I. How the Program Analyzes Pumping Costs

This section discusses how the Program Analyzes Pumping Plant Costs - Section I introduces several equations that indicate the options for lowering pumping costs. You will see that the four main options for lowering pumping costs are:

1. Reduce unit cost of energy - the dollars paid per therm of natural gas, gallon of diesel, or kilowatt-hour of electricity.
2. Reduce required system pressures.
3. Increase pumping plant efficiency.
4. Improve pumping plant management.

This discussion is somewhat technical and includes several mathematical equations. The discussion below uses a single pump supplying an irrigation system, powered by electricity. Most of the concepts are directly applicable to natural gas users also. Please contact the Program if you have questions specific to natural gas use. Annual energy costs for a water pump used for irrigation can be estimated using ***Equation I.1:***

I.1 $$\$/yr = \$/kWh \times kWh/AF \times AF/yr$$

Where:

$/yr	=	annual cost of energy (note that this excludes demand charges)
$/kWh	=	average cost per kilowatt-hour
kWh/AF	=	average number of kilowatt-hours required to pump an acre-foot of water through the system
AF/yr	=	number of acre-feet pumped each year

Equation I.1 indicates that to lower annual pumping costs you can lower the unit energy cost, lower the kilowatt-hours required per acre-foot, or reduce the number of acre-feet pumped per year.

Lowering $/kWh

The average cost per kilowatt-hour can be minimized several ways. It is most important for electricity users to be on the correct rate schedule. Various rate schedules are intended for different types of users. Contact your utility representative if you are not sure about the correct schedule, have changed your operations recently, or have not examined this option for some time.

One of the most common options for minimizing $/kWh is to use a Time-of-Use rate schedule (TOU) and refrain from pumping during "peak" hours. (Peak hours are usually from about noon to 6:00 PM, Monday through Friday, during summer months, the time when maximum energy use occurs throughout the state.) This assumes that your operations will allow for 18 to 20 hours of pumping per weekday or less. There are many different types of TOU schedules available.

Another option that is readily available is an interruptible service option. With this type of schedule, the average $/kWh is lower than normal because the customer promises to stop using energy when notified of critical energy-supply situations.

Because of recent attempts to deregulate electric utilities in California, rate schedules will probably be changing. Stay aware of the options available to you. Contact your account representative or visit your utility's web site regularly. Many agricultural organizations (such as California Farm Bureau Federation or the Western Growers Association) also provide information to their members.

Lowering kWh/AF

Equation I.2 is used to calculate the number of kilowatt-hours required to pump an acre-foot (kWh/AF) of water through a pumping system:

I.2 $$kWh/AF = 1.0241 \times TDH / OPE$$

Where:

kWh/AF	=	the number of kilowatt-hours required to pump an acre-foot of water through a pumping system
1.0241	=	a constant
TDH	=	total dynamic head in the pumping system; this is the total pressure developed by the system
OPE	=	the overall pumping plant efficiency of the system as a decimal (0 - 1.0)

Equation I.2 indicates that to lower kWh/AF one would try to either lower the required system pressure (reduce TDH) or increase the pumping plant efficiency (increase OPE).

Lowering AF/year

Equation I.3 is one method of estimating the number of acre-feet required to irrigate a field annually:

I.3 $$AF/yr = CL + \left(Ac \times \frac{(ETc - RAINeff)}{((1 - LR) \times IE)}\right)$$

Where:

AF/yr	=	number of acre-feet required to irrigate a field annually
CL	=	annual losses to move water to the field in acre-feet
Ac	=	number of acres in the field
ETc	=	annual net crop water use in acre-feet/acre
RAINeff	=	annual rainfall that is effective in satisfying crop water use in acre-feet/acre
LR	=	required leaching ratio (0 - 1.0) to maintain a salinity balance in the crop root zone
IE	=	irrigation efficiency in the field as a decimal (0 - 1.0)

Any one of the variables in ***Equation I.3*** can be changed in order to reduce AF/yr. The APEP is most interested in increasing the irrigation efficiency (IE), that is, improving the management of the system. The third and fourth components of the APEP's education message address management. The best hardware in the world is of no use if it is not managed correctly.

Summary

The discussion in Section I identifies four options for reducing energy costs:

1. Reduce the unit cost of energy. Things to look for are:

a. Make sure you are on the most appropriate rate schedule.

b. If not on a time-of-use rate schedule, investigate the possibilities.

c. Keep track of changes occurring in the energy industry that may provide opportunities, including voluntary interruptible schedules and real-time pricing meters.

2. Reduce the system pressure. Some options are:

a. When installing new systems, check with the designer to make sure that required system pressures are minimized. Make sure appropriate pipe sizes are used and that use of throttling valves is avoided or minimized. Investigate the use of low-pressure sprinkler nozzles rather than standard smooth-bore nozzles for field sprinkler systems.

b. If you are currently using a pressurized system, have a qualified engineer or technician audit the system to check for opportunities to lower required pressure.

c. If you have a water well, check with your local well driller or pump company for potential problems with the well itself that might result in excessive drawdowns.

d. Utilize the best engineering and construction methods you can when constructing new wells.

3. Improve the overall pumping plant efficiency.

As discussed later in this book, make sure you know the factors involved in specifying an efficient pump. Have periodic pump efficiency tests performed to identify potential problems.

4. Improve the management of the system.

Make sure you are using appropriate water management practices to maximize irrigation efficiency. Also, use the **Pumping Energy Calculator** supplied with this book, or some other method, to make sure you know how long to run the pump.

II. Why Pumping Efficiency is Important

Very simply, energy costs money. The less energy you use, the lower your pumping costs will be. This section presents an energy cost analysis of an irrigation system before and after improvement. The calculations were done using the equations presented in Section I.

The before situation includes:

- A drip irrigation system utilizing poor irrigation scheduling practices, pressure-regulating valves in the field set incorrectly, and excessive leakage, resulting in a sub-par 70% irrigation efficiency.
- An older water well with encrustation of the perforations, resulting in excessive drawdowns.
- A booster pump that was incorrectly matched to the irrigation system during installation. Not only is this pump producing excessive pressure, but the throttling valves used to produce the desired pressure in the field make the pump operate at a low efficiency.

The improved situation includes fixing system leaks, resetting pressure-regulating valves and improved irrigation scheduling. The well is chemically treated and swabbed to reduce encrustation and results in lowered drawdown. Finally, the impeller of the booster pump is trimmed to match the operating condition to the requirements of the irrigation system. This reduces the TDH in the pumping system, as well as improves overall pumping plant efficiency. This all results in an improved irrigation efficiency of 83%.

Note: All examples in this section use a kWh cost of $.125.

The following illustrate the before and after savings in water, energy and dollars.

II.1 Improved Irrigation Efficiency = Reduced Pumping Requirements

The comparison below indicates how improving the pumping system management, in this case irrigation efficiency, can result in reduced pumping requirements. Remember, the less water that needs to be pumped, the less energy used.

Before

AF/yr = CL + (Ac x ((ETc - RainEff)/((1 - LR) x IrrEff)

Where:

CL = 10 acre-feet/yr
AC = 100 acres
ETc = 3 acre-feet/acre
RainEff = .8 acre-feet/acre
LR = .05
IrrEff = 70% Irrigation Efficiency

AF/yr = 10 + (100 x ((3 - .8)/((1 - .05) x .7)

AF/yr = 340.82 (Approximately 341)

After

AF/yr = CL + (Ac x ((ETc - RainEff)/((1 - LR) x IrrEff)

Where:

CL = 10 acre-feet/yr
AC = 100 acres
ETc = 3 acre-feet/acre
RainEff = .8 acre-feet/acre
LR = .05
IrrEff = 83% Irrigation Efficiency

AF/yr = 10 + (100 x ((3 - .8)/((1 - .05) x .83)

AF/yr = 289

II.2 Improved Pumping Plant Efficiency = Lower Overall Energy Requirements

The comparison below shows how improving the overall pumping plant efficiency results in reduced energy use overall. The kilowatt-hours required to pump an acre-foot are reduced, so total energy use will be reduced for any amount of water pumped. Also note the increase in flow rate.

— Before —

kWh/AF = 1.0241 x TDH/OPE

Where:
TDH = 96 feet
OPE = 49%
gpm = 1000

kWh/AF = 1.0241 x 96/.49
kWh/AF = 200.64

— After —

kWh/AF = 1.0241 x TDH/OPE

Where:
TDH = 88 feet
OPE = 60%
gpm = 1350

kWh/AF = 1.0241 x 88/.60
kWh/AF = 150.20

II.3 Improved System Hardware and Management = Lower Energy Use and Costs

The comparison below indicates the overall energy use and cost reductions that occur due to the improvements in hardware and management discussed previously.

— Before —

kWh/yr = AF/yr x kWh/AF

Where:
AF/yr = 341
kWh/AF = 260

kWh/yr = 341 x 200
kWh/yr = 68,200 kWh/yr

and
$/yr = kWh/yr x $/kWh

where
kWh/yr = 68,200
$/kWh = .125

$/yr = .125 x 68,200
$/yr = $8,525.00

— After —

kWh/yr = AF/yr x kWh/AF

Where:
AF/yr = 289
kWh/AF = 150

kWh/yr = 289 x 150
kWh/yr = 43,350 kWh/yr

and
$/yr = kWh/yr x $/kWh

where
kWh/yr = 43,350
$/kWh = .125

$/yr = .125 x 43,350
$/yr = $5,418.75

Improving both the efficiency of the pumping system and its management indicates a savings of 24,850 kWh per year energy and $3,106.25 in energy costs.

III. Why Management of Pumping Systems is Important

This section discusses why changes to hardware may not be enough. Management of the system is all-important. Two comparisons are briefly examined:

III.1 Management does not take advantage of the changes to system hardware to reduce the amount of water pumped.

III.2 Management does not take advantage of the changes to pumping hardware and operates the pump for the same amount of hours.

III.1 Same Amount of Water is Pumped After Improvements

The comparison assumes that the same amount of water is pumped, even after the improvements to the irrigation system. That is although the potential irrigation efficiency is 83%, requiring only 289 acre-feet of water, the pump is still run to supply 341 acre-feet.

— Before —

kWh/yr = AF/yr x kWh/AF

Where:
AF/yr = 341
kWh/AF = 260

kWh/yr = 341 x 200
kWh/yr = 68,200 kWh/yr

and
$/yr = kWh/yr x $/kWh

where
kWh/yr = 68,200
$/kWh = .125

$/yr = .125 x 68,200
$/yr = $8,525.00

— After —

kWh/yr = AF/yr x kWh/AF

Where:
AF/yr = 341
kWh/AF = 150

kWh/yr = 341 x 150
kWh/yr = 51,150 kWh/yr

and
$/yr = kWh/yr x $/kWh

where
kWh/yr = 51,150
$/kWh = .125

$/yr = .125 x 51,150
$/yr = $6,393.75

In this form of mismanagement, the savings are only 17,050 kWh per year (instead of the possible 24,850 kWh per year) and $2,131.25 per year (instead of the possible $3,106.25).

III.2 Pump Ran for Same Amount of Time After Improvements

In certain situations pumping plants are managed in terms of time. Due to labor constraints, or possibly the rules and regulations of a water district, pumps may be operated in blocks of 12 or 24 hours only. Assume that management repairs both the irrigation system and the pumping system, but continues to operate the pump for the same amount of hours.

Before the repair it would take 1,852 hours of pump operation at 1,000 gpm to pump 341 acre-feet. After the repair, running the pump for 1,852 hours at 1,350 gpm would supply 460 acre-feet.

— Before —

kWh/yr = AF/yr x kWh/AF

Where:

AF/yr = 341
Flow = 1,000 gpm
Hours of Operation = 1,852
kWh/yr = 341 x 200
kWh/yr = 68,200 kWh/yr

and

$/yr = kWh/yr x $/kWh

where

kWh/yr = 68,200
$/kWh = .125
$/yr = .125 x 68,200
$/yr = $8,525.00

— After —

kWh/yr = AF/yr x kWh/AF

Where:

AF/yr = 460
Flow = 1,350 gpm
Hours of Operation = 1,852
kWh/yr = 460 x 150
kWh/yr = 69,000 kWh/yr

and

$/yr = kWh/yr x $/kWh

where

kWh/yr = 69,000
$/kWh = .125
$/yr = .125 x 69,000
$/yr = $8,625.00

In this form of mismanagement, the operator actually uses more energy than before and increases the power bill. Also note that this form of mismanagement negates any improvements to the irrigation system.

IMPORTANT!

In some cases, a repaired pump may actually increase the power bill, even with the correct amount of pumping hours. This can occur if the pump is in a water well and the increased flow rate results in a greatly increased drawdown (increased TDH) that offsets the improvement in efficiency and flow rate. As will be discussed in Section V, it is important to have pump efficiency tests so that objective information is used to determine if a repair will be profitable.