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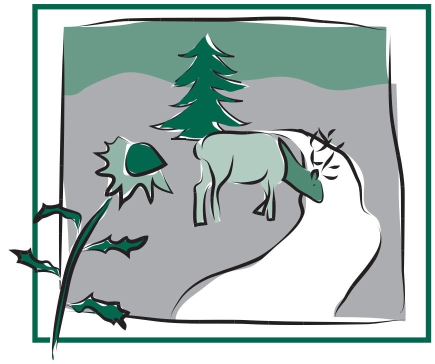

Agricultural Hydropower Generation: On-Farm

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Background

The Colorado Energy Office has identified three components of agricultural water conveyance that have the capacity to harness hydropower: 1) on-farm pressurized irrigation systems, 2) conduit drops on irrigation ditches, and 3) existing agricultural dams. This publication will only address on-farm pressurized irrigation systems.

Small scale hydropower generation, also referred to as micro-hydro, is a way of harnessing the energy of flowing water and putting that energy to mechanical or electrical use. Typical small-hydro systems are designed to generate 2 megawatts (MW) of energy or less. Harnessing the energy of water as it flows downhill has long been used to power industrial and agricultural operations. Flour mills, for example, used the water of a flowing stream to turn a waterwheel and mechanically drive the flour grinders. Today there are new technologies that allow energy to be captured from moving water and used to mechanically turn a center pivot, or even create electricity. The main benefit of small hydropower generation is the ability to use a device, called a turbine, to extract energy from moving water and convert that energy to power or electricity. Here it is important to distinguish between power, energy, and electricity. Power is the amount of work that gets done over time, energy is the ability to do work, and electricity is a charged current. To better understand how power and electricity are created we need to first look at the source of this energy.

Water at a higher elevation, say on a hillside, has *potential energy* due to its elevation above the point of use. Site characteristics including the available water and the elevation drop (also called *head*) determine the water's potential energy. Potential energy shows up as increased pressure within a pipe full of water – the bottom of the pipe is at higher pressure than the top. Pressure, however, is not enough to spin a turbine. The pressurized water in the pipe must move through a turbine, which converts potential energy to *kinetic energy*. The amount of moving water, the elevation drop, and friction inside the pipe determine the kinetic energy available for power generation.

Perhaps most importantly for power generation and irrigation is the ability to control the amount of water and rate at which it flows, both key factors in energy production. The conveyance of the water to the point of power generation can affect how much kinetic energy can be captured. For example, a large diameter PVC pipe has low friction loss because the inner walls of the PVC pipe are smooth, reducing friction between the water and pipe walls, and the large pipe diameter moves more water with less wall contact. Conversely, water in a smaller pipe or a rougher pipe will have more friction loss. These three factors - flow, head and conveyance method - are critical in determining how much energy a small hydropower system can generate.

Implementing on-farm small hydropower projects

Mechanical hydropower systems utilize the pressure of an irrigation system to spin the turbines and drive a hydraulic pump that is responsible for advancing the center pivot around the field. In this instance, no electricity is generated, or needed, to move the center pivot. Mechanical hydropower systems are the most common in Colorado because of their relatively low cost, independence from the larger power grid, and

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Quick Facts

- Colorado is leading the Nation in developing incentives for small hydropower generation
- Located mostly in mountainous areas, 7 percent of Colorado's irrigated farm land (roughly 170,000 acres) has pressurization potential to produce a total of 30 megawatts of hydropower
- On-farm hydropower generatio¬n can be used to power center pivots directly or can be connected to the electrical grid to offset on-farm electricity consumption
- Most on-farm small hydropower projects will not need to obtain a new legal water right if small hydropower generation is combined with an existing water use

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lower maintenance costs (Figures 1 and 2). The other type of hydropower system, *hydroelectric*, harnesses the energy of the water to spin a turbine and create electricity. Hydroelectric systems can be more costly but may offer an irrigator a way of producing electricity that reduces utility bills. Most commonly, the electricity generated from a hydropower system is transferred to the larger electrical grid and gets used by someone else off-farm. Each kilowatt-hour of electricity generated by a small hydropower system and transferred to this larger grid is credited against the monthly electricity use of a farm. This is achieved through a net metering agreement. Up to 120% of the electricity generated in excess of what the farm uses in a month can be rolled over to the following month, while the farm would pay for any electricity used in excess of what is generated. Net metering agreements are negotiated between the electric utility and the power generator, in this case an irrigator.

Figure 1: A mechanical hydropower system using irrigation water to drive a hydraulic pump.
Photo: Blake Osborn

Figure 2: Irrigation water diverted to a turbine before being used to irrigate.
Photo: Blake Osborn

What to consider when assessing the suitability of micro-hydro:

- Do you have access to technical, financial, and/or administrative expertise that will be necessary to execute this project efficiently?
- Do you have a legal right to use a given amount of water for power generation? If not, will you need to obtain a legal water right?
- Is the source of water reliable for your needs? For example, you would not want to install a costly micro-hydro system on a water-short ditch lateral with a non-reliable water source.
- Are the site conditions adequate to efficiently generate electricity? Necessary site conditions include adequate flow and sufficient elevation drop to both pressurize the irrigation system and power the turbine. Multiple turbines exist to operate at different flow and head conditions; the efficiency of extracting energy from water will vary with turbine type and site conditions.
- If you are producing electricity for the grid through a net metering agreement, are you near enough to existing power infrastructure? If not, this can add significant costs.
- If you are producing electricity for the grid through a net metering agreement, is your system going to be less than 25 kilowatts? If not, your local electric utility may only allow interconnection on a case-by-case basis.
- Are there local economic, political, or environmental factors that will affect the success of a project?
- Is the water relatively clear of sand & silt, or can it be removed easily? Silt in the water stream can quickly wear the turbine wheel or shaft seals.

Motivations

There are many reasons for implementing small hydropower generation at the farm scale, including: economic incentives (including low interest loans, grants from the State of Colorado, net metering, and utility rebates or incentives), the need to reduce pipe pressure, or to simply transition to a more sustainable energy source. The benefits of small hydropower systems extend beyond the farm to environmental and community benefits. For example, installing a mechanical hydropower system to turn a center pivot in rural Colorado can eliminate the need for additional electrical transmission lines or diesel generators, therefore lessening the environmental impact. Economic benefits of small hydropower generation are mentioned in Colorado's Water Plan which emphasizes lowering the cost of the "water-energy nexus" and recommends small hydropower projects be incorporated into irrigation efficiency improvements, when feasible, to increase the economic return on water use. It is common for irrigators to convert from flood to center pivot irrigation to save on labor costs and increase the precision and accuracy of water application on a field. However, one of the main costs over the life of the center pivot is the electrical costs to pump the water through the pivot and advance it around the field. Small on-farm hydropower generation offers an irrigator the opportunity to reduce their electrical costs which, depending on the size of the farm, could significantly reduce overall costs.

> "… lowering the cost of the water-energy nexus and small hydropower projects [should] be incorporated into irrigation efficiency improvements, when feasible, to increase the economic return on water use."

Although there are many potential benefits, challenges still exist in the new small hydropower landscape. The Colorado Department of Agriculture has identified some barriers and challenges associated with small hydropower generation: 1) there may be a lack of industry knowledge in a particular geographic area, 2) fear of the "unknown", 3) few equipment suppliers, 4) costs, and 5) permitting. Over 170,000 acres of irrigated land in Colorado have been labeled as suitable for pressurized irrigation systems. Although only a fraction of the small hydropower potential has been developed, the State of Colorado has been creating resources to help landowners, including irrigating farmers, build and implement small hydropower projects. Colorado has established itself as a national small-hydro pioneer by developing resources to aid in small-hydro development, including streamlining regulations. At the state level, small hydropower permitting has become much easier thanks to Colorado HB14-1030 *"Concerning the establishment of incentives for the development* *of hydroelectric energy systems"* signed into law on May 31st, 2014. To operate small hydropower facilities, the State of Colorado recognized the need for streamlined regulations that allows for new hydropower projects. Colorado is one of the first states in the country to provide the following: a low-interest financing plan for small hydropower projects; an agricultural hydropower resource assessment; a small hydropower handbook; and a Memorandum of Understanding (MOU) with the Federal Energy Regulatory Commission (FERC) to streamline permitting. As stated in the MOU, "The Commission (FERC) and Colorado have a mutual interest in streamlining and simplifying regulations for authorizing small hydropower projects." At its core, this MOU gives the State of Colorado, which oversees on-the-ground permitting of small hydropower projects, the ability to simplify the permitting regulations and encourage the small scale development of hydropower projects as a source for clean, renewable, and local energy while safe-guarding environmental and other non-developmental resources. When the MOU was signed in 2010, small hydropower projects were being permitted in as little as 6 months, instead of the 2 – 3 years previously.

Real Life Scenario

In 2012, a rancher in northeast Colorado wanted to reduce energy costs by retrofitting an existing center pivot with a new small hydropower turbine. An evaluation of the site conditions identified a head of 126 feet and a predictable flow of 560 gallons per minute (gpm). These site conditions provide enough pressure to not only pressurize the sprinklers but also produce 5.2 kW of power, equivalent to 7 horsepower. Using gravity to feed the sprinklers and produce energy eliminated the need for pumps and drive systems which reduces operating and maintenance costs.

Because of the incentives available for site and feasibility assessments, the only out-of-pocket cost to the farmer was the purchase of a Cornell turbine. The total project cost for the irrigator was $13,000.00 and an NRCS EQIP grant covered $6,000.00. The expense to the irrigator was $7,000.00 with an annual energy savings around $2,100.00. This results in payback period of roughly 3.3 years. With a life expectancy of at least 20 years for a turbine, this put the total annual cost of the hydropower project at $350.00/year over 20 years.

An irrigator can expect to get more than 20 years of use from a single turbine if turbines are properly maintained (turbine maintenance is very similar to pump maintenance). In this case, installing a small hydropower system and eliminating the electricity consumption of a center pivot, the net cost savings over a 20 year period will be around $35,000.00.

Permitting a hydroelectric facility

Although small hydropower generation may be easier to implement than before, *hydroelectric* facilities are still subject to regulation by the State of Colorado and the FERC. By streamlining regulatory processes in 2013, the FERC offered irrigators the ability to add a hydroelectric facility to an irrigation ditch or pipeline where the primary purpose of the ditch or pipeline is to deliver irrigation water to fields rather than generating electricity. *Mechanical hydropower* projects do not produce electricity and therefore do not need to go through the FERC permitting process.

Hydroelectric projects are only feasible because of the Hydropower Regulatory Efficiency Act of 2013. Before this Act was signed, the FERC permitting process would take years and cost tens of thousands of dollars for even the smallest hydroelectric projects. Among other things, the Act exempts certain conduit hydropower facilities from the licensing requirements of the Federal Power Act (FPA). This licensing exemption applies when the hydropower facility is added to a conduit, such as a pipeline or ditch, where the *primary purpose* of the conduit is not for generating electricity. This makes on-farm hydroelectric generation feasible by allowing irrigators using pipes for conveying water to their farms to simply add a hydroelectric turbine to their existing conveyance infrastructure without having to go through a costly regulatory process. In this scenario, the FERC application process begins by submitting a Notice of Intent to Construct a Qualifying Conduit Hydropower Facility with the Commission. For an irrigation *hydroelectric* project, the Notice of Intent (NOI) usually consists of about five pages, including a schematic drawing of the hydropower facility and a location map. The NOI provides a detailed description of the project and the primary purpose of the conduit. According to the FERC website, the Commission "will make an initial determination within 15 days. [Their] initial determination will be either to reject the notice of intent or to determine the facility meets the qualifying criteria." The FERC will provide a list of the missing information if more information is needed. Once you gather the missing information, you can revise the notice of intent and re-file it at any time. If FERC initially determines your facility meets the qualifying criteria:

1. FERC will issue a public notice providing the public with 30 days to file motions to intervene
2. 45 days to provide comments contesting whether your facility meets the qualifying criteria

If there are no public objections to the small *hydroelectric* facility, FERC will issue a letter deeming the project a "qualified conduit hydropower facility". Unless a statement of opposition is filed by the public, the entire FERC permitting process should take a maximum of 60 days. Installation of the *hydroelectric* system should not begin until this process is complete, so it is recommended that the NOI should be submitted early in the design process.

Financing a small hydropower system

In addition to regulatory incentives for hydropower, financial incentives are now more abundant for on-farm hydropower projects. One of the biggest incentives for an irrigator is a free program offered through the Colorado Department of Agriculture (CDA) in which CDA performs a site assessment and, when funds allow, can help reimburse the cost of a feasibility assessment. A *site assessment* will take stock of your physical site characteristics needed for hydropower generation including elevational changes, diversion amounts, and current irrigation infrastructure. A *feasibility assessment* is a more detailed look at your site conditions and typically includes engineering reports and analysis.

Another incentive comes from the Colorado Water Conservation Board which offers low interest loans for small hydropower projects. Additionally, the NRCS Environmental Quality Incentives Program (EQIP) offers federal assistance for farm improvements such as center pivots and small hydropower systems. Making use of a variety of financial incentives will help irrigators pay for a small hydropower system.

Water Rights

Small hydropower generation is the most feasible when added to existing water delivery infrastructure and an existing, decreed water use. In this sense, the additional use of the water for hydropower generation would be considered an "incidental and non-consumptive use" and would not require a new water right, so long as the hydropower is only generated during the deliveries for the original and decreed water use. For example, if a small hydropower system is added to the water delivery infrastructure of a center pivot, the water used in irrigation could also be used to generate electricity without needing a new water right as long as the amount of water used does not exceed the amount of water decreed for irrigation. Unless a new water right is issued to divert more than the historical amount for irrigation, the amount of water diverted to irrigate, and incidentally to run a center pivot, must remain the same as before the small hydropower system was installed. It is important to note that relying on already-decreed water could affect the availability of power production, depending on the seniority of the water right. If new diversions are needed for the sole purpose of generating electricity, then a new water right would need to be obtained. If you are unsure if a new water right is needed, contact the Colorado Division of Water Resources to clarify.

Additional Resources

Colorado Small Hydropower Handbook

- https://www.colorado.gov/pacific/sites/default/files/SmallHydroHandbook.pdf

Recommendations for Developing Agricultural Hydropower in Colorado

- https://www.colorado.gov/pacific/sites/default/files/AgHydroRoadmap.pdf

E^3A: Exploring Energy Efficiency and Alternatives

- www.e3a4u.info

$ACRE^3$: Advancing Colorado Renewable Energy and Energy Efficiency

- https://www.colorado.gov/pacific/ag-conservation/acre

Colorado State University 'Your Energy' Website

- http://yourenergy.extension.colostate.edu/hydropower