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A Dairy Long Day Lighting Success Story: MI Dairy Increases Production and Cuts Costs

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Abstract. *Research studies have consistently supported that long-day lighting (LDL) increases milk production of dairy cows by 5% – 9%. However, dairy farmers in Michigan have been unable to reproduce these results in their attempts to implement an LDL system. Designing and implementing a reliable LDL system increases production in dairy cows, cuts operating costs, decreases energy consumption, and reduces the emissions of harmful greenhouse gases, which incurs economic and environmental benefits for both the farmer and the state of Michigan. In cooperation with the MMPA, a long-day lighting project, funded by a grant from the Michigan Energy Office, was initiated by Biosystems and Agricultural Engineering Department researchers at Michigan State University to address the technical difficulties Michigan farmers have faced in implementing a successful LDL system. Milk production data was collected in the two years preceding and following the installation of the LED LDL system at Wing Acres Dairy. During the system's first year, milk production increased by 6.74%, or by 67,891 kg (149,674 lbs), compared to 2013. During the second year, milk production increased by 7.69%, or 77,465 kg (170,780 lbs). Averaging the data collected from 2014 and 2015 shows a 7.22% increase in milk production compared to 2013. Using LED fixtures in place of traditional metal halide fixtures to implement an LDL system resulted in an energy savings of 29,188 kWh each year, and a reduced cost of over $3,700 each year. Based on observations, the cows also appeared calmer, cleaner, and less aggressive towards each other.*

Keywords. *Barns, dairy farms, data acquisition and control, energy conservation, engineering, lighting, Michigan, milk production.*

Introduction

Research studies have consistently supported that long-day lighting (LDL) increases milk production of dairy cows by 5% to 9% (Collier, Dahl, & VanBaale, 2006; Dahl, Buchanan, & Tucker, 2010). However, dairy farmers in Michigan have been unable to achieve these results in their attempts to implement an LDL system. Determining a reliable method for the installation and management of an LDL system for dairy farm applications has many economic as well as environmental benefits.

In 2008, members of the Michigan Milk Producers Association (MMPA), the largest milk cooperative in Michigan, agreed to stop administering recombinant bovine somatotropin (rbST) to their milking herds as a response to customer requirements (Wolf, 2008). Eventually, all commercial dairy farms in Michigan also halted their use of rbST. This growth

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hormone has demonstrated its ability to increase milk yield by 10% – 15%, and its removal from dairies across Michigan resulted in a measurable decrease in milk production. Since agriculture is a major component of Michigan's economy, and dairy products are the largest contributor to Michigan's agriculture sector, these production losses have large implications for the state as well as the farmer and subsequent milk consumers.

In 2015, there were around 413,000 mature milking cows in Michigan with an annual production average of 11,176 kg of milk. This resulted in a total annual milk production of 4.359 billion kilograms valued at over $2.3 billion (USDA/NASS, 2014; USDA/NASS, 2015). This equates to roughly 27.2% of Michigan's agricultural product value. To maintain and grow the milk production that forms such a valuable asset to Michigan's economy without the use of growth hormones, farmers are seeking alternate methods. One option is to increase herd size, but this incurs high capital costs and risks management complications and unhappy cattle. This method also creates negative environmental impacts.

Additional costs to the farmer, such as the capital costs involved with investing in a larger herd, influence monetary decisions regarding whether energy and cost efficiency measures will be adopted, which are vital to energy saving initiatives across the state. Greenhouse gas emissions related to dairy production are also a concern. Assuming that the energy is produced at a coal fired generating plant, every kWh of energy used creates 1.5 pounds of carbon dioxide (USEPA, 2014). Due to this, any additional energy expended by inefficient lighting systems also poses environmental and economic concerns. It is important to note the role that cows play as major producers of greenhouse gases as well. Dairy cows produce 106 lbs of methane and 782 lbs of carbon dioxide each year (Varga & Graves, 2008). By increasing herd size to recuperate lost production, greenhouse gas emissions of these farms are also increased. Determining an alternate method that will increase milk production without increasing herd size will alleviate these economic and environmental issues.

The design and implementation of a reliable long day lighting system will increase production in dairy cows, cut operating costs, minimize energy consumption, and reduce the emissions of greenhouse gases, which will prove economically and environmentally beneficial for both the farmer and the state of Michigan. Project goals were as follows:

- Review available LED modules to determine the lowest cost, highest efficiency, and best spectrum for use in LDL on dairy farms
- Design and program an automated light control system with photocells and other light sensors to optimize lighting efficiency, control and impact
- Measure production and energy cost impacts of a dimmable LED based system
- Evaluate the environmental impacts of using dimmable LEDs for dairy LDL

Long-Day Lighting (LDL)

Long-day lighting (LDL) systems increase the daily light photoperiod of milking herds to create an increase in production of 5% to 9%, or 2 to 2.5 kg day^{-1} (Collier, Dahl, & VanBaale, 2006; Dahl, Buchanan, & Tucker, 2010). Typically, LDL regimes create 16 – 18 hours of light each day, at 15 – 20 foot-candles, followed by 6 – 8 hours of dark, at 1 – 4 foot-candles. For reference, daylight in MI during summer averages a photoperiod of 14.6 hours with a maximum intensity of over 10,000 foot-candles in full sun and 100 foot-candles on an overcast day. During the winter, daylight drops to an average of 9.8 hours with an intensity of less than 1000 foot-candles on a cloudy day. In comparison, a moon lit night can have an intensity of approximately 2 foot-candles (Time and Date AS, 2016; National Optical Astronomy Observatory, n.d.; Biernbaum, 2013). Cows that have been exposed to LDL display a 1.5 kg day^{-1} increase in dry matter intake to sustain the higher production (Collier, VanBaale, & Dahl, 2006).

LDL increases production primarily by helping regulate melatonin levels in cattle (Dahl, Buchanan, & Tucker, 2010). Light impinging on the cow's eye stimulates retinal photoreceptors, which then transmit an inhibitory signal to the pineal gland. The pineal gland regulates melatonin production in response to these signals, which affects the cow's internal clock, such that melatonin levels are high at night and low during the day. Melatonin also affects the production of other hormones that impact growth, reproduction, and lactation, such as prolactin (PRL) and the insulin-like growth factor – I (IGF-I). Through this pathway, LDL increases production of IGF-I, which stimulates lactation and boosts overall milk production by 5% – 9%. Concentrations of IGFI-I must reach peak levels for the benefits of LDL to be realized. It is also critical that the dark period of the photoperiod be present for the cow's internal clock to be regulated correctly. Studies have found that continuous lighting, with no dark period, produces equivalent milk production values as those in systems that have not implemented LDL (Dahl, Buchanan & Tucker, 2010). It should also be noted that the increase in dry matter intake lags behind the increase in production, and the composition of the milk produced is generally unaffected by LDL (Dahl, Buchanan & Tucker, 2010).

In addition to increasing production in milking cows, LDL also generates multiple benefits for heifers and dry cows. Studies have shown that LDL hastens puberty in calves, which demonstrate more rapid growth and lean tissue formation compared to calves on shorter lighting systems (Collier, Dahl, & VanBaale, 2006; Dahl, Tao, & Thompson, 2012). Heifers exposed to LDL also exhibit increased feed efficiency and growth of mammary tissues as well as enhanced body weight, withers heights, and heart girth without limitations in skeletal growth (Rius, et al., 2005). However, unlike heifers and milking cows, dry cows benefit from shorter light periods. Dry cows previously exposed to an LDL treatment during their milking period require 8 hours of light and 16 hours of darkness during their dry period to build immunity and ensure high milk production in the next lactation period. Research shows that dry cows with 8 hours of light per day produced 2.99 – 3.99 kg more milk per day during their subsequent milking period than dry cows that received 16 hours of light per day (Collier, Dahl, & VanBaale, 2006; Dahl, Tao, & Thompson, 2012). While literature reveals the benefits of controlled lighting regimes on milking cows, heifers, and dry cows, this study focused on improving milk production in the milking group only.

In addition to improving animal health, long day lighting regimes can also create a safer workplace for farm employees. The consistent lighting created through LDL can reduce the occurrence of accidents caused by obstructions and other safety hazards in dimly lit areas of barns. Overall, better lighting can prove beneficial for human safety and productivity as well (Josefsson, Miquelon, & Chapman, 2000).

Methods

In cooperation with the MMPA, a long-day lighting project, funded by a grant from the Michigan Energy Office, was initiated by Biosystems and Agricultural Engineering Department researchers at Michigan State University to address the technical difficulties Michigan farmers have faced in implementing a successful LDL system. This project sought to develop and implement a reliable LDL system for a Michigan dairy farm by applying the following methodology:

- Conduct certified farm energy audit
- Develop energy cost and installation options
- Contract installation, electrical, and facility modifications
- Measure effectiveness of system in terms of energy cost savings
- Determine payback period and production impact

A certified Type 2 farm energy audit was conducted following the standards established by ASABE/ANSI S612. The results of this audit formed the basis for selecting the most energy efficient lighting option available, in this case using LED fixtures instead of metal halide fixtures.

Installation, electrical, and facility modifications were carefully considered to implement a reliable, automatic LDL system that could adjust light output based on real-time light data collected within the barn. The LDL system consisted of three major components: LED fixtures, light sensors, and the control system. A system package was assembled using components from Lutron, illustrated in Table 1.

Table 1 - Components of the system package used to implement the LED LDL system for this project.

Product	Part #	Total Needed
GRAFIK Eye QS 3-Zone Dimming Controller	QSGR-3P	1
Sensor Input Module	QSMX-4W-C	1
Phase Adaptive Power Modules	PHPM-PA-120	3
Light Sensors	EC-DIR-WH	3
Communication Cable	GRX-CBL-346S	1

Unlike other systems found in literature, this system is designed around dimmable LED fixtures supplied by CBM Lighting. The Model 36-WP3-18WLED-DIM fixtures have three 1.2 m LED “daylight” bulbs in a weather-tight, dust-tight, and impact resistant enclosure. These specific bulbs were also selected due to their extreme ambient temperature capability (-32°C to 52°C). A major advantage of the LED fixtures is their ability to be dimmed at circuit voltage. This means the light output level is controlled by varying the voltage powering the fixture, similar to the way incandescent bulbs are dimmed, which allows for decreased power input when light output is reduced. These lights also reduce levels of infrared light emissions, which increases energy efficiency, since less energy is lost as heat to the surroundings. LEDs also offer the following advantages over other lighting sources: low operating temperatures (28°C to 45°C), quick starting time (0 – 1 seconds), high color rendering index (CRI, minimum of 60), low maintenance, long lifespan (50,000 hours on average), medium color temperature (4000 K), little to no mercury in the lamps, directional output, high efficacy (lm W^{-1}), and high lamp lumen maintenance (90%). For these reasons, LED lights were selected over other conventional lighting methods.

The primary goal of the project was to maintain a minimum illumination of 20 foot-candles throughout the dairy cattle housing area for a 16-hour light period in a non-disruptive manner. Each day, dawn was simulated as light output was slowly increased over a one half hour period. This ensured that the cows were not startled by the sudden change in light stimulus. The lamp output was varied throughout the day based on real-time data from sensors located throughout the barn to allow natural light to contribute the maximum portion of required illumination. A delay factor of 15 minutes was incorporated into the LED adjustment programming, so the LEDs would adjust their output only if the measured light level was below the required level for more than 15 minutes. This ensured that short-term, minute changes in external lighting would not cause frequent changes in the LED system output. Finally, at the end of the day, the lamps were slowly dimmed over a one half hour period until completely off, allowing the cows a chance to bed down for the night. For an effective dark period, any yard, security, or work lamps were shielded to minimize light levels where the animals were kept.

With the long axis of the barn running north-south, the lighting was broken up into three rows also running north-south, with one control bank per row labeled East, Central, and West. Each row was mounted in a manner that minimized shadowing and inhibition of regular activities. The fixtures within each row were set 3.7 m apart (center to center), approximately 3 m off the floor. The rows were staggered to provide more even lighting. Since an extra 10.16 cm of clearance was required for machinery to pass through the east side of the barn, the fixtures in the row were mounted perpendicular to the other rows, with the protective cover lens hanging just below the barn trusses. Rows closest to the east and west sides of the barn were placed approximately 0.3 m closer to the outside edge of the barn to ensure the feed area and free stalls were adequately lighted at night. This positioning of the light fixtures and sensors is shown in Figure 1. A total of 36 LED fixtures were used to light the barn, each rated at 60 W.

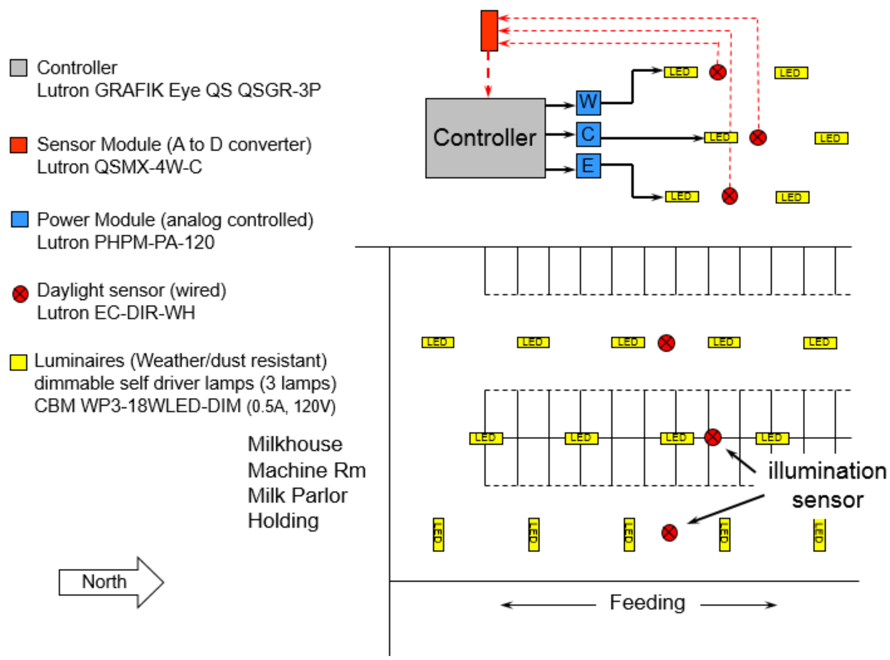

Figure 1 – LED light fixture and controller setup within the barn.

The sensors used were auto-adjusting Lighting Sensor/Processors that provided adjustable controls for greenhouse lighting applications. These photometers did not have specific photon detectors, but rather utilized a variety of detectors and filters affixed for targeting measurements for specific applications, such as illuminance (in lux or foot-candles). In this study, the detection and measurement of light solely within the visible spectrum was emphasized. The silicon detector selected demonstrated a relative spectral responsivity similar to the human eye for the 360 nm to 780 nm band that makes up the visible spectrum. The accuracy and reliability of these sensors were paramount, since if the sensors failed to measure and relay correct light information to the control system, the cycle would be disrupted. Sensors were stationed on the interior and exterior of the barn. The exterior sensors were used to collect data on natural lighting for comparison with the LED-provided lighting, but these were not associated with the control system. Approximate illumination was recorded 2.4 m above floor level to avoid equipment damage by cow traffic or farm machinery, and values were adjusted to estimate illumination at cow eye level when standing (approximately 147.3 cm above floor level), which matched the methods used in previous studies (Dahl, Elasser, Capuco, Erdman, & Peters, 1996). However, based on feedback from the farmer that the cows were spending as much time lying down as standing, measurements were also estimated at cow eye level when lying down (approximately 61 cm above floor level).

Positioning and mounting the light sensors proved to be a crucial aspect of the project. With a surface reflectivity factor of close to zero and no walls near the sensor locations, reliably measuring light levels was challenging. A sensor was positioned for each bank of lights to avoid interference from an adjacent row. The sensors had a cardioid, or wedge-shaped, sensing region, shown in Figure 2, so mounting them facing north prevented direct sunlight from impacting the measurement. During installation, it was observed that a cow with a white back could cover enough of the field of view to skew light readings. To avoid this problem, the sensors were tipped upward approximately 20° to give an increased field of view and measure more of the artificial light contribution. This adjustment is shown in Figure 3. All data collected by the light sensors was sent to a data acquisition (DAQ) system.

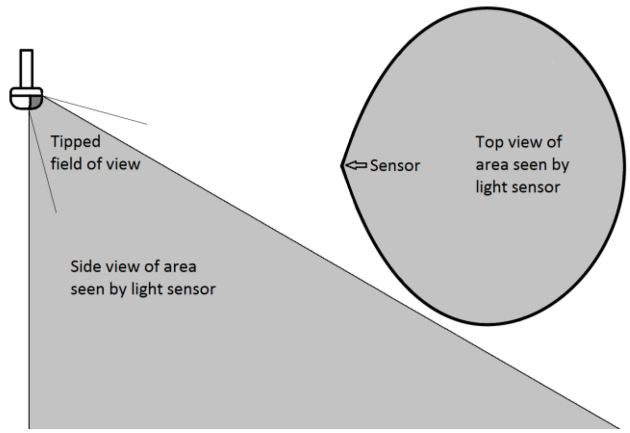

Figure 2 – Side view (left) and top view (right) of the visual area picked up by the light sensors used in this project.

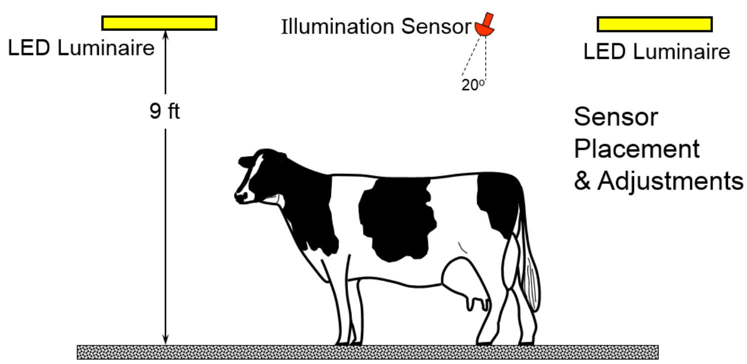

Figure 3 - Sensor setup to mitigate readings affected by the reflection of light off the backs of cows.

At the beginning of the experiment, no control system could be found that would perform the needed tasks for a self-adjusting LDL system that could respond to real-time data from light sensors. To design and implement the lighting regime, three different control systems with custom programming were adapted and installed. The DAQ system was programmed to control the individual operation of each lighting module based on data from the lighting sensors, which would increase or decrease light output to create the desired light level of 20 foot-candles evenly throughout the barn. To create the daily 16-hour photoperiod, the GRAFIK Eye QS controller used a real-time clock with battery backup. It controlled the light output according to the schedule and real-time light level measured by the sensors. The Sensor Input Module converted the analog sensor signals to digital data which was sent over a single communication cable to the controller. A wireless option was available, but, due to the added battery changing maintenance cycle, it is not recommended. The Phase Adaptive Power Modules changed the dimmer power output to be more compatible with LED bulbs. Other types of fixtures may require different power modules or potentially completely different control systems.

When programming the controller, daylight savings time was turned off. This way the simulated sunrise/sunset would not jump ahead and fall back an hour each year, creating an unneeded disturbance to the herd's biological clock. Using the farm's latitude and longitude, solar noon was calculated for the day of summer solstice, once again, according to standard time, not daylight savings time. Eight and a half hours were subtracted from solar noon to set the time to begin the simulated sunrise. Next, eight hours were added to solar noon to set the time to begin the simulated sunset. This provided a full 17 hours of operation with a one half hour period for both sunrise and sunset. This schedule is shown in Figure 4. At the Wing Acres Dairy location, the period could be shifted ±20 minutes without interference from natural sunrise. This is not true in Michigan's upper peninsula, but further south within the state a wider time shift is available.

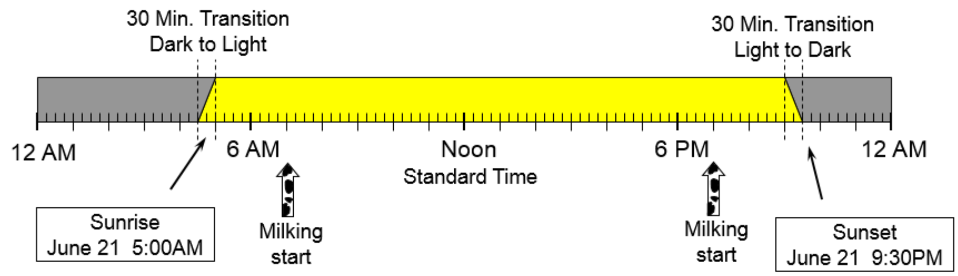

Figure 4 – Daily schedule for light and dark periods for implementing the long-day lighting regime.

To test this LDL system, MMPA members Tom and Heather Wing agreed to participate in the study. The Wing Acres Dairy farm operated in an older barn with side curtains and consisted of approximately 100 Holstein milking cows. The project was set to take place over three years. First, milk production and energy usage data was collected from January to December 2013, which acted as the base year. The LDL system was installed December 1st, 2013, and implemented January 1st, 2014, with the new LED lights replacing the metal halide fixtures originally used in the barn. Additional production and energy data was collected from January to December of 2014 and 2015 with the LDL system fully operational. Throughout the three-year study, a two-a-day milking schedule was followed and there were no changes in feed quality, herd size, or animal husbandry practices.

Results and Discussion

Milk production data was collected in the two years preceding and following the installation of the LED LDL system at Wing Acres Dairy. Though production data was collected for 2012 and 2013, 2013 was selected as the base year for comparing LDL results since it best mirrored the herd size, management strategies and facility adopted during the LDL study period. In the LDL system's first year (2014), milk production increased by 6.74%, or by 67,891 kg (149,674 lbs), compared to 2013. For the second year (2015), milk production increased by 7.69%, or 77,465 kg (170,780 lbs). Averaging the data collected from 2014 and 2015 shows a 7.22% increase in milk production (72,678 kg) compared to 2013.

Figure 5 displays the milk production values over the course of the time-lapse study. It should be noted that the characteristic 'summer production dip' is absent from the production schedule at Wing Acres Dairy. Such a production dip in Michigan dairy farms during the summer months is often due to heat stress on the cows, which can be avoided with well-ventilated barns, like those at Wing Acres. A slight drop in production is consistently observed for February which can be attributed to fewer days in the month. The significant production decrease observed in May, June, and July was a seasonal dip due to the drying out of a portion of the milking herd. This production drop was more prominent and lasted for a longer period in 2013 as compared to 2014 and 2015, when the LDL system was in place. Finally, the most obvious improvement occurred in the winter months of November, December, and January, in which production decreased in the base year, but was maintained during the LDL test period. Based on observations from this study, it should also be noted that after implementation of the LDL system, it may take 2 to 3 months to begin seeing the results of increased production. Any disruption in the LDL treatment can restart this cycle and prevent production increases. This may be the reason other farmers that have implemented less reliable systems have failed to see any results of increased production.

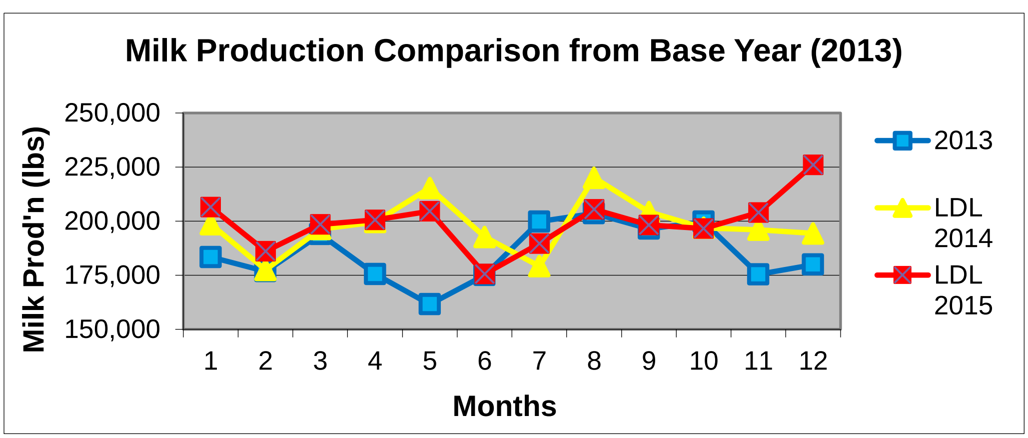

Figure 5 - Milk production data from before (2013) and after (2014, 2015) the LED LDL system was implemented at Wing Acres Dairy. Herd size was kept constant over the span of three years.

Another factor to consider is that, in the state of Michigan, even during peak daylight hours, the minimum recommended illumination levels are frequently not achieved. Supplemental lighting is required to overcome this illumination deficit. This is illustrated by Figure 6 through Figure 8, which depict the energy output of the LEDs in the long-day lighting system compared to a measurement of relative sunlight. As seen in Figure 6, even sunny summer days did not provide sufficient light in the barn for the full photoperiod required for a long-day lighting system, as seen by the LED output necessary before sunrise and just before sunset. This demonstrates the need for additional lighting in Michigan even during summer months. This also shows that a system that simply turns on and off based on sunrise and sunset will not allow for the required photoperiod in Michigan. On cloudy days throughout the year, supplemental lighting is also necessary. At the same time, even cloudy days provide some natural lighting that contributes to the required light level, as seen in Figure 7 and Figure 8. However, the provided natural lighting may be highly variable, as seen especially in Figure 7, and difficult to account for in a manual system. To best utilize natural lighting while maintaining the required light levels, an automated and dimmable LED lighting system that adjusts based on real-time light data is essential. This type of system will save energy compared to systems that cannot be dimmed, such as those that use metal halide fixtures. Though natural light is not always adequate to reduce melatonin levels and create a consistent lighting regime, an automated LED lighting system controlled by real-time light data can effectively generate increases in dairy production, as shown by the results of this study.

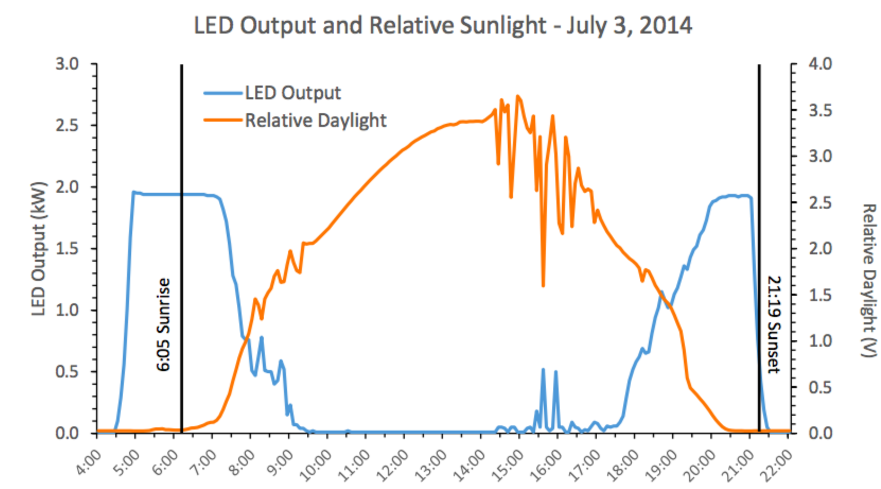

Figure 6 - LED output with side wall curtains up compared to measurements of relative sunlight during a typical summer day.

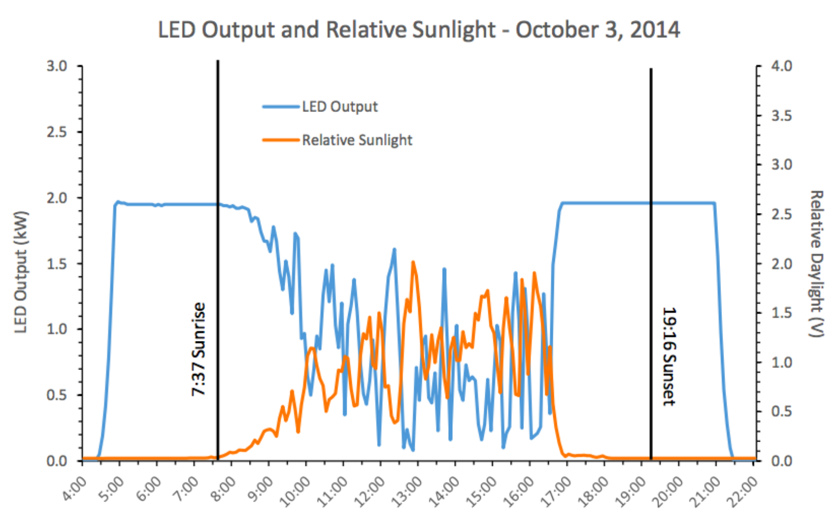

Figure 7 - LED output with side wall curtains up compared to measurements of relative sunlight during a typical fall day.

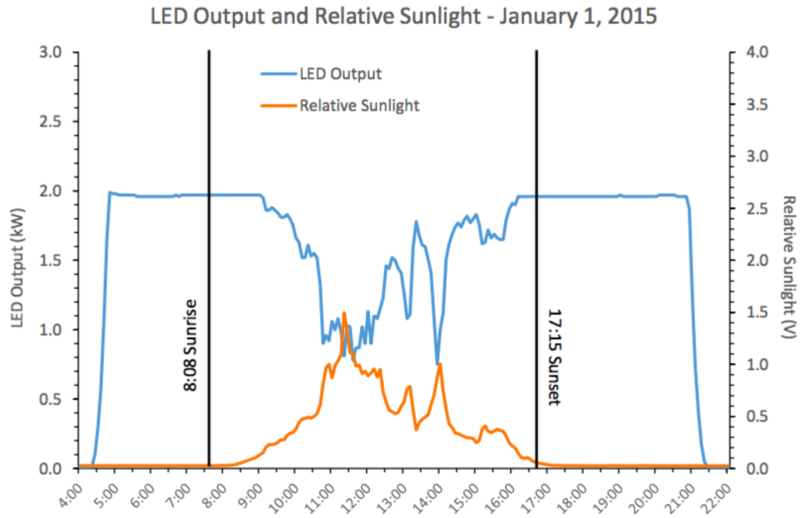

Figure 8 - LED output with side wall curtains up compared to measurements of relative sunlight during a typical winter day.

In addition to the increases in production, farmer Tom Wing provided additional observations of the behavior of the cows after the LDL system was implemented compared to the base year. Milking herds exposed to LDL:

- Spent more time lying down and resting
- Exhibited calmer behavior and less startling
- Exhibited reduced crowding behaviors, resulting in cleaner cows and reduced injuries
- Demonstrated reduced occurrences of "bullying," or instances in which larger cows prevented smaller cows from eating or drinking
- Demonstrated a decreased infestation of ticks

Most of these behaviors were due to the herd spreading out throughout the barn after adequate lighting significantly reduced dark areas typically avoided by cows. While these are anecdotal and qualitative measures of success, these observations were crucial in the farmer's assessment of the effectiveness of the LDL system.

Due to the high efficiency and dimmable nature of the LED fixtures used in this study, there was not a substantial increase in annual energy costs after implementation of the LDL system. The recorded energy usage of the LDL system is displayed in Table 2. Using LED fixtures in place of traditional metal halide fixtures to implement an LDL system resulted in an energy savings of 29,188 kWh each year, and a reduced cost of over $3,700 each year, assuming $0.13/kWh. This is due to the reduced efficiency of metal halide lights, and the fact that these fixtures cannot be dimmed when additional light is naturally provided by the sun or other external sources. Based on installation and bulb replacement costs, implementing LED lights saves $800 in capital costs and $227 in annual costs to replace bulbs. Due to the increased lifetime and energy efficiency of LED lights, it is clear that implementing LED fixtures within an LDL system is more economically efficient due to reduced energy and bulb replacement costs.

Table 2 - Energy used each month the LDL system was implemented

Month	Energy Usage 2014 (kWh)	Energy Usage 2015 (kWh)
January	650	671
February	497	478
March	493	480
April	381	436
May	335	430
June	340	399
July	327	388
August	414	477
September	442	522
October	660	716
November	724	716
December	786	876

Based only on milk production increases, the payback period was calculated to be approximately 1.2 years. However, milk prices were historically high at the start of project implementation in 2014, so payback periods in other applications may be longer. Implementing LED lighting appropriate for farm use based only on increasing energy efficiency does not yet provide a desirable investment payback under normal, non-LDL systems due to the higher costs of upgraded LEDs. The energy savings combined with increased milk production through a well-managed LDL system make the purchase of commercial-grade LED fixtures, sensors, and control systems affordable.

For future implementation of an automatic LED lighting system that responds to real-time data collected by light sensors, a few factors must be taken into consideration. First, the line-level dimming system used in this project is less efficient than recently available solutions, and thus these new dimming systems should be utilized in future applications of LDL. In addition, the Lutron controller was initially susceptible to error if a power outage occurred during the sunrise or sunset period. The controller would remain at the light level designated before the outage, and thus would not adjust the lighting up or down until the next scheduled change. This could result in a long period of time in which the lights did not reach the required level of brightness or dimness. Thus, if a power outage occurs during either the sunrise or sunset periods, the system should be observed and the controller adjusted if this error occurs. Finally, the system implemented for this project could not adjust to minute changes (within 3 – 5 foot-candles) and thus was not as precise as desired. However, newer systems are available that offer the preferred level of precision. Still, it is recommended that the target light level be set for 20 foot-candles to allow room for error and light output depreciation over the life of the bulb. When using a lighting design program for determining the lamp spacing, the surface reflectivity values should be set to zero, unless the ceiling and walls are covered with white tin and cleaned periodically. Mounting fixtures as low as reasonably possible will also reduce light loss and shadowing. If these changes are implemented, an effective LDL system that increases milk production and energy efficiency can be achieved.

Conclusions and Implications

The results of this demonstration have verified that implementing a long-day lighting (LDL) system within a standard dairy farm application can increase milk production by 5% to 9% as shown in literature. In this study conducted on a Michigan dairy farm, milk production over a two-year trial of the LDL system increased 7.22% (72,678 kg) compared to the base year before implementation. Based on observations, the cows also appeared calmer, cleaner, and less aggressive towards each other. Farmer Tom Wing was so impressed by the production increases and positive behavioral changes that he is considering future implementation of the LDL system for his heifers and dry cows.

However, these positive impacts can only be achieved by implementing a consistent, automated lighting system that controls light output based on real-time light data. It is likely that farmers that have attempted to utilize this technology in the past have failed because manual systems are too inconsistent. Outdated or improperly-designed systems may have prevented the adequate replication of required lighting regimes, or the start-up lag in production increases and subsequent disruptions prevented farmers from seeing returns.

Based on the results of this study and literature review, it is crucial that an automated control system be implemented to regulate the light output of the LED fixtures based on real-time light data collected at the eye level of cattle both standing up and lying down. It is the automation and real-time adjustment capacity of this system that allow for a consistent long-day lighting treatment that can increase milk production in dairy cows, while increasing energy efficiency. The use of commercial grade (dust-tight, water-tight, and impact resistant) LED fixtures, with operating temperatures between -32°C and 52°C, is also strongly recommended for implementing an LDL system. This is due to their high efficiency, long lifetimes, and truly dimmable light output, which requires reduced power input for decreased light output. Implementing an LDL system such as this will result in minimal changes to annual energy costs, and a payback period of approximately 1.2 years, though this value will be impacted by milk prices year-to-year.

Funding is available for the evaluation and installation of production-enhancing and energy efficient systems such as this. Utility company rebates and USDA REAP and EQIP programs list LED lighting as an approved energy conservation practice. Additional sources of funding include:

- USDA-NRCS
- USDA-REAP
- DOE/State Energy Agencies
- University Programs/Extension
- Utility Companies and Electric Coops
- State Agencies

Completing a Type 2 ASABE/ANSI S612 energy audit is the first step in securing funding to implement LED lighting. Information on energy audits and funding opportunities can be obtained at energy conservation meetings held throughout the state in January.

Questions concerning the Wing Acres Dairy LED long-day lighting system project, LED lighting, and energy audits can be directed to Al Go at goaluel@egr.msu.edu or 517-214-6128. Questions concerning the energy conservation program and energy audits can be directed to Charles Gould at gouldm@msu.edu or 616-994-4547.

Designing and implementing a successful LDL system to improve milk production and energy efficiency is possible under Michigan conditions for typical dairy operations if an accurate and reliable automated control system can be implemented.

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