Water for the World

Selecting a Power Source for Pumps
Technical Note No. RWS .4.P.4

There are many sources of energy which can be used to move water. These include people and animals, gravity flow, wind, steam, sun, and fossil fuels. These are converted to useful power through hand pumps, windmills, hydro projects, electricity production and fossil fuel engines.

The specific method chosen depends on the quantity of water required, the type of water supply and the availability and cost of a specific energy source. In fact, availability and cost are usually the controlling factors in selecting a power source in rural villages. If relatively large quantities of water are required, the options are limited since human, animal or wind power are not sufficient to produce more than a few liters of water per minute.

Useful Definitions

FURLING - The action of a windmill in high winds; the wheel swings away from the direction of the wind.

GRAVITY FLOW - Flow of water from high ground to low by natural forces.

POTABLE WATER - Water that is free from harmful contaminants, is aesthetically appealing, and is good for drinking.

Human and Animal Power

Water moved by manpower, while limited in quantity, is used in many villages. It requires carrying, hand bailing and hand pumping which take many hours of work. In most places, these hours could be used to grow more food, gather fuel and keep houses clean and in good repair.

Animal power is used extensively in villages in some countries to pump and/or haul water. This may be an efficient use of an animal if it is not needed for other tasks. Since animals can haul much more water than humans, they should not be underestimated as a method of moving water. On the negative side, the animal needs food grown on land that could be used for growing food for the family.

If water is located at a higher elevation than the users, it can be piped to the lower elevation by gravity flow. This requires no other source of energy, is very economical and is simple to operate and maintain. If the water is potable, it can be consumed at the point of delivery without any further energy being needed. Water from a source that is not potable can be used to generate power either mechanically or by producing electricity, which in turn can be used to produce potable water. With an abundant water source, gravity flow can be used to pump from a lower elevation to a higher one by means of a hydraulic ram. Gravity flow should be used wherever feasible. When deciding between gravity flow and other sources of energy, comparisons should take into account the cost of operation and maintenance as well as capital costs.

Wind Power

Wind is a very attractive energy source for pumping water. Wind is free, available everywhere and a windmill is simple to operate and maintain. Its drawbacks include moderate production of water and the need for constant, year-round wind. Wind must be blowing at 12-20km per hour to start pumping and a suitable site is needed. Many of these conditions can be met along large bodies of water, in mountain passes, on the crest of hills, on open plains and, seasonally, in many parts of the world.

Prior to selecting a site for a windmill, information on wind is necessary. If it is not available, whether through other windmill performance or by measurement, then measurements should be taken over one year's time. The site should be such that the windmill can be placed at least 5m above any surrounding wind obstructions within 120m.

Although the higher the wind speed, the greater the water production, the practical maximum usable wind speeds are 25-32km per hour. This is because the windmill is designed to "furl" or swing out of the wind at wind speeds higher than 40 km/hr to protect the mill from damage. See Figure 1. Figure 2 shows how wind speed affects water production.

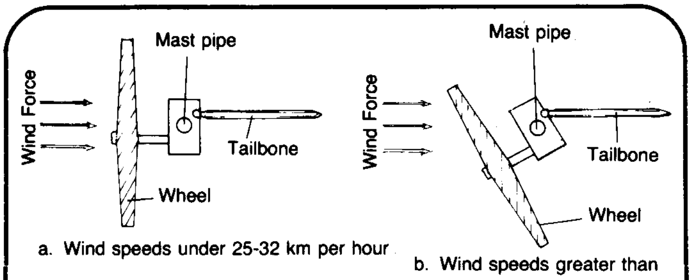

Figure 1. Furling of Windmill Wheel

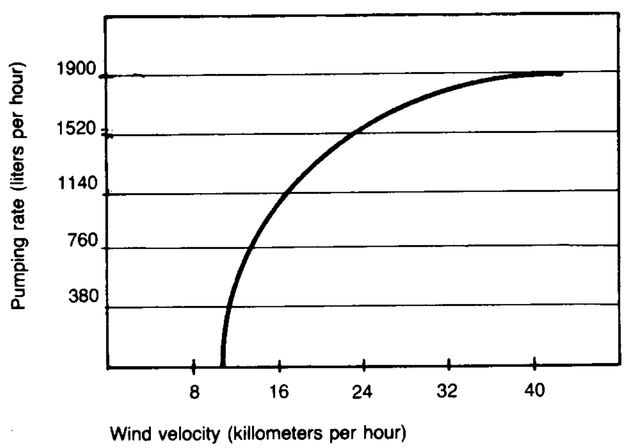

Figure 2. Windmill Output Versus Wind Velocity

Electric Power

Electricity is the most flexible means of moving water. Electric motors are available from a fraction of a horsepower to many horsepower (HP) to meet a variety of pumping needs. Most pump systems can be powered by electric motors. Electric motors are relatively economical to operate, are simple to maintain and have long useful lives. They are the most efficient motor-driven pump for producing water. If electricity has to be generated just for powering a motor, the cost can be much higher than for other energy sources since operation and maintenance of the power-generating equipment is costly and complicated. As a general rule, if a diesel oil or gasoline engine must be used to generate electricity, it is probably more efficient and less complicated to use the engine to drive the pump directly. If the electricity is to be used for other purposes, however, a generator can usually be sized for power pumps with very little additional cost. In considering power generation, Table 1 shows the minimum kilowatt rating required for specific HP pumps.

Table 1. Minimum Generator Requirements for Electric Motors

Motor Horsepower (HP) Size (single or three phase)	Minimum Kilowatt (KW) Rating of Generator
1/4	1.0
1/3	1.2
1/2	1.5
3/4	2.0
1	2.5
1 1/2	3.5
2	4.0
3	6.0
5	9.0
7 1/2	12.5
10	15.0

The ratings in Table 1 take into account the need for power to start the motor under a load which is much higher than the power needed to run continously. An estimation of the horsepower required to pump water can be calculated for any flow by using the following formula:

$$HP = \frac{\text{Liters per second (Q)} \times \text{head in meters (H)}}{76 \times \text{pump efficiency (E)}} = \frac{Q \times H}{76\ E}$$

As an example, the HP required to pump 1.5 liters per second to a height of 50m, assuming a pump efficiency of 60 percent, would be:

$$HP = \frac{1.5 \times 50}{76 \times .6} = 1.6$$

In this case, a 2 HP electric motor would be the nearest available size motor that would accomplish the requirements.

The approximate cost of electricity for different sizes of electric motors is shown in Table 2. If there are electric power lines in the community, an estimate of the power available can be made by observation as shown in Table 3.

Table 2. Estimating Pumpint Costs

Motor Horsepower	Average Kilowatt Input or Cost per Hour Based on 1 U.S. Cent per Kilowatt Hour	
	1-Phase	3-Phase
1/4	.305	---
1/3	.408	---
1/2	.535	.520
3/4	.760	.768
1	1.00	.960
1 1/2	1.50	1.41
2	2.00	1.82
3	2.95	2.70
5	4.35	4.50
7 1/2	6.90	6.75
10	9.30	9.00

Note: To find the cost for any other rate, multiply by the rate. For example, if electricity costs 5 cents U.S. currency per Kilowatt hour, for a 3/4 HP single phase motor, the electricity cost would be .760 x 5c = 3.8c per hour.

Table 3. Identification of Available Power by Field Inspection

Type of Power: Phase	Type of Power: Volts	Number of Transformers	Number of Leads from Transformer	Voltage Rating of Power Meter
1	115	1	2	120 2 wire
1	230	1	2	230 2 wire
1	115/230	1	3	230 3 wire
3	220	2 or 3*	3	220 or 240#
3	440	2 or 3*	3	440 or 480#
1 & 3	120/240	3	4	120/240##
1 & 3	120/208	3	4	120/208###

*Some power companies may only use one transformer.
#-3 phase
##-3 phase, 4 wire Delta
###-3 phase, 4 wire Wye

Conversion of sunlight to electricity through a process called photovoltaics is an alternative to using a fossil fuel engine to generate electricity. While the technology is well known and is currently being used to power pumps, the costs are quite high and it will be years before it will be economical for many applications. Photo-voltaics is an attractive alternative, though, because operation and maintenance are minimized and fuel is not required. If water is pumped to storage only when the sun shines, the need for batteries to store electricity is eliminated, thus substantially reducing initial costs and simplifying operation and maintenance.

Although fossil fuel powered motors are costly to operate and maintain, and fuel may be difficult to obtain and expensive, there often is no other choice if water is to be moved in sufficient quantities to be beneficial. When fossil fuel engines must be used, it is better to use diesel fuel than gasoline. The initial cost of the engine is generally more, but the cost of fuel is less as are the costs of maintenance and repair. The diesel engine does not require spark plugs or points and operates at a low rotating speed, thus prolonging its life. Natural or bottled gas engines are low in operating cost and have a longer life because they are very clean burning. Although natural and bottled gas are not widely available, in petroleum-producing countries gas is increasingly being bottled and piped for wide use.

Table 4 summarizes the whole range of energy sources for moving water.

Table 4. Characteristics of Energy Sources to Move Water

Consideration	Human & Animal	Gravity	Wind	From Central Station	Electricity Generated On-site: Fossil	Electricity Generated On-site: Voltaic	Fossil Fuel Engines
Quantity of H20 produced	Low to moderate	Varies with source	Moderate	High	High	Moderately high	High
Availability	Readily	Varies	Varies with site	Highly variable	Low	Low, experimental	Readily
Captial Cost	Low	Low to moderate	Moderate	Low to high	Moderate to high	Moderate to high	Moderate
Operation and Maintenance	Low	Low	Low	Low	High	Low to moderate	High
Positive Factors	Accepted, in place, understood	Low operating cost, long life	No fuel cost, simple technology	No maintenance, relatively inexpensive	Easily obtained	Very low maintenance, low operational cost	Easily available in wide range of powers
Negative Factors	Inefficient, hidden costs	None	Wind may not blow certain times	Expensive to extend lines	Expensive to operate and maintain	Still being developed, high first cost	Very high operation and maintenance costs

Technical Notes are part of a set of "Water for the World" materials produced under contract to the U.S. Agency for International Development by National Demonstration Water Project, Institute for Rural Water, and National Environmental Health Association. Artwork was done by Redwing Art Service. Technical Notes are intended to provide assistance to a broad range of people with field responsibility for village water supply and sanitation projects in the developing nations. For more detail on the purpose, organization and suggestions for use of Technical Notes, see the introductory Note in the series, titled "Using 'Water for the World' Technical Notes." Other parts of the "Water for the World" series include a comprehensive Program Manual and several Policy Perspectives. Further information on these materials may be obtained from the Development Information Center, Agency for International Development, Washington, D.C., 20523, U.S.A.

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