ELECTRIFIED AGRICULTURE
BEST PRACTICES FOR FARMERS & UTILITIES

OCTOBER 30, 2019
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ELECTRIFIED AGRICULTURE

BEST PRACTICES FOR FARMERS

OCTOBER 30, 2019
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

Non-energy benefits

Operational benefits
## Overview of Farm Beneficial Electrification Technologies

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

BEST PRACTICES IN ELECTRIFICATION
### Key USDA Programs Applicable to Farm Beneficial Electrification

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

¹RESP 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.

- 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

<table>
<thead>
<tr>
<th>Price, $/kWh</th>
<th>Electricity Total Annual Costs</th>
<th>Diesel Fuel Cost, $/Gallon</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.06</td>
<td>$18,549</td>
<td>$1,067</td>
</tr>
<tr>
<td>0.07</td>
<td>$19,119</td>
<td>$497</td>
</tr>
<tr>
<td>0.08</td>
<td>$19,689</td>
<td>-$73</td>
</tr>
<tr>
<td>0.09</td>
<td>$20,259</td>
<td>-$643</td>
</tr>
<tr>
<td>0.10</td>
<td>$20,829</td>
<td>-$1,213</td>
</tr>
</tbody>
</table>

Source: Martin et al., Evaluating Energy Use for Pumping Irrigation Water
Electrification of field crop equipment will change the face of agriculture in the next 20 years.

• 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

Source: Scott Goodwill on Unsplash

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

Horses, Mules, and Tractors in Farms, 1910-1960
## Current Dairy Equipment and Electrification Opportunities

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Percent Energy Use</th>
<th>Alternative Technology</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacuum pump</td>
<td>20-25</td>
<td>VFD</td>
<td>Reduce energy operating costs up to 60%, extend pump life with lower RPM</td>
</tr>
<tr>
<td>Precool milk direct, in-tank cooling</td>
<td>&gt;50</td>
<td>Indirect heat exchange, precooling</td>
<td>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</td>
</tr>
<tr>
<td>Water heaters/storage</td>
<td>25</td>
<td>Insulation, heat exchangers</td>
<td>Reduce heat loss by up to 3% and thereby operating costs</td>
</tr>
<tr>
<td>Refrigerant and cleaning line heat loss</td>
<td>NA</td>
<td>Insulation</td>
<td>Reduce heat loss by up to 3% and thereby operating costs</td>
</tr>
</tbody>
</table>

Source: Tate, T., Agribusiness

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### Energy Use in Milking Operations

- **Hot Water, 21%**
- **Building Heat, 24%**
- **Electricity (Unspecified Users), 30%**
- **Pressure Washer (Hot Water), 14%**
- **Milk Cooling, 6%**
- **Vacuum Pump, 5%**

Source: Tate, T., Agribusiness
Greenhouses are the second largest agricultural electrification opportunity.

• 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)

Source: Daniel Fazio on Unsplash
Automated irrigation via soil monitoring will continue to grow exponentially.

- 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
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

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

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

- 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

Source: Markus Spiske on Unsplash
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
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 MMTCO₂e savings)
BEST PRACTICES IN DEMAND RESPONSE
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
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**

- **Shape**
  - Incentivize EE and Behavior Change

- **Shift**
  - Mitigate Ramps and Capture Surplus Renewables

- **Shed**
  - Manage contingency events and coarse net load following

- **Shimmy**
  - Fast DR to smooth net load and support frequency

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

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

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

![Graph showing Time of Use Rates for Agricultural Customers](source.png)

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

Source: https://interestingengineering.com/this-farming-company-hopes-to-tackle-world-hunger-with-indoor-agriculture
It is often cheaper to implement demand response than to build new generation and infrastructure.

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

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
BEST PRACTICES IN ENERGY STORAGE
### Types of Storage

Storage comes in many forms and increases grid reliability.

### Characteristics of Selected Energy Storage Systems

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

Water 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
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**

<table>
<thead>
<tr>
<th></th>
<th>Fields</th>
<th>Livestock</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Pumping</td>
<td>PV</td>
<td>wells, ponds, streams</td>
<td>domestic uses</td>
</tr>
<tr>
<td></td>
<td></td>
<td>security and task lighting, ventilation, feed or product handling equipment, refrigeration</td>
<td>battery charging, task lighting, ventilation fans, AC needs, refrigeration</td>
</tr>
<tr>
<td>Buildings Needs</td>
<td>PV</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SH*</td>
<td>air cooling, air/pace heating, water heating</td>
<td>domestic uses of solar heat</td>
</tr>
<tr>
<td>Farm and Ranch</td>
<td>PV</td>
<td>feeder/spayer, irrigation sprinkler controls, security and task lighting.</td>
<td>electric fences, invisible fences, battery charging, compressor for fish farming, fans for crop drying, greenhouse heating</td>
</tr>
<tr>
<td></td>
<td>SH*</td>
<td></td>
<td>crop drying, greenhouse heating</td>
</tr>
</tbody>
</table>

Source: Expanded from NREL, Electricity When and Where You Need It: From the Sun. Photovoltaics for Farms and Ranches, 1997
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
The Future of Distributed Generation in Agriculture

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

- 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.

FORECASTED ELECTRICITY GROWTH IN THE AGRICULTURAL SECTOR
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.
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