SENIOR CAPSTONE

SUSTAINABLE BUILT ENVIRONMENTS

SBE 498 SP24

EFFICIENT CAMPUS, SUSTAINABLE FUTURE: A BUILDING UPGRADE STUDY

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ABSTRACT

This case study comparative analysis explores the impact of energy efficiency upgrades on three buildings on a college campus in Arkansas. The study focuses on building design, use, and age as factors influencing the effectiveness of the upgrades. The buildings, referred to as Building A, Building B, and Building C due to owner restrictions, underwent efficiency upgrades including lighting and HVAC improvements. Utility bills for chilled water, electricity, steam, and water were collected twelve months before and after the upgrades. The results show a decrease in electricity and chilled water usage in all three buildings, indicating the effectiveness of the upgrades. Building benchmarking using the Arc tool allows engineering students at the college to track utility usage and learn how real-time conditions affect energy consumption. The study highlights the importance of consistent monitoring and analysis to optimize energy efficiency in buildings.

Keywords: Sustainability, Built Environment, Energy Efficiency, Benchmarking, Arc

INTRODUCTION

College campuses present a unique mix of building design, use, and age. All three of these factors can impact the effectiveness of energy efficiency upgrades. In this case study comparative analysis, three buildings on a college campus in Arkansas were observed. Due to the owner's conditions, the name and location of the University campus and the three buildings will remain undisclosed. The buildings will be referred to by Building A, Building B, and Building C. Each building differs in age, size, and usage. They also each received a package of efficiency upgrades including lighting, HVAC programming and controls, and HVAC infrastructure and hardware.

Building A was built in 1984. It is 178,397 square feet, and houses classrooms, large lecture halls, labs, and faculty offices. For efficiency upgrades, Building A had all its T8 fluorescent lights replaced with LEDs. The building also underwent retro commissioning which led to several HVAC programming updates. Those updates include DAT resets, critical zone resets, implementation of an economizer, updated sensor controls, and Metasys point cleanup. These services were completed in July 2022.

Building B was built in 1875. It is 106,055 square feet, and houses some classrooms, offices, and large conference rooms. For efficiency upgrades, Building B had all its T8 fluorescent lights replaces with LEDs. These upgrades were completed in December 2022. No other services were performed.

Building C was completed in 1939. It is 59,749 square feet and houses classroom, offices, conference rooms, and a small auditorium. For efficiency upgrades, Building C had all its T8 fluorescent lights replaced with LEDs. It also underwent retro commissioning

which led to several HVAC infrastructure updates. Those updates included air handler cleaning, replacing air handler door gaskets, fixing a steam leak, replacing failed sensors, and functional performance testing. These services were completed in February 2023.

It is no secret that energy efficiency upgrades are effective. This capstone is not meant to prove or even to reinforce that. This is meant to be a study in building benchmarking and tracking the effectiveness of energy efficiency upgrades in real time. Arc is a free online building benchmarking tool. It is backed by the United States Green Buildings Council and gives buildings a score across five categories: energy, water, waste, transportation, and human experience. Through the lens of the Arc benchmarking tool, students at this university can track utility usage to see the impact of the upgrades at each building. They can also learn how real time conditions like weather and occupancy can affect utility usage. These three case studies track four municipal utilities: chilled water, electricity, steam, and water.

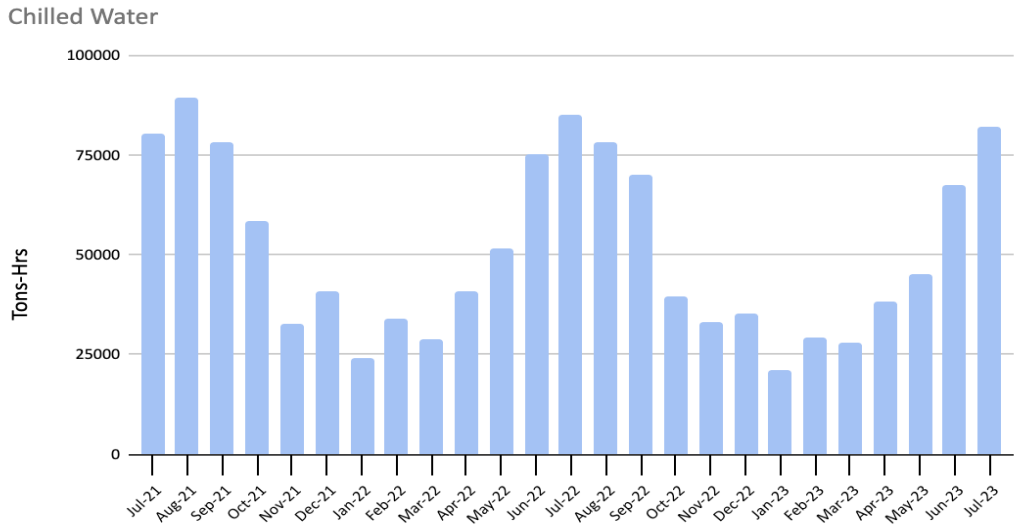
METHODOLOGY

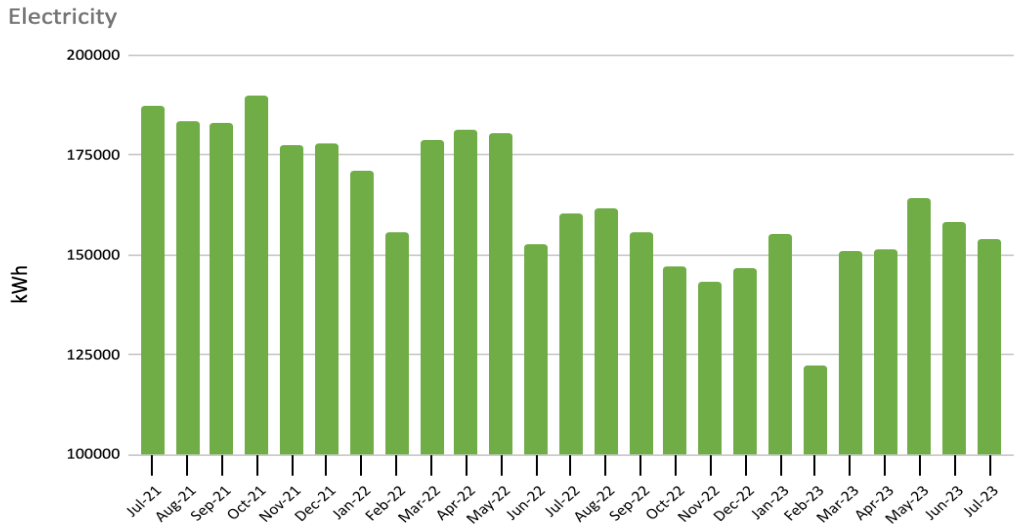
Research Question: How have energy efficiency upgrades impacted three buildings on a university campus in Arkansas in the year after the upgrades were completed?

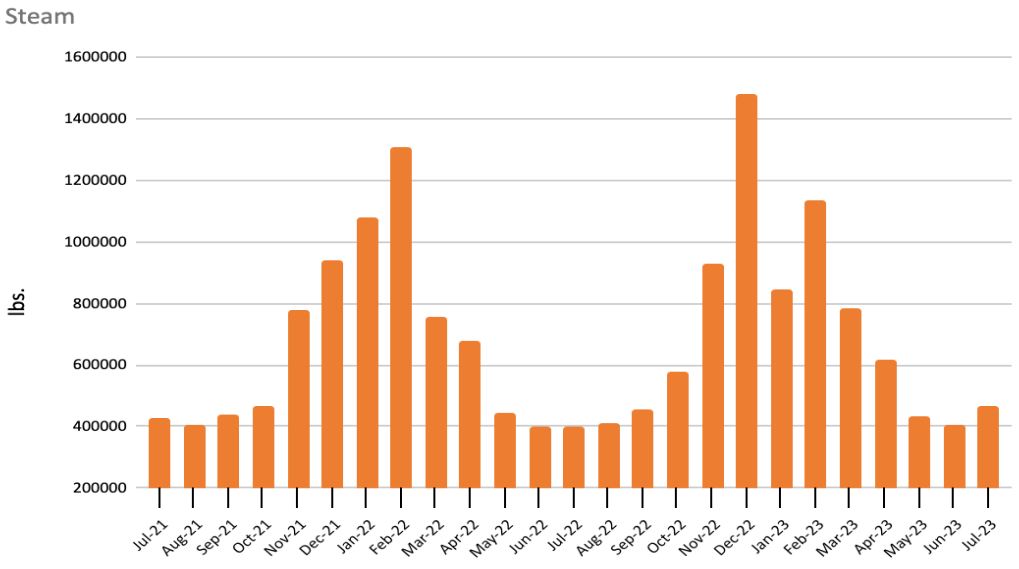
The answer to this question can be studied through a case study comparative analysis. Each building represents a separate case study. Utility bills from chilled water, electricity, steam, and water were collected twelve months before and twelve months after the energy efficiency upgrades were implemented. This allows a consistent window of observation for each building, which helps solidify any conclusions made from the case studies.

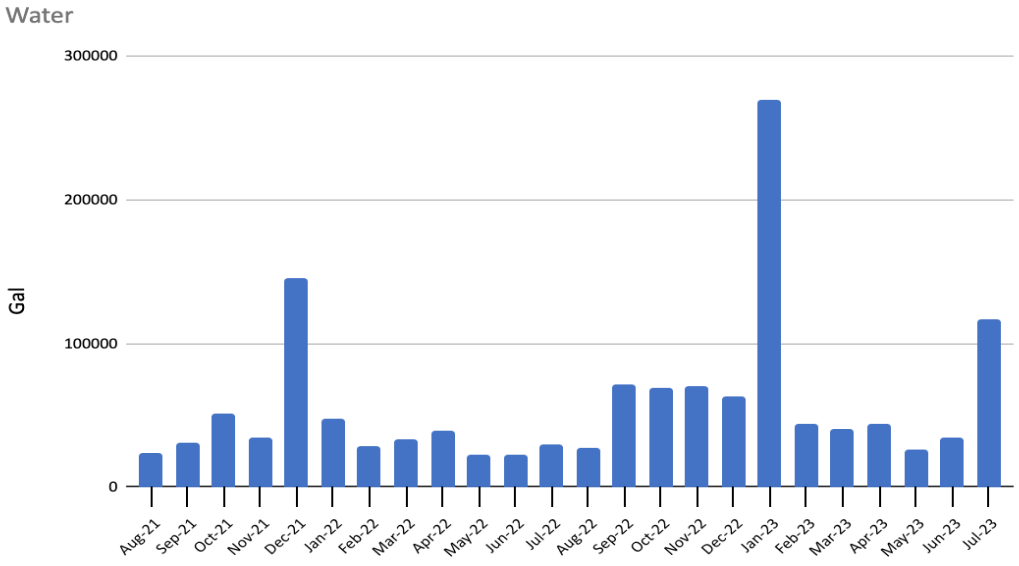
RESULTS

Building A:





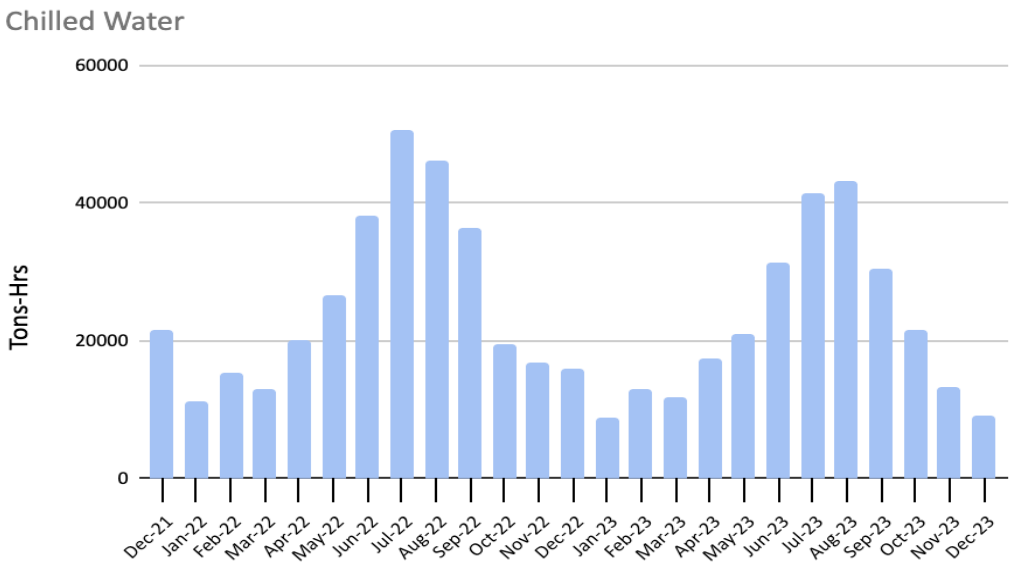


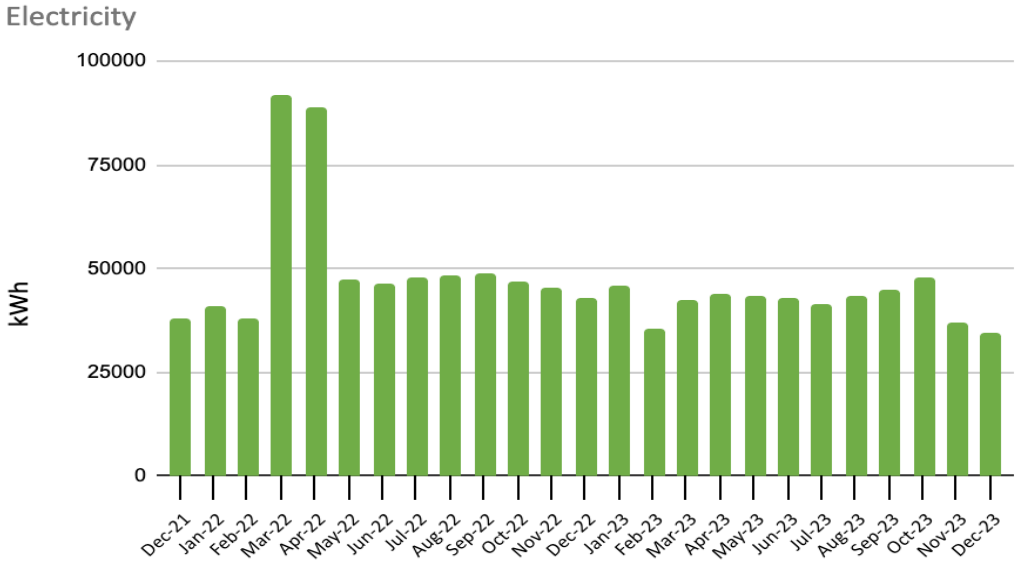


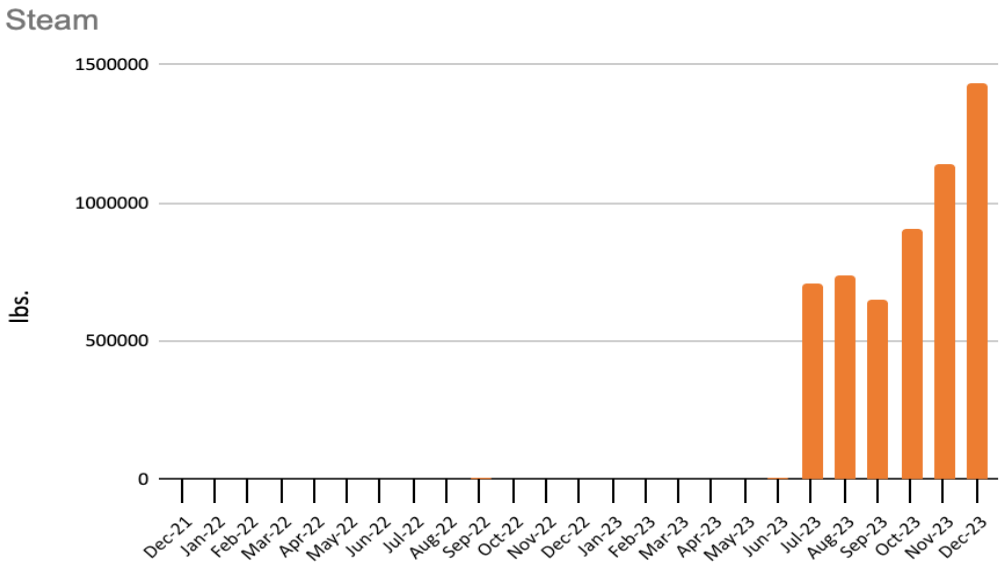
Chilled water and steam show opposite seasonal trends. Chilled water shows peaks in warmer months (June-September). There is a slight decrease in total usage in the year after the efficiency upgrades. Electricity shows an overall decreasing trend. There are unusual dips in February ’22, June ’22, and Febraury ’23. Steam shows peaks in colder months (November-February), however there is a dip in January ’23. The peak also shifts from February in the first

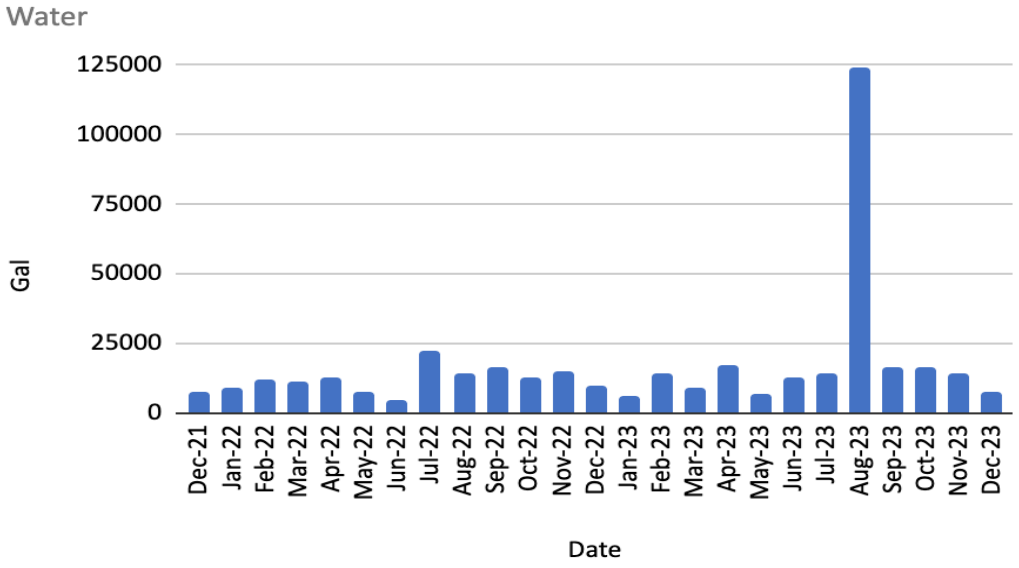
year, to December in the second year. Water shows a spike in December ’21, January ’23 and July ’23. There is also a significant increase in water usage between the two years.

Building B:





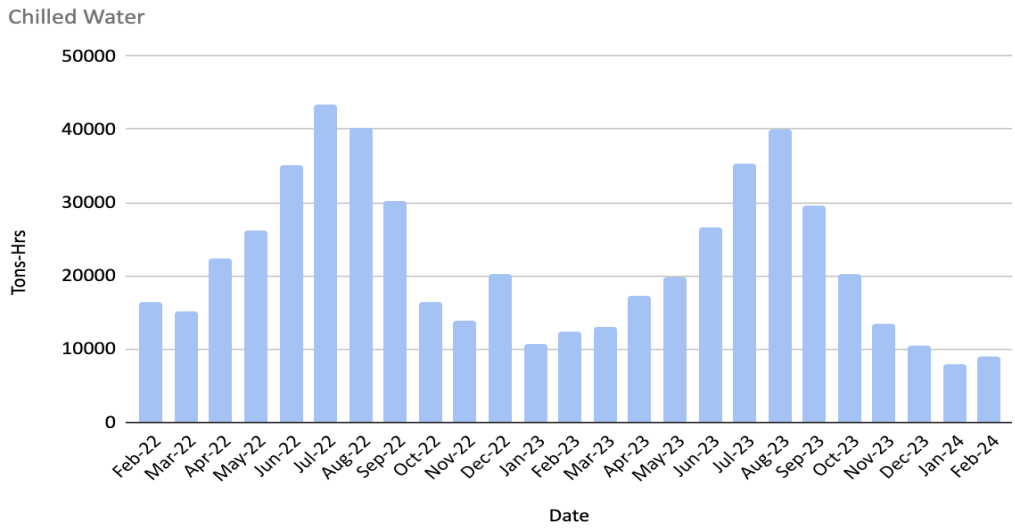


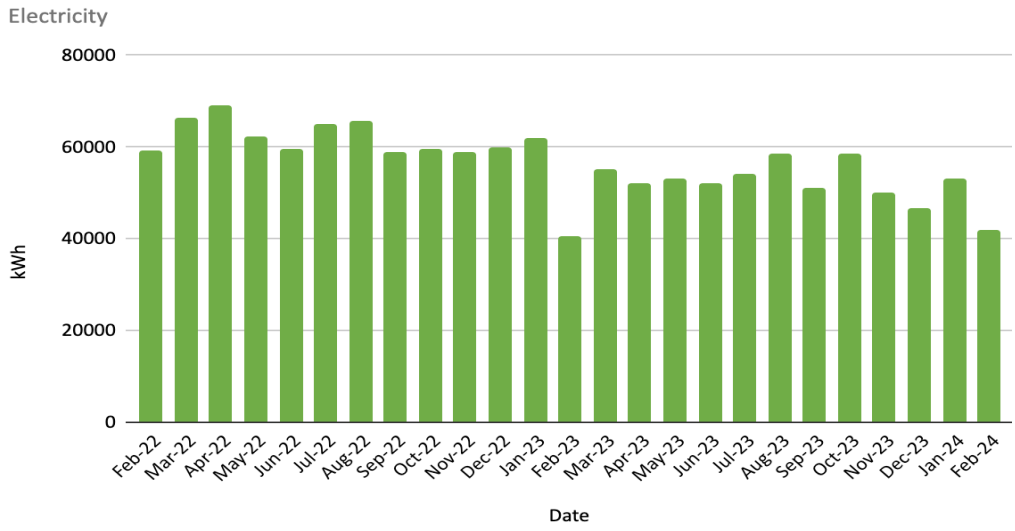


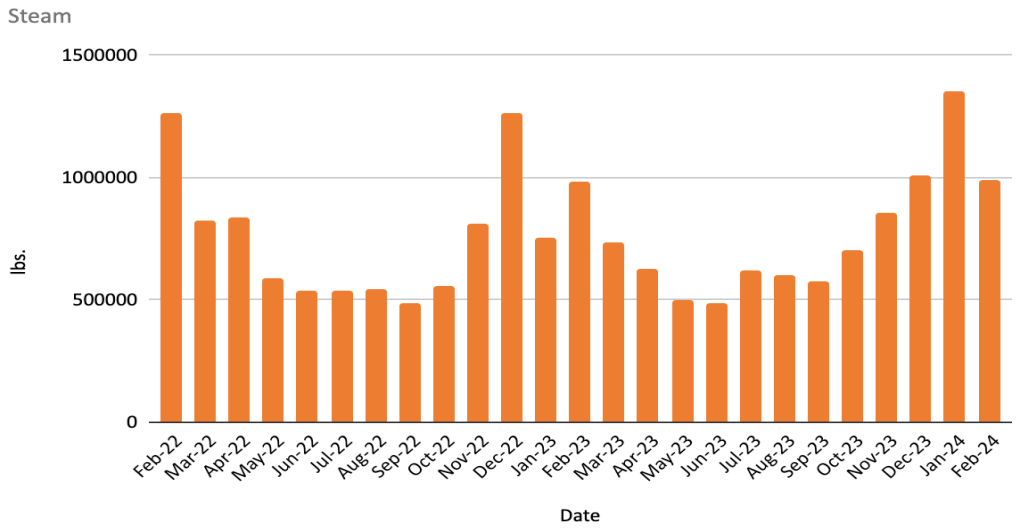
Building B shows similar trends to Building A. Chilled water peaks in the warmer months (June-September). There is a decrease in usage between the two years. Electricty shows a relatively flat usage rate, but there are slight peaks in warmer months and dips in colder months. There is a large spike March ’22 and April ’22. There is also a dip in February ’23. There was an issue with the steam meter, resulting in incomplete data. The present data does show expected results with higher usage in colder months (November-December). Water appears to increase ad

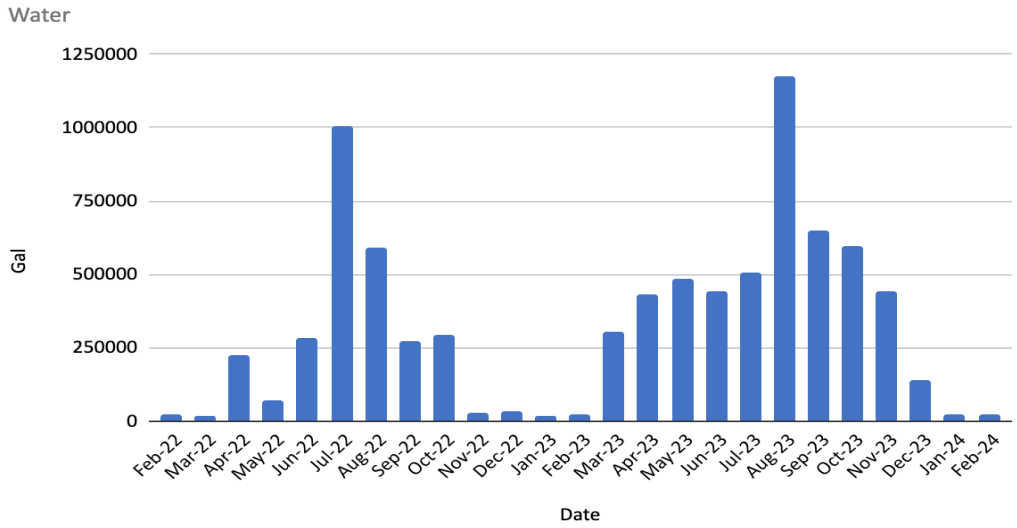
decrease with occupancy rates consistent with an academic calendar with peaks during school months (August-September and February-April). There is a large spike in August ’23.

Building C:









Chilled water and steam show opposite seasonal trends. Chilled water shows peaks in warmer months (June-September). There is a slight decrease in total usage in the year after the efficiency upgrades. Electricity shows an overall decreasing trend. There is an unusual dip in February ’23. Steam shows peaks in colder months (February ’22, December ’22, January ’24). Water shows a drastic seasonal change with high peaks in the warmer months and comparatively low usage in colder months. July ’22 and August ’23 seam to be a spike, rather than simply a peak.

DISCUSSION

Consistent building benchmarking can help lead to answers for one important question: why did this unusual utility consumption happen? In the case of this case study comparative analysis, that question can be applied to all three buildings collectively, or for each building independently, and the answer seems to usually be related to weather. For example, all three buildings show a dip in electricity usage in February ’23. According to weather.gov, there was a major ice storm in late January ’23. This caused campus to close for a few days. With buildings closed and classes canceled, electricity use dropped. This same weather event likely explains the spike in water usgae in Building A in January ’23. If temperatures were cold enough for an ice storm, it’s possible there was a frozen pipe that burst. There is another unusual utility pattern can be explained by weather. A large water spike was seen in August ’23 in Buildings B and C. According to the NOAA, August ’23 was the hottest August ever on record. Record temperatures would lead to an increase in irrigation needed on campus. Buildings B and C have extensive irrigation needs as two of the older and more ornate buildings on campus.

There is one unsualy usage pattern that does not seem to be tied to the weather. Building B shows a spike in electricity usage in March ’22 and April ’22. There were no unusual weather patterns during that time period, and the spike is pretty significant. There might have been events at the building those months causing occupancy or plug load to increase. There also might have been something happening in the building to draw more power. This building does have labs, so perhaps some equipment had to run more tha usual. These are questions that stuents using the building case studies can investigate, and perhaps prevent in future years.

CONCLUSION

Based on the utility data and the noted patterns, the efficiency upgrades are serving their intended purpose. Electricity usage decreased in all three buildings. Chilled water also decreased in all three buildings. With the summer of ’23 having record-setting heat, the usgae for both electricity and chilled water should have increased. The decrease can best be explained by the efficiency upgrades. There are a lot of variables in this study. Each building was a different age, size, and served slightly different purposes. They also received different efficiency upgrade packages. Eliminating some of these variables might lead to a better understanding of the effectiveness of the upgrades and the affect of real-time conditions. Students could look at other buildings on campus that are a similar size, or received similar efficiency upgrades and create their own comparative analysis. Students will be able to continue tracking utility usage in Arc. Hopefully, they will continue to see the energy efficiency upgrades work. The students will also be able to investigate issues as they arise, and learn to predict how usage patterns are affected by extreme weather events.

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APPENDIX

Building A - Upgrades Completed July 2022				
Date	Chilled Water (Tons-Hrs)	Electricity (kWh)	Steam (lbs)	Water (gal)
Jul-21	80494	187470.81	427285	8600
Aug-21	89618	183476.36	405096	23400
Sep-21	78360	183040	436475	30900
Oct-21	58628	189993.71	469045	51700
Nov-21	32669	177472.18	780214	34900
Dec-21	40766	177733.67	938010	145800
Jan-22	23991	171155.67	1079657	48100
Feb-22	34183	155763.56	1307447	28900
Mar-22	28978	178757.79	756832	33600
Apr-22	40906	181433.46	677398	39500
May-22	51803	180470.77	444529	22900
Jun-22	75216	152775.64	398726	22600
Jul-22	84965	160192.59	398217	29800
Aug-22	78080	161614.93	412189	27900
Sep-22	70280	155775.78	457115	72000
Oct-22	39425	147166.15	577864	68600
Nov-22	32949	143389.66	925616	69900
Dec-22	35278	146808.27	1479096	63100
Jan-23	20905	155226.3	847504	269500
Feb-23	29218	122070.33	1133550	44100
Mar-23	27828	151103.32	781099	40700
Apr-23	38301	151344.2	615279	44600
May-23	45284	164227.75	432908	25900
Jun-23	67299	158279.97	403585	35000
Jul-23	82084.3	154151.5	468406.2	117273.3
Jul21-Jun22	635612	2119543.62	8120714	490900
Jul22-Jun23	569812	1817199.25	8464022	791100
Difference	65800	302344.37	-343308	-300200

Building B - Upgrades Completed December 2022				
Date	Chilled Water (Tons-Hrs)	Electricity (kWh)	Steam (lbs)	Water (gal)
Dec-21	21624	38140.21	730	7100
Jan-22	11297	40766.65	463	9000
Feb-22	15316	37753.37	652	11500
Mar-22	13018	91886.54	514	10800
Apr-22	19979	88686.06	635	12900
May-22	26501	47549.81	797	7200
Jun-22	38285	46404.5	1100	4800
Jul-22	50642	47706.73	1006	22300
Aug-22	46080	48258.05	989	14300
Sep-22	36340	48786.77	1265	16100
Oct-22	19660	46756.43	726	12500
Nov-22	16967	45177.83	1066	14800
Dec-22	15813	43039.07	1010	9400
Jan-23	8742	45642.99	661	6300
Feb-23	12946	35556.74	920	14200
Mar-23	11839	42581.32	851	8900
Apr-23	17472	43754.04	992	17100
May-23	20932	43435.62	1006	6800
Jun-23	31405	42675.38	1404	12900
Jul-23	41362	41434.89	710129	14340
Aug-23	43336	43156.28	737771	123567
Sep-23	30424	44797.14	650303	15871
Oct-23	21451	47621.09	902169	16529
Nov-23	13266	36734.56	1137307	13727
Dec-23	9016	34438.58	1433298	7626
Dec21-Nov22	315709	627873	9943	143300
Dec22-Nov23	268988	510429	4144524	259634
Difference	46721	117444	-4134581	-116334

Building C - Upgrades Completed February 2023				
Date	Chilled Water (Tons-Hrs)	Electricity (kWh)	Steam (lbs)	Water (gal)
Feb-22	16462.5	59109.91	1260847.688	20600
Mar-22	15039.3	66297.35	823983.8125	17800
Apr-22	22282.3	69210.08	835872.9063	226000
May-22	26212.2	62215.42	587479.9063	68200
Jun-22	35071	59727.3	535673.0781	285200
Jul-22	43322.4	64963.9	535260.1406	1007600
Aug-22	40242.7	65842.06	546079.9219	588400
Sep-22	30232.1	59020.48	486486.375	269900
Oct-22	16454.1	59619.39	553241.1719	291000
Nov-22	13934.5	58791.42	808149.3125	28600
Dec-22	20194.1	59861.76	1264524.5	30400
Jan-23	10762.1	61984.66	754068.5313	14400
Feb-23	12341.4	40627.58	980041.4375	24200
Mar-23	12992.6	55089.22	736150	303700
Apr-23	17191.6	52245.12	625535.2813	428900
May-23	19749.8	53073.16	496899.125	485100
Jun-23	26676.7	52122.06	484693.5313	443900
Jul-23	35374.7	53964.90	618699.4	503732
Aug-23	39956.6	58490.05	602228.7	1172684
Sep-23	29638.4	51066.35	572916.0	648392
Oct-23	20160.1	58686.52	705704.5	596908
Nov-23	13417.2	49881.97	858720.6	442083
Dec-23	10512.8	46675.62	1009220.1	141255
Jan-24	7848.3	52965.94	1350220.8	21161
Feb-24	8903.2	41851.30	988577.1	23454
Feb22-Jan23	290209	746644	8991667	2848100
Feb23-Jan24	245860	624888	9041029	5212016
Difference	44349	121755	-49362	-2363916