2017 Project Abstract
For the Period Ending June 30, 2021

PROJECT TITLE: Generation, Storage, and Utilization of Solar Energy
PROJECT MANAGER: Bradley Heins
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WEBSITE: https://wcroc.cfans.umn.edu/research/dairy
FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2017, Chp. 96, Sec. 2, Subd. 07c as extended by M.L. 2020, First Special Session, Chp. 4, Sec. 2

APPROPRIATION AMOUNT: $500,000
AMOUNT SPENT: $500,000
AMOUNT REMAINING: $0

Sound bite of Project Outcomes and Results

The project benefited lakes and streams through the development of novel methods to reduce energy usage on farm and integrate cattle grazing and solar systems. We evaluated technology that that will reduce the carbon footprint through energy reduction from dairy farms in Minnesota that will improve environmental impact.

Overall Project Outcome and Results

The work conducted at the University of Minnesota West Central Research and Outreach Center in Morris was were to investigate electrical energy use on dairy farms located in west central Minnesota and to evaluate the effects of shade use by cattle from solar photovoltaic systems. Measurements of baseline fossil fuel consumption within dairy production systems are scarce. Therefore, there is a need to discern where and how fossil fuel-derived energy is being used within dairy production systems. Baseline energy use data collection is the first step in addressing the demand for a reduced carbon footprint within dairy production systems. Energy use on five Midwest dairy farms was evaluated from July 2018 to June 2021. Through in-depth monitoring of electricity-consuming processes, it was found that electricity use can differ quite drastically in different types of milking systems and farms. Electricity on an annual basis per cow ranged from 400 kWh/cow in a low-input and grazing farm to 1,145 kWh/cow in an automated milking farm. To reduce electrical energy consumption as well as reduce the effects of heat stress in pastured dairy cows, producers may investigate using an agrivoltaic system. Biological effects of internal body temperature, milk production, and respiration rates and behavioral effects of activity, rumination, fly avoidance behaviors, and standing and lying time of the solar shade were evaluated. Results of this agrivoltaic system suggested that grazing cattle that have access to shade had lower respiration rates and lower body temperatures compared to cattle that do not have access to shade. This project suggests that improvement in Minnesota waterways and environment may be achieved through reduced use of fossil energy through integrating livestock and solar energy production systems.

Project Results Use and Dissemination

We have provided tours of the agrivoltaic system at the WCROC to legislators, farmers, and industry representatives. We have also hosted dairy field days and the Midwest Farm Energy Conference at the WCROC that have shown the results and solar system to the public as well. Over 10,000 people have viewed the solar system and have responded with favorable interest in the system. A graduate student on the project presented an abstract at the ADSA Meeting and Waste to Worth conference. So far, 3 peer reviewed papers have been published with more to follow. The WCROC website provides the results of the project and YouTube videos for promotion of the project. A presentation was made at the global Virtual AgriVoltaics conference in 2021. This applied dairy energy and agrivoltaics projects was the Master's thesis of Kirsten Sharpe in the Department of Animal Science at the University of Minnesota and she defended her thesis in 2020.

Environment and Natural Resources Trust Fund (ENRTF) M.L. 2017 LCCMR Work Plan

Date of Submission: August 4, 2021

Date of Next Status Update Report: June 30, 2021

Date of Work Plan Approval: 06/07/2017

Project Completion Date: June 30, 2021

Does this submission include an amendment request? No

PROJECT TITLE: Generation, Storage, and Utilization of Solar Energy

Project Manager: Bradley Heins

Organization: University of Minnesota

Mailing Address: 46352 State Hwy 329

City/State/Zip Code: Morris, MN 56267

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Location: Statewide

Total ENRTF Project Budget:		
	ENRTF Appropriation:	**$500,000**
	Amount Spent:	**$500,000**
	Balance:	**$0**

Legal Citation: M.L. 2017, Chp. 96, Sec. 2, Subd. 07c as extended by M.L. 2020, First Special Session, Chp. 4, Sec. 2

Appropriation Language:
$500,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota, West Central Research and Outreach Center, Morris, to develop and demonstrate an integrated facility to generate electricity, shade dairy cattle, and provide energy storage and utilization from solar technologies at the West Central Research and Outreach Center, Morris. This appropriation is available until June 30, 2020, by which time the project must be completed and final products delivered.

M.L. 2020 - Sec. 2. ENVIRONMENT AND NATURAL RESOURCES TRUST FUND; EXTENSIONS. [to June 30, 2021]

I. PROJECT TITLE: Generation, Storage, and Utilization of Solar Energy

II. PROJECT STATEMENT:
Through past investments and institutional experience in renewable energy and dairy production research, the University of Minnesota West Central Research and Outreach Center (WCROC) has a globally unique opportunity to lead a new green revolution - a revolution that greens energy currently consumed within the agricultural industry. This proposal will leverage current efforts by further developing energy storage and utilization strategies for Minnesota. The agricultural industry consumes an immense amount of fossil-fuel in the production of food, feed, fiber, and energy. From the electricity that cools milk, to the fuel that is burned in combines and tractors in grain fields, to the trucks that bring goods to market, and to the nitrogen fertilizer that nourishes plants; the agricultural industry is captive to large and constant supplies of a wide range of fossil energy. Agriculture's dependence and thirst for fossil-fuel carries significant economic, environmental, and social risks for the nation and world. The overall objective of our project is to integrate solar technologies into dairy production systems to generate, store, and utilize electricity. The project team proposes to evaluate applicability and implementation of solar systems for shading of cattle, as well as generating electricity for charging systems that will be used to power electric vehicles from around western Minnesota. The team will leverage current research by testing clean energy charging systems and provide consumers with an evaluation of tested clean energy vehicles for livestock facilities and the highway system. Additionally, we will evaluate the cow cooling potential of solar systems in the grazing dairy system at the WCROC. The knowledge and information generated will be disseminated to agricultural producers, energy professionals, students, and other stakeholders through Extension websites, social media, and field days hosted at the WCROC.

Our general concept is to evaluate solar PV for multiple uses in a grazing-based dairy. In addition to generating electricity, the panels will be studied for use as livestock shade to improve animal comfort and productivity. The solar generated electricity will be utilized for a fast-charging station. Electric all-terrain utility vehicles will be charged by solar energy and used within the pasture and dairy farm. An electric car will be charged with solar energy and used for travel to small and mid-sized commercial dairy farms to conduct baseline energy audits. This study is the first step to convert fossil-based vehicles used in dairy farms, to clean and locally produced energy.

III. OVERALL PROJECT STATUS UPDATES:

Project Status as of *January 1, 2018*:
During the first 6 months of the project, we have identified dairy farms in Minnesota to monitor. We have made initial visits with farmers and are preparing to purchase sensors to monitor dairies. We will start monitoring these dairies during January and February of 2018. We have purchased the Polaris electric Rangers to start monitoring their efficiency for dairy production systems. The solar panel and charging system requisitions have been approved and will be installed in early spring 2018. A graduate student will start on the monitoring project in January 2018.

Project Status as of *July 1, 2018*:
During the last six months from January 1, 2018, we have installed the 30-kW solar system in the pasture at WCROC and have begun monitoring energy output. We have also installed sensors systems and have started monitoring 5 dairy farms in Minnesota for energy usage. The fast-charging system and Chevy Bolt EV have been purchased and installed. We are also monitoring data from the electric car, electric Polaris Rangers, and the fast-charging system. A graduate student and research scientist began working with this project in January 2018.

Project Status as of *January 1, 2019*:
We finalized the installation of the 30-kW solar array in the pasture at the WCROC and have begun collecting solar energy data from the solar panels. We have been monitoring dairy farms in Minnesota for energy usage and have collected about 6 months of data on all farms. We have noticed very diverse uses of energy use on the dairy farms that we have monitored. The WCROC as well as the traveling public have utilized the fast-charging system. We have collected data from the all-electric Chevrolet Bolt. A graduate student and scientist have been working with the farms and collecting data. We have been planning the Midwest Farm Energy Conference for July 2019 that will discuss some early results of the project.

Project Status as of *July 1, 2019*:
The installation of the 30Kw system was completed and we have tested 100% ATV electric vehicles and a 100% Electric Chevrolet Bolt at the WCROC. We continue to monitor these vehicles and solar system through the end of the project. During the summer of 2019 we began a study to evaluate the solar shade potential of dairy cattle. We have enrolled 24 cows in the study to evaluate shade use, as well as monitor animal health and well-being while cattle are grazing at the WCROC. This will be a part of a grad student's thesis project. We have also recorded 1 year of data from all farms enrolled in the monitoring dairy energy on farm. We will continue to monitor the energy usage on farm through the end of the project. A graduate student presented research on the on-farm dairy energy portion of the project at the Waste-to-Worth Conference in Minnesota. The student won 1st place in the graduate student poster division. The Project manager also presented research on dairy energy monitoring at the U of MN WCROC Midwest Farm Energy Conference in June 2019.

Project Status as of *January 1, 2020*:
We continue to monitor the 100% Polaris Electric ATV vehicles, the 100% Electric Chevrolet Bolt, and the 30-kW solar system at the WCROC. During the summer of 2019, we evaluated the potential of the solar shade system for dairy cattle grazing. We enrolled 24 cows and evaluated the cows for production, body temperature, and behavior. The study found that cows that had shade had lower respiration rates during the hottest part of the day compared to cows that did not have shade. Some behavioral indicators of heat stress were observed on cattle with shade because the cows that had shade grouped together in the shade and did not move. This is indicated by cows with shade had lower activity. Grazing cows used the stationary solar shade less than expected, but cows typically graze during the day and therefore the reduced use of shade during the day could be caused by the cows' desire to eat during the day. Body temperature of cows is one of the greatest indicators of heat stress. Cows that had access to shade had lower internal body temperature (~ 0.5 ˚Fahrenheit lower), which indicates that those cows would have less heat stress. We have also recorded 1.5 year of data from all farms enrolled in the monitoring dairy energy on farm. A graduate student presented research on the on-farm dairy energy portion of the project at the Minnesota Milk Expo in Red Wing, MN. The student won 2nd place in the graduate student poster division. We also had a visiting graduate student from FH Munster University of Applied Science in Germany and work on her master's Thesis related to collecting energy data at a large dairy farm in the project. She successfully defended her master's thesis with project data during December 2019.

Project extended to June 30, 2021 by LCCMR 6/18/20 as a result of M.L. 2020, First Special Session, Chp. 4, Sec. 2, legislative extension criteria being met.

Project Status as of July 1, 2020:
We continue to monitor the 30-kW solar system at the WCROC. Because of the COVID-19 virus, we were not able to finish collecting data on farms during March to June 2020. Once we are able to collect the data on farm, we will finish the data collection period. A graduate student defended her master's thesis on March 5, 2020. Here thesis was entitled "Electrical consumption on Midwestern dairy farms in the United States and agrivoltaics to shade cows in a pasture-based dairy system". We also published 2 articles in Hoards Dairyman in May and June 2020. Our University of Minnesota Dairy Extension Moos Room Podcast has 2 episodes from this study. One was on solar shade and the other was from dairy energy usage on farms. Briefly, energy use on five

Midwest dairy farms was evaluated from July 2018 to December 2019. Through in-depth monitoring of electricity-consuming processes, it was found that electricity use can differ quite drastically in different types of milking systems and farms. Electricity on an annual basis per cow ranged from 400 kWh/cow in a low-input and grazing farm to 1,145 kWh/cow in an automated milking farm. Biological effects of internal body temperature, milk production, and respiration rates and behavioral effects of activity, rumination, fly avoidance behaviors, and standing and lying time of the solar shade were evaluated. Treatment groups were shade or no shade of cattle on pasture. The results of this agrivoltaic system suggested that grazing cattle that have access to shade had lower respiration rates and lower body temperatures compared to cattle that do not have access to shade. Electricity used in dairy farms was examined to help producers find areas in their farms that have the potential for reduced energy consumption. Furthermore, the use of an agrivoltaic system on a pasture-based dairy was studied for its shading effects on the health and behavior of dairy cows.

Project Status as of January 1, 2021:
The project has slowed due to the COVID-19 pandemic where we have not been able to go to farms to finish the final data collection. However, we have been approved to go collect the final farm energy data in January and February of 2021 to conclude the final analysis of farm energy. We continue to monitor the solar system in the pasture at the WCROC. We have also had a peer-reviewed published manuscript in the Journal of Dairy Science on the Solar PV System and grazing.

Overall Project Outcomes and Results:

The work conducted at the University of Minnesota West Central Research and Outreach Center in Morris was were to investigate electrical energy use on dairy farms located in west central Minnesota and to evaluate the effects of shade use by cattle from solar photovoltaic systems. Measurements of baseline fossil fuel consumption within dairy production systems are scarce. Therefore, there is a need to discern where and how fossil fuel-derived energy is being used within dairy production systems. Baseline energy use data collection is the first step in addressing the demand for a reduced carbon footprint within dairy production systems. Energy use on five Midwest dairy farms was evaluated from July 2018 to June 2021. Through in-depth monitoring of electricity-consuming processes, it was found that electricity use can differ quite drastically in different types of milking systems and farms. Electricity on an annual basis per cow ranged from 400 kWh/cow in a low-input and grazing farm to 1,145 kWh/cow in an automated milking farm. To reduce electrical energy consumption as well as reduce the effects of heat stress in pastured dairy cows, producers may investigate using an agrivoltaic system. Biological effects of internal body temperature, milk production, and respiration rates and behavioral effects of activity, rumination, fly avoidance behaviors, and standing and lying time of the solar shade were evaluated. Results of this agrivoltaic system suggested that grazing cattle that have access to shade had lower respiration rates and lower body temperatures compared to cattle that do not have access to shade. This project suggests that improvement in Minnesota waterways and environment may be achieved through reduced use of fossil energy through integrating livestock and solar energy production systems.

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Design solar systems and fast charging stations for dairy facilities.
Description:

A 30-kW ground-mounted solar photovoltaic system will be installed at the WCROC dairy pasture. Control systems will be installed, and field tested. The control of farm-scale clean energy systems is deficient and a barrier to adoption of clean energy systems. The solar PV system will be performance tested for one year for production and reliability. Once installed, production data from the 30-kW solar PV system will be measured and analyzed over a two-year time frame to determine gross and net energy production including diurnal and seasonal variation. The project team will direct an undergraduate student intern to assist in collecting data and evaluating the results. The student intern will develop a written report and provide a public presentation summarizing the results from the field test of the solar PV system.

Efforts will be made to standardize the design of the solar installation as it potentially may then be utilized for similar on-farm dairy facilities. The use of solar photovoltaic (PV) systems is a logical choice to performance test for the production of electrical energy for dairy facilities. In addition, new solar PV programs were put in statute during the 2013 Minnesota Legislative Session. Combined with the availability of federal USDA REAP grants and declining costs for solar PV, dairy producers may be able to cost effectively generate electricity to meet their load requirements. Solar PV also has peak production capacity during hot summer days which also matches high-energy load times for dairy facilities (ventilation).

We would also incorporate a fast charging system that would be able to charge the vehicles for travel and ATV for use in the dairy pasture system. We would incorporate the charger and the solar PV system. The fast charger would be part of the high-speed charging network in Minnesota, providing for electric vehicle usage in rural parts of Minnesota. The fast charger has 50 kW charging power and will fully charge an electric vehicle in 50 minutes.

We will assist to make electric vehicle ownership viable especially in rural Minnesota. We will field test electric vehicles at the WCROC. Two electric Polaris Ranger (or equivalent) will be utilized for daily agricultural uses in the dairy pasture production system at the WCROC. The Polaris Ranger (a Minnesota company produced vehicle) has an 30HP/48V AC electric motor, allowing for quite operation. The AC motor is more efficient and extends to range of use of the ATV. Performance records, charging records, and maintenance and usage records will be collected throughout the project for the ATV vehicles to demonstrate use in an agricultural application.

Furthermore, a 100% electric vehicle will be performance tested and utilized for travel to Minnesota dairy farm to collect energy usage data. All records pertaining to vehicle usage and maintenance will be logged for the 2 years of data collection on Minnesota dairy farms. The energy and charging systems, as well as electric vehicle use and demonstration will be tested for two years for production and reliability. This research will have much wider implications across agriculture and other industries.

Summary Budget Information for Activity 1:

ENRTF Budget:	**$ 254,750**
Amount Spent:	**$ 254,750**
Balance:	**$ 0**

Outcome	**Completion Date**
1. Install a 30 kW photovoltaic solar system in a pasture at the WCROC dairy	7/1/2018
2. Install fast charging system to power clean energy vehicles	7/1/2018
3. Conduct field tests on electric vehicle charging with 100 % electric ATV and 100% electric vehicle at the WCROC	7/1/2018

Activity 1 Status as of January 1, 2018:
We have purchased the 30kW photovoltaic solar system for the dairy and we have identified a site for the system to be installed in early spring 2018. The fast charging system has also been purchased and will be installed in January 2018 at the WCROC. Polaris Ranger EVs have been purchased and are being monitored for energy usage at the WCROC dairy.

Activity 1 Status as of July 1, 2018:
We have installed the 30 kW photovoltaic solar system in cattle pastures that are very near the office building at the WCROC. The site is very accessible to all the public and people that come to the WCROC office building.

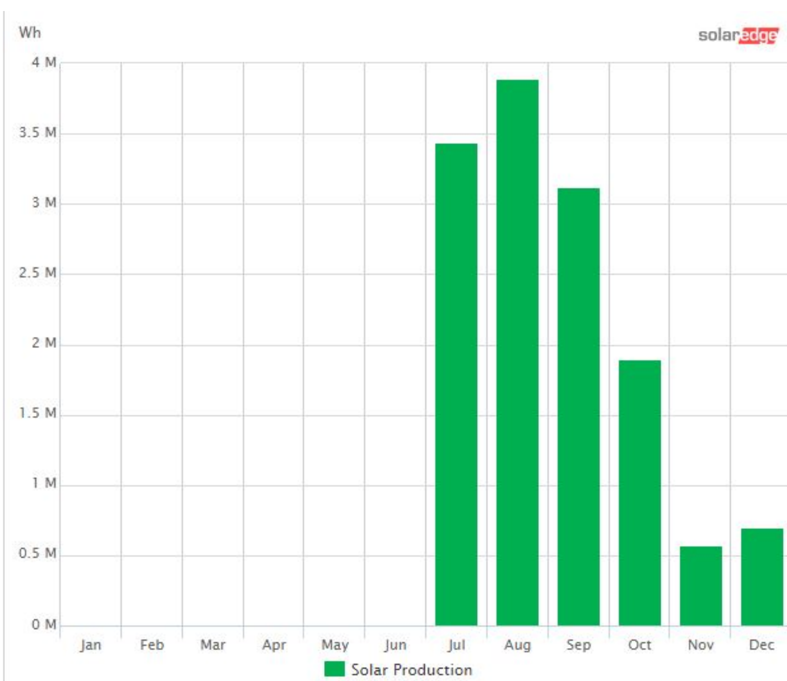
The fast charging system was installed in March 2018 and we commissioned the fast charging system on April 20, 2018. We had a large group of people here where we showcased the Chevy Bolt EV and the fast charging system. We had members from the LCCMR commission during the ceremony. Our faster charger and project was reported on MPR news on April 20, 2018. https://www.mprnews.org/story/2018/04/20/a-sign-of-the-future-in-morris-cows-solar-panels-fast-electric-car-charger. We have also begun monitoring the energy usage of the Polaris EV Rangers.

The chart is some of the initial data that we have received from Monitoring the energy usage from the Chevy Bolt EV.

		Miles Driven	kWh Consumed	Avg Miles/kWh
Long Trips (>10mi)		1723.02	508.8	3.386438679
Short Trips (<10mi)		219.12	71.09	3.082290055
		Miles Driven	**kWh Consumed**	**Avg Miles/kWh**
High Speed (>40mph avg)		223.02	71.74	3.108725955
Low Speed (<40mph avg)		1719.12	508.15	3.383095543
		Miles Driven	**kWh Consumed**	**Avg Miles/kWh**
High Speed (>65mph max)		1539.71	452.09	3.405759915
Low Speed (<65mph max)		402.43	127.80	3.15
	Avg Temp (F)	**Miles Driven**	**kWh Consumed**	**Avg Miles/kWh**
March	37.4	250	91.6	2.73
April	*39.0*	235	83.9	2.80
May	70.0	803	225.9	3.56
June	73.9	654	178.5	3.66

This is a picture of the solar panels in the WCROC just after the installation and we put the cows in the pasture for shading.

Activity 1 Status as of January 1, 2019:
We have installed the 30 kW photovoltaic solar system in cattle pastures that are very near the office building at the WCROC. The cows utilized the solar panels as shade during August 2018. During 2018, the solar panels produced 13.61 MWh of energy.

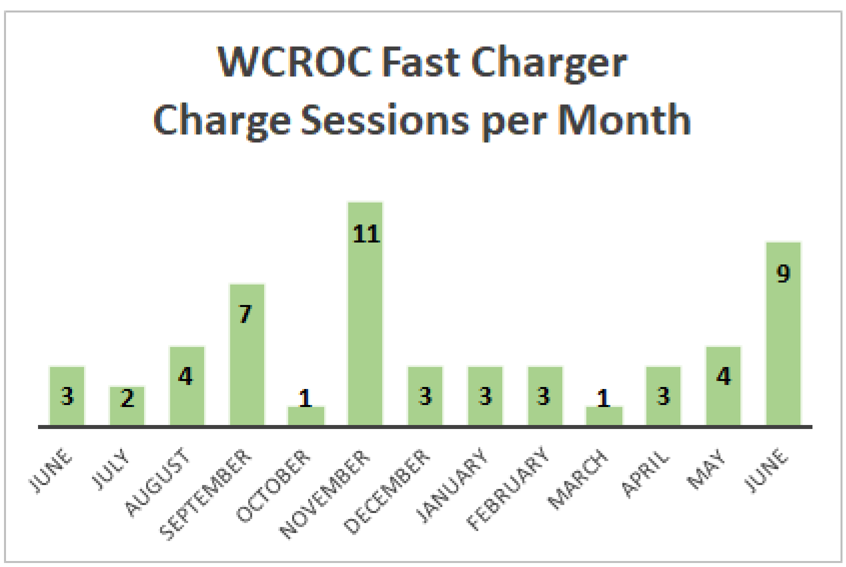


On average, the charger is getting used maybe one or two times per week. By month, the charge sessions have been, June (4), July (3), August (4), September (8), October (1), November (14), December (4). The charger has used about 900 kWh (770 if you exclude the WCROC usage) of electricity in those 6 months with an average of about 25 kWh per charge.

For the Chevrolet Bolt, the most correlated variable is still temperature, so we evaluated temperature by 10 degree ranges and evaluated the miles/kWh for the number of miles driven in that range. Our overall average driving temp was 59 degrees. The most of the miles we're driving would be right around that 3.6-3.7 miles/kWh (about a 220 mile range) but the cold weather drops it pretty considerably. Our total average over about 3700 miles is actually all the way down around 3.2 miles/kWh (about a 190 mile range).

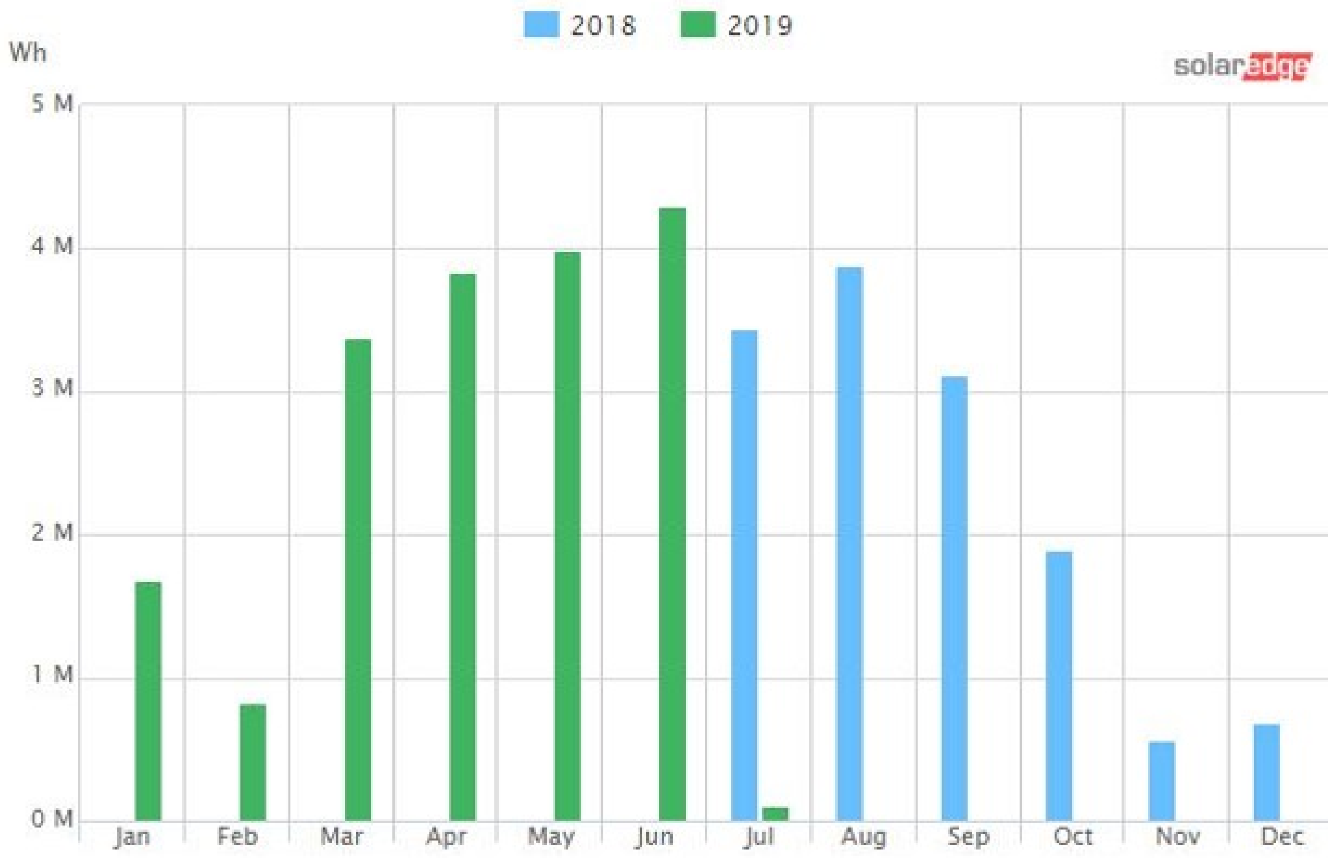
Temperature Range °F	Miles Driven	Average Miles/kWh
< 15	121	3.06
15 – 25	255	2.48
25 – 35	397	2.53
35 – 45	381	2.77
45 – 55	219	3.12
55 – 65	150	3.64
65 – 75	844	3.63
75 – 85	1,240	3.71
> 85	85	2.83

Activity 1 Status as of July 1, 2019:
We have been monitoring our DC fast charger since 2018. Data starts June 15th of 2018. Since then in total we've used 1,869 kWh of electricity, or 1,564 not counting the WROC Bolt usage. At about 10 cents per kWh that's about $156 spent by the ROC in just over a year. Average energy per charge is 25.6 kWh - just under half the Bolt's 60 kWh battery, for reference. In that year we've served 31 unique drivers. (30 not counting ourselves) Not counting our usage, we see an average of 4.2 charge sessions per month with the breakdown of each month shown in this graph**.**



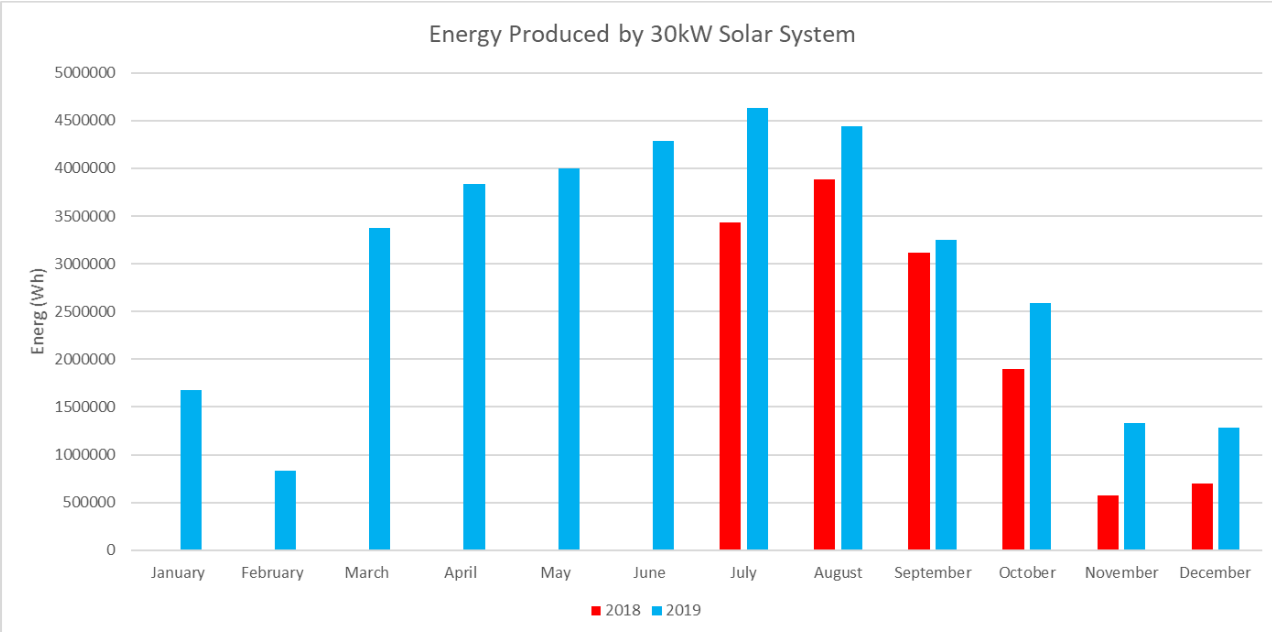
WROC Bolt:
We have been monitoring our 100% Electric Chevrolet Bolt since early 2018. Data starts March 20th of 2018. Since then we've driven about 6,600 miles and used 1,980 kWh of electricity. That's about 3.3 miles per kWh or 300 Wh per mile. At 10 cents per kWh we've used about 3 cents per mile, or just under $200 of electricity. Temperature seems to be the most pertinent factor. For example, the 300 Wh per mile total average is 425 Wh per mile if you average just the months of December, January, and February.

During 2018, the solar array produced 13.61 Mwh and in the first six months of 2019 the solar array produced 18.006 Mwh.

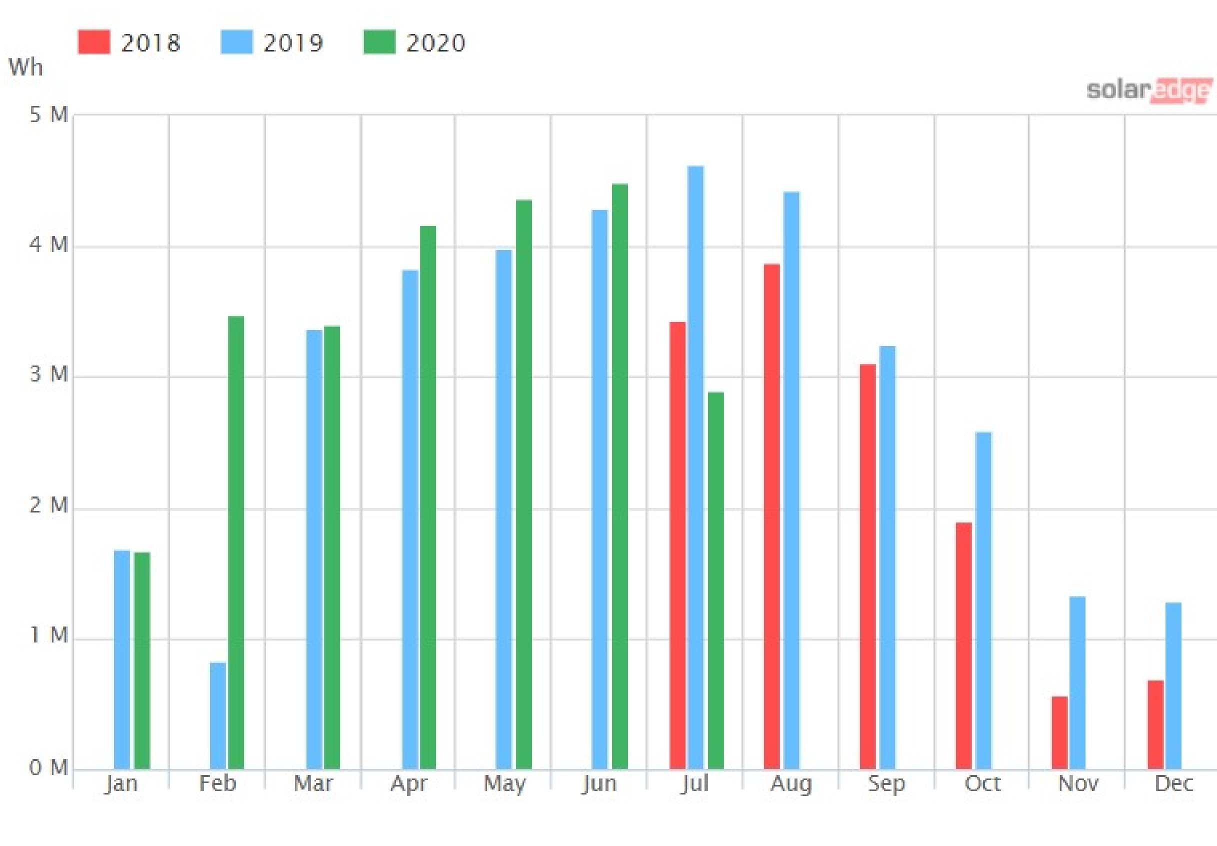


Activity 1 Status as of January 1, 2020:

We have monitored the 30 kW photovoltaic solar system in cattle pastures that are very near the office building at the WCROC. The cows utilized the solar panels as shade during June to October 2019. During 2019, the solar panels produced 35.535 MWh of energy. Based on environmental benefit calculations, we have saved 37, 238 kg of CO_2 emissions which is the equivalent of 2,066 trees planted. All of the outcomes have been completed, and we are analyzing the final data from the Chevrolet Bolt, Electric ATVs, and the DC Fast Charger at the WCROC.

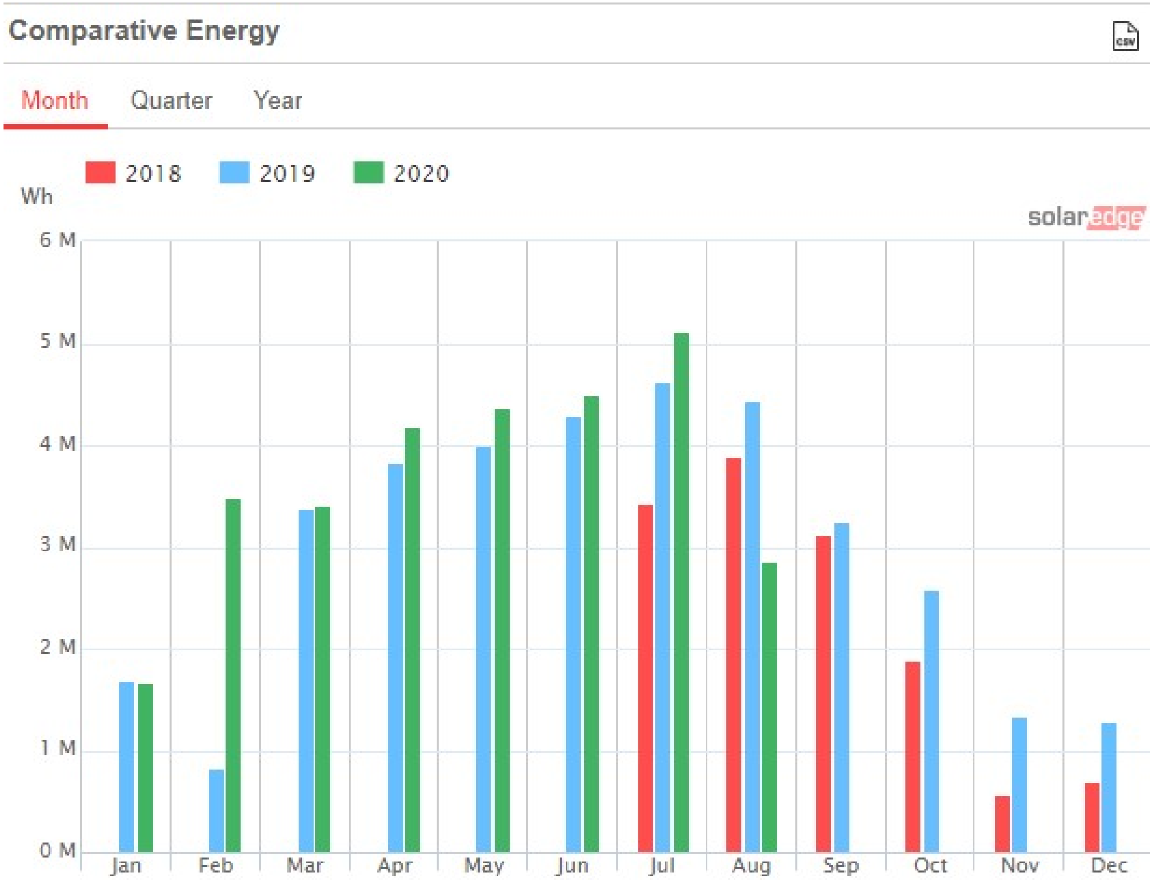


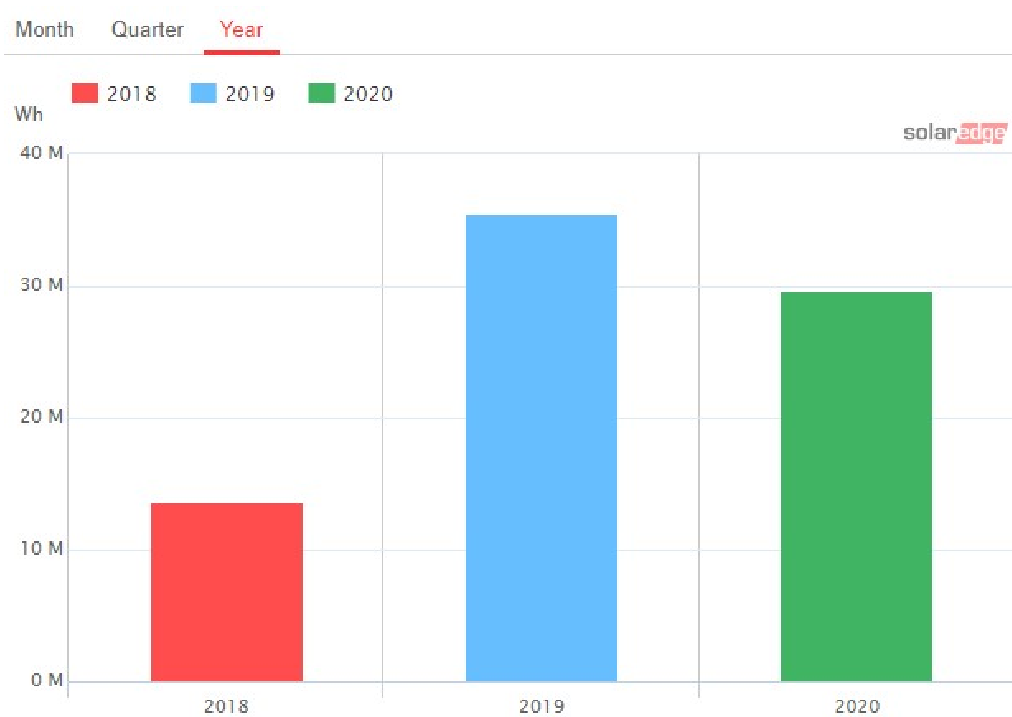
Activity 1 Status as of July 1, 2020:
We have monitored the 30-kW photovoltaic solar system in cattle pastures that are very near the office building at the WCROC. During the first 6-months of 2020, the solar panels produced 21.60 MWh of energy. Based on environmental benefit calculations, we have saved 53,401 kg of CO_2 emissions which is the equivalent of 888.75 trees planted. All of the outcomes have been completed. We are finalizing the data from the Chevrolet EV Bolt.



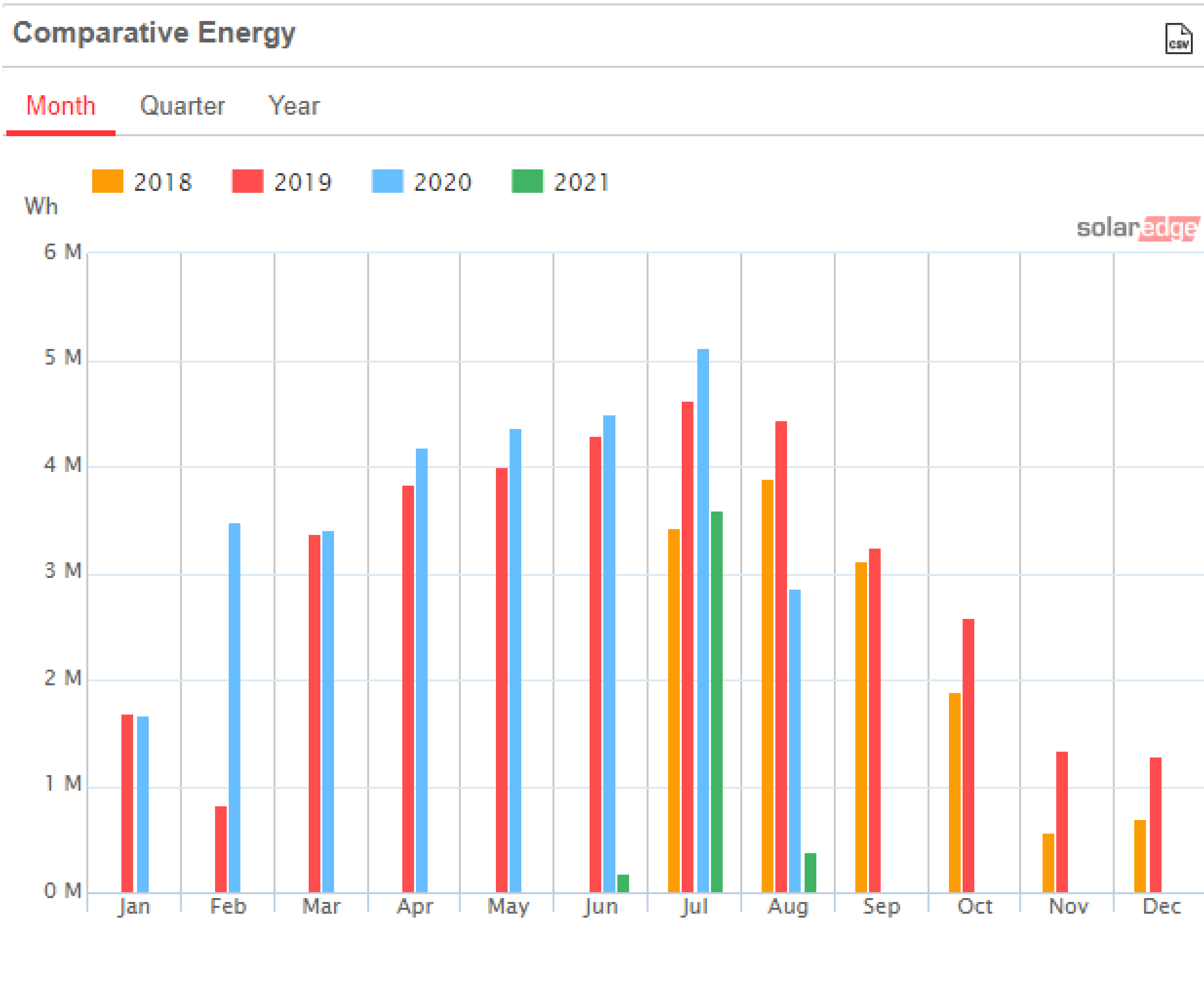
Activity 1 Status as of December 30, 2020:

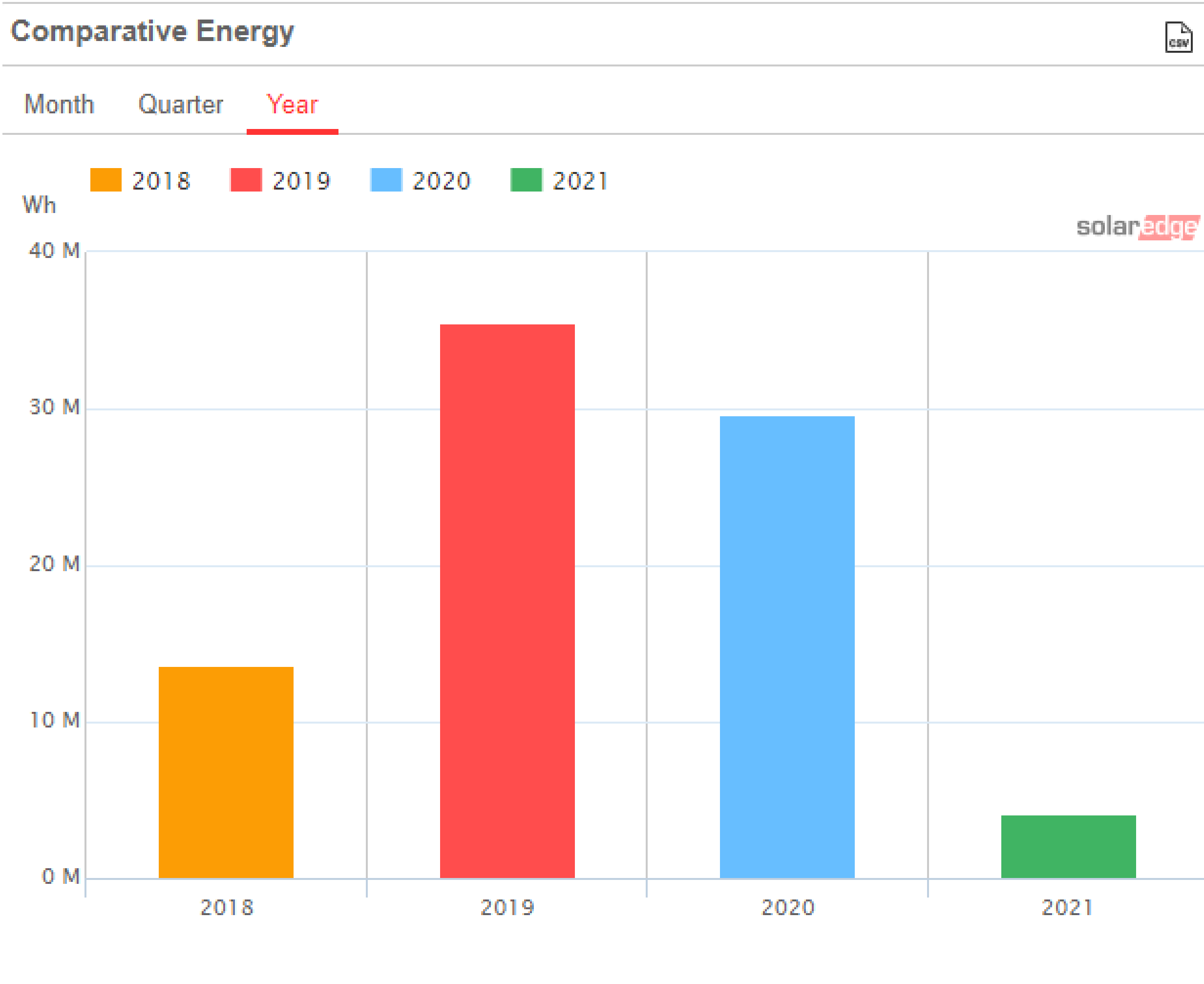
We have monitored the 30-kW photovoltaic solar system in cattle pastures that are very near the office building at the WCROC. During 2020, the solar panels produced 29.6 MWh of energy. Based on environmental benefit calculations, we have saved 56,833 kg of CO_2 emissions which is the equivalent of 946 trees planted. All of the outcomes have been completed.





Final Report Summary:
We have monitored the 30-kW photovoltaic solar system in cattle pastures that are very near the office building at the WCROC. Based on environmental benefit calculations, we have saved 83,721 kg of CO_2 emissions which is the equivalent of 1,393 trees planted. All of the outcomes have been completed.





ACTIVITY 2: Evaluate the shade potential of solar systems for pastured-cattle
Description:
The team will utilize the solar production system in the pasture to effectively evaluate the cow-cooling and animal welfare benefits of using solar systems for shade potential at the WCROC. The Holstein and crossbred dairy cows at the WCROC will be divided into sub-herds balanced by parity, breed, and calving date, and assigned to two different shade treatments. The treatments will be shade with the solar PV system, or no-shade. Solar protection will be provided by the 30 kW PV structure in the pasture that will be mounted 7 to 8 feet off the ground. The lactating cows will be introduced to their respective treatments during the early portion of the grazing season (typically the end of May), and will be removed from pastures in the fall (typically in October). Throughout each summer, animals will be housed continuously in their respective settings on pasture, be milked twice a day, and be fed free-choice minerals on pasture.

Milk production will be quantified as daily milk weights and bi-weekly measures of fat, protein, SCC, and milk urea nitrogen while cows are under the solar PV shade structure compared to no shade. To evaluate animal health, cow body weights will be recorded monthly using a digital scale as cows exit the milking parlor, and all cows in each housing system will be visually scored for locomotion, body condition, hygiene, and hock lesions once monthly. Lameness will be scored using a 5-point locomotion scoring method, with 1 = normal locomotion to 5 = severely lame (Flower and Weary, 2006). Body condition scores will be 1 = excessively thin to 5 = excessively fat (Wildman et al., 1982). Locomotion and body condition scoring will be performed by a single observer as cows are exiting the milking parlor. Hygiene scores will be assessed by udder and lower hind leg cleanliness, with 1 = clean to 5 = dirty (Reneau et al., 2005). Hock lesions will be classified as 1 = no lesion, 2 = hair loss (mild lesion), and 3 = swollen hock with or without hair loss (severe lesion). Hygiene and hock lesion scoring will be done in the milking parlor before milking units are attached. To monitor mastitis, cows will be examined monthly for clinical mastitis and milk samples from mastitis cases will be collected, frozen, and later cultured for bacterial populations in accordance with the identification procedures recommended by the National Mastitis Council (NMC, 2004).

Lying behavior will be measured in all cows using data loggers once monthly for a period of 5 consecutive days. A behavior data logger (Hobo Pendant G Acceleration Data Logger, Onset Corporation, MA) will be placed on the rear lower leg of all cows during the same five consecutive days to record lying behavior, including lying time, and number and length of lying bouts. Additionally, both treatment groups will be observed for fly abundance and concurrent frequencies of defensive behaviors. Cows will be observed between 1:00 and 3:00 pm. Cows will be observed from a distance of 1 to 2 meters to allow for accurate fly counts without disturbing the cow's natural behaviors. An observer will approach an individual focal cow as available, then count and record the number of horn flies, stable flies, and face flies present on the animal. After counting flies, the focal cow will be observed for five minutes to tally defensive behaviors. A stopwatch will be used to keep track of time, and behaviors are tally marked on a data sheet. Behaviors recorded are head throws, front leg stamps, back leg stamps, skin twitches and tail flicks using definitions found in Mullens et al. (2006) and Dougherty et al. (1993): After five minutes, flies are counted again, and then pre- and post-observation counts are averaged to characterize abundance during the observation period. These processes are repeated until all cows are observed. Observations are compared with the next day's recorded milk production, presuming that any stress effects would be observed the following day.

Air temperature and relative humidity will be recorded automatically at 10-min intervals with environmental loggers (Hobo Pro Data loggers, Onset Computer Corp., Bourne, MA) for each day of the grazing season. Data loggers will be placed near the pastures, ensuring that they are always under the sun. Furthermore, data loggers will be placed under the shade structures directly under the solar PV shade on the northeast corner of the structure.

Dairy cattle behavior has been studied for years to identify factors that affect performance and health (Rutter et al., 1997). Grazing activities are sensitive to environmental variables such as pasture management and shade, and those factors in turn affect forage intake and behavior (forage selection, time spent grazing, pasture rate and consumption). We will assess grazing behavior in all cows with Heatime® HR Tags from SCR Dairy (SCR Engineers, Ltd., Netanya, Israel) around the neck of each cow in the study. This system allows us to track rumination (chewing) in addition to monitoring activity levels of cows. The monitors hold 24-hours of data and correspond with a long distance (LD) antenna placed atop the milking center. Unique to the HR Tag, we are also able to monitor rumination through a microphone installed around the neck. This microphone is actually picking up jaw movements as bones rub together during rumination. Rumination is measured in minutes per day. Additionally, behavior will also be assessed with the CowManager system (Agis Automatisering BV, Harmelen, The Netherlands). This system allows us to track feeding behavior, activity levels, rumination, and body temperature.

The project team will direct a Master's degree research assistant (graduate student) to assist in collecting data and evaluating the results that will become part of a Master's degree thesis.

Summary Budget Information for Activity 2:	**ENRTF Budget:**	**$ 81,250**
	Amount Spent:	**$ 81,250**
	Balance:	**$ 0**

Outcome	Completion Date
1. Evaluate solar PV as a potential for shade for grazing dairy cattle in Minnesota	7/10/2019
2. Evaluate behavior of cattle with the use of the solar PV system	7/10/2019
3. Complete designs of clean energy systems for field testing at the WCROC	8/1/2019

Activity 2 Status as of January 1, 2018:
This portion of the project will be completed in March 2018.

Activity 2 Status as of July 1, 2018:
We have just installed the 30 kW solar system in the WCROC pasture in June 2018. We had the dairy cows in there for 1 day as a test to see the shading potential for the cows. We will be monitoring the data from the cows and conducting studies in later 2018 and 2019.

Activity 2 Status as of January 1, 2019:
We have just installed the 30 kW solar system in the WCROC pasture in June 2018. The dairy cows have been under the solar panels as test to observe what happens when cows are under the solar structure. We will collect monitoring data during the summer of 2019 when the cows are under the solar panels.

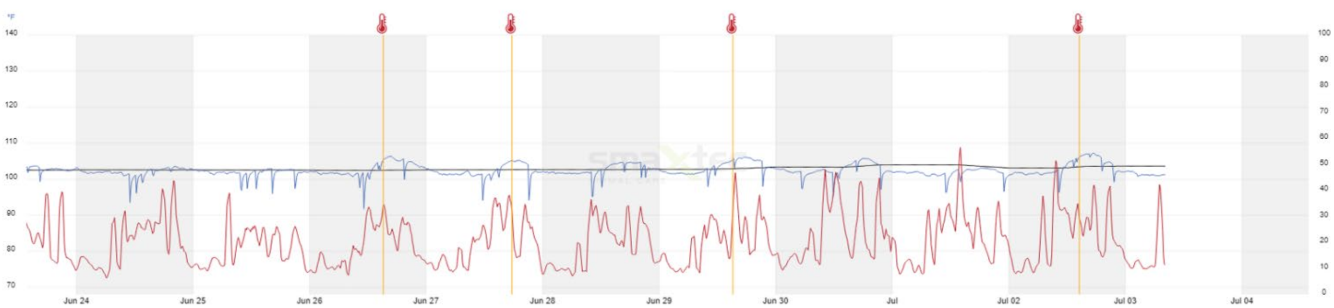
Activity 2 Status as of July 1, 2019:
During the spring of 2019, we began the solar shading study with 24 cows. Two replicated groups of 6 cows were on pasture without shade and 2 replicated groups of 6 cows each were on pasture with the solar shade structure.
To evaluate animal hygiene and well-being, all cows in each shading system were visually scored for hygiene, locomotion, and hock lesions daily during the study. Hygiene scores of the tailhead, upper leg (thigh), abdomen, udder, and lower hind leg were recorded, with 1 = clean to 5 = dirty (Reneau et al., 2005). Lameness was evaluated using a 5-point locomotion scoring method, with 1 = normal locomotion, 2 = imperfect locomotion, 3 = lame, 4 = moderately lame, and 5 = severely lame (Flower and Weary, 2006). Hock lesions were classified as 1 = no lesion, 2 = hair loss (mild lesion), and 3 = swollen hock with or without hair loss (severe lesion; Lobeck et al., 2011).

Fly counts were taken on cows at 2 time periods in the morning and 2 periods in the evening. Observers distinguished horn flies from face flies and stable flies. Horn flies were counted individually or in groups of 10 on one side of each cow. Face flies were counted on the cows' faces viewed head on. Stable flies were counted on the visible faces of front and rear legs separately. Fly counts were made from a distance of 2 to 4 m (Denning et al, 2014; Kienitz et al., 2018).

Behavior events of cows were recorded on all cows. Events were head tosses, skin twitches, tail swishes, front leg stomps, and back leg kicks. A head toss was recorded if the animal's head was thrust back toward its body, far enough that the nose crossed an imaginary plane across the front of the animal's chest (Mullens et al., 2006). A skin twitch occurred if an isolated twitch took place in a localized area or as a continuous shiver over the whole flank for several seconds (Dougherty et al., 1995). A tail swish occurred if the tail was moved from its resting position to one side of the animal's body; a separate swish occurred if the tail crossed to the opposite side of the body (Dougherty et al., 1994). A front leg stomp was defined as a raising of either front leg (while not walking) followed by a forceful thrust back to the ground.

Shade use of the solar array by cows was recorded every 10 minutes for 1.5 hours in the morning and 1.5 hours in the afternoon. Smaxtec temperature recorders in the cow's rumen will record internal body temperature every second and will provide information on heat stress.

Lying behavior will be measured in all cows using data loggers once monthly for a period of 5 consecutive days. A behavior data logger Hobo Logger or IceRobitics Tag will be placed on the rear lower leg of all cows during the same five consecutive days to record lying behavior, including lying time, and number and length of lying bouts.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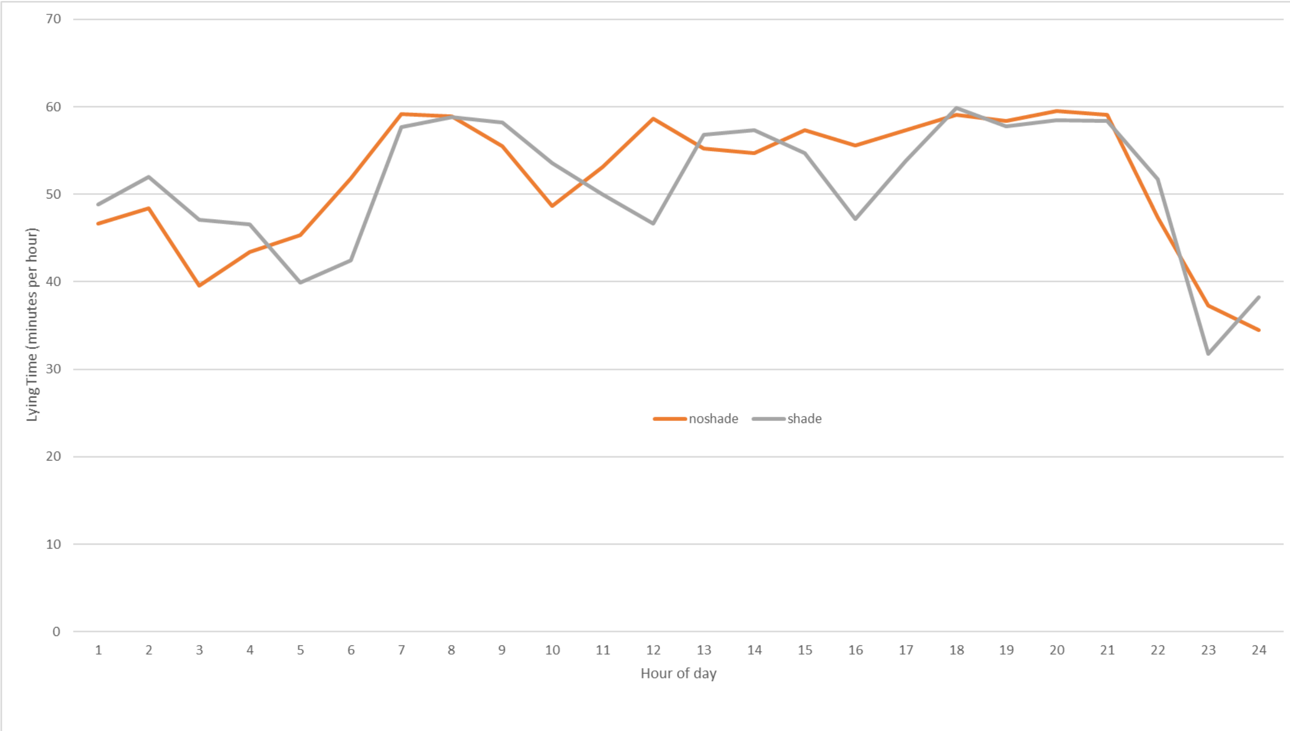
The figure is a graph of an example cow in the study that measures body temperature and this cow had 4 heat stress events during the study.



The preliminary graph shows the lying time from Hobo loggers for cows during the first period of the solar shade study. During the day, on average, the cows that had access to the solar shade has less lying time, indicating that they were standing under the shade structure during the day.

Activity 2 Status as of January 1, 2020:

We have completed the solar shading grazing project and the Master's degree student will defend here Thesis in March 2020. We have evaluated the solar PV as a potential for shade for grazing dairy cattle at the WCROC, analyzed production and behavioral components for dairy cattle. We have also completed a designs for clean energy system at the WCROC and at the farm that we are working with on the project. During the summer of 2019, we evaluated the potential of the solar shade system for dairy cattle grazing. We enrolled 24 cows and evaluated the cows for production, body temperature, and behavior. Smaxtec Bolus (https://smaxtec.com/en/) were used to monitor the internal body temperature of all cows in the study. The study found that cows that had shade had lower respiration rates during the hottest part of the day compared to cows that did not have shade. Some behavioral indicators of heat stress were observed on cattle with shade because the cows that had shade grouped together in the shade and did not move. This is indicated by cows with shade had lower activity. Grazing cows used the stationary solar shade less than expected, but cows typically graze during the day and therefore the reduced use of shade during the day could be caused by the cows' desire to eat during the day. Body temperature of cows is one of the greatest indicators of heat stress. Cows that had access to shade had lower internal body temperature (~ 0.5 ˚Fahrenheit lower), which indicates that those cows would have less heat stress.

Figure 1. The West Central Research and Outreach Center's dual-purpose 30 kilo-watt solar photovoltaic ground-mounted system.

Table 1. Summary of meteorological records for the periods during which the observations occurred

	Period 1[b]			Period 2			Period 3			Period 4		
Weather variable	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Temperature (°C)	21.0	10.0	33.9	21.5	13.9	28.9	20.1	12.2	27.2	21.6	11.7	30.6
Humidity (%)	64.0	22.5	96.9	83.6	50.5	102.2	86	48.2	102.4	82.4	35.8	102.8
Irradiation (W/m^2)	287.5	0	983.2	267.2	0	960	244.9	0	884.4	164.4	0	747.2
THI[a]	62.5	47.0	76.2	68.1	57.3	76	68.0	56.9	77.4	61.3	51.7	73.3
Total precipitation (mm)	33.8			11.7			45.0			34.8		

[a] Temperature-humidity index
[b]Period 1= 06/03/19-06/10/19, Period 2= 07/08/19-07/12/19, Period 3= 08/12/19-08/17/19, Period 4=09/16/19-09/20/19

Table 2. Least squares means and standard errors of means for fly avoidance behaviors, fly counts, and respiration rates of cows by shading treatment and time of day[1]

	Morning				Afternoon			
	Shade (n = 12)		No Shade (n = 12)		Shade (n = 12)		No Shade (n = 12)	
Measurement	LSM	SE	LSM	SE	LSM	SE	LSM	SE
Behaviors (n/30 sec)								
Tail swish	8.36	1.94	11.14	2.58	7.81	1.81	11.62	2.69
Foot stomp	3.64	0.55	3.89	0.59	4.59	0.70	5.18	0.78
Head toss	1.57	0.24	1.54	0.24	1.82	0.28	1.49	0.23
Skin twitch	15.18	1.69	9.69	1.08	14.28	1.59	9.24	1.03
Ear flick	13.19	1.13	11.52	0.99	11.40[a]	0.98	8.58[b]	0.74
Fly counts								
Total stable flies	22.74	0.07	21.83	0.06	24.47	0.07	25.73	0.07
Face fly	2.62	.01	1.07	.01	3.12	.01	1.01	.01
Horn fly	28.82	0.17	21.94	0.12	24.69	0.15	17.91	0.1
Total flies	62.93	0.22	52.87	0.16	61.72	0.22	53.14	0.17
Respiration rates (breaths/30 sec)	50.91	3.51	52.48	3.39	66.42[a]	3.41	78.32[b]	3.32

[1]Reported means and SE are based on shading treatment averages.

[a,b]Means within a row by time of day without common superscripts are different at $P < 0.05$.

Table 3. Least squares means and standard errors of means for hygiene, locomotion, and hock injury scores and milk production by shading treatment[1]

	Shade		No Shade	
Measurement	LSM	SE	LSM	SE
Hygiene				
Tail head	2.95	0.24	3.15	0.23
Upper leg	2.41	0.11	2.22	0.11
Belly	2.18[a]	0.13	1.85[b]	0.13
Udder	2.24	0.14	2.22	0.14
Lower leg	3.23[a]	0.12	2.93[b]	0.12
Locomotion	1.14	0.08	1.03	0.08
Hock injury	1.0	0.04	1.03	0.04
Milk production (kg)	13.89	1.52	15.45	1.52

[1]Reported means and SE are based on shading treatment averages.

[a,b]Means within a row without common superscripts are different at $P < 0.05$.

Table 4. Least squares means and standard errors of means for drinking bouts per day and hourly activity of cows by shading treatment[1]

	Shade		No Shade	
Measurement	LSM	SE	LSM	SE
Daily drinking bouts	4.44	0.37	3.73	0.35
High activity (min/hr)	6.7[a]	0.34	7.8[b]	0.34
Activity (min/hr)	5.58	0.83	7.47	0.83
Eating (min/hr)	21.27	0.84	19.67	0.85
Ruminating (min/hr)	17.27	0.73	17.62	0.73
No activity (min/hr)	9.36	0.5	7.52	0.5
Ear temperature (˚C)	26.77	0.55	26.52	0.55
Lying time on right side (min/hr)	41.08	0.89	42.0	0.89
Lying time on left side (min/hr)	10.03	0.76	9.4	0.76
Lying time (min/hr)	51.13	0.4	51.43	0.4
Standing time (min/hr)	8.87	0.4	8.57	0.4

[1]Reported means and SE are based on shading treatment averages.

[a,b]Means within a row without common superscripts are different at $P < 0.05$.

Table 5. Least squares means and standard errors of means for minutes spent by cow using shade versus not using shade during a 180 minute observation period on any given day during the study period[1]

	Using shade		Not using shade	
Period	LSM	SE	LSM	SE
1	68.83	4.81	111.17	4.81
2	79.5	4.81	89.5	4.81
3	71	4.81	107	4.81
4	70.17	4.81	109.83	4.81

[1]Reported means and SE are based on period averages.

Table 6. Least squares means and standard errors of means for body temperature of cows during hour blocks of the day, daylight hours between milkings, nighttime hours between milkings, during milkings, and activity of cows during hour blocks of the day by shading treatment[1]

	Shade		No Shade	
Time of day	LSM	SE	LSM	SE
Body temperature				
6:00 PM- 12:00 AM	39.19[a]	0.06	39.4[b]	0.06
12:00 PM- 6:00 AM	38.96	0.06	39.01	0.06
6:00 AM- 12:00 PM	38.66	0.06	38.67	0.06
12:00 PM- 6:00 PM	38.99[a]	0.06	39.31[b]	0.06
Daylight between milkings	38.86[a]	0.07	39.09[b]	0.07
Nighttime between milkings	39.08	0.07	39.16	0.06
During milkings	38.97	0.1	39.07	0.1
Activity				
6:00 PM- 12:00 AM	16.15	0.64	17.09	0.6
12:00 PM- 6:00 AM	9.65	0.64	9.88	0.6
6:00 AM- 12:00 PM	15.42[a]	0.64	18.15b	0.6
12:00 PM- 6:00 PM	16.7[a]	0.64	19.46[b]	0.6

[1]Reported means and SE are based on shading treatment averages.

[a,b]Means within a row by hour block without common superscripts are different at $P < 0.05$.

Figure. Least squares means and standard errors of means for body temperature recorded by Smaxtec boluses by hour of day for shaded cows (▲ black) versus non-shaded cows (■ yellow). *= Means within an hour of day for treatment groups are different at $P<0.05$

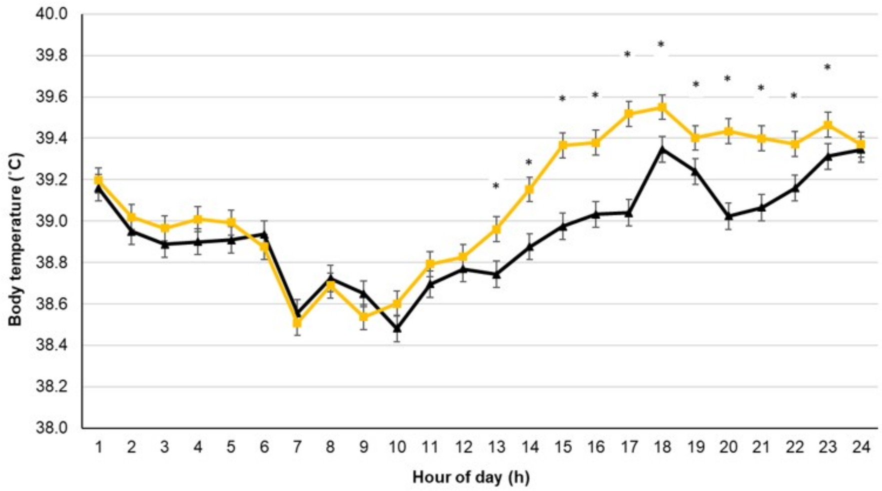
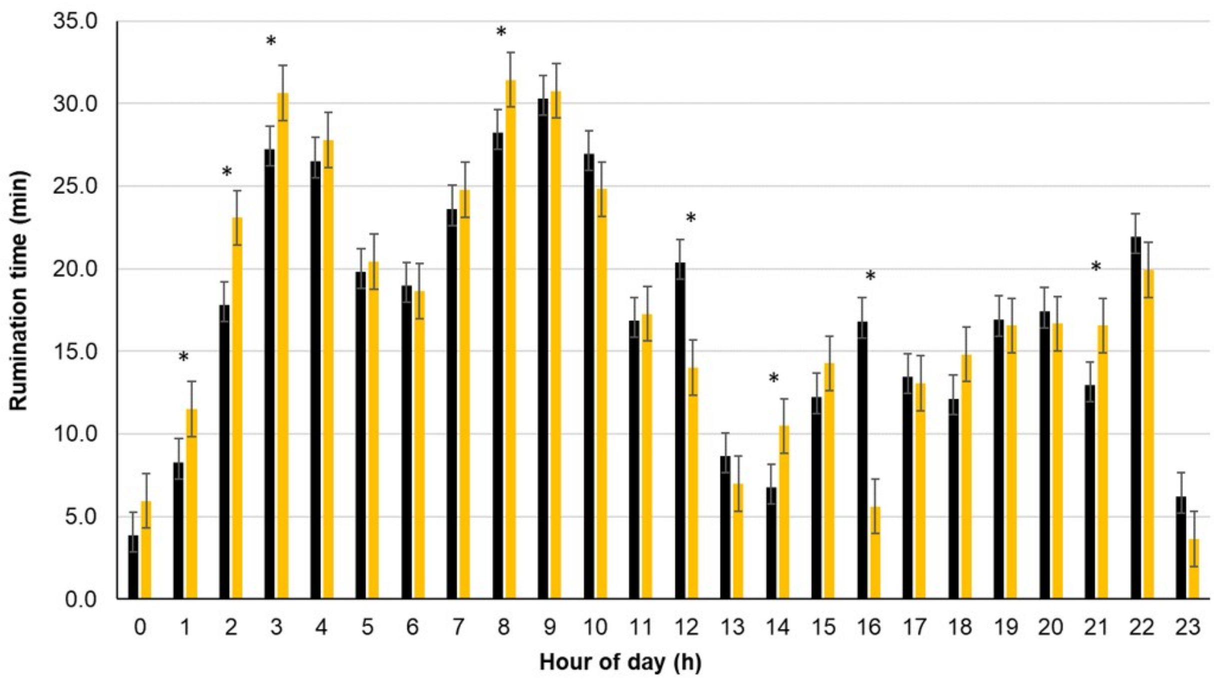


Figure 6. Least squares means and standard errors of means for Cow Manager rumination minutes per hour for shaded cows (black) versus non-shaded cows (yellow). *= Means within an hour of day for treatment groups are different at $P<0.05$.



Activity 2 Status as of July 1, 2020:

We have completed the solar shading grazing project and the Master's degree student defended her Master's Thesis on March 5 2020. In summary, the objective of this study was to determine the effects on grazing cattle under shade from a solar photovoltaic system. The study was conducted at the University of Minnesota West Central Research and Outreach Center, Morris, MN grazing dairy. Twenty-four crossbred cows were randomly assigned to 2 treatment groups (shade or no-shade) from June to September 2019. The replicated (n = 4) treatment groups of 6 cows each were provided shade from a 30-kilowatt photovoltaic system. Two groups of cows had access to shade in paddocks and two groups of cows had no shade in paddocks and cows were located in the same pasture during the study period. Behavior observations and milk production were evaluated for cows during four periods of summer. Smaxtec boluses (smaXtec, Graz, Austria) and an eartag sensor

(CowManager SensOor, Agis Automatisering BV, Harmelen, the Netherlands) monitored internal body temperature and activity and rumination on all cows, respectively. Data were analyzed with PROC MIXED of SAS. Independent variables were the fixed effects of breed, treatment group, coat color, period, and parity, and random effects were replicate group, date, and cow. No differences in fly prevalence, milk production, fat and protein production, body weight, body condition score, drinking bouts, hock lesions, or locomotion were observed between the treatment groups. Shade cows had more ear flicks (11.4 ear flicks/30 sec) than no-shade cows (8.6 ear flicks/30 sec) and had dirtier bellies and lower legs (2.2 and 3.2, respectively) than no-shade cows (1.9 and 2.9, respectively). During afternoon hours, shade cows had lower respiration rates (66.4 breaths/min) than no-shade cows (78.3 breaths/min). From 1200 to 1800 h and 1800 to 0000 h, shade cows had lower body temperature (39.0 and 39.2˚C, respectively) than no-shade cows (39.3 and 39.4˚C, respectively). Furthermore, during daylight hours and between milkings, the shade cows had lower body temperature (38.9˚C) than no-shade cows (39.1˚C). Agrivoltaics incorporated into pasture dairy systems may reduce the intensity of heats stress in dairy cows and increase well-being of cows and increase the efficiency of land use.

Activity 2 Status as of January 1, 2021:
We had published a peer-reviewed paper in the Journal of Dairy Science. Currently, the paper is in Press and it has published online (Open-Access) at https://www.journalofdairyscience.org/article/S0022-0302(20)31073-0/fulltext A Masters' Thesis has also been published by a graduate student that includes the solar grazing portion of the project. https://conservancy.umn.edu/handle/11299/216058

Final Report Summary:

Our peer-reiviewd paper was published in the March 2021 issue of the Journal of Dairy Science.
https://www.journalofdairyscience.org/article/S0022-0302(20)31073-0/fulltext
The paper was the Editor's choice paper for the March 2021 issue.

A conference proceeding was developed and presented at the Virtual AgriVoltaics Conference in 2021. A summary of the AgriVoltaics research from the conference is presented below.

The objective of this study was to determine the effects of grazing cattle under shade from a solar photovoltaic system. The study was conducted at the University of Minnesota West Central Research and Outreach Center's, Morris, MN, organic dairy. Twenty-four crossbred cows were used for the study from June to September 2019. The treatment groups of 6 cows had shade from a 30-kilowatt photovoltaic system in a pasture or no shade on pasture. Behavioral observations and production were evaluated on cows during four periods of the summer months. Smaxtec boluses (smaXtec, Graz, Austria) and a sensor (CowManager SensOor, Agis Automatisering BV, Harmelen, the Netherlands) monitored internal body temperature and activity and rumination on all cows. No differences in fly prevalence, milk production, fat and protein production, body weight, body condition score, drinking bouts, hock lesions, or locomotion were found between the groups. Shade cows had dirtier bellies and dirtier lower legs (2.2 and 3.2, respectively) than no shade cows (1.9 and 2.9, respectively). During the afternoon, shade cows had lower respiration rates (66.4 breaths/min) than no shade cows (78.3 breaths/min). From 12:00 to 18:00 h and 18:00 to 00:00 h, shade cows had lower body temperatures (39.0 and 39.2 ˚C, respectively) than no shade cows (39.3 and 39.4 ˚C, respectively). Incorporating agrivoltaics into a pasture dairy system may increase the health of dairy cows, reduce heat stress, and increase the efficiency of the land.

ACTIVITY 3: Field test dairy farm clean energy systems and develop effective control strategies
Description:

The team will utilize the dairy facilities at the WCROC to determine baseline energy use. Other on-farm clean energy systems will be monitored to determine production. A project team and graduate student will use the information to recommend clean energy systems and rank them based on energy savings and / or return on investment.

The objective will provide actual energy consumption data for commercial dairy production systems. The data will be invaluable to our group and other researchers that seek to improve the energy efficiency of dairy production systems. We propose to monitor the energy consumption of operating, commercial dairy production systems for two years. Two years of monitoring is essential to understand influences of cow numbers, seasons, weather patterns, and milk production and harvesting on energy use in commercial systems.

We will identify commercial milk producers that operate dairy facilities that are characteristic of production systems in Minnesota. We will select 5 Minnesota dairy farms for farms for monitoring. The farms will include one small grazing based or tie-stall facility, 1 robotic dairy facility, and other mid-sized dairy farms that have developed a relationship with the UMN WCROC.

At each farm, we will record monthly the consumption of electricity, water usage, and fuel. Electric metering / sensing devices will be installed at each farm to record the total amount of electricity and water used by the farm, and for the milk harvesting procedures. Most farms use natural gas to heat their buildings so we will record the gallons of natural gas used each month. In addition, we will record monthly inventory of cows in the barns, cows milked per day, and milk production per day for the farm. Additionally, bulk tank production records (milk, fat percentage, protein percentage, and SCC), along with weekly cow numbers on farm will be collected from dairy farms. Daily milk production will be calculated as total bulk tank production divided by the average cow numbers on farm. In addition, we will collect monthly weather conditions from the NOAA weather observation site closest to each dairy farm that we are monitoring.

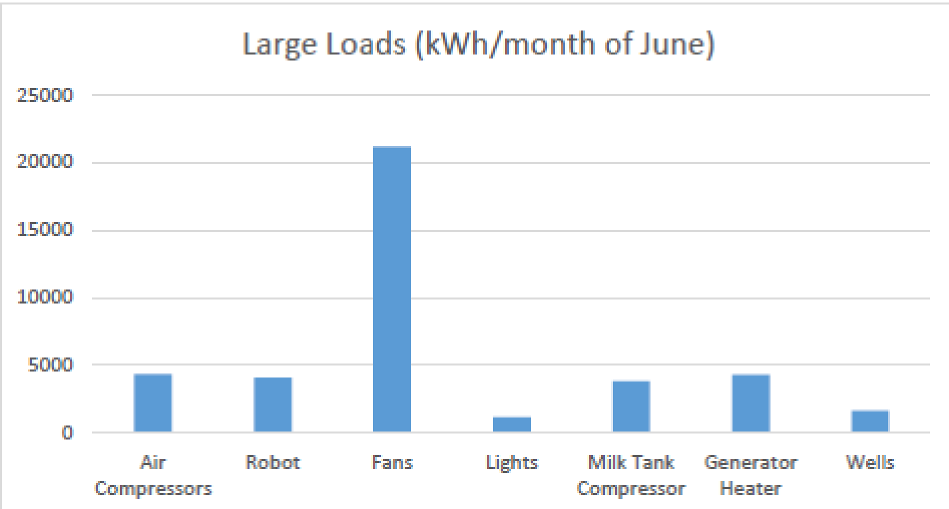
Based on the analysis of the data, a graduate student will model clean energy alternatives for Minnesota dairy facilities and. The student will utilize the baseline energy consumption data measured at the WCROC and on-farm dairy facilities to model energy-optimized retrofits. The project team will direct a graduate student and undergraduate student intern to project the economics for a suite of energy-optimized retrofits. Within the model, potentially all energy loads may be converted to electricity and these loads will be made as small as possible with efficiency upgrades. Eventually, on-site renewable electric generation could supply some or the entire electric load allowing the buildings to approach net-zero (producing as much energy as is used).

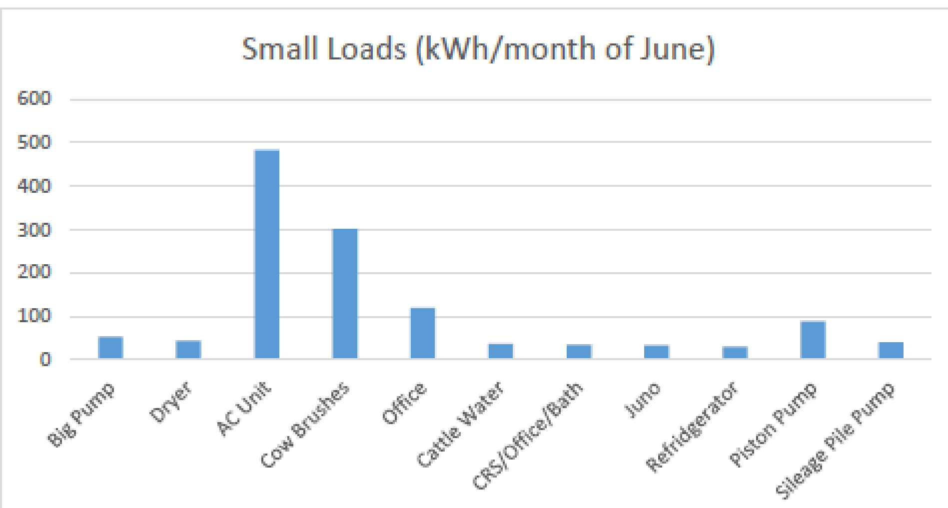
Summary Budget Information for Activity 3: **ENRTF Budget: $ 157,000**
Amount Spent: $ 157,000
Balance: $ 0

Outcome	Completion Date
1. Install energy meters and record energy consumption data for 2 years at MN dairies	7/10/2019
2. Model clean energy alternatives with projected return-on-investment	7/10/2019
3. Complete designs of clean energy systems for field testing at the WCROC	8/1/2019

Activity 3 Status as of January 1, 2018:
Initial visits to dairy farms in Minnesota have been conducted. We are working with dairy farms to install energy meters and sensors on farms and will be monitoring the dairies by the end of February 2018.

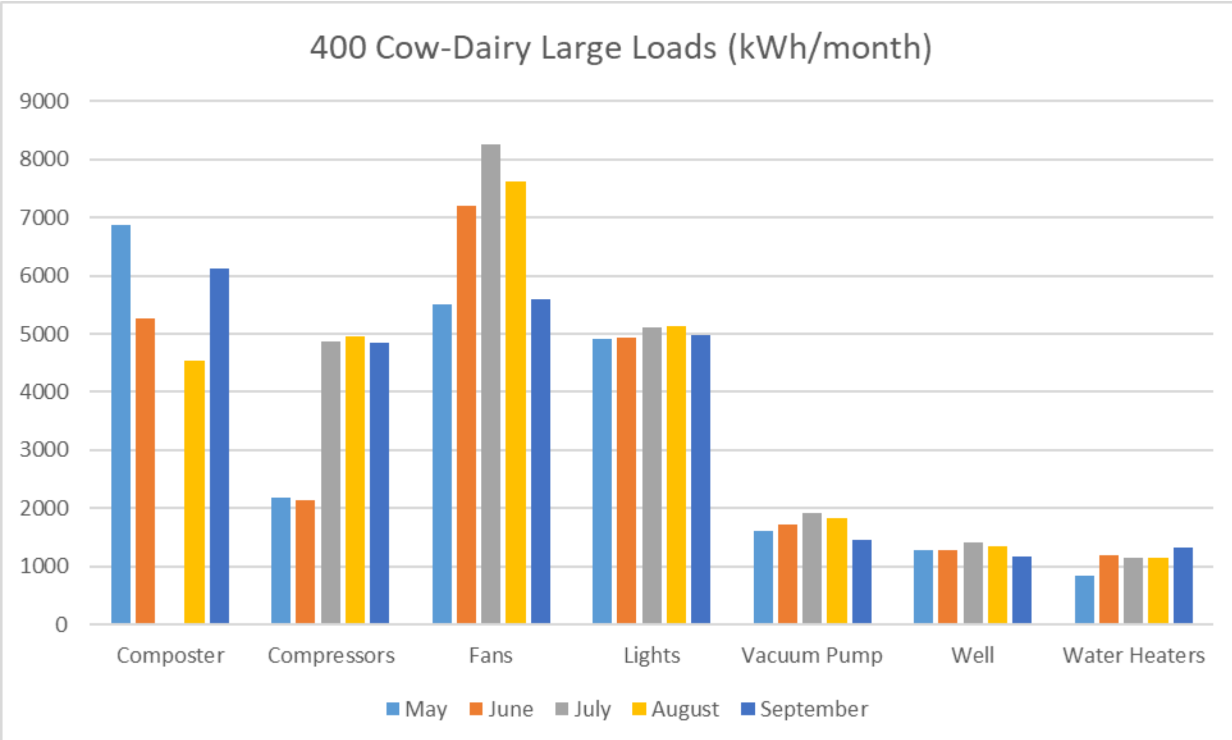
Activity 3 Status as of July 1, 2018:
We have installed over 450 sensors on 5 different dairy production systems in Minnesota that range from grazing to large-scale conventional dairy production systems. So far, we only have about 1 month of good data from farms after we had all of the installations up and going. We continue to visit these farms once per month to retrieve data and provide feedback to farms about energy usage on their dairy. The 2 graphs illustrate some of the large and small energy loads from a 300-cow automatic milking (robotic) dairy facility during June 2018. The large electrical loads are coming mostly from fans for cow cooling during the hot, summer months. These data are preliminary and more updates from all of the farms for 6 months will be available at the end of 2018.

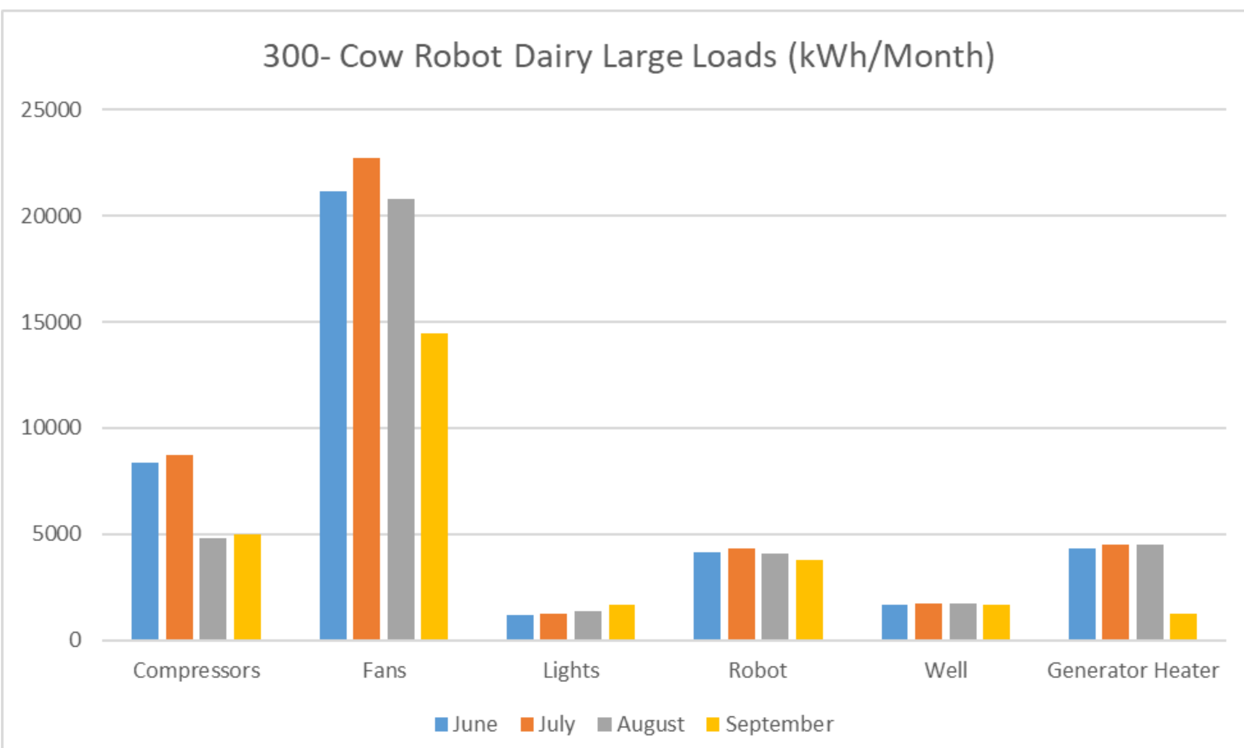


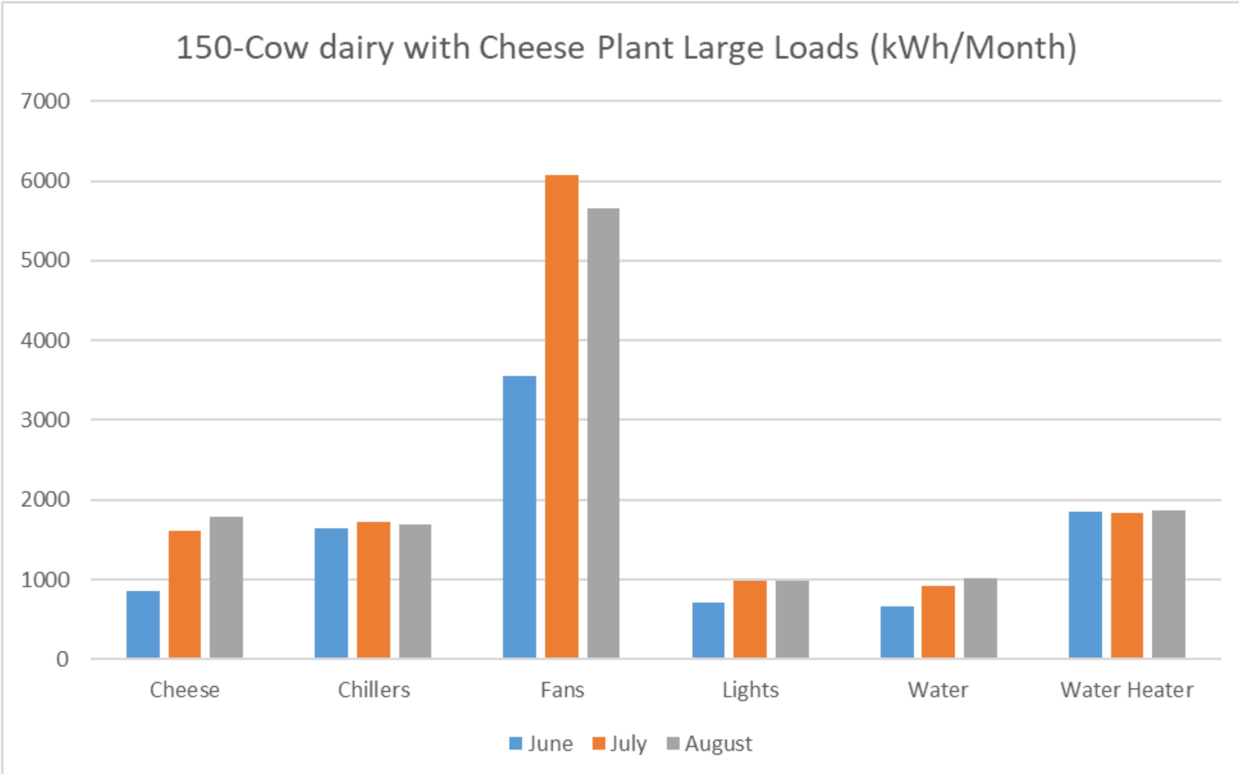


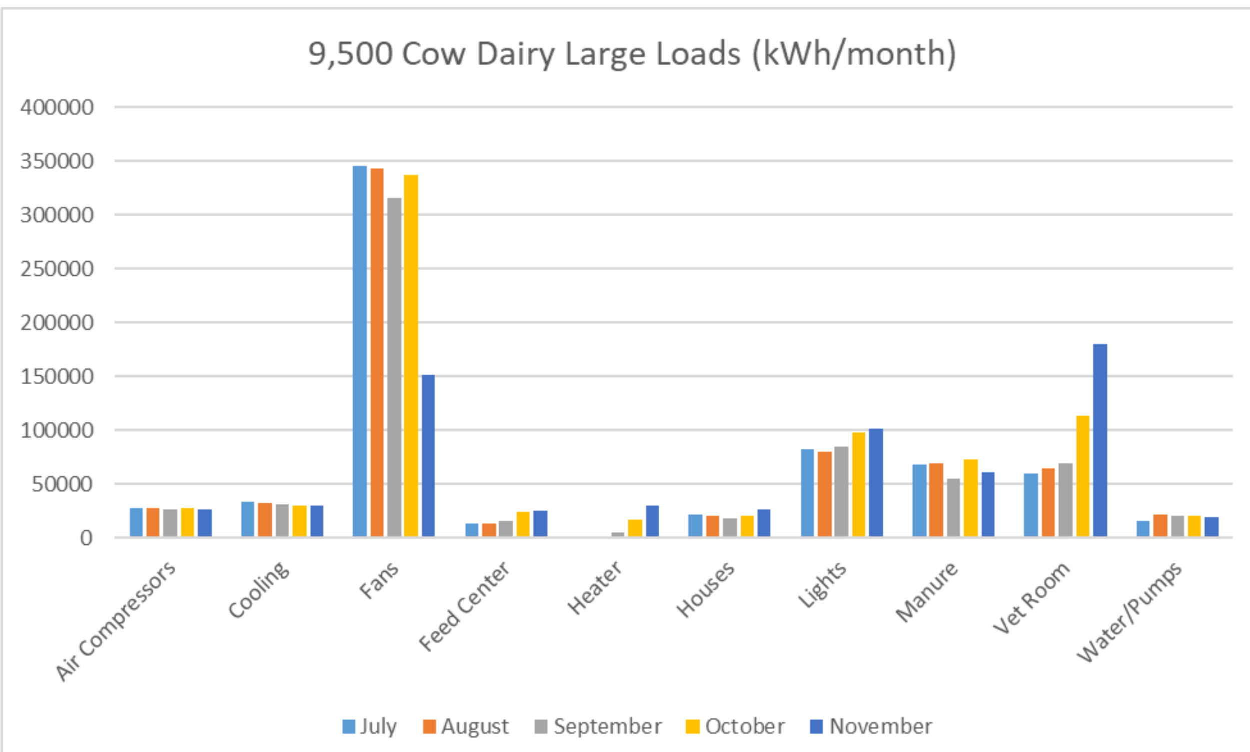
Activity 3 Status as of January 1, 2019:
We continue to visit these farms once per month to retrieve data and provide feedback to farms about energy usage on their dairy. We have gathered a lot of information about energy loads on these farms. For all of the farms, a majority of the energy usage is for fans to cool cows during the summer. In addition, lighting are also a large consumer of energy on farms. On the robotic dairy farm, we discovered through energy monitoring that their power generator heater was broken, and we were able to have them fix the generator to conserve energy.

We estimated that this saved the farm over $5,000 per year. No matter the size of the dairy, cows cooling is very important during the summer and will be the biggest challenge for renewable energy systems in the future.

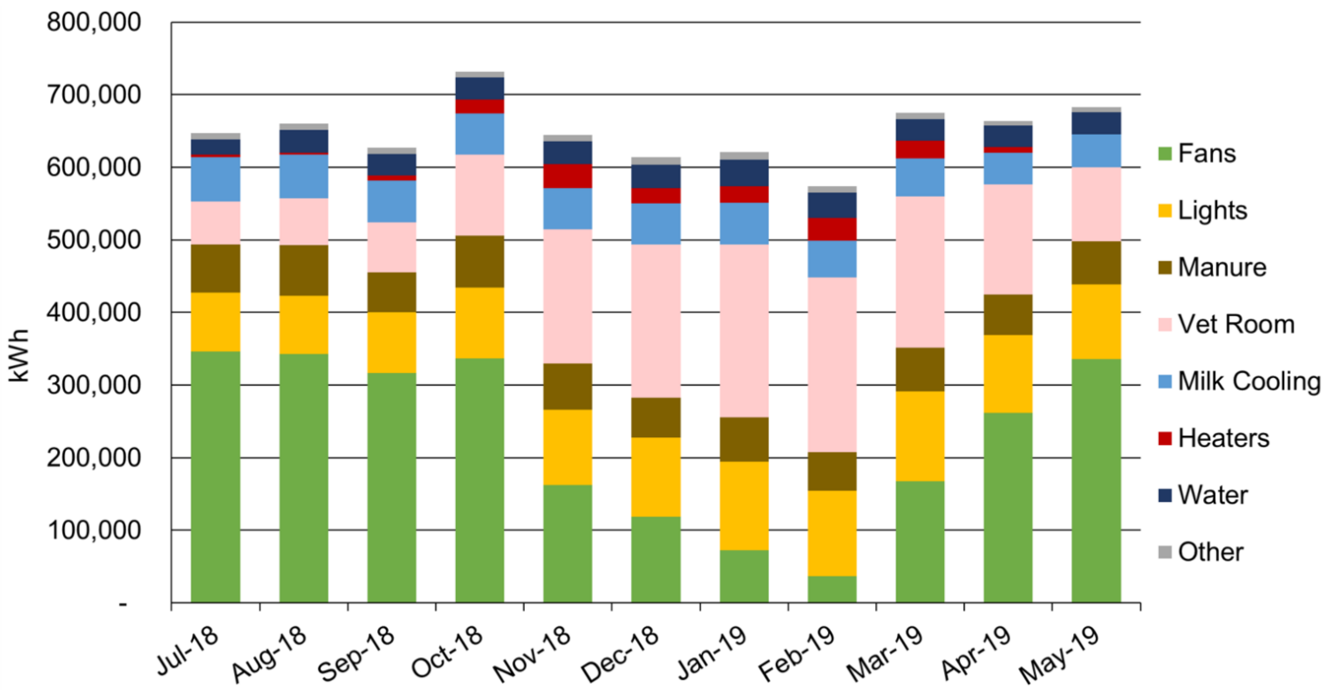


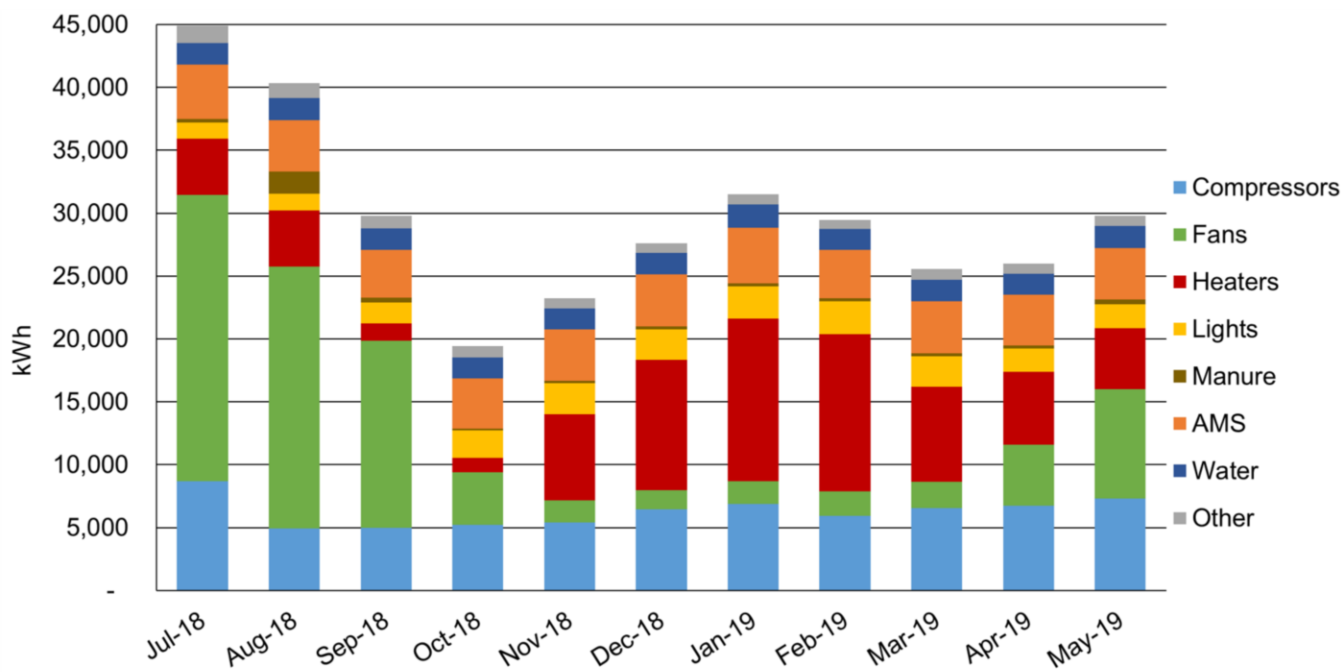






Activity Status as of July 1, 2019:
We continue to visit these farms once per month to retrieve data and provide feedback to farms about energy usage on their dairy. We have gathered a lot of information about energy loads on these farms. We have recorded almost 1 year worth of data on all farms. All the farms are variable in their energy use and energy use of specific components on farm. A graduate student will be gathering the remaining information during 2019 and will be incorporating the final information into her master's thesis.


800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
-
kWh
Jul-18
Aug-18
Sep-18
Oct-18
Nov-18
Dec-18
Jan-19
Feb-19
Mar-19
Apr-19
May-19
Fans
Lights
Manure
Vet Room
Milk Cooling
Heaters
Water
Other


45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
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-
kWh
Jul-18
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Sep-18
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Nov-18
Dec-18
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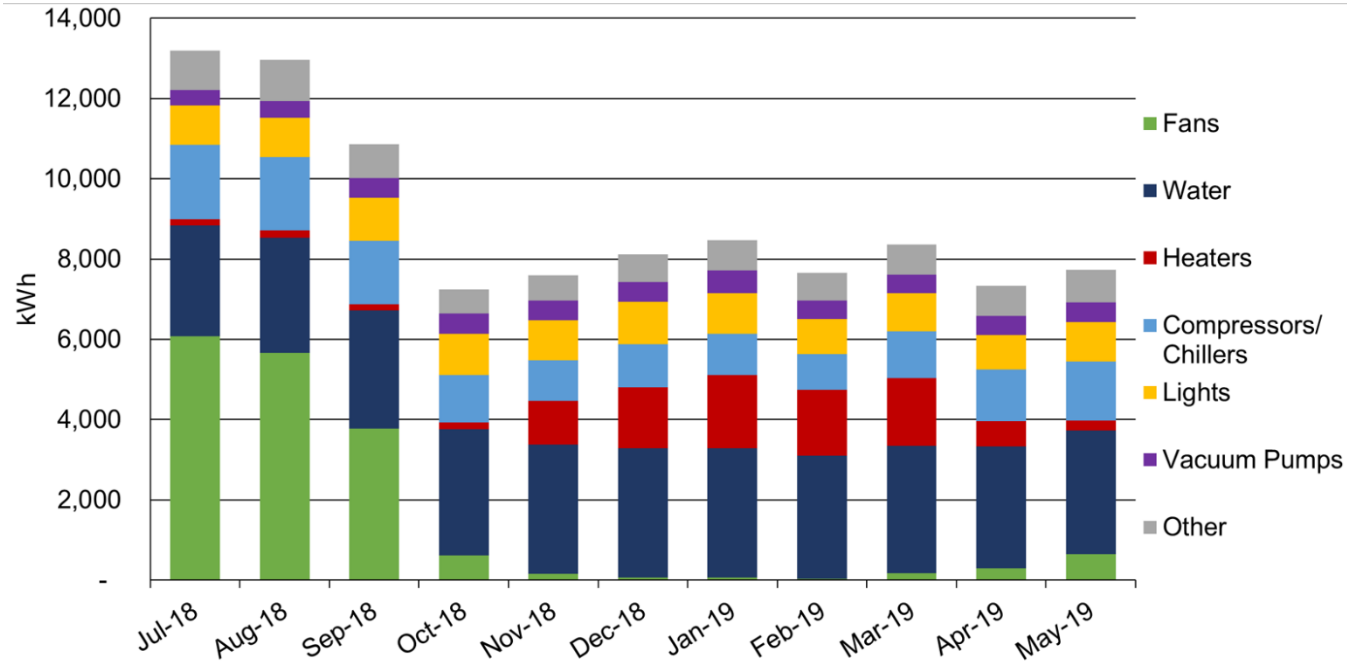
Feb-19
Mar-19
Apr-19
May-19
Compressors
Fans
Heaters
Lights
Manure
AMS
Water
Other



14,000
12,000
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8,000
6,000
4,000
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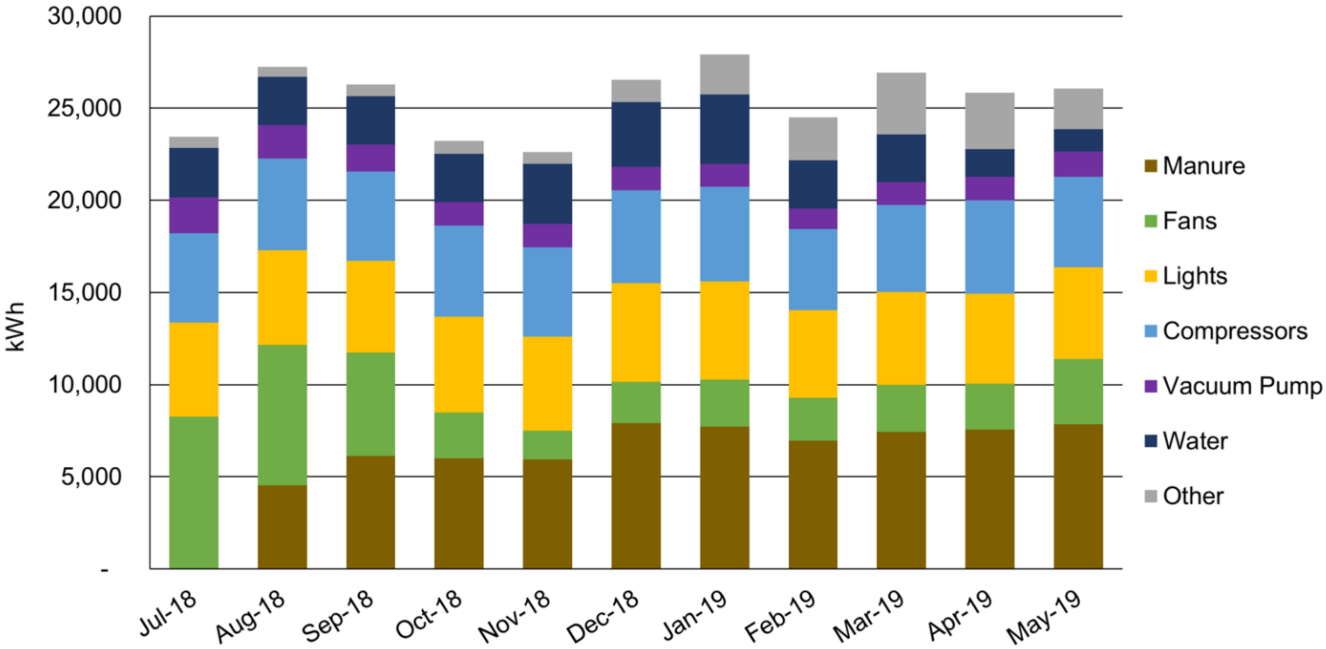
-
kWh
Jul-18
Aug-18
Sep-18
Oct-18
Nov-18
Dec-18
Jan-19
Feb-19
Mar-19
Apr-19
May-19
Fans
Water
Heaters
Compressors/ Chillers
Lights
Vacuum Pumps
Other



30,000
25,000
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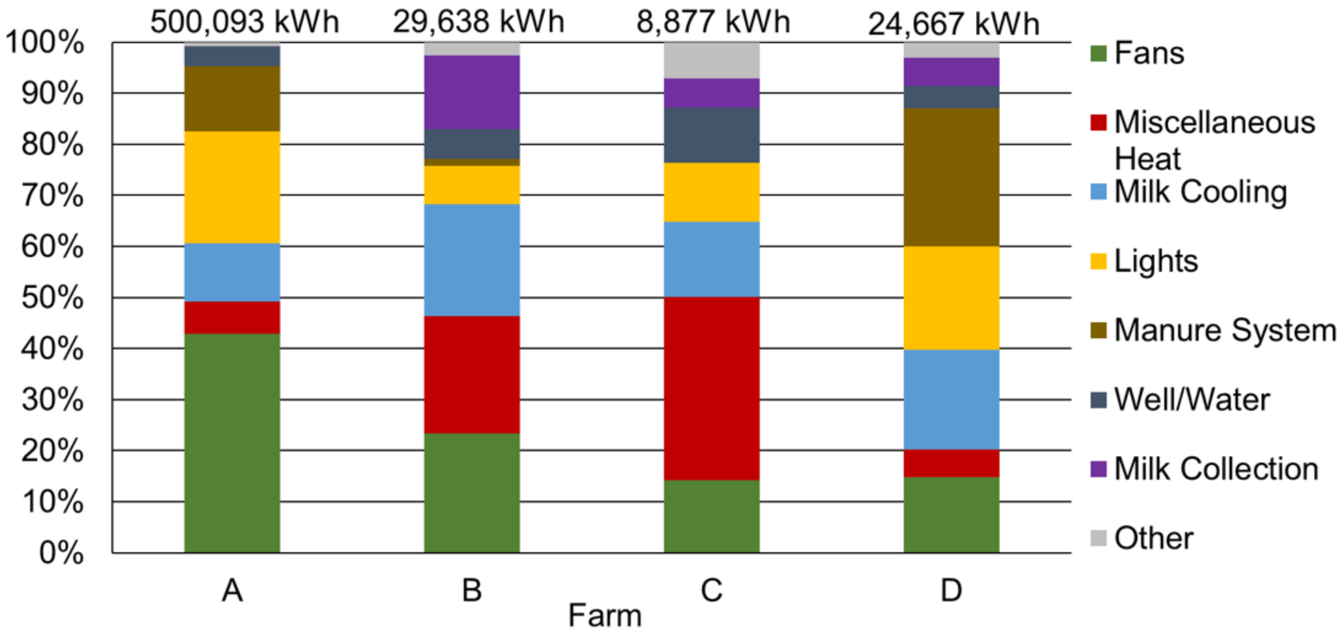
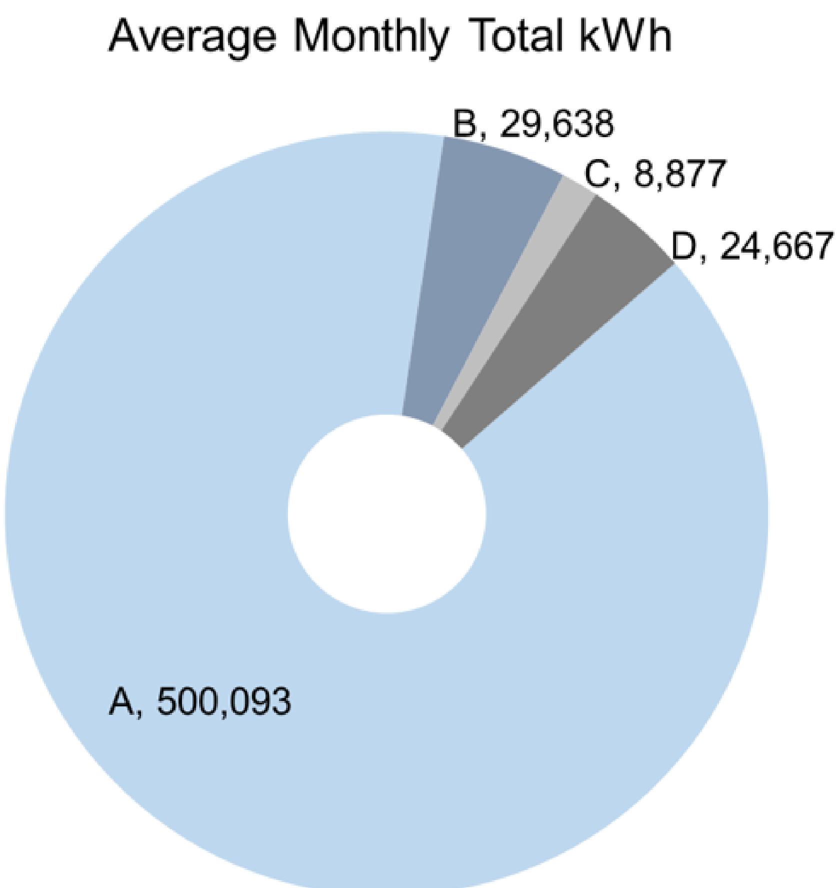
kWh
Jul-18
Aug-18
Sep-18
Oct-18
Nov-18
Dec-18
Jan-19
Feb-19
Mar-19
Apr-19
May-19
Manure
Fans
Lights
Compressors
Vacuum Pump
Water
Other


500,093 kWh
29,638 kWh
8,877 kWh
24,667 kWh
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
A
B
C
D
Farm
Fans
Miscellaneous Heat
Milk Cooling
Lights
Manure System
Well/Water
Milk Collection
Other


Average Monthly Total kWh
B, 29,638
C, 8,877
D, 24,667
A, 500,093

Activity 3 Status as of January 1, 2020: We continue to visit these farms once per month to retrieve data and provide feedback to farms about energy usage on their dairy. We have gathered a lot of information about energy loads on these farms. We have recorded 18 months of data on all farms. All of the farms are variable in their energy use and energy use of specific components on farm. A graduate student will be defending her Master's thesis in March 2019 based on the analysis of the data. Additionally, a student from FH Munster in Germany defended a Master's thesis based on data from the WCROC and as well as the 9,5000 cow dairy. The conclusion was that for the 9,500 cow dairy, a cost-optimized PV-Wind hybrid system was calculated, which can cover 79 % of its energy requirements. The electricity costs are $56.6 per MWh. The system in consideration would consist of a combination of 4 MW solar power and a 1.65 MW wind turbine.

Table 1. Monthly total electricity use per milking cow and per kilogram of fat and protein produced.

	kWh/cow					kWh/ kg fat and protein				
Month	Farm A	Farm B	Farm C	Farm D	Farm E	Farm A	Farm B	Farm C	Farm D	Farm E
2018										
July	58.6	69.7	137.1	82.0	34.0	1.33	1.79	0.96	0.88	0.99
August	78.5	66.8	128.7	83.0	36.6	1.32	1.88	0.96	1.17	0.96
September	81.2	58.4	92.9	78.1	30.7	1.25	1.75	0.78	1.17	0.93
October	72.7	37.5	62.5	91.9	19.7	1.36	1.19	0.49	1.04	0.50
November	64.5	35.5	70.5	74.8	22.9	1.16	0.79	0.48	0.92	0.54
December	70.2	35.6	84.8	73.8	27.6	1.11	0.83	0.50	0.95	0.59
2019										
January	73.3	35.7	95.6	73.8	36.0	1.11	0.98	0.47	0.98	0.81
February	61.8	32.1	89.6	68.4	36.0	1.14	1.24	0.47	0.92	0.99
March	64.6	36.9	79.7	82.8	39.1	1.25	1.05	0.50	0.88	1.06
April	60.7	37.6	83.0	81.6	33.6	1.29	1.01	0.49	0.88	1.00
May	63.3	41.5	92.6	84.7	38.1	1.31	0.97	0.53	0.89	1.08
June	72.9	64.1	122.7	79.2	38.4	1.28	1.14	0.86	1.08	1.00
July	77.6	68.1	139.1	80.8	36.4	1.29	1.55	0.98	1.11	1.21
August	73.0	64.7	121.2	82.0	41.9	1.23	1.70	0.83	1.04	1.33
September	62.0	57.0	99.6	84.0	40.5	1.27	1.53	0.76	0.89	1.33
October	37.0	42.5	69.6	90.4	28.5	1.29	1.23	0.54	0.53	0.94
November	47.1	36.9	73.5	82.8	27.4	1.26	0.89	0.47	0.67	0.74
December	43.8	41.0	74.5	73.4	32.9	1.10	0.91	0.50	0.60	0.83

Figure 1. Monthly total kWh by load category used by Dairy Farm A.

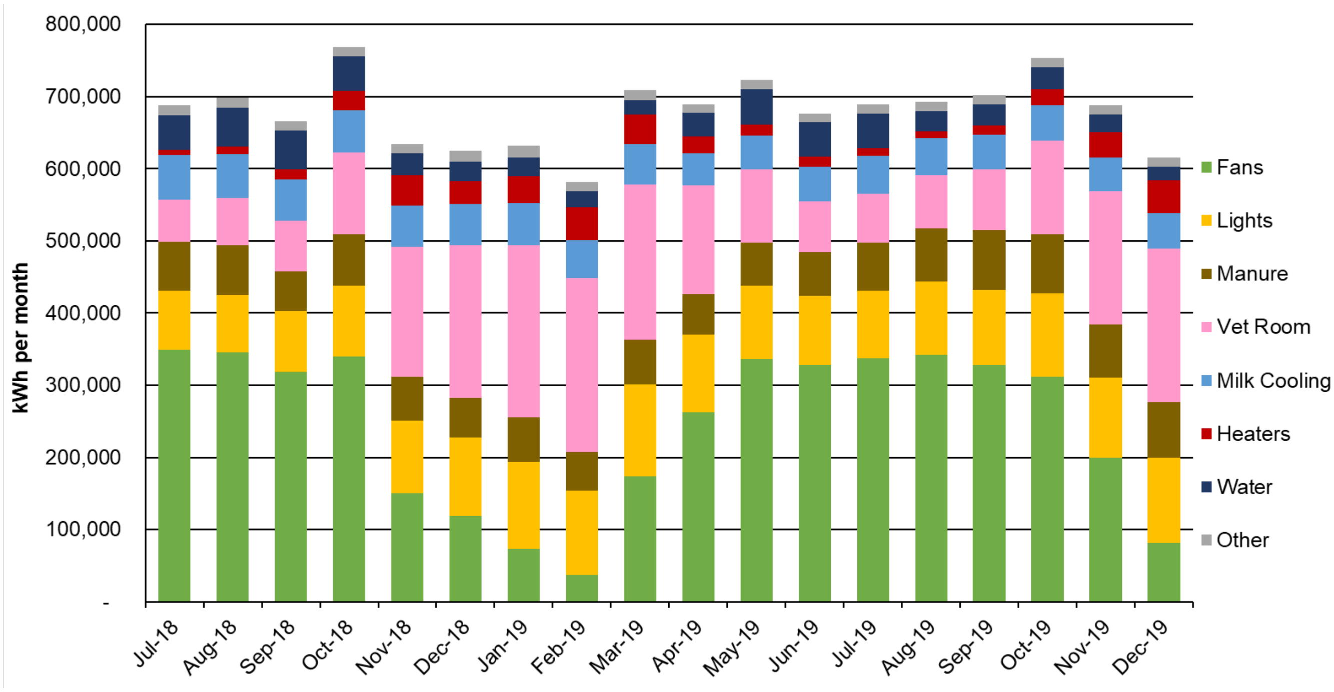


Figure 2. Monthly total kWh by load category used by Dairy Farm B.

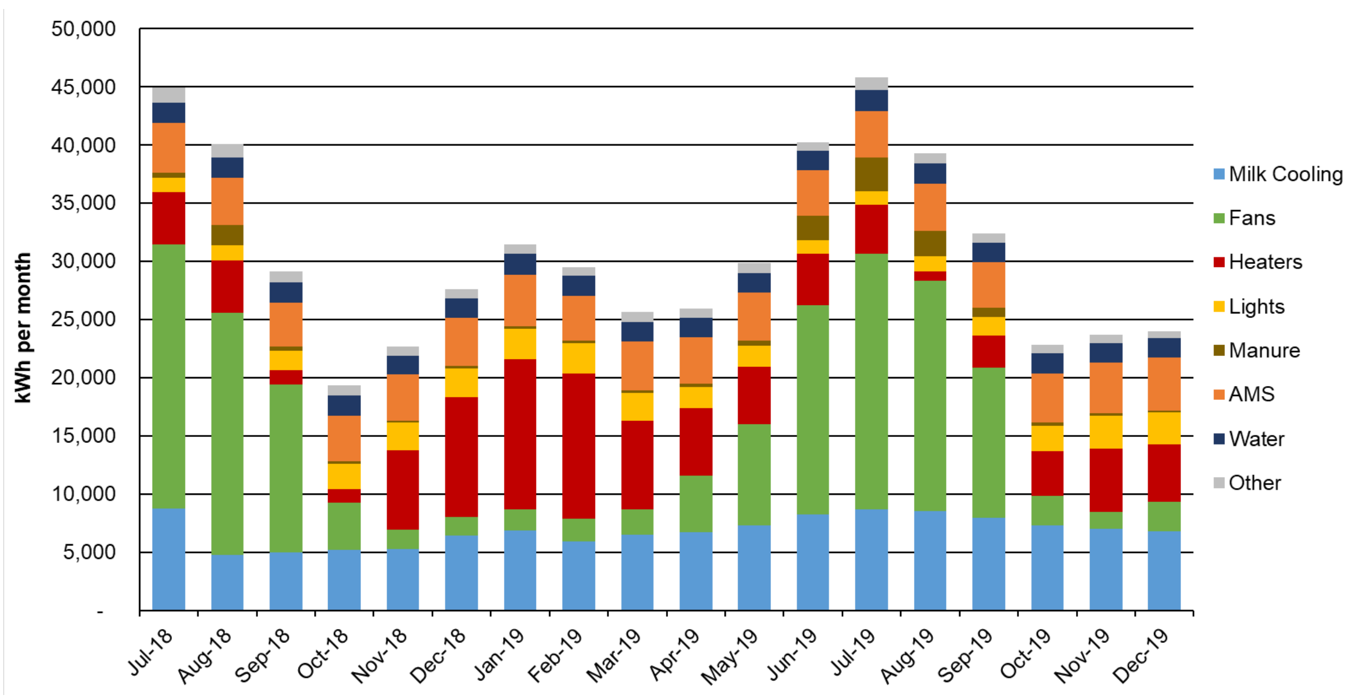


Figure 3. Monthly total kWh by load category used by Dairy Farm C.

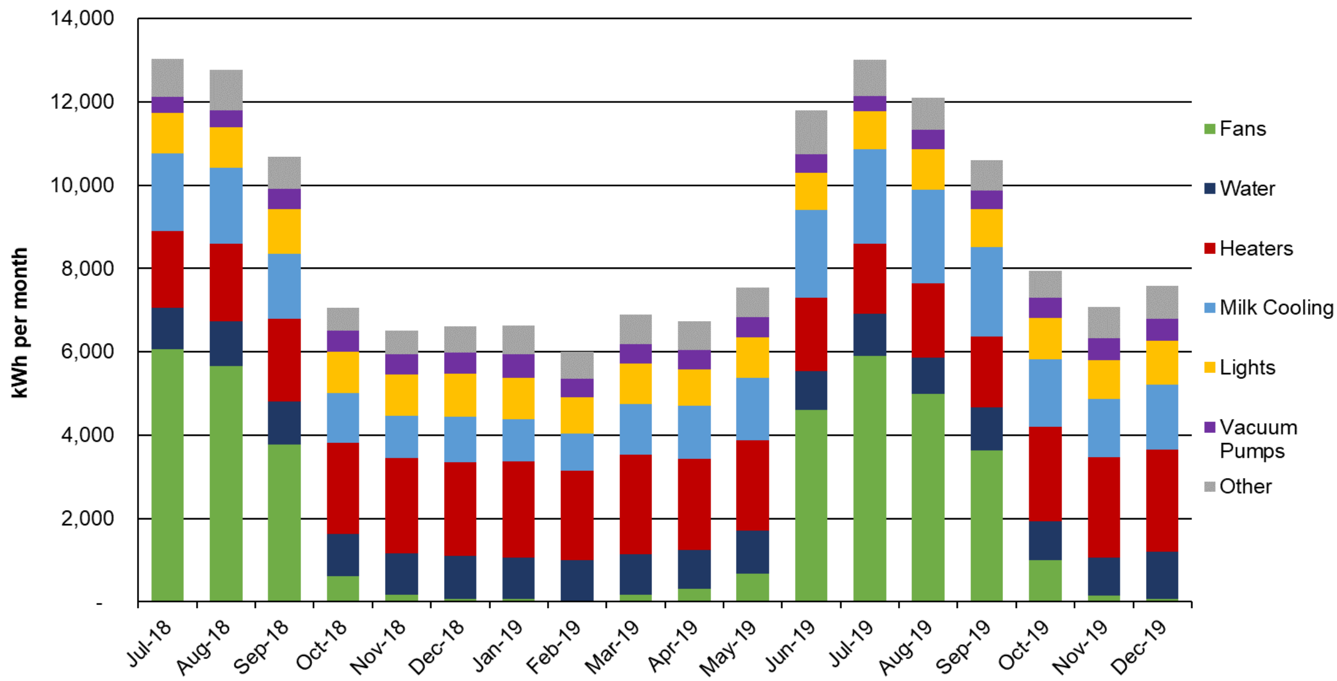


Figure 4. Monthly total kWh by load category used by Dairy Farm D.

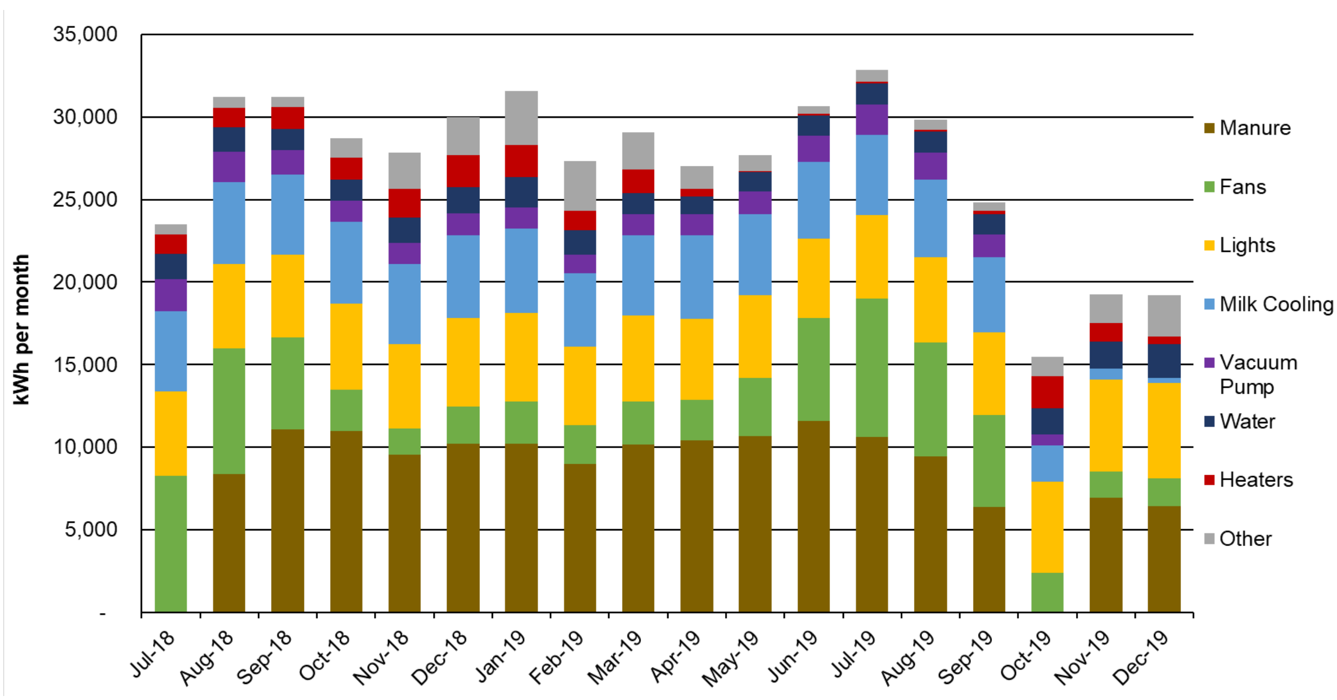


Figure 5. Monthly total kWh by load category used by Dairy Farm E.

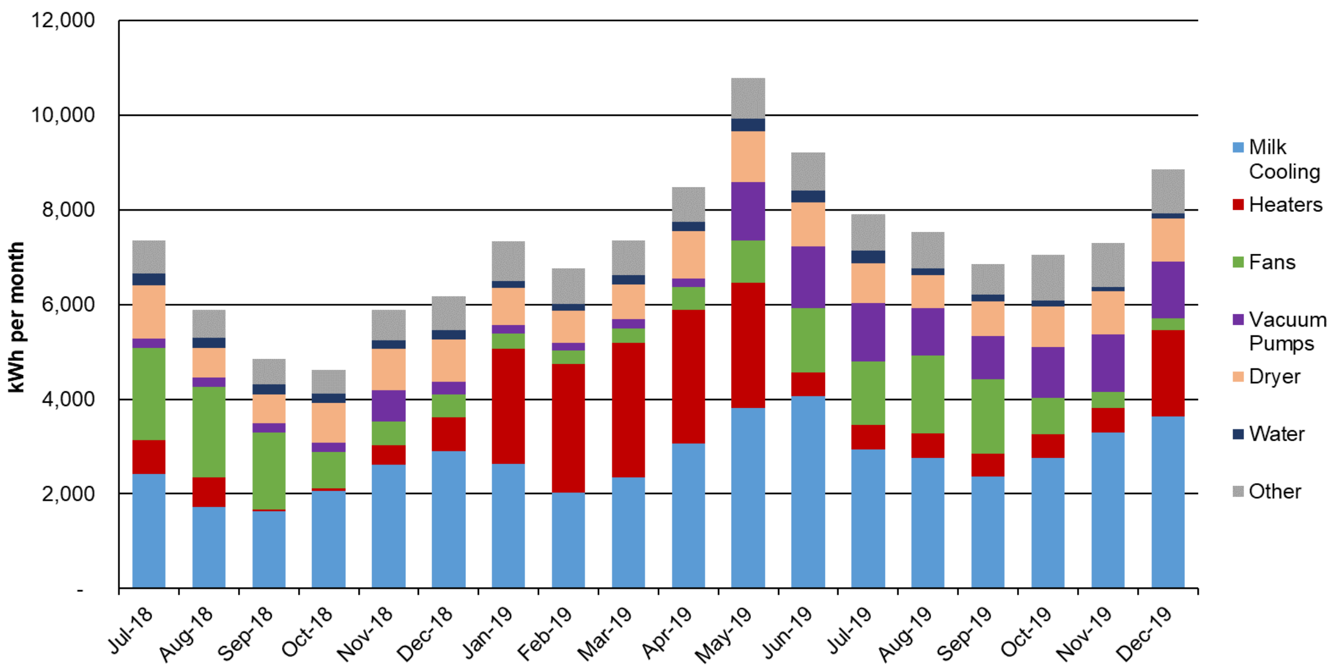
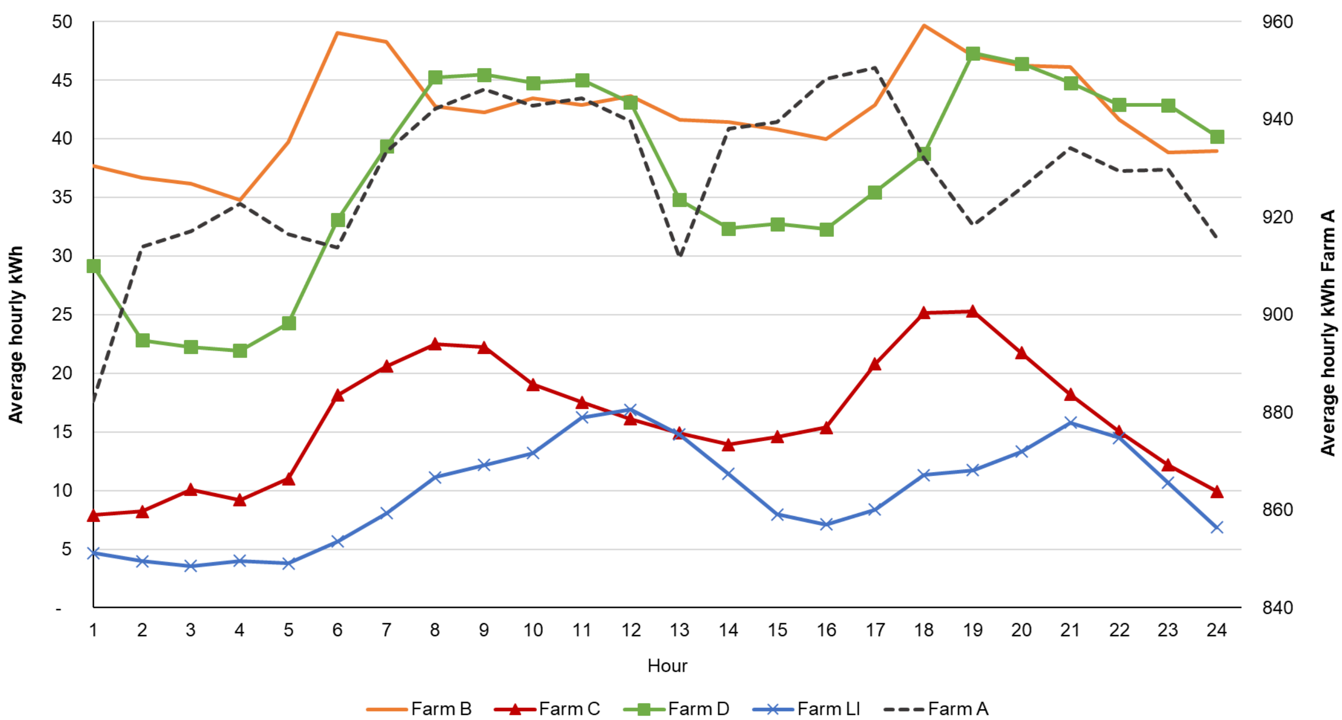


Figure 6. Hourly average total kWh across all farms.



33

Activity 3 Status as of July 1, 2020:
Data is still being generated on farm with the sensors. Because of COVID-19 we have not been able to finish the data collection on farm. Once we are able to safely collect the data, we will finish the analysis of the data. The objective of this study was to evaluate electricity use on five dairy farms in the Midwestern United States. Data were collected from commercial farms representative of typical Midwestern dairy farms and located in west central Minnesota. Farm A was a 9,500-head, cross-ventilated barn with a rotary milking parlor, Farm B was a 300-head, naturally-ventilated barn with 6 automatic milking systems, Farm C was a 200-head, naturally-ventilated barn with a parabone milking parlor, Farm D was a 400-head, naturally-ventilated barn with a parallel milking parlor, and Farm E was a 275-cow, low-input grazing herd with a swing-9 parabone milking parlor. Multiple electric loads across all dairy farms were monitored from July 2018 to December 2019 on the farm side of the electric utility meter at circuit panels to determine electrical usage. Monthly electricity data were summed across farms and averaged per cow, per kg of milk produced, and per kg of fat plus protein produced. Hourly data were analyzed with PROC MEANS of SAS to determine seasonal and hourly trends on farms. Fans for cow comfort had the largest use of electricity on farms A, B, and C, and ranged from 15 to 38% of total electricity used across farms. The automated milking system on Farm B, consumed 14% of total electricity. On Farm D, a manure composter used the greatest percentage of electricity (34%). On Farm E, milk cooling (38%) had the highest percentage of total electricity usage. Milk cooling from compressors and chillers ranged from 6 to 32% of total electricity on farms. On a monthly basis, electricity from lighting ranged from 3 to 37% and manure handling systems ranged from 0.02 to 55% of total electricity usage on farms. Monthly total electricity use per cow ranged from 20 kWh on Farm E to 139 kWh on Farm B. Monthly electricity per kg of fat and protein produced averaged 1.24 kWh on Farm A, 1.25 kWh on Farm B, 0.64 kWh on Farm C, 0.92 kWh on Farm D, and 0.94 kWh on Farm E. The results of this study provide contemporary energy usage that can be used as farm energy benchmarks which then can inform decisions to reduce energy usage in dairy production systems.

Activity 3 Status as of January 1, 2021:
A Masters' Thesis has also been published by a graduate student that includes the dairy energy portion that has been collected so far for the project. https://conservancy.umn.edu/handle/11299/216058. We will collect the final data in January and February of 2021.

Final Report Summary:
Final data was collected from farms during February 2021. Data from all farms are presented in Figures. The results follow those of the previous results and find that electricity use varied across farms.

Annual electricity use per cow ranged from 400 kWh per cow on Farm E to 1,145 kWh per cow on Farm B. On a kWh per cwt basis, Farm C had the least electricity per cwt at 2.3 kWh while Farm A had the most electricity per cwt at 4.5 kWh. The higher electrical use to produce milk at Farm A was likely because the dry cows were housed in the cross-ventilated barn with the milking cows. About 11% were dry cows on Farm A, and those cows used electricity, but did not produce any milk.

Regular fan maintenance, proper fan control settings, location of fans, and energy efficient motors all could influence the efficiency of ventilation systems. Farms A and B did not have variable frequency drives installed on any of their fans. Variable frequency drives, fan staging, and thermostatic controls are all opportunities for producers to help them reduce electrical consumption as well as save money. Variable frequency drives on fans also reduce the amplitude of variations in air temperature and humidity in the barn. Lighting use ranged from 7 to 19% of the total electricity use measured across the farms which suggests there is potential to reduce energy usage by upgrading to more efficient lighting systems such as LEDs.

Other options for producers to investigate are renewable energy systems such as solar photovoltaic or small-scale wind turbines. Renewable energy generation on-farm is one way to reduce reliance on fossil fuel-derived electricity while providing the farm revenue and decreasing electric costs. Using an agrivoltaic system, which is the integration of solar photovoltaics and agriculture, could increase land efficiency up to 75%. Potential on-site renewable electric generation could also supply some or the entire electric load allowing farms to approach net-zero (producing as much energy as is used).

The results of this study provide recent energy usage for farm energy benchmarks, agricultural energy policy, economic evaluations, and further research into dairy farm energy studies. The data will also be useful to producers who are searching for areas for reduced energy usage in their own production systems. Improving the efficiency of electrical components in dairy operations could provide opportunities to improve the carbon footprint of dairy production systems.

Figure 1. Monthly total kWh by load category used by Dairy Farm A across the 3 years.

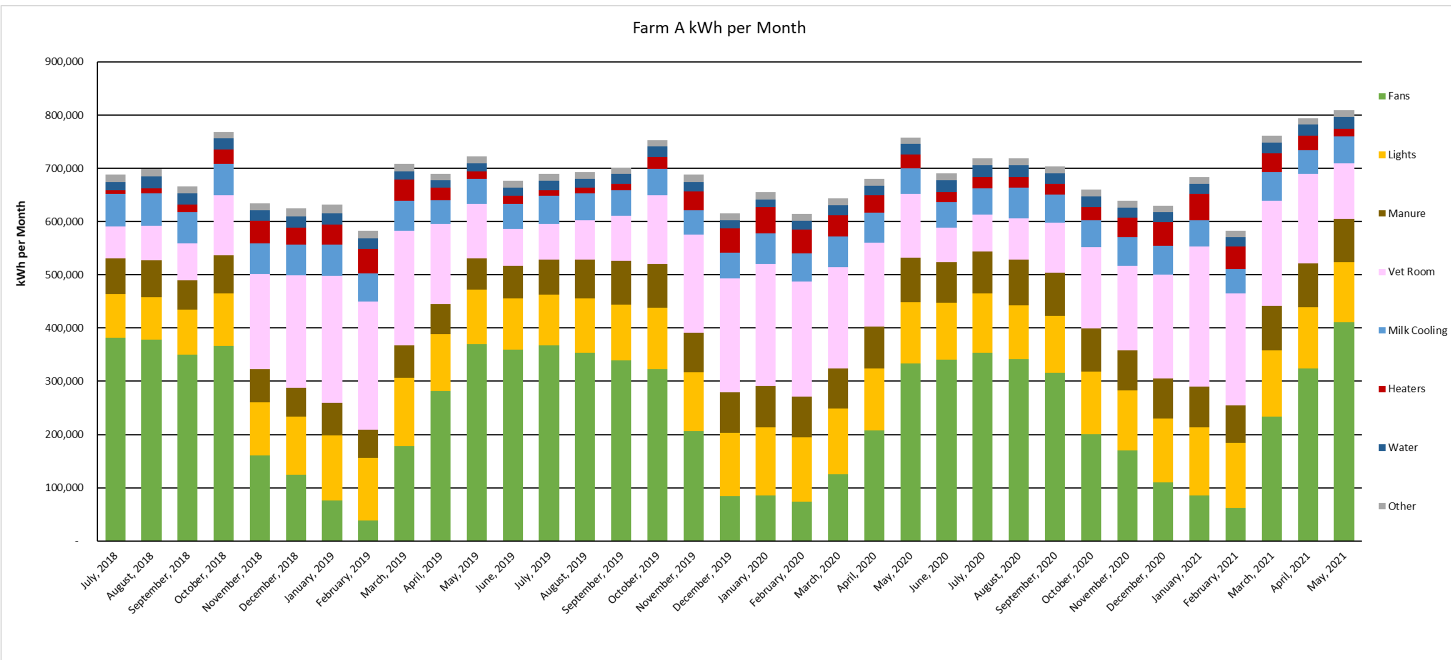


Figure 2. Monthly total kWh by load category used by Dairy Farm B across the 3 years.

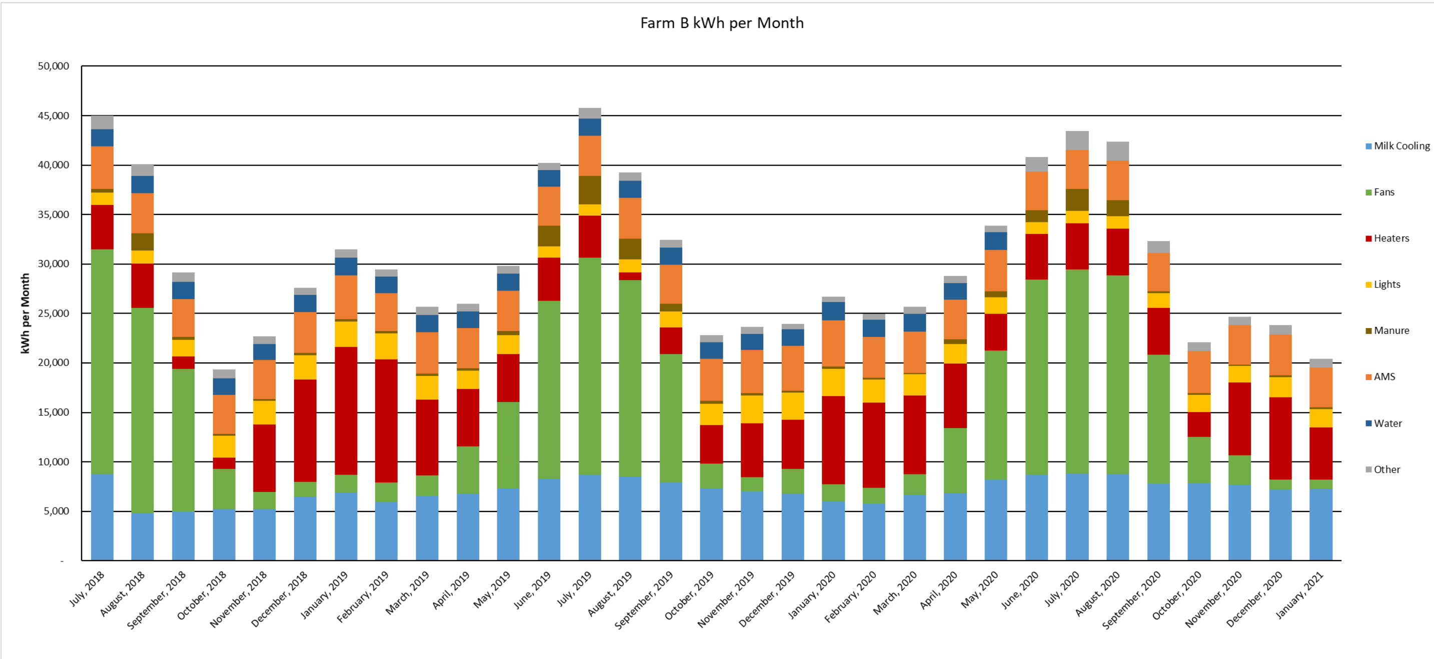


Figure 3. Monthly total kWh by load category used by Dairy Farm C across the 3 years.

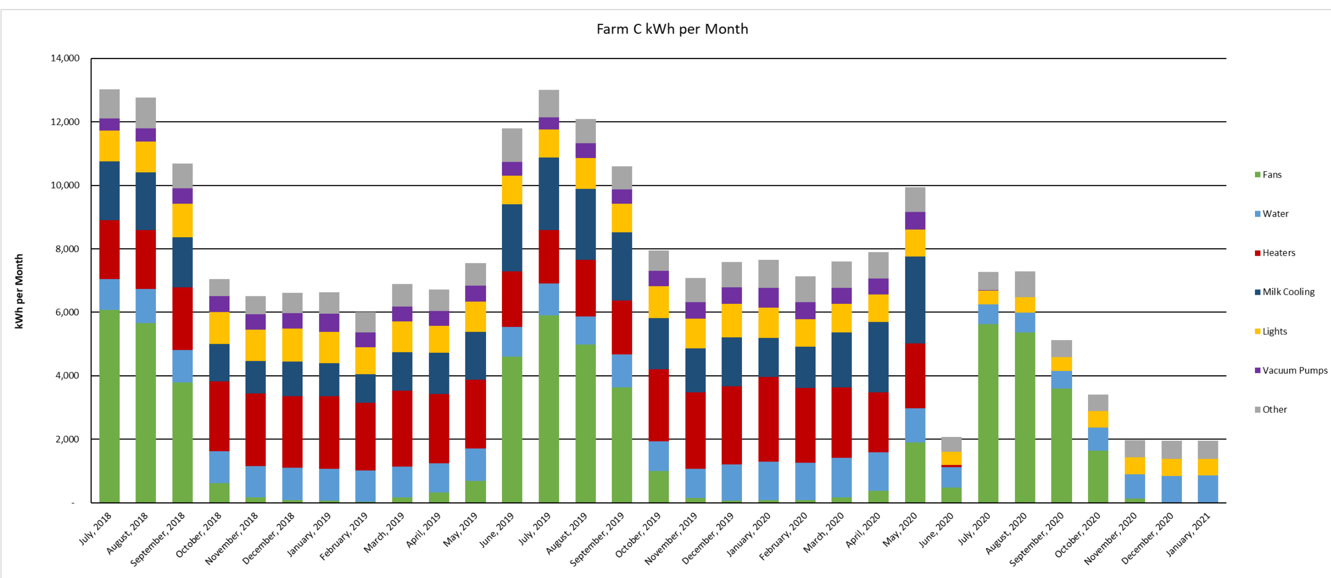


Figure 4. Monthly total kWh by load category used by Dairy Farm D across the 3 years.

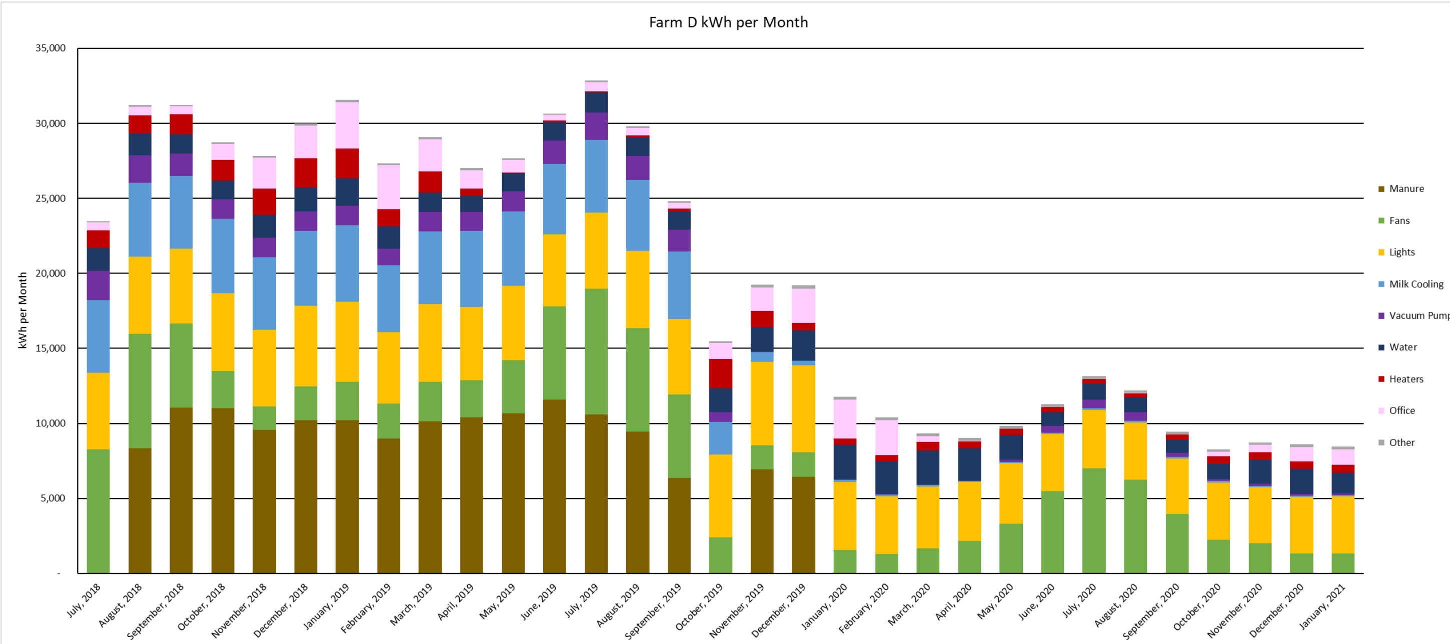
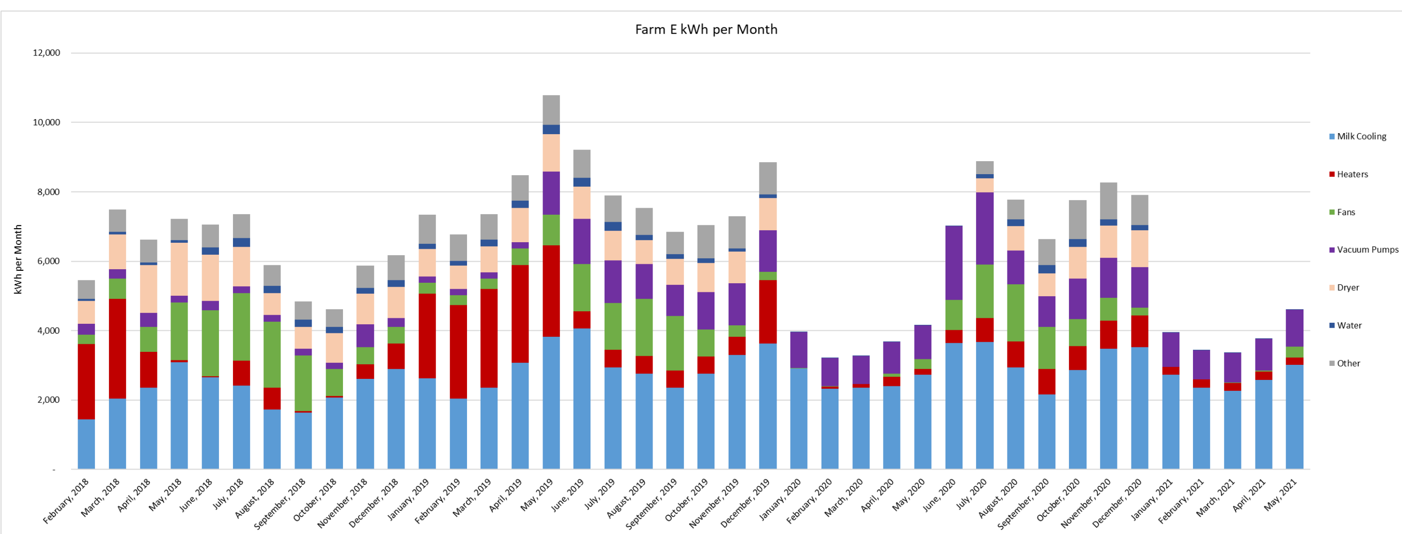
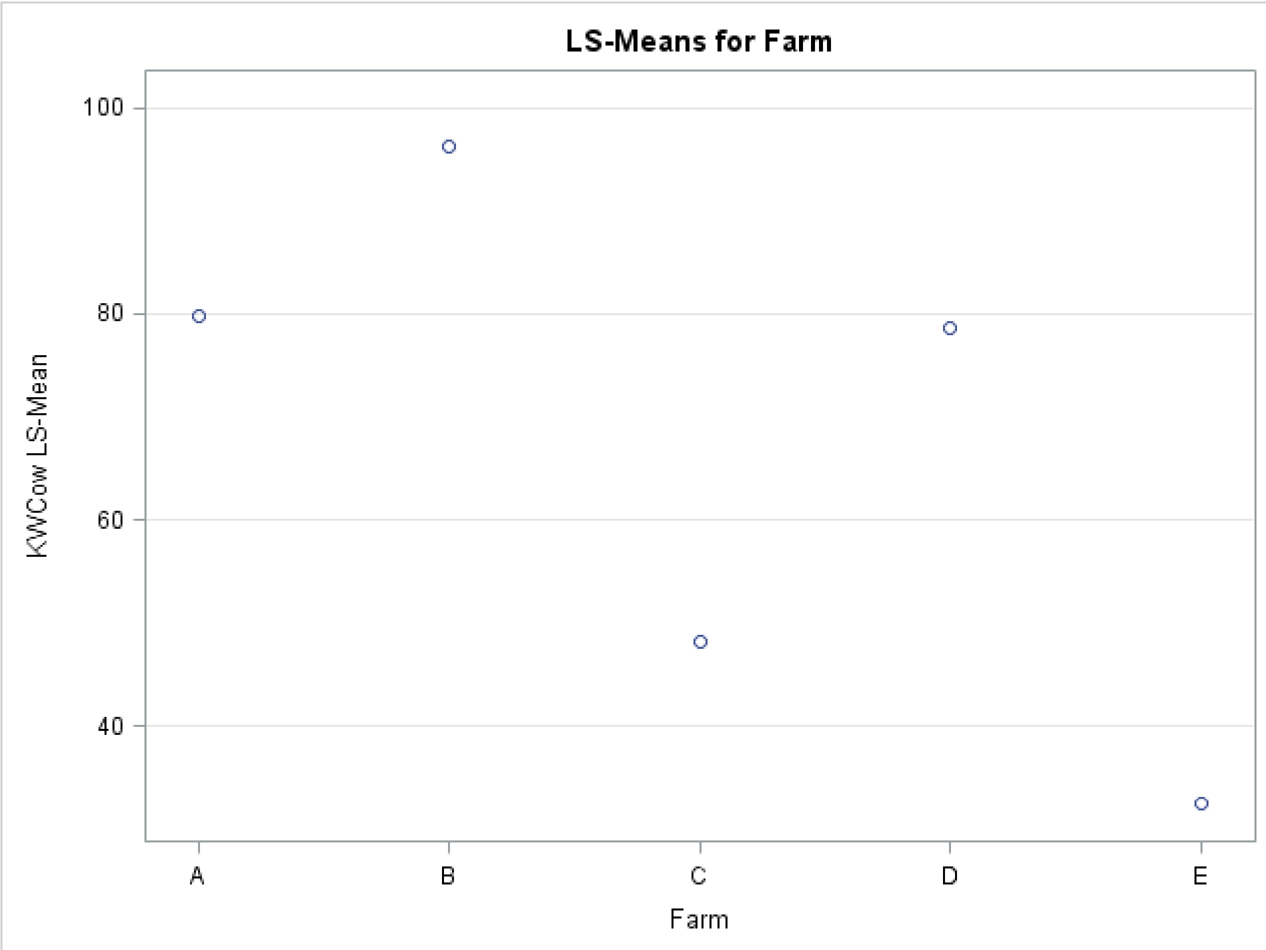


Figure 5. Monthly total kWh by load category used by Dairy Farm E across the 3 years.



Figures. Graphs for farms from final statistical analysis   KW per cow for farms.



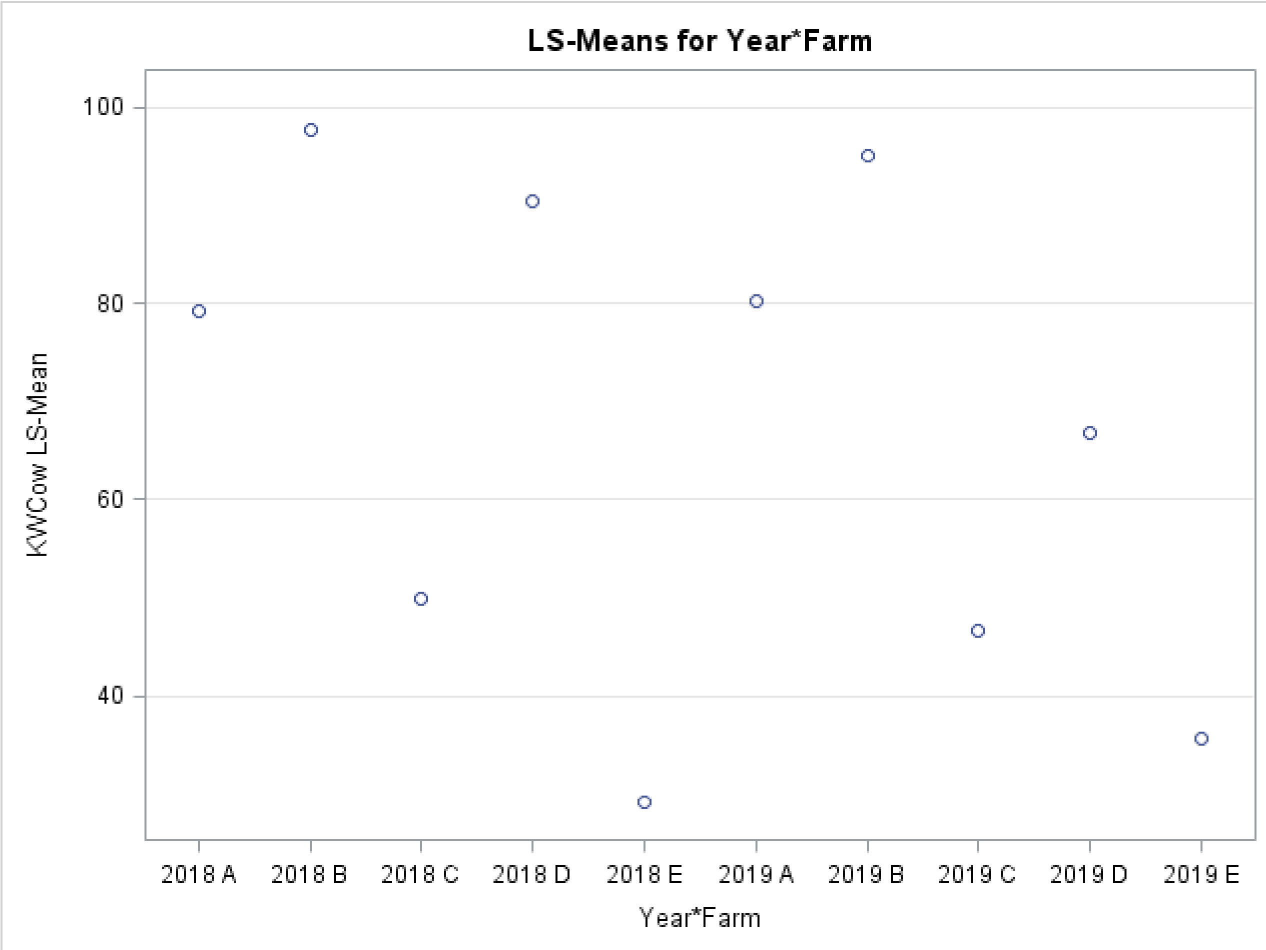


Figure. KW per cow for farms and years.

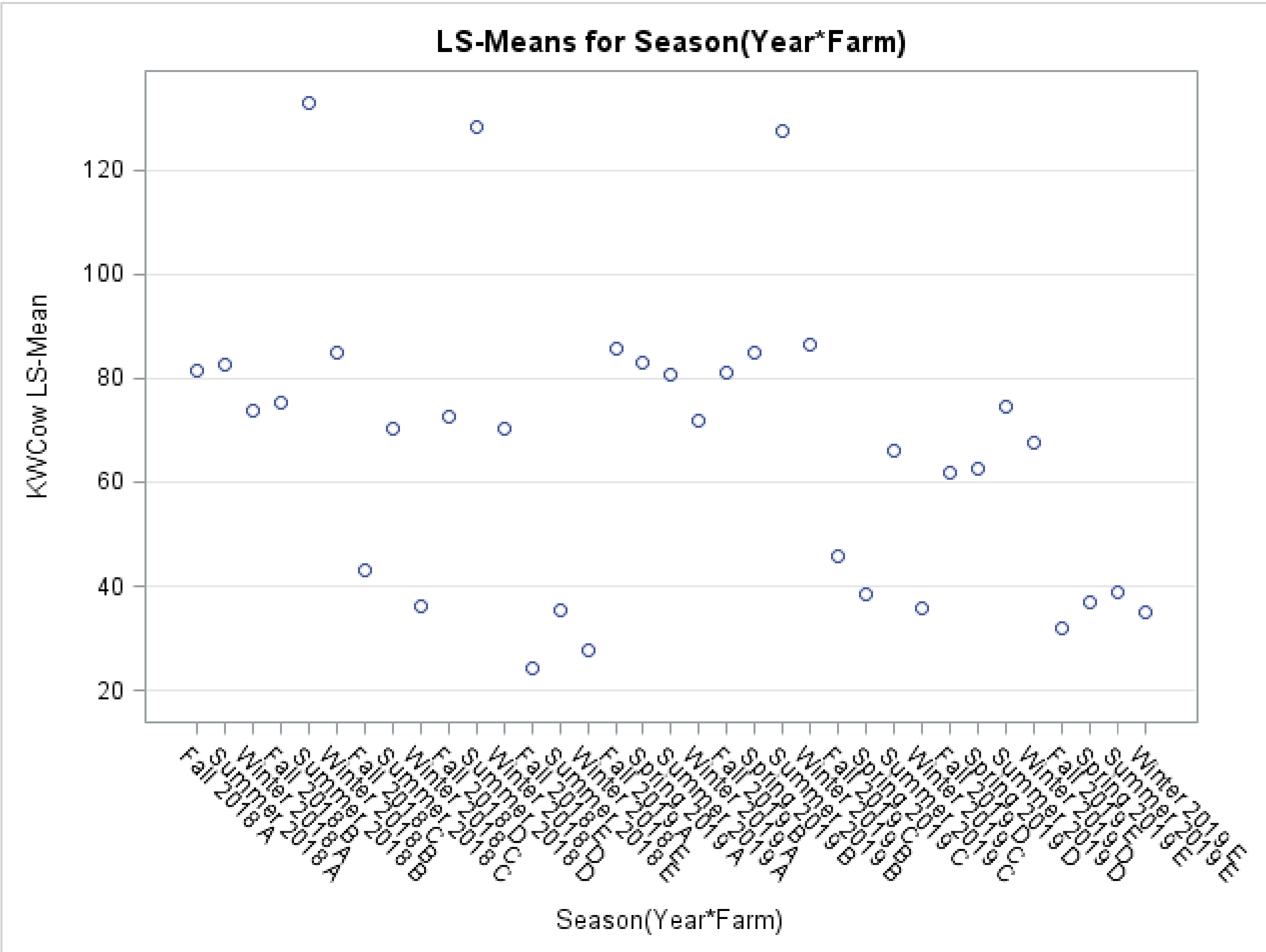


Figure. KW per cow for farms by seasons and years.

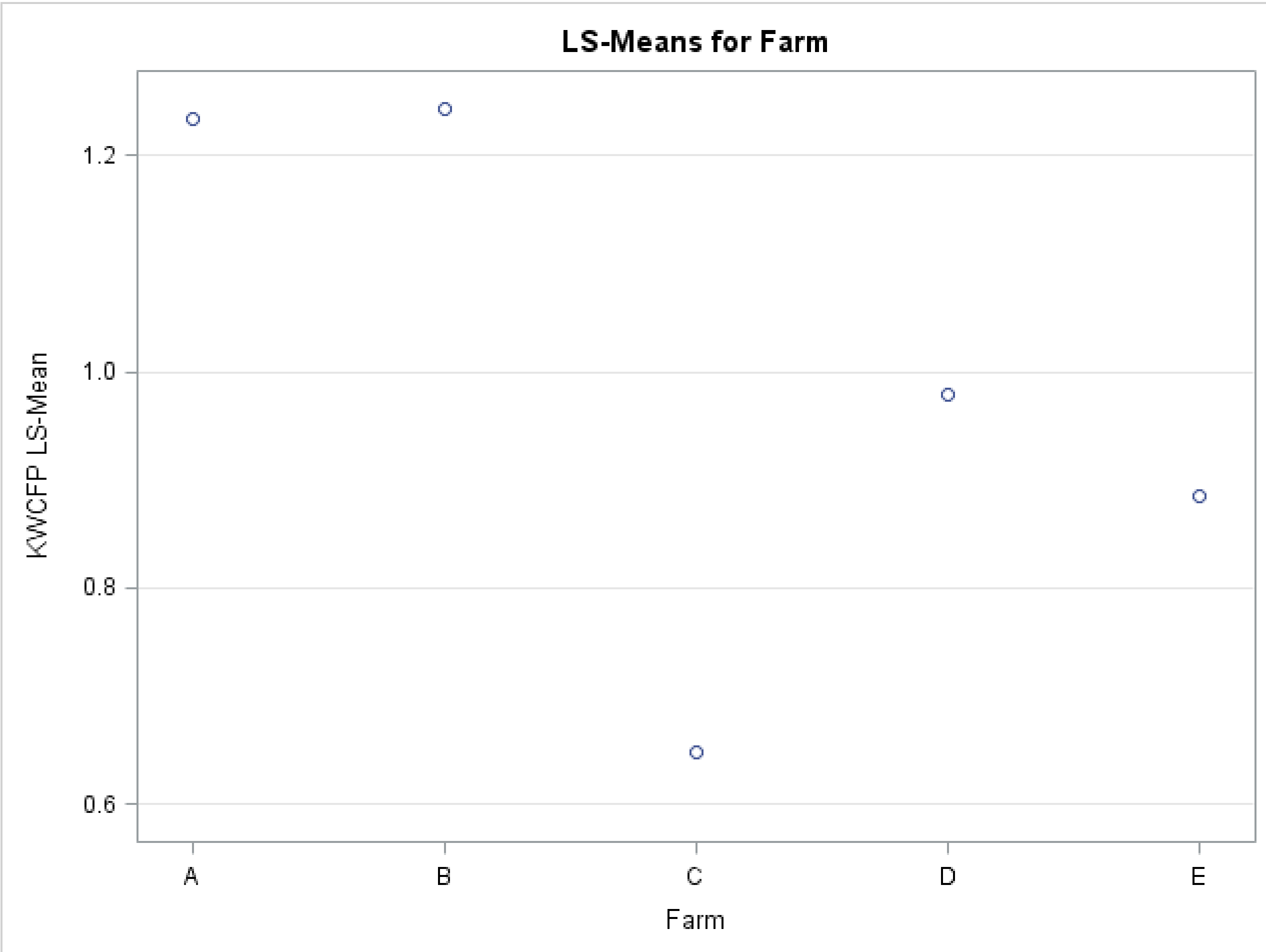


Figure. KW of fat plus protein per cow for farms.

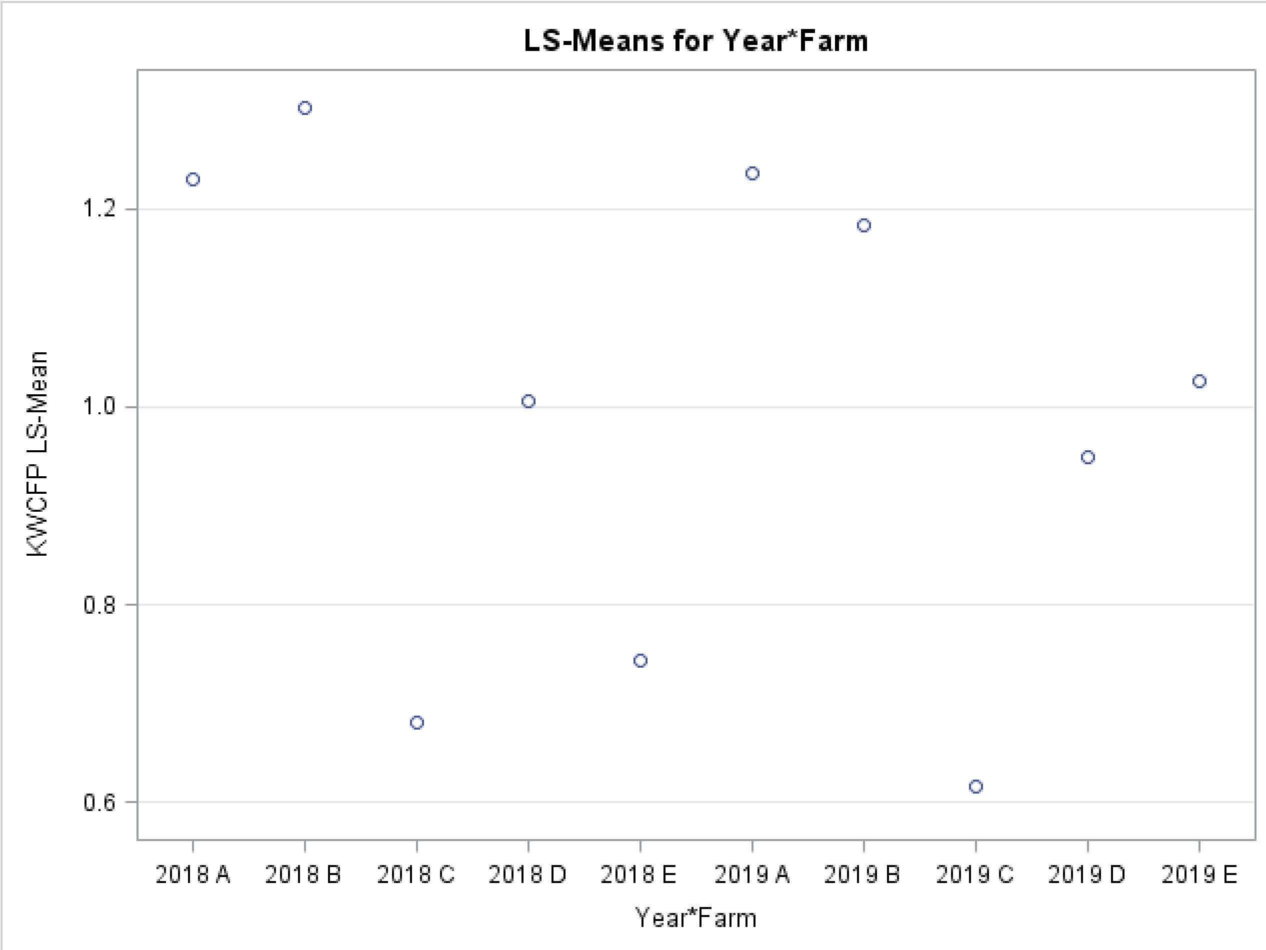


Figure. KW of fat plus protein per cow for farms by years.

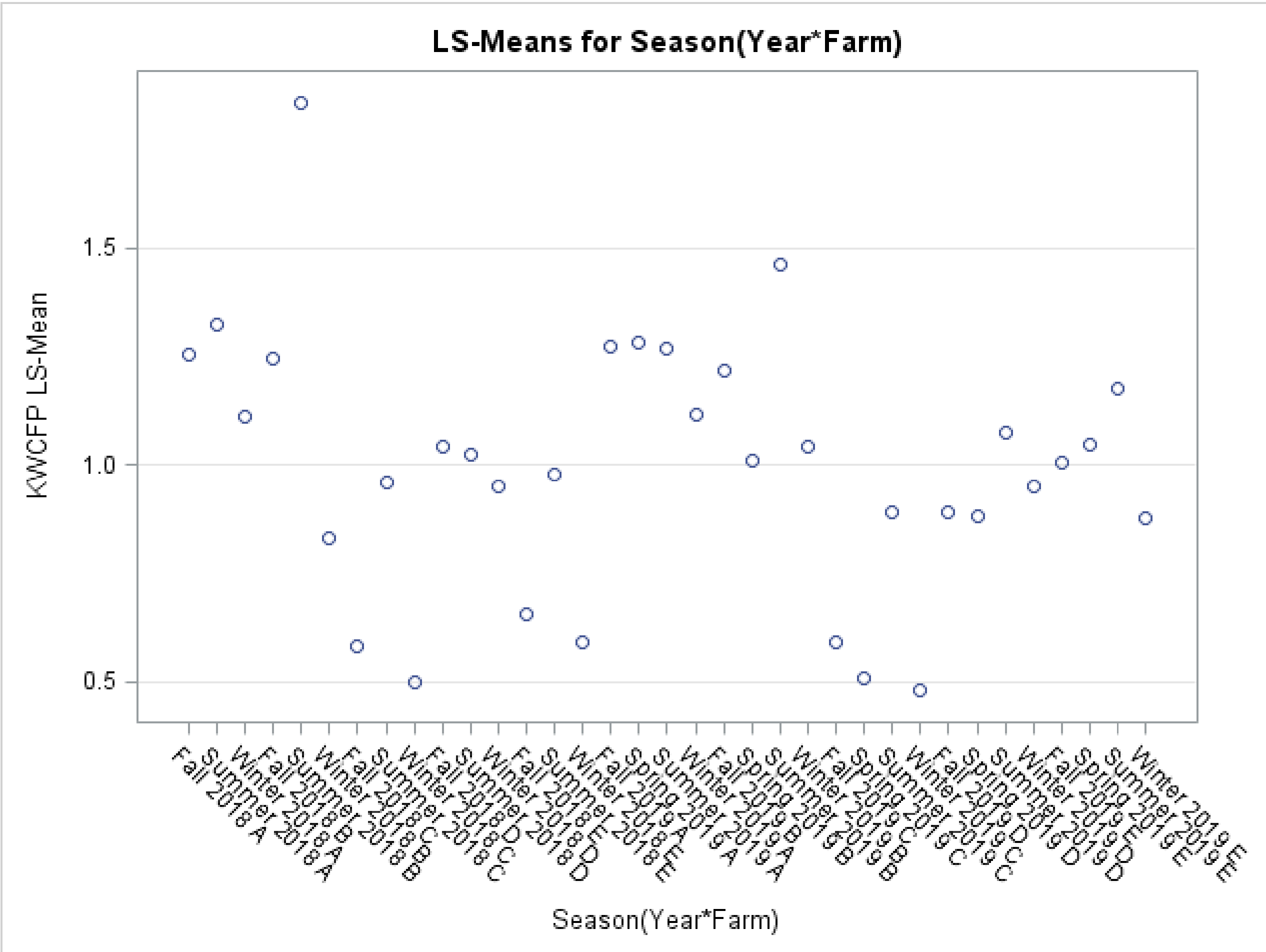


Figure. KW of fat plus protein per cow for farms by seasons and years.

ACTIVITY 4: Educate consumers, industry representatives, dairy producers and the general public about technology to generate, store, and utilize electricity from solar energy technologies

Description:
The most effective way to educate livestock producers and consumers to adopt new technologies is to demonstrate improved solar systems. The results from all activities will be used to demonstrate the potential of the electric charging systems. The research and outreach center will be used as the demonstration site to educate all of Minnesota about solar energy technologies.

We will develop a comprehensive extension program to educate producers, dairy professionals, and other stakeholders on the implementation of Solar PV, and electric vehicle testing in the pastures of WCROC, through the following activities: 1) Maintaining a web page within the University of Minnesota WCROC and Dairy Extension websites throughout the project and beyond dedicated to dissemination of electronic information, 2) Disseminate results and educational information via social media (Facebook and YouTube, and 3) Present study results at extension and professional conferences in the state and region. For all outreach activities, we will solicit feedback using standard survey documents, and these surveys will determine the impacts of our activities on audience knowledge and farmers' behaviors related to adopting practices that that will incorporate solar energy into Minnesota dairy farms.

Summary Budget Information for Activity 4: **ENRTF Budget: $ 7,000**
Amount Spent: $ 7,000
Balance: $0

Outcome	**Completion Date**
1. Tour the Solar Shade PV system as a field stop for the WCROC Organic Dairy Day	12/30/2018
2. Host a tour and demonstration of the site and charging facility during our Midwest Farm Energy Conference at the WCROC.	5/30/2019
3. Conduct energy workshops and webinars across the State.	6/30/2020
4. Prepare Extension factsheets to inform stakeholders of the solar technologies.	6/30/2020

Activity 4 Status as of January 1, 2018:
No update as this portion will begin later in the project.

Activity 4 Status as of July 1, 2018:
We will be having our planning meeting for our Midwest Farm Energy Conference in September 2018. We will be showcasing the solar system at our Organic Field Day in August 2018. We will do more with this portion of the project during the latter half of 2018 and 2019.
Activity 4 Status as of January 1, 2019:
We highlighted the solar system at our Organic Field Day in August 2018. We will do more with this portion of the project during 2019. We are planning our Midwest Farm Energy Conference at the WCROC in Morris in July 2019. We will be presenting information on the solar energy project.

Activity 4 Status as of July 1, 2019:
We continued to off many tours of the Solar shading system to farmers, consumers, dairy industry representatives, and legislators. During 2019, the WCROC hosted the Midwest Farm Energy Conference, where we highlighted to solar shading studies in presentations and tours. The project has garnered lots of attention all over the United States.

Activity 4 Status as of January 1, 2020:

The project continues to garner a lot of attention from around Minnesota and the United States. During July 2019, the WCROC hosted the Midwest Farm Energy Conference, where we highlighted to solar shading studies in presentations and tours. The LCCMR Commission visited the WCROC in September 2019 and was provided a tour of the solar shading system. The Minnesota Commissioner of Agriculture, Thom Peterson, visited the Solar Shade project during the summer of 2019. There are many places where the study has been written in popular press magazines. Graduate student, Kirsten Sharpe, presented her research at the 9th annual Global Agenda for Sustainable Livestock (GASL) Multi Stakeholder Partnership (MSP) meeting, September 9 – 13, 2019 at Kansas State University in Manhattan, Kansas. Also, a YouTube video was created showing the solar shade project.

https://www.morningagclips.com/solar-panels-double-as-summer-cow-shades/
https://landstewardshipproject.org/repository/1/3129/lsl_no_3_2019.pdf
https://www.youtube.com/watch?v=ba1ACaGXADA

Solar Shading for Dairy Cows

Activity 4 Status as of July 1, 2020: We have disseminated the information with 2 articles in Hoards Dairyman and 2 podcasts with the University of Minnesota Moos Room. The Clean Energy Resources Team wrote an article about the project as well.

The Moos Room

University of Minnesota Extension

Subscribed   Visit website

Hosted by members of the University of Minnesota Extension Beef and Dairy Teams, The Moos Room discusses relevant topics to help beef and dairy producers be more successful. The information is evidence-based and presented as an informal conversation between the hosts and guests.

The Moos Room

Episode 11 - Solar panels and grazing - UMN Extension's The Moos Room

May 29, 2020

Play episode

In part 1 of 2, Brad and Joe sit down with Kirsten Sharpe to discuss research combining solar panels and grazing. Finding ways to incorporate solar energy on-farm with benefits for your cows can make for a great investment.

Links: extension.umn.edu

Email: themoosroom@umn.edu

The Moos Room

Episode 12 - Dairy farm energy use - UMN Extension's The Moos Room

May 29, 2020

Play episode

Part 2 of our time with Kirsten Sharpe. This episode we discuss research about energy usage on dairy farms. What is the biggest energy draw? How can you monitor energy use? How can this help your dairy? Listen to find out!

Links: extension.umn.edu

Email: themoosroom@umn.edu

The Moos Room

Episode 11 - Solar panels and grazing - UMN Extension's The Moos Room

May 29, 2020

Play episode

In part 1 of 2, Brad and Joe sit down with Kirsten Sharpe to discuss research combining solar panels and grazing. Finding ways to incorporate solar energy on-farm with benefits for your cows can make for a great investment.

Links: extension.umn.edu

Email: themoosroom@umn.edu

Activity 4 Status as of January 1, 2021:

We had our Organic Dairy Day online on August 11, 2020 where we showcased the solar grazing project as one of the videos on the virtual platform. The website is **https://wcroc.cfans.umn.edu/events-education/organic-dairy-day** We continue to have search out opportunities to publish our research related to the project. We will publish more in early 2021.

UNIVERSITY OF MINNESOTA Driven to Discover™

Organic dairy production research at the WCROC aims to help producers and farmers transition from conventional to organic herds, as well as to provide herd management strategies for existing organic dairy producers. We hope to mitigate challenges and provide practical, innovative solutions for those raising organic dairy herds.

Organic Dairy Day - August 11, 2020
Event to be held ONLINE only
Brought to you by the U of MN West Central Research and Outreach Center, Morris

Take a Pasture Walk

Our 2020 Organic Dairy Day will be held virtually. Follow along with Brad Heins, WCROC Dairy Scientist, as he takes us through a few of the newest projects with the organic dairy herd at the WCROC.

Sessions

- Calf rearing: individual hutches, group housing, auto-feeding and raising calves on cows
- Solar shading for grazing dairy cows
- Breeding for A2 milk

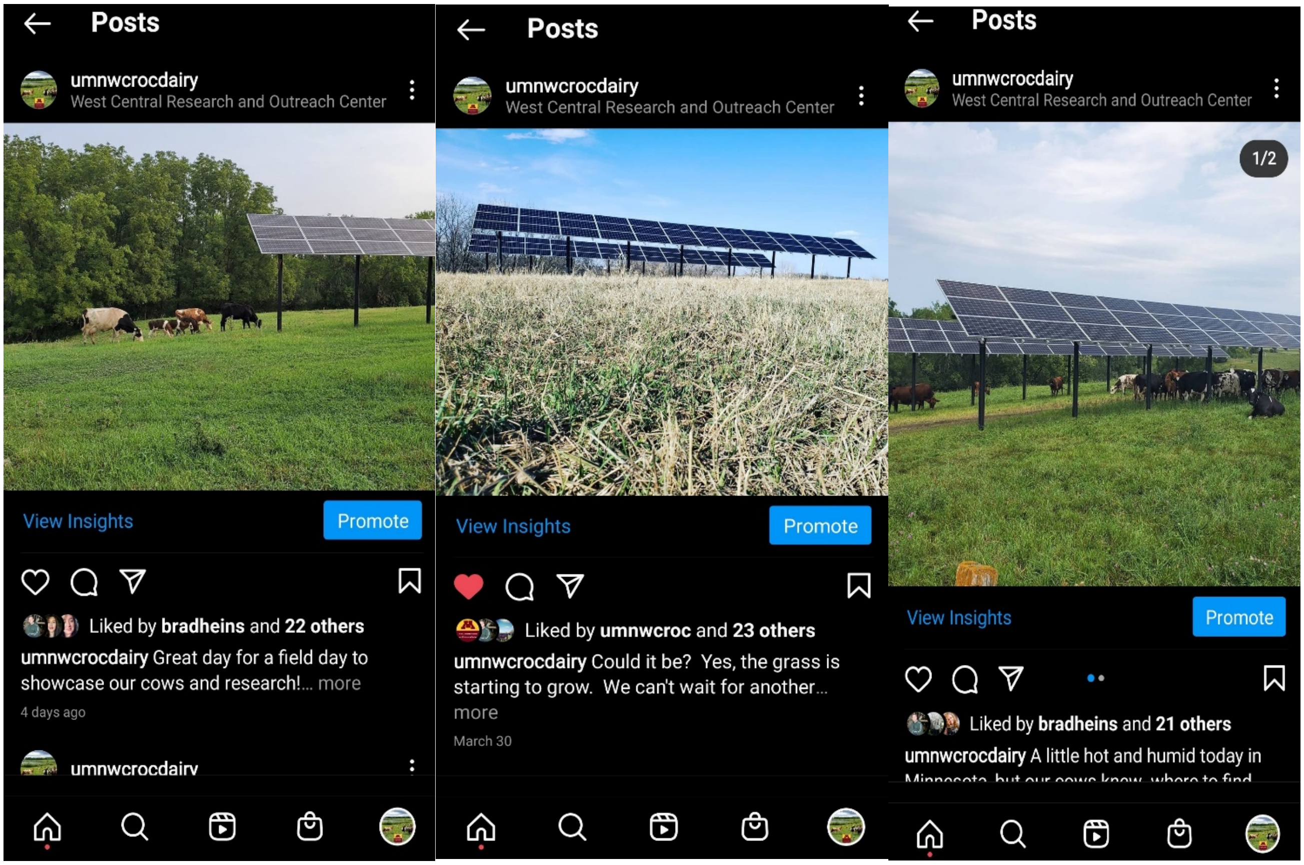
Information

All segments have been pre-recorded, and will be made available on August 11 beginning at 10 am. Feel free to watch them all back-to-back, or pick and choose your topic of interest.

Videos will be posted on the WCROC website.

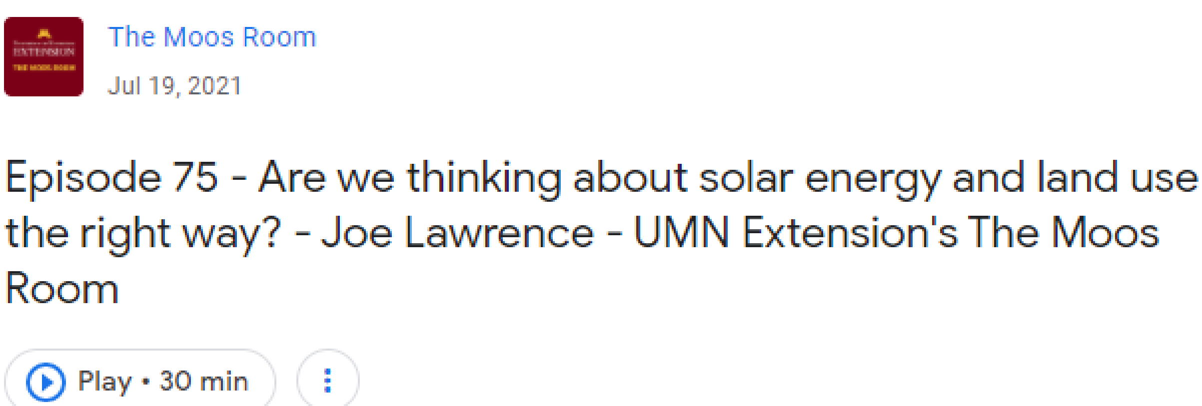
Final Report Summary:

We started an Instagram page. https://www.instagram.com/umnwcrocdairy/
We have showcased our solar grazing systems on various posts for the page. We currently have 602 followers.



We have presented at the AgriVoltaics 2021 conference on the solar grazing project. https://www.agrivoltaics-conference.org/home

We also developed another podcast for The Moos Room on Agrivoltaics and land use with Joe Lawrence from Cornell University.



V. DISSEMINATION:

Description:
The most effective way to educate and motivate livestock producers to adopt new technologies is to demonstrate improved profitability with the incorporation of solar energy into Minnesota dairy farms. The results from Activity 1 ,2, and 3 will be used to demonstrate the potential of the Solar PV system for Minnesota farms. The research and outreach center will be used as the demonstration site to showcase the opportunities for solar energy for farms, as well as generate new opportunities for the 5,000+ Minnesota dairy producers to utilize a solar energy to reduce the environmental footprint of their farm. These activities are well within the capabilities of the WRCOC and the University of Minnesota.

Status as of *January 1, 2018*:
Brad Heins authored an article in the Dec 10, 2017 issue of Progressive Dairy magazine that reported on results at the University of Minnesota West Central Research and Outreach Center, and introduced the idea of monitoring dairy farms in the article.
https://www.progressivedairy.com/topics/barns-equipment/greening-of-ag-renewable-energy-systems-for-dairy-production

Status as of *July 1, 2018*:
Elizabeth Dunbar of MPR News had an article on MPR News on April 20, 2018 about the solar panels, shading for cows, and fast charger. Brad Heins and Eric Buchanan also provided an interview for MPR News on the project.
https://www.mprnews.org/story/2018/04/20/a-sign-of-the-future-in-morris-cows-solar-panels-fast-electric-car-charger

Graduate student, Kirsten Sharpe, also presented preliminary information from the WCROC Organic Dairy on energy usage. She presented this information at the American Dairy Science Association Annual Meeting in Knoxville, TN in June 2018.

Thermal and electrical energy and water consumption in a Midwest dairy parlor. 2018. K. T. Sharpe, B. J. Heins, E. S. Buchanan, M. H. Reese, J. E. Tallaksen, and L. J. Johnston, University of Minnesota West Central Research and Outreach Center, Morris, MN. J. Dairy Sci. Vol. 101, Suppl. 2, Abstr: 328.

Status as of *January 1, 2019*:
During the summer of 2018, Brad Heins mentored a University of Minnesota Morris McNair Scholar on renewable energy systems for dairies. He presented his research at the McNair Symposium during September 2018. His poster was entitled "Cost-Benefit of Incorporating Renewable Energy into Dairy Production Systems".

Additionally, two abstracts were accepted to be presented at the Waste 2 Worth Conference in Minneapolis, MN in April 2019.

Status as of *July 1, 2019*:

Two abstracts were presented at the Waste 2 Worth Conference in Minneapolis in 2019.

Energy Consumption in Commercial Midwest Dairy Barns
https://lpelc.org/energy-consumption-in-commercial-midwest-dairy-barns/

Thermal and Electrical Energy and Water Consumption in a Midwest Dairy Parlor
https://lpelc.org/thermal-and-electrical-energy-and-water-consumption-in-a-midwest-dairy-parlor/

The Univeristy of Minnesota Department of Bioproducts and Biosystems Engineering recently hosted the Waste to Worth Conference at the Graduate Hotel on the Minneapolis campus. Waste to Worth is a national conference that highlights advances in manure management, air quality, and agricultural sustainability.

The Ron Sheffield Memorial Student Poster Competition is held in conjunction with the conference to recognize students who conduct quality applied research or Extension education related to livestock and poultry environmental management. Twelve students participated in the competition. Kirsten Sharpe (advised by Brad Heins) won first place with her poster entitled "Energy consumption in commercial Midwest dairy barns". The research projects were conducted at the West Central Research and Outreach Center.
https://wcroc.cfans.umn.edu/news/w2w-poster-win

An abstract was presented by Kirsten Sharpe at the American Dairy Science Association Annual Meeting in Cincinnati, Ohio in June 2019.

Electrical energy consumption in four commercial Midwest dairy barns.
K. Sharpe*1, B. Heins1, E. Buchanan1, M. Cotter1, M. Reese1, 1West Central Research and Outreach Center, University of Minnesota, Morris, MN.

An article on project was also printed in the Dairy Star Magazine.

Status as of *January 1, 2020*:
Presentations were given at the Midwest Farm Energy Conference in July 2019 and at the 9th annual Global Agenda for Sustainable Livestock (GASL) Meeting in September 2019.

https://wcroc.cfans.umn.edu/events-education/2019-midwest-farm-energy-conference

https://wcroc.cfans.umn.edu/sites/wcroc.cfans.umn.edu/files/dr_brad_heins_mfec_dairy_energy_july_2019.pdf

Brad Heins presentation from Conference https://www.youtube.com/watch?v=SNjw1t0hjF0&feature=youtu.be

Article and extension publications will be forthcoming in 2020.

Status as of July 1, 2020:

B. Heins. Making money in the shade. Hoards Dairyman. June 2020.

K. Sharpe. Where does the energy go? Hoards Dairyman. May 25, 2020

Clean Energy Resource Teams article: https://www.cleanenergyresourceteams.org/researchers-test-solar-energys-shade-benefits-dairy-cows

Moos Room Podcast: https://blog-moos-room.extension.umn.edu/search/label/Podcast

Two abstracts were presented by Kirsten Sharpe at the American Dairy Science Association Annual Meeting. The meeting was virtual during June 2020.

Energy consumption on five Midwest dairy farms. 2020. K. Sharpe, B. Heins, E. Buchanan, M. Reese, 1West Central Research and Outreach Center, University of Minnesota, Morris, MN. J. Dairy Sci. 103 (Suppl. 1) Abstract #138.

Use of agrivoltaics to shade cows in a pasture dairy system. 2020. K. Sharpe, B. Heins, E. Buchanan, M. Reese, 1West Central Research and Outreach Center, University of Minnesota, Morris, MN. J. Dairy Sci. 103 (Suppl. 1) Abstract #139.

Status as of January 1, 2021:

Sharpe, K.T., B.J. Heins, E.S. Buchanan, and M.H. Reese. 2020. Evaluation of solar photovoltaic systems to shade cows in a pasture-based dairy herd. Journal of Dairy Science 0. doi:10.3168/jds.2020-18821. https://www.journalofdairyscience.org/article/S0022-0302(20)31073-0/fulltext

YouTube video on Solar Grazing https://www.youtube.com/watch?v=3or3vL7X01U&feature=youtu.be

WCROC Organic Dairy Day 2020
https://wcroc.cfans.umn.edu/events-education/organic-dairy-day

Final Report Summary:

We have provided tours of the agrivoltaic system at the WCROC to legislators, farmers, and industry representatives. We have also hosted dairy field days and the Midwest Farm Energy Conference at the WCROC that have shown the results and solar system to the public as well. Over 10,000 people have viewed the solar system and have responded with favorable interest in the system. A graduate student on the project presented an abstract at the ADSA Meeting and Waste to Worth conference. So far, 3 peer reviewed papers have been published with more to follow. The WCROC website provides the results of the project and YouTube videos for promotion of the project. A presentation was made at the global Virtual AgriVoltaics conference in 2021. This applied dairy energy and agrivoltaics projects was the Master's thesis of Kirsten Sharpe in the Department of Animal Science at the University of Minnesota and she defended her thesis in 2020.

Heins, B.J., K.T. Sharpe, E.S. Buchanan, M. H. Reese. Agrivoltaics to Shade Cows in a Pasture-Based Dairy System. AgriVoltaics 2021 Virtual Conference. June 14-16, 2021. https://www.agrivoltaics-conference.org/program

Final Citation:
Sharpe, K.T., B.J. Heins, E.S. Buchanan, and M.H. Reese. 2021. Evaluation of solar photovoltaic systems to shade cows in a pasture-based dairy herd. J. Dairy Sci. Volume 104, Issue 3, 2794 – 2806. https://doi.org/10.3168/jds.2020-18821

Presentations on the project that included results from the solar grazing project from the last year

ASGA TeatimeSolar Grazing with Cattle – Presented to the American Solar Grazing Association Teatime Virtural Webinar on April 21, 2021

6/15/21 - Agrivoltaics to shade cows in a pasture-based dairy. AgriVoltaics 2021 Online Conference, France.

5/26/21 - Put a Sensor In It! University of Minnesota Extension Water Cooler Wednesday Online Seminar

3/9/21 - The cows are talking- can you hear? Using precision dairy technologies to improve management, health and welfare of dairy cattle. ADSA Graduate Student Division Webinar

2/23/21 - WCROC Dairy Projects 2020-2021. University of Minnesota WCROC Advisory Meeting

2/8/21 - Agrivoltaics to Improve the Environment and Dairy Farm Resiliency. University of Minnesota ANSC 8510 Seminar

VI. PROJECT BUDGET SUMMARY:

A. Preliminary ENRTF Budget Overview:

Budget Category	$ Amount	Overview Explanation
Personnel:	$ 211,000	1 MS graduate student research assistant at 100% FTE in years 1 and 2; 1 junior scientist at 100% FTE for 2 years; and 1 undergraduate student intern for two years during summer term
Professional/Technical/Service Contracts:	$70,000	Up to 5 contracts with dairy producers for stipends to participate in baseline energy auditing study, 1 contract with a general contractor for the installation of the solar PV system and fast charger; and 1 contract with a mechanical contractor for installation of energy meters
Equipment/Tools/Supplies:	$63,500	Energy meters and data loggers for the dairy facilities. Fast charging system for electric vehicle charging and testing
Capital Expenditures over $5,000:	$130,000	30 kW solar PV system at the WCROC dairy pasture facilities; 2 Polaris or equivalent electric ATV for use at the WCROC pasture and for performance testing for Minnesota dairies
Travel Expenses in MN:	$20,000	Mileage, lodging, meals to regional conference and workshops; Lease of a 100% electric vehicle from the University of Minnesota for travel to Minnesota dairy farms participating in the study.
Other:	$5,500	Publication and regional workshop materials, and extension bulletins
TOTAL ENRTF BUDGET:	**$500,000**	

Explanation of Use of Classified Staff:

Explanation of Capital Expenditures Greater Than $5,000:
One solar photovoltaic system is being purchased and installed in the dairy pastures at the University of Minnesota West Central Research and Outreach Center. The system will be performance tested with results added to the models for optimizing commercial dairy facilities. In addition, 2 Polaris or equivalent elective ATVs will be purchased for performance testing and use at the WCROC for showcasing clean energy vehicles for farm use. Following the project, the WCROC will continue to use the equipment on similar projects for its expected serviceable life. If the equipment is sold prior to the end of its serviceable life, the proceeds will be paid back to the Environment and Natural Resources Trust Fund.

Total Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: ~3.5 FTEs

Total Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: 2

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			
University of Minnesota (In-kind support)	$260,000	$0	The 52% foregone federally negotiated ICR funding constitutes the University of Minnesota cost share to the project.
State	0	0	
TOTAL OTHER FUNDS:	**$260,000**	**$0**	

VII. PROJECT STRATEGY:

A. Project Partners:

Dr. Bradley Heins, U of MN Dairy Scientist, will serve as PI and project manager. He will be responsible for all reports and deliverables. He will also manage the activities of the dairy production system at the research and outreach center, conduct solar studies, and manage the demonstration site. Michael Reese, U of MN WCROC Renewable Energy Director, and Dr. Lee Johnston, U of MN Swine Scientist, will be co-investigators managing the activities within their respected specialties. They will assist with outreach and dissemination of results. Eric Buchanan, WCROC Renewable Energy Scientist, will be the project coordinator assisting in the design, installation, testing, and control strategies of the solar charging technologies. He will also assist with the outreach and dissemination of results. AKF Engineering (Minneapolis) or equivalent will provide consulting services for clean energy modeling, designing, commissioning, and control strategies.

B. Project Impact and Long-term Strategy:

The WCROC has a 10-year strategic plan to reduce fossil energy consumption and the carbon footprint within dairy production systems. This collaborative project will build on renewable energy and solar technology activities of the project investigators. Previous funding has been received through the U of MN Initiative for Renewable Energy and the Environment and Xcel Energy RDF funds to measure energy consumption within the WCROC dairy and test clean thermal energy systems. This proposed project will facilitate and demonstrate the need for energy charging systems in an agricultural setting. Additional long-term funding will be sought to conduct research with alternatives to fossil energy within all agricultural crop and livestock enterprises.

C. Funding History:

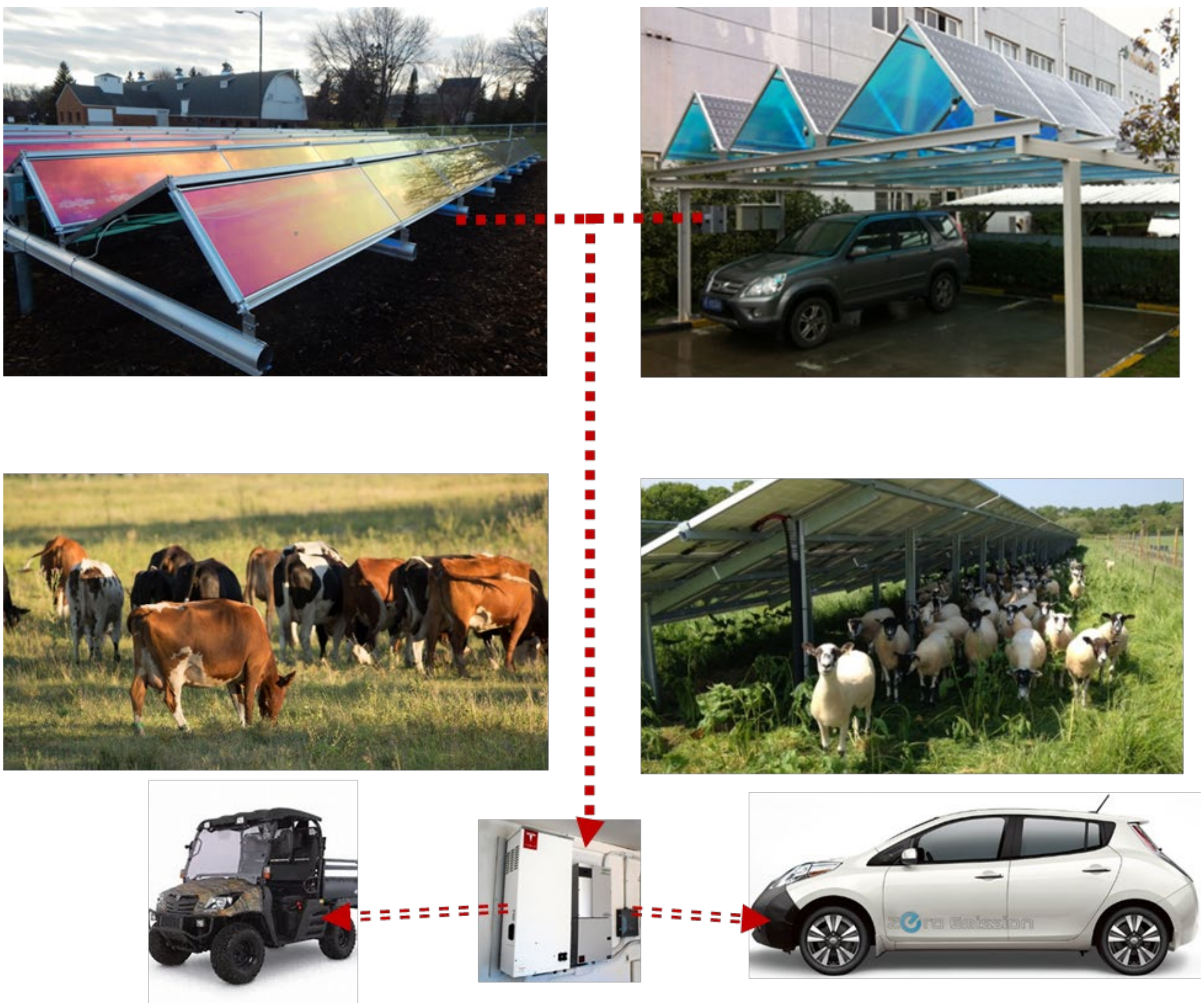
Funding Source and Use of Funds	Funding Timeframe	$ Amount
Funding was provided by the U of MN Initiative for Renewable Energy and the Environment (IREE) and the College of Food, Agricultural, and Natural Resource Sciences. The original IREE source of the funding was through Xcel Energy customers through MN Dept. of Commerce. Xcel Energy RDF has also provided funding for research at the WCROC dairy. This proposal leverages past and current work implementing clean energy technologies, life cycle, and economic analysis of energy-optimized crop and dairy production systems.		$1,350,000

2016 LCCMR Appropriation 148-E, Titled: Utilization of farm wastewater for sustainable dairy production		$475,000
		$1,825,000

VIII. REPORTING REQUIREMENTS:

- The project is for 4 years, will begin on July 1, 2017, and end on June 30, 2021.
- Periodic work plan status update reports will be submitted no later than January 1, 2018; July 1, 2018; January 1, 2019; July 1, 2019, January 1, 2020, July 1, 2020, and January 1, 2021. A final report and associated products will be submitted between June 30 and August 15, 2021.

IX. VISUAL COMPONENT or MAP(S):



X. FEE TITLE ACQUISITION/CONSERVATION EASEMENT/RESTORATION REQUIREMENTS: N/A

A. Parcel List: N/A

B. Acquisition/Restoration Information: N/A

Environment and Natural Resources Trust Fund
M.L. 2017 Project Budget

Project Title: Generation, Storage, and Utilization of Solar Energy
Legal Citation: M.L. 2017, Chp. 96, Sec. 2, Subd. 07c
Project Manager: Bradley Heins
Organization: University of Minnesota
M.L. 2017 ENRTF Appropriation: $500,000
Project Length and Completion Date: 4 Years, June 30, 2021
Date of Report: August 16, 2021

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	Activity 3 Budget	Amount Spent	Activity 3 Balance	Activity =4 Budget	Amount Spent	Activity 4 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	*Design Solar System and charger*			*Evaluate Solar Shade potential*			*Field test dairy farm clean energy systems*			*Educate consumers and producers about solar*				
Personnel (Wages and Benefits)	$44,000	$44,000	$0	$80,500	$80,500	$0	$86,500	$86,500	$0				$211,000	$0
Animal Science Graduate Research Assistant for 2 years; 17.60% fringe, plus tuition remission during the academic year and 17.60% fringe summer; estimated $85,000														$0
WCROC Junior Scientist for 2 years; Technician for data collection and testing; 100% FTE in Year 1 and 2, 33.7% fringe; estimated $114,000														$0
Undergraduate student intern - Solar Energy for Minnesota Dairy Farms (2 Yrs) 7.9 fringe; estimated $12, 000														$0
Professional/Technical/Service Contracts	$30,000	$30,000	$0				$40,000	$40,000	$0				$70,000	$0
Farmer Contracts -TBD - Monitoring of on-farm systems and supply of system specs							$35,000	$35,000	$0				$35,000	$0
General Contractor TBD - Installation of solar systems and charger	$30,000	$30,000	$0										$30,000	$0
Mechanical Contractor TBD - Installation of energy meters							$5,000	$5,000	$0				$5,000	$0
Equipment/Tools/Supplies	$50,000	$50,000	$0				$13,500	$13,500	$0	$3,000	$3,000	$0	$66,500	$0
Energy Meters and Supplies for Dairy Facilities							$5,000	$5,000					$5,000	$0
Data Loggers and Supplies for Dairy Facilities							$8,500	$8,500					$8,500	$0
Electric vehicle fast charging system	$50,000	$50,000	$0										$50,000	$0
Costs include Extension programming, workshops, field days, factsheets, and dissemination of information at the WCROC										$3,000	$3,000		$3,000	$0
Capital Expenditures Over $5,000	$130,000	$130,000	$0										$130,000	$0
30 kW solar photovotaic (electric) system	$100,000	$100,000	$0										$100,000	$0
100% Electtic ATV (Polaris or equivalent) 48 Volt AC electic drivetrain. 2 units	$30,000	$30,000	$0										$30,000	$0
Travel expenses in Minnesota							$16,000	$16,000	$0	$4,000	$4,000	$0	$20,000	$0
Lease of University of Minnesota 100% electric vehicle. $600/month X 24 months; Will be utilized for traveling to dairy farms to collect energy data on farm							$15,000	$11,205					$15,000	$0
Travel, Lodging and meals for WCROC project team at conferences and to dairy farms to collect data: Lodging and meals at two regional workshops (4 people / 2nights @90 room and $40 ea for meals); mileage for travel to workshops, farm demonstrations - $0.56/mile							$1,000	$1,000		$4,000			$5,000	$0
Other	$750	$750	$0	$750	$750	$0	$1,000	$1,000	$0				$2,500	$0
Publication of research and demonstration in Open Access Journals - 3 publications	$750	$750	$0	$750	$750	$0	$1,000		$0				$2,500	$0
COLUMN TOTAL	**$254,750**	**$254,750**	**$0**	**$81,250**	**$81,250**	**$0**	**$157,000**	**$157,000**	**$0**	**$7,000**	**$7,000**	**$0**	**$500,000**	**$0**