ORNL/TM-2024/3409

Workshop Summary Report on Conduit Hydropower Development in the United States – Opportunity and Challenges

Scott DeNeale
Antonia Chu
Lora Davis
Lindsay Ashworth
Jeremy Wells

May 2024

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Environmental Sciences Division

WORKSHOP SUMMARY REPORT ON CONDUIT HYDROPOWER DEVELOPMENT IN THE UNITED STATES – OPPORTUNITY AND CHALLENGES

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for the
US DEPARTMENT OF ENERGY
under contract DE-AC05-00OR22725

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ACKNOWLEDGMENTS

US Department of Energy, Water Power Technologies Office

The authors would like to acknowledge and express their appreciation to the US Department of Energy (DOE) Water Power Technologies Office (WPTO) for overseeing and funding this virtual workshop and the broader conduit hydropower portfolio of research and development. The following DOE WPTO staff and subcontractors were heavily involved in reviewing this report and supporting this study:

- Colin Sasthav
- Michelle Zamperetti
- Melissa Ladd
- Sebastian Grimm
- Amanda Lounsbury

Workshop Attendee Organizations

ORNL is grateful to the workshop attendees for spending time and providing insights on and feedback about conduit hydropower. The following organizations participated in the virtual workshop:

45north Renewable Energy, LLC
Acquisition Partners, LLC
Amjet Turbine Systems, LLC
BGH Designs LLC
Canyon Hydro
Denver Water
DOE Water Power Technologies Office
Energy Trust of Oregon
Green Power Technologies Puerto Rico
HSB (Hartford Steam Boiler Inspection & Insurance Co.)
Idaho National Laboratory
InPipe Energy
Lindahl Reed Inc., Contractor to the DOE
Littoral Power Systems, Inc.
Low Impact Hydropower Institute
Mavel Americas, Inc.
Mesa Associates
New York Power Authority
NLine Energy
North Side Canal Company
NYC Department of Environmental Protection
Oak Ridge National Laboratory
Ohio State University
Pacific Northwest National Laboratory
Rentricity Inc.
San Bernardino Valley MWD
Small Hydro Consulting
US Bureau of Reclamation
Wells Engineering LLC
Xylem Inc

1. BACKGROUND

Conduit hydropower, as the name suggests, is a means of producing hydropower using *conduits*—defined as "any tunnel, canal, pipeline, aqueduct, flume, ditch or similar manmade water conveyance that is operated for the distribution of water for agricultural, municipal, or industrial consumption."[1] Conduit hydropower development offers several advantages over conventional hydropower development, including that it (1) does not require the construction of new dams or impoundments, (2) involves minimal environmental concerns, (3) is eligible for net-metering in most states, (4) yields high value for the energy generated, (5) entails reduced development timelines, and (6) may qualify for an expedited 45-day regulatory approval process.

In addition, some projects may be defined as a "qualifying conduit facility," which falls outside of the Federal Energy Regulatory Commission's (FERC) jurisdiction. A determination can be reached within 45 days, provided that a facility (1) is less than 40 MW, (2) uses a non-federally owned conduit, (3) serves a primary purpose other than hydropower generation, and (4) is not currently licensed or exempted.

There is approximately 530 MW of existing conduit hydropower in the United States, and a 2022 study by Oak Ridge National Laboratory (ORNL) found that an additional 1,414 MW of power potential exists within existing water conduits. The 2022 ORNL resource assessment provided a reconnaissance-level study, which estimated hydraulic head, water flow, hydropower potential, and annual energy generation at both county and state levels throughout the 50 states. Power potential was estimated for (1) municipal, (2) agricultural, and (3) industrial conduit sectors. Specific conduit applications evaluated include water supply pipelines for municipal and industrial uses; wastewater discharge conduits from municipal and industrial systems; agricultural water conduits, including irrigation canals and ditches in the 17 western states that rely heavily on irrigation; and thermoelectric power plant cooling water discharge conduits. For additional information, see Appendix F or consult Kao et al. (2022).[2]

[1] According to the Code of Federal Regulations Title 18, Chapter 1.B.4.D, Section 4.30 (b).
[2] Kao, S.-C., L. George, C. Hansen, S. DeNeale, K. Johnson, A. Sampson, M. Moutenot, K. Altamirano, and K. Garcia (2022), An Assessment of Hydropower Potential at National Conduits. ORNL/TM-2022/2431, Oak Ridge National Laboratory, Oak Ridge, TN. https://doi.org/10.2172/1890335.

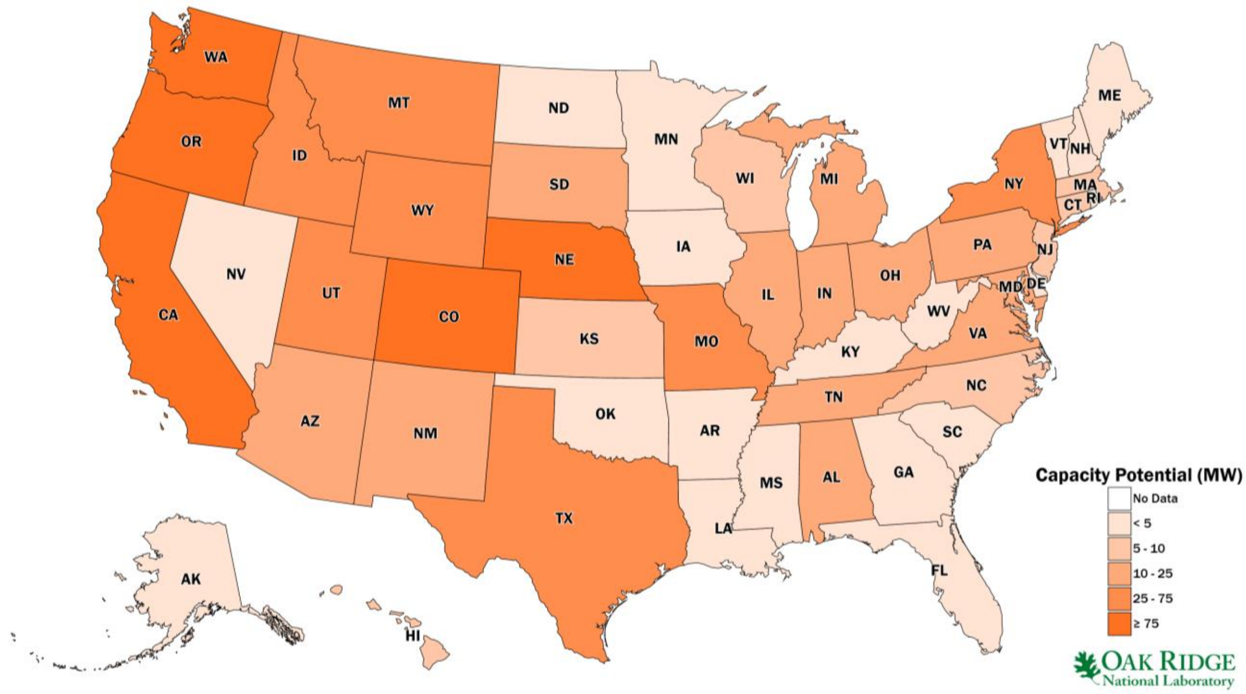


Figure 1. National conduit hydropower capacity potential, by state. Source: Kao et al. (2022).

2. WORKSHOP PURPOSE

On April 18, 2024, ORNL and the US Department of Energy (DOE) Water Power Technologies Office (WPTO) hosted a virtual workshop with the goal of (1) highlighting research findings on US conduit hydropower potential, (2) identifying common industry challenges and lessons learned, and (3) informing the federal government in establishing a program to assist conduit hydropower project development. The workshop accomplished these goals through presentations of information as well as interactive sessions. Whereas the workshop presented background information on conduit hydropower, including the 2022 resource assessment approach and findings, the interactive sessions focused on municipal and industrial conduit development. A diagram of an example water distribution system with agricultural and municipal/industrial conduit hydropower highlighted is shown in Figure 2.

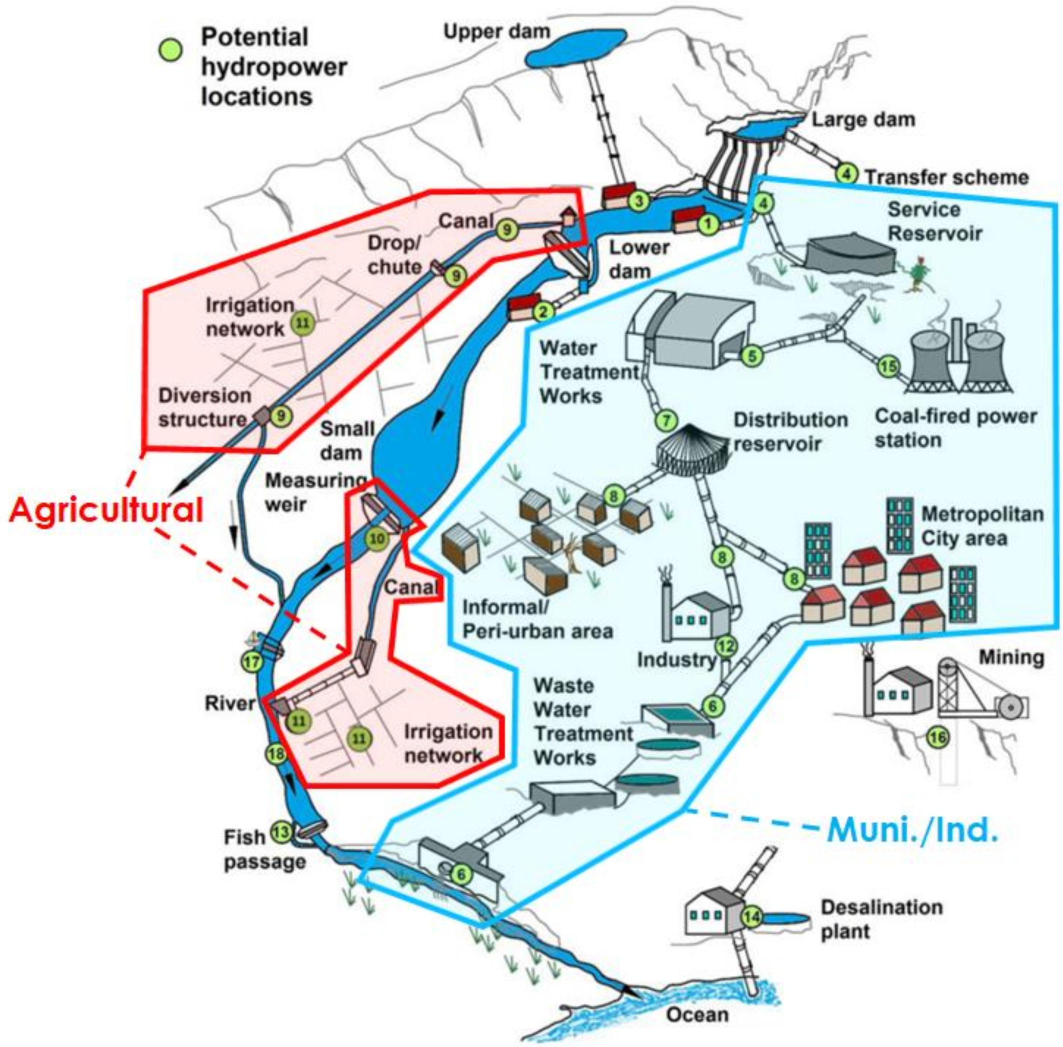


Figure 2. Conceptual sketch of a water distribution system, including canals/conduits and other hydropower development locations. Modified from Bekker et al. (2021).[3]

3. STAKEHOLDERS AND ATTENDEES

In addition to the staff from WPTO and the project team at ORNL, the meeting was attended by various other stakeholders, including technology developers, project developers, utilities, asset owners, academics or other researchers, federal government employees, and researchers from other national laboratories. The workshop was open to anyone. The invitees were identified based on prior engagement with the previous project (pilot study and resource assessment report reviewers) and engagement in the conduit hydropower space (e.g., ORNL gathered information on organizations that received a qualifying conduit exemption for their project from FERC, involvement in case studies). A registration form was sent out and filled in by the attendees. This form can be found in Appendix D, along with a full list of organizations represented at the meeting and statistics about registrants.

[3] Bekker, A., M. van Dijk, C. M. Niebuhr, and C. Hansen (2021), Framework development for the evaluation of conduit hydropower within water distribution systems: A South African case study, *Journal of Cleaner Production*, 283.

4. WORKSHOP LOGISTICS

This workshop was held online on Zoom and lasted two hours. The overall meeting agenda included the following highlights:

- Overview of the current state of conduit hydropower
- Presentation on a recent nationwide assessment of conduit hydropower development opportunity
- Brainstorming session on current challenges facing stakeholders
- Breakout groups to navigate challenges across project development phases
- Opportunity to share your challenges, needs, and successes

Two external facilitators helped guide the discussion, and they navigated participant input on the platform xLeap. The meeting was divided into two main parts. The first half (the plenary session) was used to present to the attendees a brief overview of WPTO's goals and focus regarding conduit hydropower development (see Appendix E). Furthermore, the results of the prior conduit hydropower resource assessment were presented by ORNL, as well as the current focus of R&D (see Appendix F). An overview of different perspectives regarding challenges from the larger group was gathered.

In the second half of the workshop (the breakout session), the attendees were split into two groups by sector (Agricultural or Municipal/Industrial), based on their preference chosen during the registration process. The participants were asked to rank different development stages by their perceived level of challenge and went on to discuss them, guided by a moderator in each breakout room. This allowed participants to share their individual experience and challenges they have encountered as well as voice suggestions to WPTO and ORNL.

Finally, at the end of the workshop all attendees were reconvened, and key takeaways and next steps were shared among the group. The following statistics are associated with workshop registration and participants:

- 87% of Zoom attendees participated on the xLeap platform
- 33% of those who were invited registered
- 80% of those who registered attended the workshop

5. PLENARY SESSION

Following the WPTO presentation (Appendix E) and ORNL presentation (Appendix F), a brainstorming session was held to share challenges in 5 words or less. The provided feedback is summarized in the following.

Key challenges mentioned include economic constraints associated with developing conduit hydropower projects, such as low power prices coupled with high interconnection costs and the need for a quick payback period (2–3 years). Regulatory and lengthy approval processes from involved federal agencies such as the United States Forest Service (USFS) represent significant hurdles, as do local utility requirements and interconnection capacity constraints. A lack of awareness about the benefits of conduit hydropower, hesitancy from agricultural communities to engage with federal agencies, and difficulties in keeping the project champion engaged were also reported. Funding, site access and control, as well as competing operating priorities were also regarded as challenging.

The complete list of comments without attribution can be found in Appendix A.

At the end of the plenary session, attendees were separated into two breakout groups, either agricultural or municipal/industrial, based on their selection during registration or as requested during the Zoom call. The breakout sessions utilized the xLeap online platform.

6. BREAKOUT SESSION

The breakout sessions each included a facilitator and a moderator. The same procedure was used in the agricultural and municipal/industrial breakout rooms. The first breakout room question involved rating each phase of conduit hydropower project development on a scale of 1 to 5 based on how challenging each phase has been based on experience, with 1 being not at all challenging and 5 being very challenging. For the purposes of this activity, project development included the following phases:

1. Internal and External Stakeholder Engagement
2. Site Selection and Feasibility Assessment
3. Design and Technology Selection
4. Permitting and Licensing
5. Financing and Power Sales
6. Construction and Supply Chain
7. Operations and Maintenance

For the municipal/industrial sector (36 attendees), the top three most challenging phases were notably higher than the rest: financing and power sales, internal and external stakeholder engagement, and permitting and licensing.

The difference in the perceived level of challenge of each development phase by stakeholder type can be seen below.

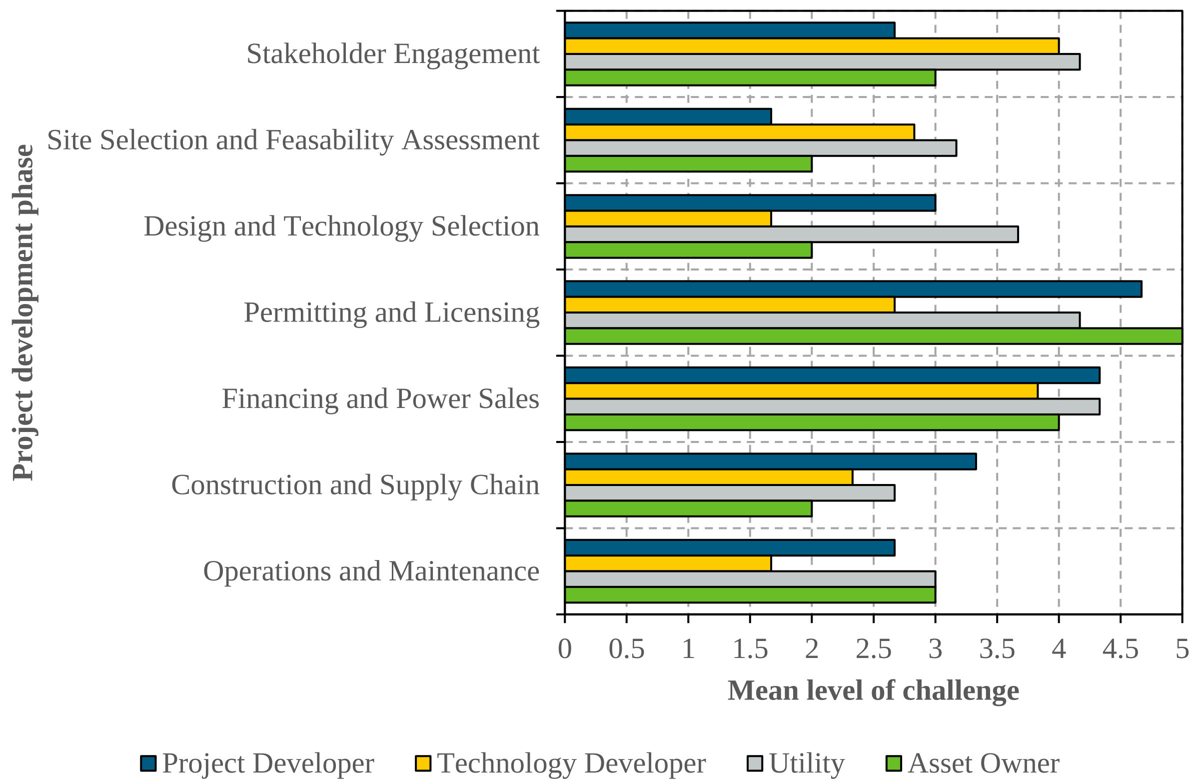


Figure 3. Level of challenge by development phase and stakeholder type for municipal/industrial breakout session.

Following the rating of the most challenging phases, the participants conducted a challenges deep dive in which both typed and verbal feedback was provided to elaborate on experiences with and perspectives on the various phases of development. A summary of this discussion, which was guided by a moderator, is provided in the paragraphs that follow. For the complete written comments, see Appendix B.

Participants voiced that identifying key project contributors, especially in early-stage development, is difficult due to the involvement of multiple public and private entities, making initial stakeholder engagement challenging. New ideas are perceived to lack development due to insufficient site development, leading to reliance on older pump as turbine (PAT) technology. One participant commented that they had installed over 30 PAT systems due to their off-the-shelf-design and cost-effectiveness. Despite potential for an expedited 45-day regulatory approval process, there are still regulatory hurdles with respect to permitting, such as jurisdictional issues between different federal agencies. This also influences financing of projects: projects with potential permitting hurdles are less likely to get developed due to the risk of additional cost. Similarly, newer technologies are more likely to get shelved due to higher uncertainties and associated risks. The power sales in many cases are too low to warrant development of a project, especially when a quick payback period of 2–3 years is required or expected. Having qualified staff for operation and maintenance is instrumental in successful implementation of conduit hydropower.

For the agricultural sector (26 attendees), the same top three most challenging phases rose to the top. However, the order was slightly different: here, the order was financing and power sales, permitting and licensing, and internal and external stakeholder engagement.

The difference in the perceived level of challenge of each development phase by stakeholder type can be seen below.

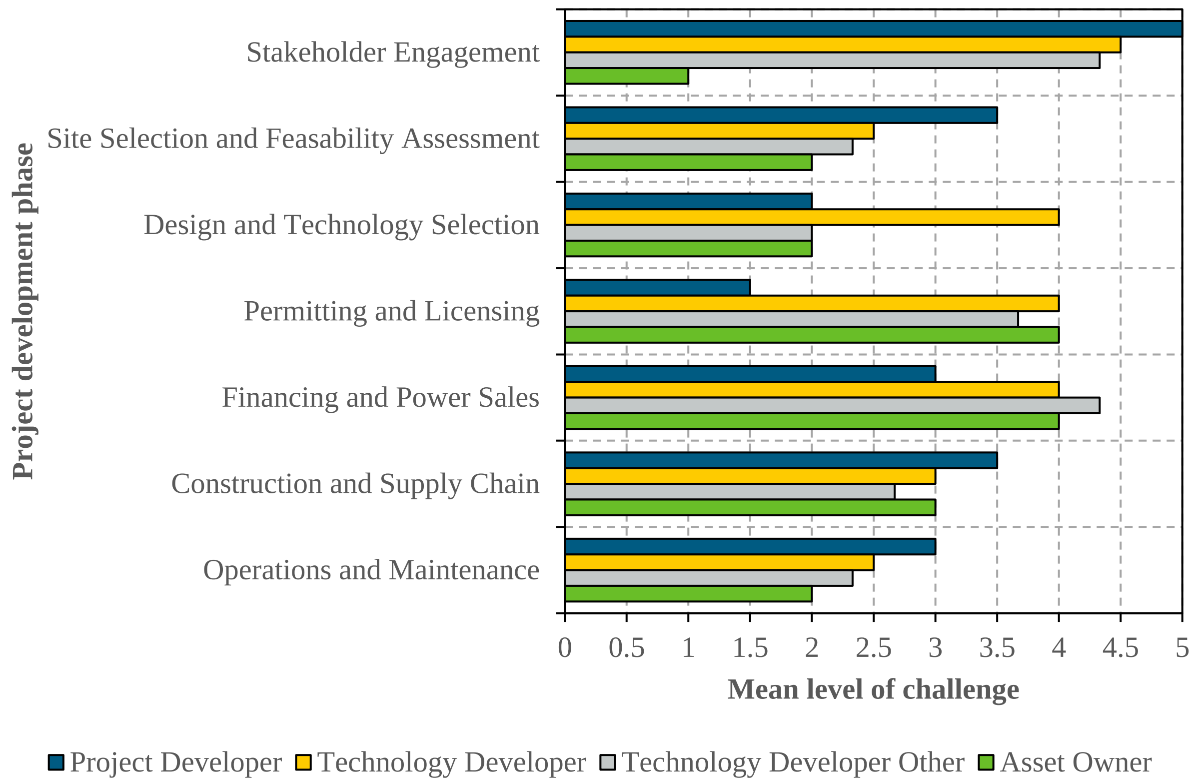


Figure 4. Level of challenge by development phase and stakeholder type for the agricultural breakout session.

The same format was followed in the agricultural breakout session as that previously mentioned. After the ratings, the group conducted a deep dive into experiences and perspectives. A summary of this discussion, which was guided by a moderator, is provided in the paragraphs that follow. For the complete written comments, see Appendix C.

Although financing and power sales were identified as the top challenge in the ratings, during the group discussion it became apparent that one of the major challenges regarding conduit hydropower development in the agricultural breakout room was internal and external stakeholder engagement. As one person pointed out during the meeting, "getting everyone onboard, motivated, and excited is the most challenging. After that, everything else falls into place." The initial establishment of new relationships with potential clients is considered difficult, and the lack of education of external stakeholders and finding value in the project were all cited as hurdles. The cost of interconnection requirements and the low power prices—reportedly around 2 cents per kWh—especially in the Western United States cause project economics to suffer: smaller projects more so than larger ones due to generating less revenue despite similarly extensive development process costs. Regulatory requirements pertaining to conduit hydropower pose additional hurdles to project developments, such as fish passage and screening rules. Finding local qualified staff for equipment maintenance can be challenging, and lack thereof leads to prolonged outages.

Following the deep dive, all workshop attendees regrouped into a single Zoom room, and a brief report summarizing the discussions in the respective breakout rooms was shared with everyone. There was a consensus among the participants that this was a highly beneficial and important effort, and that there was interest in the next steps.

Additional results from the xLeap breakout sessions are provided in Appendix B (municipal/industrial) and Appendix C (agricultural).

Key takeaways are the need for better stakeholder engagement and education. Regionality plays a key role for conduit hydropower development; therefore, more site specific data and information is needed. Additional development of tools and resources would be immensely helpful.

7. NEXT STEPS

The information gathered during this workshop will be used to inform an ORNL cost and market barrier report on municipal conduit hydropower as well as the next phase of this project, which have been proposed and will be further evaluated by DOE WPTO in the coming months. Proposed future work includes additional stakeholder engagement, so stay tuned for opportunities to engage with DOE and the national labs on the topic of conduit hydropower.

APPENDIX A. CHALLENGES IN 5 WORDS OR LESS

These are the unedited comments the workshop participants provided when asked to describe challenges regarding conduit hydropower development in five words or less.

1.	Price we get paid for power
2.	getting to know the interested developers
3.	<1 benefit:cost
4.	FERC, USFS, and regulatory approval
5.	low power prices in PNW
6.	Need for short term payback from industrial water operators - 2 to 3 year payback requirement is a challenging requirement.
7.	Project owner education/outreach/motivation
8.	Nowhere to put the power
9.	Interconnection costs
10.	FERC and other regulatory agencies
11.	Local utility requirements for interconnection and state utility commission hurdles
12.	Utility interconnection capacity constraints
13.	Interconnection distance
14.	keeping the project champion engaged, when their primary job function has no requirement to pursue conduit hydro
15.	Funding sources/incentives
16.	Understanding of the hydraulics
17.	Ag community hesitance to engage with federal government
18.	competing operating priorities
19.	Interconnection rules and processes
20.	Inability to gain site control
21.	Lack of definition/awareness on the total suite of benefits of conduit hydro to both owner/community and utility
22.	Concern about regulatory burden and siting, especially with respect to time. Also concern that scale is too small to make the economics work
23.	Regulatory process & Utility/Interconnection
24.	Regulatory policies-, utility incentivization, and interconnection standards
25.	Awareness of successful projects compared to other sources of renewables
26.	Business case frameworks
27.	Fish passage rules applied to the existing conduit
28.	Lack of development funding
29.	poor unit economics
30.	Initial capital and ongoing maintenance costs.

APPENDIX B. XLEAP RESULTS FOR MUNICIPAL/INDUSTRIAL BREAKOUT ROOM

Challenges Deep-dive

Prompt: Tell the story of a specific challenge in this phase - how did it affect outcomes (time, cost, risk)? what were lessons learned? what would have been helpful?

1. Internal and External Stakeholder Engagement

- Challenging to identify the individuals that can be most beneficial to anyone developing a project at the earliest stage. The issue is numerous entities, public & private.
- Power Sales kill most of these projects unfortunately. We do not have a good end user for the power or way to get it into the distribution system that is close to most of these facilities. Also, our local power producer pays next to nothing for the power. They are far more interested in large scale wind and solar farms. This is just too small for them to get overly interested in.
- Long sales cycles with bidding and procurement risk - staying focused and fully understanding the stage of the project is critical. Many entities are fishing for information to assess feasibility.

2. Site Selection and Feasibility Assessment

- As a water provider, it is difficult to sell this internally or provide money, space and time to install, operate, and maintain these systems when they compete with our core function.
- Garbage in - garbage out...start with gratis top line assessment and move to concept design study for nominal fee to make the project shovel-ready for grants and internal funding.

3. Design and Technology Selection

- I am representing new tech in this area but company is not position to take their patented systems to market. Difficult to determine where to start engagement so the tech can be available to the market.
- We have a chicken and egg situation where there are some new ideas but limited development of the technology because of the lack of development of the sites. We are sometimes forced to look at older Pump as a Turbine Technology for some of these sites.
- We have installed over 30 PAT systems primarily because the designs are "off-the-shelf" and the least expensive hardware approach. We follow a classic 30/60/90 design process with the client engaging them along the way to refine the design and bid documentation for a constructor. Typically a 9 to 12 month process from contract signing to commissioning. Low risk portion of the project as long as the client is fully engaged.

4. Permitting and Licensing

- Water utility's facilities were on US Forest Service land. Permission to add hydropower took years to get due to staff turnover at USFS and delays in their review. Project was only 40 kW.
- Tribal case ~200kW: had to sort out jurisdictional issues between FERC and USBR, then get approvals from 3 different utilities including $5500 fee for independent interconnection study.
- Working on a remote project which would use a 300 kW turbine to power a remote village and WTP on USFS land. It's taken over 4 years and still haven't received approval or any type of commitment from USFS or FERC.
- We avoid projects with permitting risk...it is a tax on the project and increases risk, cost and length of project. However, on the projects that have permitting hurdles, we include that review as part of the initial assessment work.

5. Financing and Power Sales

- New technology has a more difficult time getting financed, whether through conventional sources - banks - or private equity investment. It requires a very knowledgeable sales person and a financing rep who may be willing to take on more uncertainty.
- The amount the local electric utility is willing to pay for the power we could generate from potential conduit sites is not enough to offset the cost of developing and maintaining the project, which makes it a difficult sell to decision makers on whether to go forward with a project or not.
- Working on a remote project which would use a 300 kW turbine to power a remote village and WTP on USFS land. It's taken over 4 years and still haven't received approval or any type of commitment from USFS or FERC.
- We avoid projects with permitting risk...it is a tax on the project and increases risk, cost and length of project. However, on the projects that have permitting hurdles, we include that review as part of the initial assessment work.
- Issues with tariffs and operating at a loss.
- Find a way to partner with loads behind the meter.
- It would be nice if small hydropower was incentivized more. Renewable Energy incentives seem to favor the larger projects. The economy of scale is not in our favor.
- The Inflation Reduction Act allows in-conduit hydro projects to be eligible for PTC's even for municipal governments. This averages at 2.66 cent per kWh which greatly improves the payback of the project.

6. Construction and Supply Chain

- Had issues getting different pieces of equipment from various manufacturers on site at the same time, which led to construction delays and contractor overruns. In the end, it would've been better to hold off on getting the contractor on site until all equipment was shipped.
- We typically provide bid documentation for constructor as part of our projects and have recently adopted a CMAR approach to accelerate transition to construction phase and reduce costs.

7. Operations and Maintenance

- Finding local operators or training and retaining folks who can operate the projects. Keeping a detailed maintenance log.
- We are currently developing SMA's for multiple clients whose systems have been in operation over 10 years.

APPENDIX C. XLEAP RESULTS FOR AGRICULTURAL BREAKOUT ROOM

Challenges Deep-dive

Prompt: Tell the story of a specific challenge in this phase - how did it affect outcomes (time, cost, risk)? what were lessons learned? what would have been helpful?

1. Internal and External Stakeholder Engagement

- How do we speak the language of the stakeholder, in articulating value of the technology/energy/economics AND speaking to their specific infrastructural operations and pain points. We have wonderful ag/irrigation clients from personal relationships, but it's difficult to engage clients where there's no existing relationship.
- The core responsibilities of water delivery are at times in competition with hydropower. Irrigation districts need to deliver water.

2. Site Selection and Feasibility Assessment

- A power company seems to use any opportunity they can to place more onerous requirements in interconnection agreements (generator output limiting control, O&M charges) without justification simply to make it harder and more expensive to keep existing projects operating and new ones to be developed.
- Not having funding to pay for feasibility or initial design can slow things down. One irrigation district that is currently trying to move forward with an initial study has 50% grant funding already available but can't afford the other 50% They are applying for another grant but it may take 6-12 months to get it. This delays the study by up to a year. If they then need additional funding to move on to additional steps they may face the same challenge again.
- Distance to three phase interconnection has been an issue on projects in the past. I've seen a few projects that were relatively close to single phase power but it was too far to cost effectively bring three phase power to the area.

3. Design and Technology Selection

- With early supplier involvement, we managed to help developers shorten their project development time and most importantly have a lean installation concept with high civil savings.

4. Permitting and Licensing

- Fish passage and screening rules in Oregon prevent hydro being added anywhere on an irrigation conduit until screening and passage at the diversion are updated to current standards. That means canals/conduits that aren't currently up to standards will remain out of compliance for screening/passage AND not be making clean renewable hydropower.
- A power company applies language to energy sales agreements that applies to wind and solar to address issues that don't pertain to hydro such as generator output limiting control (GOLC) without explanation.

5. Financing and Power Sales

- Low power prices in the west, some sites can only sell power for around 2 cents a kWh.
- Doing a very small project requires most of the same steps and capabilities as a larger project, but the project makes much less money pushing challenging economics onto the whole project. getting benefit for supporting DERS and flexibility might bring some uplift but its still a fundamentally hard thing because small projects have fundamentally limited economic benefit.

- Interconnection costs are outside of a project developers control and can show up very late in the development process, challenging projects that have seemed like they were financially viable prior to the utility having a chance to weigh in. Many projects need support to negotiate with the utility on the requirements that are specified through interconnection studies.
- And many of those values that we are talking about are ultimately defined at the regional/state level, which means it is a lot of work to create a more even playing field.
- I know of one irrigation district that has existing conduit hydro with a PPA that is about to expire and additional conduit opportunities. They are unwilling to move forward on new projects unless they are able to get a new PPA for their existing project at a high enough rate to keep it financially viable.

6. Construction and Supply Chain

- There are a lot of limitations on sub-system components. I have a project where the team had to re-design an entire control system because of the interaction between the plant SCADA and our PLC. These issues are pretty common and the projects are small and necessarily inexpensive so you can't just "buy your way out".

7. Operations and Maintenance

- Finding local expertise to provide maintenance services on equipment (quickly) can be challenging, resulting in long outages.

APPENDIX D. REGISTRATION FORM AND STATISTICS

Conduit Hydropower Development in the US - Opportunity and Challenges Virtual Workshop

Thursday, April 18th, 2024 | 1-3pm ET

Description: Join the US Department of Energy and Oak Ridge National Laboratory (ORNL) for an engaging event exploring opportunities and challenges associated with conduit hydropower development in the US. This virtual workshop will aim to (1) highlight research findings on US conduit hydropower potential, (2) identify common industry challenges and lessons learned, and (3) inform the federal government in establishing a program to assist conduit hydropower project development.

Please RSVP by April 15, 2024

* Required

1. First Name *

2. Last Name *

3. Email *

4. Organization *

5. Job title *

6. What stakeholder type are you most closely associated with? *

- ◯ Project developer
- ◯ Technology developer
- ◯ Utility
- ◯ Asset Owner
- ◯ Regulator
- ◯ Federal government
- ◯ National laboratory
- ◯ Academia or Other researcher
- ◯ Advocate
- ◯ Other

7. What sectors of conduit hydropower are you most interested in? (select all that apply) *

- ☐ Agricultural
- ☐ Municipal Public Water Supply
- ☐ Municipal Wastewater
- ☐ Industrial Public Water Supply
- ☐ Industrial Wastewater
- ☐ Industrial Thermoelectric Cooling
- ☐ Other

8. During the virtual workshop, which breakout room would you rather be in? *

- ◯ Agricultural Conduit Hydropower
- ◯ Municipal/Industrial Conduit Hydropower

9. What size projects are you most interested in? (select all that apply) *

- ☐ <100 kW
- ☐ 100 kW - 1 MW
- ☐ 1-5 MW
- ☐ 5-10 MW
- ☐ >10 MW

10. What regions of the US are you most interested in? (select all that apply) *

- ☐ Northeast
- ☐ Mid-Atlantic
- ☐ Southeast
- ☐ Midwest
- ☐ Northwest
- ☐ Southwest
- ☐ Alaska, Hawaii, or Other

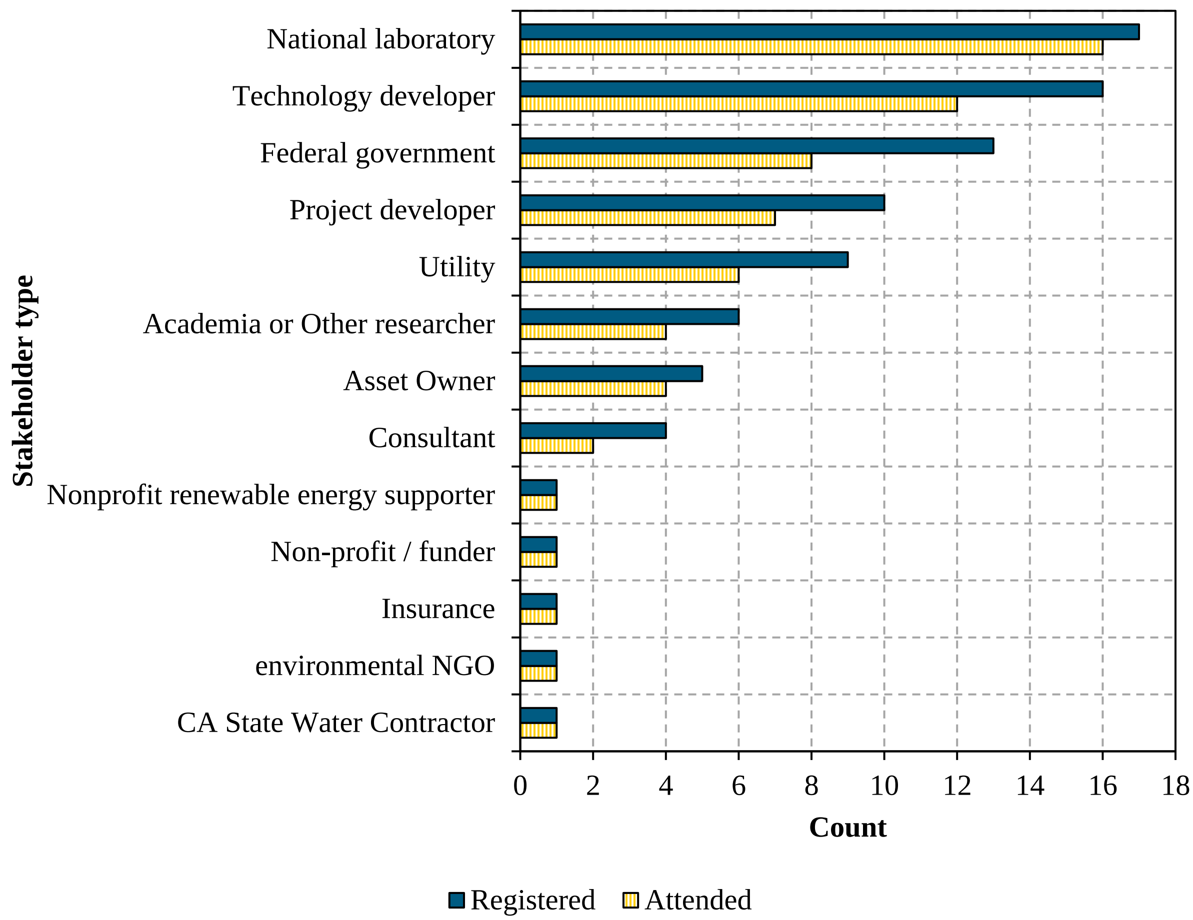


Figure D-1. Number of registrants and attendees, by stakeholder type.

- We had 87% participation in the X-Leap Platform compared to those who attended the Zoom meeting
- 33% of those who were invited registered
- Of those who registered, 80% attended the workshop

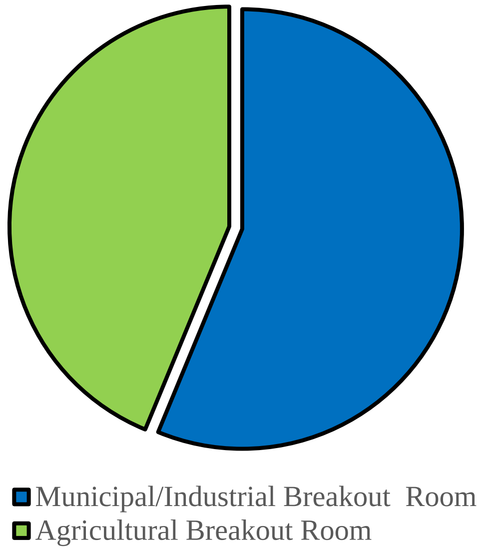


Figure D-2. Number of xLeap attendees in each breakout room.

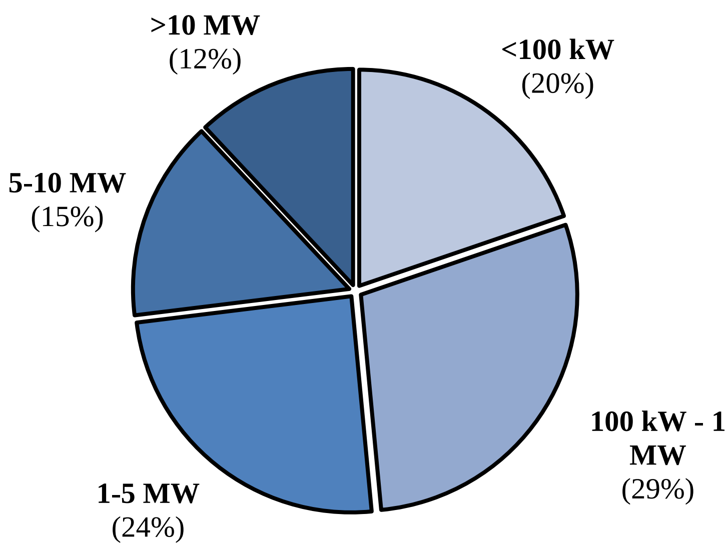


Figure D-3. Project size of interest for attendees, based on registration information.

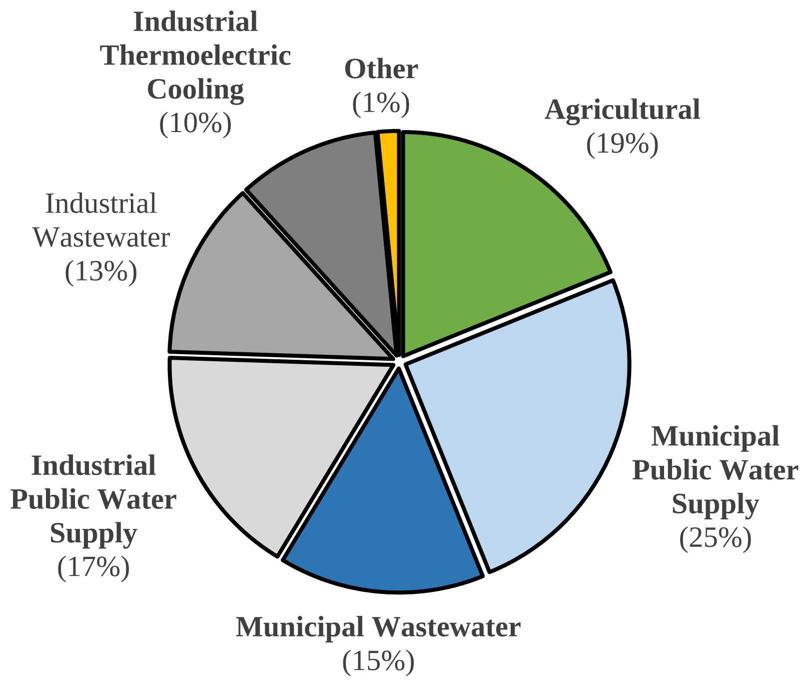
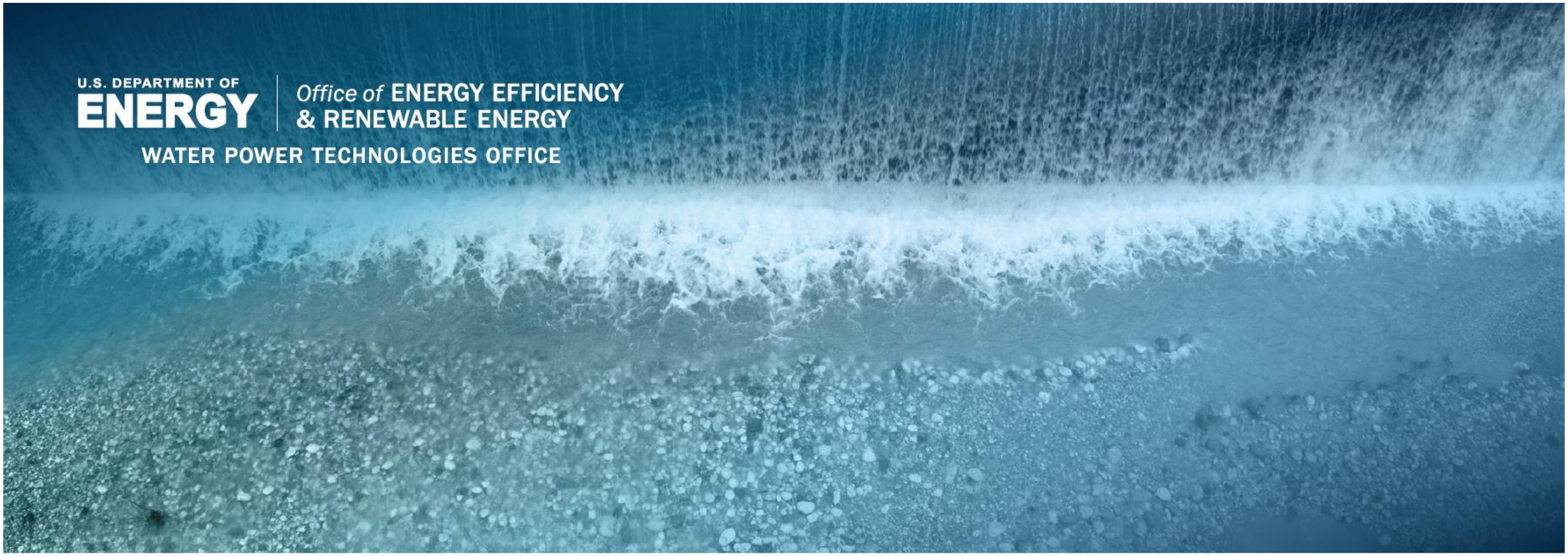


Figure D-4. Sector of interest for attendees, based on registration information.

APPENDIX E. DOE WPTO PRESENTATION



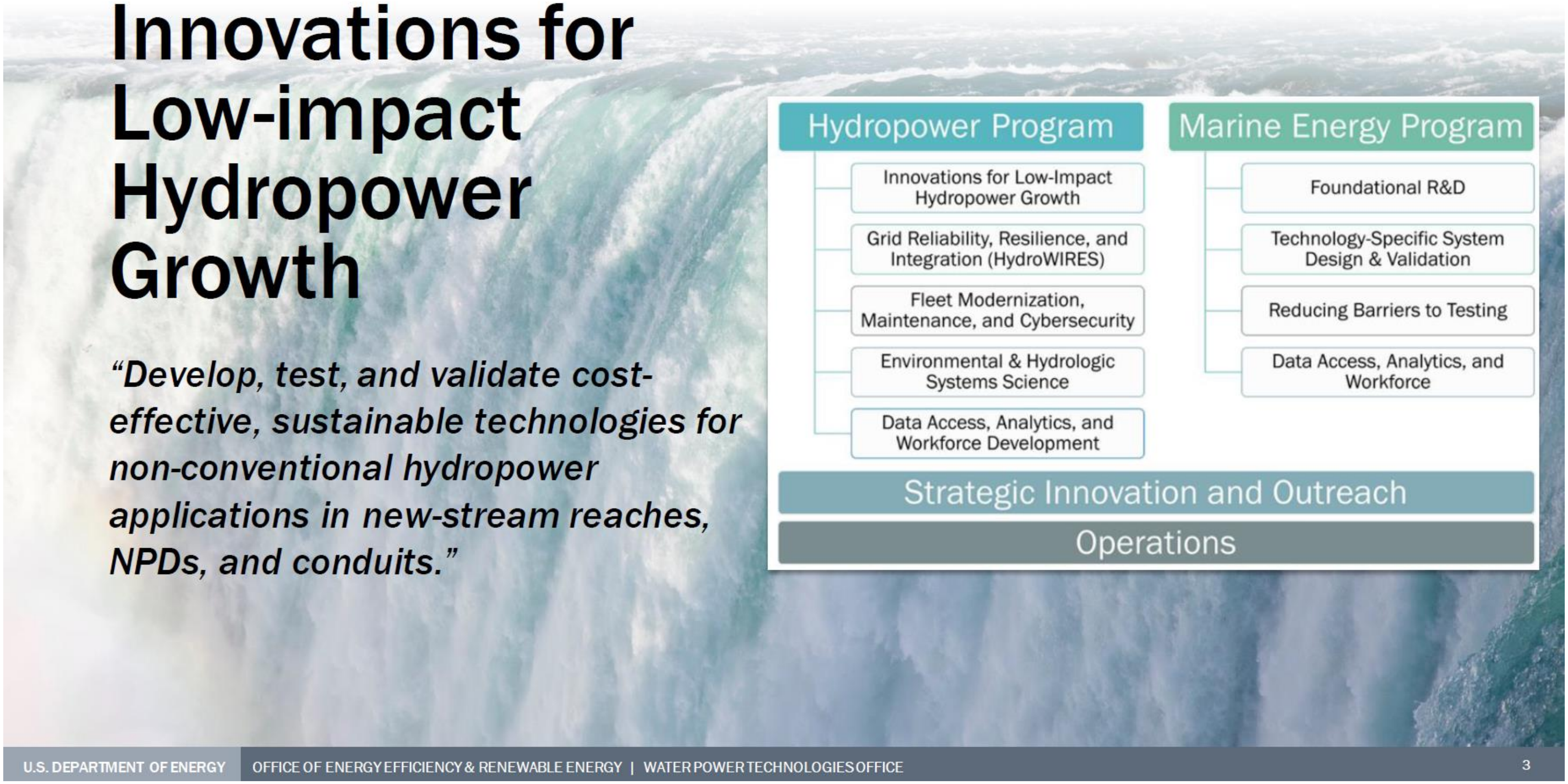
Conduit Hydropower Development – WPTO Perspective

Colin Sasthav
Water Power Technologies Office, U.S. Department of Energy

ORNL Conduit Hydropower Workshop
April 18, 2024

WPTO Mission

"The mission of WPTO is to enable research, development, and testing of new technologies to advance marine energy as well as next-generation hydropower and pumped storage systems for a flexible, reliable grid."


Innovations for Low-impact Hydropower Growth
“Develop, test, and validate cost-effective, sustainable technologies for non-conventional hydropower applications in new-stream reaches, NPDs, and conduits.”
Hydropower Program
Innovations for Low-Impact Hydropower Growth
Grid Reliability, Resilience, and Integration (HydroWIRES)
Fleet Modernization, Maintenance, and Cybersecurity
Environmental & Hydrologic Systems Science
Data Access, Analytics, and Workforce Development
Marine Energy Program
Foundational R&D
Technology-Specific System Design & Validation
Reducing Barriers to Testing
Data Access, Analytics, and Workforce
Strategic Innovation and Outreach
Operations
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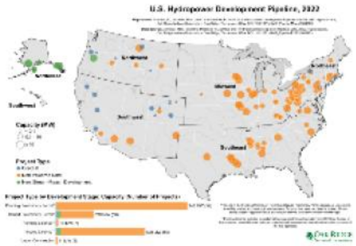
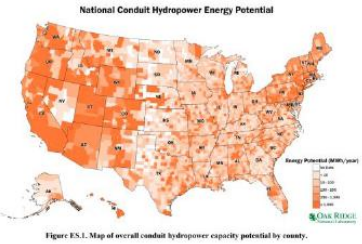
Opportunities for small hydropower

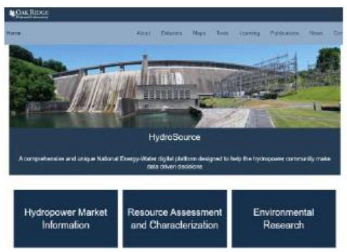
Existing Hydropower Assets
(2265 plants – 80.9GW)



Hydropower Development Pipeline
(118 plants – 1.16GW)



	New Stream Reach Development (NSD)	Non-Powered Dams (NPD)	Conduit Hydropower
Estimated Resource Potential	84.7GW*	12GW*	1.4GW
Projects Constructed (2010-2022)	8 (34MW)	32 (505MW)	87 (140MW)
Notes	• *65.5GW excluding protected rivers	• >91,000 NPDs • ~500 NPDs (8.2GW) with >1MW of potential, which could power ~2.8M homes • *Update coming late 2024	• Agriculture (662MW) • Industry (378MW) • Municipal (374MW) • Est. 992k homes potentially powered



Check out HydroSource for the latest and greatest data!
https://hydrosource.ornl.gov/

Why focus on conduit hydropower?

Innovation bottlenecks

Improving the number of deployments enables innovation validation.

Simplified Licensing

Conduit projects exist within a built environment, reducing regulatory burden.

(*in theory*)

Local Benefits

Opportunities for distributed energy, resilience opportunities, and co-development.

Investing in Technology - Standard Modular Hydropower

How to standardize and modularize?

New Stream Reach

SMH

Non-powered Dams

Technology Development

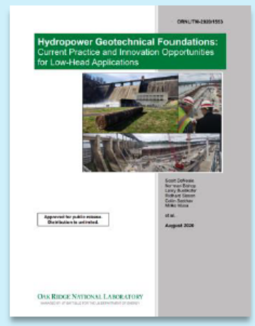
Modeling Capabilities Report

waterSHED

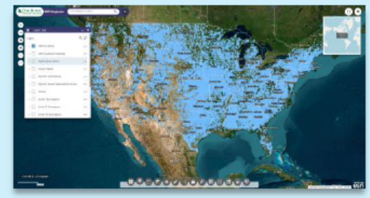
The Water Allocation Tool Enabling Rapid Small Hydropower Environmental Design

The WaterSHED Model

SMH Explorer



Geotechnical Report



NPD Explorer

LITTORAL POWER SYSTEMS

NATEL ENERGY

Percheron Power

UNIVERSITY OF MINNESOTA

Technology Development Awards

Lessons Learned:

- Projects are **unique and site-specific**
- Technologies are available, but need **deployments** to validate and scale
- Project barriers often come from the **project development process**

Project development process

1. Internal & External Stakeholder Engagement
- Identifying a project champion
- Gaining buy-in from leadership
- Engaging with communities

2. Site selection & Feasibility Assessment
- Desktop studies
- Identifying red flags
- Conceptual design
- Project scoping

3. Design & Technology Selection
- Detailed engineering design
- Procurement
- Scheduling
- Site investigation

4. Permitting & Licensing
- FERC license/exemption
- State permits
- Local permits
- Interconnection

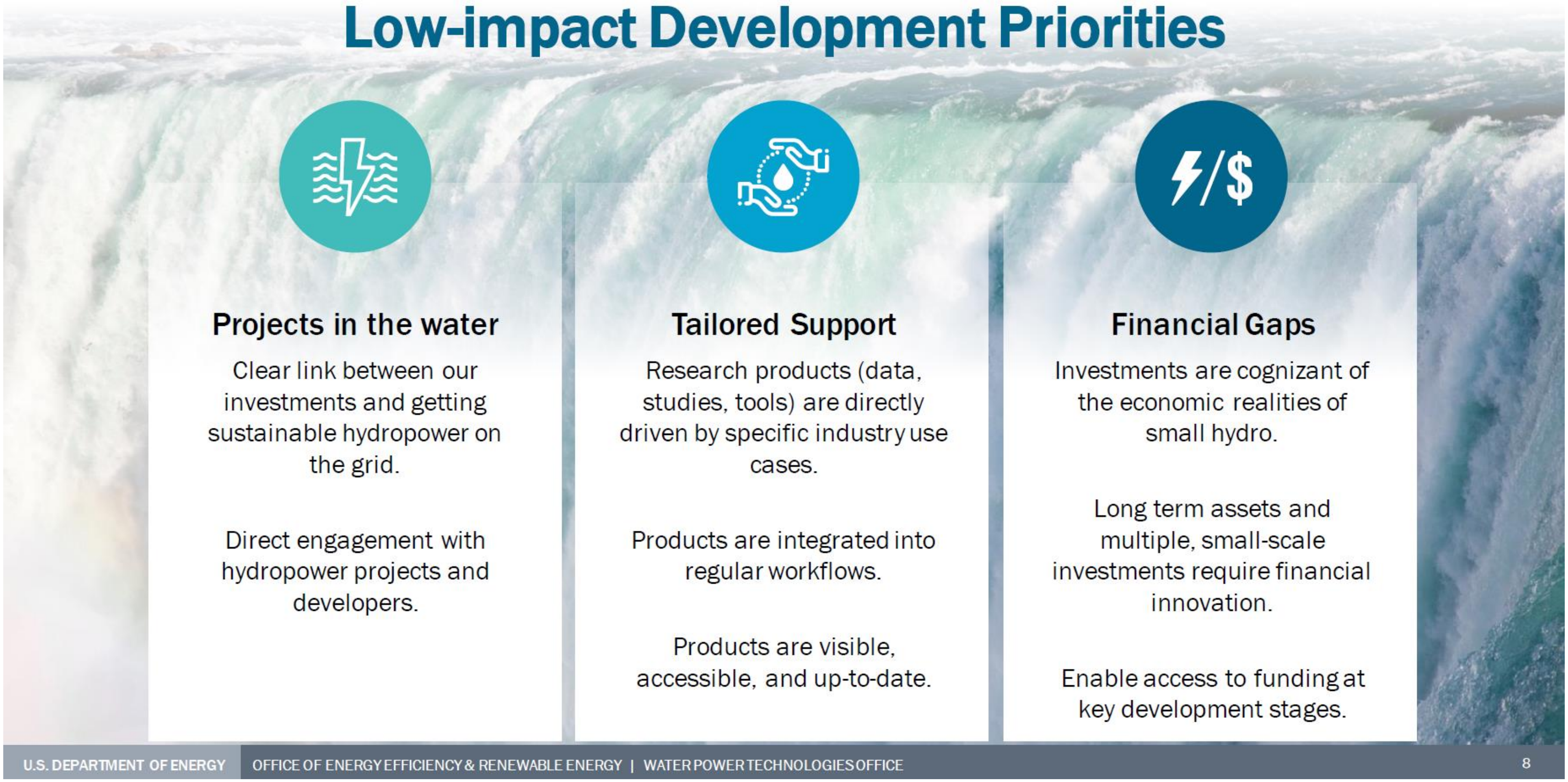
5. Financing & Power Sales
- Finding off-takers
- PPA design
- Incentives analysis
- Development funding
- Late-stage financing
- "Batching" or grouping of projects

6. Construction & Supply Chain
- Dewatering
- Staging and site access
- Transportation
- Contracting
- Commissioning

7. Operations & Maintenance
- Operation optimization
- Outage management
- Staffing
- Sensor analysis
- Inventory management

Example activities

Note:
- These are simplified categories for the purpose of today's conversation
- The process is iterative and often not linear


Low-impact Development Priorities
Projects in the water
Clear link between our investments and getting sustainable hydropower on the grid.
Direct engagement with hydropower projects and developers.
Tailored Support
Research products (data, studies, tools) are directly driven by specific industry use cases.
Products are integrated into regular workflows.
Products are visible, accessible, and up-to-date.
Financial Gaps
Investments are cognizant of the economic realities of small hydro.
Long term assets and multiple, small-scale investments require financial innovation.
Enable access to funding at key development stages.
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What we want to hear today?

"A well-defined problem is a problem half solved." – John Dewey

- Stories – what challenge did you face?
- Impacts – how did it affect your project?
- Metrics – what was the scale of the challenge?
- Data and information gaps – what information would've helped you?
- Best practices – what worked well and what lessons did you learn?

Drill-down

Get specific about the barriers. What are the forms, studies, processes, decision points, calculations, etc. that give you the most issue? Who was involved in those barriers and what were their needs?


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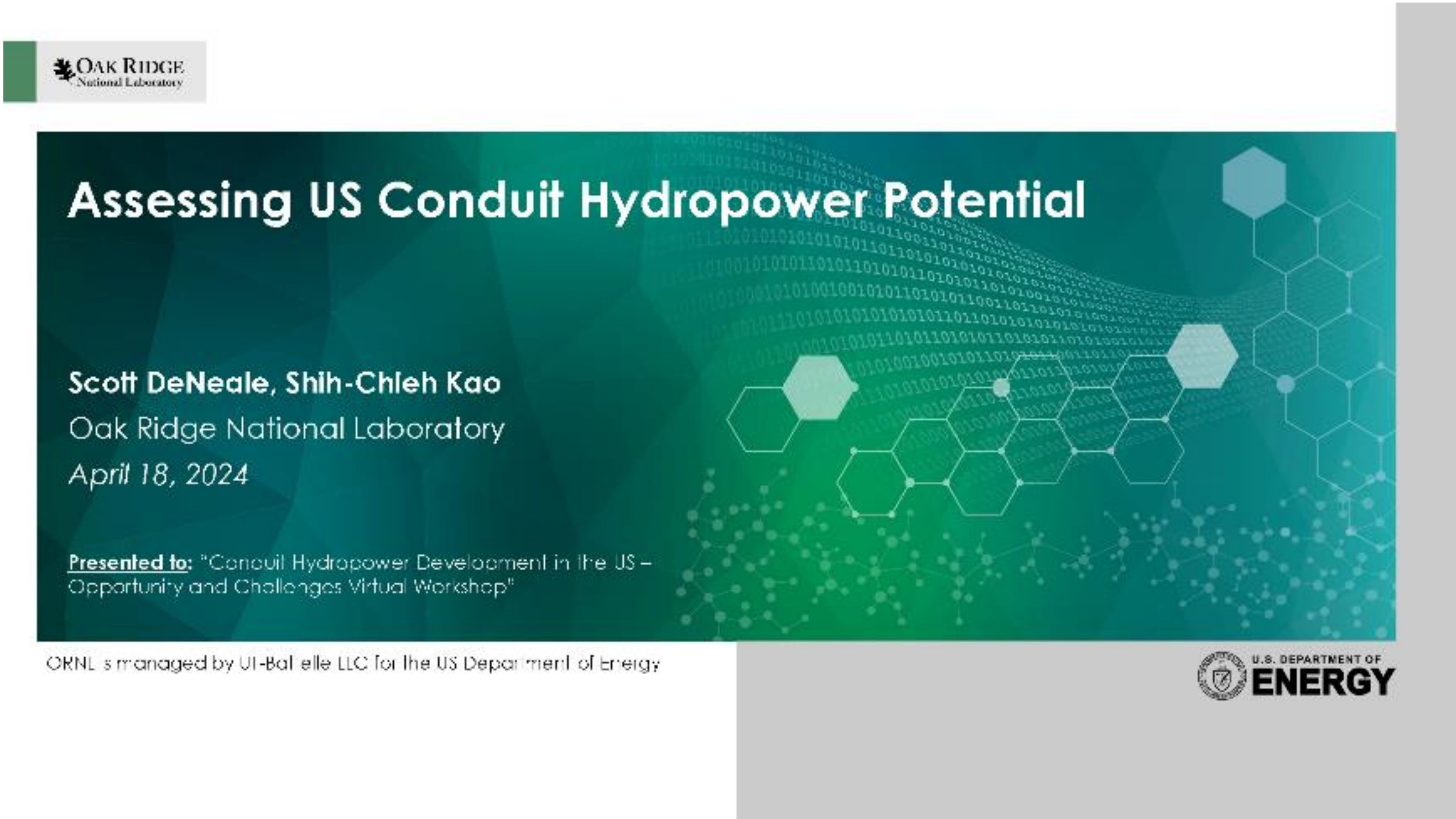
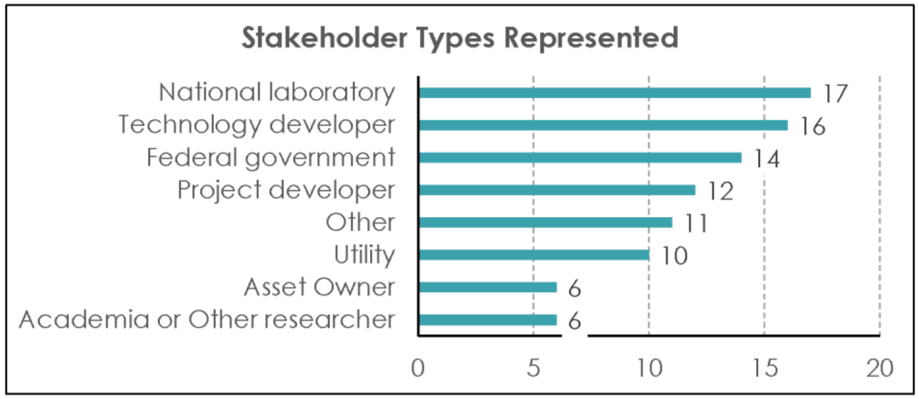
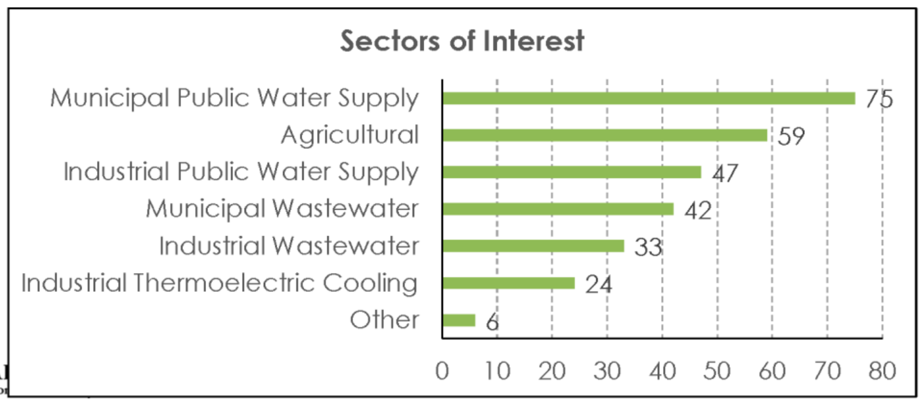
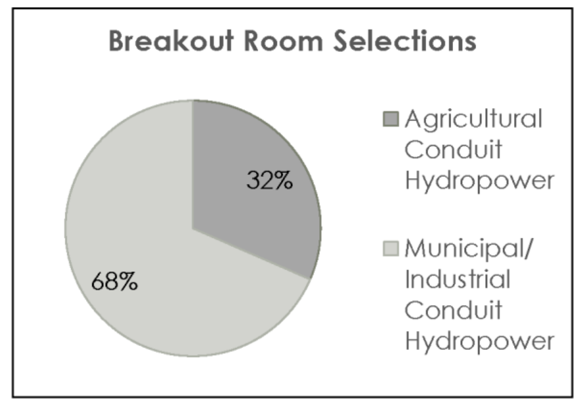
APPENDIX F. ORNL PRESENTATION



92 Registrants – thank you for attending!







Agenda

- Background on Conduit Hydropower
- DOE Programmatic Research Priorities
- Resource Assessment
  - Overview
  - Methodology
  - Results

Conduit Hydropower

- According to the Code of Federal Regulations (CFR) Title 18, Chapter 1.B.4.D § 4.30 (b) (2), conduit means "any tunnel, canal, pipeline, aqueduct, flume, ditch, or similar manmade water conveyance that is operated for the distribution of water for **agricultural**, **municipal**, or **industrial** consumption and not primarily for the generation of electricity."
- **Conduit hydropower development:**
  - does not require the construction of new dams or impoundments,
  - involves minimal environmental concerns,
  - is eligible for net-metering in most states,
  - yields high value for the energy generated,
  - entails reduced development timelines, and
  - may qualify for an expedited 45-day regulatory approval process.

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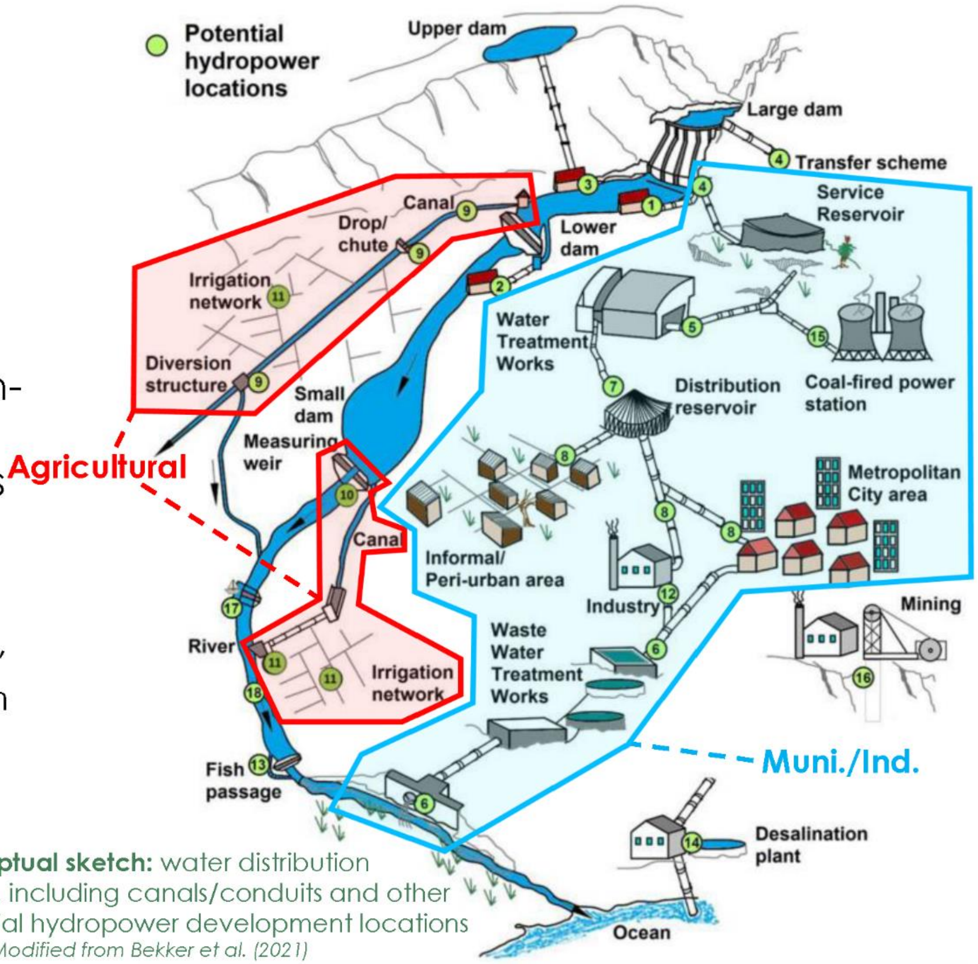
Conduit Hydropower

- **Estimated existing US conduit hydropower:** 530 MW
- **Qualifying conduit facilities** are considered outside of FERC jurisdiction and can secure a non-jurisdictional determination from FERC per the HREA within 45 days provided that they
  - are less than 40 MW,
  - use a nonfederally owned conduit,
  - serve a primary purpose other than hydropower generation, and
  - are not currently licensed or exempted.

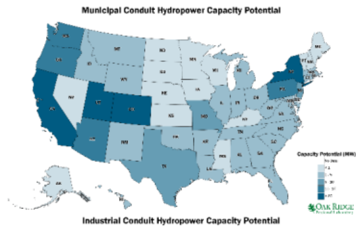


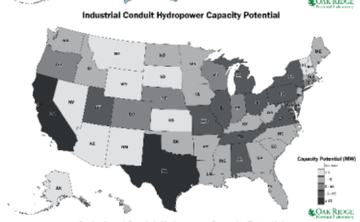
Conceptual sketch: water distribution system, including canals/conduits and other potential hydropower development locations
Source: *Modified from Bekker et al. (2021)*

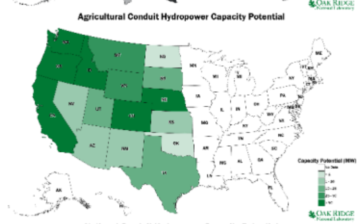
DOE Programmatic Research Priorities: Conduits

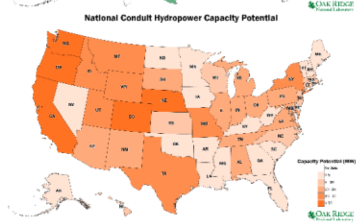
(per 2022 multi-year program plan)

- **Assess hydropower resource potential at existing conduits:** Perform a geospatial study to identify existing U.S. water conveyance systems and quantify available hydropower resource potential.
- **Develop new hydropower technologies for conduit applications:** Develop technologies and methods to cost-effectively add hydropower to existing conduits and canals.
- **Test new technologies for conduit applications:** Evaluate the performance of developed technologies for conduits and canals at a partial and/or full scale.
- **Demonstrate new conduit technologies:** Conduct a field demonstration to validate new technologies at an existing conduit or canal.









Resource Assessment Overview

- **Scope:** reconnaissance level study
  - Estimate hydraulic head, water flows, hydropower potential (MW), and annual energy generation (GWh/year)
  - Aggregate at county and state levels for all 50 states
- **Sectors:** municipal, agricultural, and industrial
  - Water supply pipelines for municipal and industrial uses
  - Wastewater discharge conduits from municipal and industrial systems
  - Agricultural water conduits including irrigation canals and ditches in the 17 western states that rely heavily on irrigation
  - Thermoelectric power plant cooling water discharge conduits
- **Results:** nationwide total of 1,414 MW across all sectors

Four Types of Analysis

- Public Water Supply System
  - Analyze public water system (PWS) info from EPA and state agencies
- Agricultural Irrigation System
  - Analyze irrigation canal drop sites identified from remote sensing imageries and feature detection techniques
- Thermoelectric Cooling System
  - Analyze ~800 national facilities accounting for 95% of total deliveries
- Wastewater Treatment System
  - Analyze potential sites from the National Pollutant Discharge Elimination System (NPDES) dataset

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Public Water Supply Systems

- Generating facilities located at pressurized pipelines used for drinking water supply in the public water system (PWS)
- Installed in parallel to existing pressure-reducing values (PRVs)
- Project sizes are typically small, but can be developed very quickly
- May be used for net-metering in most states

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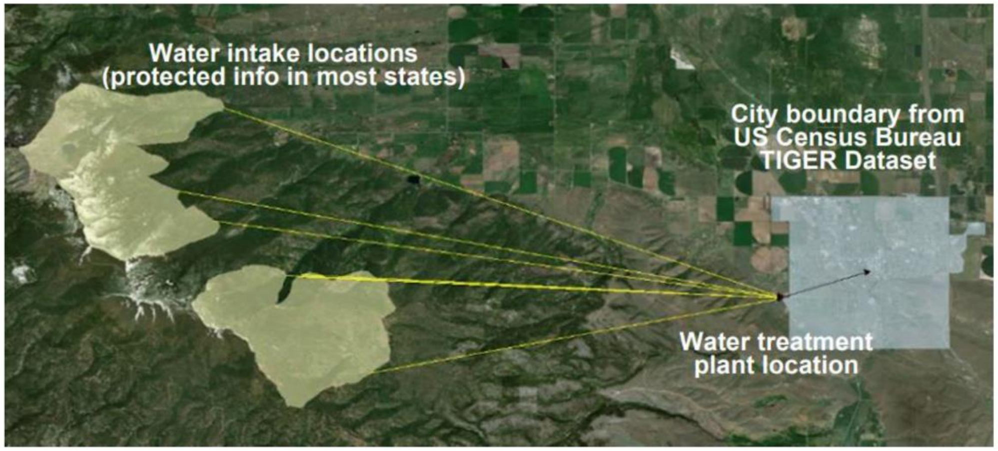
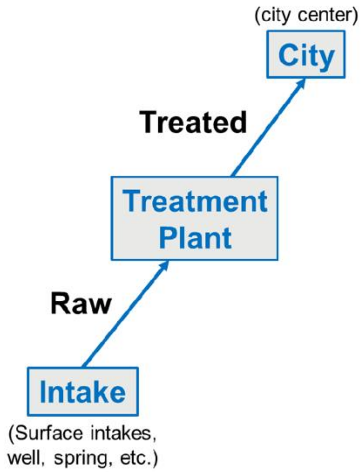
Methodology: Public Water Supply (Municipal/Industrial)

- Use existing data sets on water system/city locations, elevation, water use
- Two-part analysis (raw water and treated water)

Data type	Data source
PWS information	EPA Safe Drinking Water Information System
Water intake and treatment plant locations	EPA
City boundary	US Census Bureau Topologically Integrated Geographic Encoding and Referencing Dataset
Digital elevation	USGS National Elevation Dataset
Historical water use	USGS National Water-Use Science Project





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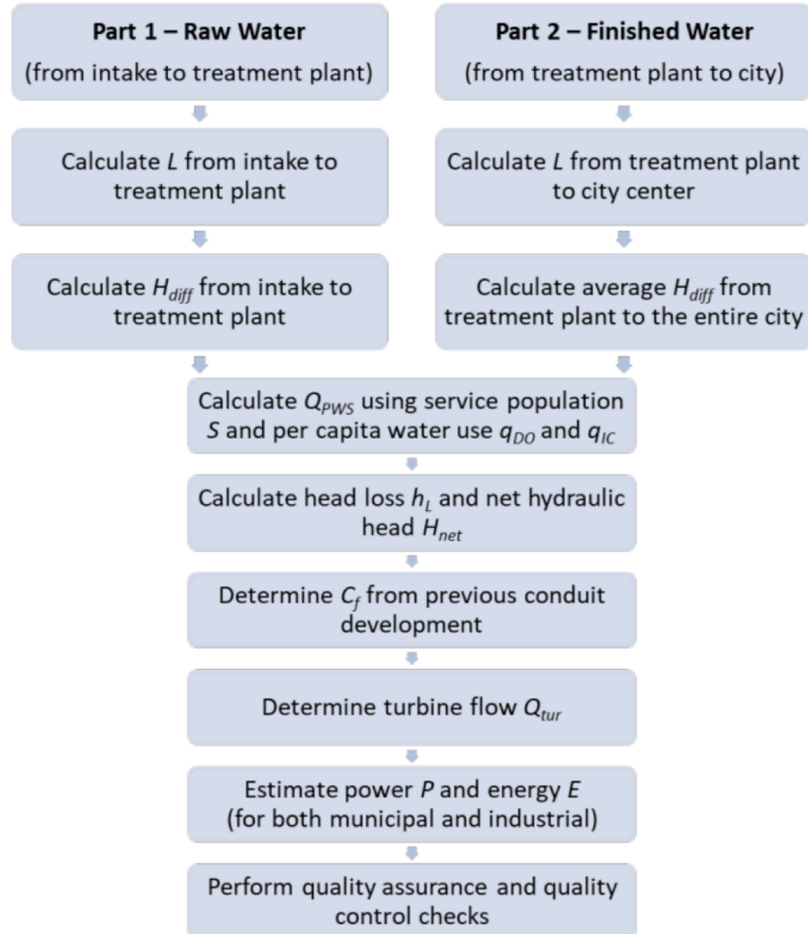
Methodology: Public Water Supply (Municipal/Industrial)

- Calculate head and flow, using assumptions
  - Head: elevation difference, less head loss
    - Head loss: Darcy-Weisbach and Colebrook formulas
  - Flow: use water withdrawal and water use data
  - Power and Energy: assume 85% efficiency and 68% capacity factor
  - Assume gravitational head only (no pumping); other assumptions



Agricultural Irrigation Systems

- Generating facilities located at drop locations within open water ditches and canals that are primarily used for irrigation
- Typically larger in capacity, but the flow is only available seasonally

Example of canal drop sites identified through remote sensing images (Upstream Tech):

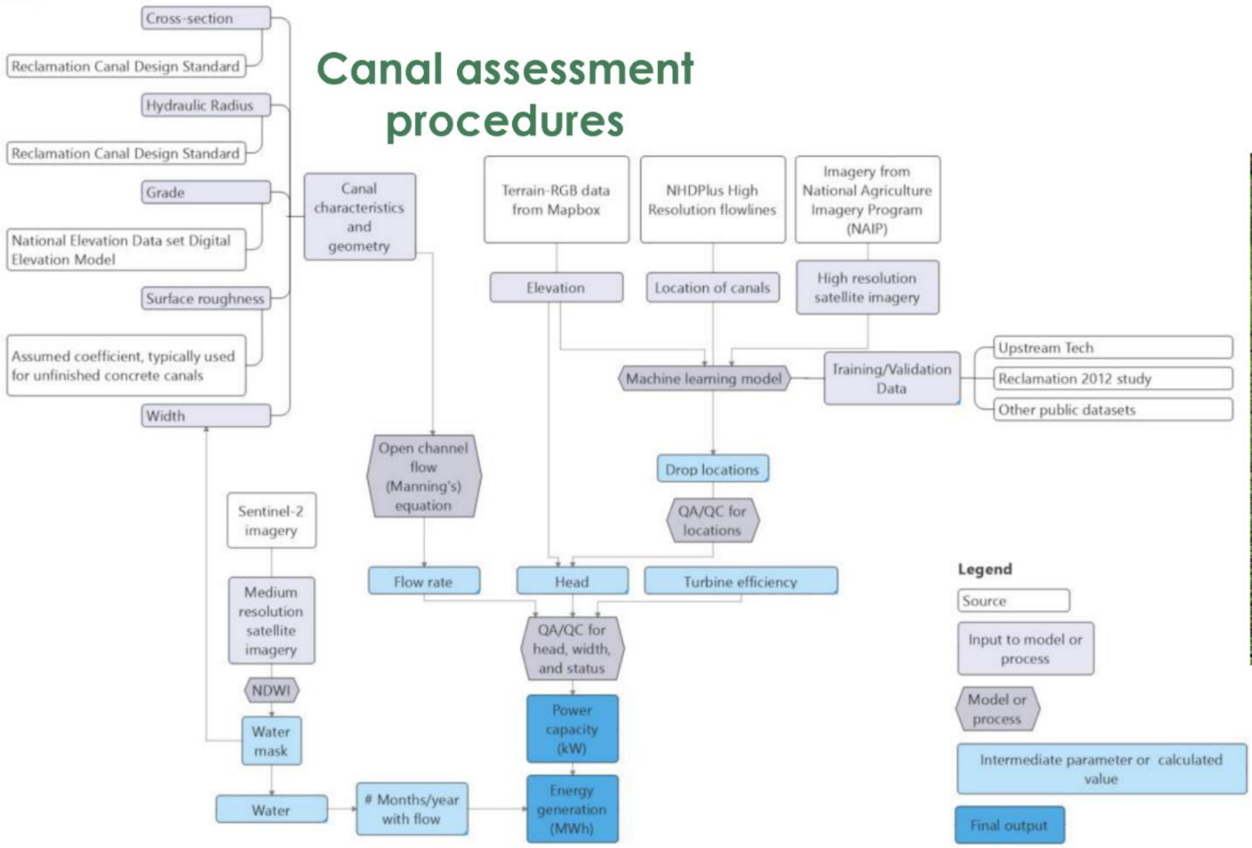
Methodology: Irrigation Canal Systems (Agricultural)

- Limited to 17 western US states (following 2012 Reclamation study)
- Identify irrigation canal drops using aerial and satellite imagery and georeferenced hydrographic data
  - Use Upstream Tech's existing commercial drop-detection model, which leverages machine learning
- Removed Reclamation sites
- Considerable QA/QC

Data type	Data source
Known canal drop location	Reclamation 2011 and 2012 Canal Resource Assessment Other sites known by the research team
Aerial and satellite imagery	NAIP Sentinel-2
Digital elevation	USGS National Elevation Dataset (NED) Mapbox Terrain-RGB
Flow line	USGS NHDPlus High Resolution
Existing hydropower asset	ORNL HydroSource EHA Dataset
County boundary	TIGER Dataset

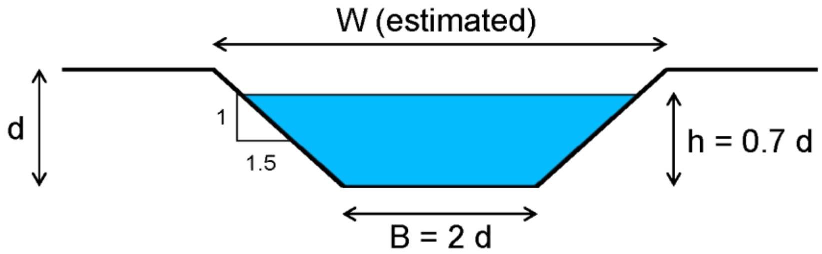
Methodology: Irrigation Canal Systems (Agricultural)

Canal assessment procedures



Methodology: Irrigation Canal Systems (Agricultural)

- Flow: use Reclamation Canal Design Standard to approximate canal geometry
  - Estimate canal width from water mask (with manual QC)
  - Estimate slope from DEM
  - Using Manning's formula to estimate flow
  - Set max velocity V = 2 m/s
- Head: estimated using elevation data



$$Q = \frac{1}{n} A R^{2/3} S^{1/2}$$

Thermoelectric Cooling Systems

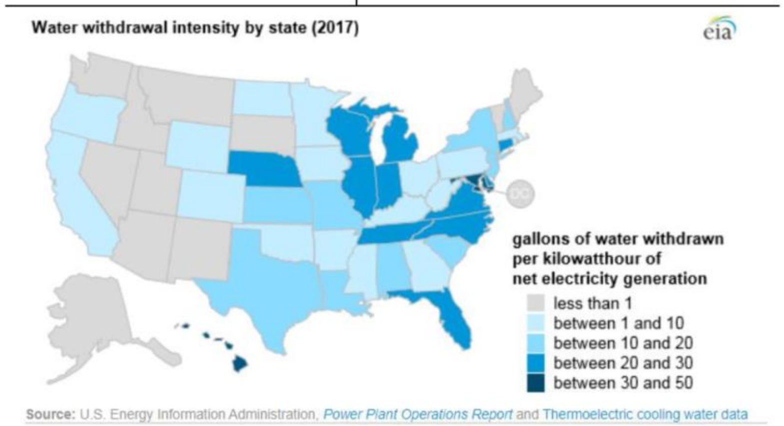
- Largest source of US water withdrawals (45%)
- Example applications in Europe, not US
- Approach focused on discharge canals for the largest 95% of thermoelectric cooling water withdrawal sites

Water withdrawals by sector (Maupin et al., 2014)

Methodology: Thermoelectric Cooling System (Industrial)

- Data: EIA Annual Water Withdrawal
- Flow: annual average water withdrawals
- Head: estimate elevation of plant and receiving waterway manually using Google Earth for 186 of 798 facilities, accounting for 95% of total deliveries
  - Assumed 10 feet of headloss

Data type	Data source
Thermoelectric plant information	EIA Form 860 Dataset
Annual water withdrawals and consumption	EIA thermoelectric cooling water data
Discharge water body	USGS NHDPlus
Digital elevation and aerial photographs	Google Earth Pro
County boundary	TIGER Dataset



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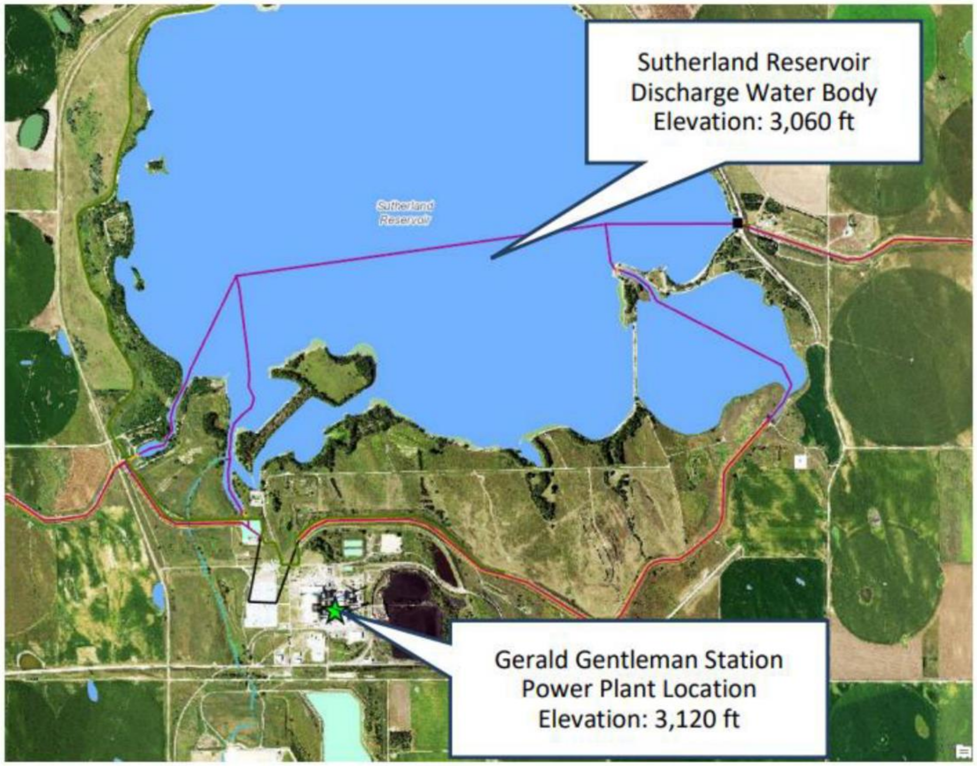
Methodology: Thermoelectric Cooling System (Industrial)

Example elevations collected for thermoelectric power plant



- Locate power plants using EIA info imported in Google Earth Pro
- Import NHDPlus Water Bodies
- Determine the elevation at the power plant location
- Determine the elevation at the discharge location
- Calculate H_{diff} and H_{net}
- Determine turbine flow Q_{tur}
- Estimate power P and energy E
- Perform quality assurance and quality control checks

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Wastewater Treatment Systems

- Hydropower potential only exists when discharge point is above receiving waterway
- US examples: Deer Island, Massachusetts (2 MW) and Point Loma, California (1.35 MW)
- International examples: Canada, Australia, United Kingdom

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Methodology: Wastewater Systems (Municipal/Industrial)

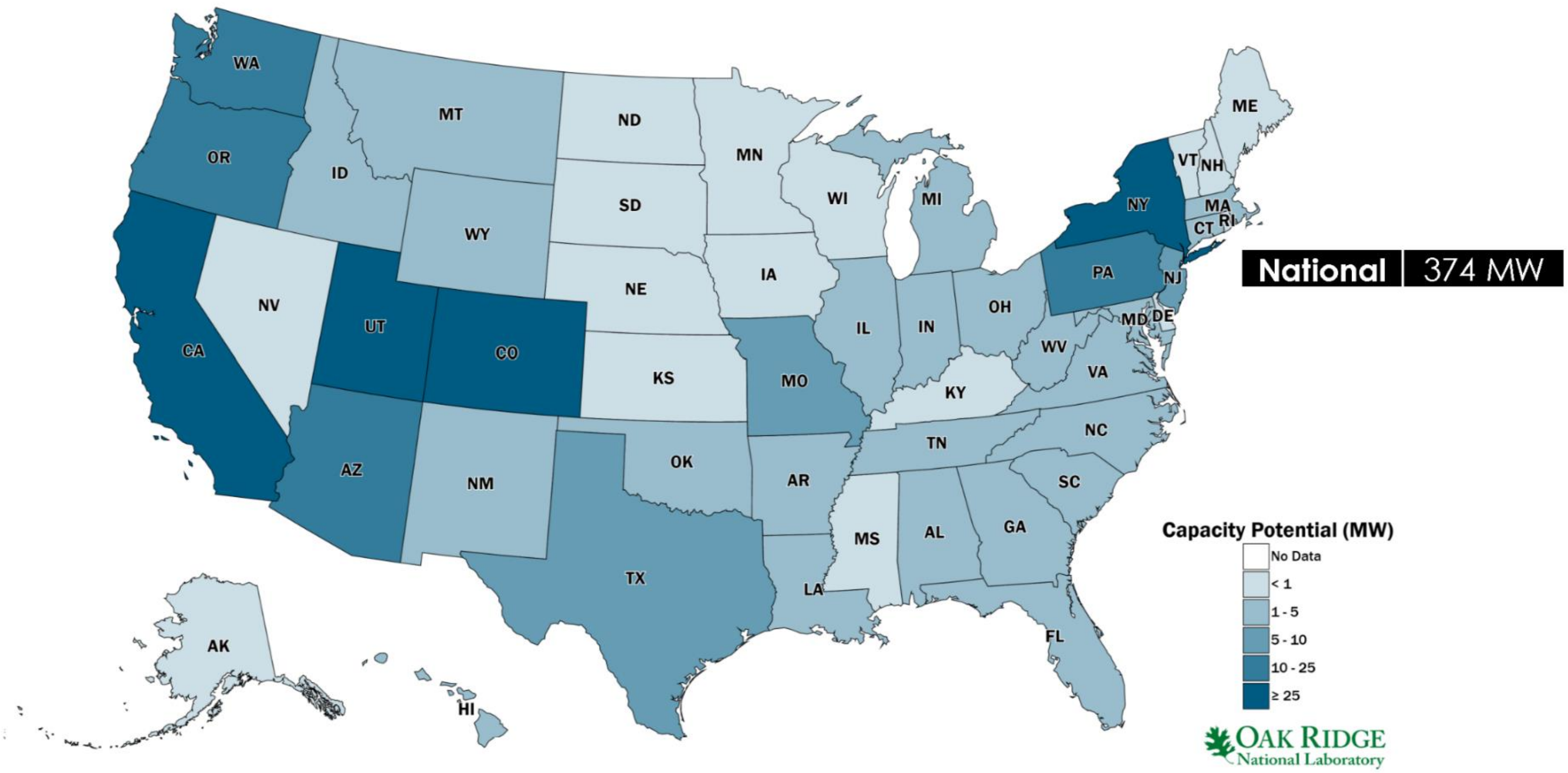
- Data: EPA Enforcement and Compliance History Online (ECHO) database of NPDES Permits: 59,190 facilities with individual, active permits
- Flow: use minimum of flow reported (Design Flow, Annual Average Flow or Monthly or quarterly flow reporting)
- Head: assumed 6 ft, with 2-10 ft being typical

Data type	Data source
Wastewater facility information	NPDES Dataset
County boundary	TIGER Dataset

1. Obtain active and individual permit data from 2019 NPDES (location, SIC, flow rates)
2. Determine annual average flow as the minimum of all reported flow
3. Check quality control of flow by manual inspection and estimate Q_{tur}
4. Identify permits with SIC 4952 for allocation to the municipal sector
5. Assume H_{net} is in the range from 2 to 10 ft, and use the average 6 ft for further assessment
6. Estimate power P and energy E

RESULTS

Results (estimated)



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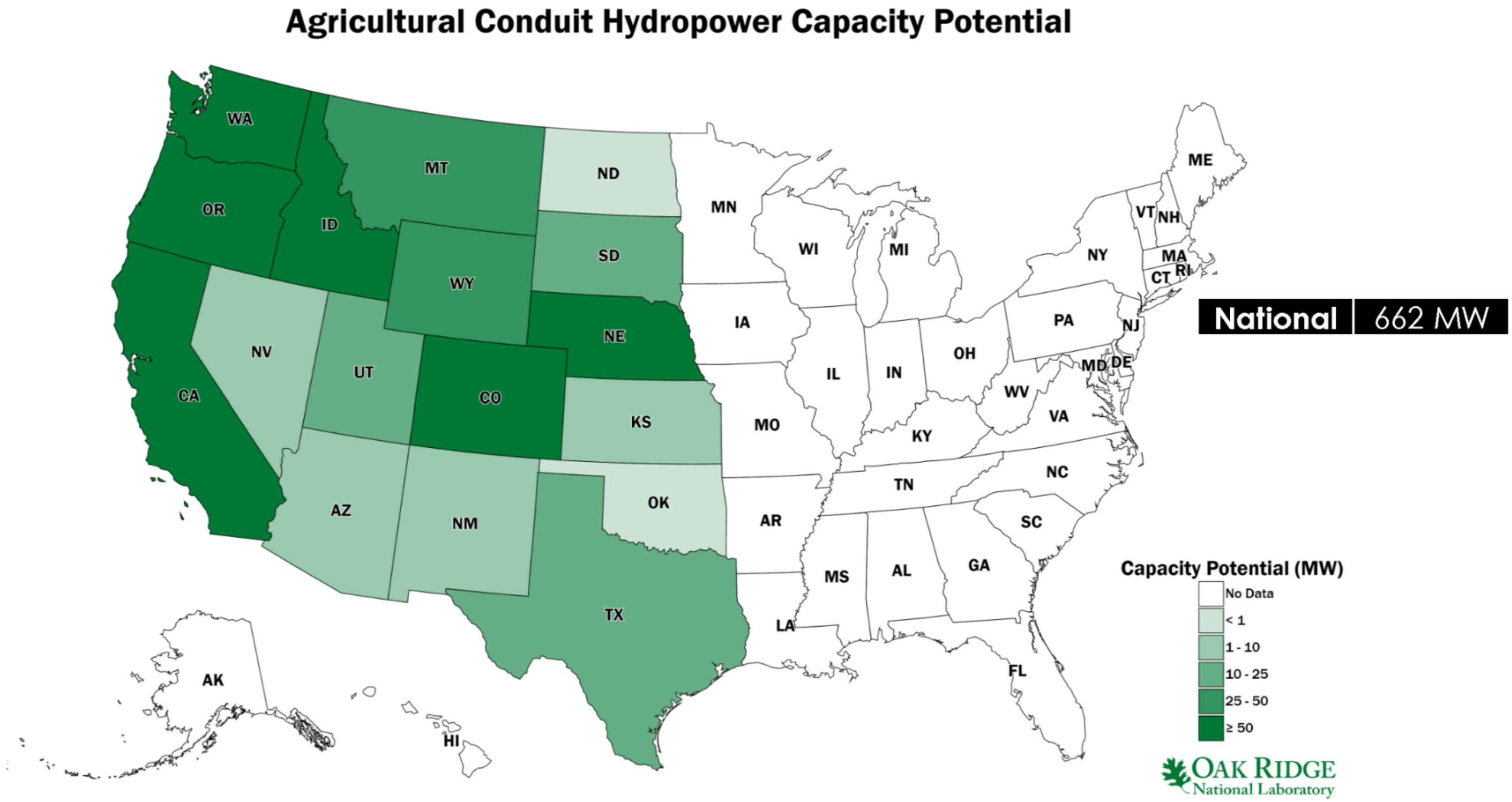
Results (estimated)



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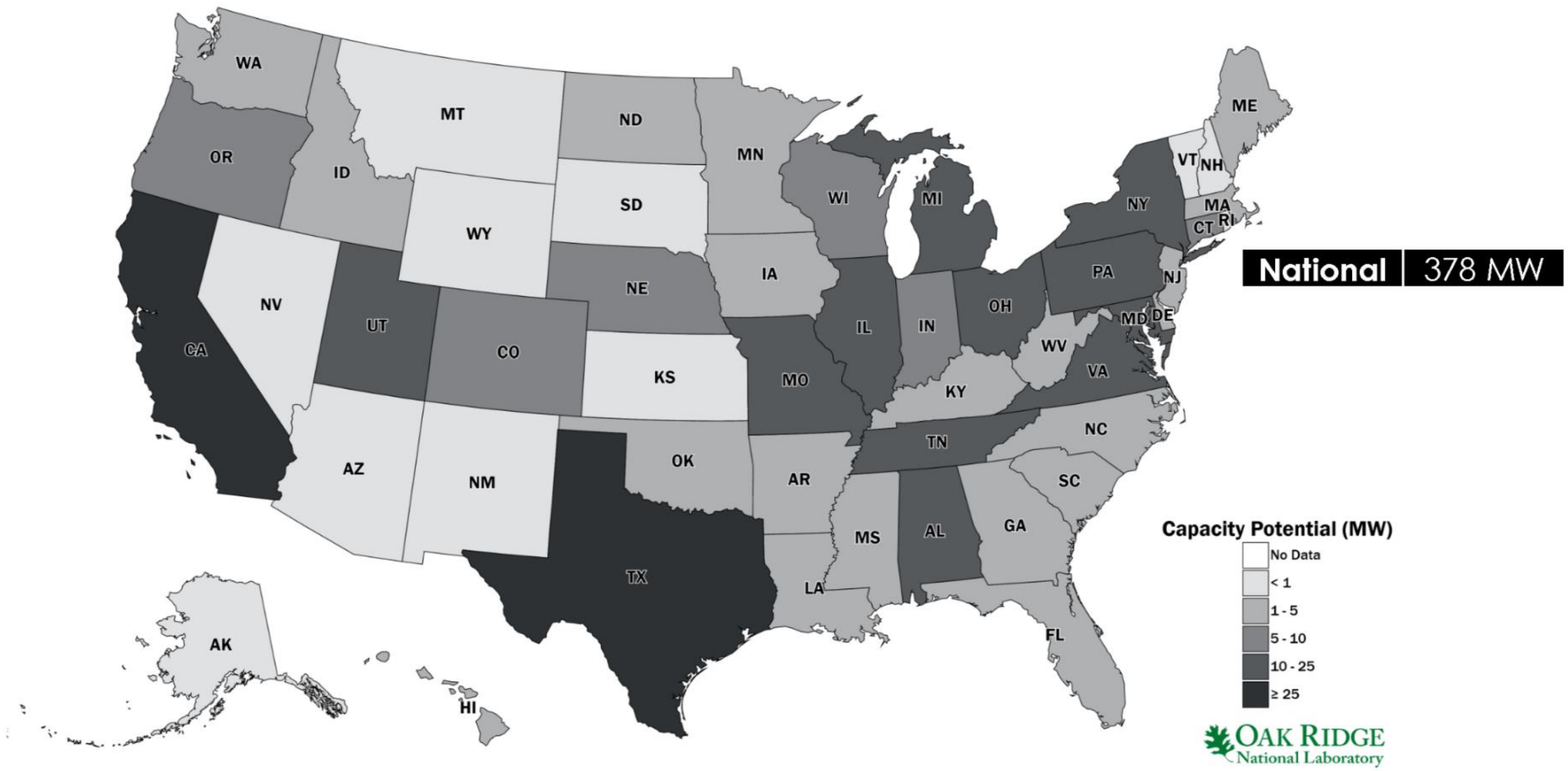
Results (estimated)

Industrial Conduit Hydropower Capacity Potential



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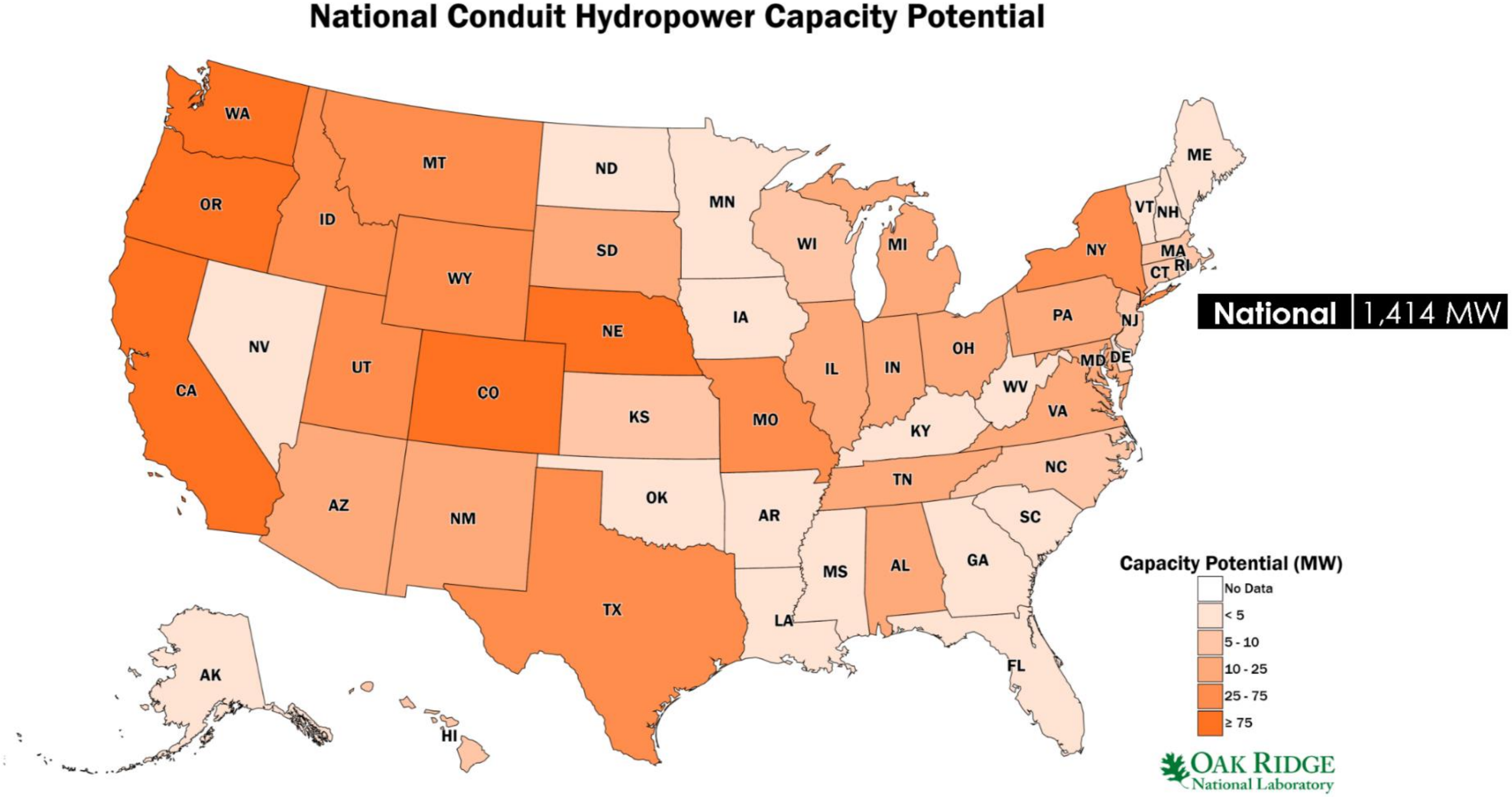
Results (estimated)



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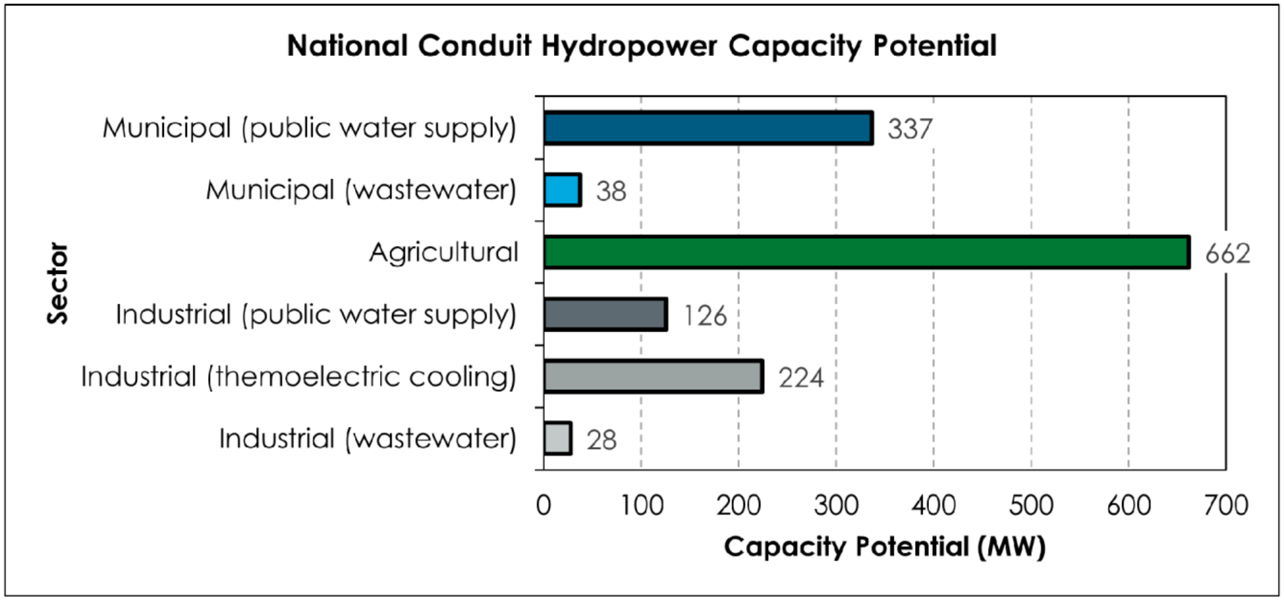
Discussion and Conclusions

- The study estimates **a total of 1.41 GW of new conduit hydropower potential** across the United States, with the largest portion of conduit hydropower potential found in the agricultural sector (662 MW), followed by industrial (378 MW) and municipal (374 MW) sectors.



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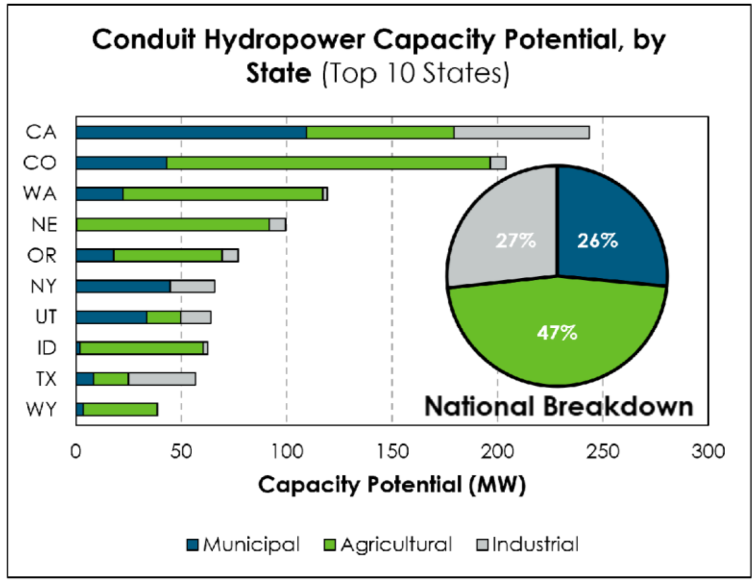
Discussion and Conclusions

- The study estimates **a total of 1.41 GW of new conduit hydropower potential** across the United States, with the largest portion of conduit hydropower potential found in the agricultural sector (662 MW), followed by industrial (378 MW) and municipal (374 MW) sectors.
- In general, **the largest resource potential exists in the western states**,
  - California (243 MW),
  - Colorado (204 MW),
  - Washington (119 MW),
  - Nebraska (99 MW), and
  - Oregon (77 MW).



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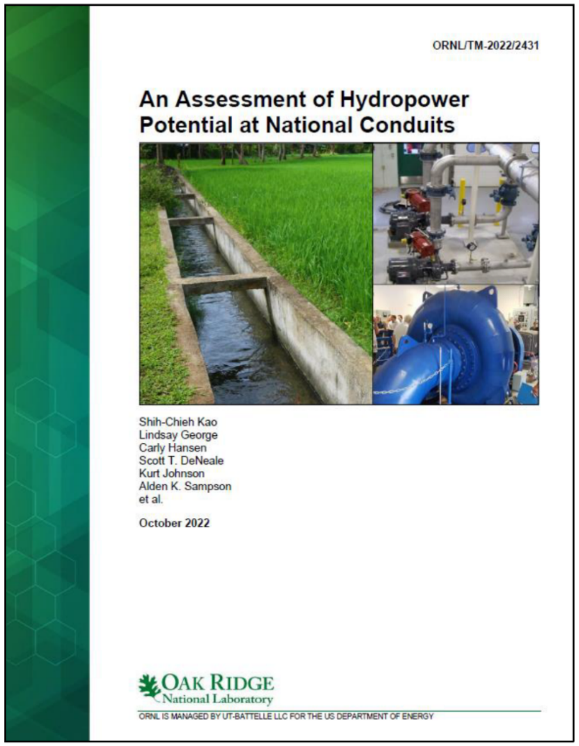
US Conduit Hydropower Report



ORNL/TM-2022/2431

An Assessment of Hydropower Potential at National Conduits

Shih-Chieh Kao
Lindsay George
Carly Hansen
Scott T. DeNeale
Kurt Johnson
Alden K. Sampson
et al.

October 2022

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https://doi.org/10.2172/1890335

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ORNL HydroSource

https://hydrosource.ornl.gov/

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THANK YOU!

QUESTIONS?

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Acknowledgments: Shih-Chieh Kao, Lindsay George, Carly Hansen, Scott DeNeale, Kurt Johnson, Alden K. Sampson, Marshall Moutenot, Kevin Altamirano, Kathryn Garcia, Jim Downing, Mary Beth Day, Kelsey Rugani