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C&I CASE STUDIES IN BENEFICIAL ELECTRIFICATION

Rock Crushing Equipment

Coles-Moultrie Electric and Charleston Stone

BY PATRICK KEEGAN, COLLABORATIVE EFFICIENCY, OCTOBER 2017

SUBJECT MATTER EXPERT FOR QUESTIONS ON THIS TOPIC

Keith Dennis, NRECA Assoc. Director, Strategic Initiatives: *keith.dennis@nreca.coop*

Robbin Christianson, NRECA Sr. Manager, Engagement & Strategy: *robbin.christianson@nreca.coop*

INTRODUCTION

The wise use of electricity, *Beneficial Electrification*, has sparked widespread re-thinking of policies that encourage or mandate less electricity use and promote infrastructure planning. Advancements in electric technologies continue to create new opportunities to use electricity as a substitute for on-site fossil fuels like natural gas, propane, gasoline and fuel oil, with increased efficiency and control. It also offers local economic development and enhances the quality of the product used by the customer.

Electrifying industrial and commercial processes is a proven method to help local businesses stay competitive. Beneficial electrification strengthens the cooperative presence in the community and offers benefits to the electric system, such as environmental performance. Cooperatives working with C&I customers to assess need is a good place to start. To provide examples of various approaches to working with C&I customers on beneficial electrification initiatives, NRECA is developing a series of case studies.

This case study focuses on a cooperative in Illinois and its quarry system member. Electrification of the quarry system reduced the member's costs, enhanced productivity and reliability, and improved its product to open new market opportunities.

MEMBER PROFILE

Coles-Moultrie Electric (CMEC) serves about 9,500 members spread across eight counties in Southeast Illinois. The service territory is rural, with a few small cities (e.g., Charleston and Mattoon).

More than 8,000 of CMEC's meters are residential, but significant load is spread across 850 small commercial members — as well as a few large commercial members, industrial members, and educational facilities.[1] About 60 percent of CMEC's electric sales are residential; the remaining 40 percent is spread across commercial, institutional, industrial, and agricultural sectors.[2]

FIGURE 1: CMEC Service Territory

Overall load growth has been slow in recent years. Between 2010 and 2016, electric sales increased by about 1.4 percent, which is an average annual growth rate of 0.24 percent.[3] Inflation averaged 1.6 percent over this same time period. When electric demand growth does not keep up with increases in costs, utilities are forced to raise rates or cut expenses.

DESCRIPTION OF PROBLEM/OPPORTUNITY

CMEC provides electric service to Charleston Stone, a quarry that produces a variety of stone, gravel, and aggregate products. The quarry has depended upon a diesel-fired "primary rock crusher" that is aging and becoming less reliable. Charleston Stone was aware of the advantages of electric rock crushers and inquired with CMEC about a change in electric service. The co-op was receptive to this discussion, because they saw the possibility to serve their member and benefit the community, while increasing their electric sales.

The stone and aggregate industry is critical to the economy because it produces the materials "found in every home, building, road, bridge and public works project".[4] It is an especially important industry to electric co-ops. Products extracted from quarries are heavy and shipping costs are high, so quarries tend to be located near the customer. The State of Illinois has 188 quarries, more than three-quarters of them in rural areas.[5]

FIGURE 2: Entry Road in Early Days

Electric rock crushers require less maintenance and less down time.

Charleston Stone employs 20 people and is an important part of the local economy.[6] The industry requires highly skilled workers to operate heavy equipment that extracts and processes stone into a variety of products. Compensation and benefit levels are attractive, and job retention is high. Many of the employees have worked at Charleston Stone for more than 20 years.

The Tarble family has been in the quarry business in Illinois since the mid-1930s. Charleston Stone Company was formed in 1958 by Van Tarble, who is the grandfather of the current owners. The original plant was on the West side of the Embarras River near Charleston, Illinois. The company expanded in 1963, by purchasing the quarry directly across the river. The two quarries were operated independently until 1999 when a new plant was built.[7]

For Charleston Stone, the primary rationale for the project was improvements in production, not energy savings.

John Tarble, co-owner of Charleston Stone, says the core process in this business has not changed since his grandfather's time, "we crush big rocks into smaller rocks."[8] Mined materials are conveyed into a series of crushers. The rock crushing process begins with a primary crusher that breaks down large, two to three feet diameter rock into rocks six to eight inches in diameter. A secondary crusher can then break it up into pieces about one-quarter as large. Charleston Stone also has tertiary crushers that turn smaller rock into gravel, sand, or lime. This rock crushing process enables the company to offer consumers a wide variety of aggregate products, from agricultural lime to the largest of landscaping boulders.

Charleston Stone utilizes both quarries. They mine one side of the river at a time and use a mobile primary crusher that they can move back and forth as needed. When they are mining on the West side of the river, the rock coming out of the primary crusher is conveyed to the East side, where the remainder of the crushing and screening takes place.

FIGURE 3: Van Tarble Founded the Charleston Stone in 1958

Charleston Stone's primary crusher was installed in 1999 and had become less reliable. In addition to needing frequent repairs, it also limited the kind of products Charleston Stone was able to produce. Because it was diesel fired, it was expensive to operate when diesel prices were high. The 18-year-old crusher needed to be replaced.

Management at Charleston Stone is familiar with electric rock crushing, because several of the company's secondary and tertiary crushers are electric. The Tarble family owns another rock crushing operation elsewhere in Illinois that was converted to electricity many years ago. This experience demonstrated that electric rock crushers required less maintenance and less down time. The Tarbles estimated the cost to replace their primary crusher at $1.2 million, which is a larger expense than they incurred in 1999 when the entire plant was replaced. This was a major investment for the company.

This case study explores the benefits of converting to electric rock crushing. A benefit that is often uppermost in the minds of co-ops and other utilities on industrial projects is the energy savings. The primary rationale for this project is improvements in production, which

makes it similar to many industrial projects. Energy savings was not an important driver and was not analyzed. This case study includes estimates of energy savings, but these estimates are not based on a detailed energy analysis, which typically includes on-site testing and measurement.

Many quarries still have diesel engines because it can be easier to start up a new quarry with diesel.

DESCRIPTION OF THE TECHNOLOGY APPLICATION

John Hutchins, the CEO of Aggregate Processing, which supplied the new primary crusher to Charleston Stone, says that quarry operators prefer electric motors to diesel for a number of reasons, including operating cost. Even so, there are many diesel engines in use in the quarries John supplies, so Charleston Stone's use of a diesel powered crusher is not unusual. Hutchins says that many quarries still have diesel engines because it can be easier to start up a new quarry with diesel.

Comparing the cost of operating a diesel crusher and an electric crusher can begin by looking at the price for each fuel and the efficiency of each motor. The amount of electricity needed to provide the equivalent amount of energy as a gallon of diesel depends on the efficiency of the motors. The old diesel engine likely operated at 35 to 45 percent efficiency. The new electric crusher motor is 95 percent efficient. Figure 4 shows how much less the cost of an equivalent amount of electricity would cost than the price of a gallon of diesel. It only costs $1.04 for the electricity needed to run a 95 percent efficient electric motor that will provide the same output that a 35 percent efficient diesel engine will produce with a $2.50 gallon of diesel.[9]

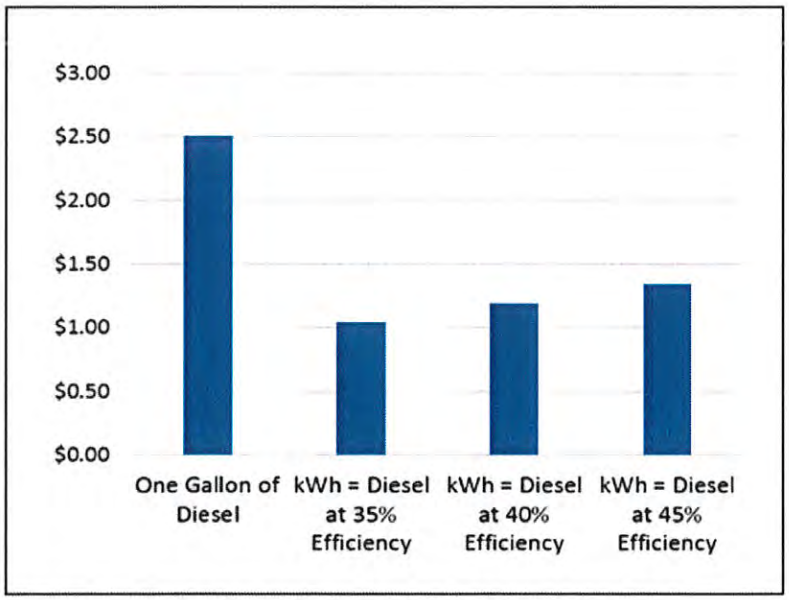

FIGURE 4: Price of kWh's Equivalent to One Gallon of Diesel

An important factor is not addressed on this graph. The price of the electricity does not include demand charges. Some co-ops do not charge for demand, others do, and this can have a dramatic effect on this comparison.

Charleston Stone's aging portable diesel-fired crusher was powered by a 300 to 350 HP diesel engine. This engine also powered a 100 KW generator which, in turn, powered several smaller electric motors on the crushing station.[10]

The replacement crushing station was designed, fabricated, and installed by Aggregate Processing.[11] (See **Figure 5**.) It can process 400 to 500 tons per hour of material. The station is made up of a number of components:

- Portable Chassis Mainframe Assembly
- Collection Transfer Conveyor with 40 HP Drive Motor
- 300,000 Pound Hydraulic Leveling Package Kit with 20 HP Drive Motor
- 100,000 Pound Quad Axle Running Gear Package.
- Hazemag 1515 HD Horizontal Impact Crusher with 400 HP Drive Motor
- Deister 5220 Vibrating Grizzly Feeder with 60 HP Drive Motor

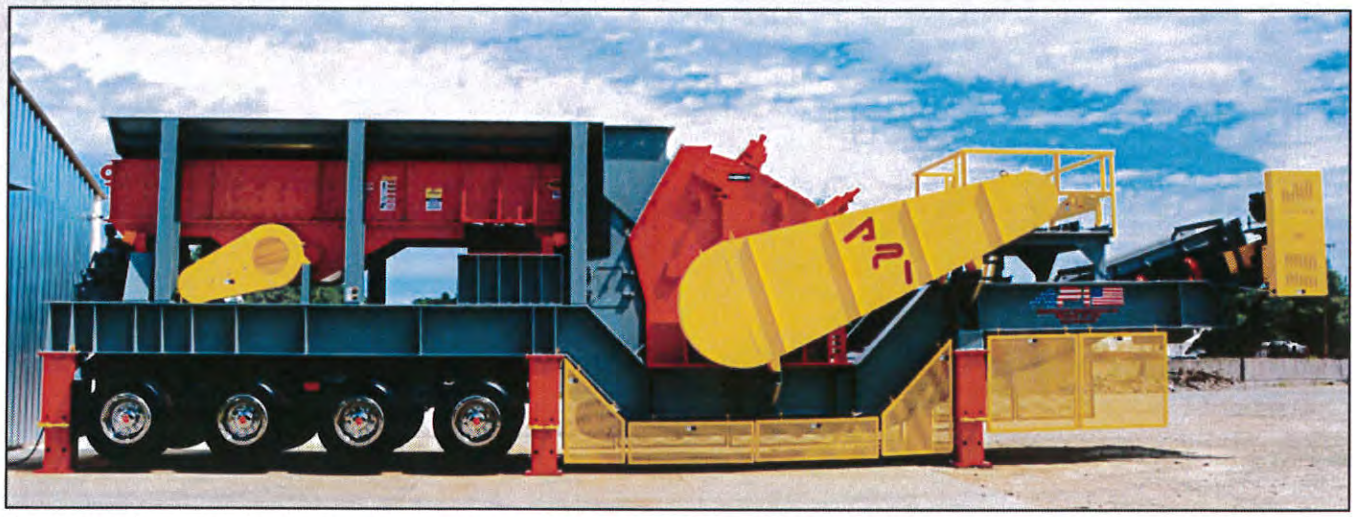

FIGURE 5: Primary Crusher Station. Hazemag Horizontal Impact Crusher on a Chassis. (Courtesy, Aggregate Processing, Inc.)

The company was experiencing 80 to 120 hours of downtime annually with their diesel primary crusher.

The crusher station is mobile. To move it, power is disconnected at the pole and the connecting wire and plugs travel on the trailer to the new location (see Figure 6). The transformer is even mobile. Charleston Stone purchased and installed the transformer on the trailer, which they expect will help reduce demand charges.[12]

HOW DOES THE COMMERCIAL/INDUSTRIAL CUSTOMER BENEFIT?

The primary benefits to Charleston Stone are reductions in maintenance costs and down time. Diesel engines require overhauls and servicing of costly engine parts, such as the clutch, radiator, and generators. The primary crusher at Charleston Stone was a jaw-type crusher, which experiences a lot of wear. The frame was installed in 1999, and was requiring a lot of attention and welding repairs. The new electric primary crusher crushes the rock through impact, by throwing the rocks against a large plate in the machine. Impact crushers run more smoothly, and therefore, it is anticipated less maintenance of the crusher frame will be required.

Electric motors perform better in cold weather than diesel engines, which results in greater productivity on cold winter days. According to owner John Tarble, the reduction in downtime is expected to be the most beneficial outcome to result from the conversion.[13] Mike Vaughn, who manages the operation at the quarry, estimates the cost to Charleston Stone is "$2,000 to $3,000 per hour in maintenance performed, wages, and lost productivity" when the primary crusher is down.[14] The company was experiencing 80 to 120 hours of downtime annually, so eliminating this could save $160,000 to $360,000 each year.

FIGURE 6: Mike Vaughn of Charleston Stone Shows Electrical Connections to Sam Adair of CMEC

At today's diesel price, which is slightly higher than $2.50/gallon, Charleston Stone could see energy savings of almost $5,000 per year.

Product quality is critical for all manufacturing processes and was an important factor in the decision to convert to an electric rock crusher. The impact crusher is very effective at separating the shale from the limestone in the rock. The screening process is then able to collect more of the high quality limestone out of the raw material.

Diesel prices have been relatively low in the last few years, but quite volatile over the last decade. Figure 7 shows retail diesel prices (including road tax) over the last decade.[15] Charleston Stone does not have to pay road tax for the diesel used in the crusher, but would still experience the same volatility. John Tarble recalls diesel prices as low as $1.50/gallon and as high as $3.75/gallon. Electricity prices, however, tend to be relatively stable. Converting from diesel to electricity provides Charleston Stone a more stable expense ledger, which enables them to plan and invest with less risk.

FIGURE 7: Diesel Price Volatility

A comparison of energy costs for the diesel crusher to the new electric crusher must consider a range of possible diesel prices. The new electric crusher had just been installed in August of 2017, as this case study was being written, and was beginning to operate at full capacity before mid-month — which may be enough time to begin seeing the long term operating cost. Charleston Stone purchases electricity on a "Large Power — Peak Sharing" rate schedule that provides CMEC with the ability to interrupt much of their power in times of peak system demand. This gives them a $.07/kWh rate for energy and an $8.00/kW rate for all demand above a base level that they cannot exceed during periods of curtailment.[16]

Basing a projection on the first month of operation of the new crusher injects considerable uncertainty. Presumably, Charleston Stone will learn to operate the crusher more efficiently as time goes on, so the projection of energy savings shown in **Figure 8** is probably conservative. Demand charges made up 42 percent of Charleston Stone's electric bill in 2016.[17] CMEC has offered to assist the quarry in managing demand by providing real-time access to meter data, which would show 15-minute interval demand. This would provide the means for Charleston Stone to observe their demand and adjust operations to reduce demand charges. The co-op is offering to pay about half the cost of setting up this capability. Charleston Stone has not taken CMEC up on the offer yet, but may do so once all the changes to the crushing operation have been made.

The projected annual energy cost for the new electric rock crusher is expected to be higher than diesel when diesel is at historically low prices, and much lower than diesel when it is at historically high prices (see **Figure 8**). At today's diesel price, which is slightly higher than $2.50/gallon, Charleston Stone could see energy savings of almost $5,000 per year.

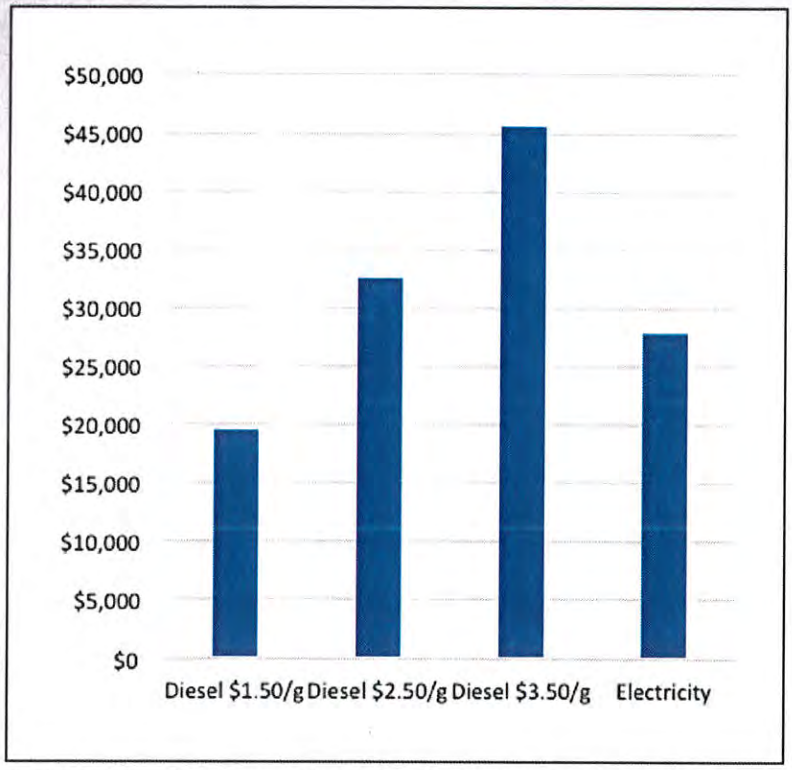

FIGURE 8: Diesel Crusher vs Electric Crucher Energy Cost/Year at Different Prices per Gallon

Any reduction in energy costs will be welcome, of course, but it is clear that the change in energy costs is just a fraction of the financial benefits Charleston Stone should realize from increased productivity and product quality. The company expects that the net result of more stable operating costs, increased productivity, and reduced downtime will make them more competitive. The company should be able to retain the existing workforce and even add up to five new employees as they expand production over the next three years.[18]

TABLE 1: Charleston Stone Electric Crusher Upgrade

	Actual Pre-Upgrade	Estimated Post-Upgrade
Annual energy (kWh)	615,000	808,000
Demand (KW)	524	673
Annual electric bill ($)	$113,000	$141,000

HOW DOES THE COOPERATIVE BENEFIT?

There are several potential benefits to CMEC:

Improved Member Relations

CMEC began investing more time into their relationship with Charleston Stone a few years ago as part of a Key Accounts initiative. The relationship became much stronger after working together on this project. CMEC "has been really good to work with," according to Charleston Stone co-owner John Tarble. He believes that working with co-ops is a lot easier because they are smaller and more responsive. "Coles-Moultrie," he says, "can help us out on a few minutes' notice."

Positive Local Economic Impact

Concern for community is one of the seven cooperative principles, and electric co-ops demonstrate that concern by participating in economic development efforts. Rural areas usually lack large employers. Charleston Stone's 20 employees are an important part of the local economy. CMEC's assistance on this project has helped Charleston Stone become more competitive, which strengthens the company's ability to retain its 20 local employees and supports the company's plan to hire five more employees over the next three years.

A local quarry is an economic asset for a community. If Charleston Stone did not exist, local construction projects would be more expensive, because the high cost of transporting stone and aggregate would need to be covered. Farmers in the area benefit from the lime that they use to reduce the acidity in their fields, which enhances productivity.

Increased Electric Sales

Based on the preliminary estimate of the electric usage for the new crusher, electric sales to Charleston Stone could increase by about $28,000/year, an increase of almost 25 percent (see Table 1).

CMEC was eligible to apply for zero interest financing from USDA's Rural Economic Development Loans & Grants Program.

WHAT ARE THE EXPECTED REDUCTIONS IN FOSSIL FUEL USE AND COST?

The diesel crusher burned about 13,000 gallons of diesel fuel each year. Diesel prices have been volatile over the years. Charleston Stone has paid $1.50 to $3.75 per gallon, so they will save about $20,000 to $48,000 in diesel purchases.

In order for an electrification project to be truly beneficial, it should have positive environmental impacts. An important environmental metric is carbon emissions. Switching to an electric crusher will reduce CO_2 emissions from diesel, but increase emissions associated with electric generation. The mix of electric generation resources in a region determines the level of CO_2 emitted for each MWh of electric consumption.

This conversion project should reduce CO_2 emissions slightly, even though the Illinois/Ohio region has higher levels of CO_2 emissions per MWh than the national average. Figure 9 shows what the CO_2 impact of this project would have been if it had been undertaken in different regions in the country. In many regions around the country where there is less coal generation, this project would have reduced CO_2 emissions to a much greater degree.

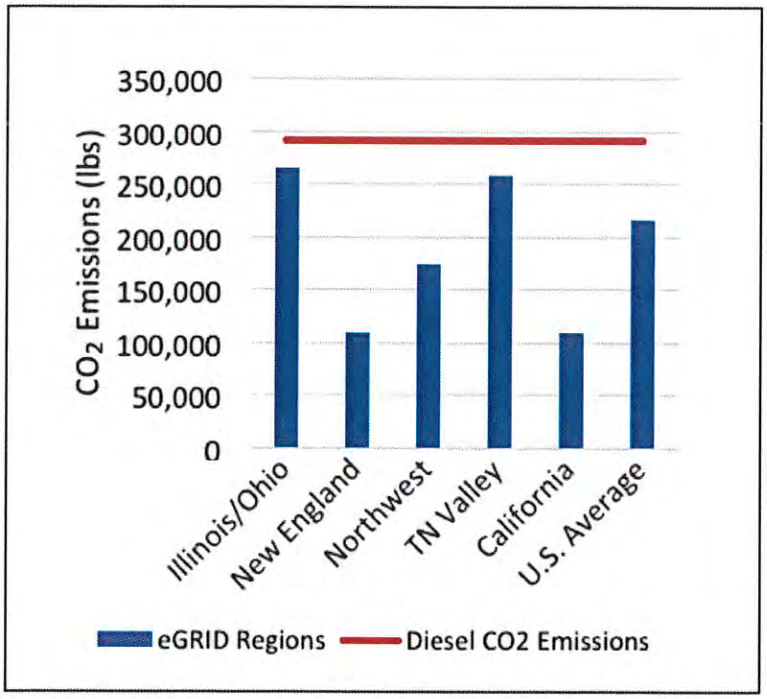

FIGURE 9: CO_2 Emissions/MWH from Crusher Conversion if it were in Different Regions

The data from EPA that was used to determine CO_2 emissions per MWh is from 2014. Since then, notes Kim Leftwich, General Manager of CMEC, Illinois has seen 4,000 to 5,000 MWs of coal generation shut down, which should substantially reduce carbon intensity.[19] CO_2 emissions from electric generation are projected to decline an additional 20 percent over the next five years. When 2017 CO_2 emissions data becomes available, it may very well show this project having greater CO_2 emission reductions. If projections of continued reductions in CO_2 emissions per MWH hold true for CMEC, this project could produce an even more substantial reduction in CO_2 emissions.

WHAT CHALLENGES DID THE CONVERSION POSE?

Charleston Stone is a large, sprawling complex and the Tarbles own another quarry elsewhere in Illinois, but putting up the money for a million-dollar plus investment was a challenge. As an electric cooperative, CMEC was eligible to apply for zero interest financing from USDA's Rural Economic Development Loans & Grants Program (REDLG).

Changing out the machinery that lies at the heart of an industrial process is a risky enterprise. Many things could go wrong that would delay the completion of the project, and delays mean lost production and lost income. Charleston Stone found a supplier that could install the new crusher, but still ran into delays in getting the new crusher operating at maximum efficiency. CMEC turned in a stellar performance on their part of the project, according to Charleston Stone, obtaining the REDLG

financing and installing the new electric service. Charleston Stone was effusive in their praise for CMEC's performance.

HOW DID THE CO-OP MAKE THE SALE?

The idea of converting the primary crusher to electricity came from Charleston Stone. The Tarbles were well aware of the advantages of electric crushers. When Charleston Stone approached CMEC with the idea, the discussions went well, largely because CMEC had been investing time into developing a good relationship.

The conversion project went well in large part because CMEC had been investing time into developing a good relationship with Charleston Stone.

In years past, CMEC had devoted almost all of its member relations resource into the residential sector. The co-op made some efforts to reach out to the larger accounts, delivering calendars and inviting commercial and industrial members to the annual meeting, but did not have a Key Accounts program even though 40 percent of the load was C&I. CMEC had eight member service representatives to focus on residential, but no one on key accounts.

FIGURE 10: Primary Metering Pole Feed to Switch Cabinet

When Kim Leftwich was hired to be the new General Manager in 2015, CMEC initiated a Key Accounts program and became better acquainted with Charleston Stone. Sam Adair, CMEC's Manager of Member Services, made personal visits to the quarry. So, when Charleston Stone approached CMEC to talk about the electric service they would need for their new crusher, the discussion was built on an established relationship.

CMEC worked with Charleston Stone to figure out how it could be most helpful to the conversion project. The co-op then developed a plan for expanded electric service and determined that it would be advantageous for Charleston Stone to purchase the new transformer and install it on the mobile crusher station. CMEC ran an upgraded, 7,200 Volt line to a primary metering pole on each side of the river. A switch cabinet was installed at the base of the pole (see Figure 10).

CMEC decided to pursue a REDLG loan that, if successful, could provide $400,000 in interest free financing to Charleston Stone. REDLG is a competitive program from the Rural Utility Service of the U.S. Department of Agriculture. CMEC has had success with REDLG before, thanks to assistance from its G&T, Prairie Power. Prairie Power had a staff person for many years that assisted distribution co-ops in preparing and submitting REDLG program applications.[20] This staff person had left Prairie Power, but CMEC hired him on contract. CMEC guaranteed repayment to RUS, which was an important factor in the REDLG application being successful.

John Tarble was pleased, commenting that "the REDLG loan was a big help!" The $400,000 zero

interest loan made the project more feasible. John noted that he didn't even know what REDLG was, and that the co-op brought the idea to him.

WERE THERE LESSONS LEARNED?

This project provides a number of lessons from which co-ops could benefit:

It's About Production

Energy use and energy costs are important, and it is human nature for any of us working in or with electric utilities to see projects in terms of energy use. But, an industrial plant exists to produce a product, and anything that diminishes or enhances production is likely to be of paramount importance. Charleston Stone was motivated to convert to an electric crusher primarily because it would increase production by reducing downtime. Co-ops should try to understand the key factors influencing production in their industrial members' facilities.

Co-ops should try to understand the key factors influencing production in their industrial members' facilities.

Know Your Key Accounts

CMEC launched a Key Accounts program and invested time in developing their relationship with Charleston Stone. This created a great atmosphere for dialog, which enabled CMEC and Charleston Stone to work well together during project planning and implementation. A Key Accounts program is critical in the industrial sector, because even a large utility is unlikely to have staff with expertise in each industrial process or technology. It is not practical for a utility to hire this kind of expertise, so it is important to be able to communicate and build relationships that will enable good collaboration.

Conducting an Energy Analysis Adds Value

Charleston Stone decided to proceed with this project because the electric crusher would reduce downtime and increase productivity. Energy savings were not a high priority and an energy analysis was not needed to justify the investment. An energy analysis would have identified other measures that likely would have increased the value of the project to Charleston Stone and perhaps to CMEC.

Be the Star Performer

CMEC impressed Charleston Stone with their delivery on the financing and on the electric service. Member satisfaction, which was already good, is now even better.

WHAT DO COOPERATIVES NEED TO KNOW ABOUT IT?

A promising area for beneficial electrification is the stone and aggregate business. John Hutchins of Aggregate Processing, a supplier of rock crushing equipment, says quarry owners favor electric motors, but he believes many of the motors in quarries are diesel because it is sometimes easier to get a rock crushing operation set up without having to negotiate for power line extensions and transformers. The potential from this sector is especially promising for co-ops because many quarries are located in rural areas. Student researchers from Eastern Illinois University found that more than three-quarters of the 180 quarries in Illinois were in areas with populations under 25,000.[21]

The most important take-away for co-ops from this project, according to Kim Leftwich, is that "we were able to reduce costs for an industrial member that is an important employer, help them improve their product, and make them more competitive in the marketplace. This should be a role we play." ■

ENDNOTES

1 REDLG] Rural Economic Development Loans & Grants application submitted to the US Department of Agriculture's Rural Utility Service in 2016.

2 [CMEC] **Coles Moultrie 2016 Year-End Financial Report**

3 [EESI] Unpublished report from the Environmental & Energy Study Institute, lead authors from Collaborative Efficiency.

4 [NSSGA] **National Stone, Sand and Gravel Association**.

5 [EIU] Unpublished Eastern Illinois University student research, contributed to this report as part of the new Center for American Rural Energy (CARE) initiative.

6 [REDLG]

7 [REDLG]

8 [Tarble] Personal communication with John Tarble, co-owner of Charleston Stone, August 2, 2017.

9 [EIA] Energy Information Administration, **"Petroleum & Other Liquids" table**. Electric rate from **CMEC website**.

10 [Wallace] Personal communication from James Wallace, CMEC, 6/21/17.

11 [Hutchins] Personal communication with John Hutchins of Aggregate Processing, 7/5/17

12 [Tarble]

13 [Tarble]

14 [Leftwich] Personal communication (email) from Kim Leftwich on 8/14/17.

15 [EIA]

16 [CMEC Tariff] "Schedule LP-PS, Large Power – Peak Sharing," Schedule A-16, **www.cmec.coop**

17 [Charleston Stone] Electric usage data provided by John Tarble of Charleston Stone, August 2017.

18 [REDLG]

19 [Dennis] "Environmentally Beneficial Electrification: The Dawn of 'Emissions Efficiency'" Dennis, Keith; Colburn, Ken; Lazar, Jim. *The Electricity Journal 29* (2016).

20 [Ridenour] Personal communication from Aaron Ridenour, former staff person at Prairie Power who was hired by CMEC to write the REDLG application, June 9, 2017.

21 [Khamisanit] Personal communication on 8/2/17 from Ayaz Khamisani, who was part of the student team from Eastern Illinois University that assisted on this project.

About the Author

Patrick Keegan is the founder of Collaborative Efficiency, an energy services firm specializing in support for all phases of energy efficiency program development at electric cooperatives and municipal utilities. Pat been involved in energy efficiency programs since the 1980s. He has worked on solar energy and demand response. He's the author or co-author of over 20 reports for co-ops about demand side energy technologies and programs. He has often been a speaker at national co-op conferences and has recently focused on electric vehicles, financing and beneficial electrification

Contributors

Coles-Moultrie Electric Cooperative had four staff involved, making multiple trips to the quarry, taking photographs and providing data. CMEC led the formation of the Center for American Rural Energy (CARE), a consortium dedicated to demonstrating and evaluating innovative energy technologies and approaches. CARE is designated as a Center of Excellence for Energy Innovation by the National Rural Electric Cooperative Association (NRECA).

Eastern Illinois University, a founding partner along with CMEC in CARE, provided student research. The student team identified data sources and determined that a large portion of quarries are located in rural areas. The team contributors were: Tajdar Ahmed, Tanmay Pant, and Ayaz Khamisani.

Advanced Energy, a North Carolina based nonprofit with a strong industrial energy efficiency program, provided guidance and advice on energy usage data and on the calculations used to estimate energy savings.

Questions or Comments

- Keith Dennis, NRECA Assoc. Director, Strategic Initiatives: **Keith.Dennis@nreca.coop**
- Robbin Christianson, NRECA Sr. Manager, Engagement & Strategy: **Robbin.Christianson@nreca.coop**
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