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From the Ground Up: The Changing Energy Demands of Agricultural Irrigation

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Inside...

Key Points:

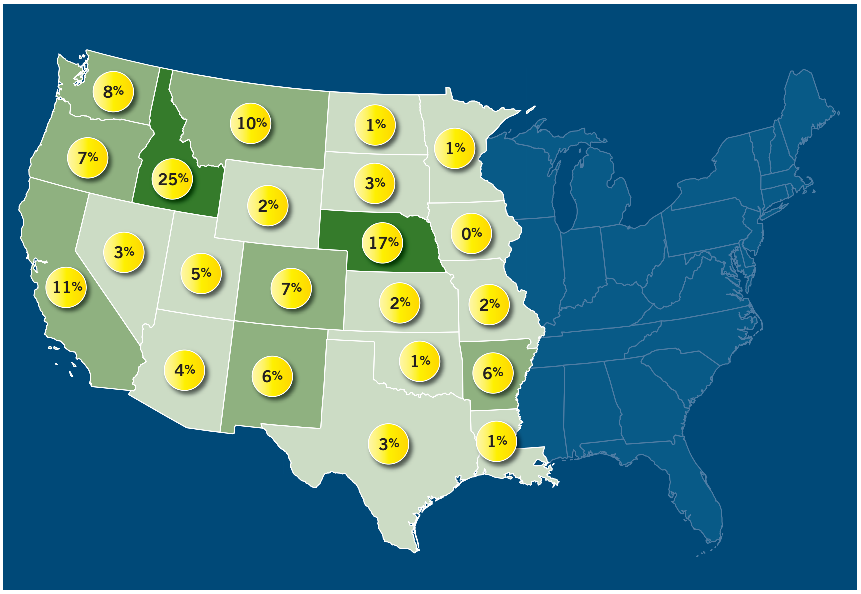
- In 2018, U.S. farmers and ranchers spent nearly $1.9 billion powering electric pumps to provide approximately 30.8 million acre-feet of groundwater to their crops and livestock.[1]
- Agricultural irrigation accounts for over one-third of all freshwater consumption in the U.S.[2] and approximately 6% of all industrial electricity sales in Central and Western states.[3]
- The growth of electricity consumption for agricultural irrigation will be subject to conflicting pressures from falling groundwater levels, rising use of electric groundwater pumps, and increasing water use efficiency (WUE), among other factors.
- By the late 2020s, many U.S. agricultural producers could find that it would cost them no more to independently power their electric irrigation pumps with solar and battery energy storage systems than it would to source power from their electric utility.
- Electric utilities will continue to be well-positioned to help their customers identify the best means of addressing their irrigation energy needs over time. Some may conclude that building a solar and battery energy storage project – either in front of or behind the customer's meter – could be an appropriate solution, both technologically and economically.

Introduction

Agricultural irrigation accounts for a significant share of the industrial electrical load served by U.S. utilities, especially in rural and semi-rural areas of Western and Central states. This research brief provides high-level estimates of the importance of agricultural irrigation to electric utilities, both in terms of energy consumption and revenue. It also previews factors likely to influence the economic relationship between agricultural irrigation and electric utilities in the coming years.

We have paid particular attention to trends affecting agricultural irrigation that are most likely to place downward pressure on electric utilities' revenues. To that end, this research brief also provides an estimate of the unsubsidized levelized cost of

EXHIBIT 1: Irrigation's Share of Industrial Electricity Sales in Central and Western States



Source: 2018 FRIS, Table 13, pg. 38 and CoBank review of data from forms EIA-861- schedules 4A & 4D and EIA-861S.

energy (LCOE)[4] for a hypothetical behind-the-meter solar photovoltaic plus battery energy storage system ("PV + BESS") project capable of serving the electrical load of a typical agricultural irrigation system. This analytical exercise utilizes the most current data available for the sector's groundwater consumption and groundwater levels, as well as the costs required to install such a PV + BESS project now and in the future.[5] See the appendix for more discussion of the method used to calculate the LCOE.

Loads of Irrigation

In 2018, U.S. farmers and ranchers spent nearly $1.9 billion powering electric pumps to provide approximately 30.8 million acre-feet of groundwater to their crops and livestock. Assuming that the electric pumps lifting and pressurizing[6] that groundwater operated at 55% efficiency,[7] we estimate agricultural irrigation consumed approximately 8.9 TWh of electricity in 2018. That's an increase over 2013 by almost 9%, and it equates to 2% of all bundled retail sales by U.S. electric utilities in 2018, including the country's larger investor-owned utilities.[8]

Accounting for the 135,300 agricultural producers that reported utilizing electric irrigation pumps in 2018,[9] we estimate that each of those operations consumed over 65 MWh of electricity for irrigation in that year. For context, that amount of energy equated to about six times the average U.S. household's annual electricity consumption in the same year. A typical rural electric cooperative is not projected to realize that level of consumption from their customers' electric vehicles (in total) until the late 2030s or early 2040s.[10]

Of course, the amount of money spent on power for agricultural irrigation varies significantly across the U.S., with the greatest demand coming from Central and Western states *(Exhibit 1)*.[11]

The Situation Remains Fluid

Although electric utilities' electricity sales for agricultural irrigation have been rising in recent years, that trend may change over the coming decade. Some factors, such as the ongoing switch to electric groundwater pumps, will continue to drive agricultural producers to consume more electricity for irrigation in the near term. However, the rate of growth in the electric load for agricultural irrigation may begin to moderate.

Electric Pumps Bring the Pressure

A primary factor driving demand for irrigation power is the ongoing switch from diesel- and natural gas-fueled groundwater pumps to electric groundwater pumps. What were once mainstays at every wellhead, diesel and natural gas-fueled pumps by 2018 were used on just 17% and 7% of irrigated acreage, respectively. Meanwhile, electric groundwater pumps were used on about 74% of irrigated land in 2018[12] compared to 61% in 2013. Nationwide, we estimate that by 2018, the transition to electric groundwater pumps increased the irrigation load by approximately 820 GWh annually.

EXHIBIT 2: Change in Efficiency of Groundwater-based Irrigation (2013-18)

Survey Year	Volume of Groundwater Applied (acre-ft)	Acreage Irrigated with Groundwater	Efficiency of Groundwater Use (acre-ft / acre)
2013	48.5 million	38.9 million	1.25
2018	41.3 million	49.8 million	0.83

Source: CoBank review of FRIS 2013 and 2018

A Bigger Lift

Falling groundwater levels have also driven increased consumption of energy for irrigation. From 2013 to 2018, the volume-weighted average depth of groundwater used for irrigation in the U.S. fell by more than 7 feet, from 93.0 feet to 100.3 feet below ground.[13] Although that may not sound like much, lifting water this extra distance requires serious amounts of energy – over 60 GWh of additional consumption per state, on average, in 2018 compared to 2013. However, falling groundwater levels won't drive electric irrigation higher forever. If and when wells in some parts of the country run dry and are capped, the utilities serving those areas will likely see a rapid decline in electricity consumption from those customers.

Variation on a Theme

Although a detailed discussion of the impacts of climate on agriculture are beyond the scope of this research brief, it is notable that rising average air temperature and weather variability are likely to impact consumption of electricity for irrigation. Rising temperatures can heighten evapotranspiration of water applied to plants and soil, requiring the application of greater volumes of water to maintain a crop.[14,15] Meanwhile, greater climatic variability can drive greater frequency and intensity of flooding, drought, etc., which can have highly geography-specific impacts on irrigation.[16] However, current and future caps on agriculture producers' water withdrawals will likely mitigate the upward pressure on electricity demand applied by these drivers in the near term.

Farmers are Growing More Crop per Drop

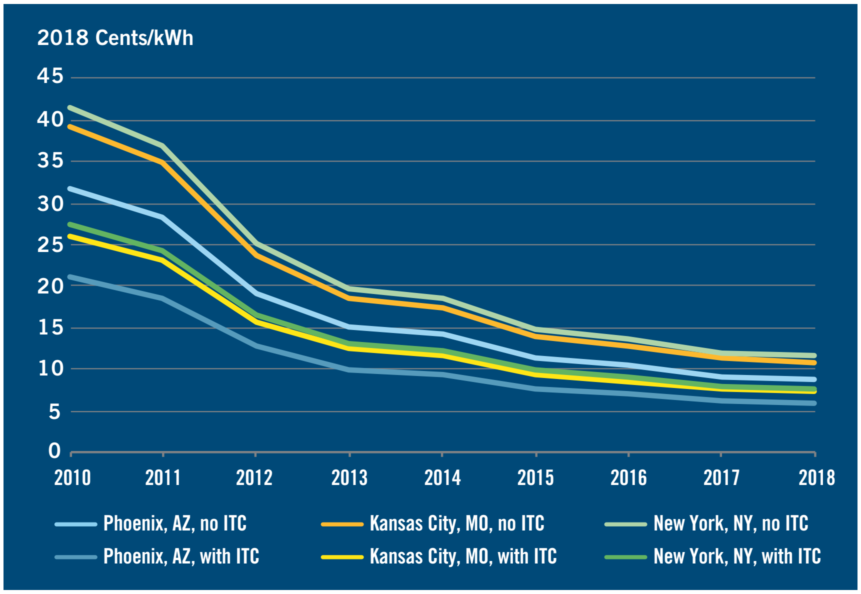
Electric utilities' revenue from agricultural irrigation is under pressure as agricultural producers are generally using groundwater more efficiently than ever before. Based on the latest Farm and Ranch Irrigation Survey (FRIS) *(Exhibit 2),* farmers reported applying less groundwater to more acres in 2018 compared to 2013.[17]

More specifically, over the last five years WUE for corn grain, corn silage, cotton, alfalfa, and hay has either improved or been stable.[18] This increased efficiency has come from several factors including innovation in irrigation equipment (e.g., drip irrigation), development of novel crop varieties and crop rotation strategies, improved soil management practices, and better understanding of irrigation techniques in the agricultural community, to name a few.

When Might Farmers Generate Their Own Power?

From 2013 to 2018, there was a four-fold increase in the acreage irrigated using behind-the-meter solar arrays.[19] However, irrigation often occurs in the early morning hours when evapotranspiration and power costs are both relatively low, but when solar irradiance is minimal or non-existent. As such, it is worth considering how soon the typical agricultural irrigation load could be served economically by a hypothetical behind-the-meter PV + BESS project that provides for hours of irrigation before sunrise.

EXHIBIT 3: Commercial Solar PV System LCOE Benchmarks



Source: Fu et al, "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018." NREL, November 2018.

Based on the 2018 data on groundwater usage, well depth, the water pressure of irrigation systems, pump efficiencies, etc., a typical groundwater irrigation system would require a PV + BESS installation with a power rating of approximately 70 kW and energy capacity of roughly 435 kWh.[22] In modeling the installation and hourly operation of such a system using current costs for solar PV modules, Li-ion batteries, inverters, etc.,[23,24] we estimate that it would have an unsubsidized LCOE of approximately 16.75¢/kWh.[25,26] That's significantly more than what many, though not all, agricultural producers pay for power today.

The historically high cost of solar modules and other project costs have long hindered the technology's widespread adoption. However, this has become less of a hurdle in recent years as the LCOEs of standalone solar PV projects (i.e., without battery energy storage) have declined precipitously. For instance, over the last decade, commercial-scale solar PV projects in Arizona, Missouri, and New York have all demonstrated rapidly declining LCOEs on both a subsidized and unsubsidized basis *(Exhibit 3)*.[20]

However, electric utilities typically provide power to agricultural producers very reliably at industrial rates lower than the LCOE of such systems. As of 2018, the average rate for industrial electricity customers (e.g., farms, manufacturing facilities, etc.) in the U.S. was 6.92¢/kWh.[21] When commercial PV + BESS project installers can beat this price on a levelized basis, electric utilities may need to reconsider strategies to best serve their agricultural customers. Using an unsubsidized LCOE, we have estimated when such a behind-the-meter solar PV + BESS project may become a reasonable investment.

How long will it take before such a project's LCOE reaches 6.92¢/kWh? Assuming that solar module costs and battery packs decline at 7% and 10% per year, respectively,[27] with similar price declines in operations and maintenance costs, then we project some agricultural producers may begin to make the switch in the 2026-28 timeframe depending on their solar resource. Obviously, agricultural producers in the Western U.S. are likely to consider acquiring such a system sooner than others due to their longer growing seasons and lesser precipitation levels.

However, such LCOE estimates may be somewhat conservative. Accounting for the availability of the federal Investment Tax Credit – 26% for projects that begin construction in 2020, 22% in 2021, etc. – this hypothetical project could become feasible sooner.[28] Nor do the aforementioned LCOEs account for any net metering opportunities or avoidance of demand charges that such an asset may enable. And while not quantified here, a PV + BESS project would undoubtedly hold significant value for farms located in areas lacking reliable power service.

Conclusion

Electric cooperatives and other utilities serving rural America receive significant revenue from the sale of energy for agricultural irrigation. However, future consumption of that energy will be subject to multiple conflicting pressures from factors largely outside of utilities' immediate control.

Increasing use of electric pumps and falling groundwater levels are likely to continue to place upward pressure on the consumption of electricity for agricultural irrigation in the near term. Conversely, increased efficiencies in irrigation practices, the potential for well depletion, and ongoing advancements in solar PV + BESS technologies could all dampen electricity consumption among irrigators in some areas.

Electric utilities will continue to be well-positioned to help agricultural producers to address their unique and changing needs for irrigation energy. Some may conclude that building a PV + BESS project – either in front of or behind the customer's meter – could be an appropriate solution, both technologically and economically. Others may find that traditional sources of power generation better suit their needs.

Appendix: Levelized Cost of Energy (LCOE) Methodology

This analysis provides an LCOE for a hypothetical PV + BESS project capable of serving the electrical load of a typical agricultural irrigation system. It represents an economic assessment of the various costs to build and operate a system over an assumed useful life of 20 years, including the initial investment, operations and maintenance, cost of capital, etc.[29]

The LCOE of a given PV + BESS project is highly dependent on the use case, which dictates the battery chemistry used, the system's capacity and energy requirements, cycling rates, battery replacement schedule, financial assumptions, price environment, etc.[30] As such, we have modeled the design and hourly operation of the PV + BESS using data inputs specific to the requirements of a typical agricultural irrigation operation.

This analysis utilizes the most current and detailed data available concerning the amount of groundwater consumed for agricultural irrigation, the depths from which that groundwater is pumped,[31] the typical efficiency of electric irrigation pumps, and other key variables. The analysis also utilizes current cost estimates for the various components of PV + BESS projects, including nickel-manganese-cobalt battery packs, solar PV modules, power conversion systems, balance of plant components, engineering, permitting, and construction services, and financing costs, among others.[32] Assumptions concerning the hour-by-hour solar resources referenced herein are also based on historical observations.[33]

The LCOE for the PV + BESS project modeled here were derived by inputting these assumptions into the National Renewable Energy Laboratory's (NREL) System Advisor Model.[34] This tool was chosen for its ability to accurately account for the aforementioned assumptions specific to an agricultural irrigation use case, as well as an appropriate hourly schedule of battery charging and discharging. The software is freely accessible to anyone who may want to build on this research for their own purposes.

Endnotes

[1] CoBank analysis of USDA's "2018 Farm and Ranch Irrigation Survey" ("2018 FRIS").

[2] USDA Economic Research Service.

[3] This includes electric utilities' revenue from both bundled and unbundled customers, per CoBank review of data from forms EIA-861- schedules 4A & 4D and EIA-861S, as well as the 2018 FRIS.

[4] All LCOE estimates are expressed in real 2019 dollars for ease of comparison to other publications.

[5] https://www.nrel.gov/analysis/tech-lcoe-documentation.html

[6] Assumes the water is pressurized to 30 psi once brought to the surface. This is purposefully a rather conservative assumption relative to the equipment pressure estimates offered in the 2018 FRIS, Table 11, page 30.

[7] This is likely a conservative assumption. Tidwell et al note average pump efficiencies in CA and TX of 40-57%. Tidwell et al "The Geographic Footprint of Electricity Use for Water Services in the Western U.S." Sandia National Laboratories. See page 7.

[8] CoBank review of data from forms EIA-861- schedules 4A & 4D and EIA-861S.

[9] 2018 FRIS, Table 13, pg. 35.

[10] "Electric Vehicle-to-Grid Integration: From Concept to Reality" CoBank's Knowledge Exchange Division.

[11] 2018 FRIS, Table 13, pg. 38 and CoBank review of data from forms EIA-861- schedules 4A & 4D and EIA-861S.

[12] These estimates are based on the acreage irrigated with groundwater and surface water with each type of pump in 2018 and 2013, respectively. Per CoBank's review of the USDA's FRIS from 2013 and 2018, respectively. Pumps fueled with gasoline, ethanol, and blends thereof make up the remainder.

[13] USDA 2013 Farm and Ranch Irrigation Survey ("2013 FRIS"), Table 8, pg. 23; 2018 FRIS, Table 9, pg. 24. These metrics pertain to water levels at the start of the relevant irrigation season.

[14] Fischer et al, "Climate change impacts on irrigation water requirements: effects of mitigation, 1990–2080." Technological Forecasting and Social Change, Volume 74, Issue 7, September 2007, Pages 1,083-1,107.

[15] McDonald et al, "Two Challenges for U.S. Irrigation Due to Climate Change: Increasing Irrigated Area in Wet States and Increasing Irrigation Rates in Dry States." PLoS ONE 8(6): e65589, Published: June 5, 2013.

[16] Kukal et al, "Climate-Driven Crop Yield and Yield Variability and Climate Change Impacts on the U.S. Great Plains Agricultural Production." Scientific Reports, Volume 8, Article number: 3450, Published February 2018.

[17] USDA conducts the Farm and Ranch Irrigation Survey once every five years.

[18] CoBank's review of data on irrigated crop yields in 2013 and 2018, respectively. This data was sourced from the USDA's National Agricultural Statistics Service.

[19] 2013 FRIS, Table 13, pg. 47; 2018 FRIS, Table 14, pg. 48.

[20] Fu et al, "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018." NREL, November 2018.

[21] CoBank review of data from forms EIA-861- schedules 4A & 4D and EIA-861S.

[22] Assumes 940 hours of pumped irrigation per year per the USDA's latest estimate in the 2013 FRIS.

[23] Assumes $0.25/Wdc for the solar modules, $315/kWhdc for the battery pack, and a total installed cost per capacity of $2.80/Wdc.

[24] Feldman et al, "Q3/Q4 2016 Solar Industry Update" SunShot, U.S. Department of Energy. See slide 13.

[25] Fu et al, "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018" October 2018. National Renewable Energy Laboratory.

[26] Mongird et al, "Energy Storage Technology and Cost Characterization Report" July 2019. U.S. Department of Energy.

[27] These assumed cost declines are similar to those observed in recent history. See Feldman et al, "Q2/Q3 2019 Solar Industry Update," November 12, 2019. See also Mongird, et al, "Energy Storage Technology and Cost Characterization Report." July 2019. See also Fu et al, "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018," NREL, November 2018.

[28] While the projects described here are unsubsidized, they could qualify for the ITC in that the batteries charge entirely from the co-located solar PV array.

[29] https://www.nrel.gov/analysis/tech-lcoe-documentation.html

[30] NRECA, "Battery Energy Storage Overview." April 2019.

[31] 2018 FRIS.

[32] Same sources as citation 27.

[33] Solar irradiance assumptions used in this analysis were sourced from the National Solar Radiation Database.

[34] The 2018.11.11 version of the SAM model was used to model all of the LCOEs provided in this brief.

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