*Proceedings of the 23rd Annual Central Plains Irrigation Conference, Burlington, CO., February 22-23, 2011*
*Available from CPIA, 760 N. Thompson, Colby, Kansas*

# EVALUATING ENERGY USE FOR PUMPING IRRIGATION WATER

**Derrel L. Martin, Tom W. Dorn, Steve R. Melvin, Alan J. Corr, William L. Kranz**
Associate Professor Biological Systems Engineering
University of Nebraska
Haskell Agricultural Laboratory
Concord, Nebraska
VOICE: 402-584-3857 FAX: 402-584-3859
wkranz1@unl.edu

## ENERGY USE IN IRRIGATON

Irrigation of 13.8 million acres of cropland accounts for a large portion of the energy used in Colorado, Nebraska, and Kansas. Analysis of data from the 2008 USDA Farm and Ranch Irrigation Survey shows that the average energy use for irrigating crops in Nebraska alone would be equivalent to about 340 million gallons of diesel fuel annually if all pumps were powered with diesel engines. While use varies depending on annual precipitation, average yearly energy consumption in Nebraska is equivalent to about 40 gallons of diesel fuel per acre irrigated.

The cost to irrigate a field is determined by the amount of water pumped and the cost to apply a unit (acre-inch) of water (Figure 1). Factors that determine pumping costs include those that are fixed for a given location (in the ovals in Figure 1) and those that producers can influence. The factors that producers can influence include: irrigation scheduling, application efficiency, efficiency of the pumping plant, and the pumping pressure required for center pivot system. Pumping costs can be minimized by concentrating on these factors. Irrigators may also consider changing the type of energy used to power irrigation if they determine that one source provides a long-term advantage.

Irrigation scheduling can minimize the total volume of water applied to the field. Demonstration projects in central Nebraska have indicated that 1.5-2.0 inches of water can be saved by monitoring soil water and estimating crop water use rates. The goal is to maximize use of stored soil water and precipitation to minimize pumping.

Improving the efficiency of water application is a second way to conserve energy. Water application efficiency is a comparison between the depth of water pumped and the depth stored in the soil where it is available to the crop. Irrigation systems can lose water to evaporation in the air or directly off plant foliage. Water is also lost at the soil surface as evaporation or runoff. Excess irrigation and/or rainfall may also percolate through the crop root zone leading to deep percolation. For center pivots, water application efficiency is based largely on the sprinkler package. High pressure impact sprinklers direct water upward into the air and thus there is more opportunity for wind drift and in-air evaporation. In addition, high pressure impact sprinklers apply water to foliage for 20-40 minutes longer than low pressure spray heads mounted on drop tubes. The difference in application time results in less evaporation directly from the foliage for low pressure spray systems. Caution should be used so that surface runoff does not result with a sprinkler package. Good irrigation scheduling should minimize deep percolation.

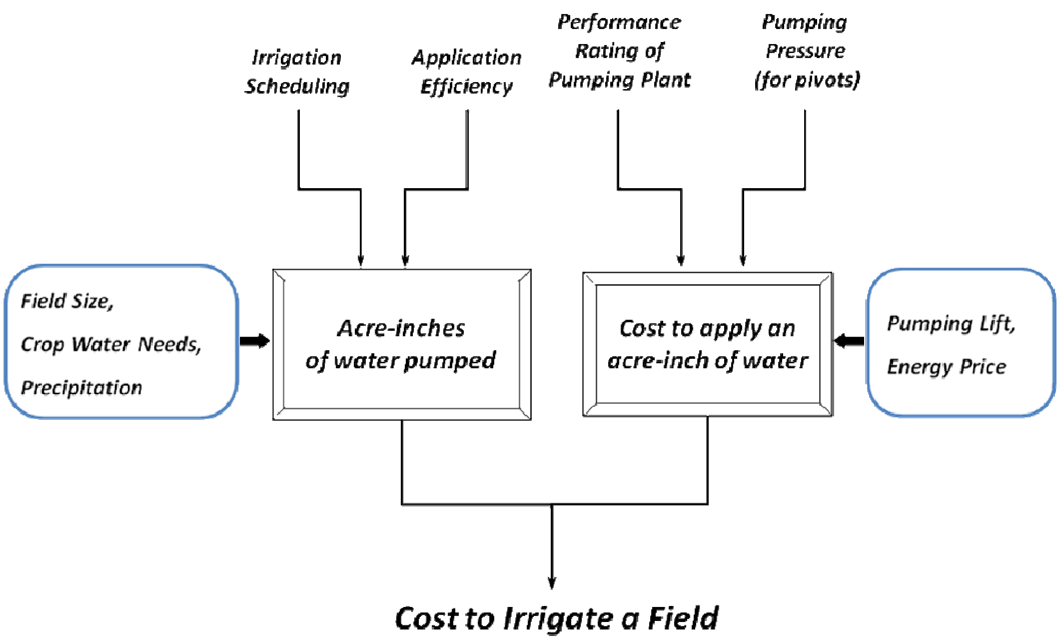



**Figure 1.** Diagram of factors affecting irrigation pumping costs.

Energy use can also be reduced by lowering the operating pressure of the irrigation system. One must keep in mind that lowering the operating pressure will reduce pumping cost per acre-inch, but reducing the pressure almost always results in an increased water application rate for a center pivot. The key is to ensure that the operating pressure is sufficient to eliminate the potential for surface runoff. Field soil characteristics, surface roughness, slope and tillage combine to control how fast water can be applied to the soil surface before surface runoff occurs. If water moves from the point of application, the savings in energy resulting from a reduction in operating pressure is counterbalanced by the need to pump more water to ensure that all portions of the field receive at least the desired amount of water.

Finally, energy can be conserved by ensuring that the pumping plant is operating as efficiently as possible. Efficient pumping plants require properly matched pumps, systems and power sources. By keeping good records of the amount of water pumped and the energy used, you can discover if extra money is being spent on pumping the water and how much you can afford to spend to fix components that are responsible for increased costs.

This document describes a method to estimate the cost of pumping water and to compare the amount of energy used to that for a well maintained and designed pumping plant. The results can help determine the feasibility of repairs.

## ENERGY REQUIREMENTS

The cost to pump irrigation water depends on the type of energy used to power the pumping unit. Electricity and diesel fuel are used to power irrigation for about 76% of the land irrigated in the region. Nebraska uses electricity or diesel fuel to power pumping plants used to irrigate approximately 7.58 million acres of cropland. Natural gas and Propane are used on about 20 and 4% of the land in the 3-state region, respectively. Kansas leads the region in the use of natural gas for pumping plant power with approximately 1.4 million acres irrigated. Very little land is irrigated with gasoline powered engines.

The cost to pump an acre-inch of water depends on:

- The work produced per unit of energy consumed,
- The distance water is lifted from the groundwater aquifer or surface water source to the pump outlet,
- The discharge pressure at the pump outlet,
- The performance rating of the pumping plant, and
- The cost of a unit of energy.

The amount of work produced per unit of energy depends on the source used to power the pump (Table 1). One gallon of diesel fuel will generate about 139,000 BTU of energy if completely burned. The energy content can also be expressed as the horsepower-hours of energy per gallon of fuel (*i.e.,* 54.5 hp-hr/gallon). Not all of the energy contained in the fuel can be converted to productive work when the fuel is burned in an engine. The Nebraska Pumping Plant Performance Criteria (NPPPC) was developed to provide an estimate of the amount of work that can be obtained from a unit of energy by a well designed and managed pumping plant (Table 1). Values were developed from testing engines and motors to determine how much work (expressed as horsepower-hours) could be expected from a unit of energy. An average efficiency for the pump and drive system for well designed and maintained pumping plants was used to provide the amount of work that could be expected from a "good" pumping plant.

The overall performance of the engine/motor and pump system is expressed as water horsepower hours (whp-hr). Research conducted to develop the NPPPC showed that diesel engines produced about 16.7 hp-hr of work per gallon of diesel fuel and that good pumping plants would produce about 12.5 whp-hr/gallon of diesel fuel. The performance of the engine and pumping plant systems can also be expressed as an efficiency, *i.e.,* the ratio of the work done compared to the energy available in the fuel. Results show that a diesel engine that meets the Nebraska Pumping Plant Criteria is only about 30% efficient and that the overall efficiency is only about 23%. Diesel engines are more efficient than spark engines (Table 1).

The amount of energy required for a specific system depends on the location of the water source relative to the elevation of the pump discharge. For groundwater the pumping lift depends on the distance from the pump base to the water level when not pumping (static water level) plus the groundwater drawdown as shown in Figure 2. Note that the lift is not the depth of the well or the depth that the pump bowls are located in the well. The lift may increase over time if groundwater levels decline during the summer or over the years. It is best to measure the pumping lift directly but the value can be estimated from well registration information for initial estimates. Well registration information for the 3-state region can be obtained on the internet at the following URL's:
Colorado: http://www.dwr.state.co.us/WellPermitSearch/default.aspx
*Kansas:* *http://www.kgs.ku.edu/Magellan/WaterWell/index.html*
Nebraska: *http://dnrdata.dnr.ne.gov/wellssql/ .*

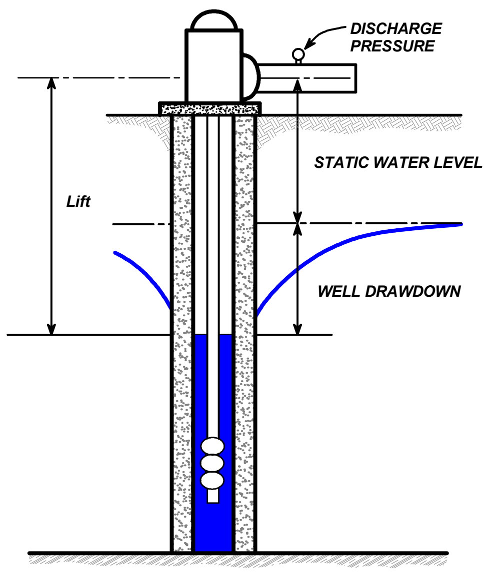



**Figure 2.** Diagram of pumping lift and discharge pressure measurements needed to assess pumping efficiency.

## PUMPING PLANT EFFICIENCY

The amount of energy required for a properly designed and maintained pumping plant to pump an acre-inch of water can be determined from Tables 2 and 3.

**Table 1.** Energy Content of Fuels for Powering Irrigation Engines‡

| Energy Source | Average Energy Content | | Nebraska Pumping Plant Performance Criteria | | Engine or Motor Efficiency % | Pumping Plant Conversion % |
|---|---|---|---|---|---|---|
| | BTU | Horsepower hour | Engine or Motor Performance hp-hr/unit | Pumping Plant Performance whp-hr/unit† | | |
| 1 gallon of diesel fuel | 138,690 | 54.5 | 16.7 | 12.5 | 31 | 23 |
| 1 gallon of gasoline | 125,000 | 49.1 | 11.5 | 8.66 | 23 | 18 |
| 1 gallon of liquefied petroleum gas (LPG) | 95,475 | 37.5 | 9.20 | 6.89 | 25 | 18 |
| 1 thousand cubic foot of natural gas | 1,020,000 | 401 | 82.2 | 61.7 | 21 | 15 |
| 1 therm of natural gas | 100,000 | 39.3 | 8.06 | 6.05 | 21 | 15 |
| 1 gallon of ethanol ✓ | 84,400 | 33.2 | 7.80 | 5.85 | X | X |
| 1 gallon of gasohol (10% ethanol, 90% gasoline) | 120,000 | 47.2 | 11.08 | 8.31 | X | X |
| 1 kilowatt-hour of electrical energy | 3,412 | 1.34 | 1.18 | 0.885 | 88 | 66 |

‡ Conversions: 1 horsepower = 0.746 kilowatts, 1 kilowatt-hour = 3412 BTU, 1 horsepower-hour = 2,544 BTU

† Assumes an overall efficiency of 75% for the pump and drive.

✓ Nebraska Pumping Plant Criteria for fuels containing ethanol were estimated based on the BTU content of ethanol and the performance of gasoline engines.

For example, a producer who has a system with a pumping lift of 150 feet and operates at a pump discharge pressure of 60 pounds per square inch (psi) would require 2.63 gallons of diesel fuel to apply an acre-inch of water. If the producer uses electricity the value of 2.63 should be multiplied by the factor in Table 3 to convert energy units. So, for electricity (2.63 x 14.12) = 37 kilowatt-hours would be needed per acre inch of water from a well with a pumping lift of 150 feet and an outlet pressure of 60 psi.

The amount of energy required for an actual pumping plant depends on the efficiency of the pump and power unit. If the pumping plant is not properly maintained and operated, or if conditions have changed since the system was installed, the pumping plant may not operate as efficiently as listed in Table 2. The energy needed for an actual system is accounted for in the NPPPC. Table 4 can be used to determine the impact of a performance rating less that 100%. For a performance rating of 80% the multiplier is 1.25, so the amount of energy used would be 25% more than for a system operating as shown in Table 2. The amount of diesel fuel for the previous example would be (2.63 x 1.25) = 3.29 gallons per acre-inch of water.

**Table 2.** Gallons of diesel fuel required to pump an acre-inch at a performance rating of 100%.

| Lift | Pressure at Pump Discharge, psi | | | | | | |
|---|---|---|---|---|---|---|---|
| feet | 10 | 20 | 30 | 40 | 50 | 60 | 80 |
| 0 | 0.21 | 0.42 | 0.63 | 0.84 | 1.05 | 1.26 | 1.69 |
| 25 | 0.44 | 0.65 | 0.86 | 1.07 | 1.28 | 1.49 | 1.91 |
| 50 | 0.67 | 0.88 | 1.09 | 1.30 | 1.51 | 1.72 | 2.14 |
| 75 | 0.89 | 1.11 | 1.32 | 1.53 | 1.74 | 1.95 | 2.37 |
| 100 | 1.12 | 1.33 | 1.54 | 1.75 | 1.97 | 2.18 | 2.60 |
| 125 | 1.35 | 1.56 | 1.77 | 1.98 | 2.19 | 2.40 | 2.83 |
| 150 | 1.58 | 1.79 | 2.00 | 2.21 | 2.42 | **2.63** | 3.05 |
| 200 | 2.03 | 2.25 | 2.46 | 2.67 | 2.88 | 3.09 | 3.51 |
| 250 | 2.49 | 2.70 | 2.91 | 3.12 | 3.33 | 3.54 | 3.97 |
| 300 | 2.95 | 3.16 | 3.37 | 3.58 | 3.79 | 4.00 | 4.42 |
| 350 | 3.40 | 3.61 | 3.82 | 4.03 | 4.25 | 4.46 | 4.88 |
| 400 | 3.86 | 4.07 | 4.28 | 4.49 | 4.70 | 4.91 | 5.33 |

**Table 3.** Conversions factors for other energy sources.

| Energy Source | Units | Multiplier |
|---|---|---|
| Diesel | gallons | 1.00 |
| Electricity | kilowatt-hours | 14.12 |
| Propane | gallons | 1.814 |
| Gasoline | gallons | 1.443 |
| Natural Gas | 1000 cubic feet | 0.2026 |

**Table 4.** Multiplier when pumping plant performance rating is less than 100%.

| **Rating, %** | 100 | 90 | 80 | 70 | 50 | 30 |
|---|---|---|---|---|---|---|
| **Multiplier** | 1.00 | 1.11 | 1.25 | 1.43 | 2.00 | 3.33 |

Producers can use Tables 2-4 and their energy records to estimate the performance rating for their pumping plant and the amount of energy that could be saved if the pumping plant was repaired or if operation was adjusted to better match characteristics of the pump and power unit.

Producers can also use hourly performance to estimate how well their pumping plant is working. For the hourly assessment an estimate of the pumping lift, discharge pressure, flow rate from the well and the hourly rate of energy consumption are required. The acre-inches of water pumped per hour can be determined from in Table 5.

**Table 5.** Volume of water pumped per hour.

| **Pump Discharge gpm** | **Water Pumped per Hour acre-inch/hr** | **Pump Discharge gpm** | **Water Pumped per Hour, acre-inch/hr** |
|---|---|---|---|
| 250 | 0.55 | 1250 | 2.76 |
| 300 | 0.66 | 1300 | 2.87 |
| 350 | 0.77 | 1350 | 2.98 |
| 400 | 0.88 | 1400 | 3.09 |
| 450 | 0.99 | 1500 | 3.31 |
| 500 | 1.10 | 1600 | 3.54 |
| 550 | 1.22 | 1700 | 3.76 |
| 600 | 1.33 | 1800 | 3.98 |
| 650 | 1.44 | 1900 | 4.20 |
| 700 | 1.55 | 2000 | 4.42 |
| 750 | 1.66 | 2100 | 4.64 |
| 800 | 1.77 | 2200 | 4.86 |
| 850 | 1.88 | 2400 | 5.30 |
| 900 | 1.99 | 2600 | 5.75 |
| 950 | 2.10 | 2800 | 6.19 |
| 1000 | 2.21 | 3000 | 6.63 |
| 1050 | 2.32 | 3200 | 7.07 |
| 1100 | 2.43 | 3400 | 7.51 |
| 1150 | 2.54 | 3600 | 7.96 |
| 1200 | 2.65 | 3800 | 8.40 |

The performance of the pumping plant ($P_p$) in terms of energy use per acre-inch of water is then the ratio of the hourly energy use divided by the volume of water pumped per hour:

$$P_p = \frac{\text{hourly fuel use rate (in gallons / hour}}{V_w \text{ (in acre} - \text{inches / hour)}}$$

For example, suppose a pump supplies 800 gallons per minute and the diesel engine burns 5.5 gallons of diesel fuel per hour. A flow rate of 800 gpm is equivalent to 1.77 acre-inches per hour (Table 5). The pumping plant performance is computed as 5.5 gallons of diesel per hour divided by 1.77 acre-inches of water per hour. This gives 3.11 gallons of diesel per acre-inch.

Suppose that the pumping lift is 150 feet and the discharge pressure is 60 psi for this example. If the system operates at the Nebraska Pumping Plant Performance Criteria only 2.63 gallons of diesel per acre-inch would be required (Table 2). The pumping plant performance rating (R) would be:

$$R = \frac{100 \times \text{Value from Table 2}}{P_p} = \frac{100 \times 2.63}{3.11}$$

For this case the performance rating is 85 meaning that the system uses about 18% more diesel fuel than required for a system at the Nebraska Criteria. The multipliers in Table 2 can also be used with the hourly method for other energy sources.

## PAYING FOR REPAIRS

Energy savings from repairing the pumping plant should be compared to the ability to pay for the repairs. The money that can be paid for repairs is determined by the length of the repayment period and the annual interest rate. These values are used to compute the series present worth factor (Table 6). The breakeven investment is the value of the annual energy savings times the series present worth factor.

The series present worth factor represents the amount of money that could be repaid at the specified interest rate over the repayment period. For example, for an interest rate of 7% and a repayment period of 10 years each dollar of annual savings is equivalent to $7.02 today. Only $4.10 could be invested today for each dollar of savings if the investment was to be repaid in 5 years rather than 10 years.

## Example

Suppose a pivot was used on 130 acres to apply 13.5 inches of water. The pumping lift was about 125 feet and the discharge pressure was 50 psi. Energy use records for the past season show that 5500 gallons of diesel fuel were used. The average price of diesel fuel for the season was $3.00 per gallon.

Using the value of 2.19 gallons of diesel fuel per acre-inch from Table 2, an efficient pumping plant would require about 3843 gallons of diesel fuel for the year (*i.e.,* 2.19 gallons/acre-inches times 13.5 inches times 130 acres = 1755 acre-inches of water). The annual records show that 5500 gallons were used to pump the water, then the performance rating would be (3843 / 5500) x 100 = 70%. This shows that 1657 gallons of diesel fuel could be saved if the pumping plant performance was improved. The annual savings in pumping costs would be the product of the energy savings times the cost of diesel fuel; *i.e.,* $3/gallon times 1657 gallons/year = $4971/year. If a 5-year repayment period and 9% interest were used, the series present worth factor would be 3.89 from Table 6. The breakeven repair cost would be $4971 × 3.89 = $19,337. If repair costs were less than $19,337 then repairs would be feasible. If costs were more than $19,337 the repairs may not be advisable at this time.

**Table 6.** Series Present Worth Factor

| Repayment Period, years | Annual Interest Rate | | | | | |
|---|---|---|---|---|---|---|
| | 6% | 7% | 8% | 9% | 10% | 12% |
| 3 | 2.67 | 2.62 | 2.58 | 2.53 | 2.49 | 2.40 |
| 4 | 3.47 | 3.39 | 3.31 | 3.24 | 3.17 | 3.04 |
| 5 | 4.21 | 4.10 | 3.99 | 3.89 | 3.79 | 3.60 |
| 6 | 4.92 | 4.77 | 4.62 | 4.49 | 4.36 | 4.11 |
| 7 | 5.58 | 5.39 | 5.21 | 5.03 | 4.87 | 4.56 |
| 8 | 6.21 | 5.97 | 5.75 | 5.53 | 5.33 | 4.97 |
| 9 | 6.80 | 6.52 | 6.25 | 6.00 | 5.76 | 5.33 |
| 10 | 7.36 | 7.02 | 6.71 | 6.42 | 6.14 | 5.65 |
| 12 | 8.38 | 7.94 | 7.54 | 7.16 | 6.81 | 6.19 |
| 15 | 9.71 | 9.11 | 8.56 | 8.06 | 7.61 | 6.81 |
| 20 | 11.47 | 10.59 | 9.82 | 9.13 | 8.51 | 7.47 |
| 25 | 12.78 | 11.65 | 10.67 | 9.82 | 9.08 | 7.84 |

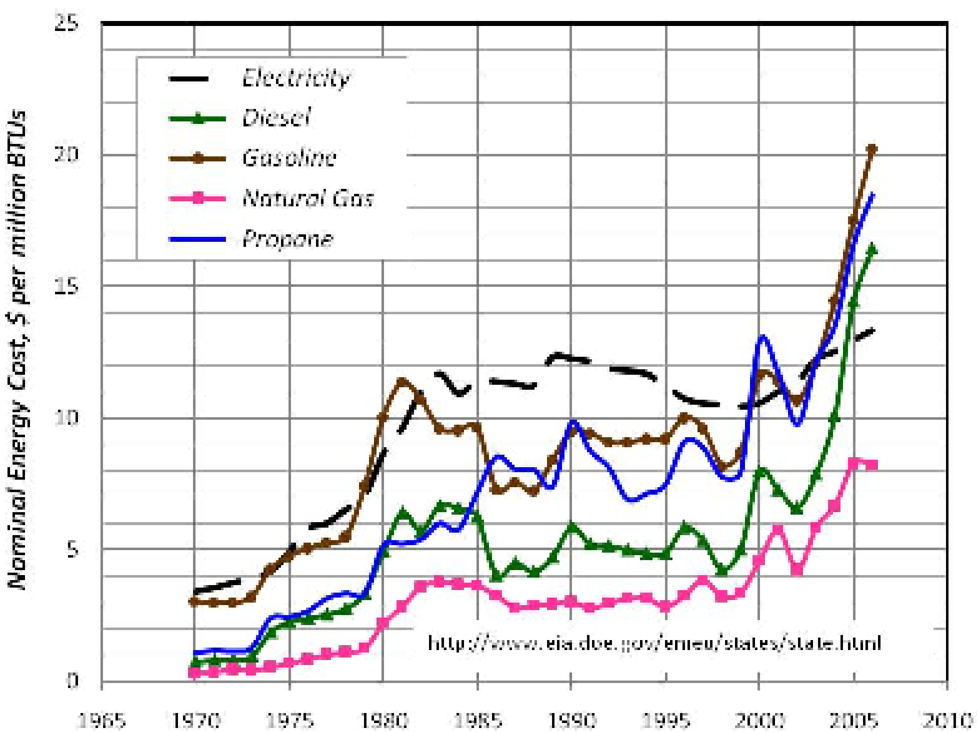
## COMPARING ENERGY SOURCES

The optimal type of energy for powering irrigation engines depends on the long-term relative price of one energy source compared to another. Energy prices have varied considerably over time. The nominal cost of energy per million BTUs is illustrated in Figure 3 for the types used to power irrigation systems for the period from 1970 through 2006. These results show that electricity was expensive relative to other energy sources from about 1983 through about 2000. Electricity has become more favorable especially recently when fossil fuels prices have increased rapidly. While diesel fuel once was very economical the situation has recently changed.

Two methods can be used to analyze power source alternatives for irrigation. The previous section illustrated how to determine the amount one could afford to pay through annual energy savings if one changed from an energy source to another type. A more detailed analysis based on the average annual ownership cost can be found at the URL http://lancaster.unl.edu/ag/Crops/irrigate.shtml. A demonstration of the technique is illustrated to compare diesel and electricity as energy sources for a typical center pivot. Representative costs are included in Figure 4 for an electrically powered pivot and in Figure 5 for a pivot powered with a diesel engine. The cost for the electric motor should include any extra expenses for control panels and to bring three-phase service to the motor. The diesel engine should include the cost of the fuel tank and an electric generator if one is not present. The costs listed in the figures are approximate values and local conditions should be use for specific comparisons.

Results of using the spreadsheet to compare the total annual cost of an electrically powered and a diesel powered irrigation system are shown in Table 7 for a range of electricity and diesel fuel prices. The annual savings is the difference between the annual costs for diesel minus the cost for an electrically powered system. The results show that electricity is generally preferred except when diesel is less than $2.25 /gallon and electrical rates are above 8¢/kWh. If the price of electricity is 6¢/kWh and diesel fuel is $2.25 per gallon then switching to electricity could save over $3,000 annually as long as service can be brought to the field. Again, these are representative costs and producers should analyze their unique situation.

**Figure 3.** Historical energy prices since 1970.



# Annualized Cost of Owning and Operating an Irrigation System

**Center Pivot with Electric Pump Mot(**  Written by: Tom Dorn, Extension Educator  UNL-IANR  Lancaster County, NE  revised 02/02/2009

| | | | |
|---|---|---|---|
| Select Distribution System | Pivot | | |
| Acres Irrigated | 130 | | |
| Pumping water level, ft. | 150 | | |
| System Pressure, PSI | 50 | | |
| Gross Depth applied, inch | 12 | | |
| Select Power Unit Type | Electricity | | |
| $/kW-h | $0.060 | | |
| Labor Chrg, $/hour | $15.00 | | |
| Irrigation District, $/ac-ft | 0 | | |
| Return on Invest. (R.O.I), ¶ | 6 | | |
| Drip Oil, $/gal | $4.50 | | |
| Increase in Property Tax Due to Irrig.Development, $/ac | $0.00 | | |
| Annual Elec Hookup Cost | $2,500 | HP= 100 | $/HP= $25.00 |

**Note: Users are encouraged to replace values in blue font with values that represent their unique situation.**

**Select Distribution system and energy source for the pump motor from pull down menus.**

| Component | | | | Ownership Costs | | | Operating Costs | | | | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Initial Cost | Life | Salvage[4] | R.O.I. | Insurance + tax | Depr | Repairs[2] | Oper. labor | Electricity | Energy $[1] | Total Costs |
| Irrigation Well | $16,500 | 25 | ($825) | $491 | $165 | $693 | $215 | $23 | Kw-hour | kW+Hookup | $1,587 |
| Irrigation Pump | $11,163 | 18 | $558 | $369 | $112 | $589 | $340 | $94 | | $/kW-h | $1,504 |
| Gear Head | $0 | 15 | $0 | $0 | $0 | $0 | $0 | $0 | | $0.11 | $0 |
| Pump Base, etc. | $1,100 | 25 | $55 | $36 | $11 | $42 | $17 | $23 | | | $129 |
| Electric Motor& Switches | $8,500 | 30 | $425 | $276 | $170 | $269 | $550 | $351 | 53,182 | $5,691 | $7,307 |
| Center Pivot System | $52,000 | 20 | $2,600 | $1,712 | $1,040 | $2,470 | $2,028 | $702 | | $70 | $8,022 |
| | | | $0 | $0 | $0 | $0 | $0 | $0 | | $0 | $0 |
| | | | | | | | | | | | $0 |
| Add'l Property Tax | | | | | $0 | | | | | | $0 |
| Totals | $89,263 | | $2,813 | $2,884 | $1,498 | $4,063 | $3,150 | $1,193 | | $5,761 | $18,549 |

| | Ownership Costs | Operating Costs | Total Costs |
|---|---|---|---|
| Total annual $ | $8,445 | $10,104 | $18,549 |
| Annual $/ Acre | $64.96 | $77.72 | $142.68 |
| $/ac-in | $5.41 | $6.48 | $11.89 |

1 Energy Cost assumes operating at 100% of the NPC. Hookup charge added for Electric Units.
2 Drip oil added to repair costs. For internal combustion engines, 5% o energy costs added to repair costs for oil, filters, and lube.
3 Energy Cost for Center Pivot assumes 7/8 hp-h per acre inch of water delivered. Other systems require no additional energy for distribution
4 End of life salvage value 5% of purchase price except for irrigation well.
**End of life cost for well = 5% to plug the well.**

**Figure 4.** Detailed analysis for an electrically powered center-pivot irrigated field with the conditions shown.

# Annualized Cost of Owning and Operating an Irrigation System

**Center Pivot with Diesel Engine** Written by: Tom Dorn, Extension Educator UNL-IANR Lancaster County, NE revised 02/02/2009

| | |
|---|---|
| Select Distribution System | Pivot |
| Acres Irrigated | 130 |
| Pumping water level, ft. | 150 |
| System Pressure, PSI | 50 |
| Gross Depth applied, inches | 12 |
| Select Power Unit Type | Diesel |
| $/Gallon | $2.250 |
| Labor Chrg, $/hour | $15.00 |
| Irrigation District, $/ac-ft | 0 |
| Return on Invest. (R.O.I), % | 5 |
| Drip Oil, $/gal | $4.50 |
| Increase in Property Tax Due to Irrig.Development, $/ac | $0.00 |

**Note: Users are encouraged to replace all values in blue font with values that represent their unique situation.**

**Select Distribution system and energy source for the pump motor from pull down menus.**

| Component | | | | Ownership Costs | | | Operating Costs | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Initial Cost | Life | Salvage[4] | R.O.I. | nsurance + tax | Depr | Repairs[2] | Oper. labor | Diesel Gallons | Energy $[1] | Total Costs |
| Irrigation Well | $16,500 | 25 | ($825) | $409 | $165 | $693 | $215 | $23 | | | $1,505 |
| Irrigation Pump | $11,163 | 18 | $558 | $308 | $112 | $589 | $340 | $94 | | | $1,442 |
| Gear Head | $2,800 | 15 | $140 | $78 | $28 | $177 | $36 | $23 | | | $343 |
| Pump Base, etc. | $1,100 | 25 | $55 | $30 | $11 | $42 | $17 | $23 | | | $123 |
| Diesel Engine & Tank | $11,500 | 12 | $575 | $325 | $230 | $910 | $782 | $351 | 3,765 | $8,472 | $11,070 |
| Center Pivot System | $52,000 | 20 | $2,600 | $1,427 | $1,040 | $2,470 | $2,028 | $0 | | $185 | $7,150 |
| | | | $0 | $0 | $0 | $0 | $0 | $0 | | $0 | $0 |
| | | | | | | | | | | | $0 |
| Add'l Property Tax | | | | | $0 | | | | | | $0 |
| Totals | $95,063 | | $3,103 | $2,576 | $1,586 | $4,882 | $3,419 | $515 | | $8,657 | $21,634 |

1 Energy Cost assumes operating at 100% of the NPC. Hookup charge added for Electric Units.
2 Drip oil added to repair costs. For internal combustion engines, 5% of energy costs added to repair costs for oil, filters, and lube.
3 Energy Cost for Center Pivot assumes 7/8 hp-h per acre inch of water . delivered. Other systems require no additional energy for distribution
4 End of life salvage value 5% of purchase price except for well.
**End of life cost for well = 5% to plug the well.**

| | Ownership Costs | Operating Costs | Total Costs |
|---|---|---|---|
| Total annual $ | $9,044 | $12,591 | $21,634 |
| Annual $/ Acre | $69.57 | $96.85 | $166.42 |
| $/ac-in | $5.80 | $8.07 | $13.87 |

**Figure 5.** Detailed analysis for a center-pivot irrigated field powered with diesel fuel for the field conditions shown.

**Table 7.** Annual Savings by Using Electricity

| Electricity | | Diesel Fuel Cost, $ / gallon | | | |
|---|---|---|---|---|---|
| | | 1.75 | 2.00 | 2.25 | 2.50 |
| Price, $ / kWh | Total Annual Costs | $19,616 | $20,625 | $21,634 | $22,643 |
| 0.06 | $18,549 | $1,067 | $2,076 | $3,085 | $4,094 |
| 0.07 | $19,119 | $497 | $1,506 | $2,515 | $3,524 |
| 0.08 | $19,689 | -$73 | $936 | $1,945 | $2,954 |
| 0.09 | $20,259 | -$643 | $366 | $1,375 | $2,384 |
| 0.10 | $20,829 | -$1,213 | -$204 | $805 | $1,814 |

## SUMMARY

This publication demonstrates methods to estimate the potential for repairing pumping plants to perform at the Nebraska Pumping Plant Performance Criteria and the annual cost for varying energy sources. Producers frequently have several questions regarding the procedures.

First they want to know ***"Can actual pumping plants perform at a level equal to the Criteria"***. Tests of 165 pumping plants in the 1980's indicated that 15% of the systems actually performed at a level above the Criteria. So producers can certainly achieve the standard. Recent evaluations in Nebraska have identified pumping plants that were operating at above 100% of the NPPPC, but many were between 80 and 100% of the NPPPC.

The second question is ***"What level of performance can producers expect for their systems?"*** Tests on 165 systems in Nebraska during the 1980s produced an average performance rating of 77% which translates to an average energy savings of 30% by improving performance. Tests on 200 systems in North Dakota in 2000 produced very similar results. These values illustrate that half of the systems in the Great Plains could be using much more energy than required. The simplified method can help determine if your system could be inefficient.

The third issue focuses on ***"What should I do if the simplified method suggests that there is room for improving the efficiency?"*** You should first determine if the irrigation system is being operated as intended. You need to know if the pressure, lift and flow rate are appropriate for the irrigation system. For example, some systems were initially installed to deliver water for furrow irrigation and are now used for center-pivot systems. If the pumping plant is not redesigned, conditions for the new system are likely not appropriate and you need to work with a well driller/pump supplier to evaluate the design of the system.