Alternative Billing Structures for Watauga County Municipal Buildings

by:

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Abstract

Advances in metering technology open up opportunities for alternative billing structures for electricity customers. Physical or virtual aggregation offer customers the chance to aggregate their electricity accounts that might otherwise be metered and billed separately. This can lead to financial savings as well as allow customers to more efficiently run and schedule their electric loads.

Watauga County has a group of five accounts that are ideal candidates for virtual account aggregation. The Watauga County Courthouse and the Administration Building house these five accounts and these buildings are located on adjacent parcels of land.

Detailed consumption records allowed for a thorough analysis of these accounts' electricity use patterns on an hourly, daily, and seasonal basis. The analysis shows that many of the accounts peak at different hours of the day, thus making them the perfect group to aggregate and see significant savings in demand charges. Aggregating the bills would also save the county money in the form of reduced facilities charges and one account being charged on a lower usage rate.

Overall, the study found that energy consumption varied significantly based on the day of the week, hour of the day, and season. The analysis results anticipated approximately $8,500 worth of savings for the county with an aggregated billing approach.

List of Figures and Tables

List of Abbreviations

AC..Air Conditioning

CACR……………………………………………………………Coal Ash Cost Recovery

CBECS...Commercial Buildings Energy Consumption Survey

DOE ....Department of Energy

EIA...US Energy Information Administration

EPA...Environmental Protection Agency

HVAC ....Heating, Ventilation, and Air Conditioning

kW...Kilowatt

kWh...Kilowatt-hour

LED...Light-Emitting Diode

LEED .... Leadership in Energy and Environmental Design

NREL...National Renewable Energy Laboratory

NRLP…………………………………………….……………..New River Light and Power

US ....United States

Chapter I: Introduction

Background

Previous Analysis

In the spring of 2018, an analysis was done of the energy usage patterns for Watauga County municipal buildings in the town of Boone, North Carolina. This analysis was done on 18 accounts representing 14 different buildings. Many of these accounts are for buildings or energy consumers that existed on the same or adjacent parcels of land. The county is paying a facilities fee as well as a demand charge for each of these accounts.

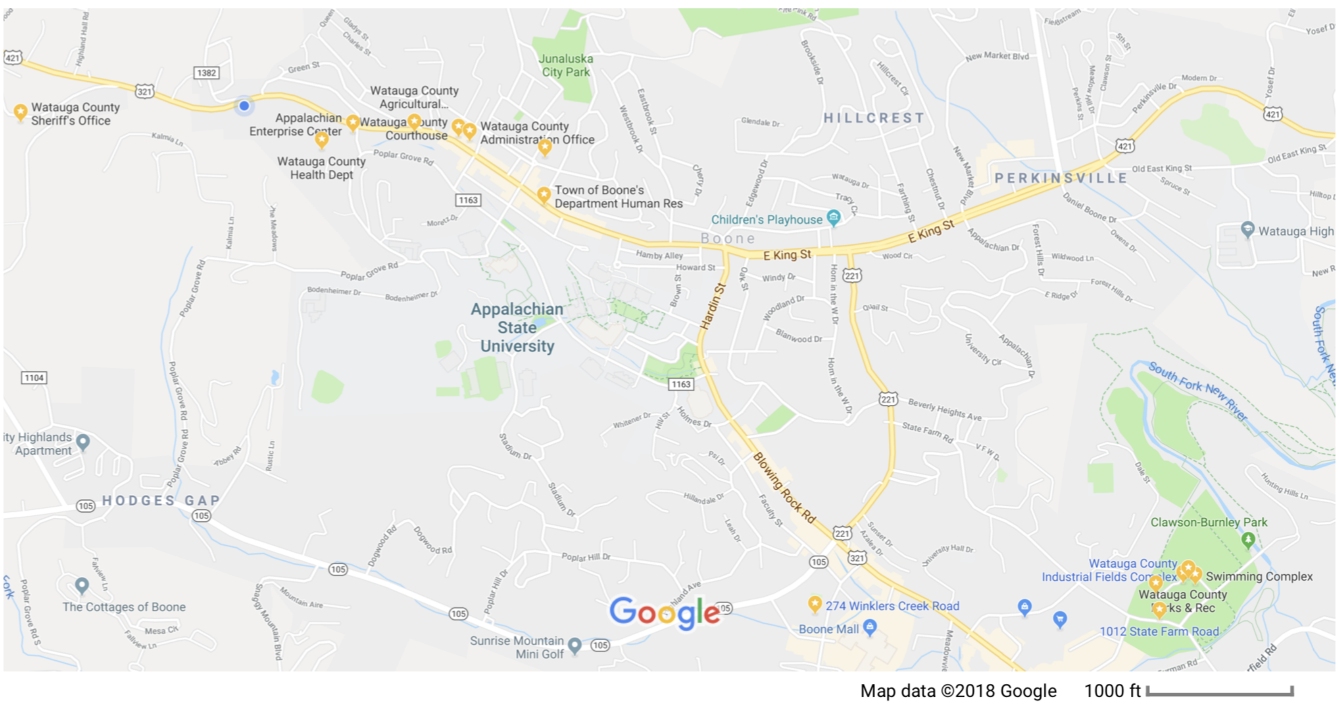

Figure 1. Map of Watauga County municipal buildings included in the spring 2018 study

The spring 2018 study found that an aggregated billing approach to the accounts in question would save Watauga County close to $17,000 annually. Additionally, the study found that aggregating the accounts could potentially reduce demand prices by having a bill that reflects the *coincident* peak for all of their accounts as if they were one, as opposed to multiple bills that reflect the sum of all demand spikes for each account.

The previous analysis was done using the monthly energy bills for the 18 accounts. As will be gone over in more detail later, the current study used energy usage data collected at 15-minute intervals, and thus served to confirm and reiterate the benefit of this account aggregation.

Focus group

In this study, five accounts were selected for analysis. The chosen accounts represent energy consumers that exist on the same or adjacent parcels of land. These five accounts were chosen because together they are excellent candidates for rate restructuring and strategic energy use adjustment.

Figure 2.Map showing land parcels of the buildings in the study

Figure 3. Map of the Watauga County Courthouse and New Administration Building

Four of the accounts are located in the Watauga County Courthouse; these are the east annex of the courthouse (82100), the complex B of the east annex (35100), and the east annex elevator (4700). The final account is for new administration building (60201). They will be referred to by their account numbers (given in parentheses above) moving forward.

Building Name	Account Number	Schedule
Courthouse	54200	GL
East Annex	82100	GL
Complex B	35100	GL
Elevator	4700	G
Administration Building	60201	GL

Table 1. Focus group buildings, account numbers, and descriptions

Accounts 54200, 82100, 35100, and 4700.

Account 54200 is the Watauga County Courthouse. It is open from 8 am to 5 pm Monday through Friday and is closed on holidays. In addition to regular employees, visitors to the building are frequent. Account 54200 is billed on a large commercial (GL) schedule.

Accounts 82100, 35100, and 4700 represent structures that were added to the building attached to account 54200. As such, these have the same hours as account 54200's building and experience similar baseline energy use patterns as well as consumption patterns associated with traffic in and out of the building.

Accounts 82100 and 35100 are also billed on a GL schedule. Account 4700 is billed on a commercial (G) schedule.

Name	Schedule	Facilities Cost ($/month)	Energy Cost ($/kWh)	Demand Cost ($/kW)	CACR ($/kWh)
Residential	R	$12.58	$0.080027	$0.00	$0.003791
Commercial	G	$17.42	$0.076666	$0.00	$0.003791
Large Commercial	GL	$23.22	$0.044205	$8.27	$0.003791
Commercial Demand High Load Factor	GLH	$23.22	$0.041783	$10.00	$0.003791
Appalachian State	A	$10.63	$0.030933	$8.75	$0.003791

Table 2. NRLP electricity rates by type of customer

Account 60201.

Account 60201 is the Watauga County administration building. It is open from 8 am to 5 pm Monday through Friday and is closed on holidays. The Watauga County financial and administrative departments are located in this building. According to the director of human resources, Monica Harrison, there are about 8 employees that work full-time in the building. In addition to the regular staff, there is minor traffic in and out of the building for meetings and other business conducted there. Account 60201 is billed on a large commercial (GL) schedule.

Purpose

The purpose of this study was first and foremost to analyze the electricity usage data, collected at 15-minute intervals, for a group of Watauga County government buildings located adjacent to one another. Through this analysis, the energy consumption pattern of each account was determined and compared to one another.

To further the analysis, a sixth, hypothetical "account" consisting of all five accounts' aggregated values was calculated. These values helped to establish what the baseline energy use is of these buildings as a whole.

Through the analysis of these accounts' energy usage, we were able to identify patterns of consumption that appear to correlate with certain seasons, days of the week, and hours of the day.

The hope for the outcome of this study was to identify key targets for financial savings for the county's electric bill. Once there was a clear picture of how seasonality, the day of the week, and the time of the day affect energy consumption, areas where load-shaving techniques and energy-saving consumption approaches could be employed were identified. Then, the financial impact that these changes would have on the county's electricity bill was modeled.

Scope

This study analyzes the energy usage patterns of the accounts on an hourly, daily, and seasonal basis. For the purposes of this study, days and months were grouped into descriptive categories.

The daily analysis was done on two groups of days: weekdays and weekend-days. Weekdays encompass Monday through Friday. Weekend-days are Saturday and Sunday. These groups were chosen because the accounts are for structures that are largely used during the work week, so it is safe to assume that the consumption on weekdays follows a similar pattern to one another, as will weekend-days.

The monthly analysis was done on four groups: spring, summer, winter, and fall. The spring season includes the months March, April, and May. The summer season includes the months of June, July, and August. The fall season includes the months of September and October. Finally, the winter season includes the months November, December, January, and February. Months were put into seasonal groups with other months that have similar climates.

Group	Days included
Weekdays	Monday, Tuesday, Wednesday, Thursday, Friday
Weekend-days	Saturday, Sunday

Table 3. Categories of days

Group	Months included
Spring	March, April, May
Summer	June, July, August
Fall	September, October
Winter	November, December, January, February

Table 4. Categories of months

Chapter II: Literature Review

Energy Use in Governmental Buildings

In 2012, the US Energy Information Administration (EIA) conducted a Commercial Buildings Energy Consumption Survey (CBECS) on approximately 12,000 commercial buildings in the US. The EIA estimates there are approximately 5.6 million commercial buildings in the US. The 12,000 sampled for the CBECS survey were from 687 geographical areas, 10 age groups, 5 climates, and numerous size and use classifications. The data collected included a section of 776 buildings classified as governmental [9].

There were 558 local governmental buildings in the survey; 98 of these classified as local government office buildings [9]. Local governmental buildings consumed 518 trillion BTUs of energy in 2012. A breakdown of these 518 trillion BTUs is shown in the chart below.

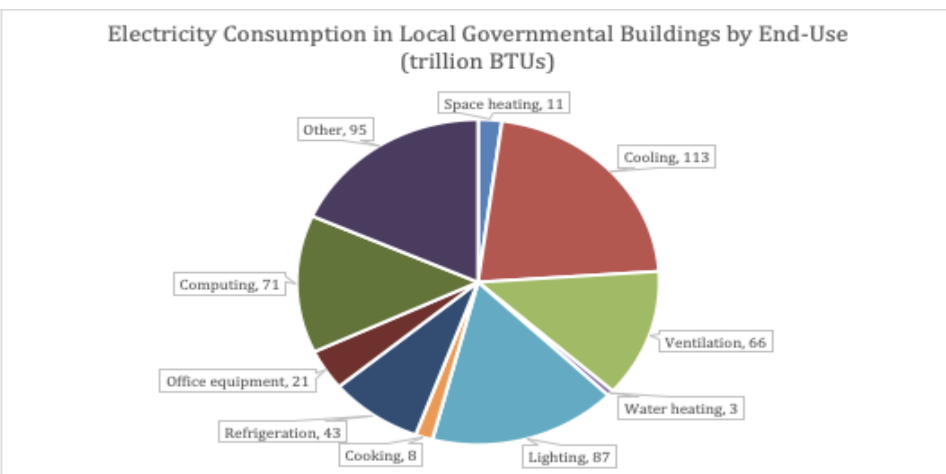

Figure 4. Electricity consumption in local governmental buildings by category

As with most buildings, lighting, ventilation, and cooling are three activities that consume the most energy in governmental buildings.

Utility Rate Structures

Utility rate structures are designed to cover the costs that a utility incurs when it generates and distributes power. Utility rate structures generally have three components: a customer charge, a demand charge, and a usage charge.

The customer charge, or facility charge, is a flat-rate fee included in monthly billing that covers the cost of installing and maintaining infrastructure, things such as meters, power lines, and other equipment. These charges are typically based on the type of building that is consuming power [1].

The demand charge is a charge based on the highest instance of usage recorded by an account's meter in a given month. This charge is priced per kilowatt (kW) and is designed to ensure utilities can meet their customers' peak demand. It isn't unusual for the demand charge to comprise 30-70% of the customer's electricity bill [3]. This charge covers the costs associated with producing, transmitting, and storing energy, as well as covering the cost of equipment such as transformers.

The usage charge (also called the energy charge) is the charge determined by how much energy a consumer uses in a month. The energy charge is priced per kWh, and covers the cost of producing and/or buying electricity and dispatching it to the consumer [1].

Factors Affecting Electricity Prices

The price of electricity paid by the customer varies depending on how much it costs the utility to provide it. There are several factors that can raise or lower the cost of electricity, the most common variation stemming from peak demand times, days, and seasons. The price of electricity also depends on the type of customer or building being powered [4].

Demand charges.

Utilities must meet customer demand at all times, including when coincident usage among customers is at its highest. Peak demand is the term used to describe this time of coincident usage. It describes the time of the season, day, or even hour when the utility has to provide the most energy to its customers. Typically, peak demand occurs in summer months because air conditioning units use a lot of energy.

Utilities charge their customers a demand charge based on their highest average usage recorded by their meter in a given month. Demand charges are typically charged per kW. These charges ensure that the utility has the capacity to dispatch enough energy to cover all their customers during times of peak demand [3].

Type of customer.

The cost of electricity per kWh is generally highest for commercial and residential customers and lowest for industrial customers. Since industrial customers use the most energy and use it at a consistent and higher voltage, it's efficient and financially advantageous for utilities to dispatch electricity to them [4].

Strategies to Reduce Electricity Bills

Commercial and residential customers alike aim to save money on their electricity bills wherever they can. There are many strategies that customers can use to do this, such as load shifting, and taking advantage of time-of-use electricity pricing.

Load shifting.

For accounts that have multiple energy-consuming appliances that tend to be run at the same time, load shifting is an advantageous option to keep demand pricing low.

When certain loads are shifted so that an account does not have multiple appliances or applications peaking in energy consumption at the same time, it can lower the accounts' peak energy demand significantly. This translates into lower demand charges for the accounts.

Today there are options for automated systems that shift loads so that there are fewer times of the day when multiple loads are consuming a significant amount of energy at the same time [11].

Time of use rates.

Electricity use tends to follow a general trend for most homes and businesses. The trend similarities of energy consumers result in peak demand times, when the utility must power many customers' loads at once. Many utilities charge more for energy during these peak demand times, as it puts excess stress on the utility to dispatch energy during these times.

Account aggregation.

When multiple electricity accounts exist in the same or adjacent facilities, it can be beneficial to aggregate these accounts and treat them as one customer. The savings associated with account aggregation can be seen if the utility charges larger customers a lower energy rate. There are also savings that come from the customer paying one facility cost.

If multiple buildings are counted as one facility with one aggregated account, it can be much easier to program certain loads to not coincide with one another, therefore reducing the overall demand cost on the customer's energy bill [11].

Electricity accounts can be aggregated physically or virtually. A physical account aggregation would require that each energy consumer is wired together and to one, shared meter. Another option is to virtually aggregate the accounts. This is done when the utility combines the usage data from each account electronically before billing.

Chapter III: Methodology

Data

The data used in this study were provided by New River Light and Power (NRLP). The AMI meters on the account send a snapshot of the cumulative kWh usage every 15 minutes for each account. This study was done using one full year of AMI measurements; this data was all that was available since the AMI meters were installed in August 2017.

Data Preparation

Before the data set could be analyzed, some preparation was required in order to get it into a usable form. For one, the values were given in meter increments, not kilowatts. A multiplier was determined and applied to all except one account. It was decided that the multiplier would be applied at the end of the data preparation process, since the smaller, meter increments were initially simpler to work with.

Additionally, there were many values that were missing from the data. This will be discussed more in the *Limitations* section.

To organize the data for analysis, all the values were sorted into various classification categories as defined above; season, day of the week, and time of the day.

Conversion from Meter Increments to kW

The data used for this analysis came from NRLP's Advanced Metering Infrastructure (AMI) meters. For four of the five accounts, the given increment has a multiplier of 80, meaning that they must be multiplied by 80 in order to convert them from meter increments to kWhs.

These four accounts were 54200, 82100, 35100, and 60201. Account 4700 was already represented with the correct unit. For clarity's sake, the multiplier was applied at the end when the data set was ready for further analysis.

Limitations

While the data set was complete for the most part, there were certain points in time when the meter reported 0 kW being used. The data provided also recorded a cumulative kWh value for the accounts. Since the accounts' cumulative kWh usage went up during the time that the meter was reporting 0 kWh, observers were able to discern that these points were inaccuracies. In order to fill in these blanks, multiple methods were tried to estimate the missing data as accurately as possible.

Table 4 below summarizes the amount of data missing, as well as the frequency of various lengths of missing increments. Tables 5 and 6 further describe the missing data by summarizing in what months and on what days the missing intervals occur.

Account number	Total missing intervals	Runs with 3-30 missing intervals	Runs with 31-60 missing intervals	Runs with 61-90 missing intervals	Runs with 91-110 missing intervals
54200	306	32	3	0	0
82100	217	29	1	0	0
35100	780	28	1	0	3
4700	223	33	0	0	0
60201	202	32	1	0	0
Totals	**1,728**	**154**	**6**	**0**	**3**

Table 5. Quantitative description of missing data

Account number	Total missing intervals	Missing intervals in spring	Missing intervals in summer	Missing intervals in fall	Missing intervals in winter
54200	306	22	9	243	32
82100	217	7	0	191	19
35100	780	7	3	709	61
4700	223	7	3	157	56
60201	202	7	13	159	23
Totals	**1,728**	**50**	**28**	**1,459**	**191**

Table 6. Qualitative description of missing data, seasonal

Account number	Total missing intervals	Missing intervals on weekdays	Missing intervals on weekends
54200	306	291	15
82100	217	163	54
35100	780	538	242
4700	223	216	7
60201	202	146	56
Totals	**1,728**	**1.354**	**374**

Table 7. Qualitative description of missing data, type of day

Overall, approximately 5% of the intervals were missing in the data set. Fortunately, this is not an overly significant number of intervals to be missing. With these intervals identified, the next step was to find a way to calculate the missing values.

Method 1: Linear approximation.

For runs of missing data with 1 to 2 missing intervals in a row, a linear approximation formula was used to estimate the missing intervals. This method was used under the assumption that the electricity consumption over the duration of the series of runs with missing values is equally distributed across all the increments in the series. Below is the formula used for this linear approximation.

$$Mi = (Cend - Cstart) / N$$

Where,

Mi = value of net meter increment with missing data

$Cend$ = cumulative meter increment count at end of last meter increment with missing data in series

$Cstart$ = cumulative meter increment count at end of meter increment immediately preceding the series with missing data

N = count of net meter increments with missing data in series

After this linear approximation formula was applied to the data, all the missing points in the newly generated column were now a part of a series of 3 or more missing points in a row.

Example:

Date	Hour	Cumulative increment usage	Known net increment usage	Estimated net increment usage
8/20/17	11:00	829.437	0.48	0.2117
8/20/17	11:15	0.00	0.00	0.1164
8/20/17	11:30	829.669	0.00	0.1164

Table 8. Example of linear approximation method applied to a series of missing values in account 54200

$$Mi = (Cend - Cstart) / N$$
$$Mi = 829.669 – 829.437 / 2$$
$$Mi = 0.1164 \text{ increment count}$$

Linear approximation would not be as accurate a method of estimating values in increments with more than 3 missing cumulative kWh values because there are times during the day when electricity consumption changes rapidly. For example, on a cold winter morning the first thing that employees will do is crank up the heat in the building and put on a few pots of coffee. This would represent a significant change in electricity consumption when compared to the building sitting unoccupied during the evening and early morning.

Method 2: Seasonal, daily, and hourly index.

In order to accurately estimate the remaining missing values, one can choose to estimate missing data with a seasonal index. A seasonal index usually describes how a particular season compares to what that season looks like on average. This helps to smooth out any extreme values that may not be the norm for that season.

For this study, the index generated served to describe how the average energy consumption of each particular 15-minute interval compared to the average consumption of all 15-minute intervals throughout the day. Further, the index included individual columns for weekdays and weekend-days in every season to account for consumption trends that are associated with the season and/or type of day.

To calculate the indexes, an average value was first found that reflects every 15-minute interval of a specific type of day in a specific season. This generated a 24-hour picture of what the average weekday and weekend-day consumption is in each season.

Next, the index was generated by dividing each of these averages by the average usage of all intervals throughout the day.

Below is an example from the data. This example shows the average consumption on a fall weekday at 12 am to 1 am in account 54200. Next, the example shows a generated index based off of the average usage for each interval during the whole day.

Calculated from averaging consumption on every fall weekday at time interval in column 1.

Calculated by dividing the avg. value found in column 2 by the average of all the values found in column 2 for the whole day.

Hour	Average value	Index
0:00	0.5441	2.489
0:15	0.1090	0.499
0:30	0.1108	0.507
0:45	0.1088	0.498
1:00	0.1097	0.502

Index value = Ai / Ad

Where,

Ai is the average value for a particular time interval on a specific type of day in a specific season

Ad is the average value for all intervals on the same type of day in the same season

The index value can be read as a percentage that tells us how much the consumption at that time interval differs from the average consumption of all the variables on that type of day in that particular season. The example above shows that consumption during hour 0:15 on a fall weekday tends to be 50% of what the average consumption is for any 15-minute interval on that particular type of day.

The seasonal index represents the usual consumption pattern based on the time of day, day of the week, and season of the year of any given interval. To use the seasonal index to calculate missing intervals, the formula first calculated the amount of energy consumed in a missing time period using the known cumulative kWh consumption values before and after the missing run. Then, the seasonal index percentage value that corresponded to each missing time interval was multiplied by this total missing consumption in order to calculate how much energy was likely consumed at each of the missing intervals.

While more accurate than the approach in Method 1, this approach presents its own set of challenges and inaccuracies. First, the data provided a limited number of observations to average since there were only records for a single year. Additionally, it was found that using this method was inaccurate in that the sum of the estimated values do not equal the *known* difference in cumulative kWh consumption. An example of this is shown below.

Date	Hour	Known cumulative increment usage	Known net increment usage	Estimated net increment usage using method 3	Cumulative increment using estimated net usage
8/17/17	0:30	765.346	0.0852	0.0852	765.346
8/17/17	0:45	0.00	0.00	0.1184	765.464
8/17/17	1:00	0.00	0.00	0.1124	765.577
8/17/17	1:15	0.00	0.00	0.1168	765.694
8/17/17	1:30	765.783	0.00	0.1152	765.809

Table 9. Example of method 3 applied on account 54200

In order for this method to be accurate enough to use, the values of the last cumulative increment usages in columns 3 and 6 would have to be equal. Since they are not, it can be concluded that the estimated net increment usage values are inaccurate, and the method was ultimately not used.

Method 3: Adjusted seasonal, daily and hourly index.

The method ultimately used to estimate the rest of the missing increment values was an adjusted form of the indices used in method two. For this approach, the formula first sums the average values (from the index calculated in method 2) for each of the missing intervals in the series.

$\sum_{t,d,s}$ = sum of the averages of the same time, day-type, and season values corresponding to the intervals in the missing series.

Next, each missing interval is divided by this sum so that the percentage that that particular interval is responsible for among just the intervals that are missing.

$A_{t,d,s}$ = Average interval value for a particular time, day-type, and season.

$I2_v$ = Index 2 value (index value taking into account just the intervals in the missing series)

$$A_{t,d,s} / \sum_{t,d,s} = I2_v$$

Lastly, this percentage, or "index" value is multiplied by the total missing usage in order to distribute the missing usage among the missing intervals in the same proportions calculated in the index.

With this formula, the rest of the missing values were able to be calculated as accurately as possible.

Anomalous values present in account 4700.

In account 4700, the elevator, there was an anomalous spike of usage in early July of 2018. It is suspected that this unusual spike is due to a recording error or an equipment malfunction.

After much deliberation, it was decided that these values were to be removed from the dataset as they were unusual and extremely unlikely to repeat. These values were removed and filled in as the other missing values were.

Chapter IV: Findings and Analysis

Identification of Consumption Patterns

Hourly Patterns

The daily consumption of each account tends to follow a similar pattern in relation to the time of the day. Below is a graph showing the average hourly kWh consumption over the course of a day in each account.

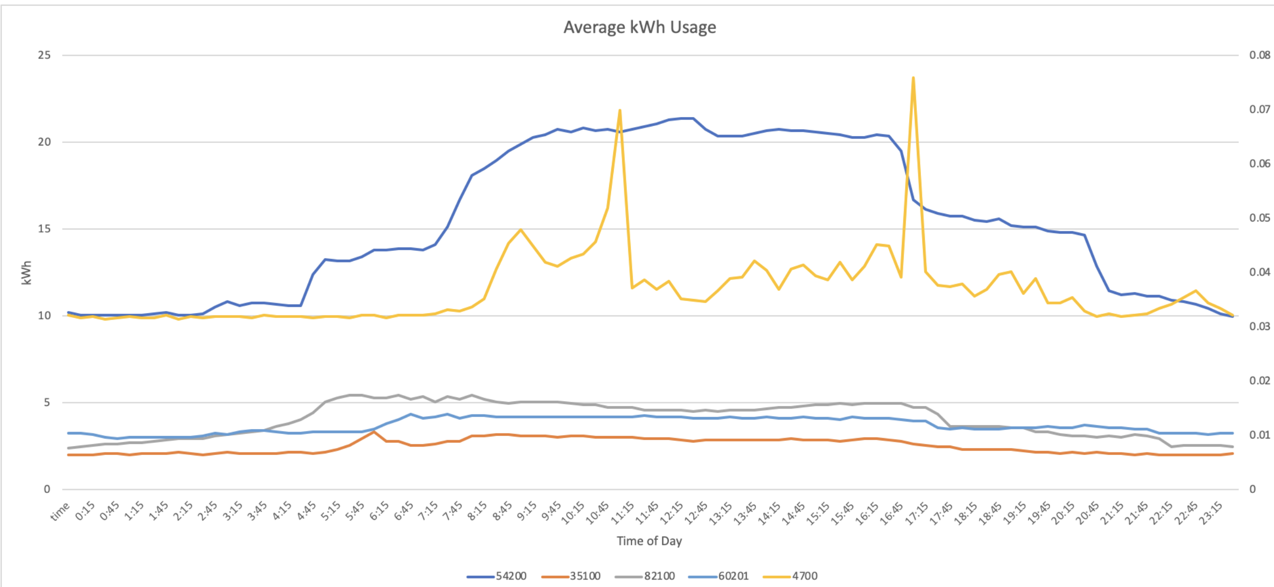

Figure 5. Average kWh usage by hour. NOTE: Account 4700 is on a secondary axis.

This graph averages the hourly kWh consumption of all days of the week and all months of the year. The average kWh consumption between the hours of 8 and 5 is approximately 32% higher than hours outside that time period. This is unsurprising because these buildings are only open from 8 am to 5 pm.

Accounting for the day of the week.

Since consumption on the weekends tends to be lower than consumption on weekdays, splitting the data into weekdays and weekend-days gives a better idea of the average hourly kWh usage of each account. The graphs below represent the average hourly kWh consumption of each account during the workweek and the weekend.

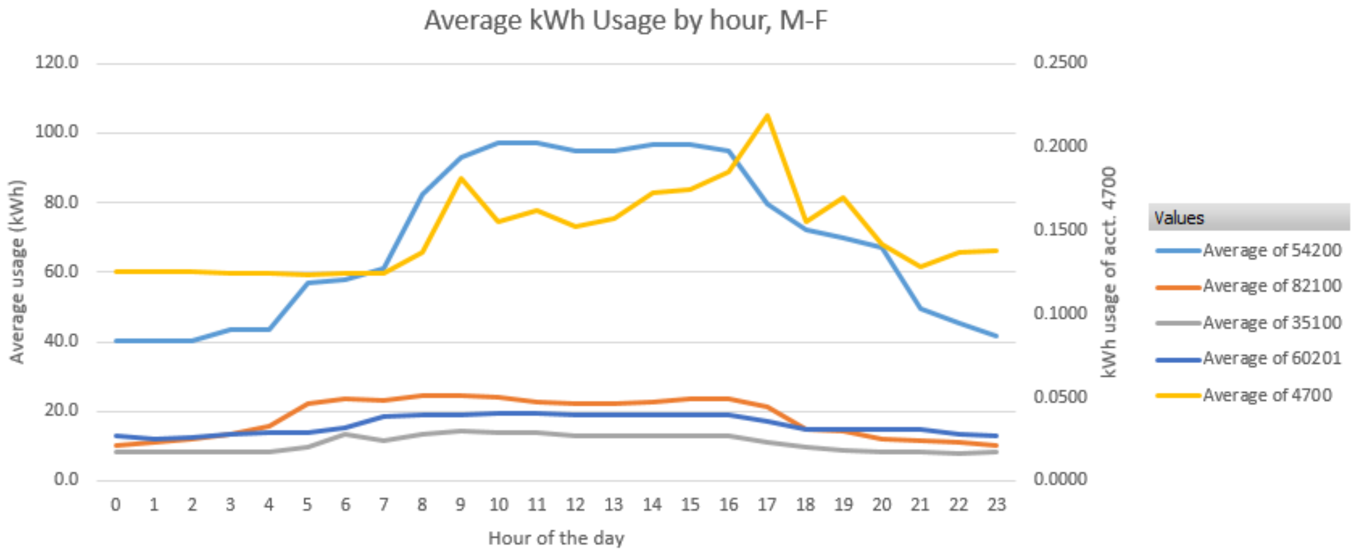

Figure 6. Average hourly kWh usage during weekdays. NOTE: Account 4700 is on a secondary axis.

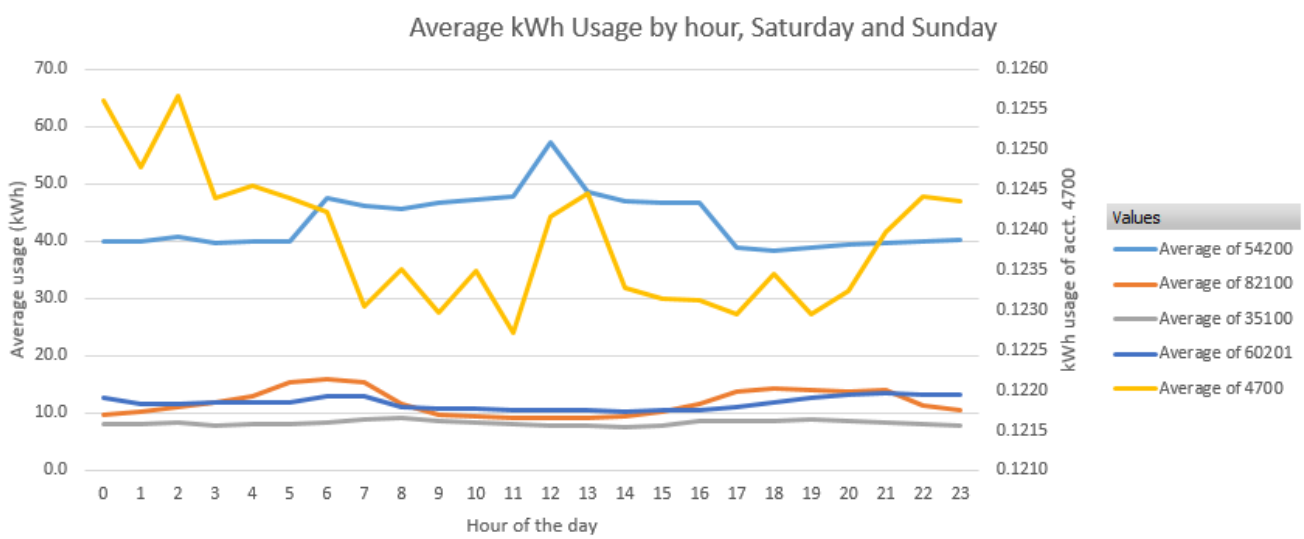

Figure 7. Average kWh usage by hour during weekends. NOTE: Account 4700 is on a secondary axis.

The kWh consumption is approximately 34% higher on weekdays than weekend-days. This is easily explained by the fact that these accounts are for structures that are generally used most heavily during the work week. The kWh consumption during the work week tends to be highest between the hours of 8 am and 5 pm. The increase in usage begins at 8 am, when many employees arrive at work, and remains steady throughout the day before the usage decreases again at 5 pm as employees depart. The spikes in usage at the beginning and end of each work day could be explained by the fact that some building systems kick on automatically around these times.

Seasonal Patterns

The data showed that the accounts' energy consumption varied with the seasons. Below is a graph representing how the season affected daily energy consumption for each account.

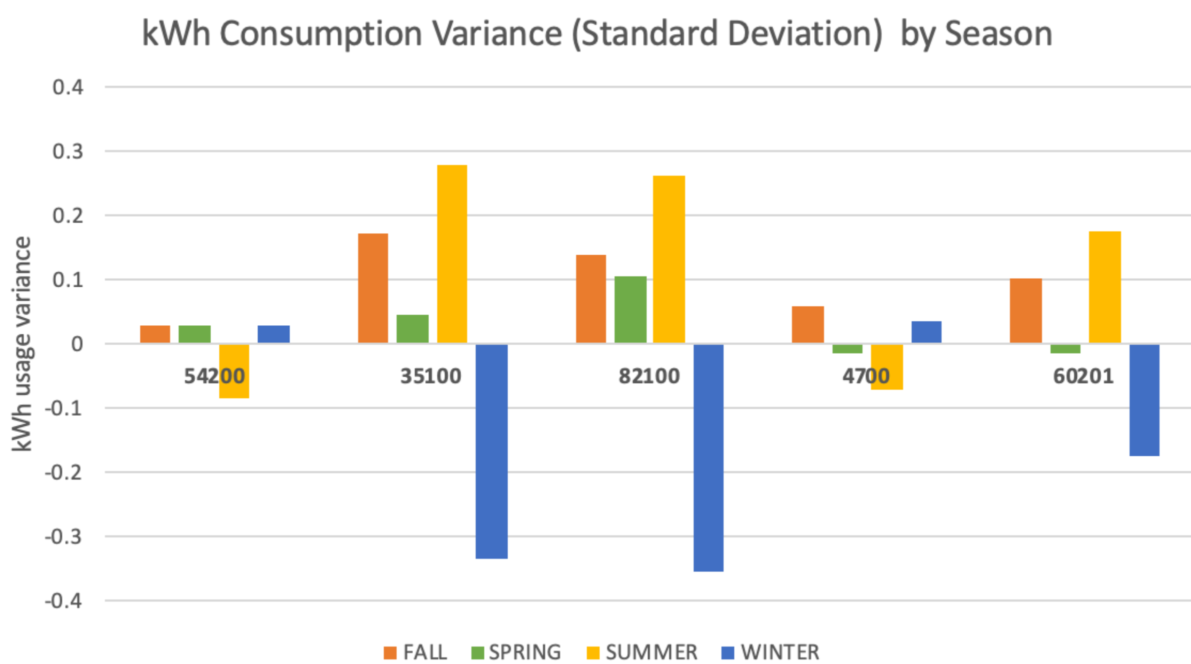

Figure 8. Standard deviation of average daily consumption by season

For most accounts, the average daily kWh consumption is highest in the summer and winter seasons. These seasons are when Watauga County experiences the most extreme weather, so the increased consumption can be explained by an increased usage in heating and cooling systems.

Seasonal effect on weekdays.

The graphs below show how the season affects the average daily energy consumption of each building. The first figure is a graph depicting how the average kWh consumption on weekdays varies during each season.

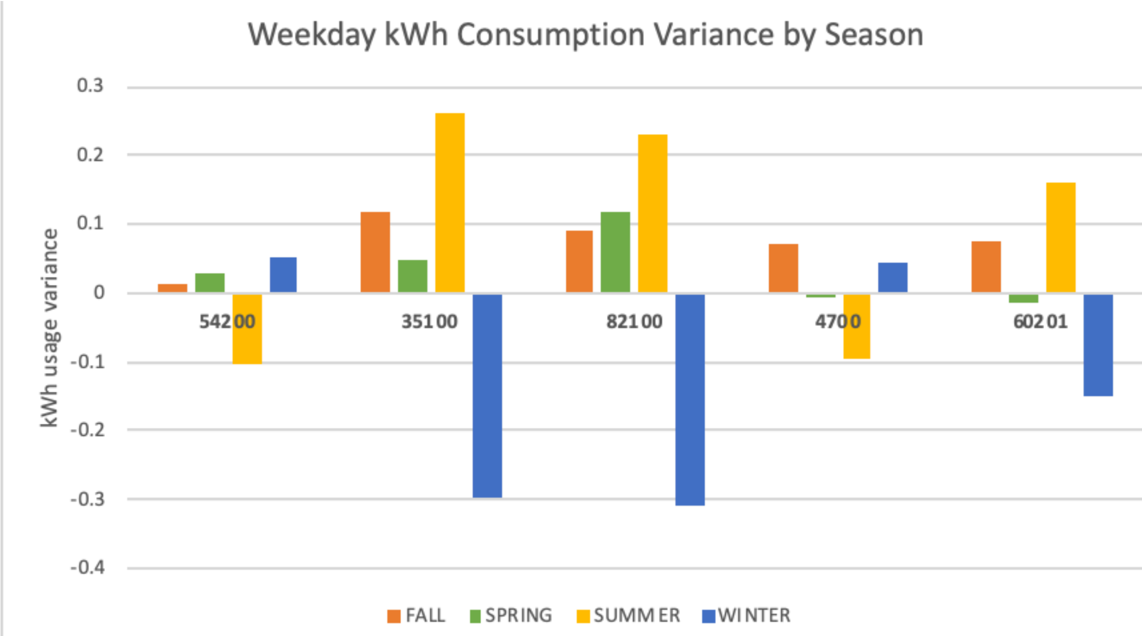

Figure 9. Variance of average weekday consumption by season

The next figure illustrates the average daily kWh consumption for weekend-days in each season.

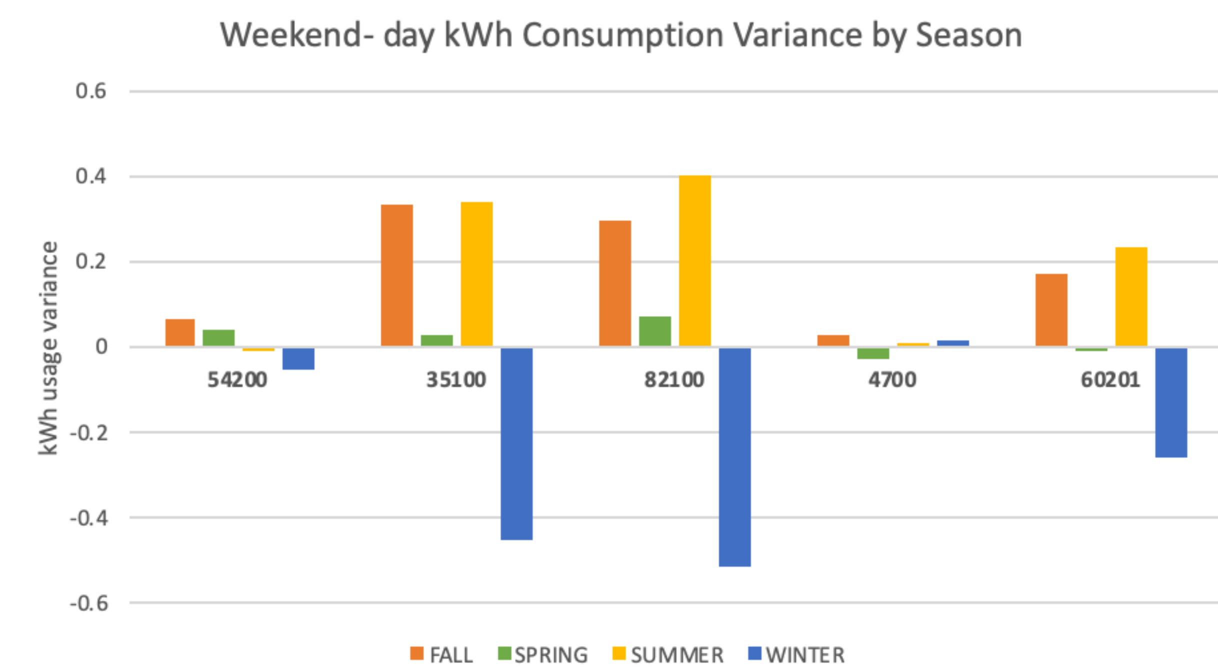

Figure 10. Variance of average weekday consumption by season

As can be seen in the above graphs, the average daily consumption for each account is affected by the season. The table below summarizes these findings by identifying which season has the highest and lowest average kWh consumption for weekend-days and weekdays.

	54200	**35100**	**82100**	**4700**	**60201**
Season with highest weekday kWh consumption	Summer	Winter	Winter	Summer	Spring
Season with lowest weekday kWh consumption	Winter	Summer	Summer	Fall	Summer
Season with highest weekend-day kWh consumption	Winter	Winter	Winter	Summer	Winter
Season with lowest weekend-day kWh consumption	Fall	Summer	Summer	Winter	Summer

Table 10. Seasons in which the highest and lowest weekday and weekend-day kWh consumption occurs

Winter is the season in which most accounts have their highest average weekday kWh consumption, while summer is the season in which most accounts have their lowest kWh consumption. This suggests that cooling the buildings in the summertime consumes less energy than heating the buildings in the wintertime.

Calculating Watauga County's Bills

Once the data was filled in, the parts of each account's monthly bills were able to be calculated.

Aggregated vs. Non-Aggregated Account

This study aimed to determine if aggregating Watauga County's electricity accounts would result in economic savings. Thus, values for this hypothetical aggregated account were compared to values that were calculated by adding the existing bills for individual accounts. These two accounts are referred to as the aggregated account and the non-aggregated account.

Both the aggregated and non-aggregated account's kWh usage were calculated by adding together each individual account's kWh usage at each given interval.

Energy and Coal Ash Cost Recovery Charges

New River Light and Power charges its customers an energy charge that is charged per kilowatt-hour. Each account's energy charge was calculated by multiplying the month's total kWh consumption by the corresponding price for the accounts' billing schedule. Below are tables showing each account's total monthly kWh usage as well as their calculated energy charge.

	54200	35100	82100	4700	60201	aggregated	Non-aggregated
January	49183.424	13283.340	23451.800	102.367	14529.208	100550.139	100550.14
February	39328.560	7244.160	12409.243	94.742	10841.128	69917.832	69917.83
March	43558.840	9126.664	15636.987	107.160	12728.152	81157.803	81157.80
April	42098.440	6841.920	9010.064	104.432	10685.968	68740.824	68740.82
May	46747.642	5069.216	7315.968	110.579	9702.000	68945.406	68945.41
June	47470.512	5032.800	8102.036	102.892	8740.994	69449.235	69449.23
July	50600.344	5240.776	9002.704	128.752	8831.296	73803.872	73803.87
August	50019.096	5589.528	9199.621	109.040	9314.360	74231.645	74231.65
September	43171.144	6129.648	9889.555	98.359	9136.096	68424.802	68424.80
October	44796.368	5962.712	10526.816	100.166	10332.248	71718.310	71718.31
November	41119.312	7450.874	10877.936	99.616	11314.840	70862.578	70862.58
December	43195.232	10354.168	16348.304	103.479	13380.352	83381.535	83381.54

Table 11. Total monthly kWh consumption

	54200	35100	82100	4700	60201	Aggregated	Non-aggregated
January	$186.45	$50.36	$88.91	$7.85	$55.08	$381.19	$388.65
February	$149.09	$27.46	$47.04	$7.26	$41.10	$265.06	$271.96
March	$165.13	$34.60	$59.28	$8.22	$48.25	$307.67	$315.48
April	$159.60	$25.94	$34.16	$8.01	$40.51	$260.60	$268.21
May	$177.22	$19.22	$27.73	$8.48	$36.78	$261.37	$269.43
June	$179.96	$19.08	$30.71	$7.89	$33.14	$263.28	$270.78
July	$191.83	$19.87	$34.13	$9.87	$33.48	$279.79	$289.17
August	$189.62	$21.19	$34.88	$8.36	$35.31	$281.41	$289.36
September	$163.66	$23.24	$37.49	$7.54	$34.63	$259.40	$266.57
October	$169.82	$22.60	$39.91	$7.68	$39.17	$271.88	$279.18
November	$155.88	$28.25	$41.24	$7.64	$42.89	$268.64	$275.90
December	$163.75	$39.25	$61.98	$7.93	$50.72	$316.10	$323.64

Table 12. Monthly energy charges

It is at this point that one can start to see the advantage of an aggregated billing approach. Alone, account 4700 is billed on the commercial schedule (G). Since accounts under this schedule are charged more per kWh than accounts on the large commercial (GL) schedule, the non-aggregated account pays more per kWh for account 4700's consumption.

NRLP also charges its customers a Coal Ash Cost Recovery (CACR) charge. This charge is charged per kWh for accounts on all schedules. Below is a table showing the CACR charges for each account.

	54200	35100	82100	4700	60201	Aggregated	Non-Aggregated
January	$186.45	$50.36	$88.91	$0.39	$55.08	$381.19	$381.19
February	$149.09	$27.46	$47.04	$0.36	$41.10	$265.06	$265.06
March	$165.13	$34.60	$59.28	$0.41	$48.25	$307.67	$307.67
April	$159.60	$25.94	$34.16	$0.40	$40.51	$260.60	$260.60
May	$177.22	$19.22	$27.73	$0.42	$36.78	$261.37	$261.37
June	$179.96	$19.08	$30.71	$0.39	$33.14	$263.28	$263.28
July	$191.83	$19.87	$34.13	$0.49	$33.48	$279.79	$279.79
August	$189.62	$21.19	$34.88	$0.41	$35.31	$281.41	$281.41
September	$163.66	$23.24	$37.49	$0.37	$34.63	$259.40	$259.40
October	$169.82	$22.60	$39.91	$0.38	$39.17	$271.88	$271.88
November	$155.88	$28.25	$41.24	$0.38	$42.89	$268.64	$268.64
December	$163.75	$39.25	$61.98	$0.39	$50.72	$316.10	$316.10

Table 13. Monthly CACR charges

Identifying Billing Demand

The demand charge of each accounts' bill was found by identifying the time interval during each month where the accounts' kWh was at its highest, then multiplying this value by 4. These values were multiplied by four in order to convert the units from kWh to kW, as the data is represented in 15-minute intervals which is one fourth of an hour.

The non-aggregated account's billing demand was found by adding together all of the individual accounts' billing demands. The aggregated account's kW demand was found by pinpointing the highest incident of kWh usage and multiplying it by four. This is where a major difference between the aggregated and non-aggregated account was identified.

The kW demand for the aggregated account was significantly lower than the non-aggregated account. This is due to the fact that with the non-aggregated billing approach, Watauga County is paying for each individual account's peak demand, even if the demand is peaking at different times. With the aggregated billing approach, the county would be paying for one peak demand value, which in this case, is cheaper than the sum of each account's demand charges.

Below is an example to illustrate this concept. Imagine the county is deciding if 3 accounts, A, B, and C, should be aggregated. The demand charge in this scenario is $1 per kW. These accounts only consume energy 4 hours a day, and their peak kW demand for each hour is represented in the table below.

Account	Hour 1 kW demand	Hour 2 kW demand	Hour 3 kW demand	Hour 4 kW demand	kW demand charge ($)
A	1	3	**9**	1	$9
B	2	3	1	**6**	$6
C	7	**9**	4	3	$9
Aggregated	10	**15**	14	10	$15

Table 14. Example data set illustrating aggregated vs non-aggregated demand calculations

With the non-aggregated approach, the county would be paying for each accounts' peak demand (bolded values), a total of $24. With an aggregated approach, the demand charge would be lower because its kW demand would be the highest instance of coinciding usage, which in this example is just 15 kW. Instead of paying $24 in demand charges, the county would be paying only $15.

The tables below show the peak kW demand of each account and their corresponding demand charges.

	54200	35100	82100	4700	60201	Aggregated	Non-aggregated
January	169.376	85.728	102.112	1.076	41.008	284.558	399.087
February	174.176	61.056	66.048	0.767	40.032	223.699	342.588
March	167.808	46.976	77.632	1.276	32.896	219.379	326.308
April	169.696	45.312	56.064	0.976	32.32	216.821	304.343
May	166.592	33.760	32.000	0.968	28.992	216.053	262.312
June	181.760	26.368	34.560	0.925	30.24	239.218	273.841
July	184.160	21.824	35.040	4.458	28.72	237.322	316.113
August	167.360	22.784	34.752	1.023	32.992	215.122	258.834
September	174.864	25.952	41.088	1.154	33.728	243.588	276.312
October	181.408	71.328	67.840	0.940	32.256	230.708	353.772
November	192.640	44.672	67.360	0.747	47.584	308.052	353.262
December	174.848	61.536	81.280	1.006	32.896	232.226	351.636

Table 15. Maximum monthly kW demand

The analysis found that the aggregated account's kW demand was an average of 24% lower than the non-aggregated account's kW demand. The aggregated account was charged for 951.138 kWs fewer than the non-aggregated account all together.

The next table shows the calculated billing demand charges for each account. Since the non-aggregated approach would have the county paying for each account's peak, the non-aggregated column is the sum of each account's monthly demand charge.

	54200	35100	82100	4700	60201	Aggregated	Non-aggregated
January	$1,400.74	$708.97	$844.47	$ -	$339.14	$2,353.29	$3,293.31
February	$1,440.44	$504.93	$546.22	$ -	$331.06	$1,849.99	$2,822.65
March	$1,387.77	$388.49	$642.02	$ -	$272.05	$1,814.27	$2,690.33
April	$1,403.39	$374.73	$463.65	$ -	$267.29	$1,793.11	$2,509.05
May	$1,377.72	$279.20	$264.64	$ -	$239.76	$1,786.76	$2,161.31
June	$1,503.16	$218.06	$285.81	$ -	$250.08	$1,978.33	$2,257.11
July	$1,523.00	$180.48	$289.78	$ -	$237.51	$1,962.65	$2,230.78
August	$1,384.07	$188.42	$287.40	$ -	$272.84	$1,779.06	$2,132.73
September	$1,446.13	$214.62	$339.80	$ -	$278.93	$2,014.47	$2,279.48
October	$1,500.24	$589.88	$561.04	$ -	$266.76	$1,907.95	$2,917.92
November	$1,593.13	$369.44	$557.07	$ -	$393.52	$2,547.59	$2,913.16
December	$1,445.99	$508.90	$672.19	$ -	$272.05	$1,920.51	$2,899.13

Table 16. Calculated demand charges

As can be seen in the table above, an aggregated billing approach would save the county $7,398.99 every year in demand charges alone.

Total Bill Calculations

Once the demand, energy, and CACR charges were calculated, the final monthly bills were found by adding these values to the facility charge that corresponded with each account. The aggregated account is billed on a large commercial (GL) rate, while the non-aggregated account had to pay a facility charge for each of the accounts that it is comprised of.

The CACR cost for both the aggregated and the non-aggregated accounts was $3,416.49. The annual energy charge for the aggregated account was $3,416.39, while for the non-aggregated account the total was $3,508.33. The $91.94 difference comes from the savings generated by aggregating account 4700 and not paying the additional $0.072875 per kWh that it is charged as when it is billed as an individual account. The aggregated approach would save the county approximately $7.66 per month on energy charges. The demand charge for the aggregated account was $23,707.98. The annual demand charge for the non-aggregated account was $31,106.98. The $7, 398.99 difference is the result of the aggregated account being charged on the highest instance of coincident usage instead of each account paying for individual peaks. Below is a table showing the final monthly of these accounts.

	Aggregated	Non-aggregated
January	$3,138.67	$4,173.60
February	$2,403.32	$3,469.90
March	$2,452.84	$3,423.93
April	$2,337.74	$3,148.25
May	$2,332.90	$2,802.20
June	$2,528.31	$2,901.47
July	$2,545.52	$2,912.01
August	$2,365.10	$2,813.82
September	$2,556.47	$2,915.66
October	$2,472.55	$3,579.34
November	$3,112.22	$3,568.03
December	$2,578.29	$3,649.08
TOTALS	**$30,823.93**	**$39,357.30**

Table 17. Monthly bill calculations

Using the monthly bills above, the yearly bill for the county was calculated to be $39,357.30 using a non-aggregated billing method. The total yearly bill for the aggregated account was calculated to be $30,823.93, an impressive $8,533.37 fewer.

The $8,533.37 difference comes from the savings in demand, energy usage, and facilities charges.

Conclusion

The purpose of this study was to determine if an aggregated billing approach applied to Watauga County municipal buildings would result in financial savings for the County. After a thorough analysis of the consumption patterns of each individual account, it was determined that an aggregated billing approach would save the county over $8,500 annually.

To determine if it would be worth the effort to aggregate these 5 accounts, one would need to weigh the cost of the aggregation with the benefits of the change. It could be significantly expensive to physically wire together all metered accounts up front, so that is a cost that would definitely need to be taken in to consideration.

The analysis results point towards account aggregation being valuable in ways other than financially. Account aggregation opens the opportunity for further electricity consumption adjustments and control over loads.

Opportunity for Further Changes

Now that there is a clear picture of how energy is consumed in each building as well as when each account peaks, the county is able to use these known usage patterns to its advantage.

Shifting larger loads so that they do not occur at the same time would further reduce demand charges. Large loads such as air conditioning and heating can easily be shifted so that they are staggered over the course of the morning or afternoon and no accounts are consuming these large amounts of energy at a single time.

Doing this would not only reduce peak kW demand, but also opens more financial savings opportunities for the county. By shifting large loads to off-peak consumption hours, the county could benefit from any time-of-use rates that NRLP might offer.

Further studies to determine the full impact of load shifting on peak kW demand as well as the impact of time-of-use savings on the county's electricity bill would be a wonderful way to further take advantage of the detailed AMI meter data.

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