DATA 604: Minor Final Deliverable

Energy Consumption Analysis and its effects in Calgary

Group: Code 404

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Introduction

DATASET 1: **Building Energy Benchmarking – City of Calgary** **What is it?** • **Annual Data** • **2019-2021**	**DATASET 2:** **Corporate Energy Consumption – City of Calgary** **What is it?** • **Monthly Data** • **2014-2021**
DATASET 3: 6 Building Data - University of Calgary What is it? • Daily Data • 2018-2021	DATASET 4: Current and Historical Alberta Weather Station Data – ACIS What is it? • Daily Data • 2014-2022

Heating Energy Efficiency Analysis on Campus Building

Guiding Question

- Has the efficiency of heating energy usage on campus buildings improved?

Background and Motivation

- University of Calgary is working to become a Canadian post-secondary leader in sustainability.

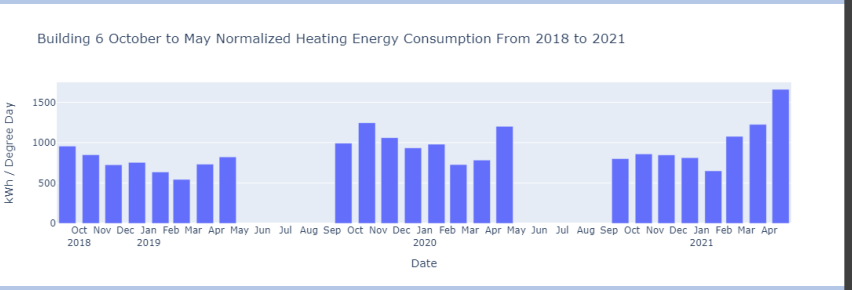
Weather Normalization for Energy Consumption

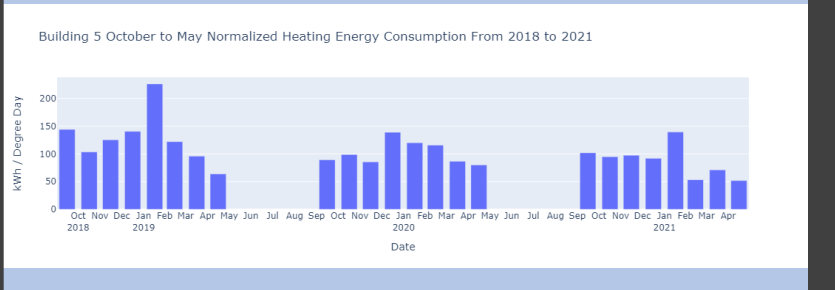
- Heating Degree Days

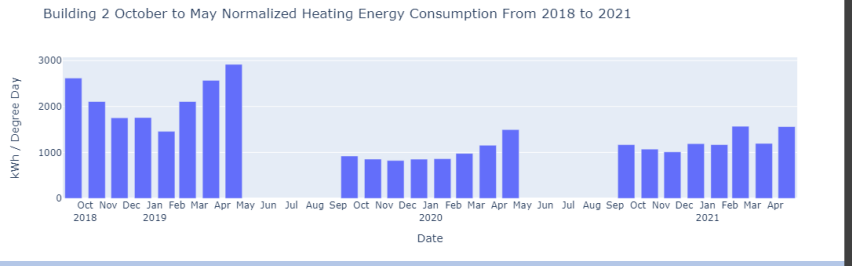
$$\frac{EnergyConsumption(kWh)}{HDD} = \boldsymbol{kWh/degreeday}$$

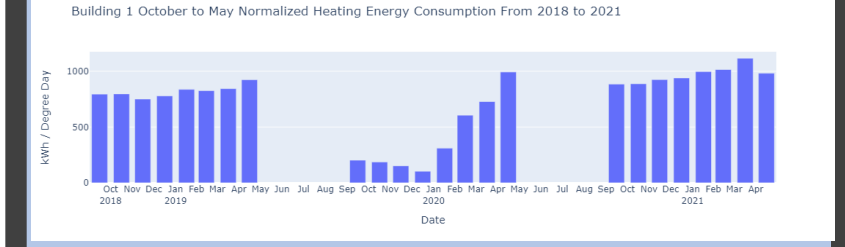
Dataset Description

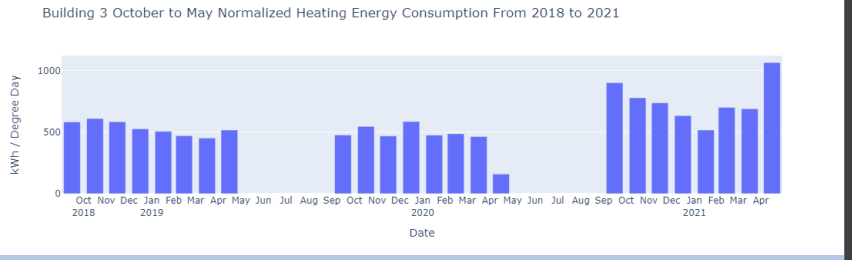
- Daily temperature recorded from Calgary Int'L CS weather station
- Provided by the Alberta Climate Information Service (ACIS)
- Campus Building Energy Consumption Dataset was retrieved through the Office of Sustainability Campus as a Learning Lab initiative collected as energy consumption at different buildings
- The names of specific buildings will be concealed in the following analysis as a part of non-disclosure agreement.

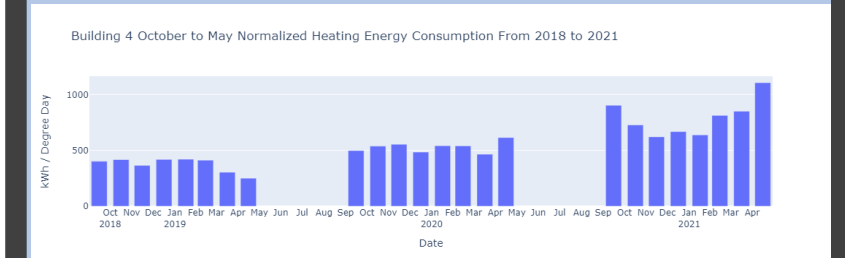








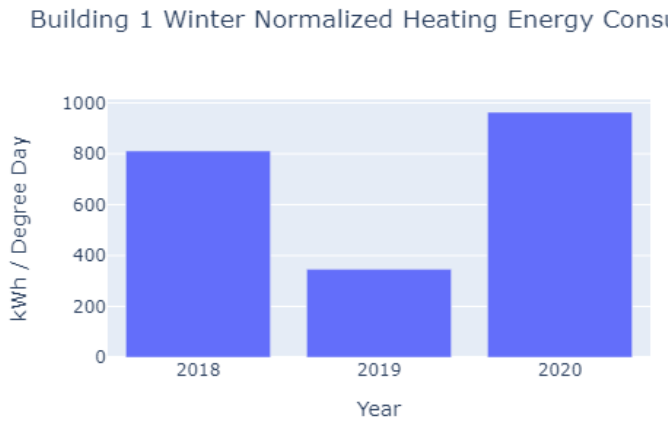


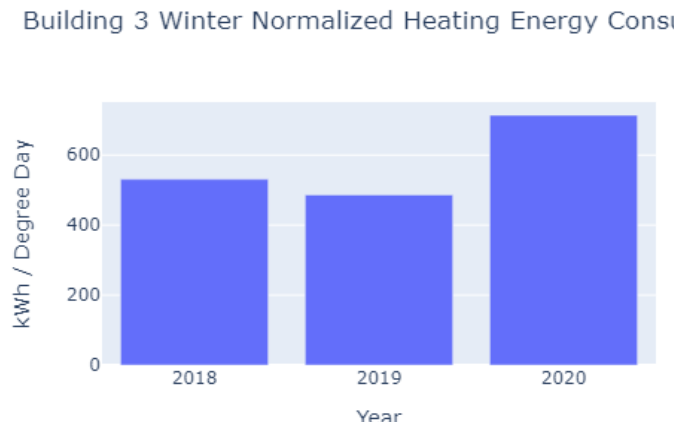


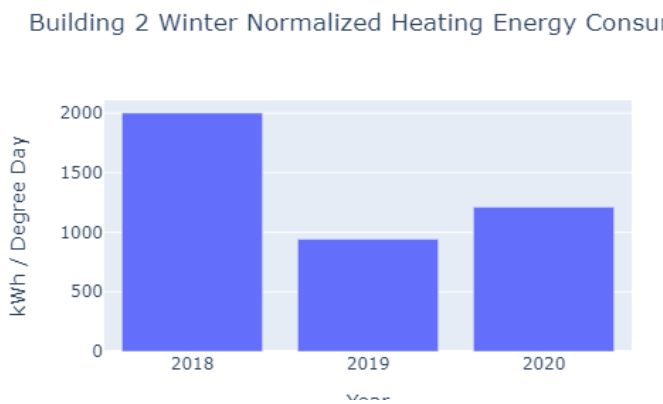
Monthly Winter Normalized Heating Energy Consumption

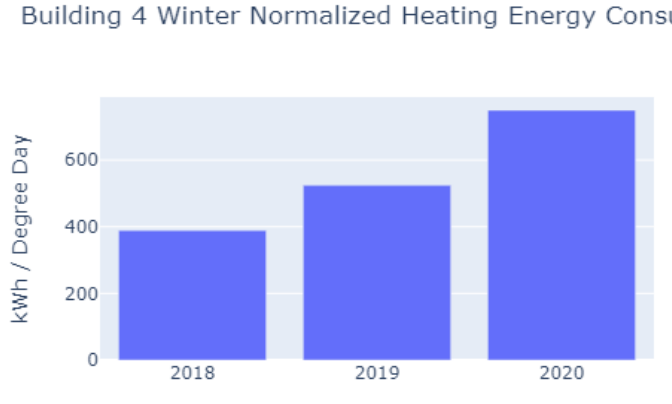
Annually Winter Normalized Heating Energy Consumption

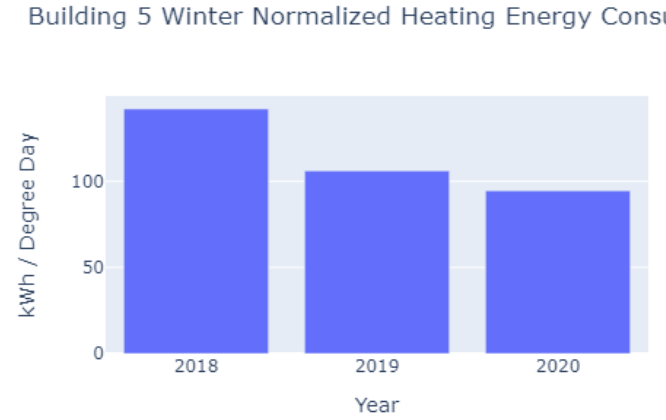
	Building	Percentage Change 18 to 19	Percentage Change 19 to 20
0	b1	-57.36	178.45
1	b2	-52.93	28.44
2	b3	-8.43	46.80
3	b4	34.73	42.91
4	b5	-25.34	-10.81
5	b6	33.99	-6.36

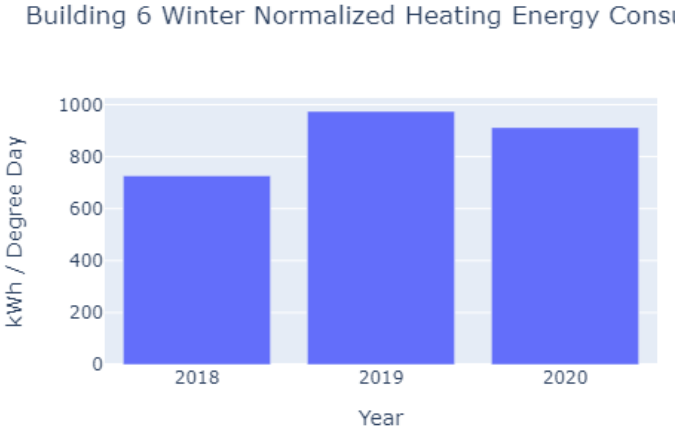




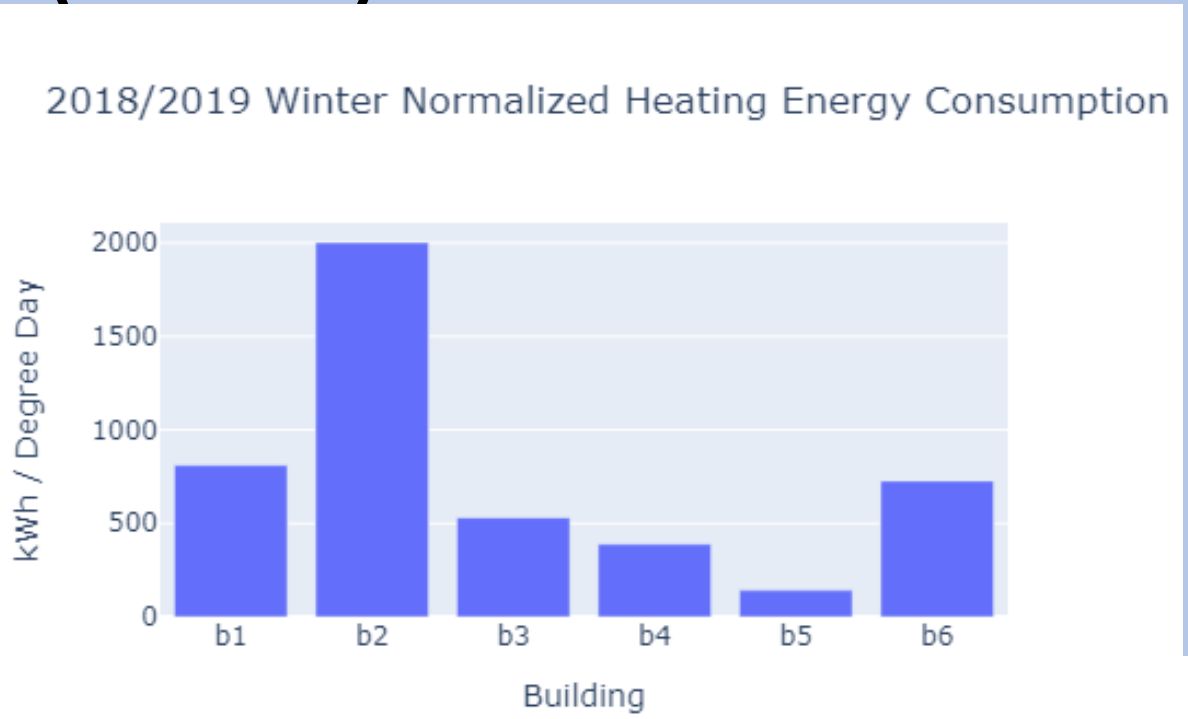


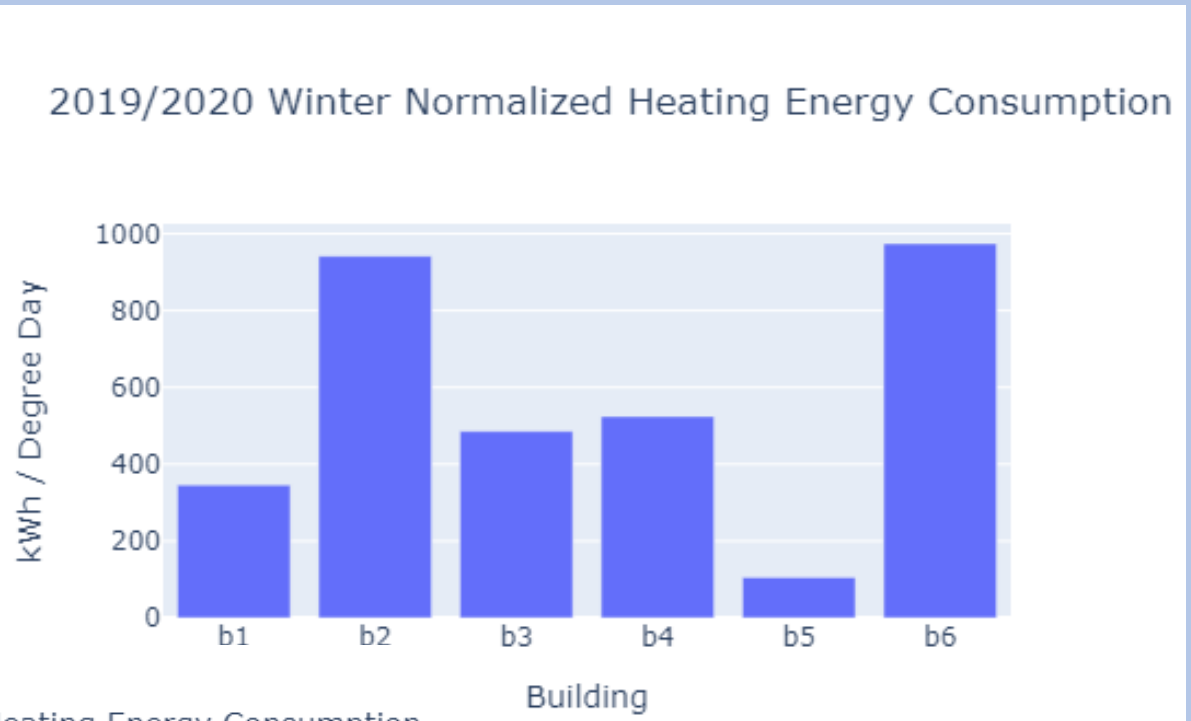


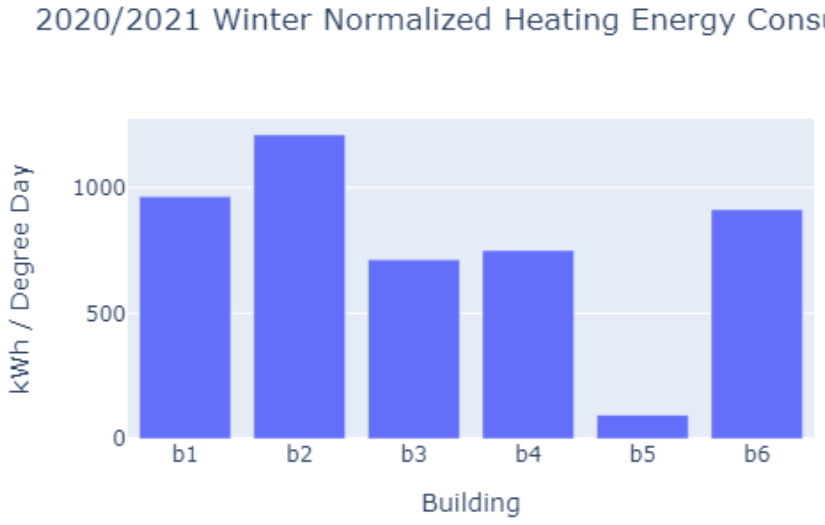




Heating Energy Efficiency Analysis on Campus Building (cont'd)







Conclusion

Apart from building 5, there has not been an improvement in the efficiency of heating energy consumption in campus buildings.

From 2018 to 2019, the use efficiency of heating energy consumption of most campus buildings has increased.

From 2019 to 2020, the majority of campus buildings exhibited decreased or sustained efficiency in their utilization of heating energy.

The efficiency of heating energy consumption in building 5 is increasing steadily, whereas the efficiency of heating energy consumption in building 4 is declining annually.

The heating energy use efficiency of building 2 and building 6 is relatively lower compared to other buildings, building 5 has the best heating energy use efficiency.

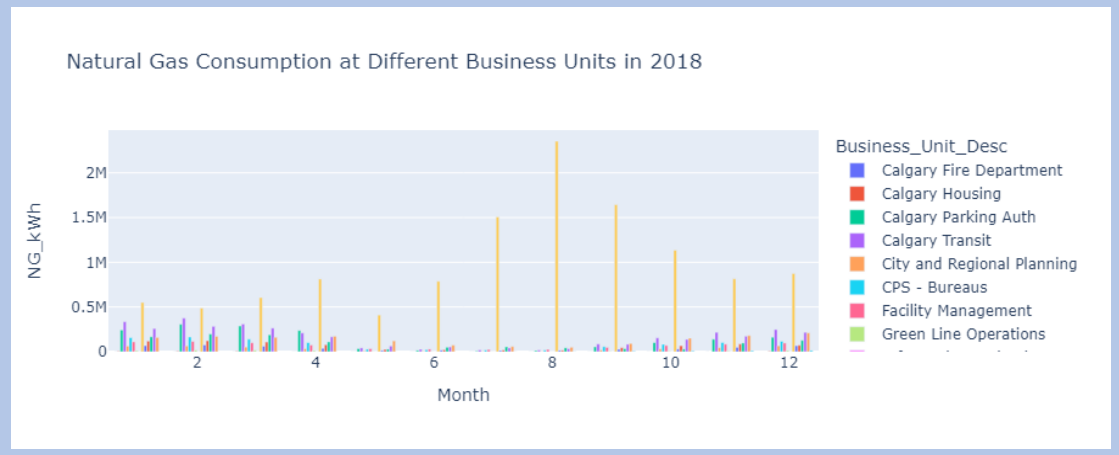
Corporate energy consumption - City of Calgary

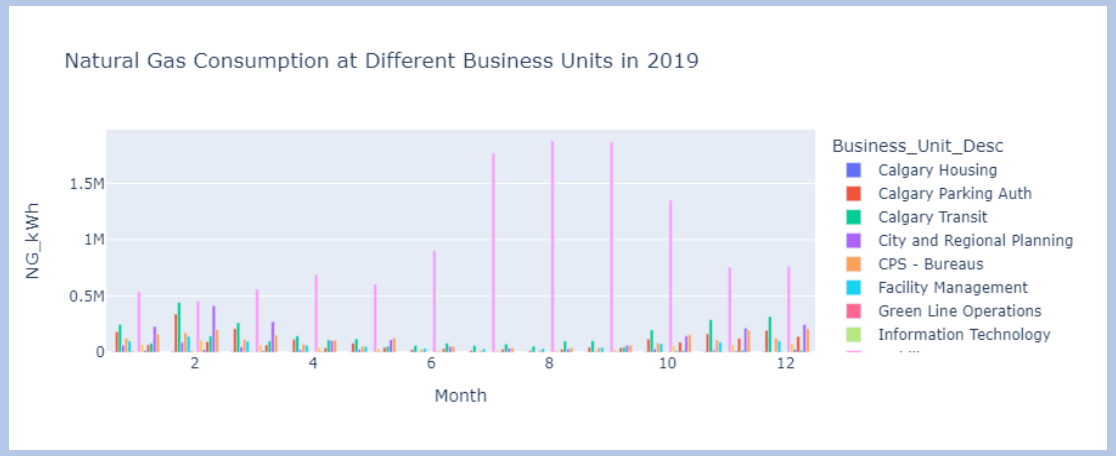
- **Dataset Overview**
- Domain: Energy Consumption data recorded monthly
- Open data available at City of Calgary webpage
- Tabular format with 300k rows and 9 columns
- Data Collection Period of 2014 to 2021
- 20 different business facilities/units

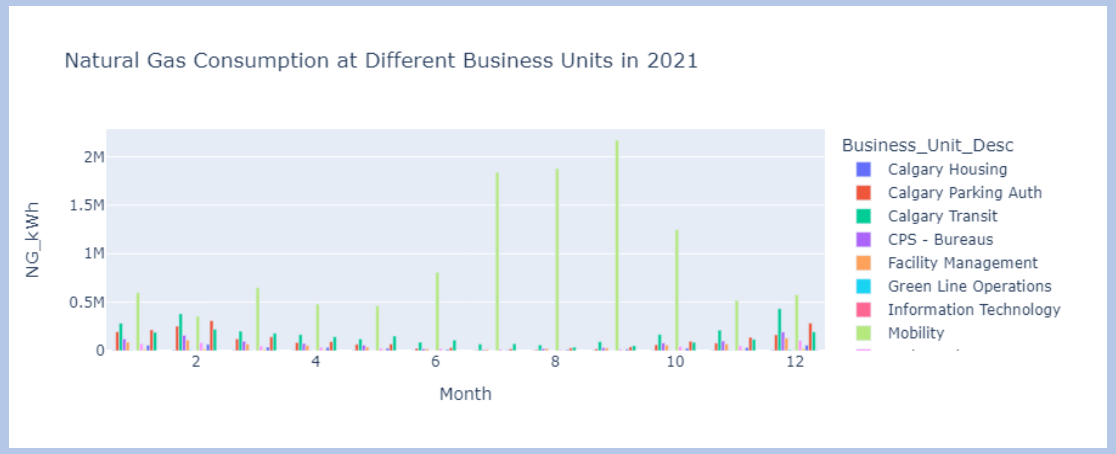
- **Guiding Questions**

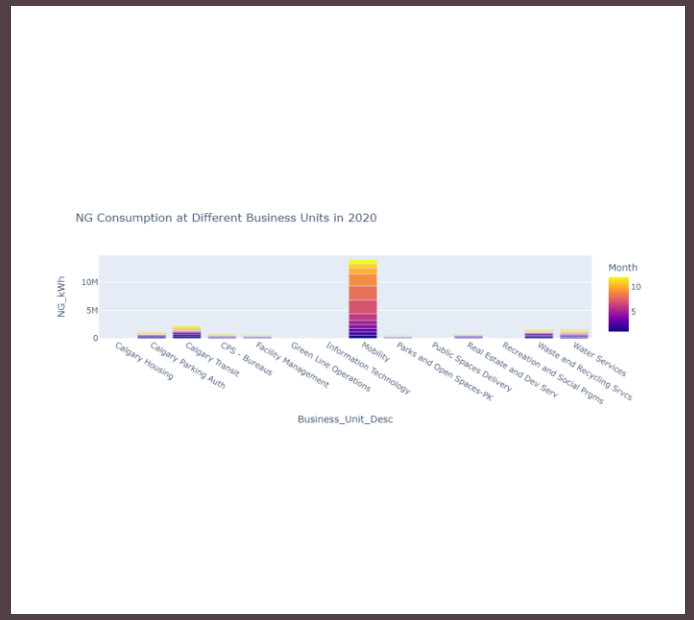
  - What is Energy consumption situation at each facility?
  - How did the Covid – 19 pandemic affect energy consumption? What is the maximum and minimum normalized energy consumption for year 2019-2021?

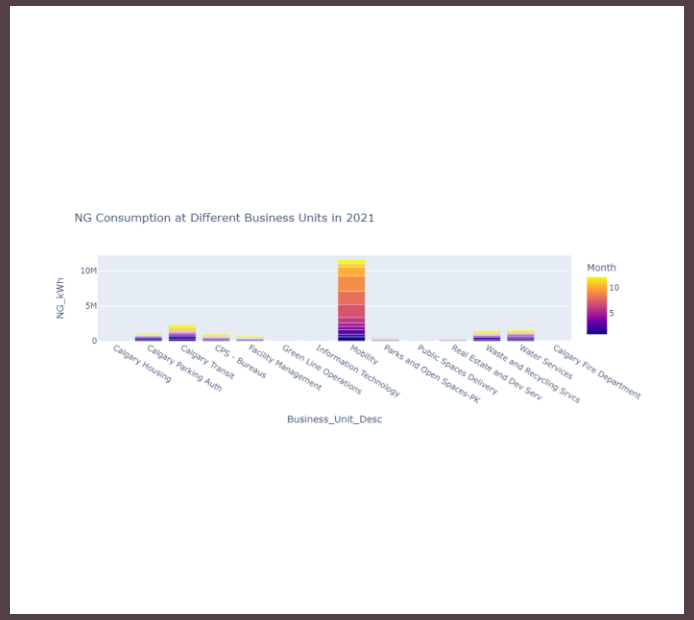
Natural Gas Consumption at Different Business Units

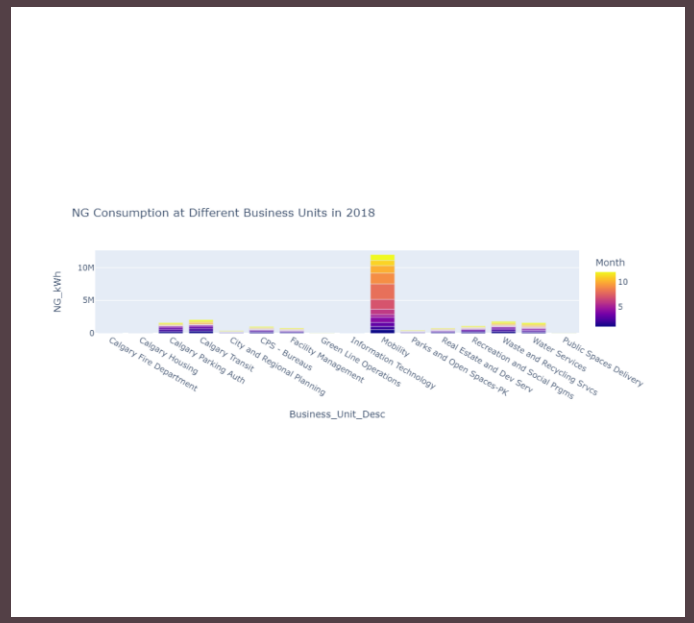


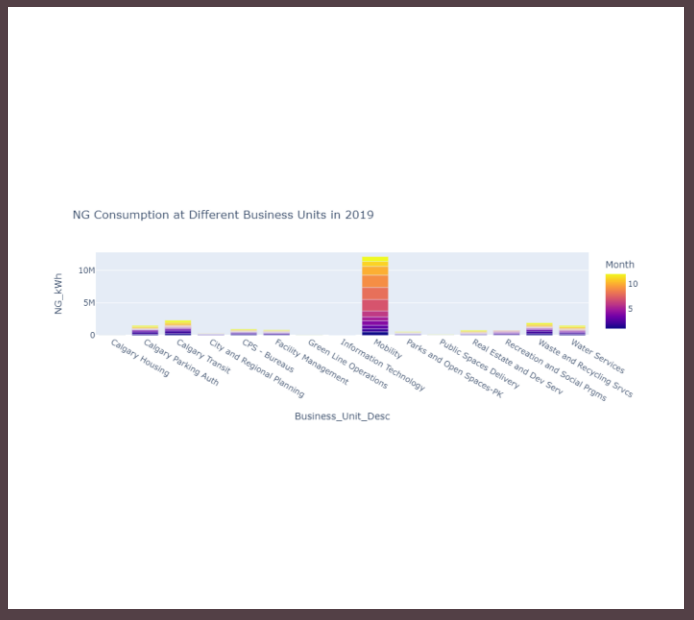




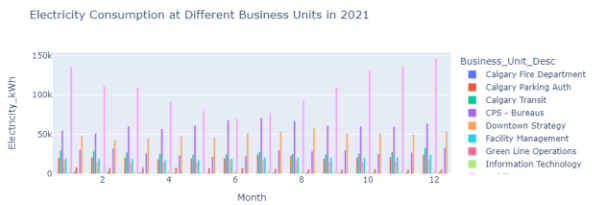


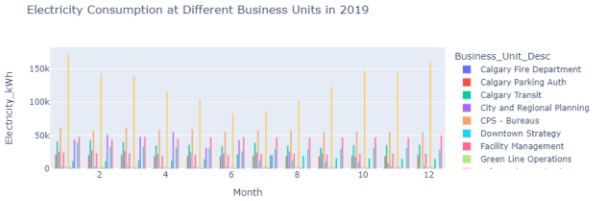


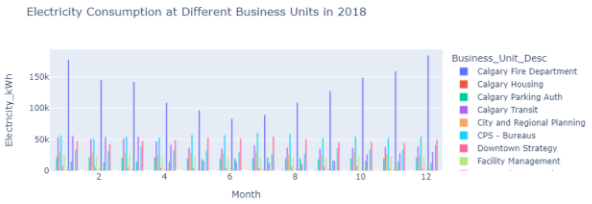




Natural Gas Consumption at Different Business Units (cont'd)

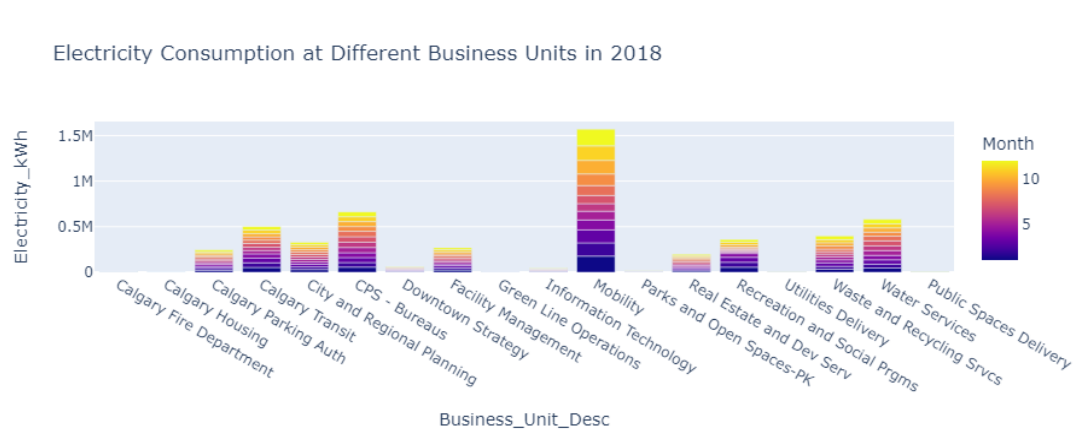


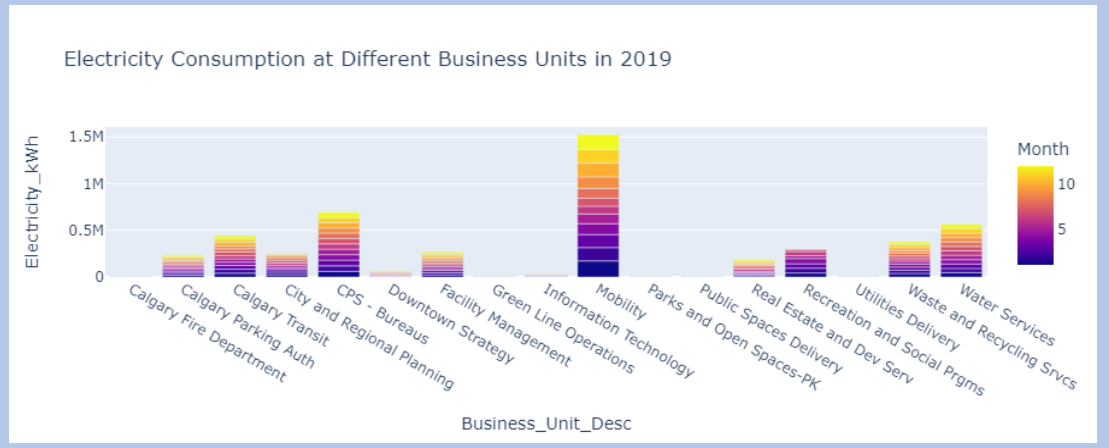


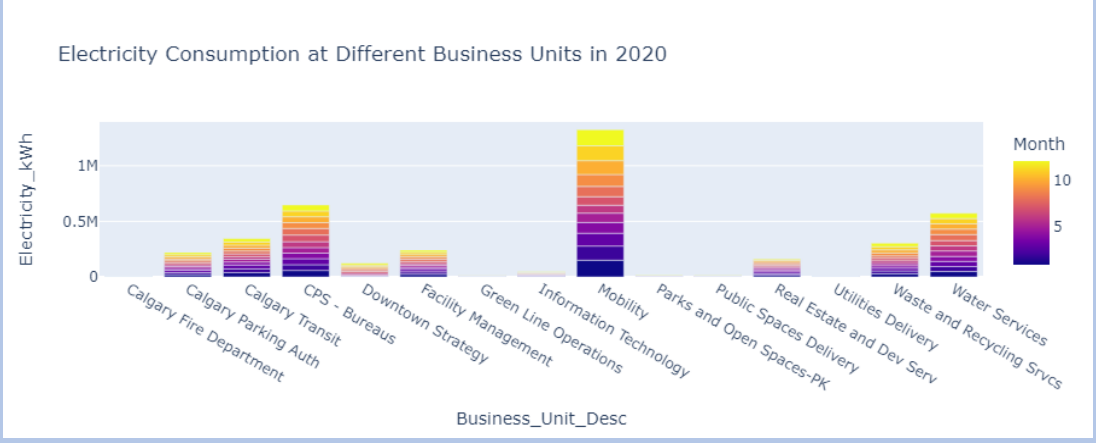


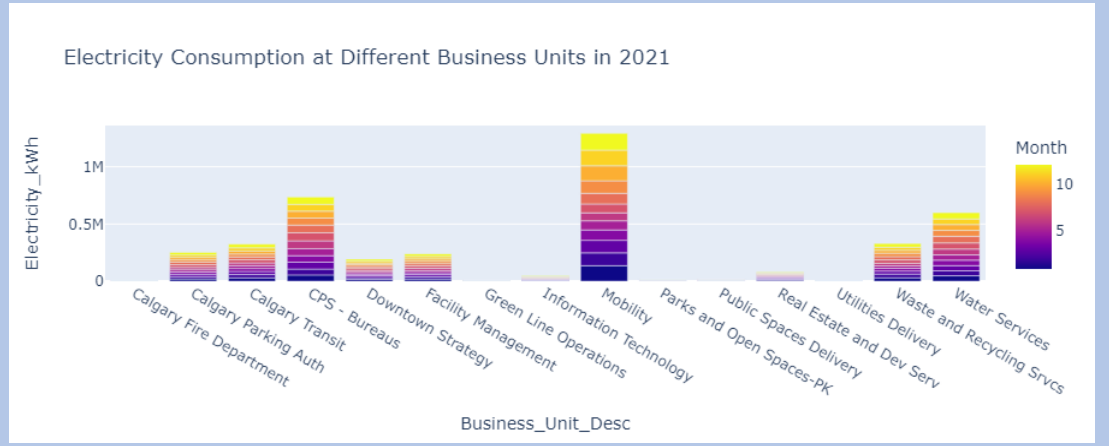
Electricity Consumption at Different Business Units

Electricity Consumption at Different Business Units (cont'd)

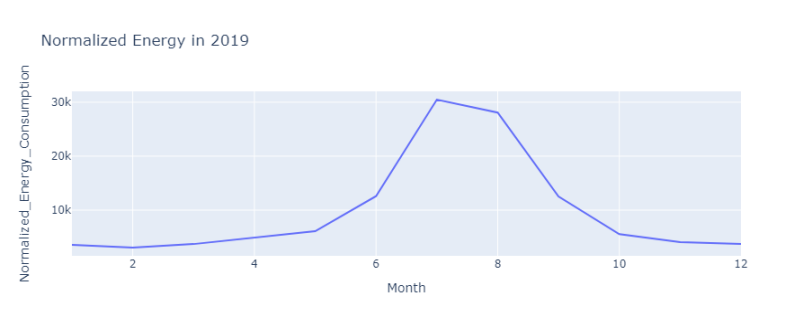




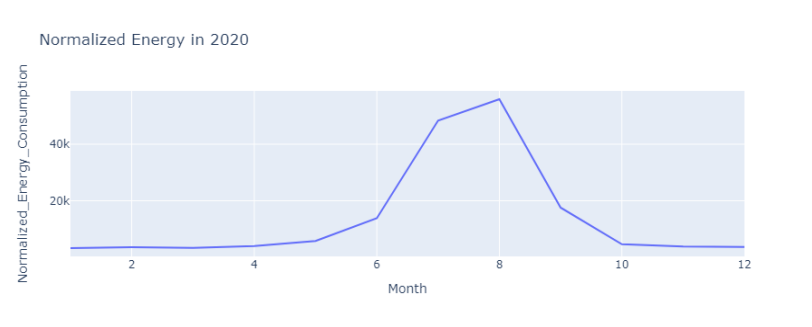




Normalized Energy for Year 2019-2021



Average Normalized Energy Consumption for 2019: 9855.05 kWh/Degree Days
Maximum Normalized Energy Consumption for 2019: 30491.41 kWh/Degree Days in July
Minimum Normalized Energy Consumption for 2019: 3043.42 kWh/Degree Days in February



Average Normalized Energy Consumption for 2020: 13791.62 kWh/Degree Days
Maximum Normalized Energy Consumption for 2020: 55901.20 kWh/Degree Days in August
Minimum Normalized Energy Consumption for 2020: 3261.23 kWh/Degree Days in January

Average Normalized Energy Consumption for 2021: 23905.64 kWh /Degree Days
Maximum Normalized Energy Consumption for 2021: 189984.42 kWh/Degree Days in July
Minimum Normalized Energy Consumption for 2021: 2701.24 kWh/Degree Days in February

Conclusion

- Natural Gas consumption is at its peak during summer months
- Electricity Consumption is higher in colder months than summer months, it is lower during the months of May-July and start rising from August. Electricity consumption is at its peak during the month of December and January of each year
- Normalized energy consumption is increasing over the years from 2019 to 2021

Annual Data

"Building Energy Benchmark - City of Calgary": has been sourced directly from the City of Calgary website: https://data.calgary.ca/Environment/Building-Energy-Benchmarking-City-of-Calgary/8twd-upbv. It consists of detailed data for every building in Calgary, including the Property ID, the year it was built in, the overall energy use and the individual types of energy it uses, for a span of 3 years: 2019-2021.

Guiding Questions:

1. How do we identify the Property type that uses the most energy?
2. How does age of the building affect the energy consumption?
3. How dependent is each building on a) Natural Gas b) Electricity?
4. Visual representation of Use of Natural Gas vs Electricity per Property Type?
5. What is the Normalized Energy Usage value based on Heating Degree Days?
6. What is the average energy consumption for each year?

1. Office type of building uses the maximum amount of energy in the City of Calgary: 620236.9 GJ

2. No effect of age on the Energy Consumption of the buildings.

3. Dependency of Building Types on Natural gas: approximately 50%

4. Dependency of Building Types on Electricity: approximately 20-45%.

16		Office	620236.9

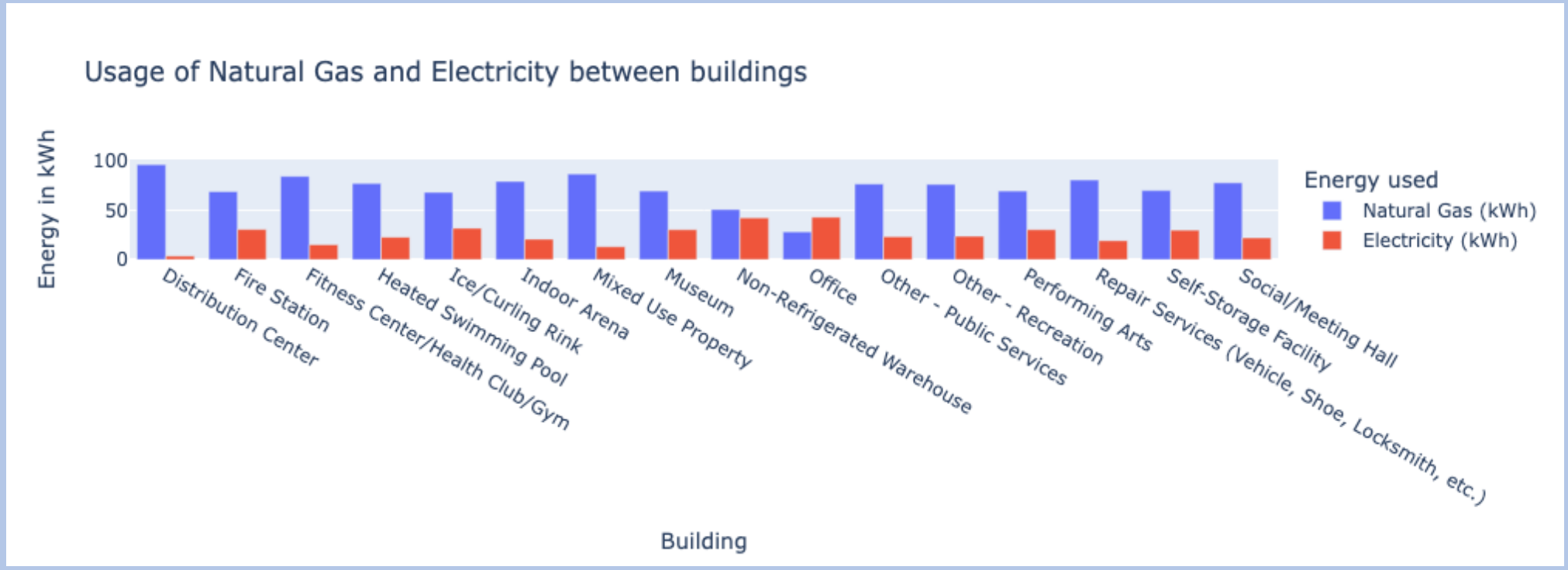
	Primary Property Type - Self Selected	MAX(`Year Built`)	Site Energy Use (GJ)
0	Office	2018	10118.0

	Primary Property Type - Self Selected	MIN(`Year Built`)	Site Energy Use (GJ)
0	Office	1919	10118.0

	Property Id	Natural Gas Use (GJ)	Site Energy Use (GJ)	Percent
0	6169481	6308.2	10118.0	62.3
1	6305956	24.5	4792.7	0.5
2	6506773	7052.5	11983.9	58.8
3	6731628	2159.1	3653.5	59.1
4	6867796	363.0	506.1	71.7
...	...	...	...	...
292	21988624	964.5	1069.9	90.1
293	21988625	936.5	1238.3	75.6
294	21988627	835.2	920.2	90.8
295	21988628	688.4	1080.6	63.7
296	21988629	251.7	335.5	75.0

	Property Id	ConvertedValues	Site Energy Use (GJ)	Percent
0	6169481	3809.9	10118.0	37.7
1	6305956	1929.8	4792.7	40.3
2	6506773	4931.6	11983.9	41.2
3	6731628	1429.9	3653.5	39.1
4	6867796	143.2	506.1	28.3
...	...	...	...	...
292	21988624	105.4	1069.9	9.9
293	21988625	301.9	1238.3	24.4
294	21988627	84.9	920.2	9.2
295	21988628	387.4	1080.6	35.9
296	21988629	83.7	335.5	24.9

Visual representation of Use of Natural Gas vs Electricity per Property Type



- Average Energy Consumption per year:

	Avg Annual Energy	Year
0	8463.562626	2019
1	7391.614141	2020
2	7765.873737	2021

Energy Consumption in University of Calgary

Guiding Questions

- Compare the energy consumption of buildings.
- What type of energy are the top 3 energy consuming buildings dependent on?
- Which type of energy the buildings are majorly dependent on?
- What was the effect of COVID 19 on the major energy dependency of the buildings?

- **The data for this project was retrieved through the Office of Sustainability Campus as a Learning Lab initiative.***
- ***The assumptions and conclusions of this project have not been reviewed by the University of Calgary's operations staff.**

Comparison of Energy

We can see the overall consumption of energy of each building over three years.

- The B1 used the most energy, which can be accounted by the heavy machinery used by the students, instructors and PhD scholars during the practical work. Which can be regarded for the next building as well.
- B2 is a residential building, which explains that why is the energy consumption is the least when compared to corporate or educational buildings. It consists of simple appliances such as bulbs, microwave, oven etc.

	building	SUM(total)
0	B1	55136658.16
1	B4	35530751.76
2	B6	20592558.92
3	B5	19225006.65
4	B3	18934155.18
5	B2	4587295.89

Comparison of Domestic water

- Comparing water of residential building because from the above inferences we could see that there no match of energy consumption by educational buildings and corporate buildings. The consume far more energy than a residential building. Hence the study of water consumption was interesting.
- We can see that water consumption by B2 was far more than most of the corporate as well as educational buildings. This can be regarded by the fact that student use a lot of water in their daily life, be it for cooking, washing or bathing.

	Building	TOTAL
0	B1	45798.11
1	B5	41417.38
2	B2	20737.91
3	B4	17933.85
4	B3	9827.85
5	B6	3328.05

Comparison of Energies

	Building	SUM(Chilled_wat)	SUM(Heating_wat)	SUM(Electricity1)	SUM(Natural_g)	Top_cons
0	B1	5249432.58	22423730.37	26650009.79	813485.42	55136658.16
1	B4	6519962.40	11434309.16	12304599.59	5271880.61	35530751.76
2	B6	1398845.15	15144668.85	3928326.75	120718.17	20592558.92
3	B5	3739888.17	10263594.63	5221523.85	0.00	19225006.65
4	B3	2333663.08	9378667.58	7221824.52	0.00	18934155.18
5	B2	925983.75	1738856.93	1922455.21	0.00	4587295.89

- We can see that, the B1 is mostly dependent on electricity and most as well when compared to other buildings but quite equally dependent on heating water.
- The B4 is also dependent on the same types of energy as B1, but there is a stark contrast when it comes to using Natural gas. This is also consuming its most energy in Chilled water when compared to other buildings.
- The B6 is using its most energy in heating water and chilled water consecutively.
- It was also interesting to see that the 3 buildings consuming the least energy don't even used Natural gas.

Energy Consumption in University of Calgary

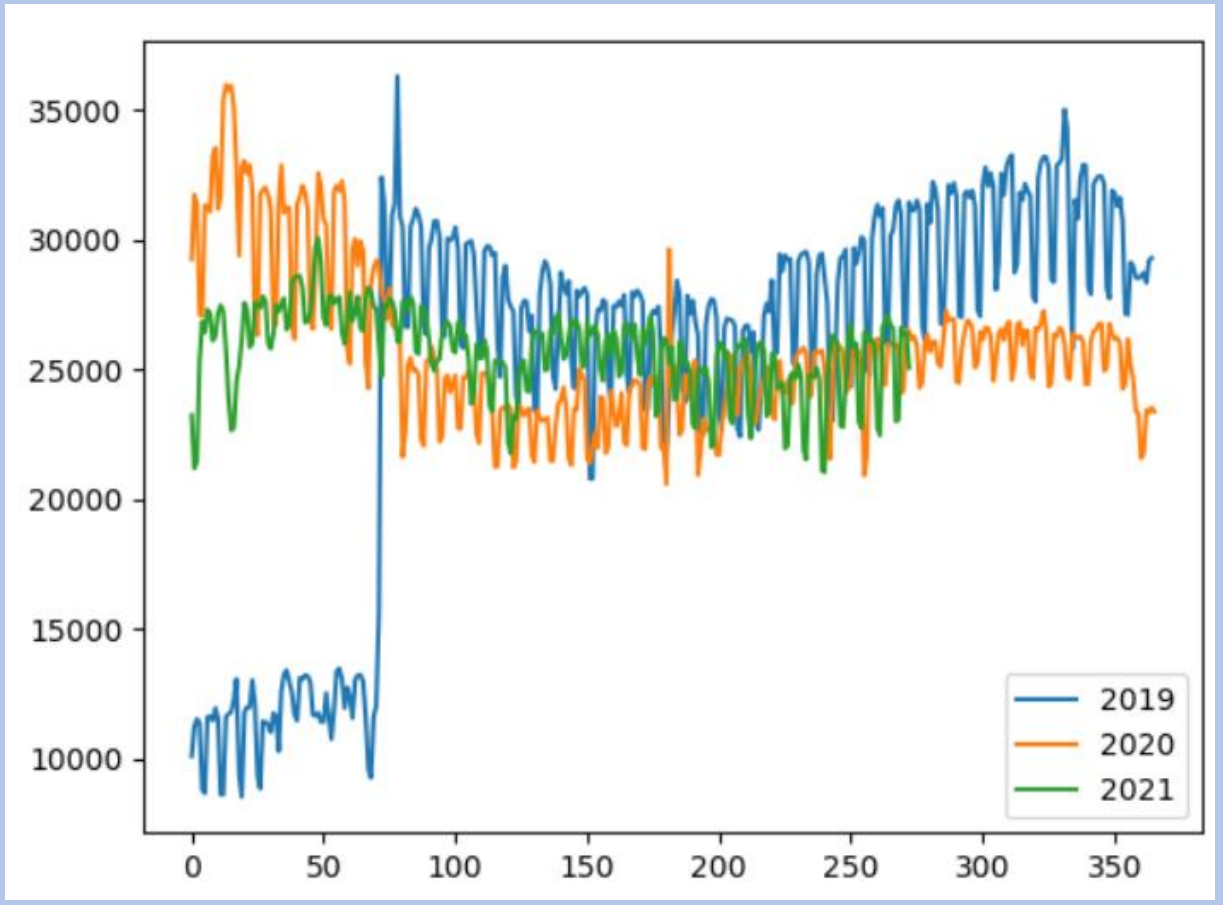
	Building	Elec_Percent
0	B1	48.334467
1	B2	41.908245
2	B3	38.141784
3	B4	34.630845
4	B5	27.160063
5	B6	19.076438

- B1 and B2 are majorly dependent on Electricity as their source of energy.
- While B5, B5 and B3 are majorly dependent on Heating Water as their major source of Energy.

	Building	Heat_Percent
0	B6	73.544375
1	B5	53.386690
2	B3	49.533066
3	B1	40.669368
4	B2	37.905925
5	B4	32.181445

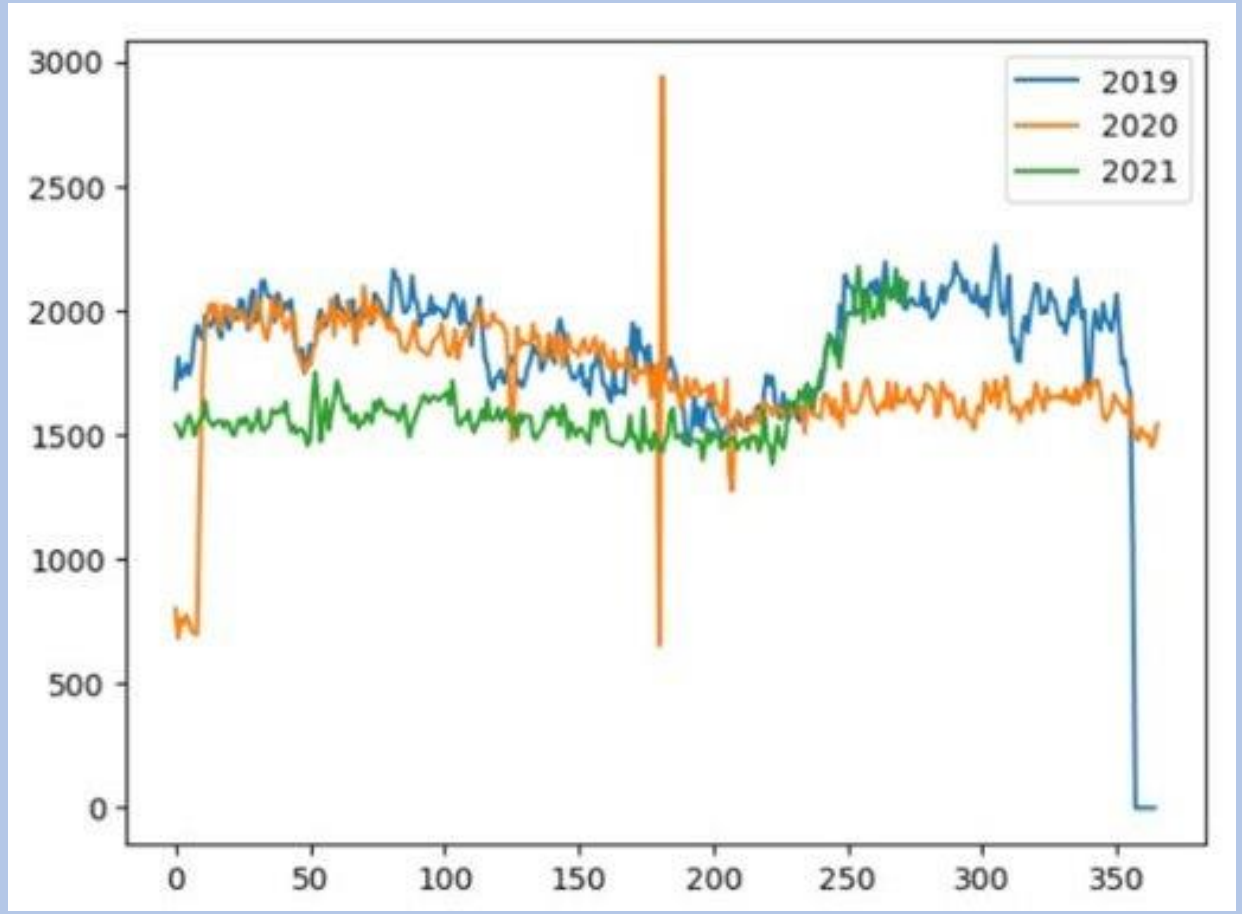
COVID 19 Impact on B1's Electricity

- In 2020 we see a drop of around 10,000 KwH of Electricity.
- The meter was broken in the building for a few months in the starting of 2019.
- In 2021 the electricity consumption gradually started to grow in the B1.



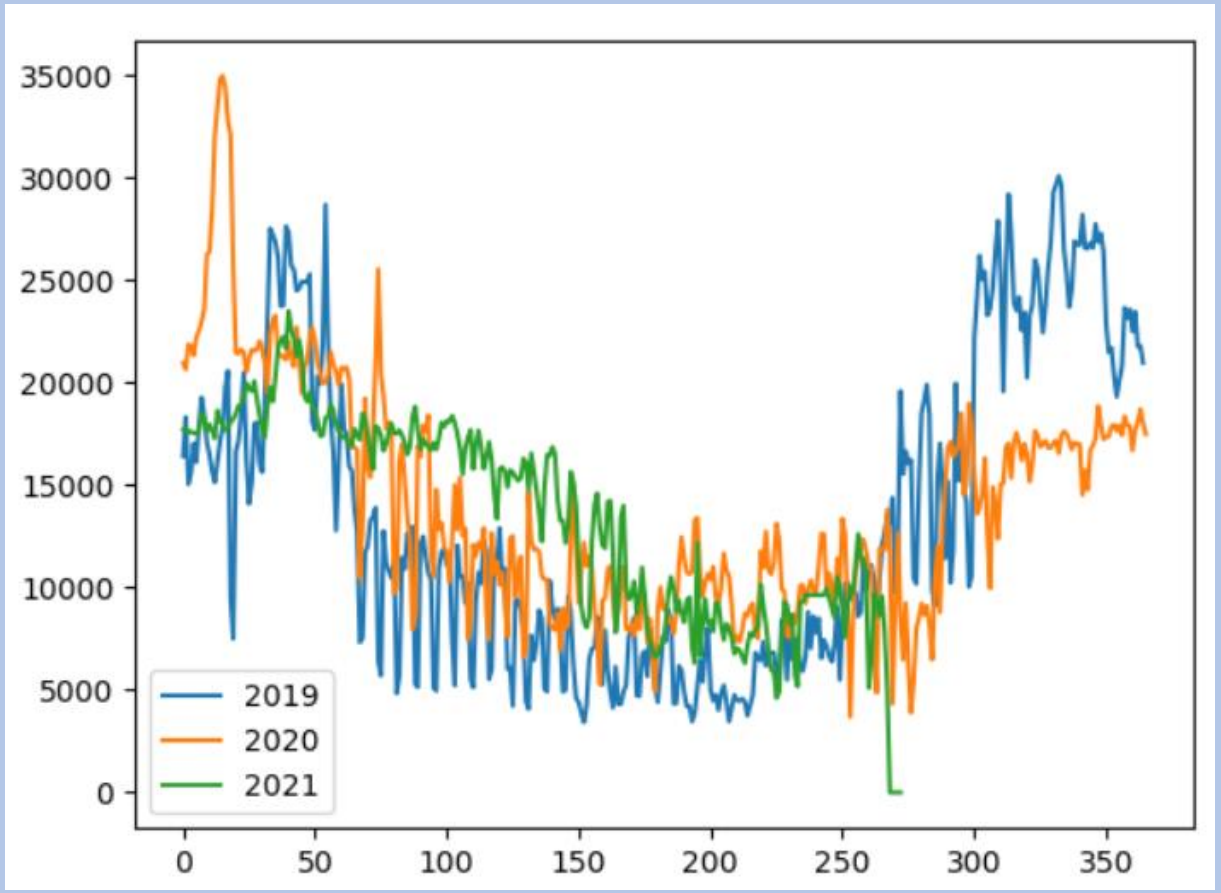
COVID 19 Impact on B2's Electricity

- B2 being a residential building shows a drop in electricity when the city was hit with major lockdowns in 2020.
- But here also we can see that it started to become normal during the mid of 2021.



COVID 19 Impact on B6's Heating Water

- B6 can be classified as an office type building which shows very little impact of COVID 19.
- We can see that Heating water consumption increased a little bit in 2020 which shows that the office was still open and in use during the pandemic.



Conclusions Drawn from the Project: Dependency on Natural Gas and Electricity

	Natural Gas/Heating percentage	Electricty
Percentage of dependency of buildings in City of Calgary	50%	20-45%
Percentage of dependency of business buildings in City of Calgary	15-20%	75-85%
Percentage of dependency of Campus buildings in University of Calgary	30-75%	30-50%

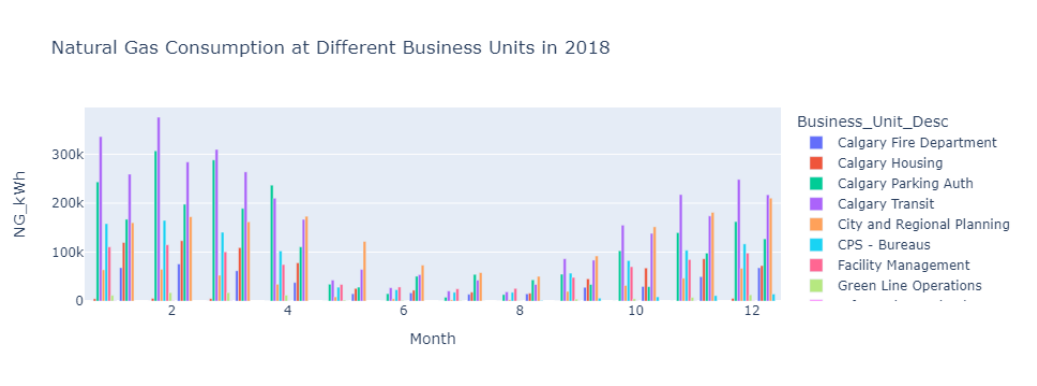
Current Status

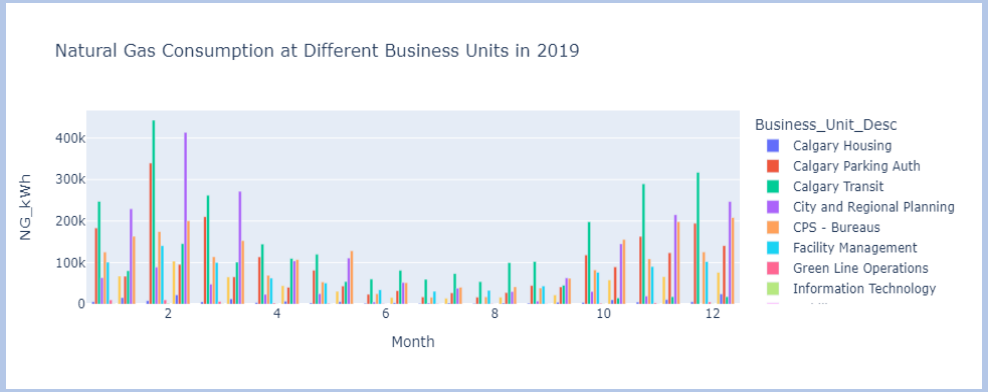
- Overall, there has not been an improvement in the efficiency of heating energy consumption in campus buildings from 2018 to 2021.
- "Office" type building uses the most amount of energy, and age has no effect on the Energy consumption.
- From the year 2018-2021 the most energy consumed in terms of Natural Gas and Electricity Consumption at Mobility business unit, and it is at it is at peak around July-August.
- Comparison of the Campus Energy use pre, during and post Covid was done visually.

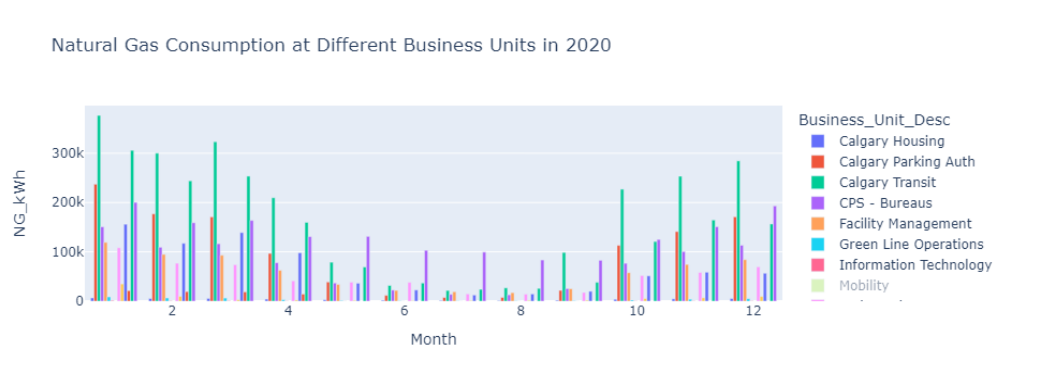
Future Steps

- Improver visualization to derive more detailed energy efficiency analysis.
- There will be more detailed calculation and visualization for normalized energy of the business units.
- We will draw a correlation between Temperature and Energy for Annual, Monthly and Campus Data.
- We will draw a correlation between Normalized Energy for Annual, Monthly and Campus Data.

Question#1


Natural Gas Consumption at Different Business Units in 2018
NG_kWh
300k
200k
100k
0
2
4
6
8
10
12
Month
Business_Unit_Desc
Calgary Fire Department
Calgary Housing
Calgary Parking Auth
Calgary Transit
City and Regional Planning
CPS - Bureaus
Facility Management
Green Line Operations


Natural Gas Consumption at Different Business Units in 2019
NG_kWh
400k
300k
200k
100k
0
2
4
6
8
10
12
Month
Business_Unit_Desc
Calgary Housing
Calgary Parking Auth
Calgary Transit
City and Regional Planning
CPS - Bureaus
Facility Management
Green Line Operations
Information Technology


Natural Gas Consumption at Different Business Units in 2020
NG_kWh
300k
200k
100k
0
2
4
6
8
10
12
Month
Business_Unit_Desc
Calgary Housing
Calgary Parking Auth
Calgary Transit
CPS - Bureaus
Facility Management
Green Line Operations
Information Technology
Mobility


Natural Gas Consumption at Different Business Units in 2021
NG_kWh
400k
300k
200k
100k
0
2
4
6
8
10
12
Month
Business_Unit_Desc
Calgary Housing
Calgary Parking Auth
Calgary Transit
CPS - Bureaus
Facility Management
Green Line Operations
Information Technology
Mobility

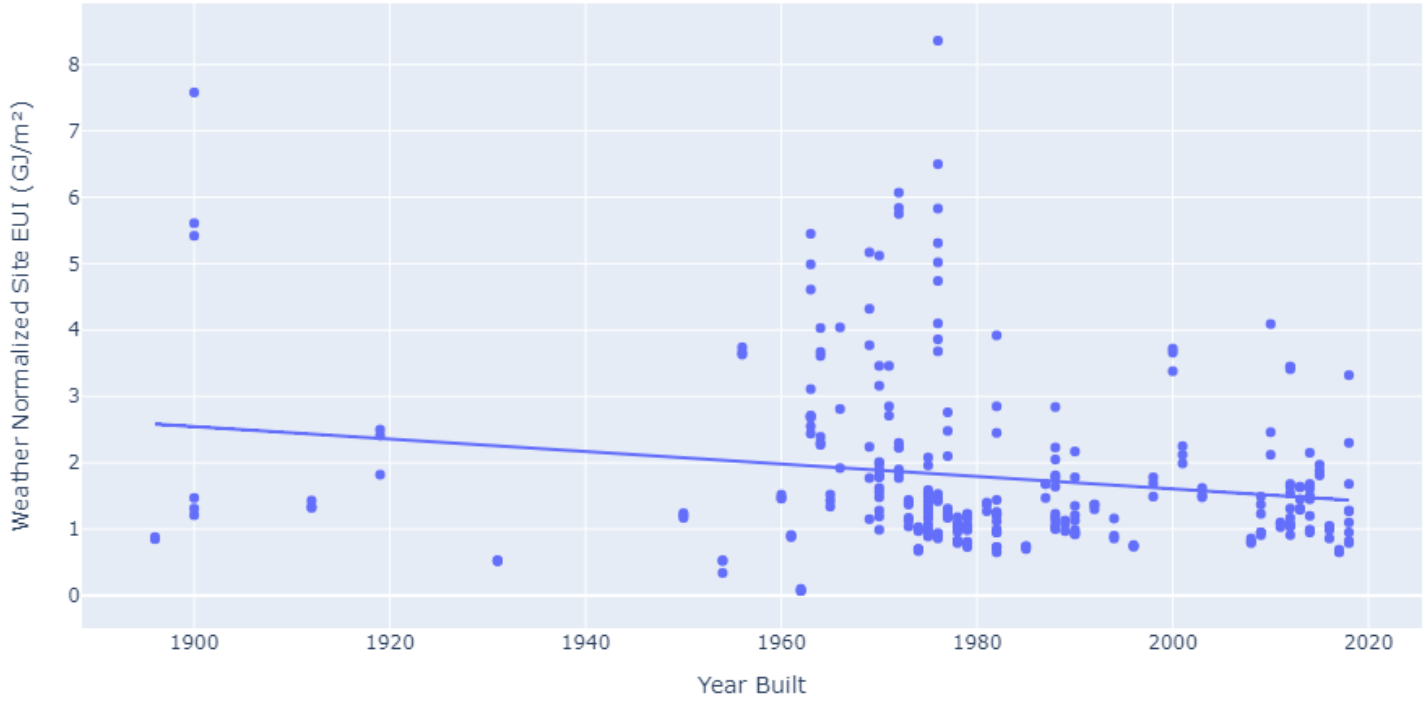
Question 2: Age vs Energy vs Efficiency

	Primary Property Type - Self Selected	MAX(`Year Built`)	Property GFA - Self-Reported (m²)	Site Energy Use (GJ)
0	Office	2018	7770.0	10118.0

	Primary Property Type - Self Selected	MIN(`Year Built`)	Property GFA - Self-Reported (m²)	Site Energy Use (GJ)
0	Office	1919	7770.0	10118.0

The relationship between building age and energy consumption

- Is the newer building more efficient in terms of energy usage?




```
correlation = df['Year Built'].corr(df['Weather Normalized Site EUI (GJ/m²)'])

correlation
```

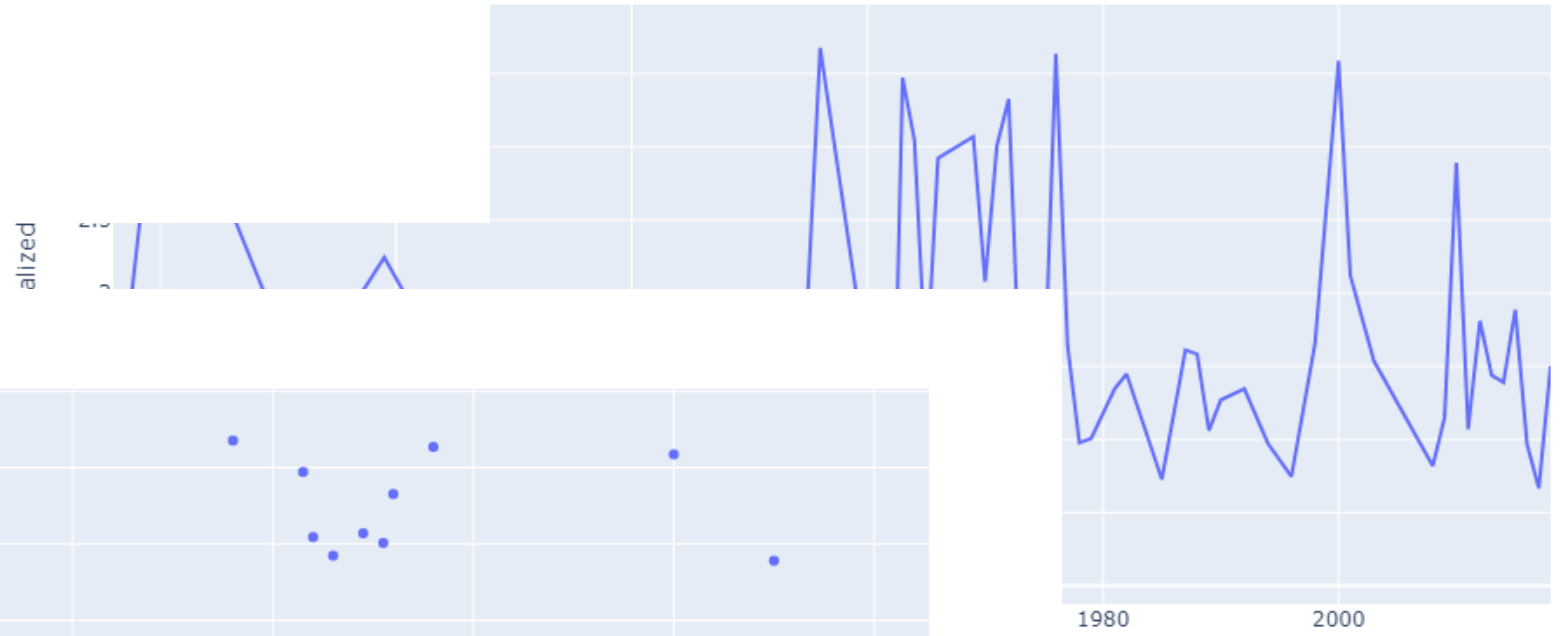
```
-0.1826760418022149
```

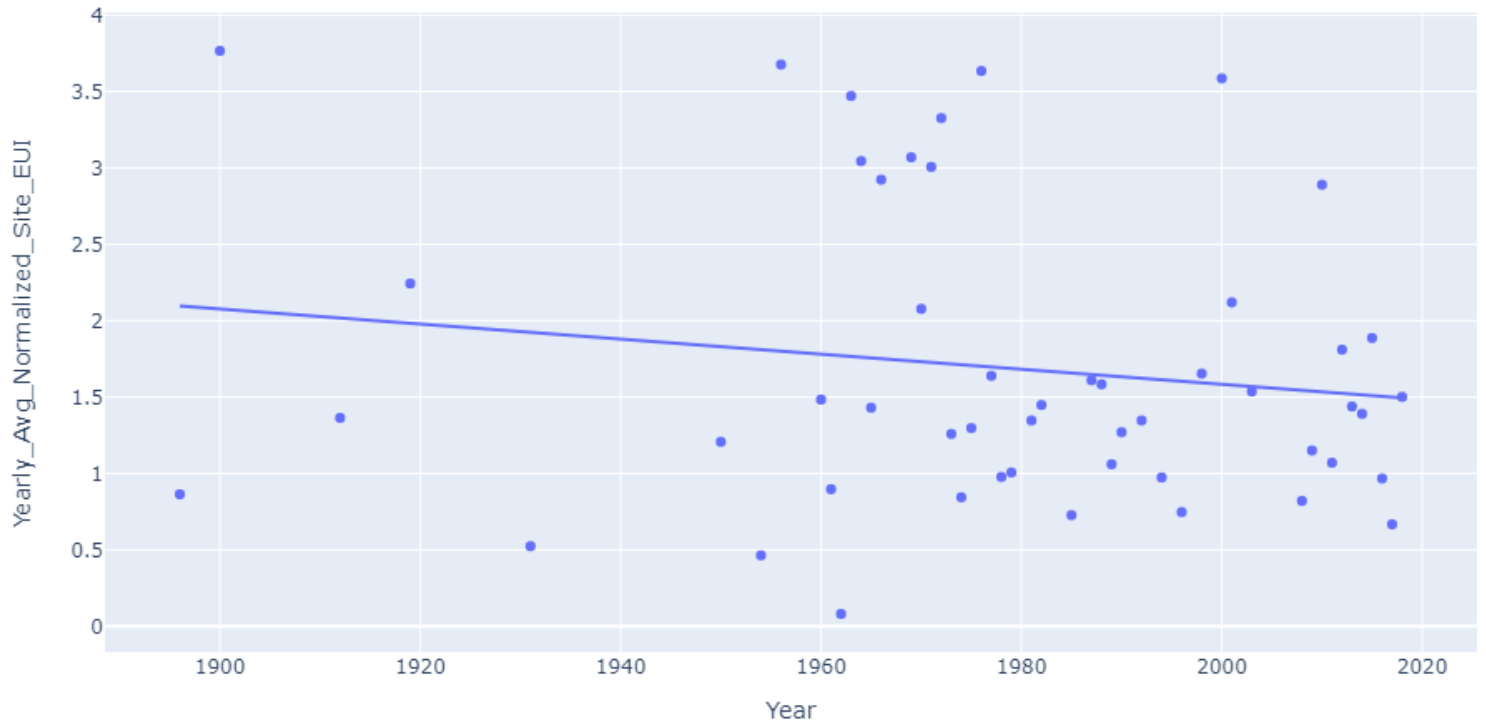
```
statement = '''select `Year Built` as Year, avg(`Weather Normalized Site EUI (GJ/m²)`) as Yearly_Avg_Normalized_Site_EUI
from ebm
group by `Year Built`;'''

query1_table = pd.read_sql_query(statement, engine)
display(query1_table.head())
```

	Year	Yearly_Avg_Normalized_Site_EUI
0	1896	0.863333
1	1900	3.766667
2	1912	1.363333
3	1919	2.243333
4	1931	0.523333

Site EUI Trends





References

- Corporate energy consumption - City of Calgary https://data.calgary.ca/Environment/Corporate-Energy-Consumption/crbp-innf
- Building Energy Benchmarking - City of Calgary https://data.calgary.ca/Environment/Building-Energy-Benchmarking-City-of-Calgary/8twd-upbv
- University of Calgary data - The data for this project was retrieved through the Office of Sustainability Campus as a Learning Lab initiative.
- Current and Historical Alberta Weather Station Data - Alberta Agriculture, Forestry and Rural Economic Development, Alberta Climate Information Service (ACIS) https://acis.alberta.ca (November 2022)
- 2022 Sustainability Report - University of Calgary https://www.ucalgary.ca/sustainability/strategy/2022-sustainability-report/2022-sustainability-report-climate-change-and
- Degree Days - Energy Lens https://www.energylens.com/articles/degree-days

Thank You!