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Table of Contents

Table of Contents **1**

List of Figures **3**

Executive Summary **5**

Background **6**

Real-Time Monitoring/Metering Tools 6

Agriculture Modeling Tools 7

Promising Potential 8

Methodology **10**

Original Research Plan 10

Step 1 – Participant Identification 10

Step 2 – Set Up Power TakeOff Accounts and Install Data Collection Hardware 11

Step 3 – Farm Equipment Inventory 11

Step 4 – Develop Preliminary Farm Energy Models 12

Step 5 – Analyze Real-Time Data to Identify Energy Efficiency Opportunities and Iteratively Improve Models 13

Step 6 – Implement Energy Efficiency Opportunities 15

Difficulties Encountered 15

Participant Recruiting 16

Monitoring Equipment Installation Costs 16

Cellular Reception 16

Agriculture Sector Priorities and Participant Effort 17

Conservation Opportunity Identification 17

Project Redirection 20

Specialized Screening Tool 20

Load Profiles 22

Program Design Recommendations to Achieve Conservation in the Agriculture Sector 23

Conclusions **27**

Appendix A: Outreach Flier **28**

Appendix B: Participation Agreement Form 30

Appendix C: Example Farm Inventory 31

Appendix D: Farm Audit Example 37

List of Figures

Figure 1: PTO Platform Main Menu 6
Figure 2: PTO Metering Hardware Kit and CT Clamps 7
Figure 3: Screenshot from Dairy Energy Audit Tool 8
Figure 4: Example Screenshot from a Populated Hog Energy Audit Tool 13
Figure 5. Example of typical demand fluctuation in one day at a dairy site 19
Figure 6. Screenshot of Specialized Screening Tool Sample Definitions Inputs 22
Figure 7. Aggregate Load Profile for Dairy Facilities in Minnesota 23

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Executive Summary

GDS Associates (GDS) was commissioned by the Minnesota Department of Commerce to investigate the possibility of applying real-time energy consumption data analysis tools available in the energy management platform Power TakeOff (PTO) to identify energy conservation opportunities in agriculture settings. PTO's data analysis tools have been shown to be effective in commercial settings. The goal of the project was to combine the analysis tools with modeling tools GDS uses in agriculture settings to develop new methods of quickly identifying conservation opportunities at agriculture sites. This would help utilities to identify savings to meet their Conservation Improvement Program (CIP) goals while engaging a sector historically underrepresented in CIP initiatives. CIP is the collective term for utility ratepayer-funded energy efficiency programs across Minnesota.

We were not able to demonstrate that existing real-time consumption data analysis tools can be modified to become an effective method to identify conservation opportunities at agriculture sites. There are several reasons for this, including limitations of the existing data analysis tools and models, naturally unpredictable consumption patterns at agriculture sites, and competing priorities that marginalize energy considerations on farms.

When it became clear that the study was not going to produce positive results by following the planned methodology, we redirected our efforts to produce a different set of resources to provide value to CIP programs in the agriculture sector. The outcome of this project includes:

- Load profiles for agriculture facility types
- An Excel-based screening tool to analyze real-time data for conservation opportunity
- Recommendations for utilities attempting to reach agriculture customers with conservation offerings
- Examples of inventories and audits performed on agriculture sites

This report outlines the originally proposed goal of the study, difficulties encountered, and the plan to redirect efforts toward the deliverables listed above. It also contains a description of the Excel-based interval data analysis tool and complete recommendations for utility agriculture conservation programs based on lessons learned from the study.

Background

Real-Time Monitoring/Metering Tools

Power TakeOff (PTO) is a partner on this project because they offer a unique electric energy monitoring/metering software platform with data analysis tools to identify actionable energy savings opportunities at participating sites. The platform has been used in the commercial sector to successfully identify no- and low-cost energy savings opportunities, most as part of utility conservation programs. The tools identify usage anomalies by comparing metered data to historical data for the site or to a baseline model for the building type. Identified anomalies often arise from unnecessary electric consumption that can be conserved once the site owner is aware of the opportunity. The platform provides analysis and diagnostic tools to help users (individuals or utility programs) process metered data to identify anomalies in energy usage patterns and capture the associated available savings opportunities.

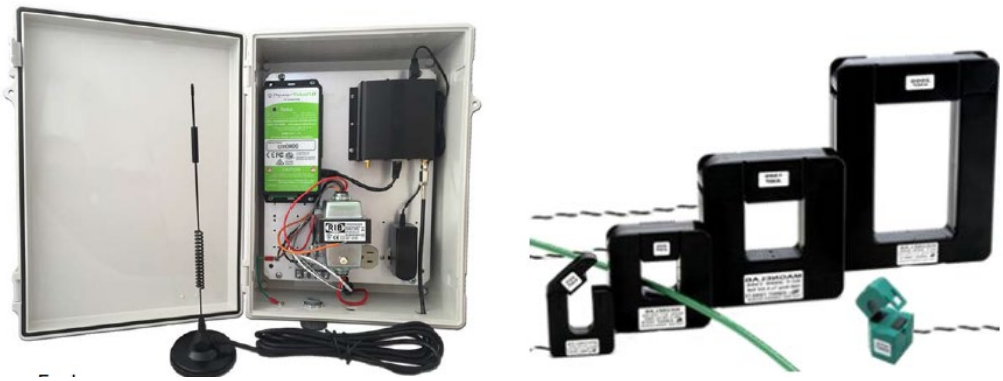
The PTO platform is a web-based software tool that interfaces with advanced metering infrastructure (AMI) utility meters to give users immediate access to energy consumption data and analysis tools. Figure 1 is a screen shot of the main menu. The platform allows users to monitor real-time consumption directly, generate graphic representations of the data, run reports, and set automatic alarms based on desired demand parameters. For applicable site types, the platform can also be used to set up an Energy Star Portfolio Manager account.

Figure 1: PTO Platform Main Menu

The PTO software relies on real-time usage data as an input, which can come from AMI utility meters or from specially-designed metering hardware equipment (also produced by PTO). The PTO hardware kit

comes in an enclosure and includes a controller, modem, and cellular antenna, which allow remote, real-time monitoring of energy metrics (demand, consumption over time, power factor, current, and voltage). The controller is powered directly from the site's main power supply (using a dedicated breaker for safety) which allows it to take instantaneous voltage measurements. The controller also connects to up to 12 sensors. Most often these sensors are CT clamps that measure current passing through the main lines or sub-metered circuits at the site. Figure 2 shows the hardware kit and CT clamps that come with the equipment.

Figure 2: PTO Metering Hardware Kit and CT Clamps

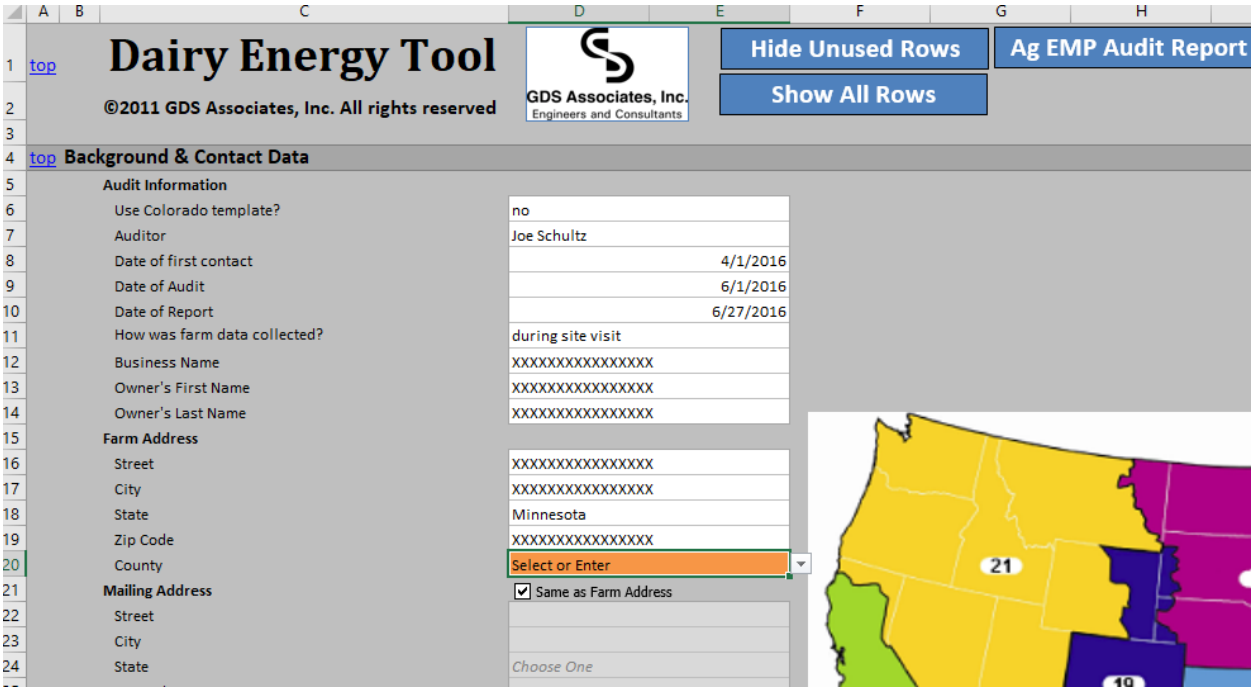


Agriculture Modeling Tools

GDS Associates has developed a suite of agriculture energy auditing tools, which have been refined over many years of experience in the field. There are separate tools for dairy, hog, poultry, greenhouse, orchard, irrigation, and crop sites. The audit tools are used to calculate predicted baseline energy usage for each site, generate energy efficiency and create energy audit reports that list recommendations for conservation opportunities at each site.

Typically, the audit tools are used to identify capital projects (requiring up-front investment from producers), estimate costs to implement those projects, and calculate payback periods for the opportunities. The reports output by the audit tools do include possible no- and low-cost opportunities, but only those that are readily identifiable during a site visit. That is, opportunities that would require monitoring the site operation over time are not necessarily captured by the current tools. Figure 3 shows a screenshot of the dairy energy audit tool

Figure 3: Screenshot from Dairy Energy Audit Tool



Promising Potential

The project team proposed to combine the PTO software metering/monitoring platform data analysis tools with GDS' agriculture audit tools to build a combined tool to identify no- and low-cost energy conservation opportunities at agriculture sites. The objective was to show that with the appropriate understanding of farm sites, the PTO platform can be used to identify no- and low-cost savings opportunities in the agriculture sector in the same way that it has been used successfully in the commercial and industrial sectors historically.

The PTO tool identifies savings by applying data analysis tools based on comparing real-time data to a baseline, which is created from capturing historical electric usage data at the site. The key to the success of the data analysis is having an accurate model of energy consumption from the historical data. In principal, the baseline model created by GDS auditing tools (described above) can be developed for agriculture sites, then the same PTO data analysis tools can be applied to identify savings. This study was designed to build models of actual sites and define energy consumption baselines, which can be used to enable usage of the PTO data analysis tools in agriculture settings.

Once the site models and data analysis tools are developed, they can be used to quickly and continuously process real-time data from a large number of sites to identify low- and no-cost conservation opportunities. The most likely application for these tools will be when AMI deployment rates rise in coming years. The data analysis tools and methods developed through this project can be applied to AMI data by a utility conservation program to remotely identify opportunities and reach out to agriculture customers with possible program offerings to capture the savings.

Based on the no- and low-cost savings opportunities identified in the commercial and industrial sectors, the team estimated that farms would be able to identify up to 7.5% of total energy consumption as possible conservation opportunities. For typical agriculture sites, 7.5% of consumption is between 13,000 and 27,000 kWh annually, depending on the size and type of farm. This level of savings could be a valuable resource for farmers and Minnesota utility CIP programs in the future. Further, agriculture is historically an underserved sector in CIP programs, which makes the development of tools that can help reach these sites an even-more valuable proposition.

Methodology

The methodology employed to complete this study changed over the course of the project. The original strategy did not result in the identification of electric savings at the rate predicted for the first several participating sites, which caused the team to examine the methodology for ways to redirect the project toward producing more valuable final deliverables. This section presents first the originally planned methodology, then the difficulties encountered during implementation, and finally the updated plan to redirect efforts. The original methodology was carried out on eight agriculture sites (5 dairies, 2 hog farms, and 1 poultry farm). Ongoing data collected from those sites was used to implement the updated methodology (no further sites enrolled after redirection).

Original Research Plan

The original research plan was to use GDS agriculture audit tools and a site inventory to develop a preliminary model of energy consumption at each participating site. Then, by continually monitoring real-time consumption at the site, we planned to hone the models so that they reflect actual, measured consumption. At the same time, we would develop PTO real-time data analysis tools calibrated to identify savings at each type of agriculture site. The objective was to show that, with the appropriate baseline model, we could apply PTO energy data analysis tools to identify conservation opportunities at participating sites. The ultimate goal was to demonstrate that utility programs could use this approach in the future to quickly, remotely, and cost-effectively identify conservation opportunities at agriculture sites.

Step 1 – Participant Identification

The first goal of the project was to identify twenty-one agriculture sites to participate in the project (7 each of hog, dairy, and poultry). To find participants, we reached out to a pork growers association, dairy cooperatives, and a MN poultry group, and we published ads in two trade newsletters. We also contacted several rural co-operative utilities that serve agricultural customers to make them aware of the study. When we identified possible participant sites, we sent a high-level informational flier (see Appendix A for flier text) and followed-up by speaking with each about the possible benefits of participating in the study.

From our initial outreach, we recorded contact information for sites that were potentially interested in participating in the study along with high-level site information. From this set of producers, we selected those that were most likely to benefit from the project and asked them to participate. When they were ready to commit to participation, we requested they sign a participation agreement (see Appendix B for participation agreement text) and enrolled them in PTO accounts.

Step 2 – Set Up Power TakeOff (PTO) Accounts and Install Data Collection Hardware

For each farm participating in the study, a dedicated PTP account and subscription was set up. The accounts allowed online access to the PTO real-time energy consumption data and analysis tools for each site. GDS had a master login for all participants to view consumption data for the purpose of completing the study. At times, GDS retrieved screenshots of relevant data for uses when discussing conservation opportunities with participants. Participants were offered the option to set up individual logins to monitor their energy usage online in real time, but no participants made use of the opportunity.

At each site, we installed a dedicated the PTO metering hardware kit (as described in the Background section) to collect and report data to the PTO platform. Originally, we had hoped that some sites would already have pulse meters or even AMI meters [1] installed so that real-time data could be collected directly from the utility without the need for installing additional equipment. Unfortunately, AMI has achieved low penetration rates in Minnesota to date and all participating sites required the installation of dedicated metering hardware kits.

There was one advantage of the metering kits, which is that we were able to collect additional sub-metering data from selected individual circuits and equipment at most sites to gain higher-resolution understanding of energy consumption patterns. However, sub-metering will not likely be an option for future users of this approach to identify savings because data will most likely come from the utility meter. Therefore, we wanted to use the meter-level data to identify savings and use sub-metering data only for honing model parameters. Eight sites completed installation of PTO metering equipment on their main electric service line. Seven of the sites also installed sub-metering. As each install was completed, the PTO software began collecting energy usage data and establishing baseline patterns for the site.[2]

Step 3 – Farm Equipment Inventory

At each site participating in the study, the project team performed an equipment inventory (see Appendix C for an example). This is arguably the most critical step, as it is necessary to have accurate information about actual equipment used at each site in order to develop the energy models needed to identify energy savings opportunities. The equipment inventory was conducted via onsite visit in

[1] AMI and pulse meters are increasingly installed by utilities to remotely collect energy consumption data. These meters are typically installed for operational (billing and outage response) purposes. AMI data could have been used in place of direct measurement tools to collect the necessary data to complete the study. Pulse meters report real time energy consumption data, but do not have additional functionality of full AMI meters. Either type would have been useful for the purposes of this study.

[2] Since all sites used PTO data collection hardware, consent for utilities to share costumer energy usage data with a third party was not necessary. The project team followed data privacy and handling protocols established by PTO in other projects where Minnesota customers' data was collected.

conjunction with the installation of the PTO metering hardware kits. Inventory data was collected on major equipment including:

- Refrigeration equipment
- Vacuum systems
- Water heating
- Lighting
- Fan motors
- Pump motors
- Laundry
- Ventilation controls
- Building envelope (insulation and fenestration)
- Livestock Waterers
- Miscellaneous equipment

Step 4 – Develop Preliminary Farm Energy Models

At each participant site, we developed a preliminary energy model for each farm by entering the inventory data collected in the previous step into GDS site auditing tools. The auditing tools are Excel-based workbooks designed to identify energy conservation opportunities based on the equipment found at the site (more detail in the Background section). Underlying the audit tools are sub-models for each type of equipment and control strategy that predict energy usage of the sub-system. The preliminary whole farm energy models comprise all energy predictions made by the auditing tools populated with inventory data. Each type of site (dairy, hog, poultry) has a different audit tool on which the model is based. Figure 4 is an example of a populated hog energy audit tool.

The models include characterizations of typical operations, incorporating:

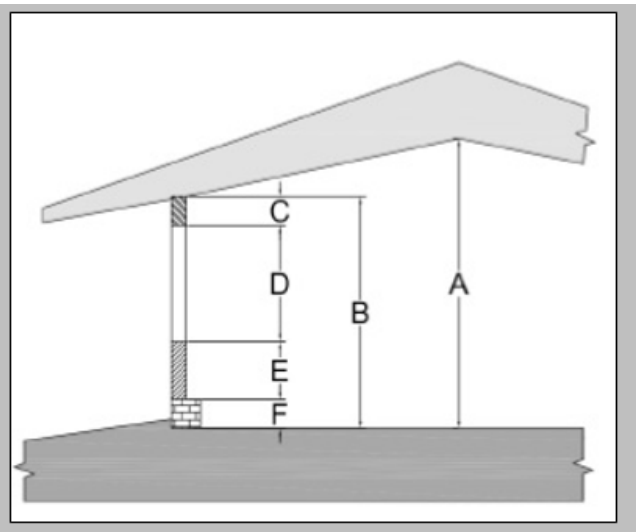
- Local weather data (TMY3)
- Type of farm operation
- Production systems (specialized models for each type of farm)
- Schedule of production periods (i.e. milking times, number and size of flocks, etc.)
- Ventilation fans and control strategy
- Lighting fixtures and schedules
- Ceiling and wall insulation
- Water heating equipment and loads
- Laundry facilities
- Air Compressors and vacuum pumps
- Auger loads and schedules
- Specialized equipment data (misc. motors, appliances, electric fences, etc.)

At each site, GDS audit tools were also used to generate a preliminary audit report which we provided to participants shortly after the site visit. The reports included a high-level summary of equipment and

operations at the site as well as energy conservation actions recommended by the audit tools. The preliminary audits are not part of the main objective of the project; they were included to provide an added benefit to participants and because it can be generated from the audit tools with minimal additional effort. Appendix D shows an example of a preliminary site audit report. The recommendations in the preliminary audit include capital projects in addition to low- and no-cost measures.

Figure 4: Example Screenshot from a Populated Hog Energy Audit Tool

(A) Ceiling peak	15
(B) Total sidewall	8
(C) Above curtain opening	1
(D) Curtain opening	4
(E) Below curtain opening	1
(F) Stem wall	2
House length	200
House width	41
Evaporative pad length	0
Evaporative Pad height	0
End wall 1-total area of fans & inlets	0
End wall 2-total area of fans & inlets	0
Side wall 1-total area of fans & inlets	20
Side wall 2-total area of fans & inlets	20
Tunnel curtain opening length	190
Perimeter	482



		Existing		
Surface	Area	Material	R-Value	Material
End Wall 1	533	Fiberglass Insulation	16	No Change
End Wall 2	533	Fiberglass Insulation	16	No Change

Step 5 – Analyze Real-Time Data to Identify Energy Efficiency Opportunities and Iteratively Improve Models

Step 5 consisted of three interrelated, iterative processes. First, we compared the preliminary models (from Step 4) to the incoming real-time data (from Step 2) to identify errors in the models and improve their accuracy over time. Second, we used the models to program the settings of PTO data analysis tools (which were re-calibrated as necessary when the underlying models changed). Third, we used the PTO data analysis tools to identify anomalies in the real-time energy usage data.

According to our plan, identified anomalies should indicate one of two things: either an opportunity to improve the underlying model or an energy conservation opportunity (due to unexpected or unnecessary energy usage). As the models improved over time and the PTO data analysis tools were calibrated accordingly, our assumption was that identified anomalies would increasingly indicate only energy conservation opportunities because the errors would be weeded out. The ultimate goal of the project is to demonstrate that, with the appropriate underlying model and associated calibrated data

analysis tools, real-time energy consumption data can be analyzed to identify conservation opportunities at agriculture sites quickly and cost-effectively.

Early in the project, we compared real-time data collected from each site to the energy consumption predicted by our preliminary models. Initially, this was a slow, manual process where we looked at incoming data and compared it to modeled consumption at a high level to find obvious discrepancies that could indicate we missed an important piece of equipment at the site. This was expected at the outset.

As the models improved, we were able to design settings for PTO data analysis tools to help automate the process of identifying anomalies. That is, using predictions from the preliminary models, we were able to set alarms to automatically alert us when demand at the site exceeded the modeled expectations. PTO tools enable setting different thresholds to trigger the demand alarms at different times of day and different days of the week. For the first iteration of the process, this worked well to start automatically identifying possible conservation opportunities.

At this stage of the project, there were two types of anomalies that we looked for. A discrepancy between the model and the real-time data indicated that we likely needed to update the model. An alarm from the PTO data analysis tool indicated either that the data analysis tools (and possibly the model) needed to be adjusted or that we had found a conservation opportunity.

Each time we identified an anomaly we investigated the cause to determine an appropriate response. For many anomalies, we reached out to the producer to help us understand possible reasons for the unexpected usage pattern. The goal was to gradually improve the models and calibrate the data analysis tools to increasingly return more conservation opportunities and fewer discrepancies. Eventually, we expected that the data analysis tools would be automatically indicating conservation opportunities with high confidence.

Unfortunately, after the first, coarse iteration of the process, the data analysis tools did not measurably improve in terms of accurately identifying conservation opportunities. There are several reasons for this outlined in the next section. For the remainder of the study, we did continue to monitor all sites, reach out to producers for explanations of anomalies, and iteratively improve the models and data analysis tools. However, the effort required to continue this process was too great for the meagre conservation outcomes the process achieved. Further, the process did not lend itself to scaling up for use in a utility conservation program. This is the point where the project team redirected the efforts of the study to focus on new goals.

Completing Step 5 was originally planned to culminate in the fulfillment of the ultimate goal of the project. By completing this Step, we would demonstrate the viability of applying real-time data analysis tools to identify conservation opportunities at agriculture sites. Further, we planned to use the final models and associated data analysis tools to define templates for future use by conservation programs. We envisioned enabling a process whereby conservation programs would only need a few pieces of information about a site (type of operation, size, and some basic specific equipment data) to identify the appropriate model template to use. The selected template would dictate the corresponding set of data analysis tools to apply. Then the utility could use those tools to process data from the site to quickly identify conservation opportunities. Once this process is established, conservation programs could ramp

up participation to continually monitor a large number of sites concurrently, identify significant conservation opportunities, and target appropriate conservation program offerings to participants.

Step 6 – Implement Energy Efficiency Opportunities

The project team intended to identify low- and no-cost energy savings opportunities at participating sites, update the models to reflect real-time data after the measures were implemented, and verify persistence of savings for implemented opportunities. We anticipated focusing on the following measures:

- Timers/photocells for lighting
- Thermostats/timers for fans
- Thermostats for livestock waters
- Fan cleaning/greasing
- Refrigeration system maintenance
- Engine block heater timers
- Behavioral changes, such as turning off unnecessary heaters
- Sequencing activities (for example, stage ventilation fans to stagger their startup instead of all turning on at once)
- Setting up automated notification of abnormal usage patterns

The actual rates of identified and implemented low- and no-cost savings fell far below what we anticipated. We identified more than more than 300 possible anomalies and reached out to all eight participants to discuss them. However, we verified only seven legitimate conservation opportunities, and implemented just four projects. The amount of effort required by farmers to respond to our inquiries was greater than anticipated and opportunities were not as large as hoped. This resulted in decreasing participation engagement over time, which hampered the process to improve the models and identify further conservation opportunities. Ultimately, there were not nearly enough identified opportunities to demonstrate viability of the methodology as planned.

Difficulties Encountered

The study ran into difficulties identifying conservation opportunities as quickly and effectively as originally anticipated. Compared to the plan, the effort and resources needed to: identify and recruit participants, monitor equipment, and hone models was greater than anticipated. Also, the models and data analysis tools did not refine into streamlined conservation identification tools as easily as anticipated. This section describes the difficulties encountered in detail. The next section describes our responses to the difficulties and a redirection of efforts to focus on achievable, valuable outcomes of the project. There were eight participant sites (5 dairy, 2 hog, and 1 poultry) when we decided to redirect the project.

Participant Recruiting

At the beginning of the project, the team anticipated identifying potential participants relatively quickly through our established contacts in the agriculture sector. Recruiting was not a major barrier to completing the project, but it did go more slowly than planned. This was partially due to the fact that we initially focused on trying to identify sites with AMI or pulse meters but were unable to find any viable sites with either. When we instead pivoted to the plan to use PTO metering kits, some farmers objected to the installation of any new hardware on their site, which limited our potential pool of participants somewhat.

The most important reason recruiting went slowly is that we wanted to find participants who were willing to spend some effort to help us identify conservation opportunities at their site. As it turned out, the amount of effort required by participants was more than we planned. Some potential participants indicated they would allow us to monitor energy consumption but were not interested in committing to expending effort to improve our models even if they did receive a free audit report. In the end, we were able to identify eight participants and had several more potential participants lined up when we began to realize the preliminary results were not promising.

Monitoring Equipment Installation Costs

All sites required dedicated real-time monitoring hardware kits. That is, no participants already had AMI or pulse meters installed. We did emphasize looking for such sites while identifying potential participants, but deployment rates of metering technologies are low in Minnesota. This made the cost of enrolling participants greater than we anticipated because we needed to purchase a PTO metering hardware kit and hire a licensed electrician to install it at each participating site.

Cellular Reception

Each site also needed a dedicated cellular account in order to report real-time data into the PTO platform. Relying on transmitting data via a cellular connection resulted in two additional issues. First, two sites we visited were not within cell range for either provider used by PTO (AT&T or Verizon), so those sites were not enrolled in the study. This challenge was not anticipated at the outset and made identification of eligible participants more difficult.

Second, some sites had intermittent cell coverage, which reduced the value of the real-time data metering kits. All data was reported, but sometimes not immediately. When a cellular connection was lost, data wouldn’t be uploaded until a connection was reestablished, which sometimes took several days. For those sites, we needed to make an additional site visit to fix this issue by installing longer range antennae on the data collection hardware.

Agriculture Sector Priorities and Participant Effort

At the time of enrollment, participants agreed to communicate with the project team periodically about possible conservation opportunities to help us develop our models. However, the effort required from producers to help track down the cause of each energy consumption anomaly was greater than anticipated. Our early models produced many false positives, or cases where identified conservation opportunities turned out to be a necessary use of energy. Rooting out false positives to hone the accuracy of the models required more detailed conversations with farmers about the specific operations at their site than we anticipated. Additionally, the actual identified savings were smaller than predicted. Over time, farmers grew impatient with the process and shifted focus toward higher priorities.

Adding to the impact of this setback is the fact that the agriculture sector has been struggling economically in recent years with dairy and crop prices remaining low over an extended time. Economic pressures necessitate prioritizing production and critical operations, which means that spending excess time on energy efficiency is difficult for farmers to prioritize at this time. After a period of mostly unsuccessful attempts to identify conservation opportunities, the project team took a break in contacting participants in the hopes that the sector may stabilize and offer a chance to reinvigorate energy efficiency efforts later. However, the sector-wide economic slump only worsened in that time. We cannot definitively say that economy-wide effects directly impacted our study, but they may have played a role in making it more difficult to complete as designed.

Conservation Opportunity Identification

The goal of combining models and real-time data into streamlined, rapid conservation identification tools did not work out as well as planned. The team understood from the outset that agriculture sites are different from typical commercial sites. The goal of this project was to show that with a site model, the same types of patterns could be found in agriculture sites as commercial sites, just with a more complicated baseline. The site models combined with real-time data analysis tools *did* allow identification of conservation opportunities, but not anywhere near the rate originally expected. There are several distinct reasons for this.

False Positives

We expected there to be some false positive indicators of energy conservation opportunities[3] in the early stages of the project as we honed the models and use of data analysis tools to develop more accurate predictions. We anticipated using approximately the first month of data/feedback to adjust the models to a point where the data analysis tools were reasonably capable of quickly identifying conservation opportunities with little effort required from the participants. In fact, each site's unique

[3] For example, a model indicated an anomaly where expected energy demand was exceeded, but the excess was caused by an electric heater used to thaw a frozen pipe – a necessary usage that does not indicate either a possible improvement to the model or an energy conservation opportunity.

operations meant that the models output more false positives than expected. This meant that updating the models required an unreasonable amount of time and effort from participating farmers. After a handful of false positives, some producers lost interest in communicating with the team about potential conservation opportunities, which in turn significantly impacted the team's ability to continue improving models for those sites.

Sample Size

We learned that the audit tools are currently successful at predicting agriculture energy consumption only when examining *average* data over long time periods (typically annual consumption). Though the models can predict daily patterns in usage (such as those caused by milking periods), they do not accurately account for differences from one day to the next.

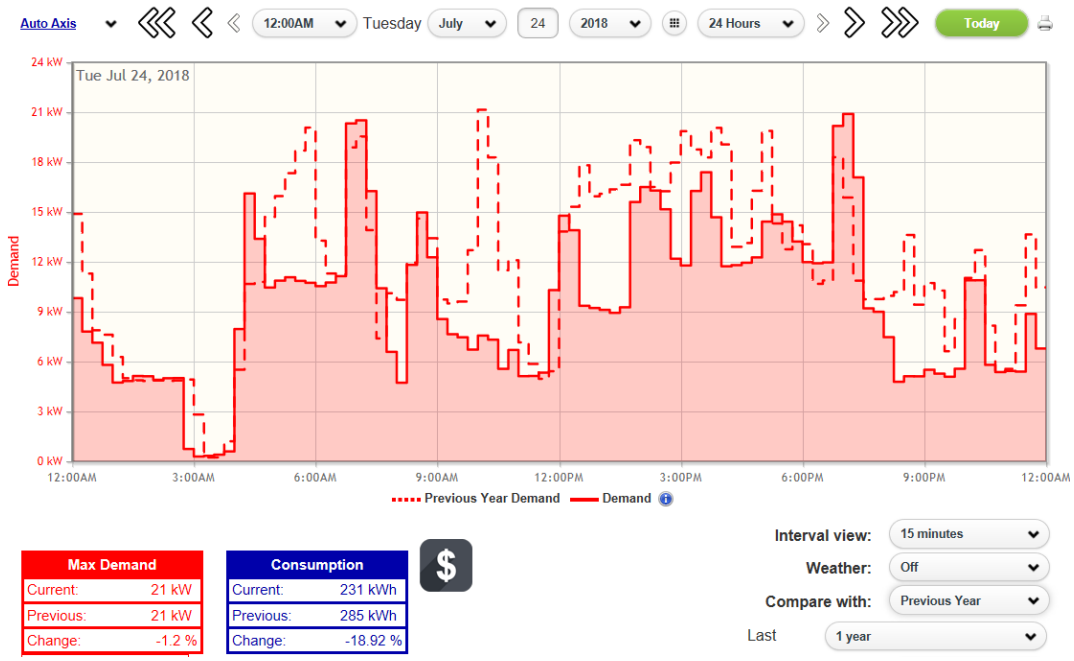
Further, unique differences among farms account for too much variability in real-time consumption that is not captured in the models, which means that a model accurate for one site cannot be assumed to represent the next site. We did anticipate this variability, but originally believed we could account for it with a small number of controlled input variables (for example, dairies with VFDs on their vacuum pumps could use the same baseline model despite other, smaller differences). It is still possible that with enough time and effort (including effort from willing farmers) we could accomplish the originally-planned goal. However, the distance between the existing models and the planned final data analysis tools is greater than anticipated. That is, there are many variables that need to be better controlled in the models to allow for the analysis of real-time data in a way that separates unexpected energy usage from necessary usage. To better control a larger set of variables, a much larger sample size would be required.

Corroborating this finding, PTO changed their approach to identifying savings in the commercial sector since the beginning of this study. PTO now exclusively examines data from customers with real-time data already generated by the utility and no longer offers the option to install metering hardware kits. Also, PTO now only provides services through utility programs rather than working directly with individual customers. This partially reflects the increasing penetration rates of AMI, but also demonstrates a pivot to large data sets. On the commercial side, PTO now believes the optimal strategy is to focus on processing data from a large number of customers and target a low percentage (1-2%) of sites to return conservation potential. Those that do are ones that demonstrate a relatively large opportunity. Unfortunately for this study, the sample size of participants is not nearly large enough to support what is now understood to be the optimal conservation identification strategy.

Limitations of Analysis Tools: Site Characterization

The real-time data analysis tools built into the PTO platform are designed for commercial sites and did not translate well for use with agriculture sites. The built-in analysis tools are not complicated enough to fully characterize agriculture sites.

Figure 5. Example of Typical Demand Fluctuation in One Day at a Dairy Site



The team did identify many potential conservation opportunities with the kW demand comparison tools built into the PTO platform. For example, the tool can create a visual depiction of the demand profile at a site for a given day compared to the average demand over the last week, month, or year (Figure 5 shows an example of a comparison graph). The data analysis tools can also create automatic alarm triggers based on day of the week, time of day, time exceeding threshold, and can be normalized for weather data. These powerful tools are what make the software successful in the commercial sector and were used with some success for this study.

However, in the agriculture sector, it was difficult to design complicated enough automatic alarms to separate anomalies from necessary usage and variations in schedules. To incorporate predictions from the site models into the automatic analysis tools, it would be necessary to design alarm conditions based on more variables. Examples include the ability to flag anomalies when a threshold is breached more than 3 times per day or when two different thresholds are both breached within 2 hours. Ultimately, due to the nature of agriculture operations, it was very difficult to set alarms accurately enough to identify anomalous usage without generating alarms for necessary usage. We designed automated alarms as detailed as possible with the available tools, but this resulted in a large number of false positive identifications of conservation opportunity.

Limitations of Analysis Tools: Demand vs. Energy

Another limitation on the analysis tools is that they are based largely on demand (kW) rather than usage (kWh). Agriculture sites are better characterized by kWh usage patterns because demand can fluctuate significantly as large equipment cycles on and off throughout the day (vacuum pumps for milking, air compressors, refrigeration equipment, etc.). Comparing *usage* to historical patterns is much more likely to uncover anomalies pointing to conservation opportunities. PTO tools do display and track daily usage,

which is somewhat helpful, but it is not possible to create automated alarms, let alone complicated ones, based on usage. Further, the site models show predictable energy usage patterns over intervals shorter than one day. For example, if we compare usage at a dairy site between 9AM and noon, we may find very consistent usage patterns that clearly flag anomalies when violated, but may not show up in analysis of a full day of data (in this example, the predictability is due to a consistent daily milking cycle).

The limitations on the analysis tools meant that the team spent significant effort identifying conservation opportunities by manually comparing real-time and historical data to look for anomalies rather than using the tools available in the PTO platform. This entailed exporting real-time data and plotting it to look for patterns by sight without automated analysis tools. While somewhat successful, this strategy is not replicable on a larger scale and cannot be used to develop useful tools for future programs or participants. Even if we had identified significant conservation opportunity manually, it would still constitute a negative result for our study thesis because it could not be used on a large scale by utility programs. From this process, we eventually began building separate, Excel-based screening tools to automate some of the pattern searching we were doing manually. This led to the development of one of our final deliverables, which is the screening tool described in the next section.

Any one of these identified difficulties would likely have been surmountable. However, they compounded one another (tool limitations led to more false positives, which strained participants' patience, which led to less feedback, which decreased the accuracy of the models…etc.) and resulted in a barrier to completing the study as planned.

In the first 6 months of monitoring real-time consumption at the sites, the team realized that preliminary results were not promising. The models were producing too many false positives, the install costs were higher than expected, and communication with participants was already slowing. The team decided to stop pursuing additional participants and redirected the project toward alternative goals. For the eight participating sites, we continually monitored the real-time data and applied the site models and data analysis tools to identify conservation opportunities as well as possible throughout the project as planned. But we shifted our focus to developing new deliverables and recommendations from our findings.

Project Redirection

After encountering the difficulties outlined above, the project team adjusted the study approach to focus on how to best leverage our findings to be most useful for future utility conservation programs and individual agricultural producers.

Specialized Screening Tool

In the later stages of the project, we developed a specialized, Excel-based screening tool to identify conservation opportunities at agriculture sites. The tool can be used by utility program administrators or by individual producers to process interval data (from utility meters or other sources) to find conservation opportunities at agriculture sites. In fact, the tool may also work at non-agriculture sites,

but it was designed to specifically identify patterns we found at agriculture sites that correlated to unexpected consumption patterns.

In the course of attempting to complete the study, we realized the proposed tools (PTO data analysis tools and GDS Ag modeling tools) had limitations to their ability to identify conservation opportunities. As a result, we began to compare exported real-time data to the site models and historic site data manually. That is, we plotted interval data to look for patterns in usage by sight to identify anomalies. This exercise enabled us to begin recognizing complex patterns of usage that could indicate conservation potential.

With this understanding of energy usage patterns, we were eventually able to characterize the criteria we were looking for in our manual efforts. We began to create Excel-based tools to help identify patterns indicating conservation opportunity. Eventually, this grew into a specialized screening tool that we developed into a final deliverable for the project. By the end of this study, using the specialized tool was the best method we found for identifying conservation opportunities.

The tool was developed to meet a specific need to compare historical usage in short time intervals at agriculture sites - for example, finding patterns and anomalies in historical usage between 5AM and 8AM at a specific dairy site (corresponding with a daily milking period). By carefully setting the screening criteria and importing the appropriate data sets, the tool can be used to:

A) Determine energy usage in one period (for example, determine the kWh consumed between 9AM and 1PM on a given day)

B) Determine average usage in multiple periods at the same time of day in one data set (for example, average usage at a site between 9AM and 1PM over one month)

C) Compare two periods within the same data set (for example, compare usage between 9AM and 1PM at one site on two separate days)

D) Compare two periods in separate data sets (for example, compare usage between 9AM and 1PM on a given day at two different sites)

E) Compare one period from one data set to average of multiple periods at the same time of day in the same data set (for example, compare usage at one site from 9AM to 1PM on a given day compared to average usage at the site between 9AM and 1PM over the last month)

F) Compare one period from one data set to average of multiple periods at the same time of day in a second data set (for example, compare usage at one site from 9AM to 1PM on a given day compared to average usage on a standardized load profile)

G) Compare the average of multiple periods at the same time of day in one data set to the average of multiple periods in a second set (for example, compare the average usage at one site from 9AM to 1PM to average usage at a second site from 9AM to 1PM over one month, or compare the average usage at one site from 9AM to 1PM over one month to the average usage at a second site from 7PM to 11PM over six weeks)

In its current form, the tool likely won't be able to process data from large numbers of sites concurrently. And it is not a prescriptive tool that can be easily deployed as a standard program measure. Instead, the most likely way the tool can be used is for program managers to familiarize themselves with the tool's functionality and deploy it selectively to appropriate candidate sites to identify conservation opportunity. Candidate sites should have available interval data (meaning that the tool will become more useful as AMI penetration rates increase). Sites should be willing to work with the utility to evaluate results and provide some back-and-forth to build understanding of energy usage at the site. If these conditions are met, we believe the tool can be a useful resource for utility conservation programs serving agriculture customers.

Figure 6. Screenshot of Specialized Screening Tool Sample Definitions Inputs

	Data set A Information	Data set B Information	
Data Start date	3/1/2018	3/1/2018	
Data Start time	12:00 AM	12:00 AM	
Data End Date	3/14/2018	3/14/2018	These fields update
Data End Time	2:45 PM	2:45 PM	automatically to
Data Interval	0:15	0:15	reflect imported
last row with data	1311	1311	interval data sets and
Number of useful data columns	12	12	inputs below
Site Name	McDonald's Farm	McDonald's Farm	

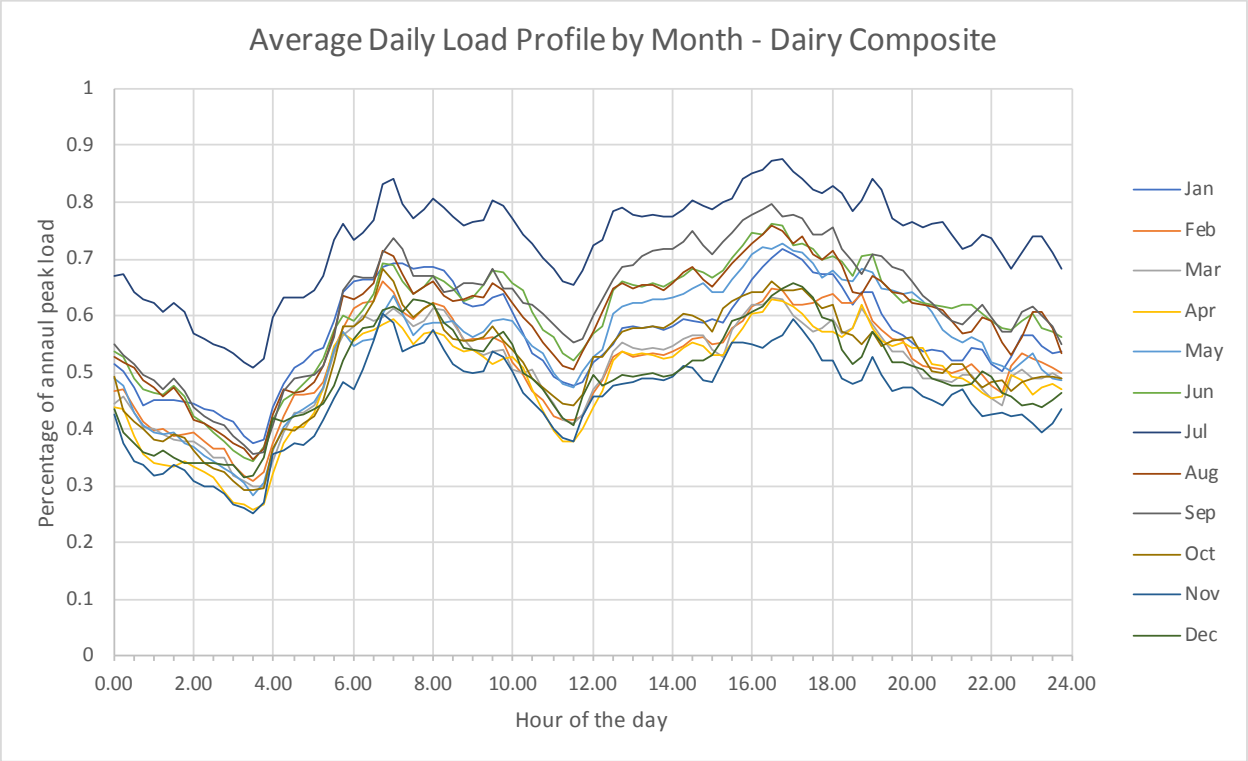
Data Labels - All lables apply to both data sets (if two data sets are imported)			
Existing data labels (from input data)	Data type	Output data label	Column in Data Set Tab
McDonald Farm - Main kWh - kWh	kWh	Main energy	E
McDonald Farm - Main kWh - kW	kW	Main power	F
McDonald Farm - Main Power Factor - %	power factor	Main PF	G
McDonald Farm - Calf Barn kWh - kWh	kWh	Calf energy	H
McDonald Farm - Calf Barn kWh - kW	kW	Calf power	I

Load Profiles

We developed representative load profiles for agriculture facility types based on the interval data collected over the course of the study. The Minnesota TRM references load profiles for a wide variety of residential, commercial, and industrial building types, as well as end uses. But the TRM does not currently include load profiles for agriculture facility types. The load profiles can be used as a baseline to compare conservation savings against or to define peak coincidence factors for agriculture facility types in TRM algorithms.

The ongoing data collection over the course of the study produced a complete set of 15-minute interval data over more than a year for all participating sites types. We used this data to create load profiles for each site. The profiles are formatted to display the average daily load, by hour of the day, for each month of the year. That is, each month produces a composite 24-hour load profile. The individual participant profiles were aggregated to generate a final average load profile for each of the facility types (i.e. hog, poultry, and dairy).

Figure 7. Aggregate Load Profile for Dairy Facilities in Minnesota



Program Design Recommendations to Achieve Conservation in the Agriculture Sector

The original objective of this study was to create tools to help utilities quickly, remotely, and cost effectively identify energy savings opportunities at agricultural sites in anticipation of AMI data becoming increasingly available. While the main methodology was unsuccessful, the team developed the following set of recommendations based on our experience with energy efficiency in the agricultural sector and lessons learned from this project to help utilities reach agriculture customers with conservation offerings.

Participant Engagement

The key to the success of any agricultural conservation offering is engaging farmers and understanding farming culture. Typically, farmers are very busy and have pressing priorities besides energy conservation. In our experience, farmers are receptive to opportunities to conserve energy, especially when it can improve processes on their farm. But if communication bogs down with slow responses or unclear objectives they may disengage quickly to focus on other issues.

Even more than in other sectors, it is important to be transparent about utility conservation goals and explain where funding comes from for conservation incentives. Utilities should emphasize that conservation programs are a valuable service and not a sales pitch. Farmers are generally skeptical of

new offers because they encounter many equipment sales representatives, often selling products with questionable value.

Finally, it is important to plan for informal, in-person communication with agricultural customers. Open-ended conversations at association or union meetings provide some of the best opportunities for utilities to develop relationships with farmers and promote agricultural conservation programs.

Specialized Knowledge

Utility programs aimed at agriculture sites should have staff available who have experience in the agricultural sector, ideally with direct farming experience. This resource will be helpful both for communicating with farmers and for ensuring conservation calculations are applied accurately. Most energy-consuming equipment on farms is similar to equipment found in commercial or industrial settings but is often used differently. This means that agriculture energy savings calculations often require adjustments when applied in a farming context.

Site visits should also be conducted by a person familiar with farming operations. There are three reasons for this. First, it helps to establish rapport with the customer. In our experience, participants easily recognize whether a visitor has familiarity with farming operations and that recognition drastically improves engagement. Second, a person with farming experience will understand specialized equipment or operations to ensure that site data is collected accurately and that conservation calculations are applied appropriately. A person with farming experience should also be able to identify whether a conservation measure may compete with another objective and will be able to present conservations opportunities and tradeoffs appropriately. Third, someone with farming experience is much more likely to notice additional conservation opportunities on the site. It is also especially important for utility program staff to be aware of biosecurity issues and follow appropriate protocols during on-site visits.

It is also important to show interest in the farm as a utility customer and demonstrate understanding of unique issues faced by farmers. Before recommending any specific conservation opportunities, utilities should consider how the conservation recommendation may affect operation or availability of equipment and how that fits into the farmer's larger needs. Often there are opportunities to conserve energy *and* improve operations (ex: collect waste heat from dairy refrigeration to preheat laundry water), but sometimes they are competing objectives. If uncertain about the potential impact of a conservation recommendation, ask the farmer directly. This approach will also help the program develop specialized agriculture knowledge over time.

Outreach and Marketing

We highly recommend establishing ties with local agricultural groups to help promote conservation initiatives. Association newsletters and membership meetings are excellent opportunities to promote conservation programs. Some statewide groups that may be worth reaching out to include:

- Minnesota Turkey Growers Association
- Minnesota Farmers Union

- Minnesota Milk Producers Association
- Minnesota Sustainable Farming Association
- Minnesota Corn Growers Association
- Minnesota Pork Producers Association
- Southern Minnesota Sugar Beet Cooperative
- Minnesota Nursery and Landscape Association
- Minnesota Fruit and Vegetable Growers Association
- Minnesota Soybean Research Promotional Council and Minnesota Soybean Growers Association (combined as Minnesoyta)
- Minnesota Commercial Flower Growers Association
- Minnesota Maple Syrup Producers Association

Utilities should also reach out to local, state, and federal government agriculture programs. In particular, the USDA (through REAP[4]) and NRCS (EQIP program[5]) both offer historically successful energy efficiency initiatives that utilities can use to leverage their own conservation programs. It is important to keep in mind that federal program requirements often add significant lead time to planning projects.

It is also possible to work with agriculture equipment dealers similar to commercial trade ally networks. However, agriculture dealers are often affiliated with specific vendors and farmers are often loyal to their preferred dealer or vendor. Utilities may not want to reach out directly to dealers until their programs are well established and they have a full understanding of dealer/vendor/farmer relationships.

Specific Measures, Equipment, and Programs

One of the main difficulties in reaching agriculture customers with conservation offerings is that energy consumption patterns on farms are different from other sectors and there is significant variation among agriculture sites. These characteristics suggest that utilities need to balance making adjustments to existing offerings and practices versus offering specialized agriculture offerings.

The most direct way to provide an agricultural-specific service is to offer site audits that identify conservation opportunities and prioritize them by expected payback period. Utilities may want to also offer Level-2 ASABE audits that allow farmers to qualify for federal funding. If this is the case, utilities must hire or train a certified Technical Service Provider (TSP)[6] to perform these audits. A certified TSP will add value to any agriculture conservation program beyond their ability to conduct audits.

Typical standard CIP offerings can be applied to agriculture sites, with slight adjustments. Lighting, ventilation fans, refrigeration, compressed air, insulation, and variable frequency drives all have existing, well-established calculation methodologies that can be adapted for agriculture sites by making small adjustments to relevant variables (typically hours of operation or assumed equipment efficiencies).

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[4] https://www.rd.usda.gov/programs-services/rural-energy-america-program-renewable-energy-systems-energy-efficiency

[5] https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/

[6] https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/technical/tsp/

Utilities may also want to invest in the development of specialized tools and calculators as their programs mature.

Using AMI Data

Agriculture sites will likely be prime candidates for sophisticated load control programs and dynamic rate structures as AMI achieves greater penetration. Utilities can also use the Excel-based Interval Data Screening tool developed during the project to analyze interval data, identify conservation opportunities, and explore potential conservation strategies for the future.

Conclusions

This study was not able to achieve the originally-proposed objective of demonstrating a method to use meter interval data to identify conservation opportunities at agriculture sites remotely, quickly, and cost effectively. In short, the reason for this is that all the barriers identified prior to the project are more difficult to overcome than anticipated. We redirected the study efforts to produce different deliverables than originally proposed.

The project team developed an Excel-based tool to analyze interval data to identify anomalies that may lead to conservation opportunities. The tool proved to be the best option for identifying conservation opportunities and may be useful in future projects that need to analyze interval data to identify anomalies.

The study also produced a set of load profiles for agriculture sites based on more than a year of data collected at each participating site. These can be added to the suite of building type load profiles used to inform TRM inputs and improve the accuracy of energy savings estimates.

Finally, the team distilled experiences from this study and related projects into a set of recommendations for utilities hoping to reach agriculture customers. As a summary, utilities should take a long view of developing targeted conservation programs. They should expect to invest a fair amount of effort up front to plant the seed of conservation with outreach efforts and work to build specialized, agriculture-specific knowledge. In particular, a utility should plan to have at least one person with farming experience either on staff or available to consult as needed. Over time, the engagement process should be honed to nurture relationships with farmers and continually improve the services offered and tools available. With appropriate effort and engagement, efficiency programs can help utilities harvest agriculture conservation opportunities as a long-term component of their CIP portfolio.

Appendix A: Outreach Flier

Whole Farm Energy Management – Participant Information

GDS Associates is seeking 21 agricultural sites to participate in an energy efficiency study. Specifically, we are looking for 7 each of hog, dairy, and poultry producers.

Objective: The goal of the study is to determine if a whole-farm energy management strategy can successfully and cost-effectively identify energy efficiency opportunities to reduce farmers' energy costs and meet utilities' efficiency goals. The strategy we are studying has been successfully implemented in commercial and industrial settings and we would like to show whether farmers can benefit from it as well.

How it works:

1) Once participants are identified, we will first perform a site audit and develop a model of energy consumption for the farm based on the equipment and schedules found during the audit.
2) We will then enroll the site in a software tracking platform created by Power TakeOff, a partner in the study. The platform tracks energy usage in real time using the utility meter at the site.
3) Comparing metered usage to the model, we will identify potential energy efficiency opportunities. Over time, we will improve the model of the farm's energy usage to find cost-effective options for investing in energy efficient equipment and practices.
4) The participant may choose to implement as many or as few of the identified opportunities as they deem valuable to their operation.

What are the benefits to participants?

- GDS Associates has a long track record of helping farmers reduce energy costs. Participants are very likely to learn about opportunities to save money and improve their farms' efficiency.
- Enrolling in the Power TakeOff program typically costs approximately $30/month, which will be paid for 1-2 years by the study grant at no cost to the participant, with no commitment to continue subscription after the study is complete.
- For all identified energy saving opportunities, farmers will be provided a financial breakdown of estimated costs and savings to determine ROI periods and help prioritize decisions.
- If higher-cost opportunities exist on the farm (such as investing in new capital equipment), GDS can help the farmer apply for rebates and grants through the NRCS and USDA programs.

- Participants will benefit from neutral, unbiased energy advice. GDS has no interest in selling equipment or influencing decisions. The study is funded by the state, so there will be no pressure on the farmer to make any decisions they don't want to.
- All findings from the study will be anonymized. No identifying information about any participants will ever be made public for any reason.

What's required of participants?

- Participating farmers will need to allow GDS Associates to perform the initial energy audit, which will take approximately 2-3 hours on-site including access to energy-consuming machinery.
- Participants should also be eager to engage with GDS researchers periodically to discuss findings. We anticipate that this will take ~30 minutes per month to talk about energy consumption irregularities and possible no- and low-cost opportunities for conserving energy.
- Participants should be willing to consider installing energy efficient equipment upgrades and making process updates that result in reduced energy consumption. All decisions will, of course, be up to the farmer. The objective of the project is to identify cost effective opportunities to save energy, so we expect that participants would be willing to consider acting on those opportunities.

Appendix B: Participation Agreement Form

Whole Farm Energy Management – Participant Agreement Form

Farm Producer Contact Information

Full Name _____ home phone _____

Email _____ cell _____

Farm Address _____ County:_____

GDS Associates, with funding from the Minnesota Department of Commerce Conservation Applied Research and Development program, is conducting a study of real-time energy management strategies at agricultural sites. The producer named here has agreed to participate in the study and share information about energy consumption at their site. They have made no commitment to implement any identified energy conservation opportunities.

GDS Associates Deliverables
GDS Associates, Inc. staff and partners will conduct an energy audit and ventilation control technology evaluation. For participation in this project, GDS will supply to the producer the following:

1. Farm equipment inventory audit.
2. Energy consumption model of the site.
3. Enroll the site in the Power TakeOff energy monitoring platform at no cost to the producer.
4. Ongoing periodic recommendations for how to conserve energy and save money at the site along with estimated costs and payback periods for the recommendations.

Producer Deliverables and Right to Access
GDS Associates will need access to the farm facilities on one occasion for approximately 3-4 hours, and will need permission to access the site's historical electric consumption data from the utility. As detailed in this agreement, the producer is authorizing GDS Associates staff and partner to the following:

1. Review and completion of the "Producer Input Form" (PIF).
2. Access to the site on one occasion for 3-4 hours to perform the equipment inventory.
3. Access to the site's electric consumption data (requires utility release form).
4. The participant must be willing to communicate with GDS about energy consumption practices at the site – we expect this to take less than 30 minutes per month.
5. There is no commitment to implement any identified energy conservation opportunities, but the participant should be willing to consider them.

GDS Associates, Inc. is able to offer this study and enrollment in Power TakeOff accounts thanks in part to a Minnesota Department of Commerce Conservation Applied Research and Development (CARD) Grant. Participation in the research project will aid in the understanding and improved implementation of agricultural energy management strategies.

Certification and Signature
I agree to share project related technical information with GDS Associates, Inc for project purposes, and that GDS may share project specific information with applicable contractors and agency personnel.

Name _____ Signature _____ Date_____

Appendix C: Example Farm Inventory

Date: Auditor: Gary Gilles/Joe Schultz

Dairy Name:	Identifying information removed from published version of this document	Contact Name:	XXX			Title:	XXX
Address:		City:	XXX			Zip:	XXX
Phone No.:	XXX	Electric Utility:	XXX	Account #:	XXX	$/kWh:	XXX
Cell No.:	XXX	Gas or LP Utility:	XXX	Account #:	XXX	$/unit:	XXX
Business Type:	XXX	Dairy Supplier:	XXX			Monthly Bill ($):	XXX
E-mail:	XXX	Electrician:	XXX				
Billing Type:	XXX	Milk Pickup Times:	XXX				

Project Description Notes and Producer Concerns:

PTO EQuipment Installed 11/25/2016

Followup Site Visit performed on Jan 18th, 2018

Current Energy Savings Equipment:

RHR:	Yes	No	VS Milk Pump:	Yes	No	Precooler:	Yes	No
			VS Vacuum Pump:	Yes	No	HVLS:	Yes	No

Farm Information

Free Stall	Animal Housing		kWh Price-WATER HEATING ONLY	Notes:
Parallel	Milking or Parlor System		kWh Peak Rate	
210	Number of Milking Cows	96	Milk Temp in Pipeline	
15,000	Summer Milk Prod (total lbs./day)	24	# of Milking Units	
12,500	Winter Milk Prod (total lbs./day)	38	Milk Storage Temperature	
Every Day	Milk Pick Up	3	Milk Pipeline Diameter (inches)	
2	Milkings Per Day	95	Total Length of Milk Pipeline (ft)	
3.5	Hours Per Milking	1.5	Milk Discharge Line Diameter (in.)	
2	Pipeline Washings Per Day	35	Length Discharge Milk Pipeline (ft)	
20	Vac. Pump Run Time for Washing	Single	Single or Three Phase	
365	Milking Days per Year	1.5	Well Water Pump Horsepower	Well Pump make
5 AM	#1 Milking Time	52	Well Water Temperature (°F)	Well pump model
5 PM	#2 Milking Time	165	Water Heater Set Point (°F)	Well pump age: Unknown
	#3 Milking Time	No	Are Milk Meters Present?	VFD on Well pump? ~~NO~~ no

Water Usage

LP	Water Heater Type	Make	AO Smith	Notes:
0.60	Do you know the units energy factor?	Model	GCG50461	LP Water Heater Capacity = 200,000 BTUH
	Thermal Efficiency (%)	Age	Newer	
	Tank size (gal.)	kW Rating (if applicable)		Secondary Water Heater in Parlor: Electric Bradford White 120 Gallon Tank (0.86 EF)
	btu/hr Loss OR			
	Hourly Loss Percentage (%)			
	Energy Factor			

sink information		*pipeline information*	
Standard Sink or Vert. Vat	Vert Vat	1	# of Hot Cycles
	Length (inches)	1	# of Warm Cycles
25	Width/Diameter (inches)	1	# of Cold Cycles
25	Depth/Height (inches)	*Additional water use per day*	
			Hot Water (gal)
	Or, Total Gallons		Warm Water (gal)
			Cold Water (gal)

Bulk Tank Information

# of bulk tanks	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5
Size (gal.)	2000	1000			
Brand of Tank:	Mueller	Mueller			
Gal of Hot water per washing					
How often is BT Washed	Once/Day	Every 3 Days			

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Refrigeration Heat Recovery

0	# of RHR's Present		Make	Notes: Propose to save LP Use
	Total Capacity of All RHR Units (gal.)		Model	
	Does current unit have a heating element?		Age	

Plate Precooler

70	Temperature of Milk Leaving the Plate Cooler IF known			Notes:
No	Are there issues of scaling on water pipes?			
100	How far from the Well is the Plate Cooler?	Surge	Make	
0.75	Water Line Feeding Plate Cooler (inches)	V8 18-W9	Model #	
Selonoid	How is a bypass used to regulate income water Flow when not needed?			

Milk Pump

No	Is A VSMP Currently Installed?	Surge	Make	Notes:
2	Milk Pump Horsepower	Washgard SST	Model #	
0.89	Efficiency	10	Age	

Compressors

	Comp. 1	Comp. 2	Comp. 3	Comp. 4	Notes:
Make	Copeland	Copeland	Copeland		Comp 2 and 3 serve the secondary bulk tank
Model	ZR61K3E	CR38K6E-PFV	CR38K6E-PFV		
Age	Newer?	Older?	Older?		
kW					
Horsepower					
Voltage					
EER					
Ton Rating	5.0	5.0	5.0		
Location	Inside	Inside	Inside		
Tied to RHR unit?					
# of Condens. Fans	2	1	1		

Vacuum Pumps

1	# of Vacuum Pumps	Notes:
Yes	Is there a VFD present?	

	Pump 1	Pump 2	Pump 3	Pump 4
Horsepower	10			
Make	Unreadable			
Model				
Age	Approx 10 Yr			
Voltage	240			
Phase of power	single			
Style of Pump	Blower			
Motor Efficiency	92.0			
Used for milking, washing, or both?	Both			

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Laundry

Current Washer:		*Current Dryer:*		Notes: (Make/Model/Age)
Res Front	Washer System	LP	Fuel Source	
Hot-Cold	Wash-Rinse Cycle Setting	2	Loads Per Day	
2	Loads Per Day	60	Run Time Per Load (minutes)	
25	Run Time Per Load (minutes)	180,000 BTU	Wattage/Dryer Energy Rating	

Pasteurizer

	Gallons of Milk Pasteurized per Day		Retention Time of Milk		
	Calf Feedings Per day		Flow Rate (gal/min)		
	Temp of Milk Entering Pasteurizer		Plate Heat Exchanger Present?		Make
	Type of Pasteurizer		Efficiency of Heating System		Model
	Gal Milk / Cycle		kW or BTU Rating		Age
	Set Temp of Pasteurizer °F		Gallons of Hot Water per Wash		

Notes:

None Being Used

Infloor Heating

1	Number of Heating Zones (Other Than Parlor Area):	Electro Boiler	Boiler Make
Entire Palor	Will you be heating a parlor or pit area?	EB-MO-20	Model
.92	Efficiency of Current Boiler System:	10 Yr	Age
Electric	Fuel of Current Boiler:		
20 kW	KW of Current Boiler		

	Zone 1	Zone 2	Zone 3	Zone 4	Parlor
Minutes Cattle Doors Open per Exchange					
Total Square Feet of All Cattle Doors					
Description of Area	2				
Width of Area (ft)	50				
Width of Pit (ft)					
Quantity "Width" Walls = Exterior Walls	1				
Length of area (ft)	60				
Length of Pit (ft)					
Quantity "Length" Walls = Exterior Walls	1				
Height of wall (ft)	8				
R-Value of Insulation in Walls	14				
R-value of Insulation in Ceiling	20				
R-value of Insulation Under Slab	2				
R-value of Insulation on Side of Slab	2				
Thickness of slab (in)	2				
Number of Windows Present	3				
R-Value of Windows	3.5				
Estimated Height of Window (ft)	3				
Estimated Width of Window (ft)	3				
Temperature Set Point of Zone (°F)	62				

Notes:

Main Space Heating for Parlor/Milk House and Barn Office

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Air Compressors

	Number of Air Compressors				Notes:
	do the crowd gates operate off the compressor?				
	Compressor 1	Compressor 2	Compressor 3	Compressor 4	
Location					
Make					
Model					
Motor HP					
Motor eff					
line size leaving tank (inches)					
is there a air drier present					
is there a localized tank present					
Pressure tank Size					
low pressure pt.					
high pressure pt.					
Estimated operation (hrs/day)					

Livestock Waterers

	# of Existing Livestock Waterers						
	# of Qualifying Waterers for Grant						
# of Waterers	Make	Model	Age	Location	Size (gal)	Element Type	Element Wattage

Engine Block Heaters

Location	Brand	hours/day	days/year	Quantity	Watts	Notes:
Skid Steer	Unknown	3	90	1	1500	

Motors

Location	Make	Model	Age	HP	Efficiency	Hours/day	Days/year	# of Motors
Sec. Water Pump	Unknown	Unknown	Approx 10	.75	.72	4	365	1
Well Pump	Unknown	Unknown	Approx 10	1.5	.78	8	365	1
Cheese Vat	Unknown	Unknown	Approx 10	1.5	.78	3	120	2
Pasturizer Pump	Unknown	Unknown	Approx 10	5	.78	3	120	2
Pasturizer Pump	Unknown	Unknown	Approx 10	.25	.78	2	120	2

Notes:

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Lighting

Location	Type of Fixture	Watt/ Fixture	# of Fixtures	Days/ Year	Hours/ Day	Replacement Fixture	Notes:
Parlor	T8-6 Bulb x 4 FT	221	15	365	9	Tube LED	
Free Stall	Metal Halide	455	13	365	8	LED High Bay	
Creamery Office	T8-4 Bulb x 4 FT	111	5	260	6	Tube LED Lamp	
Creamery Store Ent	Incandescent	75	5	100	10	Tube LED Lamp	
Cremery	T8-6 Bulb x 4 Ft	221	13	365	12	Tube LED Lamp	
Shop Exterior	Metal Halide	205	1	365	10	LED Wall Pack	
Creamery Utility Rm	Metal Halide	205	1	365	10	LED Wall Pack	
Creamery Store Ent	Metal Halide	205	1	365	10	LED Wall Pack	
Vet Office	T8-2 Bulb x 4 Ft	68	2	365	6	Tube LED Lamp	
Parlor Ent	Incandescent	75	1	365	10	LED Screw In lamp	
Maternity Area	8 FT T-12 Flour. 2 Bulb	156	3	365	24	Tube LED Lamp	
Maternity Area	T8-2 Bulb x 4 Ft	68	3	365	24	Tube LED Lamp	
Parlor Walkway Rm	T8-4 Bulb x 4 Ft	111	2	365	10	Tube LED Lamp	
Parlor Milkhouse	T8-2 x 4 Ft	68	1	365	10	Tube LED Lamp	
Free Stall Exterior	Metal Halide	205	1	365	10	LED Exterior	
Parlor Utility Rm	T8-2 Bulb x 4 Ft	68	2	365	10	Tube LED Lamp	
Creamery Utility Rm	T8- 4 Bulb x 4 Ft	111	3	365	4	Tube LED Lamp	

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Circulation

Description	Location	# of Fans	Fan Diameter	Est. HP	Usage (hrs/day)	Usage (days/yr)	Make	Model	Age
Free Stall Circ	Free Stall Barn	12	48"	1	12	220	Unknown		
Holding Circ	Holding Area	1	48"	1	7	240	Unknown		
Dry Cow Circ	Dry Cow Area	1	48'	1	12	220	Unknown		
Parlor Circ	Parlor Walk Room	2	16"	1/8	5	365	Unknown		
Maternity Circ	Maternity Area	2	16"	1/8	12	220	Unknown		
Maternity Circ	Maternity Area	1	36"	1/3	12	220	Unknown		
Parlor Circ	Parlor Utility Room	1	16"	1/8	5	220	Unknown		
Parlor Circ	Parlor Utility Room	1	24"	1/4	6	220	Unknown		
Parlor Circ	Parlor Ceiling Exhaust	3	48"	1	3	200	Unknown		

Notes:

Ventilation (Tunnel or Cross)

	(ft) Facility Width		(mph) Air-flow Velocity					Notes:
	(ft) Facility Length		(ft) Baffle or Air In-let height					
	(ft) Facility Height		(ft) Baffle or Air In-let length					
	Fan Type		Cooling pads?					
	Fan Size (in.)		# Fans	Temp on		# Fans	Temp on	
	Number of Fans	Stage 1			Stage 7			
	Total Fans	Stage 2			Stage 8			
	Number of Control Stages	Stage 3			Stage 8			
	CFM per fan	Stage 4			Stage 10			
	kW per fan	Stage 5			Stage 11			
	Motor Efficiency	Stage 6			Stage 12			

Water Heater 2

	Water Heater Type	Make		Notes:
	Do you know the units energy factor?	Model		
	Thermal Efficiency (%)	Age		
	Tank size (gal.)	kW Rating (if applicable)		
	btu/hr Loss OR	Temp set point:		
	Hourly Loss Percentage (%)	Gallons used per day:		
	Energy Factor			

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Appendix D: Farm Audit Example

July 6, 2018

GDS Associates, Inc.
Engineers and Consultants

Dear Farmer:

GDS Associates and the MN Department of Commerce are pleased to provide you the results of your energy efficiency analysis based upon the site visit conducted on January 11, 2018. The results of the analysis are presented below along with your baseline energy use and associated greenhouse gas (GHG) emission values. Baseline energy usage only encompasses the equipment analyzed during the farm energy audit and correlates with what has been monitored with the Power Take Off equipment installed through the Whole Farm Energy Program. This document can be used as a project checklist as you complete energy efficiency projects.

The energy savings described below are based upon actual farm data obtained at your facility. The analysis assumes that you are milking 210 cows, 2 times per day, with an average daily milk production weight of 13,700 pounds. This analysis assumes that the farm herd size will not change in subsequent years.

Energy and cost savings are based upon researched and monitored farm equipment installations on similar sized farms, peer reviewed studies, and literature reviews of farm technologies. Such data has been used in conjunction with actual farm data to obtain savings approximations. Energy savings are subject to changes in fuel cost, maintenance, seasonal variations, and farm herd increases or decreases.

We appreciate the opportunity to learn and work with your farm. For further assistance, please contact your energy advisor via the information provided below.

Sincerely,

Gary Gilles
Energy Analyst – GDS Associates
608-354-0199
gary.gilles@gdsassociates.com

Farm Statistics:

Herd Size
210

Milking Per Day
2

Daily Milk Production
13.700

Milking System
Parallel Parlor

Water Heater
LP Gas

KWh Cost
$0.12/kWh

Energy Savings Summary:

Measure	Annual Savings	Project Cost	Payback (years)	kWh Savings	kW Savings	Carbon Offset (Metric tons CO_2)
Lighting	$3,042	$11,882	3.9	25,353	8.6	17.7

- Replace existing old lights with LED lamps/fixtures throughout the dairy facility

Energy Savings Summary Descriptions:

Details regarding each energy efficiency project are listed below.

1. Lighting

It is recommended the farm install high efficiency LED lighting throughout the farm to replace the existing outdated lighting. LED lighting can last over twice as long as fluorescent technology and use 25% less energy. Best practices for LED lighting installations suggest checking to see if the LED brand and model of lighting is approved by the Design Lights Consortium, and/or if the fixture type is on the Energy Star list for LED lighting. When considering new farm lighting, consult with a qualified electrician to ensure fixtures are installed to meet code and safety regulations as well as any selected lighting fixture will produce the amount of light needed for the specific area it is being installed in. National Electric Code 547 requires that light fixtures installed in animal housing or milk house areas be wet or damp location gasketed fixtures. The farm could save $3,042 (25,353 kWh) if all light fixtures are upgraded to LED.

Table 1 summarizes the recommended lighting upgrades with associated energy and cost savings for each application.

Table 1: Lighting upgrade summary by location

Location	Energy Efficiency Project	Annual Cost Savings	Estimated Project Cost	Estimated Payback (years)	Annual kWh Savings	Number of New Fixtures
Parlor	Tube LED lamp – 108 W	$668	$2,250	3.4	5,568	15
Free Stall	LED High Bay – 220 W	$1,070	$6,500	6.0	8,921	13
Creamery Office	Tube LED lamp – 108 W	$48	$300	6.3	398	5
Creamery Store Entrance	LED screw in lamp – 15 W	$131	$60	0.5	1,095	5
Creamery	Tube LED lamp – 90 W	$245	$1,170	4.8	2,044	13
Shop Exterior Wall Pack	LED Wall Pack – 40 W	$72	$150	2.1	602	1
Creamery Utility Exterior Wall Pack	LED Wall Pack – 40 W	$72	$150	2.1	602	1
Creamery Store Entrance Wall Pack	LED Wall Pack – 40 W	$72	$150	2.1	602	1
Vet Office	Tube LED lamp – 30 W	$20	$60	3.0	166	2

Location	Energy Efficiency Project	Annual Cost Savings	Estimated Project Cost	Estimated Payback (years)	Annual kWh Savings	Number of New Fixtures
Parlor Entrance	LED screw in lamp – 15 W	$26	$12	0.5	219	1
Maternity Area	Tube LED lamp – 60 W	$303	$450	1.5	2,523	3
Maternity Area	Tube LED lamp – 30 W	$120	$90	0.8	999	3
Parlor Walkway Room	Tube LED lamp – 60 W	$45	$120	2.7	372	2
Parlor Milk House	Tube LED lamp – 30 W	$17	$30	1.8	139	1
Free Stall Exterior Wall Pack	LED Exterior – 40 W	$72	$150	2.0	602	1
Parlor Utility Room	Tube LED lamp – 30 W	$33	$60	1.8	277	2
Creamery Utility Room	Tube LED lamp – 60 W	$27	$180	6.7	223	3

Baseline Energy

Metz Creamery (Includes only monitored electric equipment	Baseline	Units
Baseline Energy Usage	668.8	MMBtu
Annual Electric Usage	195, 957	kWh
Total Annual Energy Cost	23,514	U.S. Dollars
Baseline Greenhouse Gas Emissions	137.4	MTeCO2

Potential Energy Efficiency Funding Opportunities

Funding Source	Type of funding	Requirements for funding	Maximum amount funded	Further information found at:
NRCS - EQIP	Federal Agriculture Conservation Incentive Program	Development of Agriculture Energy Management Plan (AgEMP) for facility and installation of recommendations.	Up to 75% of project cost	*https://www.nrcs.usda.gov*
Utility	Electric Utility Equipment Rebate	Electric Saving Equipment Installed	Varies Based on Lighting Technology	*http://www.tec.coop*