Energy and Cost Required to Lift or Pressurize Water

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Power Requirements to Lift Water

It takes a lot of power to lift water. To appreciate how much, consider the following example.

Example: A pump is discharging 452.5 gallons per minute. How much water is discharged in 12 hours and what is the weight of the water pumped during this period? One gallon weighs 8.3 pounds. The answers are: 325,851 gallons which happens to equal one acre-foot, and 2,719,226 pounds or 1,359 tons, which is the weight of one acre-foot of water.

Calculated as follows:

1. 452.5 gallons per minute x 60 minutes per hour x 12 hours = 325,851 gallons

2. 325,851 gallons x 8.345 pounds per gallon = 2,719,226 pounds

> A pump discharging 450 gallons per minute is lifting 1.87 tons of water every minute.

The energy requirement increases with every foot the water is lifted. To determine the energy requirement, simply multiply the weight of water in pounds by the lift in feet: this calculates energy in units of foot-pounds (ft-lb).

Example: How much energy does it take to lift an acre-foot of water (325,851 gallons) one foot in elevation? 100 feet in elevation? **The answers are: 2,719,226 ft-lbs and 271,922,600 ft-lb.**

Calculated as follows:
Equation: Energy Required = weight of water x feet of lift

Weight of one acre-foot = 325,851 gallons x 8.345 pounds per gallon = 2,719,226 pounds

1) **Lift = 1 foot**
    Energy Required = 2,719,226 pounds of later x 1 foot of lift = 2,719,226 ft-lbs of energy

2) **Lift = 100 feet**
    Energy Required = 2,719,226 pounds of water x 100 feet of lift = 271,922,600 ft-lbs

Power or energy, especially electric power, is usually measured in kilowatt-hour (kWh) rather than ft-lbs. The conversion from ft-lbs to kWh is simple enough.

> 1 kilowatt-hour (kWh) = 2,655,220 foot pounds (ft-lb).

Another example: We calculated that the energy required to lift one-acre foot of water (325,851 gallons) one foot is 2,719,226 ft-lbs. What is the energy in kilowatt-hour?

Calculated as follows:

1) Kilowatt-hour = 2,719,226 ft-lbs/2,655,220 ft-lbs per kWh = **1.02 kWh.**

Note that this energy requirement assumes 100% efficiency in the pumping plant.

Pumping plants do not operate at 100% efficiency. Energy is lost in the motor and column shaft, and friction losses occur through the strainer, suction pipe and column (see Figure 1). A properly designed and adjusted pumping plant will operate at about 70% efficiency; that is, 70% of the power goes to lifting water, the rest is used up in the mechanics of the pumping plant. The efficiency can be as low as 40% when the pumping plant is poorly designed, worn, or improperly adjusted.

Table 1 shows the amount of energy in kWh required to lift an acre-foot of water one foot in elevation over a range of overall pumping plant efficiencies. Also given is the cost to pump one acre-foot of water one foot in elevation figuring electrical power at $0.10 per kWh. Note that the energy required to lift one-acre foot of water one foot of elevation and assuming 100% efficiency is **1.02 kWh**. This is the value we calculated above.

Power Requirement to Pressurize Water

Drip and sprinkler systems are operated at 20 to 40 pounds per square inch pressure (psi). This requires energy and costs money.

> 1 psi pressure = 2.31 feet of water head
>
> The energy required to create a pressure of 43 psi is the same as the energy required to lift water 100 feet.

Next to the last example: You have a drip system and are using ditch water that must be pressurized to 30 psi. A pressure of 30 psi is equal to lifting the water how many feet? How much energy is required to pressurize one acre-foot (325,851 gals) to a pressure of 30 psi and using a pump operating at 70% efficiency? A kWh costs $0.10. **The answers are: 30 psi is equal to lifting the water 69.3 feet; the energy required to pressurize one acre-foot to 30 psi is 100.8 kWh; and the cost is $10.08.**

Calculated as follows:

1. 30 psi x 2.31 feet per psi = 69.3 feet of water head; in other words, pressurizing to 30 psi is equal to lifting the water 69.2 feet.
2. One acre-foot weighs 2,719,226 pounds (325,851 gallons x 8.345 pounds).
3. Energy required in ft-lbs = weight of water x feet of lift. Therefore, 2,719,226 pounds of water x 69.3 feet of lift = 188,442,361 ft-lbs of energy per acre-foot of water.

4. Next, convert energy units of ft-lbs to units of kWh. A kWh = 2,655,220 ft-lbs; therefore, 188,442,361ft-lbs/2,655,220 ft-lbs per kWh = 70.9 kWh.

5. The pump is operating at 70% efficiency; therefore, 70.9 kWh/0.70 efficiency = 101.4 kWh.

6. Energy cost = 101.4 kWh x $0.10 per kWh = $10.07 per acre-foot (325,851 gallons). The energy necessary to pressurize a drip or sprinkler system is significant and often overlooked by farmers when comparing drip and furrow irrigation systems.

Most crops require a minimum of 2 acre-feet per acre during the growing season. The cost to pressurize a drip system operating at 30 psi is $20.14 per acre using the above example.

> The cost of energy underscores the importance of designing drip and sprinkler systems that apply water efficiently and at low pressure. Also, keep in mind that the most energy efficient irrigation systems are furrow or flood that are designed and managed to apply water uniformly and efficiently.

Checking Pump Efficiency

The efficiency of your pumping plant can be easily determined with the following information: (1) the volume of water pumped; (2) the lift (including discharge head); (3) the amount of power used. A water meter indicates the volume of water pumped. The electric meter measures power usage. The total pumping head is measured by the electric power company or your pump dealer.

> **Last Example:** A water meter indicates your pumping plant discharged 80 acre-feet during the irrigation season. During this period the electric meter showed you used 30,720 kWh. The total lift is 150 feet: the lift includes draw-down and pressure head. What is the efficiency of the pumping plant? **The answer is 40%.**
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> Calculated as follows:
>
> 1) The energy used to lift an acre-foot
>
>   150 feet = 30,720 kWh/80 acre-ft
>   = 384 kWh per acre-foot to lift the water 150 ft
>
> 2) The energy used to lift an acre-foot
>   1 foot = 384 kWh/150 ft
>   = 2.56 kWh/foot of lift

Table 1 shows kilowatt-hours per acre-foot per foot of lift at various pumping plant efficiencies. An energy requirement of 2.56 kWh per acre foot shows an overall plant efficiency of 40%. This is very poor efficiency and costing you money. An electric pumping plant should have an energy use efficiency around 70%.

Table 1. The Amount of Energy in Kilowatt-Hours (kWh) Required to Lift One Acre-foot of Water (325,851 gallons) One Foot of Elevation

Overall Plant Efficiency (%)	Energy to Lift One Acre-foot (325,851 gallons) One Foot in Elevation (kWh)	Cost to Lift One Acre-Foot One Foot in Elevation ($0.10/kWh)
100	1.02	$.102
75	1.37	.137
70	1.46	.146
65	1.58	.158
60	1.71	.171
55	1.86	.186
50	2.05	.205
45	2.28	.228
40	2.56	.256

In Case You Do Not Like to Work in ft-lbs or kWh, Here are Some More Units of Energy and Power

1 foot-pound (ft-lb)	= amount of work required to lift an object weighing one pound a foot in elevation.
1 horsepower (HP)	= 550 foot-pound per second = 746 watts = 0.746 kilowatt (kW)
1 watt (W)	= 0.738 foot-pound per second.
1 kilowatt-hour (kWh)	= 2,655,220 foot-pounds. = 3,600,000 watts (W). = 3,600 kilowatt (kW). = the amount of energy generated by 1.34 horsepower over a one hour period.
1 calorie	= 3.086 foot-pounds.
1 Btu =	252 calories (Btu stands for British Thermal Unit) = 777.7 foot-pounds

Figure 1. Power balance in a deep well burbine. This figure is typical of large pumps. Motor and pump efficiencies are generally lower in small pumping plants. *(Compliments of Pacific Gas & Electric.*