SOLAR-POWERED WATER PUMPING SYSTEMS FOR LIVESTOCK

PART 2: WHEN AND WHERE DO THEY PAY?

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SOLAR-POWERED WATER-PUMPING SYSTEMS FOR LIVESTOCK PART 2: WHERE AND WHEN DO THEY PAY?

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Ranchers and small-acreage owners must deliver dependable pumped water to livestock when surface water is unavailable. What is the most cost-effective way to provide this water? Utility-sourced electricity, generators, and solar powered water pumping systems (SPWPS) can each be cost-effective in different situations. Using the information about costs and performance from *Part 1: Overview and Costs*, we explore a theoretical installation in Kaycee, WY, to compare these three options. The scenarios offer rules of thumb for quick determination of which options merit thorough evaluation for a particular situation.

As emphasized in *Part 1: Overview and Costs*, the analysis is very site-specific. If you disagree with the assumptions used in the following assessment, you can access the UW Extension spreadsheet used for the calculations (see Additional Resources at the end of the bulletin). The assessments are not universally applicable. As any honest economist will tell you – "It depends on…"

Our theoretical install in Kaycee

For our analysis, we consider an example system in Kaycee. The quality of the solar resource matters, as the same system in Laramie would have better production and a system in Afton would provide less output. Figure 1 shows the amount of solar energy available in Kaycee for an installation tilted at latitude (44°) and facing true south.

The core scenario is an attempt to explore a typical livestock water pumping application. Our Kaycee installation is a seasonal system, used for 120 days in the summer. The well previously used a temperamental mechanical windmill one-half mile from utility power. Electricity at the well costs the average energy and facility charge rates of Wyoming rural electric associations. The total dynamic head is 120 feet. Approximately 100 cow-calf pairs graze the pasture, requiring 3,000 gallons per day (gpd) in the summer. Less water is required (2,000 gpd) if the pasture is used in the winter. Tables 1-6 provide details to the system cost assumptions described in *Part 1: Overview and Costs.*

Table 1: The required system parameters for costing SPWPS

System characteristics	Required measure	Unit
Total dynamic head	120	feet
Water required		
Summer	3000	gallons per day
Fall/spring	2500	gallons per day
Winter	2000	gallons per day
Duration of use	120 (summer)	days

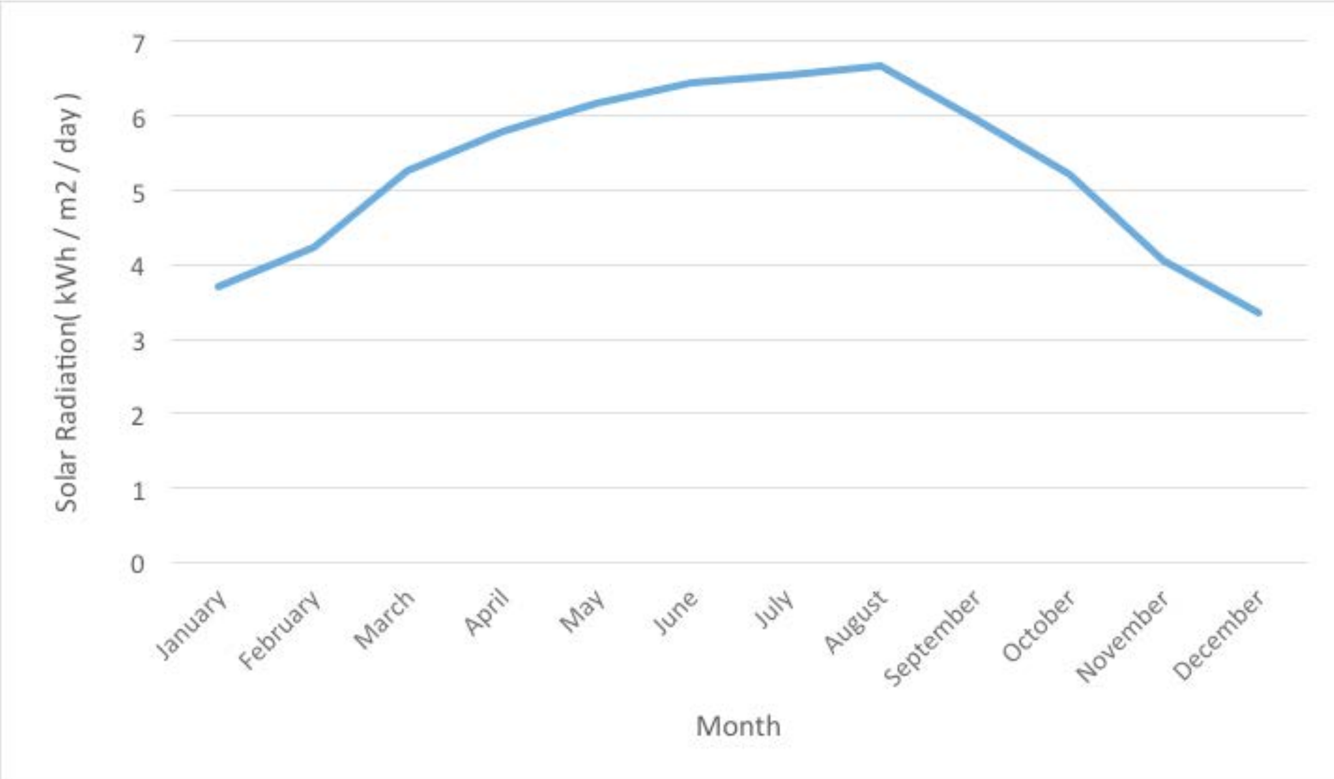

Figure 1: Annual solar resource by month for Kaycee, WY (43.7097° N, 106.6386° W)

Table 2: Energy required to pump water

System characteristics	Required measure	Unit
Energy used		
Summer	3.14	kilowatt hours per day
Fall/spring	2.62	kilowatt hours per day
Winter	2.09	kilowatt hours per day
Solar capacity required	900	Watts
Fuel used (generator)	0.429	gallons per day

Table 2 uses the USDA Natural Resources Conservation Service's *Solar-Wind Water Pumping Energy Self-Assessment Tool* to calculate the amount of energy needed. The formulas for estimating energy required to deliver water are well defined, but the NRCS tool simplifies calculation. The system size required is the minimum amount (with 25 percent contingency) to supply the necessary energy over a three-day average period. New Mexico State University Cooperative Extension Service's *Solar Water Pumping Design Spreadsheet Version II* provides a useful tool to estimate this need. Fuel usage assumes 1 gallon of gasoline produces 7.32 kWh of electricity, which includes generator efficiency losses.

Table 3 summarizes the fixed cost for the theoretical Kaycee installation. Importantly, the PV panels and wiring are assumed to cost $1.50/watt. Also, the cost of a utility line extension is expected to be $20,000 per mile, although this value can vary widely based upon terrain and circumstance.

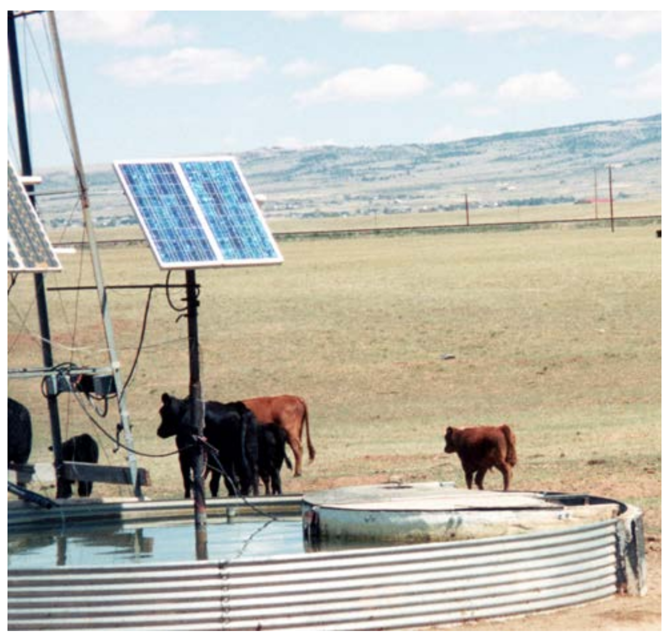

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Table 4 summarizes the characteristics that influence variable and fixed costs. Important factors, such as driving distance and labor input, significantly affect system costs.

The variable costs, found in Table 5, heavily influence the ongoing operations and maintenance expense associated with pumping water for livestock.

The suggested gasoline and diesel prices are the five-year national average. The recommended rates for utility-sourced are the average for the 16 rural electric associations that serve Wyoming. Maintenance costs are admittedly subjective estimates based upon producer reports.

Table 3: Equipment and installation costs for SPWPS, utility-sourced, and generator water pumping systems

Equipment	Price ($)
SPWPS	
PV array and wiring	$1,350.00
PV support structure	$450.00
DC pump	$2,100.00
DC pump controller	$250.00
Installation	$1,037.50
Utility-sourced	
Distribution line extension	$10,000.00
AC pump	$700.00
AC pump controller	$125.00
Installation	$206.25
Generator	
Generator	$2,500.00
AC pump	$700.00
AC pump controller	$125.00
Installation	$103.13

MANAGEMENT DEPRECIATION VS. FINANCIAL DEPRECIATION

Lifespan is similar to management depreciation. For example, if a pump is estimated to last 10 years, then a five-year-old pump has lost half of its original value. Financial depreciation, which is for accounting and tax purposes, can follow a much different schedule. For example, a PV system with an estimated lifespan of 25 years may be entirely financially depreciated in only five years. This management and financial depreciation can provide radically different values.

Table 4: System characteristics informing operating costs for the Kaycee example

System characteristic	Measure	Unit
Distance (round trip)	10	miles
Vehicle efficiency	15	miles per gallon
Site visit frequency		
SPWPS	2	per week
Utility-sourced	2	per week
Generator	7	per week
Labor required		
SPWPS	30	minutes per visit
Utility-sourced	30	minutes per visit
Generator	35	minutes per visit
Lifespan		
PV	25	years
Pump (AC and DC) and controller	10	years
Utility connection	50	years
Generator	7	years

Table 5: Variable costs for SPWPS, utility-sourced, and generator systems

Input	Price	Units
Gasoline	$3.22	per gallon
Diesel	$3.55	per gallon
Utility-sourced electricity	$0.122	per kWh
Utility-sourced base charge	$265	per year
Maintenance		
SPWPS	$50	dollars per year
Utility-sourced	$25	dollars per year
Generator	$150	dollars per year
Labor	$14.90	per hour

Table 6: Discount, inflation, real energy escalation, and tax rates

Factor	Value	Units
Discount rate	5	Percent
Inflation rate	1.85	Percent
Real energy escalation rate	0.6	Percent
Tax rate	25	Percent

The discount rate is a relatively conservative assessment of the cost to borrow funds (e.g., Farm Credit Service). The inflation rate is a five-year average. The U.S. Energy Information Administration predictions through 2025 are the basis for the estimated real energy escalation rate. The tax rate is a median tax rate for a middle-class agricultural producer. The values could certainly be altered to reflect individual preferences and expectations.

The information in Tables 1-3 lead to an initial system cost of:

- SPWPS = $5,188
- SPWPS with Business Investment Tax Credit (BITC) = $4,414
- Utility connection and pump = $11,031
- Generator and pump = $3,428

These values serve as the foundation for specific scenarios where SPWPS, utility-sourced electricity, and generators are the most cost-effective option.

DON'T LIKE THE ESTIMATED VALUES?

UW Extension is always happy to learn from our Wyoming agricultural producers. If you think these estimates could be enhanced, let us know! You are also welcome to do your analysis using the UWE-created spreadsheet that is the foundation for this bulletin.

When comparing options, ranchers, and small-acreage owners will have different desired metrics for payback. Most will want the costs annualized. The core analysis annualizes costs using the equivalent annual cost (EAC) method, which allows comparison of alternatives with different lifespans. For example, some ranchers may want costs considered over seven years, which approximates the life of a generator. Thus, the lifespan of a utility connection or solar array does not matter beyond seven years.

EQUIVALENT ANNUAL COST

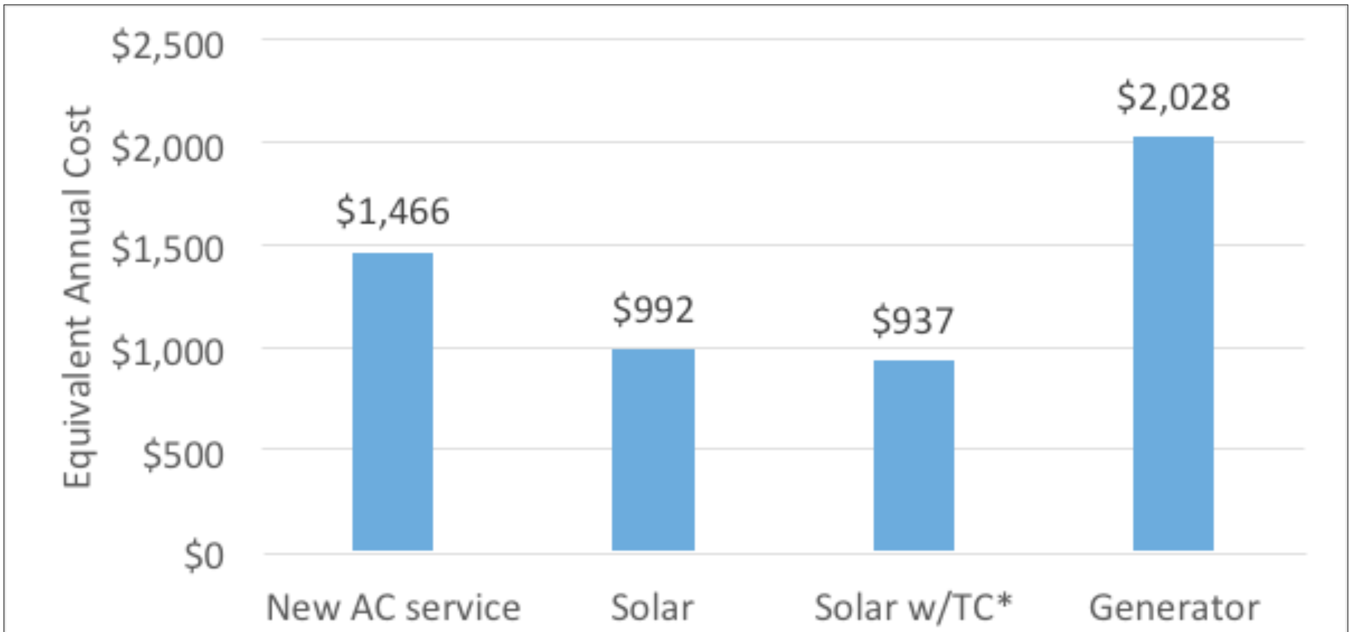
If you are a "numbers nerd," the formula for the EAC is:

$$EAC = \frac{NPV}{A_{t,r}}, \text{ where } A_{t,r} = \frac{1 - \frac{1}{(1+r)^t}}{r}$$

where NPV = Net present value, = Annuity factor, t = time, and r = discount rate

SPWPS have a growing presence on the ranch

SPWPS are supplanting incumbent methods for pumping water and opening up new opportunities for delivering water in remote locations. For the example described above, SPWPS is the most cost-effective option, despite having a higher initial installed cost than a generator. Figure 2 shows the EAC for each system based upon the information in Tables 1-6.



"Solar w/ TC" describes SPWPS using the Business Investment Tax Credit

Figure 2: Equivalent Annual Cost for Kaycee example

The EAC values show that SPWPS, even without incentives, are the most cost-effective systems to pump water for our Kaycee example. Since the costs are annualized, we are able to compare the systems despite their different lifespans. The high initial cost and ongoing utility charges make the line extension cost prohibitive. The high operational costs of generators make them a very expensive method to use in this scenario.

This type of analysis opens up many "What if…" questions. To pick a few:

- What if the SPWPS is more expensive than this estimate? – For a utility connection to be viable, the SPWPS would need to be much more expensive, costing more than $11,867.
- What if the utility line extension is cheaper than this estimate? – The line extension would need to cost less than $1,348 for utility-sourced electricity to be competitive.
- What if I use the well year-round? – SPWPS is still the lowest cost alternative (EAC of $1,735 vs. $2,408 for new utility service)
- What if it is a deep well, even 800 feet? – Assuming 5,400 watts of PV required, then the total installed cost for a SPWPS balloons to $16,438. The utility connection ($2,408) is still more expensive than incentivized SPWPS ($2,251), although un-incentivized SPWPS is now more expensive ($2,533).
- What if I use other incentives, such as the NRCS Environmental Quality Incentive Program? – Using other incentives makes SPWPS a very attractive investment. If you do not consider your time required for the application process and increase the installed cost by 10 percent to account for stringent NRCS requirements, then the SPWPS system has an EAC of $995 with an installed cost of just $1,452.
- What if there is utility-provided electricity at the well already? – We will explore this in the second scenario, "When utility sourced electricity is a winner."

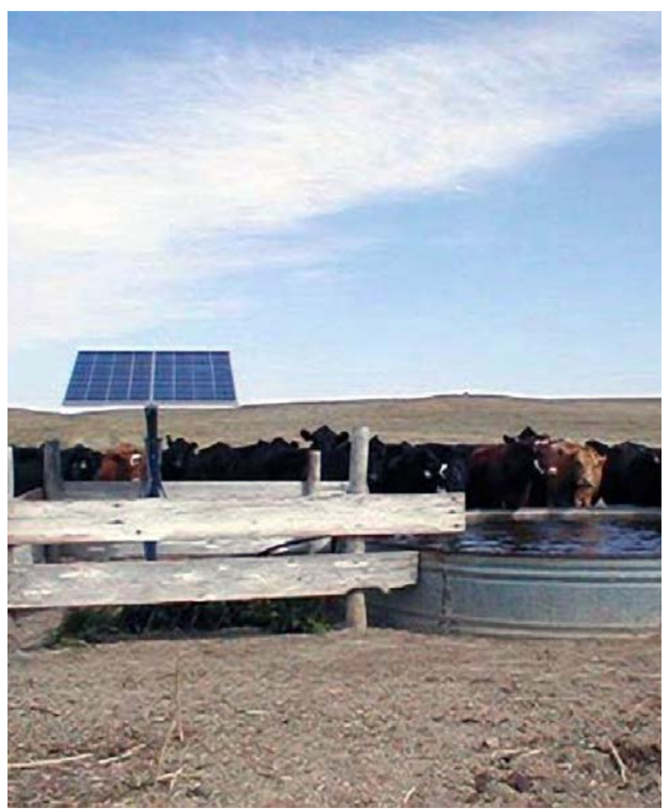
The core analysis and the "What ifs" show that, in this application, SPWPS is likely the preferred option to provide water in this pasture.

WHAT ARE THE OTHER SPWPS INCENTIVES?

The use of USDA NRCS Environmental Quality Incentive Program, USDA Rural Development Rural Energy for America Program, or local Conservation District programs improve the cost-effectiveness of SPWPS. For example, EQIP offers predetermined cost share rates depending upon well depth. These payments can amount to more than 60 percent of the installed cost of a system, so EQIP can make SPWPS very cost effective for private landowners. For projects not suitable for EQIP funding, the Rural Energy for America Program cost shares at a lower rate, 25 percent on the PV equipment and installation. Some conservation districts provide up to $5,000 for SPWPS. Also, individual utilities, mainly rural electric associations, may provide financial or technical assistance.

POTENTIAL TAX IMPLICATIONS

If SPWPS replaces a generator or utility-sourced electricity, then it may reduce tax-deductible expenses for fuel or electricity. This could potentially increase taxable income. To account for this tax impact, the benefits of accelerated depreciation (e.g., MACRS) are not considered as incentives.



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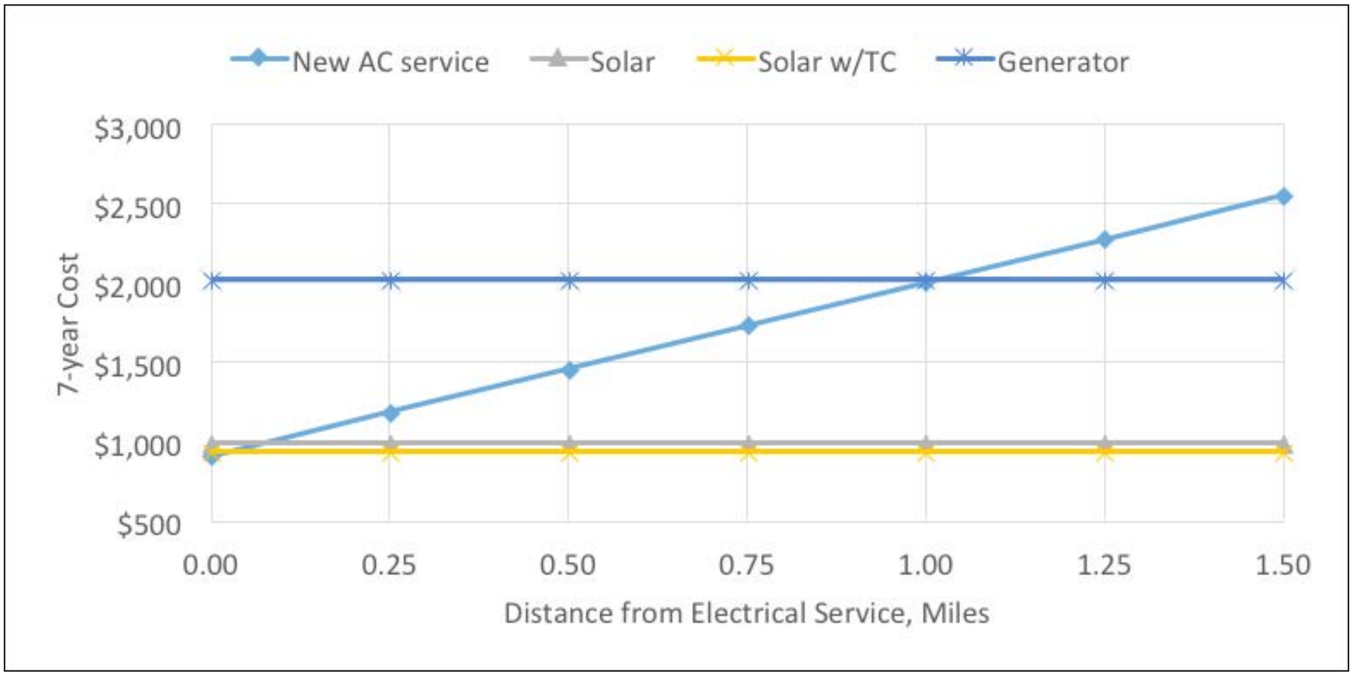

Figure 3: Comparing water pumping alternatives relative to the distance from utility-sourced electricity.

When utility-sourced electricity is a winner

Connecting to the electric utility provides highly reliable, low-cost, relatively maintenance-free energy for water pumping systems. When available, utility-provided electricity is often considered the most cost-effective option. Still, connecting to the utility exposes producers and landowners to changes in energy prices and service fees. In this scenario, the same Kaycee ranch is exploring a theoretical installation, except this time:

- Utility-sourced electricity is available at the well (no line extension), but a new AC pump is required.

As the distance to utility power is changed from the core example, Figure 3 shows the EAC plotted against distance.

The EAC at the power pole (no line extension) is $918 for utility-sourced systems while SPWPS is $992 ($937 with the BITC). A generator costs $2,028. Assuming linear costs for utility extensions (perhaps a simplified assumption), then utility-sourced electricity is more cost-effective than unsubsidized solar if the line extension costs less than $1,348, which is approximately 1/16 of a mile. If solar receives the BITC (no other incentives), then the line extension must cost less than $346, which is approximately 91 feet. As no line extension is required in this scenario, this Kaycee rancher should connect to the local electric utility to deliver energy to pump water.

Many "What ifs" can also be examined in this scenario, including:

- What if your payback timeframe is shorter, say seven years with no annualization? – If the systems are forced to pay for themselves in seven years (no value for equipment lasting beyond seven years), then utility-sourced and incentivized SPWPS both have a total seven-year cost of $6,559. Unsubsidized SPWPS costs $6,944, while a generator is still a very expensive option at $14,195.
- What if my utility costs are higher than the assumed rates? – In this scenario, the fixed annual charge is the most important component of energy costs, as the system only use 360 kWh over the grazing season. Fixed fees would need to rise only slightly, to $317/year from $265, to make SPWPS cost effective in this scenario.

Utility-supplied electricity is a cost-effective option when immediately available from the power pole, especially if no additional meters (new fixed charges) are needed (e.g., at a barn or other electrical load). Still, SPWPS is a close competitor. Thus, SPWPS should be considered any time a line extension. The declining cost of PV may make SPWPS cost-effective even when utility-supplied power is being considered.

When generators are best

As shown in Figures 2 and 3, generators are clearly an expensive method to pump water for livestock. Still, applications exist where generators are a cost-effective alternative. The same Kaycee ranch now explores a scenario where:

- Rotational grazing leads to brief (30 days) pasture use;
- The well is only a one-mile roundtrip from the ranch house;
- Water pumping uses a generator that is occasionally needed elsewhere on the ranch; thus, only $500 of the cost is assigned to water pumping.

Using these rather specific assumptions, the EAC values in Figure 4 show that a generator is the most cost-effective water pumping option.

The EAC is $536 for a generator vs. $659 SPWPS and $1052 for new utility service. In this scenario, the very short duration of use and brief travel times limit the effects of high operation costs (e.g., labor, travel, and maintenance).

The "What ifs" for pumping water with generators includes:

- What if I want to make a short-term investment, one that only has a seven-year timeframe with no annualization? – If making a decision that does not consider values beyond seven years, then a generator is the lowest cost alternative at a total cost of $2,791 compared to $7,615 for SPWPS and $17,557 for utility-sourced electricity.
- What if I already have the equipment (generator and pump) for other reasons, how far can I travel and still have it be worthwhile? – As the system is only used for 30 days, travel can be fairly extensive and still have a generator be cost-effective. In fact, you could go nearly 31 miles roundtrip before SPWPS becomes a better option
- What if I want to use the generator more than 30 days? – The labor and maintenance required to support a generator quickly become a burden. SPWPS becomes preferable if the generator is used for more than 60 days.

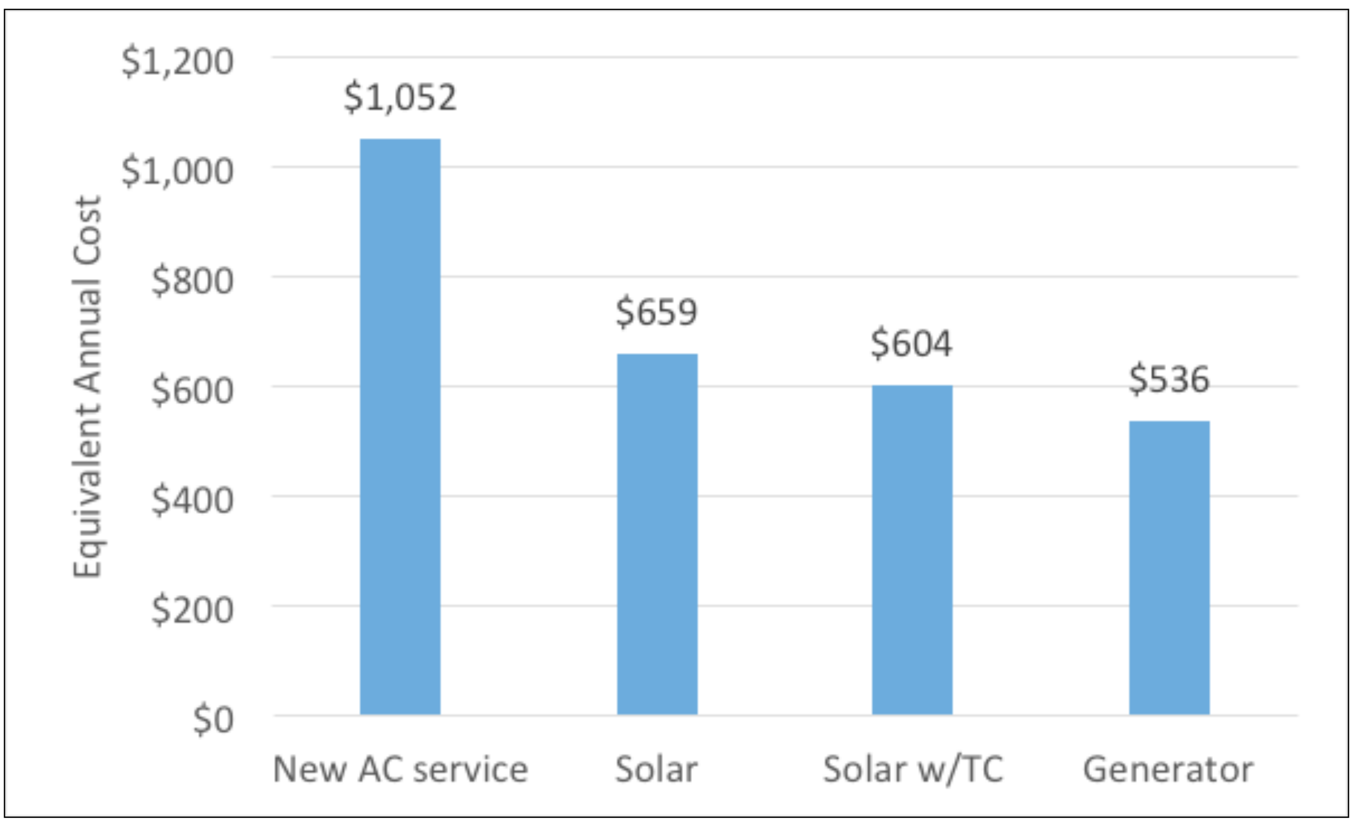

Figure 4: Equivalent Annual Cost for Kaycee example with generator-favoring assumptions

In sum, generators can provide a cost-effective option for a short duration, close-proximity water pumping situation. SPWPS or utility-sourced electricity is likely a better choice if you prefer a longer investment period (greater than seven years).

> **WHAT ABOUT THE WIND?**
>
> The iconic western wind-powered water pump helped bring Wyoming rangelands into more intensive grazing regimes. SPWPS now serve many of the areas previously served by the wind. SPWPS is more reliable and typically more cost-effective than wind-powered alternatives. Should a perfectly functioning wind system be removed? Likely no, but when the time for replacement comes, SPWPS are often the preferred option. Small wind turbines, which generate electricity, can also be used as an alternative or in combination with solar, but lower costs and maintenance requirements favor SPWPS in most applications.

What critical factors would likely make SPWPS viable for my operation?

Through exploring the scenarios and exploring further nuances in the referenced spreadsheet, certain "rules-of-thumb" help identify when and where SPWPS is most likely to be viable. If your existing or planned well has these characteristics, SPWPS is certainly worth exploring:

1. *Is your existing unpowered well over 1/16 of a mile from a power pole?* – Extending utility lines is expensive. If your well will be a dead-end line (i.e., does not continue to another electric load), this line extension cost makes SPWPS attractive. Anytime a line extension is needed, SPWPS are likely a viable option.
2. *Are you driving any distance to check a generator at an existing well?* – The cost of time and mileage to check a generator makes these systems very expensive to operate compared to alternatives, including SPWPS.
3. *Do you use shallow wells seasonally, especially in the summer grazing season?* – If you have a shallow well (i.e., less than 120 feet) that is used seasonally, especially in the summer, then SPWPS have a greater likelihood of being cost-effective.
4. *Does your electric utility have a fixed meter charge higher than the $265 Wyoming average?* – The fixed charge, especially if charged annually on a seasonal well, significantly increases the costs of utility-sourced electricity compared to SPWPS.
5. *Are you willing to install your SPWPS?* – The installation cost of the SPWPS (much greater than other alternatives) is a major factor in determining viability. If you are willing and able to safely install the SPWPS yourself or can reduce expenses in another fashion, then SPWPS are more likely to be cost-effective.
6. *Does your AC pump at an existing well need replaced?* – If an AC pump needs replacing, this cost can be subtracted from the net cost of the SPWPS, making the system relatively more affordable.
7. *Are you able/willing to use incentives, including tax credits?* – Your ability to use tax credits and deductions (i.e., a profitable agricultural operation or personal tax liability) makes SPWPS more affordable. Also, if you are willing to use USDA Natural Resources Conservation Service or Rural Development, conservation district, or electric utility incentives, then SPWPS are likely to be attractive.
8. *Do you believe utility energy or fixed meter charges will escalate more rapidly than the nominal rate of 2.45 percent assumed in this analysis?* – If you think energy will get drastically more expensive, then SPWPS present a viable hedge against these price increases.
9. *Do you value renewable energy for other reasons, such as environmental or personal independence?* – Personal preference for renewable energy can lower your required rate of return for SPWPS to be viable. A lower discount rate is one way to reflect personal preferences for future benefits.

Conclusion

For our core Kaycee pasture example, SPWPS are a viable alternative, especially when considering the cost of utility line extensions and the labor requirement for generator operation and maintenance. Specific scenarios exist where utility-sourced electricity and generators are the preferred energy sources, but SPWPS are now cost-effective in many, if not most, livestock water pumping applications. As the cost of PV equipment and DC pumps continues to decrease, and the cost of utility-sourced electricity increases, SPWPS are likely to become the default option for livestock water pumping, even supplanting some existing utility connections.

UW Extension will gladly aid agricultural producers and small-acreage owners in determining their most cost-effective livestock watering system. Please feel free to contact your local UW Extension office to discuss your individual situation.

Additional resources:

Solar-powered Water Pumping Systems for Livestock: Where and when do they pay? Spreadsheet and calculations are available from: www.INSERT

Jenkins, Thomas. Solar Water Pumping Design Spreadsheet Version II: User Manual. New Mexico State University Cooperative Extension Service Circular 671. 2012. Available from: http://aces.nmsu.edu/pubs/_circulars/CR671.pdf

Jenkins, Thomas. *Solar Water Pumping Systems for Livestock.* New Mexico State University Cooperative Extension Service Circular 670. 2014. Available from: http://aces.nmsu.edu/pubs/_circulars/CR670.pdf

United States Department of Agriculture Natural Resources Conservation Service. *Design of Small Photovoltaic (PV) Solar Powered Water Pump Systems.* Technical Note No. 28. 2010. Available from: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_046471.pdf

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