

Small Hydro Introduction and Feasibility Guide



Prepared for the Governor's Energy Office by



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How to Use This Guide

The Governor's Energy Office (GEO) offers this document to assist in development of small hydro projects.

This document provides guidance on implementing small hydro projects, and identifying and addressing the issues necessary for completing a small hydro feasibility study.

Within each section, the pertinent issues are discussed and at the end of each section.

The document also provides a template or road map for completing a project feasibility study. Each section is designed to cover a different aspect of feasibility and includes general guidance on how to obtain the necessary information.

Background

Every small hydro project is unique in some way or another. The intent of this section is to provide: background information, reasons for pursuing the project, what information has been gathered to date and general information to bring the reader 'up to speed' on the project.

This background information is important for several reasons. For instance some projects are driven by financial return from the sale of electricity. Some are driven by the desire to produce clean, renewable energy. Other reasons might even include redundancy for PRV (pressure reducing valves), protecting water rights or a host of other reasons. The point is that different priorities might require different analysis and decision points so it is valuable to state the priorities clearly. Likewise it is useful to include any research, testing, evaluation or physical improvements that have been made in the past that might affect the project, either positively or negatively.

This section might also include a statement of purpose for the feasibility study, such as "The intent is to explore the capital costs, revenue potential and any legal issues associated with constructing and operating a hydroelectric facility."

Legal Considerations

Overview

This section should analyze the legal issues associated with constructing and operating a small hydroelectric facility, including:

- Whether the entity is within its legal rights to construct and operate a power generation facility.
- The legal requirements to utilize existing or future water rights for the purposes of power generation.
- Any minimum stream flow requirements.
- The legal requirement to apply for and obtain any and all permits.

Findings

Include any information pertaining to the legality of operating a power generation facility. It is recommended that an attorney and/or consultant knowledgeable about hydroelectric project implementation be consulted.

Water Rights

Water rights, particularly in Colorado are extremely complex. There are several different types of water rights, some that would allow use in a hydroelectric facility, some that would not, and some that are a bit ambiguous; generally these types of projects file for non-consumptive water rights. It should be clearly stated in this section whether there is a sufficient quantity of water available to achieve the projected power generation and whether these rights will allow use for power generation. It is recommended that an attorney and/or consultant knowledgeable about water rights and their use in hydroelectric facilities be consulted.

So that the water rights can easily be referenced in the future, it is recommended that they be listed in this document, perhaps in a table similar to the one shown below.

Example:

<u>Name</u>	<u>Quantity</u>	<u>Seniority</u>
_____	_____ cfs	year acquired

There should also be a description of the water right and any other relevant information about it.

This sub-section should also include any information relating to any minimum in-stream flow requirements – the minimum level of water that is legally required to flow in the river/creek/stream by a governmental entity at any given time.

Permit Requirements

Permit requirements are dependent on various components of implementation. Any project producing electricity to be fed into the grid requires a Federal Energy Regulatory Commission (FERC) permit.

Legal Considerations

Some project developers will utilize a Preliminary Permit from FERC to protect their right to develop a potential drainage area for 3 years. The Preliminary Permit sets up a process for evaluating the project by FERC through: Notification of Interested Parties, developing a Preliminary Application Document (PAD), and a meeting of interested parties with FERC and the public. Depending on the outcome of this process additional studies maybe required prior to drafting an application for FERC permit.

Depending on the size of the project and the environmental impacts, this permit can take a great deal of time and effort to obtain, so it is highly recommended that the application process begin as soon as is feasible. The major issues with FERC permitting are the environmental impact to the stream and fish and wildlife.

The FERC process has two exemption routes to simplify FERC permitting: for existing hydrological structures, a conduit exemption or the small megawatt exemption for systems less than 5MW. A more comprehensive permitting process is needed for larger projects.

However, for some very small projects the process can be less complicated. An owner or operator of a generating facility may be eligible to obtain ‘Qualifying Facility Status’ (QF) status by either submitting a self-certification or applying for and obtaining a Commission certification of QF status. **The FERC should be contacted as early as possible so that a decision can be rendered as to whether ‘Qualifying Facility Status’ is applicable for the specific project.***

A complete list of permits that may be required follows:

Federal:

Federal Energy Regulatory Commission (FERC)
 United States Forrest Service (USFS)
 Bureau of Land Management (BLM)
 Environmental Protection Agency (EPA)
 Bureau of Reclamation
 Department of the Interior
 US Fish & Wildlife

State:

State Engineer Office
 Colorado Water Court
 Colorado Water Resources and Power Development Authority (*public projects only*)
 Colorado Water Conservation Board
 Colorado Water Quality Control Commission
 Colorado River Water Conservation District
 Department of Wildlife

Local:

Planning & Zoning Commissions
 County Commission and/or City/Town Council

System Capacity

Overview

This section should analyze the capacity of any existing infrastructure to generate power and what improvements are necessary to construct a small hydroelectric facility. Some projects may have multiple development alternatives for a hydroelectric system. All alignments should be discussed with the appropriate level of analysis invested into each one.

Existing Infrastructure

All relevant information pertaining to the existing infrastructure, including diversions, head gates, penstock, pressure reducing valves (PRV), treatment plants, and any other components should be described here. Included in this description should be topographical elevations of each component so that head (the vertical distance water flows between two points) can be determined. This information is critical to determining the potential power production and therefore the overall feasibility of the project, so it is advised that accurate information be obtained as early as possible. This will likely require surveying the area and locating the components accurately with current horizontal and vertical datum. There are however alternative methods to determining head. For more information, please refer to [Canyon Hydro's Guide to Hydro Power - A Tutorial](#) for additional information.

Average Flows

Equally important to what infrastructure is in place is how much water is available for use in a hydroelectric system. There can be any number of water sources that will supply water for the hydro system, including rivers, creeks, raw waterlines, reservoirs, treatment plants, etc. Regardless of the source it is important to document as much historic flow data as possible. It is very possible that the flow fluctuates from year to year and/or from month to month, particularly if the source is a river or creek. There may be other factors that impact flow, so the data should be collected at regular intervals, at the same location and ideally conditions should be noted. This information is absolutely critical to project future power generation capabilities so the more accurate information the better.

If your water source is piped, and you do not have a flow meter installed, it is recommended that you consult an engineer to assist with determining flow.

If your water source is a river or creek, the easiest way to determine flows is by accessing [USGS data](#), if flow can be extrapolated from their data. There are however alternative methods to determining flows. For more information, please refer to [Canyon Hydro's Guide to Hydro Power](#) for additional information.

Pipeline Capacity

If a pipeline exists that you are planning to utilize as a penstock for a hydroelectric facility, it is important to verify that it, as well as any other infrastructure such as diversions, head gates, etc. has adequate capacity. Every project will be unique so there

System Capacity

are aspects of each project that will vary. However there are some common issues that need addressed. Some basic questions include:

- Can every component of the system meet the demands required of it by the addition of a hydroelectric facility?
- Is the diversion and headgate adequate to reliably supply the projected quantities of water?
- Specifically, is the penstock an adequate size and material to handle the projected water pressure?
- If the answer is no to any of the above mentioned question, what improvements need to be made?
- Will reducing the pressure to atmospheric pressure downstream of the turbine negatively impact the system?
- Are there pressure reducing valves that might benefit by the addition of a turbine?

To assist in accurately answering these questions, it is recommended that a qualified individual or team of individuals familiar with hydroelectric systems be engaged. Identifying many if not all of these answers will require significant effort, however there is a need for accurate information to inform the decision as to whether to proceed or not, what improvements are necessary and how successful the project will be.

Transmission Line

Unless the proposed project will be off the grid, it will require a utility grid connection. The specifics of connecting to the grid will be determined by the utility servicing the project. The first order of business is verifying that the utility will accept the power, you plan to produce. From there it needs to be determined what specific grid connection requirements will be enforced by the utility.

The utility's transmission lines that will tie to the meter to service the proposed hydroelectric facility must have adequate capacity to carry the capacity of the power plant. Some utilities have set standards that require three phase service for systems over a certain size. There are significant costs for up-grading power lines if this is required. The transmission lines will need to be extended to the powerhouse where the turbine will be located.

Power Generation Potential

Overview

This section should analyze the power generation potential for the facility.

What Makes Water Power*

Water power is the combination of head and flow. Both must be present to produce electricity. Consider a typical hydro system. Water is diverted from a stream into a pipeline, where it is directed downhill and through the turbine (flow is the amount of water to be put through the turbine). The vertical drop from the top of the penstock to the turbine (head) creates pressure at the bottom end of the pipeline. The pressurized water emerging from the end of the pipe creates the force that drives the turbine. More flow or more head produces more electricity. Electrical power output will be less than water power input due to turbine and system inefficiencies.

* This is an excerpt from the article “Intro to Hydropower” in the October/November 2004 issue of Home Power, written by Dan New.

Power Potential

By now the key critical factors, such as head and flow have been identified and it is time to estimate the potential power generation. Estimating ‘theoretical power’ is relatively simple, and is a necessary first step to estimate overall feasibility. Taking it beyond an estimate to account for several other factors, such as efficiency and transmission loss can be slightly more complex.

Because hydroelectric power production can vary from season to season, or even day to day, it is important to identify the timeframe for which you are estimating potential power production. Regardless of the timeframe, it is important to outline all of the different conditions, such as varying seasonal flows and downtime for maintenance, and estimate a weighted average accordingly.

There are various tools available to estimate potential power generation, however it is recommended that you follow [Canyon Hydro’s Guide to Hydro Power](#). Canyon Hydro’s website provides a very useful guide to walk you through the process and it is recommended as a ‘must read’ at this point. The guide provides the necessary formulas, an example to reference and most importantly, an explanation of what it is you are calculating.

Estimated Capital & Operating Costs

Overview

This section should estimate soft and hard capital costs, as well as annual operating & maintenance expenses.

Analysis

Below is a budget template that can be used as a guide. It is likely that your budget will require either adding or subtracting line items, however this template is designed to cover the typical costs associated with developing a small hydroelectric project. The following is a general description of each line item:

Expenses: Hard Costs

Feasibility Study – Include any costs associated with studying the feasibility of the project, including efforts to obtain essential data.

System testing – Include pressure testing and/or any type of infrastructure inspection.

Survey work – Include any costs associated with verifying locations of the various components of the existing and/or proposed system.

Engineering: design and construction – Include any design costs for infrastructure improvements and/or new diversion, penstock, powerhouse, etc. Also include costs for field engineering during construction if applicable.

Project management – Include any costs for managing the overall project, which can include grant writing, permitting, and/or managing the feasibility study, design and construction and any other tasks required to complete the project.

Permit fees – Include any fees associated with obtaining the necessary permits.

FERC License – Include any costs associated with obtaining a FERC license or exemption.

Expenses: Hard Costs

Turbine & switch gear – Include all costs associated with the turbine & switch gear equipment. This is often what is offered by the supplier of a turbine.

Structure and foundation – Include any costs associated with upgrading a building or constructing a new powerhouse to house the turbine. Include costs associated with constructing the tailrace.

Excavation, pipe connection & associated fees – Include any costs to upgrade or construct a diversion and/or penstock, essentially all infrastructure upstream of the powerhouse.

Flow meter – If a flow meter does not currently exist on the system, it is recommended that one be included in the budget for the proposed hydroelectric facility.

Electrical work – Include any costs associated with providing electrical service to the turbine and switch gear.

Estimated Capital & Operating Costs

Utility grid connection – Include any costs associated with connecting the turbine to the utility grid. Verify that this includes any upgrade or extension of transmission lines.

Labor – Include any labor costs not included in other line items.

Installation & crane – Include any costs associated with installing the turbine, including crane costs.

Contingency – It is recommended that a contingency be included, reflective of the level of uncertainty in budget numbers.

Estimated Capital & Operating Costs

Small Hydro Preliminary Budget Capital Costs	
EXPENSES	
Soft Costs	
Feasibility Study	
System testing (pressure test, flow gauge, etc.)	
Survey work	
Engineering: design & Construction	
Project Management (including permits, grants, construction)	
Permit fees	
FERC License	
Sub Total	\$ -
Hard Costs	
Turbine & switch gear	
Structure & foundation	
Excavation, pipe connection & associated fees	
Flow meter	
Electrical work	
Utility grid connection	
Shipping	
Labor	
Installation & crane	
Contingency	
Sub Total	\$ -
EXPENSE TOTAL	\$ -
REVENUE	
Grants	
Rebates	
Other	
Sub Total	\$ -
GROSS REVENUE	\$ -
Net Capital Cost	\$ -

Table 5.1 - Preliminary Capital Expense Template

Estimated Revenue Potential

Overview

This section should estimate the potential revenue to offset capital expenses, such as grants and rebates and for operating revenue, such as through a net-metering or power purchase agreement with the electric utility.

Capital Expense Revenue Potential

There are several funding opportunities that have emerged recently that apply to small hydroelectric projects. Grants from a number of different entities can be a significant source of funding, as can rebates from some utilities. Other potential sources of funding include: Colorado Water Conservation Board ([CWCB](#)), Colorado Water Resource and Power Development Authority ([CWRPDA](#)), and US Department of Agriculture's [Rural Loans and Grants](#).

Net Metering

Net metering is a method of crediting utility customers for electricity that they generate on site in excess of their own electricity consumption. Customers with their own generation (such as a hydroelectric facility) offset the electricity they would have purchased from their utility. If such customers generate more than they use in a billing period, their electric meter spins backwards to indicate their net excess generation. Different utilities structure this arrangement differently, so it is recommended that before any revenue assumptions are made, there is a firm understanding of how net-metering will be handled by the utility.

Power Purchase Agreement

Another option to generate revenue from the utility by selling the power generated by a hydroelectric facility is through a Power Purchase Agreement. A Power Purchase Agreement (PPA) is a legal contract between an electricity generator and a purchaser of electricity. Such agreements play a key role in the financing of electricity generating assets. By clearly defining the output of a generating asset (such as a hydroelectric facility) the utility can quantify the value and negotiate a price per kilowatt hour accordingly, in addition to other fees that may be part of the agreement. The value of a particular project can vary wildly with different utilities. Factors that affect this include how much power will be produced, when will it be produced, how reliable it is, and how important renewable energy is to the utility. Recent state legislation that requires most utilities to acquire a portion of their electricity from renewable resources has certainly increased the value of renewable energy. The following is a general list of issues that might be included in a PPA:

- Disclosure of all associated costs for the project.
- Agreement on which entity owns the 'renewable energy credit' (aka 'REC').
- Additional fees from the utility including: 1) Avoided Energy Cost; 2) Avoided Coincident Peak (CP) Demand Cost; 3) any other costs deemed reasonable by both parties.

Estimated Revenue Potential

- Any impacts to the utility grid resulting from the project.

Renewable Energy Credits

The utility company maybe interested in paying for the environmental benefits for the clean renewable hydro power. The environmental benefits are generally sold as a product called a REC (renewable energy credit). Compensation for the renewable energy credit (aka 'REC') is revenue source that can be included into other agreements, such as a PPA or net metering, or can be separate. Similar to carbon financing, the REC market is changing rapidly and can vary considerably. A REC can be sold to the utility or on the open market to third party resellers of REC's.

Other Revenue Sources

Another funding opportunity exists through the emerging market of carbon financing. The objective of carbon finance is to find the lowest cost carbon emissions reduction projects. An alternative market is developing for carbon. Carbon finance firms work primarily under two different models. Both models speculate on the future value of a carbon credit, generated through a carbon reduction project (such as renewable energy generation). It is speculation because with no federal 'cap & trade' program in place now in the U.S., the value of these projects is very low. So acquiring the credits now is relatively cheap, compared to the value if and when a federal program is enacted. There is some consensus that such a program will be enacted in the future. It should be noted that this is a relatively new form of financing in the US market, so the various aspects of this opportunity is likely to change. It is recommended that the Governor's Energy Office be contacted to get more information before proceeding with this financing mechanism.

Analysis

Because of the many funding alternatives, it is very important to evaluate each of them to determine which approach is most beneficial. Because of the complexity of utility rates and therefore net metering and power purchase agreements, it is recommended that the financial forecasting of the different options be done in cooperation with the utility.

Estimated Revenue Potential

Small Hydro Financial Analysis Template			Generation Capacity			
Generation	Nameplate Capacity (kW)					
	Average Capacity (kW) @	%				
	Monthly Avg. Production (kWh)					
	Annual Energy Production (kWh)					
	Estimated Annual Use (kWh)					
	Annual Net Energy Production (kWh)					
	Lifecycle Net Generation (kWh)					
	Lifecycle Gross Generation (kWh)					
Estimated Revenue and Expenses			Power Purchase Agreement		Net metering	
Revenue	Revenue Options	Unit costs	Monthly Revenue	Annual Revenue	Monthly Revenue	Annual Revenue
	Avoided Energy Costs (per kWh)	\$ 0.035				
	Avoided CP Demand (per kW)	\$ 10.00				
	RECs (per MW)	\$ 30.00				
	Net metering rate (per kWh < estimated use)	\$ 0.063				
	Net metering rate (per kWh > estimated use)	\$ 0.048				
	SUBTOTAL					
Expenses	Expense Categories		Monthly Expenses	Annual Expenses	Monthly Expenses	Annual Expenses
	Maintenance labor					
	Manitenance parts					
	SUBTOTAL					

Cost Benefit Analysis

Overview

This section should review all the data and include a return on investment analysis.

Analysis

Although cost is a common metric, benefit is in the eye of the beholder. The return on investment analysis allows you to evaluate when the initial capital investment will be returned, considering projected O & M costs and revenue.

In order to accurately evaluate the return on investment, it is important to make informed decisions about future conditions. This includes calculating O & M costs, projecting an expected life of the system, and projecting future electricity prices and the respective rate the utility will pay for power.

Of course the term ‘benefit’ can include more than financial return. Other benefits can include the production of non-polluting energy, utilization of water rights, redundancy on pressure reducing valves, locally generated power, etc. It is sometimes difficult to place a monetary value on these benefits, so how they are evaluated is up to the project team.

Estimated Return on Investment (ROI)		Power Purchase Agreement	Net metering
Costs	Est. lifecycle maintenance expenses		
	Est. capital cost		
	Total project cost		
Units	Est. project life (years)		
	Est. annual generation (kWh)		
	Est. lifecycle generation (kWh)		
ROI	Est. annual revenue		
	Est. lifecycle revenue		
	Average annual ROI		
	Est. simple payback (years)		

Table 7.1 –Estimated Return on Investment Template