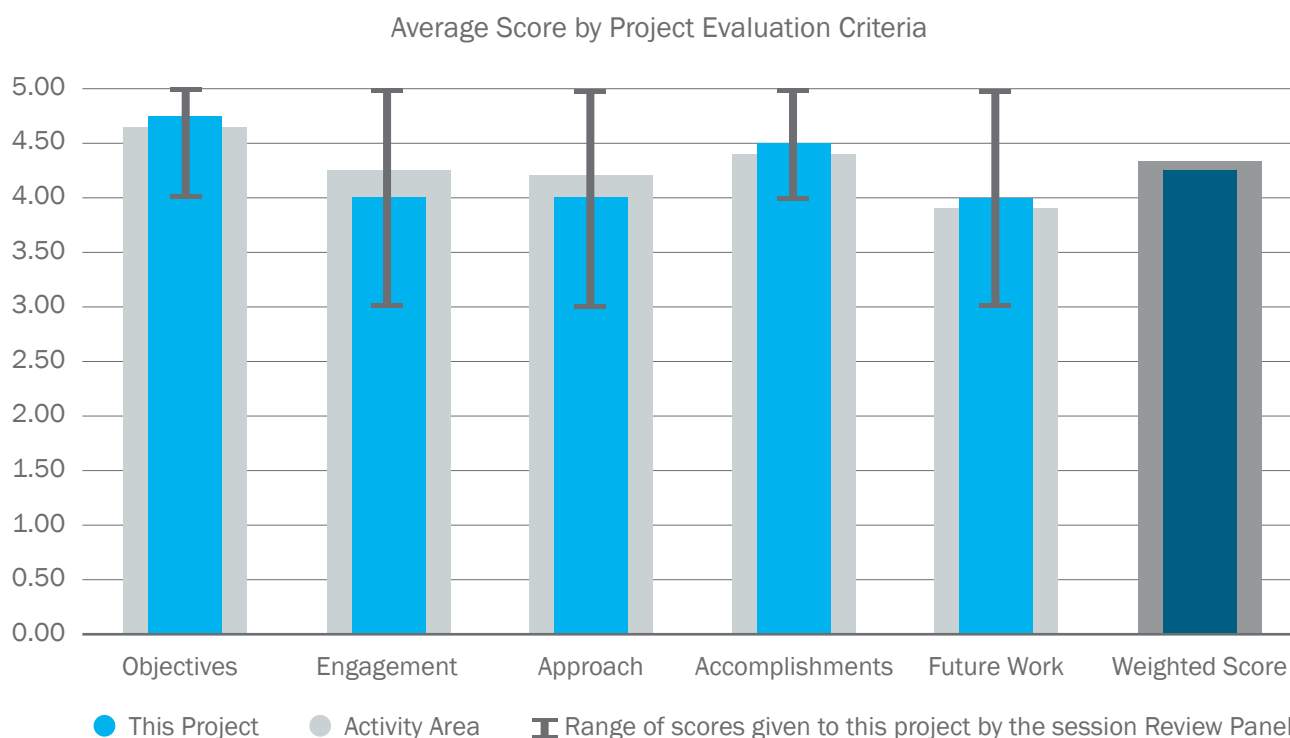
Recipient:	PNNL and ORNL
Principal Investigator:	Alison Colotelo
Project Type:	AOP
Project Category:	Ongoing Projects
Total Authorized:	\$5,192K
Total Costed:	\$3,566K

## Project Description

This project is a multi-lab, long-term initiative between Pacific Northwest National Laboratory (PNNL) and ORNL. The goal of this project is to develop, demonstrate, and transfer a suite of tools and technologies that can be used by the hydropower community to evaluate the biological performance of proposed and existing hydropower turbines. The first tool, the Biological Performance Assessment toolset, provides a computational fluid dynamics (CFD) model overlay to relate in-turbine forces (e.g., strike, barotrauma, and shear) to impacts on fish and is derived from empirical data. The second tool, the Hydropower Biological Evaluation Toolset, is a software that supports similar analyses and works with field data collected by the Sensor Fish instrument, a neutrally buoyant juvenile salmon-sized sensor package that can be released through downstream fish passage routes (e.g., hydropower dam draft tubes). A third project product is dose-response data on a variety of U.S. fish species of concern. Fundamental experiments conducted at the DOE national laboratories provide data, information, and analyses on the impacts of in-turbine forces to fish to quantify passage survival indexes in the Biological Performance Assessment and the Hydropower Biological Evaluation Toolset.

## Weighted Project Score: 4.3

*Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.*



## Summary of all Reviewers' Comments

### Overall Impressions

All reviewers strongly supported this project and thought that the software package has broad potential applicability, including rivers with different kinds of fish and different environmental criteria. There seem to be significant commercial applications. Reviewers thought that it would have been helpful to see more information on the go/no-go decision making, as well as points along the way where such decisions were/will be made. The set of tools produced or in the works should be very useful to turbine designers.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The project objective relates to a very important issue of assessing and improving fish survival during the turbine passage. The reviewers agreed that the explanation of project objectives was clear and aligned with DOE program objectives. Work accomplished so far is highly valued by the industry. All thought that the tools that will result from this project will be useful to many in the industry, assuming all tools will be commercialized in a timely manner. All reviewers supported this project.

### End User Engagement and Dissemination Strategy

Reviewers agreed that the engagement and dissemination strategy is robust, with targeted market research into relevant hydropower operators/owners. Reviewers appreciated the emphasis on technology transfer to the end users, including identifying use cases to inform future research and to guide strategic engagement.

### Management and Technical Approach

All reviewers agreed that the management and technical approaches were sound. It was not clear whether the project relied primarily or solely on data and information generated by the labs or whether the large body of peer reviewed and gray literature from the hydropower industry was used to inform this project. Information on milestones and go/no-go decision points along the timeline either were not conveyed.

### Technical Accomplishments and Progress

Generally, reviewers were impressed by the substantial technical accomplishments. In fact, industry is already using some of the tools. A timeline for technology transfer of tools in development would have been helpful.

### Future Work

Future work is well explained through FY 2020, although key milestones and go/no-go decision points were not included. This suite of tools should be well used by turbine manufacturers and perhaps others.

# THIRD SECURE WATER ACT SECTION 9505 ASSESSMENT

(WBS #: 1.3.2.501)

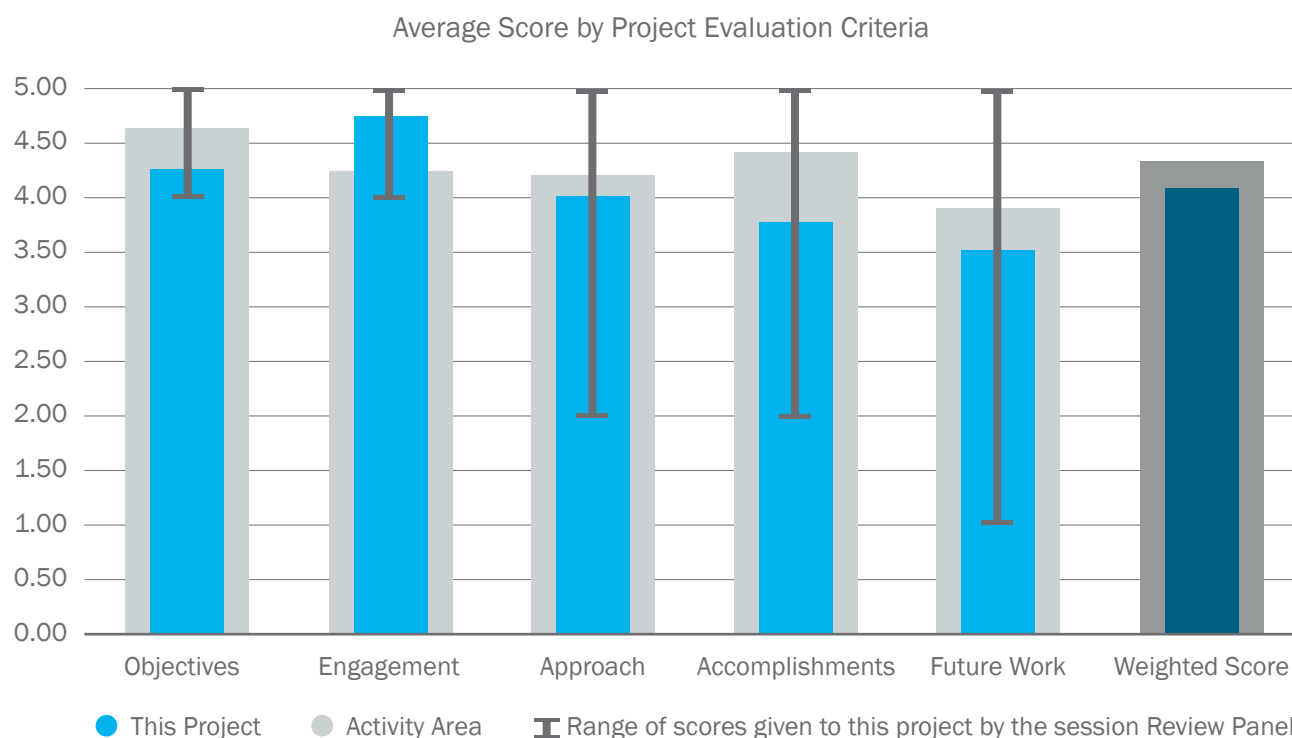
Recipient:	ORNL and PNNL
Principal Investigator:	Shih-Chieh Kao
Project Type:	AOP
Project Category:	Ongoing Projects
Total Authorized:	\$809K
Total Costed:	\$572K

## Project Description

The objective of this project, as directed by Congress in Section 9505 of the SECURE Water Act (Public Law 111-11) of 2009, is to evaluate “each effect of, and risk resulting from, global climate change with respect to— (A) water supplies used for hydroelectric power generation; And (B) power supplies marketed by each Federal Power Marketing Administration.” The Secretary of Energy is designated as the lead for this assessment, and it is to be conducted in consultation with the Power Marketing Administrations and other federal and state agencies every 5 years until 2023. The third 9505 (9505-V3) assessment started in 2018 and will provide the technical basis for the third DOE Report to Congress, which the SECURE Water Act requires.

## Weighted Project Score: 4.1

*Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.*



## Summary of all Reviewers' Comments

### Overall Impressions

Although the SWA mandates this project, the reviewers strongly agree that it is critically important to DOE and the hydropower industry to understand the effects of future hydrologic conditions on hydro generation, and thus highly aligned with the Program approaches and strategies. The project team is highly qualified,

and the project has had a strong start in engaging the Power Marketing Administrations and other water management agencies in the methodology workshop. The plan to include the non-federal hydro industry through Hydropower Operations and Planning is also important. There are some concerns about the extensive technical work proposed without technical milestones or discussion of risk and critical success factors. Also, some concern about the technical focus on hydrologic techniques rather than hydropower analysis. The budget for this project should be analyzed with some comparison with the previous study to ensure a successful outcome.

### **Project Objectives, Impacts, and Alignment with the Program Strategy**

This project is mandated by Section 9505 of the SECURE Water Act, which requires a study every 5 years to project potential effects of long-term hydrologic change on water availability for federal hydropower generation, hence the future of renewable energy and grid reliability. In addition to this congressional mandate, the reviewers agree the stated project aligns with the approach. Reviewers would welcome even more information on this Program alignment; they remarked on the importance of considering climate change on hydropower; and they encouraged including project benefits that go beyond federal hydropower projects.

### **End User Engagement and Dissemination Strategy**

The project has reported on the extensive consultations that were held with Power Marketing Administrations, USACE, the Bureau of Reclamation, the U.S. Geological Survey, and the National Oceanographic and Atmospheric Administration (NOAA) to agree on a plan for methodology and assessment. The federal agency engagement is very strong and on track, and outreach to non-federal power stakeholders through Hydropower Operations and Planning is also useful and important. Reviewers recommend that the project should have more detailed plans for dissemination, especially to the non-federal stakeholders, in addition to the planned review by external experts of the final assessment.

### **Management and Technical Approach**

The reviewers laud the expertise and collaboration among the project team members. Most reviewers are favorably impressed with the description of the technical plan of sequencing models from general circulation models to regional power projections. One reviewer was concerned that the very ambitious technical work plan is described only as tasks, without milestones or critical success factors or go/no-go decision points; the reviewer was also concerned that no risks have been identified. There are also some concerns about the technical focus of the work was on developing new hydrologic techniques (downscaling, multiple hydrologic models), but there was no mention of developing more sophisticated hydropower analysis, including flexibility and impact on grid analysis, which should be the main focus for DOE.

### **Technical Accomplishments and Progress**

Progress to date includes the methodology workshops and likely some technical work, although without a schedule, milestones, or specific details, the progress cannot be accurately assessed. The reviewers applauded progress reported by the completion of the 2017 report but pointed out that this is not formally part of the current project.

### **Future Work**

Most reviewers are satisfied with the outline of future work and “timely accomplishment of this important project.” One reviewer is concerned that the future work is described only in terms reports and meetings, and that there is not a schedule for the challenging and intense technical aspects of the work. Also, there are no budget numbers available to assess the future work.

# ADVANCING MODELING TOOLS FOR ASSESSMENT OF LONG-TERM ENERGY/WATER RISKS FOR HYDROPOWER

(WBS #: 1.3.2.601)

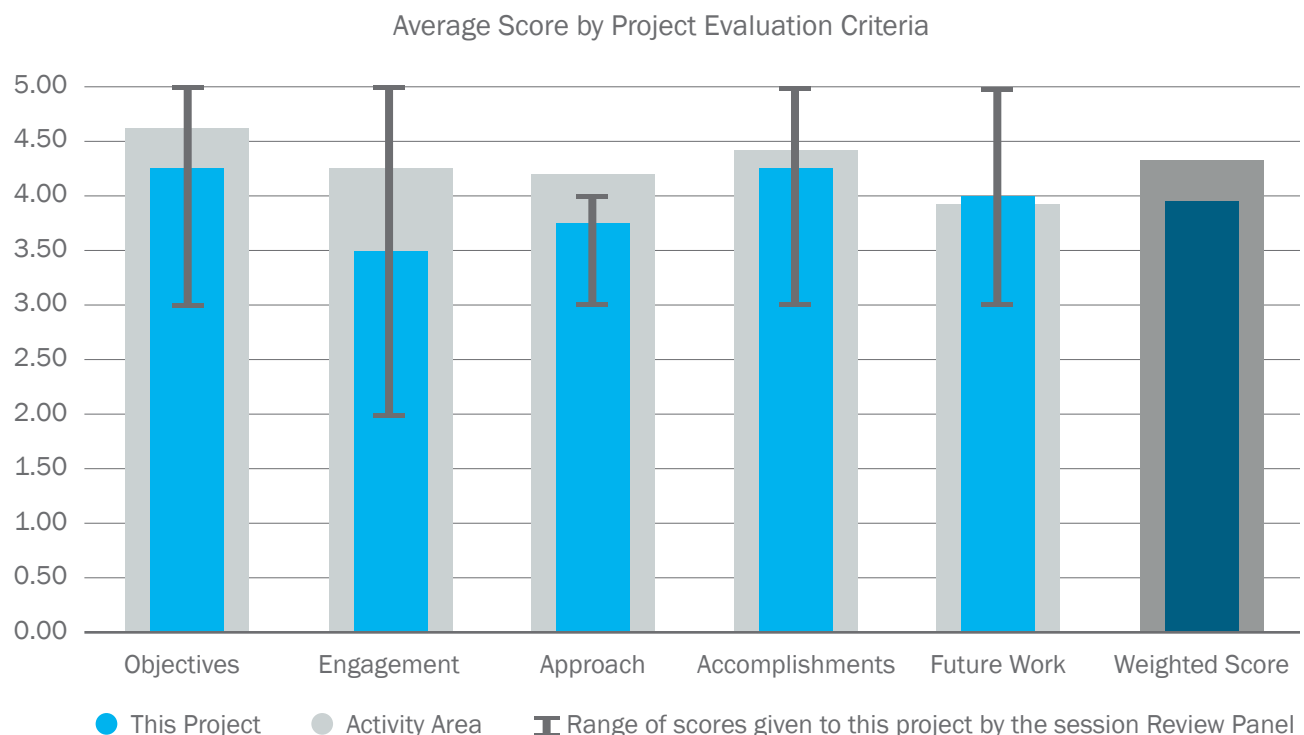
Recipient:	PNNL
Principal Investigator:	Mark Wigmosta
Project Type:	AOP
Project Category:	Ongoing Projects
Total Authorized:	\$2,111K
Total Costed:	\$1,800K

## Project Description

This project is developing and demonstrating a scalable, physics-based modeling framework to better understand and evaluate hydropower investments and operational decisions in the face of changing hydrologic regimes. Of specific interest is the relationship among, and potential future risks regarding, changing water temperature regimes in rivers; electric power generation from hydropower; thermoelectric plant cooling and discharge; and water-quality and habitat needs for sensitive species. The project is developing and demonstrating an advanced modeling framework at the plant and system levels to evaluate the potential likelihood and severity of water temperature events under a range of possible future scenarios. The project will also evaluate alternative operations and infrastructure investments to mitigate such events.

## Weighted Project Score: 4.0

*Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.*





## Summary of all Reviewers' Comments

### Overall Impressions

Reviewers agreed with the value of improved (higher resolution) models for environmental analysis, although it is noted that specific need and use cases have not been identified as justification for the effort. The project leads are highly qualified, and early release of the improved model to the research community reflects substantive success. There is concern that the model cannot express hydropower operations or know about the grid, which may be a deficit in the ability to develop improved or optimized hydropower plant operations to support evolving grid needs. The plan to apply the model to a second basin in the eastern United States was considered potentially valuable by the reviewers, although there is concern about the enhancements that would be needed and about the lack of a general management plan guiding this and the work in general.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The reviewers unanimously agreed that project objectives are well described and aligned with the Hydropower Program's goals and strategies, and they agreed that the project is valuable and worth pursuing. Reviewers agreed that modeling river basins is a vital component of predicting future risks to hydropower generation and water quality due to the changing climate. High spatial resolution of the proposed approach, combined with the use of high-performance computing, will allow for a better understanding of multiple elements of system dynamics.

### End User Engagement and Dissemination Strategy

All but one reviewer was satisfied with the description of the beneficiaries and end users identified, which includes "a broad cross section of the diverse interests in the hydropower arena," and also of the plans for dissemination. However, the only beneficiaries so far have been universities and research institutes, and there is some uncertainty expressed regarding future distribution and possible commercialization of the ultimate "product." One reviewer notes the lack of plan for stakeholder input to the process and notes that most hydropower stakeholders (such as hydropower plant owners/operators, tribes, NGOs, etc.) will not have the technical expertise or resources to benefit from this modeling platform.

### Management and Technical Approach

The reviewers agreed that project managers are well qualified and capable of delivering the technical results. The main technical concern is that, although the physical process modeling seems sound and will be an improvement for environmental assessment, it is not clear how assessment of operating plans can be achieved. One reviewer thought that the models would also be improved by the inclusion of reservoirs, which have significant temperature implications. Critical success factors were not described.

### Technical Accomplishments and Progress

Several technical accomplishments were reported: quantitative results presented indicate success of the modeling computations, computational performance is improved, and early transfer to external researchers reflects the acceptance and value of the computational work. Reviewers suggested that the project team include a comparison with the older modeling platform to demonstrate improvement.

### Future Work

The project team indicated that the next steps are applying the framework to a second basin, likely the Connecticut River, for geographic and other differences. Most reviewers agreed with this project's value in that it would require model enhancements that are important to the hydropower industry;; although some pointed out that it does not fit into a described management plan, and specific work products are not described.

# SELF-POWERED ACOUSTIC TRANSMITTER

(WBS #: 2.5.0.602)

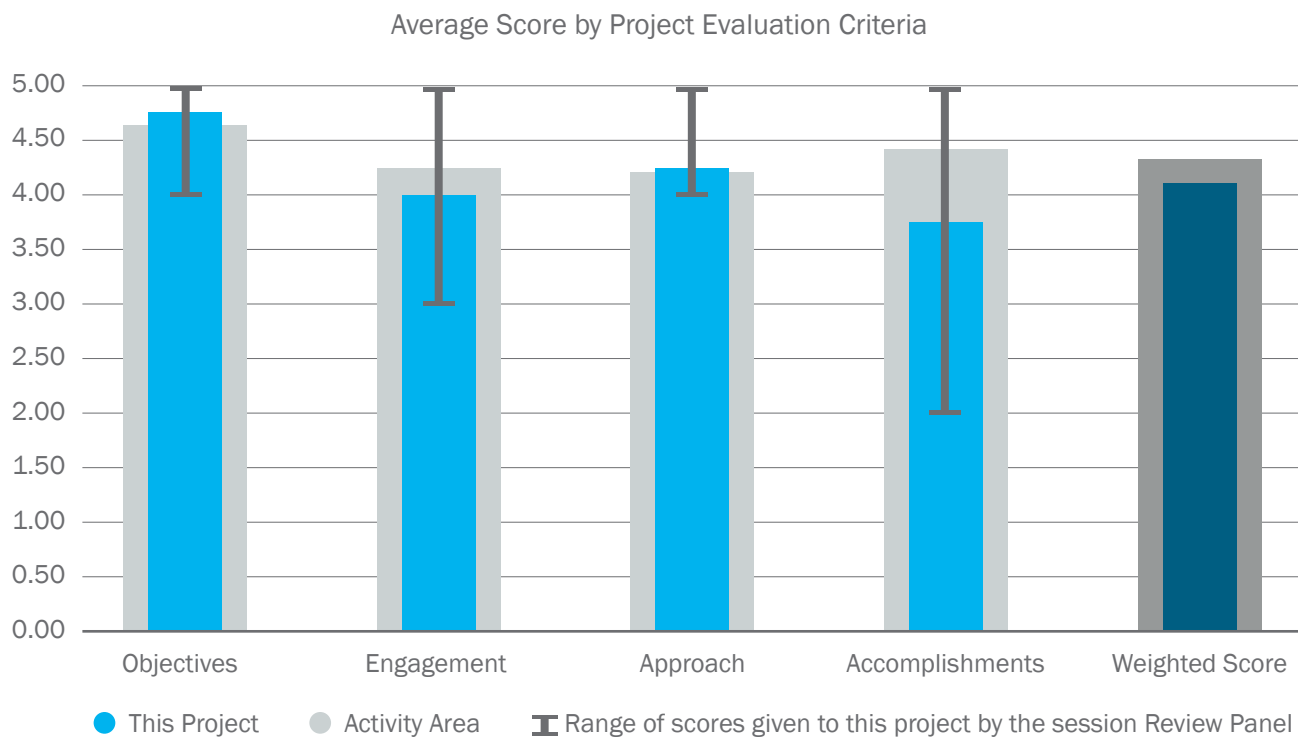
Recipient:	PNNL
Principal Investigator:	Daniel Deng
Project Type:	AOP
Project Category:	Completed and Sunsetting Projects
Total Authorized:	\$150K
Total Costed:	\$125K

## Project Description

The goal of this project is to prepare the self-powered transmitter for commercialization by demonstrating its viability and market impact in collaboration with private partners. The self-powered transmitter is a unique technology developed by PNNL and has generated interest from the private sector for application and technology transfer. This project is part of TCF Laboratory Call for Proposals in June 2016 and is extended without additional funds into 2019 to complete the field study component.

## Weighted Project Score: 4.1

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%.



## Summary of all Reviewers' Comments

### Overall Impressions

All reviewers were very favorably impressed with this tag. It would likely be widely used to better understand fish movements and behavior if it can be developed for commercialization.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The reviewers agreed that the explanation of project objectives was clear and aligned with DOE program objectives. All agreed that this is a great idea, with substantial range of potential applications to facilitate tracking and protecting fish migration at hydroelectric facilities. One reviewer commented that, while objectives were well described, it was not clear if objectives will be met.

### End User Engagement and Dissemination Strategy

In general, reviewers agreed that the engagement and dissemination efforts were good and included partnerships with a range of companies, presentations at conferences, and well-read articles published. One reviewer would have appreciated more details on how project partners were selected and how many licensees were queried regarding the utility of this tag.

### Management and Technical Approach

In general, reviewers agreed that the management and technical approach was sound. In spite of some hurdles, good decisions have been made to date. It is not clear whether this tag will continue toward full development for use in the field.

### Technical Accomplishments and Progress

All reviewers were impressed with the accomplishments in spite of some problems. Reviewers appreciated the candid description of problems. Some more details on tag specifications would have been appreciated. It is not clear whether this project will continue to fruition, which would be disappointing, as this tag has significant potential to be valuable in long-term monitoring of fish. Of course, it will only be useful if the price point for it is affordable; if that becomes an issue, then perhaps it should be shelved until other ideas come along. A description of the various go/no-go decision points (past and future) would have been helpful.

# COMMERCIALIZATION OF SENSOR FISH TECHNOLOGY TO SUPPORT HYDROPOWER DEVELOPMENT (TCF)

(WBS #: 2.5.0.604)

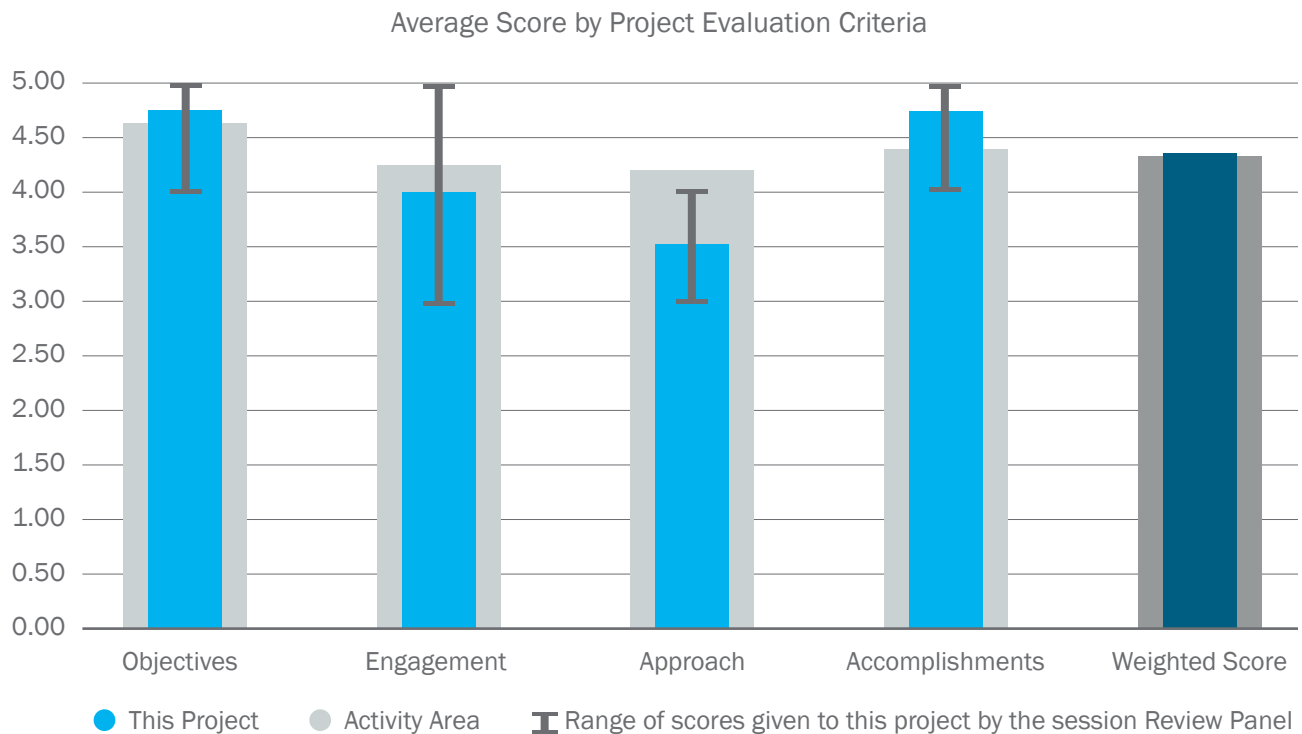
Recipient:	PNNL
Principal Investigator:	Daniel Deng
Project Type:	AOP
Project Category:	Completed and Sunsetting Projects
Total Authorized:	\$150K
Total Costed:	\$150K

## Project Description

The objectives of this project were to (1) commercialize the Sensor Fish Technology to support hydropower development and evaluations; and (2) develop a prototype of a smaller version (Sensor Fish Mini) to characterize the growing need for sustainable small hydropower and testing scale-turbine models. It will provide information, data, and tools for dam operators and turbine designers to use to improve turbines and structures, as well as to understand and mitigate the environmental effects of hydropower operations on fish. It will also reduce regulatory review times and costs by reducing the need to conduct studies with live fish.

**Weighted Project Score: 4.4**

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%.



## Summary of all Reviewers' Comments

### Overall Impressions

The commercialization process was a success, and the product was highly useful for improvement of fish conditions in turbines. Reviewers were positive about this PNNL support for commercialization and about the business model that was set up that brings license royalties back to the inventors and lab, and they encourage this support for other innovations. The need for ongoing user support for the product has not been addressed but needs to be. One concern was with the selection of partners for commercialization—the rationale and decision process were not provided. The project could not be evaluated as thoroughly as reviewers would have liked because of a lack of budget information. The reviewers would have also liked to see a schedule for commercialization of the Sensor Fish Mini.

### Project Objectives, Impacts, and Alignment with the Program Strategy

Reviewers agree that this project is well aligned with the Hydropower Program objectives under the environmental R&D and hydrological systems pillar, as well as the technology R&D for low-impact hydropower growth pillar. They are enthusiastic about the value and success of the sensor and point out “the substantial interest in the hydropower industry to use this device. The effort to commercialize it does make sense and has been welcomed by the users. The development of a mini version of the device broadens its range of applications to small hydropower and possibly model test facilities.”

### End User Engagement and Dissemination Strategy

Half the reviewers were favorably impressed with the engagement with Natel, Advanced Telemetry Systems, and the farmers and irrigation organizations, as well as with the dissemination strategy that included licensing of IP, presentations and workshops, peer-reviewed journal articles, and media reports. However, reviewers also felt that the process for selecting the participants was not explained and could have been broader or more aligned with larger markets. Some reviewers expressed some dissatisfaction with the timeline of commercialization and limitations to PNNL during that process, as well as with “marginal industry participants,” noting that the project should have mentioned wider industry applications.

### Management and Technical Approach

The commercialization process, once started, happened efficiently and successfully. The reviewers expressed several concerns, including (1) selection of the commercialization partners was not described nor criteria provided; although ATS appears to be “the right way to successful dissemination of the sensor,” (2) working with major turbine suppliers and users would be more appropriate; and (3) it took too long—well over a decade—for this commercialization, during which time data were collected for decisions, whereas other acoustic tags were being pushed out to commercial market more quickly. The project did not present a schedule, milestones, or success criteria for the testing.

### Technical Accomplishments and Progress

Reviewers noted that the project is a success in that commercialization has been achieved and the product already contributed to the knowledge of turbine environment, testing new designs, and improving conditions for fish by operations. However, it is noted that this project is not the development of the product, but rather the commercialization. The three main tasks were accomplished: (1) the prototype design and lab field investigations of the mini; (2) development of a manufacturing process for commercialization; and (3) the patent was obtained, IP established and licensed, and papers published.

# EVALUATION OF THE WHOOSH H FISH TRANSPORT SYSTEM

(WBS #: 3.1.0.604)

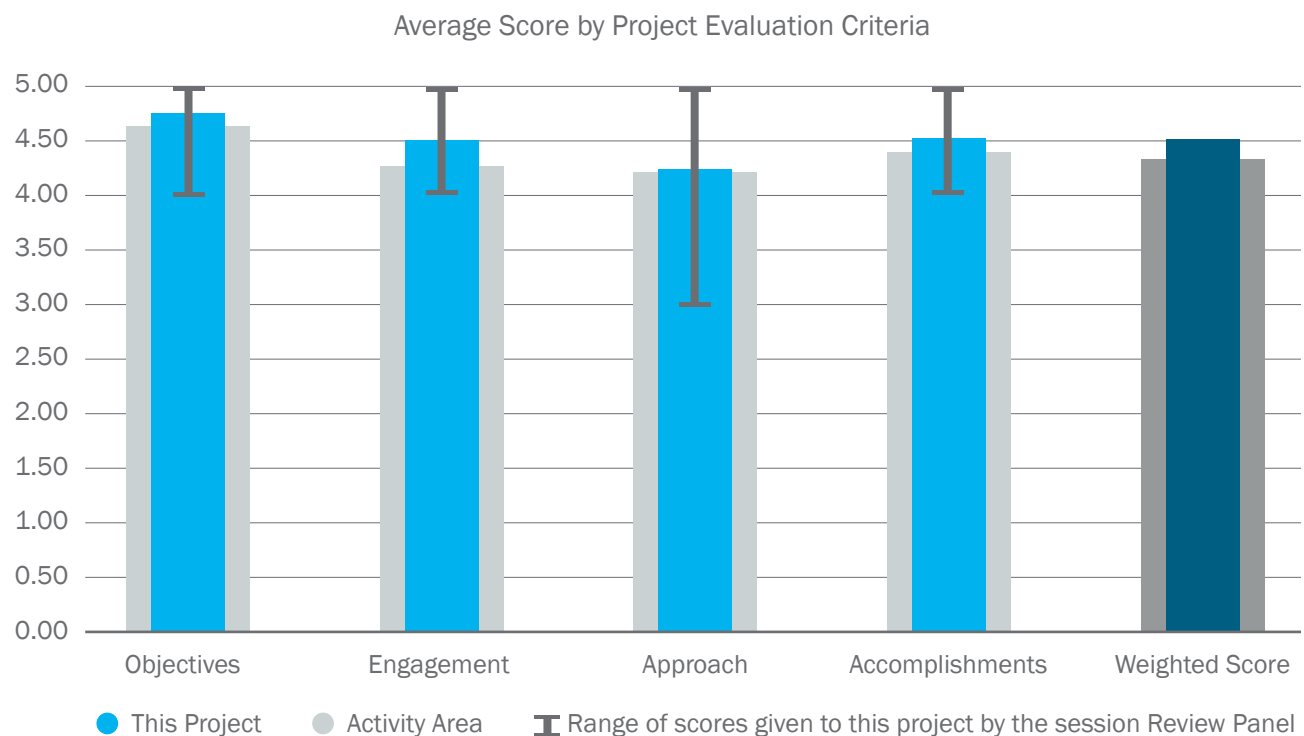
Recipient:	PNNL
Principal Investigator:	Alison Colotelo
Project Type:	AOP
Project Category:	Completed and Sunsetting Projects
Total Authorized:	\$375K
Total Costed:	\$300K

## Project Description

The evaluation of the Whooshh Fish Transport System project provided laboratory technical services to Whooshh Innovations, Inc. (Whooshh) in response to their SBV award. Under this program, PNNL supported Whooshh by (1) developing a flow chart roadmap that defined the limits and criteria for new fish passage technologies and (2) designing and executing an independent evaluation of the capabilities of the Whooshh Fish Transport System to sort fish by size. This project provided Whooshh with access to intellectual and technical resources found within PNNL, specifically experts in fish passage. PNNL conducted a third-party evaluation of the Whooshh Fish Transport System and published results in peer reviewed literature. This increased access of information about this technology to regulatory agencies and spurred regular meetings to share information about developments. These results aided Whooshh in their mission to fully commercialize the technology, specifically for river systems with species of regulatory concern.

## Weighted Project Score: 4.5

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%.



## Summary of all Reviewers' Comments

### Overall Impressions

Even though all of the objectives were not met, the reviewers provided high marks for this project. This system is an innovative fish passage option. Whooshh has struggled to get acceptance by agencies because it is new and untested. This test, along with a few others conducted or soon to be conducted, should help with the demonstration and acceptance of this option for fish passage. It promises significantly lower costs than conventional fishways because, in part, it requires much less, if any, civil works. Multiple reviewers appreciated the assistance provided to private firms.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The reviewers agreed that the explanation of project objectives was clear and aligned with DOE program objectives. The project had two primary objectives: (1) to develop a decision tree for evaluating new technologies and (2) to test the Whooshh Fish Transport System in the field under controlled conditions. One reviewer did not think that development of the decision tree was worthwhile because of differences in agencies' approaches and review processes. The field evaluation was supported by all.

### End User Engagement and Dissemination Strategy

Reviewers agreed that the engagement and dissemination strategy of this project team appears to be sound. This project benefits Whooshh directly. Hopefully there will be indirect benefit to hydropower project owners.

### Management and Technical Approach

Reviewers were divided on the management and technical approach. One criticized the lack of details on challenges and performance criteria (for the project itself). Another reviewer did not think the decision tree task was worthwhile. Other reviewers liked the Whooshh/PNNL partnership aspect and how it was conducted.

### Technical Accomplishments and Progress

The project scored well for technical accomplishments and progress, with a minor hit for the fact that the decision tree was not accepted by regulators. The publishing of results is a strong point. One reviewer suggested publication in Hydro Review.



# MODULAR AND SCALABLE DOWNSTREAM PASSAGE SYSTEMS FOR SILVER AMERICAN EELS

(WBS #: EE0008338)

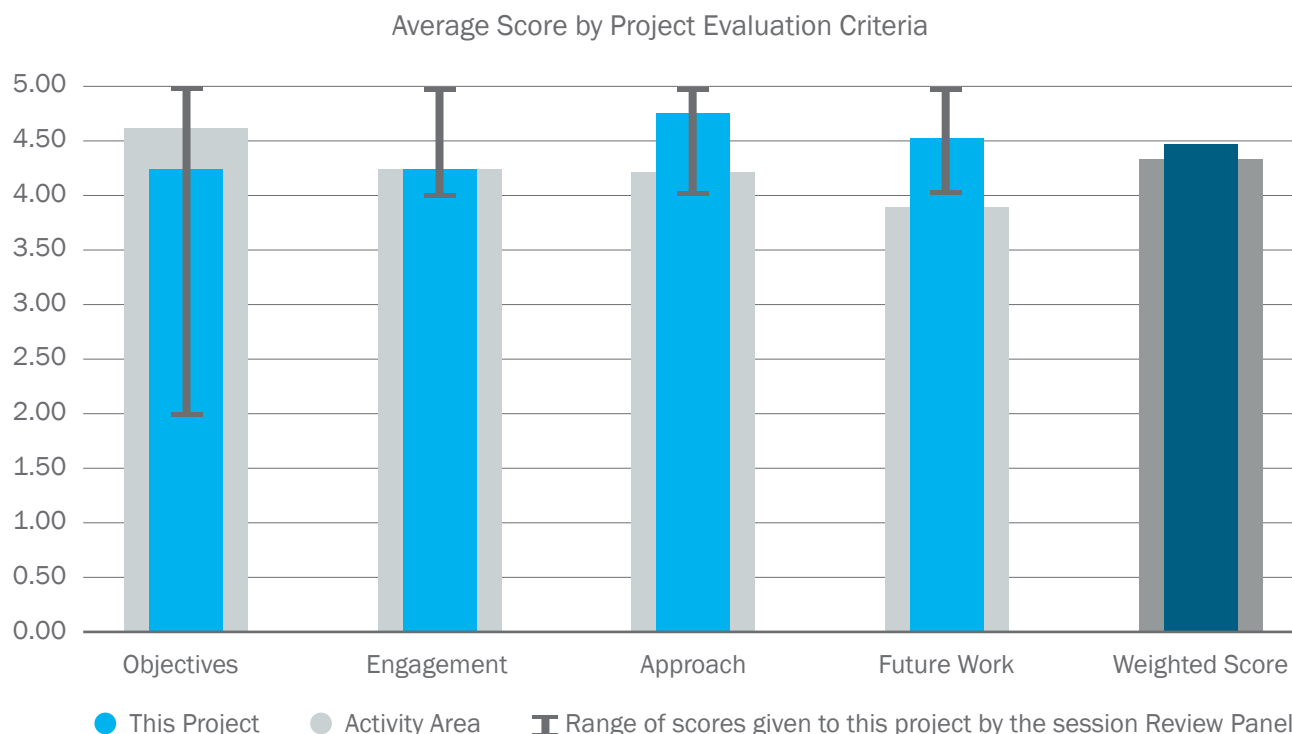
Recipient:	Alden Research Laboratory, Inc.
Principal Investigator:	Steve Amaral
Project Type:	FOA 1662: Innovative Solutions for Fish Passage at Hydropower Dams
Project Category:	New Projects
Total Authorized:	\$1,020K
Total Costed:	\$284K

## Project Description

The goal of this project is to address the need for biologically and cost-effective downstream passage for silver American eels at hydropower dams. To achieve this goal, the project team is evaluating and optimizing the design and operation of two new bypass systems developed specifically for silver eels. The study includes lab, field, and hydraulic modeling evaluations of each system to determine biological performance. A desktop assessment of potential application at U.S. East Coast hydropower projects is also being conducted. The combination of evaluation methods will produce a robust set of biological and operational performance data to guide future applications of each technology.

**Weighted Project Score: 4.5**

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Future Work–40%.



## Summary of all Reviewers' Comments

### Overall Impressions

This project applied several tools to reach its stated goals. In addition to laboratory and field testing, CFD modeling allowed the team to inform on design parameters in a way that physical testing alone would not be able to do. The reviewers noted that this promising technology should be made available as soon as possible to implement in the hydropower industry.

### Project Objectives, Impacts, and Alignment with the Program Strategy

Reviewers generally agreed that the project was well-aligned with the program's strategic approaches and addresses a key problem of eel passage at hydropower facilities. Numerous facilities will benefit from this program, and successful completion of the project will lead to establishment of two downstream eel bypass designs that are modular, scalable, and cost-effective.

### End User Engagement and Dissemination Strategy

Reviewers agreed that the end-user engagement and dissemination strategy was strong. Reviewers agreed that positive project aspects include strong outreach and generation of industry interest before the final results are known. The reviewers wished for more engagement of NGOs and entities that do not attend NHA conferences.

### Management and Technical Approach

The reviewers positively scored the management and technical approach for this project, emphasizing that the project had a very strong group of project executors, including leading organizations in their respective fields. The combination of computational simulation followed by laboratory and field testing will lead to the conclusion of the program. One noted concern is the missing go/no-go point.

### Technical Accomplishments and Progress

The achievements to date are strong, despite some understandable delays. The accomplishments to date have met or exceeded expectations and all technical targets have been achieved.

### Future Work

Reviewers scored the planned future work positively. They felt that the project summary document lacked details, but they believed that work completed so far was well presented. More information was delivered during the presentation.

# FISHWAY ENTRANCE PALISADE

(WBS #: EE0008340)

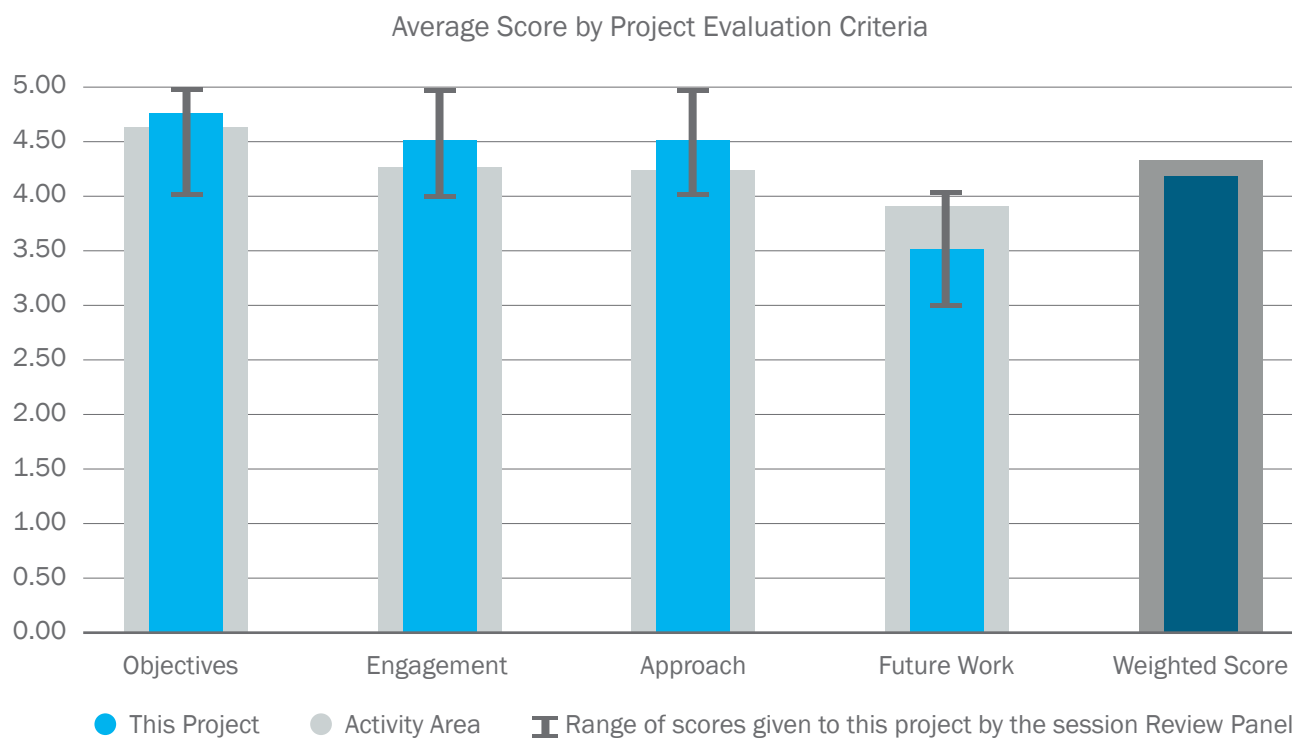
Recipient:	University of Massachusetts Amherst
Principal Investigator:	Richard Palmer
Project Type:	FOA 1662: Innovative Solutions for Fish Passage at Hydropower Dams
Project Category:	New Projects
Total Authorized:	\$388K
Total Costed:	\$46K

## Project Description

The Entrance Palisade represents a fundamental shift in how to deliver auxiliary water to a fishway entrance. Unlike a conventional auxiliary water system, the Entrance Palisade discharges attraction water through an angled palisade (i.e., louvered exclusion diffuser) adjacent to the actual entrance. This eliminates the adverse, confusing hydraulics created by in-channel diffusers that have been linked to fish falling back out of a fishway. An Entrance Palisade can reduce construction and maintenance costs by using smaller diffusers.

## Weighted Project Score: 4.2

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Future Work–40%.



## Summary of all Reviewers' Comments

### Overall Impressions

The presented design offers the possibility of an economically attractive way to deliver water to the fishway entrance. The attraction method is based on fish behavior and eliminates disadvantages of traditional in-channel diffusers. The concept is simple and appears easy to implement. It also may offer a possibility of reduction of the rate of the flow of water, increasing its cost of operation.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The reviewers agreed on the high value of the project, its impact, and its alignment with program strategy. The only objection noted was a desire for more information on how the project aligns with the program. A noted value is in the applicability of this concept to many target species.

### End User Engagement and Dissemination Strategy

The reviewers agreed that the end user engagement and dissemination strategy was sound but noted that the project could benefit from more engagement and targeted outreach with resource agencies. One reviewer pointed out insufficient clarity on who will promote this design to the users.

### Management and Technical Approach

The reviewers agreed that the project appears to be well managed and coordinated, with a diverse team from several agencies and research programs. No specific items lowering the score were identified.

### Technical Accomplishments and Progress

Reviewers agreed that the preliminary results are promising, and a lot has been achieved so far. Notes from the reviewers pointed out that lab results may not be sufficient to satisfy needs by the regulators. It is also uncertain if conversion of the existing fishway to the proposed design will be feasible.

### Future Work

Future work, as described, was scored at four by two reviewers and three by the others. The primary reason for the lowest score was the brevity of information provided. It would be desirable to provide a description of purpose or methodology of future work, as well as what is needed to make this innovative design used.

# DEEP LEARNING FOR AUTOMATED IDENTIFICATION OF EELS IN SONAR DATA

(WBS #: EE0008341)

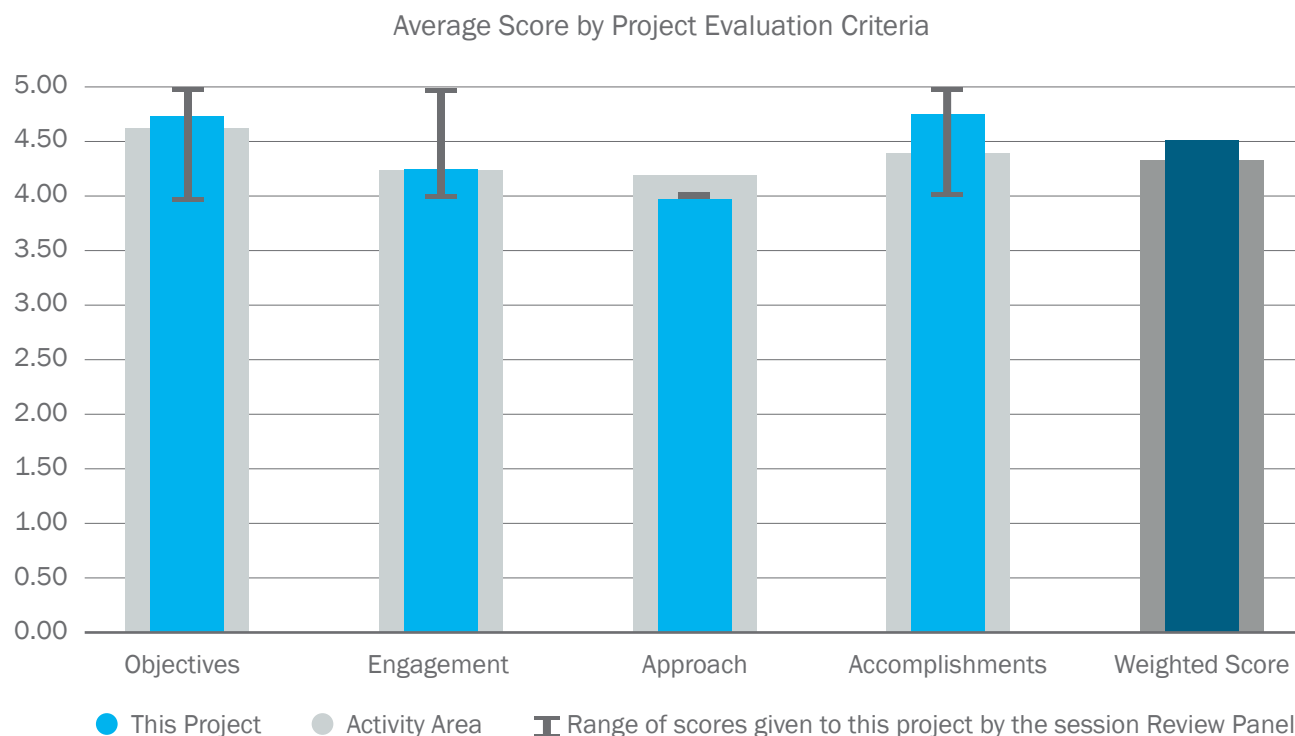
Recipient:	Electric Power Research Institute
Principal Investigator:	Paul T. Jacobson
Project Type:	FOA 1662: Innovative Solutions for Fish Passage at Hydropower Dams
Project Category:	Completed and Sunsetting Projects
Total Authorized:	\$500K
Total Costed:	\$37K

## Project Description

This project has the objectives of (1) developing machine-based detection of American eel from ARIS sonar data; (2) demonstrating automated classification accuracy commensurate with human-supervised classification accuracy; (3) encapsulating the analysis tools in open-source, computer language packages; and (4) disseminating the results to the relevant technical community. The project uses wavelet filtering to enhance the video images and applies convolutional neural networks for deep learning and object classification. The results will facilitate R&D and monitoring of eel passage facilities at hydropower projects, thereby reducing costs and enhancing environmental performance.

**Weighted Project Score: 4.5**

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Accomplishments–40%.



## Summary of all Reviewers' Comments

### Overall Impressions

The project addresses an important issue of identification of American eels passing through hydropower plants. The traditional process of reviewing collected data by a human is cumbersome and time consuming. An automated identification will substantially reduce cost and time, as well as provide better accuracy of detection. As a result, eel losses in hydropower plants can be reduced. The reviewer recommendations included marketing the software that results from this project.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The reviewers were mostly in agreement on Project Objectives, Impacts, and Alignment with the Program Strategy. Outlined values of the program include the use of innovative technologies to advance the state of the art of eel monitoring. There were no comments substantiating score reduction.

### End User Engagement and Dissemination Strategy

Most of the reviewers' comments were very positive, outlining that the work products will be available to outside users. Issues that reduced the score included lack of specific information and an insufficient explanation on how end user groups have been and will be engaged, including market assessment planning, dissemination, and adoption of the technology. Also, specific end users were not identified.

### Management and Technical Approach

The reviewers scored the management and technical approach positively. Acknowledged positive elements are a strong team, composed of qualified individuals, as well as the fact that the project ends on budget. The identified weaknesses of the presentation include insufficient explanation of critical success factors and risks.

### Technical Accomplishments and Progress

The reviewers agreed that the project has met its objective of developing machine learning algorithms for eel detection that are as good as the accuracy achieved by human analysts. Though there was some discrepancy between level of detail in the project summary and the presentation, reviewers agreed that the results are encouraging, with relatively high accuracy of detection.

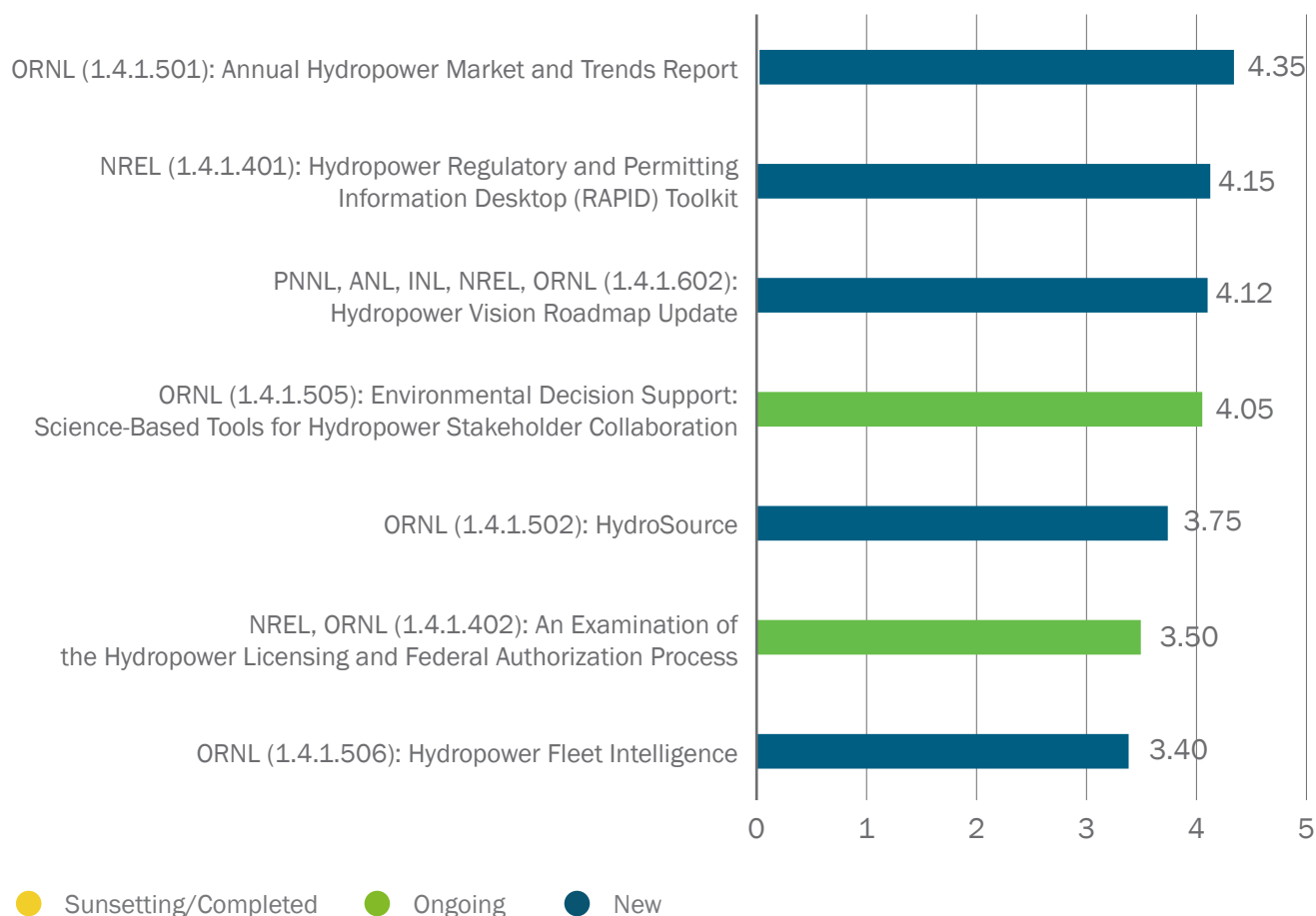
## Big-Data Access and Management

This section provides an overview of the scoring for all projects within the Big-Data Access and Management activity area (see Figure 16); the review panel lead's summary of reviewer comments in response to the evaluation criteria; and full evaluation results for individual projects.

### Activity Area Score Results

Name	Average Weighted Score of All Projects
Big-Data Access and Management	3.95

**Figure 16. Big-Data Access and Management activity area—average weighted score by project**





## Activity Area Summary Report

*Prepared by the Review Panel Lead*

### *Feedback from the Review Panel to WPTO*

In general, reviewers supported the projects in this activity area, but with some concerns and skepticism. All these projects are monumental undertakings. If done well, they should provide useful tools, but will likely need to be never ending because of a need to update information continuously. Some of the skepticism was based on whether seemingly small sample sizes would be representative (there were not explanations for how sample sizes were determined, nor how samples were selected). If these projects can be completed as proposed, the tools should be useful, although the value (utility/cost) may be lower than expected.

### *Summary of All Reviewers' Comments*

#### **Overall Impressions**

Reviewers generally supported the projects' objectives. There were several comments on sample sizes and how samples were selected, the perceived lack of go/no-go decision frameworks, and the value of existing information to support a larger compiled database. Reviewers thought that some projects seemed to be more academic than applied. However, acknowledging the constraints of the peer review period in which projects were reviewed, the review panel evaluated projects using the snapshot of information provided in a brief timespan and with limited resources. Reviewers understood that there may have been additional background information that was not seen or reviewed. Under those constraints, the review panel was intent on offering thoughtful, constructive comments for WPTO to consider.

#### **Program Strategy and Objectives**

Given the power of computing, analytical, and compilation tools at hand today, the focus of the projects in the portfolio is understandable. Compiling, categorizing, and analyzing data are overarching traits of scientists and engineers. That said, reviewers were not convinced that all approaches and future direction will achieve the objectives. While there were no calls to stop any of the projects, an objective look at multiple reasonable points along the timelines of these projects would be worthwhile for DOE to take to ensure the wise use of taxpayer dollars.

In a sense, it appears that the program is compiling information because the information is there to compile. It is not clear whether that is the first step in a broader scheme or whether these projects are what were most appealing at the time of proposals regardless of a broader scheme. Certainly, the regulatory aspects of the industry continue to be a major concern. It is not clear that any of the big data projects presented will go a long way toward solving those problems. In fact, the one project with the objective to examine licensing and federal authorization explicitly states that no regulatory recommendations will be made as an outcome of the project. There may be DOE rules or policies preventing such recommendations, but they are needed to resolve the licensing problems. Reviewers thought that engaging with experienced licensing professionals in a short workshop could help to determine multiple well-reasoned potential solutions to licensing issues. With those potential solutions identified, big data support may be more useful, whether on the hydro growth or hydro curtailment side of the spectrum.

With respect to more technical issues, one reviewer was impressed with the huge amount of information gathered but could not see how it would contribute to improving grid reliability, resilience, or integration, or how it would promote further growth of hydro. The nexus between the more regulatory focused projects in this program and an acceleration of the development of innovative technologies is unclear. The nexus for

the HydroSource and Hydropower Fleet Intelligence projects is more apparent. The reviews submitted for consideration in development of this summary recognized the potential for important outcomes, if the projects are done well. It was not clear to that reviewers how the desired outcomes would be achieved.

No reviewers explicitly stated that taxpayer funds have not been invested wisely. There were comments on the lack of attention (even though prompted by the review topics) to go/no-go decision points or frameworks. Given that the projects under peer review are in various stages along their timeline, it can be difficult to judge whether wise investments have been made. More attention to the go/no-go frameworks and presentation of what decisions were made (and why) during a project's timeline would be helpful.

### **Program Portfolio**

If the projects are completed cost effectively and deemed useful by the end users, this program will contribute to meeting the strategy and objectives. For most in this program, it is simply too early to draw conclusions on this bullet item. If the regulatory-focused projects can be completed cost effectively, they may be useful tools for some. It is not clear at this time that they will address key challenges and reduce barriers in the regulatory arena. For the more technical-focused projects, they may also be useful tools, and, if completed cost effectively, they could help to address key challenges and advance technologies; it just was not clear to the reviewers of these projects how the teams intend to accomplish those goals.

There was mixed input from reviewers on whether presentations effectively conveyed the rationale and organization of the projects. One aspect that would be helpful to reviewers is for them to receive all materials (including presentations) well in advance of the peer review. Complete budget information was not presented in many cases, and few effectively described those milestones in the timeline where go/no-go decisions were made and why. In all cases, reviewers saw some or great merit in the projects, assuming they are completed in a cost-effective manner. Without complete budget information, reviewers had difficulties in assessing whether priorities and resources were allocated appropriately. One suggestion was to have a specific team of reviewers stay with a project (and perhaps program) from proposal to completion. There may be some difficulties in implementing such an approach, reviewers would like WPTO to consider it. Finally, the reviewers agreed that the projects within this program portfolio are appropriate for WPTO's role as a public R&D organization.

### **Program Management Approach**

In most cases, reviewers agreed that the program team effectively manages and directs the activities needed to meet its objectives, which is exemplified by the high score for this evaluation criterion. There were some questions about how they might accomplish various aspects (e.g., how to deal with historical data that may not be of high quality or reliability, and how to incorporate intangible variables such as personalities and biases into a database intended to assist with study development).

While no reviewers suggested the termination of a project, there was mixed input on the value of some projects. Some reviewers thought a project had great promise, while others questioned whether the tools developed would have the impact desired. Regarding communicating the allocation of resources, reviewers indicated that presentation of budget and future work aspects would have been more useful if complete project budgets were included.

In all cases, the reviewers thought that the teams were well qualified. However, some of the PIs have not led the work that they are building a big dataset for. The inclusion of focus groups or advisors is a good approach for these types of projects. The reviewers agreed that the Hydropower Program team is robust and works well together, but it difficult to assess that with any rigor or detail within the limited amount of time to observe the team in action.

**Stakeholder Engagement, Outreach, and Dissemination**

Regarding transparently communicating how WPTO funds are being utilized, reviewers agreed that more information on the budgets and their use would have been appreciated. Some project presenters only presented budget used for the past two years and not the full project, so it was virtually impossible to assess whether funds were used efficiently over the course of the project.

In gathering feedback from stakeholders to inform and improve WPTO's projects and strategy, reviewers recommended continuing to consult with its current strong ties to NHA, NWhA, and The Hydropower Foundation. The Hydropower Foundation is anxious to find the next program with WPTO to make a difference in the hydro industry. With Linda Ciocchi as the new Executive Director, the organization is well positioned to tackle new initiatives. Reviewers recommended engaging in a series of regional meetings with high-level representatives of individual hydro, regulatory, consulting, and special interest groups. It is unclear whether such meetings would be more productive if groups were to segregate or integrate based on their position along the hydro value spectrum, perhaps attempts at both would be informative. WPTO should pose questions and situations that test the representatives of each sector to justify their positions and broker meaningful conversations between articulate advocates for important issues/positions and policymakers.

Overall, reviewers thought that the dissemination of WPTO-supported research results was extensive. The panel lead questioned the importance of focusing on primary literature publications in journals that are relatively obscure to the industry. Reviewers recommended that PIs focus information dissemination to the end users.

Reviewers generally agreed that the program provides access to accurate and objective information and data that can help to accelerate industry development and inform decision makers. Reviewers agreed that the program has the potential to accomplish this goal, as several projects are in 'midstream.'

## Project Evaluations

# HYDROPOWER REGULATORY AND PERMITTING INFORMATION DESKTOP (RAPID) TOOLKIT

(WBS #: 1.4.1.401)

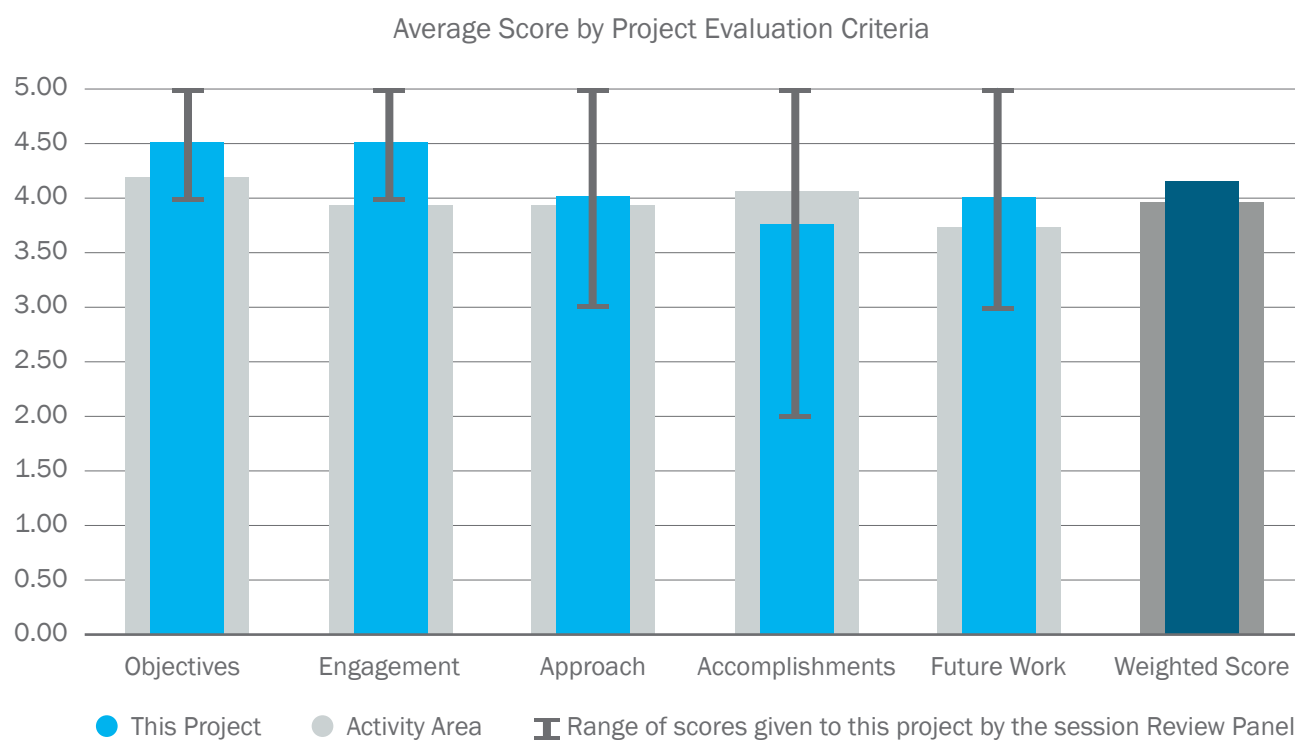
Recipient:	NREL
Principal Investigator:	Aaron Levine
Project Type:	AOP
Project Category:	Ongoing Projects
Total Authorized:	\$1,211K
Total Costed:	\$1,087K

## Project Description

The Hydropower RAPID Toolkit project aims to increase the transparency and efficiency of the regulatory process for hydropower projects in the United States. Key aspects of the RAPID Toolkit project include performing significant stakeholder outreach and engagement to frame and guide the project for significant impact; reviewing federal and state permits and regulatory processes/approvals required for developing hydropower projects in the United States; developing/curating a regulatory and permitting database; cataloguing reference material; and documenting hydropower regulatory best practices and lessons learned. Federal and state agencies, as well as industry stakeholders, have reviewed and provided feedback on permitting processes for conventional hydro, non-powered dam development, and PSH projects.

## Weighted Project Score: 4.2

*Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.*



## Summary of all Reviewers' Comments

### Overall Impressions

The RAPID toolkit successfully serves to increase transparency and efficiency in the hydropower licensing and permitting process, and it should be useful for stakeholders in the licensing process. All reviewers recommended that the toolkit be maintained past the stated project closure date, as otherwise, it will quickly become obsolete.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The project clearly contributes to the program's strategy and approaches. The greatest contribution of the project is in helping hydropower developers understand and navigate the complex regulatory process. It also has the potential to help inform policymakers and improve coordination among resource agencies, although the success of this last is unclear. One reviewer said the discussion would benefit from a description of how the licensing process works in the absence of the tool and how it is improved by using the tool. The website is well-designed, and the potential use of the toolkit is strong.

### End User Engagement and Dissemination Strategy

The beneficiaries and end users of the toolkit have been clearly identified, conducting early outreach to multiple key groups (industry and federal agencies) that helped inform the organization and functionality of the toolkit. This helped align the toolkit with industry expectations and needs. One reviewer pointed out that less outreach has been done with stakeholders from the non-government organization community, which can be improved. The various beneficiaries have different uses for the tool, which are not explicitly differentiated. Overall, the engagement and dissemination are strong.

### Management and Technical Approach

The management approach is sound, with a highly qualified project team. The technical approach is thorough and appears to cover all the important elements of the processes covered by the toolkit. The use of search engine optimization and web-based tools to increase the reach of the toolkit are very good. Two reviewers pointed out the lack of critical success factors identified for the project, despite a description of metrics used to monitor progress. These reviewers disagreed on whether or not the project showed clear milestones.

### Technical Accomplishments and Progress

The reviewers had the greatest differences in this section; all agree that the accomplishments have been clearly listed, but while one reviewer says these accomplishments are "impressive," another says it is impossible to judge their success without performance metrics. The lack of targets provided makes it difficult to judge how the milestones relate to overall project success. A wealth of information is contained within the toolkit website. The web analytics show increased access to the tool, but not how the tool has been used.

### Future Work

The end date of the project is not clear, but the review team believes it's winding down. One reviewer questioned if all the data is already in the tool and suggests a plan for testing and feedback on data evolution and update needs. Another reviewer suggests that if sufficient time remains, it would be useful to develop additional best practices and other knowledge products, which do not appear in current plans for future work. A third reviewer suggested including a section in the toolkit on licensing delays (characterizations of why, how long, what the resolutions have been, and what strategies have been effective in reducing delays, with specific examples provided), as well as a characterization of mandatory conditions and trial type hearings. The reviewers recommend that a plan be made to keep the tool up to date, including the addition of new content, over the coming years to prevent early obsolescence.

# AN EXAMINATION OF THE HYDROPOWER LICENSING AND FEDERAL AUTHORIZATION PROCESS

(WBS #: 1.4.1.402)

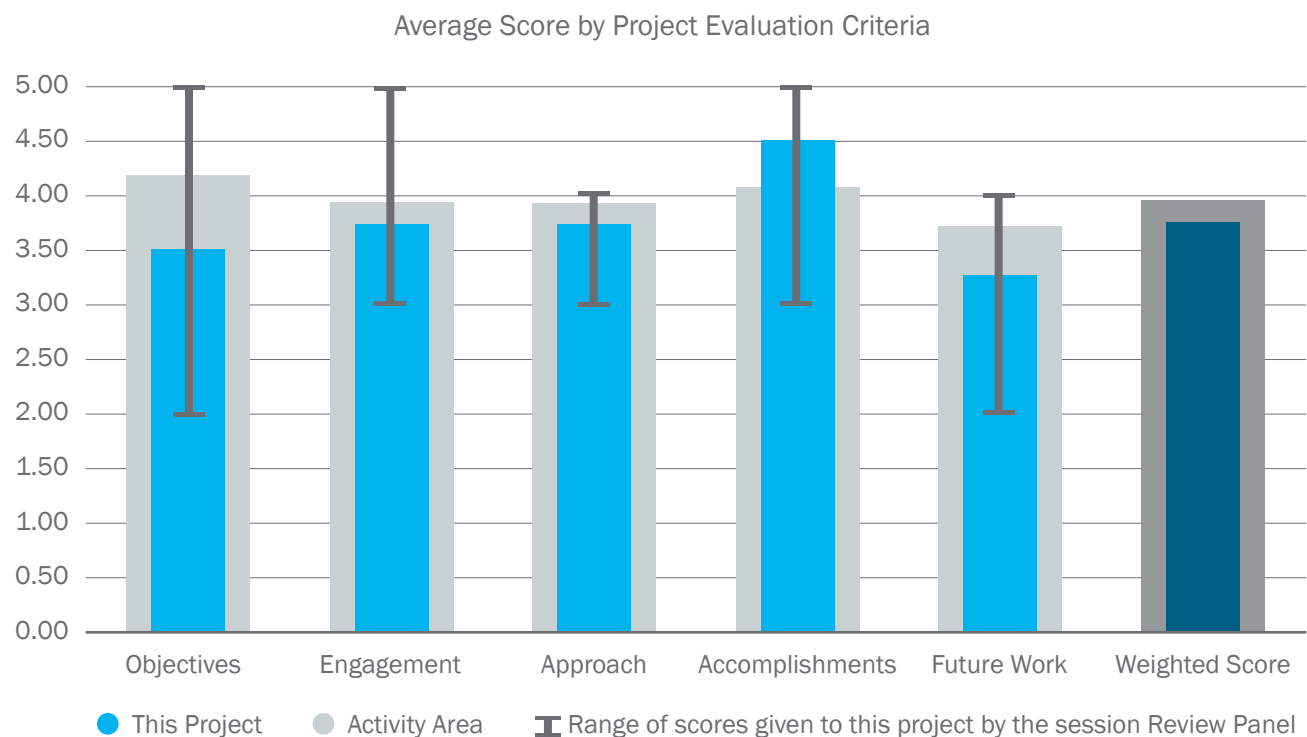
Recipient:	NREL and ORNL
Principal Investigator:	Aaron Levine
Project Type:	AOP
Project Category:	New Projects
Total Authorized:	\$1,538K
Total Costed:	\$342K

## Project Description

The process to acquire a hydropower license and associated approvals for an individual development project is uncertain, impacting the length and cost of project development. As a result of this uncertainty, policymakers have relied solely on anecdotal information when proposing regulatory reform. This project will use scientifically based quantitative and qualitative analyses and a “multiple-lines-of-evidence” approach to examine hydropower licensing timelines; causal factors; and the implications of timelines on risk, cost, and deployment.

**Weighted Project Score: 3.5**

*Weighting: Objectives–20%; Engagement–20%; Approach–20%; Future Work–40%.*



## Summary of all Reviewers' Comments

### Overall Impressions

The reviewers all agreed that the broad objectives of the project are worthwhile—to shed light on the licensing process with the ultimate goal of reducing time and cost. However, although the management team seems qualified, there is general skepticism about the technical approach, especially the potential success of the quantitative analysis due to sample size limitation, the possibility of finding a meaningful set of drivers of variability, and the likelihood that key factors such as personality of participants will not be considered. One reviewer suggested a feasibility level analysis to determine if the technical approach is sound; this could serve as the missing go/no-go decision point. Most reviewers felt that the project's outcomes will not be useful unless policy change recommendations are made, but this is not planned. Reviewers were not satisfied with the range of participants engaged in the project, with different reviewers wanting to see various additional entities included.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The reviewers all agreed that the broad objectives of the project are worthwhile; however, all reviewers pointed out conceptual flaws. These included the failure to focus on or make recommendations to decision makers who could alter policies, the challenge of being able to identify common obstacles because each case is so different, and the lack of identification of a specific use case for the results.

### End User Engagement and Dissemination Strategy

References to almost all participants in the licensing process, as well as policymakers, are listed as end users or beneficiaries; these also include the various permitting agencies themselves who could identify redundancies in requirements. The reviewers were divided on how effective the engagement strategy is, reflecting satisfaction with the effort to get input on the methodology and scope, but noting concern that it has not been broad enough, has not targeted the most key entities, and that not enough information was provided about the engagement.

### Management and Technical Approach

The project is managed by a strong, well-qualified team and has well-implemented processes, but began without a clear research approach. The reviewers had concerns that the current technical approach may not yield useful results, especially that the sample size of cases may be inadequate, that it may not be possible to extract a useful set of drivers in the statistical analysis, and that these would likely omit key considerations like personalities and geographic regions. The “multiple lines of evidence” approach was not explained, leaving uncertainty about the prospect of getting meaningful outcomes, and critical success factors listed are simply general tasks; meaningful success factors were not identified.

### Technical Accomplishments and Progress

The main accomplishment for this project thus far is the identification of the collection of cases that will be used for the analysis, reports to stakeholders, and webinar. The project has been proceeding according to the timeline and has made great progress while being well under budget.

### Future Work

The reviewers had varying opinions about the adequacy and quality of future project plans, with some satisfied that the description of future work is enough to give confidence in successful completion, and others noted that schedules and milestones for all the tasks were not provided in the project summary or presentation, nor were the go/no-go points identified.



# ANNUAL HYDROPOWER MARKET AND TRENDS REPORT

(WBS #: 1.4.1.501)

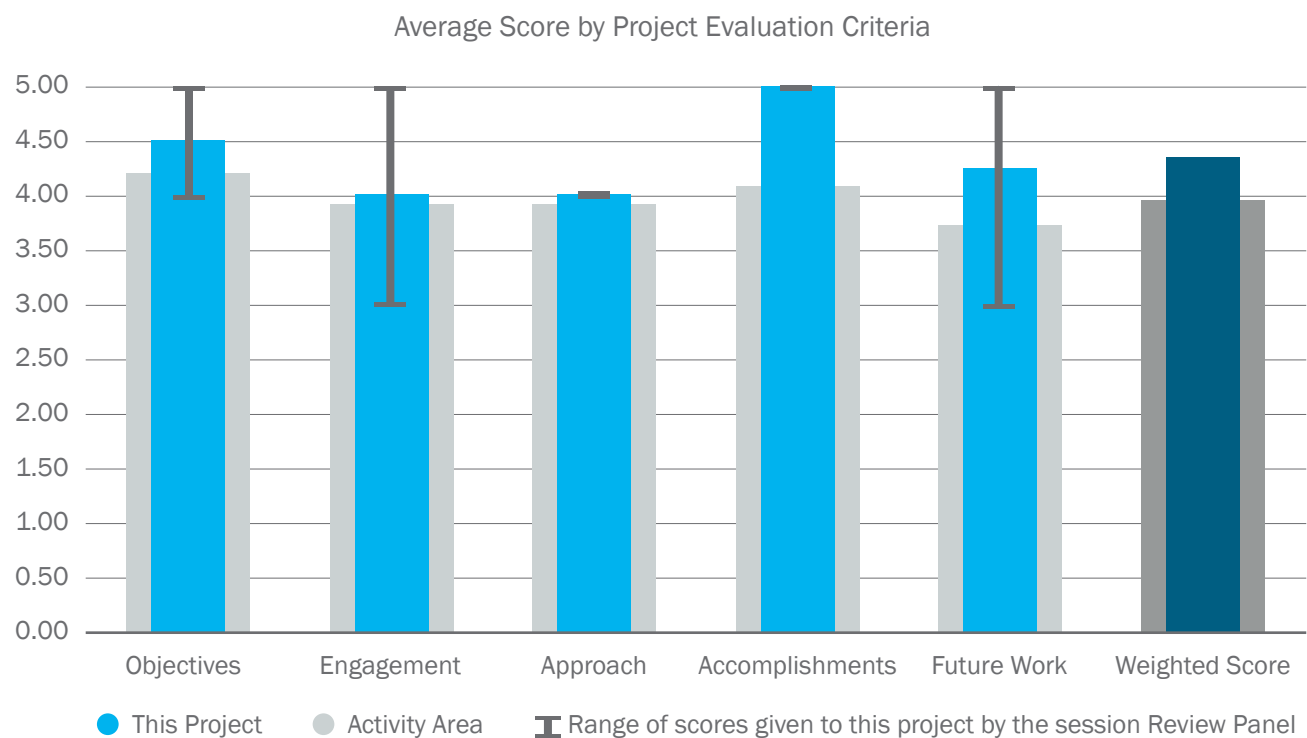
Recipient:	ORNL
Principal Investigator:	Rocio Uria-Martinez
Project Type:	AOP
Project Category:	Ongoing Projects
Total Authorized:	\$1,033K
Total Costed:	\$873K

## Project Description

The Hydropower Market Report project is a data-driven summary of key trends in the U.S. hydropower industry. It provides up-to-date, comprehensive, objective data to industry, policymakers, and other interested stakeholders on U.S. hydropower development, operations, cost, and supply chain. The Hydropower Market Report aims to assemble datasets that are representative of the entire fleet and can be segmented by region or key plant attributes to provide more meaningful summary statistics.

## Weighted Project Score: 4.4

*Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.*



## Summary of all Reviewers' Comments

### Overall Impressions

The Hydropower Market Report is a valuable resource for the entire hydropower industry, providing important information that would not otherwise be available. The datasets analyzed and the results provided cover a sound depth and breadth of issues relevant to the hydropower industry. However, reviewers noted that project performers could improve report dissemination and should develop quantitative performance metrics. Reviewers also recommended that the project team creates project plans that include how the database will be developed and maintained in the future.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The reviewers were unanimous in their approval of the project objectives and contributions to the program strategy, as well as the overall value of the report. The project team did a good job considering and describing the applications of the report, which is a useful tool to all hydropower stakeholders.

### End User Engagement and Dissemination Strategy

The dissemination efforts have been a good start, including the review of each version of the report by various experts, site/report views, and other efforts. Three of the reviewers thought the dissemination strategy could be improved. Recommendations included asking NHA, NWA, and the Hydropower Foundation to post a link to the report on their sites; expanding outreach to resource agencies and NGOs; sending annual email blasts to all FERC licensees and preliminary permit holders; and adding a “subscribe” option to the report itself. Reviewers believed that end user engagement could also improve by collecting feedback data from users beyond what is done through surveys and increasing performance metrics, including tracking downloads and questions or requests received.

### Management and Technical Approach

The reviewers agree that the project team is well qualified, with unique skillsets and a strong overall management approach. The technical approach is thoughtful and well-defined, containing the steps necessary for project success. One reviewer thought the project value was somewhat reduced in cases where specific information at the plant level is required, although noted that it is understandable that it would be difficult to obtain this level of data. Another reviewer recommended including the changes to the grid over time in each version of the report to support and provide more detail on the “rapidly evolving grid.” No risks were reported for the project, and no critical success factors were described to the reviewers.

### Technical Accomplishments and Progress

The reviewers agree that the major accomplishment of the project is the publication of the 2017 report, with additional milestones achieved each quarter of the project. The achievements are clearly described, and the project appears to be on track. Technical barriers for the project were not described.

### Future Work

The plan for future work is well defined. One reviewer is concerned that no mention was made of how the team will continue to develop and maintain the database in the future, which is important for maintaining its usefulness. Another reviewer suggested that the number of users for each report could be factored into future dissemination strategies or into adjusting the frequency of future reports and updates. The project team did not provide project decision points, but it appeared that because the project has been active for a number of years, most of the challenges have already been addressed.

# HYDROSOURCE

(WBS #: 1.4.1.502)

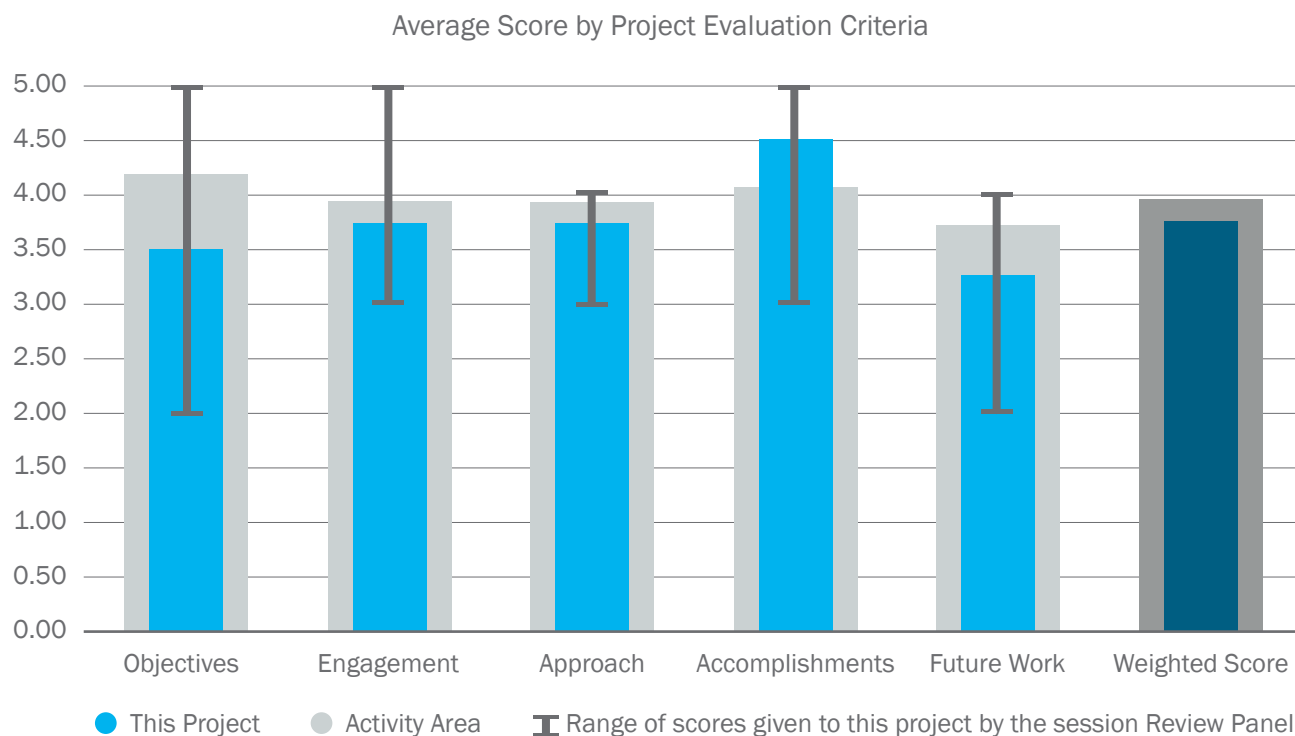
Recipient:	ORNL
Principal Investigator:	Brennan Smith
Project Type:	AOP
Project Category:	Ongoing Projects
Total Authorized:	\$1,913K
Total Costed:	\$1,731K

## Project Description

Knowing the characteristics of the hydropower fleet and potential hydropower resources for the United States is critical to WPTO stakeholders and the research community. The U.S. hydropower fleet includes assets owned and operated by federal, state, municipal, and private interests, engendering a diversity of regulatory, market, management, and physical contexts. HydroSource accomplishes data stewardship (acquiring, aligning, refreshing) and data dissemination (website and provision of limited subject matter expertise) for U.S. hydropower stakeholders. The pre-cursor to HydroSource began in 2010 with the National Hydropower Asset Assessment Project. The transition to the new HydroSource web portal in FY 2017–FY 2018 brought together data sets and tools from 10 years of WPTO-funded hydropower analyses of the existing fleet, hydropower marketing, resource potential, environmental context, and baseline energy-water data.

## Weighted Project Score: 3.8

*Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.*



## Summary of all Reviewers' Comments

### Overall Impressions

HydroSource is a significant undertaking, with a focus on data collection and associated analytics. The purpose and usability of this data is less understood and not appreciated among the hydropower community as the goals and deliverables, in the form of user access tools, are not described. This project has a good head of steam, and the team should expand the project and develop user-friendly tools, such as online search functionality and a mechanism for updates to the data file. It is important to recognize that DOE has been in a unique position to be able to accomplish this work and has moved this data collection far beyond where it would have been otherwise.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The goal of HydroSource was succinct and straightforward and aligned with Program Strategy, describing the continuing desire for a comprehensive database of information on hydropower facilities and river systems that could aid hydropower research and stimulate hydropower development by providing site-specific geospatial data on a variety of biotic and abiotic variables. Researchers have garnered a huge amount of information that could inform stakeholders and users across the country, but it is hard to see how the data sets created contribute to improving grid reliability, resilience, or integration or how they promote growth in the hydropower sector. The use of the expected product has not been described, and its value to users is limited in its current form. There needs to be a means of searching or even sorting the data with web-based tools or even simple macros.

### End User Engagement and Dissemination Strategy

The project summary clearly describes the multiple parties (utilities, agencies, etc.) who are and would be the end users of HydroSource. Project performers described presentations and demonstrations of HydroSource in various settings and locations, as well as a process of providing background data from user-specific information requests. Additionally, the project team described how they created a number of “data layers” that focus on the interests of hydropower assets, or perhaps environmental factors, in discrete states, regions, and basins. In this sense, HydroSource has already demonstrated a working and ongoing relationship with end users.

However, the program does not provide tools that are readily usable to allow online search and source documentation. Naturally, the program is only as good as how recently the data was updated, but no provision has been made for corrections and updates. HydroSource is posted publicly, and the project team stated that it is regularly accessed. The reviewers wanted to know if there is a success story where HydroSource provided critical information beyond the U.S. Energy Information Administration or other publicly available datasets that was integral in furthering the WPTO mission.

Outreach efforts appear to be increasing for the HydroSource website, but the project could benefit from additional exposure (e.g., conferences, webinars, e-magazines, etc.). Adding “where to find” links to other websites, such as [hydrowise.energy.gov](http://hydrowise.energy.gov), or the ability to redirect from the search function to those other DOE websites/resources could be extremely helpful. One way to do that may be to include a mechanism where users can add comments on how to improve HydroSource in real time as they are using the programs. Encouraging online users to comment on their experiences and provide suggestions for improvement is a vital aspect of any dynamic database system. Without providing much in the way of detail, the project presenters stated that the ORNL staff will continue to integrate new environmental data into HydroSource. All these enhancements are sound.

## **Management and Technical Approach**

The actual management plan for the execution of this project is left to the reader's imagination, as this section of the summary report focuses entirely on the technical disciplines of the ORNL staff. Reviewers noted that there is clearly an organizational structure within ORNL that manages the activities of the staff and directs their work on the creation of the HydroSource input data.

The site improvement system to track usage and downloads is an excellent approach and can help determine what areas need future work. Also, the Kearns and West surveys of how HydroSource is actually being used externally are an excellent way to foster continual improvement.

## **Technical Accomplishments and Progress**

The project presenters focused less on the technical accomplishments and progress made to date, more on the historical trajectory of developing and maintaining a database on hydro-relevant information across the United States. Since its earlier versions focusing on hydropower assets, HydroSource has expanded to include environmental aspects of hydroelectric facilities. This includes importing information from SMH Explorer and creating a number of environmental attributes such as species, conservation lands, impaired streams, and licensing proceedings.

The National Hydropower Asset Assessment Project was a significant step forward and is incorporated into this database. HydroSource is a valuable addition to stakeholders looking for previous research information. The environmental module of the HydroSource will/does include an environmental mitigation predictor that is based on the above data, including prior issues associated with existing projects. Reviewers believed that the mitigation predictor may be a stretch, noting that while it's informative to licensees and potential new developers, the information on mitigation measures is determined by a number of factors, including resource agency staff involved in the relicensing process. Predictors of environmental issues of importance may be of limited use, as there is so much site specificity associated with environmental factors at hydropower facilities.

## **Future Work**

HydroSource should continue to improve on its promise to provide relevant and useful information to the hydropower industry and other entities. This includes the continued need to take data from hydropower facilities throughout the country and convert their sometimes-disparate information/data into the model structure. Based on a review of the HydroSource tool and database, it seems that the project team should focus future effort into making the tool more useful to users. In using the stream classification web tool, layers that included plants and U.S. Geological Survey gage sites were available, but the markers do not display relevant information (plant names, U.S. Geological Survey gage numbers, river names). The plant database is similarly not much different from, and in some cases less than, information that can easily be tracked down via the U.S. Energy Information Administration, USACE's public data tool, and other public data sources. The team should focus on addressing these issues. A clear vision of the future state of HydroSource is lacking.

## ENVIRONMENTAL DECISION SUPPORT: SCIENCE- BASED TOOLS FOR HYDROPOWER STAKEHOLDER COLLABORATION

(WBS #: 1.4.1.505)

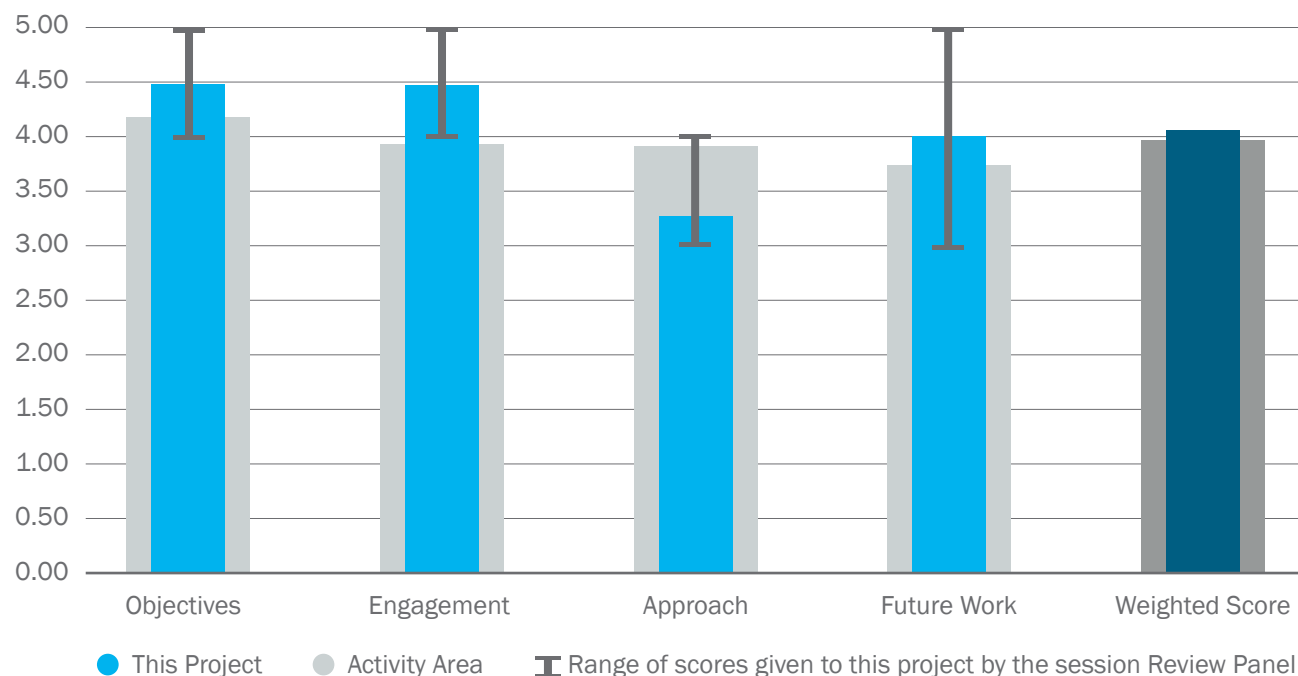
### Project Description

The Environmental Decision Support project is the second phase of a strategic, long-term effort to characterize and summarize the best-available science for use by the diverse body of hydropower stakeholders looking to determine environmental and ecological impacts of hydropower development and operation. This project provides hydropower developers, owner/utilities, regulators, consultants, NGOs, agencies, and other stakeholders involved in the hydropower licensing process a transparent and consistent methodology based on the best available science for determining what studies to conduct during hydropower licensing. Since the environmental impact studies conducted may vary from project to project and may be subject to different negotiations and practices, the project's toolkit aims to provide a template for understanding which environmental impacts have project nexus. This may enable greater consistency in studies requested and help stakeholders communicate and determine the "right" environmental impact studies for a project, thus promoting transparency among stakeholders. Products created in this project are augmented by stakeholder advisory boards that provide input and feedback on methods content.

### Weighted Project Score: 4.1

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Future Work–40%.

Average Score by Project Evaluation Criteria



Recipient:	ORNL
Principal Investigator:	Brenda Pracheil
Project Type:	AOP
Project Category:	New Projects
Total Authorized:	\$263K
Total Costed:	\$236K

## Summary of all Reviewers' Comments

### Overall Impressions

Reviewers generally supported this project, but they believed that its waivers in certain aspects. Reviewers thought it would have been helpful to have more information on the go/no-go decision-making process and that the team should have identified points along the way where such decisions were/will be made. There are some concerns about how this tool will be used, whether it will streamline the scoping process (or in some cases increase the scoping time), and ultimately whether it will be embraced in licensing processes.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The reviewers agreed that the explanation of project objectives was clear and aligned with DOE program objectives. This project aims to develop a questionnaire-based tool for determining the relevant environmental impact studies as part of the FERC licensing process. One of the four reviewers is not convinced that this tool is needed.

### End User Engagement and Dissemination Strategy

Reviewers agreed that the engagement and dissemination strategy appear to be sound. The project team included a group of advisors that provided feedback along the way to date; it sounds like that was a very good move because it facilitated some 'midstream' adjustments to key facets of the planned tool.

### Management and Technical Approach

The tool that this project team intends to develop is a monumental task because of the variability in the environments, biota, and issues across the United States; policy and practice differences across agencies, licensees, and special interest groups; and specific representatives and their personalities, knowledge, backgrounds, and biases. While it is hoped that this tool will help to streamline the process, it's not clear at this time that this objective will be realized. That said, no reviewers thought the project should be stopped. The inclusion of an advisory group as part of the team was a wise decision and should significantly improve the likelihood of a useful tool.

### Technical Accomplishments and Progress

There were mixed reviews on accomplishments and progress. It was not clear whether the budget presented was just for the 2-year period or for the entire project to date. One reviewer thought that the two publications cited should be included in a different project and not this one. One reviewer thought that too much focus was placed on international projects and not enough on U.S. projects. One reviewer would have liked an explanation of how the approximately 10% of FERC licensed projects were selected for inclusion and why that was determined to be representative.

### Future Work

Multiple reviewers thought that more details on future work and go/no-go decision points would have been helpful. There were also questions about the planned beta testing (e.g., how will it be done; how will projects be selected; and what if results show something significantly different than what actually happened at a completed project?)



## HYDROPOWER FLEET INTELLIGENCE

(WBS #: 1.4.1.506)

Recipient:	ORNL
Principal Investigator:	Stephen Signore
Project Type:	AOP
Project Category:	New Projects
Total Authorized:	\$895K
Total Costed:	\$769K

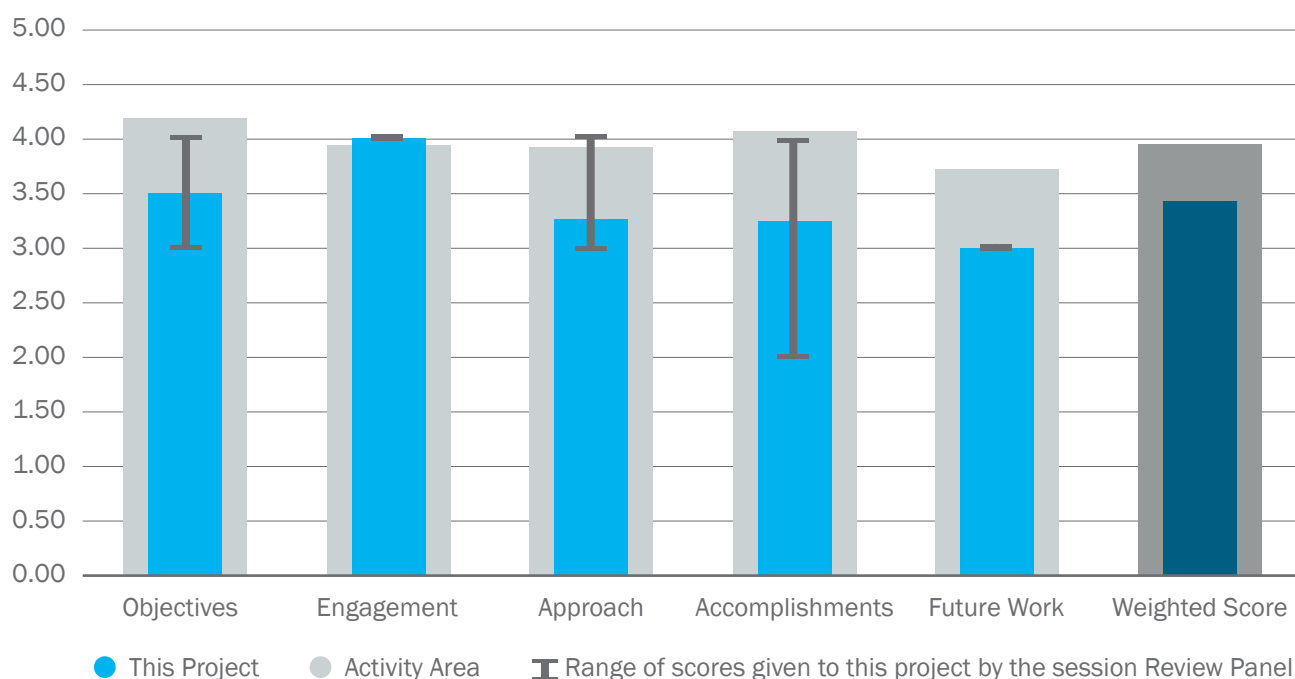
### Project Description

The HFI project addresses the challenge of developing, sharing, and implementing data-driven decision-making best practices for fleets of hydropower facilities that are hydraulically and electrically linked within river and power systems, respectively. The hydropower facilities provide a unique link between the electrical grid and the river system and, as such, must be effectively managed to ensure sustainability and to maximize stakeholder value in both systems. In the near-term, HFI work is focused on developing and implementing a methodology to understand the O&M effects of intensifying hydropower dispatch variability (also referred to as Use-Case 1). Use-Case 1 work focuses on the synthesis and analyses of disparate cost, condition, and reliability data to reveal correlations, causes, and effects of dispatch patterns on O&M strategies and outcomes. Previous attempts at correlation analyses have only correlated unit starts to cost while neglecting other variables of possible significance, including ramping and synchronous condensing. By excluding other variables of possible significance to asset degradation, it is possible to overestimate the impact of starts and stops on the assets. Engagement with industry consortia of EUCG and hydroAMP provides a data synthesis beyond what was previously achieved.

### Weighted Project Score: 3.4

Weighting: Objectives–20%; Engagement–20%; Approach–20%; Future Work–40%.

Average Score by Project Evaluation Criteria



## Summary of all Reviewers' Comments

### Overall Impressions

This is a very complex undertaking, melding disparate databases to provide hydropower operators with new tools. While the relevance of this program is real, there is limited explanation or quantification of how much it could impact O&M costs or result in changes in operational regimens. The databases utilized are insufficient and inaccurate, and drawing them together accomplishes little at this stage.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The objectives of the project are summarized as collecting data of a sufficient level of granularity on hydropower facilities that are hydraulically or electrically linked to inform decision making regarding when and how to dispatch conventional and PSH units.

However, the project team did not effectively make the case that hydropower operators feel the need for this information and that they don't already implement internal decision-making strategies that integrate utility-specific goals and rules governing the operation of their fleet of hydropower facilities. The fact that the researchers are working within a CEATI sub-committee and have a willing test-case utility in Pacific Gas and Electric, suggests there is potential value to this exercise.

It is known that HydroAMP and GADS are humanly inputted and thus are extremely subjective to human judgement and personal convenience. EUCG data is at least a step up by providing detailed cost line items. It is not a given that data of this nature is of use except as a benchmarking tool for hydropower operators. The ability to link this data to an operational regimen is a real stretch. Specific datasets such as bearing temperature profiles pre-failure would be useful to any operator in predicting outages versus how much time is spent on repair at another facility.

### End User Engagement and Dissemination Strategy

The project presenters describe their work with the hydroAMP steering committee within CEATI as a means of advising and informing the development and progress of the project. They also describe a combination of publications and conference presentations that will get the word out as to the ongoing findings and results of the statistical analyses that are at the heart of their work. They have done a reasonably good job of reaching out and working within industry to move their work along.

### Management and Technical Approach

The management structure, defined by the various staff within ORNL and members of academia, is adequately described, including how they will integrate the various tasks that need to be accomplished. The schedule presented only goes through September 2019.

The technical approach is fairly well described, but dense, promoting a general need to ensure that quality data is derived from different hydropower plants (condition, cost, and maintenance data) to develop correlations to help individual plant operators understand where their practices fit into the mix of operators across the country and improve their decision making.

The challenges of poor data quality are recognized, and the project team is taking steps to improve future data quality issues moving forward. Unfortunately, the existing historical data is often not of sufficient quality and completeness to be able to confidently draw meaningful conclusions. Many relevant historical equipment characterizations and conditions since commissioning (initial design margins, installation quality, historical

operational dispatch, and quality of prior maintenance) cannot ever be determined, so cause and effect relationships can be extremely difficult to establish for future reliability or cost projections on aging assets.

Reviewers felt that the project was well-organized but felt that a clearer explanation of the key milestones in the schedule was necessary. Reviewers also felt that the project presentation lacked the details necessary to understand the technical approach.

### **Technical Accomplishments and Progress**

The technical accomplishments to-date on this new project are aligned with the schedule presented in the project management section of the project summary:

- The development of a foundational concepts report to crystalize and organize the project
- The formation of a data quality improvement plan within the HydroAMP, including regular data quality checkpoints
- An examination of data coherency and a ranking system based on numerical scores ascribed to different plants.

The team has made progress in collecting data, but it is not clear what technical accomplishments they have achieved. While these are good first steps, the final determination of success of the effort will come as the project matures.

### **Future Work**

The project presenters merely listed the tasks from their schedule that will be performed in the future for the project, with expected milestones or completion dates. They did not identify any technical challenges associated with the execution of the steps/accomplishments to-date and how these might alter the manner in which they address future tasks. There was little discussion of upcoming decision points and potential issues, which is where the researchers should be more specific about what they hope to achieve.

The project will face other challenges, as well, including the impact of the potential sale of hydropower assets by Pacific Gas and Electric, as well as defining ownership of the data, who has access to the datasets in HFI, and who will do the analysis.

# HYDROPOWER VISION ROADMAP UPDATE

(WBS #: 1.4.1.602)

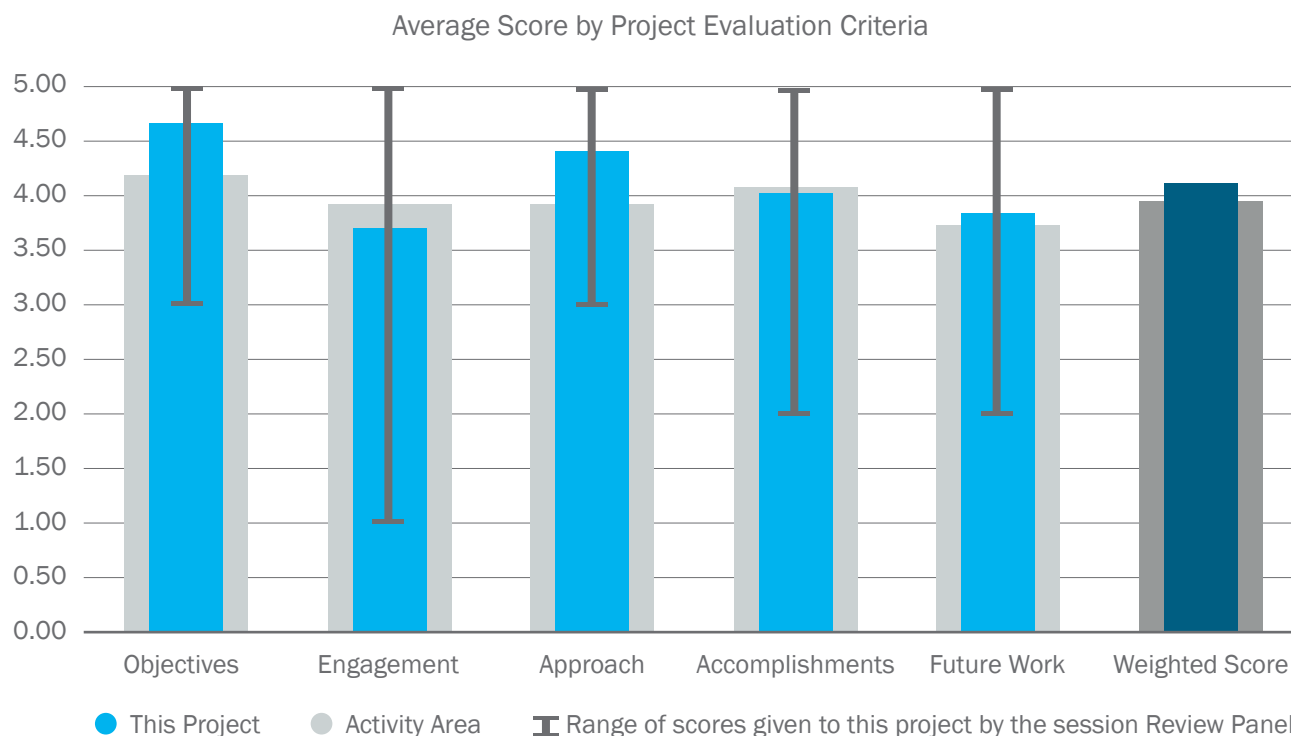
Recipient:	PNNL, ANL, INL, NREL, and ORNL
Principal Investigator:	T.J. Heibel
Project Type:	AOP
Project Category:	Ongoing Projects
Total Authorized:	\$1,326K
Total Costed:	\$776K

## Project Description

DOE made a commitment to the hydropower community when it released the national Hydropower Vision Report in 2016 that it would be a living document. DOE acted as a convener in compiling and publishing the original report and will continue in this facilitating role to update the Hydropower Vision Roadmap (Roadmap) for publication in 2021, 5 years after the original report. The Roadmap is a series of detailed actions recommended to advance sustainable hydropower in the United States, allowing it to grow nearly 50 GW (13 GW of new hydropower and 36 GW of new PSH) by 2050. This project focuses on furthering the Roadmap as an evolving plan against which DOE can track progress of its own research, as well as activities throughout the broader hydropower community, toward realizing the Hydropower Vision. The project will continue to engage the hydropower community in gathering feedback and new information to update the Roadmap.

## Weighted Project Score: 4.1

*Weighting: For ongoing projects, there is equal weighting across all five evaluation criteria: Objectives, Engagement, Approach, Accomplishments, and Future Work.*



## Summary of all Reviewers' Comments

### Overall Impressions

This project represents an ambitious effort by WTPO to develop a comprehensive roadmap over a 5-year period to increase hydropower penetration in the United States by 50 GW. The development of that significant amount of hydropower will contribute to the strategic efforts within the United States to reduce its overall carbon footprint while contributing to grid reliability. The Roadmap is transparent and will address the following key areas: grid reliability, hydropower growth, R&D environmental impacts, and dealing with the significant amount of “big” data that will need to be collected and analyzed to assist in meeting these goals. The review team recognizes that this is a significant and important goal with nationwide implications.

### Project Objectives, Impacts, and Alignment with the Program Strategy

The review team felt the Roadmap represented an extremely relevant proposal, while outlining a set of concrete steps toward achieving all the objectives WPTO set forth. It is also well aligned with other initiatives throughout the hydropower community, both internal to the United States and internationally. The original draft of the Roadmap was created in 2016. The reviewers felt there would be value in having the original drafters of the document come back and review the document to ascertain progress and alignment with the original vision as part of conducting a valid review.

### End User Engagement and Dissemination Strategy

This project represents a significant effort between DOE, the hydropower community, DOE's national labs, and various hydropower subject matter expert groups. The reviewers felt WPTO has made significant inroads in communicating the roadmap and milestones within the hydropower community. However, the review team also felt the dissemination of valuable information was contained almost solely within the hydropower community silo. The reviewers felt that to advance the goal of higher hydropower penetration, it is critical to seek involvement and input from other key industry stakeholders, including regulators (FERC/NARUC/etc.), ISO/RTO (planners/operators/markets), USACE, environmental groups, etc.

### Management and Technical Approach

With PNNL serving as a project lead, the other five national laboratories were all organized to work on the project. Each national lab was assigned a specific task within the framework of the Roadmap. The labs used their own tools and expertise to work on their slice of the project autonomously and then report back to the larger group. In the summary document, results for only two lab efforts were discussed, leading the review team to wonder what the other labs contributed. While the reviewers liked the task list, it was not intuitively clear where on the Roadmap the tasks and milestones were. A detailed list of milestones by task with a current status update would have been very beneficial.

### Technical Accomplishments and Progress

The 2018 deliverables as presented in the summary do support progress toward both reaching the Roadmap goals and staying aligned with the plan. Efforts toward the 2019 goals were presented and summarized. The significant 2019 goal is to finalize database work and to develop a multi-year project plan laying out the necessary tasks to complete the Roadmap by 2021 and to attain the envisioned 50 GW hydropower penetration goal. While results were presented, the reviewers would have preferred to see detailed milestones to check on specific progress, which would have made the review of accomplishments easier. The results are funneled through the hydropower visionary group. The review team felt the membership may be too small and not broad enough to ensure efforts remain on track.

## **Future Work**

The reviewers felt that timelier progress reporting is justifiable due to the strategic nature of this effort. As part of that, reviewers recognized that the industry is evolving at a rapid pace, and more frequent checks of the plan versus current state of the industry is warranted. Because of this, the Roadmap should be a dynamic document. The future Roadmap should have key milestones and decision points spelled out. There was also a feeling that the process needs to be expedited; 5 years in the industry is a very long time in this day and age. For hydropower to make inroads and meet its goals, work needs to continue in an expedited manner. As mentioned previously, broader industry engagement is strongly encouraged, as well as getting grassroots industry subject matter expert support.