Forest Service Handbook
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Forest Service Handbook 2709.15 – Hydroelectric Handbook
Zero Code

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Table of Contents

06 - Calculation of Outputs, and Values

Exhibits 1, 2, 3, and 4 show the user how to analyze the tradeoffs associated with various alternatives and understand the developer's interest in a project. Perform the calculations for projects being evaluated when necessary or desirable.

Exhibit 1

Value of the Energy Resource

$$kW = \frac{(Q)(H)}{11.8}(e)$$

Where kW = Power in kilowatts.
Q = Volume of flow in cubic feet per second (cfs).
H = Usable head in feet. (static head less friction losses in penstock).
11.8 = Factor to convert units of potential energy into kilowatts.
e = Average efficiency factor: 70 percent efficiency for a small generating system; 80 percent efficiency for large systems.

Exhibit 2

Maximum Capacity of a Power Plant

Calculate the installed or maximum capacity for a hypothetical project with the following parameters:

Given:

Maximum diversion flow = 100 ft3/s
Average annual diversion flow = 20 ft3/s (during operating season).
Plant operates 10 months per year.
Penstock = 10,000 linear feet and 48-inch diameter.
Gross Head = 400 feet.
Head loss @ 100 ft3/s = 60 feet.
Net head @ max. flow = 340 feet.
Average plant efficiency = 70 percent.

Calculation:

Installed capacity in kilowatts =

$$\frac{(Q)(H)(e)}{11.8} = kW$$

$$\frac{(100)(340)(.70)}{11.8} = 2{,}016 \text{ kW or } 2.02 \text{ MW}$$

Exhibit 3

Changes in Head

In order to evaluate the monetary effects of locating the proposed structure or powerhouse up or down the stream, calculate the value of 1 foot of head for the hypothetical project, using the givens in exhibit 2 and assuming the selling price to a utility is $.05 per kWh, as follows (note that relocation distance is measured by the amount of vertical change in feet):

Annual Value:

$$\frac{(.70\ \text{eff})(20\ \text{ft3/s})(1\ \text{ft})(24\ \text{h/d})(30.5\ \text{d/mo})(10\ \text{mo/yr})(\$.05/\text{kWh})}{11.8}$$

= $434.24/year for 1-foot change in head.

Consider this change in project benefits along with other changes in costs due to changes in penstock length or size of generating equipment, ease of construction, and changes in volume of diversion flow.

The present worth (PW) of a 25-foot change in head for this project over 20 years @ 10 percent interest is:

PW = (SPWf of 10% @ 20 yrs.)($434/ft. x 25 ft.) = $92,372.

Exhibit 4

Hydroelectric Comparisons

Where:

SPWf is the uniform series present worth factor from the formula $SPWf = \frac{(1 + i)^{n-1}}{i(1+i)^{n}}$

Where:

i = interest rate
n = number of payments
note: if n is in months, then i must be a monthly interest rate.

60-100 watts = typical light bulb.
1,000 watts = 1 kilowatt (kW).
1,000,000 watts = 1,000 kW = 1 megawatt (MW).
1,000 MW = 1 Gigawatt (GW) = 1 billion watts.
1 Kilowatt-hour (kWh) = 1,000/watt-hours (Wh) = energy consumed by a 100-watt bulb lit for 10 hours.
1 Gigawatt-hour (Gwh) = 1,000 MWh.
1.5 MW = about 2,000 horsepower.

The following information may help to put the units of generated capacity into perspective:

1. The average home in California uses 15 Kwh/day, or 5,475 Kwh per year.

2. The town of Yreka (population 5,916) consumes 12,500,000 Kwh per year (12.5 Gwh). Discounting peak energy demands, this is equivalent to the power produced annually by a 1.5 MW (1,500 KW) plant (typical small hydro project size).

3. 12.5 Gwh is equivalent to the power produced in a thermal plant burning 21,500 barrels (903,000 gallons) of crude oil per year (42 gallons equals 1 barrel).

4. At $30 per barrel, the value of 21,500 barrels of oil would be $645,000 per year.

07 - References

1. U.S. Congress, Federal Power Act, 16 U.S.C. 797 and Federal Power Commission, U.S. Government Printing Office, April 1, 1975, stock number 015-000-00324-3.

2. Code of Federal Regulations, Title 18, Chapter 1, U.S. Government Printing Office. (Contains Federal Energy Regulatory Commission rules and regulations.)

3. U.S. Department of Agriculture, Agriculture Handbook 478, National Forest Landscape Management, Volume 2, Chapter 2, "Utilities," 1975.

4. U.S. Department of Agriculture and the Interior Environmental Criteria for Electric Transmission System, 1970. U.S. Government Printing Office, Washington, D.C. 20402, stock number 404-9320-70-2.

5. U.S. Congress, Federal Land Policy and Management Act of 1976, Public Law 94-579 (90 Stat. 2743 - 2794).