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Using Renewable Energy to Pump Water

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You can save money and help reduce air pollution by using renewable energy sources — such as solar or wind power — for your home, for drip irrigation or for livestock water wells.

Wind and solar energy can be excellent options in remote areas where the costs of extending transmission lines are high. Extending transmission lines over 1/4 mile usually costs $5 per foot. At that rate, a 1-mile transmission line extension will cost more than $25,000.

Renewable energy sources are also a good option when only a small amount of water needs to be pumped. Generally, very little water is required for livestock and home use.

To make a wise decision on renewable energy sources, it helps to understand some basic concepts about renewable fuels, including:

- How solar and wind energy pumps work
- The main components of these pumps
- The advantages and disadvantages of solar and wind energy pumps
- How to calculate your pumping requirements

It is also important to consider the costs of buying and using a pumping system, which include the initial cost, energy costs and maintenance costs.

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Wind power

Wind is often used as an energy source to operate pumps and supply water to livestock. Because of the large amount of water needed for crops, wind power is rarely used for irrigation. As larger and/or more efficient wind turbines are developed, groups of these wind turbines (or single wind turbines) are expected to be able to generate enough electricity to be used for irrigation projects. Wind generators are also used to charge batteries and to provide electricity for small communities.

The most common wind device used is the American farm and ranch windmill (Fig. 1). These windmills are common on the North American Great Plains and across the Southwest.

A windmill consists of:

- A very large fan with 15 to 40 steel or galvanized blades
- A gear box mechanism driven by the blades. This mechanism converts the rotary motion of the blades to an up-and-down motion
- A piston pump, which is driven by the up-and-down motion produced by the gear box mechanism
- A pump rod that descends from the windmill to the well
- A pump cylinder, which is placed in the water near the well bottom and is driven by the pump rod

The propeller must have many blades to develop a high starting torque, which is needed to start the piston pump. Generally, windmills begin working when the wind speeds exceed 7 mph.

Solar power

Solar energy is used mainly for pumping water for livestock or for home use. It is seldom used for irrigation because of the amount of water needed for crops. However, solar pumps are economically feasible for irrigation that uses very low heads or has very low lifting requirements, such as drip irrigation, which uses less water than other types.

Solar pumps work by converting solar radiation into electricity through the use of photocells made of silicon, usually called photovoltaic cells. The photovoltaic cells are enclosed in a glass frame, which makes up the solar module.

Sometimes an array of solar modules is needed to produce enough energy for the pump. The modules are mounted on a frame in an assembly called a photovoltaic (PV) array. The PV array is connected to a controller and then with an electrical power cable to the motor/pump subsystem in a well (Fig. 2).

Submersible pumps usually use a direct current (DC) motor. Motors that use alternate current (AC) must have a DC-to-AC inverter. DC motors are recommended because using an inverter costs more, and power is lost in the DC-to-AC conversion.

The most common DC motors work at a nominal voltage of 24, 36 and 48 volts, which can perform at 32, 42, and 64 volts. A problem with DC motors in the past has been that they needed carbon brushes, which wore out and needed regular replacement. New, maintenance-free DC motors have recently been developed that use an electronic circuitry to perform the same function as the brushes. Today, most submersible pumps use brushless DC motors or AC motors with an inverter.

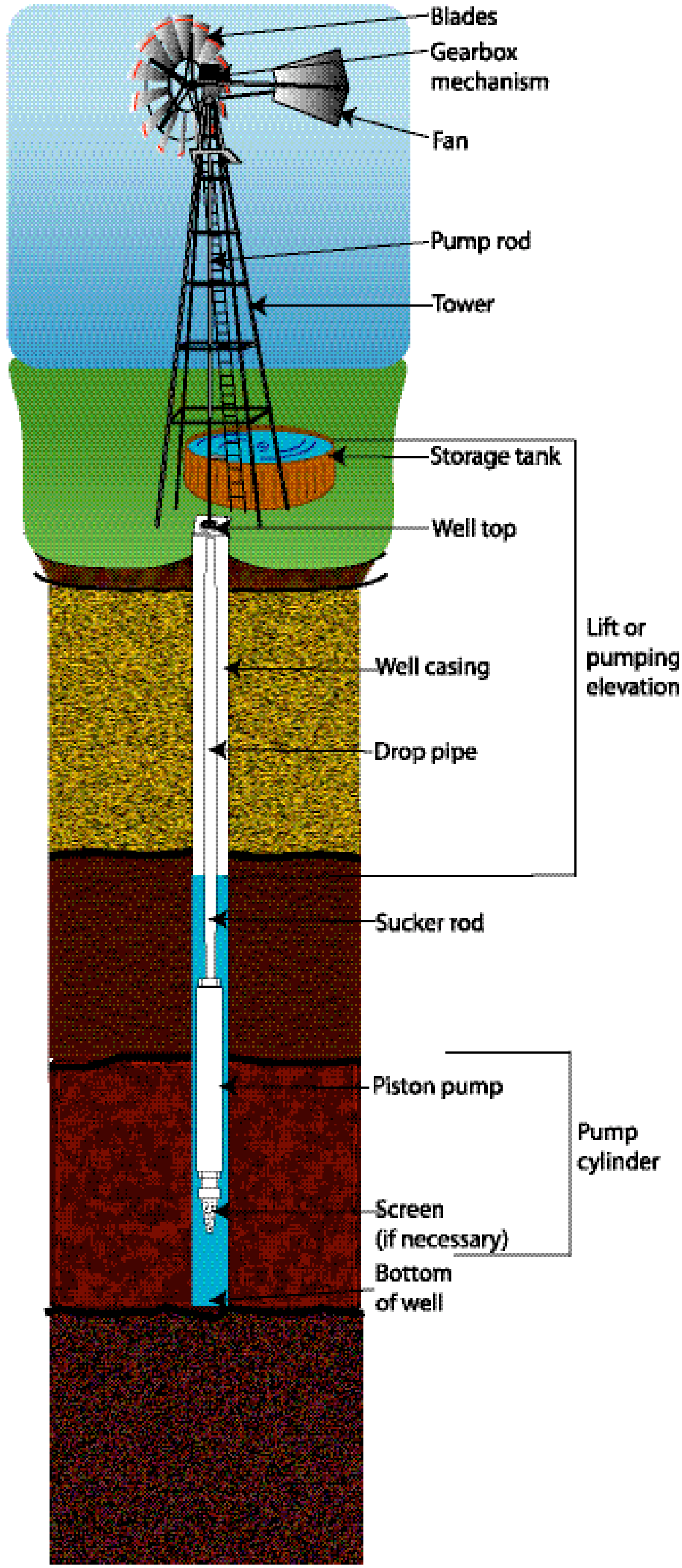

Figure 1. An American farm and ranch windmill.

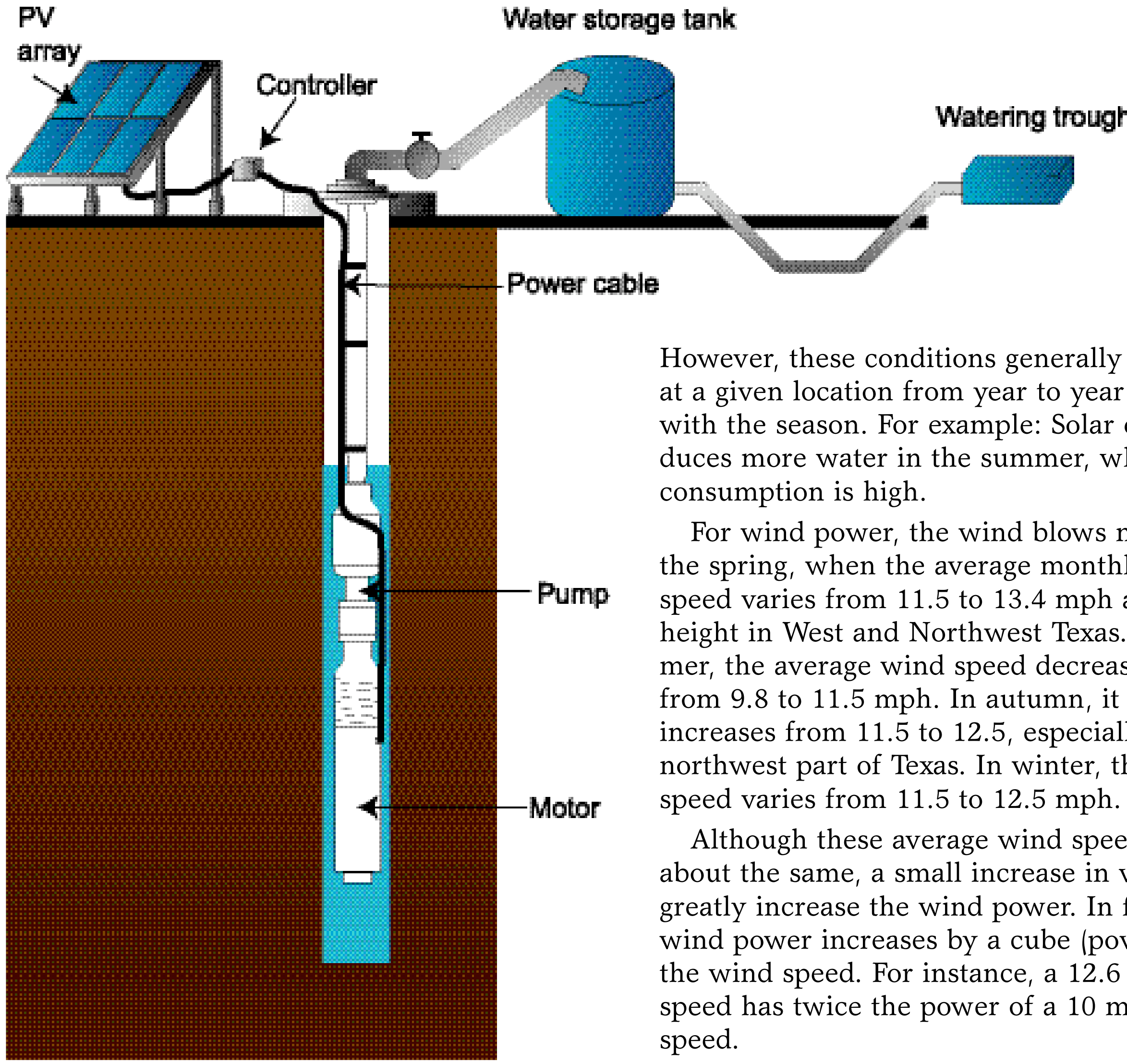

Figure 2. A solar-powered water pump.

In recent years, the cost of solar modules has dropped considerably. As large-scale solar consumption and production increases, the costs are expected to continue to fall. A solar module costs about $5 per watt; a 75-watt module costs about $375.

Advantages and disadvantages of solar and wind energy

Some advantages and disadvantages for using solar or wind energy are presented in Table 1. The main advantage of using renewable energy is that there is no energy cost to pump the water.

The power source – either wind for a wind pump or sunshine for solar pump – depends on the weather conditions for a given place. However, these conditions generally are constant at a given location from year to year and vary with the season. For example: Solar energy produces more water in the summer, when water consumption is high.

For wind power, the wind blows more during the spring, when the average monthly wind speed varies from 11.5 to 13.4 mph at a 33-foot height in West and Northwest Texas. In the summer, the average wind speed decreases, ranging from 9.8 to 11.5 mph. In autumn, it slightly increases from 11.5 to 12.5, especially in the northwest part of Texas. In winter, the wind speed varies from 11.5 to 12.5 mph.

Although these average wind speeds seem about the same, a small increase in wind will greatly increase the wind power. In fact, the wind power increases by a cube (power of 3) of the wind speed. For instance, a 12.6 mph wind speed has twice the power of a 10 mph wind speed.

The water pumped from wind and solar systems is generally stored in tanks. Keep in mind that your storage tank needs to be big enough to store several days' supply of water in case of breakdowns or poor pumping conditions (unfavorable weather).

When the water tank is full, the extra generated solar or wind energy can be stored in lead acid batteries. However, there are several drawbacks to storing energy in batteries:

- It is expensive.
- Only small amounts of energy can be stored (in some cases, less than 1,000 or 2,000 watts per hour, depending on the amount of batteries and their capacity).
- The batteries need to be replaced at least every 5 years.
- Storage batteries raise the initial cost of the total system much higher.

Table 1. Comparisons of the advantages and disadvantages of solar and wind energy systems.

Factor	Wind systems	Solar systems
Advantages		
Favorable weather	Steady winds are most productive.	Pump water consistently all year.
Portability		Can be portably mounted to use in different locations.
Lifetime	Can exceed 50 years, except for the piston pump, which requires maintenance every 1 to 2 years.	More than 20 years. The pump lasts less time.
Disadvantages		
Stormy weather	Wears more rapidly in high winds. Destructive winds can ruin system.	Panels can be damaged by hail. Cloudy weather and short days reduce energy production.
Time of year power requirements	Power production stopped when wind speeds are low, which occurs in July and August when water is needed most.	
Initial cost	Lower initial cost.	Higher initial cost.
Maintenance cost	Requires more maintenance.	Less maintenance.

Estimating the size of the pump

Both solar and wind energy systems use pumps to lift the water from underground to a storage tank. To estimate the size of the pump to meet your needs, you must consider several factors:

- The amount of water needed each day
- The pumping capacity, or the number of gallons per hour the pump must be able to lift
- The amount of horsepower required to lift that amount of water

To calculate your pumping needs, first estimate how much water will be used each day and how far the water must be lifted from underground (the depth of the well). Table 2 offers guidelines for estimating the water requirements for people and livestock.

To estimate the total water requirements per day, multiply the number of people or animals by the amount of water they are expected to consume each day.

Example: How much water is needed for a herd of 100 head of beef cattle?

Water requirement = 100 head of cattle x 10 gallons/day/head = 1,000 gallons/day

Pumping capacity

Next, calculate the number of gallons per hour that the pump must be able to lift, which is the pumping capacity. Because the wind does not blow all day and the sun does not shine all day or every day, it is highly recommended that you assume that an average of 5 hours of the day are available to collect wind or solar energy.

To estimate the pumping capacity, divide the number of gallons needed per day by the number of hours available to collect energy.

Table 2. Water requirements in gallons per day for different species.

Species	Gallons per day
Human	100 per person
Beef cattle	7-12 per head
Dairy	10-16 per head
Horses	8-12 per head
Swine	3-5 per head
Sheep and goats	1-4 per head
Chickens	8-10 per 100 birds
Turkeys	10-15 per 100 birds

Example: What is the pumping capacity needed for the 100 head of beef cattle in the example above?

Pumping capacity = 1,000 gallons/day divided by 5 hours = 200 gallons/hour

Estimating the horsepower required

Next you need to figure the amount of horsepower the pump will need to have. To estimate the horsepower needed, first convert the pumping capacity from gallons per hour to gallons per minute.

Example: For the same 100 head of beef cattle above, you will need to convert the 200 gallons per hour of pumping capacity to gallons per minute:

Gallons per minute (GPM) = 200 gallons/hour divided by 60 = 3.33 GPM

Next, to calculate the horsepower needed, multiply the pumping capacity by the lift, which is the distance that the water must be lifted; then divide that number by 3,960.

HP = Q x H / 3,960

Where:

HP = Horse power

Q = Pumping capacity, in gallons per minute (GPM)

H = lift, in feet

The well on that cattle ranch in the example above is 100 feet deep. For the formula above, the factors are:

Q = 3.33 GPM

Lift = 100 feet

The calculation would be:

Horsepower = 3.33 GPM x 100 feet/3,960 = 0.084 HP

Converting horsepower to watts

The horsepower used above describes the mechanical work needed to lift a volume of water per unit of time from the pumping water level up to the storage tank. You can convert this measure of horsepower to watts of electricity by multiplying it by 746:

Watts = 0.084 HP x 746 watts = 62.7 watts

Next, you need to adjust the wattage to take into consideration the loss of electricity in the cable and controls during transmission and in converting electricity to the mechanical movements of the pump. The average efficiency rate of these pumps is about 45 percent. To adjust for this inefficiency, we must recalculate our power input by dividing the number of watts by 0.45:

Wattage needed = 62.7 divided by 0.45 = 139.3 watts

Last, for a solar system, we must choose the number of solar panels that will produce the number of watts needed by the pump. Solar panels or modules have different capacities. There are modules of 25, 50, 70 or 75 watts.

It is less expensive to use a more efficient motor than to add an extra solar panel. For the example above, the rancher could buy six 25-watt panels, but it would be much less expensive to buy two 70-watt solar panels to generate the 139.3 watts needed.

Estimating the size of the windmill

When buying a windmill, you will need to know the lift and daily water requirements. Use the formulas above to determine the horsepower your pump needs to have.

The primary components of a windmill are the blades, the tower and engine, pump rod, the drop pipe (usually 2-inch galvanized pipe), sucker rod (wood pole, steel rod or fiberglass) and the piston pump (see Fig. 1).

If there are tall trees in the area, you may need or want a taller tower to raise the fan blades above the trees and into the wind. However, windmills are usually no more than 35 feet tall; otherwise, the towers become very expensive.

A windmill's pumping output is affected by three factors: wind speed, wheel or blade diameter, and the diameter of the cylinder (Table 3).

Wind speed has an important effect on the pumping output. In fact, the power available from the wind is proportional to the cube of the wind speed. This means that when the wind speed doubles, the power increases eight times.

Most windmills do not operate at wind speeds of less than 7 mph or more than 30 mph, as the mill can be damaged by high winds.

Example: From Table 3, to pump 470 gallons per hour and lift the water 220 feet, a cylinder diameter of 3 inches would require a blade diameter of 14 feet.

Table 3. Pumping capacities as influenced by the diameter of the cylinder and blade diameter of the windmill.

Cylinder diameter (inches)	Pumping capacity (gallons per hour) Wheel diameter (feet)		Blade diameter (feet)					
	6	8 to 16	6	8	10	12	14	16
			Pumping elevation (feet)					
2	130	190	95	140	215	320	460	750
2 1/2	225	325	65	94	140	210	300	490
3	320	470	47	68	100	155	220	360
3 1/2	440	640	35	50	76	115	160	265
4	570	830	27	39	58	86	125	200
4 3/4	—	1,170	—	—	41	61	88	140
5	900	1,300	17	25	37	55	80	130
6	—	1,875	—	17	25	38	55	85
8	—	3,300	—	—	14	22	31	50

For more information

State Incentives for Alternative Energy in Texas http://www.ies.ncsu.edu/dsire/library/includes/map2.cfm?CurrentPageID=1&State=TX

Texas Solar Energy Society http://www.txses.org/

Texas State Energy Office http://www.infinitepower.org/

U.S. Department of Energy - Renewable Energy Clearinghouse http://www.eere.energy.gov/

Acknowledgments

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