Micro Hydro Sites in Agriculture Applications

Interim Report

for

Colorado Department Of Agriculture

October 1st, 2011

CONTACT
Ravi Malhotra
Executive Director
Email ravi@iCASTusa.org
Phone (303) 462-4100
www.iCASTusa.org

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Introduction

This report is the interim report for progress to date on the Micro Hydro in Agriculture Applications Project funded by the Colorado Department of Agriculture's (CDA) Advancing Colorado's Renewable Energy (ACRE) Program. The outline of this report is in accordance with the CDA's interim report format.

Work completed to date and any relevant findings:

Since the inception of the project, Painted Sky & iCAST (project team) has worked on identifying and analyzing micro hydro applications within the agriculture community. The project team performed outreach through networking to identify agriculture sites that had an irrigation canal and or natural stream as well as an interest in pursuing micro hydro applications. Once the sites were identified, the project team performed initial feasibility studies through site visits and interviews to analyze if the sites would be both technically and financially feasible. Data analyzed included; flow rates, head, capital costs, operational costs, electricity generated, electricity generate, return on investment and more.

Potential Micro Hydro Site Located in Hillside Colorado

Upon completion of the study the team developed preliminary feasibility reports for each site. An example of a preliminary report is illustrated in Appendix A. Upon a final review of the preliminary feasibility reports with the site owner the project team revises and finalizes the reports.

Through working with site owners and reviewing site data, the team is moving forward with 2 sites in performing a high level feasibility study for each site.

The team also worked on and completed additional outreach materials and held outreach events to educate and outreach to agriculture communities throughout the western slope.

Progress toward expected outcomes & Key Accomplishments

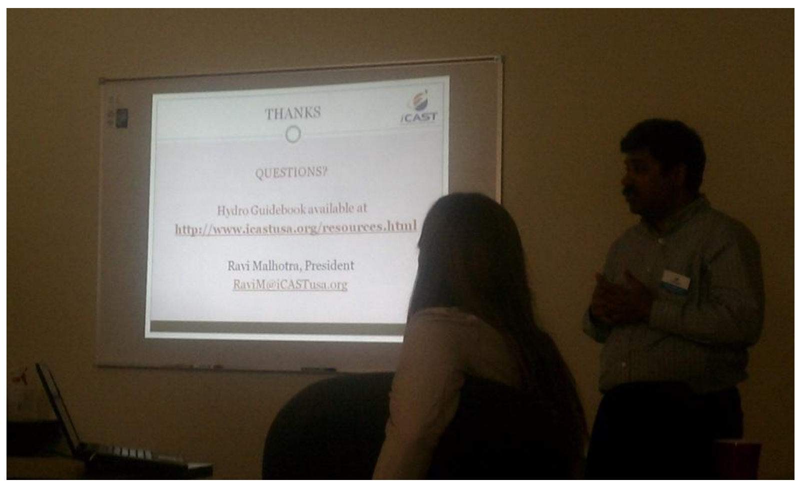
Progress towards expected outcomes & key accomplishments includes:

- Development of 6 preliminary feasibility studies for micro hydro sites for agriculture applications
- Developing in-depth feasibility studies on the 2 most viable micro hydro sites
- The team submitted one micro hydro site into the Colorado's Governor's Energy Office Renewable Energy Development Team and FERC Permitting Streamline Program. Appendix B illustrates the sites acceptance into the project.

- The team developed a total of 2 Micro Hydro resources guide to distribute at outreach events and post on websites
- The team has held a total of 4 outreach events located in cities including:
  - Montrose Colorado
  - Grand Junction Colorado
  - Glenwood Springs Colorado
  - Denver Colorado
- The Grand Junction outreach event marketing material is illustrated in Appendix C
- A copy of one of the outreach events presentation is in Appendix D
- Appendix E is an example of educational material developed in the project

Preliminary findings

The preliminary findings of this project conclude that there are an adequate amount of micro hydro applications in Colorado within the agriculture community predominantly thru irrigation ditches. The key factors determining if the sites are both technically and financially viable include:



Micro Hydro Outreach Event

- Site Characteristics including; available water flow (CFS), available head (Ft), site proximity to the grid and or a load, and sites geographic restraints for construction and access for maintenance
- Water rights must be obtained in order to implement a micro hydro site
- The option to sell the electricity generated to the utility or use it directly on a load makes a significant difference on the sites return on investment
- Most importantly, the site owner must have and enduring interest and patience in developing the site.

In general not all irrigation ditches and stream were found both financially and technically viable options, however if sites meet a significant portion of the above criteria, micro hydro is a great source of renewable energy within agriculture applications and is a realistic goal.

Problems being encountered and/or mitigating circumstances;

Overall, there has been little to no problems encountered throughout the project. The biggest challenge has been seeking buy in from site owners to take the nest steps in developing the micro hydro site. Several of the sites analyzed are both financially and technically viable and would be ideal sites, however, the site owners are reluctant, too busy, or have other interests than developing a micro hydro site. Although the next steps of site development is not within the project scope, the team is interested in will continue to engage with site owners and outreach to additional interested parties in hopes of implementing micro hydro sites within agriculture applications.

Next steps

The next and final steps for the project are to finalize the in-depth feasibility studies for the selected top two sites. This involves engaging further with the site owners and analyzing in further detail the;

- Estimated development costs in further detail
- Selecting the appropriate technologies for each site
- Outlining development steps
- Researching potential financing options including debt, equity, and grants
- Review reports with site owners

Any anticipated changes to project timeline.

At this time the project team anticipates to complete the project scope and deliverables ahead of the project due date of April 1, 2012.

Micro Hydro Feasibility Study

for

Ross Allen

July 27, 2011

Contact
Ravi Malhotra
Executive Director
Email ravi@iCASTusa.org
Phone (303) 462-4100
www.iCASTusa.org

This report was developed with the following partners

Painted Sky RC&D Council, Inc.

&

University of Colorado, Boulder CO

Funded by:

The Colorado Department of Agriculture

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Executive Summary

This report is an initial feasibility study for a potential micro hydro site at a canal referred to as railroad tunnel #2 located near Hotchkiss, Colorado. iCAST partnered with Painted Sky RC&D and the University of Colorado to conduct the study which was performed by reviewing site conditions and data provided by Ross Allen, the site owner.

The site has the electrical generation capacity of approximately 37,000 kWh per year. Assuming the energy generated can be used to offset current loads, and the retail cost of electricity for the site is $0.10 per kWh, the potential feasibility for the site is:

Table 1: Hydro feasibility analysis of traditional technology, displacing power at $0.10 per kWh

System Capacity (KW)	Power Generation (kWh/yr)	Capital Expenditure	Electricity Offset ($/kWh)	Annual Utility Offset	Payback Period (years)
4.2	37,000	$28,000	$0.10	$3,400	8

Table 1 demonstrates displacing current usage with traditional technology. Another option is to utilize an emerging technology, as presented in Table 2. The cost is lower but the risk of the new technology might be in higher operating and maintenance costs and/or lower life span.

Table 2: Hydro feasibility analysis of utilizing 2 stream engines, displacing power at $0.10 per kWh

System Capacity (KW)	Power Generation (kWh/yr)	Capital Expenditure	Buyback Price ($/kWh)	Annual Sales Profit	Payback Period (years)
4.2	37,000	$19,000	$0.10	$3,400	5.6

With additional funding mechanisms such as grants, rebates, and incentives, the initial capital cost could be reduced by as much as 50%, to effectively half the payback periods.

Site Background

A potential micro hydro site exists at a canal referred to as railroad tunnel #2 located near Hotchkiss, Colorado. Ross Allen, the site owner, expressed interest in developing the site. The study began by gathering site specific characteristics from the site owner including: seasonal flow, flow-rate, head, current utility needs, existing loads, and other relevant data. This data is essential for initial analysis to determine the technical & financial feasibility of the site. Table 3 illustrates all site data gathered from the site owner.

Table 3: Site characteristics

Site Data	
CONTACT INFORMATION	
Phone Number	970-872-3044
Email	rallen@allentool.com
Address	29736 St. Rte. 92 Hotchkiss, CO 81419
Site Name	Railroad Tunnel 2
TECHNICAL SITE SPECIFICS	
Flow rate	1.25 cfs
Availability of production	Year Round
Site specific heads	50 feet
How far is the closest substation?	Hotchkiss Substation (distance?)
How far is the ditch from the nearest electric line?	0.25 mile
ENERGY PROVIDER	
Who is their power provider?	Delta Montrose Electric Association (DMEA)
Is there a renewable energy buy-back program?	Yes

Site Analysis

Site characteristics indicated a Kaplan turbine would be the most appropriate turbine for the site with an assumed 80% efficiency rating. The information provided indicated that the location was approximately one quarter of a mile from a local utility line and that the utility provider, Delta Montrose Electrical Association (DMEA), has a renewable energy buyback program at a rate of $0.04/kWh. If there are buildings or other loads nearby to the hydro installation, the generated electricity can be used to displace current costs. If this is not an option, the electricity could be sold at a wholesale rate to DMEA. Both scenarios were analyzed for reference.

It was calculated that the site would have a capacity of 4.2kW and generate approximately 37,000 kWh annually. At $0.10/kWh and annual savings would be approximately $3,700. Operating and maintenance was estimated at $300/year, reducing the annual savings to $3,400. The capital cost includes $26,000 for the system and an estimated $2,000 for a line to connect to buildings. A summary of the findings is presented in Table 4.

Table 4: Hydro feasibility analysis assuming power is used to offset current load

System Capacity (kW)	Power Generation (kWh/yr)	Capital Expenditure	Electricity Offset ($/kWh)	Annual Utility Offset	Payback Period (years)
4.2	37,000	$28,000	$0.10	$3,400	8

If there are no adjacent buildings or load to use the energy generated, the electricity will need to be sold back to DMEA. The key differences between the two scenarios lie in the price of electricity ($0.04 as opposed to $0.10) and the capital cost (which requires an investment in a transmission line to the site). The transmission line, which was assumed to be a $50,000 investment, substantially increases the required capital expenditure of the project. This, along with the lower price of electricity, results in a much longer payback period of 46 years. A summary of these results are shown below in Table 5.

Table 5: Hydro feasibility analysis assuming power is sold at wholesale price

System Capacity (KW)	Power Generation (kWh/yr)	Capital Expenditure	Buyback Price ($/kWh)	Annual Utility Offset / Savings	Payback Period (years)
4.2	37,000	$76,000	$0.04	$1,200	63

Offsetting electricity use is a much more preferable option with a much lower associated payback for the investment. Grants and other incentives could potentially lower the payback even further.

Emerging Hydro Technology

Another approach is to utilize systems that are specifically designed for small-scale generation. The hydro industry is developing technologies which offer effective solutions to high-head, smaller generation applications. After reviewing emerging technologies, the team recommends the ES&D Stream Engine (Figure 1) as a possible technology for power generation. The generator is designed to generate power up to 2 kW in high-head conditions. A picture of the Stream Engine is presented as Figure 1 below. Based on this value, the Stream Engine could provide a possible solution to powering the proposed irrigation system. Details and specifications from the manufacturer can be found in *Appendix I.*

Figure 1: Layout of the Stream Engine.

An estimated capital cost for two stream engines, each 2KW would be approximately $19,000. A summary of these costs are outlined in Table 6.

Table 6: Cost summary of a Stream Engine System Installation

Component	Estimated Cost
ES&D Stream Engines	$6,500
Design & Installation	$4,000
Inverter	$4,000
Permitting	$2,500
Line costs	$2,000
Total	**$19,000**

The installation cost includes factors such as pipe diversion, wiring, and other site preparation costs. The inverter is necessary to convert the generated DC power to AC power to power traditional electrical systems.

The generation would be approximately 4 kW at the correct conditions. These conditions result in the annual production of $3,700 in electricity assuming electricity is being displaced. Assuming maintenance costs of approximately $300 per year (bearing replacement and other standard maintenance procedures), the associated payback of the investment without grants or other incentives would be about 5.6 years. See Table 7 for a summary of the analysis.

Table 7: Utilizing a pair of Stream Engines, displacing power at $0.10 per kWh

System Capacity (KW)	Power Generation (kWh/year)	Capital Expenditure	Electricity Offset ($/kWh)	Annual Savings	Payback Period (years)
4	37,000	$19,000	$0.10	$3,400	5.6

If electricity cannot be displaced, it can be sold at $0.04 per kWh. However, in this case a utility line would have to be constructed to the nearby infrastructure, increasing the capital investment drastically. This scenario is presented in Table 8.

Table 8: Utilizing a pair of Stream Engines, selling power at $0.04 per kWh

System Capacity (KW)	Power Generation (kWh/year)	Capital Expenditure	Electricity Offset ($/kWh)	Annual Savings	Payback Period (years)
4	37,000	$69,000	$0.04	$1,200	57.5

The Stream Engine may be a good financial choice for a micro hydro installation option when power is being displaced rather than sold. Assuming grants or tax credits exist, the required capital investment could be lowered even further to make the investment more desirable.

Conclusion

This report was an initial feasibility study on several different hydro options for the site. Additional studies and site visits are encouraged prior to investing into any of the technologies. For additional hydro development services including; permitting, financing, design, and construction please contact Chris Jedd (ChrisJ@icastusa.org) or 720-833-5592.

Appendix I: Stream Engine Specifications

Energy Systems & Design Ltd. (ES&D)

"Innovative Renewable Energy Systems Since 1980"

Postal Address:
P.O. Box 4557
Sussex, NB.
E4E 5L7 CANADA

Email, Internet, Tel/Fax Particulars:
hydropow@nbnet.nb.ca
www.microhydropower.com
T: + 506 433-3151; / F: + 506 433-6151

Energy Systems & Design's Stream Engine is a micro hydro electric turbine generator designed for use in battery-based power systems, with electricity generated at a steady rate, and stored in batteries for use at higher rates than is generated. During times of low demand, power is stored. An inverter is used when AC power is required.

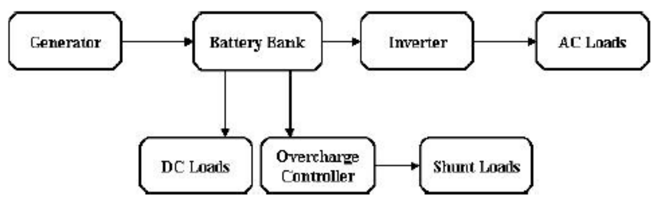
Water from a stream is channeled into a pipeline to gain enough head (the vertical distance the water falls) to power the system. The Stream Engine operates at heads of about two meters (6 feet) and upward. The water passes through a nozzle, where it accelerates, strikes the bronze turgo wheel and turns the generator shaft. Up to four universal nozzles can be installed on one machine, depending on conditions. Each Stream Engine is supplied with a digital multimeter as well as extra nozzles.

<u>Energy Systems & Design 2 Nozzle Stream Engine</u>

Stream Engine Output (Watts Continuous)

Net Head		Flow Rate Liters/sec (Gallons/min)						
		0.67 (10)	1.33 (20)	2.50 (40)	5.00 (75)	6.67 (100)	7.50 (112)	9.50 (150)
Meters	Feet							
3	10	-	20	40	75	100	130	150
6	20	15	40	80	150	200	250	350
15	49	45	100	200	375	500	650	800
30	98	80	200	400	750	1000	*	*
60	197	150	400	800	1500	*	*	*
90	295	200	550	1200	*	*	*	*
120	394	300	700	1500	*	*	*	*
150	492	400	850	1900	*	*	*	*

A Typical "Stand-Alone" Renewable Energy System



Chris Jedd

From: Broshar, Ryan <Ryan_Broshar@sra.com>
Sent: Thursday, June 09, 2011 3:34 PM
To: Chris Jedd
Subject: Renewable Energy Development Team Project Consultation Kickoff - 30 kW_LaSalle_Jedd_Small Hydro

Dear Chris

Congratulations! This notice is to inform you that our team of experts has finished the Phase I Project Review of your Technology and Business Development application to the Governor's Energy Office Renewable Energy Development Team. Your project has been chosen to move forward into our Phase II Project Consultation. The Phase II Project Consultation will include our team of experts devoting ***FREE*** technical assistance and business development hours towards your project.

The next step is to setup a **Phase II Project Consultation Kickoff Call** where we discuss our review of your project and highlight the strengths and risks identified. From there, we will outline areas where our team can help your project the most and set goals for the Phase II Project Consultation. This will include investigations into the project specifics not identified with the generic technology questions on the original application.

Please let us know a time that works for you in the next two weeks where we can schedule a one hour conference call with our team of experts and individuals associated with your project. Thanks in advance for a suggested time and date.

If you have any questions about the program or the Phase II Project Consultation, please do not hesitate to contact us.

Congratulations and thanks again for participating in Renewable Energy Development Team program; we look forward to executing the **Phase II Project Consultation Kickoff Call** with you soon!

All the best,

Ryan Broshar
Renewable Energy Development Team
SRA International, Contractor to the Colorado Governor's Energy Office

Office: 303.233.1275 **|** Fax: 303.233.1392
Email: Ryan_Broshar@sra.com **|** Web: www.sra.com
12600 W Colfax Ave, C-440 **|** Lakewood, CO 80215

Micro Hydro Power Generation Workshop

Is Micro Hydro Right for you?

<u>When</u>: August 5th, 2011

<u>Time</u>: 1:00 PM to 2:00 PM

<u>Where</u>:

Natural Resources Conservation Service Center

2738 Crossroads Boulevard, Suite 104
Grand Junction CO 81506-8715

Please park on the street for this event.

<u>Cost</u>: Free!

<u>Please RSVP- Space is Limited!</u>

Email: events@icastusa.org or call 720-833-5592

<u>Agenda</u>:

- Micro Hydro Basics
- Micro Hydro Feasibility Process "Is micro hydro right for me?"
- Micro Hydro Technology Overview
- Case Studies of viable and not viable hydro sites
- Next Steps
- Q&A Session

<u>Sponsored by:</u>

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SMALL HYDRO FEASIBILITY PROCESS
&
CASE STUDIES

PRESENTATION BY:
RAVI MALHOTRA
iCAST

Feasibility Steps

Self Assessment: Technical Analysis

- Determining Water Rights
- Permitting: Federal, State, Local
- System Components

Self Assessment: Economic Analysis

- Site Survey: Flow Rate, Duration & Head
- Preliminary Economics

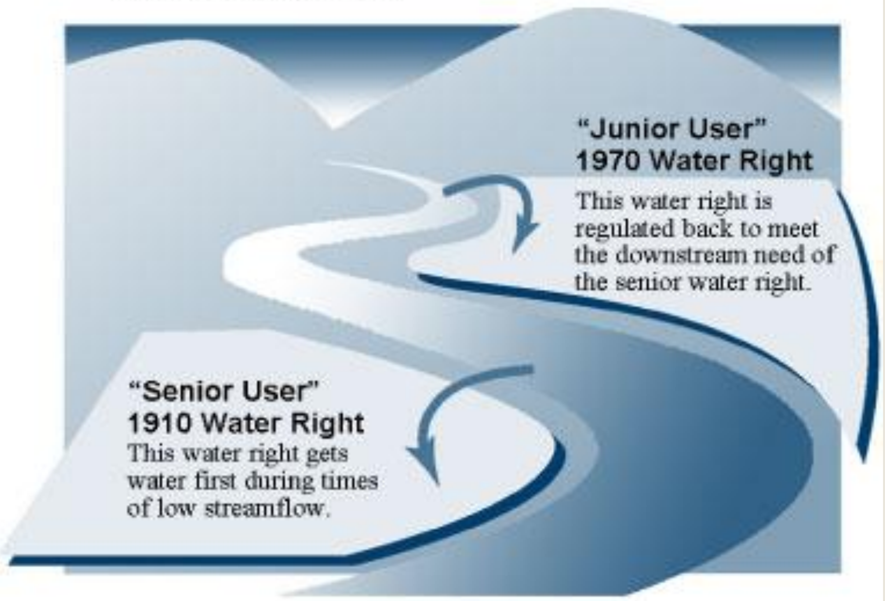
Professional Feasibility Study

- Present self assessment to developers and engineers to finalize the design, permitting and financing of a new micro-hydro site

Determining Water Rights

- Rule of Thumb for Appropriation: “First in time, first in right”
- Appropriation is the act of deriving water from its source and putting it to beneficial use.
- Water rights are:
  - Acquired through appropriation
  - A property right to use a specified quantity of the state’s water resource for a specific purpose.

Prior Appropriation: an example
“First in time, first in right”

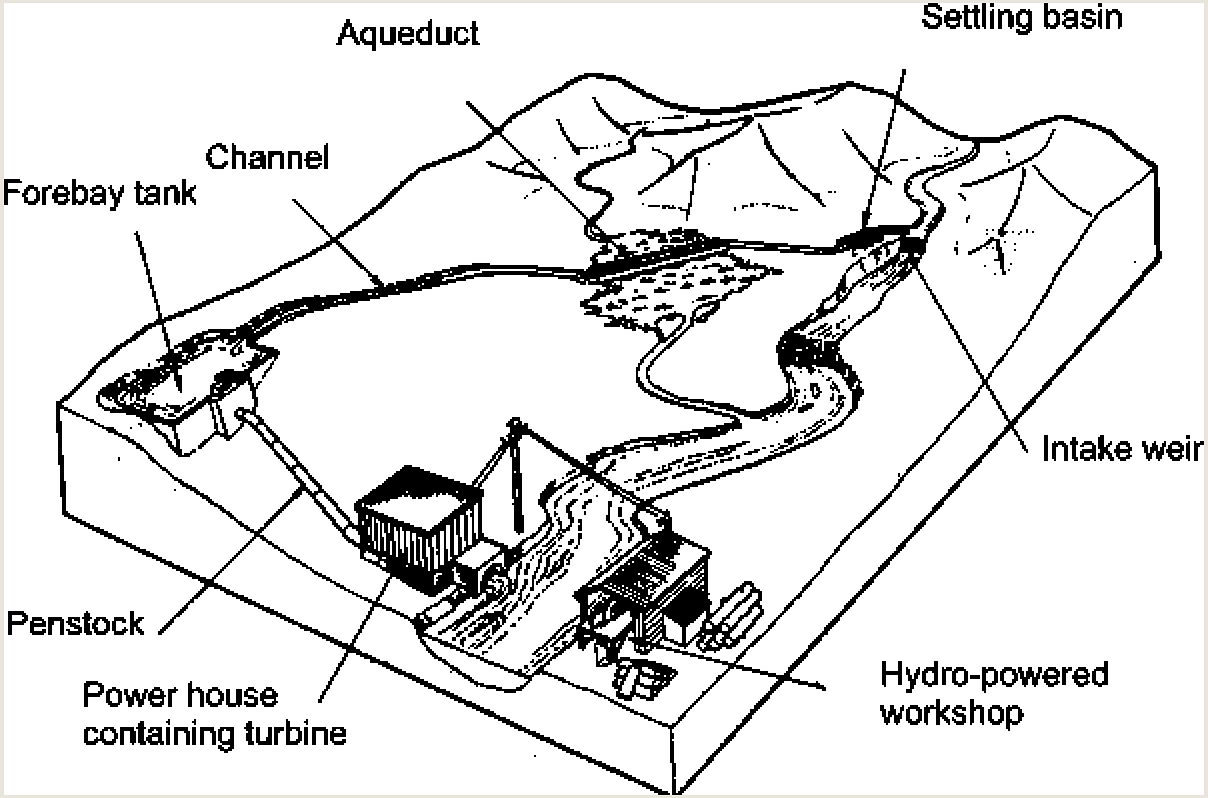


An example of prior appropriation at work
Prior appropriation ensures that the first water user to obtain water rights has first access to water in times of shortage. If a “downstream” landowner has the earlier priority date (they initiated their water right in 1910) the “upstream” landowner may have to let the water pass unused to meet the needs of the senior, downstream water right holder.

Permitting

- Federal Energy Regulatory Commission (FERC) exemptions:
  - Small megawatt exemption (less than 5MW)
  - Conduit exemption (utilize existing man-made hydrological structures)
- State and local permits

System Components



Site Survey: Flow Rate, Duration & Head

- Site Characterization
  - Water source: flow rate, pressure head, availability & potential power generated
  - Site location: proximity to access roads, power grid, vicinity to users, preexisting structures
- Use site characterization date to estimate the potential kW generated
  - Determines if the energy will be sold
    back to grid, or used onsite

Preliminary Economics

- Economic feasibility is evaluated using the potential power generated from the site survey
- Ballpark cost estimates:
  - Permitting, design, development, construction, implementation, operating & maintenance
- Financing: debt/equity, loans, grants & other incentives
  - Return on investment
  - Payback periods

Preliminary Economics

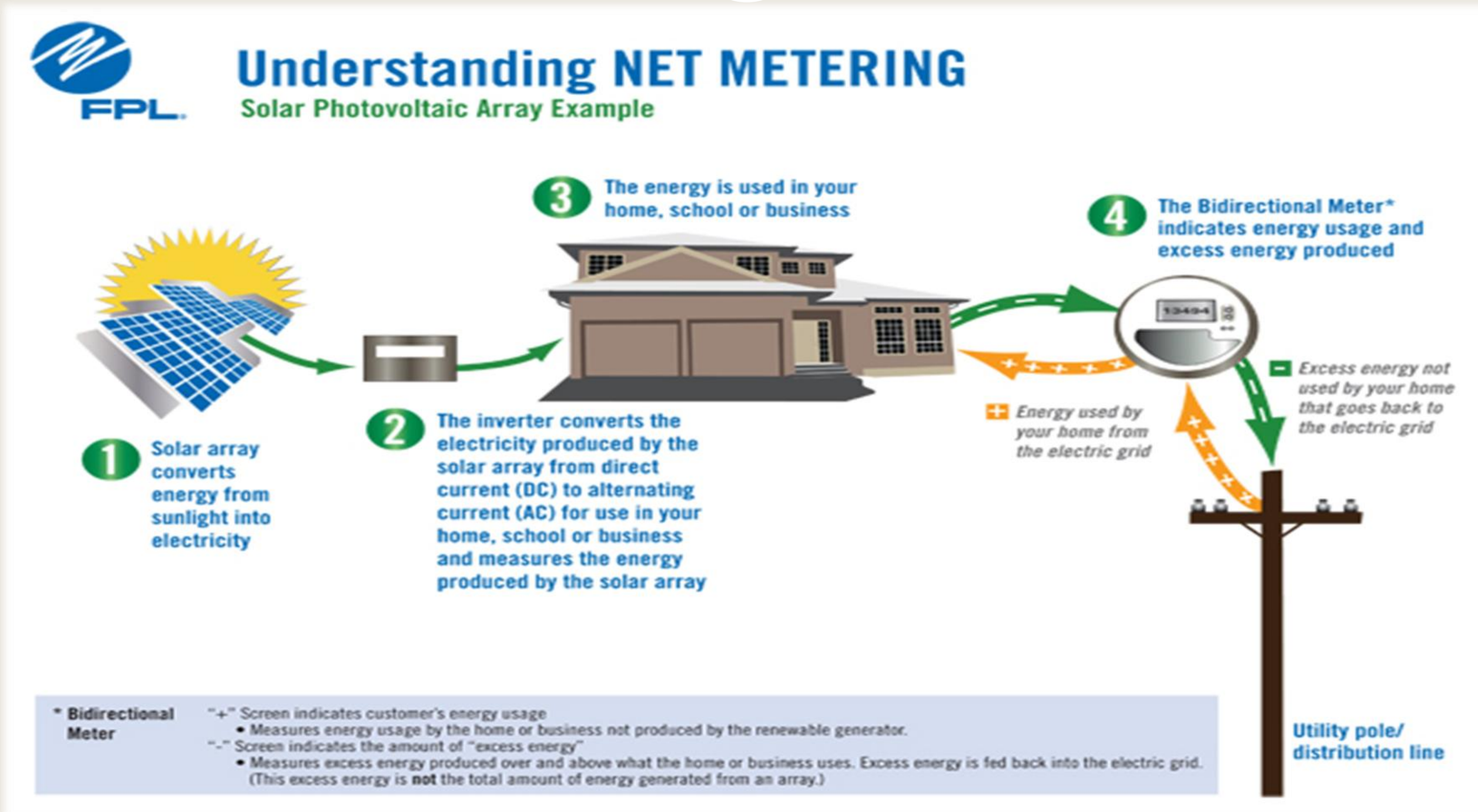
POWER ONSITE LOADS

- Micro-hydro power is typically generated April – October, when energy consumption is at a pick for agricultural use.

SELL BACK TO UTILITY

- Power Purchasing Agreements
  - Legal contract between site owner and utility
  - Negotiated all costs associated with project
- Net Metering:
  - Monitors renewable energy sold back to power grid

Preliminary Economics



Professional Feasibility Study

- If the site is technically and financially viable per the above process, then we suggest the site owner hire a professional who can help with the accurate:
  - Financial assessment
  - Technical assessment
  - Design
  - Permitting
  - Interconnect
  - Engineering
  - Procurement
  - Construction

International Center for Appropriate and Sustainable Technology

SMALL HYDRO POWER GENERATION:
SITE ASSESSMENTS

PRESENTATION BY:
RAVI MALHOTRA
iCAST

Characteristics of a Successful Site

- Utilizes preexisting infrastructure
- Site is easily accessible
  - construction
  - long term O&M
- Ability to obtain necessary permits
  - FERC exemptions
- Low Level of debris in system

Characteristics of a Successful Site

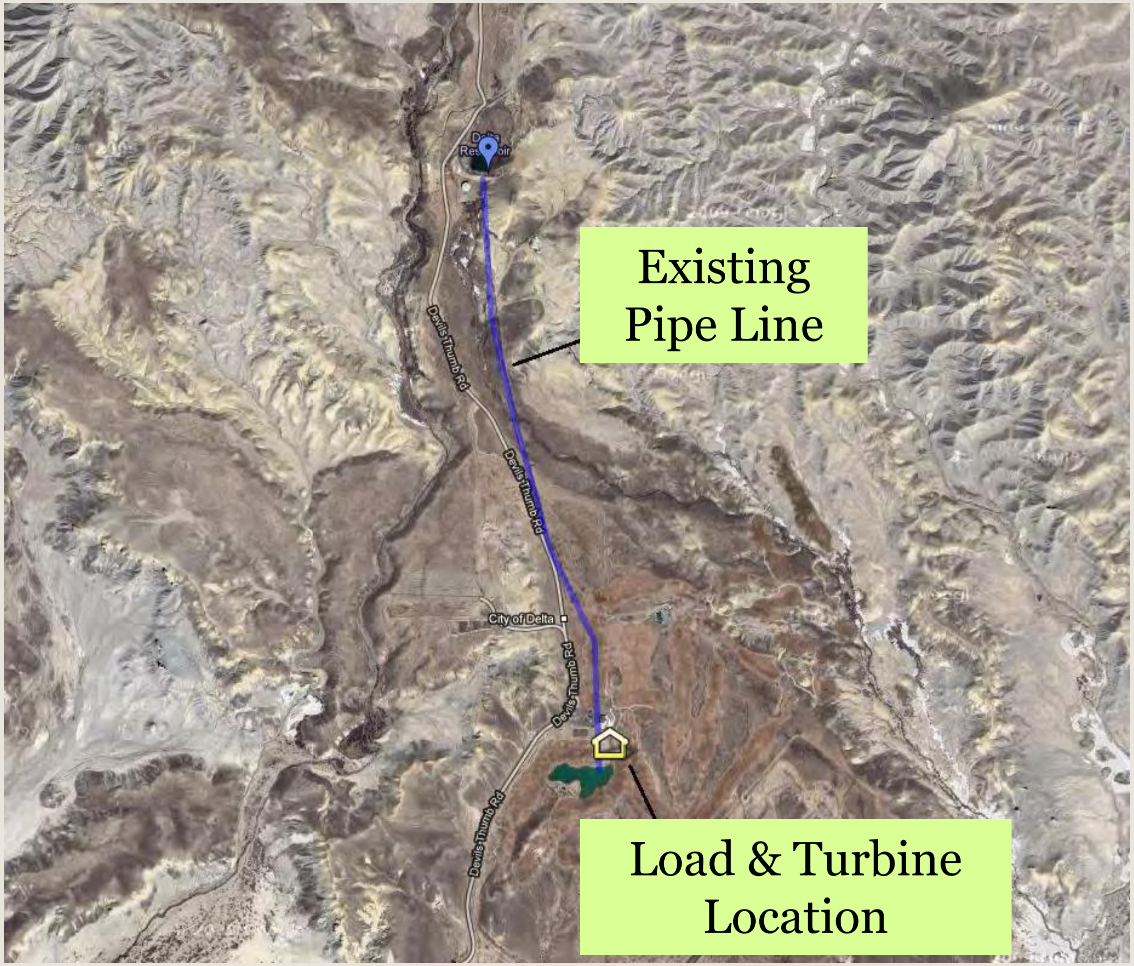
- Hydraulic Conditions:
  - At least five feet of vertical drop
  - Consistent flow rate and duration
- Proximity to Load or power grid
  - If you are measuring in miles you are too far
- Property ownership
- Motivation and Desire!

Case Study: Background

- Site Characteristics
  - Irrigation canal fed from a mountain reservoir
  - Western Slope
  - Head – 150'
  - Flow Rate – 1 cfs
  - Seasonal flow 8 months
  - Load will service irrigation system and additional facilities.

Reservoir

Case Study: Site Design



Initial Design

- 10 KW System
- 45,000 KW Hours
- Impulse Turbine
- Grid Tied – 100% Power used for own load

Case Study: Financial Analysis

Scenario 1

25% USDA REAP Grant
Offsetting Utility Cost at $0.10/KWH

Cap Ex	Grants/ Incentives	IRR	Pay Back
$73,000	$20,000	13%	8 years

Financial Analysis ($)							
	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7
Electrical Cost Savings	4,815	5,056	5,309	5,574	5,853	6,145	6,453
Cash Flow	12,526	10,146	7,370	6,299	6,577	4,066	3,971

Case Study: Financial Analysis

Scenario 2

No Grants

Offsetting Utility Cost at $0.10/KWH

Cap Ex	Grants/ Incentives	IRR	Pay Back
$73,000	**$2,000**	**6 %**	**15 years**

Financial Analysis ($)							
	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7
Electrical Cost Savings	4,815	5,056	5,309	5,574	5,853	6,145	6,453
Cash Flow	1,379	8,999	6,223	5,152	5,431	2,919	2,824

Case Study: Financial Analysis

Scenario 3

25% USDA REAP Grant

Selling to Utility at $0.045/KWH

Cap Ex	Grants/ Incentives	IRR	Pay Back
$73,000	$20,000	2 %	19 years

Financial Analysis ($)							
	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7
Electrical Cost Savings	2,234	2,345	2,463	2,586	2,715	2,851	2,994
Cash Flow	9,944	7,435	4,524	3,311	3,440	771	512

Case Study: Financial Analysis

iCAST community powered results.

Scenario 4

No Grants

Selling to Utility at $0.045/KWH

Cap Ex	Grants/ Incentives	IRR	Pay Back
$73,000	**$2,000**	**-4 %**	**N/A**

Financial Analysis ($)							
	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7
Electrical Cost Savings	2,234	2,345	2,463	2,586	2,715	2,851	2,994
Cash Flow	8,798	6,288	3,377	2,164	2,293	(375)	(635)

Case Study: Financial Analysis

Scenario 5 – Alternative Technologies

2 - 2 KW Stream Engines

Offsetting Utility Cost at $0.10/KWH

Cap Ex	Grants/ Incentives	IRR	Pay Back
$10,000	$00.00	55 %	2 years

Financial Analysis ($)							
	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7
Electrical Cost Savings	4,815	5,056	5,309	5,574	5,853	6,145	4,815
Cash Flow	5,545	5,425	5,262	5,344	5,623	5,530	5,545

Emerging Technologies

Energy Systems & Design Stream Engine

- Flows up to ~0.4 cfs
- 10-500 feet of head
- Generate 20-2000 W
- $3,000 per unite

Linear Hydroengine

- 20-1100 cfs
- 3 to 25 feet of head
- 20 to 1000 kW power generation
- ½ the price of Turbines

Emerging Technologies

Axial Propeller Small Turbine10-500 feet of head

- 1.1 cfs flow
- 2 feet of head
- Up to 1kW
- $3,200 per unit

Axial Flow Helical Turbines

- Currently in research stages
- Low Head
- Originally designed for harnessing tidal power

Grants, Incentives, & Rebates

Incentives & Rebates

Federal

State

Local

Utilities

www.dsireusa.org

Grants

- USDA - REAP Grant
  - 25% of project cost
- USDA - CIG Grant
  - Up to 50% of project cost
- US Treasury ITC
  - Up to 30% of project cost

THANKS

QUESTIONS?

Hydro Guidebook available at

http://www.icastusa.org/resources.html

Ravi Malhotra, President

RaviM@iCASTusa.org

A Practical Approach to Micro-Hydro Power in Colorado

An Educational Outreach Guidebook

2011

iCAST

community powered results.

This guidebook was developed with the following partners

Painted Sky RC&D Council, Inc.

Funded by:

The Colorado Department of Agriculture

Table of Contents

Preface

This guidebook is designed to introduce the basics of micro-hydro. It will take you step by step through the process of identifying if a micro-hydro facility is right for you. There are a total of seven steps throughout the book including:

1. **Site Survey:** This section looks at the factors to be considered in determining a location for a hydropower facility.
2. **Potential Power Calculations:** This is a short section showing a method of calculating how much power you can expect a site to generate.
3. **Preliminary Economics:** The third step emphasizes the importance and method of analyzing the project's viability from the financial perspective, which is called the financial feasibility of a project. It also suggests ways to finance the project.
4. **Permitting:** As the name suggests, the fourth step describes the different permits you may be required to obtain in order to legally run or administer a hydropower facility.
5. **Design and Components of the System:** This section includes detailed, technical explanations about the system's components, functions, and more.
6. **Construction and Commissioning:** This step focuses on the construction of the generator.
7. **Operations and Maintenance:** Whenever machineries are involved, a thorough understanding of operation and maintenance is crucial. Included in this section is detailed information that will ensure the proper functioning of your system.

NOTE: This guide is not intended as a comprehensive design or technical document. It was created solely for educational outreach purposes. Professional services and consultations on the assessment and design of a micro-hydro facility are recommended.

Introduction to Hydropower

Figure 1: Hoover Dam

Man has been harnessing the power of water for millennia. Water wheels and mills have been put to a variety of uses since ancient times. In the 19^{th} century, with the advent of electricity, people began to use the force of water to create electricity, first in Northumberland, England, in 1878.

Today, there are dozens of large hydroelectric facilities such as Hoover Dam in Nevada and thousands of other small hydroelectric facilities worldwide. According to the Department of Energy, these facilities provided 2,998 billion kilowatt hours of clean and renewable energy in 2006, approximately 20 percent of worldwide demand. (1) Most of this was undoubtedly from the larger facilities, but, recently, micro-hydro facilities have begun to grow in number. Given a sufficient flow rate, micro-hydro power stations can be built on small streams, creeks and canals to help provide clean energy for small communities. These facilities have a much lower environmental impact than their larger counterparts and typically consist of a small diversion of water used to turn a turbine and generate electricity. As such, they often do not require a dam. In many cases, these facilities are profitable investments. But where you begin if you are interested in having a micro-hydro facility on your property?

Step 1 - Site Survey

The first step in determining if micro-hydropower is the right technology for you is to conduct a site survey. The goal of a site survey is to estimate the flow rate, duration of flow and head (or elevation drop) of the site. This information is needed to determine the potential power for the given site and it will also allow you to perform a preliminary economic analysis. Additionally, vendors need this information to identify the right equipment for site conditions. This document may be useful in the field when conducting a site survey. There may be other ways to determine a good location and the calculation of these factors. In either case, you will it helpful to start with the basics.

a. Hydrology: Flow Rate and Duration

The ***hydrology*** of a site is the amount of water that flows through the site and the length of time the water flows during the year. Of the two, determining the length of time that water flows at the site is easier to establish. An important factor is whether the site freezes or runs dry at any point. For instance, if water at the site is available only from April-October due to irrigation timing, then the flow is available seven out of 12 months. The more specific you can be in collecting the data, the more useful the data will be in the long run.

There are several methods for measuring the flow rate of the ditch or stream. The University of Arizona has written a field guide entitled, "Measuring Water Flow in Surface Irrigation Ditches and Gated Pipe" which outlines several methods that can be used to determine flow quantity. (2) The link to the full document, along with a similar reference guidebook, published by Canyon Hydro, is listed at the back of this guidebook in the Additional Resources. The first and most easily implemented of the methods is the float method - described on pages 2-6. Other methods are outlined in the text and may also be useful for determining the flow of a ditch or stream.

b. Evaluation of Head: Elevation Difference

The ***head or elevation difference*** of the site is the height the water falls from the drop site. Elevation differences can be measured with a tape measure or some sort of measuring device. For instances where elevations drop over long distances, it may be necessary to survey the difference. For more information on measuring elevation changes, the website www.energybible.com is a useful resource. (3)

Step 2 - Potential Power Calculations

Figure 2: Micro-Hydro Facility

After gathering data from a site survey, the results can be used in the second step to calculate the potential power available at the site. Determining the potential power of the site allows for a quick evaluation of the possible costs of installing and maintaining the equipment in comparison to the possible revenue of selling the power or offsetting power purchased for use on site. Power calculations depend on the site's available head and flow rate. After completing the site survey, potential power can be calculated using Equation 1, as follows. The constant number, 11.82 accounts for the unit conversion from meters to feet, the conversion from watts (W) to kilowatts (kW), the gravitational constant and the density of water. (4) Equation 1 also considers imperfections in the system by including a system efficiency factor. As a conservative estimate, the constant 0.7 represents an assumed turbine efficiency. For these reasons, Equation 1 is only an estimate of the potential power for low head hydro systems.

Equation 1:

$$Potential\ Power\ (kW) = \frac{(Water\ Flow\ Rate\ in\ cfs) \times (Availabe\ Head\ in\ ft) \times (0.8)}{(11.82)}$$

Step 3 - Preliminary Economics

After performing the preliminary technical evaluation above, the third step is to consider the project's financial feasibility. The preliminary economics section addresses: ballpark cost estimates, potential funding, net metering and power purchasing agreements.

a. Ballpark Cost Estimates

The Additional Resources section of this guidebook contains an Anticipated Expense Spreadsheet to assist potential site owners in estimating the full cost of installing a micro-hydro system. The worksheet breaks down capital and operating costs into ***soft expenses, hard expenses*** and ***revenue generated***. Not every system will include all of the expenses or revenues listed. Rather, the spreadsheet is meant to encourage potential site owners to consider all of the prospective expenses and revenues available to them. (5)

Expenses: Soft Costs

- Feasibility Study – Include any costs associated with studying the feasibility of the project, such as expenses incurred in obtaining necessary 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 all 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 the 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.
- Licensing – Include any costs associated with obtaining a FERC license or exemption, or a Lease of Power Privilege from USBR.

Expenses: Hard Costs

- Turbine and Switchgear – Include all costs associated with the turbine and switchgear equipment. This is often provided by the supplier of a turbine.
- Structure and Foundation – Include all costs associated with upgrading a building or constructing one to house the turbine.
- Excavation, Pipe Connection and 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 for the proposed hydroelectric facility.
- Electrical Work – Include any costs associated with providing electrical service for the turbine, generator and switchgear equipment.
- Utility Grid Connection – Include any costs associated with connecting the turbine generator equipment to the utility grid. Be sure this includes any upgrade or extension of transmission lines.
- Labor – Include any labor costs not included in other line items.
- Installation – Include any costs associated with equipment installation, including crane costs.

- Contingency – It is recommended that a contingency factor be included, reflective of the level of uncertainty in budget numbers. The contingency should be reduced as more detail is known about the project. For example: you would expect a relatively high contingency in the feasibility stage and a much lower one following a detailed project design and permitting.

Because micro-hydro systems present a significant capital cost, it is important to consider the lifetime of the project. Return on Investment (ROI) is the most important aspect to the cost analysis for the site. If there is no positive ROI, the chances of implementation are slim. ROI is the difference of cash outflows (i.e., the investment) required for the project and the cash inflows (i.e., gains from the investment). ROI is expressed as a percentage of the amount of investment made.

Equation 2:

$$ROI = \frac{Gain\ from\ Investment - Cost\ of\ Investment}{Cost\ of\ Investment} * 100\%$$

Payback periods (PP) assess the amount of time it takes to earn back the capital investment. Payback periods are calculated using the ROI values calculated and assessing the amount of time it takes for the ROI to reach zero.

Equation 3:

$$PP = \frac{Cost\ of\ Investment}{Annual\ Gain\ from\ Investment}$$

b. Potential Funding

There are several potential funding options available for micro-hydro projects. Project site developers can generate equity from outside investors, or invest their own money, or use secured or unsecured debt, or apply for a grant. Additionally there are several state and federal incentives for developing renewable energy. The Department of Treasury offers grants to site owners who initiate construction by December 31, 2011. The United States Department of Agriculture also offers grants and loans. The Colorado Water Conservation Board and Colorado Water Resources and Power Development Authority solicit grants for feasibility site assessment (up to $15,000) and 2-percent loans to up $2 million for site implementation. (6)

The Database of State Incentives for Renewables and Efficiency (DSIRE) provides a comprehensive list of state, local, federal and utility incentives and policies that promote energy efficiency and renewable energy. Each financial incentive listed on the DSIRE website http://www.dsireusa.org/ includes an outline and a brief description, as well as contact information for the rebate. DSIRE is funded by the U.S. Department of Energy and is affiliated with North Carolina Solar Center, North Carolina State University and the Interstate Renewable Energy Council. (7)

c. Net Metering

Net metering is a consumer-based renewable energy incentive which monitors the renewable energy a project feeds back into the power grid. The term "net" refers to the excess energy that is produced, above and beyond the energy that is used on-site. The power generated by the customer offsets the electricity they would have purchased from the utility. (5) The owner accumulates “in store credit” from the utility which counts toward reducing his electricity bill. Net metering also includes “roll over” energy credit from month to month. An electricity meter accurately monitors both the electricity produced by the micro-hydro system, as well as any electricity consumed. This fluctuation in production and consumption varies with peak and low flow rates. Under the Energy Policy Act of 2005 (Section 1251), all public utilities in the United States are required to make net metering available upon request to their customers. (8) So this arrangement is a potential option for all micro-hydro sites. Figure 3 illustrates the process of net metering using solar power as its renewable energy source.

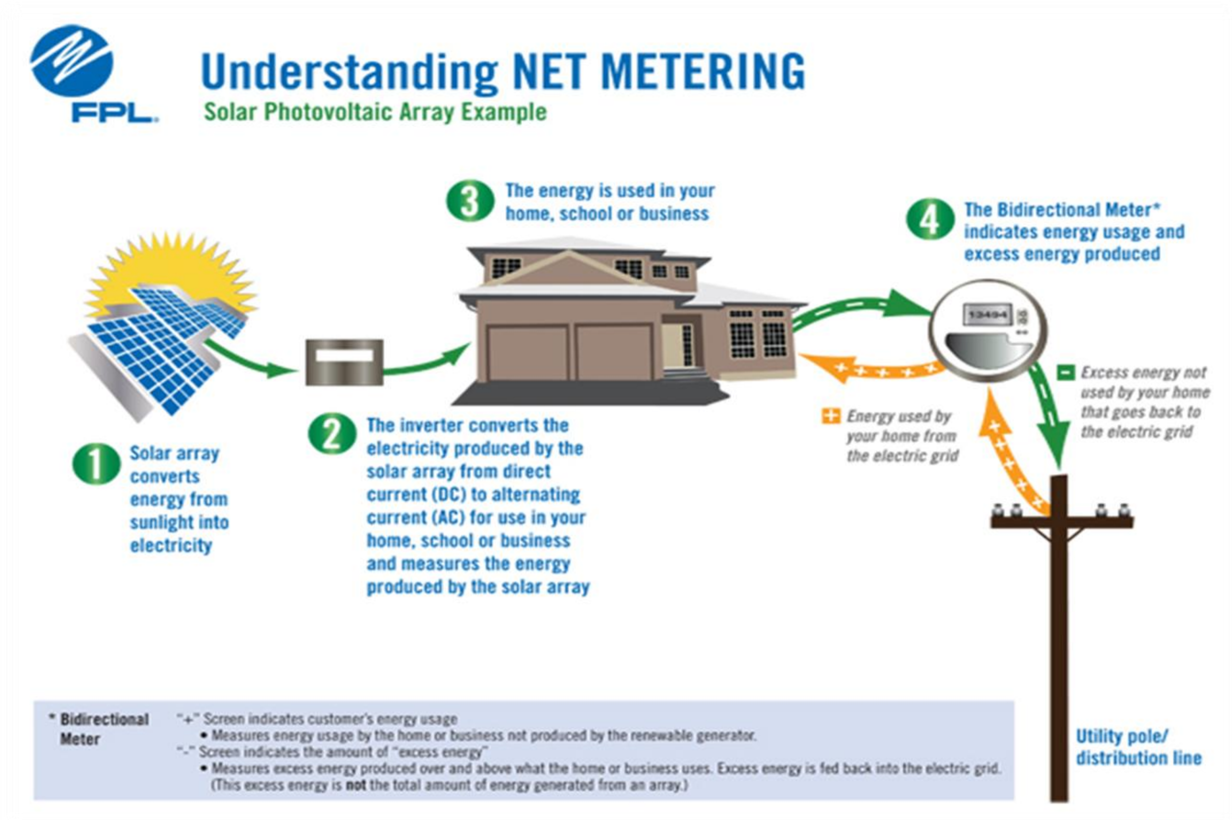


Figure 3: Net Metering (9)

d. Power Purchase Agreements

Project financing can also be obtained by selling the renewable energy generated back to the utility through a ***Power Purchase Agreement (PPA)***. A PPA is a contact between the utility and a site owner. The utility is specified as the power purchaser, or buyer, and the site owner as the independent power producer, or provider. A PPA includes an explicit description of all costs associated with the project, a clear specification of which entity owns the renewable energy credit, and other costs deemed reasonable by both parties. The price (per kilowatt of renewable energy) that the utility company will offer is a function of the amount of power produced, when the power is produced (year round vs. seasonally), the reliability of the energy source, and how the utility company values renewable energy credits (REC).

Step 4 - Permitting

When a project has been deemed technically and financially feasible, the fourth step is to address project permitting. Most micro-hydro projects require some form of permitting. This portion of the guidebook is meant to serve as an overview of the permitting process, and to further direct you to other documents. In the references section of this guidebook you will find links to several FERC and USBR permitting resources.

a. Federal Energy Regulatory Commission (FERC)

A license from the ***Federal Energy Regulatory Commission*** (FERC) is required for all non-federal projects that would:

1. Occupy U.S. lands
2. Be located on navigable water of the U.S.
3. Utilize surplus water or water power from a U.S. government dam
4. Be constructed on a stream over which Congress has Commerce Clause jurisdiction, where project construction or expansion occurred on or after August 26, 1935 and the project affects the interest of interstate or foreign commerce.

Because permitting can be a lengthy process, it may be beneficial to file for a FERC Preliminary Permit. The Preliminary Permit "reserves" the site for the applicant and allows the owner three years to evaluate the feasibility of the site and apply for a license. Periodic reports on the status of the feasibility studies are required to maintain a Preliminary Permit. (10) Many micro-hydro projects qualify for one of two FERC exemption permits which simplify FERC processing. Applicants for either type of exemption are required to have all real property interests (or an option to obtain the interest) and cannot occupy federal lands.

1. *Conduit exemptions* apply to hydro projects which produce up to 15MW of electricity (or up to 40MW of electricity for a municipal project) that utilize existing man-made conveyance structures.
2. *Small megawatt exemptions* are issued for projects which produce less than 5MW. The applicant may install or add capacity to a natural water feature or pre-2005 dam.

Figure 4: Pre-existing Hydrological Structure

FERC licenses are issued for fifty years and must be renewed at the end of each term while a FERC Exemption is issued in-perpetuity. (11) The Colorado Governor's Energy Office, Renewable Energy Development Team offers up to 120 hours of free assistance to site owners who quality for the above FERC exemptions. Contact information for the Energy Office is listed under the Additional Resources section of this guidebook.

b. Lease of Power Privilege – Bureau of Reclamation

A lease of power privilege (lease) is a contractual right given to a non-federal entity to use a Reclamation facility for electric power generation consistent with Reclamation project purposes. A lease is an alternative to federal power development and is used where Reclamation has authority to develop power on any or all features of a federal project. This authority is usually found in the authorizing legislation for the project but can also be found in congressional reports and documents.

A. The lessee is responsible for any state or federal environmental planning or certification and for the design, construction, operation, and maintenance of the power plant facilities and transmission facilities, if required, unless contracted otherwise. Access by Reclamation to its facilities must be maintained at all times during construction, operation, and maintenance of the power plant facilities.

B. Reclamation will review and approve all designs, plans, specifications, environmental documentation, and related materials associated with the proposed power plant facilities. Such reviews will be to the level of detail necessary to ensure environmental compliance and that the structural and operational integrity of the Reclamation project is not impaired by construction, operation, or maintenance of the lessee's power plant facilities.

C. Power plant construction, operation, and maintenance must not interfere with construction, operation, and maintenance of the Reclamation project; nor must it jeopardize water rights, water quality, federal power sales and deliveries, or environmental commitments. In addition, it must not create any safety or security problems. Reclamation will inspect the power plant and related facilities to the extent necessary to ensure the continued safe operation and structural integrity of Reclamation facilities. Reclamation retains the right to determine if activities impair the purposes of the project, and if such a determination is made, the lessee shall make appropriate modifications within a reasonable time. The lessee will be required to compensate Reclamation and/or other project users for lost generation and other interruptions to operations at Reclamation facilities due to the operations and maintenance of the lessee's facilities.

D. Physical security of existing facilities shall be maintained by Reclamation, or its designee, during construction, operation, and maintenance activities. The lessee shall not interfere with Reclamation security activities and will be subject to access controls, searches and background investigations, as deemed necessary by Reclamation, to maintain the physical security of Reclamation facilities. The lessee will be responsible for any security costs incurred by Reclamation as a result of the lessee's power plant. The lessee shall be required to have security practices commensurate with Reclamation security practices.

E. National Environmental Policy Act (NEPA) and Endangered Species Act (ESA) compliance will be the financial responsibility of the lessee and will be completed prior to execution of the lease. Terms and conditions resulting from NEPA and ESA compliance will be incorporated in the lease. The adequacy of NEPA and ESA compliance will be determined by Reclamation.

F. Reclamation will not be responsible for the economic and technical feasibility of the lessee's power plant facility. The lessee must agree to indemnify the United States for any injury, loss, or damage resulting from actions under the lease and any negligent act or omission of the lessee in connection with its performance under the lease. The lessee shall have no claim against the United States for loss of generation caused by the normal or extraordinary operation and maintenance of the Reclamation project including, but not limited to, the quantity, quality, or timing of water delivered by the Reclamation project. The lessee will be required to modify operations if future legislation modifies the project purposes.

c. Other Federal, State & Local Permits

Additional federal, state and local permits may also be required for implementation. Permitting specifications on the federal, state and local level will be different for each site. Depending on the site specifics, a potential list of permits may include: (5)

Federal:

Army Corps of Engineers, Section 404 permit
U. S. Fish and Wildlife, Threatened and Endangered Species Consultation
U. S. Forest Service, Special Use Permit

State:

State Engineer Office, dams and water rights
Colorado Department of Health and Environment, Section 401 permit

Local:

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

d. Water Rights

The current system of water rights in Colorado originated historically from western settlement. For the first settlers, the law was simple: first come, first served. This basic rule best describes the heart behind Colorado's current prior appropriation system: first in time, first in right. Appropriation is the act of deriving water from its source and putting it to beneficial use. A water right is acquired by appropriation and is independent of land ownership. A water right is a property right to use a specified quantity of the state's water resource for a specific purpose. It can be sold, leased or rented. Water rights are subject to abandonment, or can be lost if the resource is not going toward proper

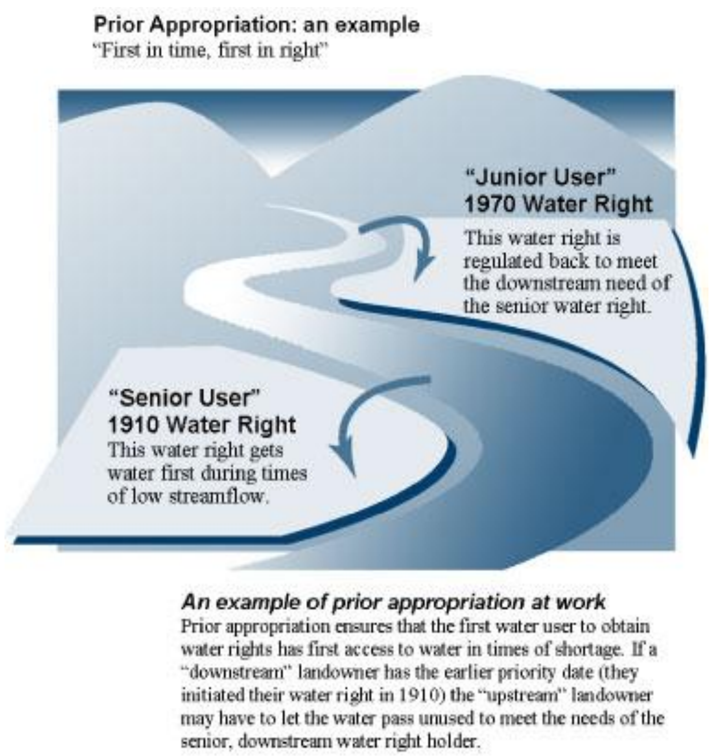


Figure 5: Water Rights in Colorado

beneficial use. (12) The oldest rights have the most priority, and receive the first allocations of water shares. Seniority trumps equity in an appropriation system. (13)

Some micro-hydro projects are passive systems, and can therefore fall under non-consumptive water right permits. The power generated by these micro-hydro systems are incidental. If water rights for the site are not specified as "non-consumptive," the decree needs to be changed to avoid legal issues. This can be simply done through a petition to the Colorado Division of Water Resources. For the water rights that are already owned, another beneficial use (non-consumptive use correlated with hydropower generation) will need to be added. This will allow for the site owners to legally use the water in their ditches for hydropower generation. Owners need to be mindful of two requirements for stream flow when determining the feasibility of a micro-hydro system. (14)

1. Minimum inflow stream requirements. The in-stream flow requirement is the minimum level of water that is legally required to flow in the river/creek/stream at any given time.
2. Minimum flow requirements for hydropower. The minimum quantity of water required to maintain sufficient power generation must be considered in light of the minimum inflow stream requirements. Power generation is subject to the available pressure head, flow rate and availability.

As stated, a water right is decreed for a specific beneficial water use, a specific amount of usage, and at a specific time of year. If a user deviates from these specifications at all, he is violating his water right, and another stakeholder (water right holder who is affected by the user's actions) can sue the user for incorrect diversion, or the user may be audited by the State Engineer. It is therefore extremely important to make sure that water rights are being followed. This is especially true for farmers, because much of their livelihood depends on their access to a supply of water. If the sites do not have year-round water rights, power cannot be generated all through the year. In order to maintain year-round generation, an additional water right needs to be acquired. A petition will need to be filed with the Colorado Division of Natural Resources to obtain a winter, non-consumptive 2011 water right. This water right will be junior to all previous water decrees.

Step 5 - Design & Components of the System

The design of each micro-hydro system depends on the specific conditions of each individual location. However, to provide a context for design, the components of a typical micro-hydro system are presented. Many micro-hydro projects are considered "run of the river" systems when they operate within the natural confines of water flow. Run of the river operations do not require a dam or the storage of water. The main components of a generic run of the river system are illustrated in Figure 6.

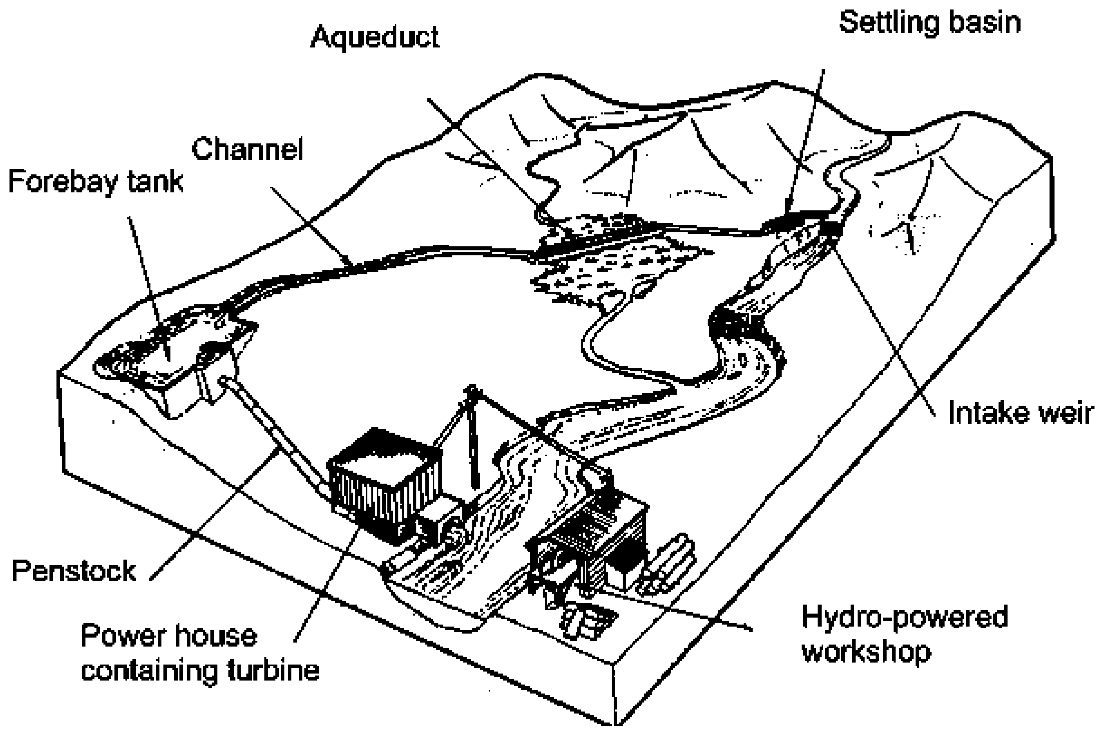


Figure 6: Run of the River System Components (15)

Each hydro project is unique, and a site specific design must be developed as a local solution. Not all hydroelectric projects will require all of the components, as shown in Figure 6. The system components (civil works, turbines, generator, switchgear protection and transmission) are discussed as follows to provide a general understanding of micro-hydro subsystems.

a. Civil Works (15)

Settling Basin

The diverted water will likely carry suspended solids or particles in the water. Settling basins allow suspended materials such as sand, gravel, sticks, leaves or other debris to be removed before the water enters the mechanical portion of the system. Periodically, it will be necessary to remove the settled debris from the basin. This maintenance can be performed in the off seasons of production, or during the winter months.

Canals

The canal transports water from the natural source to the forbay tank. In Figure 6, the aqueduct and channel are both components of the canal network. Canal length and width is an optimization of reducing friction losses (head loss) and reducing construction costs. The longer the canal, the more frictional losses from water flow. Canals can be sealed or open depending on local conditions.

Forbay Tank

Similar to the settling basin, the forbay tank allows for any remaining fine particles (sand, silt, gravel) to settle before entering the penstock. Screens or sluice gates can be installed in the inlet and outlet channels to reduce the transport of debris downstream. The screen can be cleaned with a rake as needed.

Penstock

Figure 7: Penstock

The penstock is a pipeline which transports pressurized water from the project forebay to the turbine. This subsystem represents a major expense in the civil works of a hydropower system. Similar to canals, the final project design represents a balance between cost and performance. For penstock, price increases with the diameter of the pipe. However, an increase in diameter decreases frictional head losses in the water.

Turbines

Hydropower turbines are characterized as either an impulse type, or a reaction type. Kaplan and Crossflow turbines are best suited for micro hydro projects that operate under low head conditions. Several impulse and reaction turbines are explained briefly below to provide a comprehensive perspective on hydropower turbine selection. In the end, available flow rate and head are the two most important technical metrics in determining the type of turbine. (15)

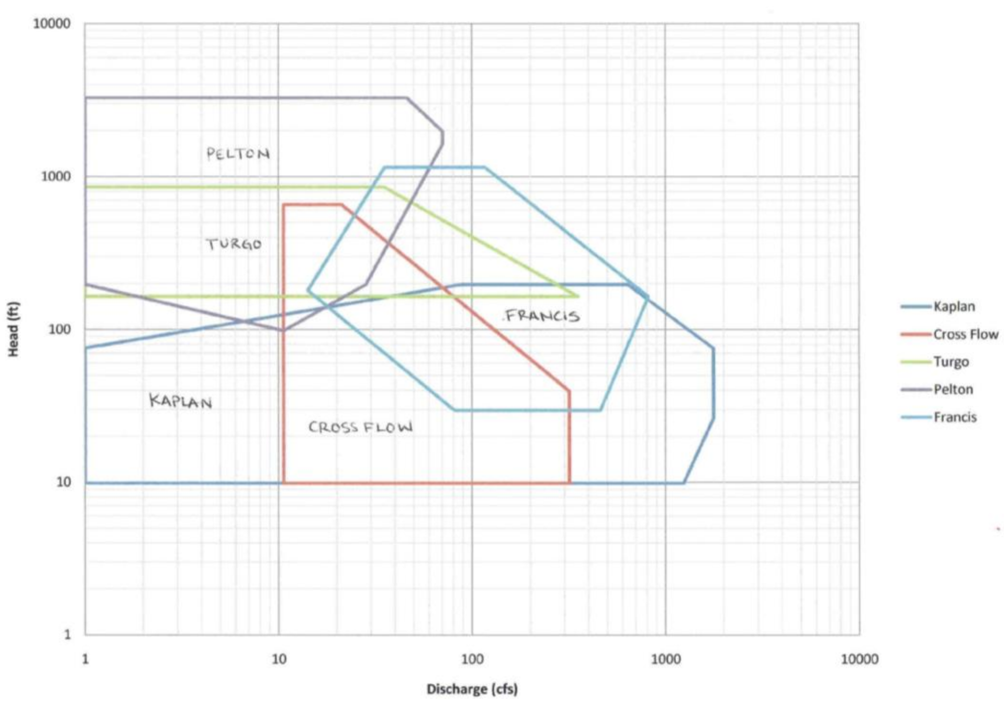


Figure 9: Turbine Selection Chart (6)

The Turbine Selection Chart in Figure 9 compares flow rate and head with respect to each turbine discussed. The Turbine Selection Chart provides an initial comparison between designs. The combination of available head and water flow rate characterize the stream flow for potential hydroelectric power and correspond to an appropriate turbine. Choosing the appropriate technology encompasses more than just selecting the correct turbine. There are a variety of nontechnical factors which should be considered such as, cost, availability, maintenance, and more.

➢ *Impulse Turbines: Pelton, Turgo, Crossflow*

Impulse turbines can be conceptualized as similar to paddle wheel machines. There is a central disc which is mounted on a shaft. Along the edges of the disc are several buckets or paddles which get pushed by the flow of water. When the water moves the turbine, kinetic energy from the stream is converted to shaft power. The Pelton, Turgo and Crossflow turbines can be characterized as impulse turbines.

A Pelton Turbine has a central disc with several paddles mounted around the edge. A Turgo Turbine is essentially an adapted Pelton turbine for faster moving currents. Because Turgo turbines operate in swift waters, they typically have a smaller-in-diameter disc. Turgo and Pelton Turbines can be assembled in either a horizontal or vertical shaft orientation.

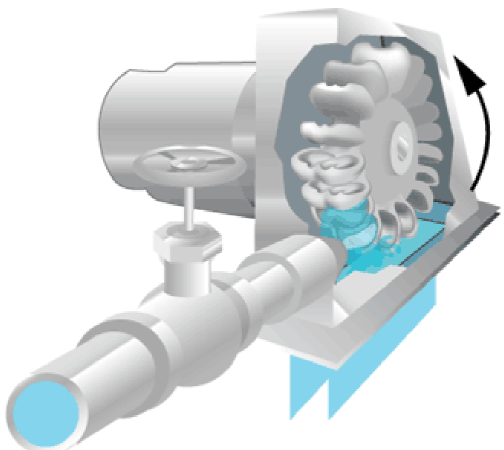


Figure 8: Pelton Turbine (16)

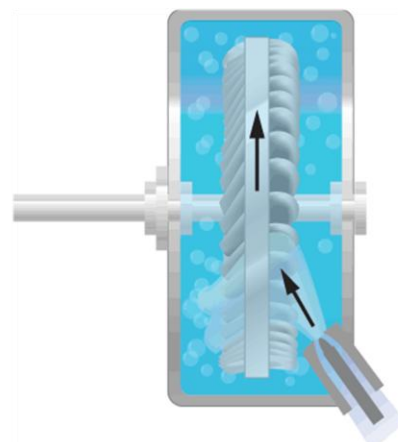


Figure 9: Turgo Turbine (16)

Cross flow turbines are specifically designed to be used in a horizontal shaft orientation. Water flow is channeled up around the wheel, following the perimeter of the discs' curvature. This maximizes the surface area and contact time of the water with the buckets, increasing efficiency and power production. Cross flow Turbines offer variability in flow because the required intake channel can be opened or closed. This variability in design allows the owner to control and maximize turbine efficiency.

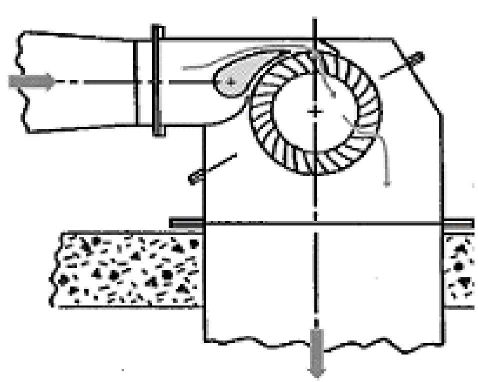


Figure 10: Crossflow Turbine (17)

➢ *Reaction Turbine: Francis, Propeller, Bulb, Kaplan*

Reaction turbines are fully submerged in the water flow. They produce mechanical energy by harnessing the water kinetic energy, angular momentum and linear momentum. Essentially, reaction turbines utilize the stream velocity and head to generate shaft power.

Francis turbines can be arranged as either a horizontal or vertical shaft unit. The spiral casing is an intake which decreases steadily in diameter as it reached to runner. Spiral casing equalizes flow anomalies as well as assuring a uniform distribution of flow. The water exits through the draft tube axially from the runner.

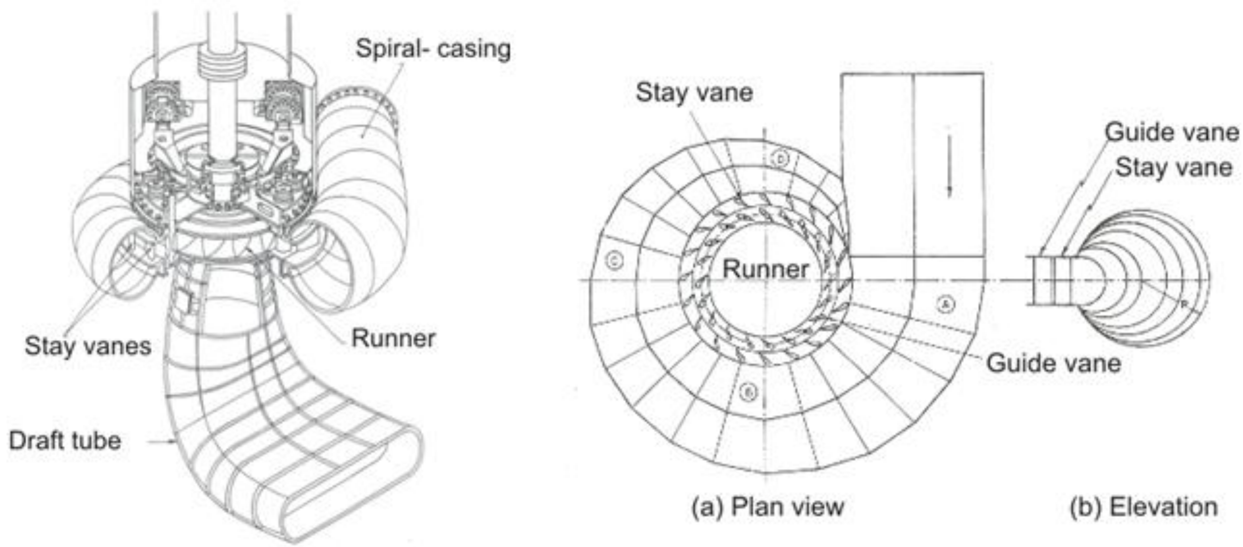


Figure 11: Francis Turbine (18)

A propeller turbine is oriented axially inside penstock tubing. The propeller typically consists of three to six blades, which are oriented at a fixed angle. Propeller turbines are very sensitive to variations in flow, and efficiency rates are critically dampened when the penstock is not operating at full capacity.

Bulb and Kaplan turbines are specialized types of propeller turbines. Both types of turbines are suited for low head, high flow rate systems. However, the Bulb turbine is more popular because the intake (penstock) normalizes and improves flow characteristics for hydropower generation. This translates to a smaller unit and a cost savings over a Kaplan turbine. Bulb turbines are also used to generate hydroelectricity with tidal power. The Kaplan turbine operates with a vertical shaft. This design adjusts to a wide variability of flow without compromising efficiency by changing the pitch of the blades.

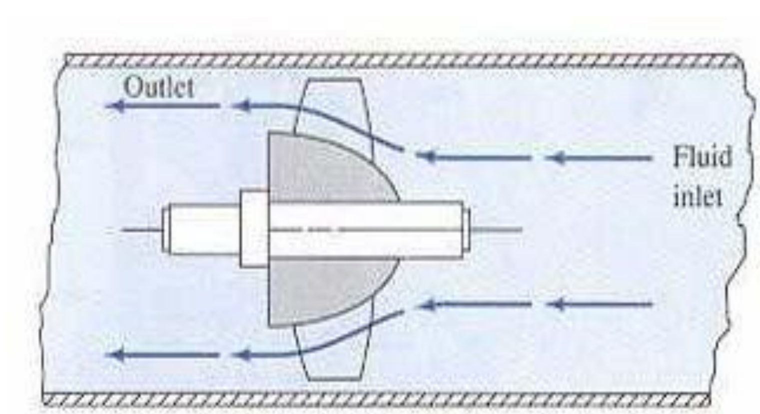


Figure 12: Propeller Turbine (15)

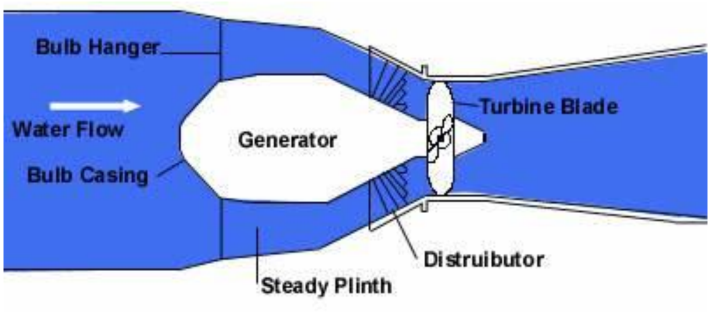


Figure 15: Bulb Turbine (19)

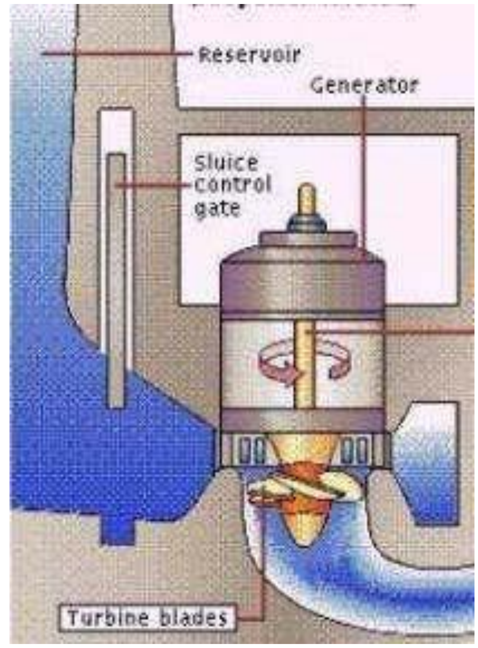


Figure 16: Kaplan Turbine (15)

b. Generators

Generator selection depends on type and proximity of a power source. Induction type generators usually must be connected to the electrical grid. Synchronous type generators can be connected to the grid, or operated as independent system. If a synchronous generator is used in connection with the electrical grid, the speed is constant. (15)

c. Switchgear

Switchgear refers to the fuses, circuit breakers and other electrical equipment that isolate the hydroelectric power system from the grid. Switchgear is required to properly interconnect the hydropower system to the power grid. Its primary functions are: to de-energize electrical equipment for maintenance, combine sources to feed a load and monitor and correct aberrations in electrical equipment operation.

d. Transmission

Unless the project is in a remote location and off grid, it will require a connection to the local utility. Site owners should contact their utility company directly to verify that they will accept the power generated. The specifics of interconnecting to the power grid must be discussed and outlined by the utility company. Not all power lines have the same capacity, and some utilities require three phase service for larger systems. In some cases it may be necessary to upgrade the power lines in order to accommodate the power generated from a micro-hydro system. There are significant costs associated with up-grading power lines. (5)

Step 6 - Construction and Commissioning

If the site is technically and financially viable per the previously mentioned process, then we suggest the site owner hire a professional who can help with the accurate financial and technical assessment, design, permitting, interconnect, engineering, procurement and construction phases. A turbine/generator/control system for a micro-hydro project needs to be designed and developed for the specific site conditions. Many vendors will supply a complete micro-hydro system and assist the customer through the installation process. For construction and commissioning, companies will require the data gathered during the financial and technical assessment as outlined previously in steps 1-5.

Step 7 - Operations and Maintenance

In general, micro-hydro technology is designed to operate as a passive system and does not require extensive maintenance. Often the most routine maintenance is to remove debris build up in the civil works structures. This may include raking screens, mucking out settling basins or repairing leaks in canals. Cleaning should be done on an as-needed basis. The water-flow rate entering the turbine should be monitored regularly to ensure that the machine is operating efficiently. If the intake to the turbine is a sluice gate or has some other flow control mechanism (such as a valve or nozzle) it can be adjusted as needed to maintain an optimum flow. (20)

Figure 13: Sluice Gate for Flow Control

Additional Resources

Flow Rate Measurement

- The University of Arizona "Measuring Water Flow in Surface Irrigation Ditches and Gated Pipe"
    - Narrative and illustrative reference guide to measuring onsite flow rates.
    - http://ag.arizona.edu/pubs/water/az1329.pdf

- Canyon Hydro "The Guide to Hydropower"
    - Electronic and pdf publication which walks readers through a preliminary measurements, and feasibility study.
    - http://canyonhydro.com/guide/index.html

FERC Permitting Resources

- FERC "Preliminary Permits"
  - Narrative guide to filing for a preliminary permit
  - http://www.ferc.gov/industries/hydropower/gen-info/licensing/pre-permits/filing-comments.asp

- FERC "Handbook for Hydroelectric Project Licensing and 5 MW Exemptions from Licensing"
  - Users guide to the entire licensing process for exempt hydroelectric projects
  - http://www.ferc.gov/industries/hydropower/gen-info/handbooks/licensing_handbook.pdf

- FERC "Small/Low Impact Project Comparison Chart"
  - Illustrates both exemption and licenses and provides direct references to the Code of Federal Regulations (CFR) and the United States Code (USC).
  - http://www.ferc.gov/industries/hydropower/gen-info/licensing/small-low-impact/get-started/exemp-licens/project-comparison.asp

Supplier Index

Applegate Group Inc. is a water resource consulting service with offices in Denver and Glenwood Springs. Applegate can assist with manufacturing needs and specifications.
Contact Information:
1499 West 120th Avenue, Suite 200
Denver, CO 80234
Phone: 1-303-452-6611
Fax: 1-303-452-2759
Phone: 970-945-9686
Email: lindsaygeorge@applegategroup.com

Canyon Hydro is a micro-hydro system designer. Canyon Hydro takes data specific to your site, and will design a full-fledged hydroelectric system specifically for your system. The hope of these all-in-one designs is to increase efficiency of the final product and reliability of the system. Canyon Hydro provides cost estimates for perspective sites free of charge.
Contact Information:
5500 Blue Heron Lane
Deming, WA 98244 USA
Phone: 360-592-5552
Email: info@canyonhydro.com

Engineering Systems & Design Ltd. Manufactures cost-effective water-powered generators in the 1kW range. The company makes alternative energy equipment for hydropower and offers a wide array of products and services for the renewable energy marketplace and international installation services.
Contact Information:

Mailing address:	Shipping address:
P.O. Box 4557	12949 Route 114

Sussex, NB	Penobsquis, NB
Canada E4E 5L7	Canada E4G 2X3

Telephone: (506) 433-3151
Fax: (506) 433-6151
Website: http://www.microhydropower.com/index.htm

Gilbert Gilkes & Gordon Ltd, is a manufacturer, as well as engineering specialist in fluid movement. The company's extensive knowledge of both pumping applications and hydropower systems allows it to offer innovative, customized engineering, across numerous products and industrial applications to meet the individual requirements of an expanding worldwide customer base.

Contact Information:
471 Columbia Memorial Parkway,
Kemah, TX 77565
Phone: 281 554 2335
Email: gilkes@gilkesinc.com

Hydrovolts is a turbine manufacturer that specializes in in-canal placements. These are easily deployable turbines. Hydrovolts' turbine design is unique to the company, allowing for small modular, easy access for fine-tuning, cleaning, or repair. Installation is similarly simple, with claimed installation as low as one hour.

Contact Information:
210 S. Hudson St. #330
Seattle, WA 98134
Phone: 206-658-4380
Email: Burt@hydrovolts.com

Mavel is a manufacturing and engineering company focusing on the production of turbines for hydro electric power plants ranging in size from 25 kW to 25+ MW.

Contact Information:
121 Mount Vernon Street
Boston, MA 02108
Phone: 1-617-242-2204
Fax: 1-617-242-2205
Email: Jeanne@marvel.cz

Natel Energy is a turbine manufacturer. They specialize in turbines with low head (height differential), high flow, and low velocity (normally wide, full streams of water with a gentle current). These turbines work well in wildlife areas (creeks, streams, rivers) because fish and other aqueous species easily pass through the turbine unharmed.

Contact Information:
2175 Monarch Street
Alameda, CA 84501
Phone: 602-309-3395
Email: Joe@natelenergy.com

Pyramid Solar is a Colorado-based company that specializes primarily in solar power systems. However, they do have a small presence in the micro-hydro industry (primarily turbines and inverters). Pyramid Solar is one of the only options available if local companies are a priority for site owners.

Contact Information:
5100 W.35 RD. P.O. Box 808
Norwood, Colorado USA 81423
Phone: 970-708-0454

RockyHydro is a company that specializes in providing custom hydroelectric systems for homes and other remote areas (primarily in mountain areas). The company will work with site owners to find the products that will most benefit the owner. It offers full stand-alone systems, or smaller components such as turbines or inverters.

Contact Information:
Located in Longview, WA
Phone: 360-423-1218
Email: sales@rockyhydro.com

Telluride Energy is a consultancy and developer of small hydro projects for commercial, government, and utility clients. Telluride Energy simplifies small hydro development -- helping clients to navigate federal, state and local regulations as well as environmental, economic and technical issues associated with construction of small hydro projects.

Contact Information:
100 West Colorado, Suite 222
PO Box 1646
Telluride, CO 81435
Kurt Johnson
Phone: 970-729-5051
Email: kurt@tellurideenergy.com

Hydropower Help in Colorado

Blue Earth, a dba of FlyWater, inc. provides design/build services for small and incidental hydropower.

Contact Information
P.O. Box 973
Fort Collins, CO 80522
Ph: 970.231.5498
Email: Brad@Flywater.com

Community Hydropower Consulting, LCC renewable energy consulting firm specializing in community-based hydroelectric plants. The company has over 50 years of combined field engineering and management experience. Its background includes designing and managing hydroelectric projects as well as working with federal and other regulatory agencies.

Contact Information
P.O. Box 1091

Fort Collins, CO 80522
Phone: 970.221.4474

Email: contact@communityhydro.com

iCAST (International Center for Appropriate & Sustainable Technology) is a 501(c)(3) nonprofit organization whose mission is to "provide economic, environmental, and social benefits to economically disadvantaged individuals and communities; and to provide education and training that builds local capacity."
Contact Information:
777 South Wadsworth Boulevard, Building 4, Suite 205
Lakewood, Colorado 80226
Phone: 303.462.4100
Fax: 720.881.4639
Email: info@icastUSA.org

Kleinschmidt Associates is a consulting group for energy and water resources with several offices located throughout the United States. Since 1966, Kleinschmidt has focused on the needs of energy and water resource clients throughout the country. Kleinschmidt specializes in the integration of engineering, regulatory, scientific, and planning disciplines to create solutions for complex regulatory and management projects.
Contact Information:
412 E. Main Street Suite B
Grass Valley, CA 95945
Phone: (530) 477-8808
Fax: (530) 477-8885
Email: info@KleinschmidtUSA.com

Painted Sky Resource Conservation and Development Council, Inc. is not a governmental entity; it is a 501(c)3 incorporated in the state of Colorado. Painted Sky helps people protect and develop their economic, natural and social resources while improving their local economy, environment, and quality of life.
Contact Information:
690 Industrial Blvd.
Delta CO, 81416
Phone: (970) 874-5735 x 138
Phone: (970) 874-5735 x 135
Fax: (970) 874-4706
Email: admin@paintedskyrcd.org

State of Colorado Governors Office: Recharge Colorado provides general information concerning the pilot program in Colorado for micro-hydro projects as well as contact information for state staff in the program. Recharge Colorado (http://rechargecolorado.com/) has useful information regarding permits for micro-hydro and other energy-related programs. The Governor's Renewable Energy Development Team provides assistance with FERC permitting and feasibility evaluation, up to 120 hours of free consultation.

Contact Information:
The Governor's Energy Office
1580 Logan Street, Suite 100
Denver, CO 80203
Phone: 1-303-866-2100
Fax: 1-303-866-2930
Email: geo@state.co.us

Worksheets

Anticipated Expense Spreadsheet

EXPENSES			
HARD COSTS	**$ -**	**SOFT COSTS**	**$ -**
Turbine & Switch-gear		**Feasibility Study**	
Structure & Foundation		**System Testing**	
Excavation & Pipe Connection		**Survey Work**	
Flow Meter		**Engineering Design & Consultation**	
Electrical Work		**Project Managements**	
Utility Grid Connection		**Permit Fees**	
Shipping		**FERC License**	
Labor			
Installation			
Contingency			
HARD COST SUB TOTAL	**$ -**	**SOFT COST SUB TOTAL**	**$ -**
EXPENSE TOTAL			**$ -**
REVENUE			

Grants	
Rebates	
Other	
SUBTOTAL	**$** **-**
REVENUE TOTAL	**$** **-**
NET CAPITAL COST	**$** **-**

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