ENERGIZING AGRICULTURE
Policy Opportunities for Beneficial Electrification on the Farm

How beneficial electrification in agriculture fosters a robust electric grid, reduces greenhouse gas emissions, and cuts energy costs for both consumers and utilities

BY: MARNIE AVILA ALVAREZ, GENEVIEVE BYRNE, & WILL FRIDLUND

Institute for Energy & the Environment
VERMONT LAW & GRADUATE SCHOOL

FARM AND ENERGY INITIATIVE

Center for Agriculture & Food Systems
VERMONT LAW & GRADUATE SCHOOL

JUNE 2024

Authors & Acknowledgements

Unsplash photo by Erwan Hesry

The lead authors of this report are Marnie Avila Alvarez, LLM Fellow in Energy Law ’23; Genevieve Byrne, Professor of Law, Interim Director of Energy Clinic, and Staff Attorney for the Farm and Energy Initiative; and Will Fridlund, Program Coordinator and Researcher, Institute for Energy and the Environment.

The following student authors at the Institute for Energy and the Environment also contributed significant research and writing to this report: Noah Corbett JD’24; Belen Delgado-Mio, Clean Energy Intern; Trent Hagedorn JD’24; Nicolas Harris JD’24; Alec Kerestedjian JD/MERL’24; Lauren Kobayashi JD/MERL’24; Sarah Pardee JD/MERL’23; Jacquelynn Perez JD’25; Peyton Renard JD’24; Sonja Rzepski JD’25; Jon Small AJD/MERL’24; Caroline Smith JD’24, Ryan Sterling JD’24; and Bobby Turner JD/MERL’23.

This report was made possible by support from the National Agricultural Library, Agricultural Research Service, U.S. Department of Agriculture. The report also benefited from the editorial review of Mark James, Interim Director of the Institute for Energy and the Environment at Vermont Law and Graduate School. It also benefited from editorial and design support from several members of the Center for Agriculture and Food Systems at Vermont Law and Graduate School, including Laurie J. Beyranevand, Director and Professor of Law; Lihlani Nelson, Deputy Director and Senior Researcher; Claire Hermann, Senior Communications Manager; and Lindsey Cole, Program Manager and Research Fellow.

ABOUT THE FARM AND ENERGY INITIATIVE

The Farm and Energy Initiative (FEI) is a collaboration between the Institute for Energy and the Environment and the Vermont Law and Graduate School's Center for Agriculture and Food Systems, supported by funding from the National Agricultural Library at the U.S. Department of Agriculture. FEI seeks to lead research and create open-access resources for farmers, researchers, and public citizens alike, to promote the future sustainability of the agricultural industry. Our projects examine legal and practical issues at the intersection of energy and agriculture with the goal of improving agricultural energy management nationwide. Learn more about our work at farmandenergyinitiative.org.

Institute for Energy & the Environment VERMONT LAW & GRADUATE SCHOOL

FARM AND ENERGY INITIATIVE

Center for Agriculture & Food Systems VERMONT LAW & GRADUATE SCHOOL

SUGGESTED CITATION

Marnie Avila Alvarez, Genevieve Byrne, & Will Fridlund, Farm and Energy Initiative, Energizing Agriculture: Policy Opportunities for Beneficial Electrification on the Farm (June 2024).

DISCLAIMER

Table of Contents

Glossary

AVOIDED CAPACITY COSTS: savings and benefits achieved by reducing the need for investments in electricity generation, transmission, and distribution infrastructure

AVOIDED ENERGY COSTS: savings and benefits realized by reducing the need to purchase additional electricity

COLD CHAIN: an uninterrupted system of temperature-controlled transport and storage of refrigerated food products between upstream producers and final consumers, designed to maintain the quality and safety of products

CURTAILMENT: intentional reduction in energy supply or demand to maintain system reliability

CUSTOM SUPPORT FOR ELECTRIFICATION: support tailored to the unique needs of operations, which can include measures such as new construction, retrofits, and building upgrades

DEMAND-SIDE MANAGEMENT: the planning, implementation, and monitoring activities of electric utilities that encourage customers to modify their level and pattern of energy usage

ENERGY AUDITS: comprehensive evaluations of current energy usage that offer recommendations for improvements to reduce energy usage

LOAD SHEDDING: the intentional and temporary reduction of electrical power to a specific area or group of customers

LOAD SHIFTING: changing the timing of energy consumption to maximize system utilization, usually from periods of high demand to periods of lower demand

PEAK DEMAND: point of highest consumption on a system, can be measured by individual, aggregated, or sectoral customers and at daily, weekly, monthly, or annual intervals

PRESCRIPTIVE REBATES: set rebate amounts based on defined equipment and efficiency qualifications

RATES FOR INTERRUPTIBLE SERVICE: rates that reward customers willing to have their service temporarily stopped in return for financial incentives or lower prices

SMART METERS: devices that enable real-time monitoring of energy consumption, providing customers and utilities with detailed insights into usage patterns

TIME-OF-USE RATES: rates that encourage customers to voluntarily shift electricity consumption away from periods of peak demand through price signals

Introduction

USDA photo by Lance Cheung

Achieving a net-zero emissions future will require a significant expansion in the use of zero or low-carbon electricity. This transition will demand an economy-wide shift, including in the agricultural sector. If "electrify everything" is the answer to increasing the use of clean electricity and reducing emissions, "beneficial electrification" is the key to making that shift while ensuring grid reliability and limiting customer costs.[1]

In 2022, the agricultural sector produced 10.0% of total U.S. greenhouse gas (GHG) emissions—equivalent to 635.8 million metric tons of carbon dioxide (CO_2).[2] While most agricultural emissions are attributable to livestock and soil management practices, fuel combustion still contributes 6.4% of national agricultural emissions.[3] This varies significantly by state, with fuel combustion making up 7.6% of agricultural emissions in California and 17.3% in Delaware.[4] Fortunately, electric utilities across the United States are offering significant rebates and special rates to encourage a transition to efficient electric equipment. However, these programs often overlook the agricultural sector, focusing instead on residential and commercial customers. This report explores the need for additional education and policy solutions to ensure farms and agribusinesses can access these cost-saving incentives and contribute to the clean energy transition.

Electrification removes dependence on fossil fuels by exchanging fossil-fuel-powered tools and equipment for electric versions. Electrification is considered beneficial when it lowers costs, reduces emissions, and facilitates better grid management. Replacing fossil fuel combustion with electricity consumption usually increases the overall energy efficiency of an activity, meaning an electric-powered device requires less energy to complete the same task than its fossil fuel-powered counterpart. In addition, electrified equipment can be coupled with special electric rates intended to modify energy consumption behavior, also known as demand-side management or demand response, that lowers the cost of electricity and allows increased reliance on renewable energy. When paired with continued growth in renewable energy generation, beneficial electrification can reduce emissions even as global energy consumption increases.[5]

DEMAND SIDE MANAGEMENT

"Demand-side management (DSM) programs consist of the planning, implementing, and monitoring activities of electric utilities [that] are designed to encourage consumers to modify their level and pattern of electricity usage."[6]

Electrification is already reshaping energy sector policies and practices. In 2022, the transportation sector accounted for 28.4% of all GHG emissions in the United States.[7] The Congressional Budget Office of the United States predicts transportation-related CO_2 emissions will decrease by 9% over the next decade, largely due to efforts to electrify passenger vehicles through the adoption of plug-in hybrid and fully electric models.[8] In the agricultural sector, utility programs that encourage electrification can reduce emissions while providing additional benefits to both farmers and utilities in the form of more efficient electric consumption, lowered long-term costs, and better electric grid management. Additionally, it is common to find underserved communities and those with low incomes located near agricultural employment opportunities.[9] By reducing emissions, electrification can also mitigate the air-quality impacts of agricultural vehicles and machinery on the local community.

FIGURE 1: U.S. GREENHOUSE GAS EMISSIONS BY ECONOMIC SECTOR, 2022

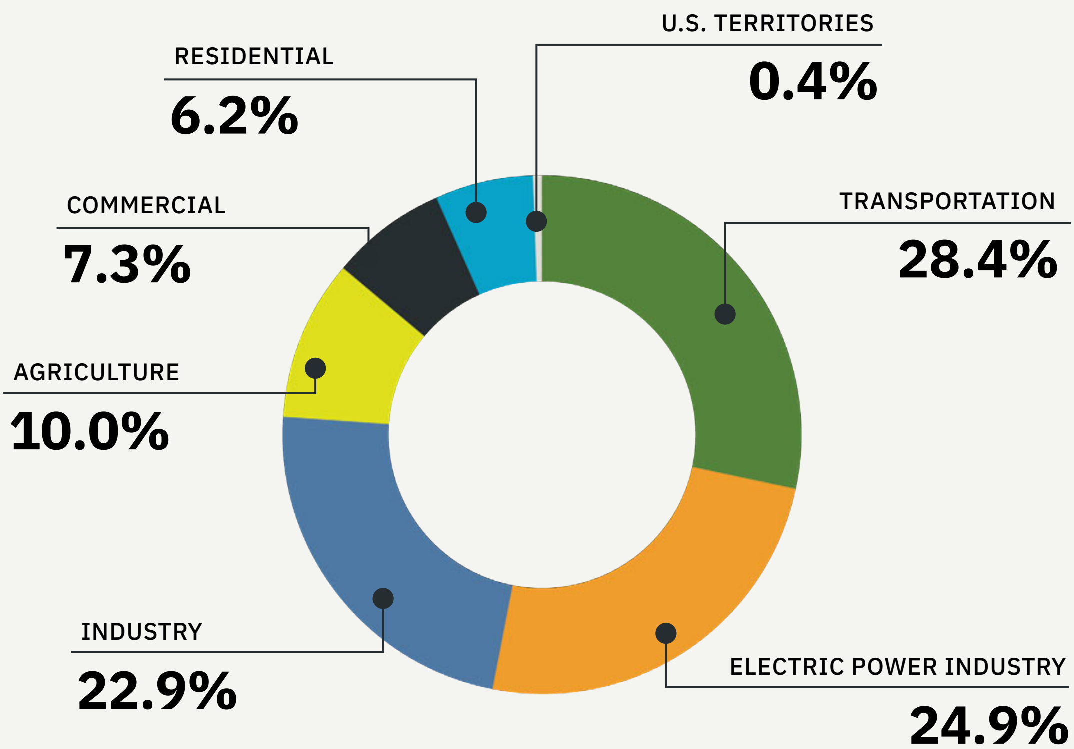
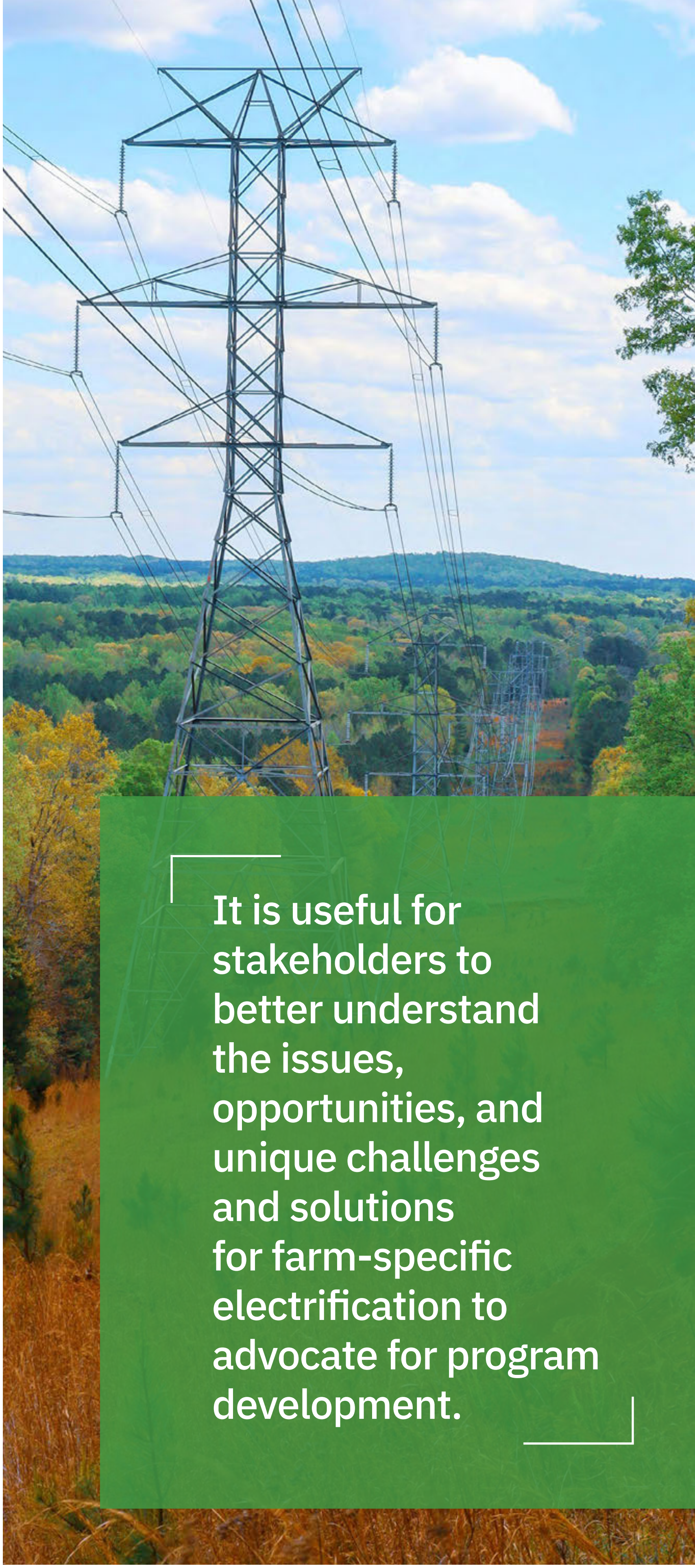


Figure: Greenhouse Gas Inventory Data Explorer, EPA, https://cfpub.epa.gov/ghgdata/inventoryexplorer/#agriculture/entiresector/allgas/category/current (last updated Aug. 18, 2023).

Utilities that offer programming tailored to specific agricultural end uses, such as grain drying and irrigation, are most effectively expanding beneficial electrification on farms and in the agricultural industry. Good examples of such programs can be found at rural electric cooperatives, which have historically served agricultural operations. However, programs specific to agriculture are also emerging at larger electric utilities across the country. Where utility programs do not encourage agricultural electrification, it is useful for stakeholders to better understand the issues, opportunities, and unique challenges and solutions for farm-specific electrification to advocate for program development.

This report highlights the opportunities and challenges associated with meeting electrification goals in the agricultural sector and the role electric utilities can play in overcoming these challenges. It is intended to assist thought leaders in the agricultural industry attempting to secure new electric rates and incentives designed to accommodate the needs of working farms and agribusinesses. It describes the range of agricultural electrification and demand response programs currently offered by electric utilities in the United States and provides insight into how stakeholders might overcome the special challenges presented by existing programs. This report offers valuable insights for public utility commissions, electric utilities, state and local energy offices, organizations, and other stakeholders interested in improving the economic and environmental sustainability of agricultural operations.

Section I of this report addresses the definition of beneficial electrification and its role in electric grid management, emissions reduction, and decreased costs. Section II describes the role of electric utilities in encouraging agricultural electrification. Section III explores the types of agricultural end uses ideal for electrification and provides examples of utility incentives specifically designed for each end use. Section IV discusses special challenges arising in the context of agricultural electrification and opportunities for successful program design. Section V provides recommendations for discussions with legislators, public utility commissions, and utilities and introduces a searchable database of utility programs encouraging beneficial electrification in agriculture, available at farmandenergyinitiative.org.



It is useful for stakeholders to better understand the issues, opportunities, and unique challenges and solutions for farm-specific electrification to advocate for program development.

Unsplash photo by Brandon Griggs

I. Beneficial Electrification Basics

> *"Widespread electrification could transform the end-use equipment stock; alter the mix and quantity of fuel and energy consumed; require substantial growth and change in power system infrastructure; and impact the operation and flexibility needs of the power system."*[10]
>
> **- National Renewable Energy Laboratory, 2021**

Unsplash photo by Spencer DeMera

Electrification breaks the direct relationship with fossil fuels by swapping out fossil-fuel-powered tools and equipment for electrical models. When widely implemented, beneficial electrification supports the long-term climate mitigation strategy of decarbonizing total energy consumption.[11] Electrification of farms, when paired with renewable energy generation, can decrease the carbon footprint of farming by 44–70%.[12] Beneficial electrification can capture even more benefits.

To be considered beneficial, electrification must satisfy at least one of the following criteria without adversely affecting the other two. It should:

- improve electric grid management,
- reduce long-term costs for utilities and consumers, and
- decrease end-use emissions.[13]

Satisfying all three criteria best supports climate change mitigation efforts.[14]

A. IMPROVE GRID MANAGEMENT

The electric grid must always be in balance with supply (generation) equaling demand (load). Widespread electrification without intentional demand management can both threaten grid reliability and increase costs because the additional electric loads can exacerbate periods of **peak demand** when the grid is most reliant on fossil fuels.[15] Although widespread electrification increases the overall load on the electric grid, it also provides utilities an opportunity to improve grid operations by actively managing consumer demand through demand response programs that incentivize load flexibility.[16]

> ## Electrification breaks the direct relationship with fossil fuels by swapping out fossil-fuel-powered tools and equipment for electrical models.

These programs encourage consumers to shift their electricity consumption to economically and environmentally optimal periods. Effective electrification policy must coordinate electric supply with demand while maximizing reliance on renewable energy resources like solar and wind. When utilities and electric systems planners can better balance supply and demand, it lowers costs, improves integration of existing renewable electricity supply, and reduces the need for fossil-fueled power.[17]

THE PEAK DEMAND PROBLEM

"Peak demand periods are created by patterns of consumer behavior and can be measured at daily, weekly, monthly, and annual intervals. Electricity consumed during periods of peak demand typically has more pollutant emissions per unit of electricity and a higher per-unit cost than electricity consumed during off-peak hours."[18]

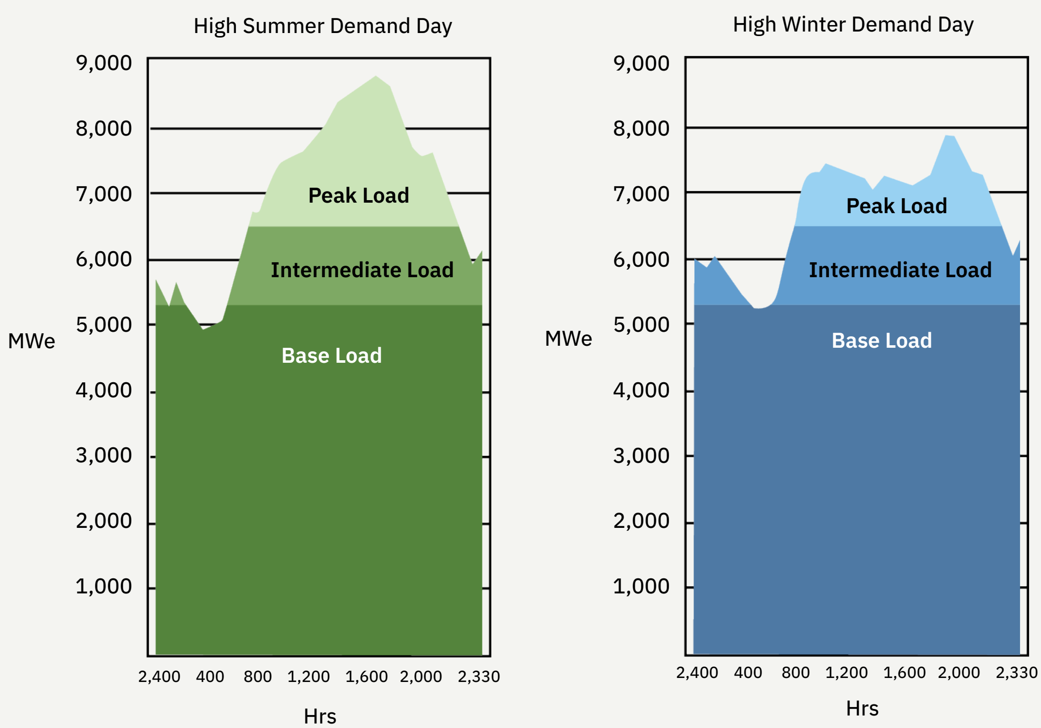
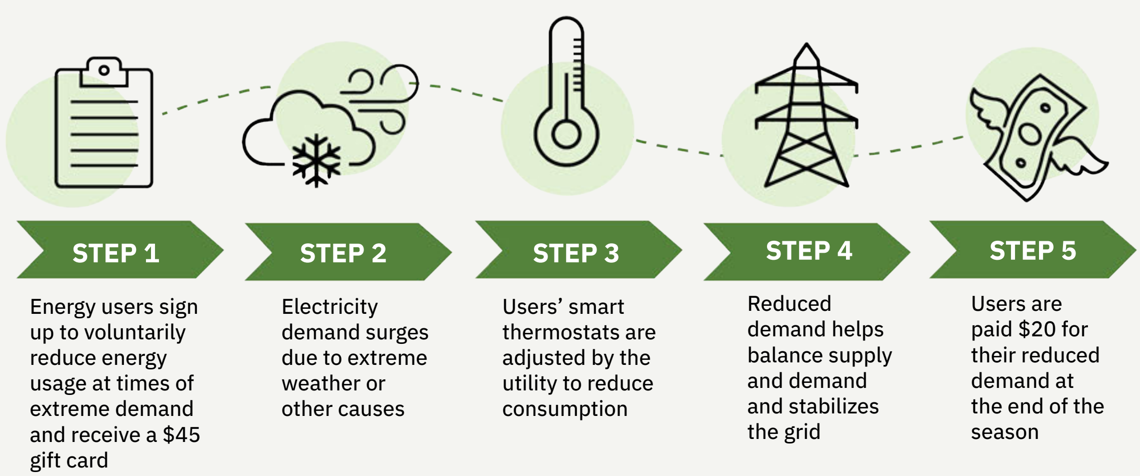


Image: Alexandra Aznar, *Phrase of the Day: Peak Load*, NREL (Aug. 27, 2015), https://www.nrel.gov/state-local-tribal/blog/posts/phrase-of-the-day-peak-load.html.

Utilities employ a variety of active and passive demand management practices to influence electricity consumption behavior. One common approach is **load shifting**, which aims to change the timing of energy consumption from periods of high demand to lower demand periods.[19] The goal is to reduce peak demand on the grid, which can help prevent blackouts, lower electricity costs, and reduce the need for new power plants.[20] Utilities achieve load shifting by incentivizing customers to use electricity during off-peak hours or by implementing automated systems to directly adjust energy consumption based on grid demand. **Time-of-use rates** encourage customers to voluntarily shift electricity consumption away from periods of peak demand through price signals. Instead of paying a flat rate for electricity, the per-kilowatt-hour price changes based on the time of day, day of the week, and even the season, creating an incentive for behavioral change. The cost of electricity typically comprises two primary elements: a volumetric charge based on the total electricity consumed and a demand charge based on the customer's highest kW demand over the billing period; both can be structured to increase during busier hours.[21] Further, time-of-use rates can steer energy consumption toward times of excess renewable generation. Solar production typically peaks during midday, and wind production typically peaks overnight. Both periods are lulls in aggregate demand, and time-of-use rates can shift demand toward these times.

Utilities also employ strategies to quickly reduce the total electricity required at critical moments. **Load shedding** is the intentional and temporary reduction of electrical power to a specific area or group of customers.[22] It can be accomplished by either reducing voltage levels or cutting power to selected areas or customers for a limited time.

DEMAND RESPONSE PROGRAMS



Demand Response Community Campaign – Smart Savings Rewards, Town of Newfield (Aug. 9, 2022), https://newfieldny.org/demand-response-community-campaign-smart-savings-rewards/.

> **The above graphic provides an example of New York's Smart Savings Reward Program, which provides financial incentives for voluntary participation.**

Monitoring and control technology will play a pivotal role in successfully implementing electrification and demand response strategies, particularly through the integration of smart meters.

US Navy photo by Kiona Miller

While load shedding can cause inconvenience for affected customers, it is often necessary to prevent more widespread and prolonged power outages that can cause significant disruption and economic losses.[23] **Rates for interruptible service** reward customers willing to have their service temporarily stopped in return for financial incentives or lower rates.[24] These programs work by interrupting electricity services to customers when agreed-upon conditions occur, such as during peak hours, extreme weather conditions, electric system emergencies, or other contingencies.

Utility support for automating and integrating electrical technologies and control systems is essential for enabling enhanced grid management. As the agricultural sector transitions to clean energy, various technologies will be necessary, including heat pump systems, solar panels, batteries, and electric farm equipment. Managing these systems to best support a reliable, low-cost, low-carbon electric grid is a complex challenge that requires proper communication and control.[25]

Monitoring and control technology will play a pivotal role in successfully implementing electrification and demand response strategies, particularly through the integration of **smart meters**. These advanced devices enable real-time monitoring of energy consumption, providing both consumers and utilities with detailed insights into usage patterns.[26] Smart meters facilitate communication between consumers and utilities, which enables better understanding of grid conditions. This enhanced information exchange supports utilities in maintaining reliable electrical service while empowering consumers to reduce their consumption and costs.[27] Additionally, smart meters can integrate with energy management systems, including web-based tools provided by utilities or other devices installed within a residence, business, or farm to manage appliances and thermostats.[28] Building energy and appliance controls are key to optimizing electric consumption.[29] These range from consumer-controlled technologies, like smartphone apps, to complex control systems in two-way communication with utilities.[30]

B. REDUCE COSTS

Electrification can provide both short-term and long-term economic benefits for customers. By transitioning from fossil fuels to electricity, customers gain greater control over their energy bills. The volatility of fossil fuel prices is replaced by the stability of electricity prices and the controllability of electricity consumption.[31] Significant rebates are available to reduce the up-front cost of new electric equipment, and for many, powering equipment with electricity instead of fossil fuels will result in immediate savings.[32] By participating in demand response programs like time-of-use rates and rates for interruptible service, consumers can enjoy significant savings on their electric bills. When electrification investments are paired with on-site renewable energy, consumers are often able to offset their increased electric consumption and even sell excess generation back to the grid.

The electrical grid is built and operated to ensure a reliable supply of electricity at the highest point of demand. The load flexibility created by demand response programs can translate to cost savings for all ratepayers by increasing the efficiency of the grid. By shifting consumption away from peak demand periods, utilities may be able to delay or avoid the need for new investments in generation capacity and grid infrastructure, resulting in **avoided capacity costs**.[33] Additionally, reductions in peak demand can avoid the need to burn expensive, supplemental fossil fuels, resulting in **avoided energy costs**.[34]

Slight changes in individual consumption can also amount to significant savings when aggregated together. Technical estimates for the residential and commercial sectors indicate that extensive adoption of energy efficiency and demand flexibility measures would reduce annual U.S. electricity consumption by 742 TWh and summer peak demand by 181 GW by 2030.[35] Less consumption and lower demand translate to less fuel use and reduced investment in generation and transmission infrastructure. The National Renewable Energy Laboratory (NREL) estimates that in scenarios where electrification is widespread, the grid services provided by load flexibility are worth $5-10 billion in savings compared to a less flexible system.[36]

Finally, demand flexibility programs can encourage high-demand end uses, like electric vehicles, to consume low-cost renewable energy that might otherwise go to waste. An abundance of solar in the middle of the day often creates more supply than demand, requiring grid operators to intentionally reduce or **"curtail"** this renewable output to maintain system balance.[37]

CURTAILMENT

"While curtailment has sometimes been viewed as 'wasting clean, free electricity,' curtailment programs offer the opportunity to make the electric grid more resilient."[38]

Curtailment percentages have been increasing as more renewable energy generation is connected to the grid. In California, solar and wind curtailment increased by 63% between 2021 and 2022.[39] As solar production drops in the evening before demand has begun to ebb, grid operators must call upon other, often more expensive, resources to preserve system reliability.[40] By leveraging demand flexibility to better align high-demand end uses with periods of abundant renewable generation, utilities can maximize the utilization of low-cost, clean energy sources and minimize the need for curtailment.[41] For example, utilities can encourage consumers to charge electric vehicles during the day, when solar generation is plentiful.[42] In the electrification scenarios modeled by NREL, systems with the highest penetration of renewable energy resulted in the greatest cost savings.[43]

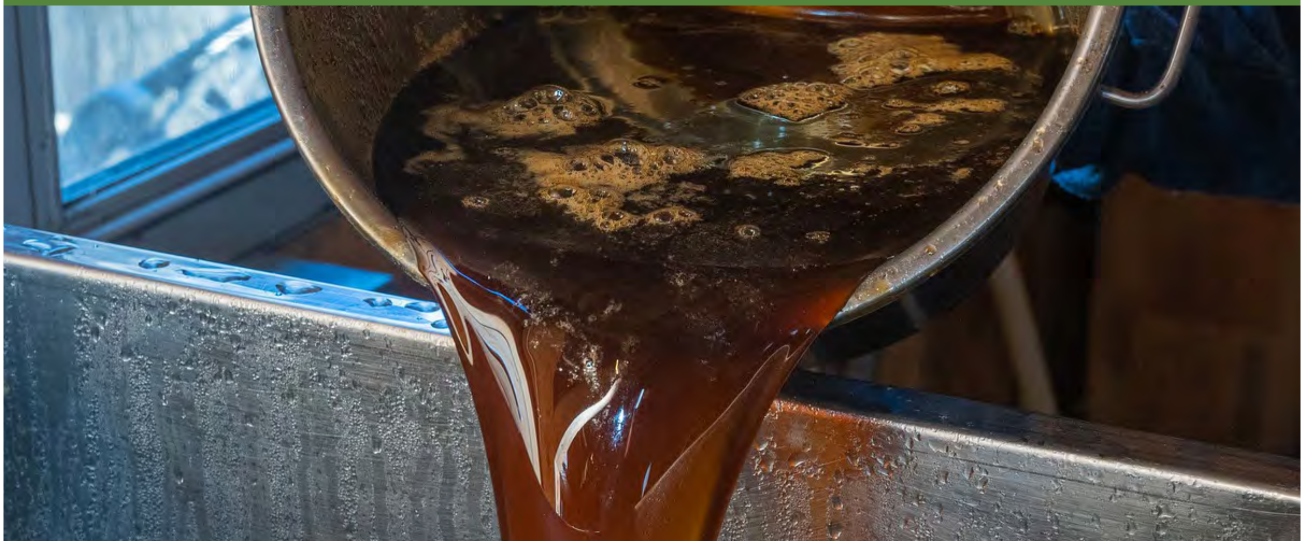
C. DECREASE EMISSIONS

Beneficial electrification provides climate benefits by both reducing the total amount of energy needed for a particular end use and by switching the energy source to a less polluting form. Electrical equipment is more efficient and uses less energy to deliver the same services, thus reducing the total amount of energy required.[44] Electrification benefits occur even if the generation mix does not change.[45] Due to the superior efficiency of electric vehicles and heat pumps, "the quantity of electricity required to produce a certain output (e.g., miles driven or heat delivered) is less energy-intensive and less expensive than the quantity of the fossil fuel currently being used to provide the same output."[46]

> Slight changes in individual consumption can also amount to significant savings when aggregated together.

The climate benefits of electrification are further amplified when paired with load flexibility. NREL modeling suggests that when electrification incorporates significant load flexibility, it results in 8.3% fewer emissions than scenarios without load flexibility.[47] The load flexibility of electric equipment is an attribute that allows consumers and electric grid operators to take advantage of cleaner (and less expensive) energy when it is available and to avoid drawing power when the grid is serving high levels of demand, when power is likely to come from higher emissions sources.[48] Where beneficial electrification is widely implemented, nearly all future energy needs could be met using zero-emission sources.[49]

CASE STUDY



USDA photo by Brandon O'Connor

Electrification of Maple Syrup Production at Sunrise Farms[50]

Sunrise Farms, a family-owned agricultural enterprise located in Colrain, Massachusetts, embarked on a transformative journey four years ago. The Lively family decided to replace their traditional wood chip combustion evaporator with an $80,000 electric maple sap evaporator. This significant investment was driven by the need to boil maple sap for extended periods to evaporate excess water, thereby converting the sap into maple syrup. The electric evaporator operates akin to a large-scale electric steam kettle, boiling the sap and producing syrup.

During the sugaring season, the electric sap evaporator yields between eight and 15 gallons of syrup per hour, mirroring the productivity of the previous wood chip evaporator. However, the economic efficiency of the electric evaporator is significant. The daily operational cost of the electric evaporator is estimated at $50, a stark contrast to the cost of using wood or oil as fuel. The farm's calculations suggest that a wood-fired evaporator consumes two cords of wood daily during the sugaring season, translating to an approximate cost of $200. By adopting the electric evaporator, Sunrise Farms not only saves on the cost of wood but also eliminates the labor costs associated with chipping the wood.

Additionally, the farm's electricity costs are offset by an on-site net-metered solar array. During the summer months, the farm generates surplus solar power, which is sold back to the grid, accruing net-metering credits. These credits are then used to cover the farm's electricity bills throughout the sugaring season. The transition to an electric sap evaporator at Sunrise Farms exemplifies beneficial electrification in the agricultural industry. Electrification has enabled the farm to reduce its costs, reduce its greenhouse gas emissions, and meet its electricity needs with on-farm generation.

II. The Role of Utilities in Agricultural Electrification

"The agricultural industry could be restructured to utilize larger amounts of renewable energy such as wind and solar and provide a great deal of flexibility to the grid."[51]

- Arian Aghajanzadeh & Peter Therkelsen, 2019

Unsplash photo by the American Public Power Association

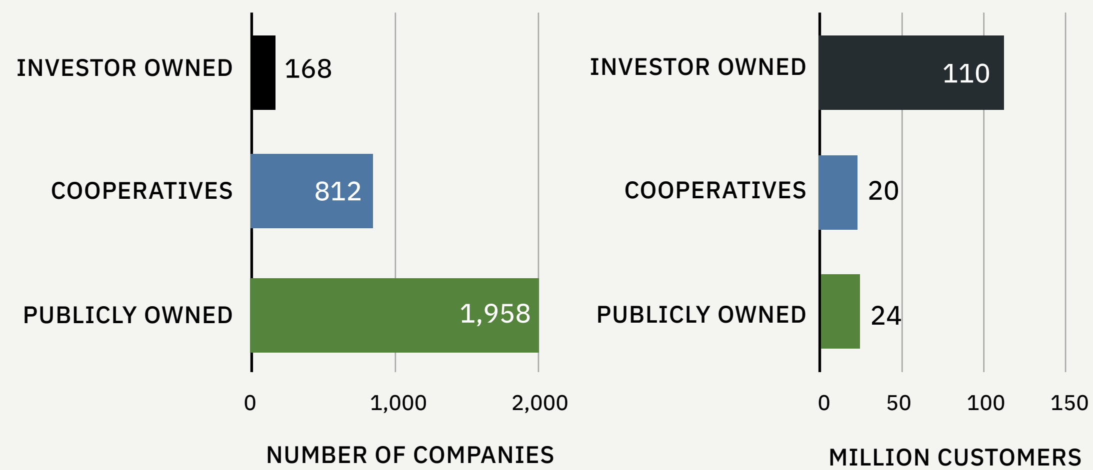
Electric utilities connect customers to the distribution grid and serve as a gateway to electrification efforts. The availability of and support for electrification programs varies among utilities and their regulators. Some utilities offer programs that assist customers in purchasing new electric equipment or have rate schedules that incentivize consumption at specific times of the day. Other utilities offer limited electrification and demand response incentives to their customers. The difference is often due to the specific energy efficiency and demand management programs required by state law and utility regulators.[52] Support for state energy policies that enable better utility programming and specifically include agricultural customers in legislative mandates and utility initiatives can increase opportunities for beneficial electrification in the agricultural sector.

Support for state energy policies that enable better utility programming and specifically include agricultural customers in legislative mandates and utility initiatives can increase opportunities for beneficial electrification in the agricultural sector.

A. TYPES OF ELECTRIC UTILITIES

To effectively encourage improved utility programs and policies, it is imperative to understand the kind of utility that locally serves agricultural customers and the factors that may affect utility decision-making and program offerings. Agricultural customers across the United States are served by a variety of electric utilities that differ widely in their ownership, governance, regulatory oversight, and objectives. Electric utilities are broadly categorized into three types based on their ownership and how they are regulated: investor-owned utilities (IOUs), municipal utilities, and cooperative utilities (co-ops).[53] Investor-owned utilities are the smallest in number but serve most customers. The composition of utilities can vary greatly from state to state. For example, Nebraska is the only state served exclusively by public power, while other states can have a combination of investor owned utilities (IOUs), municipal utilities, and coops.

FIGURE 2: NUMBER OF U.S. ELECTRIC UTILITIES BY OWNERSHIP TYPE, 2017



Pavitra Srinivasan et al., State Industrial Decarbonization Policy Handbook For Utilities 1, 5 Fig.1 (2023).

The business model of the utility often determines how it is regulated. Across the country, state laws vary widely in defining the types of electric utilities that may operate, and in what capacity.[54] In some states, utilities are vertically integrated businesses that provide generation, transmission, and distribution services. Other states enable retail competition where customers can select their energy provider. Every state has a public utility commission which provides oversight of IOUs. In some states, the public utility commissions have full, partial, or no oversight of the activities of municipal utilities and cooperatives. The diversity of regulation extends to energy efficiency programs. Several states have developed separate energy efficiency utilities (EEUs) dedicated to conserving energy. In other states, energy efficiency programs may be offered directly by the load-serving entity.

TYPES OF ELECTRIC UTILITIES[55]

- **INVESTOR OWNED UTILITIES (IOUs)** are private enterprises owned by shareholders. They are the largest type of utility in the United States in terms of the number of customers served. IOUs are regulated by public utility commissions at the state level, which oversee their rates and services to ensure they are fair and reasonable. Rates cover the costs of procuring and delivering electricity and include a rate of return, or profit, used to invest in new infrastructure and provide dividends to shareholders.

- **ELECTRIC CO-OPS** are non-profit organizations owned by their members—the customers they serve. Cooperatives are usually governed by a board of directors elected by their members and are regulated by their members rather than state utility commissions.

- **PUBLIC AND MUNICIPAL UTILITIES** are owned and operated by a city, town, or other public entity and governed by local government or an elected or appointed board. Their focus is serving the residents of the municipality but might be extended to serving surrounding rural areas. Municipal utilities are usually regulated by local government policies rather than state utility commissions.

- **COMMUNITY CHOICE AGGREGATION AND ALTERNATIVE ELECTRICITY SUPPLIERS** are "energy only" providers that sell electricity to end-use customers, but the electricity is delivered by full-service utilities, usually the local IOU.[56] State law must enable market participation in electricity sales by these non-traditional entities.

- **ENERGY EFFICIENCY UTILITIES (EEUs)** do not supply electricity to end-use customers; rather, these utilities provide programs and services to improve energy efficiency and reduce energy consumption. EEUs are typically public or non-profit organizations funded by governmental sources, grants, and/or a public or efficiency charge levied on all ratepayers. EEU operations and investments may be regulated by state law, state public utility commissions, and/or internal bylaws. EEUs frequently provide energy efficiency services to consumers, including energy audits, rebates for energy-efficient appliances, and advice on energy-saving practices.

B. UTILITY INCENTIVES FOR ELECTRIFICATION AND DEMAND RESPONSE

Electric utilities are the largest provider of energy efficiency services in the United States. The largest investor-owned electric utilities spend more than 2% of their revenues on efficiency programs every year, which adds up to billions of dollars annually directed to reduce energy consumption.[57] Many utilities are responding to state mandates and policies to prioritize energy efficiency and demand flexibility programs for customers.[58] These utility efficiency programs are funded by ratepayers through fees and charges levied on their utility bills.[59]

Utility programs target energy efficiency savings across the spectrum of their customers, from residential customers to industrial customers to agricultural customers.[60] Additionally, improvements in technology, like smart meters, and distributed energy resources, like customer-owned batteries, are creating even more opportunities to diversify programs and improve system operations at a lower cost. It is important to note that utility programs come in many forms, including special rates that encourage changed customer behavior, **energy audits** to identify on-site opportunities for improved energy management, **prescriptive rebates** on efficient electric equipment, and **custom support for electrification** projects.

i. Demand Response and Rate-Based Incentives

An interconnected grid is an opportunity to expand load management programs. Demand response programs offer monetary incentives to change consumer behavior to support grid reliability by better balancing electricity supply and demand.[61] By charging consumers different rates that reflect the varied demand levels throughout the day, utilities motivate consumers to modify their energy usage. Well-designed time-varying rates can reduce a participating customer's use of electricity during peak periods by 25% or more.[62] The rates intended to incentivize demand flexibility are frequently designed for a specific end-use or customer class. For example, a utility could provide a dairy using large refrigeration units with a favorable electric rate if it agrees to turn the system off for one hour during peak demand periods. The relative ease of implementation makes demand response a valuable tool for managing electric loads to improve grid stability, particularly when more complex and expensive technological solutions may not be feasible.

ii. Energy Audits

Farm energy audits are another essential tool to identify opportunities for energy efficiency and cost savings. An audit provides a comprehensive evaluation of a farm's current energy usage and offers recommendations for improvements that can reduce energy consumption and improve the farm's bottom line. These audits are typically performed by an experienced energy professional who examines past utility bills and surveys all major energy-using equipment for efficiency opportunities. The resulting analysis can provide farmers with a clear understanding of their current energy usage and specific recommendations for improvements. The scope and depth of the audit can be tailored to the farm's needs. For example, in New York, the New York State Energy Research and Development Authority offers "financial assistance to identify energy efficiency upgrades for eligible farms and on-farm producers, including but not limited to dairies, orchards, greenhouses, vegetables, vineyards, grain dryers, and poultry/egg."[63] Farmers can select the level of energy audit that best meets their needs.

iii. Prescriptive Rebates

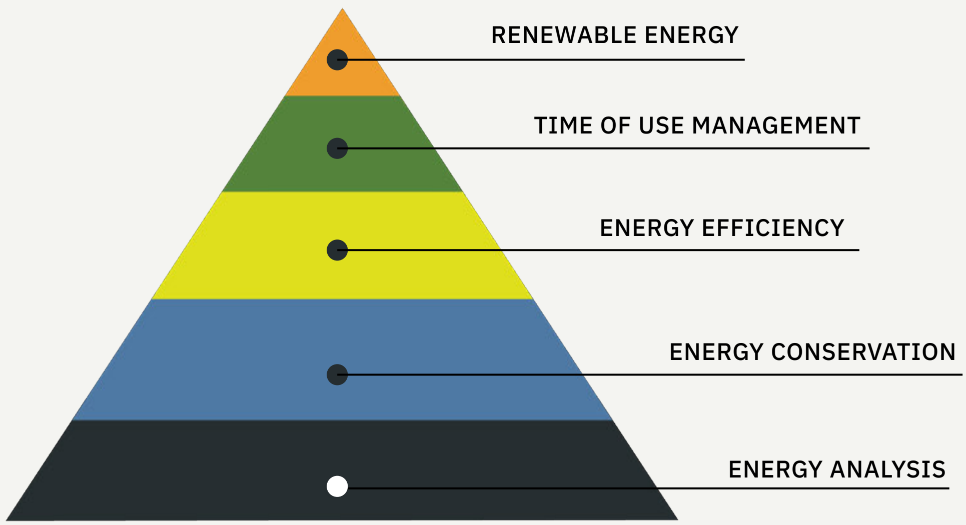
Many utility energy efficiency programs include prescriptive rebates for purchasing and installing energy-efficient equipment. Prescriptive rebates are set rebate amounts based on defined equipment and efficiency qualifications. Many rebates can only be applied after proof of product purchase, meaning that customers must first pay the total upfront cost before being eligible to receive the rebate.

The financial burden of initial costs is a barrier to the adoption of energy-efficient technologies that can be overcome with directed assistance. Farmers with lower incomes or those who may have difficulty accessing farm loans often face higher energy burdens and may not have the financial resources to invest in energy-efficient technologies without assistance. To address this, utilities and government programs can offer financing, including zero- and low-interest loans and grant options to help cover upfront capital and installation costs.[64]

iv. Custom Project Support

Some electric utilities offer custom energy efficiency program development and implementation support for agricultural customers. This support is tailored to the unique needs of agricultural operations and can include a variety of measures such as new construction, retrofits, and building upgrades. For example, Wisconsin's Focus on Energy "offers custom project incentives for non-standard equipment installations or replacements and renewable energy upgrades not found in the Focus on Energy Incentive Catalogs."[65] These incentives are "based on the project's first-year energy savings" (measured in kW, kWh, and therms) and require pre-approval before purchasing equipment or upgrading.[66]

FIGURE 3: ENERGY PYRAMID



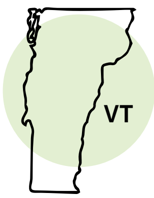
Drew Schiavone, *Energy 101: Energy Priorities*, Univ. Md. Extension (Apr. 25, 2024), https://extension.umd.edu/resource/energy-101-energy-priorities/.

C. ENERGY EFFICIENCY UTILITIES

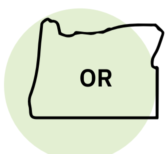
Energy Efficiency Utilities are a unique entity in the electricity sector. The traditional electric utility makes money by selling electricity to its customers. EEUs make money by conserving electricity rather than selling it. EEUs do not have the conflict of being asked to reduce sales when their business model is built on selling electricity. A few states have created EEUs: Vermont, Oregon, Maine, and Wisconsin, as well as the District of Columbia (see *Agricultural Programs Offered by Energy Efficiency Utilities*, below.). Several EEUs have dedicated staff for agricultural ratepayers, which builds expertise in the EEU and facilitates communication and education about available programs. An EEU's ability to promote and support agricultural electrification depends on the availability of funding for their services, the level of awareness and acceptance of energy efficiency among farmers, and the presence of supportive policies and regulations. Therefore, it is important for EEUs to work closely with farmers, policymakers, and other stakeholders to overcome these challenges and maximize their impact. For example, Energy Trust of Oregon targets irrigation districts for the development of hydroelectric generation.[67] In doing so, the EEU partners with a wide array of groups to fund the replacement of canals with pipes and then install hydroelectric generators. Partners include entities interested in farm welfare, river health, fish, and community welfare, as there are benefits for all these stakeholder groups.[68]

AGRICULTURAL PROGRAMS OFFERED BY ENERGY EFFICIENCY UTILITIES

Several EEUs offer programs specifically designed to promote energy-efficient agricultural equipment, including the following:

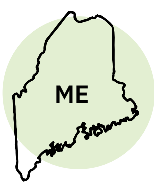


EFFICIENCY VERMONT the nation's first statewide EEU, is funded by a small statewide charge on customers' electricity bills, collected by the state's utilities. It partners with distribution utilities, heating fuel suppliers, building trades, and other stakeholders to offer technical consulting, energy audits, and rebates on energy-efficient equipment to homes and businesses, including an Agricultural Energy Efficiency Program.[69]



ENERGY TRUST OF OREGON is an independent nonprofit organization funded by utility customers through a system benefit charge or public purpose charge on customer bills. Programming includes incentives for energy efficiency in agriculture, targeting irrigation, greenhouses, agricultural equipment, and lighting.[70]

Wisconsin's **FOCUS ON ENERGY** is a statewide program for energy efficiency and renewable development, funded by 108 participating electric and natural gas utilities. Its Agricultural Energy Efficiency Program offers financial incentives and valuable technical guidance to encourage energy efficiency on Wisconsin farms.[71]



EFFICIENCY MAINE[72] is an independent agency, overseen by the Maine Public Utilities Commission and funded by municipal, state, federal, and private grants; capacity payments generated by agency work; and revenues from the state's Energy Infrastructure Benefits Fund.[73] Agricultural incentives are available for "specialized equipment found in the dairy and potato-growing industries, including milk scroll compressors, dairy vacuum pumps, and potato storage exhaust fans."[74]

III. Utility Incentives Targeting Agricultural End Uses

"Modern agriculture is heavily based on the energy supply obtained mainly from fossil fuels. In this sense, it can be defined as a technology that transforms fossil fuels into food." [75]

- Ugo Bardi, et al., 2013

Unsplash photo by Getty Images

Electrifying agricultural operations requires targeting specific activities for conversion to electricity. Beneficial electrification of agricultural operations requires that the electrification reduces environmental externalities, enables better grid management, and cuts costs. Many existing agricultural uses of fossil fuel have comparable electric technologies that can be easily swapped in (see Table 1). Utilities are already incentivizing this transition through rebates and demand response programs targeting agricultural end-uses like irrigation and water heating, as well as product-specific processes such as grain drying and maple sap evaporation.

Many existing agricultural uses of fossil fuel have comparable electric technologies that can be easily swapped in.

TABLE 1: OVERVIEW OF FARM BENEFICIAL ELECTRIFICATION TECHNOLOGIES

ELECTRIC TECHNOLOGY	PRIMARY FARM TYPES
Irrigation pumps	Orchards, vegetables, field crops
Water heaters	Dairy
Grain dryers	Field crops
Maple sap evaporators	Maple
Thermal electric storage systems	Poultry, swine, greenhouse
Radiant heaters	Poultry, swine, greenhouse
Heat pumps	Greenhouse
Heat exchangers	Poultry, swine, greenhouse
Tractors	All, especially field crops

Kyle Clark & EnSave, Farm Beneficial Electrification: Opportunities and Strategies for Rural Electric Cooperatives 4 tbl.1 (2018).

A. PUMPING AND IRRIGATION

For those engaged in crop irrigation, there has been widespread adoption of electric pumps, but there is an opportunity for more growth. Estimates suggest that irrigation pumps account for 11.5% of national farm beneficial electrification potential in areas served by co-ops.[76] According to the U.S. Department of Agriculture (USDA), of the approximately 600,000 irrigation pumps used in the United States in 2018, about 444,000 are electric.[77] However, the remaining quarter of fossil-fuel (natural gas, propane, diesel, gas) powered irrigation pumps consume nearly 40% of all energy used for irrigation.[78] Continued transition to electric pumps could dramatically reduce energy use in irrigation, as electric pumps are 50-60% more energy efficient than their diesel-powered counterparts.[79]

Electrifying irrigation presents both a challenge and an opportunity. Electrifying irrigation will increase the total electric load on farms. The USDA estimates that converting all 12,700 diesel-powered irrigation pumps to electric motors would require 5,600 GWh of electricity annually.[80] Converting gasoline, natural gas, and propane-fueled pumps would require an additional 1,000-2,000 GWh.[81] For consumers and utilities, electrification offers potential savings in money and energy through time-of-use rates and rates for interruptible service.[82]

Unsplash photo by Getty Images

FIGURE 4: NUMBER OF IRRIGATION PUMPS IN THE UNITED STATES BY FUEL

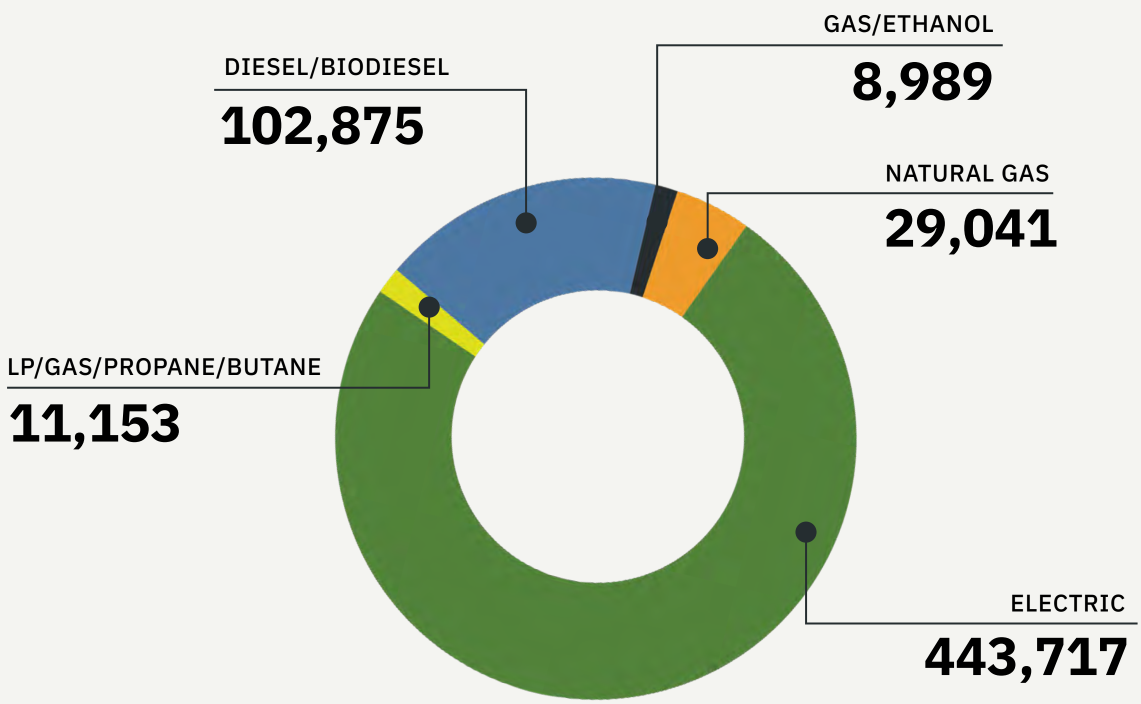


Table 13. Energy Expense for All Well Pumps and Other Irrigation Pumps by Type of Energy Used: 2018, USDA (Apr. 11, 2019), https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/Farm_and_Ranch_Irrigation_Survey/fris_1_0013_0013.pdf.

Because irrigation is likely to increase electric demand on hot days when demand on the grid is already high, integrating this end-use into demand response programs that can control for this increase is particularly important. Several of the states most reliant on irrigation have already established aggressive renewable electricity targets and are urgently seeking flexible loads to counterbalance the intermittent nature of renewable resources.[83] When utility rates incentivize irrigation during off-peak hours or reward farmers who turn their pumps off for immediate electric load shedding, this facilitates better grid management.[84]

Continued transition to electric pumps could dramatically reduce energy use in irrigation.

Importantly, the upfront costs of switching to electric irrigation pumps may slow the transition if they are not mitigated. While electric irrigation pumps are more energy efficient, they often come with high capital and installation costs, particularly if the farm lacks the requisite electric infrastructure.[85] The associated energy and economic savings also take time to accrue. On average, a new electric irrigation pump costs $4.74 per hour to operate, compared to $13.74 for a diesel pump.[86] Electric irrigation pumps also enjoy lower annual maintenance costs of approximately $25 per year.[87]

Ultimately, the superior efficiency of electric pumps saves consumers money over time, while significantly reducing fossil fuel emissions. However, it is critical that concerns about initial investment and the amount of time to realize savings are addressed for this transition to materialize.

Several utilities offer incentives that make switching to an electric pump more affordable. For example, the Energy Trust of Oregon and Wisconsin's Focus on Energy both offer rebates for variable frequency drives to reduce the operating costs of electric irrigation pumps.[88] The Energy Trust of Oregon offers additional incentives for irrigation upgrades such as sprinklers, nozzles, and gaskets to prevent leaks, irrigation system conversions to minimize water and energy use, scientific irrigation monitoring to irrigate at optimal times, and low-energy precision application technology.[89] Energy Trust of Oregon even offers irrigation modernization support that encourages farmers to generate hydropower electricity on-site through their irrigation canals.[90]

CASE STUDY

Idaho Power's Peak Irrigation Rewards Program[91]

Idaho Power offers agricultural customers an opportunity to participate in the Irrigation Peak Rewards program, which offers payments in exchange for direct load control over the customer's irrigation pumps. This program allows Idaho Power to remotely turn off irrigation pumps during periods of high electricity demand, June 15 to August 15 annually. Participants receive a fixed incentive payment of $5.25 per kW of controlled load, along with a minor per kWh energy credit. If more than four control events occur, the kWh incentive for actual events significantly increases. Each irrigation pump has a load control device installed at its location. Customers are typically notified four hours prior to each event by the company. However, the company also provides an option for customers to opt out of a specific load control event for a fee.

CASE STUDY

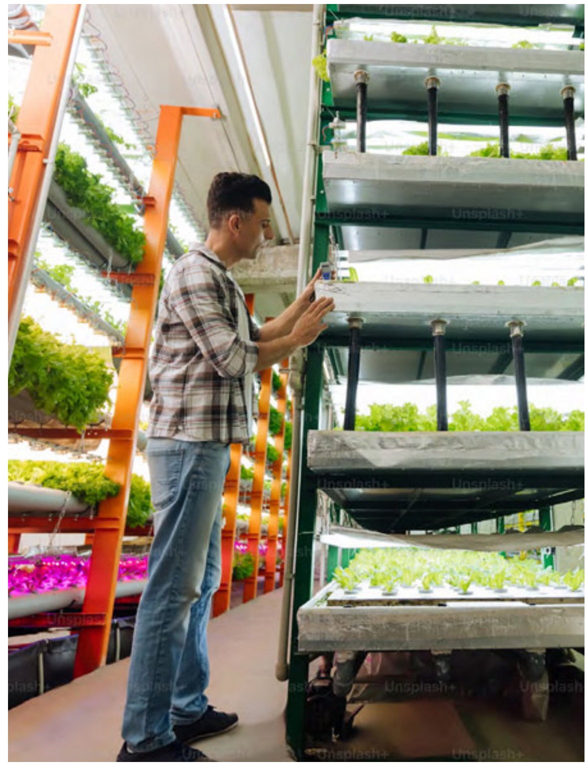
Valley Clean Energy's "AgFIT" Pilot Program for Irrigation

Valley Clean Energy is a California community choice aggregator that offers a flexible irrigation pilot program for agricultural customers, in partnership with Polaris Energy Services. The AgFIT program "provides growers with incentives for irrigation automation and uses scheduling software to better manage electricity costs."[92] AgFIT offers incentives of up to $150 per unit of pump horsepower for automation technology that improves irrigation operations and reduces costs. Participation in the program ensures that customers never pay more than their old rate, gives customers an app to help schedule irrigation at the most cost-effective times possible, and allows customers to choose who they purchase their irrigation technology from and whether they use automated or manual equipment.[93] The program does not include mandatory load reduction events or any penalties.

All indications are that the AgFIT pilot program has been a success. In a filing to the California Public Utilities Commission, the California Community Choice Association contended that the program has been successful in shifting load during ramp and peak hours and recommended that the Commission expand the program to more service areas and customers. The Association claims irrigation represents a "low-hanging fruit" for load shifting,[94] as agricultural pumping and processing constitute a substantial portion of load shift potential in California and can provide supply flexibility at low cost.[95]

B. SPACE HEATING AND COOLING

The heating and cooling needs of livestock barns, warehouses, and greenhouses provide a significant electrification opportunity. The potential energy savings from electrification in poultry farming alone are considerable. Annually, the United States produces more than six billion broiler chickens requiring substantial amounts of heat over their lifetimes. The vast majority of broiler barns are heated with fossil fuels, with around 85% relying on propane and 15% on natural gas.[96] Similarly, a University of Minnesota survey of commercial swine barns in the Midwest found that approximately 90% of the energy consumed in nursery barns came from propane and natural gas, primarily for purposes of heating.[97] Greenhouses also rely heavily on fossil fuels. A Michigan State University study found that 88% of energy used in greenhouses was for space heating.[98] To replace fossil fuels used to heat greenhouses and livestock barns served by rural electric co-ops, between 14,000 to 20,000 GWh of electricity would be required, representing 36% of total agricultural beneficial electrification in those areas.[99]



Unsplash photo by Getty Images

Heat pumps are the ideal electric replacement for furnaces and other fossil-fuel-powered heating elements. A heat pump does not create heat; rather, it redistributes heat from the air or ground utilizing a refrigerant-based heat exchanger.[100] According to Rewiring America, an electrification nonprofit, heat pumps are "3-5 times more efficient than most current fossil fuel heating systems."[101] Financial savings can add up to hundreds of dollars annually and increase when fossil fuel prices increase.[102] Because heat pumps have no emissions, there are direct air quality benefits available to farmers, farmworkers, and the animals on the farm.[103] Heat pumps also offer grid flexibility because they can be interrupted for short periods of time and used to pre-heat or pre-cool to avoid periods of high demand. Heat pump technology continues to improve as it gains market share and new gains are occurring in industrial heat pump technology.[104]

The electrification of heating and cooling will create additional seasonal and daily variation in energy consumption requiring more management. The new load will not always coincide with renewable energy generation and thus technologies and operational strategies that maximize load flexibility should be prioritized.[105] Utilities already have demonstrated success in applying demand response strategies in residential applications because heating and cooling are suitable for direct and semi-direct load control by utilities and indirect load control by consumers.[106] Florida Power and Light's On Call program permits the utility to shut off a residential building's central electric air conditioner and electric heater in exchange for a monthly bill credit.[107] Austin Power's Power Partner program allows the utility to control a residential building's smart thermostat in exchange for a one-time $50 credit and an annual $25 credit for every connected thermostat.[108] Similar programs could be implemented for smart thermostats on agricultural buildings with uses that permit flexible service. Utilities can also offer financial incentives that allow customers to control the decision of whether to alter their consumption. Utility rates have a significant impact on customer costs and behavior and can present either an incentive or barrier to heating and cooling electrification.[109] As previously discussed in Section I, time-of-use rates send market signals to customers to decide when to take advantage of lower rates. Moreover, several EEUs offer generous rebates for heat pumps in agricultural operations.

CASE STUDY

Unsplash photo by Adam King

Heating in Swine Nursery Barns[110]

A study on the use of Reduced Nocturnal Temperature (RNT) regimens in swine nurseries has shown that lowering the temperature at night can lead to substantial fuel savings without negative impacts to pig welfare. The RNT regimen involves reducing the overnight temperature in swine nursery barns by 10 to 15 °F. This approach is based on the understanding that pigs, like humans, require less heating during rest periods. The study found that implementing RNT can result in a 30% reduction in heating fuel consumption. These findings are significant, considering that approximately 88% of the fossil energy used in swine nurseries is for heating.

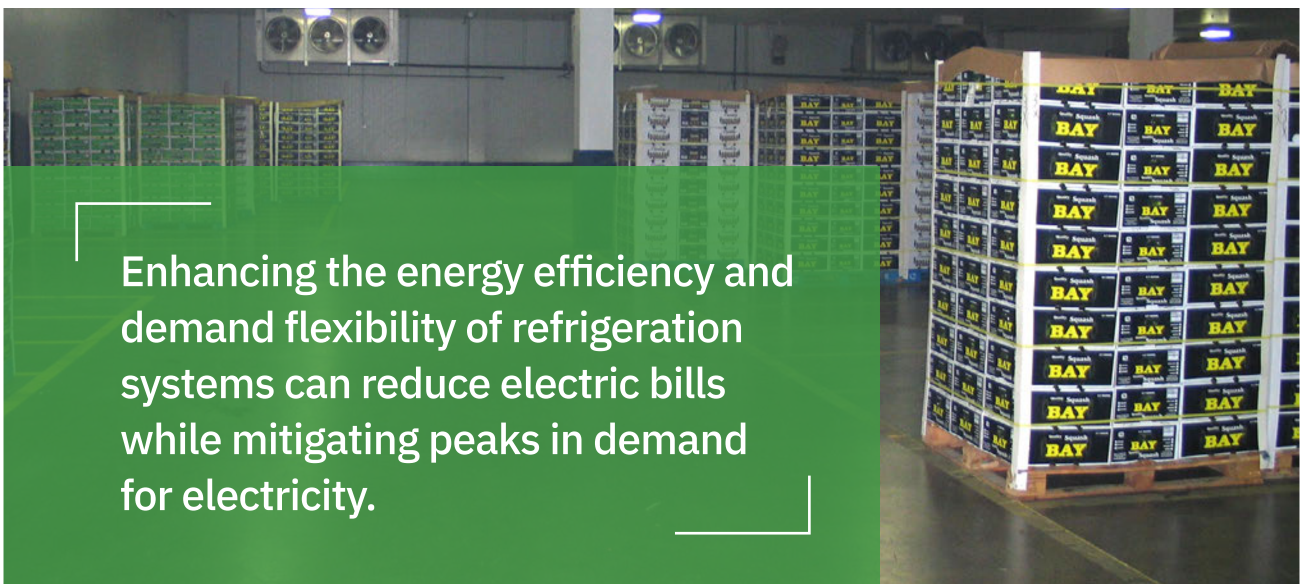
The principles of RNT align well with the goals of demand response programs. By reducing the heating setpoint during off-peak hours (nighttime) and/or for short periods of time during peak hours, swine nursery barns can significantly lower their energy consumption. This reduction in demand can be coordinated with utility programs to provide additional financial benefits to the farmers while contributing to grid stability.

C. REFRIGERATION

Energy-efficient cooling systems play a crucial role in advancing sustainable agricultural practices. Emissions from "cold chain" technologies used to preserve food, combined with emissions from food waste from lack of refrigeration, amount to 4% of global GHG emissions.[111] While most refrigeration systems are already powered by electricity, there is significant potential for reducing energy consumption and emissions through enhanced equipment efficiency, improved temperature management, and the adoption of lower-impact refrigerants.[112] The majority (60%) of cold chain emissions come from electricity consumption, with 22% attributable to refrigerants and 18% to diesel fuel used in refrigerated transportation.[113] Improving the energy efficiency of refrigeration systems not only reduces emissions and alleviates strain on the electric grid but also leads to substantial cost savings on electric bills.[114]

COLD CHAINS

“A cold chain is an uninterrupted system of temperature-controlled transport and storage of refrigerated food products between upstream producers and final consumers, designed to maintain the quality and safety of these products.”[115]



University of Vermont photo by Vern Grubinger

Cooling systems are particularly critical for dairy, fruit, and vegetable farms. These farms depend on cooling during the hottest times of the year, often coinciding with peak electricity costs.[116] Cooling is the largest use of energy on dairy farms.[117] A range of technology is available to make dairy cooling processes more efficient, and several EEUs offer rebates directed at reducing the cost of improved equipment for dairy farmers. For example, milk pre-coolers help cool milk faster and more efficiently, which can increase milk quality while decreasing cooling costs.[118] Moreover, waste heat from milk refrigeration can be repurposed to lower water heating costs. Refrigeration Heat Recovery (RHR) units use recaptured heat to preheat well water to up to 140 degrees for use in washing; they provide one of the fastest returns on investment on a dairy farm. [119]Fruit and vegetable operations also rely heavily on cooling during the summer months to preserve crops for storage and shipping. Enhancing the energy efficiency and demand flexibility of refrigeration systems in these operations can reduce their electric bills while mitigating peaks in demand for electricity.[120]

CASE STUDY

Demand Response in California's Refrigerated Warehouses[121]

Refrigerated warehouses, which are key to the agricultural supply chain, consume substantial amounts of energy to keep products cold as they move from production facilities to consumers. With over 130 million cubic meters of industrial refrigeration warehouse capacity in the United States, strategies to manage and reduce their power consumption are of significant interest. These warehouses represent a unique opportunity for targeted demand response programs, which could provide energy savings of 13 MWh in California alone.

In 2016, the California Energy Commission awarded funding to the Electric Power Research Institute to demonstrate the demand response capabilities of a modern refrigerated warehouse using a sophisticated control system and communications protocol called OpenADR 2.0b, which sent demand response signals to the warehouse to tell it to use energy. The warehouse consisted of 11 different rooms held at different temperatures for distinct functions, from dry storage (over 0 degrees Celsius) to freezer rooms (-18 degrees Celsius). While the temperature of non-frozen food must be carefully controlled, most frozen food can be over-cooled without damage, thereby allowing the storage of thermal energy.

To implement demand response, the temperature setpoint of one or more rooms was adjusted—warmer to reduce load, and colder to increase load. Thanks to the variable speed drives on the refrigerant compressor motors, power consumption could be fine-tuned without cycling the compressors on and off. The facility was able to modulate compressor power up to 30% during a demand response event, without any adverse effects on the quality of the food stored in the warehouse.

D. WATER HEATING

Water heating presents another significant opportunity for electrification in agricultural operations. Water heating is a primary energy use on dairy farms[122] and accounts for 11% of energy consumed by greenhouses.[123] Natural gas and propane hot water heaters are commonly used on farms,[124] but electric hot water heaters and heat pump models can offer the same service with additional environmental and economic benefits.[125] A 50-gallon heat pump water heater requires only an eighth of the electricity[126] needed to power a comparable electric resistance model, with 30% of the operating costs.[127] A heat pump water heater may cost up to three times more than an electric resistance model, but its lower operating costs can make it cheaper to own after only three years of use, without factoring in any rebates a consumer may have received.[128] The high-volume needs of agricultural operations can shorten the payback period.

The electrification of water heating in agriculture is an opportunity for emissions reduction and grid management.

The electrification of water heating in agriculture is an opportunity for emissions reduction and grid management. Stored hot water in insulated tanks can maintain thermal energy so effectively that it stays hot even when the power source is turned off for short periods.[129] This capacity to store thermal energy creates an opportunity to interrupt or flexibly shift the electric demand of water heaters without affecting end-use quality.[130] Electric resistance water heaters can be turned on and off quickly to respond to the intermittency of renewable energy generation and can be scheduled to pre-heat during optimal times.[131] This flexibility is less developed in heat pump water heaters. Their load shifting capability is approximately half that of electric resistance heaters, in part because they use less total electricity and operate more slowly.[132] The National Rural Electric Cooperatives Association has voiced concerns that heat pump water heaters do not function as well in demand response programs as those using electric resistance.[133] Fortunately, heat pump technology is getting better all the time. A recent U.S. Department of Energy (DOE) analysis found that several heat pump water heaters capable of demand response are commercially available and manufacturers are developing control strategies to enable participation in utility programs.[134] When utilities and consumers better control the electric demand of water heaters in aggregate, this equipment becomes “a key grid resource to reduce peak demand, lower electricity costs, improve power reliability, and enable better use of intermittent renewable power.”[135]

To optimize the grid management benefits, water heaters must be able to respond to signals from the electric utility to participate in demand flexibility programs. Some utilities are offering compensation to customers willing to install controls on existing hot water heaters. For example, Pennsylvania’s Valley Rural Electric Cooperative asks its members to install a demand response unit on their water heaters so the cooperative can shut down water heaters during peak demand periods. In exchange, members receive a one-time bill credit of $100, and the cooperative’s savings are passed on to members.[136]

It is, however, much more efficient for control technology to be installed on water heaters in the factory than to retrofit existing models.[137] Several states, including Washington, Oregon, and Colorado, already require new electric water heaters to include controls that enable demand response participation.[138] The American Council for an Energy Efficient Economy estimates that if factory-installed demand response controls were required of all residential water heaters by 2030, it could provide over 13 GW of summer demand flexibility by 2050—the equivalent of 27 large power plants.[139] The estimate increases to 23 GW of potential winter demand flexibility capacity.[140] While most utilities have historically worried about summer peaks in demand, peak demand may shift to winter mornings as more electric space heating is installed, making the capacity for demand flexibility in water heating even more important.[141]

CASE STUDY

USDA photo by Lance Cheung

Electric$ense Load Management at Minnesota's Dairyland Power Cooperative

Dairyland Power Cooperative is a generation and transmission cooperative providing wholesale power to 24 distribution utilities and 29 municipal utilities in rural Wisconsin, Minnesota, Iowa, and Illinois. Dairyland estimates that load management "can reduce demand for electricity by approximately 80 [MW] in the summer and 140 [MW] in the winter—the equivalent size of a small power plant."[142] To realize these demand reductions and achieve a more balanced grid, Dairyland offers its Electric$ense Load Management program through its member cooperatives, including their agricultural customers.

Electric$ense enrolls on-farm equipment, including irrigation pumps, grain drying systems, and dairy electric water heaters, into demand response programs. To participate, the equipment must be capable of being "turned off, cycled, or otherwise modulated during periods of high electricity prices, peak demand or constrained energy supply."[143] In the summer, peak hours are typically from 2 p.m. to 6 p.m., and in the winter, from 6:55 a.m. to 11 a.m. or 4:55 p.m. to 8 p.m. Any service interruptions made by the program are time-limited and the co-op strives to use automated demand response whenever possible.[144]

E. ELECTRIC MAPLE SAP EVAPORATORS

Maple syrup is an agricultural product with a large environmental footprint. The maple syrup industry produced 4.2 million gallons of maple syrup in 2022.[145] Producing a can of maple syrup is estimated to emit 600g of GHGs, with 80% of these emissions occurring during processing.[146] By contrast, the carbon footprint of a bottle of water is the equivalent of about 280g CO_2.[147]

Electric maple sap evaporators can dramatically reduce the carbon footprint of maple syrup production. Sap evaporators use 22 times less energy than oil-fired alternatives, saving 30 tons of CO_2 per year per evaporator.[148] An electric maple sap evaporator heats sap in a sealed unit with electric heating elements, then collects and pressurizes the resulting steam, which funnels back into the heating system.[149] This process continues until all the water evaporates, leaving behind the maple syrup. Electric maple sap evaporators are also cheaper to operate and less polluting than oil-fired and wood-fired evaporators.[150] Ontario's Ministry of Agriculture and Food estimates that it takes 2.7-3.4 gallons of fuel oil to produce one gallon of maple syrup. The University of Wisconsin-Madison estimates that oil and wood energy costs account for 26-34% of maple syrup production costs for non-reverse osmosis systems and 8-11% of reverse osmosis systems.[151] Sap boiling can be scheduled to minimize grid impacts, making it an attractive option for demand management.

CASE STUDY

NRCS photo by Brandon O'Connor

VEC Funds Line Extensions for Electric Maple Sap Evaporators[152]

Vermont Electric Co-op's Clean Air Program (CAP) offers its members customized opportunities to replace fossil fuel usage with electricity in off-grid and underserved areas. VEC is willing to share the cost of electric service upgrades and line extensions to serve new electric equipment, specifically including electric maple sap evaporators. The co-op's service territory includes a high number of maple syrup producers using diesel, oil, or propane generators to power sap collection and processing. Without a cost-sharing agreement, it can be prohibitively expensive to extend electric service to a seasonal sugaring operation. VEC's program allows maple producers to connect to electric service, saving them time, money, and thousands of gallons of fossil fuel annually.[153]

F. GRAIN DRYERS

Drying grain for long-term storage is one of the most widely used agricultural practices and an opportunity for electrification. Electrification of grain dryers can lead to significant energy cost savings for farmers.[154] Traditional grain drying methods primarily use high-heat dryers powered by natural gas or liquid propane, accompanied by electricity-driven fans and motors. These systems can lead to substantial energy expenses for producers. Grain dryers consume up to 300 million gallons of propane and natural gas annually, with 80% of grain dyers reliant on propane as of 2015.[155] Innovative technologies such as electric microwave and radio wave grain dryers offer an opportunity to reduce energy costs and emissions while improving grain quality.[156] Microwave and infrared processes also show promise for energy reductions in grain processing.[157] Natural-air or low-temperature methods that increase temperature by only a few degrees are the most energy efficient. Low-temperature grain dryers can operate at efficiencies of 1,200-1,500 BTU/lb.[158] However, this method increases drying time and may not work for high-capacity production.[159] High-temperature dryers work quickly and can be carefully controlled, but also consume more energy—between 2,000 and 3,000 BTU/lb.[160] Ultimately, many factors influence total energy consumption, including outdoor and operating temperatures and the grain's moisture level.[161]

The switch to electric grain drying must be carefully planned to manage costs. Integration of heat pumps can substantially improve the cost and efficiency of grain drying, particularly at low temperatures.[162] At large scale, three-phase electric drive mobile dryers are starting to outsell traditional machines.[163] However, electric rates can be a deterrent to farmers hoping to swap out fossil fuels because high-heat dryers can carry a significant electric load and bill. Grain drying is an intensive harvest activity that may occur day and night during the season.[164] Time-varying electric rates with high peak prices can be a burden if the consumer cannot avoid consumption during peak periods, leading some farmers to switch back to a fossil fuel generator when electricity prices are high.[165]

The process of drying grain can accommodate demand response. Grain can sometimes be dried in stages, allowing for periods of high and low consumption that can be harnessed to avoid peak demand periods.[166] Combination drying uses high temperatures followed by low temperatures delivered as tempering and in-bin cooling.[167] Farmers may be able to adjust the dryer temperature down for short periods of time for immediate load shedding without serious impact on product quality. Dryers integrating moisture measuring equipment that allows adjustments to be made to avoid over-drying and under-drying could also help identify opportunities for load shifting or shedding while preserving product quality.[168] Increased efforts could stimulate further development of special electric rates for grain drying, as well as pilot programs to investigate and encourage demand flexibility.

Drying grain for long-term storage is one of the most widely used agricultural practices and an opportunity for electrification.

CASE STUDY

Unsplash photo by Daniela Paola Alchapar

MWEC Promotes Electric Grain Drying with Low Rates

Mountrail-Williams Electric Cooperative (MWEC), serving the rural regions of Williams and Mountrail Counties in North Dakota, offers a discounted electricity rate for low-temperature grain drying.[169] Participants pay a discounted rate of 5.4 cents per kWh for electric dryers and fans used in the grain drying process. The program is designed to accommodate equipment permanently mounted on a single grain bin, as well as portable units that can be used on multiple bins. Additionally, MWEC offers loans for the installation of grain drying equipment, further supporting farmers in upgrading their infrastructure.[170]

MWEC requires participating electric grain drying equipment to be separately sub-metered. While the co-op provides the new metering equipment, customers may incur expenses for wiring.[171] In addition to the per-kWh charge for electricity, customers served by single-phase power pay a base charge of $9 per month, while those served by three-phase power pay $25.[172] Comparatively, customers paying MWEC's regular agricultural rate for three-phase power are charged between 7.2 and 8.4 cents per kWh, along with a $25 monthly fee.

By offering a reduced electricity rate, the cooperative helps farmers lower their operational costs during the critical drying season. This support is particularly significant given the energy-intensive nature of grain drying, which can account for a substantial portion of a farm's energy usage. Moreover, the program aligns with broader energy efficiency and grid management goals. By incentivizing the use of electric grain dryers, MWEC is encouraging the shift away from fossil fuels, contributing to reduced greenhouse gas emissions and promoting cleaner energy use in agricultural practices.

G. ELECTRIC VEHICLES

Of all electric farming technologies, electric vehicles (EVs) have the most transformative potential. Farms use a wide range of fossil-fuel-powered tractors, all-terrain vehicles, backhoes, and farm trucks to plant, cultivate, and harvest crops.[173] The U.S. Environmental Protection Agency (EPA) estimated that off-road agricultural vehicles, including tractors, released 100,000 million metric tons of CO_2 equivalent emissions in 2019, accounting for about 14% of total agricultural emissions.[174] Nearly 770,000 tons of global CO_2 emissions could be saved annually by turning off fossil-fuel-powered tractors while idle.[175] Pairing battery-electric and/or fuel cell tractors with on-site renewable energy generation and storage could reduce emissions from this agricultural end-use by up to 97% in 2050.[176] It would also improve air quality for farmworkers who face exposure to higher levels of particulate air pollution than the general population.[177] The National Rural Electric Cooperatives Association found that it would take 28,200 GWh of electricity to power widespread adoption of electric tractors and farm vehicles for field crop production in co-op service territories, representing 42% of co-ops' beneficial electrification potential.[178] The global electric farm tractor market size is projected to grow from 132 million in 2021 to $336.3 million by 2030. [179]

The usage patterns of agricultural vehicles are the biggest obstacle to electrification. Agricultural vehicles have intense energy demand over relatively short work periods.[180] Some tractors might only be used for a few very intense weeks out of the year. While a diesel-powered machine may operate for ten hours before refueling, heavy battery-powered vehicles do not currently have the same potential for extended work periods.[181]

As battery technology and performance continue to improve, electric tractors become an easier choice for farmers. Some manufacturers are solving the stamina problem with replaceable battery packs. For example, Solectrac electric tractors promise three to six hours of operation per battery.[182] Moreover, electric tractors generally require less maintenance and offer attractive opportunities for autonomous and precision agriculture not compatible with fossil fuel models.[183]

Of all electric farming technologies, electric vehicles have the most transformative potential.

The high upfront costs of EVs are a concern that can be offset by fuel savings, operations savings, and tax credits. Farmers can realize thousands of dollars in savings in fuel and operational costs annually from a single electric tractor.[184] Furthermore, the Inflation Reduction Act (IRA) offers tax credits of up to $7,500 for light- and medium-duty vehicles and $40,000 for heavy-duty trucks.[185] Utilities are also starting to offer incentives for the heavier-duty electric vehicles frequently used by agricultural operations, but they may not do enough to defray the purchase price. For example, Vermont Electric Cooperative offers a $1,000 bill credit to customers who purchase a new or used electric forklift.[186] The utility is even covering the cost of transformer upgrades, approximately $2,500, for members purchasing electric vehicles.[187] While generous, these incentives may not be sufficient to encourage adoption when some farmers are struggling financially—even relatively small electric forklifts can cost $10,000-$30,000 and the price of heavy-duty forklifts can be over $60,000.[188]

Charging time and infrastructure are also significant challenges for the adoption of EVs in agriculture. Lower-cost chargers are more affordable but charge batteries more slowly, which can limit the flexibility of use and risks insufficient charging during the vehicle's available downtime.[189] High-capacity chargers offer more flexibility and can even accommodate multiple vehicles charging simultaneously but can exceed $100,000 including installation costs.[190] Incentives and subsidies for charging infrastructure help defray up-front costs, including state and federal funds that reduce costs for both utilities and farmers. The IRA's nonrefundable tax credit covers up to 30% of charger costs up to $100,000.[191] Still, the prohibitive costs and extended lead time to acquire charging infrastructure and implement necessary grid upgrades can act as a barrier to EV adoption.[192]

States are starting to encourage a transition to electric and fuel cell power in medium and heavy-duty vehicles, including those used in agricultural operations. Large farms in California, those with at least $50 million in gross annual revenue or 50 vehicles over 8,500 lbs., must begin transitioning to zero-emission vehicles in 2024 under the state's Advanced Clean Fleet regulation.[193] While smaller operations and certain off-road diesel vehicles used 100% for agriculture are specifically exempted from compliance, California is nonetheless offering large subsidies to farmers for vehicle electrification.[194] The California Air Resources Board's Funding Agricultural Reduction Measures for Emissions Reductions (FARMER) Program strives to "reduce agricultural sector emissions by providing grants, rebates, and other financial incentives for agricultural harvesting equipment, heavy-duty trucks, agricultural pump engines, tractors, and other equipment used in agricultural operations."[195] Incentive levels in the FARMER program must cost less than $66,000 per weighted ton of emission reductions and can fund up to 80% of the replacement equipment cost, including charging equipment and battery packs.[196] The program is also running a funding pilot to support the purchase of used electric and fuel cell equipment for small farms in the San Joaquin Valley.[197]

As EV adoption accelerates, deliberate management of vehicle fleets can turn them into powerful distributed energy resources. Time-varying electric rates can help optimize the advantages of EVs for both utilities and consumers. Charging EVs at beneficial times helps to enhance the efficiency of the electrical grid, promote integration of renewable energy sources, reduce the need for costly upgrades, and mitigate the need for additional peak power generation capacity.[198] Time-of-use rates are typically more effective when there is a wider differential between the cost of peak and off-peak hours.[199] For example, the largest IOU in Nevada offers a time-of-use rate for EVs that ranges from 40.7 cents/kWh for on-peak power and 5.53 cents/kWh for off-peak power during the summer season.[200] Little work has been done to analyze the impact of time-of-use rates for EV charging in the agricultural sector. Agricultural end-uses are likely to have EV charging patterns, or load shapes, that differ significantly from commercial or residential customers.

Electric tractors and other agricultural EVs also show exciting potential for energy storage and demand response capacity. Vehicle-to-grid technology, or V2G, facilitates communication and exchange of electricity between EVs and the power grid. This technology allows EV batteries to be treated as energy storage resources capable of returning stored energy to the grid or other power system.[201] The stored energy can be used to help meet peaks in demand or even provide essential back-up power during emergencies.

CASE STUDY

EV Tractor Batteries as Emergency Power Source[202]

The California Energy Commission awarded a $3 million grant to the Farm Electrification Consortium, which includes Monarch Tractor, an advanced electric autonomous tractor manufacturer, along with Gridtractor, Rhombus Energy Solutions, Current Ways, and Polaris Energy Services. This grant is intended to expedite agricultural electrification and showcase the capability of agricultural EV batteries to provide essential power to farms during grid failures. Their collective efforts will focus on developing technologies that integrate tractors into the power grid to manage charging and discharging and critical farm operations during outages.

IV. Special Challenges in Agricultural Electrification

USDA photo by Lance Cheung

The electrification of agricultural practices must acknowledge and accommodate the unique concerns and needs of the industry. Farmers must have access to electrified equipment that can match existing fossil-fuel-powered equipment for power, endurance, predictability, and maintenance.[203] The equipment must be price-competitive in the short and long term. Widespread agricultural electrification will require improvements in rural grid infrastructure, digital connectivity, careful consideration of the timing and sensitivity of end-uses and agricultural practices, and increased collaboration between utilities and farmers. Many of these improvements are needed in the rural environment generally and would provide universal benefits to rural communities. Along with its challenges, electrification enables the creative use of technology to modernize agricultural practices. Informed advocates are crucial in overcoming barriers and maximizing the benefits of electrification in the agricultural industry.

> Farmers must have access to electrified equipment that can match existing fossil-fuel-powered equipment for power, endurance, predictability, and maintenance.

A. DEFINING AGRICULTURAL CUSTOMERS AND END-USES

Facilitating the electrification of the agricultural sector starts with recognizing the unique needs of the sector and creating a system that can target those needs. Electric utilities serve a wide variety of customers with diverse needs. Generally, utilities sort these customers into a series of defined customer classes based on the profile of their electricity consumption. Common customer classes include industrial, residential, and commercial. Some utilities have an agricultural customer class. Customers within a class are offered the same rates and obligated to pay certain charges based on the impact of their usage on the electric grid. While utilities historically use customer classes to appropriately allocate costs among ratepayers, utilities also use these classes to target certain customers for special rates or incentives benefitting both the customer and the utility, like energy efficiency and demand response programs. Some utilities offer special rates for specific agricultural end-uses, like barn lighting or water pumping, and may require that the use be served by its own electric meter. Programs designed for non-agricultural customers are not usually tailored to meet the needs of working farms and agribusinesses.[204]

The criteria for an agricultural customer class must be precisely tailored which can lead to issues. For example, consider the distinction made between "farm" and "commercial" service by Oklahoma's Choctaw Electric Cooperative:

> **"Farm service shall include, in addition to all other uses of energy on farms, the use of energy for processing of materials produced on the farm served; for example, feed grinding, or milk pasteurizing. On the other hand, if the materials are produced elsewhere as in the case of commercial feed grinding plants, commercial poultry hatcheries, creameries, etc., the service shall be classified as commercial."[205]**

Under this provision, if a farm is grinding feed produced on-site, it may do so on the farm service rate; however, if the feed was produced off-site, it is only eligible for the commercial rate. Many utilities treat agricultural production and processing differently. For example, Southern California Edison draws a similar distinction:

> **"Agricultural Power Service is the electric energy and service used by a customer on the same Premises where the customer produces agricultural or horticultural products, including poultry and livestock. Notwithstanding the foregoing, Agricultural Power Service also applies to electric usage for: (1) packing houses that pack only whole fruits or whole vegetables, and associated cold storage on the same Premises as the packing houses; (2) cotton gins; (3) nut hulling and shelling operations; or (4) the production of unflavored fluid milk fit for human consumption by way of pasteurization, homogenization, vitaminization or fat standardization."[206]**

Where Chocktaw Electric Cooperative draws a distinction between on and off-site production in its farm service rate, Southern California Edison instead limits the amount of value-added activity that may occur before a metered end-use is considered commercial: nuts may be hulled and shelled, but not roasted; milk may be pasteurized and homogenized, but not flavored. In both cases, a singular farm, agribusiness, or agricultural "customer" may retain electric utility service for a variety of metered end-uses ranging across residential, commercial, and industrial classes, as defined by the utility.

It is easier for farms, utilities, and policy advocates to think of each meter as belonging to a specific class, rather than seeking to categorize the farm or farmer into a singular class. Meters are tied to specific end-uses, which are more predictably similar than the "customers" carrying out those end-uses. However, utility programs should target specific agricultural end-uses like irrigation, maple sap evaporation, or barn heating for special rates and programs because each end-use has individualized characteristics that may differently support (or inhibit) grid flexibility and demand response opportunities.[207]

B. GRID AND ON-SITE ELECTRICAL INFRASTRUCTURE

Fully capturing the potential of electrifying agriculture will require updating aging infrastructure in rural areas. Many existing distribution systems in rural areas have not seen significant updates in decades.[208] As farms incorporate more electric technologies, infrastructure upgrades may be necessary to manage the increased electric load.[209] For instance, farms expanding or modernizing with heavy-duty electric machinery may require an upgrade to 400 Amp service panels supported by three-phase power.

Electric equipment rebates and special rate schedules may not be sufficient to overcome the costs of a new electric panel or service upgrade. Typically, the costs of grid upgrades are shared between the customer and utility, with broader support from ratepayers, while individual customers usually bear the cost of on-site infrastructure upgrades.[210] An electric panel upgrade alone can cost approximately $2,000-$5,000, in addition to the cost of the new electric equipment it serves.[211] The price of a service transformer upgrade is likely to be $5,000-$6,000, and a new service line could be an additional $8,000.[212] The scattered nature of farm buildings and meters adds complexity to the electrification process, and complexity equates to additional costs.

As farms incorporate more electric technologies, infrastructure upgrades may be necessary to manage the increased electric load.

Unsplash photo by tanerardali

Electrification initiatives must include programs that provide technical assistance for customers and financing for system infrastructure upgrades. First, building and zoning codes could mandate that certain facilities be prepared for a transition to electric equipment. For example, the California Energy Code requires most new construction to be capable of supporting solar generation, battery storage, and electric equipment.[213] In California, if a new gas appliance is installed in a residence, a dedicated electric circuit must also be installed next to the appliance in anticipation of its eventual electric replacement.[214] While these provisions do not apply to existing agricultural facilities, similar measures could be developed to foster electric readiness in farms and agribusinesses.

Second, utility and government electrification programs can help identify, promote, and finance electric infrastructure upgrades. For instance, applying for a rebate for an electric water heater could trigger an energy audit to evaluate the customer's other gas appliances and overall electrical capacity.[215] An energy audit might reveal that the customer owns appliances that could share a circuit because each is used infrequently or at different times.[216] Broad financial support should be available for additional dedicated circuits to facilitate future electrification, circuit sharing devices, electric charging infrastructure, and panel upgrades.[217] When programs offer technical assistance and financial support to plan and create future electrical capacity, it encourages further decarbonization by making it easier to continue to choose electrification.[218]

Finally, rural agricultural customers are often well-suited for on-site distributed generation of renewable energy.[219] Agricultural customers are uniquely positioned among utility customers to develop and utilize a variety of distributed energy resources to provide a wide range of services to the grid.[220] These customers may have ample space, access to site-specific fuel sources like biogas, as well as storage options like water tanks.[221] Several states have created policy incentives for agrivoltaic solar arrays that co-locate energy generation with a wide range of agricultural uses from grazing to specialty crop production.[222] When distributed generation and energy storage resources are located closer to end users, it enhances energy efficiency, increases grid stability, and can reduce the need for extensive grid upgrades.[223] Pairing agricultural electrification with on-site renewable energy generation reduces emissions and promotes fossil fuel independence.

> When programs offer technical assistance and financial support to plan and create future electrical capacity, it encourages further decarbonization by making it easier to continue to choose electrification.

PREPARING FOR ELECTRIFICATION

- **Building and zoning codes could mandate that certain facilities be prepared for a transition to electric equipment.**
- **Utility and government electrification programs can help identify, promote, and finance electric infrastructure upgrades.**
- **Rural agricultural customers are often well-suited for on-site distributed generation of renewable energy.**

C. RURAL BROADBAND AND DIGITAL CONNECTIVITY

A lack of robust rural broadband infrastructure is a significant obstacle to managing the electric demand of new electric equipment among agricultural utility customers, in addition to other concerns including compliance with federal food safety mandates. Demand response technologies, which are essential for managing electricity consumption during peak periods, increasingly integrate real-time pricing and transactive energy to best respond to the complex fluctuations of the grid.[224] While utilities can often send demand response signals directly to equipment through power lines, consumers need internet connectivity to control smart appliances or to use management apps integrated with demand response programs. This requires a robust internet connection that can handle the transmission of copious amounts of data quickly and reliably. Without improved digital connectivity, the potential benefits of demand management, including enhanced grid stability, optimized energy usage, and reduced electric bills cannot be fully realized in the agricultural sector.[225]

The absence of broadband connectivity hampers the overall efficiency and competitiveness of farms by limiting their ability to modernize practices. The USDA estimates that if producer demand were met for broadband infrastructure and digital technologies, the benefit to the U.S. economy would equal nearly 18% of total agriculture production.[226] The electrification of agricultural equipment is a key factor in advancing automation and precision agriculture. Technologies such as real-time crop monitoring, robotic milking machines, and autonomous tractors are poised to reduce emissions, improve yields, and save time and labor, but usually require digital connectivity for operation and management.[227] Initiatives like the USDA's ReConnect Loan and Grant program aim to improve internet services in rural areas.[228] However, the pace of development must be accelerated to ensure that agricultural producers are not left out of electrification and modernization opportunities.

D. TIMING AND SENSITIVITY OF END-USES

The time-sensitive nature of agricultural activities is a significant challenge to electrification. Agricultural tasks such as watering and harvesting can have short windows to perform them based on crop needs and employee availability, which can limit the available time for charging electric equipment.[229] It also constrains the design and/or efficacy of any demand management programs intended to influence the time of day, week, or season equipment is used.

The time-sensitive nature of agricultural activities is a significant challenge to electrification.

Moreover, farm equipment can have irregular usage patterns that further complicate electrification efforts. Many farm businesses operate across multiple locations.[230] It is not unusual for farm equipment to be used on one farm property before moving on to the next, often not returning to the home base for days or weeks. This rotational schedule means that even if the battery for large electric farm equipment could run for a full day, the equipment would not necessarily return to a singular charging station at night, adding cost and complexity to the installation of charging infrastructure.[231] To design a successful electrification or demand response program, it is necessary to first analyze and understand the needs and energy consumption behavior of local agricultural operations.

E. LEVERAGING FEDERAL FINANCING

Overcoming the upfront costs of investing in new equipment is a major challenge to electrification. Farm equipment is getting bigger and more expensive, and new electric equipment represents a significant investment. Fortunately, a wide range of federal funding opportunities are available to offset the costs of electrification in agriculture for both consumers and utilities. To maximize the impact of available funds, available federal, state, local, and utility funding streams should be leveraged together where possible.[232] Knowledge of potential funding sources and how they complement each other can significantly reduce the financial burden of electrification and energy efficiency projects. Below is an inexhaustive list of federal funding opportunities.

For **farms and agricultural operations**:

- The **USDA's Rural Energy for America Program (REAP), Renewable Energy & Energy Efficiency Initiative** offers guaranteed financial support in the form of grants and loans to farmers and small businesses in rural areas.[233] This support is intended **to help install renewable energy systems or energy efficiency improvements**, including efficient electric equipment used in agricultural production or processing.[234] Grants can cover up to 25% of project costs, or up to 50% with the Inflation Reduction Act of 2022 (IRA), and loan guarantees can cover up to 75% of loan project costs.[235] Other REAP funding provides **grants for energy audits, renewable energy development support, and technical assistance.**[236] The IRA significantly expanded the REAP program, supporting small rural businesses and agricultural producers with renewable energy and efficiency upgrades.
- The **USDA's Natural Resource Conservation Service's On-Farm Energy Initiative** through its Environmental Quality Incentives Program (EQIP).[237] The initiative provides **technical assistance in developing an Agricultural Energy Management Plan**, as well as **financial assistance to help cover the costs of implementing the recommended improvements.**[238] The program includes a wide range of electrified agricultural equipment, including ventilation and fans, irrigation pumps, grain dryers, greenhouse improvements, maple syrup evaporators, heating and refrigeration units, motor controls, and variable speed drives.[239]

For **utilities**:

- The **USDA's Electric Infrastructure Loan & Loan Guarantee Program** provides investment capital in the form of insured loans and loan guarantees to utilities and other entities to **finance the construction of electric grid infrastructure in rural areas.**[240] The funds can be used for a wide range of investments including new electric distribution, transmission, and generation facilities, system improvements and replacements, renewable energy systems, energy conservation programs, and demand side management.[241]
- Several USDA programs provide **financing for utilities to create lending opportunities within their service territories.** The Energy Efficiency and Conservation Loan Program, Energy Resource Conservation Program, and Rural Energy Savings Program all enable eligible utilities to lend funds to customers for qualifying energy efficiency and renewable energy projects.[242]

F. IMPORTANCE OF AGRICULTURAL LIAISONS FOR OUTREACH AND EXPERTISE

Agricultural liaisons employed directly by utilities and state agencies can help farmers access the potential of beneficial electrification. Understanding local agricultural practices and products is key to successful electrification. Tailoring program designs to meet farmers' needs and implementing effective communication strategies to promote the adoption of electric technologies are essential steps. Agricultural liaisons serve as a crucial link between technology providers, utilities, policymakers, and farmers, helping farmers comprehend the benefits of electrification, navigate the complexities of implementation, and access support programs and resources.

AGRICULTURAL LIAISONS AT UTILITIES

Wisconsin's EEU, Focus on Energy "has a dedicated team of agriculture experts ready to help improve the efficiency of [a] dairy, crop, or livestock operation through technical support and financial incentives for energy-saving upgrades."[243]

Education, outreach, and stakeholder coordination are crucial for utilities to better understand the needs of agricultural operations and for farmers to embrace opportunities for cost and carbon savings. Reaching out to farms can be challenging, their availability may fluctuate seasonally based on the crops they produce, and they may show hesitation towards engaging with new programs or technologies without endorsements from trusted advisory organizations.[244] Farm bureaus, agricultural nonprofits, state extension offices, and departments of agriculture are not always included in energy policy development but are natural advocates for utility programs and rates that benefit farmers, as well as natural messengers to increase awareness of program benefits to agricultural electric customers.[245] For example, many demand response programs were developed without considering the operational constraints of farms.[246] Even where programs exist, many agricultural customers may not know about them, have time to navigate complex enrollment processes, or fully understand how to incorporate technology that enables participation.[247] These issues are significant barriers to the adoption of new and existing demand management programs within the agricultural industry.[248]

Conveying the benefits of electrification effectively is key to persuading farms to adopt it. Clear, succinct information, such as case studies, financial projections, or straightforward payback analyses for energy projects, can significantly influence farm business decisions.[249] Farms and agribusinesses benefit from tools that analyze cost and energy savings but also need support in navigating the incentives, rebates, and other financing opportunities that may be available.[250] All parties benefit when utilities employ dedicated agricultural account representatives to explain rates and programs quickly and effectively. For example, energy audits can serve as a valuable tool to initiate discussions about beneficial electrification, as they often result in compelling financial analyses.[251] These audits are also a prerequisite for most federal funding programs, which can complement financial incentives provided by utilities.[252] The USDA Agricultural Research Service has developed Virtual Grower, a tool for simulating energy savings across various greenhouse designs, and is now extending its capabilities to include models for vertical farms and to assess the effects of new technologies on crop production.[253] The agricultural industry would benefit from similar tools developed to assess the benefits of electrification.

Finally, energy performance data is increasingly vital for utility development of effective programming and for effective policymaking, including the modification of energy codes and standards.[254] Collected data should also be made widely available to all stakeholders so that they can seek support in understanding the analyses and develop options for improving their energy performance.

V. Recommendations for Effective Electrification Policy

USDA photo by Lance Cheung

Given the significant opportunities for beneficial electrification in the agricultural sector, it is crucial that advocates work to expand the number and quality of utility programs available to this industry. A key first step is ensuring that public utility commissions, state and local energy offices, legislative representatives, and other regulatory bodies understand the unique needs and challenges of farm-based electrification. By educating these stakeholders, advocates can push for the development of specialized rates, incentives, and demand response programs designed specifically for agricultural customers.

One of the most impactful ways to advocate for change is by engaging with the state agencies that regulate electric utilities. Public utility commissions are responsible for overseeing utility operations, approving rate changes, and enforcing renewable energy and efficiency targets. Attending public hearings, submitting written comments, and meeting with commissioners can sway them to encourage utilities to enhance their offerings.

> **Through thoughtful communication, sharing experiences, and providing feedback, farmers can convey the unique challenges they face and propose solutions that benefit both their operations and the broader community.**

By actively participating in forums hosted by public utility commissions and utilities, such as open floor discussions, farmers and agribusinesses can effectively advocate for their specialized needs and interests. Through thoughtful communication, sharing experiences, and providing feedback, farmers can convey the


USDA photo by Lance Cheung

unique challenges they face and propose solutions that benefit both their operations and the broader community. A prime example of this collaboration is Southern California Edison (SCE) and California's Public Utility Commission (CPUC) annual in-person and virtual public forum discussing SCE's electricity rates.[255] During this public forum, the public can make comments and raise concerns to those overseeing electricity rates. Public utility commissions across the nation host similar events, such as Maine's Public Utility Commission (MPUC). As of March 12, 2024, the MPUC began hosting its "Coffee and Conversation" forums to hear general concerns Mainers have with their utilities.[256] Public participation reinforces the value and needs of agricultural customers while fostering collaborative relationships with utilities that can constructively influence policy decisions and program offerings.

State legislatures create the framework and guiding policies within which public utility commissions operate. Rate design can be directed by legislation and used to meet policy goals such as enhancing energy efficiency, lowering peak energy demand, and encouraging electrification.[257] State legislatures have the power to instruct commissions to explore particular rate designs, carry out pilot programs and other studies, and report their conclusions.[258] To encourage a state's legislature to facilitate electrification in agriculture, advocates should seek to meet directly with the congresspeople representing their district and encourage local agricultural groups and organizations to do so.[259]

Several states, including Maine, Colorado, New York, Illinois, and North Carolina, have enacted legislation to advance beneficial electrification efforts.[260] While most of the statutory provisions focus on the electrification of transportation, housing, and commercial buildings, these state-specific efforts provide valuable case studies and successful models for other states to consider in seeking to promote beneficial electrification in agriculture. Notably, Connecticut specifically requires its electric utilities to "implement conservation and load management programs for agricultural customers," though it does so outside of an overarching policy encouraging beneficial electrification.[261]

CASE STUDY

USDA photo by Lance Cheung

Legislative Support for Beneficial Electrification in Maine and Colorado

Examining policy examples from Maine and Colorado offers a sense of how states can craft legislation to promote beneficial electrification. Notably, both states define "beneficial electrification" within their legislation, highlighting its potential to reduce reliance on fossil fuels, benefit consumers and utilities, and improve environmental outcomes.

COLORADO SB21-246: ELECTRIC UTILITY PROMOTE BENEFICIAL ELECTRIFICATION[262]

This bill directs the Colorado Public Utilities Commission (PUC) to require that investor-owned electric utilities (IOUs) in the state file a beneficial electrification plan every three years. The plan must include:

1. Programs to advance beneficial electrification for residential and commercial customers;
2. Programs targeted to low-income households or disproportionately impacted communities, with at least 20% of the total beneficial electrification program funding targeted to programs that serve these communities;
3. Projected fuel savings;
4. Projected cost-effectiveness calculations, including the social cost of methane and carbon dioxide emissions and an appropriate social discount rate in the cost-benefit analysis;
5. Projected reductions in greenhouse gas emissions;
6. Incentives to facilitate beneficial electrification, with programs targeted towards new and existing building markets;
7. An outreach plan for engagement with customers in low-income households and disproportionately impacted communities; and
8. Documentation that the utility's beneficial electrification plan is consistent with maintaining the reliability of the electric grid.

This bill further directs IOUs to incorporate the social cost of methane and carbon dioxide emissions, any avoided upstream emissions, and the incremental carbon dioxide emissions in its cost-benefit analysis of the beneficial electrification plan. The PUC can allow an electric utility to offer incentives to its customers to replace gas appliances with high-efficiency appliances and recover the cost of implementing approved beneficial electrification plans.

CASE STUDY

Legislative Support for Beneficial Electrification in Maine and Colorado (cont.)

MAINE LD 1464: AN ACT TO SUPPORT ELECTRIFICATION OF CERTAIN TECHNOLOGIES FOR THE BENEFIT OF MAINE CONSUMERS AND UTILITY SYSTEMS AND THE ENVIRONMENT[263] AND MAINE LD 1724 : AN ACT TO ENACT THE BENEFICIAL ELECTRIFICATION POLICY ACT[264]

Maine recently enacted two complementary legislative bills aimed at promoting beneficial electrification, which it defines as transitioning from fossil fuels to electricity in a way that benefits consumers, utility systems, and the environment.

LD 1464 focuses on investigating the challenges hindering the implementation of beneficial electrification in the transportation and heating sectors. Efficiency Maine Trust is tasked with assessing the potential roles of electric and natural gas utilities and recommending specific opportunities for electrification. Meanwhile, the Public Utilities Commission is empowered to solicit proposals for pilot programs designed to promote beneficial electrification in the transportation sector, such as developing electric vehicle chargers with load management features, utility investments in fast-charging infrastructure, customer awareness campaigns, and financial incentives to encourage participation.

LD 1724 builds upon this foundation by establishing a multi-year plan to promote beneficial electrification, which may include acquiring more renewable energy sources to meet the growing demand for electricity. Efficiency Maine Trust will create a separate plan to facilitate the implementation of this policy. The act also mandates collaboration between various state agencies to identify opportunities that encourage investment in adopting and developing beneficial electrification technologies, as well as offering consumers more choices in electricity supply and billing options. Additionally, the Public Utilities Commission is required to conduct a study on cost-effective ways to finance beneficial electrification products for consumers, such as energy-efficient appliances, home energy storage systems, and electric vehicle charging equipment.

Together, these legislative initiatives demonstrate Maine's commitment to transitioning towards a future powered by clean and sustainable electricity. By addressing challenges, exploring the roles of different stakeholders, and implementing pilot programs, these acts aim to pave the way for a more sustainable and secure energy future for the state.

Highlighting successful utility programs already serving the farming community can demonstrate the viability and impact of programs designed for agricultural customers.

As a companion to this report, the research team compiled a database of diverse utility programs tailored to meet the needs of agricultural businesses across various states. This database, available at farmandenergyinitiative.org/projects/beneficial-electrification-in-agriculture/utility-programs, organizes information into distinct, searchable, and filterable categories including the specific agricultural end use targeted by each program. Stakeholders can find examples of programs that help farms and agribusinesses invest in efficient electric technology, improve their bottom line, and contribute to a more sustainable and equitable future.

FIGURE 5: SAMPLE FROM THE FARM AND ENERGY INITIATIVE'S DATABASE OF UTILITY PROGRAMS FOR BENEFICIAL ELECTRIFICATION IN AGRICULTURE

Utility	State	Type of Utility	Program Type	Targeted Technology
Alliant Energy	Iowa	Investor-owned	Rebate	Space Heating, Cooling, ... Lighting
Alliant Energy	Wisconsin	Investor-owned	Rebate	Rewiring
Arkansas Entergy	Arkansas	Investor-owned	Agricultural Service Base Rate	None
Avista	Washington	Investor-owned	Agricultural Service Base Rate	None
Black Hills Energy	South Dakota	Investor-owned	Agricultural Service Base Rate	Pumping and Irrigation
Central Coast Community	California	Alternative Electricity Sup...	Rebate	Vehicle
Central Coast Community Energy	California	Alternative Electricity Sup...	Agricultural Service Base Rate	Pumping and Irrigation Space Heating, Cooling, ...
Choctaw Electric Cooperative	Oklahoma	Electric Cooperative	Agricultural Service Base Rate	None
Choctaw Electric Cooperative	Oklahoma	Electric Cooperative	Agricultural Service Base Rate	None
Connecticut Department of Agriculture	Connecticut	Non-utility program	Grant	Product Management/Pr...
Connecticut Department of Agriculture	Connecticut	Non-utility program	Grant	Product Management/Pr...
Connecticut Department of Agriculture	Connecticut	Non-utility program	Grant	Product Management/Pr...
Connecticut Department of Agriculture	Connecticut	Non-utility program	Grant	Product Management/Pr...
Dairyland Power	Wisconsin	Electric Cooperative	Interruptible Rate	Pumping and Irrigation Water Heating and Cooli...

Conclusion

USDA photo by Lance Cheung

This report serves as a guide for thought leaders, policymakers, utility companies, and the agricultural community at large, providing insights and recommendations to advance beneficial electrification in agriculture. With continued commitment and innovation, the agricultural sector can significantly contribute to a cleaner, more sustainable energy future.

Beneficial electrification in the agricultural sector is a significant opportunity to reduce greenhouse gas emissions, improve grid management, and cut costs. However, achieving these benefits requires overcoming several challenges, including improvements in rural grid infrastructure, digital connectivity, and increased collaboration between utilities and farmers. Regulatory changes, such as the implementation of performance-based regulation, can help align utility incentives with these goals. Additionally, effective communication and outreach, particularly through agricultural liaisons, will be crucial in promoting the adoption of electric technologies in the agricultural sector.

The journey towards a decarbonized agricultural sector is complex and requires a concerted effort from policymakers, utilities, and farmers.

Collaboration and education will be key in ensuring that farms and agribusinesses are not left out of the clean energy transition. Stakeholders must work collaboratively to understand and navigate the unique challenges of farm-specific electrification, advocating for the development of programs that accommodate and enhance agricultural uses. The journey towards a decarbonized agricultural sector is complex and requires a concerted effort from policymakers, utilities, and farmers.

Endnotes

1 Nadja Popovich & Brad Plumer, *How Electrifying Everything Became a Key Climate Solution*, N.Y. Times (Apr. 2023), https://www.nytimes.com/interactive/2023/04/14/climate/electric-car-heater-everything.html.

2 U.S. Env't Prot. Agency, EPA 430-R-24-004, Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2022, at ES-22 tbl. ES-5 (2024), https://www.epa.gov/system/files/documents/2024-04/us-ghg-inventory-2024-main-text_04-18-2024.pdf. By comparison, the residential sector contributed 5.8% of total U.S. GHG emissions, and the commercial sector was responsible for 6.9%.

3 *Greenhouse Gas Inventory Data Explorer*, EPA, https://cfpub.epa.gov/ghgdata/inventoryexplorer/#agriculture/entiresector/allgas/category/current (last updated Aug. 18, 2023).; *see* also U.S. Dep't of Energy, DOE/EE-2635, Industrial Decarbonization Roadmap 3 (2022).

4 *See Greenhouse Gas Inventory Data Explorer*, *supra* note 3.

5 Keith Denis, *Understanding Beneficial Electrification*, COOPERATIVE.COM (Apr. 1, 2019), https://www.cooperative.com/topics/beneficial-electrification/Pages/Understanding-Beneficial-Electrification.aspx.

6 *Electric Utility Demand Side Management – Archive*, EIA, https://www.eia.gov/electricity/data/eia861/dsm/ (last visited May 1, 2024).

7 U.S. Env't Prot. Agency, *supra* note 2 at ES-22.

8 Cong. Budget Off., Emissions of Carbon Dioxide in the Transportation Sector, 14 (2022), https://www.cbo.gov/publication/58861.

9 Cal. Climate Invs., Funding Agricultural Replacement Measures for Emission Reductions (FARMER) Program Guidelines, at iii. (2018), https://ww2.arb.ca.gov/sites/default/files/2018-07/farmerguidelines-final.pdf.

10 Ella Zhou & Trieu Mai, Electrification Futures Study: Operational Analysis of U.S. Power Systems with Increased Electrification and Demand-Side Flexibility, ix (2021), https://www.nrel.gov/docs/fy21osti/79094.pdf.

11 *Id.*

12 Arash Farokhi Soofi et al., *Farm Electrification: A Road-Map to Decarbonize the Agriculture Sector*, 35 Elec. J. 1, 1 (Jan. 20, 2022).

13 David Farnsworth et al., Beneficial Electrification: Ensuring Electrification in the Public Interest, RAP (June 19, 2018) https://www.raponline.org/knowledge-center/beneficial-electrification-ensuring-electrification-public-interest/ (stating that beneficial electrification must reduce environmental impacts, enable better grid management, and/or save money over time).

14 Beneficial Electrification League, https://be-league.org/, (last visited May. 2, 2024). It should be noted that the Beneficial Electrification League includes a fourth requirement: that beneficial electrification "[i]mproves product quality or consumer quality of life." *Id.*

15 Ella Zhou & Trieu Mai, *supra* note 10, at x.

16 *Id.*

17 *Demand Response*, ENERGY.GOV, https://www.energy.gov/oe/demand-response (last visited July. 21, 2023).

18 David Farnsworth et al., *supra* note 13 at 9.

19 Brian Gerke et al., Shift Demand Response: A Primer 4–5 (2018), https://gridworks.org/wp-content/uploads/2018/02/Shift-Demand-Response-Primer_Final_180227.pdf.

20 *Interruptible Program*, Stearns Elec. Ass'n, https://www.stearnselectric.org/save-money-and-energy/commercial-and-agriculture/interruptible-program/ (last visited May 2, 2024).

21 Garrett Fitzgerald et al., Electric Vehicles as Distributed Energy Resources 1, 51 (2016), http://www.rmi.org/pdf_evs_as_DERs.

22 Brian Gerke et al., *supra* note 19 at 2.

23 *Understanding Load Shed*, Entergy, https://www.entergynewsroom.com/storm-center/restoration/loadshed/#:~:text=When%20the%20demand%20for%20electricity,is%20called%20%E2%80%9Cshedding%20load.%E2%80%9D (last visited May 2, 2024).

24 *See Interruptible Program*, *supra* note 20.

25 Dave Inter et al., *Help! I Can't Set the Clock on My Microwave Oven and Now I Need to Program My Heat Pumps, Batteries, Solar Panels, and Electric Vehicle Charger to Save the Planet?!*, 2022 SUMMER STUDY ON ENERGY EFFICIENCY IN BLDGS., Aug. 2021, at I-133.

26 *Electric Meters*, ENERGY.GOV, https://www.energy.gov/energysaver/electric-meters (last visited May 2, 2024).

27 *Id.*

28 *Id.*

29 *See* Dave Inter et al., *supra* note 25, at I-134.

30 *Id.*

31 Tucker, T. N. et al., *Fossil Fuel–Driven Price Volatility Demonstrates the Need for a Renewable Transition*, ROOSEVELT INST., (Nov. 21, 2023) https://rooseveltinstitute.org/publications/fossil-fuel-driven-price-volatility-demonstrates-the-need-for-a-renewable-transition/.

32 DAVID FARNSWORTH ET AL., *supra* note 13 at 9.

33 NAT'L RENEWABLE ENERGY LAB'Y, CHAPTER 10: PEAK DEMAND AND TIME-DIFFERENTIATED ENERGY SAVINGS CROSS-CUTTING PROTOCOLS 10-3 (2013).

34 *Id.* ("Avoided energy costs tend to be higher during periods of higher demand because generating units available during those times tend to have lower efficiency and higher operating costs.").

35 Jared Langevin et al., *U.S. Building Energy Efficiency and Flexibility as an Electric Grid Resource*, 5 JOULE 2102, 2102 (2021).

36 ELLA ZHOU & TRIEU MAI, *supra* note 10, at x.

37 Bethany Frew, et al., *The Curtailment Paradox in the Transition to High Solar Power Systems*. 5 JOULE 1143, 1143 (2021).

38 Devonie Oleson, *Reframing Curtailment: Why Too Much of a Good Thing Is Still a Good Thing*, NREL (July 18, 2022), https://www.nrel.gov/news/program/2022/reframing-curtailment.html.

39 *Solar and Wind Power Curtailments are Rising in California*, EIA, https://www.eia.gov/todayinenergy/detail.php?id=60822 (last updated Oct. 30, 2023).

40 *As Solar Capacity Grows, Duck Curves are Getting Deeper in California*, EIA (June 21, 2023), https://www.eia.gov/todayinenergy/detail.php?id=56880.

41 Jim Lazar et al., Electric Cost Allocation for a New Era 169 (Mark LeBel ed. 2020).

42 ELLA ZHOU & TRIEU MAI, *supra* note 10, at ix.

43 *Id.*

44 DAVID FARNSWORTH ET AL., *supra* note 13 at 10.

45 Keith Dennis et al., Environmentally Beneficial Electrification: The Dawn of 'Emissions Efficiency', 29 The Elec. J.52, 52–58 (2016). https://www.sciencedirect.com/science/article/pii/S1040619016301075.

46 DAVID FARNSWORTH ET AL., *supra* note 13 at 9.

47 ELLA ZHOU & TRIEU MAI, *supra* note 10, at x.

48 DAVID FARNSWORTH ET AL., *supra* note 13 at 29.

49 Robin Lisowski, *Beneficial Electrification: What and Why?*, SLIPSTREAM (Aug. 21, 2018), https://slipstreaminc.org/blog/beneficial-electrification-what-and-why.

50 SUNRISE FARMS, https://sunrisefarmsmaple.com/p/17/About (last visited May 2, 2024).

51 Arian Aghajanzadeh & Peter Therkelsen, *Agricultural Demand for Decarbonizing the Electricity Grid*, 220 J. CLEANER PROD. 827, 827 (2019).

52 PAVITRA SRINIVASAN ET AL., STATE INDUSTRIAL DECARBONIZATION HANDBOOK FOR UTILITIES 1, 15 (2023).

53 Allison F. Takemura, *Electric Utilities 101: A Breakdown of the Basics on US Power Providers*, CANARY MEDIA (Oct. 12, 2022) https://www.canarymedia.com/articles/guides-and-how-tos/power-by-people-glossary-bundle.

54 JIM LAZAR, ELECTRICITY REGULATION IN THE US: A GUIDE, 1, 11–12 (2016).

55 *Id.*; *see also* Allison F. Takemura, *supra* note 53.

56 U.S. ENERGY INFO. ADMIN., ELECTRIC POWER ANNUAL 2022 1, Tbl. 2.2 (2023).

57 Robert Walton, *Utility Efficiency Spending Falls, Leading to 5.4% Drop in Energy Savings: ACEEE, UTILITYDIVE* (Aug. 25, 2023), https://www.utilitydive.com/news/utility-energy-efficiency-spending-declined-5-percent-from-2018-to-2021/691852/; *see also* Consortium for Energy Efficiency, 2020 State of the Efficiency Program Industry 1, 15–16 (2020). 25, 2023), https://www.utilitydive.com/news/utility-energy-efficiency-spending-declined-5-percent-from-2018-to-2021/691852/

58 Customer Energy Efficiency Programs, ACEEE, https://database.aceee.org/state/customer-energy-efficiency-programs (last updated July 2016).

59 *Id.*

60 *Id.*

61 Brian Gerke et al., *supra* note 19 at 2.

62 ANDREW SATCHWELL & RYAN HLEDIK, MAKING GRID EFFICIENT BUILDINGS A WIN FOR BOTH CUSTOMERS UTILITIES 1, 6 (2022).

63 *Agriculture*, N.Y. STATE, https://www.nyserda.ny.gov/PutEnergyToWork/Industry-Energy-Solutions/Agriculture (last visited May 2, 2024).

64 BENJAMIN ZANK ET AL., ELECTRIC PANELS FOR THE 21ST CENTURY, 2-157, 2-161 (2022).

65 FOCUS ON ENERGY, CUSTOM INCENTIVE GUIDE 1, 2 (2024).

66 *Id.* at 3.

67 Fred Gordon, Energy Trust of Oregon, Leverage—How Utility-Funded Programs are Addressing Cost Effectiveness and Rate Impact Issues Through Co-Funding (Aug. 23, 2022).

68 *Id.*

69 *Agricultural Equipment*, EFFICIENCY VT., https://www.efficiencyvermont.com/products-technologies/agricultural-equipment (last visited May 2, 2024).

70 *Agriculture*, ENERGY TRUST OF OR., https://www.energytrust.org/programs/agriculture/ (last visited May 2, 2024).

71 *Agribusiness*, FOCUS ON ENERGY, https://focusonenergy.com/business/agribusiness (last visited May 2, 2024).

72 *About*, EFFICIENCY ME., https://www.efficiencymaine.com/about/ (last visited May 2, 2024).

73 ME. STAT. TIT.35-A §10103 (2019).

74 *Is Your Business Using Energy Efficiently?*, EFFICIENCY ME. (Feb. 26, 2021), https://www.efficiencymaine.com/is-your-business-using-energy-efficiently/.

75 Ugo Bardi et al., Turning Electricity Into Food: The Role of Renewable Energy in the Future of Agriculture, 53 J. Cleaner Prod. 224, 224 (2013). https://www.sciencedirect.com/science/article/abs/pii/S0959652613002291

76 KYLE CLARK & ENSAVE, FARM BENEFICIAL ELECTRIFICATION: OPPORTUNITIES AND STRATEGIES FOR RURAL ELECTRIC COOPERATIVES 9 (2018).

77 *Table 13. Energy Expense for All Well Pumps and Other Irrigation Pumps by Type of Energy Used: 2018*, USDA (Apr. 11, 2019), https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/Farm_and_Ranch_Irrigation_Survey/fris_1_0013_0013.pdf.

78 Robert Sowby & Emily Dicataldo, T*he Energy Footprint of U.S. Irrigation: A First Estimate from Open Data*, 6 ENERGY NEXUS (2022) (showing that fossil fuel-powered irrigation used the equivalent of 23.1 TWh of the 60.6 TWh of total energy consumed by irrigation nationally).

79 KEITH DENIS, UNDERSTANDING BENEFICIAL ELECTRIFICATION 3 (2019), https://www.cooperative.com/topics/beneficial-electrification/Pages/Understanding-Beneficial-Electrification.aspx; *see also* KYLE CLARK & ENSAVE, *supra* note 76.

80 KYLE CLARK & ENSAVE, *supra* note 76 at 6.

81 *Id.*

82 *DR & Agricultural Irrigation*, BONNEVILLE POWER ADMIN., https://www.bpa.gov/energy-and-services/efficiency/demand-response/agricultural-irrigation (last visited May 2, 2024).

83 Arian Aghajanzadeh, *What Happened to Agricultural Demand Response?*, UTILITYDIVE (Mar. 20, 2019), https://www.utilitydive.com/news/what-happened-to-agricultural-demand-response/550829/.

84 *See* KYLE CLARK & ENSAVE, *supra* note 76 at 6.

85 *See Id.*

86 Electric Irrigation Pumps: A Convenient, Cost-Effective Choice for Your Farm, NC ELEC. COOPS., (last visited May 2, 2024).

87 *Id.*

88 *2023 Summary of Services and Incentives for Agribusiness*, FOCUS ON ENERGY, https://s3.us-east-1.amazonaws.com/focusonenergy/staging/inline-files/2023/BIZ-AG-Summary_of_Services.pdf (last visited May 2, 2024).

89 *Irrigation Improvements*, ENERGY TR. OF OR., https://www.energytrust.org/solutions/agriculture-irrigation-improvements/ (last visited May 2, 2024).

90 *Irrigation Modernization*, ENERGY TR. OF OR., https://www.energytrust.org/renewable-energy/irrigation-modernization/ (last visited May 2, 2024).

91 *See* IDAHO POWER, IRRIGATION PEAK REWARDS 1 (2024)

92 *A Flexible Irrigation Pilot Program for Agriculture*, VALLEY CLEAN ENERGY, https://valleycleanenergy.org/programs/a-flexible-irrigation-pilot-program-for-agriculture/ (last visited May 2, 2024).

93 *Id.*

94 Cal. Cmnt. Choice Ass'n, Comments on Assigned Commissioner's Phase 1 Scoping Memo and ruling (Dec. 2, 2022), https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M499/K659/499659049.PDF.

95 *Id.*

96 KYLE CLARK & ENSAVE, *supra* note 76 at 7.

97 *See* K. T. Sharpe et al., Electrical and Thermal Energy Consumption in Midwest Commercial Swine Facilities 1 (2019).

98 *See* Heidi Lindberg et al., *How Do I Use Less Energy to Heat My Greenhouse*, MICH. ST. UNIV. (Nov. 5, 2021), https://www.canr.msu.edu/news/how-do-i-use-less-energy-to-heat-my-greenhouse.

99 KYLE CLARK & ENSAVE, *supra* note 76 at 8.

100 Casey Crownhart, *Everything You Need to Know About the Wild World of Heat Pumps*, MIT TECH. REV. (Feb. 14, 2023) https://www.technologyreview.com/2023/02/14/1068582/everything-you-need-to-know-about-heat-pumps/.

101 *Federal Heat Pump Tax Credits*, REWIRING AM., https://www.rewiringamerica.org/app/ira-calculator/information/heat-pump-air-conditioner-heater (last visited May 2, 2024).

102 *Id.*

103 *See* Luca Alberti et al., *Geothermal Heat Pumps for Sustainable Farm Climatization and Field Irrigation*, 195 Agri. Water Mgmt. 187 (2018).

104 *See* Tina Casey, *Industrial Heat Pumps Are Coming for Your Fossil Fuels*, CLEAN TECHNICA (Feb. 2024), https://cleantechnica.com/2024/02/12/industrial-heat-pumps-are-coming-for-your-fossil-fuels/.

105 *See* Jenny Crawley, *Demand Response with Heat Pumps: Practical Implementation of Three Different Control Options*, 44 Bldg. Serv. Eng'g Rsch. & Tech. 109 (2023).

106 *Id.*

107 *Id.*; *see* also *The Easiest Way to Save—On Call®, FPL*, https://www.fpl.com/save/pdf/oncall.pdf (last visited May 2, 2204).

108 *Smart Thermostats Allow Remote Control*, AUSTIN ENERGY, https://savings.austinenergy.com/residential/learn/monitor-your-usage/pp-thermostats (last updated Feb. 1, 2024).

109 Ranal Tudawe et al., *Electric Utility Rates Are Critical to Broad Space-Heating Electrification: Data from the Midwest*, ACEEE 2022 SUMMER STUDY ON ENERGY EFFICIENCY IN BLDGS., Aug 2022, at 6-149.

110 Lee J. Johnston & Erin Cortus, *Time to Think About Controlling Heating Costs*, NAT'L HOGFARMER (Dec. 2, 2021), https://www.nationalhogfarmer.com/livestock-management/time-to-think-about-controlling-heating-costs.

111 U.N. ENV'T PROGRAME ET AL., SUSTAINABLE FOOD COLD CHAINS: THE MISSING LINK FOR SUSTAINABLE DEVELOPMENT 1, 2 (2022).

112 INT'L INST OF REFRIGERATION, THE CARBON FOOTPRINT OF THE COLD CHAIN 1, 13 (2021), https://iifiir.org/en/fridoc/the-carbon-footprint-of-the-cold-chain-7-lt-sup-gt-th-lt-sup-gt-informatory-143457.

113 *Id.* at 10.

114 FOCUS ON ENERGY, ENERGY EFFICIENCY BEST PRACTICES GUIDE: AGRICULTURE 1, 68 (2020).

115 INT'L INST OF REFRIGERATION, THE CARBON FOOTPRINT OF THE COLD CHAIN 1, 5 (2021).

116 Richard Beard, *Energy-Efficient Refrigeration for Farms*, FARM ENERGY (Apr. 3, 2019), https://farm-energy.extension.org/energy-efficient-refrigeration-for-farms/.

117 *See* FOCUS ON ENERGY, *supra* note 114 at 20.

118 *Id.*

119 *Id.* at 24.

120 *Id.* at 68.

121 Ammi Amarnath et al., Demand Response Capabilities of Refrigerated Warehouses, 12-175 (Aug. 2022).

122 *Water Heating*, WIS. ENERGY EFFICIENCY & RENEWABLE ENERGY, https://fyi.extension.wisc.edu/energy/dairy-farms/water-heating/ (last visited May 2, 2024).

123 *See* Heidi Lindberg et al., *supra* note 98.

124 Richard Beard, *Energy-Efficient Hot Water for Farms*, FARM ENERGY (April 3, 2023), https://farm-energy.extension.org/energy-efficient-hot-water-for-farms/.

125 Estimating Costs and Efficiency of Storage, Demand, and Heat Pump Water Heaters, ENERGY.GOV, https://www.energy.gov/energysaver/estimating-costs-and-efficiency-storage-demand-and-heat-pump-water-heaters (last visited May 2, 2024).

126 AM. COUNCIL FOR AN ENERGY-EFFICIENT ECO., DEMAND FLEXIBILITY OF WATER HEATERS 1, 5–6 (2023).

127 Jefferson Kolle & Chuck Bickford, *All About Heat-Pump Water Heaters*, THIS OLD HOUSE, https://www.thisoldhouse.com/plumbing/21015567/all-about-heat-pump-water-heaters (last visited May 2, 2024) (The average annual cost to operate a 50-gallon conventional electric water heater is $436, while the average annual operating cost of a 50-gallon heat pump water heater is $122).

128 *Id.*

129 *See* AM. COUNCIL FOR AN ENERGY-EFFICIENT ECO., *supra* note 126 at 1.

130 *Id.*

131 *Id.* at 2.

132 *Id.* at 1.

133 Energy Conservation Program: Energy Conservation Standards for Consumer Water Heaters, 88 Fed. Reg. 49085 (proposed July 28, 2023) (to be codified at 10 C.F.R. pt 429, 430.)

134 *Id.*

135 *See* AM. COUNCIL FOR AN ENERGY-EFFICIENT ECO., *supra* note 126 at 1.

136 Demand Response, VALLEY RURAL ELEC. COOP., INC., https://valleyrec.com/content/demand-response (last visited May 2, 2024).

137 *See* AM. COUNCIL FOR AN ENERGY-EFFICIENT ECO., *supra* note 126 at 4.

138 *Id.* at 1.

139 *Id.* at 6.

140 *Id.*

141 *Id.*

142 *Load Management*, DAIRYLAND POWER COOP., https://www.dairylandpower.com/load-management (last visited May 2, 2024).

143 *Id.*

144 *Id.*

145 M. Shahbandeh, *U.S. Maple Syrup Production 2023*, by State, STATISTA (Sept. 12, 2023).

146 Laure Patouillard, *Is Maple Syrup Good for the Planet?*, CIRAIG (Mar. 2, 2022), https://ciraig.org/index.php/blog/is-maple-syrup-good-for-the-planet/.

147 *Refillable Water Bottles: Research in Progress*, Univ. Wisconsin-Madison: OFF. SUSTAINABILITY (July 17, 2017), https://sustainability.wisc.edu/refillable-water-bottles-research-in-progress/.

148 KYLE CLARK & ENSAVE, *supra* note 76 at 11.

149 V. GEKAS, & K. ANTELLI, *Evaporators*, in ENCYC. DAIRY SCIS.955 (1st ed. 2002).

150 *See* Laure Patouillard, *supra* note 146.

151 *Maple Syrup Production*, WIS. EENERGY EFFICIENCY & RENEWABLE ENERGY, https://fyi.extension.wisc.edu/energy/maple-syrup-production/ (last visited May 2, 2024).

152 *Energy Transformation Programs*, VT. ELEC. COOP., https://vermontelectric.coop/energy-transformation-programs (last visited May 2, 2024).

153 VT. ELEC. COOP., 2024 TIER III PLAN—VERMONT ELECTRIC COOPERATIVE NOVEMBER 1, 2023, at 3.

154 BTHANY REINHOLTZ, RADIO WAVE GRAIN DRYING SYSTEMS: AN OPPORTUNITY FOR AGRICULTURAL COST SAVINGS AND GRAIN QUALITY ENHANCEMENT THROUGH ENERGY EFFICIENCY AND BENEFICIAL ELECTRIFICATION 1, 5 (2020).

155 *Id.* at 4.

156 *Id.*

157 Kabiru Ayobami Jimoh et al., Recent Advancements in the Drying Process of Grains, 15 FOOD ENG'G REVS. 548, 573 (2023).

158 James Dyck, *Grain Drying and Energy Efficiency: The Basics*, FARMTARIO (Nov. 4, 2021), https://farmtario.com/news/grain-drying-and-energy-efficiency-the-basics/.

159 *Id.*

160 *Id.*

161 *Id.*

162 *Id.*

163 *Grain Dryers: Electric v. Tractor Drive*, FARMERS WEEKLY (Nov. 21, 2012) https://www.fwi.co.uk/machinery/grain-dryers-electric-vs-tractor-drive.

164 Matt McIntosh, *Getting a Jump on the Power Grid*, FARMTARIO (June 13, 2018) https://farmtario.com/news/getting-a-jump-on-the-power-grid/.

165 *Id.*

166 *See* BETHANY REINHOLTZ, *supra* note 154 at 9.

167 *See* James Dyck, *supra* note 158.

168 *Inspirational Ideas: A Grain Dryer Which Is Both Energy and Time Efficient*, EIP-AGRI (May 3, 2018), https://ec.europa.eu/eip/agriculture/en/news/inspirational-ideas-grain-dryer-which-both-energy.html.

169 *See* MOUNTRAIL-WILLIAMS ELEC. COOP., RATE SCHEDULES 1 (2023).

170 *Grain Drying Program*, MOUNTRAIL-WILLIAMS ELEC. COOP., https://www.mwec.com/grain-drying-program (last visited May 2, 2024).

171 MOUNTRAIL-WILLIAMS ELEC. COOP., *supra* note 169 at 28.

172 *Id.* at 28.

173 Arash Farokhi Soofi, *Farm Electrification: A Road-Map to Decarbonize the Agriculture Sector*, 35 Elec. J. 1, 5 (2022).

174 Marc Heller, *Climate Change Fuels Drive Toward Cleaner Tractors*, GREENWIRE (Oct. 20, 2021), https://www.eenews.net/articles/climate-change-fuels-drive-toward-cleaner-tractors/; *Agriculture, Including Electricity Use, Accounted for an Estimated 11.2 Percent of U.S. Greenhouse Gas Emissions in 2020*, USDA, https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=104206#:~:text=From%202019%20to%202020%2C%20agricultural,share%20of%20the%20U.S.%20economy (last updated July 11, 2022).

175 Massimiliano Varani et al., *Controlling Idling: A Ready-Made Solution for Reducing Exhaust Emissions from Agricultural Tractors*, 221 BIOSYSTEMS ENG'G 283, 283–292 (2022).

176 Ville Olkkonen et al., *Electrification of the Agricultural Sector in Norway in an Effort to Phase Out Fossil Fuel Consumption*, 276 ENERGY 1 (2023).

177 Kayan Clarke et al., *A Narrative Review of Occupational Air Pollution and Respiratory Health in Farmworkers*, 18 Int'l J. Env't Rsch. & Pub. Health, Apr. 2021, at 2, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8070429/pdf/ijerph-18-04097.pdf.

178 KYLE CLARK & ENSAVE, *supra* note 76 at 8.

179 STRATIS RESEARCH, ELECTRIC FARM TRACTOR MARKET 1 (2030).

180 *See* Ville Olkkonen et al., *supra* note 176.

181 Simone Bruckner, *Electrifying Agriculture—How EV Tractors Can Support the Sector's Sustainable Shift*, AGRITECH TOMORROW (Nov 15, 2022), https://www.agritechtomorrow.com/article/2022/11/electrifying-agriculture-how-ev-tractors-can-support-the-sectors-sustainable-shift/14163.

182 Lindsey Campbell, *Going Green: Can Electric Tractors Overtake Diesel?*, MODERN FARMER (Mar. 28, 2020), https://modernfarmer.com/2020/03/going-green-can-electric-tractors-override-diesel/.

183 Jaap Sak & Jort Hoestra, *Will Farmers Go Electric? How Dutch Environmental Regulation Affects Tractor Purchase Motivations and Preferences*, 102 ENERGY RSCH. & SOC. SCI. 1, 2 (2023).

184 *Electric Power Economics: Cost Analysis of Charging EV Tractors*, MONARCH (Oct. 5, 2023), https://www.monarchtractor.com/blog/cost-to-charge-ev.

185 Inflation Reduction Act of 2022, Pub. L. No. 117-169, § 13403, 136 Stat 1818, 1964.

186 *VEC Electric Forklift Form*, VT. ELEC. COOP., https://eternityweb.formstack.com/forms/vermont_electric_forklift (last visited May 2, 2024).

187 *See* VT. ELEC. COOP., *supra* note 152, at 16.

188 *Guide to Electric Forklifts: Costs, Brands, and Advantages*, COSTOWL.COM, https://www.costowl.com/b2b/forklifts/forklift-electric-cost/#:~:text=Electric%20Forklift%20Costs%20%23%201%20Small%20capacity%20%283%2C000,-%20%2470%2C000%204%20Heavy%20capacity%20%2812%2C000%2B%20lbs%29%3A%20%2460%2C000%2B (last updated Oct. 15, 2024).

189 BEIA SPILLER, MEDIUM- AND HEAVY-DUTY VEHICLE ELECTRIFICATION: CHALLENGES, POLICY SOLUTIONS, AND OPEN RESEARCH QUESTIONS 1, 8 (2023).

190 *Id.*

191 Inflation Reduction Act of 2022, Pub. L. No. 117-169, § 13403, 136 Stat 1818, 1966

192 *See* Beia Spiller, *supra* note 189, at 9.

193 Paramveer Singh, *Navigating CARB's Advanced Clean Fleet Regulation: What Growers Need to Know*, Salinas Valley Ag. (Dec. 6, 2023), https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=58501.

194 Cal. Air Res. Bd., Guide to Off-Road Vehicle & Equipment Regulations 1, 11 (2023).

195 Cal. Climate Invs., FINAL: Funding Agricultural Replacement Measures for Emission Reductions (FARMER) Program Guidelines 1 (2018).

196 Memorandum from Sydney Vergis, Chief, Mobile Source Control Division, to Richard W. Corey, Executive Officer, California Air Resources Board (Apr. 5, 2022) https://ww2.arb.ca.gov/sites/default/files/2022-04/2022farmermemo-projectcategories.pdf.

197 *Id.*

198 Garrett Fitzgerald et al., *supra* note 21, at 51.

199 *Id.*

200 *Id.*; *see also Statement of Rates*, NVEnergy (Feb. 15, 2024), https://www.nvenergy.com/publish/content/dam/nvenergy/brochures_arch/about-nvenergy/rates-regulatory/electric-schedules-north/Statement_of_Rates_Electric_North.pdf.

201 Lori Lovely, *Trends in Fleet Electrification for 2024*, ELEC. CONTRACTOR (Dec. 18, 2023), https://www.ecmag.com/magazine/articles/article-detail/trends-in-fleet-electrification-for-2024.

202 Press Release, Monarch, Monarch Tractor and Farm Electrification Consortium Partners Awarded California Energy Commission Grant for "Vehicle-to-Building Technologies for Resilient Backup Power" (Nov. 3, 2022), https://www.businesswire.com/news/home/20221103005414/en/Monarch-Tractor-and-Farm-Electrification-Consortium-Partners-Awarded-California-Energy-Commission-Grant-for-%E2%80%9CVehicle-to-Building-Technologies-for-Resilient-Backup-Power%E2%80%9D.

203 J. Matthew Pryor, On-Farm Electrification Isn't an Equipment Change, It's a Systems Change, LinkedIn (July 12, 2023), https://www.linkedin.com/pulse/on-farm-electrification-isnt-equipment-change-its-systems-pryor/.

204 Nat'l Elec. Mfg. Ass'n, Electrified Agrculture, Best Practice Guide For Utilities 1, 9 (2019). https://www.nema.org/docs/default-source/nema-documents-libraries/nema-best-practice-guide-for-utilities.pdf?sfvrsn=14c7af78_1.

205 Choctaw Elec. Coop., Terms and Conditions and Service Rates, 1, 7 (2022) https://drive.google.com/file/d/137-eQio1DHZTc40Znz5IhpV80VezytU-/view.

206 Cal. Pub. Util. Comm'n, Rev. Cal. PUC Sheet No. 69926-E, Rule 1 1 (2020).

207 *See* Nat'l Elec. Mfg. Ass'n, *supra* note 204, at 9.

208 Nat'l Acad. of Sci., Eng'g, & Med., Enhancing the Resilience of the Nation's Electricity System 28 (2017).

209 *See* Benjamin Zank et al., *supra* note 64, at 2-160.

210 *Id.* at 2-162.

211 *Id.* at 2-160.

212 *Id.* at 2-162.

213 Cal. Elec. Code. §§ 150(n), 150(s)-(v).

214 *See* Benjamin Zank et al., *supra* note 64, at 2-160.

215 *Id.* at 2-164.

216 *Id.* at 2-163.

217 *Id.* at 2-164.

218 *Id.* at 2-165.

219 *See* Nat'l Elec. Mfg. Ass'n, *supra* note 204, at 16.

220 *Id.* at 17.

221 *Id.* at 7.

222 Michele Boyd, *The Potential of Agrivoltaics for the U.S. Solar Industry, Farmers, and Communities*, ENERGY.GOV (Apr. 17, 2023). https://www.energy.gov/eere/solar/articles/potential-agrivoltaics-us-solar-industry-farmers-and-communities.

223 *See* Ville Olkkonen et al., *supra* note 176.

224 Dave Hardin & K. Kaufmann, *Transactive Energy 101: DERs Drive Real-Time Marked Dynamics to the Distribution System—Are We Ready?*, SMART ELEC. POWER ALL. (Oct. 26, 2017), https://sepapower.org/knowledge/transactive-energy-101/.

225 Kathiann M. Kowalski, *Weight, Dawn-To-Dusk Demands Pose Challenges to Electrifying Farm Vehicles*, ENERGY NEWS NETWORK (Aug. 18, 2021), https://energynews.us/2021/08/18/weight-dawn-to-dusk-demands-pose-challenges-to-electrifying-farm-vehicles/.

226 *USDA Report Makes Case for Rural Broadband*, FARMPROGRESS (May 1, 2019), https://www.farmprogress.com/farm-business/usda-report-makes-case-for-rural-broadband; *see also* U.S. DEP'T OF AG., A CASE FOR RURAL BROADBAND 1 (2019).

227 KYLE CLARK & ENSAVE, *supra* note 76.

228 *Reconnect Loan and Grand Program*, USDA, https://www.usda.gov/reconnect (last visited May 2, 2024).

229 *Id.*

230 *See Kathiann M. Kowalski*, *supra* note 225.

231 *Id.*

232 STEVEN NADEL, HOW UTILITY ENERGY EFFICIENCY PROGRAMS CAN USE NEW FEDERAL FUNDING 1, 2 (2023).

233 *Rural Energy for America Program Renewable Energy Systems & Energy Efficiency Improvement Guaranteed Loans & Grants*, USDA, https://www.rd.usda.gov/programs-services/rural-energy-america-program-renewable-energy-systems-energy-efficiency (last visited May 2, 2024).

234 *Id.*

235 *Id.*

236 *Energy Programs*, USDA, https://www.rd.usda.gov/programs-services/energy-programs (last visited May 2, 2024).

237 *On-Farm Energy Initiative*, USDA, https://www.nrcs.usda.gov/programs-initiatives/on-farm-energy-initiative (last visited May 2, 2024).

238 *Id.*

239 *Id.*

240 *Electric Infrastructure Loan & Loan Guarantee Program*, USDA, https://www.rd.usda.gov/programs-services/electric-programs/electric-infrastructure-loan-loan-guarantee-program

241 *Id.*

242 *Electric Programs*, USDA https://www.rd.usda.gov/programs-services/electric-programs (last visited May 2, 2024).

243 *See* Agribusiness *supra* note 71.

244 KYLE CLARK & ENSAVE, *supra* note 76 at 9.

245 *Farmer Outreach Needed to Increase Adoption of Research Innovations*, NAT'L SUSTAINABLE AG. COAL. (July 29, 2019), https://sustainableagriculture.net/blog/rmf-report-extension-outreach/.

246 *See* Arian Aghajanzadeh, *supra* note 83; Arian Aghajanzadeh & Peter Therkelsen, *Agricultural Demand for Decarbonizing the Electricity Grid*, 220 J. CLEANER PROD. 827, 832 (2019).

247 *See* Arian Aghajanzadeh & Peter Therkelsen, *supra* note 245 at 832.

248 *Id.*

249 KYLE CLARK & ENSAVE, *supra* note 76 at 10.

250 *See* BENJAMIN ZANK ET AL., *supra* note 64, at 2-161.

251 KYLE CLARK & ENSAVE, *supra* note 76 at 10.

252 *Id.*

253 Gretchen Schimelpfenig, *Data-Driven Energy Efficiency in Controlled Environment Agriculture*, 2022 SUMMER STUDY ON ENERGY EFFICIENCY IN BLDGS., Aug 2022, at 3-136.

254 *Id. at* 3-138.

255 *Public Forum on Southern California Edison Company (SCE)'s Rate Requests*, CAL. PUB. UTILS. COMM'N, https://www.cpuc.ca.gov/proceedings-and-rulemaking/cpuc-public-participation-hearings (last visited May 2, 2024).

256 *Other Events Archive*, Maine Public Utility Commission, https://www.maine.gov/mpuc/news/calendar/other-events-archive (last visited May 2, 2024).

257 Glen Anderson et al., *Modernizing the Electric Grid: State Role and Policy Options*, NAT'L CONF. STATE LEGISLATORS, https://www.ncsl.org/energy/modernizing-the-electric-grid (last updated Sept. 22, 2021)

258 *Id.*

259 *How to Schedule & Conduct Meetings with Congress*, CONG. MGMT. FOUND., https://www.congressfoundation.org/resources-for-advocates/citizen-resource-center/scheduling-a-conducting-meetings/terms/summary (last visited May 2, 2024).

260 *See*, e.g., N.Y. Env't Conserv. Law § 75-0103(f)-(g) (2020) (McKinney); *see* also 20 Ill. Comp. Stat. Ann. 627/45 (2023); *see* also N.C. Gen. Stat. Ann. § 62-133.16(d)(2)(g)(2023).

261 CT Gen Stat § 16-19dd (2023).

262 S. Bill 21-246, 73rd Gen. Assemb., Reg. Sess. (Colo. 2021).

263 Support Electrification of Certain Technologies for the Benefit of Maine Consumers and Utility Systems and the Environment Act, Ch. 365, 35-A MRSA § 10102, 10110 (2019).

264 S.P. 688, 131st Spec. Sess., (Me. 2023).

164 Chelsea St, PO Box 96
South Royalton, VT 05068
farmandenergyinitiative.org