PSU Green Building Internship Final Report, 2019:
Karl Miller Center Post-Occupancy Study

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Karl Miller Center Post-Occupancy Study

PSU Capital Projects and Construction - Green Building Internship

Everett Stilley and Junyoung Lee

Summer 2019
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Executive Summary

This study examined the effectiveness of the passive cooling strategies in the Karl Miller Center (KMC) at Portland State University. Due to the warm temperatures reached in Portland during the summer months and the absence of a mechanical cooling system on the Pavilion side of the KMC, classrooms can exceed thermal comfort preferences on a number of occasions. Previous studies have recommended taking certain classrooms “offline” after 12pm in the summer, where they are only available for morning classes. This study aimed to update the classroom prioritization as well as analyze the employed cooling strategies and begin a long term air quality study. A survey was distributed to students taking summer classes in the KMC Pavilion with questions regarding their thermal comfort, air quality perceptions, and knowledge of the in-room window and ceiling fan controls. The responses were analyzed in conjunction with indoor and outdoor temperature data and input from stakeholders around the PSU campus.

We have concluded the building is operating as designed, even if that means comfort levels were exceeded. Based on a weighted average of overheating days, rooms 295 and 495 were deemed the most suitable for holding classes, rarely exceeding 80°F in summer 2019. Students were overall comfortable on average up to an indoor temperature 77°F without the ceiling fans turned on. We also continue to recommend the classrooms most prone to overheating be taken offline after 12pm during the summer term.

The most significant opportunities for improvement are user education and night flush techniques. Most students surveyed either had not used, or did not even know of the in-room wall controls that are essential to maintaining comfort levels in a naturally ventilated environment. The Campus Planning, Facilities and Property Management, and Capital Projects and Construction offices at PSU are taking the next steps to provide increased education to the building’s occupants in the form of posters and a possible how-to video.

Through a variety of field tests, we determined the most successful night flush procedure is to turn on the rooftop exhaust fans while the windows are open to draw in the largest volume of cool air possible during the nighttime hours. However, this may take away from the building’s sustainable design as the energy use of the exhaust fans is not negligible.
Purpose of Study

This study aims to evaluate the passive cooling design of the Karl Miller Center, a mixed-use and mixed-mode ventilated building on the Portland State University campus. The data collected during this study will be compared to the design-intent of the building in order to determine if the passive ventilation is performing as intended. Occupant surveys as well as building automation system (BAS) data will be used to update conclusions of previous studies regarding occupant comfort and knowledge of the building’s features. This information will also inform future planning decisions at Portland State University.

Limitations

- Building Automation System (BAS) data regarding window operation was not consistently accurate to truly reflect the state of the windows at a given date/time.
- Only a select few classrooms in the KMC Pavilion received surveys due to a lack of interest from faculty.
- Particulate pollutant levels in the Portland-Metro area stayed consistently low during the period of this study so as to render any differences in indoor and outdoor concentrations negligible.
- The majority of classrooms in the KMC Pavilion were “offline” after 12pm, meaning they were not used for classroom scheduling, and generally unoccupied. Therefore, temperatures observed in the rooms may not be representative of the temperature during a class period, due to the absence of internal heat gain from occupants.
- Air velocity in the classrooms was not measured due to the difficulty of measurement.
Previous Studies

Study of Lattin in Fall 2017

Prior to summer 2019, the KMC was subject to two post-occupancy studies. The first of which was an undergraduate architecture honors thesis by Kythetica Lattin.¹ Conducted during the Fall of 2017, this study surveyed 23 classes across 8 Pavilion classrooms totaling 743 survey responses. The majority of courses took place in the evening. In addition, the fall term at Portland State does not begin until the last week of September. Therefore, exterior temperatures during the study period were not high enough to provide a sufficient test of the natural ventilation system of the building. 80% of students taking classes in the Pavilion reported satisfactory comfort levels. This is in accordance with the ASHRAE 55 standard, which states that a building must have at least 80% of occupants experiencing thermal satisfaction to be in accordance with the standard. To compare, 82% of students taking classes on the renovated side of the KMC reported satisfactory comfort levels. This is significant, as the renovated section of the building is mechanically cooled. One would expect a notably higher rate of satisfaction from the mechanically cooled portion of the building, only here that is not the case.

Study of Abu Salaiman and Jocelyn Reynolds in Summer 2018

Omar Abu Salaiman and Jocelyn Reynolds were the Portland State University Green Building Interns for summer 2018. At this time, in response to numerous complaints of KMC Pavilion classrooms being too warm in the summer months, there were not any classes scheduled in Pavilion classrooms for the entire summer of 2018. Abu Salaiman and Reynolds surveyed students taking classes in the renovated portion of the building, which is mechanically cooled in order to calculate a “comfort band”, i.e. a set of temperatures across which occupants answered satisfactory on average. The upper limit of this band was decided to be 75°F for an empty classroom with the ideal temperature range existing between 68 and 73°F. As a result, classrooms 180 and 185 were chosen to be the most suitable for classes, with 295 and 285

recognized as semi-suitable and the remainder as not suitable for summer classes. Certain rooms were recommended to be “offline” in the afternoons, and not hold classes after 12pm in the summer months. In addition, the researchers collected daily temperature changes of the concrete slabs in the building in order to evaluate the night flush procedure. A successful night flush yielded a 1 to 1.5 degree overnight surface temperature decrease of the interior concrete slab.

**KMC Natural Ventilation Design Intent**

During the design phase of the major renovation, a study from Behnisch Architekten included a simulation of how the temperature in the interior of the KMC Pavilion would perform if constructed as intended.

![Figure 1. 2015 Behnisch Architekten Pre-Design Natural Ventilation Simulation](image)

The comfort bands of interest, calculated by the design team, are situated at 64°F and 78°F. It can be discerned from the figure that the KMC rooms would frequently have indoor air temperatures in excess of 80°F throughout the summer. This was deemed to be uncomfortable, and unfortunately the design report mistakenly states that there are not any summer classes held in the Pavilion classrooms. Also in this report is an aside that shows the upper comfort limit increasing as overhead air circulation is increased. To expand on this claim, a scale was developed in which the upper comfort limit would be raised proportionally with the increased air circulation provided from local ceiling fans installed in each classroom.
Research Goals and Methods

Research Goals

1. Distribute and analyze surveys to students taking classes in Pavilion classrooms during summer 2019.
2. Use survey results and classroom temperature data to update scheduling priorities for Pavilion classrooms.
3. Initiate long-term particulate-focused air quality monitoring by deploying sensors in selected classrooms and outside environments so as to best discern differences between particulate concentrations in naturally and mechanically ventilated spaces.

Methods

- Coordinate with PSU Campus Sustainability Office for survey design and Internal Review Board (IRB) approval.
- Consult previous studies and seek input from project stakeholders regarding survey design.
- Contact faculty with classes in the Pavilion during summer 2019 and invite to participate in the survey.
- Distribute surveys in-class during the summer 2019 term. Each participating will be surveyed once, with the exception of one in which a second survey was distributed.
- Analyze BAS reports to identify trends in temperature between classrooms and correlate to survey responses.
• Collect data from the National Oceanic Atmospheric Administration (NOAA) and National Weather Service (NWS) databases regarding outdoor air temperature in the area.
• Construct recommendations based on data analysis and occupant responses.
• Deploy air quality monitoring instruments in select classrooms and outdoor areas and preliminarily analyze summer 2019 data.

Survey Design

The survey distributed was a two-page document fitting on a single sheet of paper (printed front and back). The first page was a consent form notifying the participant of their willing participation and purposes of the study. The reverse side contained the actual survey questions. The survey featured six multiple choice and one open-ended question. Two of the questions were related to thermal comfort with the first one asking the student how comfortable they have been over the entire duration of the summer term. The second thermal question inquired how the participant felt at the exact moment they received the survey. Other questions addressed the wall-mounted fan/window controls, perceived air quality, and whether or not they were informed of the sustainable features of the KMC. The last question was left for written comments. All responses would be logged into a spreadsheet, comments included, and numerically coded for ease of analysis. The survey was distributed at a time during the class period, as decided by the instructor. The researchers also gave brief introductory remarks about the scope of the project upon delivering the survey.

Quantitative Data Collection

**Siemens Insight Reports** (Building automation system)
Metrics: Room-specific air temperature and CO2.
Intervals: 30 minutes.

**Kestrel Drop D2 Data Logger**
Metrics: Air temperature, relative humidity, dew point, heat stress index.
Intervals: 5 minutes.
Raw Data/Results

Summer 2019 Indoor/Outdoor Temperature Summary

Compared to summer 2018, the summer 2019 season has been significantly cooler. The average overall temperature for the period 6/1/2018 to 8/24/2018 was 69.3°F while the average for the same period in 2019 was 67.6°F. The 1.7 degrees difference in average temperature will
need to be taken into consideration when making future planning decisions as it is unlikely this will be the state of future summers as the overall average temperature has risen in recent years.

Figure 3. Summer 2019 KMC Indoor Pavilion Classroom Air Temperatures and NWS Outdoor Dry Bulb Temperature

In the above figure, the comfort bands at 64 and 78°F have been transferred from the pre-design study. For only 16 days during the summer of 2019 did at least one classroom exist that exceeded the upper band of 79°F. This was often classroom 390, but in rare cases included other rooms as well.

Figure 4. Summer 2019 KMC Indoor Pavilion and Outdoor Dry Bulb Temperatures: 6/10/2019-6/15/2019

The most notable time period was June 10th-14th, coinciding with final exams for spring term 2019. The high temperature for a Pavilion classroom during this time frequently exceeded the comfort band. These high outdoor air temperatures are often typical in a Portland summer.
although they were not often experienced during summer 2019. A night purge analysis was also conducted during this time.

Figure 5. Summer 2019 KMC Indoor Pavilion and Outdoor Dry Bulb Temperatures: 7/6//2019-7/14//2019

The week of 7/6/2019 to 7/14/2019 represents a variety of temperature ranges that were often replicated during the research period. At these outdoor temperatures, the indoor temperature of Pavilion classrooms stays within the prescribed comfort bands. Only when outdoor temperatures exceed 88°F do the Pavilion classrooms begin to drift out of the ideal comfort zone.
To compare, the average temperature on the renovated portion of the KMC consistently stays within the set points, as it is mechanically cooled.

**Survey Results**

**Table 1. Survey Distribution Summary**

<table>
<thead>
<tr>
<th>Survey No.</th>
<th>Classroom</th>
<th>Participants</th>
<th>Date and Time of Distribution</th>
<th>Indoor Air Temperature</th>
<th>Outdoor Air Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>185</td>
<td>23</td>
<td>7/23/2019 5:30 PM</td>
<td>74</td>
<td>74</td>
</tr>
<tr>
<td>2</td>
<td>185</td>
<td>16</td>
<td>7/24/2019 5:30 PM</td>
<td>75</td>
<td>80</td>
</tr>
<tr>
<td>3</td>
<td>295</td>
<td>19</td>
<td>7/25/2019 10:30 AM</td>
<td>73</td>
<td>76</td>
</tr>
<tr>
<td>4</td>
<td>185</td>
<td>14</td>
<td>7/25/2019 12:45 PM</td>
<td>75</td>
<td>84</td>
</tr>
<tr>
<td>5</td>
<td>190</td>
<td>21</td>
<td>8/1/2019 10:30 AM</td>
<td>77</td>
<td>77</td>
</tr>
<tr>
<td>6*</td>
<td>295</td>
<td>30</td>
<td>8/15/2016 10:30 AM</td>
<td>77</td>
<td>71</td>
</tr>
</tbody>
</table>

*Repeat of survey 3 class with increased attendance*

The first set of survey distributions were completed during the last week of July and first week of August. At this time, the outdoor air temperature was in-line with the current summer averages, but below the 2018 averages. The sixth and final distribution occurred during the third week of August. Unfortunately the ending of summer term classes and final exams provided a significant
hurdle to conducting repeat surveys in four of the five classes. However, the total number of responses, at 104 will still serve as a reliable representation of students.

Overall Comfort

![Bar chart showing comfort levels](image)

*Figure 7. Summer 2019 Cumulative Comfort Levels in KMC Pavilion Classrooms*

On average, students are satisfied with their seasonal comfort in KMC Pavilion classrooms. Only 9 out of 115 responses were registered as “very uncomfortable” while the remaining 106 lead to a 93% comfort rate. This is a 13% increase from the fall 2017 study in which 80% of Pavilion responses were deemed as comfortable. The average air temperature inside the surveyed classrooms at the time of distribution was 75.2°F. This falls in the “not suitable for classes” range as defined in the 2018 KMC study. However, those temperatures were measured in empty classrooms, and it is reasonable to assume an increase in temperature during occupancy, and therefore it is not unreasonable to label 75°F as an acceptable indoor air temperature for an occupied classroom.
Comfort at time of survey distribution

![Day-Of Comfort](image)

*Figure 8. Overall Participant Comfort Levels at Time of Survey Distribution*

Across the surveys, responses for thermal comfort at the time of execution followed a normal distribution, slightly weighted towards warmth as opposed to feeling cool. These responses will be analyzed on a room-by-room basis in the analysis section as there was a range of temperatures during the survey distribution process and a graphical representation of the entire sample may not provide all pertinent information.

Use of Wall-Mounted Controls

![Frequency of Use of Wall-mounted Controls Amongst Students](image)

*Figure 9. In-room Window and Ceiling Fan Control Use Frequency*
When asked how often they used the wall-mounted controls for the windows and ceiling fans, most students had never used them, or did not even know it was an option. This presents an opportunity for occupant education as use of the controls is sometimes necessary to create a comfortable learning environment. This will be further discussed in the Analysis section of this study.

**Air Quality Perception**

![Air Quality Perception Amongst Survey Participants](image)

**Figure 10. Air Quality Perception Amongst Survey Participants**

Air quality is seen as acceptable by students, based on the 7-point sliding scale in the survey. It is unknown what effect the natural ventilation has on these survey results as students were not questioned about air quality in the renovated portion of the building.
Analysis

Determination of Ideal Pavilion Classrooms

One goal of this study is to update the existing scheduling protocol for summer classes in Pavilion spaces. The previous guideline was to take nearly all classrooms offline after 12pm in the summer with the exception of rooms 180 and 185. Unfortunately there is no one temperature where a majority of the population will experience overheating. Previous literature has shown the comfort band in naturally ventilated spaces is typically wider than for mechanically ventilated spaces.  

In order to prioritize classrooms for scheduling, a metric would need to be chosen for which all rooms could be compared. This study will look at the number of days experienced over a chosen temperature with more attention given to higher temperatures. This was chosen over the pure average approach because classes typically run between 8am and 8pm and it only takes one moment of a hot temperature to cause discomfort for a student. Therefore, even if a class was cooler than most for a part of the day but experienced a large spike, the rooms without large temperature variations would be chosen to hold classes.

Table 2. Number of days over a given temperature 6/10/2019-8/27/2019

<table>
<thead>
<tr>
<th>Room</th>
<th>Temperature (F)</th>
<th>75</th>
<th>76</th>
<th>77</th>
<th>78</th>
<th>79</th>
<th>80</th>
</tr>
</thead>
<tbody>
<tr>
<td>180</td>
<td></td>
<td>28</td>
<td>19</td>
<td>14</td>
<td>8</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>185</td>
<td></td>
<td>34</td>
<td>20</td>
<td>11</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>190</td>
<td></td>
<td>37</td>
<td>27</td>
<td>15</td>
<td>8</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>285</td>
<td></td>
<td>43</td>
<td>31</td>
<td>15</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>290</td>
<td></td>
<td>36</td>
<td>23</td>
<td>11</td>
<td>5</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>295</td>
<td></td>
<td>28</td>
<td>17</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>380</td>
<td></td>
<td>49</td>
<td>34</td>
<td>23</td>
<td>9</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>385</td>
<td></td>
<td>48</td>
<td>31</td>
<td>19</td>
<td>9</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>390</td>
<td></td>
<td>44</td>
<td>33</td>
<td>22</td>
<td>16</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>480</td>
<td></td>
<td>45</td>
<td>34</td>
<td>22</td>
<td>14</td>
<td>8</td>
<td>4</td>
</tr>
</tbody>
</table>

It is reasonable to aim for most classrooms to stay under 78°F, as cited by the pre-design study. However, it is unreasonable to expect a naturally ventilated space to stay within the usual range of a mechanically cooled space. Each room experienced at least 28 days over 75°F, the temperature deemed “unsuitable” by the summer 2018 researchers. However, some of these peaks occurred while the classrooms were occupied. Future analysis could investigate this further.

To rank the classrooms, temperatures were assigned a point value as listed below.

**Table 3. Overheating Temperature Point Values**

<table>
<thead>
<tr>
<th>Temperature</th>
<th>75</th>
<th>76</th>
<th>77</th>
<th>78</th>
<th>79</th>
<th>80</th>
</tr>
</thead>
<tbody>
<tr>
<td>Points</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

Then each time that temperature was exceeded, the corresponding number of points would be added to the room until all days and temperatures were accounted for.

**Table 4. Final Pavilion Classroom Rankings**

<table>
<thead>
<tr>
<th>Room</th>
<th>Total Score</th>
<th>2019 Classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>295</td>
<td>87</td>
<td>1</td>
</tr>
<tr>
<td>495</td>
<td>92</td>
<td>1</td>
</tr>
<tr>
<td>185</td>
<td>127</td>
<td>4</td>
</tr>
<tr>
<td>485</td>
<td>138</td>
<td>1</td>
</tr>
<tr>
<td>290</td>
<td>140</td>
<td>5</td>
</tr>
<tr>
<td>180</td>
<td>172</td>
<td>4</td>
</tr>
<tr>
<td>285</td>
<td>187</td>
<td>4</td>
</tr>
<tr>
<td>190</td>
<td>188</td>
<td>2</td>
</tr>
<tr>
<td>580</td>
<td>203</td>
<td>2</td>
</tr>
<tr>
<td>385</td>
<td>229</td>
<td>2</td>
</tr>
</tbody>
</table>
380  238  3
590  286  1
480  299  2
390  314  1*

* denotes a limited class schedule, such as meeting a few days during the summer, and not the longevity of a typical summer term class.

Through this method, 295 and 495 have emerged as the ideal classrooms. Neither of them experienced a day over 80°F and experienced fewer days over nearly every other temperature as the remaining classrooms. Rooms 295 and 495 do share some architectural similarities. They are both on the eastern half of the Pavilion and neither have an east-facing window. Other classrooms in their position, such as 190, have large east-facing windows and tend to rise in temperature more quickly as the day progresses. Room 495 is unique in that it has windows on the north and south edifices.

Updates to 2018 Suitability Guidelines

Table 1: Average Temperatures of Classrooms by Time of Day (7/15/18 - 8/15/18) per hour (°F)

<table>
<thead>
<tr>
<th>Time</th>
<th>180</th>
<th>190</th>
<th>285</th>
<th>290</th>
<th>295</th>
<th>380</th>
<th>390</th>
<th>480</th>
<th>485</th>
<th>490</th>
<th>495</th>
<th>580</th>
<th>590</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00 AM</td>
<td>71.0</td>
<td>71.1</td>
<td>71.7</td>
<td>72.5</td>
<td>72.0</td>
<td>72.0</td>
<td>73.7</td>
<td>74.4</td>
<td>74.1</td>
<td>72.9</td>
<td>73.4</td>
<td>72.8</td>
<td>73.2</td>
</tr>
<tr>
<td>9:00 AM</td>
<td>71.3</td>
<td>71.5</td>
<td>72.2</td>
<td>72.6</td>
<td>72.5</td>
<td>72.5</td>
<td>73.9</td>
<td>74.4</td>
<td>74.3</td>
<td>73.3</td>
<td>73.8</td>
<td>73.4</td>
<td>72.8</td>
</tr>
<tr>
<td>10:00 AM</td>
<td>71.5</td>
<td>71.7</td>
<td>73.0</td>
<td>73.0</td>
<td>72.7</td>
<td>72.9</td>
<td>74.2</td>
<td>74.7</td>
<td>74.8</td>
<td>73.6</td>
<td>74.1</td>
<td>74.0</td>
<td>74.2</td>
</tr>
<tr>
<td>11:00 AM</td>
<td>72.0</td>
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<td>73.5</td>
<td>72.9</td>
<td>73.2</td>
<td>74.6</td>
<td>75.1</td>
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<tr>
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<td>72.2</td>
<td>72.0</td>
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<td>75.1</td>
<td>75.2</td>
<td>75.2</td>
<td>75.3</td>
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<td>74.3</td>
<td>73.5</td>
<td>73.7</td>
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<td>75.7</td>
<td>75.5</td>
<td>76.3</td>
<td>75.5</td>
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<td>74.3</td>
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<td>75.4</td>
<td>75.9</td>
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<td>75.7</td>
<td>76.0</td>
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<td>75.9</td>
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<td>73.9</td>
<td>74.0</td>
<td>75.9</td>
<td>76.1</td>
<td>77.0</td>
<td>77.3</td>
<td>76.0</td>
<td>78.0</td>
<td>76.6</td>
</tr>
<tr>
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<td>74.4</td>
<td>75.1</td>
<td>74.0</td>
<td>74.2</td>
<td>76.1</td>
<td>76.3</td>
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Average Temperature of Classroom

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A “suitability building diagram” was created to match that of the 2018 study. The same dates, time intervals, and classrooms were used. The biggest difference between the two years was the absence of active classes during the summer of 2018. The 2019 diagram shows overheating earlier in the day, although the averages for the rooms are not substantially different between years. The 2019 diagram also shows classrooms holding their lower temperatures for longer periods of time beginning in the morning, a possible indicator of more successful night flushes taking place. The elevation trend is not as evident in the 2019 diagram as in 2018. This could partially be explained by the increased occupancy on the lower floors of the building during the 2019 summer.
Once again, the elevation differences are not as drastic in the 2019 study as in the 2018 study. From the sidecut diagram it is easy to see the uniqueness of rooms 295 and 495. The exposure and cantilevered nature may play a role in their effective cooling properties. This could be an opportunity for further study in the future. Another notable change is the addition of 485 as a semi-suitable classroom. This may be tainted by 485 only hosting one class during summer 2019 term and the related absence of additional heating from occupants.

Night Purge Effectiveness

a. Focus
Initiation of investigating night purge effectiveness launched based on the facts that the window operation sometimes detected as a malfunction. As the passive cooling strategies on Pavilion supposed to control with precision of the window system, investigating the current night purge operation setting was inevitable. Normally, with the night purge ventilation technique, opening windows has to incorporate with a pre-set of time during the night in order to achieve effective cooling. Throughout having a meeting with the Mechanical team of Facility and Property Management, the current system has a lack of sequence of operations for the extreme weather. Moreover, the highest temperature drop was observed a maximum of $3^\circ$F during this summer.

![Figure 15. Comparison of indoor vs. outdoor temperatures from June 11th to June 14th.](image)

![Figure 16. A linear graph of CO2 levels depend on the number of occupants from June 11th to June 14th.](image)

b. Temperature

According to the temperature data, the hottest days of the summer were in the final week of the Spring term. In the period between June 10th to 14th, the temperature of a Pavilion classroom

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frequently exceeded the comfort band (76°F-83°F), and the temperature of room 480 has reached 82.6°F on June 12th. As the temperature analysis pointed out above, these temperatures are often typical in Portland summer season.

c. Data collection techniques
Currently, Siemens Insight employed to control the window operation, and the night purge operation is occurred by detection of temperature difference, not set by time. In the final week, we collected the temperature and CO2 levels from BAS and analyzed temperature changing after windows open for night purge with the current setting. The current setting for night purge is opening windows when classroom temperature reached 72°F. In addition to the last year research of Omar and Jocelyn, the night purge effectiveness with the thermal mass of the concrete slab was observed as the average of 0.94°F.

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<th>Outdoor temperature</th>
<th>Average before night purge (2 hours)</th>
<th>Average after night purge (2 hours)</th>
<th>Average drop-in</th>
<th>CO2 after night purge</th>
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<td>-2.4°F</td>
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Figure 17. Temperature drops in the final week

Figure 18. Night purge effectiveness related to outdoor temperature

d. Actual monitoring
Figure 17 represents the outcomes from BAS weekly reports. Each day of night purge operation was considered when all Pavilion classroom windows ordered as "Open" in a certain period of
hours. The shortest was 30 minutes and the longest was 90 minutes. Under the system override on window opening, the drop rate of temperature and CO2 were calculated as an average value of total running hours, which is ranged from 2 hours before night purge, running hours, and 2 hours after night purge. According to the final measurements, the average temperature drop was 0.58°F and it estimated as lower than measurements of last year.

Theoretically, the temperature of the classrooms can release their heat when the outdoor air temperature is lower than the indoor air temperature. In this period, however, night purges occurred even though there is no gap between outdoor air temperature and indoor air temperature. Ventilation studies of Mixed-mode building from Center for Built Environment suggest that 3 - 5℃ gaps will bring more cool air in during night purge operation in the summer season. In this week, night purges occurred at 7:30 am on June 11st, 7:00 am on June 12nd, 20:00 pm June 13th, and 20:00 pm June 14th. Secondly, there was no report on indoor air-velocity to analyze the fluctuation of ventilation rates. We only expected there were enough air-velocity to releasing heats and indoor pollutants by tracking the drop rates of temperature and CO2 level in BAS.

e. Perception
Throughout analyzing the effectiveness of current night purge setpoints and outcomes, we were able to briefly collect the opinions of professors to correlate the occupant’s thermal comfort to temperatures after night purge operations. The list of professors was selected based on their class schedule on the final week and the number of occupied students. During this survey, 13 professors responded among 35 professors and mostly answered the temperature was slightly warm or warm among the other five variations but they agreed on it was bearable with turning ceiling fans and opening windows.

Even though the reported temperature data and occupants satisfaction level were matched to the comfort range, a concern about the noisy was commonly pointed out that it can be a source of distracting class activities. The type of noises was varied from outdoor traffics to scratching sounds of window motions. Additionally, comments on the wall-mounted controller were reported throughout this survey that the instruction is required for use.

f. Simulation
Simulation for evaluating the night purge effectiveness on releasing heats and CO2 levels is done by planning 4 different sequences of operations with utilizing the sources. The sources that utilized for this simulation were selected based on the criteria which meet the low energy use performance and no extra adding on the facility. In the design stage, Jason Luce, Mechanical engineer in FPM cooperated to build the 4 different sequences.

In order to achieve the objective of this simulation, readings of BAS report are conducted on the sample of the classroom in Pavilion, which is Room 495. With the location setting, the 4 different individual sequences were planned at a different day, and those days share similar outdoor settings. Climatically, night flushing is only suitable for climates with a relatively large temperature range from day to night, where nighttime temperatures are below 68 or 71°F. Accordingly, nighttimes between midnight to 6:00 AM of Aug 2nd, August 5th, August 22nd, and August 23rd were chosen to be conducted for this simulation. Followed, actual readings and simulation values were obtained in the same way as we measured from the final week of Spring term.

The first simulation, conducted on August 2nd has a similar set to the current setting but conducted from Midnight to 6:00 Am which running time applied similarly to the other three simulations. The second simulation utilized ceiling fans without opening windows, and the third simulation have both ceiling fans and windows support to see how the ventilation rates increased but we did not measure air-velocity due to a lack of capacity. Finally, the last simulation is operated by turning an exhaust fan(AHU-003) while windows open.
The effectiveness of night purge was observed to success in releasing heat and CO2 level, and comments on thermal dis-satisfactions were commonly related to students feeling that they did not have enough control over their environment. In addition to complaints about thermal comfort, most professors responded it was bearable even though the classroom temperature sometimes reached to 80. However, opening windows only for night purging is measured as ineffective in terms of releasing heat. Moreover, in hot days, we assume that opening windows with ceiling fans support or exhaust fan support will bring more temperature dropdown. Even though the simulation did not measured the air-velocity, we collected the other data to measure the effectiveness of releasing heat and reducing the CO2 levels in the classrooms. Therefore, we recommend developing option 3, 4 with other data by air-velocity measurement and energy usage difference to develop a new setpoint for night purging in hot days. Moreover, occupants who have responded to the online survey provided this research very useful cues to understand how the building is working not just at their individual, but for the building as a whole. When we consider the main occupants are mostly faculty members who have their office area in Renovated side, their qualitative opinions will bring more benefits to analyze. Furthermore, as we observed the operational complaints have been started to report from this year, future research should survey for their occupational experiences to identify the relationship between the mechanical and natural systems as a whole.

Providing students and faculty with a quality indoor environment should be a goal of any building design, but is particularly important for this green building that claims to be more responsive to supporting occupant comfort level, and productivity. A combination of the
diagnosis on the current setpoints, surveys, and the simulation suggests that there is the greatest benefit in utilizing the wall-mounted controller to increase the effectiveness of night purge. In the next summer research, as we move toward embracing high-performance, we must also insist that post-occupancy evaluation on Pavilion, Atrium and Renovated sides will be a natural part of the process.

Survey Analysis

Thermal Comfort

On the day of the survey, students reported nearly equal “slightly cool” and “slightly warm” answers. Of course, this is difficult to analyze as a whole because of the variability in days and classrooms. As an example:

![Figure 21. Survey 2: Room 185, Thermal Comfort Responses at 5:30pm. Outdoor Temperature: 80°F, Indoor Temperature: 75°F](image)

The outdoor temperature during this evening class was 80°F. Oddly, a large number of students felt slightly cool in the classroom. This can be compared with a morning class with only a two-degree indoor temperature increase, as it was 77°F in the morning class and 75°F in the evening class.
Nearly all students in this class reported feeling slightly warm. Upon entering the classroom, the researchers noticed the windows were closed and the ceiling fans were not turned on. With the windows open and ceiling fans operating, the interior comfort level increased, not just as noted by the researchers, but also verbally from students in the class.

Classroom variability is important in the KMC as certain rooms have large east-facing glass windows, leading to increased morning sun exposure, while others may have windows on two sides of the room, compared to just one set of windows for most Pavilion classrooms. Elevation also makes a difference, as the classrooms on the top three floors tended to experience more frequent overheating compared with those on the first and second floors. This is due to the stack effect in which warmer air will migrate upwards in the building due to pressure differences as the day progresses.
It is difficult to find trends between indoor air temperature and comfort levels, at least within the temperature range of 71-77°F. The most obvious temperature limit arises above 75°F, where the number of warm and hot responses outnumber the neutral and cool responses. Below 75°F, the responses follow a normal distribution. One can assume this is representative of general occupant comfort.

The upper limit of 75°F is consistent with the 2018 results, with the exception that few students reported actual overheating at temperatures as high as 77°F. If the building is seeking to be optimized for maximum possible classroom use, 77°F could be used as the upper limit. This is still lower than the pre-design study that listed 78°F as the limit in the absence of overhead fans. Each room in the KMC Pavilion is equipped with overhead ceiling fans, ideally raising the overheating temperature past previous expectations.
Use of Integrated Window and Ceiling Fan Controls

As noted in Figure 9 (Raw Data/Results) the user controls in the Pavilion classrooms are largely underutilized by students. 52% of surveyed students have never used the controls, and another 25% did not even know they existed. Use of the ceiling fans can raise the upper limit of the comfort band up to 84°F, up from 78°F, according to the 2015 Pre-Design study cited earlier, therefore it is crucial that all occupants are aware of their presence and more importantly, how to use them properly.

Moving forward, the PSU Campus Planning office will work with Capital Projects and Construction (CPC) as well as Facilities and Property Management (FPM) to address the education issue regarding the controls. The most likely remedy will be a small poster displayed in every Pavilion classroom above each of the control modules. A possible draft version is displayed below.
HOW THIS CLASSROOM WORKS

This classroom is different from many standard classrooms. Passive design relies on the use of natural forces to save on energy use: daylight, natural air movement, warmth from the sun, cool morning air, and many other natural forces help this classroom function.

Just like your clothing, it may be necessary to change if the space starts to feel uncomfortable. Opening windows and/or turning on the ceiling fans to help cool down the classroom are all possibilities to assist this classroom function well.

THERMOSTAT

This building is naturally cooled by night flush ventilation and ceiling fans. With exposed concrete and air movement, research shows that human comfort is extended by 5 degrees.

CEILING FAN CONTROL

Five speed settings. Beware the upper ranges might blow papers. It is highly recommended that increased air velocity be provided via ceiling fans because it extends the operative temperature comfort range.

WINDOW CONTROL

 Held up or down for desired position. Close windows when it is warmer outside than inside. Ventilation air is provided through motorized windows. Automatic operation controlled by the Building Automation System to modulate natural ventilation flow rates depending upon indoor and outdoor conditions irrespective of space occupancy.

LIGHT CONTROL

Light fixtures adjust automatically with varying daylight. This wall switch has all on/off control and basic settings. High-efficiency LED lighting reduces electricity consumption and cooling load.

Figure 24. Draft of In-Class Control Instructions

Figure 25. In-class control system during window opening
In addition, a training video may be produced by FPM to further educate faculty. This will all take place after the conclusion of this research project and its effectiveness could be evaluated by future studies.

However, it is not sufficient to only know how to tailor the indoor environment of the Pavilion via the wall-mounted controls. Knowledge of the building processes and their environmental benefits may have an effect on student and faculty comfort levels. If they are informed of the
energy savings of the building as a result of the natural ventilation, it is possible their personal comfort range may widen as they could be more willing to be slightly uncomfortable if they know they are being part of a sustainable solution. This increased education could be achieved via increased signage, including the use of monitors that exist outside the elevators on the renovated portion of the KMC.

Inspiration could be drawn further from the SEA-TAC (Seattle) airport in which its new features are on display via signage on pillars and monitors, similar to those in the KMC.

![Figure 27. SEA-TAC Information System](image1)
![Figure 28. KMC Information Opportunities](image2)

### Conclusion

The KMC is performing as intended by the design proposal. Summer interior air temperatures stayed below those outlined in the 2015 pre-design study on average. Survey responses indicated that students are generally comfortable in KMC Pavilion classrooms, with 93% of students reporting answers registering as acceptable. In order to maintain or improve upon this rate of satisfaction, it is imperative the in-room window and ceiling fan controls are optimized. Currently, most students and faculty and unaware of the potential comfort improvements the controls aid. As of the conclusion of this study, a plan is in motion to increase user awareness through increased signage and possible other means. An additional opportunity exists to cool
the building through an enhanced night flush procedure in which the rooftop exhaust fans are
turned on during nighttime hours to draw additional cooler air into the building. However this will
need to be evaluated on an energy-use basis as well due to the building having achieved LEED
Platinum status and PSU’s sustainability goals. A long term air quality monitoring deployment
was completed as part of this study. Results can be expected in the year 2020 and analysis will
likely be performed through the Green Building Research Laboratory.

References

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53-60
conditioning challenge on mixed-mode building. Pages
https://escholarship.org/uc/item/40k1s1vd

Appendices

Appendix A: KMC Indoor/Outdoor Temperatures

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<tr>
<td>7/27/2019</td>
<td>80</td>
<td>64</td>
<td>72</td>
</tr>
<tr>
<td>7/28/2019</td>
<td>85</td>
<td>60</td>
<td>72.5</td>
</tr>
<tr>
<td>7/29/2019</td>
<td>83</td>
<td>60</td>
<td>71.5</td>
</tr>
<tr>
<td>7/30/2019</td>
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<td>60</td>
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</tr>
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<td>7/31/2019</td>
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<td>60</td>
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</tr>
<tr>
<td>8/1/2019</td>
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<td>75.5</td>
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</tr>
<tr>
<td>8/3/2019</td>
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<td>64</td>
<td>76</td>
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<td>8/6/2019</td>
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<td>61</td>
<td>73</td>
</tr>
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</tr>
<tr>
<td>8/8/2019</td>
<td>71</td>
<td>64</td>
<td>67.5</td>
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<tr>
<td>8/9/2019</td>
<td>77</td>
<td>64</td>
<td>70.5</td>
</tr>
<tr>
<td>8/10/2019</td>
<td>77</td>
<td>62</td>
<td>69.5</td>
</tr>
<tr>
<td>8/11/2019</td>
<td>76</td>
<td>62</td>
<td>69</td>
</tr>
<tr>
<td>8/12/2019</td>
<td>83</td>
<td>59</td>
<td>71</td>
</tr>
<tr>
<td>8/13/2019</td>
<td>90</td>
<td>60</td>
<td>75</td>
</tr>
<tr>
<td>8/14/2019</td>
<td>87</td>
<td>64</td>
<td>75.5</td>
</tr>
<tr>
<td>8/15/2019</td>
<td>83</td>
<td>61</td>
<td>72</td>
</tr>
<tr>
<td>8/16/2019</td>
<td>77</td>
<td>60</td>
<td>68.5</td>
</tr>
<tr>
<td>8/17/2019</td>
<td>72</td>
<td>60</td>
<td>66</td>
</tr>
<tr>
<td>8/18/2019</td>
<td>77</td>
<td>58</td>
<td>67.5</td>
</tr>
<tr>
<td>8/19/2019</td>
<td>81</td>
<td>60</td>
<td>70.5</td>
</tr>
<tr>
<td>8/20/2019</td>
<td>86</td>
<td>58</td>
<td>72</td>
</tr>
<tr>
<td>8/21/2019</td>
<td>73</td>
<td>60</td>
<td>66.5</td>
</tr>
</tbody>
</table>
Appendix B: Survey Information

KMC Survey Consent Form

Participant,

Taking part in this survey is completely voluntary. All survey results are anonymous. It is in your right to deny, refuse, and/or discontinue participation at any time with no penalty or loss of benefits.

This study includes research and data conducted on how the design of the Karl Miller Center’s new addition and remodel affects the level of occupant comfort in the building. This study is in partnership with PSU’s Institute for Sustainable Solutions Living Lab (ISS) Program, PSU Capital Projects and Construction (CPC), the School of Architecture’s Building Science Lab to Advance Teaching (BUILT), and the School of Business.

During this project, we will analyze ventilation design performance versus occupant comfort. Our research specifically focuses on how passive architecture reduces the need for conventional HVAC systems. Passive architecture is a design strategy that uses climate, orientation, and the location of a building to optimize natural environmental conditions to improve comfort.

If you have any questions, concerns, or complaints feel free to email us:

Everett Stilley                        Junyoung Lee
estilley@pdx.edu                       junyoung@pdx.edu

If you wish to contact our supervisor with questions, concerns, or complaints about the research; questions about the subjects’ rights; to obtain information or to offer input, please contact:

Capital Projects and Construction - Technical Services Manager
Quinn Soifer
soiferq@pdx.edu

Campus Sustainability Office - Education and Outreach Coordinator
Emily Quinton
equinton@pdx.edu
Karl Miller Center Comfort Survey - Summer 2019

1. Please circle the option that best includes your class period

8:00am-1:00pm       1:00pm-4:30pm       After 4:30pm

2. From your experience this summer, how thermally comfortable are you in this room? Circle one.

Very uncomfortable  Slightly uncomfortable  Neutral  Slightly comfortable  Very comfortable

3. Please circle the thermal comfort level in the classroom that best describes your situation today.

Cold  Slightly cool  Neutral  Slightly warm  Hot

4. Have you personally used the wall-mounted controls for the windows or ceiling fans anywhere in this building?

Often  Sometimes  Never  Did not know this was an option

5. In your opinion, how would you describe the air quality in the classroom with relation to freshness, smells, etc.? Please write an “x” anywhere on the scale below

|_______________|___________|_______________|

Clearly Unacceptable  Just Unacceptable  Just Acceptable  Clearly Acceptable

6. How have you been informed about the sustainability features of this building?

❏ Professor
❏ Building operator(s)
❏ Sustainability Office
❏ Other: ______________________
❏ I am uninformed about the sustainable features of this building.

7. Please provide any comments you have regarding your general comfort in this classroom
## Appendix C: Survey Results

### Table C1. Survey 1: KMC 185, 5:30pm, Outdoor Temperature: 74.0, Indoor Temperature: 74.08

<table>
<thead>
<tr>
<th>Student</th>
<th>Seasonal</th>
<th>Comfort at Time of Survey</th>
<th>Control Use</th>
<th>Air Quality</th>
<th>Information Source</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Slightly uncomfortable</td>
<td>neutral</td>
<td>never</td>
<td>neutral</td>
<td>I am uninformed about the sustainable features of this building</td>
<td>The air circulation and air conditioning in this building is poor. On multiple occasions I have been unable to focus.</td>
</tr>
<tr>
<td>2</td>
<td>Very uncomfortable</td>
<td>slightly warm</td>
<td>sometimes</td>
<td>clearly unacceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Neutral</td>
<td>slightly warm</td>
<td>never</td>
<td>moderately acceptable</td>
<td>Professor</td>
<td>I cannot stand how the windows open on their own when the room is too warm</td>
</tr>
<tr>
<td>4</td>
<td>Slightly uncomfortable</td>
<td>slightly cool</td>
<td>Often</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Slightly comfortable</td>
<td>neutral</td>
<td>sometimes</td>
<td>clearly acceptable</td>
<td>Professor</td>
<td>Need more info about how to open the fans/windows would be useful. Have had multiple folks who did not know how to adjust them</td>
</tr>
<tr>
<td>6</td>
<td>Slightly comfortable</td>
<td>slightly warm</td>
<td>never</td>
<td>moderately acceptable</td>
<td>Professor</td>
<td>The auto wall-mounted controls don't seem well regulated or set ... it often gets way too warm and stuffy</td>
</tr>
<tr>
<td>7</td>
<td>Slightly uncomfortable</td>
<td>neutral</td>
<td>never</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>Comfort</td>
<td>Temperature</td>
<td>Frequency</td>
<td>Acceptance</td>
<td>Notes</td>
<td></td>
</tr>
<tr>
<td>----</td>
<td>---------</td>
<td>-------------</td>
<td>-----------</td>
<td>------------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Very comfortable</td>
<td>neutral</td>
<td>never</td>
<td>clearly acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Very comfortable</td>
<td>neutral</td>
<td>never</td>
<td>clearly acceptable</td>
<td>#N/A</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Neutral</td>
<td>slightly warm</td>
<td>never</td>
<td>Just acceptable</td>
<td>Professor</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Neutral</td>
<td>slightly warm</td>
<td>never</td>
<td>clearly acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Slightly comfortable</td>
<td>slightly warm</td>
<td>never</td>
<td>clearly acceptable</td>
<td>The automatic windows are very loud + distracting</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Neutral</td>
<td>slightly warm</td>
<td>did not know this was an option</td>
<td>clearly acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Slightly comfortable</td>
<td>neutral</td>
<td>never</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Neutral</td>
<td>neutral</td>
<td>never</td>
<td>neutral</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Slightly comfortable</td>
<td>slightly warm</td>
<td>never</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Slightly comfortable</td>
<td>slightly warm</td>
<td>sometimes</td>
<td>Just acceptable</td>
<td>#N/A</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Neutral</td>
<td>neutral</td>
<td>never</td>
<td>moderately acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Neutral</td>
<td>slightly cool</td>
<td>sometimes</td>
<td>clearly acceptable</td>
<td>Professor</td>
<td></td>
</tr>
</tbody>
</table>

The new building is certainly an upgraded compared to the other. Its nice, open, and well structured.
<table>
<thead>
<tr>
<th>Survey Number</th>
<th>Comfort Level</th>
<th>Temperature</th>
<th>Rating</th>
<th>Reason</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>Very uncomfortable</td>
<td>slightly warm</td>
<td>did not know this was an option</td>
<td>clearly acceptable</td>
<td>I am uninformed about the sustainable features of this building. Room 190 next door (all windows) is like being in a greenhouse during warm days. It gets unbearable hot &amp; stuffy during the day.</td>
</tr>
<tr>
<td>21</td>
<td>Slightly comfortable</td>
<td>neutral</td>
<td>did not know this was an option</td>
<td>clearly acceptable</td>
<td>I am uninformed about the sustainable features of this building.</td>
</tr>
<tr>
<td>22</td>
<td>Very comfortable</td>
<td>neutral</td>
<td>sometimes</td>
<td>clearly acceptable</td>
<td>#N/A</td>
</tr>
<tr>
<td>23</td>
<td>Slightly uncomfortable</td>
<td>neutral</td>
<td>did not know this was an option</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable features of this building. The air flow is non exist in room 275 which is where I spend most of time this term. Very warm &amp; stuffy.</td>
</tr>
</tbody>
</table>

*Figure C1. Survey 1 Question 2: Seasonal Comfort*
Figure C2. Survey 1 Question 3: Thermal comfort at time of survey distribution

Figure C3. Survey 1 Question 4: Frequency of use of wall-mounted controls

Figure C4. Survey 1 Question 5: Perceived air quality
**Figure C5. Survey 1 Question 6: Source of information regarding sustainable features of the KMC**

**Table C2. Survey 2: KMC 185, 5:30pm, Outdoor Temperature: 80.0, Indoor Temperature: 75.16**

<table>
<thead>
<tr>
<th>Student</th>
<th>Seasonal</th>
<th>Comfort at Time of Survey</th>
<th>Control Use</th>
<th>Air Quality</th>
<th>Information Source</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Neutral</td>
<td>neutral</td>
<td>did not know this was an option</td>
<td>clearly acceptable</td>
<td>other</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Neutral</td>
<td>neutral</td>
<td>never</td>
<td>moderately acceptable</td>
<td>Professor</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Neutral</td>
<td>neutral</td>
<td>did not know this was an option</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Neutral</td>
<td>neutral</td>
<td>never</td>
<td>Just acceptable</td>
<td>Professor</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Slightly comfortable</td>
<td>neutral</td>
<td>never</td>
<td>Just unacceptable</td>
<td>Professor</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Slightly comfortable</td>
<td>neutral</td>
<td>never</td>
<td>clearly acceptable</td>
<td>Professor</td>
<td>automatic windows really loud and should have a minimum timeframe between each opening/closing. They often open and then immediately close.</td>
</tr>
<tr>
<td>7</td>
<td>Slightly comfortable</td>
<td>slightly cool</td>
<td>never</td>
<td>Just acceptable</td>
<td>Professor</td>
<td>Window operation is loud and disrupts classroom</td>
</tr>
<tr>
<td>No.</td>
<td>Comfort Level</td>
<td>Temperature</td>
<td>Frequency</td>
<td>Acceptability</td>
<td>Comments</td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>---------------</td>
<td>-------------</td>
<td>-----------</td>
<td>---------------</td>
<td>----------</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Slightly uncomfortable</td>
<td>slightly cool</td>
<td>never</td>
<td>clearly acceptable</td>
<td>Professor</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Slightly uncomfortable</td>
<td>neutral</td>
<td>never</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Slightly uncomfortable</td>
<td>neutral</td>
<td>never</td>
<td>clearly acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Slightly uncomfortable</td>
<td>slightly cool</td>
<td>never</td>
<td>clearly acceptable</td>
<td>Ceiling fan kind of annoying. Windows can be distracting</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Slightly uncomfortable</td>
<td>neutral</td>
<td>did not know this was an option</td>
<td>Just acceptable</td>
<td>Professor</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Very comfortable</td>
<td>neutral</td>
<td>did not know this was an option</td>
<td>clearly acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Very comfortable</td>
<td>neutral</td>
<td>never</td>
<td>clearly acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Very comfortable</td>
<td>slightly cool</td>
<td>never</td>
<td>clearly acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Very comfortable</td>
<td>slightly cool</td>
<td>sometimes</td>
<td>Just acceptable</td>
<td>I like the large windows for natural light</td>
<td></td>
</tr>
</tbody>
</table>

*Figure C6. Survey 2 Question 2: Seasonal Comfort*
Figure C7. Survey 2 Question 3: Thermal comfort at time of survey distribution

Figure C8. Survey 2 Question 4: Frequency of use of wall-mounted controls

Figure C9. Survey 2 Question 5: Perceived air quality
Figure C10. Survey 2 Question 6: Source of information regarding sustainable features of the KMC

Table C3. Survey 3: KMC 295, 11:30am, Outdoor Temperature: 76.0, Indoor Temperature: 73.18

<table>
<thead>
<tr>
<th>Student</th>
<th>Seasonal</th>
<th>Comfort at Time of Survey</th>
<th>Control Use</th>
<th>Air Quality</th>
<th>Information Source</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Neutral</td>
<td>cool</td>
<td>never</td>
<td>clearly acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td>I am uninformed about the sustainable features of this building</td>
</tr>
<tr>
<td>2</td>
<td>Slightly comfortable</td>
<td>slightly cool</td>
<td>never</td>
<td>clearly acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td>Sometimes it is too warm, today is nice</td>
</tr>
<tr>
<td>3</td>
<td>Slightly uncomfortable</td>
<td>neutral</td>
<td>never</td>
<td>moderately acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td>Noise when windows are open. Temperature is comfortable</td>
</tr>
<tr>
<td>4</td>
<td>Very comfortable</td>
<td>neutral</td>
<td>did not know this was an option</td>
<td>clearly acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Neutral</td>
<td>neutral</td>
<td>did not know this was an option</td>
<td>Just acceptable</td>
<td>building operator</td>
<td>Everything is good!</td>
</tr>
<tr>
<td>6</td>
<td>Slightly uncomfortable</td>
<td>hot</td>
<td>never</td>
<td>Just unacceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td>Request AC in this building</td>
</tr>
<tr>
<td>7</td>
<td>Very uncomfortable</td>
<td>slightly cool</td>
<td>never</td>
<td>Just unacceptable</td>
<td>sustainability office</td>
<td></td>
</tr>
</tbody>
</table>

48
<table>
<thead>
<tr>
<th></th>
<th>Comfort Level</th>
<th>Room Temp</th>
<th>Frequency</th>
<th>Acceptability</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Very comfortable</td>
<td>neutral</td>
<td>did not know this was an option</td>
<td>clearly acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Too many students wear sprays that stink up the entire classroom which is annoying. So maybe a system that sucks up air like at casinos with smoke would work. The water fountain has had flow issues all summer. Please fix it so it doesn't take up to 5 tries to fill one bottle.</td>
</tr>
<tr>
<td>9</td>
<td>Neutral</td>
<td>slightly cool</td>
<td>never</td>
<td>moderately acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Good. Hope have bigger screen or more screen.</td>
</tr>
<tr>
<td>10</td>
<td>Slightly comfortable</td>
<td>neutral</td>
<td>did not know this was an option</td>
<td>clearly acceptable</td>
<td>building operator</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Neutral</td>
<td>neutral</td>
<td>did not know this was an option</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Good</td>
</tr>
<tr>
<td>12</td>
<td>Very comfortable</td>
<td>slightly cool</td>
<td>never</td>
<td>clearly acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Slightly uncomfortable</td>
<td>slightly cool</td>
<td>never</td>
<td>clearly unacceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The windows are kind of loud but other than that the classroom is great and the building overall is the best on campus.</td>
</tr>
<tr>
<td>14</td>
<td>Very comfortable</td>
<td>slightly cool</td>
<td>never</td>
<td>clearly acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>When I get into the classroom around 10:25am it feels stuffy and</td>
</tr>
<tr>
<td>15</td>
<td>Slightly uncomfortable</td>
<td>slightly warm</td>
<td>did not know this was an option</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
</tr>
<tr>
<td>Time</td>
<td>Temperature</td>
<td>Feeling</td>
<td>Acceptability</td>
<td>Comment</td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>-------------</td>
<td>---------</td>
<td>---------------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Neutral</td>
<td>slightly cool</td>
<td>did not know this was an option</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Too warm, but as the class progresses it gets cooler and more comfortable.</td>
</tr>
<tr>
<td>17</td>
<td>Neutral</td>
<td>slightly warm</td>
<td>sometimes</td>
<td>moderately acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>When I'm in the KMC I don't think about comfortability. I think that's more of a positive than a negative. I appreciate the use of fans rather than A/C, it makes it easier to hear my professor/peers. The only thing that's uncomfortable is the interior color scheme. The lime-green walls and ceiling are distracting.</td>
</tr>
<tr>
<td>18</td>
<td>Neutral</td>
<td>slightly warm</td>
<td>never</td>
<td>moderately acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Slightly comfortable</td>
<td>neutral</td>
<td>never</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
</tr>
</tbody>
</table>
Figure C11. Survey 3 Question 2: Seasonal Comfort

Figure C12. Survey 3 Question 3: Thermal comfort at time of survey distribution

Figure C13. Survey 3 Question 4: Frequency of use of wall-mounted controls
Table C4. Survey 4: KMC 185, 12:50pm, Outdoor Temperature: 84.0, Indoor Temperature: 74.84

<table>
<thead>
<tr>
<th>Student</th>
<th>Seasonal</th>
<th>Comfort at Time of Survey</th>
<th>Control Use</th>
<th>Air Quality</th>
<th>Information Source</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Neutral</td>
<td>slightly cool</td>
<td>never</td>
<td>clearly acceptable</td>
<td>Professor</td>
<td>rooms with auto windows and fans get too cold too fast. During a 90F summer day we travel lightly clothes so entering a computer lab or classroom that is 60F with the way</td>
</tr>
<tr>
<td>2</td>
<td>Slightly uncomfortable</td>
<td>cool</td>
<td>never</td>
<td>clearly acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td>I am uninformed about the sustainable features of this building</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Neutral</td>
<td>neutral</td>
<td>did not know this was an option</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The smell of the restaurant that is in the building is not cool</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Very uncomfortable</td>
<td>hot</td>
<td>sometimes</td>
<td>clearly unacceptable</td>
<td>Should look after keeping students comfort instead of sustainability. I could care less about sustainability when I am sweating trying to learn.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Neutral</td>
<td>slightly cool</td>
<td>never</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Thank you</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Very comfortable</td>
<td>neutral</td>
<td>did not know this was an option</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Neutral</td>
<td>cool</td>
<td>never</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Very comfortable</td>
<td>slightly cool</td>
<td>sometimes</td>
<td>clearly acceptable</td>
<td>Professor</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Most of the time it's fine</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Slightly uncomfortable</td>
<td>slightly warm</td>
<td>never</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Very uncomfortable</td>
<td>hot</td>
<td>Often</td>
<td>clearly unacceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>The downstairs classrooms are always stuffy/too hot. No air flow in bathrooms. Shame.</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Slightly comfortable</td>
<td>neutral</td>
<td>never</td>
<td>Just unacceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>neutral</td>
<td>never</td>
<td>moderately acceptable</td>
<td>Professor</td>
<td>Note</td>
</tr>
<tr>
<td>---</td>
<td>---------</td>
<td>---------</td>
<td>----------</td>
<td>-----------------------</td>
<td>-------------</td>
<td>--------------------------------------------------------</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Surprisingly very comfortable and love the concept.</td>
</tr>
<tr>
<td>13</td>
<td>Very comfortable</td>
<td>neutral</td>
<td>never</td>
<td>clearly acceptable</td>
<td>Professor</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Neutral</td>
<td>slightly cool</td>
<td>never</td>
<td>clearly acceptable</td>
<td>Professor</td>
<td></td>
</tr>
</tbody>
</table>

**Figure C16. Survey 4 Question 2: Seasonal Comfort**

**Figure C17. Survey 4 Question 3: Thermal comfort at time of survey distribution**
Figure C18. Survey 4 Question 4: Frequency of use of wall-mounted controls

Figure C19. Survey 4 Question 5: Perceived air quality

Figure C20. Survey 4 Question 6: Source of information regarding sustainable features of the KMC
<table>
<thead>
<tr>
<th>Student</th>
<th>Seasonal</th>
<th>Comfort at Time of Survey</th>
<th>Control Use</th>
<th>Air Quality</th>
<th>Information Source</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Slightly uncomfortable</td>
<td>slightly warm</td>
<td>sometimes</td>
<td>Just acceptable</td>
<td>Professor</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Slightly uncomfortable</td>
<td>slightly warm</td>
<td>sometimes</td>
<td>Just acceptable</td>
<td>Students, professor</td>
<td>Good comic relief</td>
</tr>
<tr>
<td>3</td>
<td>Very comfortable</td>
<td>neutral</td>
<td>sometimes</td>
<td>clearly acceptable</td>
<td>I am uninform ed about the sustainable features of this building</td>
<td>I am very happy with it. Love hot weather.</td>
</tr>
<tr>
<td>4</td>
<td>Neutral</td>
<td>slightly warm</td>
<td>never</td>
<td>clearly acceptable</td>
<td>I am uninform ed about the sustainable features of this building</td>
<td>I love the building, just sometimes gets stuffy</td>
</tr>
<tr>
<td>5</td>
<td>Neutral</td>
<td>slightly warm</td>
<td>Often</td>
<td>Just acceptable</td>
<td>I am uninform ed about the sustainable features of this building</td>
<td>Noisy window. Too frequent opening and closing</td>
</tr>
<tr>
<td>6</td>
<td>Neutral</td>
<td>slightly warm</td>
<td>never</td>
<td>Just acceptable</td>
<td>Professor</td>
<td>Comfort is ok, just a little warm. The window noises are distracting though.</td>
</tr>
<tr>
<td>7</td>
<td>Slightly uncomfortable</td>
<td>neutral</td>
<td>sometimes</td>
<td>Just acceptable</td>
<td>I am uninform ed about the sustainable features of this building</td>
<td>Too close to the street, so the street noise is annoying. The window is working too loud.</td>
</tr>
<tr>
<td>8</td>
<td>Very uncomfortable</td>
<td>slightly warm</td>
<td>did not know this was an option</td>
<td>Just acceptable</td>
<td>I am uninform ed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Neutral</td>
<td>slightly warm</td>
<td>sometimes</td>
<td>Just acceptable</td>
<td>I am uninform ed about the sustainable features of this building</td>
<td>Can we just have A/C please?</td>
</tr>
<tr>
<td>10</td>
<td>Slightly uncomfortable</td>
<td>slightly cool</td>
<td>Often</td>
<td>Just unacceptable</td>
<td>Professor</td>
<td>Do better</td>
</tr>
<tr>
<td>11</td>
<td>Slightly uncomfortable</td>
<td>hot</td>
<td>did not know this was an option</td>
<td>neutral</td>
<td>I am uninform ed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Temperature</td>
<td>Comfort Level</td>
<td>Remarks</td>
<td>Authors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>-------------</td>
<td>---------------</td>
<td>---------</td>
<td>---------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Very uncomfortable</td>
<td>hot</td>
<td>sometimes</td>
<td>moderately unacceptable</td>
<td>Professor</td>
<td>Very uncomfortable to sit in class. Seems Skanska and architects did not consider this in the design.</td>
</tr>
<tr>
<td>13</td>
<td>Slightly comfortable</td>
<td>slightly warm</td>
<td>did not know this was an option</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Slightly uncomfortable</td>
<td>slightly warm</td>
<td>sometimes</td>
<td>clearly acceptable</td>
<td>Professor</td>
<td>The classroom is usually really warm and the glass windows are very distracting (loud opening, people/activities outside) but I appreciate the green efforts of the design. :-)</td>
</tr>
<tr>
<td>15</td>
<td>Very uncomfortable</td>
<td>slightly warm</td>
<td>sometimes</td>
<td>Just unacceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Neutral</td>
<td>neutral</td>
<td>did not know this was an option</td>
<td>moderately acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Very uncomfortable</td>
<td>hot</td>
<td>sometimes</td>
<td>Just unacceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
</tbody>
</table>

The room is also disrupted with windows and people constantly walking by and talking/shouting. Protests have gone by disrupting the class.

It's hot all the time. The windows are distracting with the noise (closing and opening) and the noise of the people. Some classrooms not all fans work at once.
<table>
<thead>
<tr>
<th>Room</th>
<th>Comfort</th>
<th>Temperature</th>
<th>Condition</th>
<th>Rating</th>
<th>Review</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>Slightly uncomfortable</td>
<td>Slightly warm</td>
<td>Did not know this was an option</td>
<td>Just unacceptable</td>
<td>I am uninformed about the sustainable features of this building. Automatic windows opening was always at the worst time possible and at ground level/street level it can get loud. Fans and window opening also doesn't always keep the room cool (I've come close to frying in the 190 room when the door wasn't open). Also the fishtank feel can make passerbys distracting. Finally, did anyone seriously read this?</td>
</tr>
<tr>
<td>19</td>
<td>Slightly uncomfortable</td>
<td>Hot</td>
<td>Sometimes</td>
<td>Just unacceptable</td>
<td>Professor, building operators</td>
</tr>
<tr>
<td>20</td>
<td>Slightly uncomfortable</td>
<td>Slightly warm</td>
<td>Did not know this was an option</td>
<td>Neutral</td>
<td>Professor</td>
</tr>
<tr>
<td>21</td>
<td>Neutral</td>
<td>Slightly warm</td>
<td>Often</td>
<td>Clearly acceptable</td>
<td>Building operator</td>
</tr>
</tbody>
</table>
Figure C21. Survey 5 Question 2: Seasonal Comfort

Figure C22. Survey 5 Question 3: Thermal comfort at time of survey distribution

Figure C23. Survey 5 Question 4: Frequency of use of wall-mounted controls
### Figure C24. Survey 5 Question 5: Perceived air quality

![Air quality perception chart]

### Figure C25. Survey 5 Question 6: Source of information regarding sustainable features of the KMC

![Source of information chart]

### Table C6. Survey 6: KMC 295, 10:30am, Outdoor Temperature: 77.0, Indoor Temperature: 71.2

<table>
<thead>
<tr>
<th>Student</th>
<th>Seasonal</th>
<th>Comfort at Time of Survey</th>
<th>Control Use</th>
<th>Air Quality</th>
<th>Information Source</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Neutral</td>
<td>neutral</td>
<td>sometimes</td>
<td>moderately acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Neutral</td>
<td>slightly warm</td>
<td>never</td>
<td>Just acceptable</td>
<td>Professor</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Slightly comfortable</td>
<td>slightly cool</td>
<td>sometimes</td>
<td>clearly acceptable</td>
<td>Professor</td>
<td>Good job!</td>
</tr>
<tr>
<td>4</td>
<td>Slightly comfortable</td>
<td>neutral</td>
<td>did not know this was an option</td>
<td>moderately acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td></td>
<td>V. comfortable</td>
<td>neutral</td>
<td>never</td>
<td>clearly acceptable</td>
<td>other</td>
<td>building</td>
</tr>
<tr>
<td>---</td>
<td>----------------</td>
<td>---------</td>
<td>-------</td>
<td>--------------------</td>
<td>------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>5</td>
<td>Very comfortable</td>
<td>neutral</td>
<td>never</td>
<td>clearly acceptable</td>
<td>other</td>
<td>Yay!</td>
</tr>
<tr>
<td>6</td>
<td>Neutral</td>
<td>neutral</td>
<td>did not know this was an option</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Slightly comfortable</td>
<td>cool</td>
<td>never</td>
<td>Just unacceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Neutral</td>
<td>slightly cool</td>
<td>Often</td>
<td>clearly acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Slightly comfortable</td>
<td>slightly cool</td>
<td>never</td>
<td>clearly acceptable</td>
<td>sustainability office</td>
<td>Feels good today</td>
</tr>
<tr>
<td>10</td>
<td>Very comfortable</td>
<td>neutral</td>
<td>never</td>
<td>Just unacceptable</td>
<td>other</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Very comfortable</td>
<td>slightly cool</td>
<td>never</td>
<td>clearly acceptable</td>
<td>sustainability office</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Slightly comfortable</td>
<td>neutral</td>
<td>did not know this was an option</td>
<td>moderately acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Neutral</td>
<td>slightly cool</td>
<td>did not know this was an option</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Slightly uncomfortable</td>
<td>slightly warm</td>
<td>never</td>
<td>Just unacceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Slightly comfortable</td>
<td>slightly cool</td>
<td>never</td>
<td>clearly acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Very comfortable</td>
<td>slightly warm</td>
<td>never</td>
<td>clearly acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td>Pleasant and quiet</td>
</tr>
<tr>
<td></td>
<td>Heating</td>
<td>Cooling</td>
<td>Humidity</td>
<td>Comfort</td>
<td>Notes</td>
<td>Sustainable Features</td>
</tr>
<tr>
<td>---</td>
<td>---------</td>
<td>---------</td>
<td>----------</td>
<td>---------</td>
<td>------------------------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>17</td>
<td>Neutral</td>
<td>neutral</td>
<td>never</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td>Thank You</td>
</tr>
<tr>
<td>18</td>
<td>Very comfortable</td>
<td>slightly cool</td>
<td>never</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Very comfortable</td>
<td>slightly warm</td>
<td>never</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Slightly comfortable</td>
<td>neutral</td>
<td>sometimes</td>
<td>neutral</td>
<td>Professor</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Neutral</td>
<td>slightly warm</td>
<td>never</td>
<td>moderately acceptable</td>
<td>Professor</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Neutral</td>
<td>slightly warm</td>
<td>sometimes</td>
<td>moderately acceptable</td>
<td>other</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Slightly comfortable</td>
<td>neutral</td>
<td>sometimes</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td>Sometimes fans get too windy</td>
</tr>
<tr>
<td>24</td>
<td>Neutral</td>
<td>neutral</td>
<td>never</td>
<td>moderately acceptable</td>
<td>Good!</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Neutral</td>
<td>neutral</td>
<td>never</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Slightly uncomfortable</td>
<td>slightly warm</td>
<td>did not know this was an option</td>
<td>Just unacceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td>It's hot</td>
</tr>
<tr>
<td>27</td>
<td>Very comfortable</td>
<td>neutral</td>
<td>never</td>
<td>moderately acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td>Nice room, little weird walking by glass walls when entering room</td>
</tr>
<tr>
<td>28</td>
<td>Neutral</td>
<td>slightly cool</td>
<td>did not know this was an option</td>
<td>clearly acceptable</td>
<td>I am uninformed about the sustainable features of this building</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>Slightly uncomfortable</td>
<td>slightly cool</td>
<td>never</td>
<td>Just acceptable</td>
<td>I am uninformed about the sustainable</td>
<td></td>
</tr>
</tbody>
</table>
Table 6: Survey 6 Question 2: Seasonal Comfort

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral</td>
<td>30</td>
</tr>
<tr>
<td>Slightly warm</td>
<td>5</td>
</tr>
<tr>
<td>Never</td>
<td>2</td>
</tr>
<tr>
<td>Neutral</td>
<td>14</td>
</tr>
<tr>
<td>Slightly warm</td>
<td>7</td>
</tr>
<tr>
<td>Very comfortable</td>
<td>3</td>
</tr>
<tr>
<td>Very comfortable</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure C26. Survey 6 Question 2: Seasonal Comfort

Figure C27. Survey 6 Question 3: Thermal comfort at time of survey distribution
Figure C28. Survey 6 Question 4: Frequency of use of wall-mounted controls

Figure C29. Survey 6 Question 5: Perceived air quality

Figure C30. Survey 6 Question 6: Source of information regarding sustainable features of the KMC
Appendix D: Deployment of Temperature & Air Quality Instruments

Deployment of Temperature & Air Quality Instruments

KMC Research

The purpose of this deployment is to examine occupant satisfaction in Karl Miller Center (KMC), with the aim of comparing patterns to holding classrooms in the summer term.

1. Instruments

<table>
<thead>
<tr>
<th>Type of Instrument</th>
<th>Department</th>
<th>Number (EA)</th>
<th>Location(s)</th>
<th>Measurement(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purple Airs</td>
<td>Elliott's Lab</td>
<td>15</td>
<td>Indoor 11 / Outdoor 4</td>
<td>Particulants</td>
</tr>
<tr>
<td>Tripods</td>
<td>CPC</td>
<td>2</td>
<td>Outdoor (3rd floor)</td>
<td>-</td>
</tr>
<tr>
<td>KMC weekly report</td>
<td>CPC</td>
<td>-</td>
<td>-</td>
<td>Temperature, CO2, RH</td>
</tr>
<tr>
<td>Kestrel Data Loggers</td>
<td>BUILT Lab</td>
<td>15</td>
<td>Indoor 11 / Outdoor 4</td>
<td>Temperature, RH</td>
</tr>
<tr>
<td>HOBO Weather Station</td>
<td>GBRL</td>
<td>1</td>
<td>Roof - Secured as the door to the roof is locked</td>
<td>Wind speed &amp; direction</td>
</tr>
</tbody>
</table>

2. Deployment Locations

- Locations: Purple Airs and Kestrel Data Loggers will be located at Indoor and outdoor areas based on its characteristics; Daylight, a location of windows, and a number of frequent complaints.

<table>
<thead>
<tr>
<th>Floor</th>
<th>Indoor</th>
<th>Outdoor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st floor</td>
<td>Room 190</td>
<td>Two spots on the patio (North and East)</td>
</tr>
<tr>
<td>2nd floor</td>
<td>Room 295, Room 255</td>
<td>Two spots on the patio (South and West)</td>
</tr>
<tr>
<td>3rd floor</td>
<td>Room 385, Room 350, Room 390</td>
<td>Weather station</td>
</tr>
<tr>
<td>4th floor</td>
<td>Room 480, Room 465, Room 495</td>
<td></td>
</tr>
<tr>
<td>5th floor</td>
<td>Room 580, Room 570</td>
<td></td>
</tr>
<tr>
<td>Roof</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Picture Reference
4. Floor Plans

- 1st & 2nd floors

- 3rd & 4th floors
## 5. Deployment Placement details

<table>
<thead>
<tr>
<th>Location</th>
<th>Purple Air (last 4 digits)</th>
<th>Kestrel (last 3 digits)</th>
<th>Placement</th>
<th>Picture reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room 190</td>
<td>EC FA BC B B1 6F</td>
<td>2209219</td>
<td>5.9m from West wall</td>
<td><img src="image_url" alt="Image" /></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7.2m from North windows</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.0m from floor</td>
<td></td>
</tr>
<tr>
<td>Room 295</td>
<td>84 F3 EB 45 31 65</td>
<td>2209180</td>
<td>7.2m from West wall 6.4m from North windows 3.0m from floor</td>
<td></td>
</tr>
<tr>
<td>Room 255</td>
<td>84 F3 EB 91 44 79</td>
<td>2209163</td>
<td>7.3m from West windows 6.1m from North wall 3.0m from floor</td>
<td></td>
</tr>
<tr>
<td>Room 350</td>
<td>84 F3 EB 45 60 5C</td>
<td>2209239</td>
<td>3.7m from North wall 2.7m from West wall 3.4m from floor</td>
<td></td>
</tr>
<tr>
<td>Room 390</td>
<td>68 C6 3A AE 59 42</td>
<td>2209182</td>
<td>6.1m from West wall 6.5m from North windows 3.0m from floor</td>
<td></td>
</tr>
<tr>
<td>Room</td>
<td>Location Details</td>
<td>Cad Number</td>
<td>Distance Details</td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>------------------</td>
<td>------------</td>
<td>------------------</td>
<td></td>
</tr>
</tbody>
</table>
| Room 385 | 84 F3 EB 91 44 3D | 2209232 | 5.6m from West wall  
6.3m from North windows  
3.0m from floor |
| Room 465 | 68 C6 3A 89 1D 78 | 2209257 | 5.0m from West wall  
6.5m from North wall  
3.0m from floor |
| Room 480 | 5C CF 7F 5C 9E 2D | 2209227 | 2.9m from West wall  
6.0m from North windows  
3.0m from floor |
| Room 495 | 68 C6 38 8E 8D 7 | 2209061 | 6.8m from West wall  
9.0m from North windows  
3.0m from floor |
| Room 560 | 60 194 4B 45 85 | 2209276 | 2.2m from West wall  
5.2m from North windows  
3.1m from floor |
|----------|----------------|---------|----------------------------------|
| Room 580 | 60 194 58 F0 D8 | 2209050 | 5.8m from West wall  
5.8m from North windows  
3.0m from floor |
| 3rd-floor Outdoor 1 | 60 194 58 D8  
60 194 58 D8 D1 | 2209248 | |
<p>| 3rd-floor Outdoor 2 | 84 F3 E8 B9 8E 9 | 2209173 | |</p>
<table>
<thead>
<tr>
<th>Location</th>
<th>ID</th>
<th>Distance Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>5th-floor</td>
<td>84 F3</td>
<td>31.6m from West wall 0m from North wall</td>
</tr>
<tr>
<td>Outdoor 1</td>
<td>EB 94</td>
<td>1.25m from floor</td>
</tr>
<tr>
<td></td>
<td>5A</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9th-floor</td>
<td>60 1</td>
<td>28.6m from West wall 0m from South wall</td>
</tr>
<tr>
<td>Outdoor 2</td>
<td>94 4B</td>
<td>1.1m from floor</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td></td>
</tr>
<tr>
<td></td>
<td>79</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roof</td>
<td>-</td>
<td>4.3m from West wall 4.8m from North wall</td>
</tr>
<tr>
<td>Weather</td>
<td>-</td>
<td>1.2m from floor</td>
</tr>
<tr>
<td>station</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figure D1: Sensor deployment details & locations*
Appendix E: AIM Complaints

**KMC AIM Complaints**

- **2018 Summer (May 1st ~ Aug 15th)**

- **2019 Summer (May 1st ~ Aug 15th)**

- **2018 Summer Work order details**

<table>
<thead>
<tr>
<th>Work Order</th>
<th>Date Created</th>
<th>Floor</th>
<th>Location</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>19-03146</td>
<td>8/1/2018</td>
<td>1st</td>
<td>Renovated</td>
<td>Too hot</td>
<td>KMC 150 -- room has been getting warmer than normal, the customer didn't indicate that any immediate action needed to be done they wanted this issue to be looking into for the future</td>
</tr>
<tr>
<td>18-27678</td>
<td>5/29/2018</td>
<td>2nd</td>
<td>Renovated</td>
<td>Too hot</td>
<td>Hello - I was wondering if you had an office fan for 230M Karl Miller School of Business. When the door is closed during appointments the room becomes extremely hot.</td>
</tr>
<tr>
<td>18-27851</td>
<td>5/31/2018</td>
<td>2nd</td>
<td>Renovated</td>
<td>Too hot</td>
<td>KMC 245 -- SECOND FLOOR -- Dept: ryan depauw --It is almost 80 degrees in this room, according ot the thermostat I can barely breathe, and it's too loud in the hallway to open a door. Could you fix the air in here? notified Jason</td>
</tr>
<tr>
<td>18-20371</td>
<td>6/21/2018</td>
<td>2nd</td>
<td>Renovated</td>
<td>Too hot</td>
<td>KMC -- Graduate School of Business -- Hello Sarah requested AC to be on for KMC, I misinformed her about the AC in the building so I'm not sure what areas she needs the AC to be on in. Please follow up with her, she needs this done for this weekend</td>
</tr>
<tr>
<td>19-01871</td>
<td>7/16/2018</td>
<td>2nd</td>
<td>Renovated</td>
<td>Too hot</td>
<td>KMC 255 -- SECOND FLOOR -- Index: CMPG01 -- Dept.: Computer Science --The temperature in Karl Miller Center, room 255, is hoovering around 75 degrees. This is a 60 person classroom. Add 60 people in the room and their c...</td>
</tr>
<tr>
<td>19-02607</td>
<td>7/30/2018</td>
<td>2nd</td>
<td>Renovated</td>
<td>Too hot</td>
<td>KMC 210 -- SECOND FLOOR -- Index: SBAG10 -- It is about 10 degrees warmer in 210 than it is out in the hallway. Please help us correct airflow issues before it gets even hotter! -- contacted Jason Luce</td>
</tr>
<tr>
<td>19-04160</td>
<td>8/20/2018</td>
<td>2nd</td>
<td>Renovated</td>
<td>Too cold</td>
<td>KMC 255 room too cold -- Left VM for Jason</td>
</tr>
<tr>
<td>19-04057</td>
<td>8/29/2018</td>
<td>2nd</td>
<td>Renovated</td>
<td>Too hot</td>
<td>KMC 220 -- SECOND FLOOR -- Index: SBAG03 -- office 220 and 220c are hot/stuffy and it seems like the vents aren't working -- called Jason Luce</td>
</tr>
<tr>
<td>Work Order</td>
<td>Date Created</td>
<td>Location</td>
<td>Floor</td>
<td>Type</td>
<td>Description</td>
</tr>
<tr>
<td>------------</td>
<td>--------------</td>
<td>----------</td>
<td>-------</td>
<td>------</td>
<td>-------------</td>
</tr>
<tr>
<td>19-01969</td>
<td>7/17/2018</td>
<td>3rd</td>
<td>Renovated</td>
<td>Too hot</td>
<td>KMC 3200 -- THIRD FLOOR -- Office is 75 degrees - too hot to work in. Can something be done for this ASAP? notified Julio</td>
</tr>
<tr>
<td>19-02495</td>
<td>7/28/2018</td>
<td>3rd</td>
<td>Renovated</td>
<td>Too hot</td>
<td>KMC 3200 -- THIRD FLOOR -- This office is too warm. It is at 74 degrees. Can someone please turn the temp down ASAP before it gets hotter outside?</td>
</tr>
<tr>
<td>19-02608</td>
<td>7/30/2018</td>
<td>3rd</td>
<td>Renovated</td>
<td>Too hot</td>
<td>KMC 3200 -- THIRD FLOOR -- Dept.: School of Business -- Please come turn down the thermostat in the Dean's Office. It is 78 degrees and climbing. Thanks! -- contacted Jason Luce</td>
</tr>
<tr>
<td>18-25974</td>
<td>5/4/2018</td>
<td>3rd</td>
<td>Pavilion</td>
<td>Too hot</td>
<td>KMC 380 -- THIRD FLOOR -- The ceiling fan nearest the instructor podium in classroom 380 clicks when running and is distracting students. Fridays are a good time because there are no classes scheduled. The room is heavily used during other days.</td>
</tr>
<tr>
<td>18-26902</td>
<td>5/17/2018</td>
<td>4th</td>
<td>Renovated</td>
<td>Too hot</td>
<td>KMC -- FOURTH FLOOR -- The KMC is too hot! I sweat through all of my clothes in every class, every single day. Instructors and students have also complained about this. I have to change my clothes every time I come home for...</td>
</tr>
<tr>
<td>18-29493</td>
<td>6/25/2018</td>
<td>4th</td>
<td>Renovated</td>
<td>Too hot</td>
<td>Room 460 in KMC was too hot. Jason Luce was notified, please add phase for systems</td>
</tr>
<tr>
<td>18-29575</td>
<td>6/25/2018</td>
<td>4th</td>
<td>Renovated</td>
<td>Too hot</td>
<td>ONE CALL: 6/23/18 Sarah Schroeder reported that room 460 in KMC was too hot. Jason Luce was notified, please add phase for systems</td>
</tr>
<tr>
<td>18-27861</td>
<td>5/31/2018</td>
<td>6th</td>
<td>Renovated</td>
<td>Too hot</td>
<td>KMC 560 -- FIFTH FLOOR -- it is currently 78 degrees in this room although it feels hotter, even though the windows are open. Please turn on the AC or bring a fan as soon as possible notified Jason</td>
</tr>
<tr>
<td>18-28741</td>
<td>6/12/2018</td>
<td>5th</td>
<td>Renovated</td>
<td>Too cold</td>
<td>KMC 570 -- FIFTH FLOOR -- The lab is very cold and some users are requesting to have the ac turned off.</td>
</tr>
<tr>
<td>18-26330</td>
<td>5/8/2018</td>
<td>6th</td>
<td>Pavilion</td>
<td>Too hot</td>
<td>KMC 580 -- FIFTH FLOOR -- Faculty member reported the ceiling fans are not working and students are complaining the room is too hot.</td>
</tr>
<tr>
<td>18-29098</td>
<td>6/18/2018</td>
<td>6th</td>
<td>Renovated</td>
<td>Too cold</td>
<td>KMC 605 -- SIXTH FLOOR -- Index: ISP110 -- Room is usually very cold. Please come and check it out, and perhaps reset the thermostat. Thank you!</td>
</tr>
</tbody>
</table>

- **2019 Summer Work order details**

<table>
<thead>
<tr>
<th>Work Order</th>
<th>Date Created</th>
<th>Location</th>
<th>Floor</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>19-26142</td>
<td>6/12/2019</td>
<td>Pavilion</td>
<td>1st</td>
<td>Operational</td>
<td>KMC 190 -- FIRST FLOOR -- The fan closest to the door won't start.</td>
</tr>
<tr>
<td>19-26292</td>
<td>6/14/2019</td>
<td>Renovated</td>
<td>2nd</td>
<td>Too cold</td>
<td>KMC KMC 265 -- SECOND FLOOR -- The classroom is 64 degrees and the class is very cold for their final exam.</td>
</tr>
<tr>
<td>20-02846</td>
<td>7/30/2019</td>
<td>Pavilion</td>
<td>2nd</td>
<td>Operational</td>
<td>KMC room 285 ceiling fans not working Jason luce</td>
</tr>
<tr>
<td>20-03647</td>
<td>8/8/2019</td>
<td>Pavilion</td>
<td>2nd</td>
<td>Operational</td>
<td>KMC -- Assistance turning on fan (contacted Mike McBride)</td>
</tr>
<tr>
<td>19-23796</td>
<td>5/16/2019</td>
<td>Renovated</td>
<td>3rd</td>
<td>Too cold</td>
<td>KMC 3200 -- THIRD FLOOR -- Office is too cold, please turn temperature up</td>
</tr>
<tr>
<td>20-02121</td>
<td>7/10/2019</td>
<td>Renovated</td>
<td>5th</td>
<td>Too cold</td>
<td>KMC 570 OIT Lab -- FIFTH FLOOR -- The AC in the room is too cold. Can you adjust it down a bit please? Thank you</td>
</tr>
<tr>
<td>19-23600</td>
<td>5/14/2019</td>
<td>Renovated</td>
<td>6th</td>
<td>Too cold</td>
<td>KMC 610A -- SIXTH FLOOR -- Dept.: International Affairs -- Please allow me to turn OFF the AC in my office.</td>
</tr>
<tr>
<td>19-23797</td>
<td>5/16/2019</td>
<td>Renovated</td>
<td>6th</td>
<td>Too cold</td>
<td>KMC 630B -- Room is too cold -- Notified Jason</td>
</tr>
<tr>
<td>19-24390</td>
<td>5/22/2019</td>
<td>Renovated</td>
<td>6th</td>
<td>Too cold</td>
<td>KMC 602 -- Room is too cold. This is a reoccurring issue with this room and Karin is requesting if someone could investigate what is going on there. Notified Julio</td>
</tr>
<tr>
<td>19-25988</td>
<td>6/10/2019</td>
<td>Renovated</td>
<td>6th</td>
<td>Too cold</td>
<td>KMC 610A -- want to close the AC vent in my office. How can we make that happen? Its cold in KMC 610A and I have two sweaters on already.</td>
</tr>
<tr>
<td>19-27037</td>
<td>6/26/2019</td>
<td>Renovated</td>
<td>6th</td>
<td>Too cold</td>
<td>KMC -- 605 -- Cold room</td>
</tr>
<tr>
<td>20-00055</td>
<td>7/1/2019</td>
<td>Renovated</td>
<td>6th</td>
<td>Too cold</td>
<td>KMC -- 605 -- Cold room. Left VMs for Jason Luce &amp; Dave Hurley.</td>
</tr>
<tr>
<td>20-02825</td>
<td>7/29/2019</td>
<td>Renovated</td>
<td>6th</td>
<td>Too cold</td>
<td>KMC 610A -- Please turn OFF the vent in this room (610A, KMC) cuz it's so freaking cold! Yes, I'm already wearing a sweater.</td>
</tr>
</tbody>
</table>

*Figure E1: Complaints on summer 2018 vs. 2019*