ELECTRIFIED AGRICULTURE

BEST PRACTICES FOR FARMERS & UTILITIES

OCTOBER 30, 2019

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OVERVIEW OF THE ELECTRIFICATION OF AGRICULTURE

Electrification has and will continue to be a driver of increased productivity and quality of life for agricultural producers

Photo by Gregory Hayes on Unsplash

Non-energy benefits

Photo by Heiko Janowski on Unsplash

Operational benefits

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OPPORTUNITIES FOR BENEFICIAL AGRICULTURAL ELECTRIFICATION

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

Source: Clark, K., Farm Beneficial Electrification: Opportunities and Strategies for Rural Electric Cooperatives, National Rural Electric Cooperative Association, 2018, https://www.cooperative.com/programs-services/bts/documents/techsurveillance/surveillance-article-farm-beneficial-electrification-october-2018.pdf.

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BEST PRACTICES IN ELECTRIFICATION

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OVERCOMING INITIAL CAPITAL COST BARRIERS TO ELECTRIFICATION

Key USDA Programs Applicable to Farm Beneficial Electrification

Program	Rural Energy Savings Program (RESP)[1]	Rural Business Development Grant (RBDG)	Rural Energy for America Program (REAP)	Environmental Quality Incentives Program (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 and 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 a population of less than 50,000	City or town with a population of less than 50,000	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 cooperatives	Rural electric cooperatives	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.
Source: Clark, Farm Beneficial Electrification

FIELD CROPS

Irrigation pumps represent a large opportunity for electrification.

Source: *Peter Gonzalez* on *Unsplash*

- Fuel prices and electricity costs determine profitability of switch (up to ~$4,000 annual savings)
- Not only energy savings, but labor as well
- Infrastructure barriers overcome by technology

Annual Savings by Using Electricity

Electricity		Diesel Fuel Cost, $/Gallon			
		1.75	2.00	2.25	2.50
Price, $/kWh	Total Annual Costs	$19,616	$20,625	$21,634	$22,643
0.06	$18,549	$1,067	$2,076	$3,085	$4,094
0.07	$19,119	$497	$1,506	$2,515	$3,524
0.08	$19,689	-$73	$936	$1,945	$2,954
0.09	$20,259	-$643	$366	$1,375	$2,384
0.10	$20,829	-$1,213	-$204	$805	$1,814

Source: Martin et al., Evaluating Energy Use for Pumping Irrigation Water

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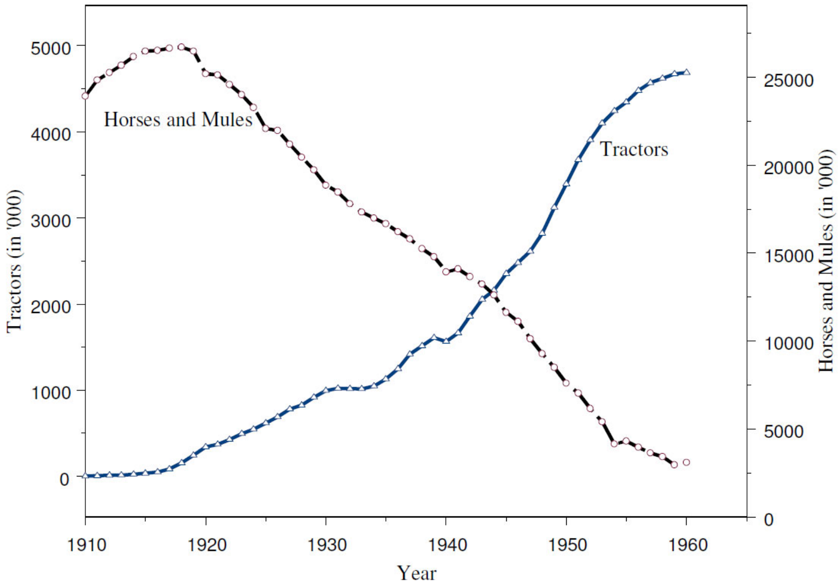
FIELD CROPS

Electrification of field crop equipment will change the face of agriculture in the next 20 years.

Source: Scott Goodwill on Unsplash

- Offers stability of fuel input prices
  - Negotiate with utility, not as volatile
- Still in research and development phase
  - Small electric tractors in Europe, not feasible yet for scale in U.S.
- Barriers to adoption
  - Capital investment
  - Battery technology
  - Familiarity with current technology

Horses, Mules, and Tractors in Farms, 1910-1960



Source: Manuelli, Rodolfo E. and Ananth Seshadri, "Frictionless Technology Diffusion: The Case of Tractors"

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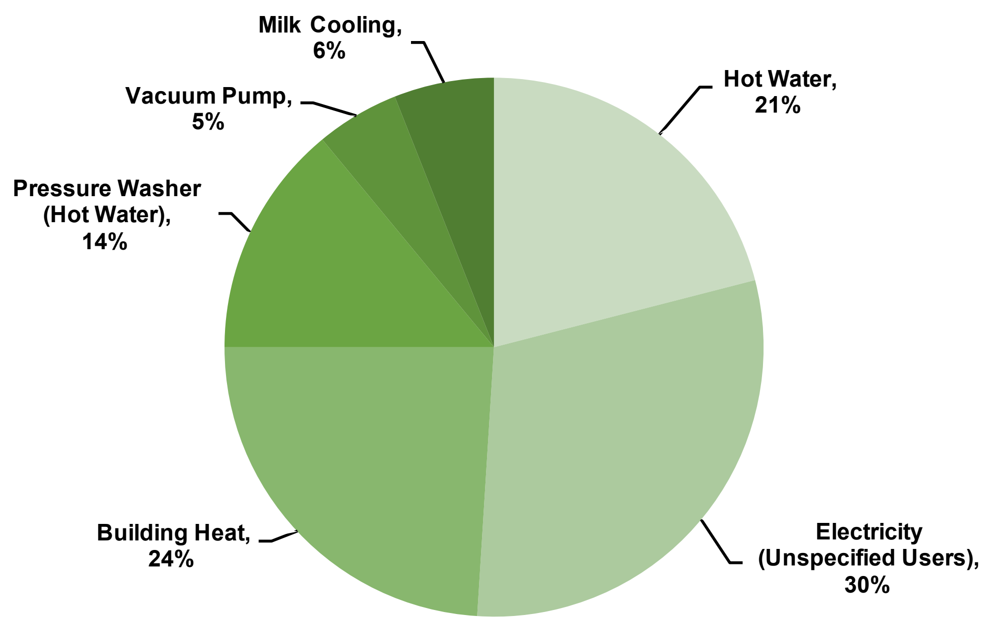
LIVESTOCK

Current Dairy Equipment and Electrification Opportunities

Equipment	Percent Energy Use	Alternative Technology	Benefits
Vacuum pump	20-25	VFD	Reduce energy operating costs up to 60%, extend pump life with lower RPM
Precool milk direct, in-tank cooling	>50	Indirect heat exchange, precooling	Reduce milk temps up to 40°F, save up to 60% of cooling costs, milk temp from cows 95°F-99°F, target is 38°F
Water heaters/ storage	25	Insulation, heat exchangers	Reduce heat loss by up to 3% and thereby operating costs
Refrigerant and cleaning line heat loss	NA	Insulation	Reduce heat loss by up to 3% and thereby operating costs

Source: Tate, T., Agribusiness

Energy Use in Milking Operations



Source: Tate, T., Agribusiness

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SPECIALTY CROPS

Greenhouses are the second largest agricultural electrification opportunity.

Source: Daniel Fazio on Unsplash

- An estimated 14,000-20,000 GWh of generation capacity would be needed to replace current fossil fuel use
- Demand for greenhouse agriculture expected to continue growing
  – Local food movement
  – Cannabis legalization
- Costs of electricity could be offset by emerging technology (i.e., transparent solar panels)

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BEST PRACTICES IN AUTOMATION

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FIELD CROPS

Automated irrigation via soil monitoring will continue to grow exponentially.

Source: Wynand Uys on Unsplash

- Enables precision agriculture techniques conserving:
  - Water
  - Soil resources (minimizing runoff, etc.)
- Key piece of comprehensive field crop automation
- Requires Internet of Things (IoT)
  - Can be barrier to implementation
- When coupled with additional automation (e.g., tractors, drones), minimal labor input further reducing costs

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LIVESTOCK

Robotic dairies outperform traditional systems and are growing in popularity.

- Modular systems, so scalable automation
- Can increase milk production (up to ~8%) and allow for more precise herd health monitoring
- Greatly reduces labor burden; turns job from physical into mental labor
- High capital cost, but quick payback period (~3-6 years) and minimal labor

Cost Comparison of Robotic vs. Retrofit vs. Traditional Milking System

	Robotic Milking System (3x per Day) (New)	Robotic Milking System (3x per Day) (Retrofit)	Traditional Parlor Milking System (2x per Day)
Life Expectancy	20 years	20 years	20 years
Initial Cost	$214,500	$273,000	$85,800
Annual Electric Cost*	$1,080 at $0.06/kWh	$1,080 at $0.06/kWh	$570 at $0.06/kWh
Other Annual Cost**	-$12,780	-$12,780	$22,800
Total Lifetime Cost	-$19,500	$39,000	$553,200
Annual Average Cost	-$975	$1,950	$27,660

**Fuel prices are national averages based on price data from the US Energy Information Administration, http://www.eia.gov/. A robotic milking system consumes 18,000 kWh annually while the alternative consumes 9,500 kWh annually.*

***Includes maintenance costs, labor costs, energy for cooling the additional milk produced, and earnings from milk production; negative number is income.*

Source: Electric Power Research Institute (2016b), Robotic Milking System

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SPECIALTY AGRICULTURE

Smart greenhouses could solve the problem of feeding 9 billion by 2050.

Source: Markus Spiske on Unsplash

- Automated lighting systems
- Automated nutrient monitoring and pumping
- Automated climate control
- Potentially higher yields than traditional agriculture
- Capital investments can be a barrier
- Infrastructure can be a barrier

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ELECTRIFIED AGRICULTURE

BEST PRACTICES FOR UTILITIES

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OVERVIEW OF THE ELECTRIFICATION OF AGRICULTURE

Electrification is an opportunity for utilities to engage with agricultural customers in new and innovative ways.

Increased electricity sales from electrified equipment

New applications for demand response, storage, and distributed generation

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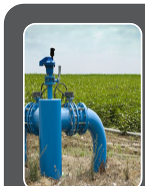
OVERVIEW OF THE ELECTRIFICATION OF AGRICULTURE

New technologies present increased benefits to customers, utilities, and regulators.



Leading end uses for electricity in agriculture

- Currently only about 18% of fuel consumed on a farm is electricity
- **Irrigation** has become increasingly electrified
- **Indoor agriculture** is projected to grow by 24% into a $3 billion industry in the US by 2024 and is a promising agricultural end-use

New opportunities for energy technology and electricity services

- Farmland is aligned with quality wind and solar locations
- Expensive rural energy makes distributed an attractive investment
- In some cases, farms are becoming net energy generators
- New technologies and services will play a key role in balancing a new, distributed electricity grid

GHG Reduction Targets

- Complete electrification of the agricultural sector, coupled with distributed generation, could result in large greenhouse gas savings (46 $MMTCO_2e$ savings)

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BEST PRACTICES IN DEMAND RESPONSE

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DEMAND RESPONSE IN AGRICULTURE

Demand response helps match electricity supply with electricity demand.

Demand Response (DR)

Must target electric loads that can be automated and allow for variable demand flexibility (i.e. do not have to occur for a certain amount of time during a certain time of the day)

DR End uses

- Water storage coupled with groundwater pumps
- Groundwater and booster pumps fitted with VFDs
- Indoor agriculture lighting, climate, and watering systems

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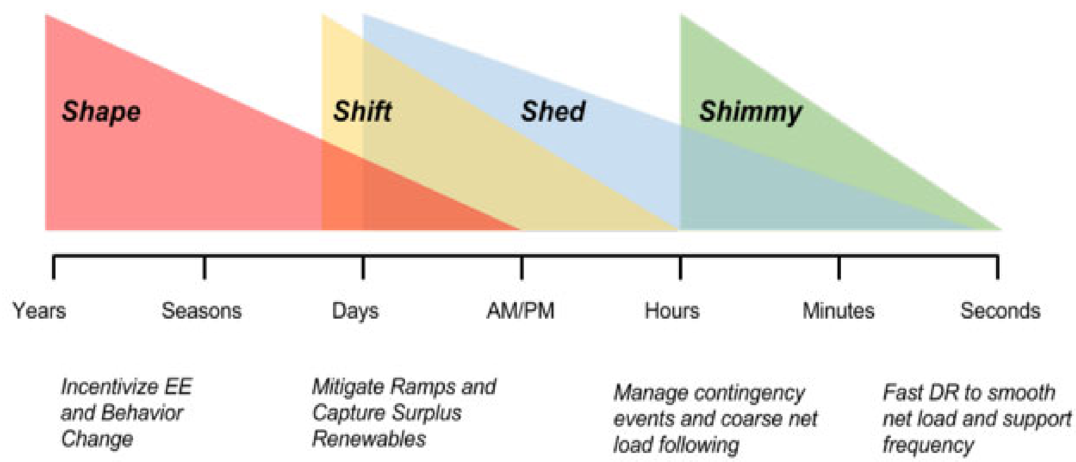
DEMAND RESPONSE PROGRAMS AND TECHNOLOGIES

Demand response strategies can operate on the order of seconds, minutes, days, or years.

- Four categories of demand response based on time for dispatch and response
- Demand response opportunities on farms are most aligned with short- to medium-response times making shifting strategies the most promising for irrigation end uses and shaping the best strategy for indoor agriculture

Types of Demand Response Services Presented Based on Time for Dispatch and Response



Source: Lawrence Berkeley National Laboratory, *Agricultural Demand Response for Decarbonizing the Electricity Grid, 2019.*

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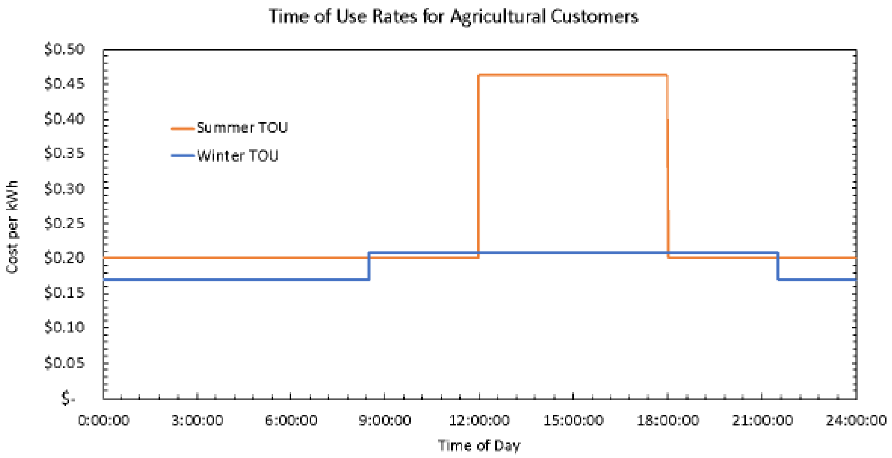
DEMAND RESPONSE PROGRAMS AND TECHNOLOGIES

Demand response strategies can vary based on the implemented program and available technology.

Programs

- Time-of-Use (TOU)
- Distribution DR
- Event-based DR



Source: *Arian Aghajanzadeh et al, Water-Energy Considerations in California's Agricultural Sector and Opportunities to Provide Flexibility to California's Grid*

Technologies

- Automatic irrigation controls that are wifi, telecommunication, or satellite service-enabled
  - – Moisture sensors
- VFDs
- Manual controls

Source: https://interestingengineering.com/this-farming-company-hopes-to-tackle-world-hunger-with-indoor-agriculture

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THE FUTURE OF DEMAND RESPONSE IN AGRICULTURE

It is often cheaper to implement demand response than to build new generation and infrastructure.

Source: https://www.ers.usda.gov/amber-waves/2017/june/understanding-irrigated-agriculture/

The Potential for Demand Response in Agriculture

- California Case Study: Shifting irrigation from 4-7pm to midday would create 1.3 GW of storage potential by pumping water when electricity supply is highest
- Cheap compared to new generation development and battery storage
- Gateway to greater engagement and innovation with agricultural customers through:
  - Enhanced service such as providing customers insight into energy use
  - System optimization resulting in lower energy costs
  - Larger potential for distributed onsite renewable generation

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THE FUTURE OF DEMAND RESPONSE IN AGRICULTURE

Lack of digitization and agriculture-specific program design are the main barriers to adoption.

Challenges in demand response

- Lack of digitization
- Failure in program and technology design

Solutions to spur adoption

- Need for stakeholder engagement from utilities and customers
- Increase ease of DR program participation
- Need for new market mechanisms specific to agriculture

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BEST PRACTICES IN ENERGY STORAGE

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TYPES OF STORAGE

Storage comes in many forms and increases grid reliability.

Source: Casey Schackow on Unsplash

- Ability to reduce costs and improve grid reliability
- Potential to shift energy loads to non-peak hours and store energy reserves in case of generation disruptions

Characteristics of Selected Energy Storage Systems

Storage Technology	Max Power Rating *(MW)*	Typical Discharge Time	Lifetime or Max Cycles	Energy Density *(watt-hour per liter)*	Efficiency
Pumped hydro	3,000	4 hours – 16 hours	30–60 years	0.2–2	70%–85%
Compressed air	1,000	2 hours – 30 hours	20–40 years	2–6	40%–70%
Molten salt (thermal)	150	hours	30 years	70–210	80%–90%
Li-ion battery	100	1 minute – 8 hours	1,000–10,000	200–400	85%–95%
Lead-acid battery	100	1 minute – 8 hours	6–40 years	50–80	80%–90%
Flow battery	100	hours	12,000–14,000	20–70	60%–85%
Hydrogen	100	mins – week	5–30 years	600 (at 200bar)	25%–45%
Flywheel	20	secs – mins	20,000–100,000	20–80	70%–95%

Source: Environmental and Energy Study Institute, “Fact Sheet: Energy Storage,” 2019, https://www.eesi.org/papers/view/energy-storage-2019.

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WATER AND BATTERY STORAGE

Water storage and battery storage are most aligned with the needs of agricultural customers.

Water Storage

- Can be in-soil storage or aboveground storage
- Water pumping typically the primary driver of electricity cost due to popularity of electric pumps
- Storage, combined with DR allows pumping during off-peak hours

Battery Storage

- Quickly decreasing costs makes batteries increasingly viable
- Current LCOE at $187/MWh
- Opportunity for behind-the-meter and in front-of-the-meter storage
- As the grid becomes more distributed, battery storage allows for electricity deployment to counteract intermittency

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BEST PRACTICES IN DISTRIBUTED GENERATION

TECHNOLOGIES AVAILABLE FOR DISTRIBUTED GENERATION IN AGRICULTURE

Distributed renewable generation is an opportunity for farms to lower energy costs and generate revenue.

Distributed Generation Technology

- Agriculture one of the first industries to use distributed generation, implementing solar PV to supply farms' energy needs
- Solar remains the most common form of distributed generation in agricultural operations
- Small-scale systems can be used to pump water, power lighting, ventilation, climate control
- Large scale systems now provide a source of energy generation by providing energy back to the grid
- Wind energy is common through land leases

Farm Applications for Solar Energy

		Fields	Livestock	Other
Water Pumping	*PV*	wells, ponds, streams, irrigation	wells, ponds, streams	domestic uses
Buildings Needs	*PV*		security and task lighting, ventilation, feed or product handling equipment, refrigeration	battery charging, task lighting, ventilation fans, AC needs, refrigeration
	*S H**		air cooling, air/space heating, water heating	domestic uses of solar heat
Farm and Ranch	*PV*	feeder/sprayer, irrigation sprinkler controls, security and task lighting,	electric fences, feeder/sprayer	electric fences, invisible fences, battery charging, compressor for fish farming, fans for crop drying, greenhouse heating
	*S H**			crop drying, greenhouse heating

Source: Expanded from NREL, Electricity When and Where You Need It: From the Sun. Photovoltaics for Farms and Ranches, 1997

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BENEFITS AND CHALLENGES OF ON-FARM DISTRIBUTED GENERATION

Utilities must work with agricultural customers to ensure distributed generation aligns with grid planning and capacity.

Benefits of Distributed Generation

- A source of power that is highly reliable, requires minimal maintenance, and provides energy independence
- Can lower the cost of energy in rural areas without robust existing infrastructure
- Benefits of agrivoltaics—growing shade crops under PV installations decreases water loss
- DG increases grid resilience, particularly in hard-to-reach areas

Challenges to Overcome

- DG may decrease energy sales if self-generation is more cost effective than purchasing from the grid
- Over-reliance on DG without complementary technology exposes utilities to intermittency or overgeneration issues
- Advance planning is required to successfully implement agricultural DG

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THE FUTURE OF DISTRIBUTED GENERATION IN AGRICULTURE

Implemented in conjunction with demand response and storage, distributed generation creates a more resilient, cost-effective grid.

Source: https://www.smithsonianmag.com/science-nature/us-could-switch-mostly-renewable-energy-no-batteries-needed-180957925/

- Utilities do not need to convince farms to install DG, they need to convince them to stay connected to the grid
- Utility-provided services can help agricultural operations maximize the value of DG
  - DR, storage, customer service, advanced monitoring, and smart inverters
- Must take DR into account during resource planning
- Leverage position in the energy landscape to educate and facilitate conversation amongst stakeholders

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FORECASTED ELECTRICITY GROWTH IN THE AGRICULTURAL SECTOR

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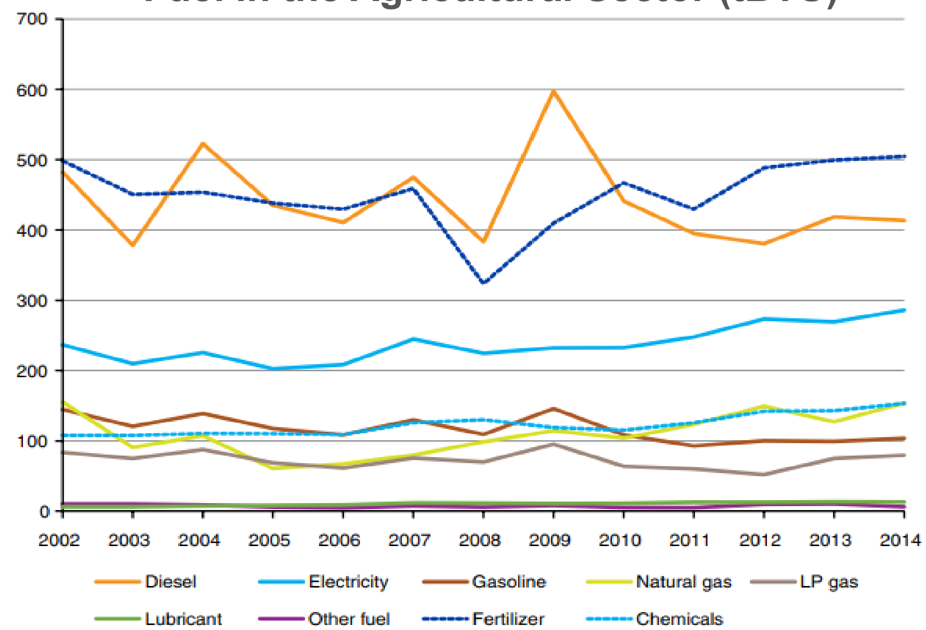
Currently agriculture makes up a small portion of electricity usage in the U.S., and national trends are not well understood.

- While agriculture makes up a large percentage of electricity use in agriculturally dense states, it is a small percentage of overall energy and electricity use in the US
- Most recent study is the 2016 *National Agricultural Statistics Service Quick Stats 2.0*
- Studies group agriculture under “industry” making it difficult to disaggregate ag-specific trends
- Data collection at a more granular level is needed to develop an understanding of the forecasted trends of agricultural electrification

Direct and Indirect Energy Consumption by Fuel in the Agricultural Sector (tBTU)



Source: Source: US Department of Agriculture, Trends in US Agriculture’s Consumption and Production of Energy: Renewable Power, Shale Energy, and Cellulosic Biomass

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- Seed suppliers
- Chemical dealers
- Crop consultants
- Local producers’ cooperative
- Trade or technical journals
- Growers’ Associations
- American (and state-level) Farm Bureau
- Agriculture technology companies
- Equipment cooperatives or suppliers
- Farmland trusts
- Universities and agriculture programs

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