



Peak Demand Energy in Agriculture

CASE STUDY: SDEM DAIRY FARM DEMAND ENERGY MONITORING



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Farm Energy Management Report # SDEM-122020

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OSU Office of Outreach and Engagement

As a land-grant university, Ohio State University is dedicated to solving societal challenges through community-engaged partnerships. The OSU Office of Outreach and Engagement funds a wide-range of community engaged programs through a variety of grant activities. This study was conducted with funding support from the OSU Office of Outreach and Engagement Connect and Collaborate Grant Program, Ohio State University Extension, the Ohio Agricultural Research and Development Center, and the OSU College of Engineering.

On Farm Research Collaborations

Special appreciation is expressed to the six farms who cooperated in this study by permitting the energy monitoring of their facilities, and by furnishing information on their farming operations. The names of farms collaborating in the on-farm research have been coded to protect their identity.



SDEM Farm

This case study is presenting data collected from the SDEM farm (Image A and B). The SDEM farm participated in a two-year Ohio State University Extension on-farm research project to measure peak energy demand. SDEM is a family-owned, multi-generational dairy farm in Northeast Ohio that started milking cows in 1924. The 300 dairy cows are housed in one of three free-stall barns and are milked three times per day at 4:00am, 12:00pm, and 8:00pm. The cows at the SDEM farm are well managed and are consistently one of the highest producing herds in the county. The farm also raises corn silage, alfalfa and grass hay, and soybeans. Several conservation practices have been implemented with assistance from the Soil and Water Conservation District (SWCD) and Natural Resources Conservation Service (NRCS) offices.

In total there are 60 fans throughout the three free-stall barns including 48” belt drive fans (41) and 36” direct drive fans (19). The fans are on three separate thermostats in each building, each set at 60 degrees. In addition, sprinklers are set at 72 degrees (low) and 85 degrees (high). When the air temperature reaches 60 degrees Fahrenheit, the fans automatically turn on and often run continuously throughout the summer to provide cooling and comfort to the cows. It is not uncommon for these fans to operate occasionally during other months, but generally not on a continual basis.

Image A: (right) is the original barn which includes the original free stalls, holding pen, and milking parlor.

Image B: (below) is the one of two new free stall barns added to the farm operations.



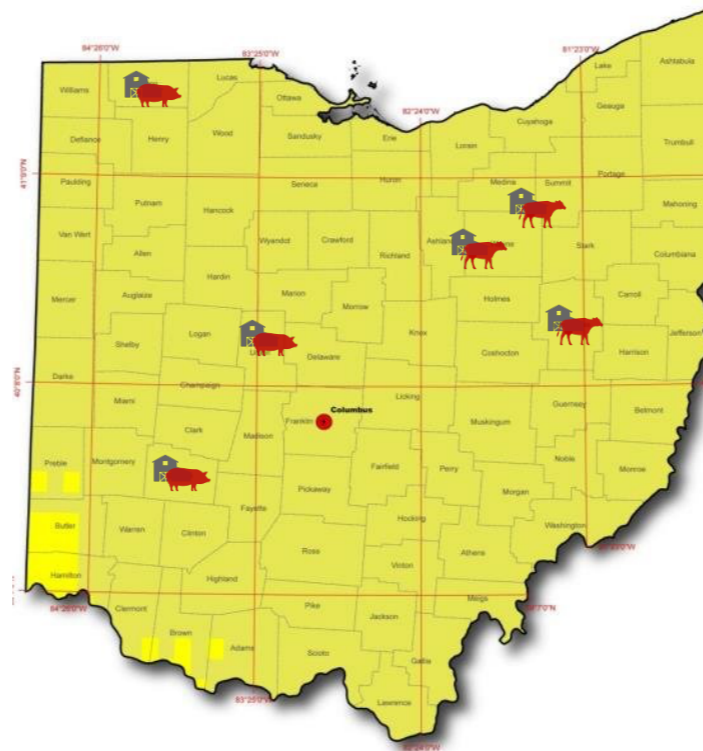
Photos by: Eric Romich, OSU Extension Field Specialist.

Study Design

Background

Unlike residential accounts, which are based only on total energy usage, commercial accounts are charged for total energy usage and the peak amount of power, called demand, used over a short time period. High demand charges can dramatically increase electricity prices for many commercial electrical consumers. On some farms, the demand charges based on 15 minutes of peak usage can account for roughly 50 percent of the farms monthly electricity bill. While demand charges are often significant, few consumers understand the costs, how they are calculated, and how the timing of their electrical usage can impact the electric bill.

As agricultural operations have become more sophisticated and automated, the electrical demands of many farms has increased. In 2014, the agricultural sector consumed 1,714 trillion BTU of energy with electricity representing 17 percent of the total energy consumed. Energy inputs are important to agriculture, as electricity costs average 1-6 percent of total expenses for farm businesses. In 2011 about three-fourths of U.S. farms had a profit margin of less than 10 percent, including roughly 61 percent operating at a negative profit margin. Higher energy expenses increase production costs, raise the prices of agricultural products, and reduce farm income.



Images C: Farm type and approximate location of the energy meter installations.

While this Ohio study included two swine finishing barns, a farrow-to-finish swine barn, a 100-head dairy farm, and two a 300-head dairy farms (Image C), we believe the equipment and technologies evaluated will have applicability in ventilated swine and dairy barns across the United States. For example, according to the 2017 Census of Agriculture, there are more than 66,000 swine farms in the U.S. producing more than 77 million head of swine. The midwest states listed in Table 1 represent an inventory of 45,555,000 head of swine which contributed more than \$14 billion in pork sales¹. In addition, there are approximately 34,187 licensed dairy farms in the U.S. with over 9 million head of dairy cattle. Table 1 provides a list of the states in the midwest representing 18,425 licensed dairy farms accounting for just over one-half (54%) of U.S. milk production².

As result of this study, the economic impact and potential for widespread adoption of new energy management strategies and technologies on swine and dairy farms is significant.

Understanding peak demand charges and energy management strategies in agriculture is a complex issue. As a result, our project partners were strategically selected around four critical disciplines including energy, swine production, dairy production, and electrical engineering. In total, over 29 project partners contributed to the project including Extension professionals, swine and dairy farmers, the OSU College of Food, Agricultural, and Environmental Sciences, the Ohio Agricultural Research and Development Center, and faculty and students in the OSU College of Computer and Electrical Engineering.



¹ Census of Agriculture (2017). United States Summary and State Data. Available at https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf

² USDA NASS (2019). Milk Production Report. Available at: <https://downloads.usda.library.cornell.edu/usda-esmis/files/h989r321c/44558m869/j3860f20k/mkpr0319.pdf>

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Table 1: Potential for Widespread Adoption of Energy Management Strategies on Swine and Dairy Farms

State	Licensed Dairy Farms	Head of Swine
Indiana	965	4,050,000
Illinois	600	5,350,000
Iowa	1,120	22,800,000
Kentucky	540	410,000
Michigan	1,520	1,190,000
Minnesota	2,980	8,500,000
Ohio	2,200	2,950,000
Wisconsin	8,500	305,000
Total	18,425	45,555,000

Project Objective

The purpose of this on-farm research project was to better understand the electrical demand on livestock farms, and identify management strategies and equipment farmers can implement to promote long-term sustainability for their farm. Six Ohio State University owned and/or private farms were enrolled in the project to conduct research to answer questions about energy usage and explore solutions farmers can implement to reduce energy cost.

The overriding objective of the agricultural energy management program was to install advanced energy metering equipment in agricultural facilities to track electric demand profiles and monitor energy use power quality to gain knowledge about energy usage patterns and, in turn, the manner by which farmers can implement energy management strategies to minimize costs and foster long-term sustainability. Specifically, we collected energy usage data for individual operational loads allowing our team to investigate energy use of specific operations and how they contribute to the farms overall peak demand charges. Study results were used to develop Extension outreach materials to disseminate the research findings to agricultural producers and stakeholders throughout Ohio and beyond to encourage the adoption of energy management best-practices.

Equipment Installation

At the SDEM farm, we measured the main electric service feed to the farm as well as seven individual electrical circuits with large electric loads that were critical to the farms day-to-day operations. To meet the research needs of this study, the project team selected the Electro Industries Shark MP200 energy metering system. The MP200 is a multifunction energy meter capable of recording energy usage data for up to eight, three phase circuits or up to 24 single phase circuits.

Image D



Image E



Image D and E: Installing the Shark MP 200 Energy Meter on the backing plate with disconnect fuses and shorting blocks.

Photos by: Eric Romich, OSU Extension Field Specialist.

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Image F



The meter complies with requirements of IE C62053-22 (Class 0.5%) and ANSI C12.20 (Class 0.5%) with accuracy of +/- 0.5% or better for voltage and current, and 0.5% for power and energy functions. While the meter can be configured with a network for real time data, internet was not available at the SDEM farm. As a result, we upgraded the memory to 32 MB of storage providing enough capacity to store up to 6 months of trending historical data-logs before the research team had to conduct a physical data download.

The meter which measures 7.6" (L) x 11.28" (W) x 4.36" (H) was mounted on a backing plate and wired to disconnect fused and shorting blocks (Image D and E) before being installed in a National Electrical Manufacturers Association (NEMA) Type 1 safety enclosure box (Image F).

A combination of solid-core and split-core current transformers (Images G - I) were installed on each of the individual electrical circuits to monitor electrical activity of specific farm operations including:

Image G



Image H



Image I



Images F - I: Preparing the Shark MP 200 Energy Meter for installation by mounting it on a backing plate with disconnect fuses and shorting blocks.

Photos by: Eric Romich, OSU Extension Field Specialist.

- Main Service Feed
- Vacuum Pump Motors
- Feed Mill and Water Pump Motors
- Cooler Compressor Motor (Left)
- Cooler Compressor Motor (Right)
- Lagoon Pump
- Free Stall Barn Sub-Panel
- Main Barn Stir Fans

The complexity of the installation, configuration, and ongoing monitoring of this utility-grade metering equipment required training of our research team. Upon the completion of training, we configured the MP200 to collect data points on 5 minute block windows with a 15 minute rolling demand window. The meter profiles were set to collect readings for voltage, current, frequency, kWh, kW, kVAR, kVA and PF using the configured demand features over the averaging period. An OSU approved electrician was secured to complete the on-site installation at the SDEM farm.



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The total cost for monitoring system including equipment and installation was roughly \$5,000. However, the installation cost for this site was higher than normal due to the multifunction energy meter capabilities to monitor multiple circuits and the additional time required for the OSU approved electricians to travel from Columbus to the SDEM farm.

The equipment utilized for this research study was highly accurate with numerous advanced features contributing to a higher overall installation cost. However, there is a growing variety of more simplified cost effective energy loggers available to interested farmers that can be purchased for between \$60 and \$400. Many of these systems communicate directly with a local network and display real time energy usage statistics to a computer screen or smartphone device.

Timeline

The equipment was installed over two days in February 2018. Following the installation, the research team monitored and calibrated the equipment for several weeks. Data collection for the SDEM farm officially started on April 6, 2018. A software update was completed in December 2018 which allowed the meters to collect demand profile data on 5-minute intervals to calculate a 15-minute rolling demand. The data presented in this case study is a 12 month window from April 2019 to March 2020.



*Image J: Electric Disconnect Box at Farms Main Service Entrance.
Photos by: Eric Romich, OSU Extension Field Specialist.*

Study Results

Electric Use by Operation

In our study we installed current transformers to monitor energy use in six different categories, including: vacuum pump, manure pump, feed and water, ventilation fans, milk cooling, and other. We collected energy usage data on each of the operations over a 12 month period from April 2019 through March 2020.

Over the 12 month period, the SDEM farm used 286,453 kWh of energy for the dairy operations. On average, the farm used 23,871 kWh per month, including the minimum of 10,865 kWh used in November 2019 and a maximum of 46,462 kWh in July 2019. Combined, the ventilation fans used 155,980 kWh or 54% of the total energy use over the 12 month period. As illustrated in Chart 1, during the months between June and September the ventilation fans accounted for over 60% of the total energy consumption, including 69% in both July and August. Milk cooling was the second largest consumer of energy using 41,023 kWh or 14% of the total energy use over the 12 month period.

Unlike the ventilation fans, energy consumption from the vacuum pump and the feed and water operations was very consistent over the 12 month period. The vacuum pump used an average of 1,902 kWh per month, including a minimum of 1,726 kWh used in April 2019 and a maximum of 2,075 kWh in October 2019. The feed and water operations used an average of 2,340 kWh per month, including a minimum of 1,573 kWh in November 2019 and a maximum of 3,527 kWh in July 2019.

Chart 1: Monthly Energy Use (kWh) by Operation

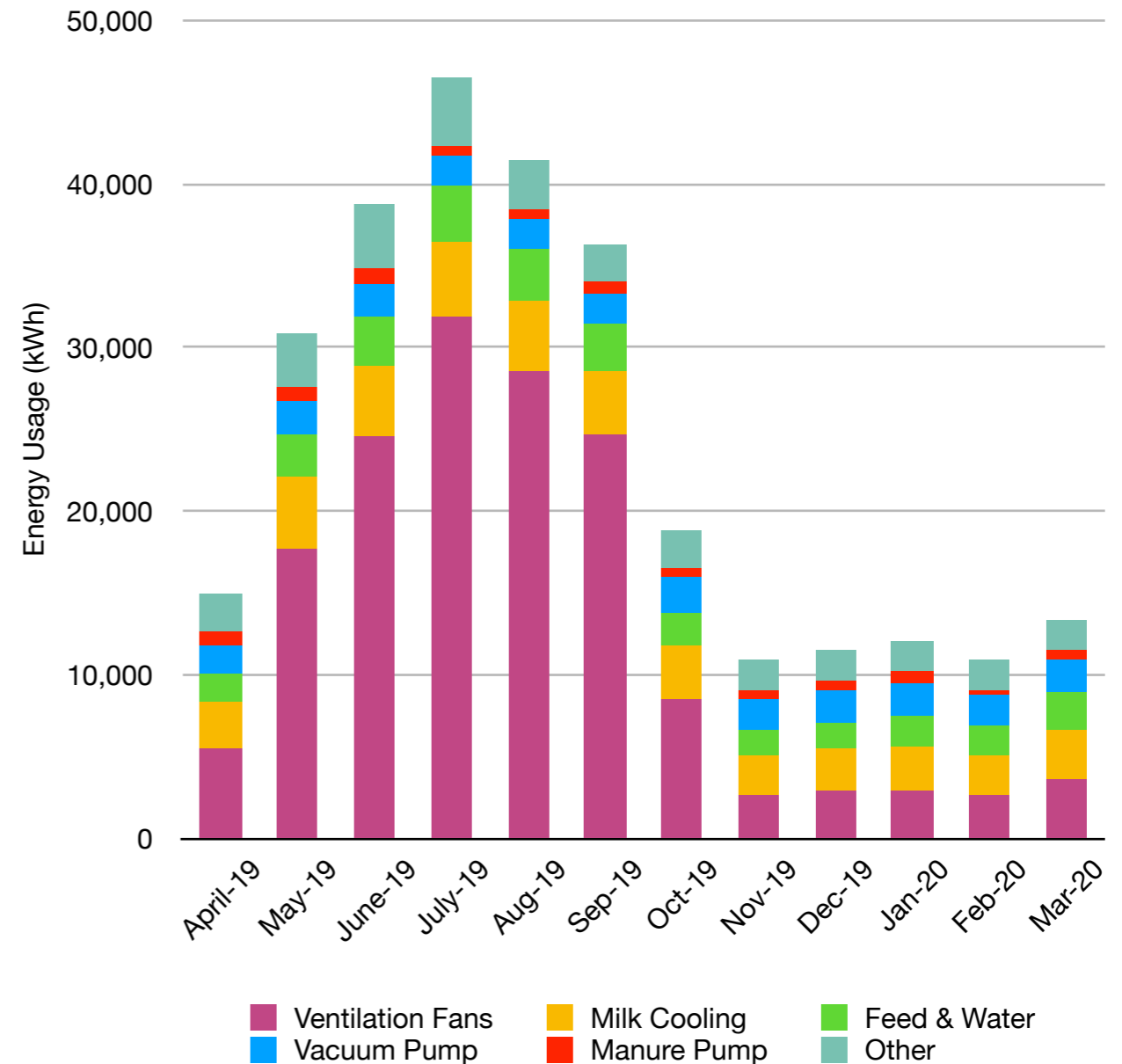
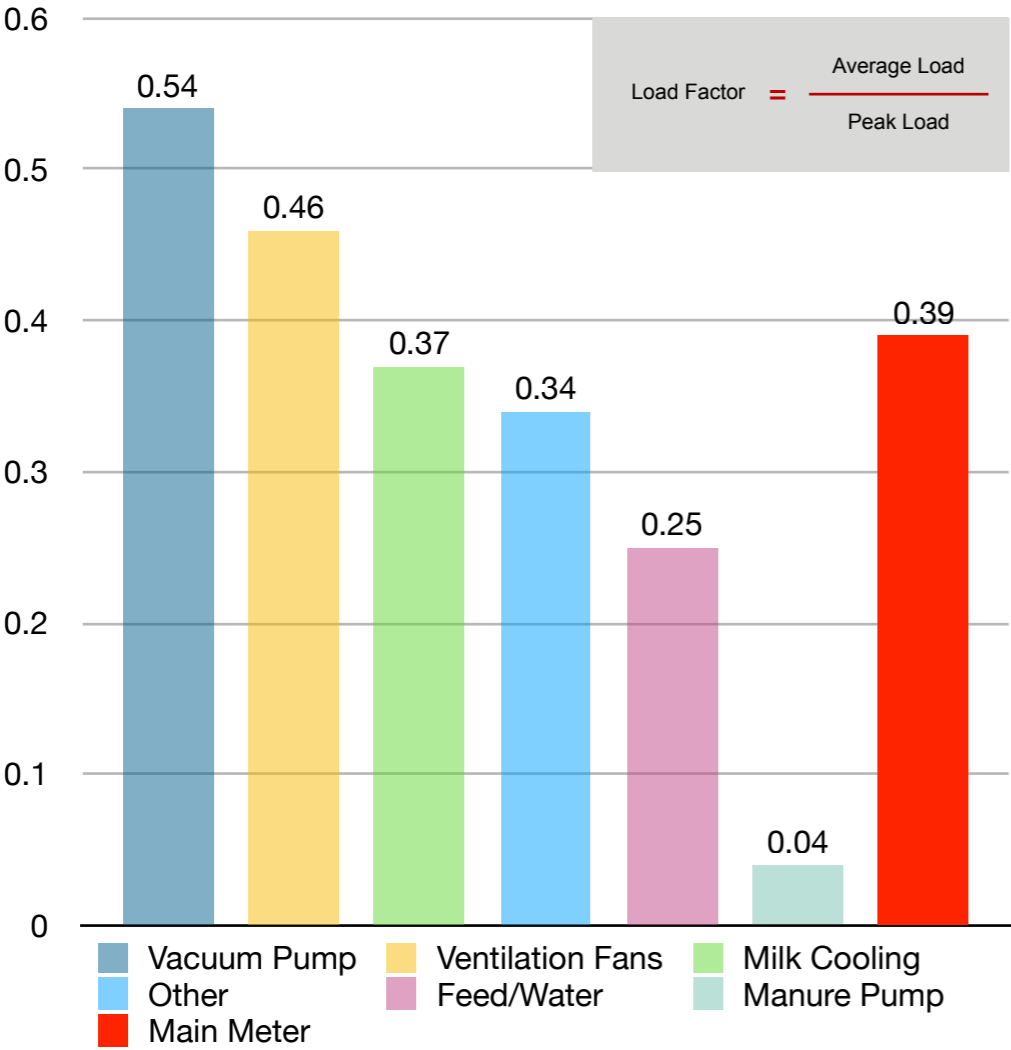


Chart 2: Average Annual Load Factor By Operation



Load Factor

We calculated monthly the load factor on each of the operations monitored over a 12 month period from April 2019 through March 2020. Load factor is a metric used to indicate if a customers electric use over a period of time is reasonably stable, or consistent. Load factor is the ratio of a facility’s average demand, compared to the measured peak demand. A load factor of “one” is perfect and indicates consistent use of electricity over the billing period, while a lower factor suggests greater variation in usage and peak demand spikes.

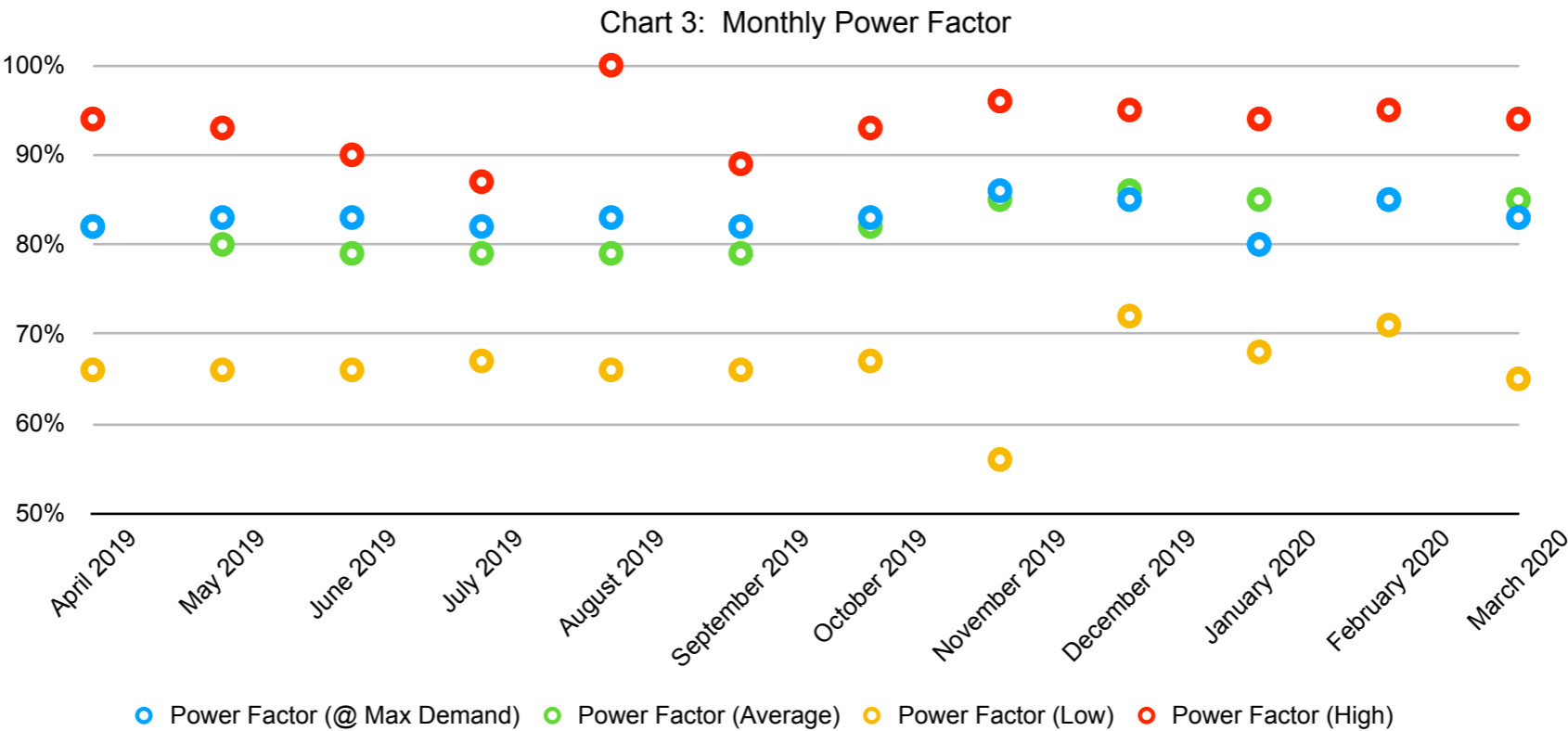
In most cases, there is adequate information on a monthly utility bill to calculate the load factor for the farms main meter. As described above, this is a useful metric to help understand how efficiently the farm is using energy. The energy meters used in this study collected the energy usage, average demand, and peak demand for each individual operation. As a result, the study team was able to calculate the load factor for each individual operation to assess how efficiently specific operations used energy. This detailed level of data is extremely helpful to identify which operations contribute the greatest to the farms overall peak demand cost.

As illustrated in Chart 2, the average load factor for the SDEM farm over the study period was 0.39. When investigating individual operations, the manure pump had the lowest load factor, ranging from 0.03 to 0.06, with a 12-month average of 0.04. This suggests improving the load factor of the manure pump by minimizing peak demand spikes will provide the greatest cost savings potential. The load factor of the feed and water operations ranged from 0.18 to 0.41 with a 12-month average of 0.25, while the load factor of the cooler compressor ranged from 0.30 to 0.41 with a 12-month average of 0.37. Making corrections to these operations has excellent potential for peak demand reduction. Investing in corrections to improve the load factor of the vacuum pump (0.54) and ventilation fans (0.46) is not optimum and will not yield benefits at the same level as will changes to operations with lower load factors.

Power Factor

Power factor is the ratio between real power and apparent power (Power Factor = Real Power / Apparent Power), typically expressed as a percentage. In general, low power factor is bad, requiring more electricity to be fed into the system with no additional energy benefit to the system or consumer. Simply put, it is a cost with no benefit. Many utility providers consider the power factor of your facility in calculating your monthly billing demand charges. While each rate structure is unique, many utilities require commercial customers to maintain a power factor of 90% or greater to avoid additional charges. In some cases, these additional charges can have a significant impact on your overall delivery charges.

Some utilities will consider the average power factor over the billing period while others will use the power factor recorded during the time window that the peak demand was established. Chart 3 illustrates the power factor data for the SDEM farm and shows the monthly data for the high power factor, low power factor, average power factor, and the power factor at the time of the monthly peak demand. The average monthly power factors were all below 90%, ranging from a low of 79% to a high of 86% over the 12 month period. Similarly, the power factor at the time of the monthly peak demand were also all below 90%, ranging from a low of 79% to a high of 86% over the 12 month period.



Energy Consumption vs. Peak Demand

Charts 4 and 5 below summarize the share of total energy use for each function and the share of peak demand for each function. When comparing the overall contributions by operation, ventilation fans are the largest contributor to both total energy use (kWh) at 54% and peak demand (kW) at 49%. The manure pump is the second largest contributor to the overall peak demand at 24%, however, it represents only 3% of the total energy usage (kWh). This suggests that the manure pump is a larger motor load, however it does not run for a very long period of time compared to other operations on the farm. Conversely, the contributions from the vacuum pump, feed and water, milk cooling, and other loads remain fairly consistent between both the total energy use (kWh) and the peak demand (kW).

The next section will further analyze the peak demand trends and financial implications analysis section which drills down into the details of the demand impacts.

Chart 4: 2019 Share of Total Energy Use (kWh) by Operation

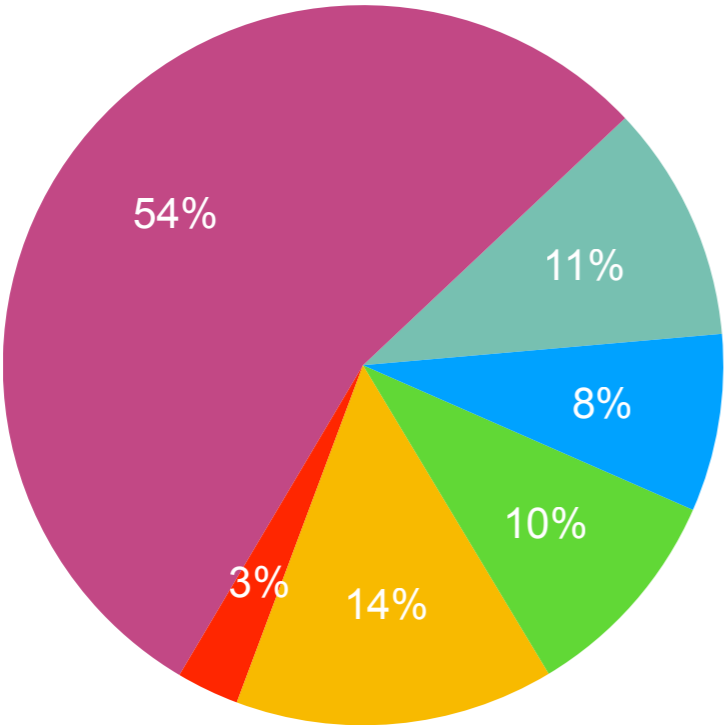
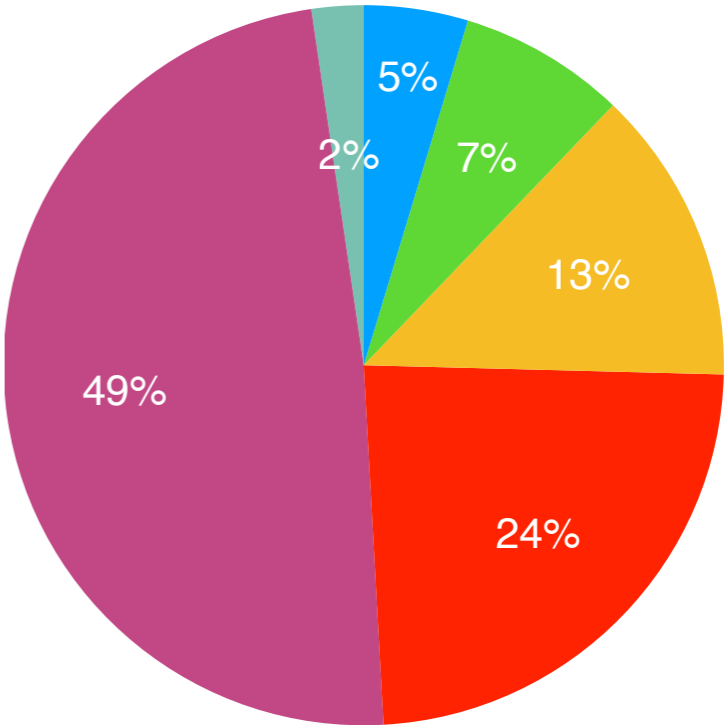


Chart 5: 2019 Share of Peak Demand (kW) Contribution by Operation



- Vacuum Pump
- Feed & Water
- Milk Cooling
- Manure Pump
- Ventilation Fans
- Other

Peak Demand Analysis

Peak Demand Trends

In this section we analyze the peak demand trends for the SDEM farm. It is important to reflect on the difference between energy consumption and peak demand. Most consumers are familiar with energy consumption, which is the total amount of energy measured in kilowatt hours (kWh) that you use over a period of time, or billing period. In comparison, energy demand charges are based on the maximum amount of electricity drawn from an electric power system at a single point in time, generally measured in megawatts (MW) or kilowatts (kW). While demand charges are based on your peak usage in a specific period in time, it is not necessarily an instantaneous peak. Instead, most utilities will measure a monthly peak demand as a rolling average over a specific time interval, typically 15 or 30-minute intervals. Data for the SDEM farm is calculated on a 15-minute rolling demand window

When comparing the monthly 15-minute demand average to the maximum monthly 15-minute demand, there is a considerable difference. For example as illustrated in Chart 6, over the analysis period the maximum monthly demand is 154 percent greater than the average monthly demand. This indicates that most of the time the farm requires an average of 50 kW less electrical demand to operate the facility than the energy actually used to set the monthly maximum demand.

Chart 6 also suggest there is a seasonal impact to the energy demand on the farm, as both the maximum monthly demand and the average monthly demand is higher in the summer months and lower from November through February. To better understand the variation of seasonal peak demand trends, it is important to consider what contributes to monthly demand charges.

Chart 6: Comparison of Average and Maximum 15 Minute Monthly Demand (kW)

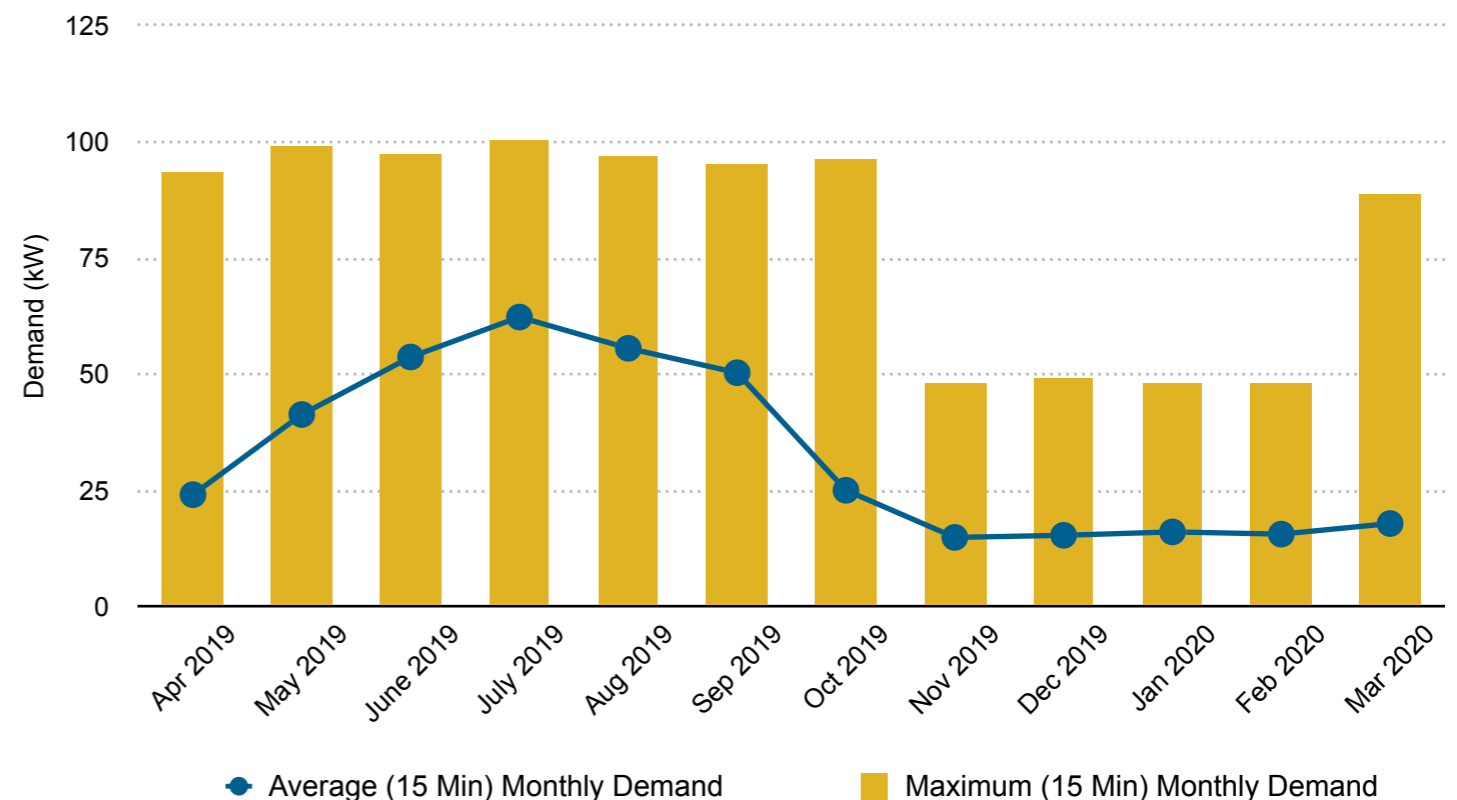
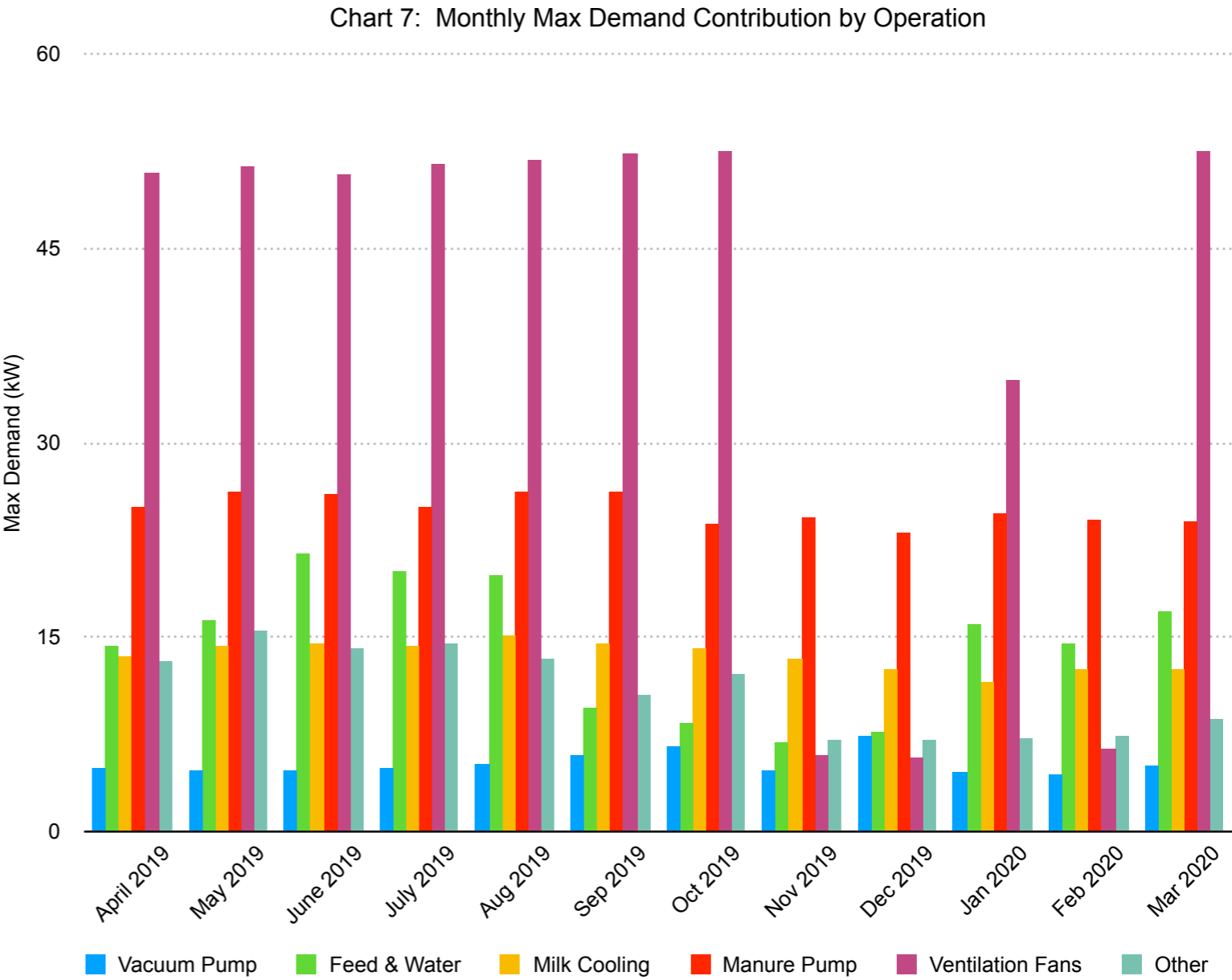


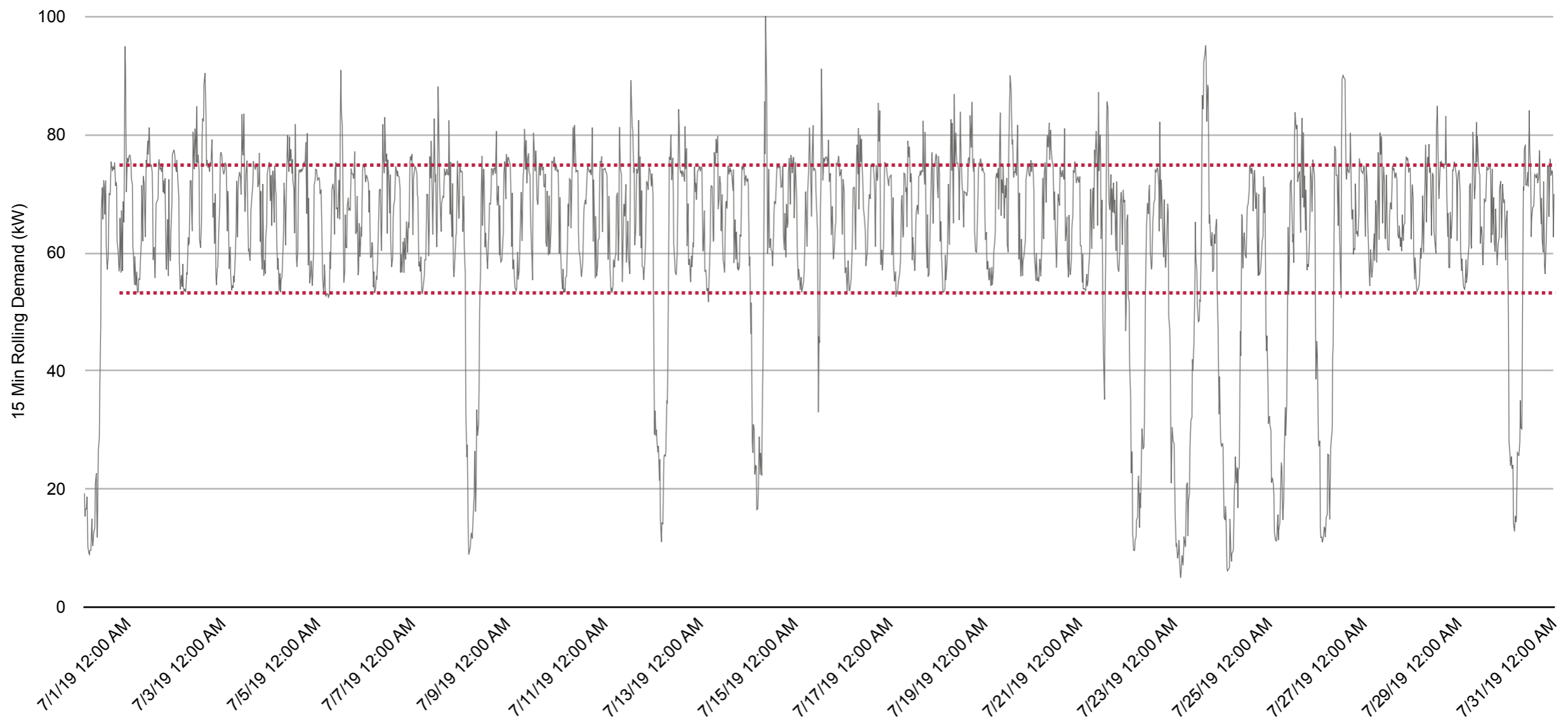
Chart 7 illustrates the maximum monthly demand by specific operation. As shown in the chart, the ventilation fans make a significant contribution to the overall peak demand in the summer months, however contribute less in the winter. Similarly, the feed and water operations had a variation in monthly peak demand contributions. Peak demand contributions from other operations such as the vacuum pump, manure pump, and milk cooling appear to be relatively consistent from month to month. The highest total monthly peak demand was in July of 2019.



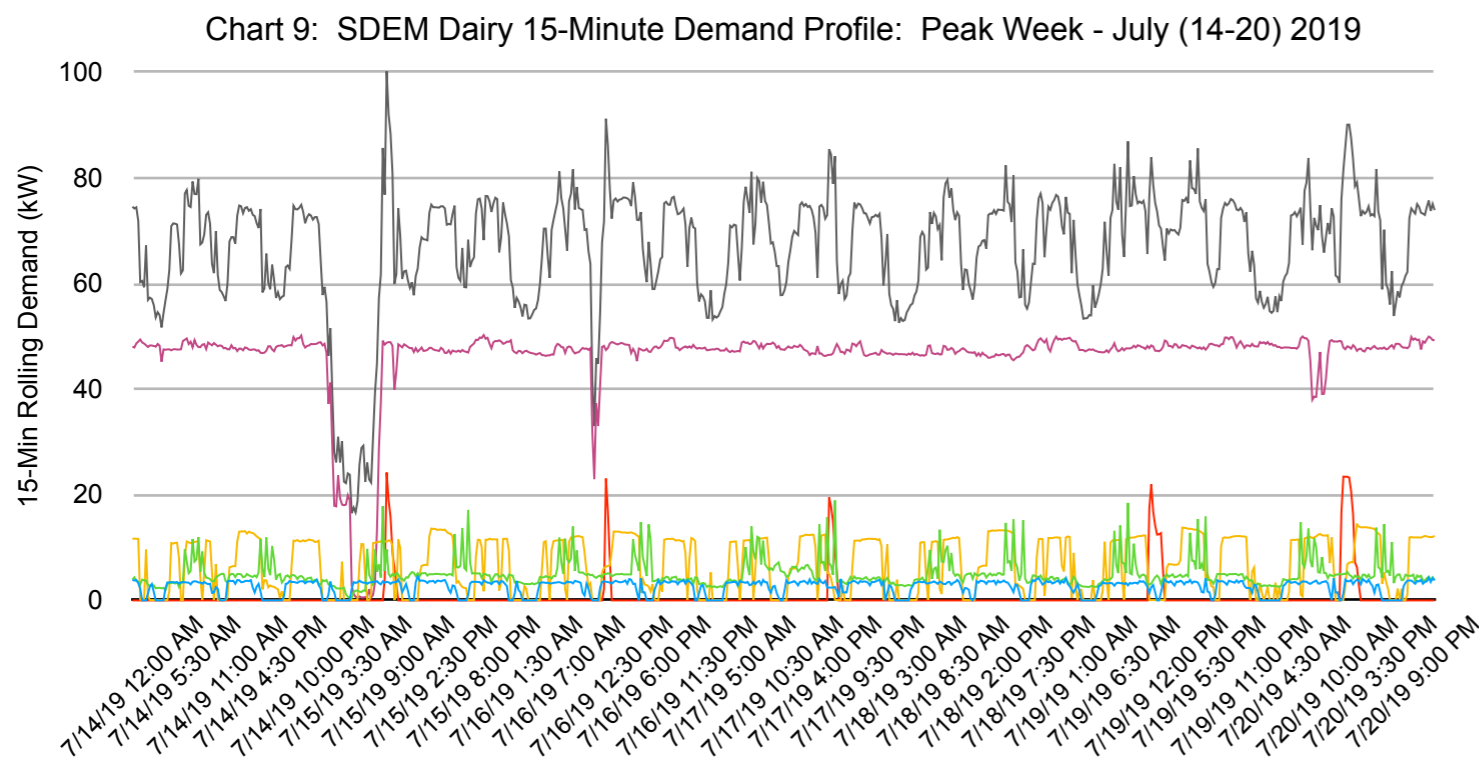
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As illustrated in Chart 8, the maximum 15-minute monthly demand of 100 kW was set in July 2019, which was the largest demand recorded at the SDEM farm during the 12-month study period. As outlined by the red dotted lines in Chart 8, most of the month the total demand was within a range of 55 kW and 75 kW, with several spikes over 80 kW. When analyzing specific operational electric loads, there were obvious differences between their average demand and the peak demand (kW) patterns which contributed to the high demand spikes.

Chart 8: SDEM Dairy 15-Minute Maximum Demand - July 2019

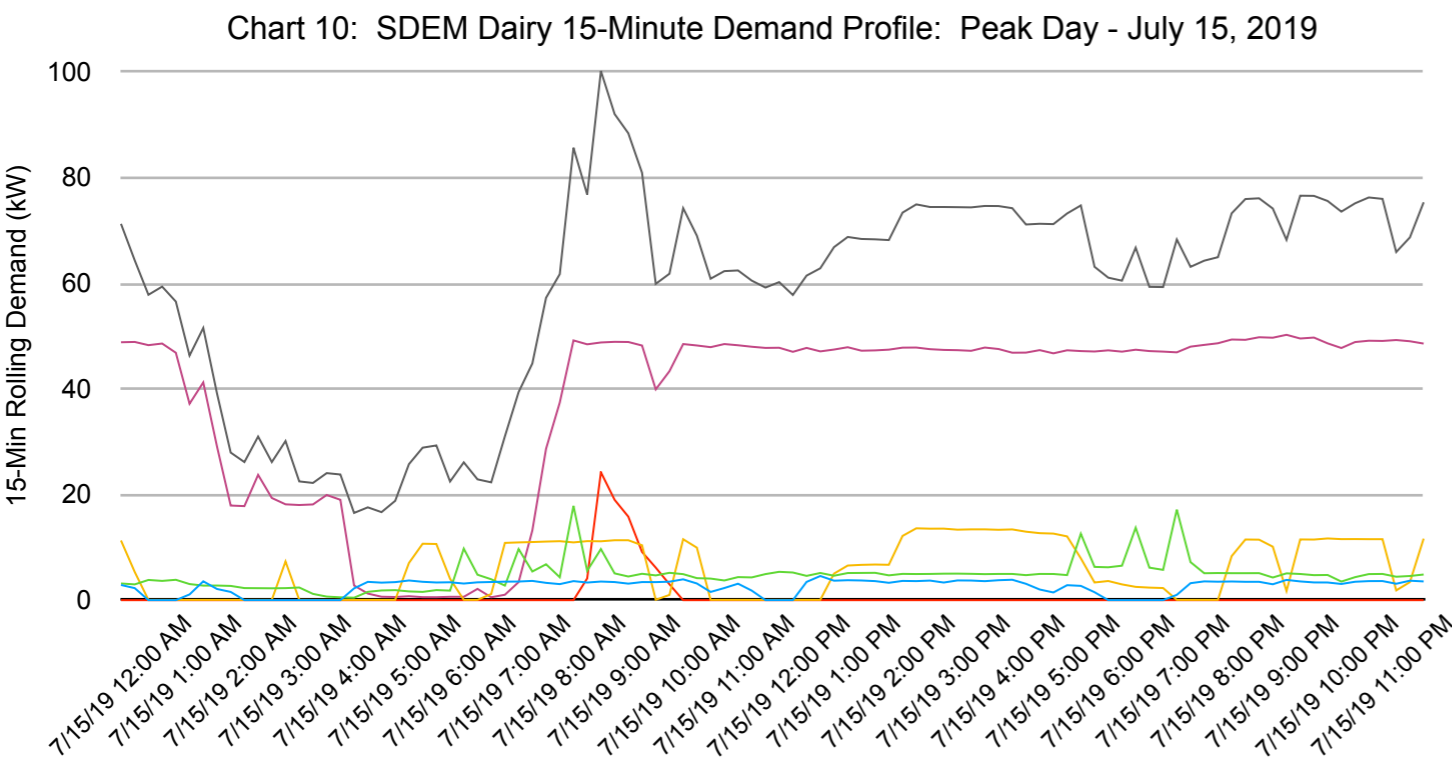


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- Vacuum Pump
- Milk Cooling
- Ventilation Fans
- Feed & Water
- Manure Pump
- Main Meter

As shown in Chart 9, electric loads associated with milking operations such as vacuum pump and cooler compressor motors followed predictable patterns as they closely aligned with the three milking times throughout the day. Meanwhile, the feed mill motor and water pump are operations that are more randomized. Ventilation fans are often the largest operational contributor to the overall peak demand and serve as the plateau in the peak demand profile. For example, nine out of the 12 months, ventilation fans contributed between 34 kW and 51 kW to the overall peak demand representing 46 percent of the annual total peak demand. Ventilation fans are controlled by a separate thermostat in each barn set at 60 degrees. While the ventilation fans tend to run sporadically in the spring and fall, in the summer months they are more consistent and rarely shut down.



Ventilation fans are critical motor loads essential to animal comfort and milk production therefore they offer little opportunity to adjust through load shifting. The manure pump is controlled manually and tends to run for around three hours every two or three days. While the operational patterns are very inconsistent, the manure pumps contribution to the overall monthly maximum demand is very consistent. Over the 12 month study period, the manure pump demand during the 15-minute peak demand window ranged between 19 kW and 25 kW with an average contribution of 20 kW to the overall monthly demand.

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As illustrated in Chart 10, the maximum 15-minute monthly demand was set on July 15th at 8:15 a.m., when the electrical loads of critical operations overlapped due to the random nature of their process. For example, during the July 15th 8:15 a.m. peak demand window the ventilation fans peaked at 48.8 kW, the manure pump at 24.2 kW, milk cooling at 11.2 kW, feed and water peaked at 9.7 kW, the vacuum pump at 3.5 kW, while miscellaneous loads contributed 2.8 kW to the total demand. This peak demand event could have been avoided if the manure pump, which is manually controlled, ran from 3:00 a.m. to 5:00 a.m. that morning when the ventilation fans were shut down, reducing the total peak demand by 24.2 kW.

Financial Implications

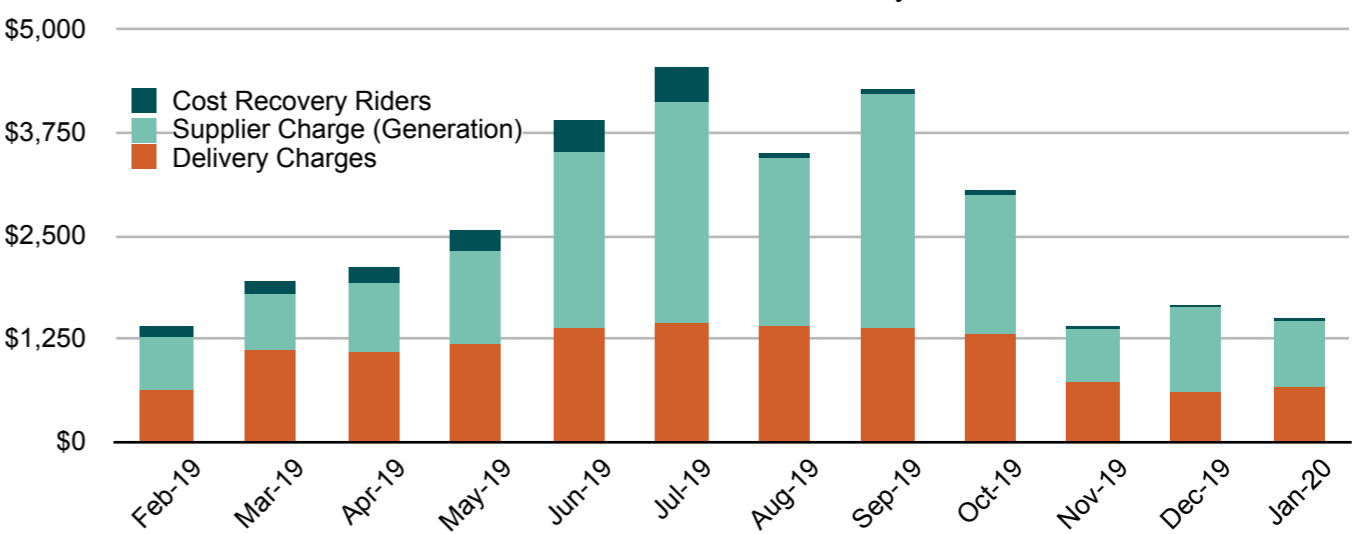
Based on the analysis period, the 15-minute monthly demand charges at the SDEM farm accounted for a minimum of 35 percent, a maximum of 58 percent, and a 12-month average of 43 percent of the total electric bill. In comparison, the 12-month average of energy generation charges were 52 percent, while cost recovery charges or riders represented an average of 6 percent of the total electric bill charges (Chart 11). When put in monetary terms, the 15-minute monthly demand charges at the SDEM farm accounted for a minimum of \$664, a maximum of \$1,388, and a 12-month average of \$1,109 of the total electric bill.

While it is helpful to review the overall demand cost, metering individual processes on the farm allowed us to better understand which operations are contributing most to the peak demand cost. As illustrated in Table 2, ventilation fans often contribute the most to overall demand cost with a maximum monthly demand cost of \$546 and an average monthly demand cost of \$460 per month. The manure pump represents the second greatest impact to the total monthly

Table 2: Estimated Demand Cost by Operation During Monthly 15-Minute Peak Demand Window

Date	Vacuum Pump	Feed & Water	Milk Cooling	Manure Pump	Ventilation Fans	Other Loads	Total Demand
4/17/19 @ 1:00 PM	\$56	\$48	\$151	\$308	\$681	\$53	\$1,297
5/23/19 @ 10:15 PM	\$52	\$73	\$170	\$329	\$682	\$71	\$1,377
6/28/19 @ 10:15 AM	\$47	\$58	\$165	\$347	\$669	\$64	\$1,350
7/15/19 @ 8:45 AM	\$49	\$134	\$154	\$336	\$676	\$39	\$1,388
8/21/19 @ 9:30 AM	\$44	\$135	\$160	\$307	\$680	\$13	\$1,339
9/14/19 @ 2:45 PM	\$48	\$73	\$166	\$306	\$685	\$39	\$1,317
10/1/19 @ 9:00 PM	\$53	\$60	\$157	\$291	\$716	\$55	\$1,332
11/21/19 @ 7:45 AM	\$52	\$84	\$138	\$323	\$65	\$5	\$667
12/17/19 @ 8:00 AM	\$51	\$106	\$134	\$319	\$61	\$12	\$682
1/11/20 @ 3:15 PM	\$56	\$36	\$84	\$0	\$478	\$12	\$667
2/13/20 @ 8:00 AM	\$48	\$88	\$134	\$313	\$58	\$23	\$664
3/28/20 @ 2:45 PM	\$56	\$38	\$150	\$267	\$718	\$2	\$1231
Note: Demand charges are seasonally adjusted ranging from \$12.02 to a high of \$14.45 per kW. This table uses an average demand cost of \$13.85 which represents charges from both transmission and distribution demand charges, but excludes cost recovery fees.							

Chart 11: Itemized Cost from Monthly Electric Bills



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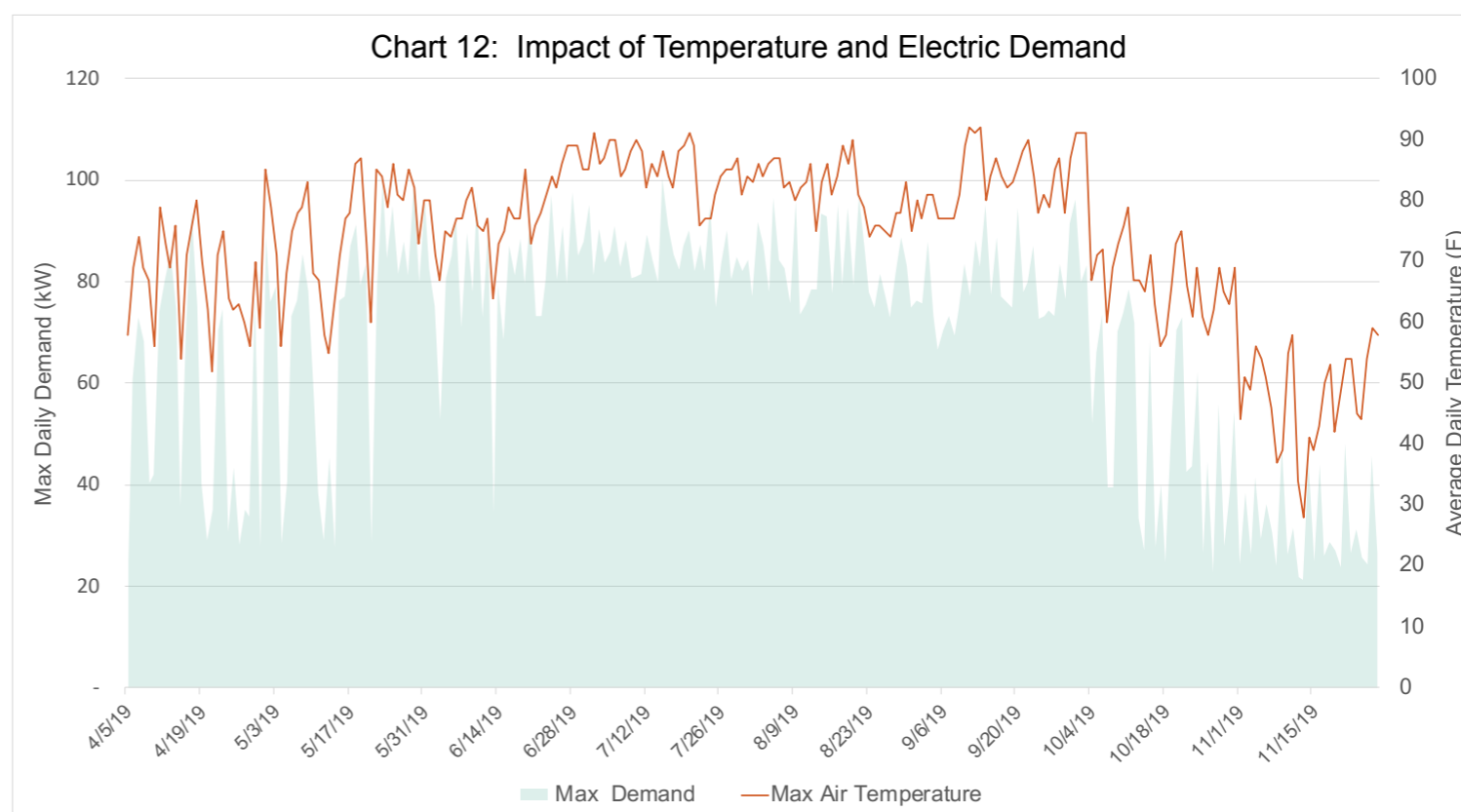
demand cost with a maximum monthly demand of \$350 and an average monthly demand cost of \$308 per month. Next, milk cooling accounted for the third highest contribution to the total monthly demand cost with a maximum monthly demand cost of \$169 and an average monthly demand cost of \$153 per month. Finally, feeding and watering operations add an average of \$82 to the monthly demand cost, while an average monthly demand of \$48 per month is a result of the vacuum pump operations. Due to the seasonal nature of ventilation fans and water pump operations, they have the greatest variation in cost. The demand cost for these operations is significantly higher in the summer when the animals are in need of additional water and ventilation to keep cool.

Observations

When reviewing the data, a key observation is related to the significant decrease of demand charges in November, December, January, and February. This suggests there is a connection between demand charges and seasonal operations. Chart 12, compares the maximum daily temperature in New Philadelphia, Ohio to the total daily maximum peak demand of the farm. The total daily peak demand profile for the farm closely reflects the profile trends of the maximum daily temperature, suggesting that temperature has an influence on peak demand cost. Select processes monitored on the farm that could be influenced by temperature include ventilation fans, feed and water operations. While it appears the feed and water consumption is higher in the summer months and drops off in September, these operations are not controlled by a thermostat and are more related to animal behavior. As a result, the demand profile of the feed and water operations does not appear to be directly linked to temperature. Conversely, ventilation fans are

thermostat controlled and therefore appear to be directly linked to the maximum daily temperature. Based on this observation, it is important to review the thermostat settings to determine if they are properly calibrated. If the thermostat settings could be increased there is an opportunity to reduce the demand. However, it is important to maintain the required ventilation needs to meet animal comfort and milk production goals.

The manure pump was the largest non-essential motor load that had the greatest impact on the farm's peak demand spikes. Previous energy studies on dairy farms found 17 percent of energy consumption was allocated to vacuum pumps, while only 4 percent of energy was related to manure handling³. Based on previous energy studies, we were surprised to observe that on the SDEM farm vacuum pumps only accounted for three



³ Ludington, D., & Johnson, E. (2003). *Dairy Farm Energy Audit Summary Report* (pp. 1-28, Rep.). Albany, NY: New York State Energy Research and Development Authority.

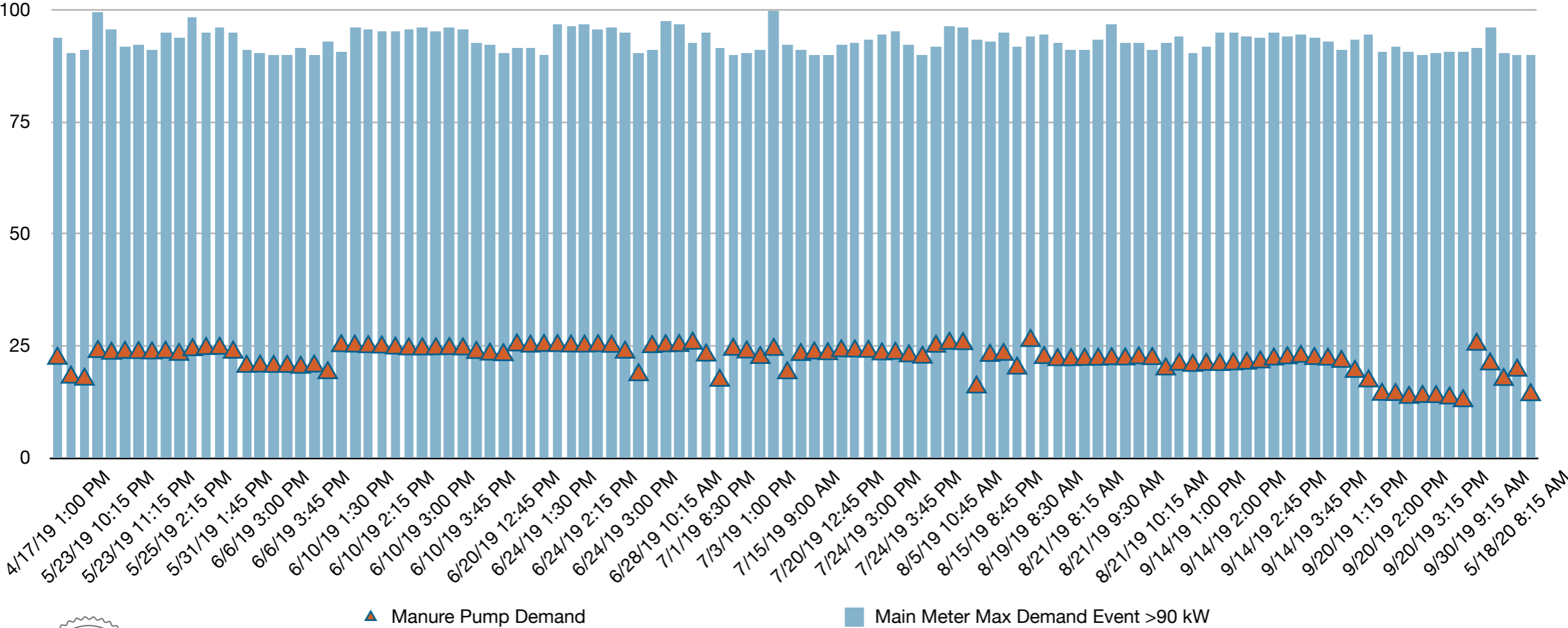
CASE STUDY: SFEM DAIRY FARM DEMAND ENERGY MONITORING

percent of the total annual energy consumption, while 24 percent of the total annual demand cost was related to the manure pump (Charts 4 and 5). This observation is a reminder of the difference between energy generation charges and demand charges.

Further investigation of the peak demand profile for the manure pump found that it is a primary driver in setting the 15-minute monthly demand. Over the 12-month analysis period, there were 35,050 recorded 15-minute demand time intervals (events) and 98.5


percent of the recorded events had a demand of less than 80 kW. When analyzing the 535 demand events over 80 kW, the manure pump was on during 86 percent of the time for demand events over 80 kW, while it was on 98 percent of the time for demand events over 85 kW, and 100 percent of the time for demand events over 90 kW (Chart 13). In summary this suggest that while the manure pump does not use a lot of energy (kWh), it is an operation with a high load that regularly contributes to the monthly peak demand.

Chart 13: Status of Manure Pump During Peak Demand Spikes over 90 kW



Closing Thoughts

Summary of Results and Recommendations

 ver the analysis period, the ventilation fans and manure pump accounted for 73% of the total peak demand. While the ventilation fans are an essential operation that is required to maintain animal comfort and milk production, the manure pump is an operation that could reduce peak demand cost by exploring load shifting options. A review of the load profiles during the study period suggest there is an opportunity to shift the manure pump loads to run during the early morning hours when there is less equipment running on the farm.

During the hot summer months of June, July, August, and September the ventilation fans tend to run throughout the night, limiting the potential for demand reduction and cost savings. However the other eight months out of the year provide periods in the early morning hours when it is cool enough for the ventilation fans to shut off, providing an ideal opportunity to run the manure pump without increasing the monthly peak demand. For example, based on a review of the load profiles, between 2:00 a.m. and 4:00 a.m. the vacuum pump load is less than 1 kW 93% of the time, while the milk cooling load is less than 1 kW 94% of the time, and the feed and water load is less than 1 kW 65% of the time. In addition, the load from the ventilation fans is significantly less than normal with a load under than 5 kW between 2:00 a.m. and 4:00 a.m. 75% of the time.

A review of the manure pump operation during the study period showed the manure pump ran an average of 15 days per month for 3 hours. However, if the manure pump were scheduled to run daily, it would only need to run for 1.45 hours per day to provide the same overall run time. Based on the average run time requirements, the manure pump operation load could be shifted to run during the time window of low activity between 2:00

a.m. and 4:00 a.m. and meet the farms required pumping needs. Additional demand reductions may be experienced during this time due to the reduced activity from the vacuum pump, milk cooling, and feed and water operations.

While the ventilation fans are essential operations that must run to maintain animal comfort, there are opportunities to reduce both energy consumption and peak demand contributions through improved design and energy efficiency. The dairy barn is currently set up with stir fans directing air from the East to the West, causing the fans to operate against the prevailing winds. Rotating the existing fans 180 degrees should increase the fan efficiency performance (CFM/Watt). In addition, consideration should be given to the replacement of 12 of the older 48-inch wooden box fans with new, energy efficient direct drive fans. In order to evaluate the improvements, anemometer measurements should be made prior to and immediately following the retrofitting of fans in the barn. The anemometer measurements will provide air speeds at cow level across the barn, ensuring the modification in fans provides the same or more air movement at cow level.

“Shifting the manure pump to run during the night when the ventilation fans are off could offer significant savings on the demand cost.”

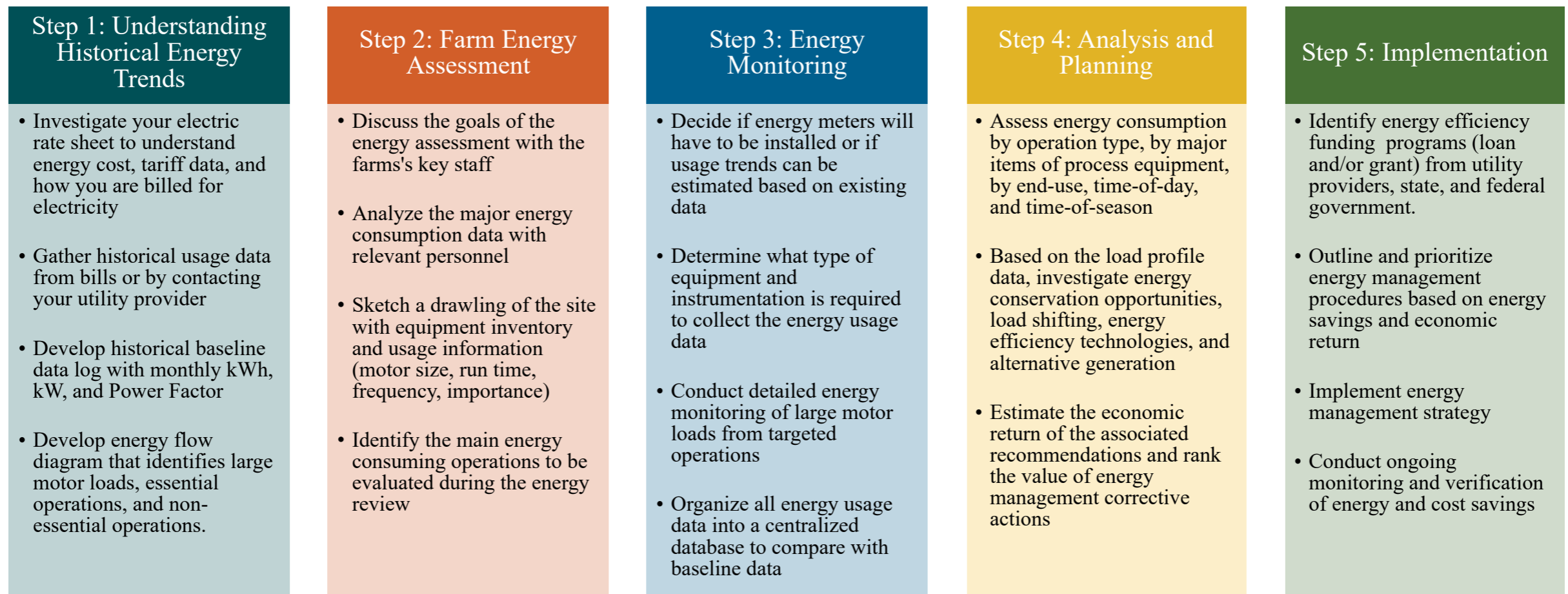
In summary, shifting the manure pump load from a time of high energy activity to a time of low energy activity appears to offer significant savings on the demand cost. In addition, because the ventilation fans are both the largest consumer of energy and the greatest contributor to peak demand, energy efficiency improvements to the fans should benefit both energy consumption and peak demand cost. Additional charges related to poor power factor contribute roughly \$500 annually to the farms energy cost. While the impact will not be as significant as load shifting and energy efficiency, there are potential cost savings from the installation of power factor correction equipment. In all cases, it is important to carefully evaluate the economic return of implementing peak demand reduction strategies.

Tips to Start Energy Management on Your Farm

Depending upon farm size, energy consumption can contribute significantly to total operating costs. This study documented that there may be opportunities to reduce energy costs by adjusting the operating time of certain loads. Farm operations interested in investigating energy consumption and costs savings strategies can get started by following the five steps of the on-farm energy management process flow outlined in Chart 14 below.

The first step to the on-farm energy management process is to understand historical energy trends by first investigating your electric rate sheet to understand how you are billed for electricity and then gathering historical usage data from past bills or by contacting your utility provider. This will require dedicating time to reading electric bills, locating and reading your rate sheet, and discussing questions with your utility provider. Using the energy data collected, develop a historical baseline data log with monthly kilowatt demand, kilowatt hours used, load factor, and power factor for the farm. Finally, use the historical baseline data and your knowledge of the farm operation to draft an energy flow diagram that identifies large motor loads, essential

Chart 14: On-Farm Energy Management Process Flow



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Image K: (above) is an example of ventilation stir fans classified as essential motor loads that cannot be manipulated or shifted because it is required to maintain animal comfort.

Image L: (right) is an example of a manure pump classified as a non-essential motor load because it could be shifted to perform the same function at a different time without negatively impacting the operations.

Photos by: Eric Romich, OSU Extension Field Specialist.



operations, and non-essential operations. While all the motors are in some way essential, motor loads that could be operated at a different time of day, or night to reduce overall load would be classified as non-essential (Image K and L).

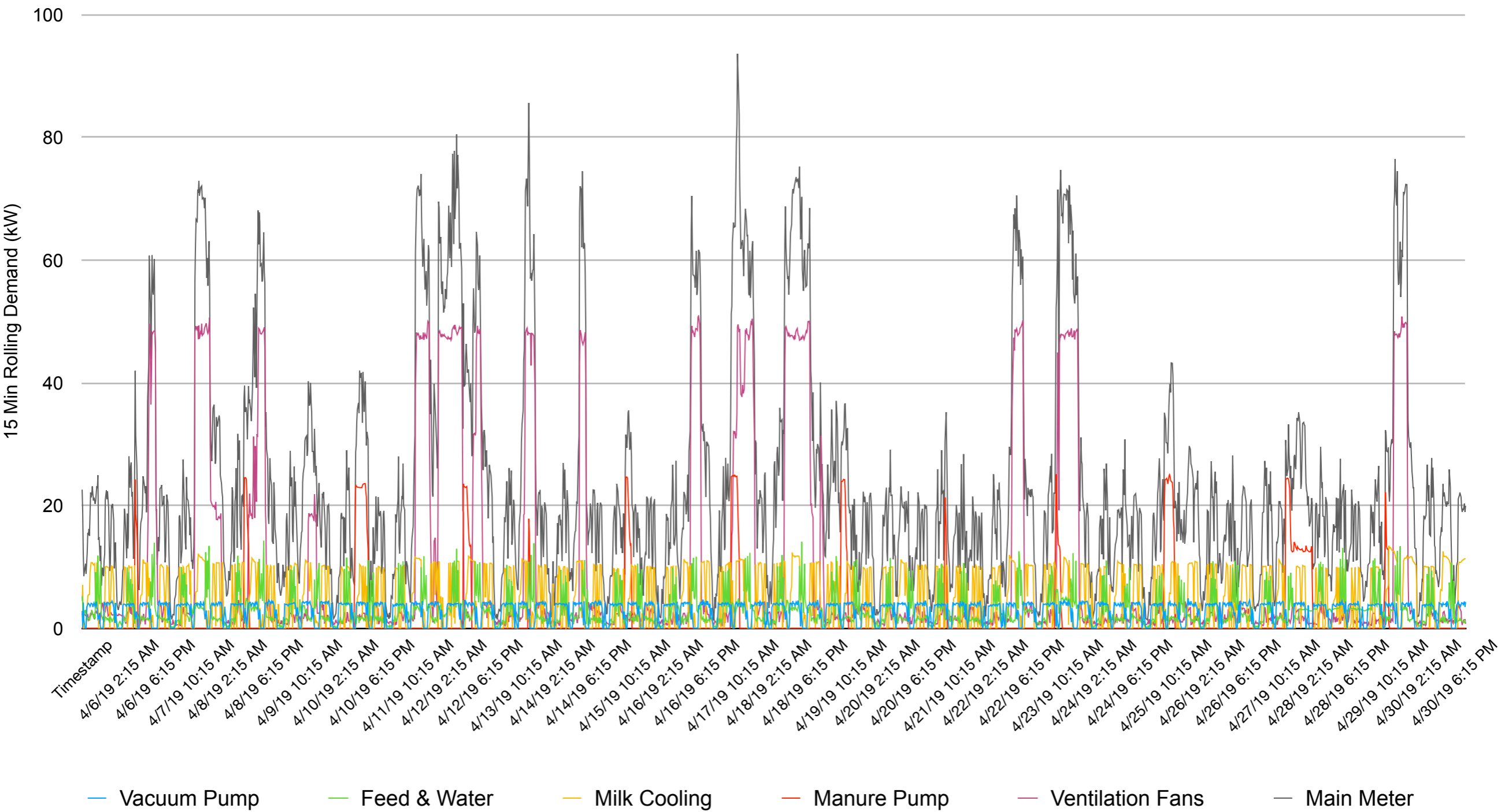
Using the historical energy trends data from the first step, you should assess energy consumption patterns to gain a clearer understanding of which farm operations to concentrate on first. This farm energy assessment process can also help clarify the level of urgency for the farm's energy cost and help establish the farm's energy management goals to produce significant energy savings. Once these steps are completed, you can begin the third step of energy monitoring. First decide if energy meters will have to be installed to collect usage data and look for savings based on how and when you use electricity on your farm, or if usage trends can be estimated based on existing data. While the monitoring equipment used in this study was very complex, there are other options that are much more affordable and will provide a basic level of analysis. For example, equipment to collect detailed energy usage and peak demand data tends to be more affordable, while equipment to collect more detailed power quality data tends to be more expensive. Determining what type of equipment and instrumentation is required to collect the energy usage data will be largely dependent on the inventory of essential and non-essential motor loads, and the information you are interested in learning.

The final steps include analysis and planning and implementation. Based on the load profile data, investigate energy conservation opportunities, load shifting, energy efficiency technologies, and alternative generation and estimate the economic return of the associated recommendations. Based on the energy savings and economic return, rank the value of energy management corrective actions. Identify energy efficiency funding programs and start implementing energy management strategies based on the ranked value. Conduct ongoing monitoring and verification after energy conservation strategies are completed, to reassess and verify the expected energy savings. The measured results should determine if the goal of the farm energy management program was achieved.

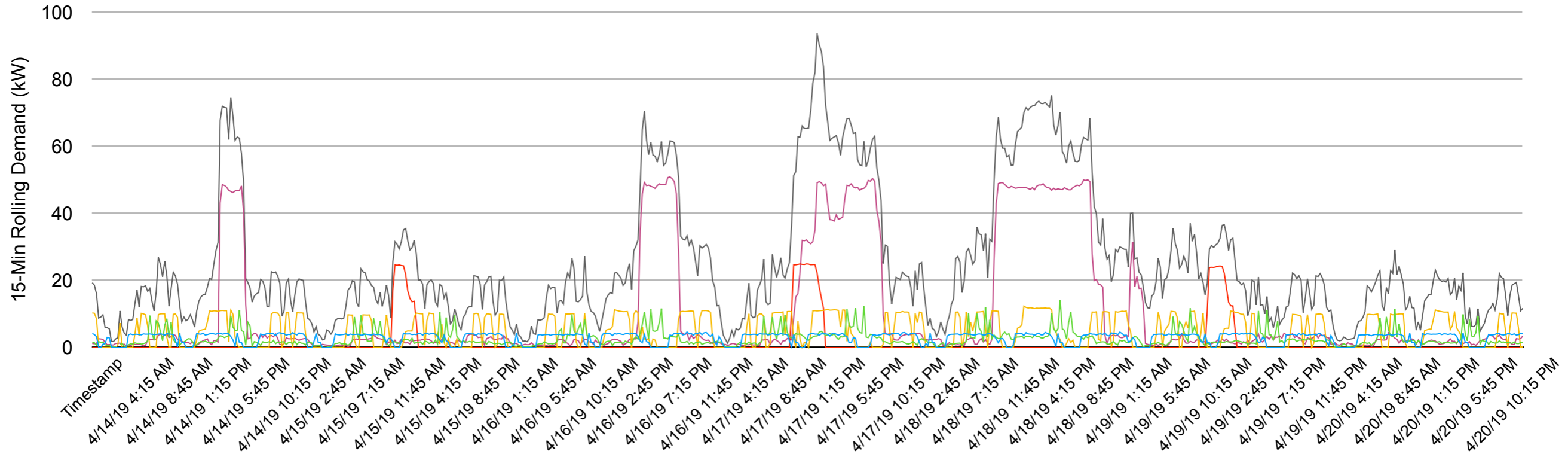
Appendix - Detailed Demand Profile Charts

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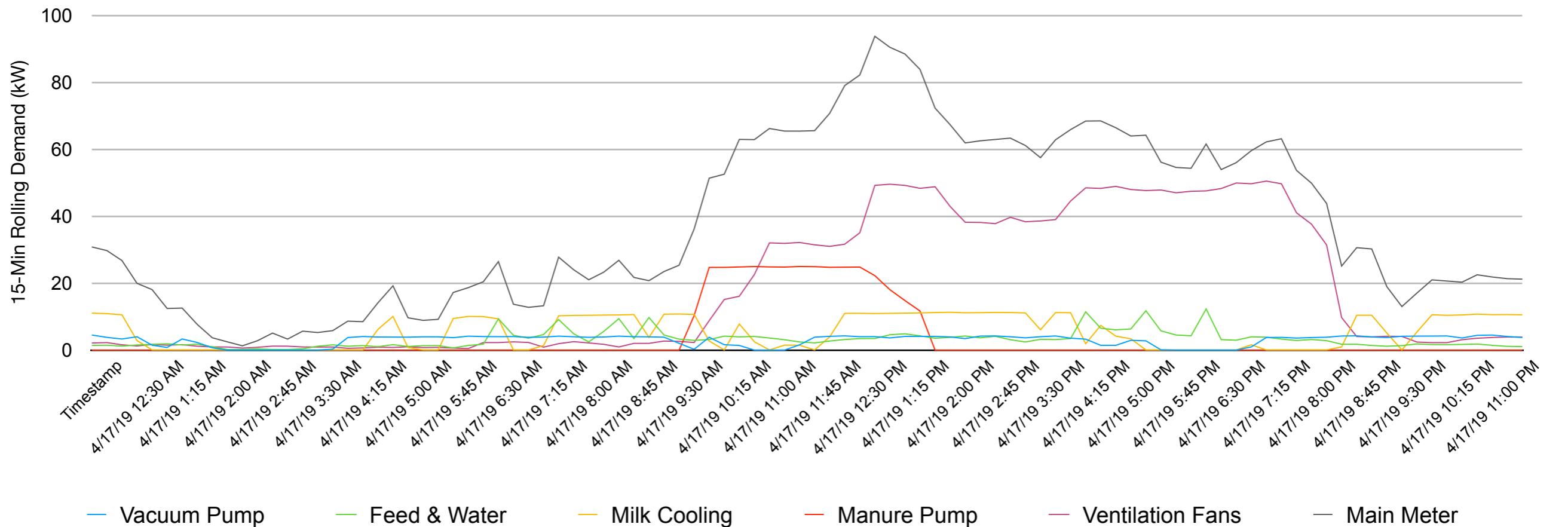
SDEM Dairy 15-Minute Demand Profile - April 2019



SDEM Dairy 15-Minute Demand Profile: Peak Week - April (14-20) 2019

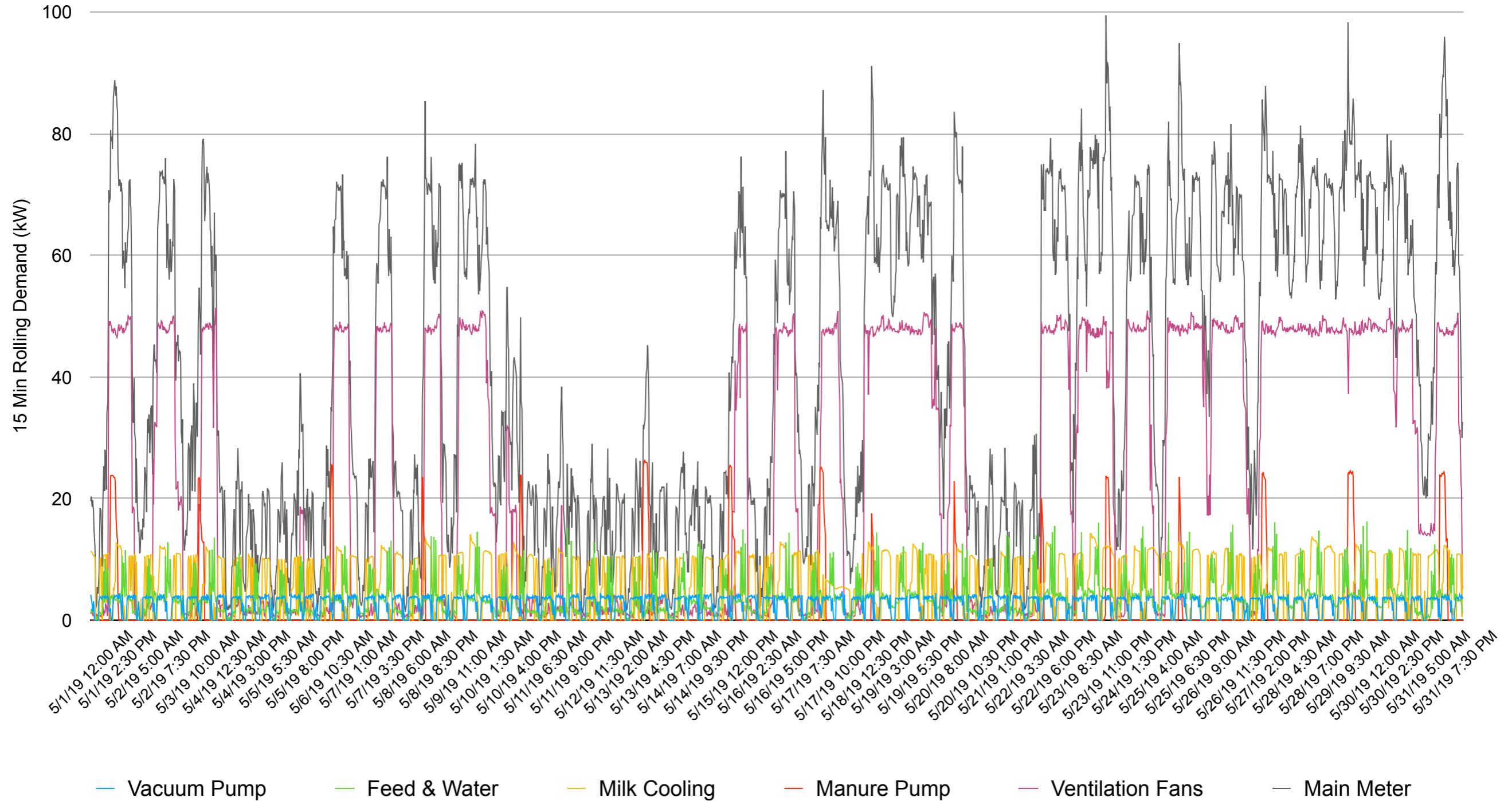


SDEM Dairy 15-Minute Demand Profile: Peak Day - April 17, 2019

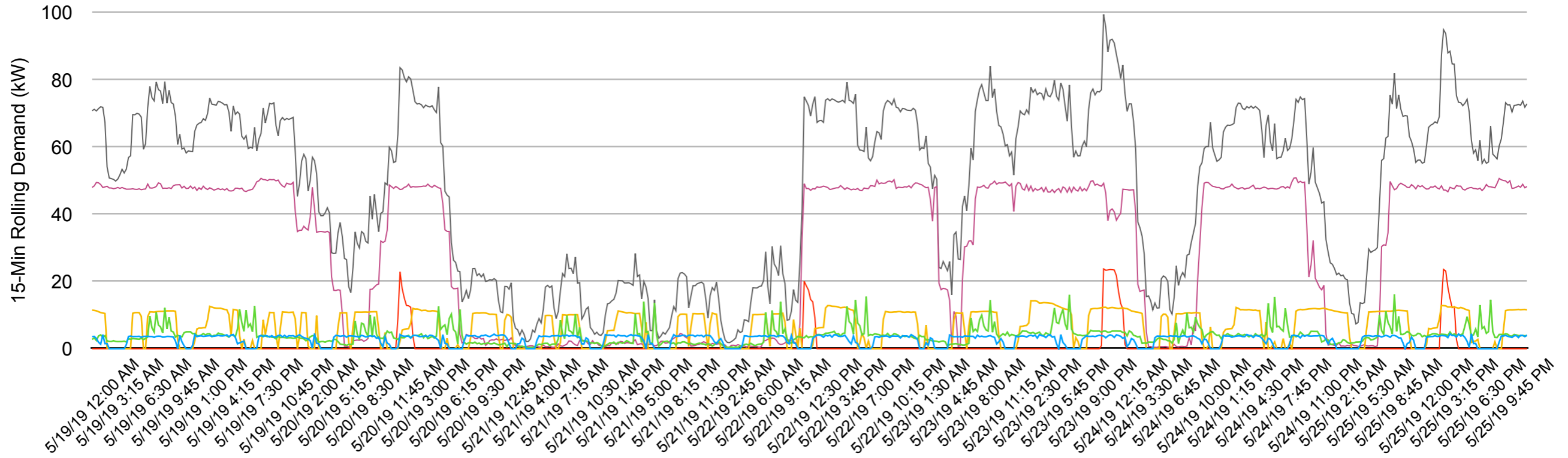


MAY 2019

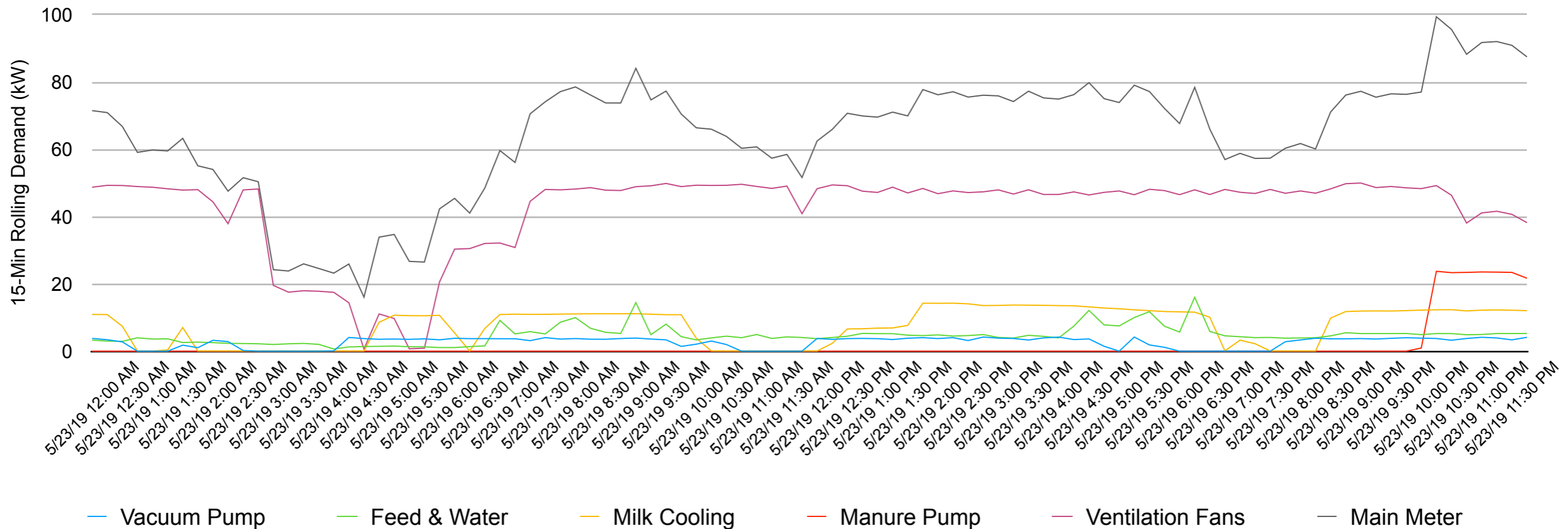
SDEM Dairy 15-Minute Demand Profile - May 2019



SDEM Dairy 15-Minute Demand Profile: Peak Week - May (19-25) 2019



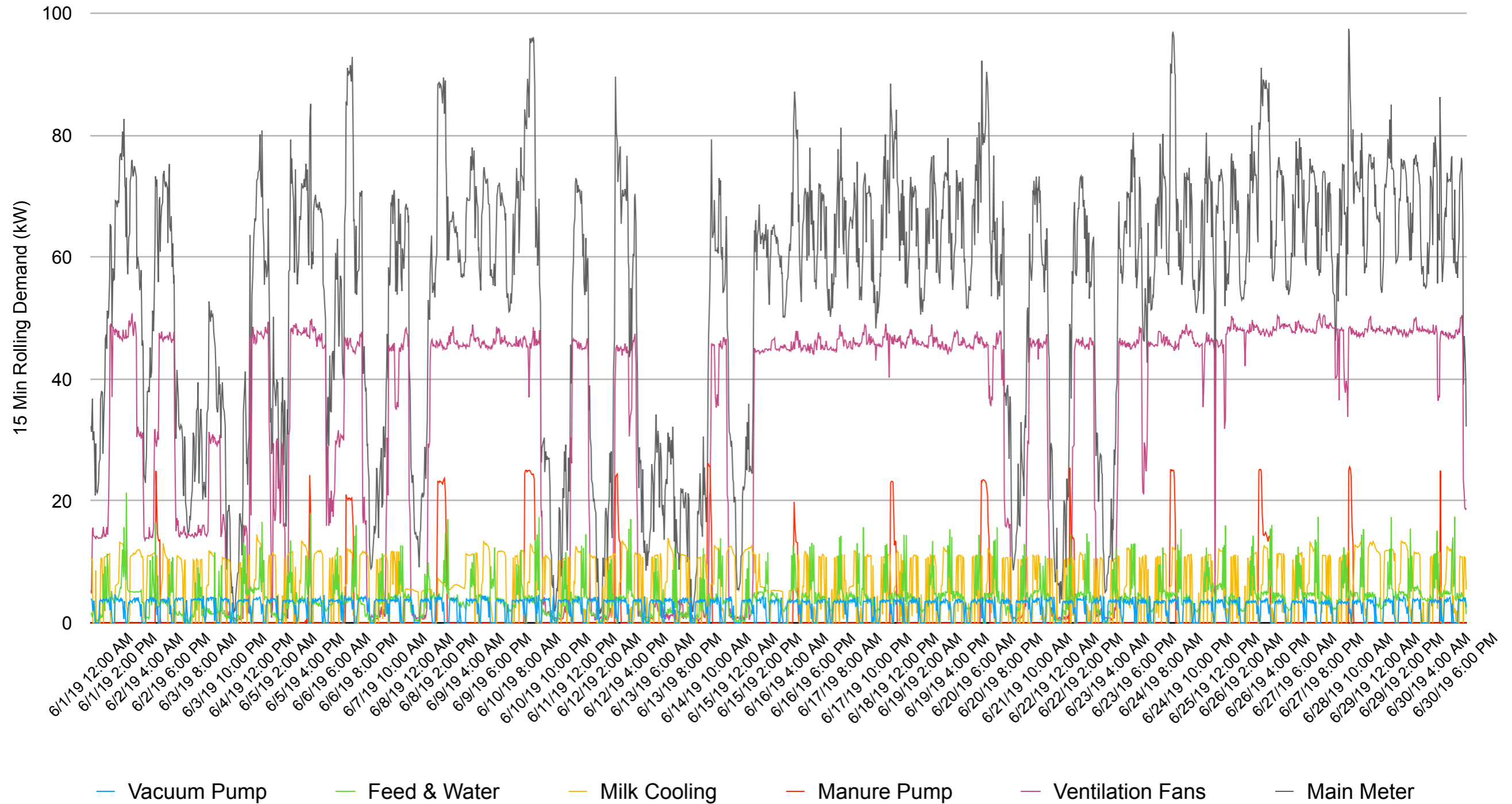
SDEM Dairy 15-Minute Demand Profile: Peak Day - May 23, 2019



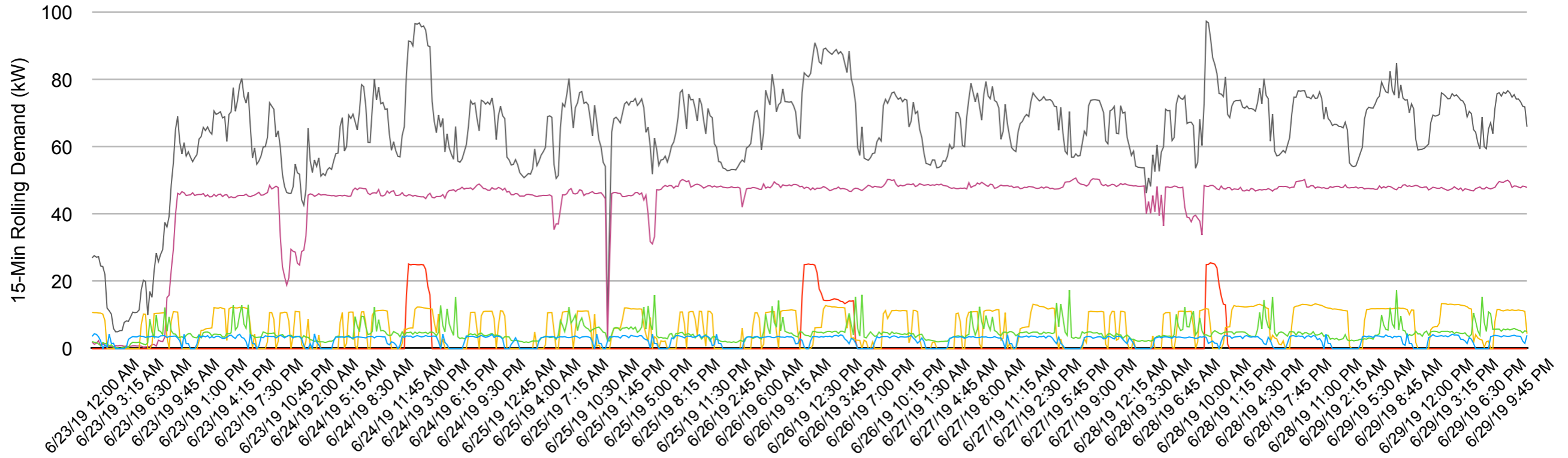
— Vacuum Pump — Feed & Water — Milk Cooling — Manure Pump — Ventilation Fans — Main Meter

JUNE 2019

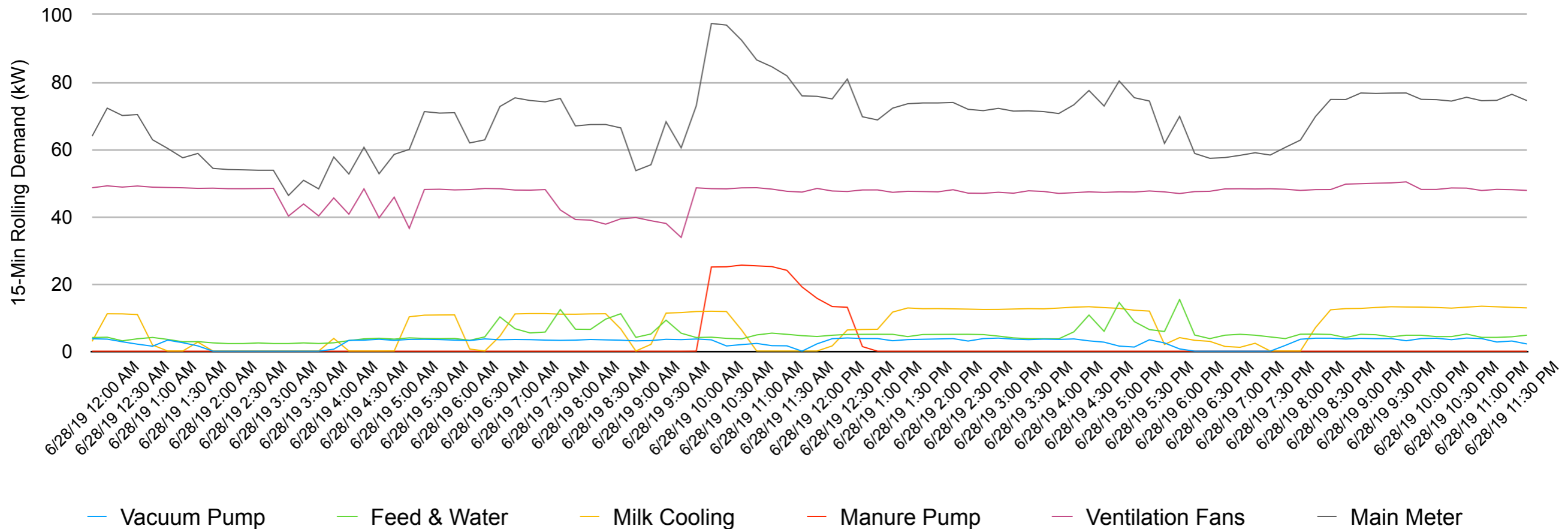
SDEM Dairy 15-Minute Demand Profile - June 2019



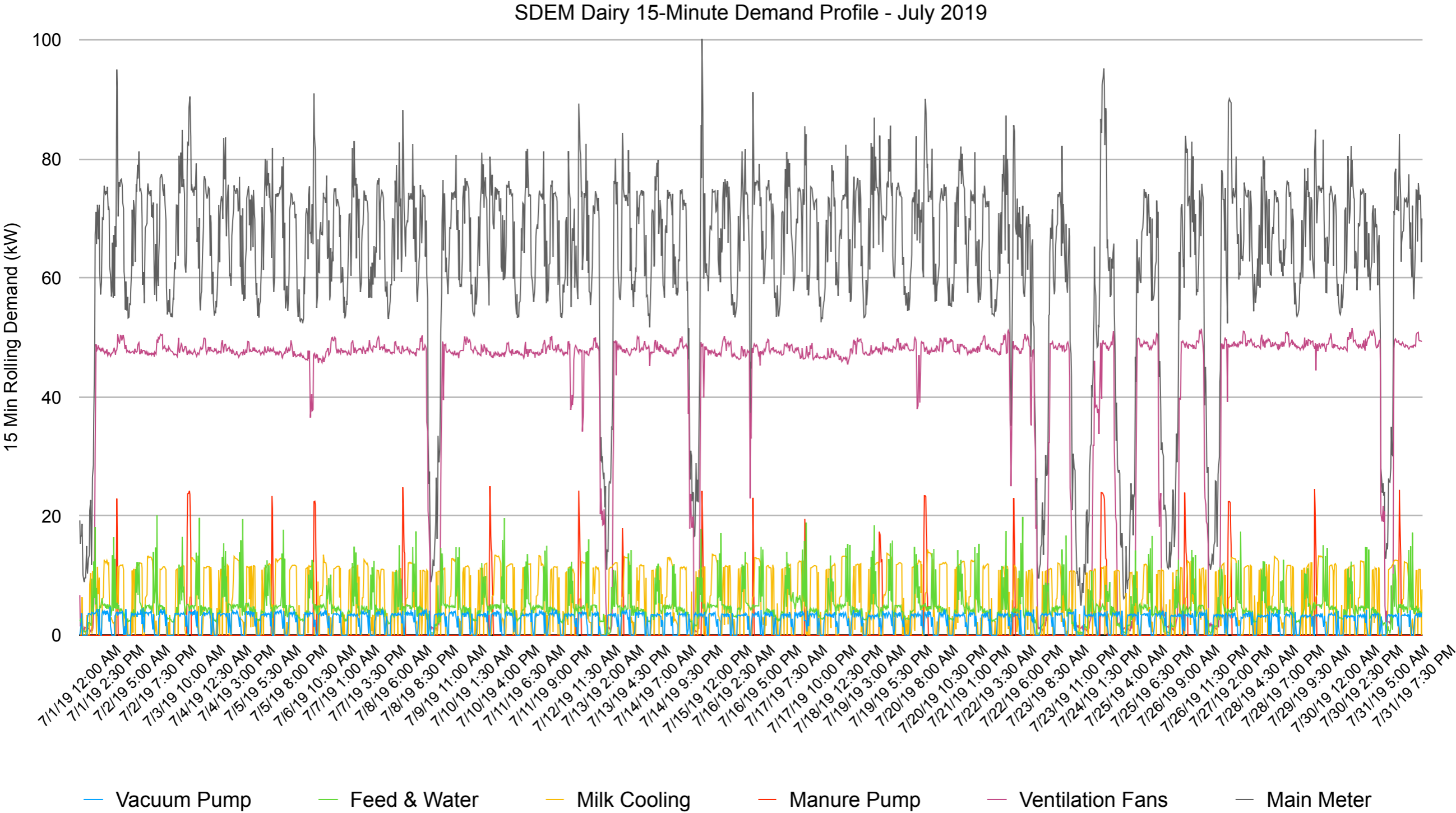
SDEM Dairy 15-Minute Demand Profile: Peak Week - June (23-29) 2019



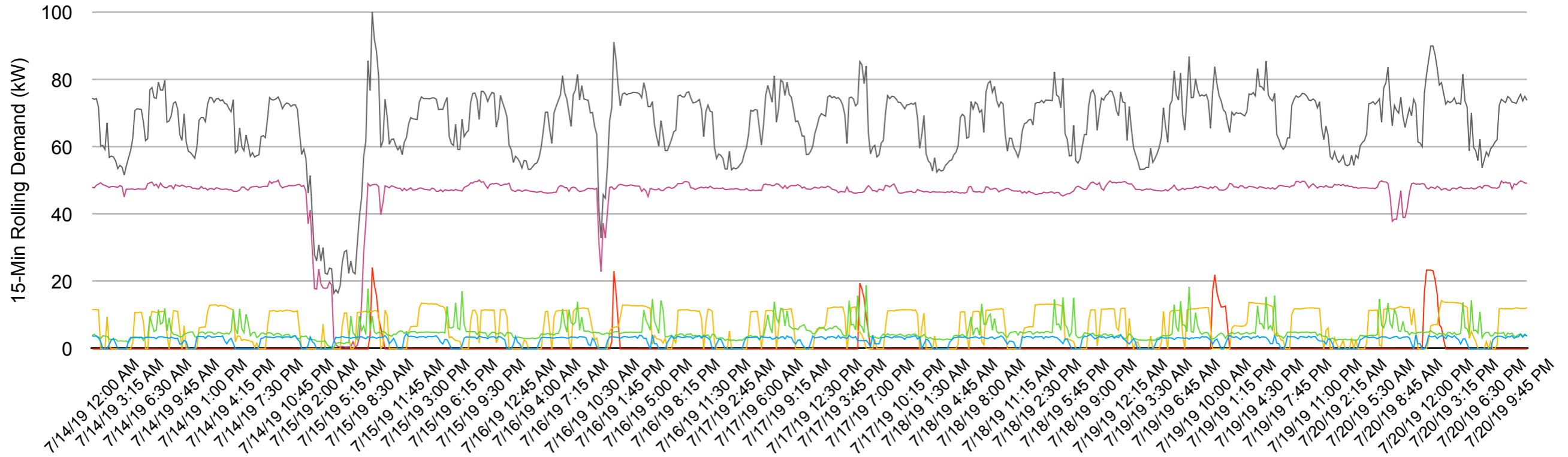
SDEM Dairy 15-Minute Demand Profile: Peak Day - June 28, 2019



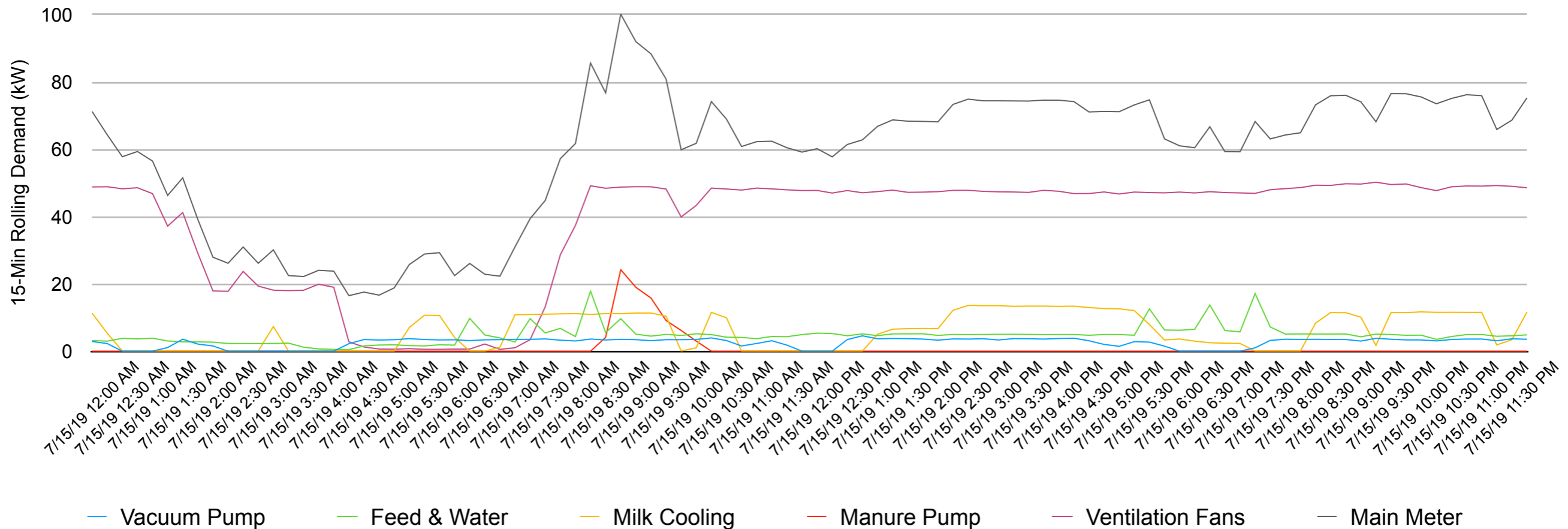
JULY 2019



SDEM Dairy 15-Minute Demand Profile: Peak Week - July (14-20) 2019

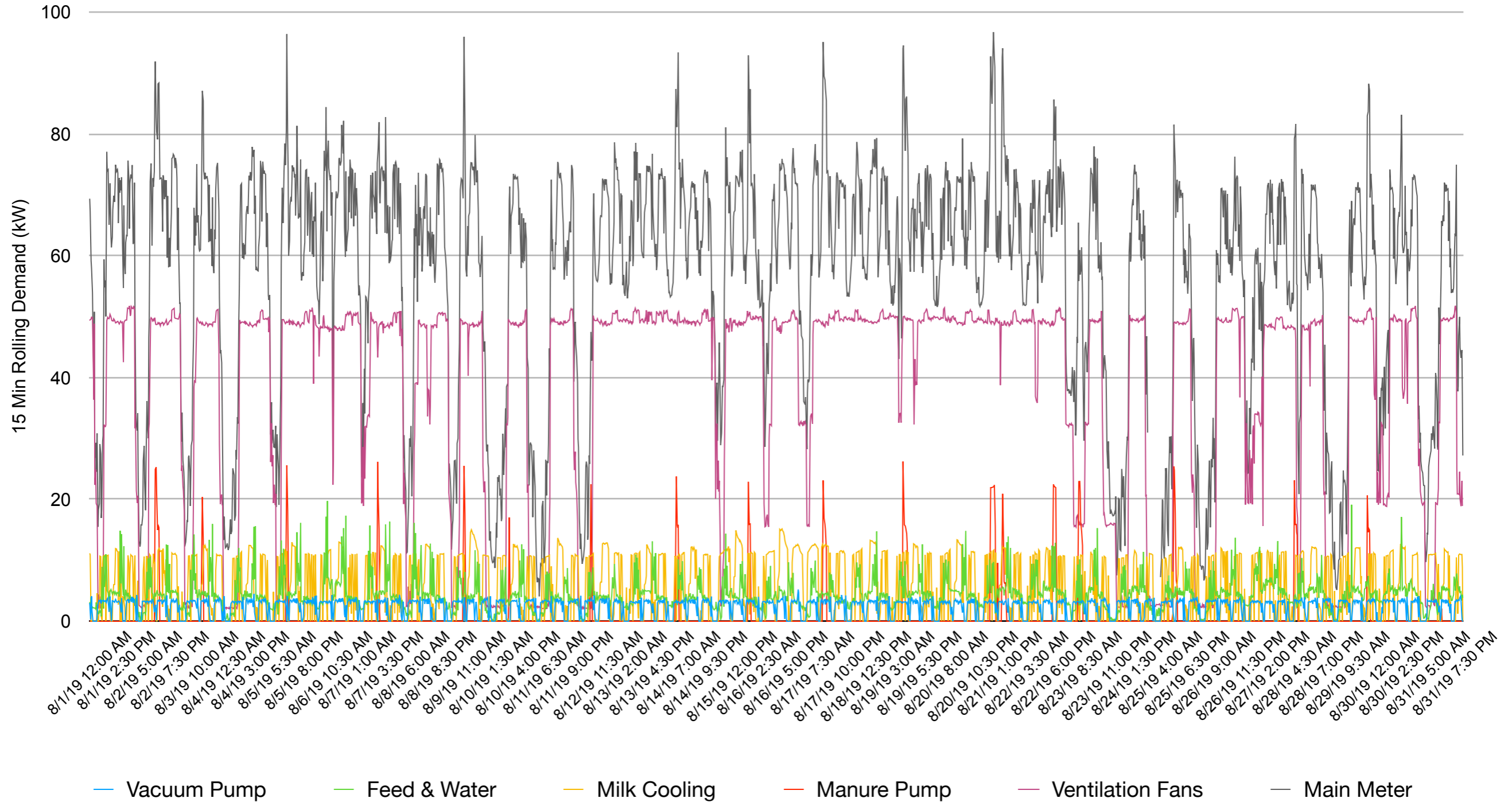


SDEM Dairy 15-Minute Demand Profile: Peak Day - July 15, 2019

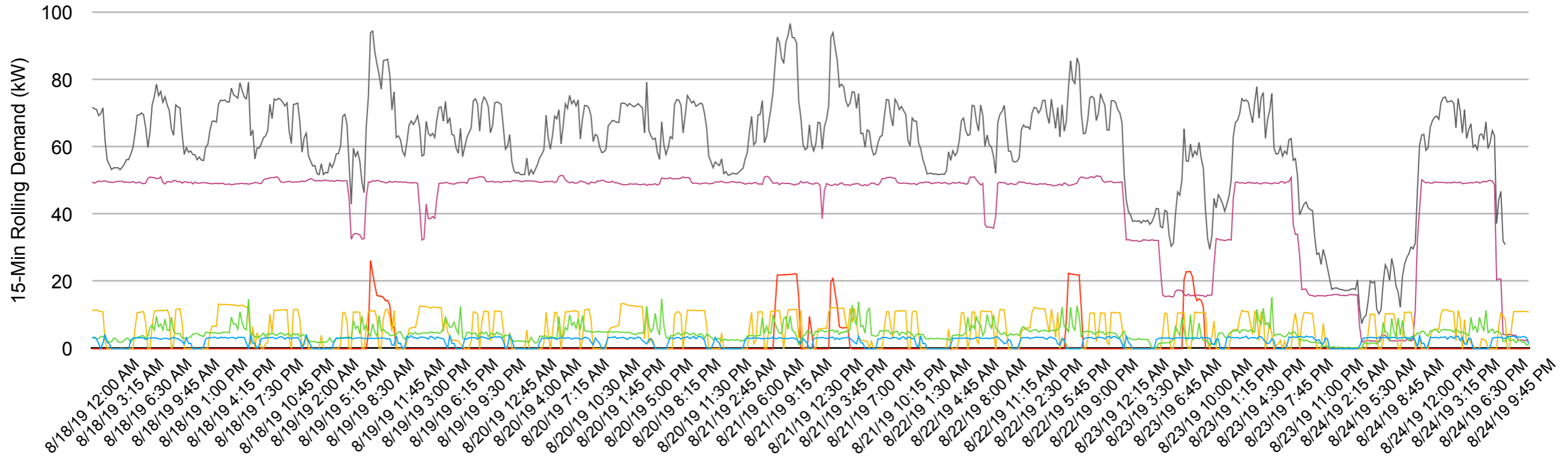


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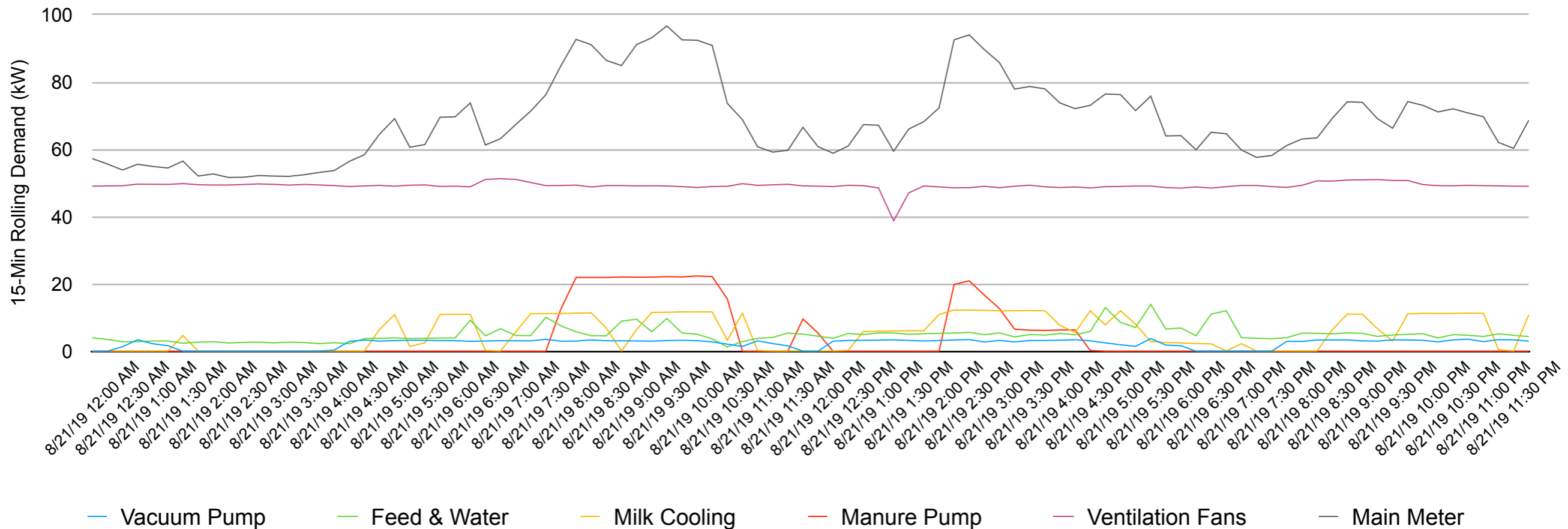
SDEM Dairy 15-Minute Demand Profile - August 2019



SDEM Dairy 15-Minute Demand Profile: Peak Week - August (18-24) 2019

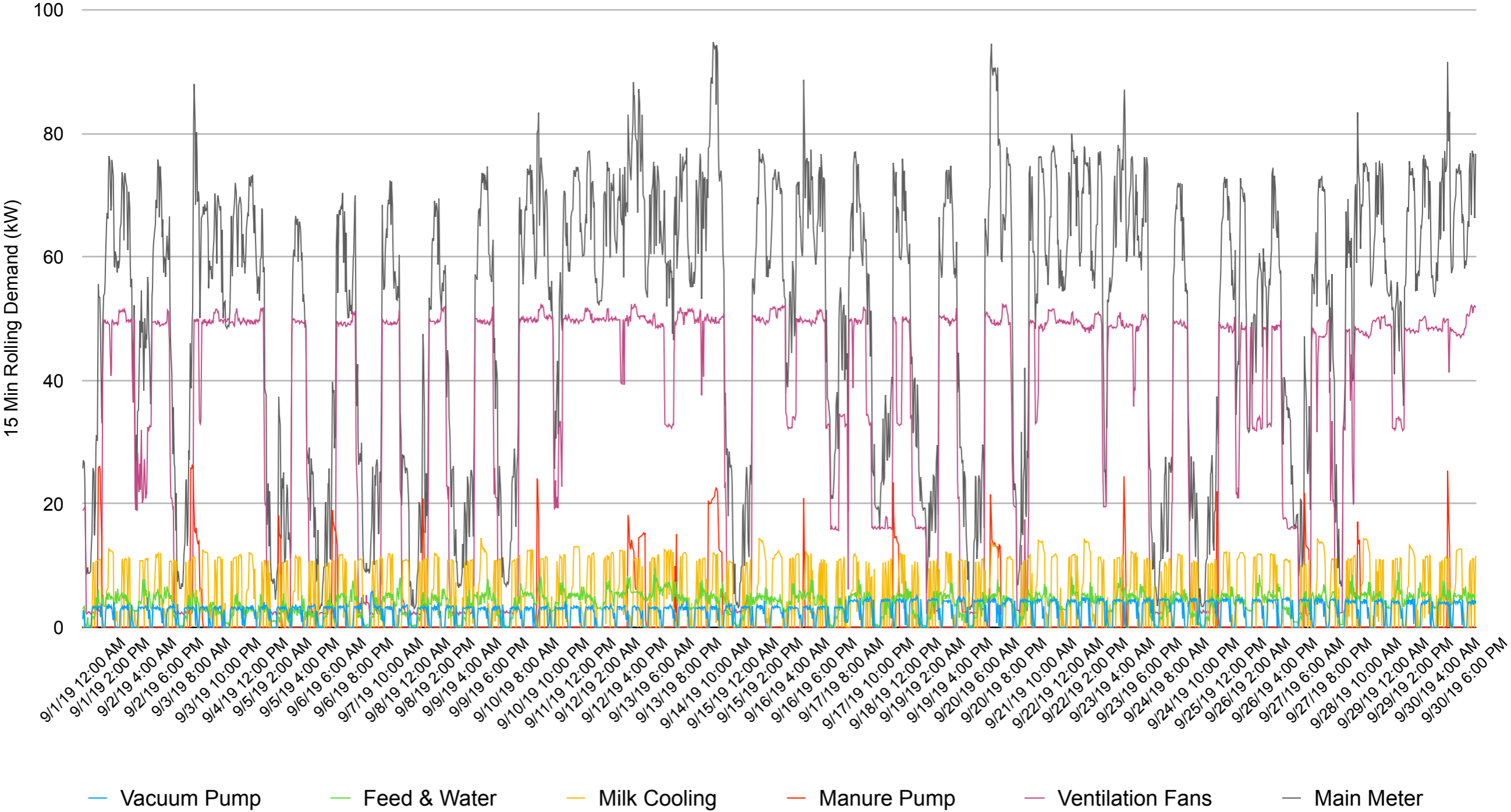


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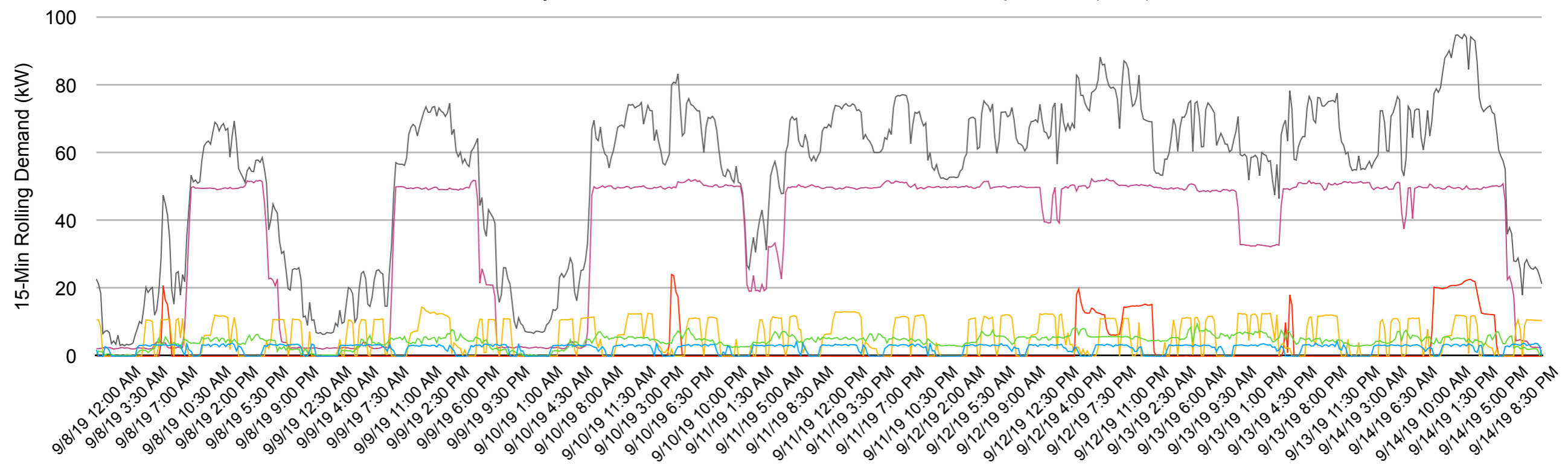


SEPTEMBER 2019

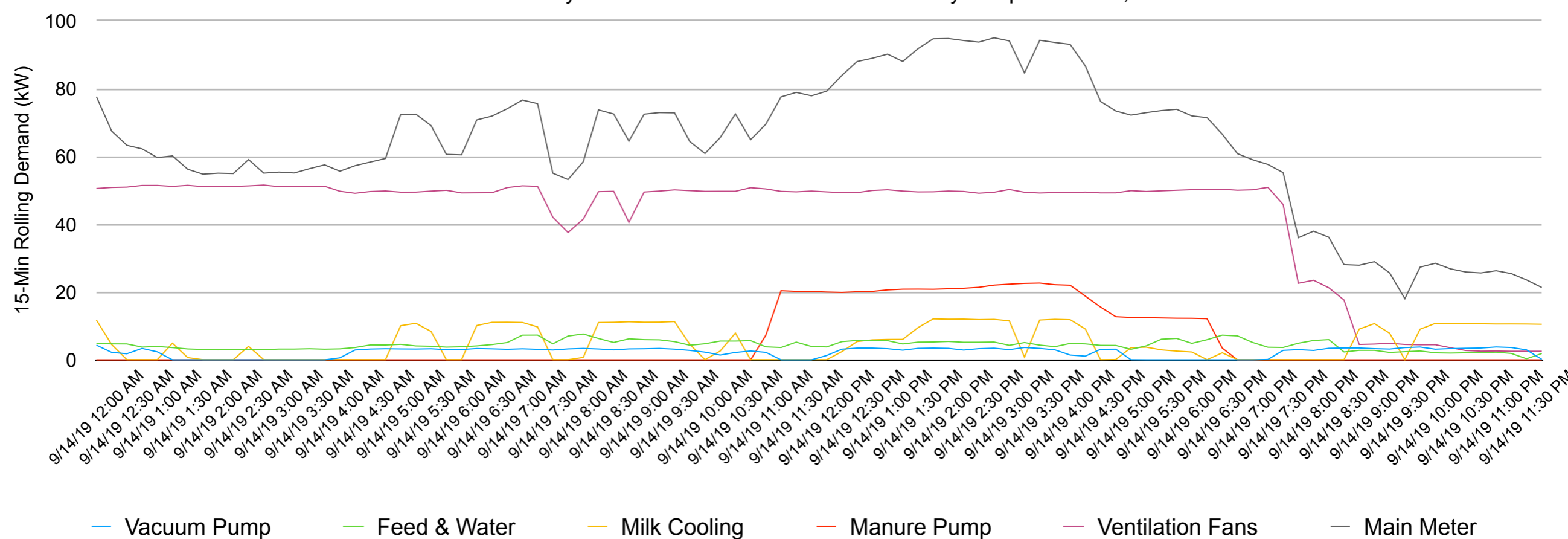
SDEM Dairy 15-Minute Demand Profile - September 2019



SDEM Dairy 15-Minute Demand Profile: Peak Week - September (8-14) 2019

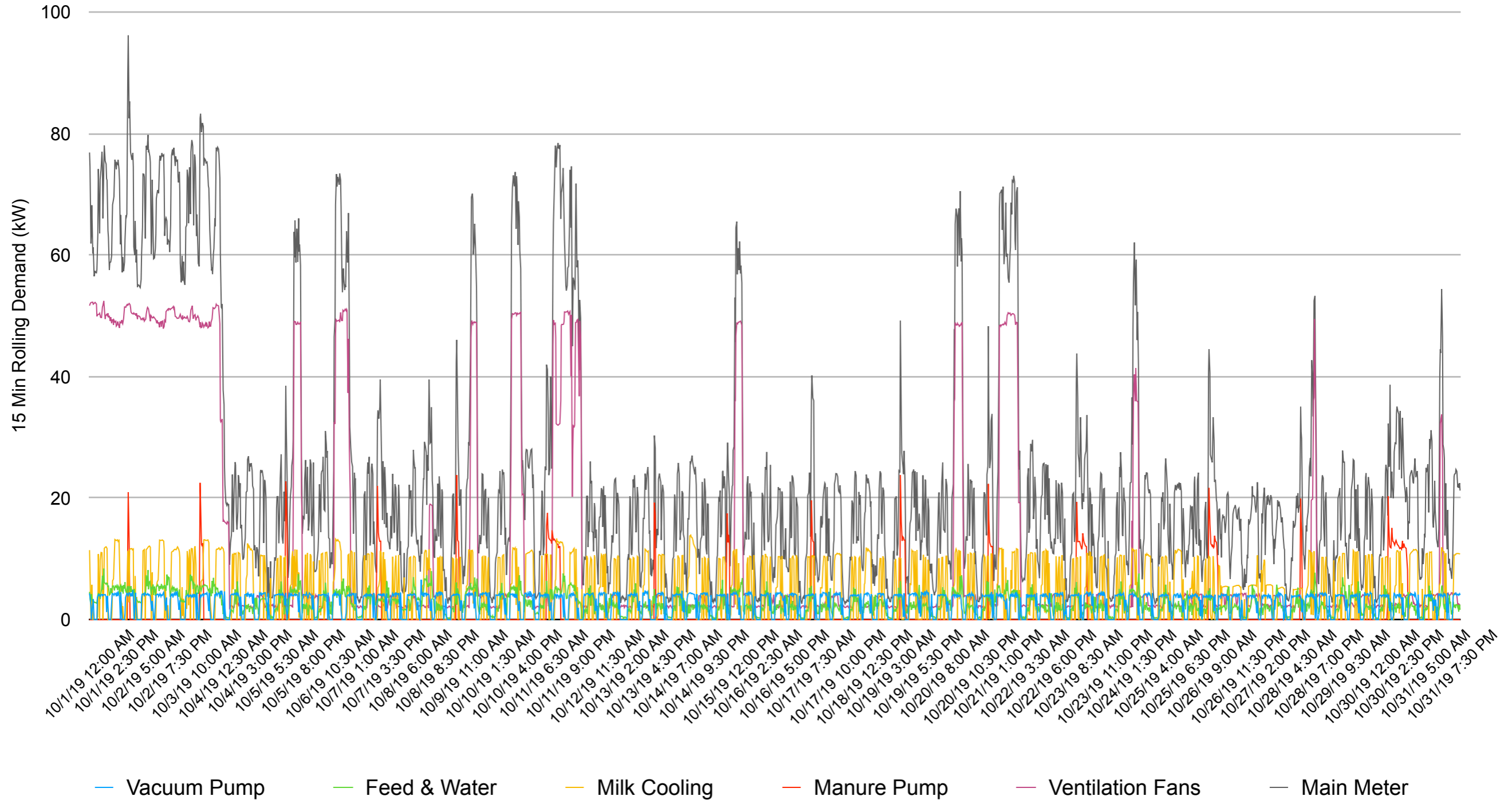


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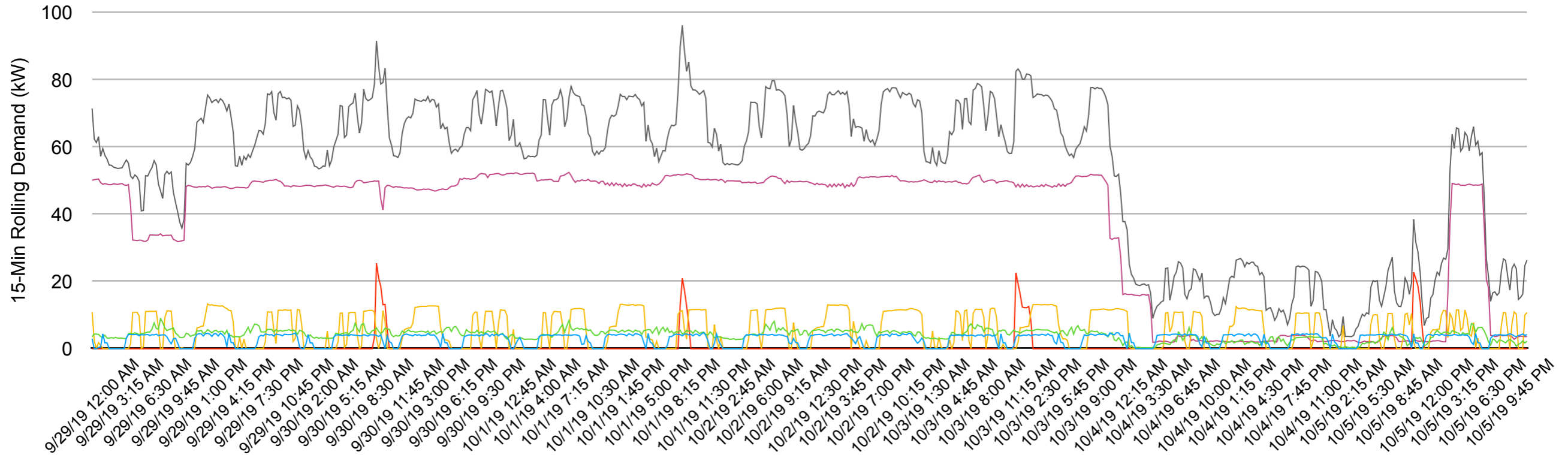


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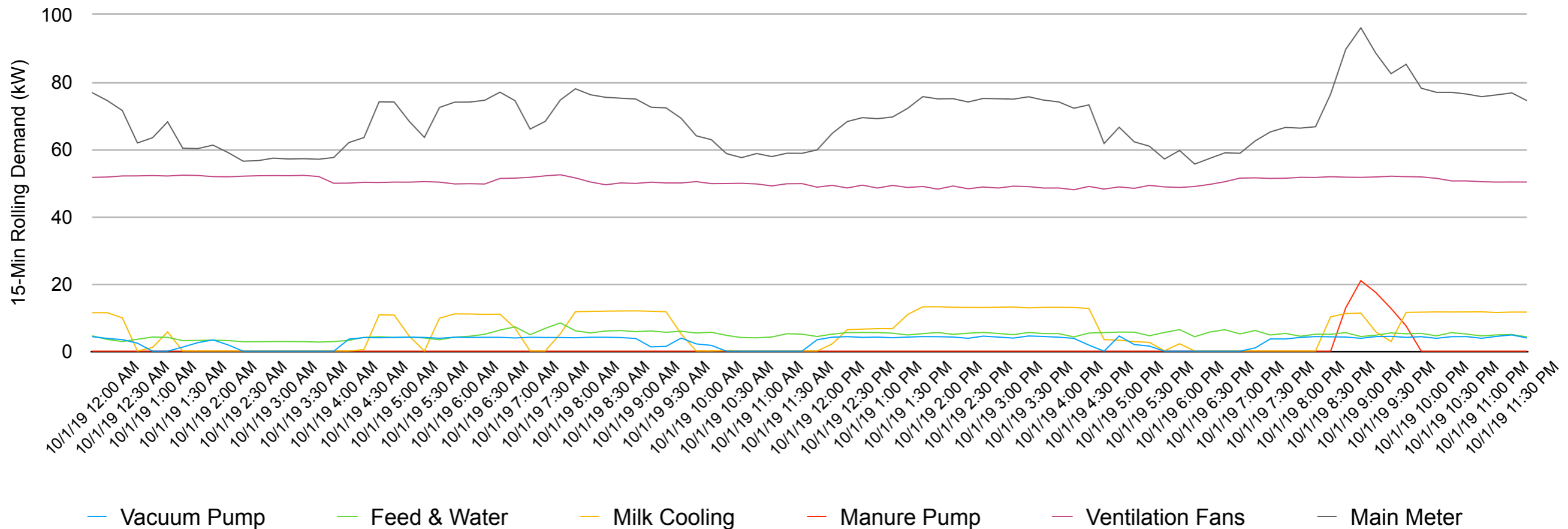
SDEM Dairy 15-Minute Demand Profile - October 2019



SDEM Dairy 15-Minute Demand Profile: Peak Week - October (1-5) 2019

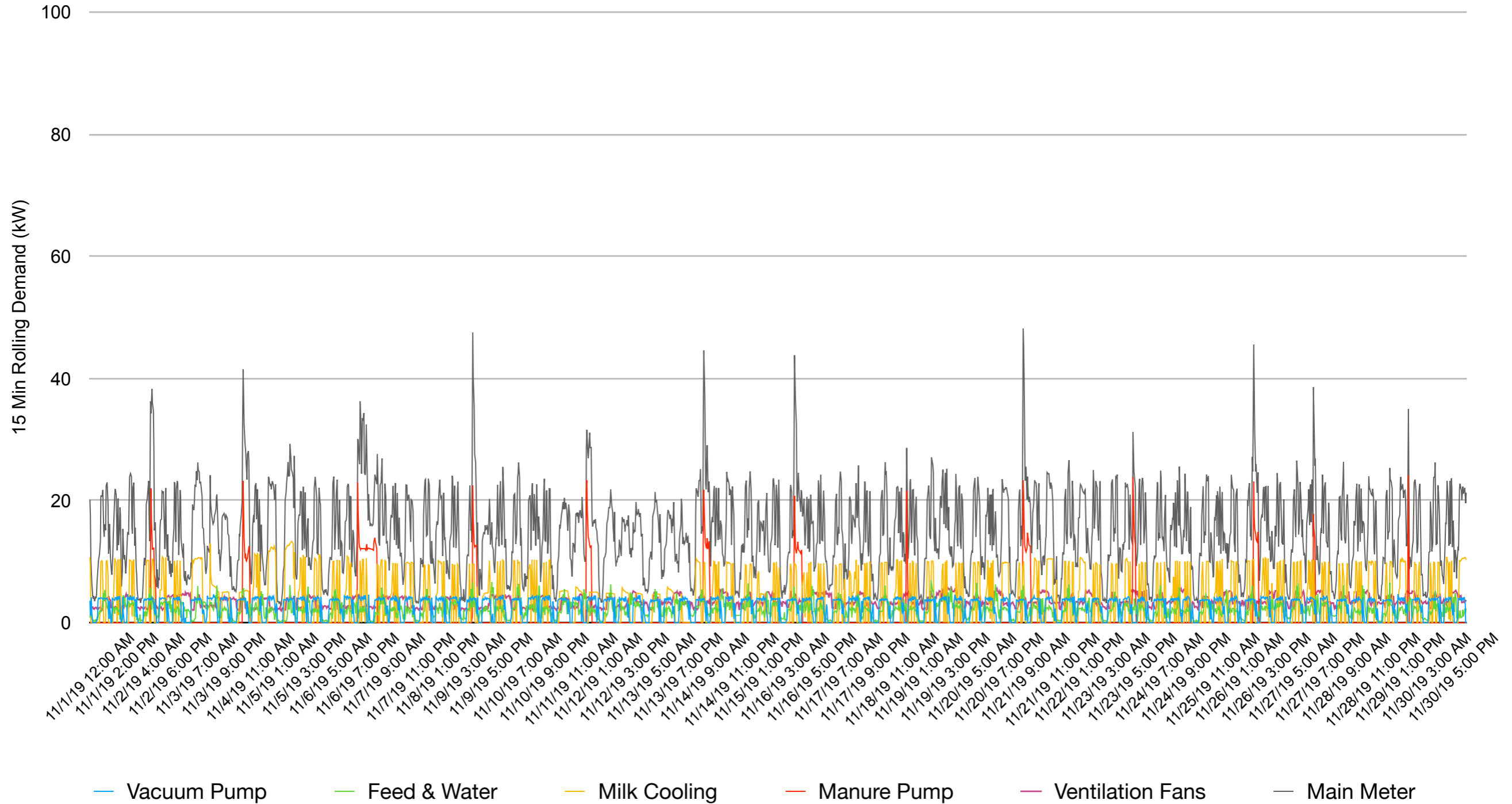


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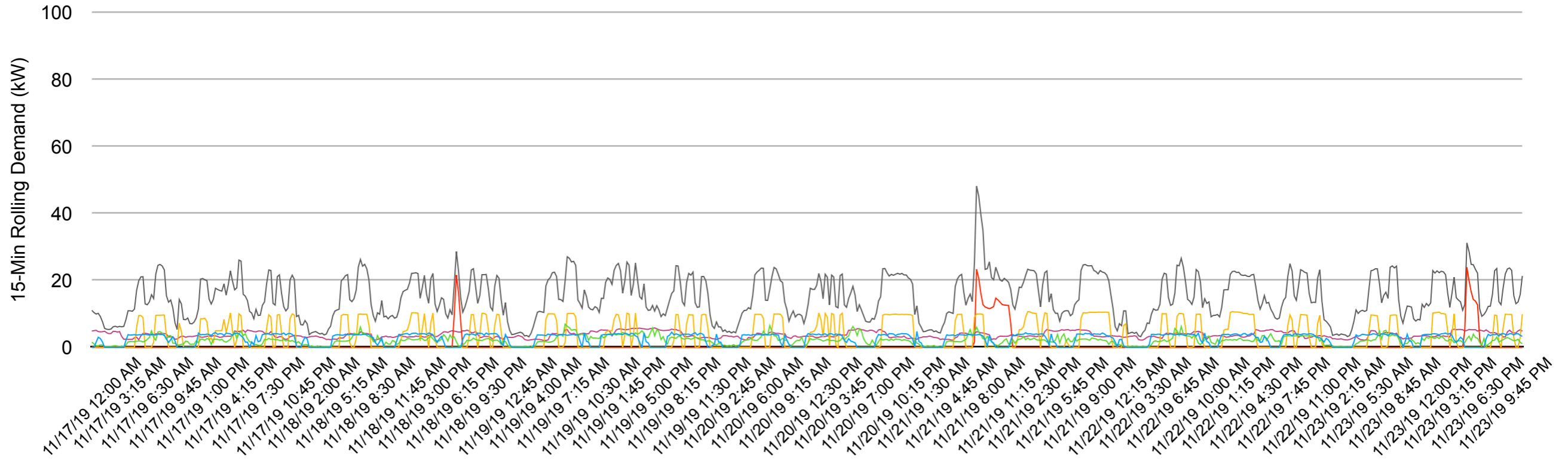


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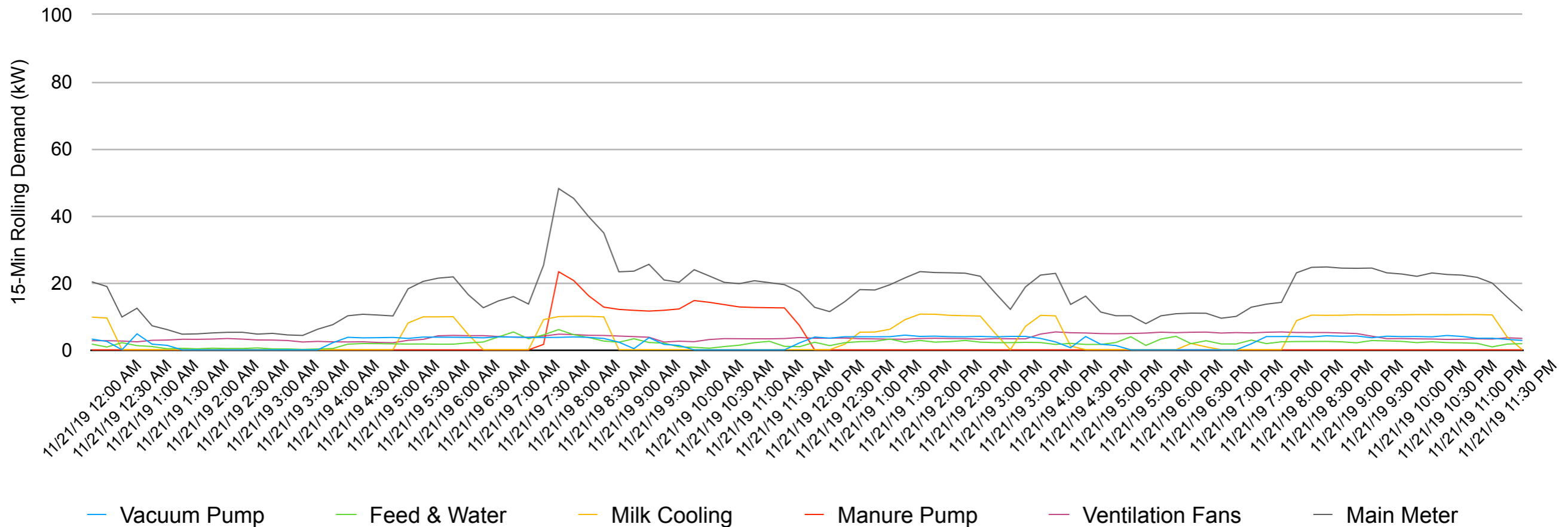
SDEM Dairy 15-Minute Demand Profile - November 2019



SDEM Dairy 15-Minute Demand Profile: Peak Week - November (17-23) 2019

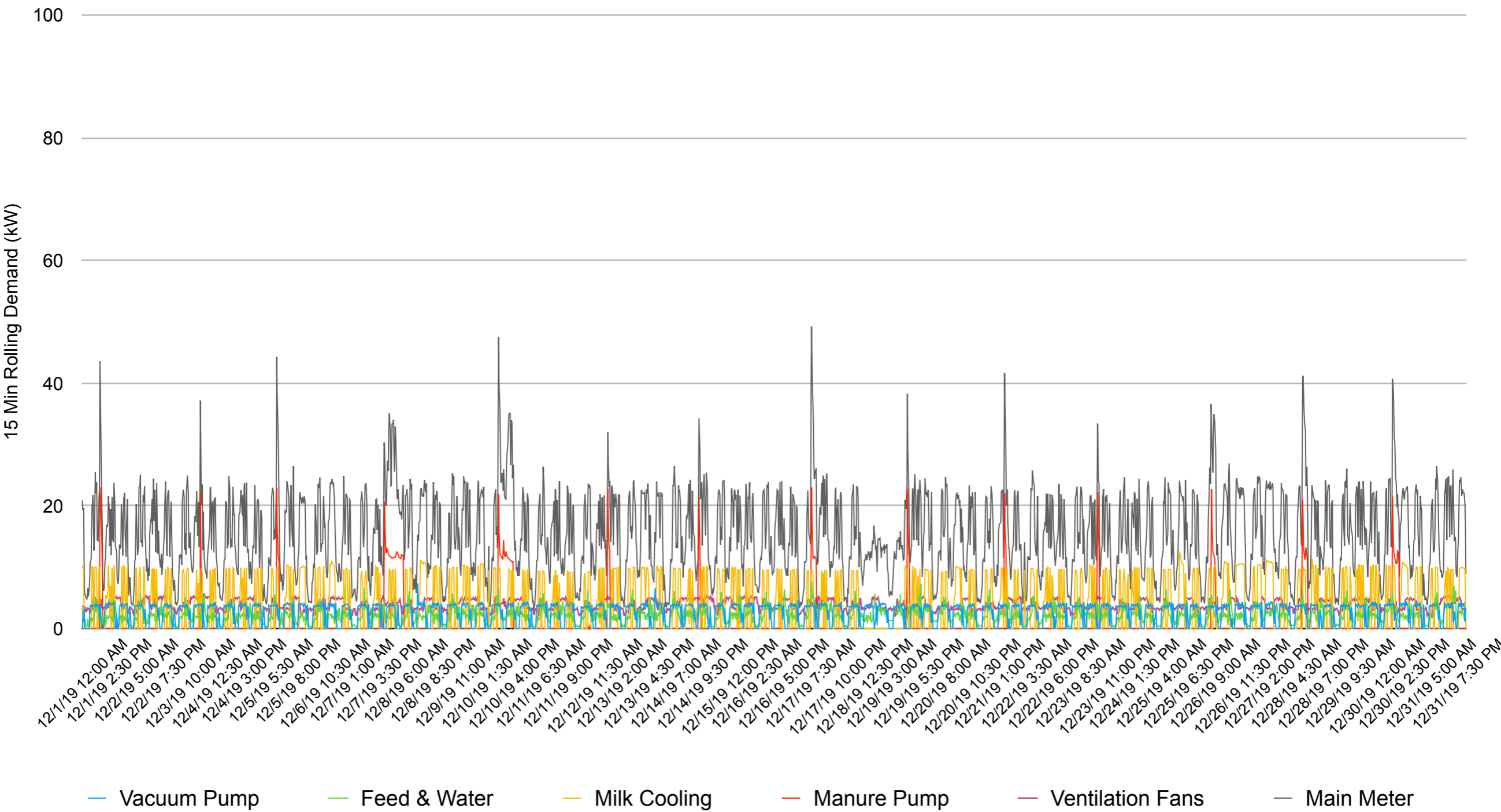


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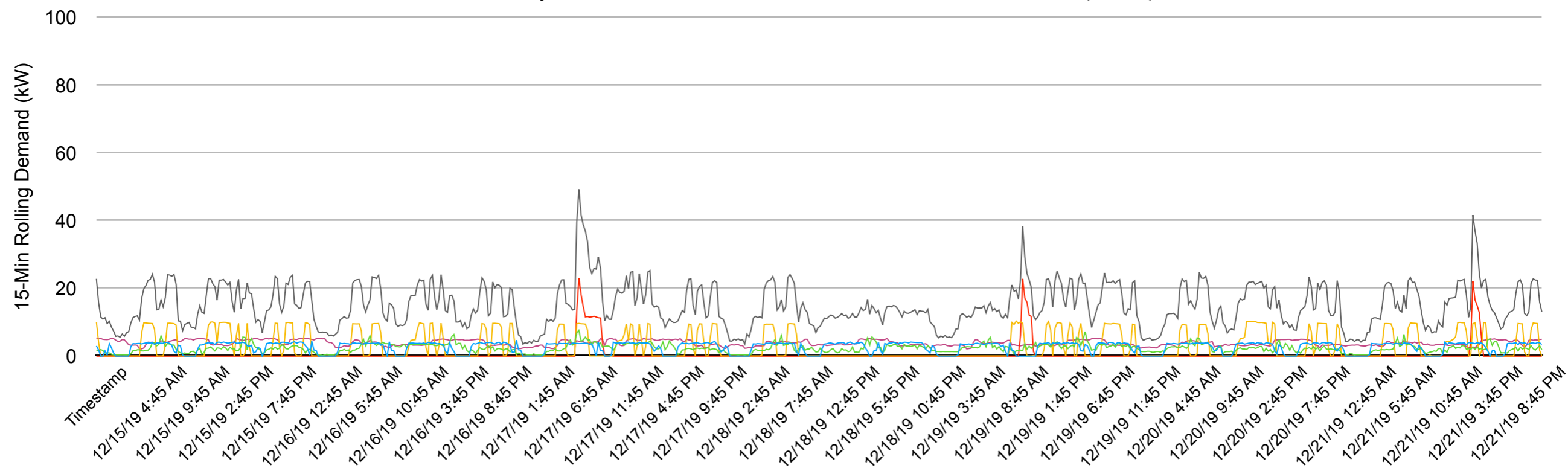


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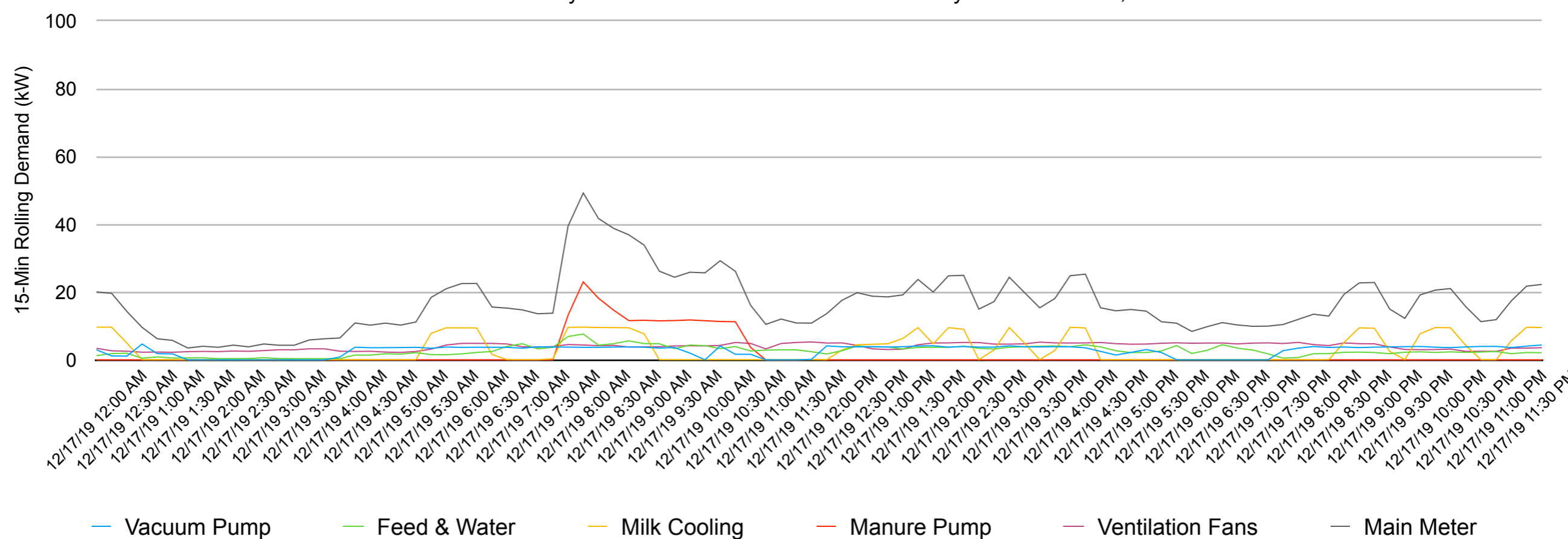
SDEM Dairy 15-Minute Demand Profile - December 2019



SDEM Dairy 15-Minute Demand Profile: Peak Week - December (15-21) 2019

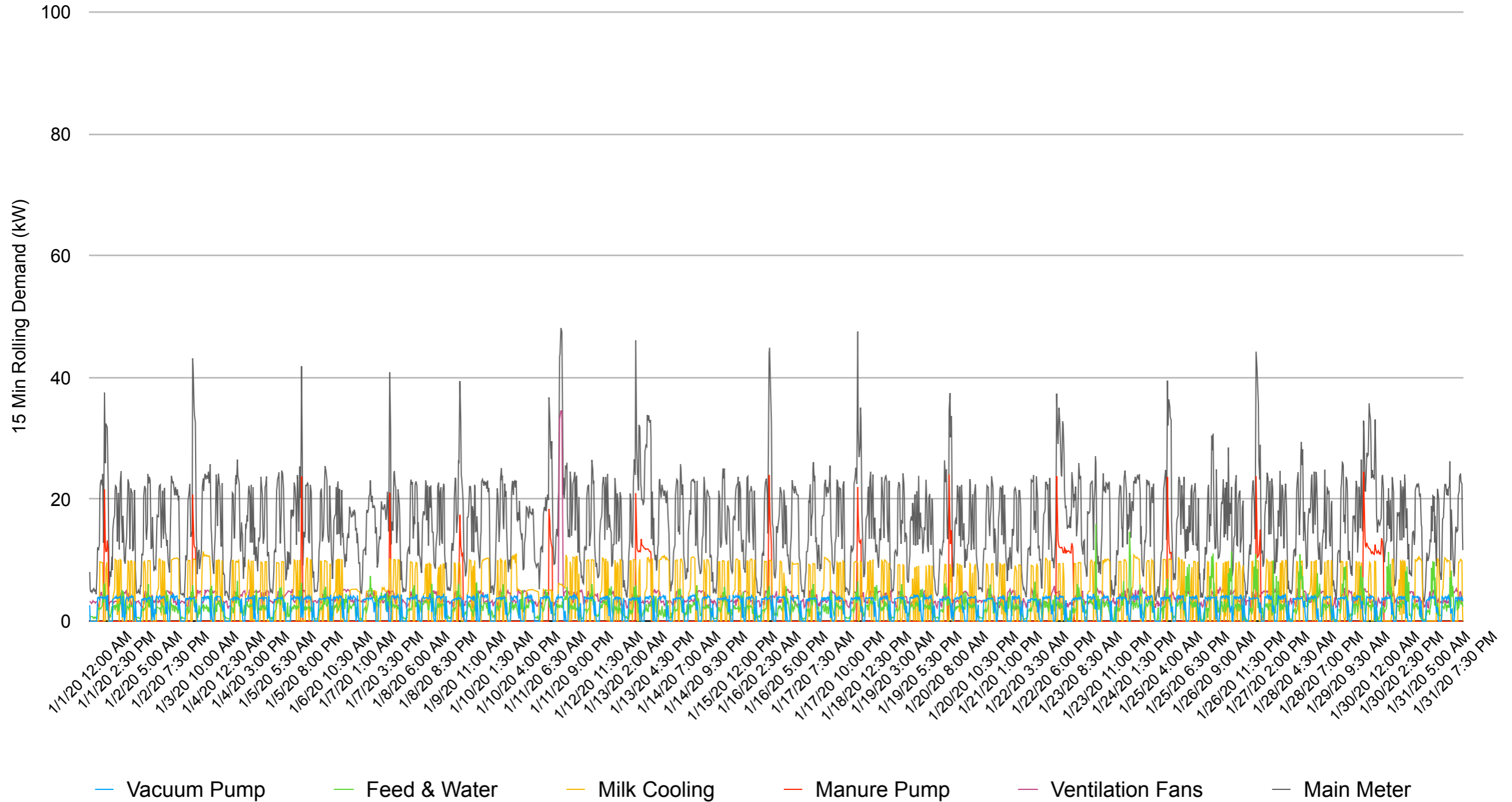


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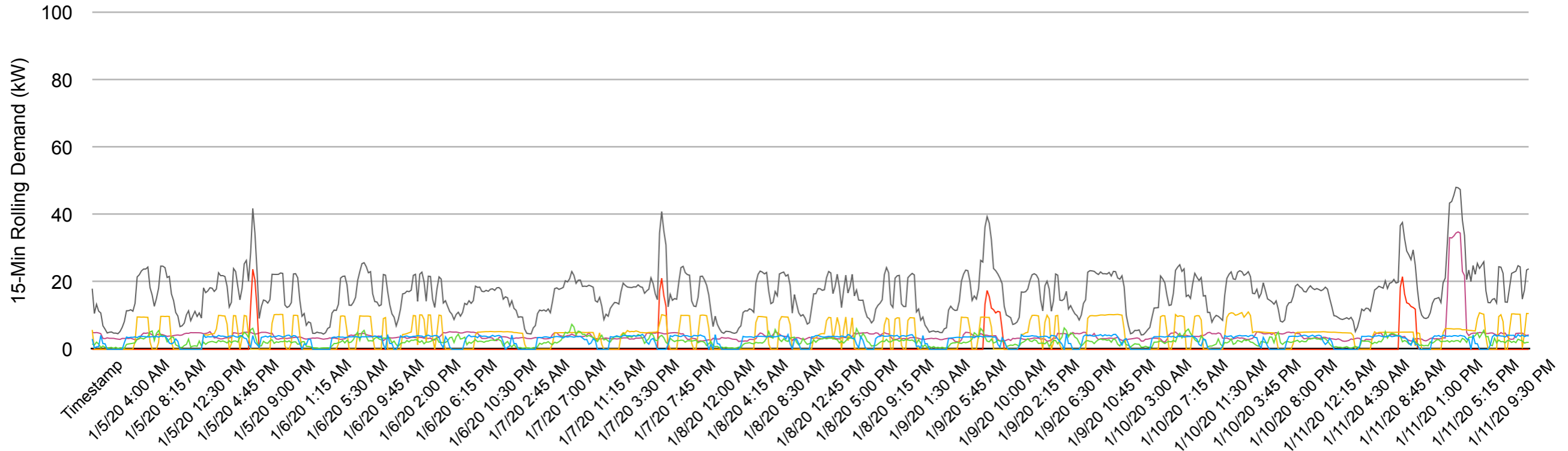


JANUARY 2020

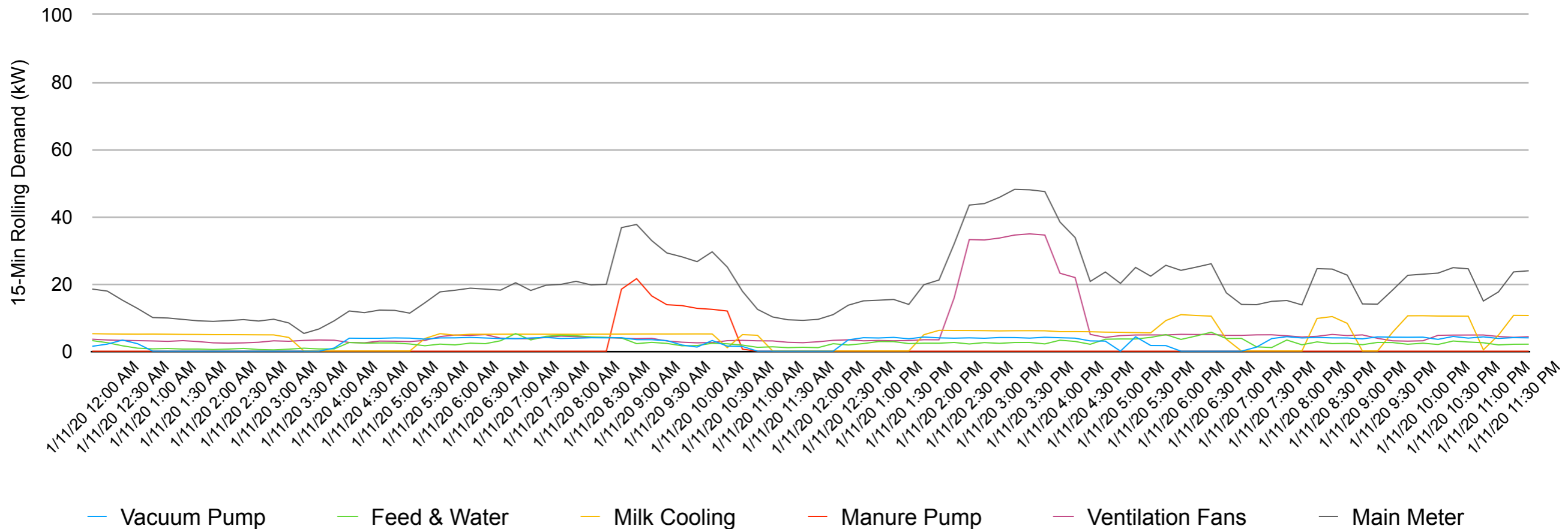
SDEM Dairy 15-Minute Demand Profile - January 2020



SDEM Dairy 15-Minute Demand Profile: Peak Week - January (5-11) 2020

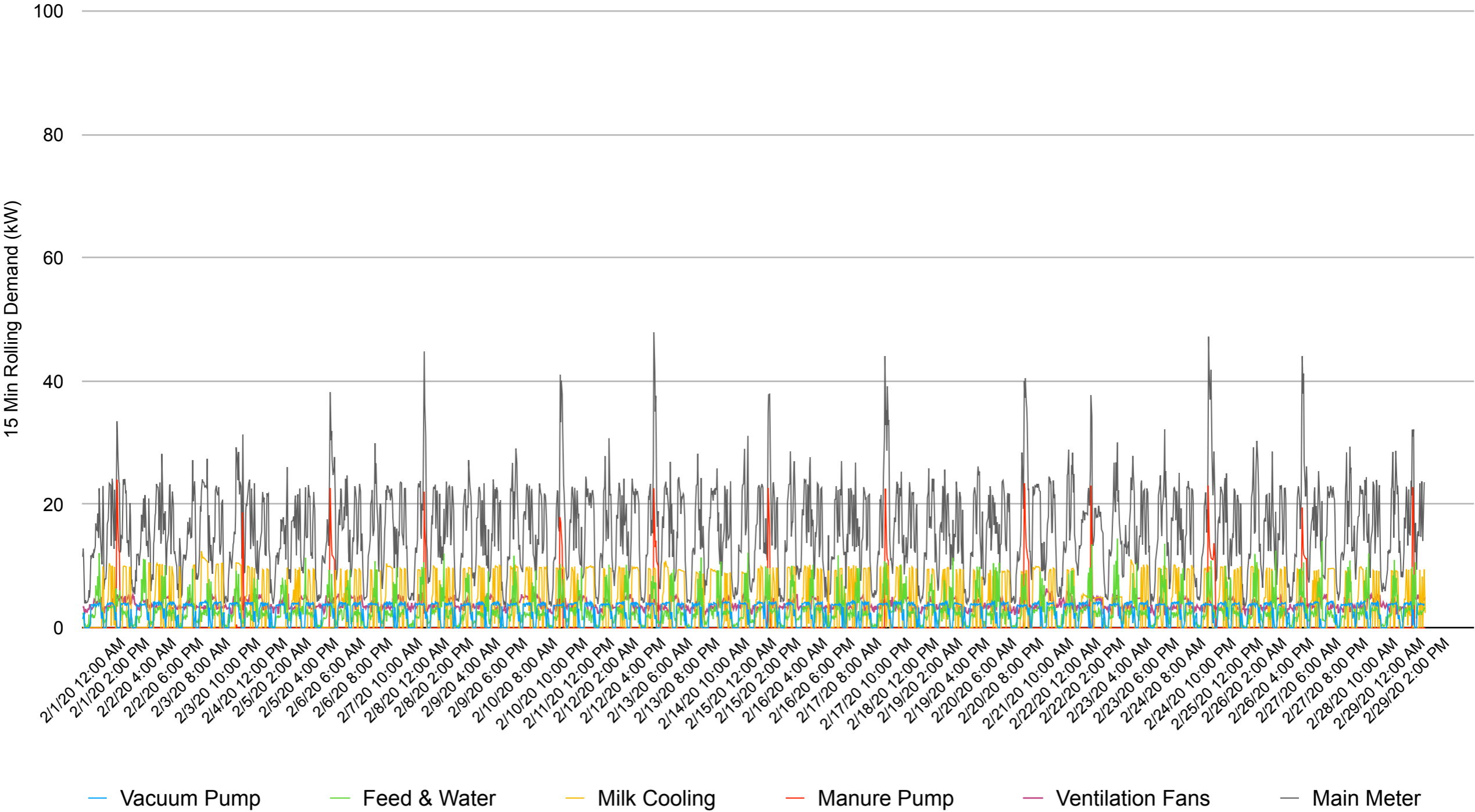


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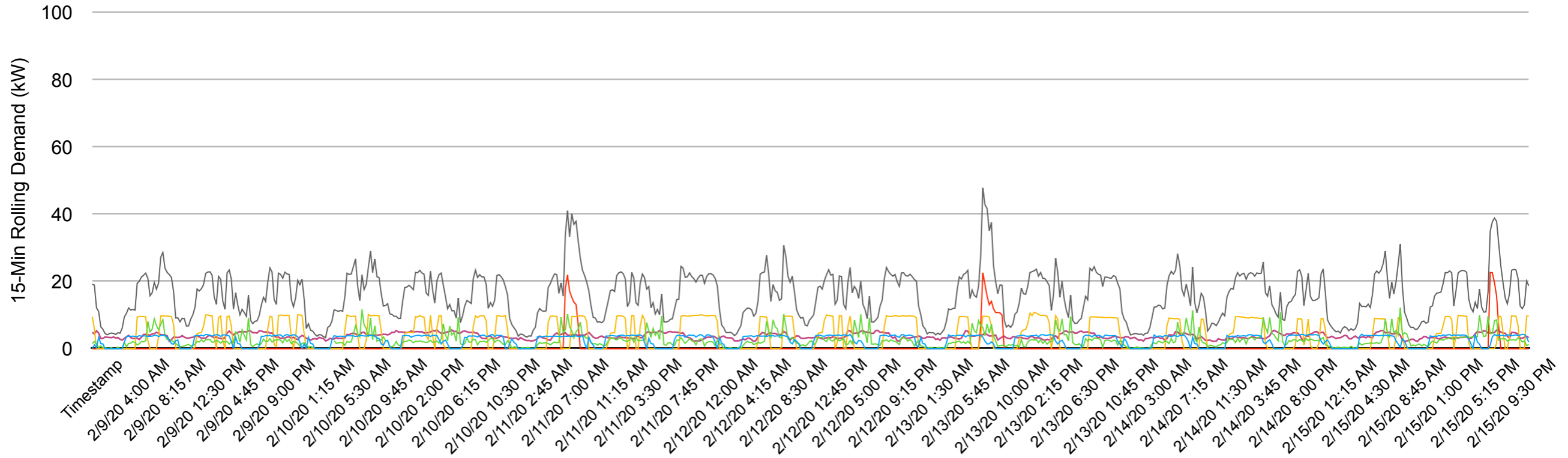


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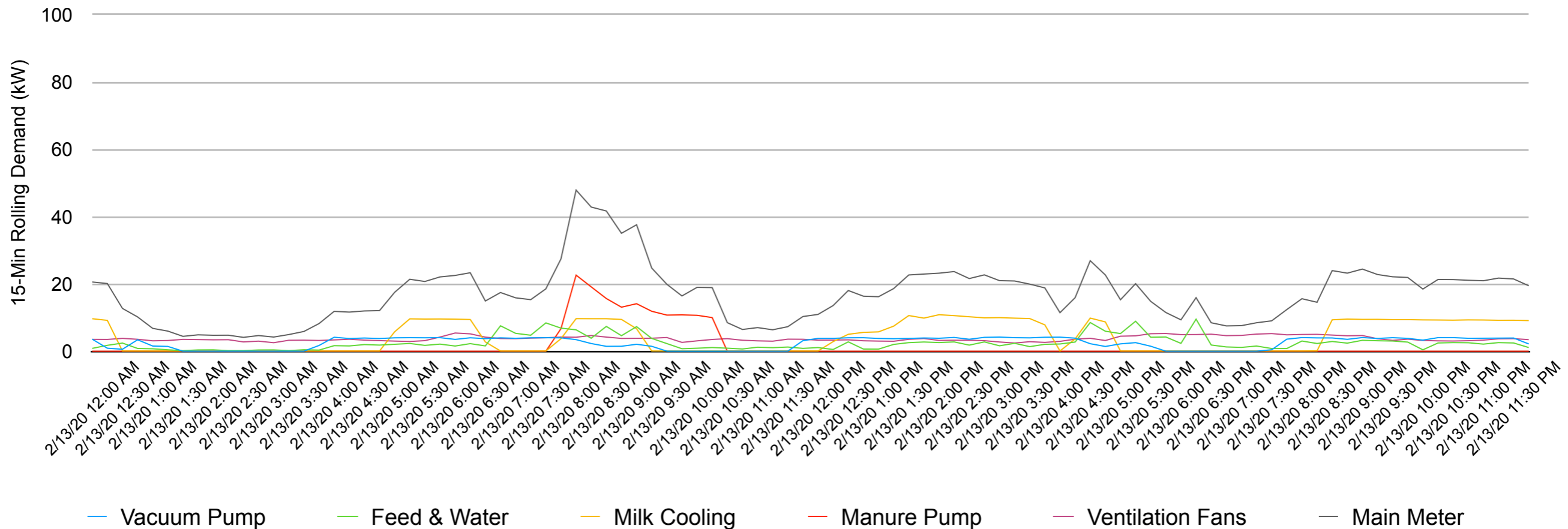
SDEM Dairy 15-Minute Demand Profile - February 2020



SDEM Dairy 15-Minute Demand Profile: Peak Week - February (9-15) 2020

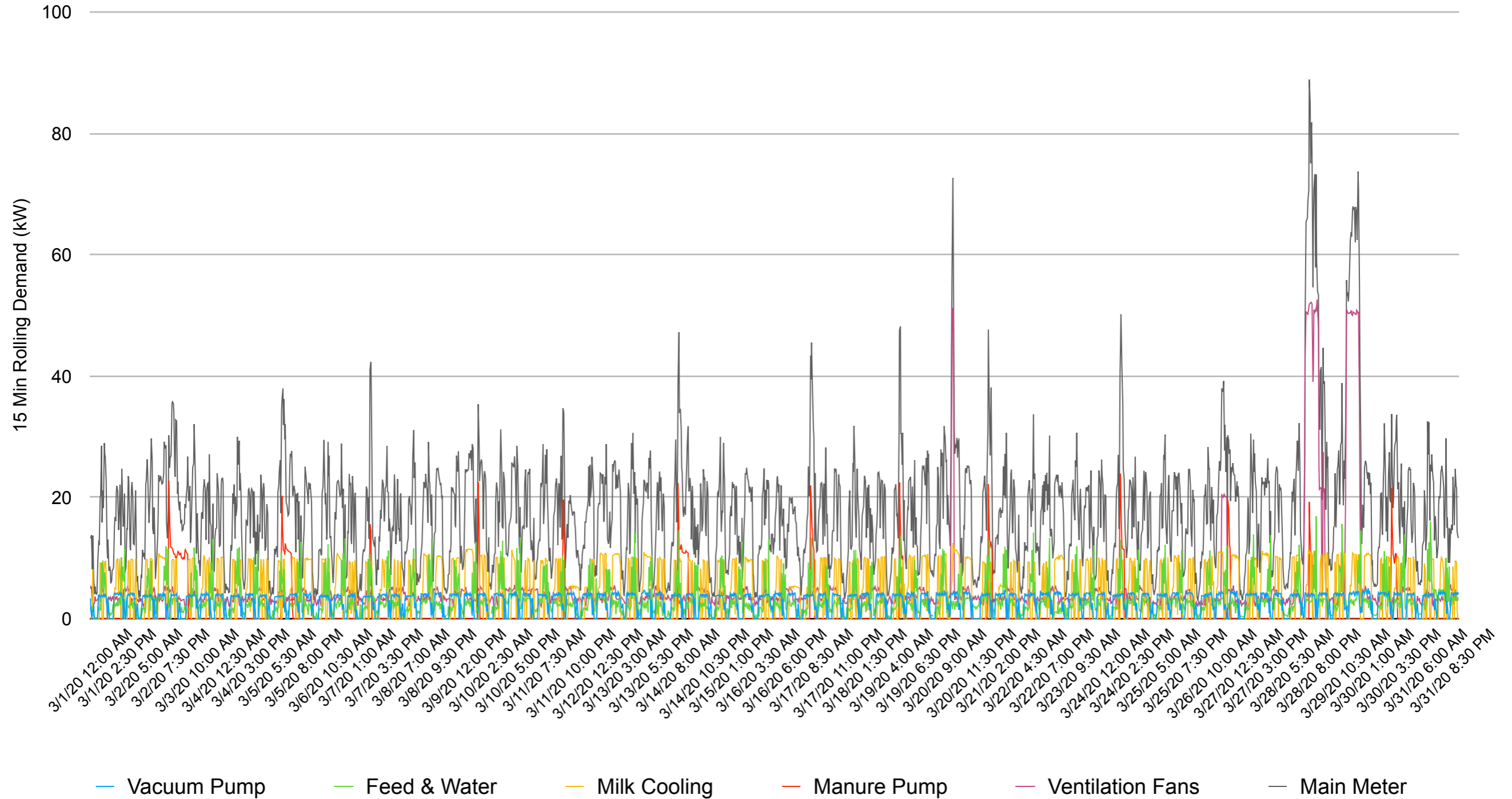


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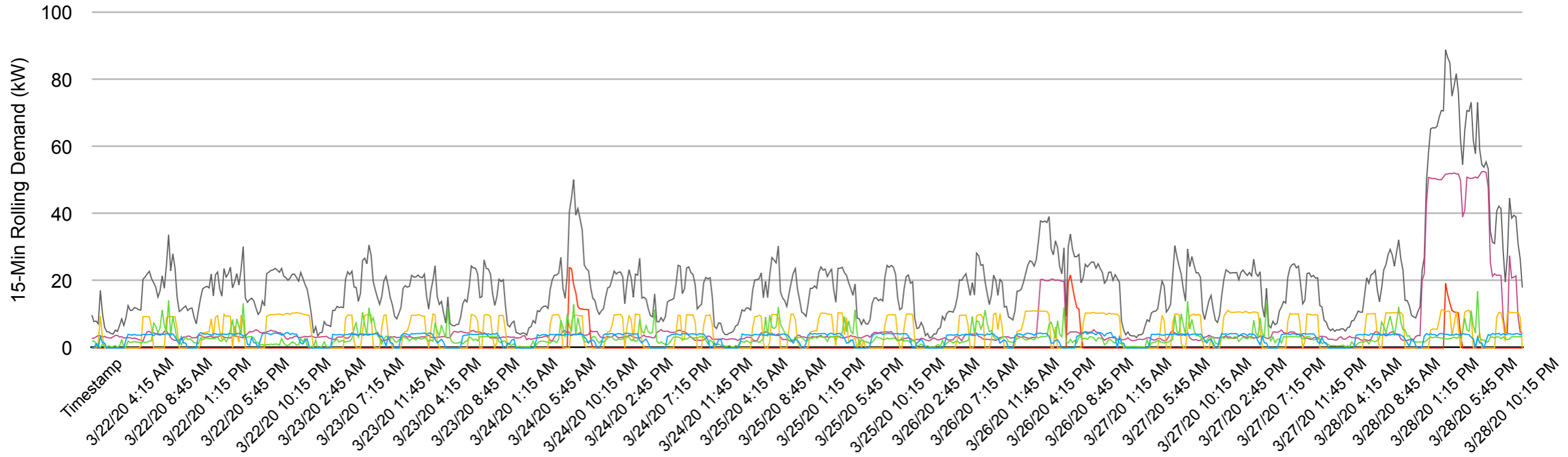


MARCH 2020

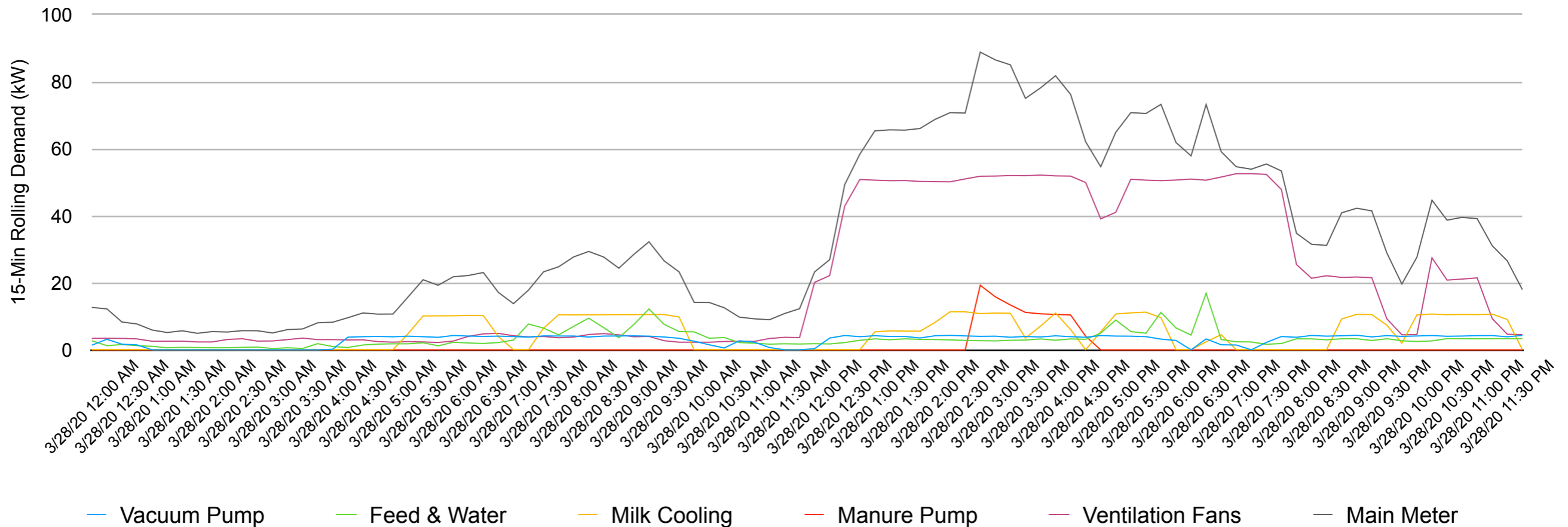
SDEM Dairy 15-Minute Demand Profile - March 2020



SDEM Dairy 15-Minute Demand Profile: Peak Week - March (22-28) 2020



SDEM Dairy 15-Minute Demand Profile: Peak Day - March 28, 2020



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