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Summary of the *Wyoming Small Hydropower Handbook:* Making informed decisions



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Many Wyoming water users have stared at water rushing over a diversion dam or through a canal and wondered, "Can we generate electricity with that?" This bulletin provides a brief overview of evaluation and development steps and serves as an introduction to the much more detailed Wyoming Small Hydropower Handbook. The full handbook addresses small hydropower development opportunities up to five megawatts (MW) at existing water infrastructure, such as irrigation or municipal water supplies. Small hydropower systems are generally designed to sell electricity to utilities or other energy users, thus creating revenue from falling water! The handbook guides water users from inquiry to action (or deliberate inaction), focusing on the fundamentals of hydropower, determining feasibility, and guiding implementation.

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Key Questions

Although the small hydropower evaluation and development process is fairly complex, the two general steps profiled below can help guide your decision.

Step 1 – Do I have a developable resource?

- Do you have legal access to existing, unpowered water infrastructure, such as canals, pipelines, dams, municipal water systems, or developed springs?
- Do you have adequate flow and head to generate useful energy?
- Do you have the legal right to access the falling water?
- Do you have an electric load or transmission infrastructure nearby; the farther the distance the greater the costs?
- Does your site have unique political or environmental aspects of the site, such as known cultural resources or endangered species?

Step 2 – I might have a developable resource, so now what do I do?

- What are the types of small hydropower systems?
- What technologies and designs can be utilized?
- What are expected costs?
- How are permits and licenses obtained?
- Where will electricity be sold or used?
- What is the value of the renewable electricity?
- What financing and incentives are available?

Micro-hydropower

Although facing many of the same issues as small hydropower, micro-hydropower is an even smaller class of hydropower. Micro-hydropower systems are less than 100 kW and used to produce mechanical energy or electricity for farms, ranches, and homes and are often designed to offset personal consumption. Micro-hydropower systems range in size and can be as small as a few watts. In Wyoming, micro-hydropower systems are typically non-commercial installations less than 25 kW due to net metering agreements (explained in later sections) for grid-tied systems or operate as off-grid systems.

Step 1 – Do I have a developable resource?

Having a potential hydropower resource available is the most important feature (e.g., no sense exploring hydropower on the flat water of a lake). Still, having the legal access to develop a site is paramount; those who already have a water right (existing water users) generally have the clearest path to development. Beyond legal access, the most feasible sites have existing water development, have adequate head, flow, and are within reasonable proximity to transmission infrastructure.

Small hydropower is certainly not feasible for every drop, dam, or pipeline, but Wyoming has many potential installation sites. Recent studies by the Department of Energy and Department of Interior, Bureau of Reclamation, identified 540 MW of new hydropower potential in Wyoming.[1] Sixty-five percent of these projects were classified as micro-hydropower projects (less than 100 kW). Harnessing the untapped potential identified in these three studies would more than double the state's existing installed hydropower capacity. In addition, there is potential for hydropower development on municipal water systems, non-federal irrigation districts, and private dams not considered in these studies.

Hydropower systems harness the energy of falling water to produce electric or mechanical energy. Hydropower is a factor of both flow and head. Flow is the volumetric quantity of available water, often expressed in cubic feet per second (cfs) or gallons per minute (gpm). The vertical drop creates pressure at the bottom of the pipeline creating the force that drives the turbine; this constitutes the head portion of hydropower (See Figure 2). Head is water pressure created by the difference in elevation between the intake and turbine and is expressed as vertical drop (feet) or as pressure such as pounds per square inch (psi).

No minimum flow or head exists, although very low head (less than 5-10 feet) is often uneconomic; systems with very low head will not produce enough electricity to justify initial investment and maintenance of equipment costs. Although the full power equation is more involved, a basic understanding of the relationship between head and flow in an 80 percent efficient system is shown in the abbreviated power formula:

Power (kW) = Head (feet) x Flow (cfs) x 0.068

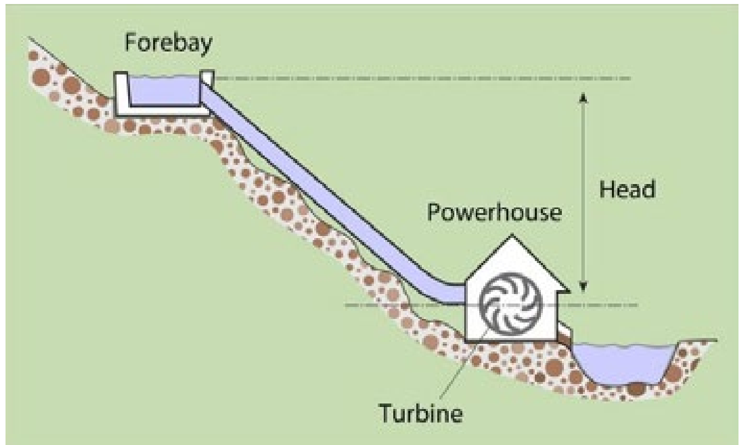

Figure 2: Vertical drop = head
Source: Department of Energy, Office of Energy Efficiency and Renewable Energy

The seasonality of water flows is also important. Although some springs and municipal systems may have consistent flows year-round, most small hydropower systems will have significant flow variations. A raging torrent during spring rains or early summer snowmelt does not typically dictate the design flow of small hydropower systems. The handbook presents detailed techniques for measuring flow, head, and seasonal variation.

Step 2 – I might have a developable resource, so now what do I do?

Small hydropower facilities fall into several broad categories, including impoundments (dams), run-of-the-river, conduit, hydrokinetic, and hydro-mechanical. Impoundments, generally at dams, are tcurrently he most common type of system in Wyoming. Figure 3 shows a typical impoundment facility. Run-of-river hydropower systems divert a portion of water from a river or canal and convey the water through a channel or pressurized pipeline (penstock) (Figure 4). Conduit facilities consist of an existing pipeline or canal. Hydrokinetic installations use the force of flowing water, like a historic water wheel, to create electricity. Finally, hydro-mechanical systems use hydro turbines to supply mechanical work to machinery, such as irrigation pivots, instead of electric generators.

Although designs and layouts of the equipment varies by site conditions, the type of turbine receives the most design attention. The amount of head and flow dictates turbine design, which include impulse (e.g., Pelton and Turgo) or reaction turbines (e.g., Kaplan and Francis). Impulse turbines are generally used in high-head, low-flow applications. Reaction turbines are generally suited for lower head, higher flow applications.

Buffalo Hydropower Plant

The city of Buffalo owns and operates a 225 kW Pelton impulse type hydropower facility. The unit is in line with their existing 14-inch municipal raw water supply pipeline to the water treatment plant. This pipeline provides 6.2 cfs with 530 feet of net head to the hydro turbine. Thus:

225 kW = 492 feet x 6.2 cfs x 0.068

During the non-irrigation season, the municipal demand on the water treatment plant is reduced, and excess water from the hydro turbine is returned to Clear Creek. Electricity from the system is sold through a power purchase agreement to PacifiCorp.

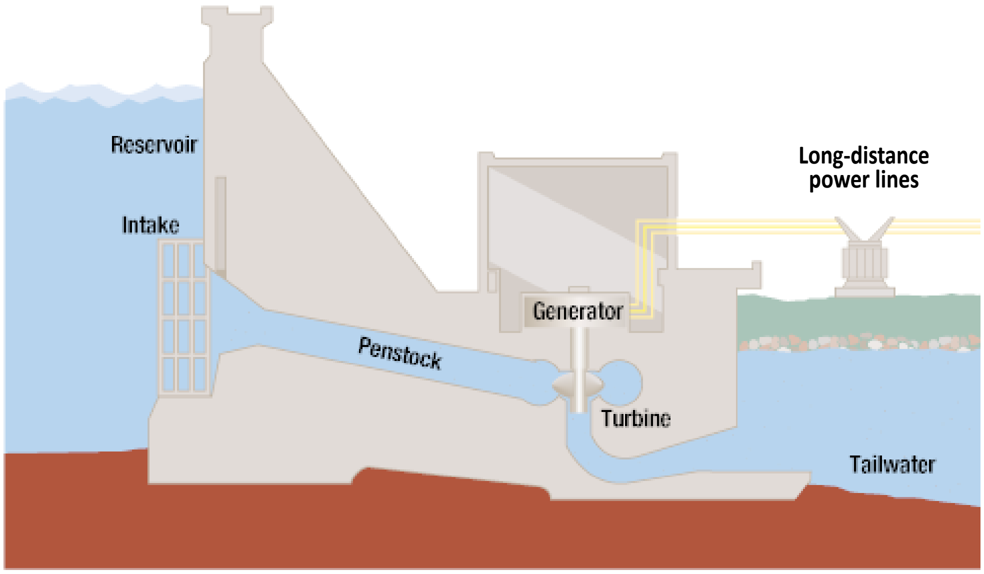

Figure 3: Schematic of a hydroelectric dam

Source: Tennessee Valley Authority

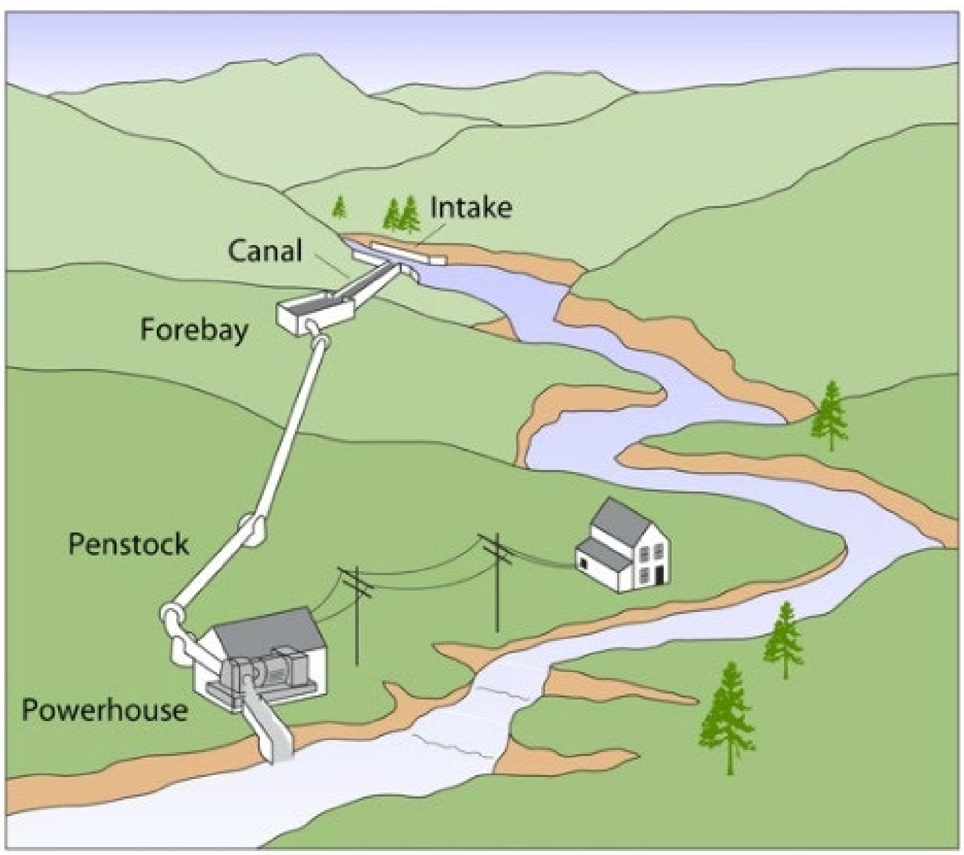

Figure 4: Run-of-the-river schematic

Source: Department of Energy, Office of Energy Efficiency and Renewable Energy

Generalizing turbine costs is difficult, as individual units are designed specifically to accommodate unique site conditions; this is espeically true for units above 100 kW. Significant cost savings can be achieved if the hydroelectric system is installed at a site with existing civil infrastructure, such as a pipeline or other conveyance method and diversion structure. According to the Electric Power Research Institute, the supply costs for the turbine, generator (less than 100 kW), and control package can range from $1,000 to $2,000 per kW depending on unit type and operation. Installation costs can be up to 50 percent of the equipment costs. As a rule of thumb, the civil works costs are less than or equal to the equipment costs (turbine, generator, and controls), and the total capital costs can range from $2,000 to $8,000 per kW of installed capacity, depending on the system's capacity and location.[2]

The regulatory and permitting requirements for hydropower systems can be extensive; however, recent federal law changes and increased state-level awareness has greatly simplified the regulatory path for small hydropower projects. The two primary agencies regulating hydropower in Wyoming are the Federal Energy Regulatory Commission (FERC) and Department of Interior, U.S. Bureau of Reclamation (USBR). Depending upon the system location, either FERC or USBR must grant permission (e.g., license, exemption, or lease) to build a new small hydropower facility.

FERC licensing is generally required for large dams, but it also provides two possible exemptions – the Conduit Exemption and the 10-MW Exemption. FERC also allows certain "Qualifying Conduit Hydropower Facilities" up to 5-MW to be forgo the full license or an exemption process. The Handbook outlines numerous exemption process conditions, but each can be attractive for small hydropower in Wyoming.

Development of non-federal hydroelectric power plants on existing USBR facilities (e.g., dams or conduits) requires either a Lease of Power Privilege (LOPP) issued by USBR or an exemption from the FERC as previously described. A LOPP is a contractual right given to a non-federal entity to use a USBR facility for electric power generation consistent with USBR project purposes. USBR's main concern in awarding a LOPP is that the integrity of USBR facilities are not impaired. A new hydropower facility must not interfere with existing operations, jeopardize existing water rights, or create safety issues.

Other federal and state agencies also may need consulting. A project at existing water infrastructure will often qualify for an Army Corps of Engineers nationwide permit, limiting their direct involvement. The State Engineers Office will address water right issues, including adding hydroelectric generation as a permitted use. The Wyoming Department of Environmental Quality will review plans to ensure the system does not degrade public water supplies. The Wyoming Game and Fish Department may also be involved in granting a FERC exemption or LOPP. Finally, local planning and development offices and Wyoming Department of Fire Prevention and Electrical Safety may need to approve new project development.

The value of electricity produced is vital to facility feasibility. For larger projects, initial discussions with the local electric utility can help determine the value of electricity and identify interconnection requirements. Interconnection requirements and the value of the energy can vary considerably depending on the electric utility and size of the hydroelectric generation facility. Utilities typically purchase energy at their avoided cost, which is essentially the marginal cost for a utility to produce one more unit of energy. This is less than the retail rate paid by consumers. A Power Purchase Agreement (PPA) defines conditions of the sale of electricity between the two parties and can include delivery of electricity, penalties for under-delivery, payment terms, and rates and termination. In addition, renewable energy credits (certificates that value the environmental amenities of renewable energy) can also generate value.

If the system size is 25 kW or less and the electricity will be used onsite, such as to supply a residence or irrigation motor, then Wyoming's net metering and interconnection law applies. This law serves as an incentive for small renewable energy projects and often means electricity will be valued at the full retail rate, with excess (annual production above annual consumption) purchased at the avoided cost rate. In addition, requirements to connect with the electrical grid are also simplified.

Financing capital-intensive, small hydropower projects can present the final obstacle to a technically feasible project. State, federal, and utility incentives exist beyond traditional financing such as private loans and equity. Wyoming state incentives include:

- Wyoming Water Development Commission (WWDC) – Grants for feasibility studies,
- Office of State Lands State Loan and Investment Board (SLIB) – Subsidized loans,
- Wyoming State Revolving Funds Program (SRF) – Subsidized loans with potential for loan forgiveness.

Each provides services to distinct entities, such as municipalities or irrigation districts. Federal incentives include:

- Bureau of Reclamation WaterSMART grant program – Financing and grants for entities with existing water delivery authority, often in conjunction water conservation improvements,
- The U.S. Department of Agriculture (USDA) Rural Energy for America Program (REAP) – Grants and guaranteed loans to rural small businesses, typically not irrigation districts,
- USDA National Resources Conservation Service Environmental Quality Incentives Program (EQIP) – Grants to agricultural producers for micro-hydropower development,
- Business Investment or Production Tax Credit – Projects greater than 150 kW, including a 30 percent investment tax credit or a 1.1¢/kWh production tax credit (for the first 10 years).

In addition, some utilities, such as Rocky Mountain Power's Blue Sky Program, also offer incentives. All the incentives can help enhance the financial feasibility of otherwise technically feasible projects.

The full *Handbook* provides detailed description of the key steps of inquiry and action. Examples of existing Wyoming hydropower projects and a basic pre-feasibility analysis example for theoretical installation is also included. The *Handbook* appendix includes many resources, such as equipment providers, to guide project consideration.

Through exploring the resources in this summary and the full *Handbook*, water users can definitively answer years of wondering "Can we generate electricity from that?" If you have any questions or desire an introductory pre-feasibility assessment, please visit http://renewables.uwyo.edu or call your local UW Extension office.

1 Hadjerioua, Boualem, Wei, Yaxing and Kao, Shih-Chieh. US Department of Energy, Office of Energy Efficiency and renewable Energy. 2012. *An Assessment of Energy Potential at Non-Powered Dams in the United States*. Pulskamp, Michael. US Department of Interior, Bureau of Reclamation. 2012. *Site Inventory and Hydropower Energy Assessment of Reclamation Owned Conduits*.

US Department of Interior, Bureau of Reclamation. 2011. *Hydropower Resource Assessment at Existing Reclamation Facilities*.

2 EPRI. 2011. "Quantifying the value of Hydropower in the Electrical Grid: Plant Cost Elements." Final Report 1023140: Palo Alta, CA.