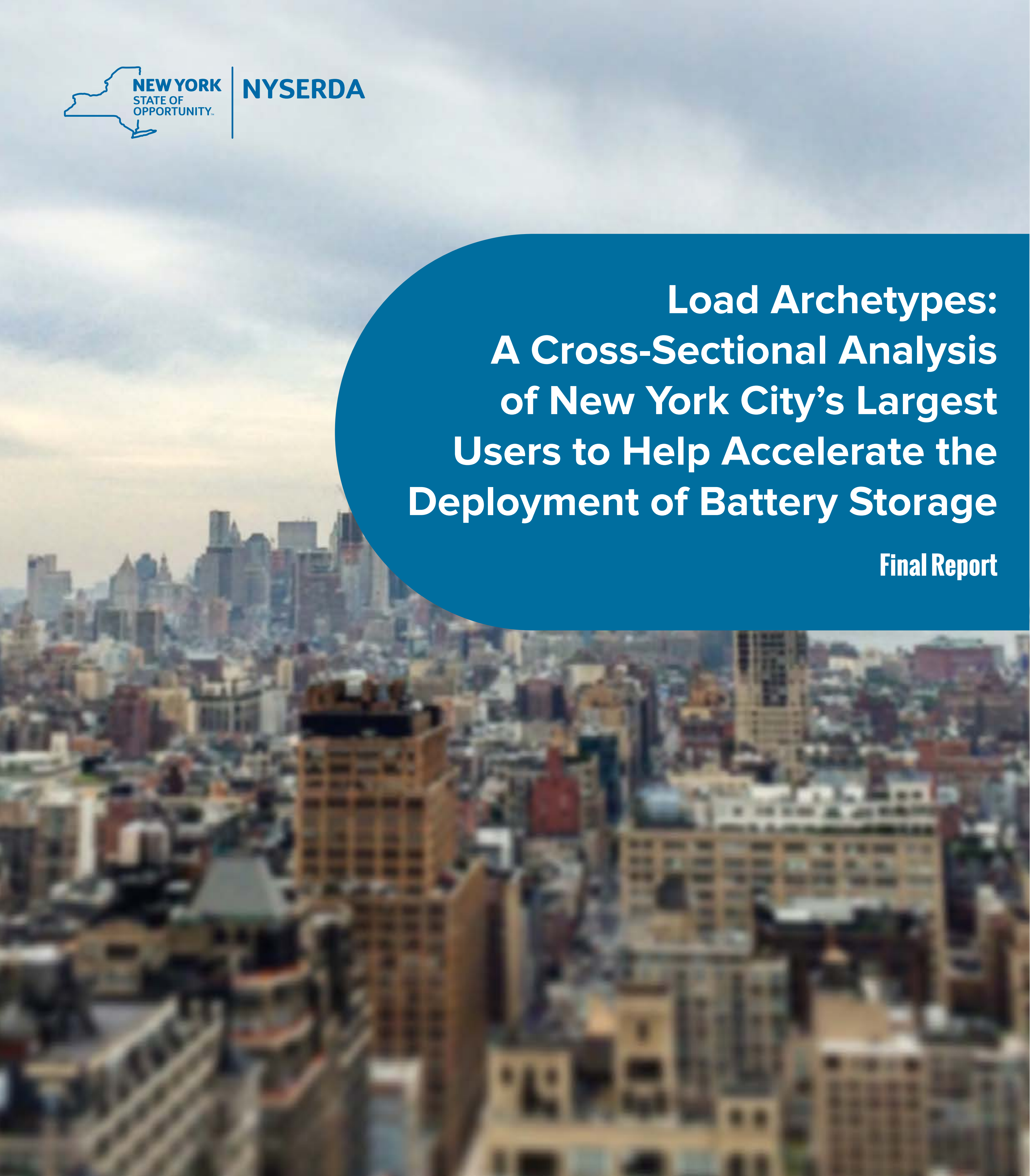

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Load Archetypes: A Cross-Sectional Analysis of New York City's Largest Users to Help Accelerate the Deployment of Battery Storage

Final Report

August 2016

Report Number 16-21

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NYSERDA provides resources, expertise, and objective information so New Yorkers can make confident, informed energy decisions.

Mission Statement:

Advance innovative energy solutions in ways that improve New York's economy and environment.

Vision Statement:

Serve as a catalyst – advancing energy innovation, technology, and investment; transforming New York's economy; and empowering people to choose clean and efficient energy as part of their everyday lives.

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Load Archetypes: A Cross-Sectional Analysis of New York City’s Largest Users to Help Accelerate the Deployment of Battery Storage

Final Report

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Notice

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Acronyms and Abbreviations

BESS	Battery Energy Storage System
CRE	Commercial Real Estate
HVAC	Heating Ventilation & Air Conditioning
kW	Kilowatt
kWh	Kilowatt-hour

Executive Summary

Battery energy storage systems (BESS) are poised to become an integral part of New York State's vision for a clean, distributed, and affordable energy sector. To support the growth of the BESS across New York, this paper seeks to explore how variation in buildings' energy demand categorizes them into distinct "load archetypes", and how those archetypes can inform the design of BESS for managing peak demand and optimizing load at a given site.

An analysis of a calendar year's worth of 15-minute or hourly load data found that five distinctive load archetypes emerged: commercial real estate, multifamily residential, manufacturing/industrial, education, and healthcare—each with distinctive characteristics that have direct impact on how BESS solutions providers design system for a given site's needs. The analysis of how peak intensity, duration, and frequency vary both across and within load archetypes presented in this report is anticipated to be of utility to BESS manufacturers, technology providers, project developers, software designers, etc.

The report then analyzes the myriad site-specific conditions observed across sites assessed by GridMarket for suitability for energy storage, and catalogues the types of spaces typically available for siting BESS assets. For each typical location a discussion of the primary physical factors that characterize the opportunity for BESS deployment, such as space, weight bearing capability, operating temperature, ventilation, fire suppression systems, and proximity to the electrical service, is conducted with the intent of providing solutions providers a broader understanding of actual conditions likely to be experienced.

Analysis of these two groups of data—electrical usage and building characteristics—yields several market insights for the BESS market as it scales, including: Different load archetypes have unique needs; ideal solutions are designed to address peak demand; size energy capacity to cover twice the peak duration; and, modular solutions offer the greatest flexibility in space constrained sites. These insights may not apply in every specific BESS project, but as a rule of thumb they offer guidance as BESS manufacturers, technology providers, project developers, software designers, and other stakeholders continue to approach the task of integrating BESS to meet New York State's evolving energy vision.

1 Introduction

The “peakiness” of a building’s load profile is the extent to which that load profile experiences spikes in demand relative to its baseline energy consumption. It is well known that the peakiness is a determining factor for designing how energy storage solutions optimize load at a given location. Analyzing a building’s 15-minute interval data can provide insight into the nature of these peak demand spikes, and inform energy storage technology providers as they develop products that can effectively meet customer needs.

Within a majority of building use classes, real-time demand for power will fluctuate, based on usage. For example: occupancy levels ebb and flow; equipment use cycles vary across hours of the day, days of the week, and weeks of the year; and seasonal heating and cooling needs must be addressed. Analyzing the interval data, comparing patterns within use categories, and extrapolating beyond the data set helps to create generalized load archetypes, which are use cases that conform to similar operational patterns within a given grouping. Technology providers use these archetypes to design energy storage solutions that meet the specifics of each customer classification’s needs.

This report describes how 15-minute and hourly interval data from individual buildings inform the nature of peak demand spikes relative to the general load profile. The data sets are registered in the GridMarket project portal. Energy storage solutions providers can find patterns in these data sets and incorporate those parameters when developing targeted products for behind-the-meter market segments.

Analysis of the GridMarket sample indicated various load archetypes across the large energy users. The primary load archetypes observed include: commercial real estate, multifamily residential, industrial/manufacturing, and healthcare facilities. Each load archetype conforms to an even narrower set of defining parameters. Although each load archetype is distinct, there are opportunities for modular storage solutions that address the distinctive characteristics of each one.

However, understanding how an appropriately sized energy storage system is installed and interconnected at a given site is equally as important as understanding how the parameters of each load archetype informs energy storage solutions.

At present, finding the “sweet spot” between load reduction potential and the appropriate physical infrastructure at the site is crucial to successfully deploying battery energy storage solutions (BESS), and can be the limiting factor when considering which BESS are appropriate for a given site. As each battery chemistry has its own discrete set of physical characteristics, each requires a different set of physical infrastructure needs be present for successful installation at a given site.

In addition to these physical infrastructure factors that shape the opportunity to deploy energy storage, additional nonelectric factors such as current and available tariff structures, customer financial position, and ability to access financing are all equally important when determining the viability of BESS at a site.

The report analyzes the physical findings that have been observed through the walkthroughs conducted by GridMarket across the data set to inform what the typical physical challenges and opportunities are for each load archetype. Although every building offers a distinctly unique opportunity, patterns are discernable as pertains to the typical location of available space, and the quality of that space for deploying energy storage.

2 Methodology and Assumptions

The following assumptions, methods, and limitations were used to prepare, analyze, and summarize the building interval data for the purpose of this analysis.

2.1 Interval Data

Interval data is the primary building block of analyzing the load profiles of the buildings that comprise this analysis, so it is important to note how interval data was normalized for analysis. Because not all of the building data gathered was in the same resolution, where necessary, 60-minute interval data was normalized into 15-minute intervals to be comparable to larger the data set.

Each building's annual data set was randomized, and three days per calendar week were isolated for analysis. To achieve this task, each day and its corresponding building data set was assigned a randomly generated number, ranked from highest to lowest (on a weekly basis) and the top three were selected for the analysis. This was inclusive of both weekdays and weekends. Data corresponding to the top 4-7 ranking was discarded from the analysis.

To depress the influence of different building types energy usage profile, the data set from above was further cleaned up by the removal of all data sets that included weekends. A formula was created in the model to discern weekdays (Monday through Friday) from weekends (Saturday and Sunday) based on the data associated with the data. Thus, the final data set utilized included only weekdays across all inputs.

2.2 Granular Data Scrubbing

To achieve a robust quality assurance process, each data set was manually analyzed for metrics like incompleteness, inconsistency, or other discrepancies. If the data had the following characteristics, it was removed from further use:

- There was a month or more of missing or "0" interval data
- Interval data was highlighted in red or labeled as having a power outage during that time frame

For data sets that were almost fully complete but had about a week or less of incomplete or missing data that hindered the analysis of that particular building, those data points were converted to “0.” Overall, it was decided that including such data sets was more valuable to the analysis than removing it for a small number of incomplete data points. Using a conservative approach, the energy usage in kilowatts (kW) for that time period was assumed to be 0, hence overall depressing the final results for that building and not overinflating. Given that a week’s worth of filled in data in the context of a whole year, and aggregated across many building figures, it is assumed that this data change will not have any measurable impact on the results.

2.3 Other Assumptions

Two data sets were used for this analysis: one had data from January to December 2014, and one had data from February 2014 to February 2015. To provide the best comparison, it was decided to use a chronological January to December timeframe. To accomplish this task, the data from the second data source was altered in the following manner: February 2015 data points were removed and January 2015 data was assumed to be representative of the previous years’ data and changed to January 2014. It is understood that this is not an ideal apples-to-apples comparison, but given the disparate data timeframes gathered, it was assumed the final results would not be skewed noticeably and aligning timeframes was more important. In future analyses, it is recommended that the data source be procured from the same time period to the extent possible to avoid needing this assumption in the modeling.

3 Findings

Analyzing the interval data yielded a number of findings regarding the nature of peaks across and within the archetypes. A number of patterns were observable that help define each archetype with respect to its typical peak intensity, peak duration, and peak frequency.

3.1 Intensity

Peak intensity is best understood as the expression of two values:

- Average monthly peak to average load - the ratio of the average monthly peak to the average monthly load.
- Maximum monthly peak to average monthly peak - the ratio of the maximum monthly demand to the average daily peak demand for a given month.

Average monthly peak to average load values provides insight into the order of magnitude between an archetype's average power demand and average daily peak, which gives a sense of how much demand varies in the site on a daily basis, whereas *maximum monthly peak to average monthly peak* values measure of how much an archetype's peak demand can fluctuate relative to its monthly average. Calculating these values across the data set reveals distinctive values for each load archetype as illustrated in Table 1, Figure 1, and Table 2.

Table 1. Average Monthly Peak Intensity

	Manufacturing (n=8)	Healthcare (n=22)	Multifamily (n=19)	Education (n=15)	CRE (n=49)
Summer	2.12	1.16	1.19	1.69	2.12
Winter	1.95	1.16	1.17	1.50	1.95

Looking at trends in the average monthly peak intensity across archetypes, Manufacturing has the highest average peak intensity, approximately two times greater than average load, while healthcare demonstrated the lowest, with average peak intensity only 15% higher than average load. Other archetypes hover in the range of 1.17-1.69 for average monthly peak intensity.

Figure 1. Average Monthly Peak Intensity by Building Load Type

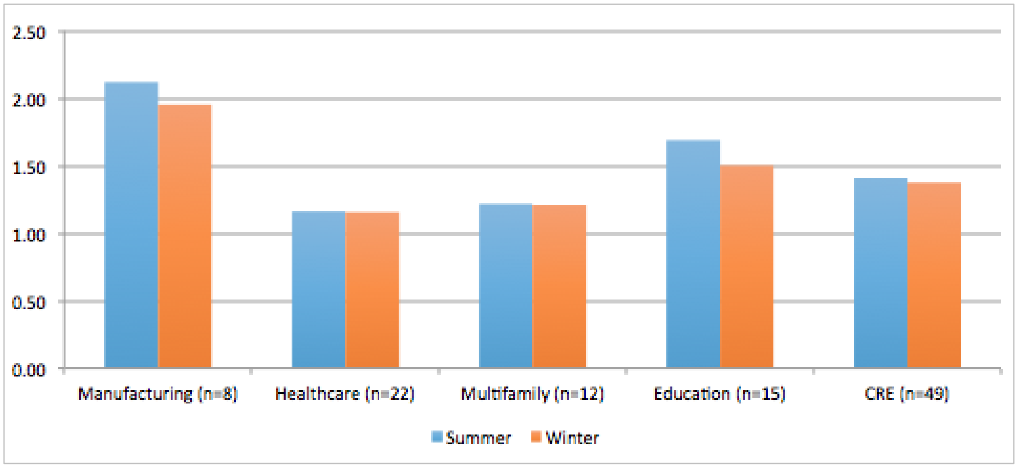


Table 2. Max Monthly Peak to Average Monthly Peak Values

Month/Year	Manufacturing (n=8)	Healthcare (n=22)	Multifamily (n=19)	Education (n=15)	CRE (n=49)
Jan 2014	1.38	1.10	1.10	1.20	1.14
Feb 2014	1.36	1.08	1.06	1.24	1.10
Mar 2014	1.35	1.07	1.07	1.11	1.11
Apr 2014	1.29	1.10	1.08	1.28	1.21
May 2014	1.22	1.12	1.16	1.32	1.20
Jun 2014	1.39	1.11	1.15	1.21	1.16
Jul 2014	1.23	1.10	1.10	1.20	1.11
Aug 2014	1.23	1.10	1.12	1.21	1.12
Sep 2014	1.40	1.19	1.23	1.47	1.17
Oct 2014	1.62	1.15	1.13	1.35	1.15
Nov 2014	1.24	1.10	1.12	1.23	1.19
Dec 2014	1.24	1.11	1.06	1.28	1.14

Looking at the max monthly peak-average monthly peak values in Figure 2 and Figure 3, observable differentiation occurs across archetypes with convergence around specific value ranges within archetypes. In manufacturing, values hover around an average of 1.33 throughout the year, with a range of 1.22-1.62 across the 12-month period. Healthcare max peak-average peak ratios clustered around an annual average of 1.11, within a range of 1.07-1.19, demonstrating that the archetype has monthly max peaks only 11% greater than the average daily peak demand. The multifamily archetype saw the same max peak-average peak ratios when averaging across all months, with a wider range between the minimum and maximum values throughout the year of 1.06-1.23. The education archetype shows an average of 1.26 for max peak-average peak ratios across all months, with ranges of 1.11-1.47. Finally, the commercial real estate (CRE) archetype has an average max peak-average peak ratio of 1.15, with a tight range of 1.1-1.21 throughout the year.

Figure 2. Ratio of Max Peak to Average Peak by Building Load Type

Seasonally there is little variation between max peak-average peak ratios across the sectors.

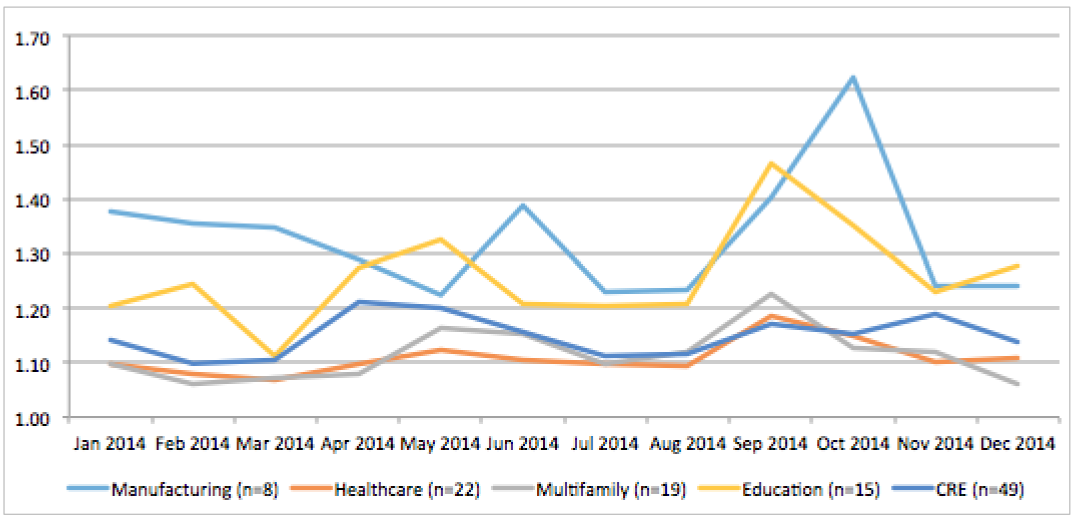
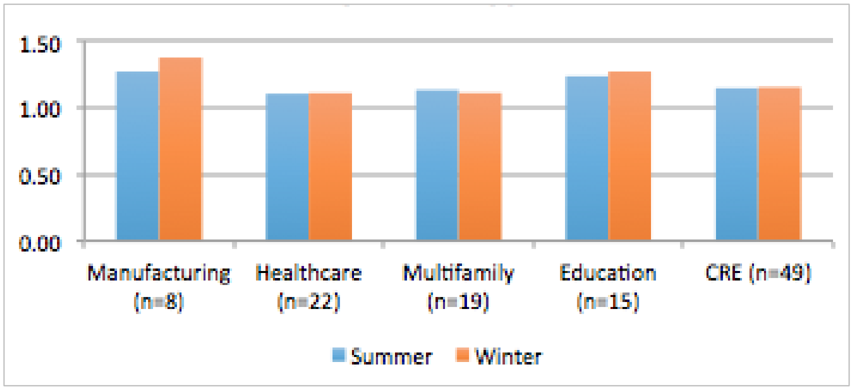


Figure 3. Ratio of Max Peak to Average Peak by Load Type

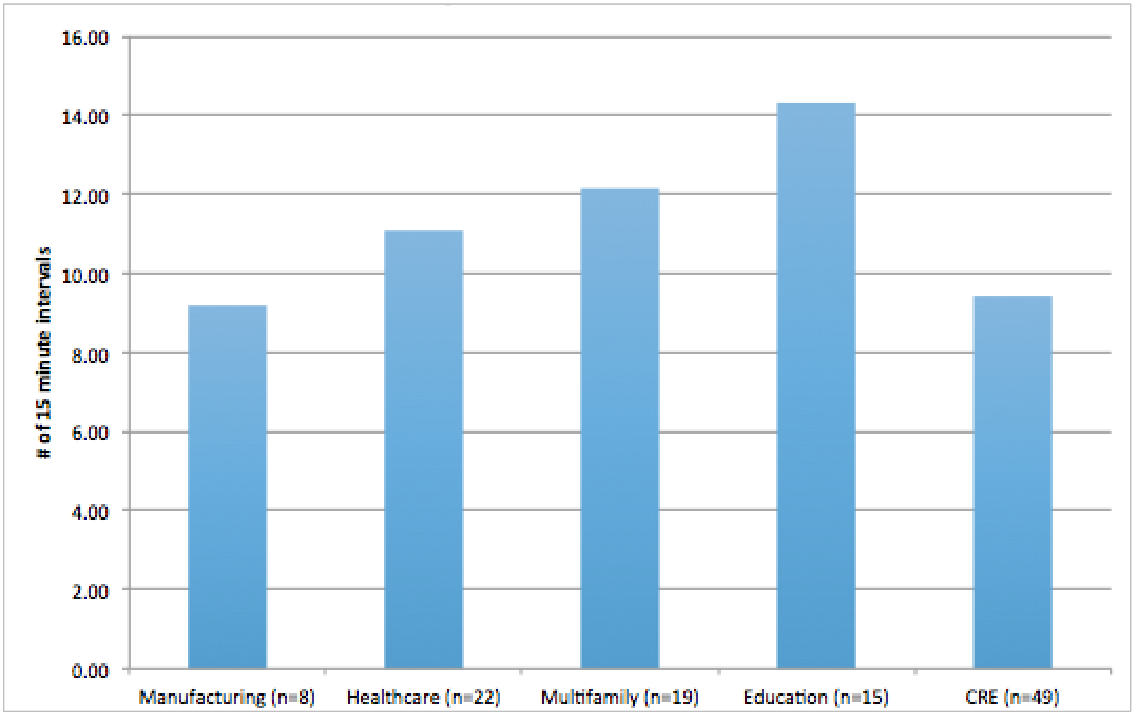


3.2 Duration

Peak duration, understood as the average number of intervals demand exceeds the average monthly peak per month, provides insight into the typical ranges peaks are experienced within each load archetype. Calculating these values across the data set reveals that distinct values emerge for each load archetype, illustrated in Figure 4 and Figure 5.

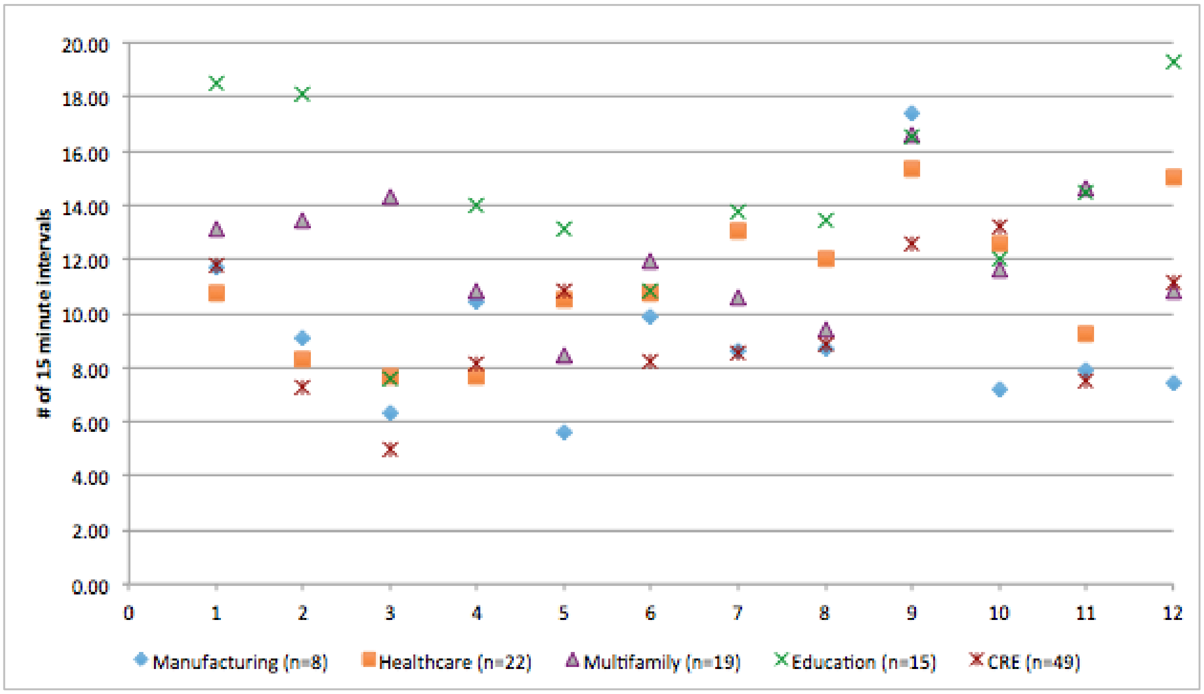
From an annual perspective, the average max peak duration range across archetypes is 8.5-14.25 intervals, or approximately 2-3.5 hours. The industrial/manufacturing and commercial real estate archetypes had the briefest max peak duration on an annual basis, indicating that these archetypes typically only exceed the daily average peak for short periods each month. The education archetype exhibited the longest annual average max peak duration period of approximately 3.5 hours. The healthcare and multifamily archetypes demonstrated 2.75 and 3 hours, respectively.

Figure 4. Average Max Peak Duration



A monthly viewpoint provides a more granular insight into how the durations vary by month. Across archetypes, there is a wider range in duration in the winter months slightly skewed toward longer duration; in the summer months, the trend has a tighter range with the distribution skewed toward the mean. As indicated by the annual max peak duration chart, a max peak duration range of 2-4 hours accounts for the majority of max peak duration values exhibited across the sample.

Figure 5. Duration: Number of 15-minute Intervals above Average Monthly Peak

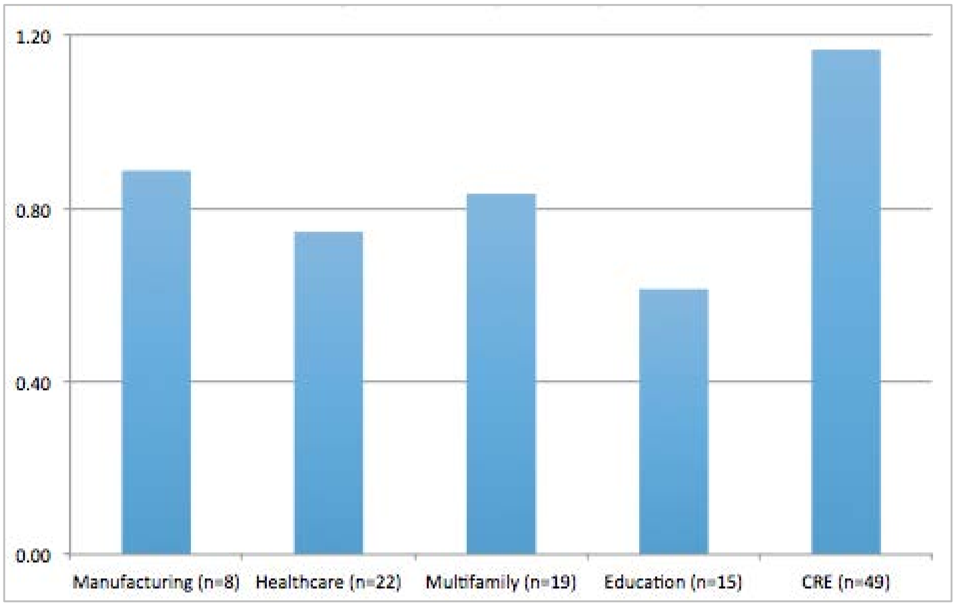


3.3 Frequency

Peak frequency, understood as the number of occurrences of load periods above the monthly average peak per day, provides insight into how often peak load values are observed within each archetype. Looking at frequency from annual and monthly perspective provides further detail into the characteristics of each load archetype with respect to peakiness.

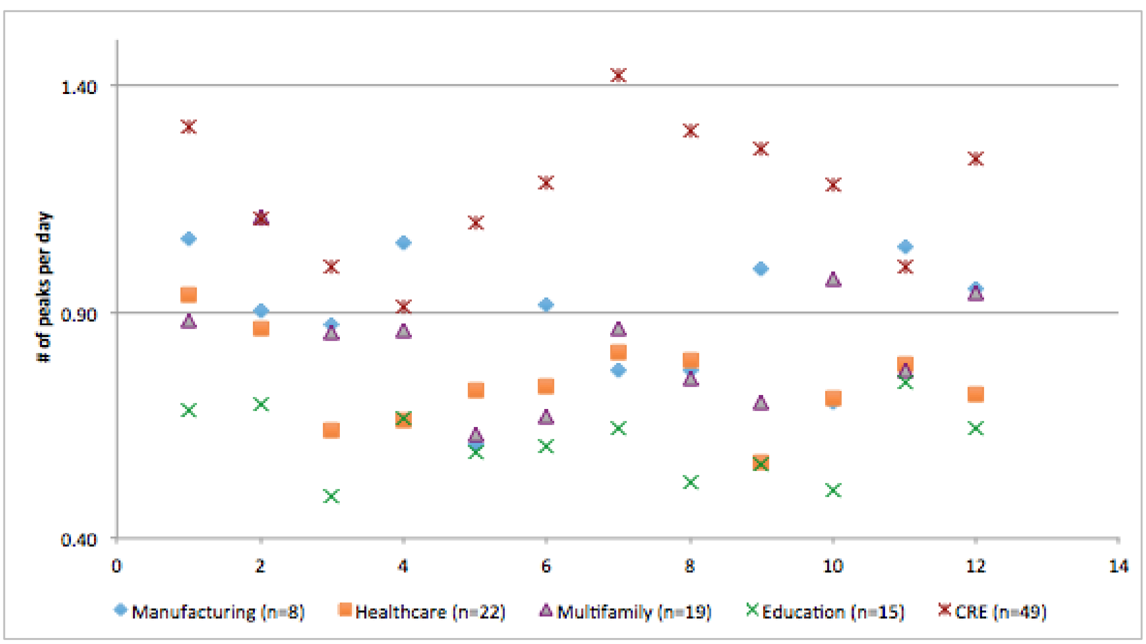
From an annual perspective, the education archetype had the lowest daily frequency at 0.61, whereas the commercial real estate archetype exhibited the highest value at 1.17 (Figure 6). The healthcare archetype exhibited a value of 0.75, multifamily exhibited 0.83, and industrial/manufacturing exhibited 0.89.

Figure 6. Annual Average Frequency of Peaks Above Average Monthly Peak Per Day



The more granular monthly view shows that within the archetypes, variability in frequency varies month-over-month within each archetype (Figure 7). Commercial real estate has the widest range, from 0.92-1.41. Education, on the other hand, exhibited a much tighter range of 0.50-0.69. Of all the archetypes, only commercial real estate exhibits a majority of frequency values greater than 1.0, with industrial/manufacturing being the only other archetype to exhibit frequency values above 1.0.

Figure 7. Frequency: Daily Average Number of Peaks above Average Monthly Peak



4 Discussion

The quantitative analysis of the data reveals a number of insights into how peak loads are observed within individual load archetypes. Table 3 and the following sections provide an interpretation of what the metrics mean for each archetype, and provides a means of comparison for archetypes across one another.

Table 3. Annual Metrics by Archetype

	Manufacturing (n=8)	Healthcare (n=22)	Multifamily (n=19)	Education (n=15)	CRE (n=49)
Average Monthly Peak/Average Load	1.99	1.16	1.18	1.56	1.38
Maximum Monthly Peak/Average Monthly Peak	1.33	1.11	1.11	1.26	1.15
Peak Duration (Number of 15-minute Intervals Above Average Monthly Peak)	9.19	11.09	12.16	14.31	9.41
Peak Frequency (Number of occurrences of load greater than Average Monthly Peak per Day)	0.89	0.75	0.83	0.61	1.17

4.1 Industrial/Manufacturing

The 1.99 average monthly peak/average load observed in the manufacturing archetype indicates that these facilities have a high variance between average load and average peak load, indicating that on a daily basis, the peak load reach almost double the daily average load.

The industrial/manufacturing archetype's 1.33 value for maximum monthly peak/average monthly peak indicates that within the archetype, the monthly peak value is on average 33% higher than the average monthly peak. Taken together, both metrics indicate that on average peak loads are pronounced relative to average loads, and within peak load values, there is substantial headroom between the average and max.

The peak duration of 9.19 intervals indicates that the industrial/manufacturing archetype has on average maximum monthly peak events that exceed average monthly peak for a period of 2.25 hours. The peak frequency value of 0.89 indicates that peak load events greater than the average monthly peak occur on average a little less than once a day, or 25 times during a 28-day period.

4.2 Healthcare

The 1.16 average monthly peak/average load observed in the healthcare archetype indicates that these facilities have a low variance between average load and average peak load, indicating that on a daily basis, the peak load only swells about 15% in excess of the daily average load.

The healthcare archetype's 1.11 value for maximum monthly peak/average monthly peak indicates that within the archetype, the monthly peak value is on average 11% higher than the average monthly peak. Taken together, both metrics indicate that on average peak loads are incrementally greater relative to average loads, and within peak load values, there is limited variation between the average and max.

The peak duration of 11.09 intervals indicates that the healthcare archetype has, on average, maximum monthly peak events that exceed average monthly peak for a period of 2.75 hours. The peak frequency value of 0.75 indicates that peak load events greater than the average monthly peak occur on average for 75 of days, or 21 times during a 28-day period.

4.3 Multifamily

The 1.18 average monthly peak/average load observed in the multifamily archetype indicates that these facilities have a low variance between average load and average peak load, indicating that on a daily basis, the peak load only swells on average 18% in excess of the daily average load.

The multifamily archetype's 1.11 value for maximum monthly peak/average monthly peak indicates that within the archetype, the monthly peak value is on average 11% higher than the average monthly peak. Taken together, both metrics indicate that on average peak loads are incrementally greater relative to average loads, and within peak load values, there is limited variation between the average and max.

The peak duration of 12.16 intervals indicates that the multifamily archetype has, on average, Maximum monthly peak events that exceed average monthly peak for a period of 3 hours. The peak frequency value of 0.83 indicates that peak load events greater than the average monthly peak occur on average a 83% of days, or 23 times during a 28-day period.

4.4 Education

The 1.56 average monthly peak/average load observed in the education archetype indicates that these facilities have substantial variance between average load and average peak load, indicating that on a daily basis, the peak load swells on average 56% in excess of the daily average load.

The education archetype’s 1.26 value for maximum monthly peak/average monthly peak indicates that within the archetype, the monthly peak value is on average 26% higher than the average monthly peak. Taken together, both metrics indicate that on average peak loads are substantially greater relative to average loads, and within peak load values, there is headroom of 25% between the average and maximum across the year.

The peak duration of 14.31 intervals indicates that the education archetype has, on average, maximum monthly peak events that exceed average monthly peak for a period of 3 hours. The peak frequency value of 0.61 indicates that peak load events greater than the average monthly peak occur on average for 61% of days, or 17 times during a 28-day period.

4.5 Commercial Real Estate

The 1.38 average monthly peak/average load observed in the commercial real estate archetype indicates that these facilities have substantial variance between average load and average peak load, indicating that on a daily basis, the peak load swells on average close to 40% in excess of the daily average load.

The commercial real estate archetype’s 1.15 value for maximum monthly peak/average monthly peak indicates that within the archetype, the monthly peak value is on average 15% higher than the average monthly peak. Taken together, both metrics indicate that on average peak loads are substantially greater relative to average loads, and within peak load values, there is limited headroom of 15 percent between the average and max across the year, indicating a level of regularity for the average monthly peak.

The peak duration of 9.41 intervals indicates that the commercial real estate archetype has, on average, maximum monthly peak durations that exceed average monthly peak for a period of 2.33 hours. The peak frequency value of 1.17 indicates that peak load events greater than the average monthly peak occur on average more than once a day percent of days, or 32.75 times during a 28-day period.

4.6 All Archetypes

Taken together, these metrics indicate that battery energy storage solutions should be tailored to address different characteristics, depending on archetype. In the industrial/manufacturing archetype, high power applications with short durations of 2-4 hours can address the substantial 33 percent surge in maximum monthly peaks relative to the average monthly peak. In the healthcare and multifamily archetypes, flatter load curves indicated by the low average monthly peak/average monthly load ratios of 1.16 and 1.18 respectively, combined with less pronounced maximum monthly peaks relative to the average monthly peak indicate that long-duration energy storage solutions are best served to drop load across long portions of the daily operating window. In the education and commercial real estate archetypes, average monthly peak/average load values of 1.56 and 1.38 respectively, taken with maximum monthly peaks that swell 25% and 15% above average monthly peak for periods of 3-3.5 hours indicate that solutions with high-power and medium-to-long duration are most applicable to consistently reduce load throughout the month.

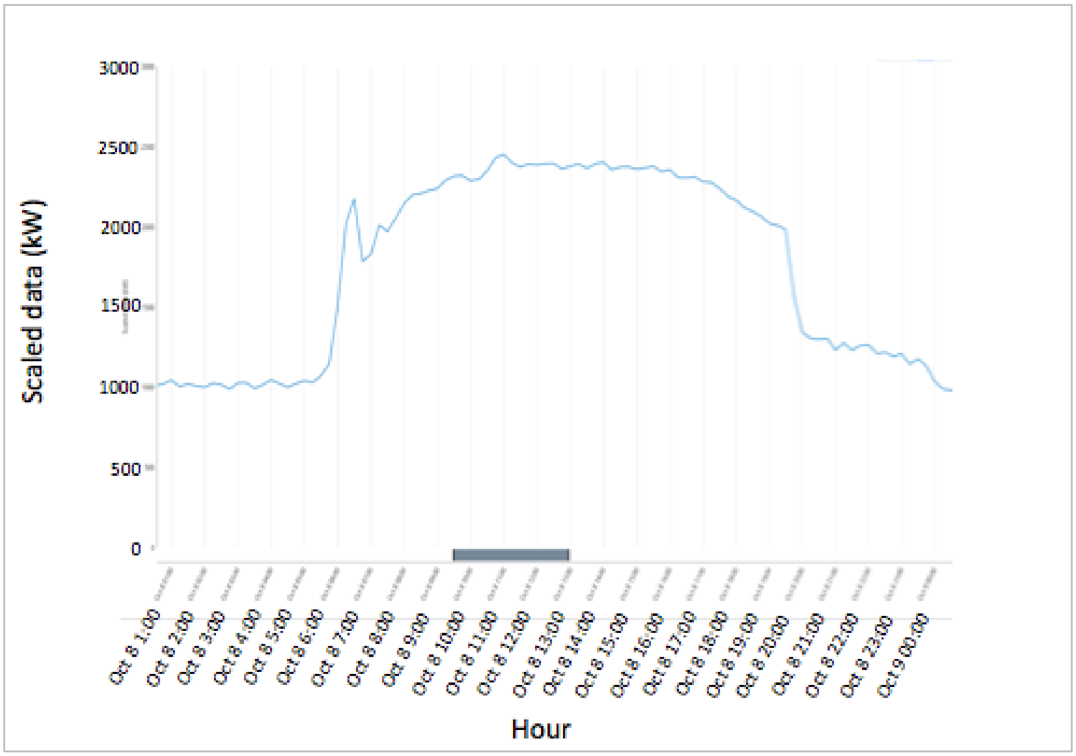
5 Load Archetype Characteristics

5.1 Commercial Real Estate

The commercial office space load archetype is characterized by operations occurring during the typical business week. Typical base load for these sites occurs during roughly 7 p.m. to 5 a.m., at which time the building begins ramping up HVAC and other systems to prepare for the workday. This ramp-up can be typically quite pronounced—ranging from 1.34-1.38 baseload—and then plateaus until the conclusion of the workday. Within the plateau, there is limited variation that occurs as equipment cycles on and off, comprising a series of micropeaks. A subsegment of the commercial office space load archetype exhibits a dip during the middle of the typical peak plateau, effectively dividing the period into two smaller-duration mid-sized peaks.

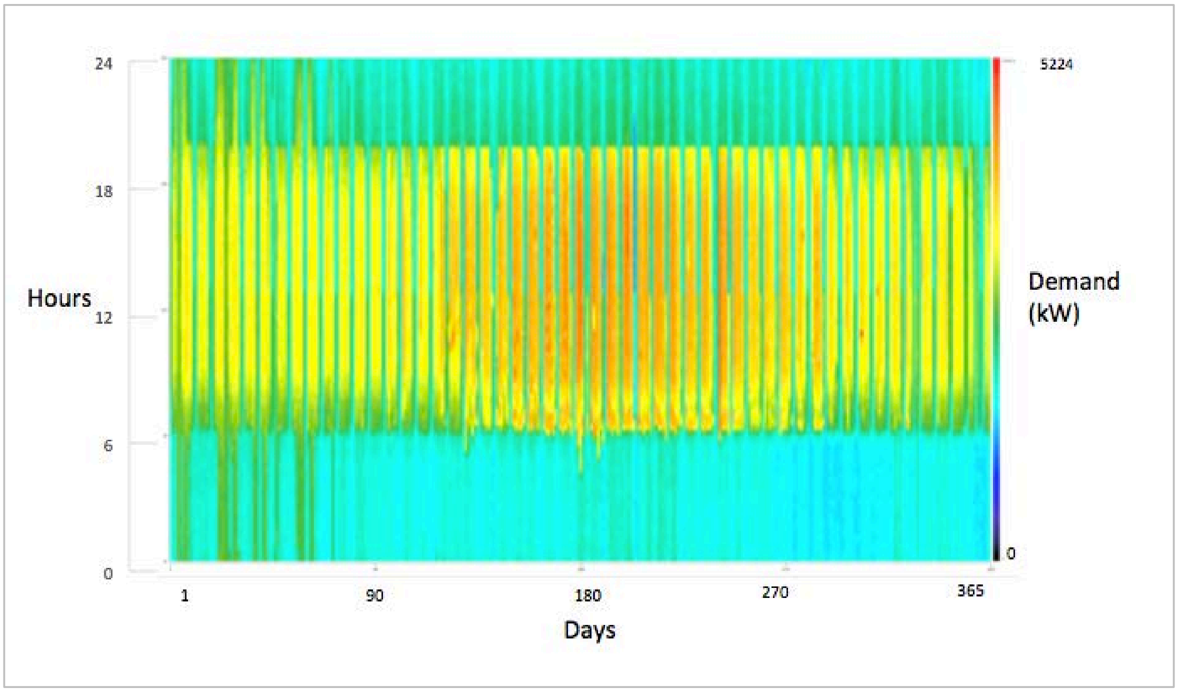
This variation primarily has to do with operational protocols within the group. For instance, some buildings may choose to deploy a preconditioning strategy with respect to HVAC, and subsequently dial back additional chillers during the mid-portion of the day. Figure 8 illustrates how these patterns occur. The pronounced ramp from 6 a.m. to 7 a.m. occurs, preparing the building for daily operations, briefly spiking to appropriately preheat or cool the building. Load then drops off for a short duration, and begins to climb to a plateau, wherein a number of micropeaks occur. At 5 p.m., the load begins to decline, then sharply drops off between 7:30 p.m. and 8 p.m., returning to the building’s baseload level.

Figure 8. Commercial Real Estate Daily Load Profile



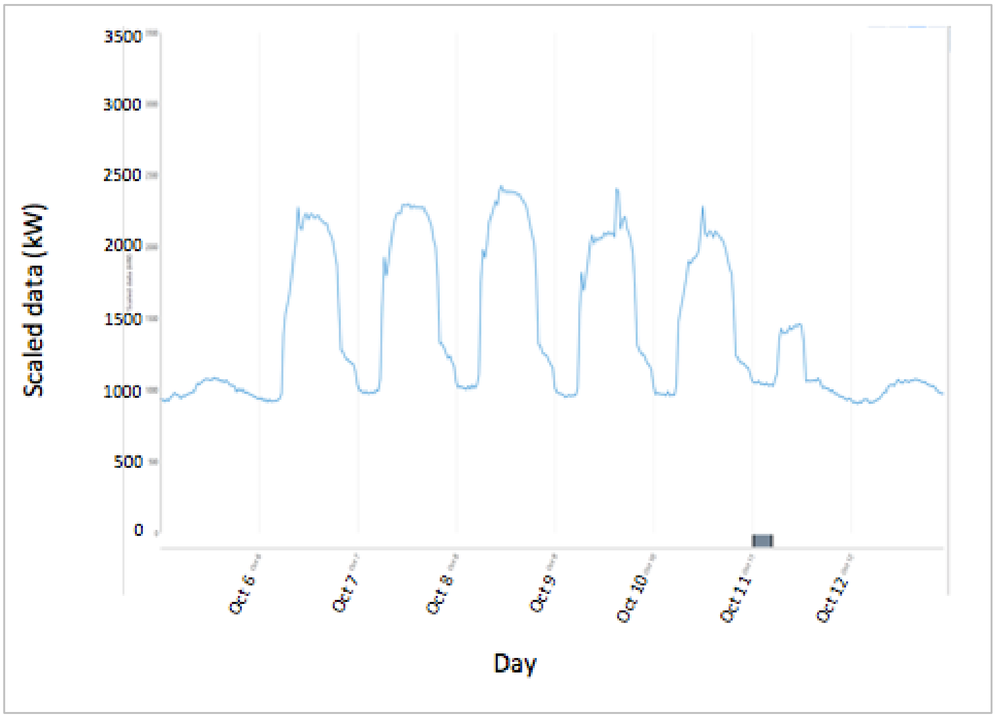
Seasonal variation within the commercial office space archetype tends be less pronounced relative to other archetypes, but there is a noticeable increase in the baseload and peak levels during the summer, as the need for cooling peaks. Figure 9 demonstrates both how consistent the scheduling is between ramp up/ramp down, and the consistency of baseload demand and average peak demand.

Figure 9. Commercial Real Estate Annual Load Heatmap



From a weekly perspective, peak demand is typically hit during the beginning-to-middle of the week, with Tuesdays and Wednesdays being most common. Fridays frequently see a pronounced drop in peak intensity and duration relative to the rest of the week (Figure 10).

Figure 10. Commercial Real Estate Weekly Load Profile (Mon-Sun)



5.1.1 Interval Distribution

Viewing the distribution of loads as a percentage of the monthly average peak provides further insight into how each load archetype exhibits peak demands. In the commercial real estate archetype, there is a pronounced clustering of intervals approaching 100% of average peak demand, with an average of 400 intervals per month clustering at 80% of average monthly peak and 250 intervals per month clustering around 90%. 100% of average monthly peak was experienced on average 100 intervals per month; values in excess of 100% of average peak dropped off precipitously, with 110% of peak typically occurring in a range of 10-20 intervals per month; above that, 120% is observed under 10 intervals per month, and 150% under one interval per month.

From a peak shaving standpoint, these distribution patterns suggest that for the commercial real estate archetype, BESS systems should be sized in a 6 to 8-hour configuration to eliminate the actual monthly demand from 150% of average peak down to 80-90% of monthly average demand during the 20 weekdays of each month (Figures 11 through 14).

Figure 11. Distribution of Load by Percentage of Average Monthly Peak (Q1, Commercial Real Estate)

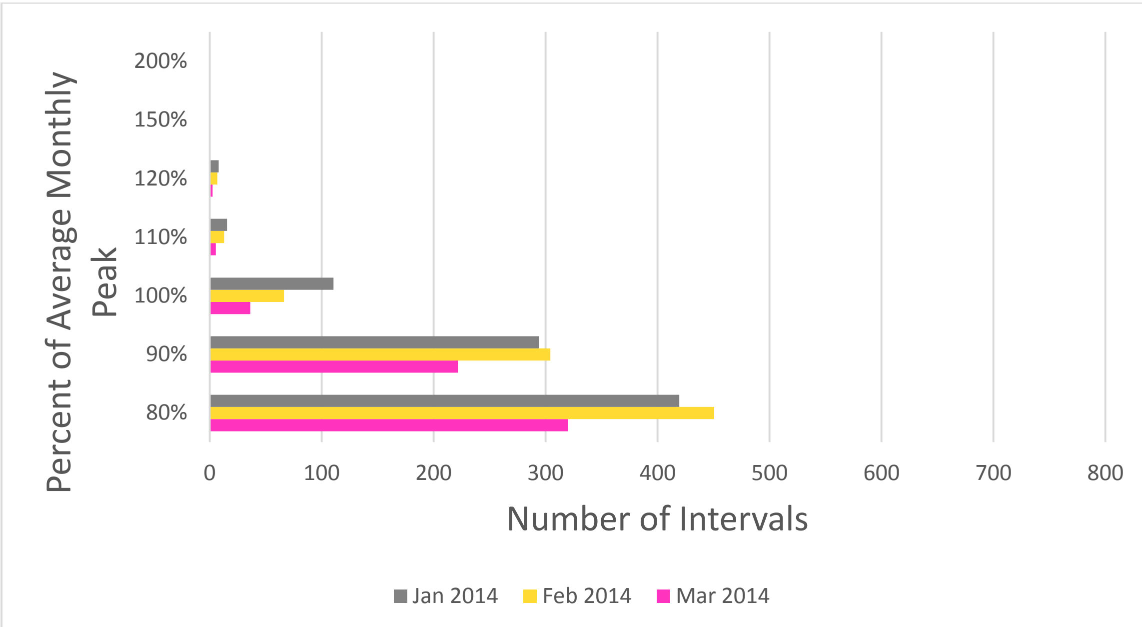


Figure 12. Distribution of Load by Percentage of Average Monthly Peak (Q2, Commercial Real Estate)

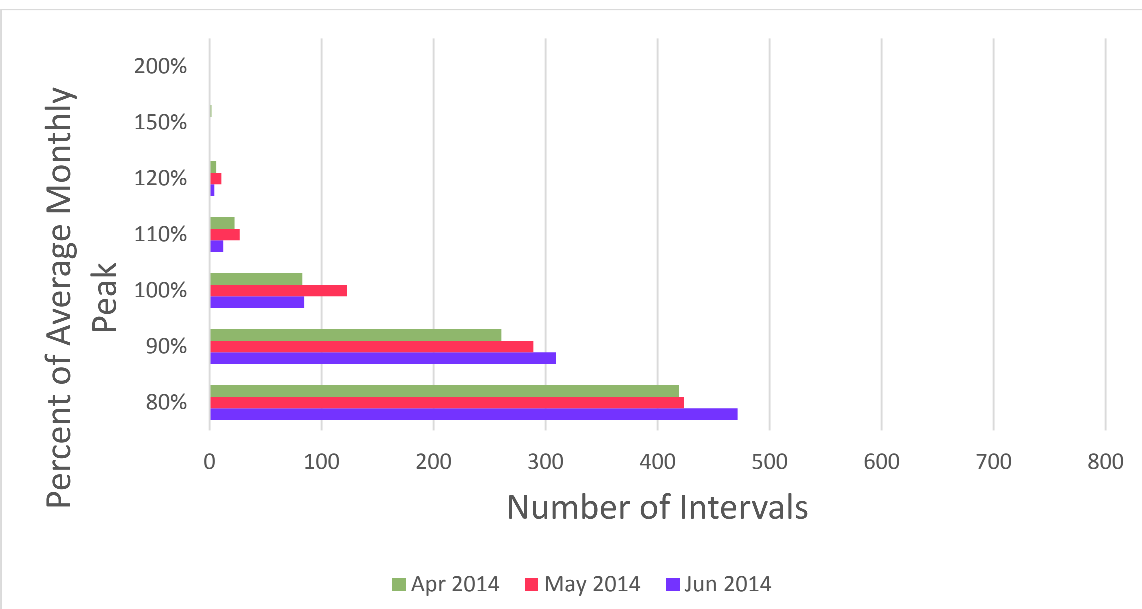


Figure 13. Distribution of Load by Percentage of Average Monthly Peak (Q3, Commercial Real Estate)

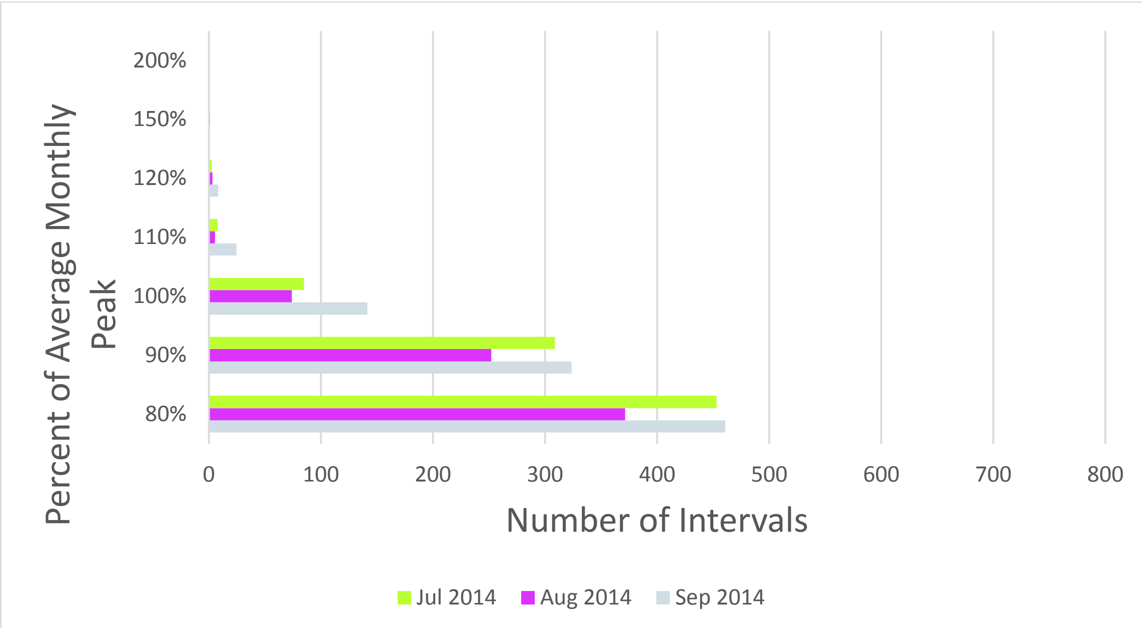
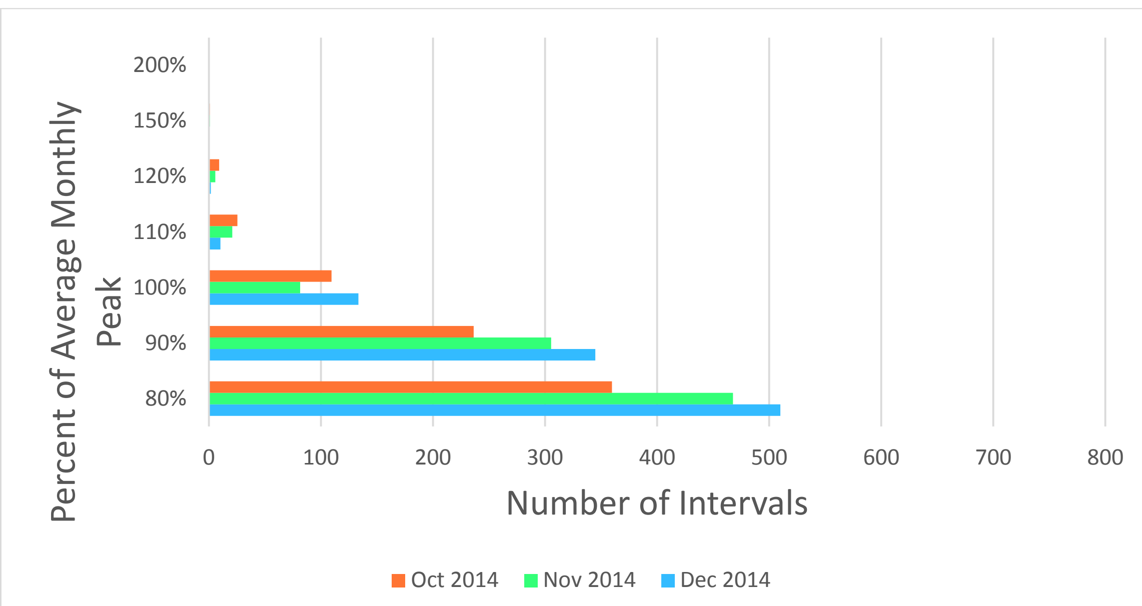


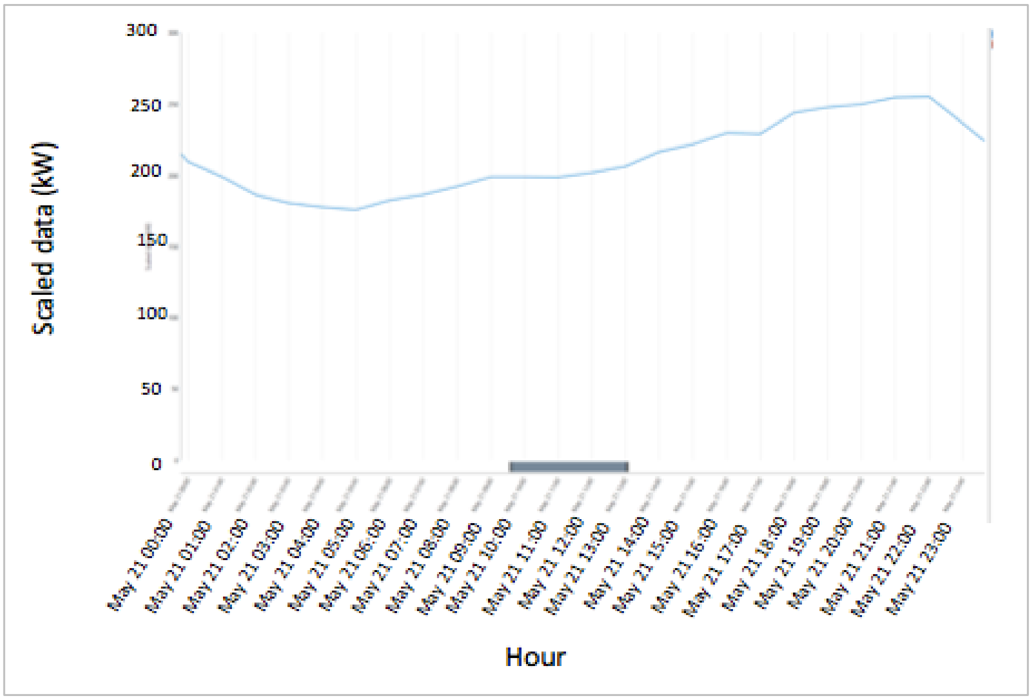
Figure 14. Distribution of Load by Percentage of Average Monthly Peak (Q4, Commercial Real Estate)



5.2 Multifamily Residential Housing

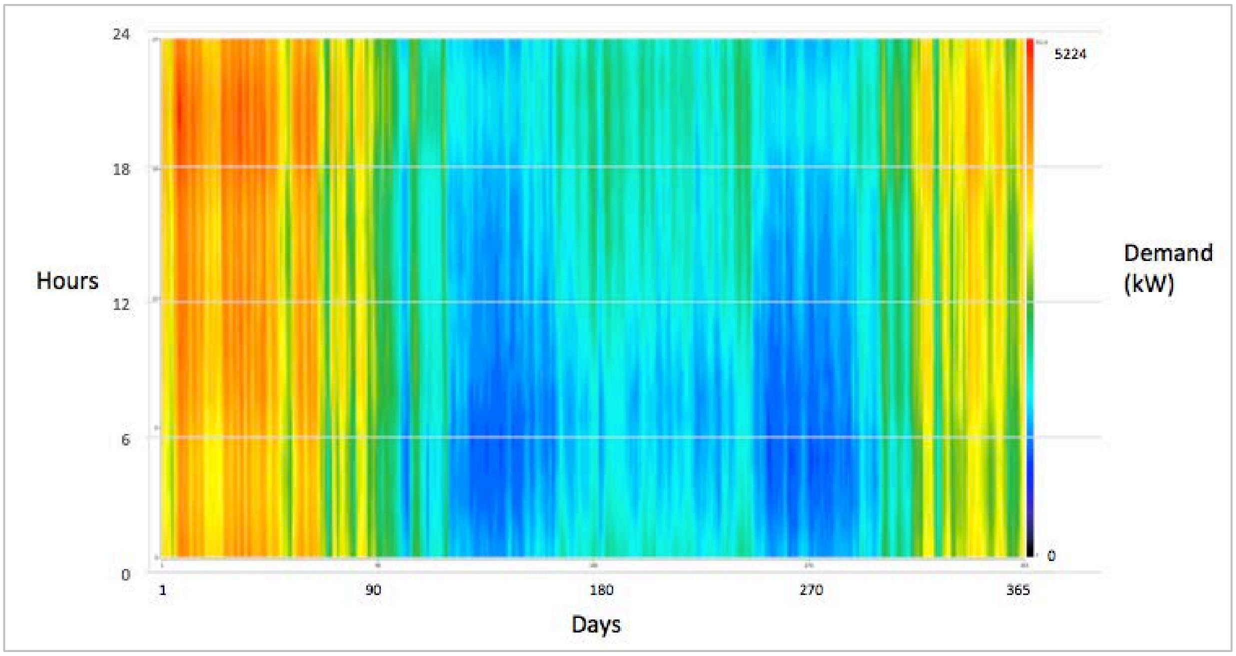
Loads in the multifamily residential archetype exhibit a pattern where demand tends to swell toward its peak in the evenings, as most people return from their daily activities and use electrically powered equipment for comfort and leisure. Whereas the commercial office archetype exhibited a pronounced differential between peak and trough, the multifamily residential archetype ramps up at a more gradual pace, reflecting more fluid occupancy patterns. The peak demand level typically occurs during the window from 7 p.m. to 11 p.m., with demand rising gradually from 12 noon through to peak (Figure 15).

Figure 15. Multifamily Housing Daily Load Profile



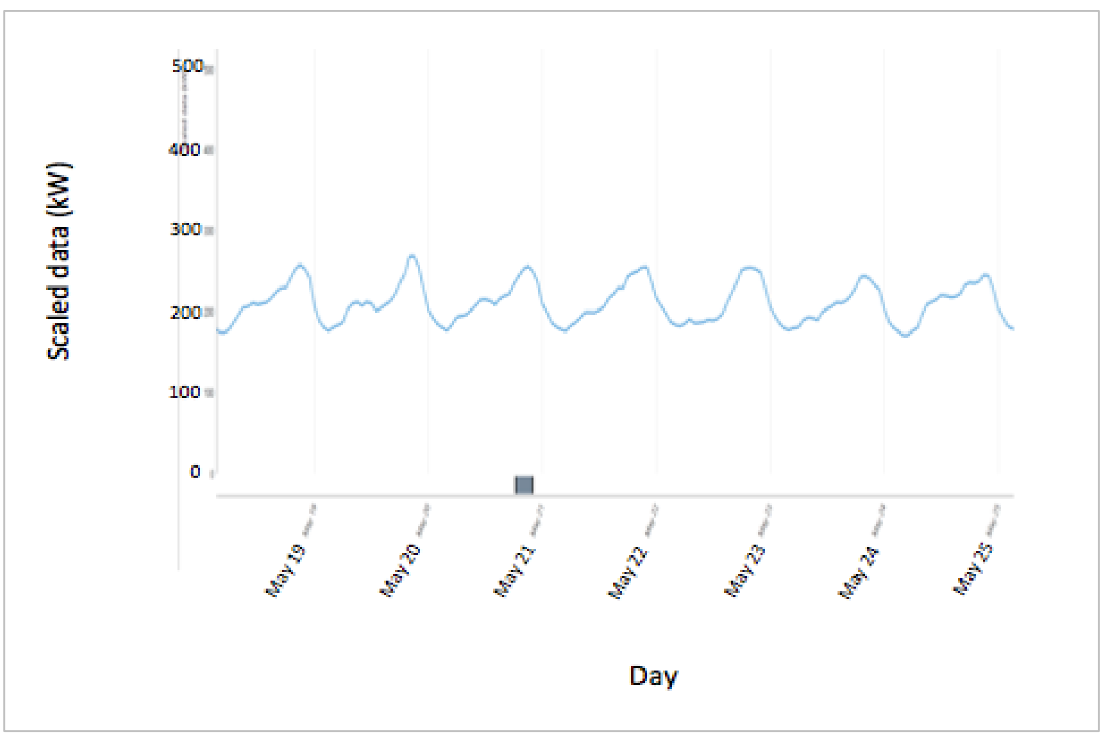
Within the archetype, there can be pronounced seasonal variation contingent on whether or not the building is electrically heated/cooled. Figure 16 shows the pronounced effect electric heating has within a multifamily load profile—with substantially higher baseloads observed during the heating seasons. A gradual ramping period can also be observed from the early morning hours through the midday, giving way to peak load occurrence in the uppermost quadrant of the heat map.

Figure 16. Multifamily Housing Annual Heatmap



Within a given season, the multifamily load shows minor daily variation between individual days, but no pronounced difference between weekday and weekend (Figure 17).

Figure 17. Multifamily Weekly Load Profile (Mon-Sun)



5.2.1 Interval Distribution

For the multifamily sector, values converge around 600 intervals per month at 80% of average peak demand, although individual months can vary greatly; for example, June exhibited a value of 510, and December had a value of 775 (Figure 18 and Figure 19). The distribution for 90% clustered around 300-400 intervals per month. 100% of average monthly peak was experienced on average 100 intervals per month, while 110% clustered in the range of 10-30 intervals, although the September stands out at 82 intervals (Figure 20 and Figure 21). Values drop rapidly at 120% of average monthly peak, with typical values ranging from 1-5 intervals per month, with September and November standing out at 42 and 28 intervals respectively. Only the month of September exhibited intervals above 120%, with 4 at 150%.

From a peak shaving standpoint, the distribution patterns exhibited by the multifamily sites suggest that BESS systems sized 8-10 hours should be able to eliminate the actual monthly demand from 120% of average peak down to 80-90% of monthly average demand during the 20 weekdays of each month.

Figure 18. Distribution of Load by Percentage of Average Monthly Peak (Q1, Multifamily)

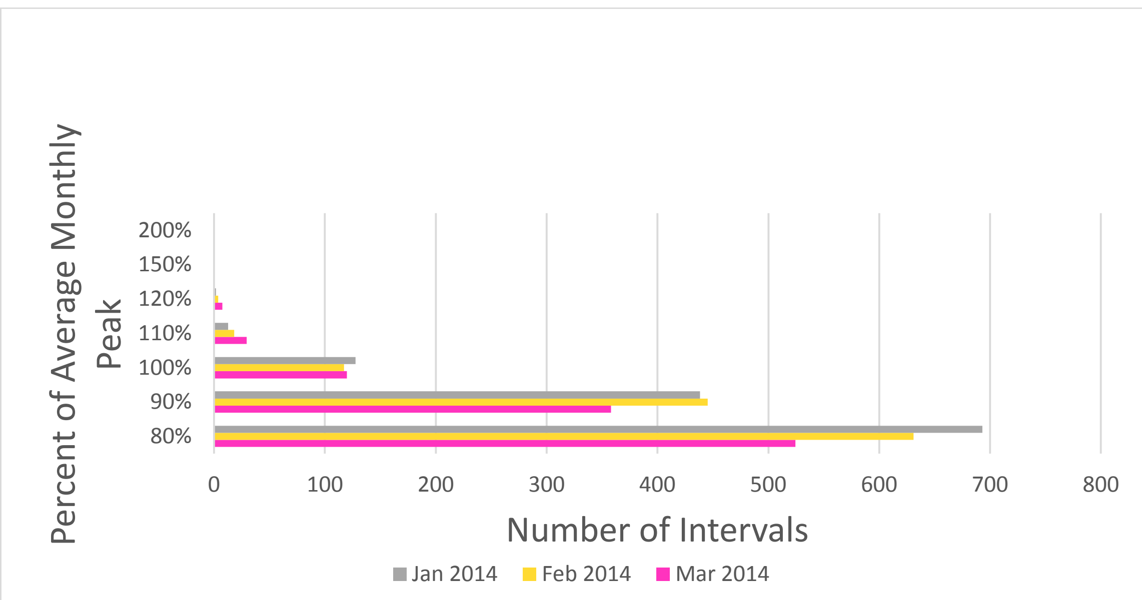


Figure 19. Distribution of Load by Percentage of Average Monthly Peak (Q2, Multifamily)

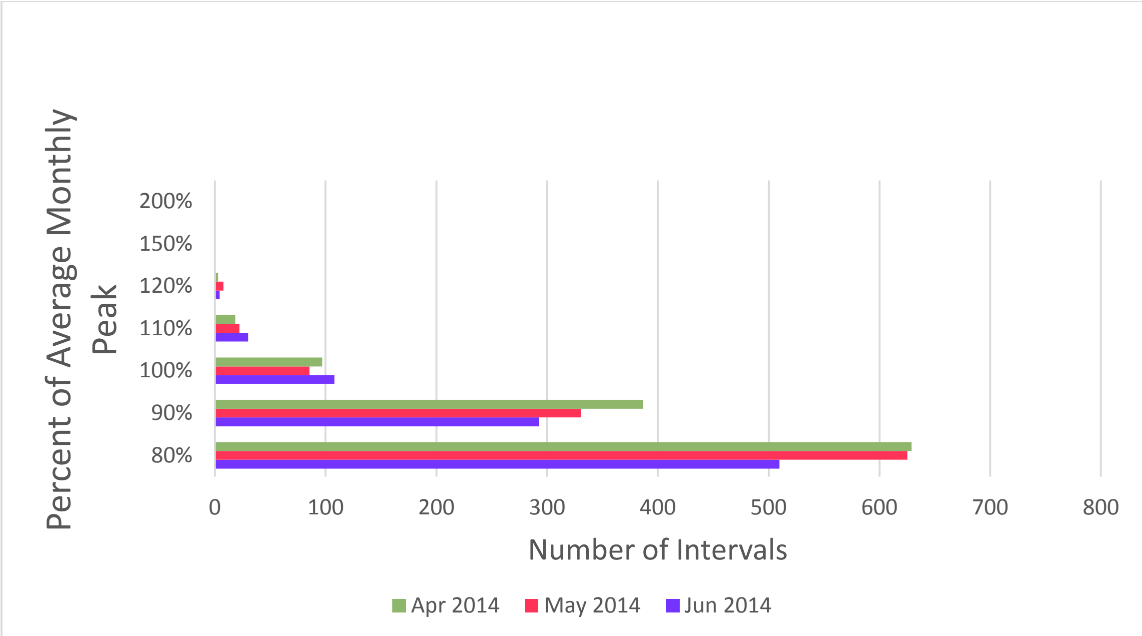


Figure 20. Distribution of Load by Percentage of Average Monthly Peak (Q3, Multifamily)

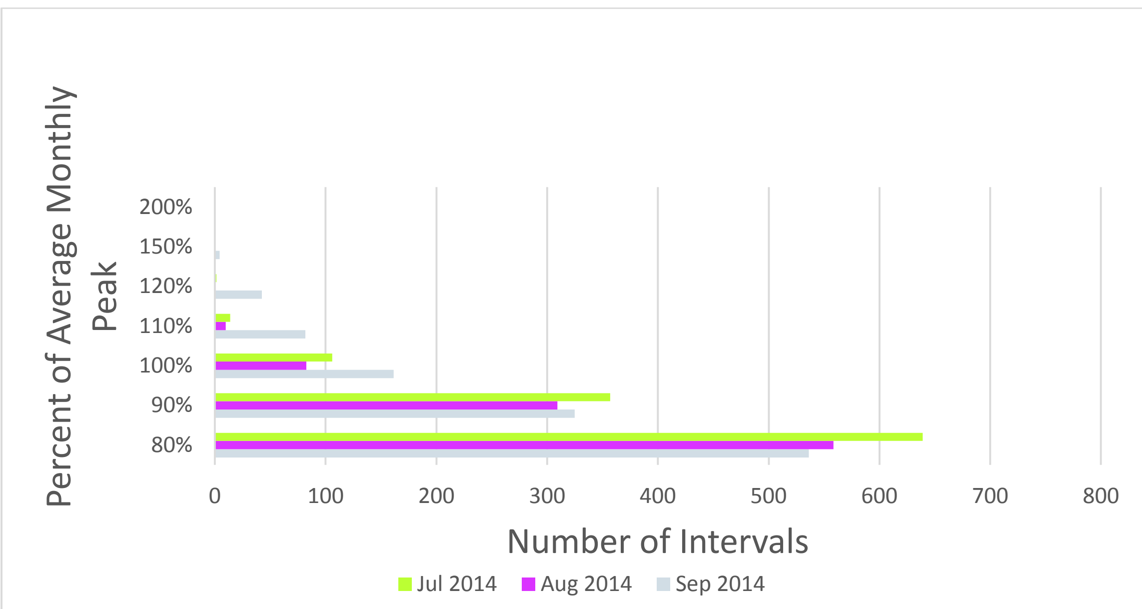
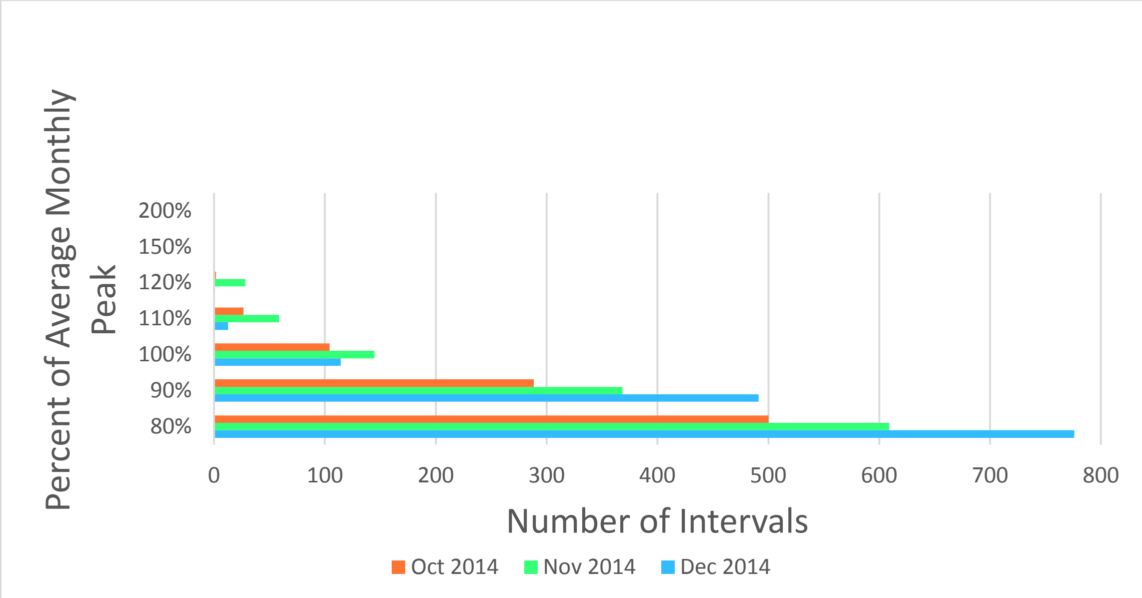


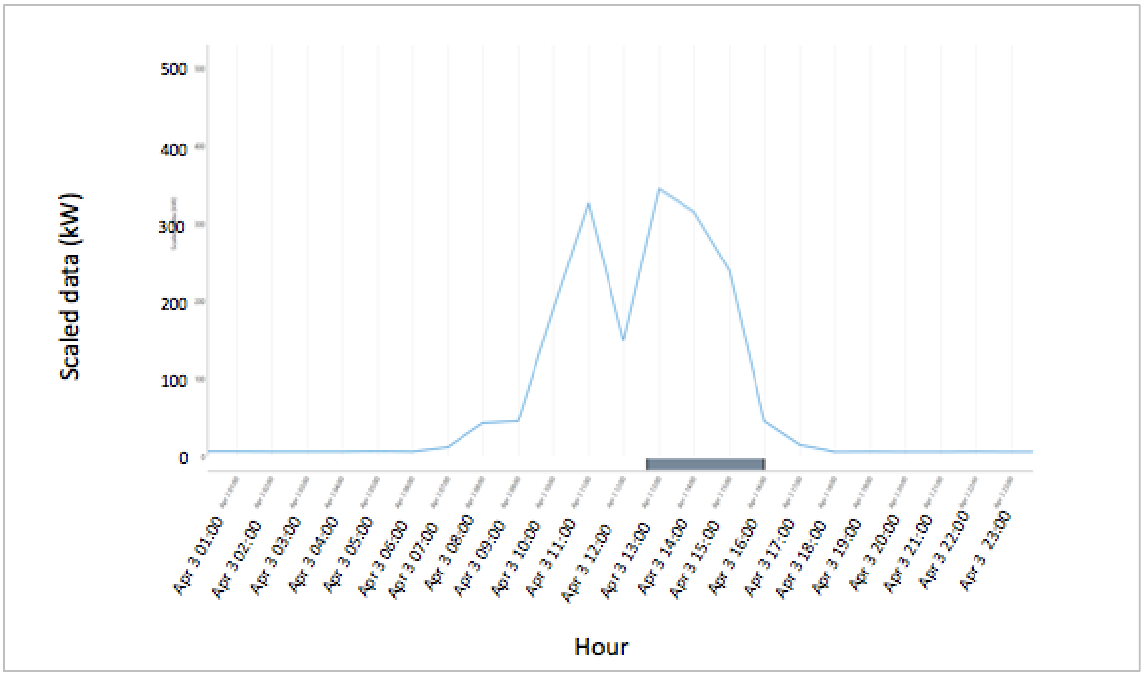
Figure 21. Distribution of Load by Percentage of Average Monthly Peak (Q4, Multifamily)



5.3 Industrial/Manufacturing

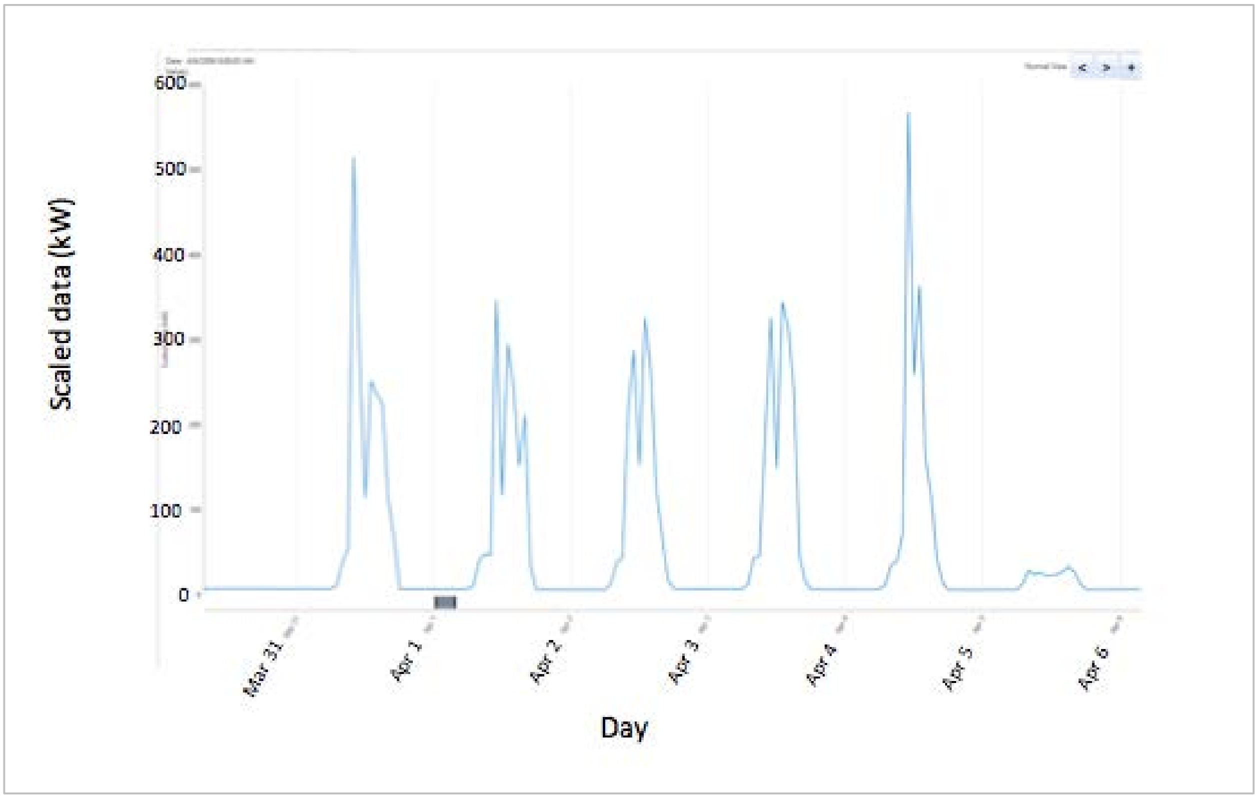
Of all the load archetypes investigated, the industrial/manufacturing space has the most variability in load characteristics, based upon energy use intensity of facility operations, number of shifts in a day, and operating days in a week. However, even given this variability, the typical industrial/manufacturing load profile is characterized by intense load spikes driven by high-power equipment cycling on/off during the production cycle of a given facility. Looking at the daily load profile, the stark difference between power usage during business and after-hours. It’s also worth noting that industrial/manufacturing operations can see their demand drop to almost zero during nonbusiness hours—a function of equipment utilization occurring only during operations, and minimal space conditioning needs after hours (Figure 22).

Figure 22. Industrial/Manufacturing Daily Load Profile



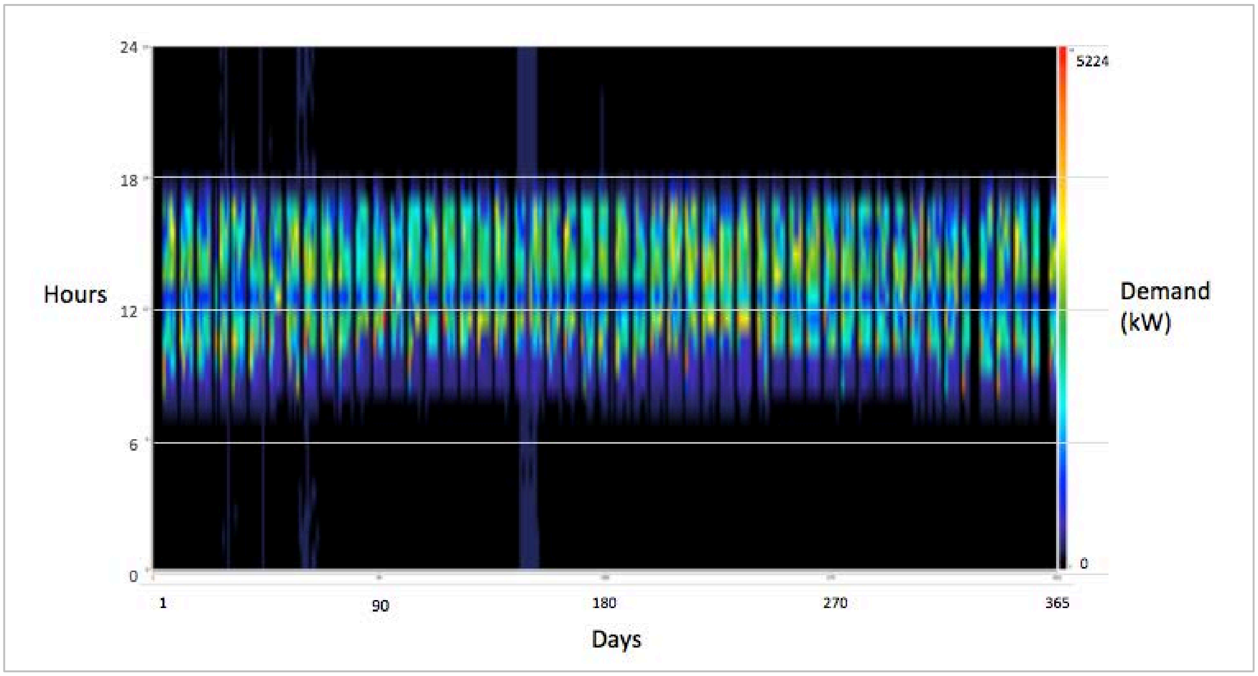
The demand spikes can be clearly observed in the weekly load profile presented in Figure 23. This particular facility powers down almost entirely during off-hours, has a brief ramp-up, followed by an immediate spike in power consumption, then a brief dip followed by 1-2 subsequent spike-dip patterns before ramping down at the close of business.

Figure 23. Industrial/Manufacturing Weekly Load Profile (Mon-Sun)



Observing the load with the aid of an annual heat map, the distinct operational pattern described in Figure 23 is borne out across the year, with stark cutoffs at the beginning/close of business, brief initial ramp-up period, initial power surge, brief dip, and subsequent surge/dip cycles occurring before a rapid ramp down (Figure 24). Seasonal heating and cooling requirements do not appear to exert demonstrable impact of the load.

Figure 24. Industrial/Manufacturing Annual Heat Map



5.3.1 Interval Distribution

The industrial/manufacturing segment exhibited a lower distribution of intervals clustered in the range of 80-200% of average monthly peak, but displayed a greater number of values above 100% of average monthly peak than either Commercial Real Estate or Multifamily. 80% of average monthly peak clustered around 300 intervals per month, falling to 200 intervals for 90%, and 75-100 intervals for 100% of peak. 110% of average peak demand ranged from converged at 30-50 intervals per month, with September standing out at 77 intervals. The values coalesced around 10-20 intervals for 120% of average monthly peak, dropping to under 10 intervals for 150%, and 0-7 intervals for 200% of average monthly peak.

From a peak shaving standpoint, this distribution suggests that commercial properties exhibit more intense but brief spikes in demand, which can be addressed by systems in the 3-5-hour range to eliminate the actual monthly demand of 200% of average monthly peak down to 80-90% of average monthly demand during the 20 weekdays of each month (Figures 25 to 28).

Figure 25. Distribution of Load by Percentage of Average Monthly Peak (Q1, Industrial/Manufacturing)

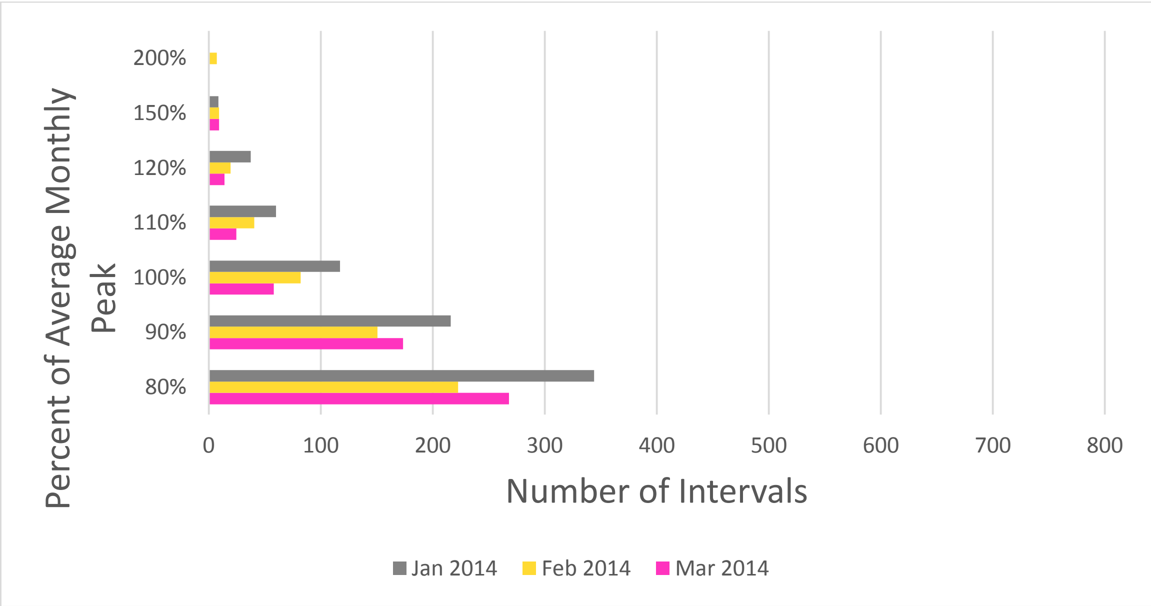


Figure 26. Distribution of Load by Percentage of Average Monthly Peak (Q2, Industrial/Manufacturing)

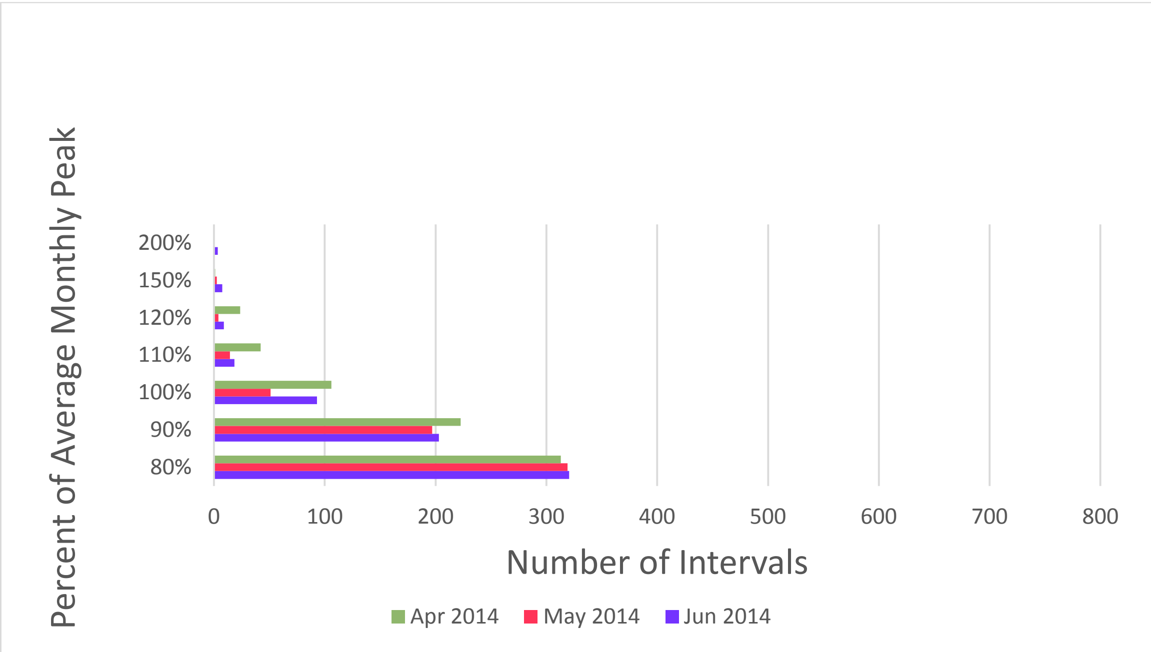


Figure 27. Distribution of Load by Percentage of Average Monthly Peak (Q3, Industrial/Manufacturing)

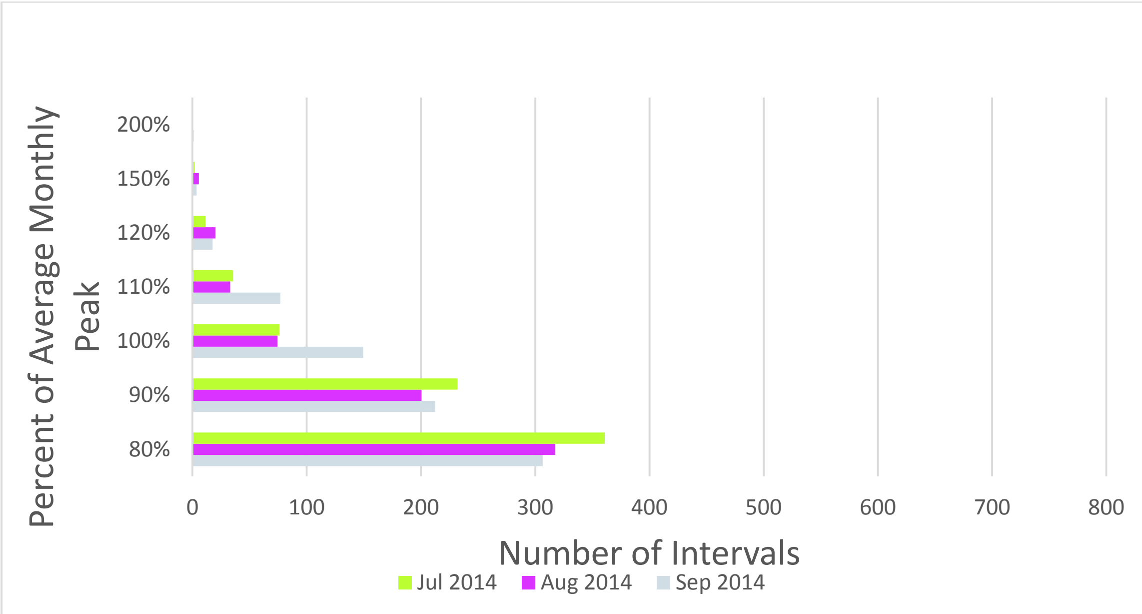
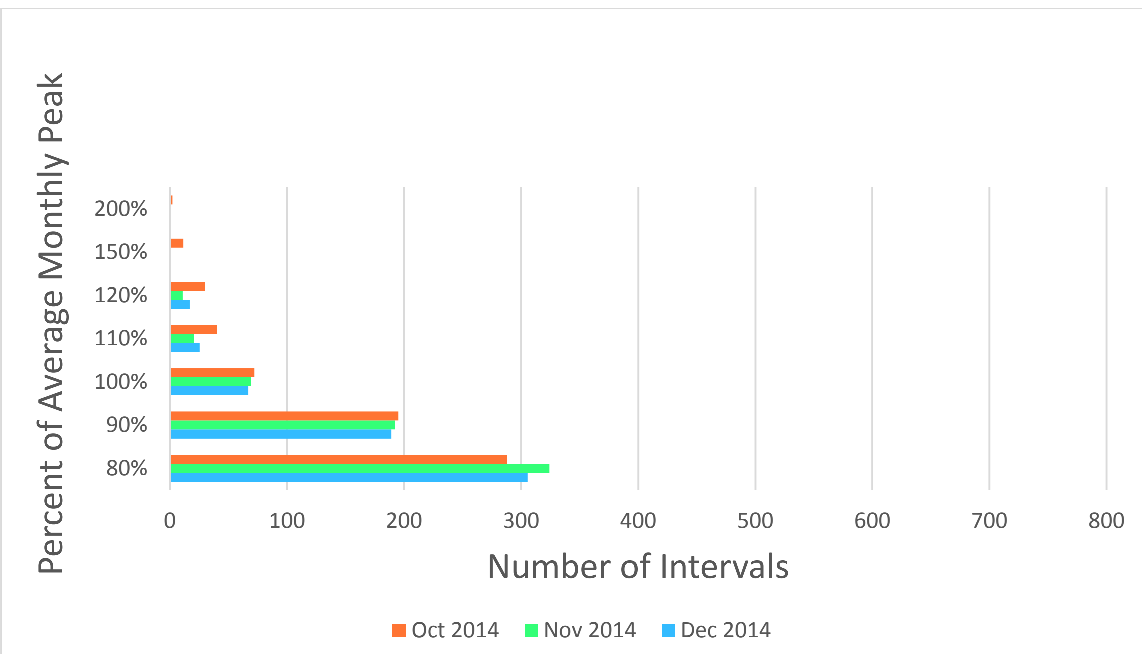


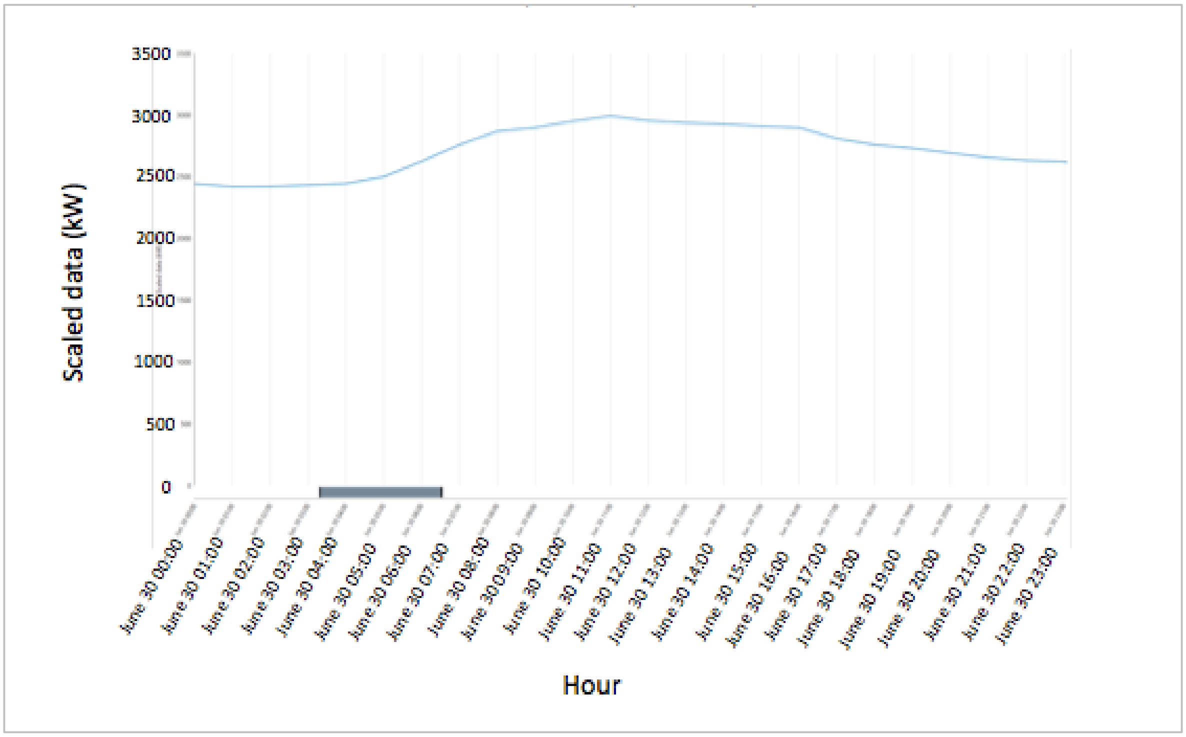
Figure 28. Distribution of Load by Percentage of Average Monthly Peak (Q4, Industrial/Manufacturing)



5.4 Hospitals

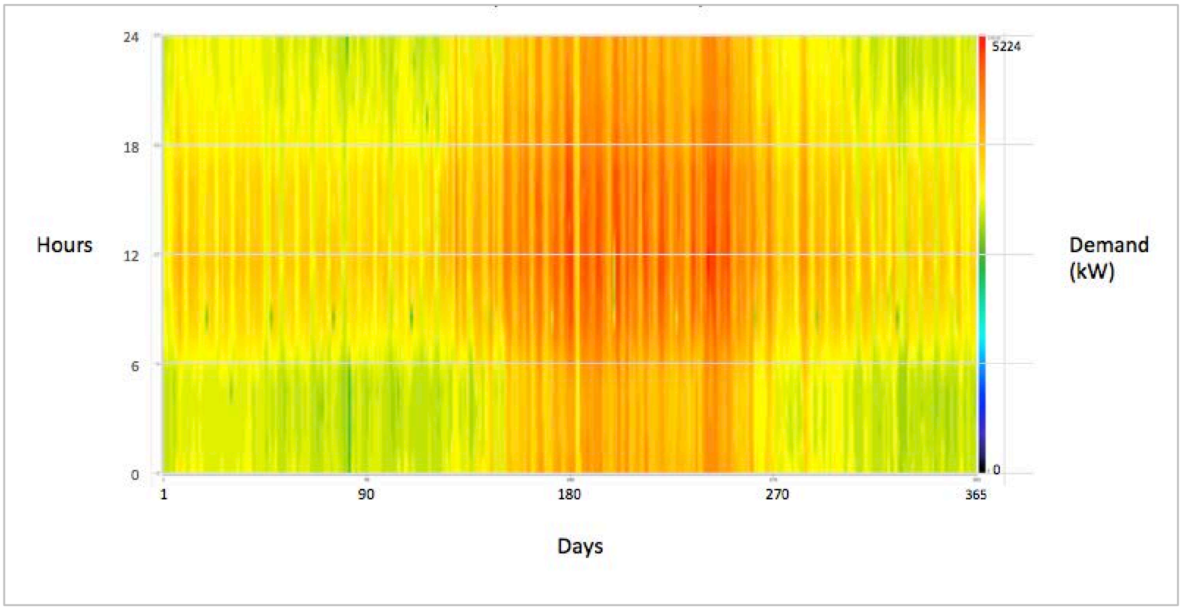
The hospital load archetype is characterized by its relatively flat load profile and consistent high demand. The load profile demonstrates some similarity to the multifamily archetype, with lower baseload demand levels occurring during the early morning hours. But unlike the multifamily archetype, the hospital archetype tends to hit peak demand levels during standard business hours (Figure 29).

Figure 29. Hospital Daily Load Profile



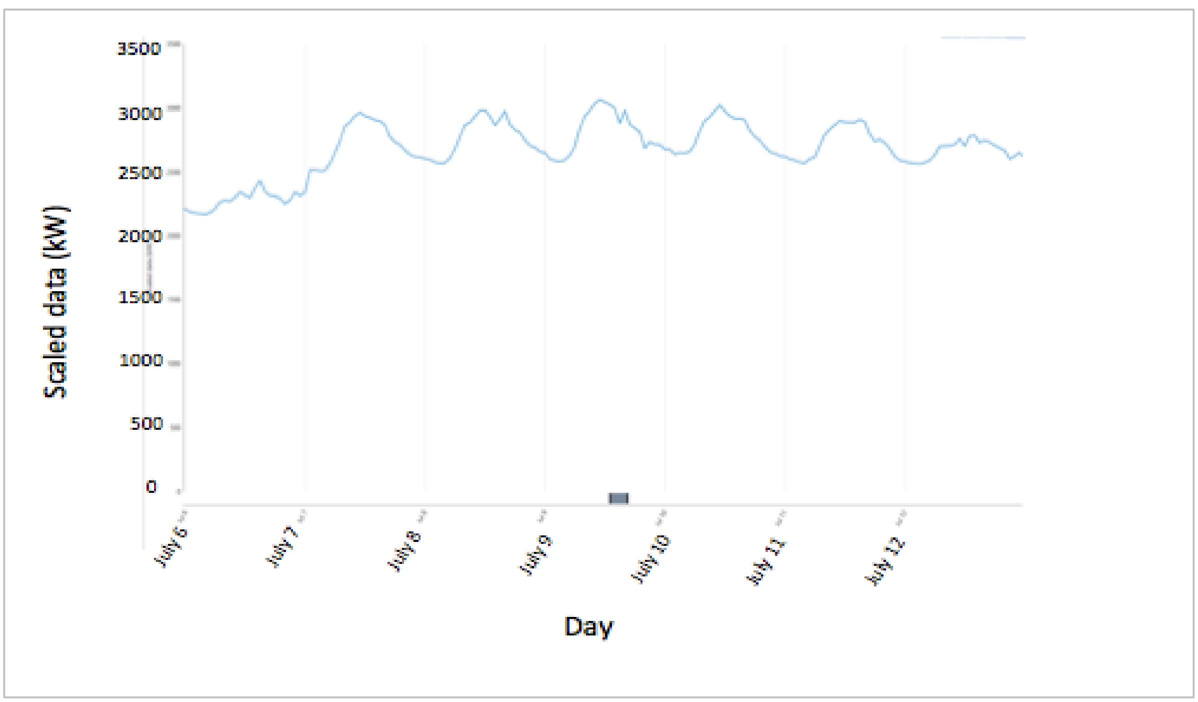
Viewing the annual heat map illustrates how these characteristics play out across the year, demonstrating the low variability in load between peak and baseload, and the occurrence of peak demand spanning typical business hours. During the summer months, cooling requirements drive the load up, but does not influence the underlying load pattern (Figure 30).

Figure 30. Hospital Annual Heat Map



A weekly view of the hospital load archetype reveals that while loads remain relatively constant, higher peak demand levels are set during the weekdays; weekends see a lower level, with Sunday exhibiting the lowest demand levels (Figure 31).

Figure 31. Hospital Weekly Load Profile (Mon-Sun)



5.4.1 Interval Distribution

The healthcare sector exhibited a large distribution of intervals in the 80-90% of average monthly peak, with lower distributions above 100% average monthly peak demand. At 80%, the distribution typically ranged between 600 and 700 intervals, with June and December outliers at 555 and 76 intervals, respectively. At 90%, this drops to approximately half, clustering around 350 intervals. 100% of average monthly peak was experienced on average 100 intervals per month, dropping off at 110% to 20-30 intervals, with March and September outliers at 2 and 54 intervals, respectively. At 120%, the values range from 0-6 intervals with February, September, and December standing out at 17, 14, and 31, respectively. Beyond 120%, there are 0-1 intervals for 150% and no intervals for 200% (Figures 32 to 35).

This distribution indicates that for peak shaving applications, the healthcare sector will need BESS durations of 9 or more hours to eliminate peaks from 120% of the average monthly peak down to 80%.

Figure 32. Distribution of Load by Percentage of Average Monthly Peak (Q1, Healthcare)

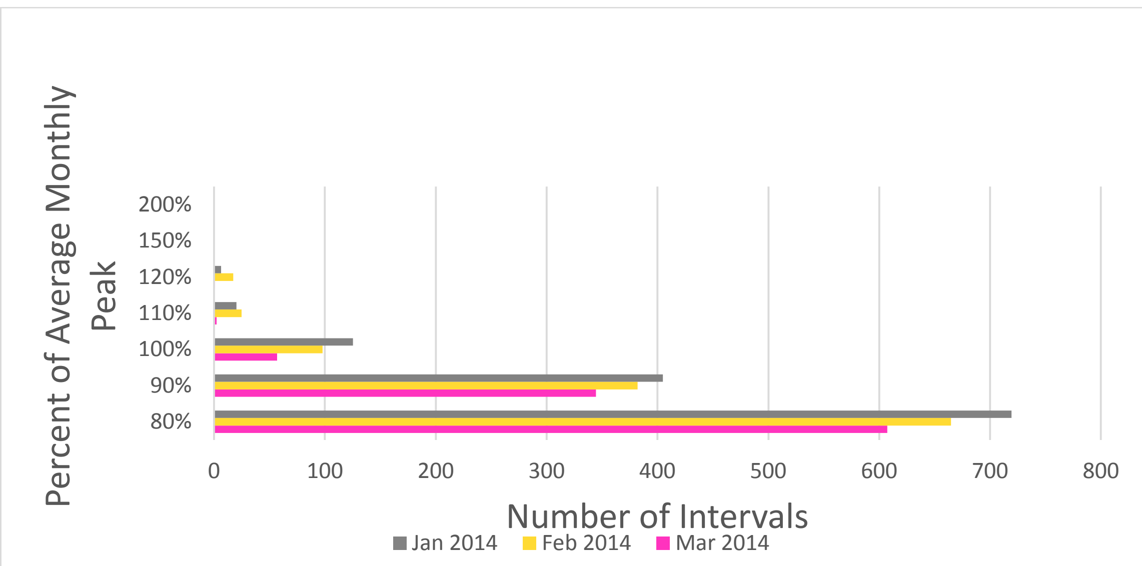


Figure 33. Distribution of Load by Percentage of Average Monthly Peak (Q2, Healthcare)

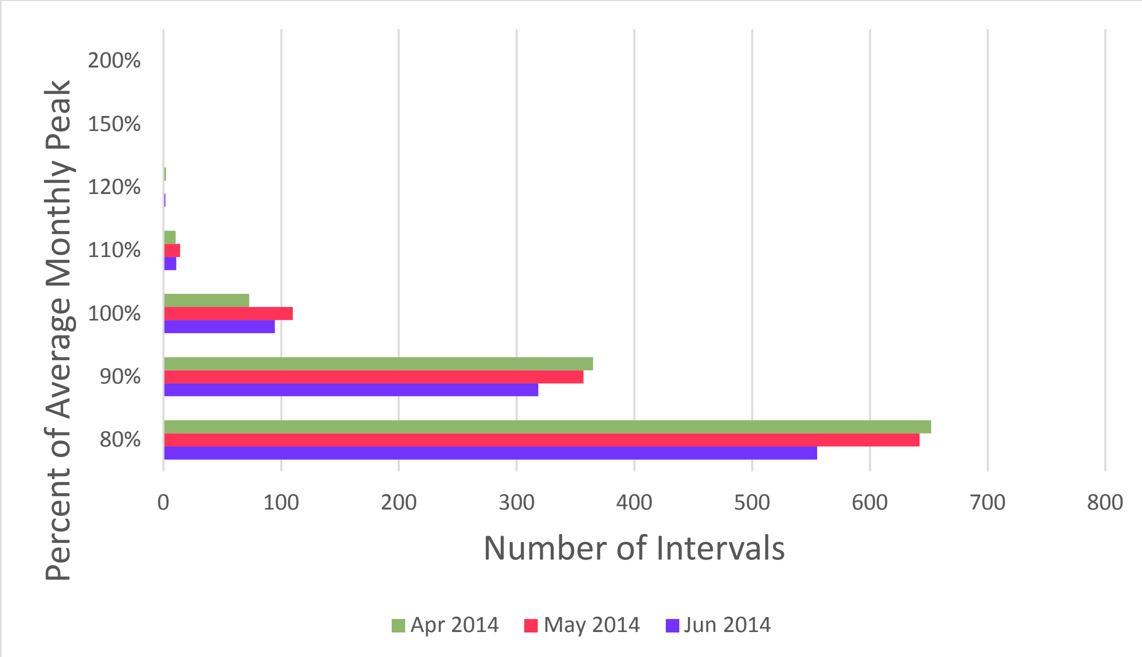


Figure 34. Distribution of Load by Percentage of Average Monthly Peak (Q3, Healthcare)

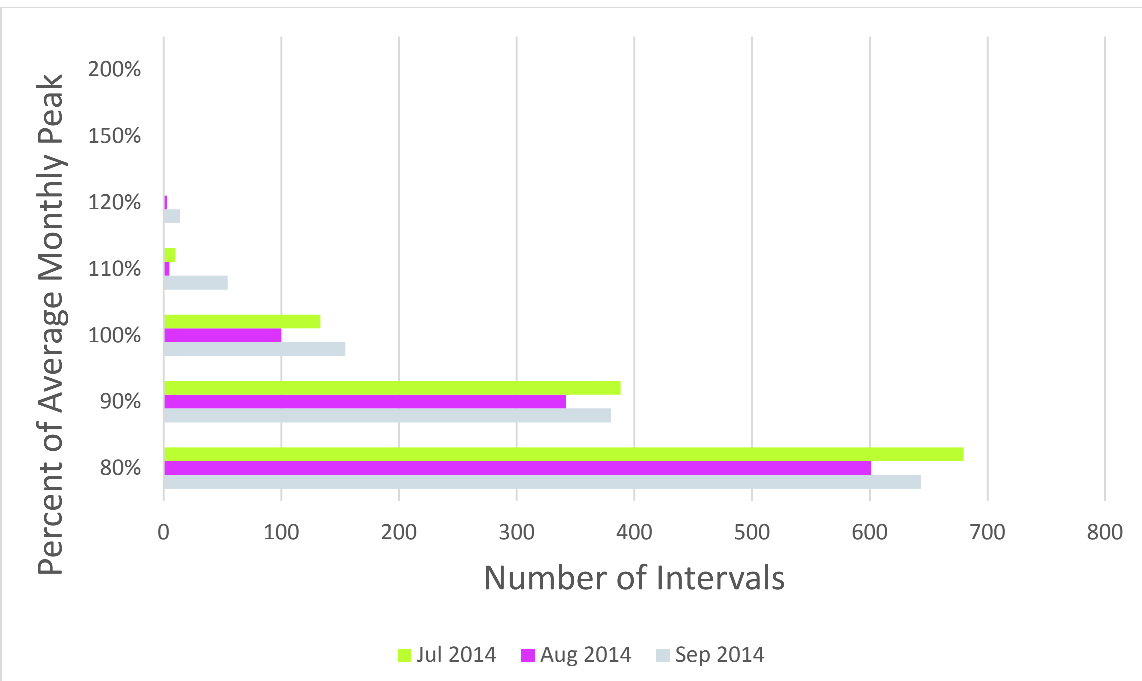
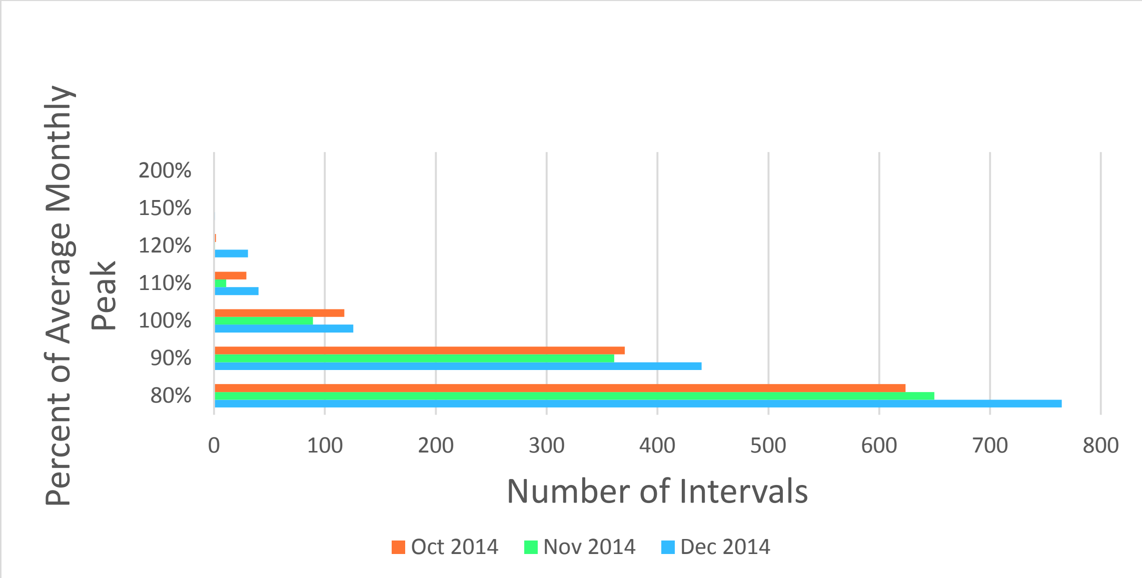


Figure 35. Distribution of Load by Percentage of Average Monthly Peak (Q4, Healthcare)



5.5 Education

The education load archetype is characterized by weekday operations coinciding with the typical business day. Figure 36 depicts that during late evenings and early mornings demand is at a baseload level, while facilities are not in use. A steep ramp-up occurs between 5 a.m. and 7 a.m., as the building systems are brought online to prepare for the day. Peak demand levels the occur between 8 a.m. and 4 p.m., while classes are in session, followed by a gradual ramp-down through the late afternoon and early evening as activity tapers off and systems shut down.

Figure 36. Education Daily Load Profile

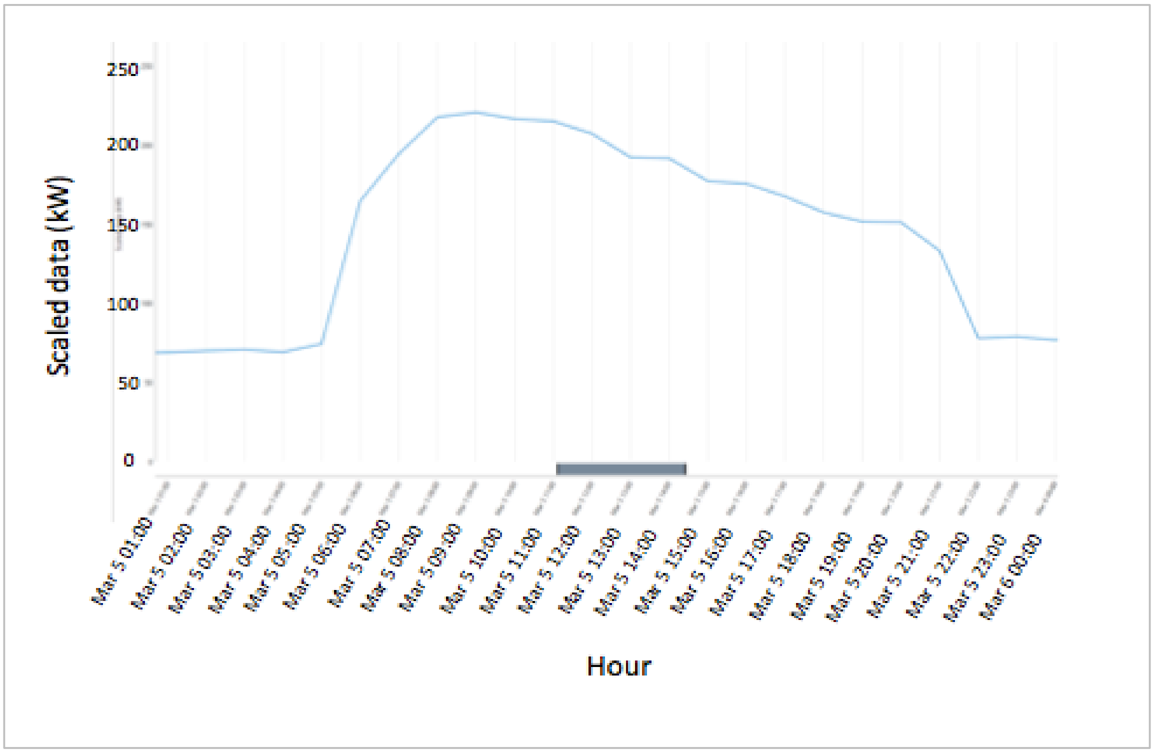
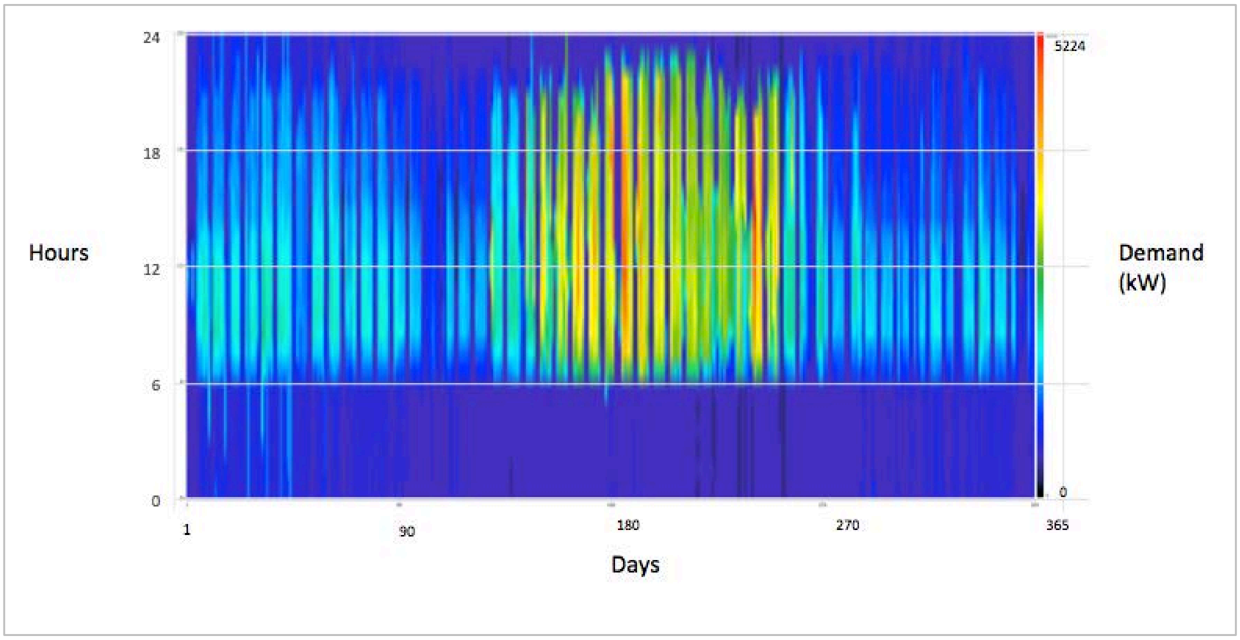


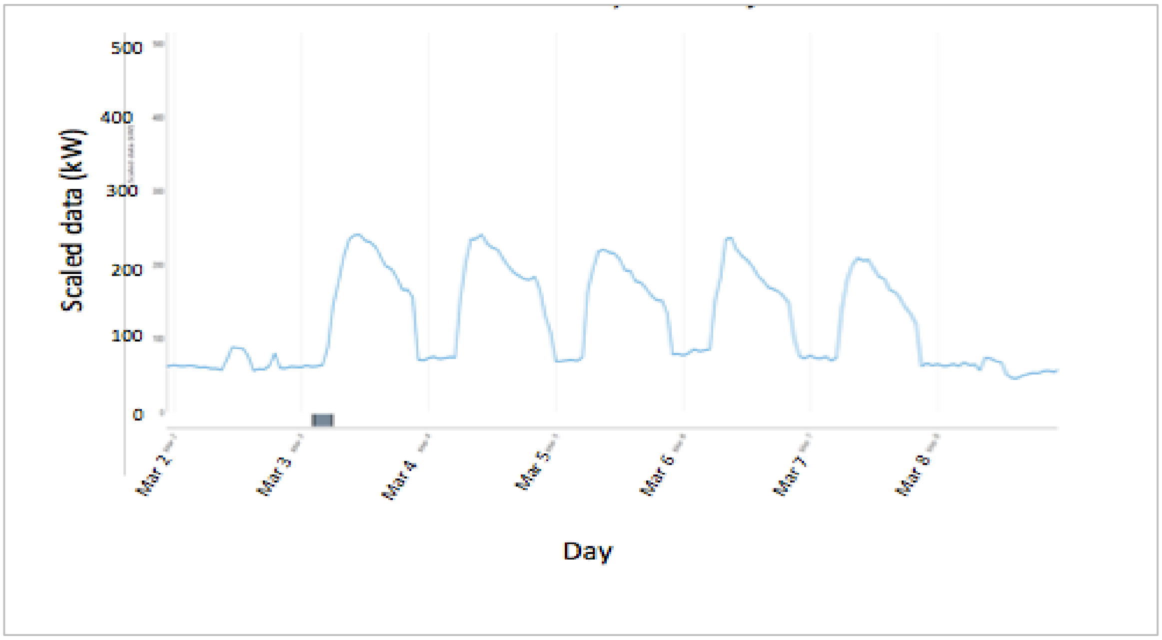
Figure 37 reveals that the previously described operational pattern plays out across the year. Although baseload remains constant, peak demand levels increase dramatically during the summer, as cooling loads increase demand across the operating day.

Figure 37. Education Annual Heat Map



Looking at the education archetype load profile from a weekly perspective, the patterns described are borne out with some variation. Loads appear to peak early in the operational day, then gradually slope down until a rapid ramp-down occurs. Weekend usage is minimal, and does not greatly deviate from baseload (Figure 38).

Figure 38. Education Weekly Load Profile (Mon-Sun)



5.5.1 Interval Distribution

The education archetype exhibits a more compact distribution of intervals around the average monthly peak, with values at 80% converging around 300-400 intervals per month, down to 200-250 intervals at 90%, 100-150 intervals at 100%, 50-100 intervals at 110%, 20-50 intervals at 120%, and 0-15 intervals at 150%.

This distribution indicates that for peak shaving applications, the education sector will need BESS durations of 5 hours to curtail peaks from 150% of average monthly peak to 80% of average monthly peak (Figures 39 to 42).

Figure 39. Distribution of Load by Percentage of Average Monthly Peak (Q1, Education)

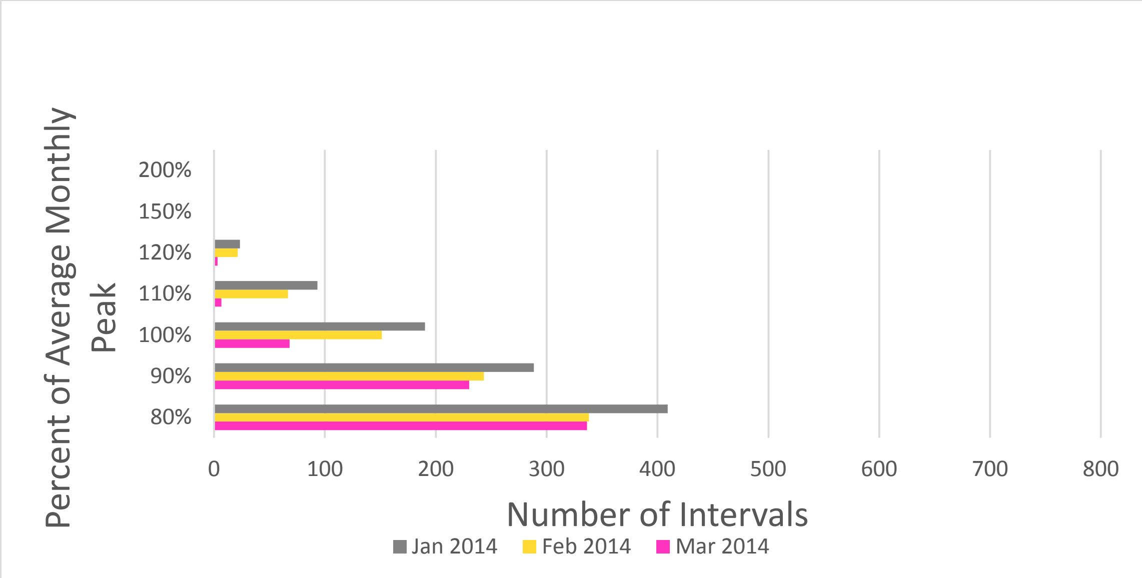


Figure 40. Distribution of Load by Percentage of Average Monthly Peak (Q2, Education)

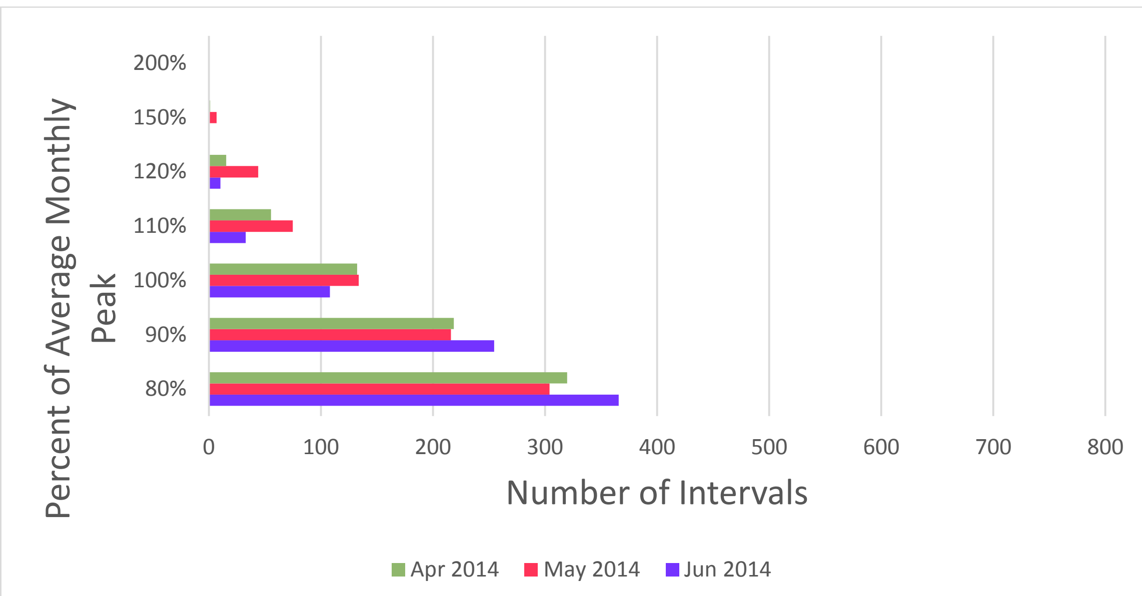


Figure 41. Distribution of Load by Percentage of Average Monthly Peak (Q3, Education)

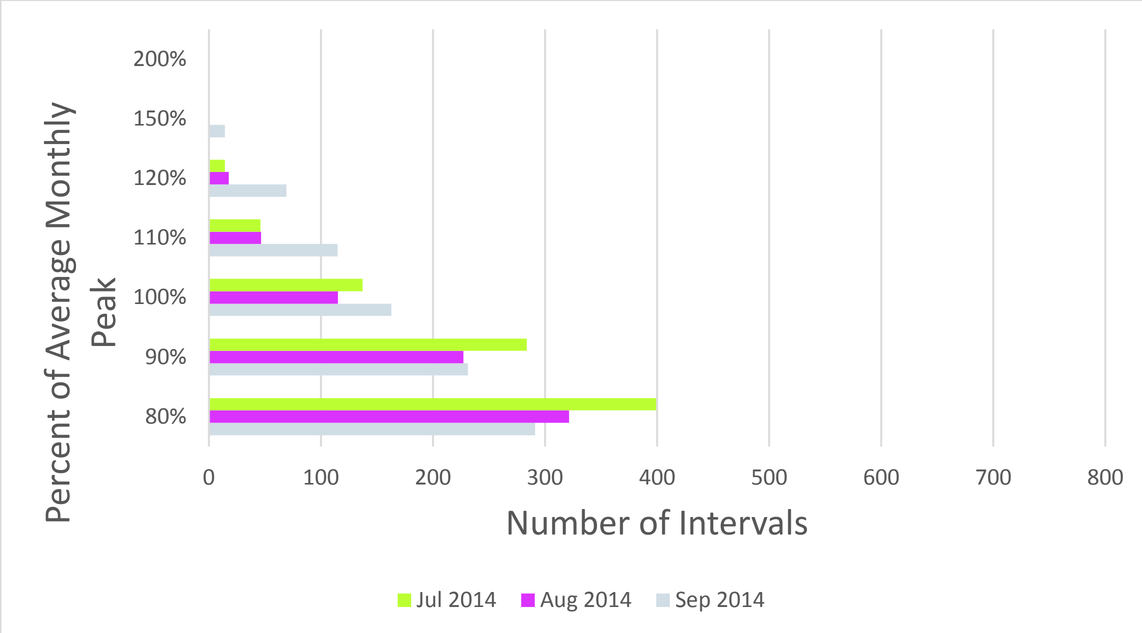
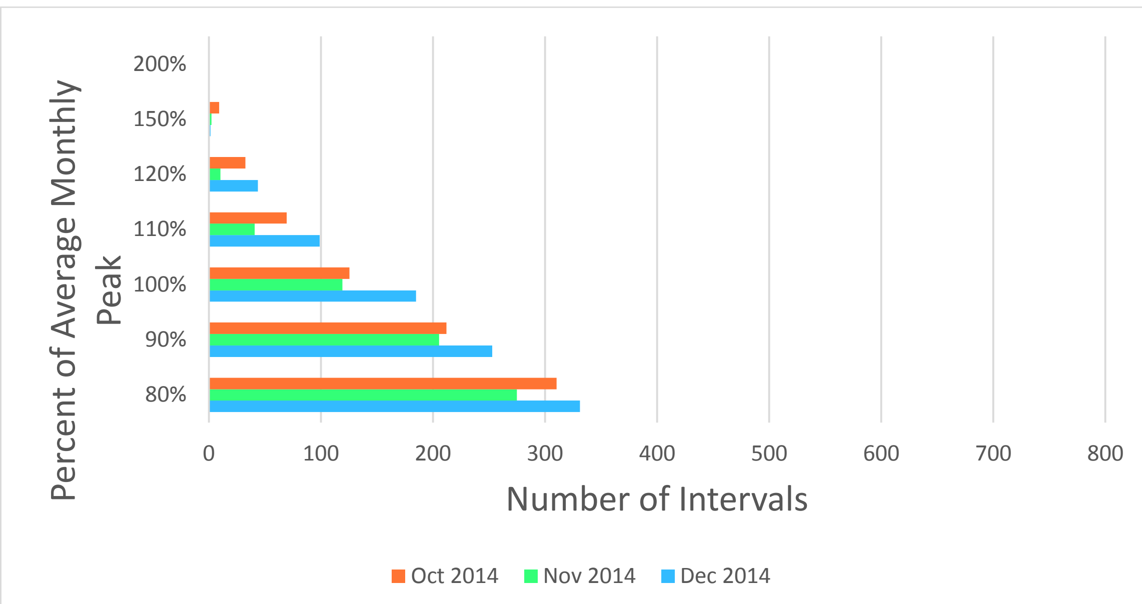


Figure 42. Distribution of Load by Percentage of Average Monthly Peak (Q4, Education)



6 Physical Characteristics

At present, finding the “sweet spot” between load reduction potential and the appropriate physical infrastructure at the site is crucial to successful deployment of BESS, and can be the limiting factor when considering which BESS are appropriate for a given site. As each battery chemistry has its own discrete set of physical characteristics, each requires a different set of physical infrastructure needs be present in order to be successfully installed at a given site.

GridMarket has conducted walkthroughs of a substantial number of sites to prequalify them for BESS feasibility. Across sites surveyed by GridMarket, the limiting factor of where to locate a BESS is the first physical characteristic evaluated at a given site. Across the surveyed sites, several primary categories of space were most frequently surveyed and evaluated for viability: basement, mechanical, parking garage, setbacks; and rooftops.

6.1 Basements

Space: In the commercial real estate and multifamily sites visited, unrented areas in the basement of a number of sites demonstrated good potential for housing BESS from an available square footage perspective. Approximately 1,000 to 5,000 square feet of space are available across nearly 10 sites. Although these locations are ideal from a space perspective, they are frequently under the control of the leasing, who typically view these spaces as untapped source of revenue, either as storage space or for other tenant amenities.

Weight-bearing capability: Although not a given, basements typically are built above the bedrock, and/or are reinforced with slab that is sufficient to house mechanical equipment. However, across sites surveyed, there was at least one instance where slab thickness was cited as a potential concern, given the weight of BESS solutions. Relative to other locations within a building, the basement often offers the greatest flexibility and low cost if concrete pads are needed to reinforce the installation site.

Operating Temperature: Although typically cooler due locations below grade, variability in conditioning across basements make BESS installations with appropriate thermal controls more viable for these locations.

Ventilation: Ventilation in basement spaces also fluctuated, as these conditioning basement spaces is a lower priority for buildings. Across sites visited, ventilation was frequently present, but it often may need augmentation depending upon the particular off-gassing of a given BESS chemistry.

Fire Suppression: Sprinkler systems were typically observed across basement spaces; installation costs to add sprinkler systems to the area may reduce the attractiveness of the location.

Electrical Service: Basement space is often located adjacent to, or proximate to the building's primary electric service, reducing the length of electrical run needed to interconnect, making these locations lower cost relative to other locations.

Figure 43. Unused basement space with pre-existing ventilation and fire suppression system

6.2 Mechanical Room Spaces

Space: Across the Commercial Real Estate sites visited, spaces in mechanical rooms often offer more limited space on square-foot basis compared to basement areas. However, across sites observed, spaces in the 300-1,000-sq ft range were common. Because facilities personnel manage mechanical spaces, there is no competition for available space from leasing, however, facilities management may have earmarked available space for future equipment installations.

Weight-bearing capability: Due to the function of mechanical spaces, weight-bearing capabilities are typically not an issue. If needed, concrete pads can be easily poured within these rooms to support heavier BESS technologies.

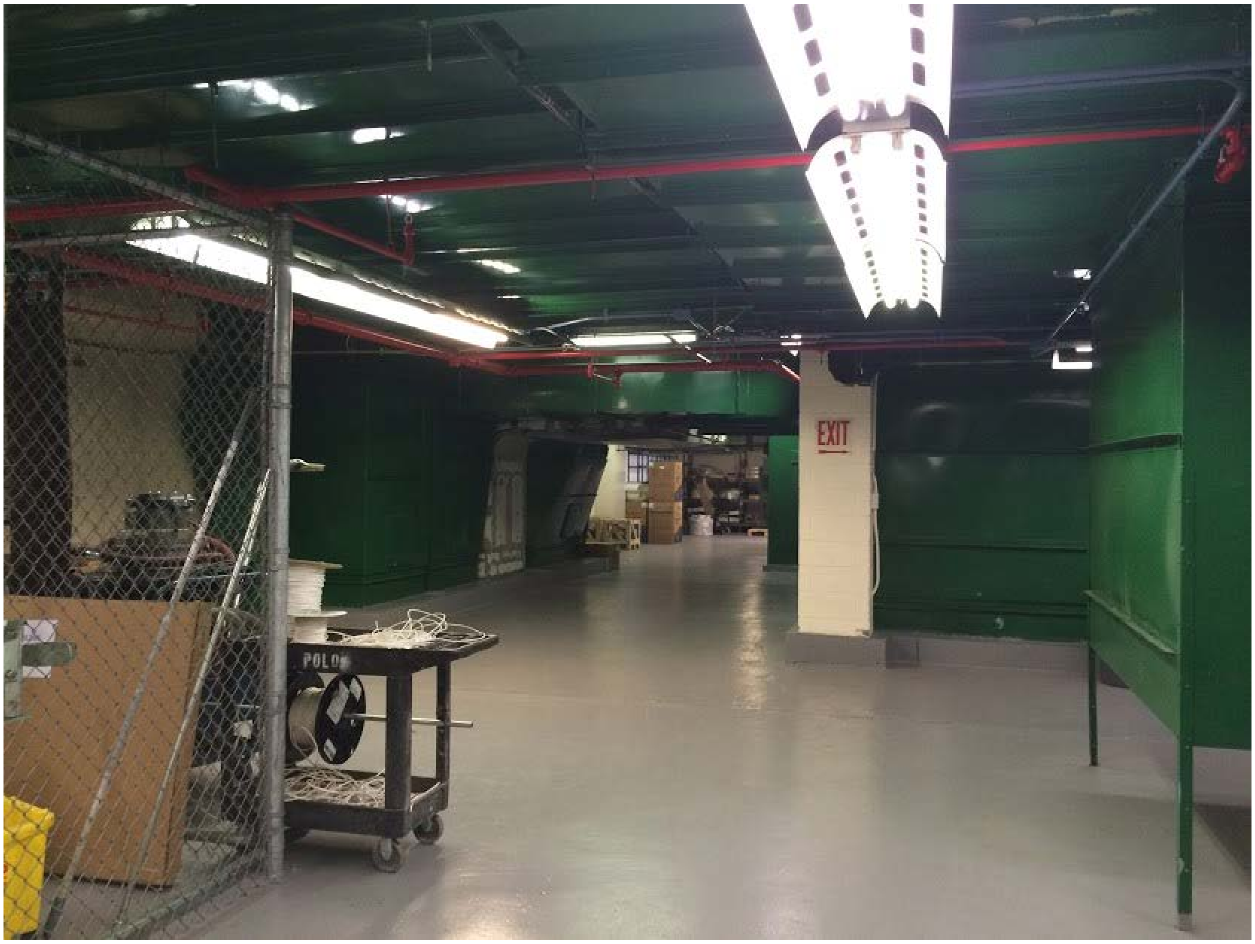
Operating Temperature: Operating temperature in mechanical room spaces is frequently a concern, as other operating equipment, particularly steam, raise temperatures above ideal operating ranges for some BESS chemistries, making specific HVAC controls necessary for most deployments housed in these areas.

Ventilation: Pre-existing ventilation is standard within most mechanical rooms, but on a case-by-case basis, a given site's ventilation operating protocol must be reviewed to ensure BESS off-gassing does not conflict with ventilation schedules/operating protocols within a given mechanical room

Fire Suppression: Sprinkler systems are common in mechanical spaces, however, earlier iterations of building code did not always mandate their installation in all mechanical spaces. The overall size of the area may make upgrading fire suppression cost-prohibitive to spaces without sprinklers.

Electrical Service: Mechanical areas located below grade are typically proximate to Switchgear rooms, reducing the length of electrical run needed to interconnect, making these locations lower cost relative to other locations. Mechanical rooms located throughout the building are frequently a substantial distance to primary electric service rooms (10 stories or more). However, there are often secondary distribution panels proximate, or existing channels for running electrical cable that can mitigate interconnection cost.

Figure 44. Small parcel of space available in a mechanical room with existing fire suppression system



6.3 Parking Garages

Space: Across the commercial real estate and multifamily sites, parking garage areas were observed to have sufficient area on a square foot basis. However, the primary obstacle is balancing the opportunity cost of parking revenue with energy savings for the property. Additionally, within the commercial real estate building sector, parking garages are frequently operated by a third party. However, there is often pockets of subprime space in parking garages that can be targeted for siting BESS. Because these areas have limited value if they are not suitable for parking, they can be compelling options.

Weight-bearing capability: Typically not an issue as parking garages are designed to bear the weight of motor vehicles.

Operating Temperature: As unconditioned spaces, ambient temperatures were observed to fluctuate with weather conditions, making solution-specific HVAC controls necessary for most deployments housed in these areas.

Ventilation: Parking garage ventilation standards for covering automobile off-gassing will typically be sufficient to cover ventilation requirements of BESS technologies.

Fire Suppression: Sprinkler systems were observed across all parking garages visited. Fire suppression standards in parking garages require the ability to extinguish fires caused by automobile-related crashes or malfunctions.

Electrical Service: Parking garage space is often located adjacent to, or proximate to the building's primary electric service, reducing the length of electrical run needed to interconnect, making these locations lower cost relative to other locations

Figure 45. Parcel of unusable space in a parking garage

6.4 Setback Spaces

Space: Across the commercial real estate building stock surveyed, setback spaces routinely had approximately 1,000-5,000 square feet or more available. In most cases, setback space was uncontested for other uses, but there may be restrictions on housing equipment from a site-line standpoint depending on a building's location and landmark status (Figure 46).

Weight-bearing capability: Setback spaces overwhelmingly are not designed for weight-bearing purposes, and in a majority of cases require the installation of steel dunnage to support the BESS, increasing installation costs.

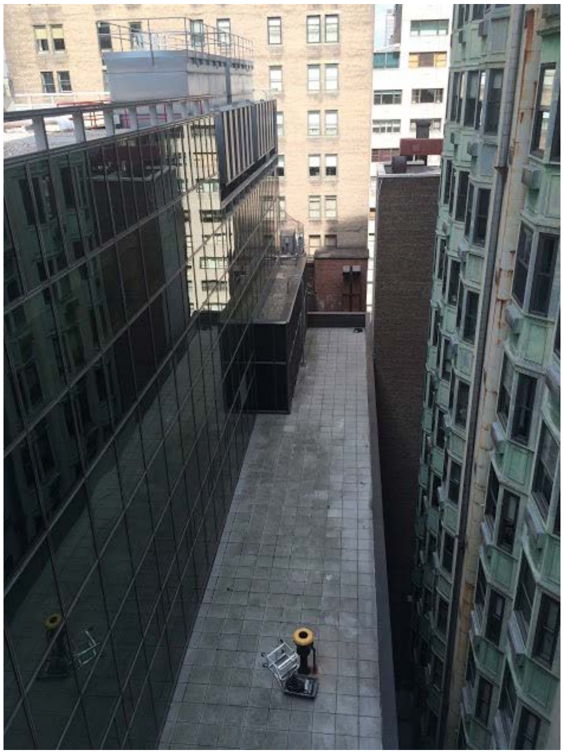
Operating Temperature: Setback spaces are exterior, requiring appropriate temperature controls.

Ventilation: Outdoor location negates the need for additional ventilation.

Fire Suppression: Outdoor location creates a challenge for siting sprinkler systems, making these locations potentially tenuous for particular chemistries of BESS.

Electrical Service: Distance to electrical service can be substantial. However, some setback locations can leverage existing channels for running electrical cable that can mitigate interconnection cost.

Figure 46. Setback space adjacent to emergency generator room



6.5 Rooftops

Space: Rooftops typically have a large amount of available space, ranging from thousands to tens of thousands of available square feet. In multifamily buildings, the space is under competition as a tenant amenity; in commercial real estate, roof space is typically used for housing mechanical equipment and can be a compelling option (Figure 47).

Weight-bearing capability: Like setbacks, roof space is not typically capable of meeting the weight bearing requirements of most BESS technologies. However, in instances where the roof space is used for mechanical purposes, existing support structures may already be in place.

Operating Temperature: Roof spaces are exterior, requiring appropriate temperature controls.

Ventilation: Outdoor location negates the need for additional ventilation.

Fire Suppression: Outdoor location creates a challenge for siting sprinkler systems, making these locations potentially more tenuous for particular chemistries of BESS.

Electrical Service: Distance to electrical service can be substantial. However, some rooftop locations can leverage existing channels for running electrical cable that can mitigate interconnection cost.

Figure 47. Rooftop space housing existing mechanical equipment

7 Market Insights for Battery Storage Solutions Providers

Both the statistical load analysis and discussion of load archetype characteristics yield a wealth of insights for solutions providers from the power and energy standpoint. Taken together with an understanding of the physical opportunities to deploy BESS in the New York City market, the following four key takeaways can help spur the continued acceleration of BESS proliferation through helping solutions providers better understand potential customers.

7.1 Different Load Archetypes Have Unique Needs

Using quantitative analysis and load characteristics, a distinct snapshot of each archetype emerges. Understanding the areas where different customer needs are aligned and in sync is invaluable information for solution providers when building out their product line. For example, the high power, high variability loads observed in the industrial/manufacturing archetype require a specific BESS product not directly compatible with Multifamily and Healthcare loads. The Commercial Real Estate and Education Archetypes on the other hand both demonstrate more pronounced peaks with mid-long duration, which could serve as a core focus for solutions providers as they develop products for the center of the market, which can then be tweaked accordingly for industrial/manufacturing applications as well as Multifamily and Healthcare.

7.2 Design Solutions that Address Peaks

As the quantitative analysis shows, there is opportunity to shave both the maximum monthly peak—the peak amount above the average monthly peak. But for each archetype, a substantial amount of load shaving potential is left relative to the monthly average load. In fact, across archetypes, the ratio of average monthly peak/average load was higher than the ratio of maximum monthly peak/average monthly peak. Where a modular approach is required, due to budgetary or space constraints, solutions providers can deploy products in a modular fashion—first addressing the Maximum monthly peak, then expanding capacity to address the average monthly peaks.

7.3 Size Energy Capacity to Cover Twice the Peak Duration

The peak duration values observed across archetypes ranged from 2.25 to 3.6 hours. To ensure a solution can address not only the maximum monthly peak, but also the average monthly peak, products would be well positioned for success if sized at least two times the peak duration for a given archetype. Additionally, deploying solutions in a modular fashion can allow solutions providers target the maximum monthly peak and then add storage capacity and power controls to address the broader average monthly peaks.

Analysis of the interval distribution as a percentage of average monthly peak also supports this approach, suggesting that a longer duration systems enable flexibility to both curtail the actual monthly peak, while additionally reducing peak demand to levels 80-90% the average monthly peak. But for archetypes that exhibit actual peaks above 150% of the average monthly peak, such as the industrial/manufacturing sector, solution providers should be cognizant that brief but intense power spikes are frequently the driving factor behind actual monthly peak levels, and design with excess power capacity in mind.

7.4 Modular Solutions Offer Greatest Flexibility for Limited Space

As the discussion of site characteristics demonstrated, finding ideal locations for BESS products is often a major challenge. To whatever extent possible, solutions providers should seek to design products that can be deployed in distributed modules. This approach will allow greatest flexibility for scaling up systems to best meet a given building's energy storage needs while avoiding obstacles in the deployment process.

Appendix A: Glossary of Terms

Average daily load (kW) - average of any daily 24-hour period of 15-minute interval data

Average monthly peak (kW) - summation of the average of the daily peaks for each day of the particular month in question

Average monthly peak intensity - average monthly peak (kw) divided by average daily load (kw), expressed as a percentage or a ratio

Average peak duration (hours) - average number of 15 min intervals above monthly average peak threshold per month divided by average number of peaks in a month divided by four, 15-minute intervals in one hour

Daily peak - the highest individual 15-minute kW reading of any given particular day

Maximum average monthly peak (kW): maximum peak in a given month (i.e., the peak of all peaks)

Maximum monthly peak intensity - maximum average monthly peak (kW) divided by average daily load (kW), expressed as a percentage or a ratio

Peak duration - the average sum of the number of 15-minute interval above monthly average peak threshold for each given particular day, as measured across all buildings of the same archetype.

Peak frequency - the average of all the average peak durations for any given month, as measured across all buildings of the same archetype.

Peak intensity - monthly max peak divided by average peak, or maximum average monthly peak (kW) divided by monthly average peak (kW), as measured across all buildings of the same archetype.

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