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Comparing the Costs of Electric Motors and Engines for Irrigation Pumping

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Introduction

Energy and pumping cost should be carefully analyzed based on different energy sources, and time of usage during the season. Time-of-use electric often rates offer reduced electric power costs for off-peak use, however many growers are unable to limit pumping only to off-peak periods without major modifications to increase the capacity of their irrigation systems, changing irrigation practices, or operational constraints (labor, system automation and control, etc.) to use irrigation systems during night time. Furthermore, the cost of fossil fuel has increased during the past 15 years and needs to be accurately considered when prospecting future energy costs.

In addition to energy cost, operational and convenience factors must be considered for grower interest in using the fossil-fuel powered engines (referred from now on as *engines*) or electric motors for pumping. Electric motors provide flip-the-switch convenience and require minimal servicing and attention. Electric motors also maintain power output levels year after year, whereas engines lose power over time because they wear out. It is also possible to install a variable-frequency drive to adjust the output of the pump to match variable operating conditions of irrigation system, but it increases capital cost. Engines also make it possible to vary speed with certain limits and thereby, vary pump output. However, engines make possible to operate irrigation systems twenty-four hours a day without regard for schedule associated with time-of-use electric rates.

Comprehensive emission regulations and controls are applied on a broader basis to various types of off-road engines. California has adopted its own emission standards for certain types of new nonroad engines, vehicles, or equipment. In those cases, manufacturers must certify their products with the California Air Resources Board; these products are also certified with EPA even though no additional requirements apply. The Environmental Protection Agency (EPA) and the California Air Resource Board have defined emission regulations for off-road engines, based on four emission standards (Tier 1 to 4). This definition is also based on the maximum rated power in kW (kiloWatts) on categories that goes from less than 8 kW up to more than 560 kW (California Environmental Protection Agency (CalEPA), Dec 2005). Depending on the tier, there are regulations for: oxides of nitrogen (NOx), hydrocarbons (HC), non-methane Hydrocarbons plus oxides of nitrogen (NMHC+NOx), carbon monoxide (CO) and particle matter (PM). For new engines manufactured after 2014, it is expected that Tier 4 emissions standards will decrease by more than

90 percent (EPA). Additionally, sulfur on diesel fuels can damage emission control devices. Therefore, ultra-low sulfur diesel fuel has a maximum limit of sulfur concentration of 15 parts per million. Under those circumstances, even though the price of regular diesel and ultra-low sulfur diesel is the same, there could be additional cost for users in terms of maintenance and engine replacement. Basic information and frequently asked questions and answers on emission standards for nonroad engines can be found at http://www.epa.gov/oms/highway-diesel/regs/420f12053.pdf as well as at http://www.epa.gov/nonroad/

Fuel and electricity costs

Figure 1 shows how the costs for electricity and engine fuels affects irrigation pumping; this cost has increased and fluctuated over the last 23-year period. Diesel cost, shown as dollars per acre-foot per foot of lift, increased rapidly after 2002; from 2004 to 2008 there was a steady increase in diesel cost mainly due to US war in Iraq. Fossil fuel was more expensive than electricity for a short period of time during 2008, but nowadays natural gas and propane are less expensive than both diesel and electricity. Over the past 10 years, diesel cost has risen almost more than double after the Middle East crisis. Fig. 1 also shows the differential cost that has developed between electricity, diesel and other fossil fuels. over the last 23-year period.

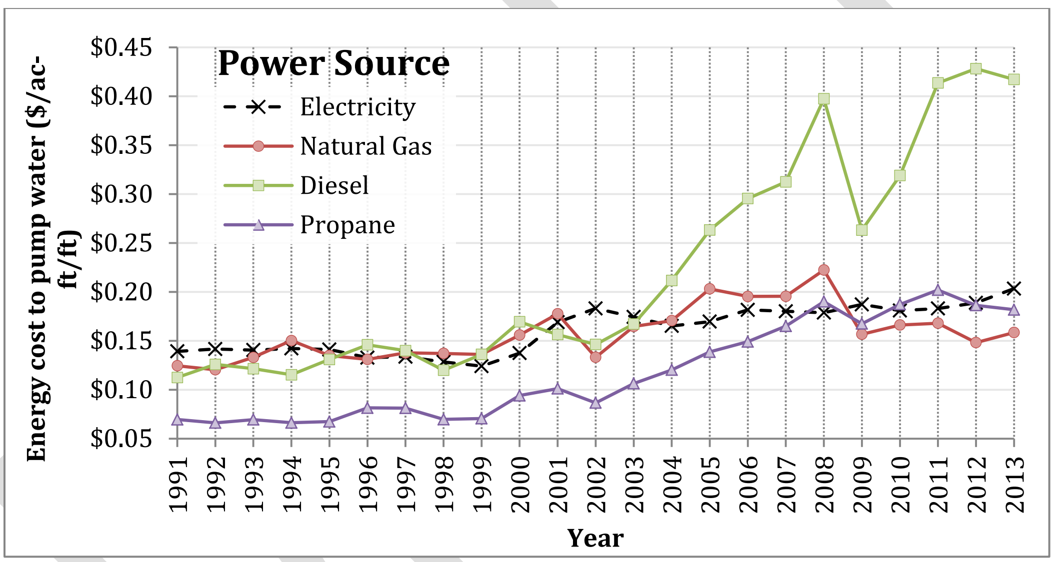

Fig.1 Energy costs for pumping irrigation well water, from 1991 to 2013. Data for four likely energy sources are presented as the dollar cost of pumping one acre-foot of water per foot of lift.

Energy prices and resulting costs to growers vary according to individual circumstances. For electricity, the price per kilowatt hour (kWh) depends on time-of-use rate (TOU) schedules which in turn depend upon several factors, including: electric rate, hours of operation per season, and daily or weekly operating schedule. Operating schedules determine the amount of energy used during on-peak periods when energy costs are significantly higher. As an example, figure 2 illustrates the cost of operating a 50-HP electric motor eighteen hours a day for 500, 1,000, 1,500, and 2,000 hours per year during summer considering electric schedule AG-4 in 2014 (PG&E, 2014). The lower curve shows the cost per kWh when there is no on-peak use. The upper curve represents the cost per kWh when the pump is operated only 12 percent of the time on-peak, and the remainder is operated during off-peak hours. The cost per kWh shown in Figure 2 includes energy, demand, and customer charge. In this example, the cost of electricity ranges from $0.18 to $0.14 per kWh depending on annual usage and operating schedule.

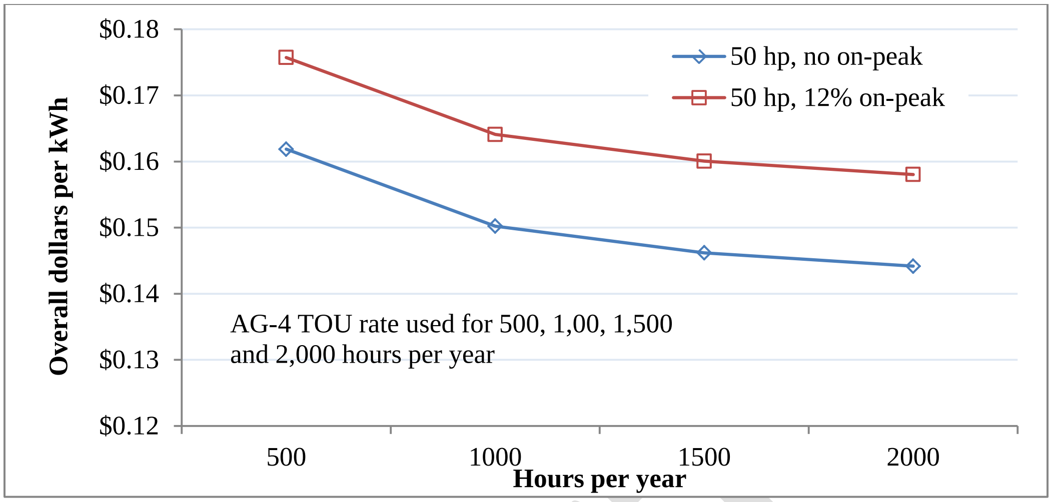

Fig.2 Dollar costs per kilowatt-hour (PG&E, 2014) of pumping water with electric power at four annual rates of use and two daily schedules: 18 hours per day with 12% of the pumping during "on-peak" hours, and 18 hours per day during off-peak hours.

Diesel and propane fuel prices vary according to location within the state and the quantity purchased per load. For example, based on the U.S. Energy Information Administration, the retail price of diesel was $4.13 dollars per gallon on average in 2013. The same source indicated an estimated residential price of $1.41 dollars per gallon for propane wholesale/resale. Because it is an unregulated commodity, no data is collected by the state of California on LPG (Liquefied Petroleum Gas, i.e. Propane) sales or usage (California Energy Commission). Natural gas prices for 2013 were in the range of $0.69 to $0.84 per therm. As shown in figure 1, there is a consistent increase cost on all energy sources, especially on diesel. It seems fairly certain that all energy prices will continue to rise for agricultural customers. Additional increases may also occur because of energy cost adjustments.

Alternative Energy Sources

As well as TOU schedules, adjusting pump performance to diverse operating conditions can be achieved by using variable-frequency drives for electric motors. This can be done by varying the rpm (revolutions per minute) for different conditions adjusting horsepower demand. As shown in Figure 3, under some circumstances the horsepower demand can be reduced by 50 percent when the rpm is reduced only by 20 percent. These are only general relations, the total head and capacity may change depending on pump design and assembly, and therefore these changes may not be necessarily attained. From an economic perspective, studies conducted by UC Cooperative Extension suggest that capital cost can be recovered in less than five years when the annual operation time is more than 1,000 hours (Hanson, 1996). Although there is a clear benefit in reducing the horsepower consumption, adjusting the rpm will somehow decrease the overall efficiency of the pump-motor system. The adjustment of AC (Alternate Current) power from DC (Direct Current) power may increase motor temperature and affect the life of the system (Hanson, 1996).

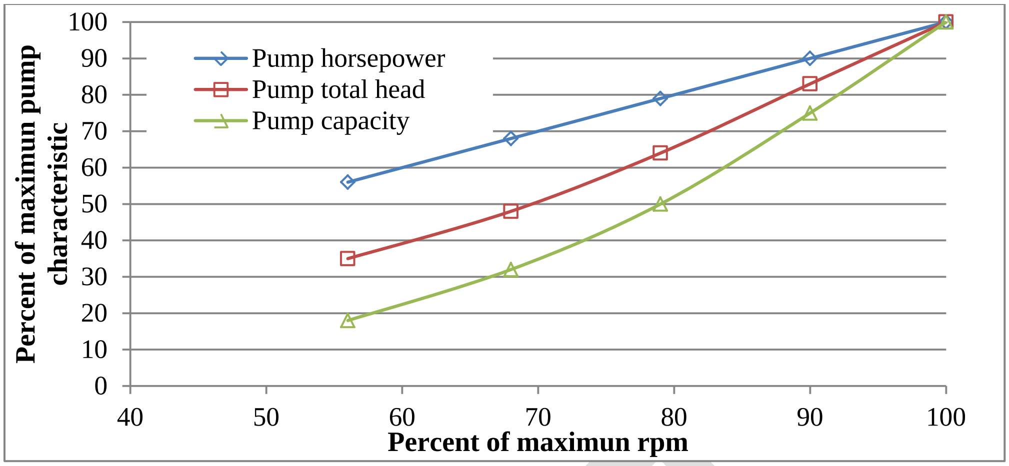

Fig.3 Pump characteristics versus pump rpm (Hanson, B., pg. 36).

Although renewable energy sources are mainly related to electricity, within the state of California there has been an increasing amount of renewable sources installation, mostly solar thermal and Photo Voltaic (PV) capacity addition (California Energy Commission). According with the Renewable Portfolio Standard (RPS), no less than 33 percent of retail electricity sales will come from renewable sources by 2020 (California Energy Commission). These new energy sources should be considered on the context of the Net Energy Metering (NEM) tariff (California Public Utilities Comission). Aggregated net metering was approved by the California Public Utilities Commission (CPUC), this policy encourages placing solar energy generation systems on the best location in the property, offsetting multiple meters devices (CalCom Solar, 2013). In spite of PV has been mainly installed in residential settings (maximum capacity is 1,000 kW), installation cost for PV has been consistently decreasing on the past 10 years (CalCom Solar, 2013); thus, it is expected that the share of this energy source will grow in the future, enhance by the NEM rates and the RPS.

Total Power Costs

The irrigation power unit costs shown in this updated Drought Tip is based on the same proportions used in 1991 considering current energy rates. The resulting cost calculations are used for comparing the total costs of operating electric motors and diesel, natural gas, and propane engines. These total costs considers: (1) fixed costs, including capital expenses (and interest), property taxes and insurance, (2) fuel or energy costs, (3) repairs, and (4) maintenance and service. Income tax considerations are not included in the analysis. These calculations are estimated in current dollars (2014). The engine adjust when necessary needs to be considered, as it can have a significant effect on actual horsepower output and fuel consumption.

Figure 4 compares the total cost per year of operating a 75-HP pump for 1,500 hours with an electric motor and an engine (diesel, natural gas, or propane). Power e unit costs used for this comparison are: electricity, $0.15/kWh: diesel, $3.0/gal: natural gas, $0.77/therm: and propane, $1.31/gal. It should be emphasized that the energy cost of $0.15/kWh for electric motor represents an overall average cost per kWh for the year, including demand charges, customer charges, etc. Figure 4 shows that using natural gas and propane engines is less expensive than electric motors, and that diesel is the most expensive. This graph also shows a breakdown in different cost categories, while it can be seen that energy cost is about 90 percent of the total power cost for the electric motor, compared to about 75 percent on diesel and about 50% in natural gas and propane.

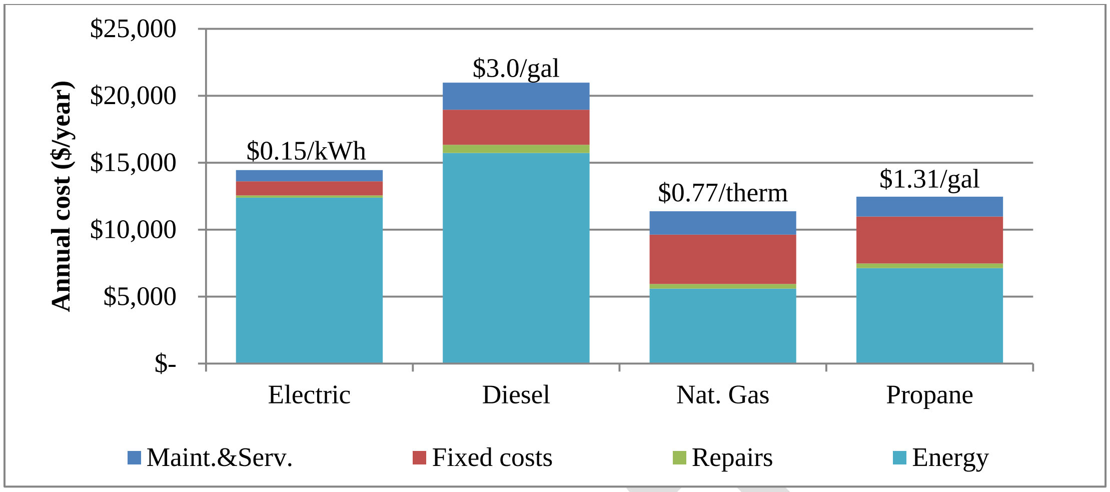

Fig.4 Total annual costs to operate a 75-horsepower irrigation power plant 1,500 hours per year using an electric motor or a diesel, natural gas, or propane engine.

Summary

In summary, engines and motors are more cost-effective for increased size (horsepower) and annual hours of operation. This is the result of: (a) fuel efficiency increases as engine horsepower increases, (b) the labor required to service and attend an engine in the field is nearly the same for a small and large engines, and (c) fixed costs are higher for an engine than an electric motor, however, this effect is less important because it is spread throughout the overall hours of operation.

As aforementioned , different energy sources have different costs throughout the season that vary upon: (1) annual usage, (2) non-energy costs like maintenance, repair and fixed costs, and (3) time schedule of use during the day, and (4) electric variable-frequency drivers or external electric generation (on-farm renewable energy sources). It should be emphasized that the comparisons shown here are based on generalized cost data and are intended to provide approximate values. Although this analysis can help growers to predict and compare potential costs from different power sources, specific costs need to be analyzed on every individual case and site-specific conditions.

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