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## July 2017 — September 2017

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*Telluride Energy*

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*National Renewable Energy Laboratory*

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**Technical Report**
NREL/TP-6A20-70483
January 2018

Contract No. DE-AC36-08GO28308

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# List of Acronyms and Abbreviations

| | |
|---|---|
| CDA | Colorado Department of Agriculture |
| CEC | California Energy Commission |
| CEO | Colorado Energy Office |
| FERC | Federal Energy Regulatory Commission |
| FPA | Federal Power Act |
| GIS | Geographic Information System |
| GW | gigawatt |
| HREA | Hydropower Regulatory Efficiency Act of 2013 |
| kW | kilowatt |
| kWh | kilowatt-hour |
| LOPP | Lease of Power Privilege |
| MW | megawatt |
| MWh | megawatt-hour |
| NEPA | National Environmental Policy Act |
| NOI | Notice of Intent |
| NREL | National Renewable Energy Laboratory |
| ORNL | Oak Ridge National Laboratory |
| PRV | pressure-reducing valve |
| Reclamation | Bureau of Reclamation |
| RPS | renewable portfolio standard |

# Executive Summary

Moving and treating water for agricultural, commercial, industrial, and residential purposes accounts for 4% of the annual electricity consumed in the United States. Some of the energy used to move and treat water can be "recaptured" through energy recovery hydropower. Energy recovery hydropower harnesses mechanical energy from moving water that is unutilized within existing pressurized water supply pipelines and converts it to electricity. Energy recovery hydropower is a subset of conduit hydropower that utilizes existing, pressurized, manmade water conveyances that are already diverting water from a natural waterway for the primary purpose of distributing water for agricultural, municipal, or industrial consumption.

Energy recovery hydropower is one of the most cost-effective types of new hydropower development because it is constructed utilizing existing infrastructure, and it is typically able to complete Federal Energy Regulatory Commission (FERC) review in 60 days. The primary market driver for this type of hydropower is the opportunity for water system operators to lower operational costs by offsetting energy use costs with on-site hydropower generation. For example, water treatment plants typically have an existing electricity load, which the plant may be able to be offset with on-site hydropower generation through net metering. Water treatment plants frequently contain pressure-reducing valves (PRVs), mechanical devices designed to reduce water pressure in order to protect pipelines and equipment (e.g., filtration membranes) from excess pressure. Energy recovery hydropower can be installed in parallel with an existing PRV.

Preliminary estimates show a conduit hydropower resource potential of 1–2 GW for the United States. However, there has not yet been a comprehensive federal assessment of the conduit hydropower sub-set that constitutes energy recovery hydropower.

Recent changes in federal and state policy have supported energy recovery hydropower. In August 2013, Congress passed the Hydropower Regulatory Efficiency Act (HREA), which expedites the FERC process for qualifying conduits. Congress also passed the Bureau of Reclamation (Reclamation) Small Conduit Hydropower Development and Rural Jobs Act, which reformed the Reclamation hydropower approval process. In 2014, Congress provided appropriations for the first time for the Section 242 program under the Energy Policy Act of 2005, a federal program that provides incentives for new hydropower generation built using existing infrastructure, including energy recovery hydropower.

In addition, some states have developed programs and policies to support energy recovery hydropower, including resource assessments, regulatory streamlining initiatives, and grant and loan programs to reduce project development costs.

As of August 2017, four years after HREA became law, FERC had approved 87 projects as qualifying conduits with a total nameplate capacity of almost 32 MW. Project development has been most active in western states and roughly evenly split between agricultural and municipal projects.

# Table of Contents

# 1 Introduction

Moving and treating water for thermoelectric power, irrigation, industrial use, and public water supply can be energy intensive, consuming 4% of the total electricity generated in the United States (Copeland and Carter 2017). Moving water is particularly energy intensive in the West—in some instances large quantities of water are pumped over long distances and significant elevations (Cohen, Nelson, and Wolff 2004). For example, a 2005 California study (CEC 2005) estimated that 19% of the state's electricity consumption was related to moving water. About 355 billion gallons of water are withdrawn daily from U.S. surface and groundwater sources (Maupin et al. 2014), and large uses of the water include thermoelectric power generation, irrigation, industrial use, and public supply (municipal water use). As noted in Figure 1, which lists states from west to east, there are substantial regional variations in water uses, with irrigation withdrawals responsible for the majority of water withdrawals in western states (Maupin et al. 2014).

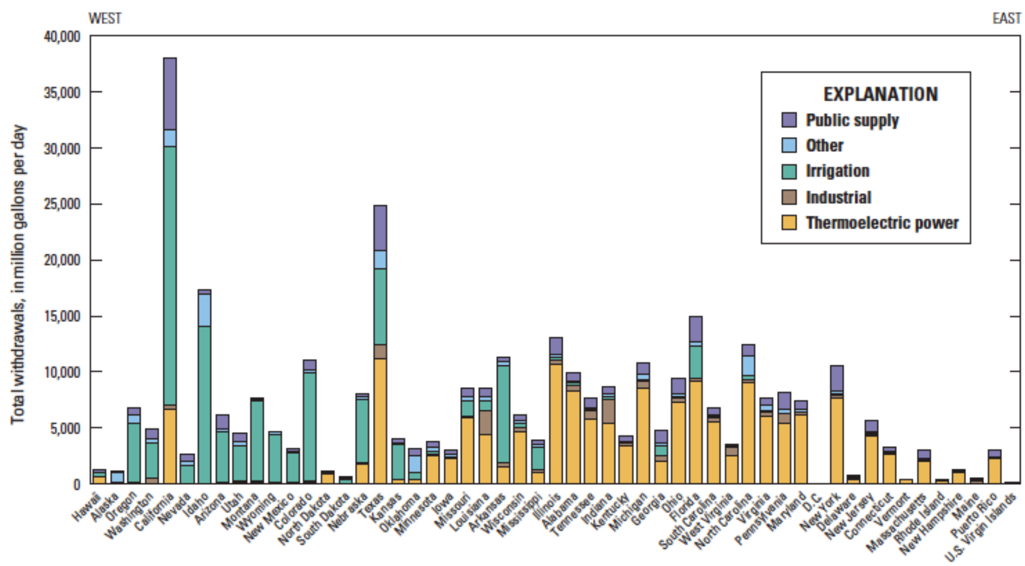


**Figure 1. Total water withdrawals by categories for U.S. states from west to east. *Source: Maupin 2014, USGS***

Some of this energy can be economically recaptured through energy recovery hydropower, harnessing mechanical energy from existing pressurized water supply pipelines.

The primary market driver for energy recovery hydropower is the opportunity for water system operators to lower operational costs by offsetting energy costs with on-site hydropower generation.

Unlike other hydropower technologies, there has not yet been a comprehensive national assessment of the potential for energy recovery hydropower, although there have been related federal and state assessments for conduit hydropower generally. A 2014 Oak Ridge National Laboratory (ORNL) study (Sale et al. 2014) identified approximately 1–2 GW of untapped hydroelectric potential at existing conduits, of which 104 MW was at 373 U.S. Bureau of Reclamation (Reclamation)-owned canals.

## 1.1 Defining Energy Recovery Hydropower

Energy recovery hydropower is a subset of what is commonly known as conduit hydropower. For the purposes of this report, energy recovery hydropower can be defined as follows:

> …hydropower built using an existing, pressurized, manmade water conveyance that is already diverting water from a natural waterway for the distribution of water for agricultural, municipal, or industrial consumption and not primarily for the generation of electricity.[1] [2]

Energy recovery hydropower differs from some forms of conventional hydropower in that it is not located on natural rivers or waterways.[3] Similar to other forms of hydropower that utilize existing infrastructure, energy recovery hydropower's environmental impact is de minimis because, by definition, it only uses water that has already been diverted from a natural waterway for other purposes. Any environmental impacts to the natural waterway would typically have been addressed before construction of the existing conduit and should already be in compliance with federal, state, and local environmental requirements.[4] Projects built entirely within existing structures (e.g., water treatment plant buildings) may have no new environmental impacts, while projects requiring construction of new facilities (e.g., powerhouse building) may have environmental impacts associated with land disturbances.

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[1] The Hydropower Regulatory Efficiency Act of 2013 defines "conduit" 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 and not primarily for the generation of electricity." Public Law 113-23(4)(a)(3)(A).

[2] This definition does not include open canals and flumes that are not already pressurized, including hydrokinetic systems.

[3] Other forms of hydropower, including closed-loop pumped storage is also not located on natural rivers or waterways.

[4] For additional information, see the question and answer discussion following the House Energy and Commerce Committee hearing "Legislation Addressing Pipeline and Hydropower Infrastructure Modernization" held on May 3, 2017. The relevant exchange with the witness representing the Federal Energy Regulatory Commission (FERC) is available at https://youtu.be/a68eU-BESZQ?t=2h12s

# 2 Federal Policy Drivers

Recent changes in federal policy have supported the development of energy recovery hydropower.

## 2.1 Hydropower Regulatory Efficiency Act of 2013

The federal regulatory process for energy recovery hydropower was substantially reformed in August 2013 when Congress passed the Hydropower Regulatory Efficiency Act of 2013 (HREA). HREA amended Part I of the Federal Power Act (FPA), creating a category of hydroelectric facilities that do not require a Federal Energy Regulatory Commission (FERC) license or exemption from licensing (Hydropower Regulatory Efficiency Act of 2013, Pub. L. No. 113-23, 127 Stat. 493). These previously licensed facilities may now qualify for a new FERC Notice of Intent (NOI) process that can be completed in as little as 60 days. HREA removed "qualifying conduit facilities" from FERC licensing jurisdiction under 30(a) of the FPA (i.e., non-jurisdictional) and replaced the licensing/exemption process with a 60-day NOI process. In order to qualify for the qualifying conduit NOI process, the facility must:

- Be constructed, operated, or maintained for the generation of electric power and use such generation only for the hydroelectric potential of a conduit (a "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)
- Generate electric power using only the hydroelectric potential of a non-federally owned conduit
- Have an installed capacity that does not exceed 5 MW
- Not be licensed under, or exempted from, FERC license requirements on or before August 9, 2013 (16 U.S.C. §823a[a][3][A]).

## 2.2 Bureau of Reclamation Small Conduit Hydropower Development and Rural Jobs Act

Hydropower projects constructed utilizing Reclamation facilities are not typically subject to FERC hydropower approval. These facilities are reviewed through the Reclamation's hydropower permitting process called Lease of Power Privilege (LOPP). [5]

The LOPP process was modified in August 2013 when the Reclamation Small Conduit Hydropower Development and Rural Jobs Act was signed into law.[6] The legislation authorized

[5] FERC and Reclamation have memorandum of understanding agreements defining jurisdictional boundaries and processes about how the agencies work together. In almost all cases a given project would be required to obtain either FERC approval or a Reclamation LOPP, but not both.
[6] The Bureau of Reclamation previously modified the LOPP process in September of 2012 in the Bureau of Reclamation Manual as a Directive and Standard, but a revision to the Directive and Standard based on the Reclamation Small Conduit Hydropower Development and Rural Jobs Act was not completed until September 2014.

small conduit[7] (under 5 MW) hydropower projects on Reclamation-owned infrastructure, providing irrigation districts and water user associations the first right to develop hydropower projects at Reclamation facilities, and directed Reclamation to apply its categorical exclusion process under the National Environmental Policy Act of 1969 (NEPA) to small conduit hydropower development (excluding the siting of associated transmission lines on federal land).[8] Per the 2013 legislation, all Reclamation conduits are within the exclusive jurisdiction of Reclamation and need to receive federal approval through the Reclamation's LOPP process.

## 2.3 New 242 Program Federal Incentives

The potential financial return for energy recovery hydropower projects was substantially improved in 2014 when Congress funded new federal payment incentives for hydropower built using existing infrastructure. In 2005, Congress passed the Energy Policy Act of 2005, legislation that authorized the creation of the "Section 242" program, which benefits energy recovery hydropower, among other hydropower technologies. In 2014, Congress provided appropriations for the Section 242 program for the first time, and has appropriated funds every year since. The program's incentive payments are paid on a per-kilowatt-hour-generated basis, with payment amounts depending upon overall program participation. Maximum payments are capped at $750,000 per year for a given project for up to 10 years, subject to availability through ongoing congressional appropriations. The 242 program has received the following funding amounts:

- For calendar year 2013 generation, $3.6 million and the per-kilowatt-hour payment amount was 1.48 cents/kWh
- For calendar year 2014 generation, $3.96 million and the per-kilowatt-hour payment amount was 1.2 cents/kWh
- For calendar year 2015 generation, $3.5 million and the per-kilowatt-hour payment amount was 0.9 cents/kWh
- For calendar year 2016 generation, $6.6 million in appropriations.

Although congressional authorization for the 242 program expired in 2015, participating hydropower facility owners already in the program are allowed to receive up to 10 years of payments provided that congressional appropriations continue to fund the program.[9]

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[7] The term "conduit" means any Reclamation tunnel, canal, pipeline, aqueduct, flume, ditch, or similar manmade water conveyance that is operated for the distribution of water to agricultural, municipal, or industrial consumption and not primarily for the generation of electricity.

[8] For additional information, see https://www.usbr.gov/power/LOPP/.

[9] For additional information, see https://www.energy.gov/eere/water/downloads/federal-register-notice-epact-2005-section-242-hydroelectric-incentive-0.

# 3 State Policy Drivers

Recent changes in state policy have supported development of the energy recovery hydropower industry. For detailed information regarding state hydropower policy, see the related 2017 NREL report, State Models to Incentivize and Streamline Small Hydropower Development (Curtis, Levine, and Johnson 2017).

Energy recovery hydropower is typically an eligible technology type for state renewable portfolio standard (RPS) programs, which have been responsible for roughly half of the growth in U.S. renewables since 2000 (Barbose 2017). As of February 2017, 29 states, the District of Columbia, and 3 territories[10] have mandatory RPSs that include eligibility for hydropower generation.[11] Standards range from California's 50%-by-2030 requirement to Pennsylvania's 8.5%-by-2020 requirement (Barbose 2017).

Some states have created programs and policies specifically to support the development of energy recovery hydropower. The following subsections present a series of examples from California, Colorado, Massachusetts, and Oregon.

## 3.1 California

State policy efforts to support energy recovery hydropower in California have included:

- The California Energy Commission (CEC)-funded research completed in 2006 estimated that California's undeveloped conduit hydropower potential was 255 MW (CEC 2006). The study showed that project development potential was roughly evenly split between irrigation districts and municipal water delivery systems. In 2017, the CEC funded a new state conduit hydropower resource assessment, which will update the 2006 study.
- Energy recovery hydropower projects in California are eligible for funding through the state's Self-Generation Incentive Program, with energy recovery hydropower currently eligible for an incentive amount of $0.60/watt.[12]
- California has a renewable energy feed-in-tariff program that includes energy recovery hydropower projects less than 3 MW. The current payment rate is 8.9 cents/kWh.[13]

## 3.2 Colorado

State policy efforts to support energy recovery hydropower in Colorado have included:

- In 2013, the Colorado Energy Office (CEO) developed a small hydropower handbook focused on energy recovery hydropower.[14]

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[10] The three territories with mandatory RPSs include Puerto Rico, the U.S. Virgin Islands, and Northern Mariana Islands.

[11] Unlike conventional hydropower and pumped storage, which may be restricted in state RPS policies based on size, installation date, and other factors, energy recovery hydropower has generally received broad RPS support. For additional state-specific information on hydropower RPS eligibility, see the DSIRE database at www.dsireusa.org.

[12] See http://www.cpuc.ca.gov/sgip/.

[13] See http://www.cpuc.ca.gov/feedintariff/.

[14] The handbook is available electronically on the Colorado Energy Office website at https://www.colorado.gov/pacific/energyoffice/atom/32666.

- In 2014, the Colorado Department of Agriculture (CDA) published a study estimating that Colorado has approximately 30 MW of conduit hydropower potential at agricultural irrigation systems across the state (CDA 2013). In part, based on the results of the agricultural hydropower resource assessment, CDA started an agricultural hydropower program that provides technical assistance and grants for project development. As of mid-2017, the CDA program had completed 36 hydropower feasibility assessments and provided funding for five hydropower projects (two complete and three under construction) (Sam Anderson, Colorado Department of Agriculture, personal communication, October 19, 2017).
- In 2016, CEO began an initiative to support the development of conduit hydropower systems that harness excess pressure currently unutilized in municipal water systems. Prompted by the 2016 Colorado PRV-Hydropower Assessment (CEO 2016) that estimated total state capacity of 20–25 MW, CEO began to sponsor technical workshops to help municipal attendees identify viable municipal hydropower projects within their water delivery systems and complete FERC NOIs. As of mid-2017, CEO had helped facilitate the submission of 12 FERC-qualifying conduit NOIs totaling 800 kW of new hydropower generation (Samantha Reifer, Colorado Energy Office, personal communication, October 19, 2017).

## 3.3 Massachusetts

State policy efforts to support energy recovery hydropower in Massachusetts have included:

- In 2013, the Massachusetts Executive Office of Energy & Environmental Affairs Department of Environmental Protection identified potential energy recovery hydropower project sites across the state and developed a screening tool that helps identify energy recovery hydropower project opportunities in water supply and wastewater treatment facilities (Allen, Fay, and Matys 2013).
- In 2016, the Massachusetts Department of Energy Resources completed a report providing federal and state permitting guidance for small and low impact hydropower (DOER 2016).

## 3.4 Oregon

State policy efforts to support energy recovery hydropower in Oregon have included:

- Streamlining the conversion of existing water rights to include hydropower as a supplemental use.
- Providing financial assistance to small hydropower developers through the Energy Trust of Oregon, an independent non-profit organization that is funded through a public purpose charge levied on investor-owned utilities. Energy Trust of Oregon's financial incentives for small hydropower provide funding for project development, including feasibility studies, final design, permitting, utility interconnection, and construction management.

# 4 Market Trends

The primary market driver for energy recovery hydropower is the opportunity for water system operators to lower operational costs by offsetting energy use costs with on-site hydropower generation. Projects installed behind the meter, offsetting electricity costs at a full retail rate via net metering,[15] [16] are likely to be particularly economically attractive compared to projects seeking to sell energy into wholesale electricity markets, where prices are currently relatively low.[17] For example, water treatment plants typically have an existing electricity load that may be offset with on-site hydropower generation through net metering.

Based on FERC data regarding approved NOIs for qualifying conduits, energy recovery hydropower project development has been particularly active in western states, as shown in Figure 3. As of August 2017, a total of 87 qualifying conduit applications from 14 states had been approved by FERC since HREA became law in August 2013. Approved projects range in size from 2 kW to 4.8 MW and have a total cumulative capacity of almost 32 MW.[18] Projects are primarily municipal or agricultural.

## 4.1 Typical Project Types

Energy recovery hydropower projects can be grid-tied or grid-independent. Because grid interconnection is one of the triggers for FERC jurisdiction, prior to HREA, there was an incentive for projects to remain grid-independent in order to avoid FERC licensing requirements. Typical energy recovery hydropower project types include municipal water supply projects and agricultural projects.

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[15] Currently, 41 states, in addition to Washington, D.C., American Samoa, U.S. Virgin Islands, and Puerto Rico, have mandatory net-metering policies in place.

[16] The average U.S. retail electricity price (combining the residential, commercial, and industrial sectors) in 2016 was 10.28 cents/kWh (EIA 2017).

[17] For additional information regarding wholesale energy pricing, see FERC market reports including the April 13, 2017, report, which summarizes 2016 market data, available at https://www.ferc.gov/market-oversight/reports-analyses/reports-analyses.asp.

[18] FERC posts monthly updates of all qualifying conduit applications; see https://www.ferc.gov/industries/hydropower/indus-act/efficiency-act/qua-conduit.asp.

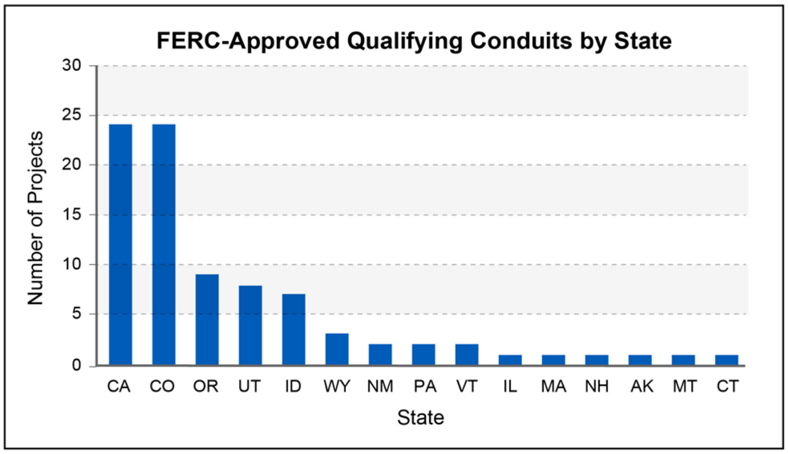



**Figure 2. FERC-approved qualifying conduits by state. *Source: FERC***

Data shown in Figure 2 are current as of August 11, 2017.

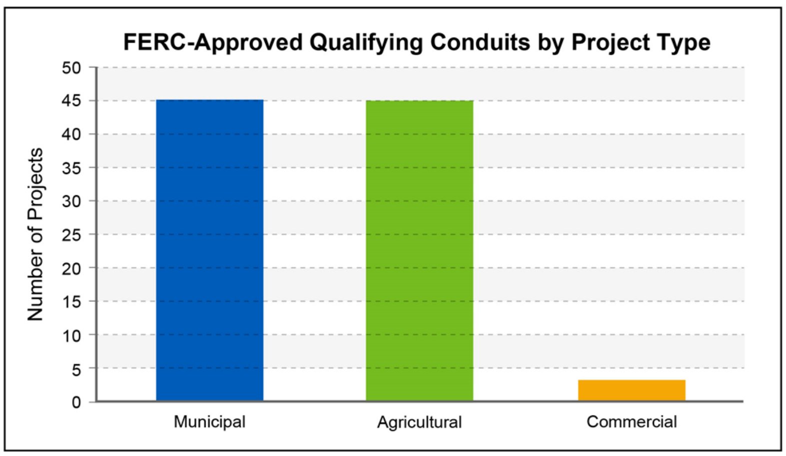



**Figure 3. FERC-approved qualifying conduits by project type. *Source: FERC***

Data shown in Figure 3 are current as of August 11, 2017.

### *4.1.1 Municipal Water Supply Projects*

The majority of U.S. public water supply consists of community water systems; there are over 51,000 community water systems in the United States, and most systems are relatively small (Pabi et al. 2013). Energy consumption by water utilities can represent 30%–40% of a municipality's energy costs, primarily due to the energy required to operate motors for pumping. Energy costs are second only to labor costs as a percentage of total operating costs for public water supply systems (Copeland and Carter 2017). U.S. public drinking water systems consume about 1% of total U.S. electricity consumption (Pabi et al. 2013).

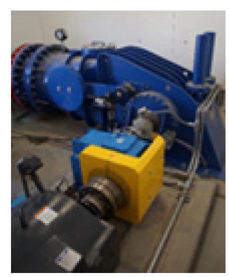
Where sufficient space is available and interconnection with a local utility is feasible, energy recovery hydropower projects can be built within water treatment plants. Water treatment plants frequently contain pressure-reducing valves (PRVs), mechanical devices designed to reduce water pressure in order to protect pipelines and equipment (e.g., filtration membranes) from excess pressure. Energy recovery hydropower can be installed in parallel with an existing PRV, providing the same function (reducing pressure) while also generating electricity.

### 4.1.2 Agricultural Projects

The U.S. agricultural industry includes a vast network of water infrastructure, which transports water for farms and ranches used for irrigation and related agricultural purposes. Some of the energy contained in water movement for agricultural purposes can be recaptured through energy recovery hydropower.

According to analysis commissioned by CEO, irrigation for farming in Colorado and its associated electricity costs are one of the largest areas of energy consumption in Colorado. Colorado farmers report spending an average of roughly $33,000 per year on electricity, while spending an average of $16,000 on diesel and $8,000 on gasoline. Electricity costs to power irrigation pumps typically make up more than 50% of total electricity expenses (CEO 2013).

## 4.2 Project Case Studies

| | |
|---|---|
| **California**<br>The Tanner Water Treatment Plant Hydropower Project, completed by Amador Water Agency in 2016, includes two pump-as-turbine generators totaling **118 kW** that capture wasted energy at a pressure-reducing station located in Sutter Creek, California. The municipal project offsets the electrical requirements of the water treatment plant and created one of the first northern California “net-energy-neutral” water treatment plants. The project submitted a FERC NOI in mid-July 2014 and received approval in mid-September 2014 (Source: NLine Energy, 2017). |  |
| **Colorado**<br>The Miller Creek Ditch Hydropower Project, a **160-kW** agricultural project completed in 2017 near Meeker, Colorado, was developed by White River Electric Association in partnership with the Miller Creek Ditch Company. The project operates during irrigation season using water from an irrigation ditch. The FERC NOI, which requested approval as a qualifying conduit, was submitted in February 2016. FERC approval was issued within 60 days (Source: Colorado Energy Office, 2017). |  |
| **Montana**<br>The Libby PRV Station Hydropower Project was an **18-kW** municipal project completed in 2017 in Libby, Montana. The project recovered energy at a pressure-reducing station. The FERC NOI, which requested approval as a qualifying conduit, was submitted in June 2016. FERC approval was issued within 60 days. The electrical output from the project was interconnected with the local utility via a net-metering agreement (Source: Canyon Hydro, 2017). |  |

| | |
|---|---|
| **Utah**<br><br>The Box Elder Hydropower Project, an **820-kW** municipal project completed in 2013 in Brigham City, Utah, was installed on the water supply line for the city. The FERC NOI, which requested approval as a qualifying conduit, was submitted in late December 2013. FERC approval was issued in early March 2014. The electrical output from the project was interconnected with the local utility via a net-metering agreement (Source: Canyon Hydro, 2017). |  |
| **Vermont**<br><br>The Nelson Street Hydropower Project, a **12-kW** municipal project completed in 2014 in Barre, Vermont, was one of the nation's first projects to receive FERC-qualifying conduit approval following passage of HREA in early August 2013. The FERC NOI to request approval was submitted in late August 2013. FERC issued the approval within 60 days. The project was installed in parallel with a PRV. The electrical output from the project was interconnected with the local utility via a net-metering agreement (Source: Rentricity, 2017). |  |

# 5 Future Outlook

FERC data suggest that there has been extremely limited development of energy recovery hydropower by commercial and industrial water users. Additional analysis is necessary to determine if there are financially viable project opportunities in industrial sectors such as thermoelectric generation, mining, aquaculture, and pulp and paper, which utilize sizable water withdrawals. In addition, pending actions discussed below may further support development of energy recovery hydropower.

## 5.1 Federal Resource Assessments

New ORNL research just getting underway may shed light on the magnitude of the U.S. energy recovery hydropower resource. ORNL is initiating a pilot study to identify project opportunities associated with water treatment plants connected to existing reservoirs. Water treatment plants can be retrofitted with hydropower in order to take advantage of the expedited regulatory process created by HREA. Experience gained from the ORNL pilot may inform development of expanded resource assessments at a regional or national scale, utilizing the same Geographic Information System (GIS)-based methodology.

## 5.2 Federal Hydropower Reform Legislation

Pending federal legislation may further streamline the regulatory process for energy recovery hydropower. In July 2017, the House of Representatives overwhelmingly passed H.R. 2786, the Promoting Conduit Hydropower Facilities Act, which is legislation that builds on HREA. The bill would eliminate the 5-MW size cap on qualifying conduit projects and reduce the FERC review period from 60 days down to 45 days.

More comprehensive hydropower legislation has passed the House of Representatives through the Hydropower Policy Modernization Act of 2017 (HR 3043, 115$^{th}$ Cong.), while in the Senate, the Energy and Natural Resources Act (ENRA) of 2017 (S. 1460, 115$^{th}$ Cong.) (under consideration) includes substantial hydropower reform provisions. Among the hydropower provisions within ENRA, include an amendment extending the Section 242 program through 2027 with the eligibility window and sunset provision expanded by 10 years each respectively (ENRA Sec. 3010).

# 6 Conclusion

Energy recovery hydropower—constructed utilizing existing infrastructure and typically able to complete FERC review in 60 days—is one of the most cost-effective types of new U.S. hydropower development, even in times of relatively low wholesale electricity prices.

Because the energy recovery hydropower industry is still relatively young (since passage of HREA in 2013), some water operators may lack knowledge of the federal reforms created by HREA and have little understanding of how small hydropower can be quickly built using existing water infrastructure. As the industry continues to develop, energy recovery hydropower could ultimately become a commonplace practice, with widespread understanding among water operators of the opportunity to lower operational costs through installation of energy recovery hydropower.

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## Federal and State Regulations

18 C.F.R §§ 4.1 – 50.11 (1947), Regulations under the Federal Power Act.