IRRIGATION PUMPING PLANT ALTERNATIVES

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Irrigation pumping costs depend on the requirements of the individual pumping plant. Energy use is the major component of pump operating costs. Pumping plant efficiency, pumping lift, water pressure and the amount of water delivered all influence the energy required to operate the pumping plant. Operating cost savings for pumping plants can come from improving the efficiency of pumps and engines, reducing water pressure, and possibly changing fuel sources.

A computerized spreadsheet was developed to calculate the operating costs for a number of possible changes to an established pumping plant. It was designed to aid irrigators in calculating the cost or savings of these changes.

PURPOSE OF SPREADSHEET

The computerized spreadsheet provides rapid calculations of operating costs for irrigation pumping plants. Two-way tables are generated by the computer to compare pumping costs if the fuel source, operating pressure or pumping plant efficiency are changed. The difference in operating cost between two alternatives is then treated as a loan payment which converts into capital available for modifying the pumping plant.

The specific calculations include: (1) brake horsepower, (2) annual operating costs including energy, repair and maintenance, (3) annual operating cost per acre, (4) annual operating costs for a range of operating pressures and system performance (efficiencies), (5) capital available for improving performance, (6) energy use, (7) annual operating costs differences between fuel sources, and (7) capital available for changing fuel sources.

BASIS FOR CALCULATIONS

Energy Use

Energy use is calculated from the irrigation system requirements and pumping plant efficiencies. The worksheet user supplies the pumping rate, acres irrigated, pumping lift, system operating pressure, operating hours, and pumping plant performance as a percent of the Nebraska performance criteria. The Nebraska performance criteria include standard operating efficiencies for a properly designed and maintained pumping plant, including the pump, drives, gearhead (if needed) and motor or engine. The Nebraska performance criteria are expressed as the ratio of the work performed by the pumping plant (water horsepower) and the fuel or energy needed to perform the work.

A pumping plant operating at 100% of the Nebraska performance criteria would have the following water horsepower to energy ratios:

Table 1. Nebraska pumping plant performance criteria.

Energy Source	water hp-hr[ab] unit of energy	Energy Units
Diesel	12.50	gallon
Gasoline	8.66[c]	gallon
Propane	6.89[c]	gallon
Natural Gas	6.17[d]	100 ft^3
Electricity	0.885[e]	kW-hr

[a]Work accomplished by the pumping plant at 100% of the Nebraska performance criteria.
[b]Based on 75% pump efficiency.
[c]Taken from Test D of Nebraska Tractor Test Reports. Drive losses are accounted for in the data. Assumes no cooling fan.
[d]Manufacturers' data corrected for 5% gear head drive loss with no cooling fan. Assumes natural gas energy content of 925 BTU per cubic foot. At 1000 BTU per cubic foot energy content use 6.67 water hp-h/100 ft^3.
[e]Assumes 88% electric motor efficiency, direct connection, no drive loss.

Water horsepower is calculated by:

$$\text{water hp} = \frac{\text{pumping rate(gpm) X total head(ft)}}{3960}$$

$$\text{total head} = (2.31 \text{ X pressure[psi]}) + \text{lift(ft)}.$$

For more information on calculating the Nebraska performance criteria, see Nebraska Cooperative Extension Service EC 81-713: "It pays to test your irrigation pumping plant".

If the pumping plant's performance is not known, but the energy use per hour or per season is known, then the pumping plant's performance can be estimated by trial and error. The average pumping plant performance found in Nebraska has been 80% of the Nebraska criteria. Start with 80% and compare the calculated energy use with your known use. If known use is higher, reduce the performance level, If known energy use is higher than calculated, increase the performance level.

Economic Analysis

Present value procedures are used to evaluate whether potential energy cost savings from changing the pumping plant or irrigation system can pay for the necessary alterations. The investment in system alterations is paid for by the operation cost savings. The time for "paying off" the cost of alterations should be based on the length of time lenders would loan money for this investment. The calculation procedure also allows loan interest costs to be covered by energy savings.

Use of the loan period as the "payoff" period normally reduces the time which fuel savings pay for system alterations compared to using the useful life of the investment. The shorter time is relevant for two important reasons. First, cash flow of the operation is not harmed by this procedure. Second, the shorter the time necessary to pay for the alterations, the less risk that fuel price trends will reverse.

The annual operating cost difference between two alternatives is converted to present values on the spreadsheet. Present values are calculated by discounting the future cost savings with an interest or discount rate. Future income is discounted because many believe that a dollar received (saved) at some future time is worth less than one received (saved) today. The rate of interest or discount depends on how the individual views future versus present income. A low discount rate implies that the individual believes future cost savings are about as good as receiving the cost savings today. The discount rate chosen is often related to interest rates on savings since a dollar today can be invested at a given interest rate and be worth that much more in the future. This spreadsheet uses the prospective loan interest rate for discounting since that method insures that the cost savings will not only pay back the principal but also the interest over the chosen time period.

The user can specify the interest rate and loan duration based on current or anticipated lending policies. If alterations are financed from savings, the interest rate and time period should reflect the opportunity cost of that money (earnings lost as a result of using the funds to make the alterations rather than leaving them in savings).

USER INPUTS

Inputs for the pumping cost spreadsheet include water pumping rate in gallons per minute, area irrigated in acres, pumping lift in feet, operating pressure in psi, and total hours pumped. Gross irrigation (total pumped inches) is a calculated value. Hours or gpm can be adjusted if gross irrigation is known. University of Nebraska pumping plant tests showed that the average performance is 80% of the Nebraska criteria. If past energy use on a particular pumping plant is known, the assumed performance of the pumping plant can be adjusted up or down so that the calculated energy use from the spreadsheet matches known energy use.

Energy prices are another input item. The annual horsepower or connect charges for electric motors must be added to the operating cost. The overall kilowatt-hour cost can be calculated by dividing the total electrical cost from last year, including horsepower or connect charges, by the total kilowatt-hours used. This is a separate calculation that the user must make before entering the electricity price into the spreadsheet. Fuel used last year is calculated by the spreadsheet from the other input values. This calculated fuel use can then be compared with actual fuel use records in order to adjust performance level or other inputs. The more the irrigator knows about these input values, the more accurate the results. However, estimated inputs can still lead to valuable comparisons of costs.

The interest rate and time period for the energy costs to pay off the original investment are also input items. The user can vary either interest rate or time period or both.

OUTPUT TABLES

Calculation of Operating Costs

Energy use is calculated from the Nebraska performance criteria in Table 1, the performance level of the individual pumping plant and the input values including operating pressure, lift, pump output (gpm), and operating hours. Energy use and energy price are then multiplied together to calculate seasonal energy costs. Repair and maintenance estimates are added to the seasonal energy costs to calculate operating costs. Repair and maintenance costs are estimated by:

Table 2. Factors for estimating repair and maintenance of pumping plants.

Power Unit	
Electric	\$0.62/BHP*/1000 hrs + 20 hrs labor/1000 hrs
Propane and Natural Gas	\$2.40/BHP*/1000 hrs + 40 hrs labor/1000 hrs
Gasoline	\$3.15/BHP*/1000 hrs + 40 hrs labor/1000 hrs
Diesel	\$3.75/BHP*/1000 hrs + 20 hrs labor/1000 hrs

*BHP = Brake Horsepower

Comparison of Two Fuel Sources

Whether or not to convert a pumping plant from one fuel source to another is a common question. The cost relationship between two fuels is the key factor in any decision to convert. Since energy savings will seldom pay for conversions in one year and future prices are difficult to predict, worksheet tables give a range of fuel prices.

Calculations assume that all of the annual energy cost savings are used to make interest and principal payments for a conversion loan. The spreadsheet calculates the maximum size loan these payments will support given the input interest rate and length of loan and relative energy prices. If the capital required to convert is equal to or less than the calculated number, the energy savings alone will pay off the loan and interest. This statement also assumes that future price spreads between the two fuels will remain at least as large and in the same direction.

Pumping plant operating costs without changing fuel source. If the same fuel source is used to power the pumping plant, the operating cost might be reduced by reducing the pressure or by improving the performance of the pump and/or motor. Reducing pressure can also increase the chances for soil surface runoff. This should be carefully considered before changes are made. (see NebGuide G88-870, Selecting Sprinkler Packages for Center Pivots).

Pump adjustments that improve pumping plant efficiency may increase operating pressure, water output (gpm) and therefore increase power requirements and energy use per hour. Cost savings would result from fewer operating hours to pump the same total water. This situation often occurs when an electric powered pump is adjusted and pump efficiency increases. The electric motor cannot be "throttled back" to compensate for the increased pump efficiency since it operates at a constant speed (rpm). This situation can be evaluated only by using the new operating conditions as inputs to the spreadsheet.

SUMMARY

The pumping cost spreadsheet can estimate the annual cost of operating a pumping plant based on pumping rate, acres irrigated, lift, operating pressure, system performance and hours of pumping. Changes in operating costs are calculated depending on changes in factors including: fuel price, operating pressure, system performance, pumping rate and fuel source. The spreadsheet then treats the savings in operating costs as payments on a loan for making a change in the system. Irrigators can compare loan principal to the cost for making the change. The spreadsheet is only a guide for determining these potential cost savings for alterations in individual pumping plants. Each irrigator must not only consider the results of this spreadsheet but also other factors such as the accuracy of the data entered, the confidence he/she has in the fuel price projections, and the individual attitude towards alternate fuel sources.

IRRIGATION PUMPING PLANT OPERATING COSTS AND ALTERNATIVES

What are the Alternatives for Cutting Costs?

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******** Press the ENTER key to continue ********

This worksheet consists of tables of irrigation pumping costs as influenced by fuel type, system pressure, and pumping plant performance. Each table occupies one screen on the worksheet. The input screen, located at cell A1, contains the input values for all the formulas in the remainder of the tables. Only the unprotected cells in the input form can be changed.

Two commands access the features of the worksheet.
Alt P activates the main menu. From there, menu selections control movement from screen to screen. PRINT and HELP commands are included. Use the ENTER key to return to the previous screen from a HELP screen. The ESC key will back you out of the menus. Also, use ALT P to return to the main menu from the input screen. The menu moves you around the wordsheet.
Alt T activates a typing or printing MACRO. Move the cursor to the upper left corner of the screen to be typed. Align the paper before printing. Hit Alt T to type the screen.
Use PgUp, Pgdn, Home and Tab keys to move around the worksheet without the menu.
***************** Press the ENTER key to continue *********************

INPUT TEMPLATE FOR CALCULATING PUMPING COSTS FOR ONE PUMPING PLANT

LOAN: INTEREST YEARS	TOTAL PUMPED INCHES	PUMPING RATE GAL/MIN	ACRES	LIFT FEET	PRESSURE P.S.I	PUMPING PLANT PERFORMANCE PERCENT	TOTAL PUMPED HOURS
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ENERGY	UNIT COST		ANNUAL COST ($/YR)	FUEL USED LAST YR.	
DIESEL	--------	$/GAL.	--------	--------	GALLONS
PROPANE	--------	$/GAL.	--------	--------	GALLONS
NAT. GAS	--------	$/100 FT3	--------	--------	100 FT3
ELECTRIC (Inc HP)	--------	$/KW-H	--------	--------	KW-HR
GASOLINE	--------	$/GAL.	--------	--------	GALLONS

INPUTS FOR CALCULATING PUMPING COSTS FOR ONE PUMPING PLANT

LOAN: INTEREST 12.0% YEARS	TOTAL PUMPED INCHES	PUMPING RATE GAL/MIN	ACRES	LIFT FEET	PRESSURE P.S.I	PUMPING PLANT PERFORMANCE PERCENT	TOTAL PUMPED HOURS
3	16.8	900	130	150	65	80	1100

ENERGY	UNIT COST	ANNUAL COST	FUEL USE (CALCULATED)
DIESEL	$0.80 $/GAL.	6,600 $/YR	6.8 GAL/HR
PROPANE	$0.40 $/GAL.	6,130 $/YR	12.4 GAL/HR
NAT. GAS	$0.40 $/100 FT3	6,760 $/YR	13.8 100 FT3/HR
ELECTRIC (Inc HP)	$0.070 $/KW-H	7,700 $/YR	105,990 KW-HR/YR
GASOLINE	$0.80 $/GAL.	9,420 $/YR	9.8 GAL/HR

INPUT RANGES FOR FUEL COSTS, AND PRESSURE

DIESEL $/GAL.	PROPANE $/GAL.	NAT. GAS $/100 FT3	ELECTRIC $/KW-H	GASOLINE $/GAL.	PRESSURE (PSI)
$0.50	$0.10	$0.10	$0.010	$0.50	35
$0.60	$0.20	$0.20	$0.030	$0.60	45
$0.70	$0.30	$0.30	$0.050	$0.70	55
$0.80	$0.40	$0.40	$0.070	$0.80	65
$0.90	$0.50	$0.50	$0.090	$0.90	75
$1.00	$0.60	$0.60	$0.110	$1.00	85
$1.10	$0.70	$0.70	$0.130	$1.10	95

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ANNUAL OPERATING COST SUMMARY FOR DIESEL, PROPANE, NAT. GAS, ELECTRICITY

DIESEL		PROPANE		NATURAL GAS		ELECTRICITY	
$/GAL.	$/YR *	$/GAL.	$/YR *	$/100 FT3	$/YR *	$/KW-H	$/YR *
$0.50	4,350	$0.10	2,040	$0.10	2,200	$0.010	1,340
$0.60	5,100	$0.20	3,400	$0.20	3,720	$0.030	3,460
$0.70	5,850	$0.30	4,760	$0.30	5,240	$0.050	5,580
$0.80	6,600	$0.40	6,130	$0.40	6,760	$0.070	7,700
$0.90	7,350	$0.50	7,490	$0.50	8,280	$0.090	9,820
$1.00	8,100	$0.60	8,850	$0.60	9,800	$0.110	11,940

EXPECTED FUEL USE FOR ELECTRIC AND DIESEL MOTORS

TOTAL PUMPED INCHES	INPUTS: PUMPING RATE GALLONS/MIN	ACRES	LIFT FEET	PRESSURE P.S.I	PUMPING PLANT PERFORMANCE PERCENT	TOTAL PUMPED HOURS
16.8	900	130	150	65	80	1100

OUTPUTS:

WATER HP	68.2 HP		BRAKE HP	91.0 HP
DIESEL	6.8	GAL/HOUR	3.4	GAL/AC-IN
DIESEL	57.7	GAL/AC	7,500	GAL/SEASON
ELECTRICITY	96.4	KW-HR/HR	48.0	KW-HR/AC-IN
ELECTRICITY	815	KW-HR/AC	105,990	KW-HR/SEASON

ANNUAL OPERATING COST DIFFERENCE (ELECTRICITY MINUS DIESEL)

DIESEL COST $ PER GAL.	ELECTRICITY COST ($ PER KW-H) HORESEPOWER & OPERATING $0.110	$0.090	$0.070	$0.050	$0.030	$0.010
	$/SEASON					
$1.10	3,080	960	(1,160)	(3,270)	(5,390)	(7,510)
$1.00	3,830	1,710	(400)	(2,520)	(4,640)	(6,760)
$0.90	4,580	2,470	350	(1,770)	(3,890)	(6,010)
$0.80	5,340	3,220	1,100	(1,020)	(3,140)	(5,260)
$0.70	6,090	3,970	1,850	(270)	(2,390)	(4,510)
$0.60	6,840	4,720	2,600	480	(1,640)	(3,760)
$0.50	7,590	5,470	3,350	1,230	(890)	(3,010)

BREAK EVEN CAPITAL FOR CONVERSION TO DIESEL FROM ELECTRIC MOTOR
Interest rate = 12.00% Loan duration = 3 years

DIESEL COST $ PER GAL.	ELECTRICITY COST ($ PER KW-H) HORESEPOWER & OPERATING $0.110	$0.090	$0.070	$0.050	$0.030	$0.010
	$/FOR CONVERSION					
$1.10	7,400	2,310	(2,790)	(7,850)	(12,950)	(18,040)
$1.00	9,200	4,110	(960)	(6,050)	(11,140)	(16,240)
$0.90	11,000	5,930	840	(4,250)	(9,340)	(14,440)
$0.80	12,830	7,730	2,640	(2,450)	(7,540)	(12,630)
$0.70	14,630	9,540	4,440	(650)	(5,740)	(10,830)
$0.60	16,430	11,340	6,240	1,150	(3,940)	(9,030)
$0.50	18,230	13,140	8,050	2,950	(2,140)	(7,230)

ANNUAL OPERATING COSTS WITH VARIOUS PRESSURES OR SYSTEM PERFORMANCE

GROSS INCHES *	PUMPING RATE GALLONS/MIN	ACRES	LIFT FEET	DIESEL $/GAL	TOTAL HOURS
16.8 *	900	130	150	$0.80	1100

SYSTEM PRESSURE (PSI)	PUMPING PLANT PERFORMANCE (%) 100	90	80	70	60	50	40
	$/SEASON						
35	4,200	4,610	5,130	5,790	6,670	7,900	9,750
45	4,600	5,050	5,620	6,340	7,310	8,670	10,700
55	5,000	5,490	6,110	6,900	7,960	9,440	11,650
65	5,400	5,930	6,600	7,460	8,600	10,200	12,610
75	5,800	6,370	7,090	8,020	9,250	10,970	13,560
85	6,200	6,810	7,580	8,570	9,890	11,740	14,510

ANNUAL OPERATING COSTS ($/AC) VS. PRESSURE OR SYSTEM PERFORMANCE

GROSS INCHES *	PUMPING RATE GALLONS/MIN	ACRES	LIFT FEET	DIESEL $/GAL	TOTAL HOURS
16.8 *	900	130	150	$0.80	1100

SYSTEM PRESSURE (PSI)	PUMPING PLANT PERFORMANCE (%) 100	90	80	70	60	50	40
	$/ACRE						
35	32	35	39	45	51	61	75
45	35	39	43	49	56	67	82
55	38	42	47	53	61	73	90
65	42	46	51	57	66	78	97
75	45	49	55	62	71	84	104
85	48	52	58	66	76	90	112

BREAK EVEN CAPITAL FOR IMPROVING PERFORMANCE OF DIESEL POWERED PUMPING
Interest rate = 12.00% Loan duration = 3 years

DIESEL COST $ PER GAL.	PUMPING PLANT PERFORMANCE (%) 90	80	70	60	50	40
	$/FOR IMPROVEMENT					
$1.10	1,760	3,970	6,800	10,570	15,860	23,790
$1.00	1,600	3,600	6,180	9,610	14,420	21,630
$0.90	1,440	3,240	5,560	8,650	12,980	19,460
$0.80	1,280	2,880	4,940	7,690	11,530	17,300
$0.70	1,120	2,520	4,330	6,730	10,090	15,140
$0.60	960	2,160	3,710	5,770	8,650	12,980
$0.50	800	1,800	3,090	4,810	7,210	10,810

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HELP 1 EXPECTED FUEL USE FOR ENGINES AND MOTORS

Water horsepower is the energy that must be delivered to the water in the well to lift it to the surface at a desired pressure.
Brake horsepower is the work that the power unit must deliver to the pump drive shaft.

Pumping plant performance in percent is the level of performance (or efficiency) in comparison to the Nebraska performance criteria. The average pumping plant performance in Nebraska is 80%.

Calculated fuel use rates in this table can be compared with known use rates for the pumping plant. If these rates do not match, return to the input sheet to make adjustments to the performance level.
Note: These calculations do not consider the energy for operating center pivot tower drive motors, which will not with pumping plant alterations. Actual fuel use would be 10-15% higher than the calculated values on this worksheet. Also, we assumed that a cooling coil rather than a radiator is used.

********* Press the ENTER key to return. ********

HELP 2 ANNUAL OPERATING COST DIFFERENCE

This table shows the difference in operating costs between two fuel sources over a range of fuel prices. If the fuel source listed first is more expensive, the numbers are positive. If the fuel source listed second is more expensive, the numbers are negative (numbers in parenthesis).

Annual operating costs include energy or fuel costs plus repair and maintenance. Repair and maintenance has been calculated from brake horsepower of the power plant, operating hours, labor costs, and the type of engine or motor.

If fuel unit prices along the column or row headers are negative, increase the input unit price in the input table (HOME) or ignore the negatives. The unit price ranges are calculated from your input price. The automatic calculation of the price range may give negative values.

********* Press the ENTER key to return. ********

HELP 3 BREAK EVEN CAPITAL FOR CONVERSION

This table shows the maximum money available to spend on converting a pumping plant from one fuel source to another. The annual operating cost difference between the two fuel sources would be used as payments on the conversion loan as specified in the input table.

If the numbers in parenthesis are negative, it means there is no money for conversion. If you are converting in the opposite direction, ie. to electric from diesel instead of to diesel from electric, the negatives become positives and positives become negative.

If fuel unit prices along the column or row headers are negative, increase the input unit price in the input table (HOME) or ignore the negatives. The unit price ranges are calculated from your input price. The automatic calculation of the price range may give negative values.

********* Press the ENTER key to return. ********

HELP 4
ANNUAL OPERATING COSTS WITH VARIOUS PRESSURES OR SYSTEM PERFORMANCE

The range for system pressure is calculated from the input pressure. Ignore information from rows with negative pressures. This may occur with low pressure systems.

Only one input unit fuel price is used for this table. Return to input table to change the fuel price.

Annual operating costs include energy or fuel costs plus repair and maintenance. Repair and maintenance has been calculated from brake horsepower of the power plant, operating hours, labor costs, and the type of engine or motor.

********* Press the ENTER key to return. ********

HELP 5
ANNUAL OPERATING COSTS ($/AC) VS. PRESSURE OR SYSTEM PERFORMANCE

The range for system pressure is calculated by adding and subtracting 10 psi increments from your input pressure.
Ignore information from rows with negative pressures. This may occur with low pressure systems.

Only your input unit fuel price is used for this table. Return to input table to change the fuel price.

Annual operating costs include energy or fuel costs plus repair and maintenance. Repair and maintenance has been calculated from brake horsepower of the power plant, operating hours, labor costs, and the type of engine or motor.

********* Press the ENTER key to return. ********

HELP 6 BREAK EVEN CAPITAL FOR IMPROVING PERFORMANCE

This table shows the maximum money available to spend on improving pumping plant performance from the level given at the head of each column to 100% of the Nebraska performance criteria. The annual cost saved by improving efficiency could be used as annual payments for the loan terms specified in the input table.

If fuel unit prices along the row headers are negative, increase the input unit price in the input table. The unit price range is calulated from your input price.

********* Press the ENTER key to return. ********