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Farming for Efficiency: A Case Study

Grand Valley Farms

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Background

Grand Valley Farms was founded in 1952 in Rives Junction, MI. A seventh-generation farm, it is owned and operated by the Gerald Surbrook Family. The Surbrook family shares management of the entire farming operation, and specializes in genetics and managing the milking operations. Grand Valley Farms is one of the top producing dairy farms in Michigan. With a total of 840 acres, the family grows approximately 300 acres of corn, 125 acres of soybeans, 120 acres of wheat, and 125 acres of alfalfa. The crops are primarily used for the 100-milking herd dairy operations.

The main objective of this farm is high milk production and efficiency. This project specifically aims to reduce energy use on Michigan farms while maintaining or improving overall productivity, safety, and operator comfort. Energy waste reduction can be achieved through the implementation of various alternative energy sources. Grand Valley Farms is accomplishing this by the replacement of an irrigation system, installation of a solar-thermal hot water heating system, and the conversion to energy efficient lighting.

Dairy farms are heavy users of hot water for tasks like preparing cows for milking and sterilizing the milking system. While also implementing the new irrigation system and upgrading their lighting scheme, the farm has most recently implemented a solar-thermal hot water heating system. When farmers mainly rely on propane or electricity to heat the water, as most dairy farms do, this leads to large annual expenses. With the average climate in Michigan, solar heating in conjunction with the electricity-run system can lead to major savings.

Central Pivot Irrigation

Grand Valley Farms obtains their water from the Grand River to irrigate their 290 tillable acres. They previously irrigated their land with the use of three traveling guns. The traveling guns utilized 125 and 75 horsepower diesel motors and were very labor intensive. When irrigating with this older system, a worker had to be present 8 hours a day throughout the season to tend the travelers. The 290 acres took 27 runs with the travelers and from June into September, this accumulated to 560 hours of labor per season. Not only was the system labor intensive, but water application was sub-par. On average about 1.5 acre inch of the optimal 2 acre inch was pumped to be put on the fields, once a week. Of the 1.5 acre inch of water dispersed, it is estimated that only about .75 to 1 acre inch of the water was actually applied. The high pressure and high trajectory nature of the old system allowed for losses due to evaporation and wind during the application process. When a Michigan Farm Energy Audit Program auditor evaluated the system at Grand Valley Farms, it was concluded that their change-over to a center pivot system would be worthwhile. The upgrades would cut the farm's energy consumption in half and Grand Valley Farms was awarded a U.S.D.A. REAP grant that covered 25% of the total cost and qualified them for a utility energy savings rebate.

The new irrigation system replaced two of the traveling guns in use. The third traveling gun using the 75 horsepower irrigation pump is still in place for a 30 acre portion of the farmland that was impractical to cover with an additional center pivot machine. The two installed center pivots use a Berkley Model, 75 horsepower irrigation pump with a flow of 1,200 gpm. This 75 hp pump replaced the 125 hp pump from the previous system and includes a variable frequency drive to accommodate flow and pressure variations. One of the Reinke center pivots has a 360° sweep, 1,231 foot arm length, and 7 spans with an end gun. The other has a 251° sweep, 1,103 foot length, and 6 spans with an end gun. The end guns allow an additional 100 feet of coverage with the use of the booster pumps, allowing the center pivot to accommodate irrigated land that is not perfectly circular. Workers must be present to set up the machinery about once a week and an additional week at the end of the season, resulting in a total labor expenditure of 240 hours. This is a labor reduction of 320 hours per season.

The low elevation spray application (LESA) distributes the water to the crops. Advantages of this application is the water is uniformly applied and water loss is minimized. The entire system is low pressure, with the center pivot operating at 50 psi and the end gun at 30 psi. The higher efficiency allowed by this application system has allowed Grand Valley Farms to see a 30 bushel/year increase in their corn yields. Specifically, the nature of the old traveling gun system allowed for significant water losses. The new center pivot system allows the farm to irrigate the crops at night, minimizing the evaporation that can occur and helping prevent mold. Gerald Surbrook estimates the new system is allowing 99% of the pumped water to reach the crops. Achieving the proper hydration for the crops led to higher yields within the first years of operating the new system.

Grand Valley Farms has experienced higher yields after the implementation of their center pivot system and have also had significant decreases in their electricity usage. Table 1 documents the electricity of the two traveling guns used before the new system. Assuming the $.14/kWh rate, the total expense was $58,220 for yearly operation. In Table 2, the electricity usage for the installed center pivot system is shown. The total electricity used is less than a third of the consumed electricity of the old system. This led to a total expense of $25,343, less than half of the original expense. Overall Grand Valley Farms achieved a 56% energy reduction.

Table 1 – Traveler Rigs Electricity Usages

Irrigation System	Pumping Rate (gpm)	Total Dynamic Head	Water Horsepower (WHP)	Electricity Rate (kWh/hr)	Operating (hours)	Electricity Usage (kWh/yr)	Cost @ $0.14/kWh
Traveler 1	650	383	62.8	71.0	2,841	201,554	$28,218
Traveler 2	650	407	66.8	75.4	2,841	214,305	$30,003
		Totals			5,681	415,859	$58,220

Table 2 – Center Pivots Electricity Usages

Center Pivot	Pumping Rate (gpm)	Total Dynamic Head	Water Horsepower (WHP)	Electricity Rate (kWh/hr)	Operating (hours)	Electricity Usage (kWh/yr)	Cost @ $0.14/kWh
Full Circle	1,200	247	74.7	84.4	771	65,099	$9,114
	1,050	268	71.1	80.4	456	36,631	$5,128
3/4 Circle	1,200	264	80.0	90.4	453	40,990	$5,739
	1,050	282	74.8	84.5	453	38,297	$5,362
		Totals			2,134	181,018	$25,343

Solar Thermal Panel Implementation

More recently, a solar thermal water heating system has been installed to further increase energy savings during daily milking operations. The water heating system is one of the largest energy expenses on a dairy farm and a popular energy alternative being used currently is solar thermal water heating panels. In Midwestern states such as Michigan, solar water heating panels have raised some concerns due to unpredictable weather conditions throughout the year. Solar panels were manufactured by a company in Reno Nevada and donated to Michigan State University for testing in the Midwest climate. These panels were successfully tested for more than a year at M.S.U. with direct comparison to a solar-thermal evacuated tube array. While the system had been successfully tested at the M.S.U. dairy farm, it was necessary to determine the savings that could be achieved at an actual operating dairy farm.

The installation of this system was more complicated than expected and therefore it took longer than anticipated to get the system fully operational. The solar panels had to be roof mounted rather than placed on the ground, which was the design tested at M.S.U. The solar panels were going to be installed as close to the water heater as possible but due to a shadowing issue from the tower silos, they were installed on the milking parlor roof rather than on the milk house roof. The silos are only an issue in the winter between mid-October and mid-March, however the current installation aims to minimize the effect of their shadows and optimize the amount of sun that reaches the panels year-round. Since the solar panels had to be placed on the roof it was necessary to ensure the stability of the system in all conditions. A custom frame was fabricated to mount the solar thermal panels on the milking parlor roof. The solar arrays and frame were tested extensively in high wind conditions from all angles. The arrays are anchored to six trusses with three-eighth-inch stainless steel cables acting as safety restraints to guard against strong winds. The solar thermal water heating panels were installed to face directly South to optimize sunlight absorption. Ultimately, due to these unforeseen issues, it took over a year to install these solar arrays. The final positioning on the roof of the milking parlor is shown in Figure 1.

Figure 1: Solar Panel Placement

The solar water heating system is constructed such that water is heated directly by passing it between two stainless steel flat plates as a thin film of water. The water freezes inside the panels in cold weather when panels are not illuminated by the sun and quickly thaws during the sunny hours. The small photoelectric panels provide power to run a small pump that circulates water through the panels only when the sun is shining. Water from a milk refrigeration system heat recovery unit (*Fre-Heater*) goes out to a storage mixing tank next to the milking parlor. Water is pumped up to solar water heaters with dc powered pumps that only operate when the PV panels indicated in the Figure 1 are in direct sunlight. From the mixing tank, the water then goes back to the water heater in the milk house for additional heating if necessary.

As a part of the energy upgrades on the farm, the old *Fre-Heater*, water heater, and plate cooler were replaced to more efficient models. The *Fre-Heater* recovers heat in the process of cooling milk. The new system has the potential to heat 119 gallons of water from 55 ^{o}F to 120 ^{o}F in one cycle. The *Fre-Heater* used in the old system operated at 45% capacity of the replacement. Just by upgrading the *Fre-Heater,* the farm saves 251,689 BTU/day. The new heater has an efficiency of 80%, compared to the 60% of the old model. Accounting for inefficiencies and standby losses, this upgrade resulted in about an 123,259 BTU/day reduction in energy consumption. With the farm's daily average water use of 430 gallons, these upgrades in the water heating process give a yearly savings of $5,615.

Additionally, the plate cooler was upgraded to measure the influence it has on system performance. Each year there is approximately 2,957,000 lbs. of milk produced that is processed by the plate cooler. The plate cooler exposes the 99 ^{o}F hot milk to the 55 ^{o}F well-water and is capable of bringing down the overall temperature by up to 30 ^{o}F before it is put in the bulk tank. By replacing the plate cooler, the farm reduced its energy consumption by 83,009 BTU/year. This resulted in a yearly savings of roughly $1,240 and a payback period of 5 years**.** These savings could be increased to up to $4,400 per year if the farm wanted to invest in implementing a variable frequency drive on the receiving pump.

The solar thermal water heating mixing tank, control valves, and data collection center is located adjacent to the milking parlor which is maintained in the winter at a temperature of about 45 ^{o}F. Day-to-day consistent water use makes it easy to compare the solar-thermal system's impact on sunny and cloudy days. With the limited data that's been collected from only the winter months, there appears to be a 23% decrease in energy consumption with the use of the solar-thermal system. Grand Valley Farms uses natural gas, indicating that monetary savings for farms using propane will be even greater. With the longer days expected in the Fall, Spring, and Summer of Michigan, even greater savings are expected.

Lighting

During the installation of the solar-thermal panels, it was determined that while although the milking parlor, milk house, and holding area had adequate lighting, an opportunity existed to increase efficiency. Cold weather noticeably affected the lighting in the milking areas and thus LED lights were chosen to replace the existing fluorescent tubes in the milking parlor. Overall, the implementation of the LED lamps decreased energy use and doubled the illumination level.

The milking parlor had 8-foot, high-output fluorescent fixtures. All 16 of the 8-foot fluorescent lamps resulted in a total of 1582 watts. In the holding area of the milking parlor, there were 4-foot fluorescent lamps that had a total of 589 watts. All of the lamps in the milking parlor were converted to LEDs. These LED lights consume less energy and have a lower light output. However, LEDs are more directional than the previous fluorescent fixtures. Thus, the conversion to LEDs have increased the illumination in the milking parlor two-fold. Assuming the lights are on for 6 hours a day, the new lights save the farm 2,721 kWh and $381 per year. Not only are they saving money, but the working environment is more pleasant and the cows have shown a positive reaction to the more illuminated environment.

The level of light output in the calf barn was an additional concern for the Surbrook family. Above the stalls there previously existed 8 CFL fixtures which have since been replaced with LEDs. The old CFLs were 23 watt fixtures and the new LEDs are 14 watt. These lights are on 16 hours a day, 365 days a year, resulting in a yearly energy reduction of 421 kWh and a cost savings of about $59. Not only is it much more pleasant working in these areas with the improved lighting, but the visibility allows for higher efficiencies during daily activities. James Surbrook stated that out of all the energy improvements the "…one that I like the most is the LED lighting and I hope to convert all the CFL lighting on the farm to LEDs within 6 months to a year."

System Impacts and Conclusions

Taking into account the cost of the conversion process, the total project savings from installing the new irrigation system is shown in Table 3. Grand Valley Farms achieved higher yields with a more efficient application process, saved money with significant decreases in their total energy usage, and minimized the amount of labor required for irrigating the crops. Although one small field still requires a traveling gun and the necessary monitoring to operate that system, the remainder of the irrigated fields require little to no supervision. The Surbrook family has saved 320 hours of human labor per growing season and have reduced their energy consumption by 56%. The impact of these changes on the farm has not gone unnoticed and according to James Surbrook, "So far I have been very pleased with the progress we have made with the energy improvements...both the LED lighting and center pivots have made a drastic impact on our daily chores we do here at the farm."

Table 3: Saving from Central Pivot Irrigation System

Irrigation System	Pumping Time (hrs)	Electricity (kWh/yr)	Cost @ 0.14/kWh	Upgrade Costs ($)	Payback (Years)
Traveler 1 & 2	2,841	415,859	$58,220		
Center Pivots	2,449	181,018	$25,343		
Savings Totals	392	234,841	$32,878	$171,000	5.2

Due to the additional time required during the installation of the solar arrays, the system has only been up and running for a limited amount of time. The period of operation thus far for the system consists of the winter months between mid-October and mid-March. Although data collection has been limited on days without significant sky cover, there has been indication that on sunny days the potential for energy savings is high. The data for the cloudy days of February 11-13 and the sunny days of February 18-20 are shown in Table 4. As indicated, on a sunny, 8-hour operational day the solar arrays produced approximately 70,000 BTUs. Comparing the average natural gas consumption for cloudy days of 444 cubic feet to the average value on sunny days of 338 cubic feet, Grand Valley Farms saw a 23% decrease in energy consumption. This value is expected to increase in the sunnier months of Michigan.

Table 4: February 11th-19th, 2017 Data

Feb. Date	Sky Cover	Gallons Used	Solar Array Collected (Btu)	Natural Gas (cf)
11	0.5	478	-130.9	424
12	0.8	472	43	437
13	0.1	510	226	471
Avg.		486.7	46.01	444
18	0	452.5	56386.1	317
19	0	469.5	68029.9	327
20	0	464.5	40272	371
Avg.		462.2	54896	338

In addition to the solar arrays, the replacement of the plate cooler, *Fre-heater*, and water heater equipment created further savings. A breakdown of energy and cost savings as a result of each replacement can be seen in Table 5 below.

Table 5: Equipment Savings

Upgraded Equipment	Fre-Heater	Water Heater	Plate Cooler
Energy Reduction (BTU/day)	251,689	123,259	83,009
Annual Savings	$3,769	$1,846	$1,243

The modifications made on the irrigation system, solar-thermal heating system, and lighting upgrades have made Grand Valley Farms a more energy efficient and profitable operation. The changes they have made have led to decreases in total energy consumption, have given higher crop yields, decreased the labor input, and has made the workplace a more well-lit and safe environment. With grants and the efforts of M.S.U., the Surbrook family could make these improvements and receive optimal results.