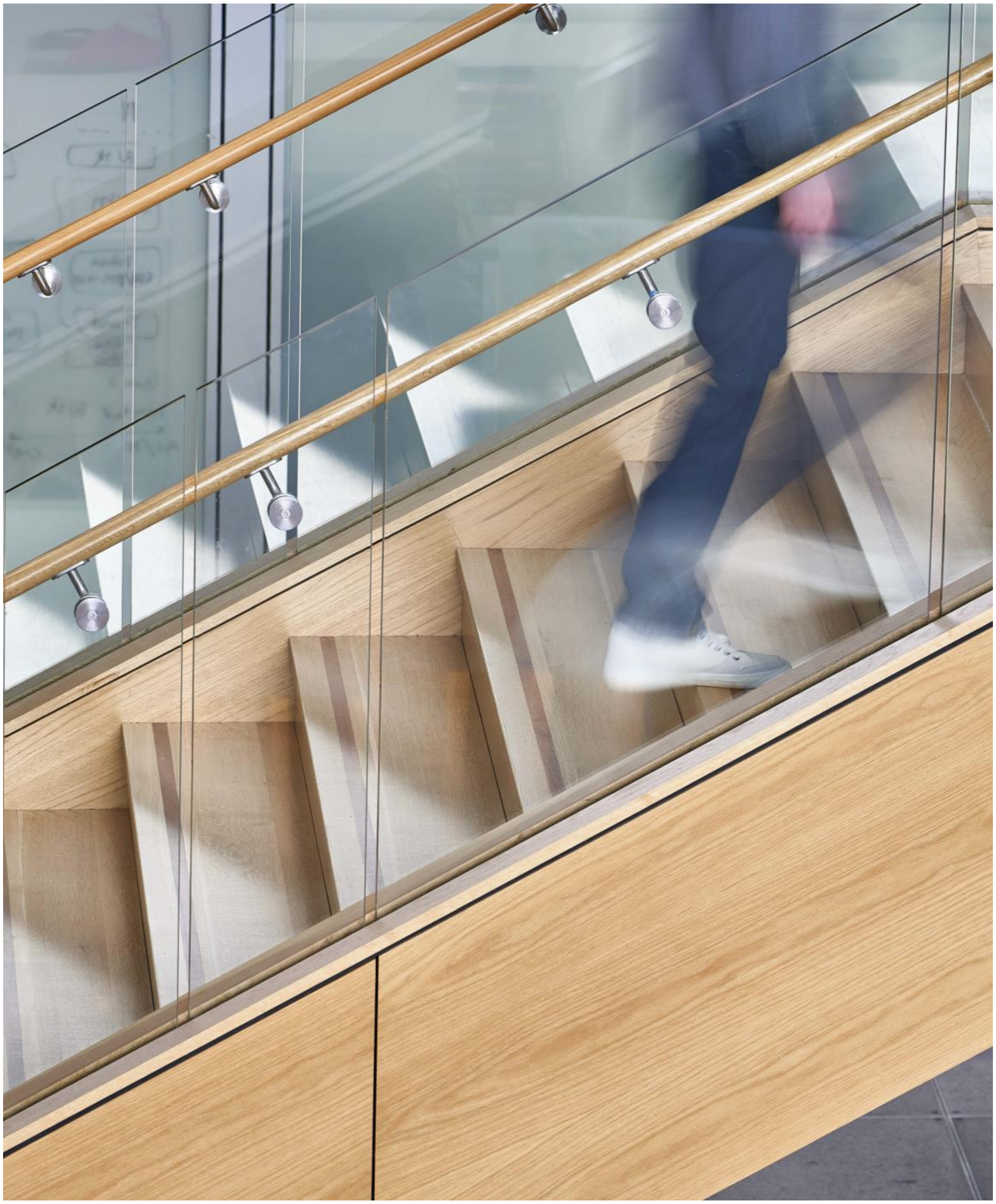
BranchPattern

AIR QUALITY & ENERGY REPORT

Gunnison Watershed School District



ENERGY AND AIR QUALITY ANALYSIS

OVERVIEW

We evaluated the energy usage and air quality of 5 schools in the Gunnison School District. The energy consumption of each school was evaluated by evaluating the utility bills of each school and comparing them against a baseline building in each climate zone. This helps identify energy efficiency savings opportunities. Indoor air quality was evaluated on January 31st, 2020. Instant readings were taken for carbon dioxide, temperature, relative humidity, particulate matter, carbon monoxide, ozone and radon. The results are presented in this report as well as general recommendations to improve the air quality and thermal comfort.

ENERGY ANALYSIS

METHOD

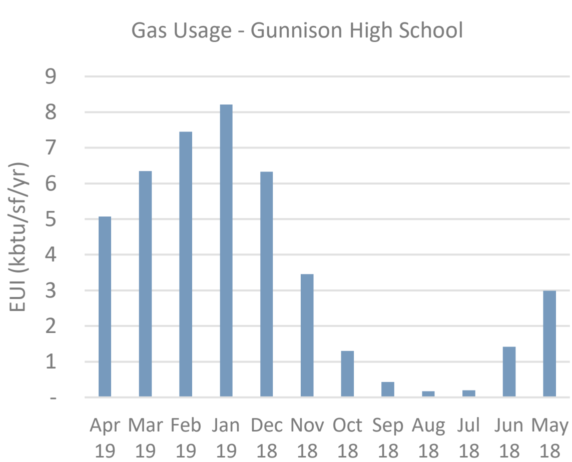
The utility bills at each school have been collected. This data is being compared against a baseline of a school in the same climate zone to identify high or out of character utility consumption. Each school has a recommendation to further investigate.

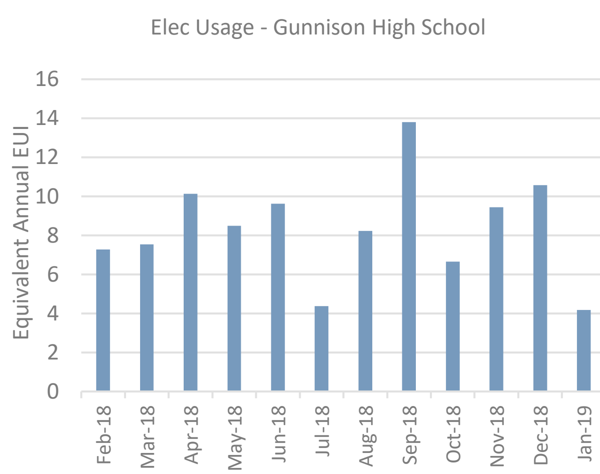
Energy consumption for schools within this climate zone, according to CBECS 2018[1], have an average of 58 kbtu/sf/yr. Of that 58 kbtu/sf/yr, 19 kbtu/sf/yr is electricity usage, and 39 kbtu/sf/yr is fuel usage. This information is considered a baseline for comparison against the existing utility data. The baseline energy summary is similar type of K-12 educational buildings in ASHRAE climate zone 7B with a similar vinatage. Gunnison and Crested Butte are both in climate zone 7B.

RESULTS

Gunnison High School

The school is an estimated 103,383 square foot of building area. The gas consumption at the school is totaling 43.4 EUI (compared to 39 EUI of the baseline school) and 11.4 EUI for electricity usage (compared to 19 EUI of the baseline school).

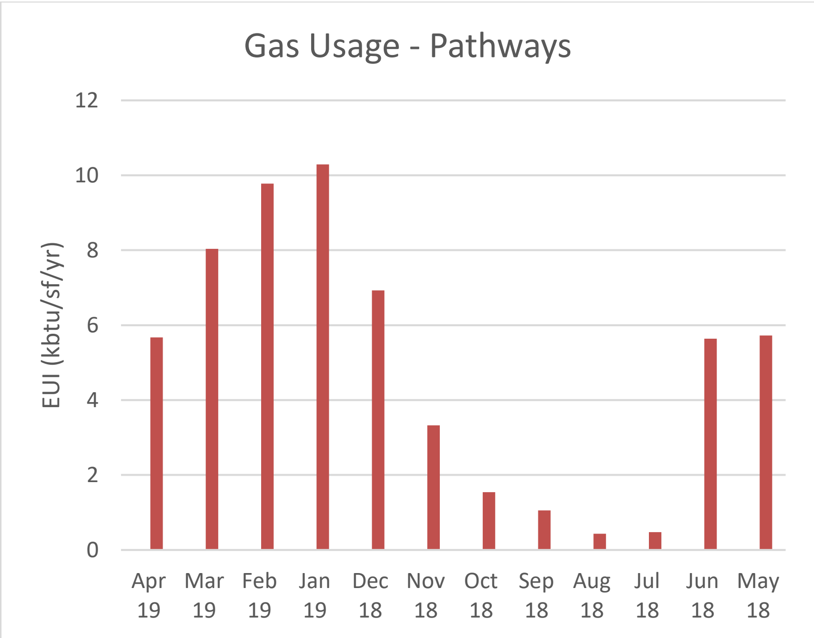




[1] Source: Commercial Buildings Energy Consumption Survey (CBECS) Data base, Department of Energy. https://www.eia.gov/consumption/commercial/

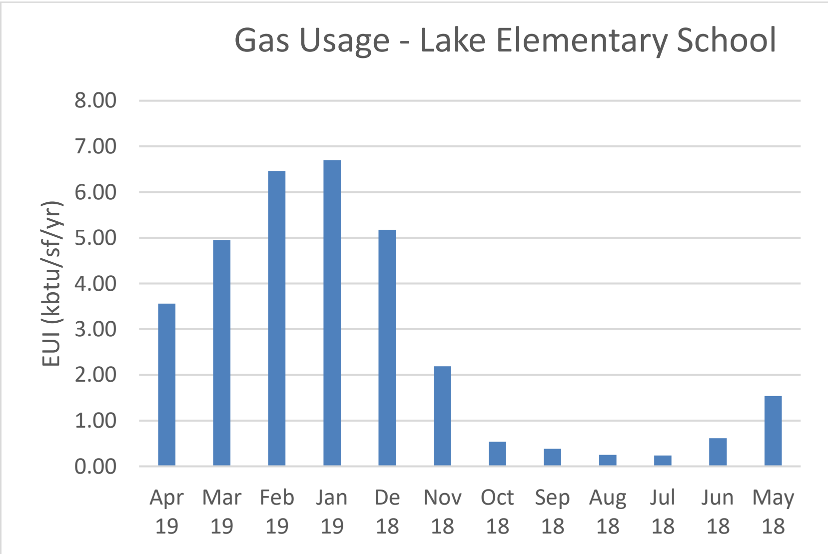
Pathways School

The school is an estimated 5,500 square foot of building area. The gas consumption at the school is totaling 58.9 EUI (compared to 39 EUI of the baseline school).



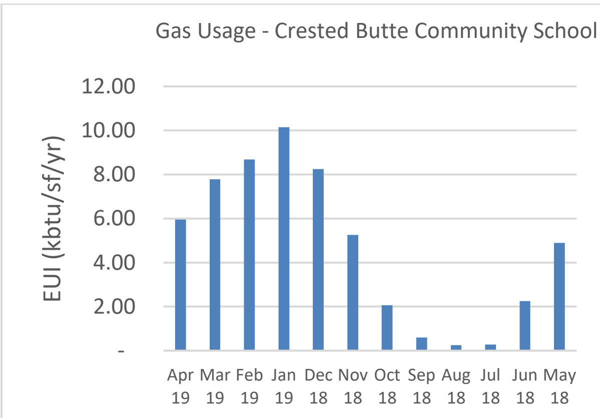
Lake School

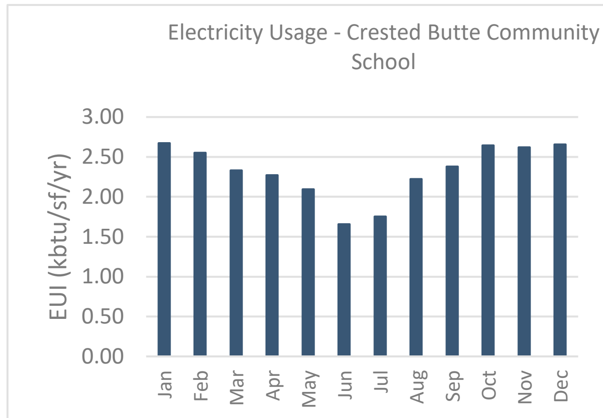
The school is an estimated 25,648 square foot of building area. The gas consumption at the school is totaling 32.6 EUI (compared to 39 EUI of the baseline school).



Crested Butte Community School

The school is an estimated 107,811 square foot of building area. The gas consumption at the school is totaling 56.4 EUI (compared to 39 EUI of the baseline school).

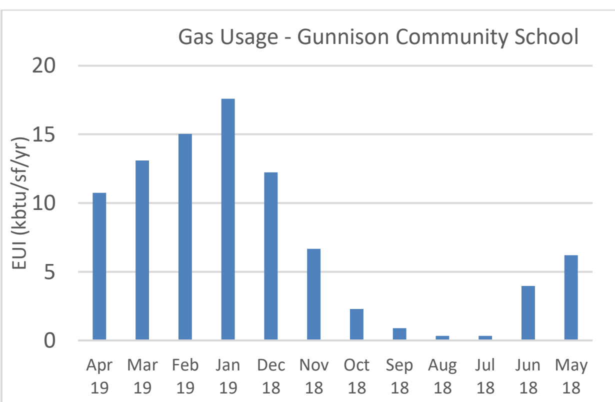


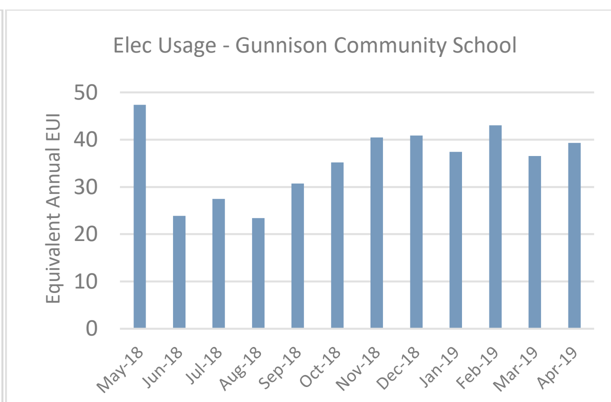


A school of this size and grade types could be expected to be in the 50 EUI range. The total EUI at Crested Butte Community School is 84 kbtu/sf/yr.

Gunnison Community School

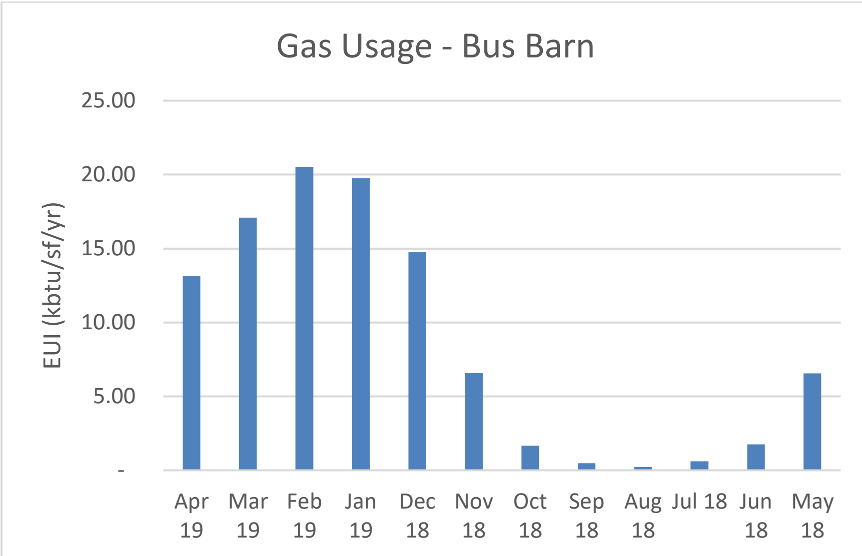
The school is an estimated 85,250 square foot of building area. The gas consumption at the school is totaling 89.4 EUI (compared to 39 EUI of the baseline school) while annual electricity EUI is 38.1(compared to 19 EUI of the baseline school).





Bus Barn

The bus facility is an estimated 11,640 square foot of building area. The gas consumption at the building is totaling 103.2 EUI (compared to 11 EUI of the baseline school).



Assumptions:

- It is believed that gas consumption information that was provided was mislabeled between the bus barn and Gunnison HS. The data was switched and the numbers seemed to better align with anticipated values.
- The gas consumption for all schools, with exception to Lake Elementary School are consuming gas energy at greater rates than expected. It is anticipated that there are a number of energy efficiency upgrades that can be implemented throughout the district on the heating side to reduce gas consumption and improve on utility costs associated with gas consumption.
- Electricity usage for Pathways School, Lake School, and the Bus Barn were not provided.

INDOOR AIR QUALITY ANALYSIS

METHOD

Measurements included particulate matter, inorganic gasses, and thermal comfort. These measurements are taken at a point-in-time and reflect a snapshot of air quality as it existed during the site visit. Measurements occurred during occupancy and in full operational mode.

Thermal Comfort and CO2
Temperature, relative humidity and carbon dioxide were estimated with field meters using electrochemical sensors. These parameters often make up the thermal environment and can be indicators of poor system design or operation. CO2 is often associated with outdoor air requirements and the ventilation system.

Particulate Matter
We used a direct-read nephelometer to estimate mass density of thoracic particulate (particulate matter of aerodynamic diameter < 10 microns) and fine particulate (< 2.5 microns). The field equipment uses an algorithm that involves assumptions about the density of the particulate.

Inorganic Gasses
Carbon monoxide (CO) and ozone (O3) are estimated with field meters using electrochemical sensors. Ozone is associated with combustion and high temperatures such as laser printers. Carbon monoxide is a product of combustion, such as automobiles and natural gas appliances.

Direct reading instruments used in the field:

SAMPLING

We used a sampling approach to estimate indoor air quality in each. We also tested spaces on multiple floors of each building. Due to the large volume of rooms in each school, two-three rooms were randomly selected to sample. The points selected are indicated of each room tested but may not be indicative of the overall air quality in the school. Additional, more comprehensive testing would be required to evaluate each and every room.

PHYSICAL MEASUREMENTS

Table 1 summarizes data collected from a sample of spaces at the five school locations. The data collected and reported here is PM2.5, PM10, CO, O3, and Radon. The spaces performed well for these parameters. They all were under the required thresholds outlined by the EPA/WHO in the LEED rating system and WELL Building Standard. No significant levels of concerns were identified.

Table 1:

Room #	Room name	Time	PM2.5 (ug/m3)	PM10 (ug/m3)	CO (ppm)	O3 (ppm)	Radon
Gunnison HS							
Conference room		9:10 am	5.5	10.5	0	0	ND
Pathways							
Open area		10:39 am	3.8	12.8	0	0.00036	ND
Community School							
D224	5th grade	11:22 am	2.9	7.9	0	0.005	ND
Lake School							
Break room		12:39 pm	3.6	13.6	0.06	0	ND
Crested Butte School							
Library		2:57 pm	6.2	18.7	0.66	0.00045	ND

*Level of concern

ND = Not Detected

Table 2 summarizes data collected from a sample of spaces at the five school locations. The data collected and reported here is the average values of CO2, temperature and relative humidity. The data collected was averaged over the time of each test and the results are indicated below.

Table 2:

Room #	Room name	Time	CO2 Avg (ppm)	TEMP Avg (F)	% RH Avg
Gunnison HS					
A113	English	9:17 am	1064	73	8
Pathways					
	Computer lab	10:30 am	1013	71	9
Community School					
D224	5th grade	11:22 am	1017	70	9
Lake School					
Conference room		10:39 am	1145	69	14
Crested Butte School					
1st floor	Classroom	2:57 am	1202	68	14

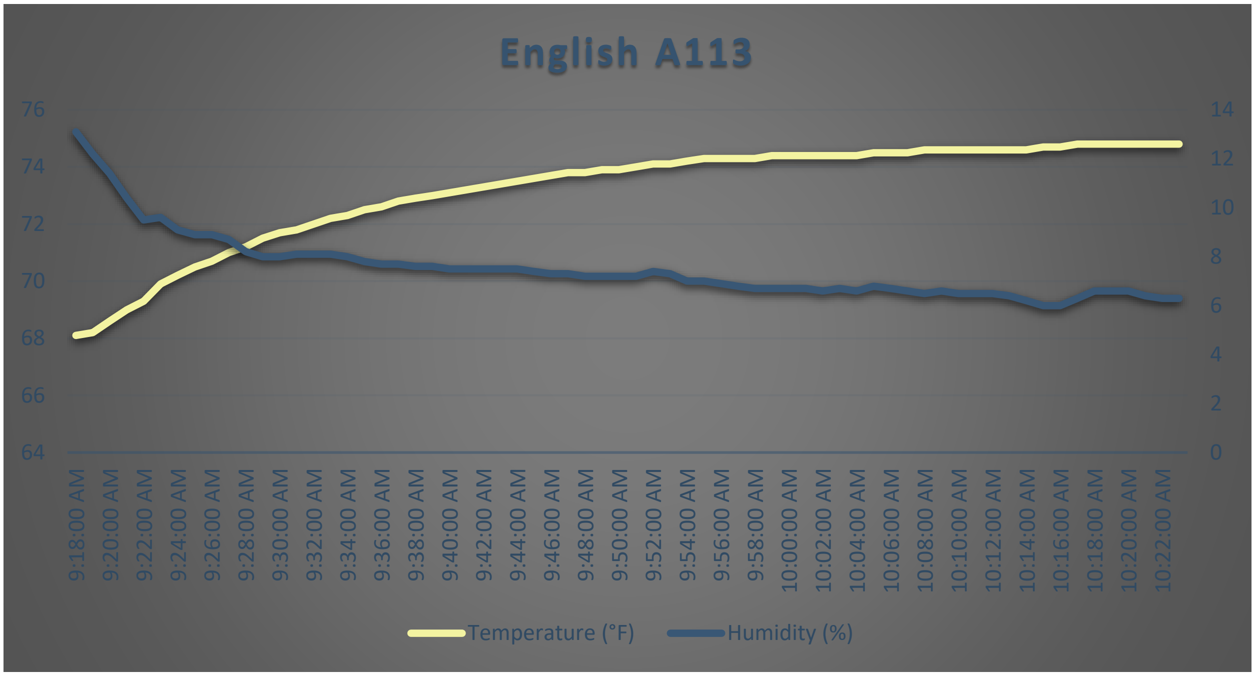
*Level of concern

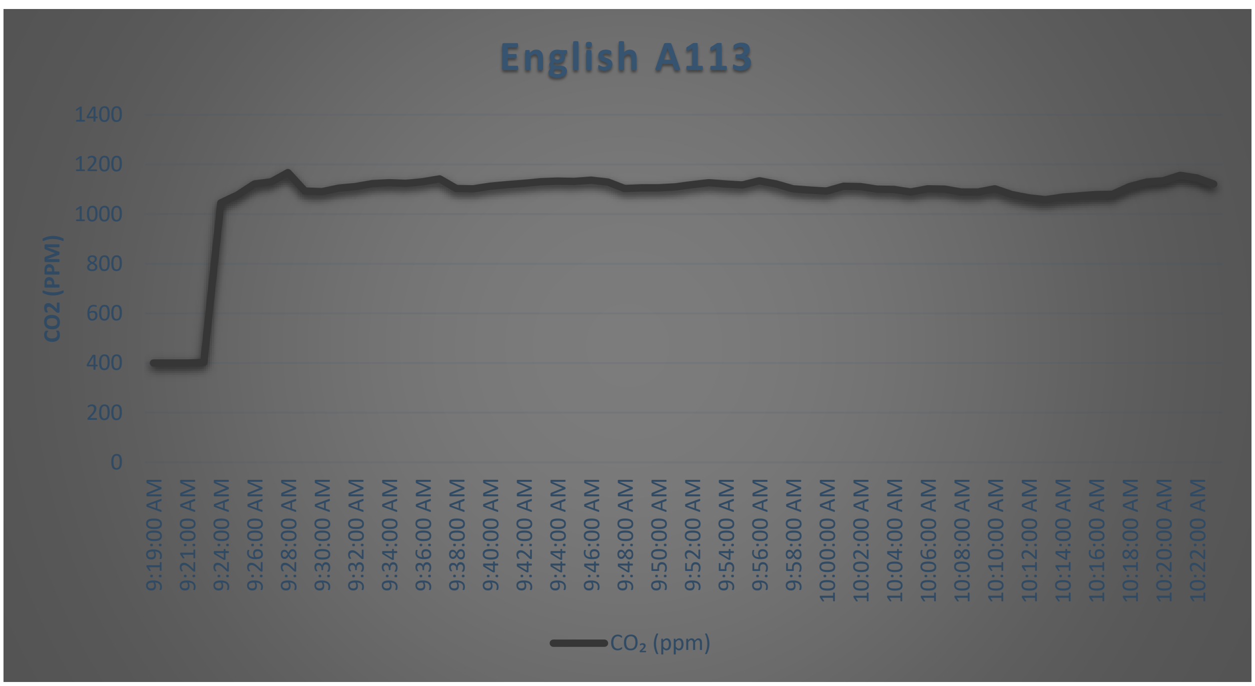
The results are mixed. In general, CO2 was well over 1000 ppm in all the rooms tested. While these levels are not uncommon for occupied areas, levels upward of 1100 ppm and greater are not ideal in school/work environments. This could possibly signal issues with outdoor air distribution and could necessitate increasing the outdoor air levels building-wide and/or rebalancing specific rooms.

When examining the temp and RH results, we are mainly looking to see if the room would be considered thermally comfortable for occupants (68-72 degrees). While thermal comfort is very subjective, with some people feeling colder/warmer than others given the same space temperature, it is worth noting values outside this range can lead to thermal comfort issues and complaints. The low relative humidity is likely due to the climate during testing (winter season). While these readings give us some indication of the thermal comfort in the space, a better indication would be to survey and ask occupants about their levels of comfort. This can be done easily with a thermal comfort survey and the results can help inform decisions related to set-points and HVAC schedules.

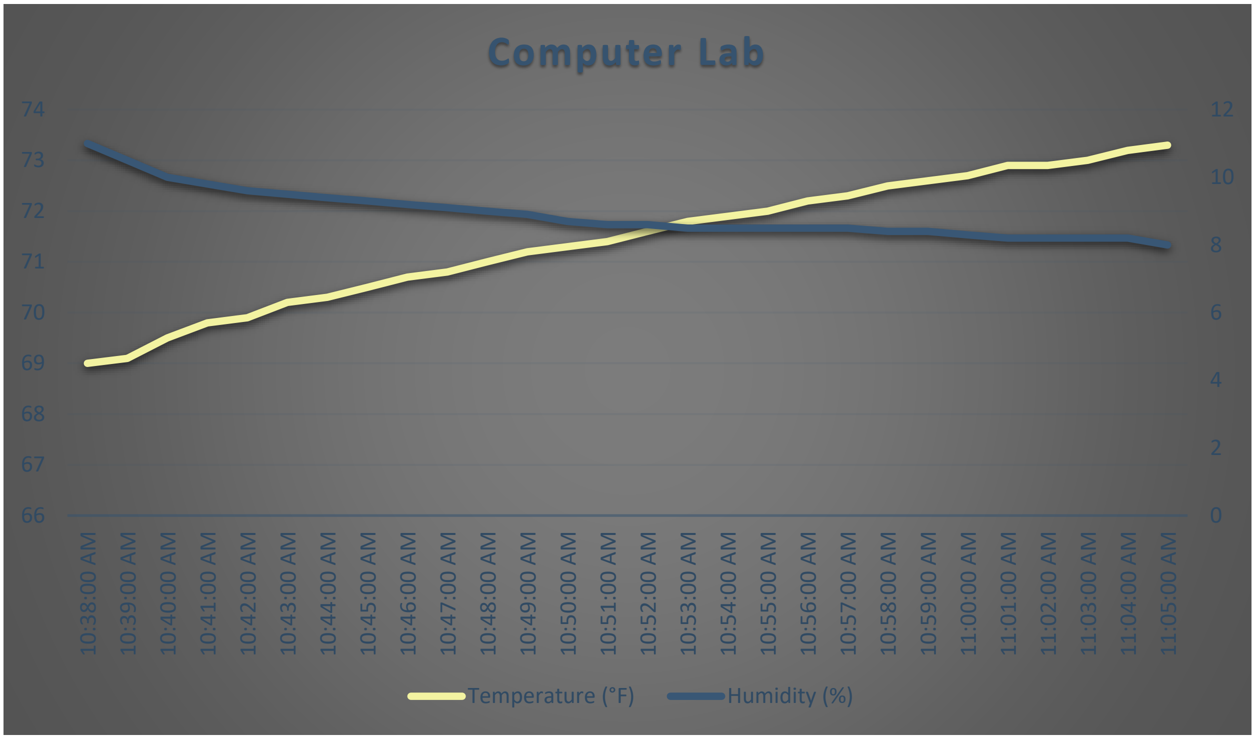
The following graphs show the relationship between time and CO2, temp and RH in each room sampled. Sampled rooms were, for the most, unoccupied at the start of the test, then occupied for the largest percentage of the test, then unoccupied.

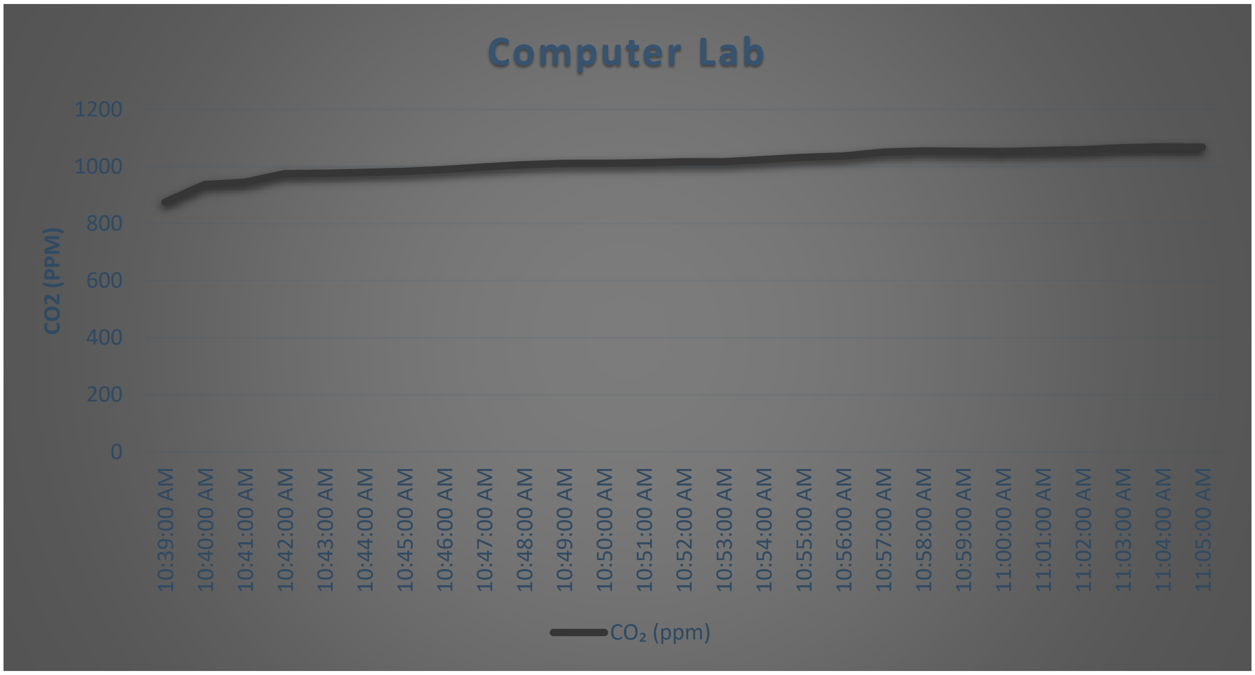
Gunnison HS


English A113
76
74
72
70
68
66
64
14
12
10
8
6
4
2
0
9:18:00 AM
9:20:00 AM
9:22:00 AM
9:24:00 AM
9:26:00 AM
9:28:00 AM
9:30:00 AM
9:32:00 AM
9:34:00 AM
9:36:00 AM
9:38:00 AM
9:40:00 AM
9:42:00 AM
9:44:00 AM
9:46:00 AM
9:48:00 AM
9:50:00 AM
9:52:00 AM
9:54:00 AM
9:56:00 AM
9:58:00 AM
10:00:00 AM
10:02:00 AM
10:04:00 AM
10:06:00 AM
10:08:00 AM
10:10:00 AM
10:12:00 AM
10:14:00 AM
10:16:00 AM
10:18:00 AM
10:20:00 AM
10:22:00 AM
Temperature (°F)
Humidity (%)

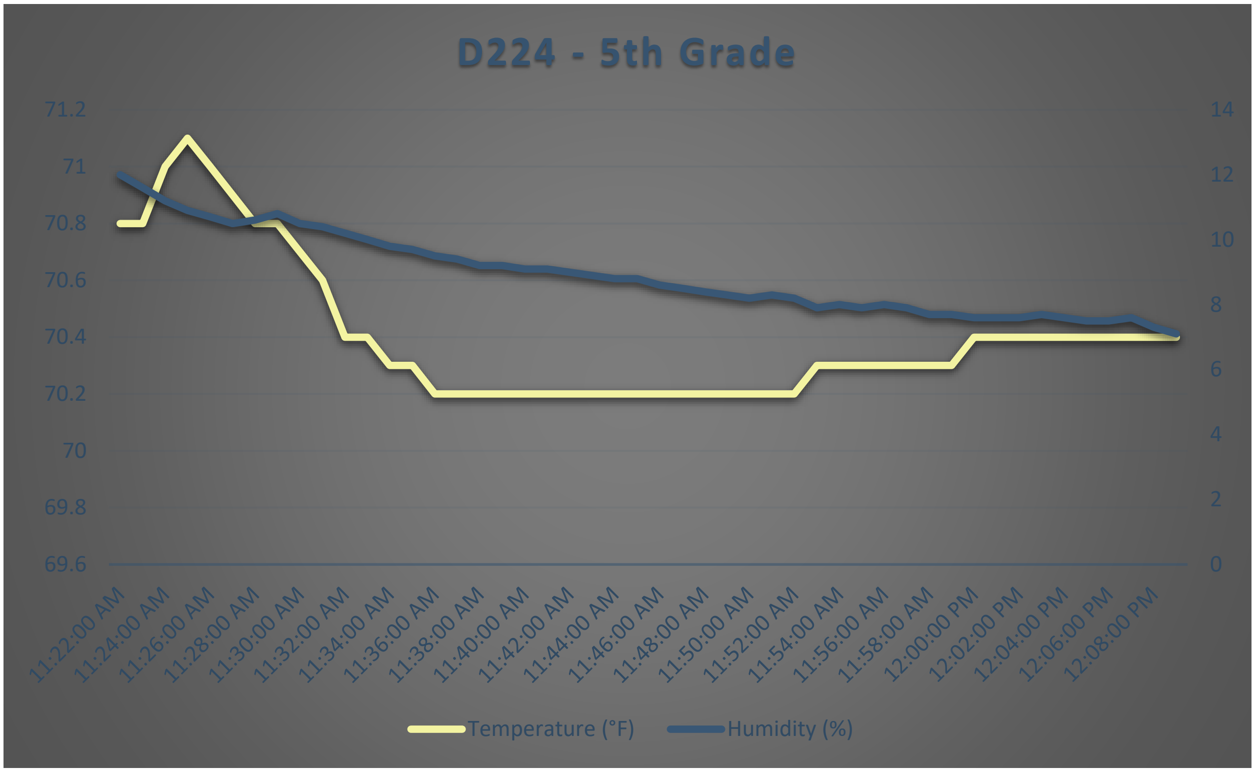

English A113
CO2 (PPM)
1400
1200
1000
800
600
400
200
0
9:19:00 AM
9:21:00 AM
9:24:00 AM
9:26:00 AM
9:28:00 AM
9:30:00 AM
9:32:00 AM
9:34:00 AM
9:36:00 AM
9:38:00 AM
9:40:00 AM
9:42:00 AM
9:44:00 AM
9:46:00 AM
9:48:00 AM
9:50:00 AM
9:52:00 AM
9:54:00 AM
9:56:00 AM
9:58:00 AM
10:00:00 AM
10:02:00 AM
10:04:00 AM
10:06:00 AM
10:08:00 AM
10:10:00 AM
10:12:00 AM
10:14:00 AM
10:16:00 AM
10:18:00 AM
10:20:00 AM
10:22:00 AM
CO_2 (ppm)

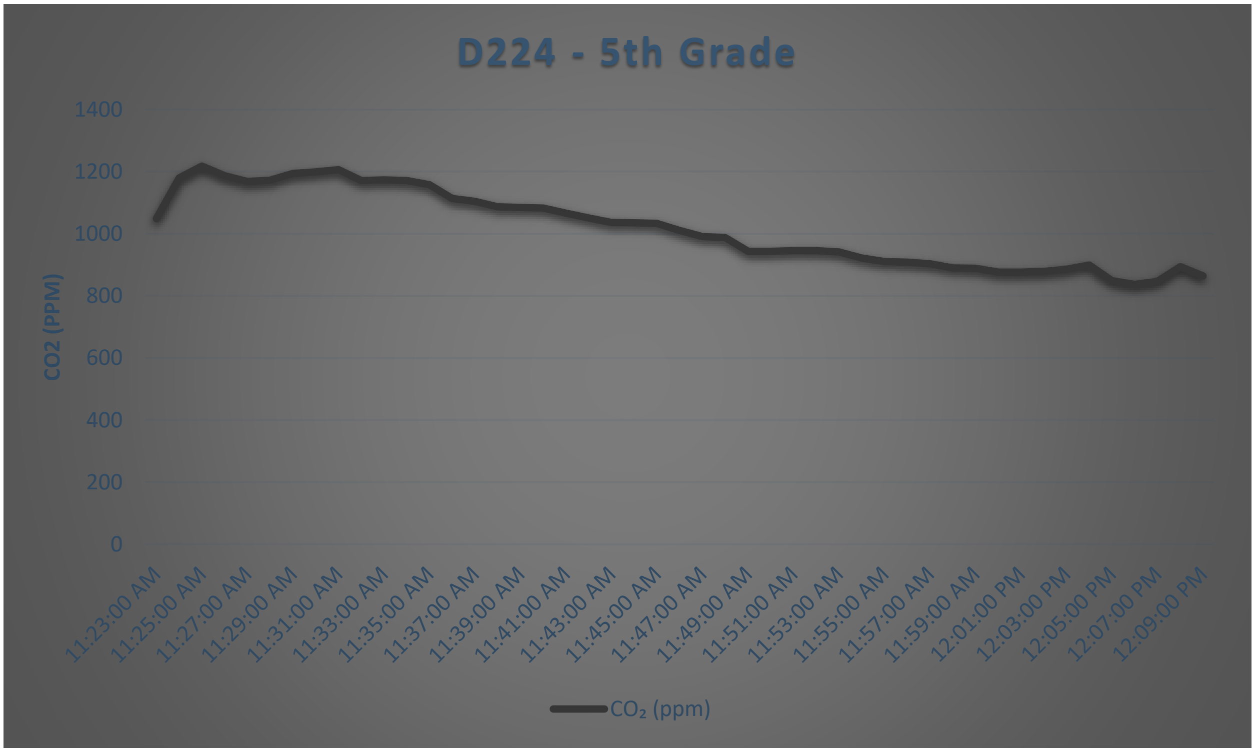
Pathways


Computer Lab
74
73
72
71
70
69
68
67
66
12
10
8
6
4
2
0
10:38:00 AM
10:39:00 AM
10:40:00 AM
10:41:00 AM
10:42:00 AM
10:43:00 AM
10:44:00 AM
10:45:00 AM
10:46:00 AM
10:47:00 AM
10:48:00 AM
10:49:00 AM
10:50:00 AM
10:51:00 AM
10:52:00 AM
10:53:00 AM
10:54:00 AM
10:55:00 AM
10:56:00 AM
10:57:00 AM
10:58:00 AM
10:59:00 AM
11:00:00 AM
11:01:00 AM
11:02:00 AM
11:03:00 AM
11:04:00 AM
11:05:00 AM
Temperature (°F)
Humidity (%)

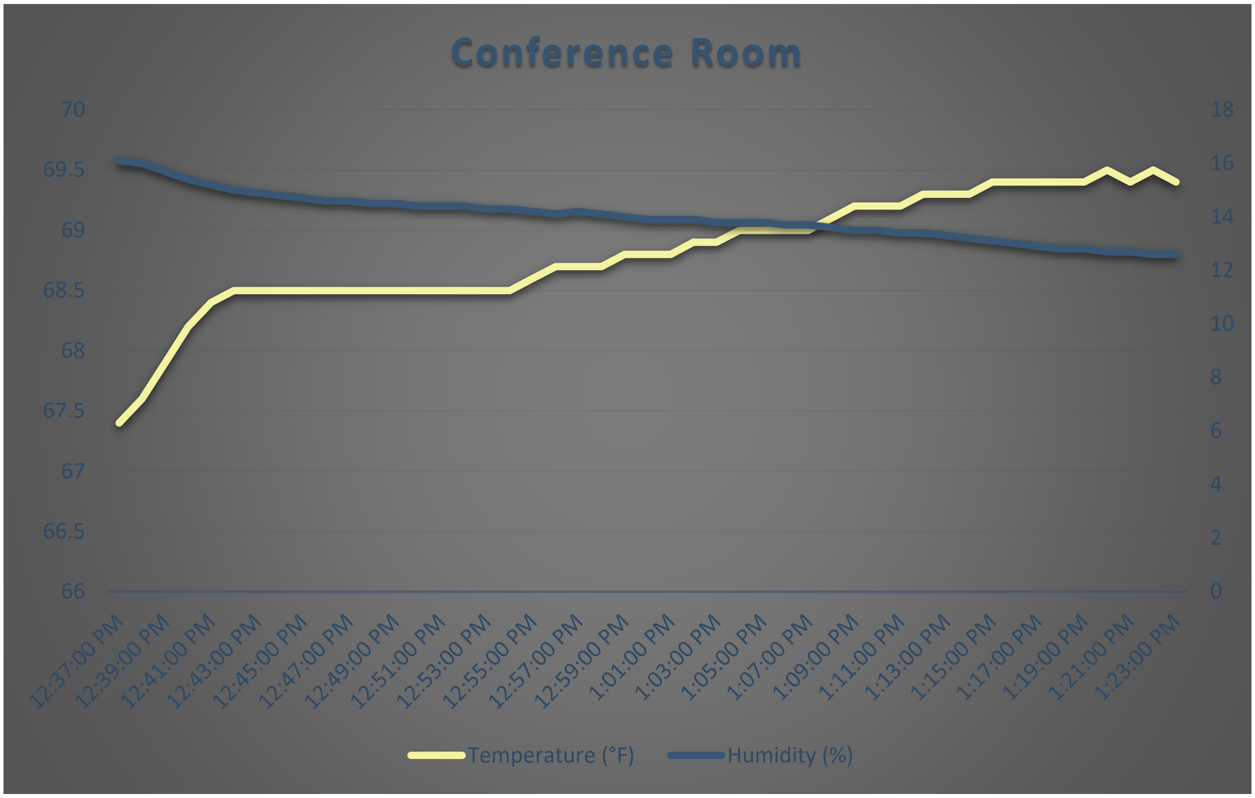

Computer Lab
CO2 (PPM)
1200
1000
800
600
400
200
0
10:39:00 AM
10:40:00 AM
10:41:00 AM
10:42:00 AM
10:43:00 AM
10:44:00 AM
10:45:00 AM
10:46:00 AM
10:47:00 AM
10:48:00 AM
10:49:00 AM
10:50:00 AM
10:51:00 AM
10:52:00 AM
10:53:00 AM
10:54:00 AM
10:55:00 AM
10:56:00 AM
10:57:00 AM
10:58:00 AM
10:59:00 AM
11:00:00 AM
11:01:00 AM
11:02:00 AM
11:03:00 AM
11:04:00 AM
11:05:00 AM
CO_2 (ppm)

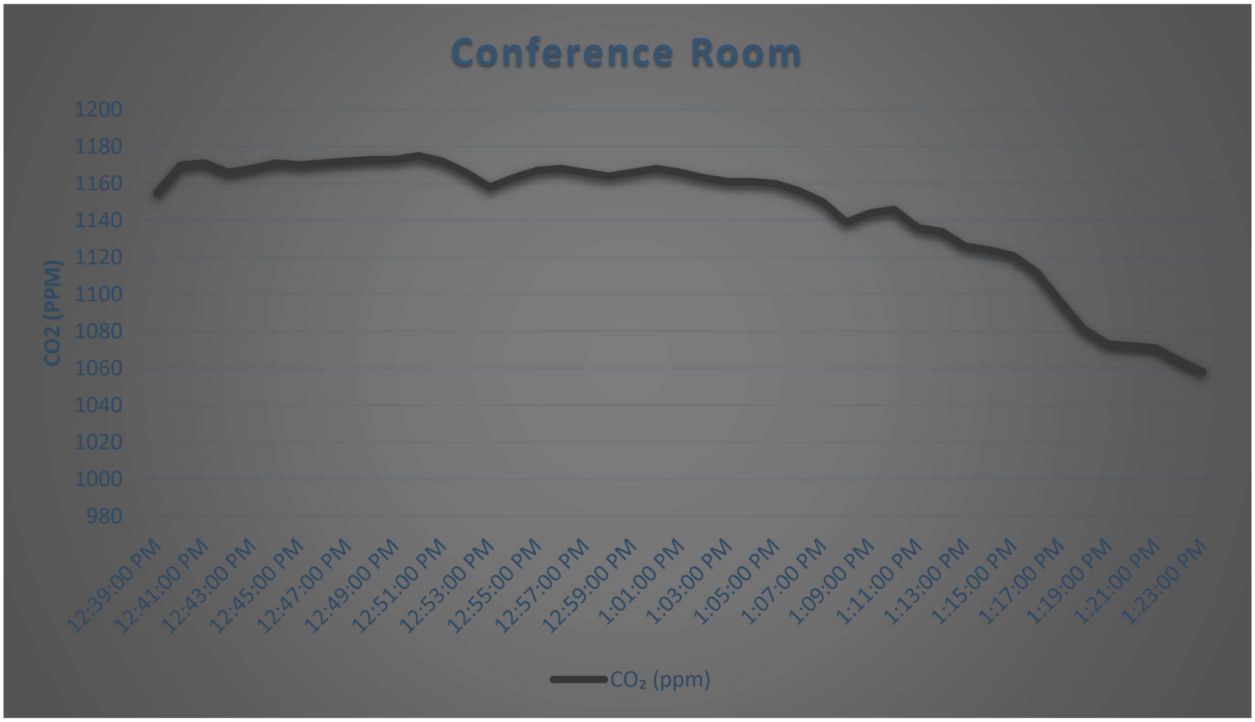
Community School



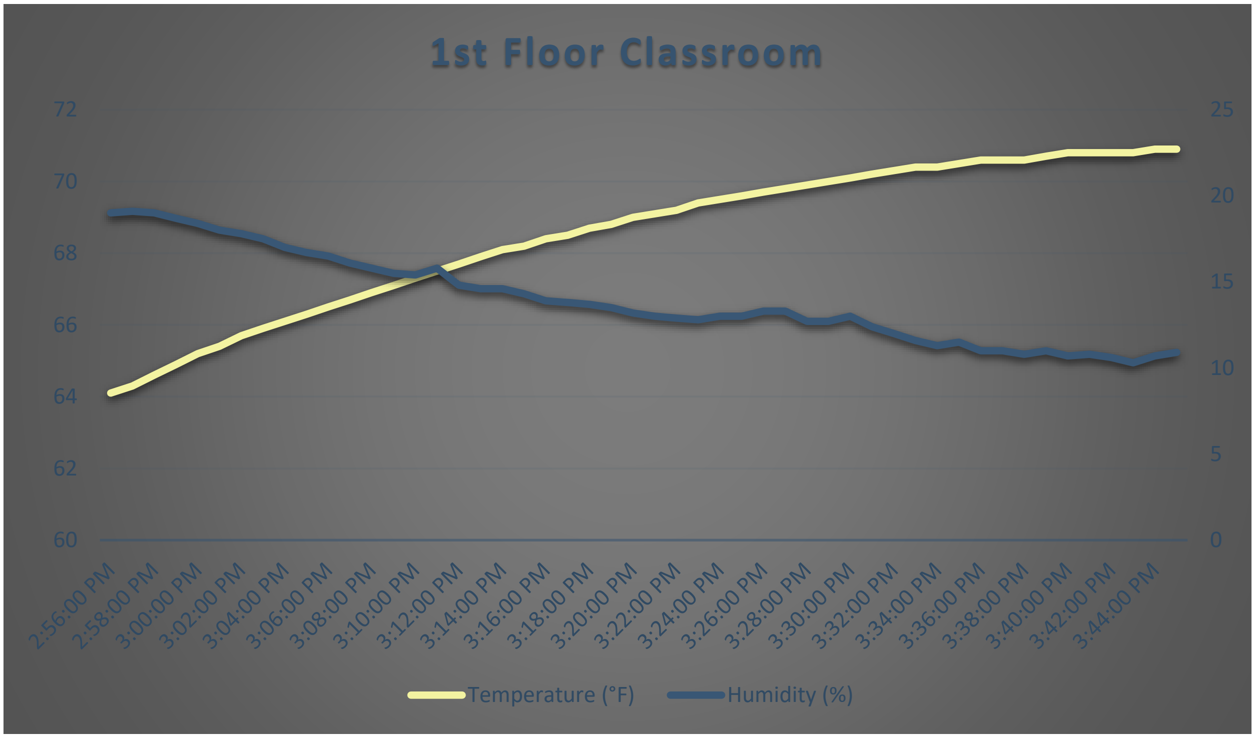


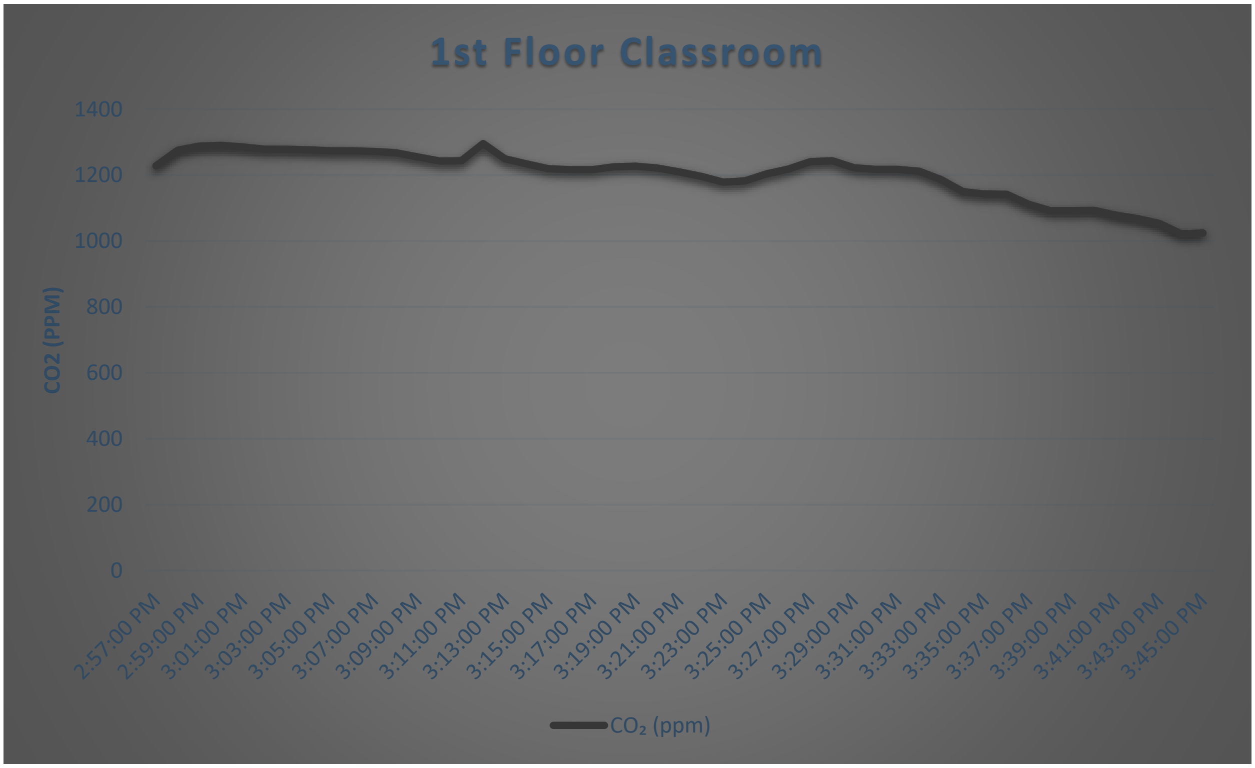
Lake School


Conference Room
70
69.5
69
68.5
68
67.5
67
66.5
66
18
16
14
12
10
8
6
4
2
0
12:37:00 PM
12:39:00 PM
12:41:00 PM
12:43:00 PM
12:45:00 PM
12:47:00 PM
12:49:00 PM
12:51:00 PM
12:53:00 PM
12:55:00 PM
12:57:00 PM
12:59:00 PM
1:01:00 PM
1:03:00 PM
1:05:00 PM
1:07:00 PM
1:09:00 PM
1:11:00 PM
1:13:00 PM
1:15:00 PM
1:17:00 PM
1:19:00 PM
1:21:00 PM
1:23:00 PM
Temperature (°F)
Humidity (%)


Conference Room
CO2 (PPM)
1200
1180
1160
1140
1120
1100
1080
1060
1040
1020
1000
980
12:39:00 PM
12:41:00 PM
12:43:00 PM
12:45:00 PM
12:47:00 PM
12:49:00 PM
12:51:00 PM
12:53:00 PM
12:55:00 PM
12:57:00 PM
12:59:00 PM
1:01:00 PM
1:03:00 PM
1:05:00 PM
1:07:00 PM
1:09:00 PM
1:11:00 PM
1:13:00 PM
1:15:00 PM
1:17:00 PM
1:19:00 PM
1:21:00 PM
1:23:00 PM
CO_2 (ppm)

Crested Butte





BENEFITS OF IEQ

Recommended IEQ targets are based on research that connects the physical environment to health and productivity. Evidence in some areas is very strong and based on high-quality experimental designs. The connection between background noise and cognitive performance is one such example. Other findings are based on quasi-experiments with naturally-occurring variation in large samples. For example, autism is more prevalent in large cities, presumably due to increased prenatal exposure to air pollution. This summary is an overview of this evidence that provides a rationale for investment in IEQ.

FRESH AIR

1. Air quality impacts humans through the tracheobronchial and pulmonary systems, which interact with airborne particulates and gases, providing a pathway to the bloodstream. Achieving indoor air quality requires that outdoor air quality, or ambient air first be appraised. Then a strategy for cleaning air enables the removal of contaminants generated indoors. Cleaning air is typically accomplished through dilution and filtration.
2. Air quality is not readily perceived by occupants unless contaminants present odors. As such, it can be challenging to identify issues, such as inadequate ventilation. A proactive approach to design and monitoring of air quality allows occupants to achieve the highest level of cognitive performance.
3. Students with additional ventilation air are more alert and more productive. An optimal humidity range also improves occupant comfort. Evidence shows that ventilation levels required for compliance with ASHRAE 62.1 are a base level for complaints regarding bio effluent. Often this is approximately 20 cfm per occupant of outdoor air (998 ppm CO_2). When occupants receive twice this amount of outdoor air (689 ppm CO_2), their cognitive performance increases as much as 40 percent. Conditioning the air to a comfortable humidity level also reduces eye and throat irritation of occupants. Optimal humidity levels (not too dry or wet) also mitigates the risk of mold spore growth.

THERMAL COMFORT

1. Occupant thermal comfort depends on air temperature, relative humidity, air velocity and the temperature of surrounding surfaces. Personal factors that affect comfort include clothing, activity level, age, sex, and individual differences. Designers predict occupant satisfaction using models of comfort. Standards governing design for thermal comfort use a common benchmark of 20% for the maximum number of occupants that should be dissatisfied with thermal conditions. The estimate is based on empirical findings from occupant surveys using a semantic differential scale of “hot” to “cold.”
2. Adaptive comfort models have emerged in the last 20 years in response to the ways occupants adjust to and control thermal variables. For these reasons, adaptive models are employed commonly in naturally-ventilated spaces. Adaptive comfort models may also address the failure

of standard heat balance model to predict satisfaction in the field. Individuals who differ from the 'standard' occupant – such as seniors and women – are more likely to be dissatisfied with the temperature than the model predicts.

3. Evidence links thermal comfort to occupant outcomes of productivity, performance, and satisfaction. Improving thermal comfort is associated with productivity gains of up to 10%.

CONCLUSIONS AND RECOMMENDATIONS

The information gathered on site has provided some insights into deficiencies that can be inferred from the information. This leads to some recommendations of how to alter the current buildings to provide better environments for learning.

General comments that apply to all schools

- Replace outdated controls interface to better monitor, control, and identify issues within the buildings HVAC system.
- Replace fluorescent lighting with LED lighting
- Replace boilers with high efficiency boilers
- It is recommended to test the facility during the spring for humidity levels and temperatures to identify any issues in the cooling season.
- CO_2 levels are generally higher than recommended for a great quality learning environment.

Gunnison High School

This school's energy usage is in line with what would be expected from a school in this climate zone. The gas usage is below a comparable baseline school in this climate zone. It appears that the controls interface is outdated and difficult to monitor the HVAC activity throughout the school.

The air quality results indicate normal CO_2 levels that we would anticipate for this system type. However, the high levels do not create the best environment for cognitive function at almost 1100 PPM of CO_2. All other tests resulted in normal levels of CO, O_3, particulates. Temperature though, was high in the classroom surveyed. There were a number of instances throughout the school that showed higher than expected temperatures in classrooms. This indicates a lack of control from the BAS system.

Recommendations:

- While more outside air can create heating capacity issues and increase energy consumptions, more ventilation air has been shown to increase cognitive function in children with lower CO_2 levels. It is recommended to increase outside air so that CO_2 levels are closer to 800 PPM.
- CO_2 levels were not monitored all day in the school, but CO_2 levels did not decrease in the classroom when it changed from occupied to unoccupied. This indicates that the level of CO_2 is anticipated to increase throughout the day in classrooms. This will result in spaces that have very high CO_2 levels towards the end of the day throughout the school. It is recommended to increase ventilation levels when the heating plant will allow.
- Upgrade the BAS system controls and interface to better monitor and control the system remotely.

Pathways School

This school's gas usage was all that was gathered because electricity consumption was not provided. The gas usage was much higher than a typical school in this climate zone. It is expected that this is due to the large glass windows provided on the exterior. While the architecture cannot be altered at this time, it is recommended that more efficient means of heating the building be considered.

The air quality results indicate normal CO_2 levels that we would anticipate for this system type. However, the high levels do not create the best environment for cognitive function at 1000 PPM of CO_2. All other tests resulted in normal levels of CO, O_3, particulates, temperature and humidity.

Recommendations:

- While more outside air can create heating capacity issues and increase energy consumptions, more ventilation air has been shown to increase cognitive function in children with lower CO_2 levels. It is recommended to increase outside air so that CO_2 levels are closer to 800 PPM.
- CO_2 levels were not monitored all day in the school, but CO_2 levels did not decrease in the classroom when it changed from occupied to unoccupied. This indicates that the level of CO_2 is anticipated to increase throughout the day in classrooms. This will result in spaces that have very high CO_2 levels towards the end of the day throughout the school. It is recommended to increase ventilation levels when the heating plant will allow.
- Consider implementing an energy recovery system to preheat incoming air and improve gas usage in the building.
- Provide electricity usage in the facility.

Lake School

This school's energy usage is in line with what would be expected from a school in this climate zone. The gas usage is below a comparable baseline school in this climate zone. The electricity consumption for this school was not provided.

The air quality results indicate normal CO_2 levels that we would anticipate for this system type. However, the high levels do not create the best environment for cognitive function at almost 1100 PPM of CO_2. All other tests resulted in normal levels of CO, O_3, particulates. Temperature though, was high in the classroom surveyed. There were a number of instances throughout the school that showed higher than expected temperatures in classrooms. This indicates a lack of control from the BAS system.

Recommendations:

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- CO_2 levels were not monitored all day in the school, but CO_2 levels did not decrease in the classroom when it changed from occupied to unoccupied. This indicates that the level of CO_2 is anticipated to increase throughout the day in classrooms. This will result in spaces that have very high CO_2 levels towards the end of the day throughout the school. It is recommended to increase ventilation levels when the heating plant will allow.
- Although electricity usage was not provided, it is recommended to consider a lighting retrofit to replace lights with LED lighting.
- Provide electricity usage in the facility.

Gunnison Community School

This school's energy usage is well above what would be expected from a school in this climate zone. The gas usage is much higher to a baseline school in this climate zone. This appears to be caused by a poor envelope that creates much thermal bridging between indoor and outdoor environments. High gas usage may be the result of inefficient operation of the building's heating plant. Electricity usage at the school is higher than expected as well. This could also be due to a poor envelope creating a greater need for fans to operate during warmer days. Furthermore, electric lighting load could be contributing to high electricity usage because of lights that are inefficient.

The air quality results indicate normal CO_2 levels that we would anticipate for this system type. However, the high levels do not create the best environment for cognitive function at 1000 PPM of CO_2. All other tests resulted in normal levels of CO, O_3, particulates. Temperature though, was high in the classroom surveyed. There were a number of instances throughout the school that showed higher than expected temperatures in classrooms. This indicates a lack of control from the BAS system.

Recommendations:

- While more outside air can create heating capacity issues and increase energy consumptions, more ventilation air has been shown to increase cognitive function in children with lower CO_2 levels. It is recommended to increase outside air so that CO_2 levels are closer to 800 PPM.
- CO_2 levels were not monitored all day in the school, but CO_2 levels did not decrease in the classroom when it changed from occupied to unoccupied. This indicates that the level of CO_2 is anticipated to increase throughout the day in classrooms. This will result in spaces that have very high CO_2 levels towards the end of the day throughout the school. It is recommended to increase ventilation levels when the heating plant will allow.
- Upgrade the BAS system controls and interface to better monitor and control the system remotely.
- Perform an analysis to understand moisture content in the walls at the school. There appears to be thermal bridging occurring between indoor and outdoor environment and possible moisture intrusion between indoor and outdoor.
- Replace lighting fixtures that are non LED type.

Bus Barn

The bus barn's energy usage is well above what would be expected from a school in this climate zone. The gas usage is much higher to a baseline facility in this climate zone. This appears to be caused by a poor envelope that creates much thermal bridging between indoor and outdoor environments. High gas usage may be the result of inefficient operation of the building's heating plant, or there not being any setbacks on the building.

Air quality was not monitored at the facility because of a lack of time on testing day.

Recommendations:

- Upgrade the BAS system controls and interface to better monitor and control the system remotely.
- Identify where gas usage is being consumed most. Then identify a solution to reducing gas usage at the facility.
- Provide electricity usage in the facility.

Crested Butte Community School

This school's energy usage is above what would be expected from a school in this climate zone. The gas usage is higher compared to a baseline school in this climate zone. The cause of the high gas usage is not readily apparent, and further investigation is recommended. It is assumed that high gas usage is due to the lack of energy recovery. The school's electricity usage is in line with electricity usage of a similar school of this type. It is anticipated that, with careful study, the school can cut 20-30% energy cost via retrofitting the school with energy efficiency measures including, but not limited to, energy recovery, more efficient pumping and fan strategies, and lower infiltration.

The air quality results indicate normal CO2 levels that we would anticipate for this system type. However, the high levels do not create the best environment for cognitive function at 1200 PPM of CO2. All other tests resulted in normal levels of CO, O3, particulates. Temperature though, was high in the classroom surveyed. The temperatures in the spaces monitored were at the low end of a comfortable range. The day testing was performed the outdoor air temperature was below freezing, but not below 0°F.

Recommendations:

- While more outside air can create heating capacity issues and increase energy consumptions, more ventilation air has been shown to increase cognitive function in children with lower CO2 levels. It is recommended to increase outside air so that CO2 levels are closer to 800 PPM.
- CO2 levels were not monitored all day in the school, but CO2 levels did not decrease in the classroom when it changed from occupied to unoccupied. This indicates that the level of CO2 is anticipated to increase throughout the day in classrooms. This resulted in high levels of CO2 at the end of the day. It is recommended to increase ventilation levels when the heating plant will allow.

- Provide electricity usage in the facility.
- Identify the cause for cold temperatures in the classrooms. If by choice, this is acceptable. However, if it is due to the heating system being undersized, this should be further investigated.
- Identify issues with high gas consumption. The possible cause of high gas consumption is that the heating system is inefficient or operating inefficiently.