Town of Carrboro
Town Hall Building; Century Center Building; Public Works Complex
Energy Modeling for Net Zero Energy Study

November 23, 2020

Background

The Town of Carrboro is considering options for renovating the Town Hall, Century Center, and the Public Works complex. The Town is seeking to develop a long-term renovation strategy while at the same time addressing immediate needs which have been identified by Town Staff. As part of the renovation effort, the Town would like to work towards the energy sustainability goals set forth in the Town's adopted Strategic Energy and Climate Action plan, which includes working toward net zero energy use.

Energy and water consumption models have been created for each of these facilities to inform decisions in the renovation planning and design process. These models are used to help understand how energy is consumed in each building, and where the most substantial opportunities for potential savings lie. They also provide valuable information in assessing the feasibility of modifying the buildings to achieve net zero carbon emissions. Further, the models create a benchmark for each building, establishing existing consumption characteristics and allowing a metric for assessing improvements.

Existing Systems

Town Hall

The Town Hall is a three-story building which houses office areas, a chamber room, a town server room, and a connected facilities maintenance shop. The exterior walls are uninsulated brick having mostly clear, double pane, operable windows. Most of the roof area is flat with recently installed rigid foam insulation above the deck.

The building is heated and cooled by 9 independent heat pump systems of varying ages. These systems are zoned to serve the basement offices, the server room, the chamber room, the north offices on the1st floor, the south offices on the 1st floor, the 2nd floor offices, the 1st floor of the west wing, the 2nd floor of the west wing, and the shop. None of these systems supply outdoor air for ventilation.

The lighting in the building is a mix of new LED fixtures, T-8 fluorescent fixtures, and T-12 fluorescent fixtures. The plug loads are mostly typical for office areas other than the facilities shop which sees typical shop usage. Hot water is provided by a tank-type electric water heater.

Century Center

Carrboro's Century Center is a two-story historic structure which houses office areas, community activity areas, a public computer resource area, a kitchen, and a large event hall. Part of the building serves the police department, which operates 24/7. Built in 1924, the Century Center has 18" thick uninsulated masonry walls with clear, double pane, operable windows. The roof is insulated at the attic floor by 9" of blown-in fiberglass insulation.

The building is conditioned by 3 variable air volume AHUs. Two of the AHUs utilize VAV boxes with hot water reheat, while the third AHU is a single-zone VAV unit serving the large event hall. Heating is provided by a 750 MBH natural gas-fired hot water boiler, and cooling is provided by a 70 ton air-cooled packaged chiller. The AHUs and chiller are controlled by a central control system, while the boiler operates on stand-alone controls.

The majority of the lighting throughout the building is T8 tube linear tube fluorescent fixtures. Most of the plug-in equipment is typical for an office building, though the computer resource area has a higher density of computers, and the all-electric kitchen contains heavy duty commercial cooking, refrigerating, and ice making equipment. Domestic hot water is provided by two tank-type natural gas-fired hot water heaters (75 gallon and 100 gallon).

Public Works

The public works complex is collection of buildings including office areas, an auto shop, sign shop, vehicle, equipment, and materials storage areas, a fuel station, and a carwash station. The primary energy consuming building is a 6,100 square foot pre-engineered metal building with an additional 2,400 square feet of unconditioned loft storage and mechanical space. This building houses public works administration offices, a small server room, and the fleet maintenance shop.

The office areas are divided into 3 separate HVAC zones, each of which is conditioned by a natural gas furnace with split system A/C. The shop area is conditioned by a 156 MBH natural gas unit heater. The sign shop utilizes a small heat pump window unit.

Lighting is provided by a mix of LED and fluorescent fixtures. The miscellaneous electrical loads in the complex are significant and highly variable in usage. Other than standard office equipment, these include air compressors, auto lifts, car vacuums, fuel pumps, garage doors, and various shop equipment. Domestic hot water is provided by natural gas-fired instantaneous water heaters.

Historical Utility Consumption

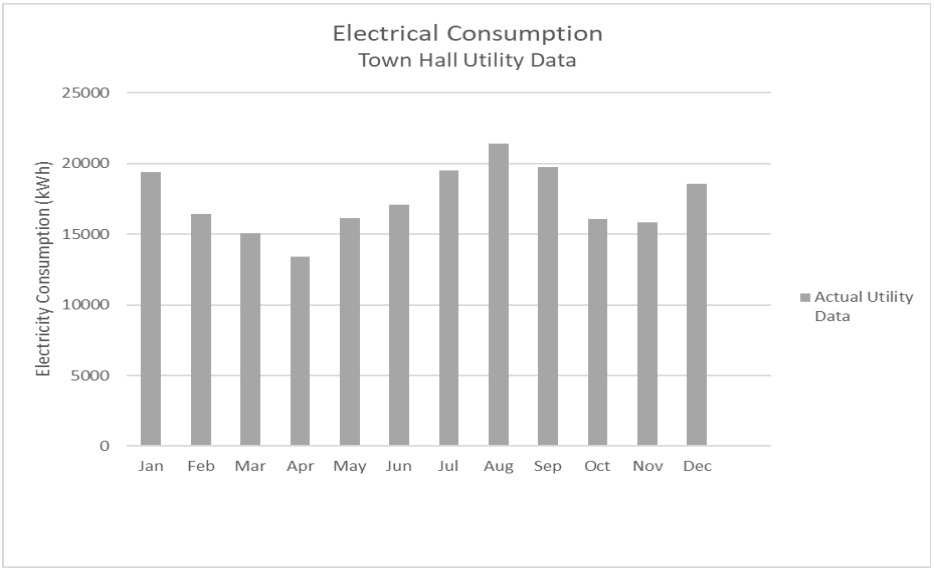
An analysis of the historical utility data was performed as a first step in creating energy and water consumption models of the facilities. 12 months for electricity, natural gas, and water utility data were obtained for the analyses. The data used were from the 2019 calendar year to eliminate any effect from the 2020 COVID-19 pandemic shutdowns. Usage by each facility was analyzed separately.

Town Hall

The town hall does not use natural gas, as all heating, water heating, and cooking use electricity.

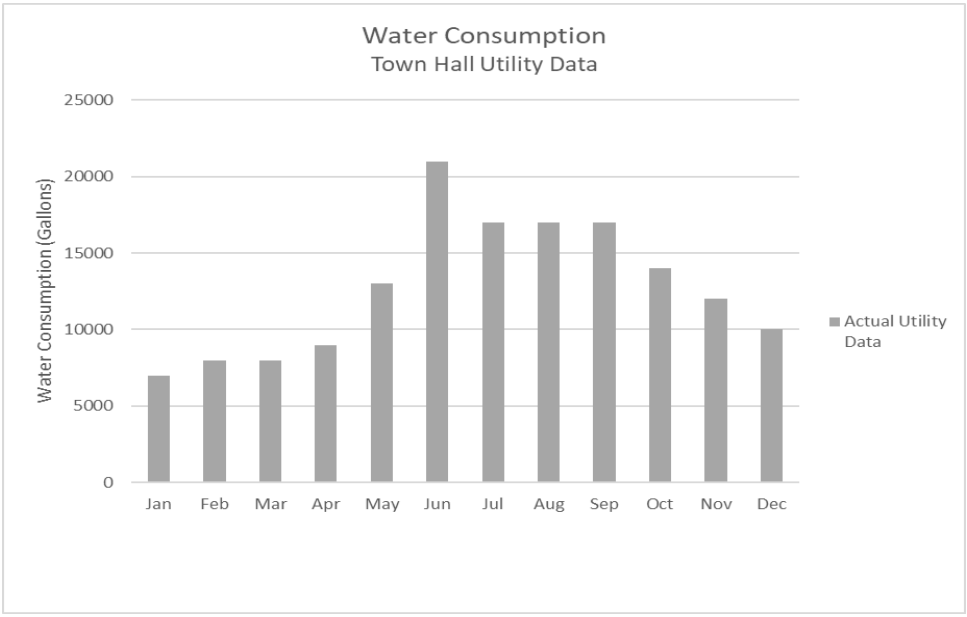
Electricity

The building is served by three separate electric meters. One meter serves the majority of the building, one meter serves the shop, and the server room is served from the meter serving Fire Station 1. Onsite power readings, in conjunction with Fire Station 1 utility data, allowed the annual energy consumption of the server room (servers plus HVAC) to be estimated and extracted from the Fire Station data. This estimate was added to the data from the main building meter and the shop meter to obtain a monthly set of consumption data for the entire building. This combined usage is presented below.



Water

A single water meter serves the building. Data from this meter are presented below.

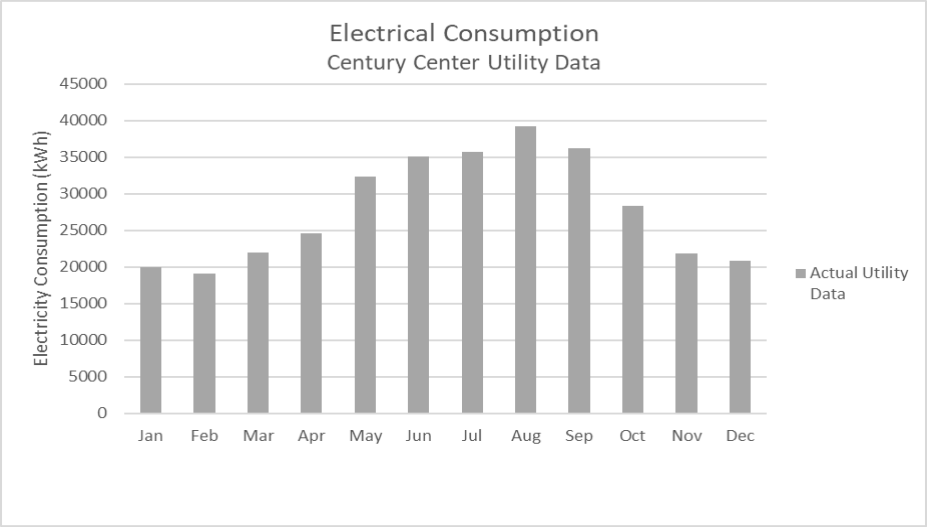


Century Center

The Century Center uses electricity, natural gas, and water.

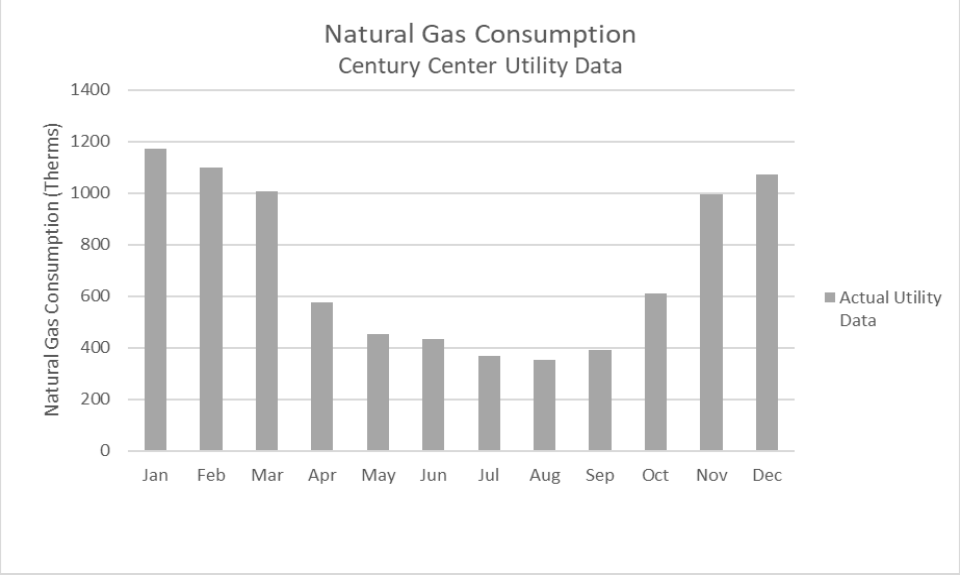
Electricity

A single electric service entrance serves the entire building. Data from this meter are presented below.



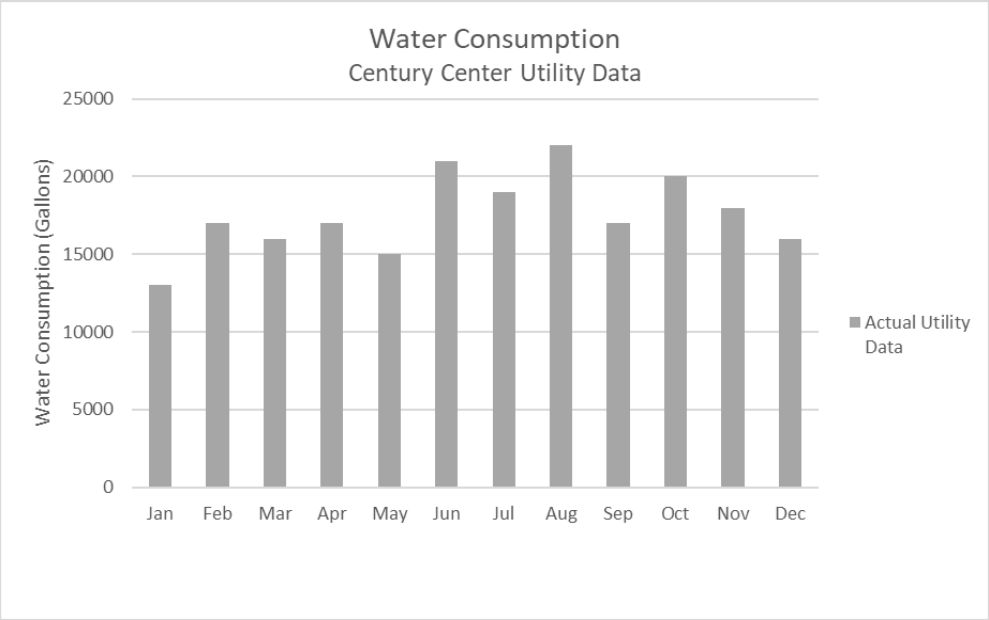
Natural Gas

A single natural gas service entrance serves the entire building. Data from this meter are presented below.



Water

A single water service entrance serves the entire building. Data from this meter are presented below.

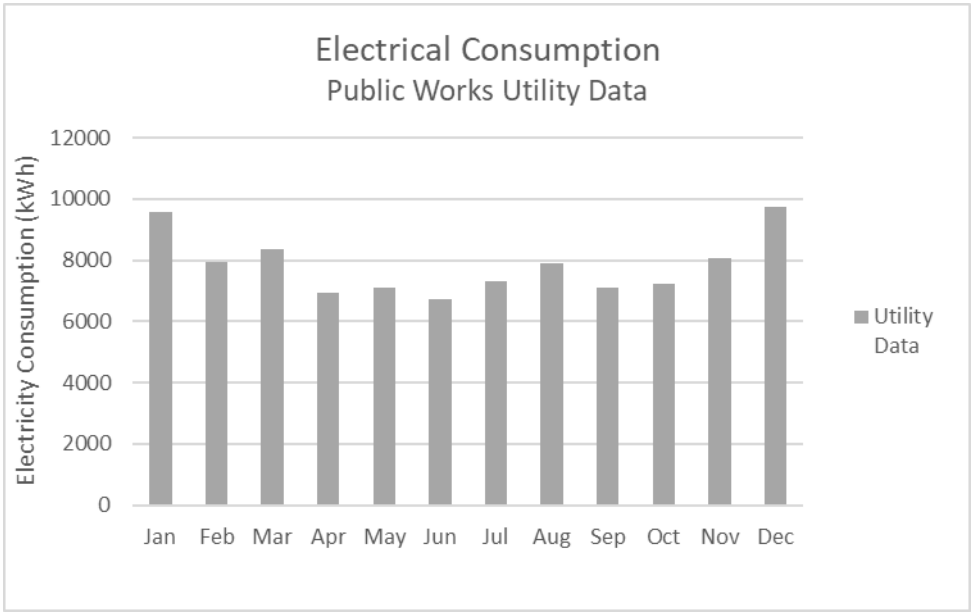


Public Works

The Public Works complex utilizes electricity, natural gas, and water.

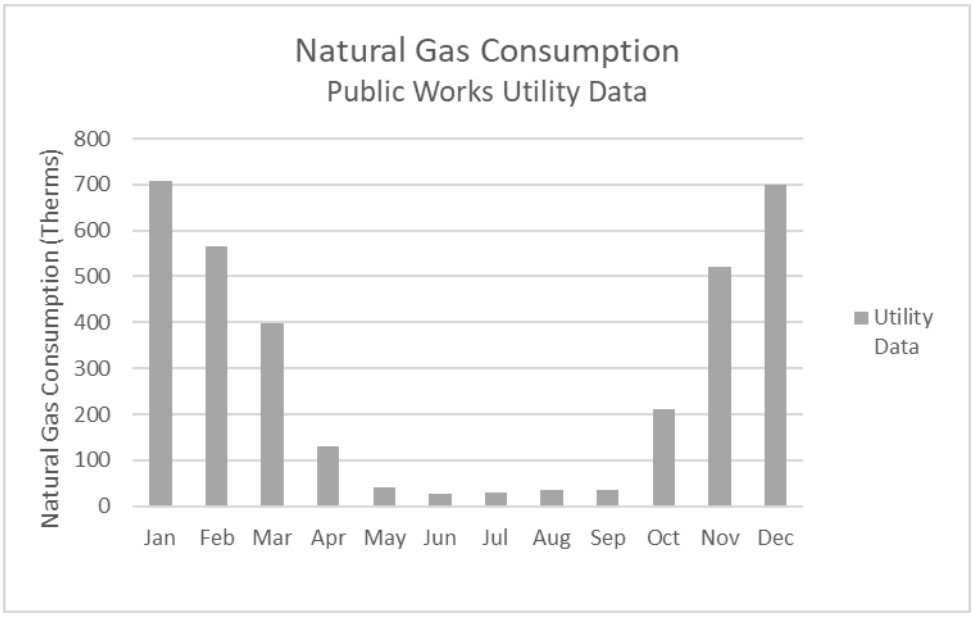
Electricity

Public Works is served by three electric service entrances. One meter currently has no load connected to it, one meter serves the server room and its A/C unit, and one meter serves the rest of the complex. The data presented below show the combined metered usage for the complex.



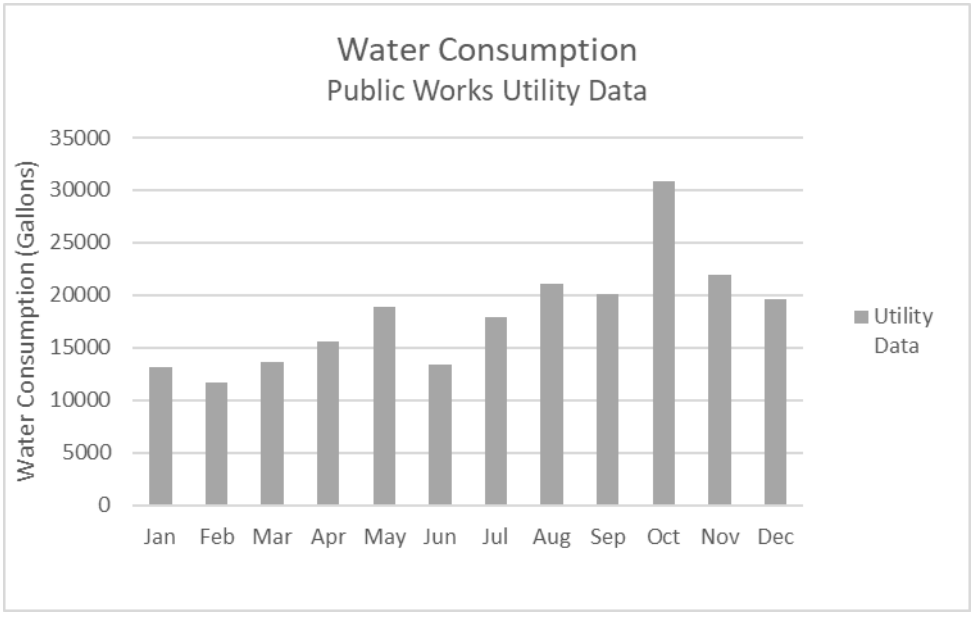
Natural Gas

Two natural gas meters serve the facility. One meter serves the generator and the instantaneous hot water heaters, and one meter serves the rest of the facility. The combined usage is shown below.



Water

A single water service serves the entire complex. Data from this meter are presented below.



Simulation Methodology

Energy and water consumption simulations were created for each building. The energy models for the Century Center and the Town Hall were generated using the Trane TRACE software. TRACE uses a comprehensive set of environmental and building characteristics to simulate the energy consumption

for the entire building each hour of a full typical year. TRACE excels at simulating the complex interactions among various end uses, schedules, and control strategies as are found at the Century Center and Town Hall.

Due to the nature of the Public Works complex, in-house spreadsheet tools were used in lieu of TRACE to simulate annual energy usage. The usage of this facility is highly dependent on inconsistent variables such as the amount of time garage doors are open, frequency of shop equipment use, frequency and duration of car washes, etc. This type of facility is best modeled using versatile, transparent, independent calculations in conjunction with known historical utility data. Through this approach a more reliable and understandable breakdown of how the facility uses energy can be obtained.

Hourly energy simulations require detailed weather data for the specific location of the buildings. TMY3 (Typical Meteorological Year) weather files for the Durham area were utilized for the Carrboro models. Building inputs include the constructions of the walls, windows, roofs, and floor systems, HVAC equipment and control strategies, room-by-room lighting systems, plug-in equipment, and occupancy, domestic hot water systems, and schedules of usage for occupants and each energy end use. The values utilized in the Carrboro models were obtained via building drawings, site visits, measurements, and conversations with Carrboro staff.

Water models are generally much less complex than energy simulations. These are usually analyzed on an annual basis, as hourly calculations would provide little additional value to understanding the facility. In-house spreadsheet tools were used for these models. The primary inputs for these models are occupancy types, general occupancy schedules, and the various water-using fixture data.

Energy and Water Model Results and Calibration

Each energy and water model was calibrated to match the historical utility consumption to within an acceptable error tolerance based on industry standard practice. The Carrboro energy models were calibrated such that the modeled electricity and natural gas consumption is within 10% of the actual consumption for each month of the year, and within 5% of the total annual consumption. The water models were calibrated to within 5% of the annual consumption.

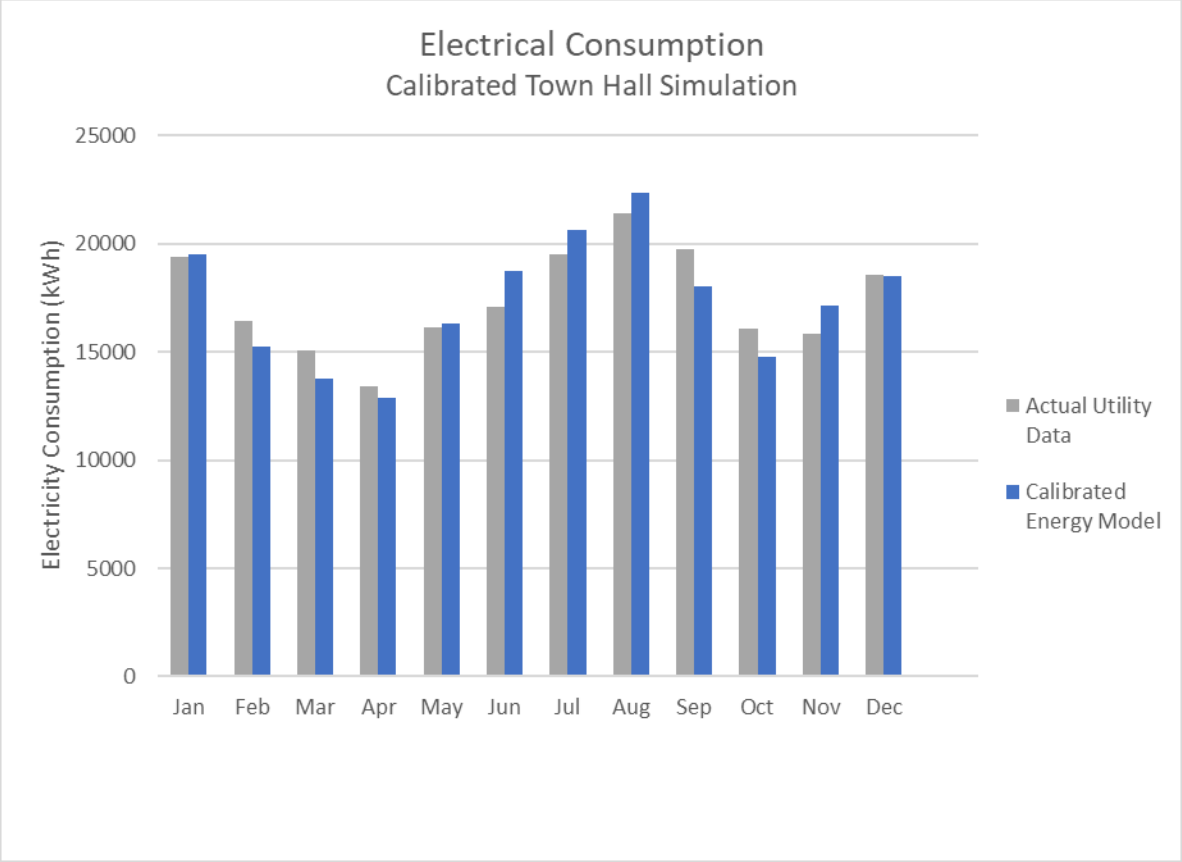
Town Hall

The energy consumption results for the Town Hall are presented below, along with its energy use intensity.

Town Hall Energy Consumption Profile		
End Use	**Energy Consumption (kBTU/yr)**	**Percent of Total**
Heating	83,044	11.7%
Cooling	169,247	23.9%
Fans/Pumps	99,651	14.1%
Lighting	119,697	16.9%
DHW	9,687	1.4%
Plug Loads / Other	228,125	32.2%
Total	709,451	100%
Conditioned Area (sf)	12,235	
Energy Use Intensity (kBTU/sf/yr	57.99	

The calibrated results for the Town Hall building are presented below. A breakdown of the energy model results is provided in Appendix I.

Electricity (Town Hall)



Town Hall Electricity Consumption (kWh)			
Month	**Actual Utility Data**	**Calibrated Model**	**% Error**
Jan	19376	19511	1%
Feb	16401	15249	-7%
Mar	15073	13769	-9%
Apr	13404	12849	-4%
May	16112	16328	1%
Jun	17091	18748	10%
Jul	19536	20641	6%
Aug	21386	22342	4%
Sep	19764	18056	-9%
Oct	16086	14755	-8%
Nov	15835	17120	8%
Dec	18583	18499	0%
Total	**208646**	**207867**	0%

Water (Town Hall)

Town Hall Water Consumption (gal)			
Period	**Actual Utility Data**	**Calibrated Model**	**% Error**
Annual	155734	155731	0%

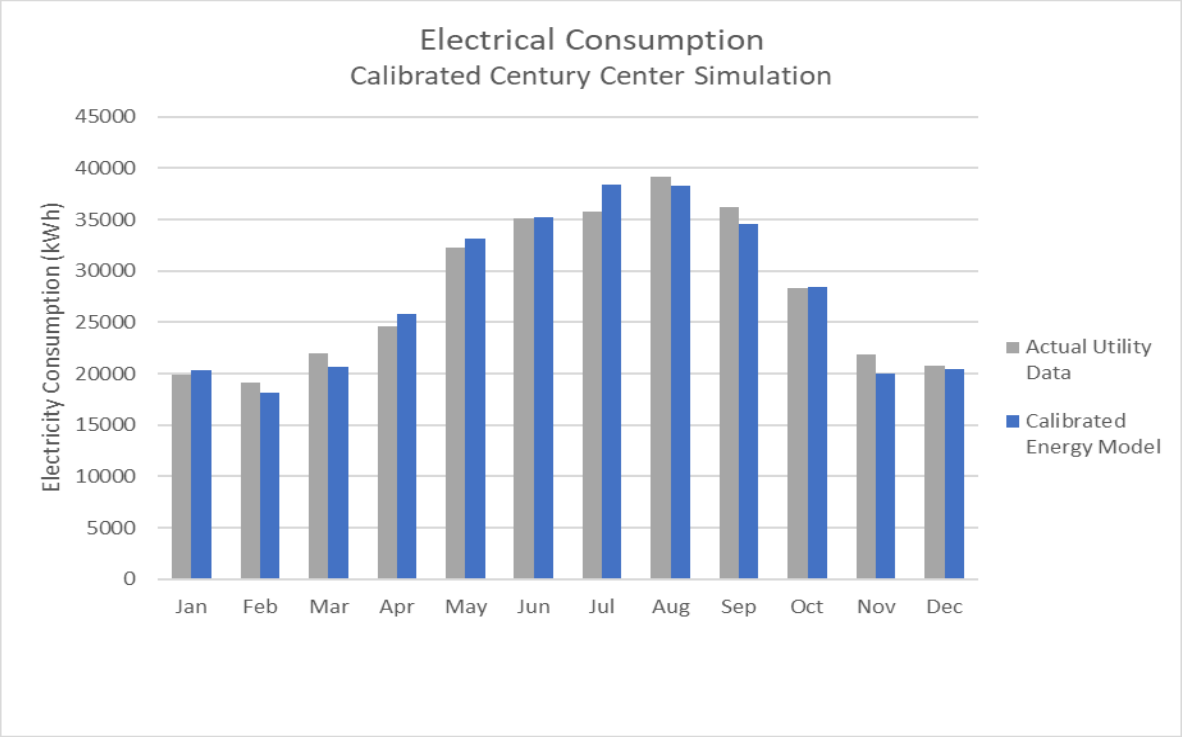
Century Center

The energy consumption results for the Century Center are presented below, along with its energy use intensity.

Century Center Energy Consumption Profile		
End Use	**Energy Consumption (kBTU/yr)**	**Percent of Total**
Heating	848,026	42.7%
Cooling	224,216	11.3%
Fans/Pumps	548,968	27.6%
Lighting	203,910	10.3%
DHW	13,420	0.7%
Plug Loads / Other	147,747	7.4%
Total	1,986,287	100%
Conditioned Area (sf)	19,912	
Energy Use Intensity (kBTU/sf/yr	99.75	

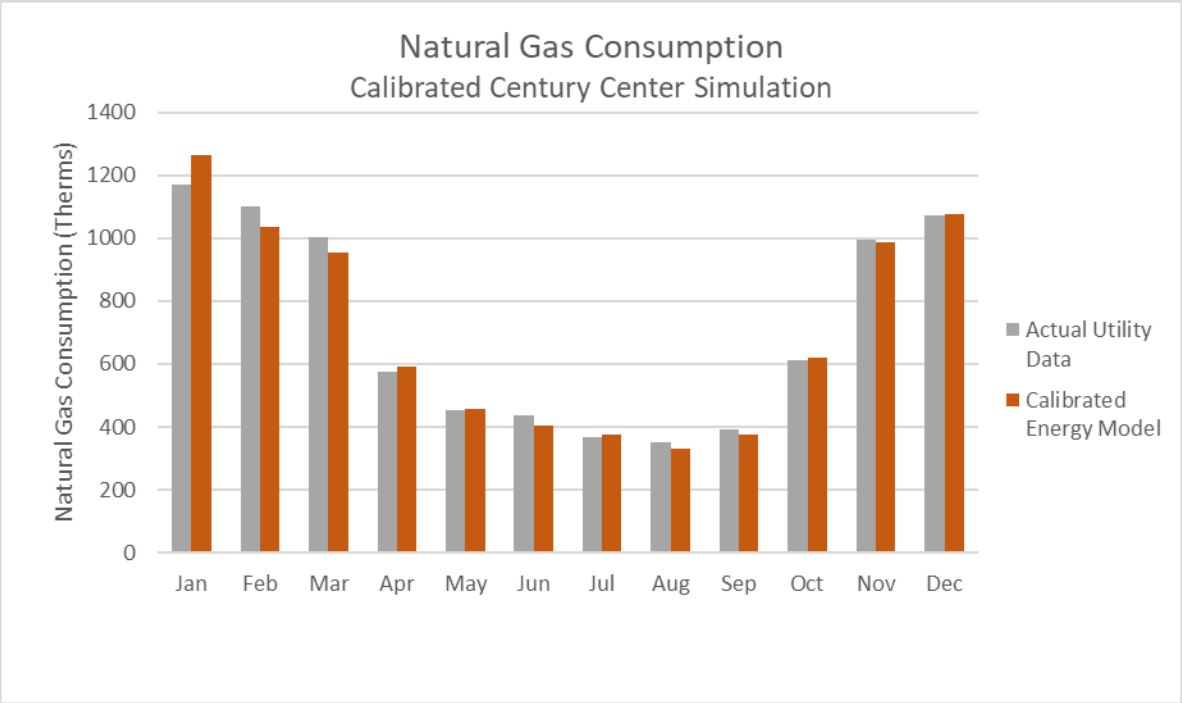
The calibrated results for the Century Center are presented below. A breakdown of the energy model results is provided in Appendix II

Electricity (Century Center)



Century Center Electricity Consumption (kWh)			
Month	**Actual Utility Data**	**Calibrated Model**	**% Error**
Jan	19932	20377	2%
Feb	19082	18203	-5%
Mar	21936	20665	-6%
Apr	24586	25760	5%
May	32315	33172	3%
Jun	35082	35268	1%
Jul	35727	38364	7%
Aug	39209	38241	-2%
Sep	36198	34531	-5%
Oct	28286	28423	0%
Nov	21833	19996	-8%
Dec	20796	20465	-2%
Total	**334982**	**333463**	**0%**

Natural Gas (Century Center)



Century Center Natural Gas Consumption (therms)			
Month	**Actual Utility Data**	**Calibrated Model**	**% Error**
Jan	1170	1263	8%
Feb	1100	1035	-6%
Mar	1005	955	-5%
Apr	574	592	3%
May	451	458	2%
Jun	435	406	-7%
Jul	366	377	3%
Aug	351	331	-6%
Sep	390	377	-3%
Oct	611	622	2%
Nov	995	987	-1%
Dec	1073	1078	0%
Total	**8522**	**8482**	**0%**

Water (Century Center)

Century Center Water Consumption (gal)			
Period	**Actual Utility Data**	**Calibrated Model**	**% Error**
Annual	219416	219264	0%

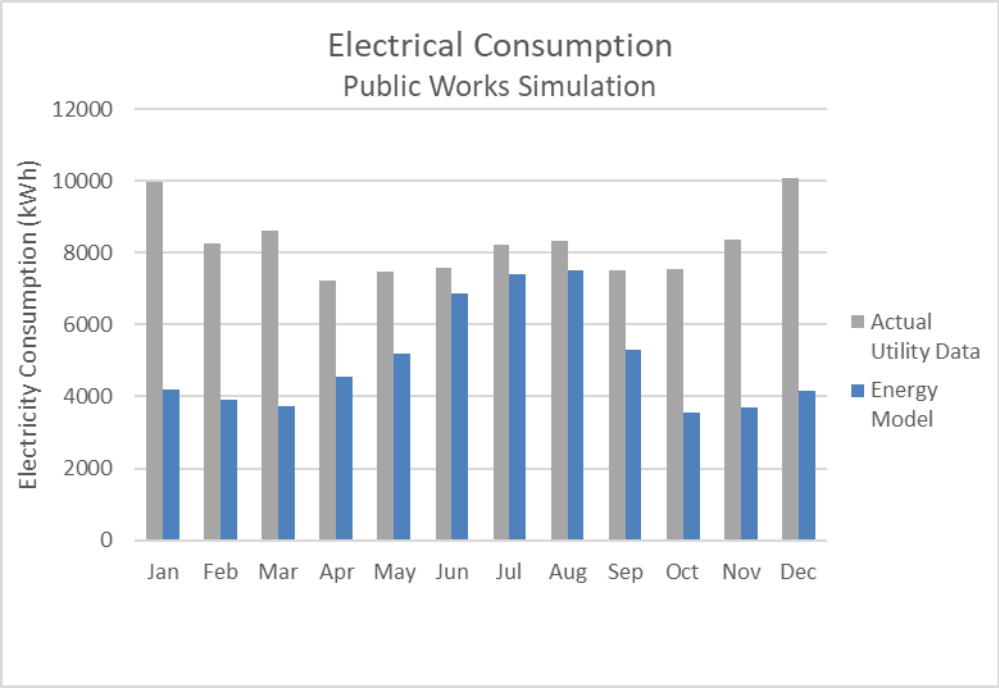
Public Works

The energy consumption results for the Town Hall are presented below, along with its energy use intensity.

Public Works Energy Consumption Profile		
End Use	**Energy Consumption (kBTU/yr)**	**Percent of Total**
Heating	306,672	44.3%
Cooling	62,858	9.1%
Fans	36,683	5.3%
Lighting	54,922	7.9%
DHW/Carwash/Generator	30,900	4.5%
Office Equipment	15,861	2.3%
Server	15,040	2.2%
Air Compressor	24,088	3.5%
Shop/Site Equipment	11,495	1.7%
Currently Unaccounted	133,601	19.3%
Total	692,120	100%
Conditioned Area (sf)	6,300	
Energy Use Intensity (kBTU/sf/yr	109.9	

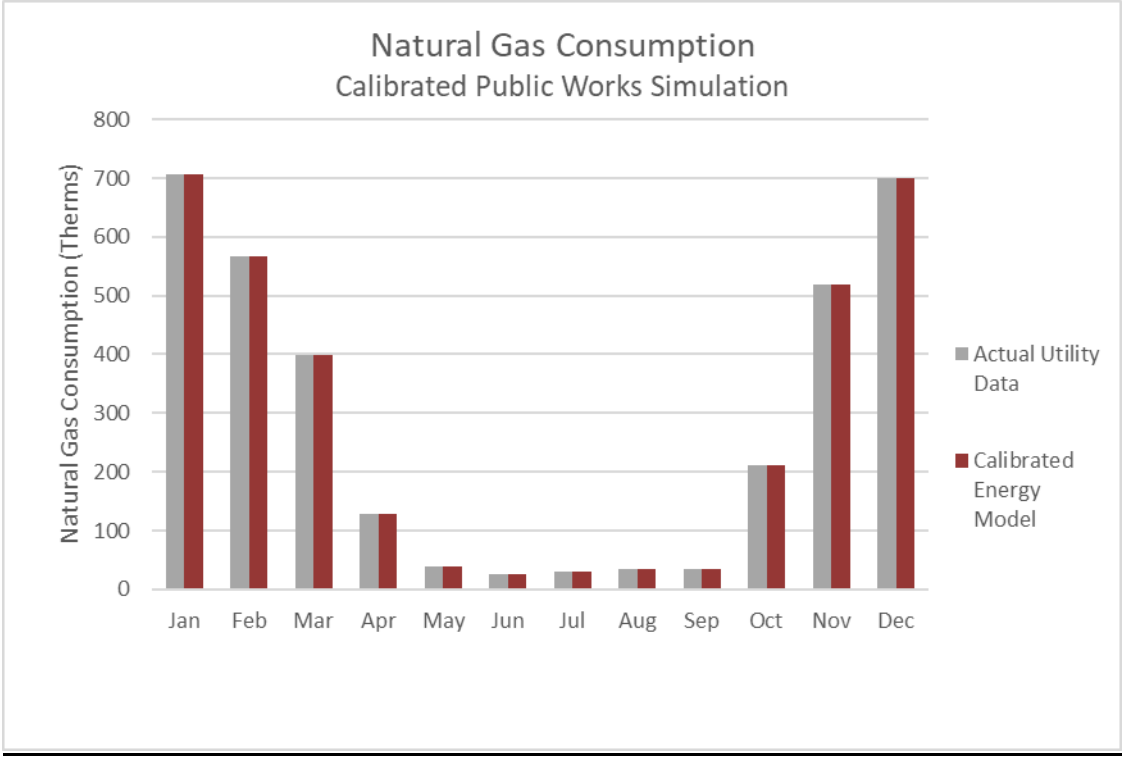
Note that the model is unable to account for a large percentage of the electrical consumption in the facility. This is shown in the table above as “Currently Unaccounted”, and in the electricity chart and table below as the percent error between the model and the utility data. The tables below show the energy model results as compared to the utility data. See Appendix III for a breakdown of modeled end uses.

Electricity (Public Works Complex)



Public Works Electricity Consumption (kWh)			
Month	**Actual Utility Data**	**Calibrated Model**	**% Error**
Jan	9965	4193	58%
Feb	8277	3919	53%
Mar	8606	3726	57%
Apr	7229	4549	37%
May	7472	5190	31%
Jun	7600	6868	10%
Jul	8231	7419	10%
Aug	8330	7522	10%
Sep	7511	5288	30%
Oct	7553	3535	53%
Nov	8355	3710	56%
Dec	10079	4143	59%
Total	**99208**	**60063**	**39%**

Natural Gas (Public Works Complex)



Public Works Natural Gas Consumption (therms)			
Month	**Actual Utility Data**	**Calibrated Model**	**% Error**
Jan	707	707	0%
Feb	566	566	0%
Mar	399	399	0%
Apr	129	129	0%
May	40	40	0%
Jun	26	26	0%
Jul	31	31	0%
Aug	35	35	0%
Sep	35	35	0%
Oct	210	210	0%
Nov	520	520	0%
Dec	699	699	0%
Total	**3397**	**3397**	**0%**

Water (Public Works Complex)

Public Works Water Consumption (Gallons)			
Period	Actual Utility Data	Calibrated Model	% Error
Annual	217948	216000	1%

Conclusions

The creation of energy models allows a better understanding of how resources are used within a facility, and can offer insight as to what opportunities there may be to save energy and water. These results will be used to guide design decisions moving forward in the process of upgrading these three facilities. The energy and water simulations for the Century Center and the Town Hall reconcile cleanly with the utility data. The natural gas and water models for the Public Works facility also match the utility data. Currently, however, there are unknown factors resulting in discrepancies between simulations and utility data for the electricity consumption at Public Works. This should be further investigated, as the large discrepancy could point to energy saving opportunities.

Appendix I

TRACE Energy Consumption Summary (Town Hall)

ENERGY CONSUMPTION SUMMARY

By Sud Associates, P.A.

	Elect Cons. (kWh)	% of Total Building Energy	Total Building Energy (kBtu/yr)	Total Source Energy* (kBtu/yr)
Alternative 1				
Primary heating				
Primary heating	24,332	11.7 %	83,044	249,156
Other Htg Accessories		0.0 %	0	0
Heating Subtotal	**24,332**	**11.7** %	**83,044**	**249,156**
Primary cooling				
Cooling Compressor	39,897	19.2 %	136,167	408,541
Tower/Cond Fans	4,758	2.3 %	16,239	48,721
Condenser Pump		0.0 %	0	0
Other Clg Accessories	4,935	2.4 %	16,842	50,530
Cooling Subtotal....	**49,589**	**23.9** %	**169,247**	**507,792**
Auxiliary				
Supply Fans	29,198	14.1 %	99,651	298,984
Pumps		0.0 %	0	0
Stand-alone Base Utilities	2,838	1.4 %	9,687	29,064
Aux Subtotal....	32,036	15.4 %	109,338	328,048
Lighting				
Lighting	35,071	16.9 %	119,697	359,128
Receptacle				
Receptacles	66,840	32.2 %	228,125	684,443
Cogeneration				
Cogeneration		0.0 %	0	0
Totals				
Totals**	**207,867**	**100.0** %	**709,451**	**2,128,567**

* Note: Resource Utilization factors are included in the Total Source Energy value .

** Note: This report can display a maximum of 7 utilities. If additional utilities are used, they will be included in the total.

Appendix II

TRACE Energy Consumption Summary (Century Center)

ENERGY CONSUMPTION SUMMARY

By Sud Associates, P.A.

	Elect Cons. (kWh)	Gas Cons. (kBtu)	Water Cons. (1000 gals)	% of Total Building Energy	Total Building Energy (kBtu/yr)	Total Source Energy* (kBtu/yr)
Alternative 1						
Primary heating						
Primary heating		833,181		42.0 %	833,181	877,032
Other Htg Accessories	4,350		27	0.8 %	14,845	44,539
Heating Subtotal	**4,350**	**833,181**	**27**	**42.7** %	**848,026**	**921,571**
Primary cooling						
Cooling Compressor	58,800			10.1 %	200,685	602,115
Tower/Cond Fans	6,315			1.1 %	21,553	64,667
Condenser Pump				0.0 %	0	0
Other Clg Accessories	580			0.1 %	1,978	5,934
Cooling Subtotal....	**65,695**			**11.3** %	**224,216**	**672,716**
Auxiliary						
Supply Fans	72,367			12.4 %	246,990	741,045
Pumps	73,385			12.6 %	250,463	751,463
Stand-alone Base Utilities	14,632	14,997		3.3 %	64,935	165,615
Aux Subtotal....	160,384	14,997		28.3 %	562,388	1,658,123
Lighting						
Lighting	59,745			10.3 %	203,910	611,791
Receptacle						
Receptacles	43,290			7.4 %	147,747	443,287
Cogeneration						
Cogeneration				0.0 %	0	0
Totals						
Totals**	**333,463**	**848,178**	**27**	**100.0** %	**1,986,287**	**4,307,489**

* Note: Resource Utilization factors are included in the Total Source Energy value .

** Note: This report can display a maximum of 7 utilities. If additional utilities are used, they will be included in the total.

Appendix III

Energy Consumption Summary Charts (Public Works)