Business & Technology Surveillance

Farm Beneficial Electrification: Opportunities and Strategies for Rural Electric Cooperatives

By Kyle Clark, EnSave, Inc.

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NRECA
America's Electric Cooperatives

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SUBJECT MATTER EXPERT ON THIS TOPIC

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ARTICLE SNAPSHOT

WHAT HAS CHANGED IN THE INDUSTRY?

Rural electric cooperatives are facing declining electricity sales due to factors such as increasing distributed generation and energy efficiency. Parallel to this trend, greenhouse gas (GHG) emission reduction and air quality improvement initiatives have ramped up, and many states have mandated reduction targets. Beneficial electrification presents an opportunity to diversify co-op service offerings and provide value to member-consumers while simultaneously reducing GHG emissions. Farms are promising candidates for end-use electrification, particularly with new electric farm technologies being developed.

WHAT IS THE IMPACT ON COOPERATIVES?

The U.S. agricultural sector represents a major source of potential new electric revenue derived from beneficial electrification. There are over 2.1 million farms in the U.S. registered with the United States Department of Agriculture (USDA), roughly 85 percent of which are located in counties served by co-ops. Based on our analysis, approximately 55,000 to 67,000 GWh of electricity would be required to power farm equipment currently using fossil fuels on these farms. This equates to between $4.4 and $5.4 billion in potential new annual revenue for co-ops (assuming an average value of $0.08 per kWh sold), an increase of 12 to 15 percent versus current co-op electric sales nationally.

WHAT DO COOPERATIVES NEED TO KNOW OR DO ABOUT IT?

Electrification of farm equipment represents a growing opportunity for co-ops that are exploring beneficial electrification programs. While many technologies are still in their infancy, there are distinct advantages to electric farm equipment alternatives. Given that farms can be particularly difficult to reach and influence, understanding the value proposition and logistical considerations of farm equipment electrification is particularly important. This knowledge will aid in designing and implementing farm beneficial electrification programs that will result in win-win outcomes for co-ops and their farm member-consumers.

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Environmental Considerations: Background on "Environmentally Beneficial Electrification"

Strong consensus is growing in research and government organizations that aggressive electrification of energy end-uses is needed in order to achieve greenhouse gas emission reduction goals set in the United States and internationally. The electrification of fossil fuel-powered energy end-uses with the aim of reducing greenhouse gas emissions is called "environmentally beneficial electrification" (Dennis, 2015; Jadun et al., 2017). This will by no means be the motivation for many electrification efforts, yet is important background to consider. While some people are motivated by these environmental considerations, others may not have much motivation to electrify end-uses for various reasons, such as the upfront cost or comfort with current technology.

Researchers and policymakers are now questioning whether the reduction of electricity consumption is an appropriate metric for measuring progress toward a low-carbon future. The transition from an "energy efficiency" paradigm to one of "emissions efficiency" is gaining popularity and complements the shift in policy goals focused on GHG emission reductions. If approached strategically, substituting electricity for fossil fuels results in decreased GHG emissions, while increasing electricity consumption and offering ancillary benefits to end-users (Dennis, 2015).

The Case for Beneficial Electrification on Farms

The 21st century has brought about major advances in agricultural technology including real-time crop monitoring by drones, robotic milking and weeding machines, and autonomous tractors. These technologies fit into the broader category of *precision agriculture*, a rapidly growing industry expected to grow from $3 billion globally in 2015 to over $10 billion by 2025 (GVR, 2017). Electrification of farm equipment will aid in advancing precision agriculture, since many of the protocols used in these technologies are better suited to interface with systems optimized to run on electricity versus fossil fuels.

Replacing old inefficient diesel irrigation motors with electric motors can result in significant cost savings.

Regardless of how innovative a technology may be, the motivation of a farmer to electrify equipment ultimately comes down to the return on investment, convenience, and assurance that the benefits outweigh the risks. Like other businesses, there can be significant resistance to new technologies and a reluctance to change entrenched practices. Co-ops can play an important role in education and promoting the benefits of electrifying farm equipment, which can include reduced energy and maintenance costs, energy use optimization through smart controllers such as variable frequency drives, noise and pollution reduction, and reduced labor requirements through process automation.

Historically, the most common end-use example of beneficial electrification on farms has been irrigation pumping. Irrigation can be a significant source of farm energy consumption and replacing old, inefficient diesel motors with high efficiency electric ones can result in substantial cost savings. Typical diesel motors operate at about 30 to 40 percent energy efficiency, whereas electric motors have efficiencies of 90 percent or higher. Electric motors have lower maintenance labor requirements and enable a farm to use a variable frequency drive, which can dramatically reduce irrigation costs. The clear value proposition of irrigation electrification has led to a high adoption rate, with the percentage of electric irrigation pumps rising from 64 percent in 2003 to 71 percent in 2013 (USDA, 2012).

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Example of Cost Savings Potential

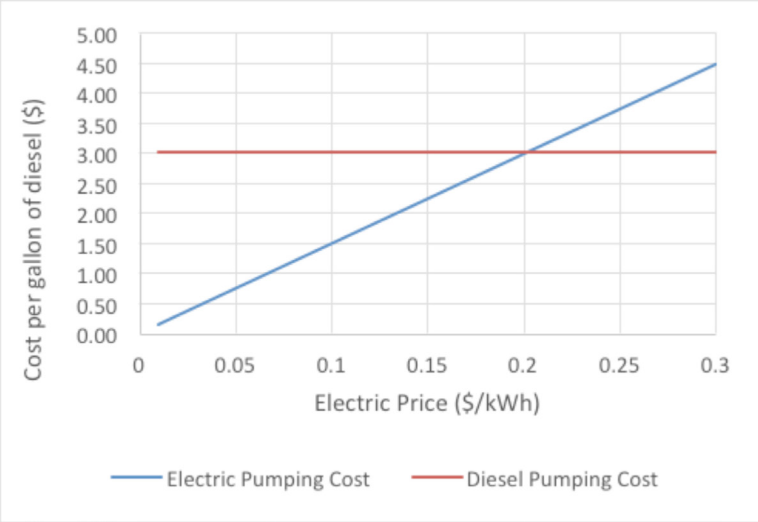

FIGURE 1: Breakeven Analysis of Diesel-to-Electric Fuel Switching for Irrigation Pumps

Figure 1 illustrates the cost savings potential associated with converting a pumping plant from diesel to electric. At a cost of $3 per gallon for diesel fuel, pumping with electricity is more cost-effective up to a rate of $0.20/kWh. Assuming a farm has a sufficiently large pumping requirement and favorable electric rates, the primary barrier to electrification is the need for power lines, which can make the payback period prohibitively long if a lengthy line needs to be installed.

Emerging technologies ranging from radio wave grain dryers to electric tractors are opportunities that mutually benefit co-ops and member-consumers.

While irrigation electrification is not a new concept for most co-ops, other existing and emerging electric technologies have potential for widespread adoption on farms, ranging from radio wave grain dryers to electric tractors. These technologies offer new opportunities for programs and services that mutually benefit the co-op and member-consumers.

Table 1 provides an overview of nine technologies that hold promise for farm beneficial electrification. Only two of these technologies, irrigation pumps and water heaters, have substantial existing implementation rates on farms. The remaining technologies, with the exception of electric tractors, are commercially available and have immediate potential for implementation. The potential impact of each technology in a given co-op service territory depends on the makeup of farms in its service territory, competitiveness of electric rates versus fossil fuel prices, and the availability of incentives to offset upfront capital costs.

TABLE 1: Overview of Farm Beneficial Electrification Technologies

Electric Technology	Primary Farm Types	Commercialization Status	Agricultural Market Penetration
Irrigation pumps	Orchards, vegetables, field crops	Available, widespread	High
Water heaters	Dairy	Available, widespread	Medium
Grain dryers	Field crops	Early, only small capacity	Very low
Maple sap evaporators	Maple	Available, limited selection	Very low
Thermal electric storage systems	Poultry, swine, greenhouse	Available, limited selection	Very low
Radiant heaters	Poultry, swine, greenhouse	Early, only small capacity	Very low
Heat pumps	Greenhouse	Early	Very low
Heat exchangers	Poultry, swine, greenhouse	Available	Very low
Tractors	All, especially field crops	Very early, not available	None

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Potential Impact on Co-ops

The electric sales potential from beneficial electrification of farms is significant, and is estimated to be between 55,000 GWh and 67,000 GWh annually. The opportunity for realizing these sales varies substantially by location depending on the type, scale, and density of agricultural operations. Using a combination of data from the USDA Census of Agriculture, NRECA, and energy benchmarks from EnSave's database of over 4,000 farm energy audits, we developed a series of maps illustrating the potential for equipment electrification on farms served by co-ops. In this section, we highlight three opportunities: tractors, irrigation pumping, and broiler barn space heating.

Electricity sales potential from farm beneficial electrification is estimated to be between 55,000 and 67,000 GWh annually.

TRACTORS

Based on USDA Census data, there are approximately 272 million acres of harvested cropland in co-op territory. Farmers practicing continuous conventional till management use just over 6 gallons of diesel fuel per acre each year, whereas continuous no-till operations (approximately 21 percent of farms) require less than 2 gallons per acre (USDA, 2017). If all farms producing field crops in co-op territory adopted electric tractors, an estimated 28,200 GWh would be required to power them, assuming the average tractor uses 5.16 gallons of diesel fuel per acre per year to produce field crops, and a 50 percent average reduction energy use due to the higher efficiency of electric motors. This estimate does not account for farm vehicles unrelated to producing field crops, such as pickup trucks and hauling trucks, which also consume a considerable amount of fossil fuels. Additionally, the adoption of no-till practices will continue to rise, which will reduce fuel usage proportionally.

FIGURE 2: John Deere 400 hp SESAM Electric Tractor Prototype
Source: https://www.deere.co.uk/assets/images/region-2/our-company/news/press-releases/2017/feb/b_john_deere_sesam_tractor_1366x768.jpg

Several major manufacturers including John Deere, Deutz, and AGCO have invested substantial resources into electric tractor development and are expected to have commercially available models within the next two to three years (Kanicki, 2017; Mowitz, 2018). Fendt, an AGCO company, has been working with select farms and municipalities to deploy its e100 Vario electric tractor and has reported surging demand from European municipalities for the tractor. The e100 Vario delivers 50 kW power output and is capable of operating for up to five hours on a charge and can be recharged up to 80 percent in 40 minutes (Fendt 2018). Larger tractors are also in the works, most notably John Deere's Sustainable Energy Supply for Agricultural Machinery (SESAM) tractor (Figure 2), which features a maximum output of 400 hp (130 kW of continuous power) and can operate for up to four hours performing typical mixed mode operations, with a recharge time of around three hours (John Deere, 2017). The SESAM is expected to be commercially available in three to four years (Kanacki, 2017).

Despite manufacturers claims of electric tractor advantages, including lower operation and maintenance costs, the initial capital cost will be a major factor in the rate of adoption. As with on-road electric vehicles, there may be initial resistance and hesitation among prospective buyers of first-generation models. Government incentives for electric tractors could help to motivate farms to make the switch, as well as the prospect of charging tractors with electricity produced on-site. Additionally, air emission regulations may play a role in driving electric tractor sales in some locations.

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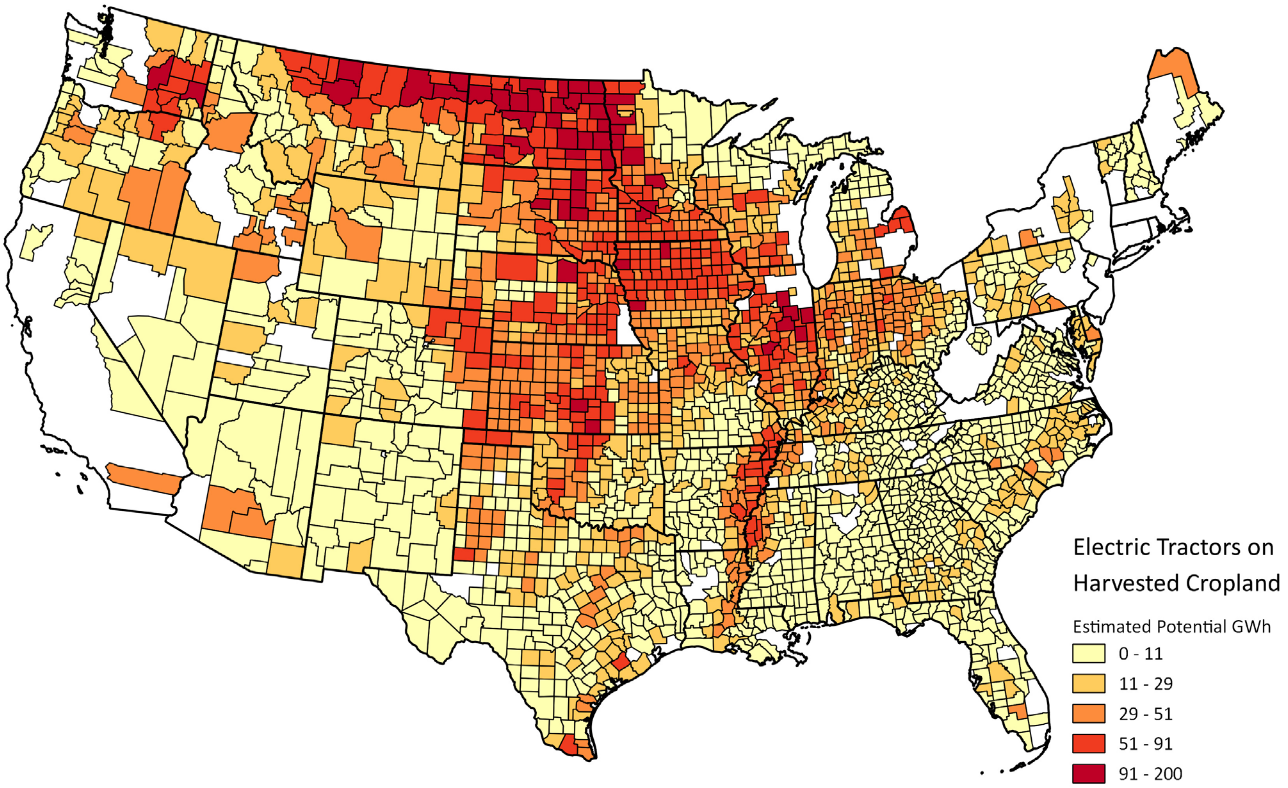

FIGURE 3: Electric Sales Potential from Farm Tractor Electrification

Electric tractors can be charged off-peak and will be ideal for grid stabilization programs.

Electric irrigation pumps are more efficient and provide the possibility for improved load management.

Figure 3 shows potential new electricity sales associated with farm tractor electrification in counties served by co-ops.

The overall potential economic value of electric tractors from new sales is approximately $2.26 billion annually, assuming an average value to co-ops of 8 cents per kWh. Electric tractors are particularly attractive to co-ops because they can be charged off-peak and will be ideal for grid stabilization programs due to the large capacity of the battery packs. Opportunity for electrifying tractors is well dispersed throughout co-op service territory, but is particularly high in Oregon, Montana, North Dakota, Minnesota, South Dakota, Iowa, Nebraska, Kansas, Indiana, and Wisconsin.

IRRIGATION

In addition to being more efficient, electric irrigation pumping offers the possibility to improve load management. Irrigation can be scheduled outside the peak demand times to alleviate pressure on the grid, becoming a powerful tool in grid management. However, an important caveat with irrigation pumps is that many require new electric lines to be run to the pump motor site (or on-site renewable energy generation), which can substantially increase project costs. Careful evaluation of project economics is especially important for irrigation electrification initiatives.

The USDA estimates that there are over 175,000 irrigation pumps currently powered by fossil fuels, irrigating 36 million acres of farmland. If all 122,700 diesel-powered irrigation pump motors were converted to electric motors, approximately 5,600 GWh would be needed to power them annually, assuming an average replacement motor size of 87 horsepower, and an average annual pump runtime of 940 hours. Pumps powered by natural gas, propane, or gasoline will require an estimated additional 1,000 GWh to 2,000 GWh.

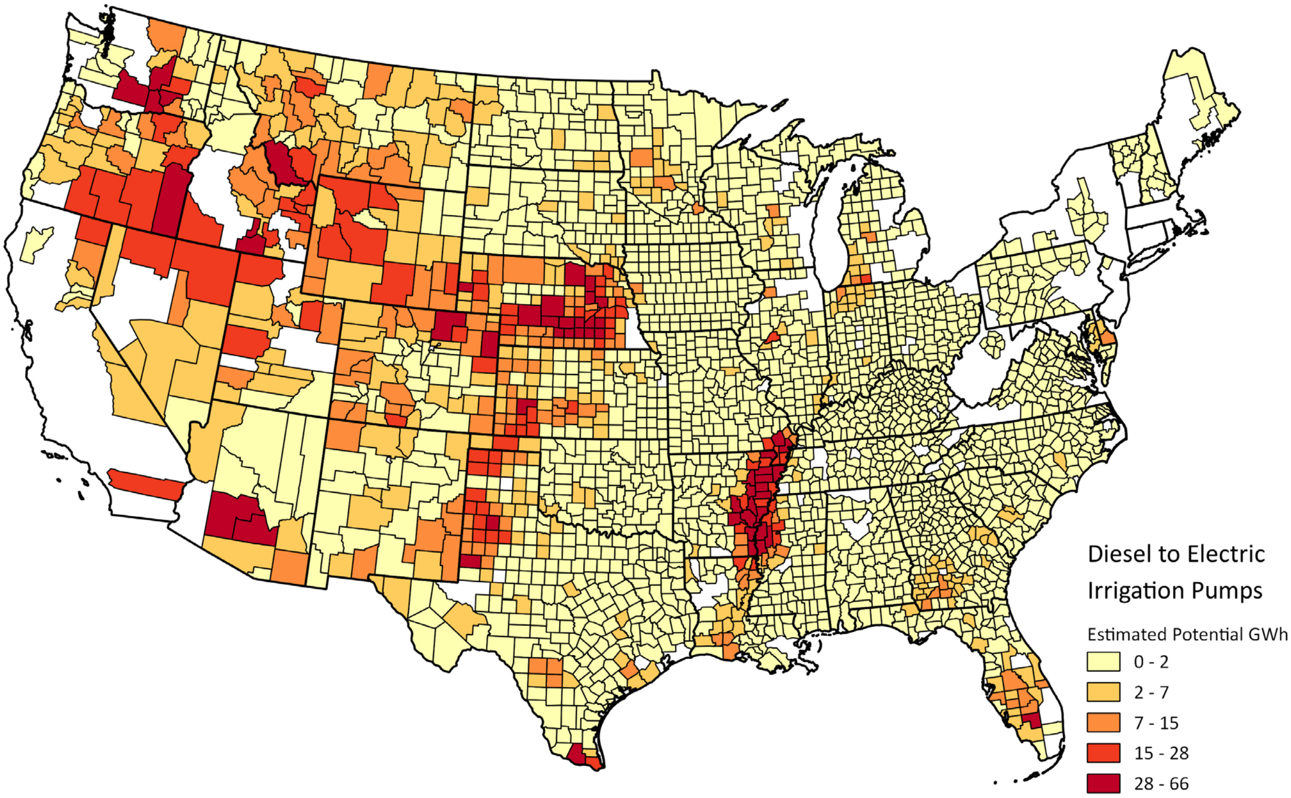

FIGURE 4: Electric Sales Potential from Irrigation Pump Electrification

Some farmers will not want to shut off irrigation loads during peak times if having complete control of irrigation timing is more important than saving energy costs.

Figure 4 shows the electrification potential associated with irrigation pumping. Opportunities are heavily weighted to states west of the Mississippi River, including Washington, Oregon, Idaho, Nebraska, Texas, Arkansas, Colorado, Wyoming, and New Mexico. It is also important to note that some farmers will not be interested in shutting off certain irrigation loads during peak times if it is more important to maintain flexibility in irrigation timing than to reduce energy costs.

SPACE HEATING

Each year, over six billion broiler chickens are grown in counties served by co-ops, each of which requires an average of 2,808 Btus of heat over its lifetime. Virtually all broiler barns are heated with fossil fuels, with around 85 percent being heated with propane and 15 percent being heated with natural gas (based on EnSave audit data). There are several commercially available electric technologies that could provide electric heating, including thermal electric storage systems, waste heat recovery systems, electric radiant heaters, and heat pumps. More research is needed to determine the optimal configuration of these technologies, and the energy prices at which electric heating becomes cost competitive.

We estimate that 4,755 GWh would be required to replace fossil fuels currently heating broiler houses in counties served by co-ops, with the largest opportunities being in Delaware, Maryland, North Carolina, Georgia, Alabama, Mississippi, Arkansas, and Oklahoma. **Figure 5** provides an overview of this opportunity. Our estimate does not include heating requirements for other livestock operations, such as turkeys, pullets, and swine, which combined would require roughly an additional 5,300 GWh annually.

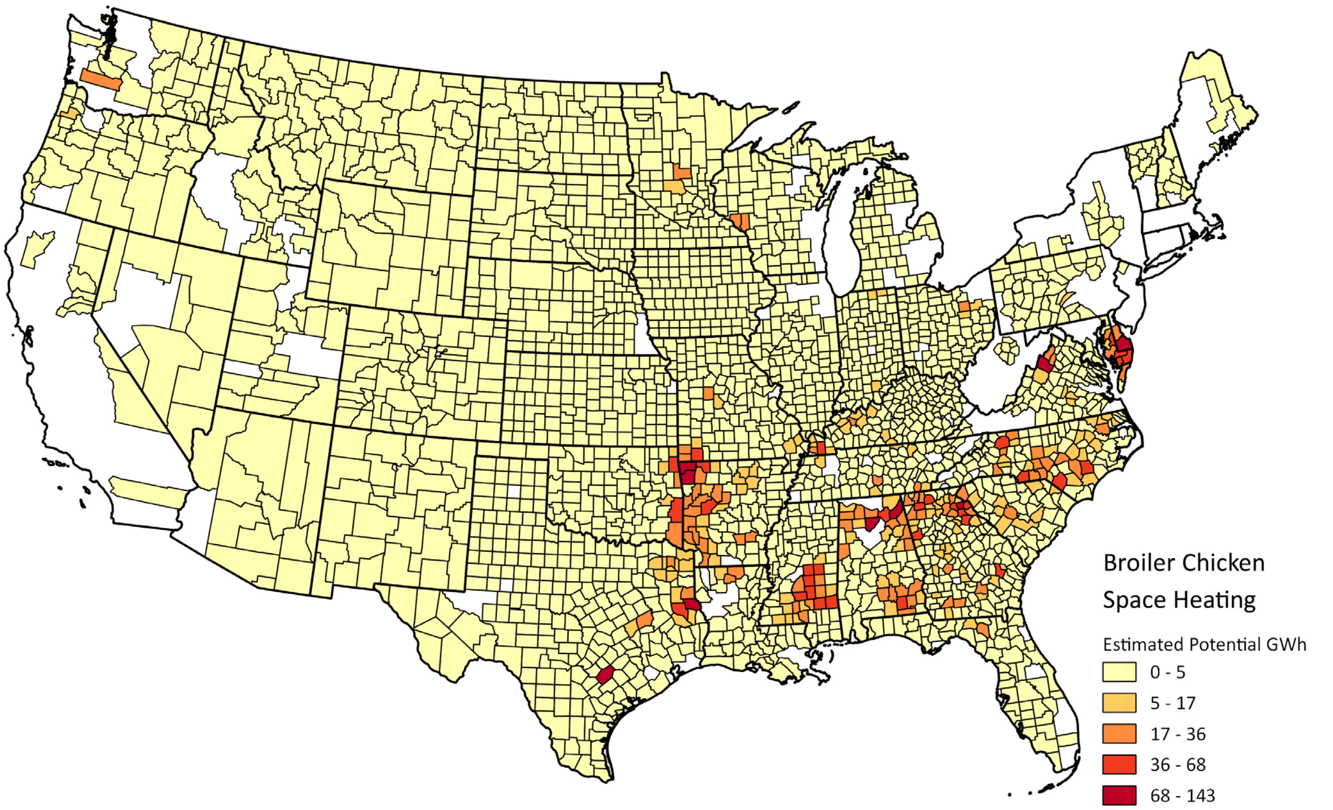

FIGURE 5: Electric Sales Potential from Space Heating in Broiler Barns

Highest Space Heating Potential: Greenhouse Industry

We estimate that the space heating potential in the greenhouse industry is higher than all livestock space heating combined. Using historical energy usage data for Canadian greenhouses published by Statistics Canada (2013) combined with USDA Census information on U.S. greenhouses, and adjusting for heating degree days, we estimate that roughly 14,000 to 20,000 GWh would be necessary to replace the fossil fuel heating needs of greenhouses located in counties served by co-ops. This estimate is preliminary, and further research is needed to refine it due to the absence of available energy usage data for U.S. greenhouses. Electrification opportunities within the greenhouse sector are expected to rise in upcoming years, driven by the trend towards cannabis legalization and the expansion of controlled environment agriculture.

POTENTIAL BY FARM ACTIVITY

Looking at the big picture of farm beneficial electrification, the most significant opportunity exists with electrifying tractors and other farm vehicles, which accounts for roughly 42 percent of the potential. The next largest opportunity is in greenhouse and livestock barn space heating, which collectively account for around 36 percent of the potential (21 and 15 percent, respectively). The remaining 22 percent of potential lies with irrigation electrification (11.5 percent) and all other technologies such as grain dryers, maple sap evaporators, and water heaters (collectively representing 10.5 percent). **Figure 6** provides a summary of high-end estimates of electrification potential by on-farm activity. Note that the GHG reduction potential associated with electrification is dependent on the electricity generation portfolio of the cooperative.

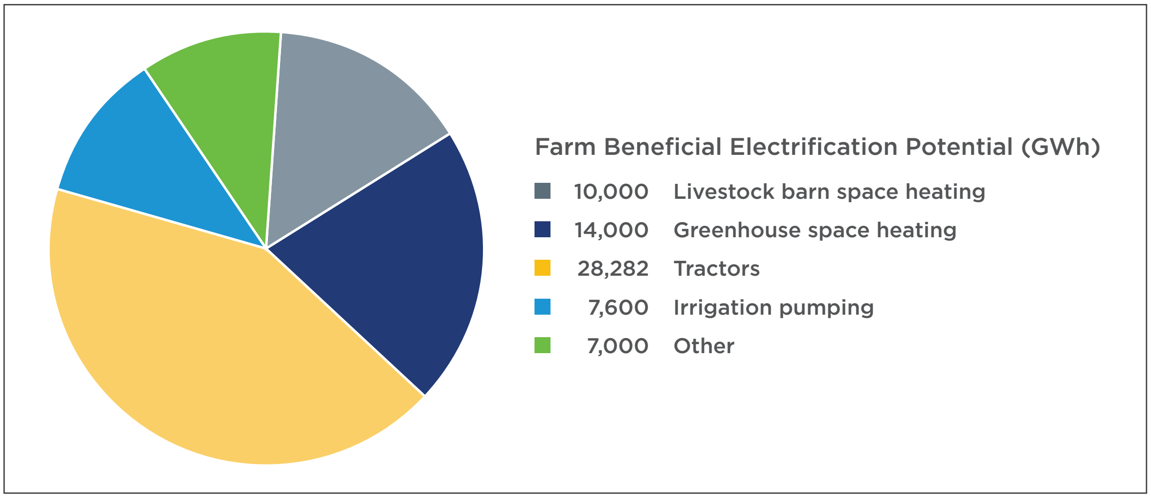

FIGURE 6: Summary of Estimated Electrification Potential by On-Farm Activity

Implementing a Farm Beneficial Electrification Program

Co-op initiatives targeting electrification of on-farm activities will require careful planning to ensure positive outcomes. Each co-op has a unique mix of farms and can maximize their impact by focusing on technologies and engagement strategies that provide the greatest benefit to their members. Furthermore, co-ops can benefit from understanding the value proposition and practical considerations of electrifying farm equipment when communicating with farms.

On-farm beneficial electrification requires a strategic approach by each co-op that considers the unique mix of farms in their area.

PRIORITIZING YOUR EFFORTS AND SERVICE OFFERINGS

Maximizing the benefit of farm electrification to your co-op should begin with a review of farm demographics within your service territory. This can be accomplished by analyzing county-level USDA census data, taking an internal inventory of farm member-consumers, or hiring a third-party consultant to develop a beneficial electrification potential study. The goal of this initial step is to identify the most cost-effective opportunities and marketing approach.

To access USDA data, go to **https://www.agcensus.usda.gov/Publications/2012/** and click on "County-Level Data." From there, click on the state your co-op serves, and then click on the PDF link for "Table 1: County Summary Highlights." In this document, you will find the number of farms by county and commodity type. To get a more accurate picture, you can view more detailed tables that will show farms by size on a county basis.

It is helpful to work with parties known and trusted by your farm member-consumers.

After determining the makeup of your farm member-consumers and the applicable technologies (summarized in **Table 1**), you can then narrow in on the value proposition to farms. Evaluation of the economics of farm end-use electrification can provide a starting point for program design and outreach to members. Speaking with equipment manufacturers, local installers, and third-party agricultural engineering firms can provide valuable insights during this stage. For most co-ops, immediate electrification opportunities may include irrigation, small scale grain drying, non-tractor electric vehicles, and water heating. Longer term opportunities that require further research or advances in technology commercialization include tractors, space heating for greenhouses and livestock barns, and large-scale grain drying.

MARKETING YOUR PROGRAM

There are several key considerations when designing and implementing a program targeting farms. It is important to remember that farms can be difficult to reach, have variable seasonal availability depending on the commodity they produce, and are often reluctant to participate in new programs or adopt new technologies without buy-in from organizations they regularly turn to for advice. For these reasons, it is helpful to work with parties that are known and trusted by farms. Ideally, a co-op program would also offer direct incentives, low-interest loans, or provide assistance to farm member-consumers in accessing government grants or incentives to defray project costs.

Working with the "extended agricultural community" is a useful strategy when attempting to reach and influence farm operators. This community includes entities such as the farm bureau, university extension, commodity trade associations, farm equipment vendors, USDA service centers, and other local groups that work directly with farms to provide financial and technical assistance. These are trusted parties that are accustomed to working with farms and will be able to effectively disseminate co-op program offering information, and possibly play a role in providing technology demonstrations to answer questions and ease concerns of farmers.

Communicating the value proposition of electrification is critical to influencing farms. Providing clear and concise information, including case studies, financial pro forma examples, or simple payback analyses for energy projects goes a long way toward influencing farm business decisions. Farm energy audits are one valuable tool to start the conversation about beneficial electrification and provide compelling financial analysis to farms. Energy audits are also required for most federal funding programs available to farms, which can supplement any financial incentives offered by your co-op.

FINANCING AND INCENTIVE PROGRAMS

Leveraging federal funding programs that provide incentives, grants, and/or low-interest loans to farm member-consumers can provide a valuable way to promote end-use electrification. Some of these programs can also provide funding to your co-op for marketing and outreach efforts and pay for energy audits or third-party technical assistance. There are several USDA programs that provide loans to co-ops or incentives to farms to reduce equipment installation costs or provide low-interest financing, including 1) Rural Energy Savings Program (RESP); 2) Rural Business Development Grants (RBDG); 3) Rural Energy for America Program (REAP); and 4) Environmental Quality Incentives Program (EQIP). Table 2 summarizes key aspects of these four programs.

TABLE 2: Key USDA Programs Applicable to Farm Beneficial Electrification

Program	RESP[1]	RBDG	REAP[2]	EQIP
Summary Description	Provides zero-interest loans to entities providing rural power to re-lend to consumers	Competitive grant designed to support small business in rural areas	Provides loan & grant funding to rural small business to make energy efficiency improvements	Provides incentives for on-farm practices that address natural resource concerns, including air quality and energy use
Eligible Area	Any area served by an entity that is an eligible borrower from Rural Utility Service	City or town with <50,000 population	City or town with <50,000 population	Any
Use of Funds	Implement measures that save energy or energy costs incurred by qualified customers, energy audits	Acquisition of machinery, equipment, utilities, energy audits	Energy efficiency, greenhouse gas reduction, and renewable energy projects	Energy efficiency improvements, including fossil-fuel-to-electric motor conversions, energy audits
Incentive Terms	20-year, 0% interest loans for relending at interest rates up to 3%; Maximum loan amount subject to credit review	No maximum grant amount	Loans up to $25 million, 85% loan guarantee, 15 years Grants up to 25% of project cost up to $250,000 for energy efficiency projects and up to $500,000 for renewable projects.	Incentives and incentivized measures vary by state, but generally cover 50%-90% of project costs
Who May Apply?	Rural electric co-ops	Rural electric co-ops	Farms and small rural businesses (energy audit required)	Farms (energy audit required)

[1] RESP is similar to the *Energy Efficiency Conservation Loan Program*, also offered by the USDA Rural Development.

[2] Note that the *Energy Audit and Renewable Energy Development Assistance* program is also under the umbrella of REAP and provides funding to co-ops to deliver discounted energy audits or renewable energy technical assistance to farms and rural small businesses.

The process of applying for funding through federal programs, or administering a project if funding is granted, can pose a challenge for co-ops that lack staffing capacity to write proposals, market programs to farms, or provide specialized technical assistance. If this is the case for your co-op, one option is to partner with a third-party engineering firm with expertise in these areas.

EXAMPLES OF CO-OP FARM BENEFICIAL ELECTRIFICATION EFFORTS

While there have been few initiatives to date focused on comprehensive farm beneficial electrification, there are numerous examples of co-op efforts that have helped electrify farm end-uses. One particularly successful grant program was launched by Delaware Electric Cooperative (DEC) in 2011 with a goal of converting diesel-driven motors to electric motors. The DEC's *Irrigation System Conversion Grant Program*, funded through the State of Delaware's Energy Efficiency Investment Fund, provides grants up to $15,000 to help farms make the switch. Since launching the grant program, their total irrigation kWh sales have increased by 375 percent without increasing demand, thereby increasing its load factor (Clamp, 2017).

Equipment manufacturers are recognizing the value in developing electric-powered equipment for farm-specific applications.

Another state government-funded program that has provided benefit to co-ops and their members is the *Florida Energy and Water Efficiency Realization Program* (FEWER), funded by the Florida Department of Agriculture and Consumer Services. This program resulted in 790,000 kWh of electricity use per year being added to the grid from diesel-to-electric irrigation pump motor conversions on 34 farms. These conversions resulted in almost $300,000 in annual cost savings to Florida farmers, while displacing 181,611 gallons of diesel fuel. Details of both programs can be found in NRECA's TechSurveillance article ***Farm Irrigation Systems*** (see Clamp, 2017).

An example of a more specialized farm beneficial electrification initiative is the incentive program run by Vermont Electric Co-op to electrify maple sugar evaporators. Electric maple evaporators (such as the "ECOVAP", manufactured by Dominion & Grimm) use 22 times less energy than oil fired evaporators, and each unit results in a reduction of roughly 30 tons of CO_2 emissions per year, the equivalent to taking about 7 cars off the road (VEC, 2015). This initiative illustrates not only the win-win proposition of beneficial electrification for co-ops and farmers, but also the fact that equipment manufacturers, are recognizing the value in developing innovative electric-powered equipment for farm-specific applications.

Several co-ops have also been exploring the potential of expanding their service territory to serve off-grid irrigation pumps. Recognizing the beneficial electrification opportunity associated with currently off-grid irrigation and oil & gas pumps in their service territory, Golden Spread Electric Co-op, in collaboration with its member-consumer distribution co-op, Rita Blanca Electric Co-op (RBEC), solicited services to quantify the economic feasibility of expanding their transmission and distribution system to serve over 20 MW of diesel-powered pumping plants. In an initial feasibility study, it was determined that RBEC could compete with diesel fuel when electric rates are as high as $0.20/kWh, or $0.12/kWh for natural gas (EnSave, 2017).

Co-op-sponsored farm beneficial electrification programs hold substantial untapped opportunity to provide value to co-op member-consumers while simultaneously reducing greenhouse gas emissions and generating new co-op revenue. This opportunity will continue to grow rapidly over the next decade as policy makers increasingly recognize the strategic value of beneficial electrification, renewable energy costs become more competitive, and equipment manufacturers continue to commercialize innovative electric technologies. ■

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ABOUT THE AUTHOR

Kyle Clark is the Vice President of Business Development at EnSave, Inc., where he oversees design and innovation of projects relating to agricultural energy use and greenhouse gas mitigation. He has extensive experience leading energy and sustainability consulting services for investor owned utilities, rural electric cooperatives, government agencies, and the nation's leading agribusinesses and farmer cooperatives. Mr. Clark holds a master's degree in Sustainability Science from Lund University in Sweden, and a bachelor's degree in Natural Resource Planning from the University of Vermont.

QUESTIONS OR COMMENTS

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- To find more resources on business and technology issues for cooperatives, visit our **website**.

DISTRIBUTED ENERGY RESOURCES WORK GROUP

The Distributed Energy Resources (DER) Work Group, part of NRECA's Business and Technology Strategies department, is focused on identifying the opportunities and challenges presented by the continued evolution of distributed generation, energy storage, energy efficiency and demand response resources. For more information, please visit **www.cooperative.com**, and for the current work by the Business and Technology Strategies department of NRECA, please see our **Portfolio**.