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Campus Electrical Map: Financial Repercussions of Failures

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CAMPUS ELECTRICAL MAP: FINANCIAL REPERCUSSIONS OF FAILURES

by

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Abstract

This thesis will find costs for electrical outages on campus. The costs will be for three different major classifications of buildings, and will be done on a square foot-hour basis. The three different classifications are academic, dining, and dormitory space. For each square foot of space that is out of power for an hour, a number will be calculated that will allow for extrapolation onto other buildings of the same classification. This thesis is a case study, and will only cover three different types of buildings determined to be an accurate representation of their classification. Also, only buildings on the West Substation feeders will be considered, as they are attached to the substation with the greatest chance of failure. This thesis begins with a short introduction to set the stage and identify the necessity of this case study. The next segment determines the cost of an academic space, followed by a dining space, followed by a dormitory space. Then, the following segment draws conclusions regarding each space, and speaks to any unaccountables, such as common spaces, conference and meeting rooms, etc.. The final section talks about implications and results, and draws conclusions regarding findings. In order to determine the costs per square foot, information was gathered from Dining Services, Facilities Management, Housing Department, and individuals who work for each department. The results are as follows:

For a square foot of space in a dormitory building, the cost is 1.1 cents/ hour.

For a square foot of space in an academic building, the cost is $3.73 dollars/hour.

For a square foot of space in a dining building, the cost is 3.2 cents/hour.

Dedication

I would like to dedicate this thesis to my family. They have worked very hard to allow me this opportunity to attend school, as well as instilled a strong work ethic that many describe as insane. I have worked my hardest to make sure that I am making this college experience one to be proud of. A thank you goes out to my mother, for always challenging me. My brothers Tristan and Kaden, and my sister Bryn, a large thank you goes out to you, I cannot say how many times you each have had to sacrifice just to let me focus on my schoolwork. To my late father, I would like to quote a poem written and read by his co-scoutmaster, James Murphy, at the funeral.

"And it's to you I thank
You've walked with me through life,
And, on this, my final hike,
I'm walking with you now,
'Over the next horizon'."

Acknowledgements

This thesis was not completed alone, and with help from the following individuals, was able to come to fruition. Acknowledgements include:

- Laurie Kenny, in the Office of Undergraduate Admission, for help with finding numbers for the in state students and out of state students. These numbers were used to determine proportions for in state and out of state students.
- Philip Dunn, in the Civil Engineering Department, for vetting calculations for the dormitories, academic, and dining halls. He was able to look over the base math and find small errors that were fixed.
- Glenn Taylor and Kenneth Violette, from Dining Services, for providing the raw data used to determine student flow per hour, as well as a ratio for dining hall usage to square footage.
- Brian Foley, from the University of Maine Engineering Shop, for providing floor plans and square footage numbers for York Dining, and Dunn Hall.
- Sally Clark in Auxiliary Services, for providing square footage numbers and floor plans for rooms in Estabrooke.
- Lori Smith, in the Office of Institutional Research, for providing me with number for the proportions of in state and out of state students.
- My advisor for my Honors Thesis and my committee, each and every individual gave amazing suggestions and input that lead to the following thesis. This could not have come together the way it has without their support and constructive criticism.

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Introduction

What this thesis seeks to do is to quantify the cost of a power outage for 3 different classifications of buildings. It seeks to provide perspective to people who are not necessarily knowledgeable regarding the fields of electricity or the financial repercussions of these outages. The thesis is written as a case study, so that the data can be expanded onto other spaces with the same classifications. The reason for doing this thesis revolves around the work I completed in my engineering capstone. I worked with two other individuals on analyzing the electrical system of the University of Maine Orono campus. We found that there were some issues that needed to be addressed, which included the removal of a substation that is less reliable than it should be. This reliability issue is due to its age, the fact it is fed by a distribution line with variable load upstream, and the overloading that the substation experiences on a regular basis. This substation is the “West Substation”, also known as the “Steamplant Substation” due to its location. In our simulations, we found that it was the weakest source on campus, and had been overloaded consistently out of necessity, and so would be the most likely to fail. These results can be seen in Appendix 14, “Results From Senior Capstone”.

The University of Maine Orono will need to keep a close eye on electricity usage and projected growth, and perform maintenance on the electrical system to keep anything catastrophic from happening to any buildings connected to the West Substation on campus. The issue stands that people making budgeting decisions do not always have a full idea of how urgent something may be, as they may lack the requisite knowledge to understand the technical aspects associated with the problem. This thesis paper will confront the problem using tuition, housing, and food cost numbers as stated by the University to determine the cost to the students if there were a power outage in either an academic, dorm, or dining facility. The size of the building will be determined via plans provided by an engineer on campus, Brian Foley. The usage of the building will either be assumed or calculated through usage numbers from the University. The final piece of the puzzle will be determining the cost of an outage for a square foot of a building, so that the approximate cost of an outage for any building of that type (academic, dining, dorm) can be calculated based on its square footage. The thesis will also consider the energy future the University hopes to achieve, as well as the roadblocks to that future imposed by a subpar electrical system.

Background

The University of Maine is becoming the most popular university in the state of Maine, and has seen continued enrollment growth since 2014 (Citation 1). The University of Maine Orono campus is the flagship of the University of Maine system, and for good reason. It is one of the foremost research institutions in the Northeast, and is one of the leaders of the green campus movement. It ranked 26th in the "Princeton Green Guide's top 50 Green College Campuses" for 2015 (Citation 2). Apart from the continued growth of the campus, The University of Maine Orono is also looking to achieve carbon neutrality by 2040 (Citation 13), and has pledged to do so. The University appears very conscious of its environmental footprint, and also is projected to have a steady enrollment increase (Citation 1). The University finds itself in a very precarious position however. Based on a recent Sightlines report, the University of Maine Orono (Citation 13) is spending less than its peers in daily service maintenance(Page 41). As you can see from Figure 1, utilities have contributed the most to growth of cost per gross square foot in the 2015 fiscal year.

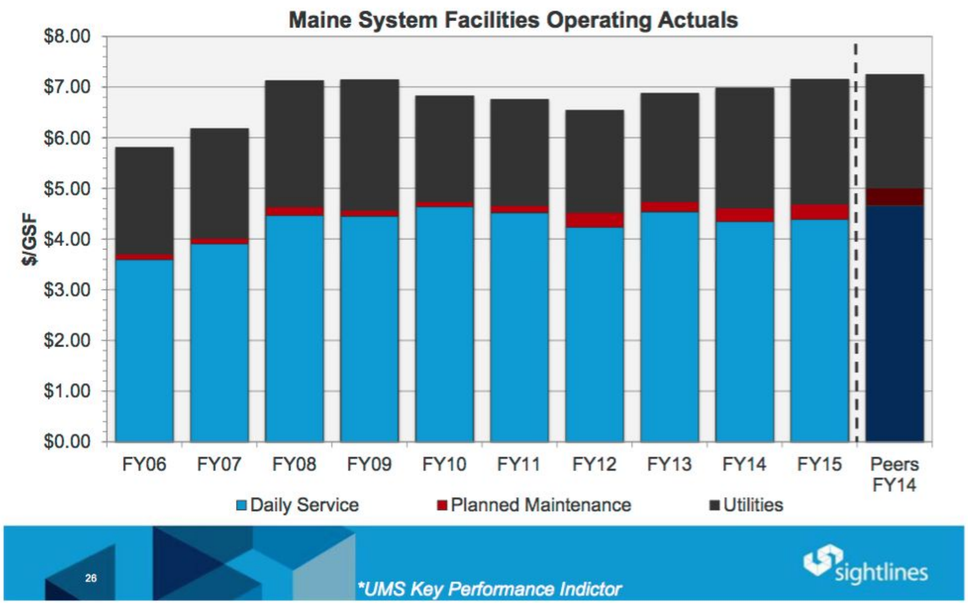

Figure 1: UMS Operating Costs/ Gross Square Foot

The University has also seen less investment in preventative maintenance on average as compared to its peers, from the same Sightlines report. This preventative maintenance is something that will play a key role in the University's future during its projected growth period. To keep costs consistent, the University needs to start performing more preventative maintenance than it is currently. With a high number of buildings over 50 years old, we are left with infrastructure that has nearly outlived its usable lifespan. This, coupled with continued growth, could create challenges for the campus. Without getting the proper funding from budgetary committees, the facilities management department will be unable to increase maintenance, as they do not have the funds. Also, if the University of Maine wants to incorporate renewable energy (solar panels for instance), which is one of the considerations for a higher score on the "Green Honor Roll", the administration will need to be prepared to invest in making the grid on campus much more robust.

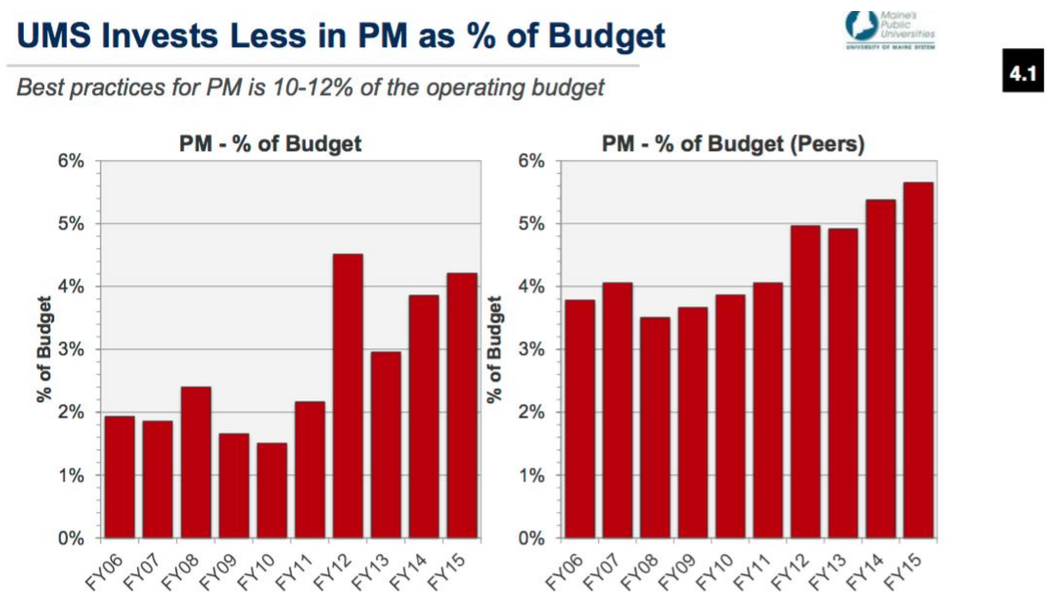

Figure 2: Investment in Preventative Maintenance per year as % of Budget

Based upon the most recent campus master plan (Citation 13), the University has also seen a steady increase in per capita emissions in the recent past, with a rise from 4.94 tonnes to 6.02 tonnes (Pg. 118, Citation 13). This steady increase means that the University, in order to maintain it's position as a sustainable and green campus, will need to increase the amount of renewable energy that is used to feed demand. This will help to offset the per capita carbon footprint. With 26% of the universities emissions coming from electricity consumption, (Pg. 119, Citation 13) a resource that provides for 19% of the energy on campus, it is apparent that the University needs to seriously consider more investment in renewable electricity.

The University of Maine is working to become the premiere destination for students in a climate conscious world, as the move towards carbon neutrality by 2040 evinces (Pg. 120, Citation 13). It is stated on page 120 as well that “As part of the overall strategy...the university will need to be transitioned to renewable sources”. The report goes on to state on page 120 that the University has purchased 30% of its energy from renewable sources, while the state mandated minimum is 30%. This minimum, while a step in the right direction, does not show that the University is truly considering the need to reduce their emissions further outside of state mandates. Even when purchasing Renewable Energy Credits (REC’s) from local utilities, there is no way for any load to ensure where its kW originated. The best way to ensure that renewable energy is being generated and used by the University is to integrate solar PV cell arrays or other generation into the building power systems, which will then generate power to offset the load of the building. This can help decrease the amount of load on the campus primary system, which in turn will increase reliability. A large assumption that is quite important to each section of this thesis is the assumption that everyone would have to leave the building due to inoperable HVAC and air recirculation systems that would make the hall uninhabitable, and therefore necessitate evacuation for the duration of the outage.

This thesis will consider the integration of renewables into the University power system, as well as provide outage numbers for certain building classifications. These numbers will hopefully be used by campus individuals in forecasting the cost of an electrical outage to the students, thereby informing their decisions on what should be changed fiscally to prevent power outages. This information can also be used by students to inform themselves, and in doing so, put pressure on the University to upgrade these utilities to better serve students. In the pages that follow, please consider the audiences, and the need for any member of the student body or faculty to be able to pick up this thesis, and use the numbers for outages to determine the costs for any building classification or length of time. Also consider the importance of sustainability in the near future, and the pledge of the University to become carbon neutral, a goal that will never be met without proper methodical steps.

Section 1, Academic Building Calculations: Dunn Hall

For the academic building calculation Dunn Hall was selected. Dunn Hall is home to the departments of Communication and Journalism, Communication Sciences and Disorders, Native American Studies, The School of Nursing, Speech Therapy Telepractice, the Tutor Program, and the Wabanaki Center. The calculations for an academic building are going to be much different, as there are more factors to take into account. First and foremost, there are different numbers of students who are in state or out of state, and pay a different amount for tuition as a result. This can be accounted for by creating a percentage of the number of students from inside and outside the state of Maine. This percentage can be calculated using data from University's Office of Institutional Research, known as the OIR. Referring to the UMaine at A Glance sheet (Citation 11) maintained by the OIR, the percentages can be calculated as shown below:

$(Eq.\ 1.1.)\ Undergraduate\ Total\ Resident: 6,705\ students$

$(Eq.\ 1.2.)\ Undergraduate\ Total\ Non-Resident: 2,592\ students$

$(Eq.\ 1.3).\ Resident\ Percentage = 6,705/(6,705+2,592) = .72,\ 72\%$

$(Eq.\ 1.4).\ Non-Resident\ Percentage = 2,592/(6,705+2,592) = .28,\ 28\%$

With these percentages, the academic building calculation can now account for the difference in tuition rates. Another important consideration is the credit hour classification of the courses taking place in the building potentially during any outage.

Since there is no way of knowing what classes will be taking place at any time, a mixture of classes will be selected. The class types considered are 1 credit, 2 credit, and 3 credit classes. In Dunn, we will be considering 4 different rooms: Rm. 130, Rm. 115, Rm. 126, and Rm. 316. Of the four rooms, two of them will be assumed to be 3 credit classes. This is because we will assume they are the most prevalent course type on campus, and you have a 60% (⅗) chance during the week of those classes occurring if you use a Monday -Wednesday-Friday schedule, as a majority of three credit classes do. One of the remaining two rooms will be a 1 credit course room. The other classroom will be a 2 credit course room. Instead of using the student count per room and assigning the courses to a specific room location, the calculation will use the total number of students in all of the rooms divided up into each room equally. This should allow for a leveled calculation, as below, we will be averaging out the square footage per person across all rooms equally to match.

The next thing to consider is the approximate square footage each student would be allotted for a course on average. The capacities of the four rooms and the square footage are listed below in the table. This data was pulled from Appendix 2, "Classroom Scheduling List", and Appendices 12 and 13, "Dunn Hall Autocad Floors 1 and 3" respectively, provided to me by Brian Foley in Facilities Management.

The final column in the table represents the square footage per person in each room. These numbers allow for an approximate square footage per person to be concluded via an average of the numbers. When these numbers are averaged, the final square foot area each student is allotted is 16.1725 square feet. The student count for each room is used to find the average allotment, instead of the student to teacher ratio of 15:1 that the University touts, as this seems unrealistic.

Dunn Hall Room Number	Sq. Ft in Room	Capacity (Students)	Sq. Ft/ person
130	336	21	16
115	549	30	18.3
126	536	35	15.31
316	377	25	15.08

Figure 3: Selected Square Footage Numbers and Capacities in Dunn Hall

The next step in the process of calculating the square foot cost per hour is to find the number of hours people are spending in their classes, for each different credit level. In this calculation, it will be important to use the exact definition of a credit hour. The Student Hour, derived from the Carnegie Unit of academic measurement, is the origin of the credit hour, which is, as it says, an hour of class time per week. As stated verbatim from an article on the Carnegie Student Hour: “As it is used today, a Student Hour is the equivalent of one hour (50 minutes) of lecture time for a single student per week over the course of a semester, usually 14 to 16 weeks (Citation 12).” This hour, although defined as an hour, is usually shorter at 50 minutes. For the purposes of this calculation, however, the number of credit hours will be considered to be equal to the number of true hours that the student spends in class with the instructor, consistent with the Carnegie Student Hour definition. Below we can see the number of hours that the student is spending in a class each semester.

(Eq. 1.5). $1\ \textit{Credit Course}:\ 1\ \textit{hour/ week} * 15\ \textit{weeks/semester} = 15\ \textit{hours}$

$(Eq.\ 1.6).\ 2\ \textit{Credit Course}:\ 2\ \textit{hours/week} * 15\ \textit{weeks/semester} = 30\ \textit{hours}$

$(Eq.\ 1.7).\ 3\ \textit{Credit Course}:\ 3\ \textit{hours/week} * 15\ \textit{weeks/semester} = 45\ \textit{hours}$

With these hours figured out, we take another step towards a final square foot calculation for academic spaces. In the next section, costs per credit hour will be used to determine what the student pays, both in state and out of state, for an hour in their course. This calculation will be completed for each different credit hour level of courses.

One Credit Course Cost/Hr.

$(Eq.\ 1.8).\ \textit{In state cost}: \$480/\textit{credit hr}.$

$(Eq.\ 1.9).\ \textit{Out of state cost}:\ \$1,089/\textit{credit hr}.$

$(Eq.\ 1.10).\ \textit{In state cost/hour per student}: \$480/(15\ \textit{hours/semester}) = \$32/\textit{hr}.$

$(Eq.\ 1.11).\ \textit{Out of state cost/hour per student}: \$1,089/(15\ \textit{hours/semester}) = \$72.60/\textit{hr}.$

Two Credit Course Cost/Hr.

$(Eq.\ 1.12).\ In\ state\ cost: \$759/credit\ hr.$

$(Eq.\ 1.13).\ Out\ of\ state\ cost: \ \$1,997/credit\ hr.$

(Eq. 1.14). $In\ state\ cost/hour\ per\ student: \$759(30\ hours/semester) = \$25.30/hr.$

$(Eq.\ 1.15).\ Out\ of\ state\ cost/hour\ per\ student: \$1,997/(30\ hours/semester) = \$66.57/hr.$

Three Credit Course Cost/Hr.

$(Eq.\ 1.16).\ In\ state\ cost: \$1,038/credit\ hr.$

$(Eq.\ 1.17).\ Out\ of\ state\ cost: \ \$2,865/credit\ hr.$

(Eq. 1.18). $In\ state\ cost/hour\ per\ student: \$1,038/(45\ hours/semester) = \$23.07/hr.$

$(Eq.\ 1.19).\ Out\ of\ state\ cost/hour\ per\ student: \$2,865/(45\ hours/semester) = \$63.67/hr.$

Next, students will be spread across the rooms equally, as stated before. There is a total of 111 students, with an equal distribution as considered before that leaves 28 students in three rooms with 27 in the fourth. Two of the rooms will be 3 credit courses, one will be a 2 credit course, and the last will be a one credit course. The number of students is now 28 in the 2 and 1 credit courses, and 28+27=55 in the 3 credit course. Now, to account for the percentages of in state and out of state students, we will apply the percentages we found earlier: 72% in state, 28% out of state. The breakdown of student costs are as follows:

1 Credit Costs Breakdown

$(Eq.\ 1.20).\ \textit{In State} : (28 * (.72)) * \$32/Hr. = \ \$640/Hr.$

$(Eq.\ 1.21).\ \textit{Out of State} : (28 * (.28)) * \$72.60/Hr. = \$1,452/Hr.$

2 Credit Costs Breakdown

$(Eq.\ 1.22).\ \textit{In State} : (28 * (.72)) * \$25.30/Hr. = \ \$506/Hr.$

$(Eq.\ 1.23).\ \textit{Out of State} : (28 * (.28)) * \$66.57/Hr. = \$532.56/Hr.$

3 Credit Costs Breakdown

$(Eq.\ 1.24).\ \textit{In State} : (55 * (.72)) * \$23.07/Hr. = \ \$922.80/Hr.$

$(Eq.\ 1.25).\ \textit{Out of State} : (55 * (.28)) * \$63.67/Hr. = \$955.05/Hr.$

The above calculations will allow the final academic calculation to take into account the different credit hour courses having the same ratio of in state students and out of state students as the campus. With these numbers, the final average can begin to be calculated. To move into the final stage of determining the per square foot cost of an academic space outage, the in state total costs from each of the courses will be determined, as well as the out of state total costs. These will then be divided by the square footage per student multiplied by the number of students in the class, in state and out of state calculated separately.

In State Cost/Sq.ft./Hr.

$(Eq.\ 1.26).\ In\ State\ Total:\ \$640 + \$506 + 922.80 = \$2,068.80/Hr.$

$(Eq.\ 1.27).\ In\ State\ Cost/Sq.ft./Hr.:$

$(\$\ 2,068.80/Hr.)/((16.1725 Sq.ft./Student) * (80\ Students) =$

$\$1.599 \approx \$1.60$ /Sq.ft./

Out of State Cost/Sq.ft./Hr.

$(Eq.\ 1.28).\ Out\ of\ State\ Total:\ \$1,452 + \$532.56 + 955.05 = \$2,939.61/Hr.$

$(Eq.\ 1.29).\ Out\ of\ State\ Cost/Sq.ft./Hr.:$

$(\$2,939.61/Hr.)/((16.1725 Sq.ft./Student) * (31\ Students) = \$5.86/Sq.ft./Hr.$

$(Eq.\ 1.30).\ Average:\ (In\ State(\$/Sq.ft./Hr.) + Out\ of\ State(\$/Sq.ft./Hr.))/(2) =$

$(\$1.60 + \$5.86)/(2) = \$3.73/Sq.ft./Hr.$

The final calculation in Eq. 1.30 to find the average yields a square foot hour cost of \$3.73. This cost is for each square foot, so a student in a class with an average of 16 square feet of space allotted to them would be looking at 16X this value, about \$60 per class for that hour based upon this average. This math can be reversed to see if the tuition values come out the other end, while remembering to take into account the student types. First, take \$60.32 per class, and multiply it by the 15 hours for a 1 credit course that meets for an hour a week. The final number is \$904.85, which falls between our lower and higher tuition values for the one credit course, \$480 and \$1089 respectively. The final number, however, should not be a simple average of \$480 and \$1089. This simple average does not take into account the differences in percentages of in state and out of state students per class as the average that yielded \$3.73 did. In order to take this into account, we need to offset the value of the average by dividing the difference between the two proportions of students. This calculation will allow us to see how important it is to calculate the proper proportion of students, both in and out of state. Offsetting is determined by the percentages of in state students and out of state students. These calculations are below, and show an error calculation for the square footage cost as well.

$(Eq.\ 1.31).\ Simple\ Average:\ (\$480 + \$1089)/(2) = \$784.50$

$(Eq.\ 1.32).\ Numerical\ Difference:\ \$1,089 - \$480 = \$609$

$(Eq.\ 1.33).\ In\ State\ Weighted\ Offset\ Portion:\ \$609 * .72 = \$438.48$

$(Eq.\ 1.34).\ Out\ of\ State\ Weighted\ Offset\ Portion: \$609 * .28 = \$170.52$

$(Eq.\ 1.35).\ Weighted\ Average:\ \$1,089 -\ (Out\ of\ State\ Weighted\ Offset\ Portion) =$

$\$1,089 - \$170.52 = \$918.48$

$(Eq.\ 1.36).\ Weighted\ Average:\ \$480 + (In\ State\ Weighted\ Offset\ Portion) =$

$\$480 + \$438.48 = \$918.48$

$(Eq.\ 1.37).\ \%\ Error:\ \$918.48/\$904.85 = 1.01506,\ or\ 1.51\%\ error$

As seen above, by finding the difference and offsetting the average, we end up with \$918.48 as the average cost with considerations for in state and out of state student proportions. Through the calculations, it becomes apparent the importance of the offset of the average, as the simple average would produce an incorrect answer, and introduce an unnecessary error level of (784.50/904.85) 13.3%. The 1.51% error found using the calculations described in this section can be attributed to rounding. For these calculations, four decimal places, when apparent, were rounded down to two decimal places as is customary when stating monetary values. The only purpose of this final calculation is to show the error incurred by using a 50/50 distribution of in and out of state students, as opposed to finding the proportional amounts. This is an important piece that is only considered in the academic calculations due to the difference between in state and out of state tuition. Throughout the rest of this thesis, the proportions of in state and out of state students do not come into play.

Section 2, Dining Building Calculations: York Dining Hall

The next building type to consider is the dining hall. For the dining hall outage calculations, York Dining Hall was chosen. York Dining Hall is one of three main dining halls on campus. The choice to pick York Dining Hall is twofold. First, York Dining Hall is connected to the West Substation via feeder 3. However, the West Substation also normally provides power to Wells Central Dining Hall. Secondly we needed to determine which building had a higher usage to size ratio. York was picked over Wells for these calculations due to it's higher square foot to usage rating. This rating can be seen on Appendix 3, "Customer Counts." This number is simply a calculation of the number of students using the dining hall per day divided by the square footage of the dining hall. The numbers are ratios that give an idea of the usage in relation to size. As indicated on the sheet, York has the highest ratio, at 0.2256. This means that York has the highest usage to square footage of dining halls on campus, and will yield a worst case cost for a square foot/ hour calculation. This dining hall also provides a convenient location for a students to eat, and is essential to the proper nutrition and health of college students.

Contact and correspondence with Ken Violette Jr., the Finance and Purchasing Manager of Dining Services, yielded a number for each day for a four week period regarding students using York Dining Hall. This information, paired with the cost of the "Unlimited" meal plan, will make it possible to calculate, on average, what the cost would be if a dining hall was to lose power for an hour. This data will then be translated down to a square foot level, and give a value for the cost of a dining building outage per square foot per hour. Consideration will be given to the number of hours that the dining hall is open as well per week.

For these calculations, there are also some assumptions . The building hours will be averaged, including weekend hours. The building usage will also be averaged. This means that, for instance, if there are 2000 people going through York Dining on Tuesday and 1500 on Wednesday, the average of 1750 will be used. The flow of students will be stated as constant also, so as to remove the consideration of lunch hour, or for instances such as “Buffalo Chicken Wednesday”, which according to employees handles about 900-1000 people for just the dinner shift. With these assumptions and averages taken into consideration, the calculations can now begin.

First and foremost, we will look at the number of students using York Dining hall on average for a typical week. After receiving the dining hall usage data from Ken, it was averaged to find the typical usage from 4 separate weeks. The four week period considered was between Sunday, Jan. 31st 2016, and Saturday, February 27th 2016. First, each week was averaged, and then the average of those four averages was calculated. These averages were calculated in Excel, and can be seen on Appendix 3, “Customer Counts”.

$(Eq.\ 2.1).\ Average\ for\ Week\ 1 : 1553.143\ people/day$

$(Eq.\ 2.2).\ Average\ for\ Week\ 2 : 1511.429\ people/day$

$(Eq.\ 2.3).\ Average\ for\ Week\ 3 : 1505\ people/day$

$(Eq.\ 2.4).\ Average\ for\ Week\ 4 : 1451.143\ people/day$

$(Eq.\ 2.5).\ Overall\ Average :\ 1505.179\ people/day$

Now that the average usage has been determined, the calculations need to determine a square footage for York Dining Hall. The square footage of York Dining overall, as calculated from the Autocad Drawing in Appendix 9, "York Dining", is 349'*466', or 162,634 square feet. This number includes bathrooms, the space of the conference room, and all of the dining hall food storage preparation space. The square footage considered for this calculation will only include the seating area open to students. These square footages are pulled from the York dining autocad drawing, and account for the total space available the students on any given day. The square footage of these areas total to 6,672 square feet, as shown below.

$(Eq.\ 2.6).\ Total\ Square\ Footage :\ Seating\ Area\ 1 +\ Seating\ Area\ 2 =\ Total$

$(Eq.\ 2.7).\ Total\ Square\ Footage :\ 4,207\ Sq.ft. + 2,465\ Sq.ft. = 6,672\ Sq.ft.\ Total$

Next, the typical number of hours per day students can use the dining hall can be considered. This is achieved by averaging the open hours of the dining hall throughout a typical week. The hours for York Dining average to about 12.5 hours, using the numbers below.

$Sunday\ Hours :\ 7AM - 8PM = 11\ Hrs.$

$Monday\ Hours :\ 7AM - 8PM = 13\ Hrs.$

$Tuesday\ Hours:\ 7AM - 8PM = 13\ Hrs.$

$Wednesday\ Hours:\ 7AM - 8PM = 13\ Hrs.$

$Thursday\ Hours:\ 7AM - 8PM = 13\ Hrs.$

$Friday\ Hours:\ 7AM - 8PM = 13\ Hrs.$

$Saturday\ Hours:\ 9AM - 8PM = 11\ Hrs.$

$(Eq.\ 2.8).\ Average\ Hours/\ Day: (87\ Hours)/(7\ Days) = 12.43\ Hours/Day$

Finally, a steady flow number for usage per hour can be derived. This will be completed by using the average number of open hours paired with the average usage per day derived before.

$(Eq.\ 2.9).\ (1505.179\ People/\ Day)/(12.43\ Hours/Day) =$

$121.09\ people/hour \approx 121\ people/hour$

Now that there is an average flow of students into the dining hall per hour, we can calculate cost/hour for each student. We can assume that each student has purchased the "Unlimited Dining Plan", which based upon Appendix 1, "Approved Undergraduate Rates", carries a cost of $2,286 for both in state and out of state students. This number will be used to get a cost per student for an hour of dining hall time, regardless of if they are using the hall.

$(Eq.\ 2.10).\ Cost\ per\ Hour\ for\ Student:$

$(Cost\ of\ Meal\ Plan)/((Weeks/\ Semester) * (Hall\ Hours/Week))$

$(Eq.\ 2.11).\ Cost\ per\ Hour\ for\ Student:$

$(\$2,286)/((15\ Weeks/\ Semester)*(87\ Hours/Week)) =$

$\$1.752/Student/\ Hour$

With a cost per student per hour, an average flow rate of people into the dining hall per hour, and a square footage of the dining space, we can begin to look at the cost per hour on a square foot basis.

$(Eq.\ 2.12).\ Cost/\ Sq.ft.:$

$(Student\,flow/Hour*(Cost/\ Student/Hour))/(Square\ Footage)$

$(Eq.\ 2.13).\ Cost/Sq.ft.\ :$

$(121\ People/Hour*(\$1.752/Student/Hour))/(6,672\ Sq.\,ft.) =$

$0.03176,\ or\ 3.18\ Cents/Hr./\ Sq.ft.$

The final per square foot cost of a dining hall classified building, derived from information pertaining to York dining hall, is 3.18 cents per hour, per square foot.

Section 3, Dormitory Building Calculations: Estabrooke Hall

For the dormitory building calculations, Estabrooke Hall was chosen. Upon correspondence with Auxiliary Services, and emails back and forth with Sally Clark, an administrative support specialist, which can be seen in Appendix 8, "Sally Clark Email", it was determined that Estabrooke was a good choice, due to it being considered a typical building with a good representation of the different types of dorm rooms. These sizes would allow for easy calculations when paired with the cost sheet maintained by the university on their website, which can bee seen in Appendix 1, "Approved Undergraduate Rates." Estabrooke is also connected to the West Substation via Feeder 3, and therefore is fed by the circuit that has been determined to be potentially problematic based upon previous capstone work.

First for the calculations, the number of purely dormitory floors need to be determined, and the number of dormitory rooms of each type determined per floor. Then the square footage of all the rooms can be calculated. Next, costs need to be determined for the floors based upon the number of people staying in each room and the type of room. Once we have completed this for each floor, we can add up each floor's square footage, and each floors total cost per semester. With these two numbers, a simple division can be done to determine the cost per square foot-semester. The overall cost/semester will be divided by the square footage. Next, we can turn the $/sq. ft.-semester into a cost per square foot for an hour. This is done by using the number of weeks in a semester (typically 15 weeks), and multiplying it by 7 days, which in turn will be multiplied by 24 hours in a day. This will leave us with what is below:

$(Eq.\ 3.1).\ ((\$XXX)/Sq.ft.\ Semester)/(15\ weeks/\ Semester * 7\ Days/week * 24\ Hours/Day) = (\$XXX)/Sq.ft./Hour$

Below, we can see the math done per floor for Estabrooke Hall. Before diving in, consider the assumptions that are made; first and foremost every room has its maximum number of students (two for doubles, one for singles), the dimensions are as stated on specification sheet provided by Auxiliary Services in Appendix 6, "Estabrooke Hall General Information", and the dormitory rooms are still organized as they are on the recent floor plan, seen in Appendix 7, which shows floor plans for Estabrooke floors 3 and 4. The traditional sizes for types of rooms as quoted by Auxiliary Services are listed below as well. The calculations for hours/semester assume a 15 week semester, which is typical.

<u>Room Sizes</u>

$(Eq.\ 3.2).\ 2\ Room\ Doubles = 16'11" * 11'10",\ 200.18\ Sq.ft.$

$(Eq.\ 3.3).\ Doubles = 16'11" * 11'10",\ 200.18\ Sq.\ ft.$

$(Eq.\ 3.4).\ Singles = 10' * 12',\ 120\ Sq.ft.$

$(Eq.\ 3.5).\ Deluxe\ Singles = 16'11" * 11'10",\ 200.18\ Sq.ft$

<u>Floor 1:</u>

No dorm rooms

Floor 2:

No dorm rooms

Floor 3:

$(Eq.\ 3.6).\ 6\ Two\ Room\ Doubles * 200.18\ Sq.ft. = 1201.08\ Sq.ft.$

$(Eq.\ 3.7).\ 3\ Doubles * 200.18\ Sq.ft. = 600.54\ Sq.ft.$

(Eq. 3.8). $27\ Singles * 120\ Sq.ft. = 3240\ Sq.ft.$

$(Eq.\ 3.9).\ 4\ Deluxe\ Singles * 200.18\ Sq.ft. = 800.72\ Sq.ft.$

$(Eq.\ 3.10).\ Total = (5,842.34\ Sq.ft.)\ on\ Floor\ 3$

$(Eq.\ 3.11).\ 6\ Two\ Room\ Doubles * (\$2,804/person * semester) * \ 2\ people/room =$

$\$33,648/semester$

$(Eq.\ 3.12).\ 3\ Doubles * (\$2,502\ /person * semester) * \ 2\ people/room = \$15,012/semester$

$(Eq.\ 3.13).\ 27\ Singles * (\$3,505/person * semester) * \ 1\ person/room = \$94,635/semester$

$(Eq.\ 3.14).\ 4\ Deluxe\ Singles * (\$3,555/person * semester) * \ 1\ person/room =$

$\$14,220/semester$

$(Eq.\ 3.15).\ Total = (\$157,515/semester)\ on\ Floor\ 3$

Floor 4:

$(Eq.\ 3.16).\ 6\ Two\ Room\ Doubles * 200.18\ Sq.ft. = 1201.08\ Sq.ft.$

$(Eq.\ 3.17).\ 2\ Doubles * 200.18\ Sq.ft. = 400.36\ Sq.ft.$

$(Eq.\ 3.18).\ 27\ Singles * 120\ Sq.ft. = 3240\ Sq.ft.$

$(Eq.\ 3.19).\ 5\ Deluxe\ Singles * 200.18\ Sq.ft. = 1000.9\ Sq.ft.$

$(Eq.\ 3.20).\ Total = (5,842.34\ Sq.ft.)\ on\ Floor\ 4$

$(Eq.\ 3.21).\ 6\ Two\ Room\ Doubles * (\$2,804/person * semester) *\ 2\ people/room =$

$\$33,648/semester$

$(Eq.\ 3.22).\ 2\ Doubles * (\$2,502\ /person * semester) *\ 2\ people/room = \$10,008/semester$

$(Eq.\ 3.23).\ 27\ Singles * (\$3,505/person * semester) *\ 1\ person/room = \$94,635/semester$

$(Eq.\ 3.24).\ 5\ Deluxe\ Singles * (\$3,555/person * semester) *\ 1\ person/room =$

$\$17,775/semester$

$(Eq.\ 3.25).\ Total = (\$156,066/semester)\ on\ Floor\ 4$

Now that we have determined the square footages of each room type and the associated costs, we can begin our final calculation for the entire building. First, we will total the entire living area. Then, we will total the cost for the entire semester. These two pieces come together to determine a cost per square foot for an entire semester. To get down to an hourly cost, we will determine the number of hours in a semester, and then divide the cost per square foot per semester by the number of hours in the semester.

Overall Building Calculations

$(Eq.\ 3.26).\ Total\ Sq\,ft.\ Living\ area =\ 11,\ 684.68\ Sq.\,ft.$

$(Eq.\ 3.27).\ Total\ Cost/\ Semester =\ \$313,581/Semester$

$(Eq.\ 3.28).\ \$313,581/11,684\ Sq.\,ft = cost\ per\ square\ foot\ per\ semester =$

$\$26.84/Sq.\,ft.\ semesterly$

$(Eq.\ 3.29).\ (15\ weeks/semester) * (7\ days/week) * (24\ hours/day) = 2520\ hours/semester$

$(Eq.\ 3.30).\ (\$26.84/\ Sq.\,ft.\ Semesterly)/(2520\ hours/semester) =$

$$\$0.0106 \approx 1.1\ cents/\ Sq.ft.\ hourly$$

As shown in Eq. 3.30, we have a cost of approximately 1.1 cents per square foot hourly. This cost is based upon the assumptions made before and the preceding calculations, and can be used to determine the cost for an outage for any number of hours and square feet for dormitory classified space at the University of Maine.

Section 4: Implications and Further Research

Implications

As for the implications of this research, it all lies with the expansion of campus. If campus continues to expand as it is projected to, then the energy demand will continue to rise. This energy rise coupled with the University's need to continue to be a green campus puts it in a strange spot. If the University wants to continue to be considered as a green campus, which it definitely does, it will need to buy more Renewable Energy Credits (REC's). If the University wants to actually integrate renewables into its existing power system, it will have a very hard time doing so if tripping offline due to unreliability becomes normal. The only way to prevent this is to continue to improve preventative maintenance and increase the amount spent per gross square foot on maintenance daily.

Integration of any sort of distributed generation is an amazing opportunity for the University to secure its name as a green campus, and with the amount of roof space on campus it would be quite easy to put large PV arrays into commission. The issue with a potentially unreliable grid and the addition of any distributed generation is that the system runs into issues with islanding concerns. As per Emeras "Interconnection Guidelines" document (Citation 5), islanding is generally prohibited due to safety concerns, and a majority, if not all distributed generation applications require anti-islanding schemes in order to connect in any way to Emera's lines, which feed campus. The University of Maine, as well, should be worried about the potential to create islands during power outages. The idea of an "islanded" power system is much like the idea of an island itself, isolated but alive. When a building or customer on a power system decides to install generation equipment to help meet or supplement their need for power, they create potential for an island. If, for instance, a house loses power, and the customer's generator, whatever that is (PV, Gas, etc.) is placed into operation, it can backfeed power on to what appears to be a dead line. In this case, you can potentially have an electrical worker cutting and pulling blown fuses or cable on a live line, which is extremely dangerous. So, what many utilities decide to do is mandate the implementation of anti-islanding configurations, whether that's a breaker that's activated or a manual switch, there needs to be an electrical disconnect between the utility system and the generating system.

These anti-islanding setups are nice, and work to keep people safe, but do not play well with renewables. Anti-islanding setups force the generation to stop, as to remove any doubt that the line could be dead. This means no export of power onto the grid for credit against your bill, and energy stops being produced, rendering your generation useless. The other configuration option is intentional islanding. What this means is that, if an intentional islanding scheme were implemented, the distributed generation would be used to feed the building that they are attached to. This scheme isolates the generation from the utility circuits, allowing the generation to feed the load even after an outage. Sadly, solar cells, to use an example, at current efficiency ratings cannot carry the load for large buildings continuously without a huge number of them, and proper energy storage. Eventually the PV cell inverter would be asked for too much power, or the battery bank would fall to too low of a charge. The solar charge controller would then shut off the solar charging of the batteries, or the inverter would lockout to avoid breaching its maximum load rating. These two conditions would render the solar useless, as the solar system itself shuts down to prevent damage.

A very striking statement is made in a *University Business* article regarding college campuses and renewable energy (Citation 6), which reads: “To claim to be carbon neutral while saving costs in energy purchases altogether--and truly lessen their carbon footprint and dependence on the local power grid--colleges and universities need to produce electricity on site through use of distributed generation. The use of solar photovoltaic systems, wind power, and cogeneration also have the potential to generate substantial cost savings.” The University should begin to move towards distributed generation and away from Renewable Energy Credits (REC’s), and if they decide to do so, they will need to consider revamping the electrical system on campus first. If the University wishes to also become a more environmentally friendly campus via renewables such as solar, it will be imperative that the grid is reliable enough to make it worthwhile.

Further Research

This case study does provide a limited scope of the potential issues and cost associated with a power outage, and does leave room for additional analysis. There are numerous additional considerations that should be made, a few of which will be touched on in this section. Some considerations to be made in an extended analysis could include monetary loss incurred by lab space, professor offices, and dining hall food storage outages.

An important consideration should be given to conference rooms. These rooms cannot be accounted for from a student's tuition point of view, as students do not pay a conference room/community room fee as part of the housing cost. If they are treated as a complementary space for students, then the cost can be discounted.

To consider the costs incurred by professors offices losing power, the calculation would get difficult. The numbers on the salaries of every person who has an office on campus would be needed to determine the cost of an hour of their time, and ultimately the revenue lost when they are not able to work in their office. Then, a typical building floor with all offices would need to be found, and used to calculate the average cost per square foot per hour for a professor's office space. This thesis, however, looks at the money paid to the school by students that is being lost. To do a proper calculation, the percent of the professor's salary that is paid by the students would need to be determined as well.

Another consideration to make is the loss of lab space not accounted for in this thesis. In many buildings on campus, there are large research facilities and laboratories on campus that are instrumental in the reinforcement of lecture topics, and the individualized research and learning of the student. There are also labs on campus with ongoing research. One of these, to use a concrete example, is the Ice Core lab at the Climate Change Institute on campus. The ice cores, gathered on expensive expeditions to places ranging from the Chilean Andes to Antarctica, are stored at -20℉, and need to be kept at that temperature to avoid any kind melting contamination. The core storage has multiple backups, including a generator, which help provide power to the building in the event of a power outage. The issue would be if the outage was of a longer duration. The cost of fuel for the generator would need to be taken into account, as a longer duration outage would surely exhaust the fuel supply on hand for the backup. If a per square foot cost for these types of buildings could be derived, then the calculations done could include much more of the space on campus.

A consideration that was suggested by dining staff was an approximation of the cost of replacing the food after a certain point, if the power was out for an extended period of time. Granted, the dining halls on campus have many contingencies in place to protect against a catastrophic power loss, each being noted in an email to Kenneth in the appendices. The cost, as approximated by the dining staff, would be about $20,000 for York to replace all perishable food in the coolers, as shown in Appendix 10, "Kenneth on Extended Outages." This cost would have to be calculated individually per each dining hall, as the square footage is not directly related to the amount of storage that the dining hall may have for food. For instance, Wells dining sees significantly more traffic due to its central location and conference center than for instance York dining, which is in the corner of campus. The increased traffic means that the amount of food moved through the dining hall must also be larger, to meet demand.

Finally, one change that would increase the level of accuracy with these calculations would be a floor by floor square footage breakdown, and added classifications for administrative space as well. So, for instance, Estabrooke has two floors of office spaces, which could mistakenly be lumped into the classification that

Estabrooke is a dormitory. Glancing at Appendix 4 and 5, the counts for offices can be pulled off for floors 1 and 2, respectively . Although not considered in the math, it merits mention that there are 51 offices in Estabrooke, assuming one person per office, there are 51 professors or administrators unable to do work as a result of a power outage. This information would be lost without proper consideration, and in further analysis would need to be calculated using the square footage and hourly cost derived from the salaries of each individual who has an office on the floor in question.

Section 5: Conclusions and Works Cited

Academic: Dunn Hall Conclusions

For the academic buildings, the number calculated is high at $3.73/ sq ft./ hour. This can be accounted for based upon the fact that only hours in class are considered. If this was compared to a dorm room for instance, a student has access to that room 24 hours a day, 7 days a week. This leads to the hours per semester to be 2,520 hours/ semester(15*24*7). A similar calculation for academic access yields about 15 hours/ semester for a one credit course. From a student tuition perspective, the student is paying for the time in class, as well as any time that the professor sets aside to meet with the student which, as we know, usually goes unused (office hours, study sessions, review nights, etc.). With this in mind, using only class hours makes sense. Another factor pulling this number higher is the disparity between in state tuition costs and out of state tuition costs. As you saw in the calculations, the in state cost was much lower for a square foot ($1.60), as the out of state cost was much higher ($5.86). This disparity caused the average to be pulled much higher, towards the out of state cost, even though the number of in state students outweighs the number of out of state students.

Dining: York Dining Hall Conclusions

For dining halls, the number calculated is quite low. This can be attributed to a few factors. First, we need to consider the amount of time a student will realistically spend in the dining hall every visit. Next, to get a more accurate number, you would also need to assume the number of meals a day that a person would consume. The average of three is usually a safe bet, but a better idea of the number of hours being spent in the dining halls as well as the frequency of those visits. The calculations are done assuming that an individual will be accessing the building for every hour that it is open. The only reason that this is used is to account for an outage at any point in the day, and level out the potential for introducing error by assuming peak usage and minimum usage. The chances of an outage happening at any point in the day, therefore, are assumed to be equal. The other factor, as stated, is the frequency of visits, or meals. If the data was collected for the amount of time a student spends eating each meal that they take, as well as the number of meals, a more accurate semesterly hour usage rate could be determined. Without these numbers, the most realistic choice to determine the cost of an outage on a per square foot basis would be the assumption that every hour of dining time is being used equally, resulting in the same cost no matter the timing of the outage.

Dormitory: Estabrooke Hall Conclusions

With the calculations finished, we saw that the cost for a power outage would be approximately 1.1 cents per each square foot per hour. The top two floors are dorm rooms, and the bottom two are mostly offices and conference rooms. The first floor is home to 2 classrooms and 20 offices, one of which (Rm. 145) is the Honors Dean's office. The second floor is home to 6 conference rooms and 31 offices. The dorm rooms on floors three and four provide a good sampling of each different type of dorm room, and therefore create a good average to use for a square footage power loss cost. The only problem that arises is considering the usage.When following through with the calculations, a 24 hour period is used. This 24 hour availability of the dorm rooms is realistic, as the rooms are available to the student for 24 hours of the day. To assume that the student is using the dorm room for 24 hours a day, however, is unrealistic. With a few exceptions, there are some peak hours of usage for dorm rooms, hours where people would usually be back in their dorm rooms. These hours, which usually range from Midnight to approximately 8AM, and from 6PM to Midnight, would decrease the hourly usage to 58% of its assumed value (14/24=.5833). If there were a way to create a better approximation for the number of hours spent, on average, in the dorm rooms for students, the calculations could be made more exact. The number of 1.1 cents would also increase, as the number of hours the building is being used goes down. What has been calculated in this thesis, as shown in the math, is a number that accounts for an outage at any point in a day. If you were to acquire numbers for the amount of time spent in the dorms on average for a student, that would increase the cost of the outage on a square foot basis. The only issue here is that if you find an average amount of time spent per day in the dorm rooms, you discount the potential for an outage to happen at any time. If a dormitory outage happens at 12 Noon, while everyone is in class, you do not see the same losses as you would at 12 Midnight, as the usage would be drastically disparate. So, it merits mention that the average used in this thesis accounts for both of these eventualities via the use of a 24 hour usage period.

Given the focus on getting an accurate cost per square foot for dormitory space, the average found for the top two floors gives us a great approximation for every hour that the power is out for any building classified as dormitory space. So, if you had a building that is out for 3 hours, is comprised of all dormitory rooms, with four floors and a square footage of 4200 (60'X70'), the cost for that outage from a tuition perspective based upon the calculated 1.1 cents per sq. ft/hr. is $554.80. For a larger dorm like for instance Hancock Hall, which has an approximate square footage of 10,600, the cost becomes much higher, at $1399.20 for a three hour power outage.

This thesis set out to find the cost of an electrical power outage per square foot per hour, based upon the educated assumption from my previous capstone that buildings on the West Substation of campus are in more imminent danger of serious power loss. These buildings are listed in Appendix 11, "Buildings on the West Sub". The calculations performed yielded cost results for the three different types of building classifications considered. The costs per square foot are as follows for each building classification: For a square foot of space in an academic building, the cost is $3.73 dollars/hour. For a square foot of space in a dining building, the cost is 3.2 cents/hour. For a square foot of space in a dormitory building, the cost is 1.1 cents/ hour.

With these numbers, it is the hope that anybody from any background can use these to determine a rough cost for a power outage of the given building types at the University of Maine Orono. The costs, paired with total square footage data for the buildings and a simple building classification, will yield a cost that the students have paid to the university via their tuition to be allowed access to. Ultimately, the hope here is that this thesis will allow the administration to see what the students, or "the customers", are losing monetarily due to an unreliable grid. This in turn should help the administration realize that an investment in this infrastructure is an investment in their future, their growth, and ultimately the University of Maine's longevity as an educational institution.

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Appendix 1: Approved Undergraduate Rates

Undergraduate Housing Room Rates - AY 2015 - 2016

	Room Type	Rates (Academic Year)	2 Installments of:
Regular Housing			
	Double	$5,004.00	$2,502.00
	Single	$7,010.00	$3,505.00
	Small Single	$6,252.00	$3,126.00
	2 Room Double	$5,608.00	$2,804.00
	Deluxe Single	$7,110.00	$3,555.00
Break Housing			
	Double	$5,104.00	$2,552.00
	Single	$7,110.00	$3,555.00
	Small Single	$6,352.00	$3,176.00
DTAV/Patch			
	Double	$5,298.00	$2,649.00
	Single	$7,200.00	$3,600.00

Rates for UMaine Dining Meal Plans for 2015 - 2016

Meal Plan	Meals per Sem.	Guest Meals	Dining Funds per Semester	Rates (Academic Year)	2 Installments of:
Unlimited	unlimited	6	$0.00	$4,572.00	$2,286.00
Unlimited Flex	unlimited	6	$150.00	$4,872.00	$2,436.00
Unlimited Flex Plus	unlimited	6	$400.00	$5,372.00	$2,686.00
Junior-Senior 120	120	6	$1,100.00	$4,814.00	$2,407.00
Senior Flex	0	6	$2,436.00	$4,872.00	$2,436.00
125 Flex **	125	2	$385.00	$2,968.00	$1,484.00
75 Flex **	75	2	$817.00	$2,968.00	$1,484.00
50 Flex **	50	2	$0.00	$890.00	$445.00
25 Flex **	25	1	$0.00	$444.00	$222.00

** DTAV/Patch residents only

Appendix 2: Classroom Scheduling

UNIVERSITY OF MAINE ~ CLASSROOM INFORMATION

LCD = LCD Projector
M/T/C = Movable Tables & Chairs
TAB = Tablet Armchair
DC = Document Camera
S/T/C = Stationary Tables & Chairs
Theatre Tabs = Padded Armchairs with Attached Tablets
Writing Boards: W-White, G-Green, B-Black
CT = Conference Table
CH = Chair

Building	Room	Cap.	Air Cond.	AV Equipment	Writing Boards	Set-up
Aubert Hall	316	210	AC	OH, LCD, VCR	B	S/T/C - 2 per table in elevated seating
Aubert Hall	428	50		OH	B	TAB
Barrows Hall	119	50		OH, LCD	B (3)	M/T/C - 25 at 1 per table and 27 TABS
Barrows Hall	123	25		OH, LCD	B (3)	TAB
Barrows Hall	124	22		OH, LCD	W (3)	Computer Classroom ~ MAC Power PC plus Instructor Station
Barrows Hall	125	50		OH, LCD	B (3)	M/T/C 2 projection screens
Barrows Hall	126	24	AC	OH	W	ITV Classroom
Barrows Hall	127			OH, LCD		
Barrows Hall	130	50		OH, LCD	B (3)	M/T/C - 40 at 1 per table and 18 TABS
Barrows Hall	131	25		OH, LCD	B	M/T/C
Barrows Hall	132			OH, LCD		
Barrows Hall	133	25		OH	B (2)	TAB
Bennett Hall	101	28		OH, LCD	B (3)	TAB
Bennett Hall	102	23		OH, LCD	B, G (3)	M/T/C - 1 per table
Bennett Hall	115	28		OH	G (3)	TAB
Bennett Hall	124	28		OH	G (3)	TAB
Bennett Hall	137	230	AC	OH/LCD VCR	B	Tiered, S/T/C - 2 per table 3 projection screens
Bennett Hall	140	100		OH, LCD	G	Tiered, Stationary TAB
Bennett Hall	141	100		OH, LCD	G	Tiered, Stationary TAB 3 projection screens
Boardman Hall	107	25		OH	G (2)	TAB
Boardman Hall	115	30		OH	B (2)	TAB
Boardman Hall	207	36		OH	G, B (2)	TAB
Boardman Hall	209	25		OH	B (3)	TAB
Boardman Hall	210	65		OH, LCD	B	TAB

UNIVERSITY OF MAINE ~ CLASSROOM INFORMATION

LCD = LCD Projector
M/T/C = Movable Tables & Chairs
TAB = Tablet Armchair
DC = Document Camera
S/T/C = Stationary Tables & Chairs
Theatre Tabs = Padded Armchairs with Attached Tablets
Writing Boards: W-White, G-Green, B-Black
CT = Conference Table
CH = Chair

Building	Room	Cap.	Air Cond.	AV Equipment	Writing Boards	Set-up
Boardman Hall	309			OH, LCD		
Boardman Hall	216	35		OH, LCD	B	TAB
Boardman Hall	310	65		OH, LCD	B (2)	TAB, 1 table
Bryand Global Sciences Center	100	57	AC	OH, LCD VCR, DVD, DC	W	TAB
Carnegie Hall	202	65		OH	G	TAB
Deering Hall	17	30		OH, LCD	B	TAB
Deering Hall	101C	30		OH, LCD	W	M/T/C
Deering Hall	113	50		OH, LCD, VCR	B	TAB
D.P. Corbett Bus. Bldg.	100	350	AC	OH, LCD 3 VCR's, DC	W	Tiered, Theatre TAB, VCR, DVD player, CD Player, Slide Projector, 3 large screens, Satellite Downlink
D.P. Corbett Bus. Bldg.	105	68	AC	OH, LCD 2 VCR's, DVD, DC	W	Tiered S/T/C. Video-conferencing
D.P. Corbett Bus. Bldg.	107	80	AC	OH, LCD VCR/DVD, DC	W	Tiered S/T/C
D.P. Corbett Bus. Bldg.	109	25	AC	OH, LCD	W	M/T/C - 2 per table
D.P. Corbett Bus. Bldg.	111	20	AC	OH, LCD	W	Computer Classroom - 20 Digital DOS computers, Laserwriter & Tech Commander. MaineCard needed to use printer
D.P. Corbett Bus. Bldg.	113	25	AC	OH, LCD	W	M/T/C - 2 per table

UNIVERSITY OF MAINE ~ CLASSROOM INFORMATION

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Theatre Tabs = Padded Armchairs with Attached Tablets

Writing Boards: W-White, G-Green, B-Black
CT = Conference Table
CH = Chair

			Cond.	**Equipment**	**Boards**	
Jenness Hall	116	52 – 62	AC	OH, LCD VCR, DC	W	Elevated, theatre seating in padded armchairs with data jacks. Videostreaming for teleconferences. Videotaping equipment also in room. Fixed, tiered seating for 52. Addl. chairs can be moved from the conference room to the lecture hall.
Lengyel Hall	121	20		OH, LCD	W	Computer Classroom ~ 20 MACS, Laserwriter, Tech Commander. Maine Card required to use printer.
Lengyel Hall	125	50		OH	W	Tbls and Chairs
Lengyel Hall	127	50		OH, LCD	W	Tbls and Chairs
Little Hall	110	93-97	AC	OH, LCD VCR	W (4) sliding	Tiered, Stationary TAB
Little Hall	120	200	AC	OH, LCD VCR, DC	B (10) sliding	Tiered, Stationary TAB
Little Hall	130	200	AC	OH, LCD VCR, DC	B (10) sliding	Tiered, Stationary TAB
Little Hall	140	100	AC	OH, LCD VCR	B (4) sliding	Tiered, Stationary TAB
Little Hall	202	25		OH	B	TAB
Little Hall	203	75		OH, LCD VCR	B	TAB
Little Hall	204	18		OH	B (2)	TAB, 1 M/T/C
Little Hall	205	40		OH, LCD, VCR	B	TAB
Little Hall	206	25		OH	B (2)	TAB
Little Hall	211	60		OH, LCD VCR	W	Tbls and Chairs(1 per table), carpeted. VCR in podium
Little Hall	212	20		OH	B (2)	TAB, 1 M/T/C
Building	**Room**	**Cap.**	**Air Cond.**	**AV Equipment**	**Writing Boards**	**Set-up**

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CH = Chair

Little Hall	215	24		LCD, DVD/VCR	W	Computer Classroom ~ 25 PC Computers, Instructor Station, Scanner, Laser Printer, Telephone, Maine Card to use printer
Little Hall	218	20		OH	B	TAB
Little Hall	219	50		OH, LCD	B	42 TABS
Little Hall	220	25		OH	B (2)	TAB
Lord Hall	100	60		OH, LCD, SP	W	M/T/C 15 tbls, 4/tbl. Large projection screen that is wall width, flat top podium that accommodates a laptop for projection, carpeted
Lord Hall	200	20		OH, LCD 2 SP	W	M/T/C 10 tbls, 2/tbl. Flat top podium that accommodates a laptop for projection, carpeted, 2 electronic screens
Lord Hall	311	22		LCD	W	Mac computer classroom ~ Via New Media Program
Merrill Hall	228A	24		OH, LCD	W	PC Computer classroom, Tbls & Chairs, carpeted
Merrill Hall	330	50		OH, LCD	W	TAB
Merrill Hall	335	26		OH, LCD VCR	W	M/T/C - 4 per table
Murray Hall	102	142		OH, LCD VCR	W	Tiered, Theatre TAB
Murray Hall	106	60		OH, LCD	B	TAB
Neville Hall	100	95	AC	OH, LCD VCR, DC	W	Tiered, Theatre TAB
Neville Hall	101	350	AC	OH, LCD VCR, DC	W	Tiered, Theatre TAB, 2 large proj. screens
Neville Hall	204	28		OH	B	TAB
Neville Hall	206	28		OH, LCD	B	TAB
Neville Hall	208	28		OH	B	TAB

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Writing Boards: W-White, G-Green, B-Black
CT = Conference Table
CH = Chair

Little Hall	215	24		LCD, DVD/VCR	W	Computer Classroom ~ 25 PC Computers, Instructor Station, Scanner, Laser Printer, Telephone, Maine Card to use printer
Little Hall	218	20		OH	B	TAB
Little Hall	219	50		OH, LCD	B	42 TABS
Little Hall	220	25		OH	B (2)	TAB
Lord Hall	100	60		OH, LCD, SP	W	M/T/C 15 tbls, 4/tbl. Large projection screen that is wall width, flat top podium that accommodates a laptop for projection, carpeted
Lord Hall	200	20		OH, LCD 2 SP	W	M/T/C 10 tbls, 2/tbl. Flat top podium that accommodates a laptop for projection, carpeted, 2 electronic screens
Lord Hall	311	22		LCD	W	Mac computer classroom ~ Via New Media Program
Merrill Hall	228A	24		OH, LCD	W	PC Computer classroom, Tbls & Chairs, carpeted
Merrill Hall	330	50		OH, LCD	W	TAB
Merrill Hall	335	26		OH, LCD VCR	W	M/T/C - 4 per table
Murray Hall	102	142		OH, LCD VCR	W	Tiered, Theatre TAB
Murray Hall	106	60		OH, LCD	B	TAB
Neville Hall	100	95	AC	OH, LCD VCR, DC	W	Tiered, Theatre TAB
Neville Hall	101	350	AC	OH, LCD VCR, DC	W	Tiered, Theatre TAB, 2 large proj. screens
Neville Hall	204	28		OH	B	TAB
Neville Hall	206	28		OH, LCD	B	TAB
Neville Hall	208	28		OH	B	TAB

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Building	Room	Cap.	Air Cond.	AV Equipment	Writing Boards	Set-up
Neville Hall	210	28		OH, LCD	B	TAB
Neville Hall	227	40		OH, LCD VCR	B (2)	TAB
Neville Hall	327	16			B (2)	TAB
Neville Hall	406	30		OH, PLASMA TV	B (2)	TAB (Eng. Dept. placed wall-mounted plasma TV in room)
Nutting Hall	100	192	AC	OH, VCR LCD, DC	W (2)	Tiered, Stationary TAB
Nutting Hall	102	60		OH, LCD, VCR	B (2)	TAB
Nutting Hall	203	14		LCD	B	TAB
Nutting Hall	212	15			B	TAB
Nutting Hall	213	32		OH, LCD	B	M/T/C - 10 at 2 per table and 10 TABS
Nutting Hall	254			LCD		
Nutting Hall	255	12		OH, TV/VCR	W	M/T/C
Nutting Hall	257	37		OH	B (2)	M/T/C - 10 at 2 per table, 24 chairs and 11 TABS
Rogers Hall	206	45		OH, LCD VCR	W (2)	TAB, Carpeted, Electronic Screen
Shibles Hall	201	34		OH	W	M/T/C 11 tbls
Shibles Hall	202	35 - 50		OH, LCD	W (3)	M/T/C 8 Round Tables
Shibles Hall	207	38		OH	W	ITV Classroom ~ typically not available
Shibles Hall	217	35		OH, LCD	W (3)	TAB, Carpeted
Shibles Hall	311	34		OH	W (2)	M/T/C – 16 tables with 34 chairs
Shibles Hall	313	30		OH	W (2)	M/T/C – 10 tables with 3 per table

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CT = Conference Table
CH = Chair

Building	Room	Cap.	Air Cond.	AV Equipment	Writing Boards	Set-up
Shibles Hall	316	40		OH, LCD	W (2)	TAB
Shibles Hall	320	26		OH	W (2)	M/T/C – 13 tables with 2 per table
Social Work Building	104	30		OH	W	M/T/C, carpeted
Stevens Hall	155	40		OH, LCD, VCR	B	TAB
Stevens Hall	310	18		OH, TV ON CART, DVD/VCR	B	M/T/C
Stevens Hall	355	40		OH	W	TAB
Stevens Hall	365	40		OH, LCD	W	TAB
Stevens Hall	370	35		OH	W	TAB
Stevens Hall	375	40		OH	B	TAB
North Stevens Hall	117	24		OH	B	TAB
North Stevens Hall	119	30		OH	B	TAB
North Stevens Hall	121	30		OH	B	TAB/M/T/C
North Stevens Hall	235	40		OH	W	TAB
North Stevens Hall	237	54		OH, LCD, VCR	B	TAB
Winslow Hall	201	40		OH, LCD	B	TAB

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TAB = Tablet Armchair
DC = Document Camera
S/T/C = Stationary Tables & Chairs
Theatre Tabs = Padded Armchairs with Attached Tablets
Writing Boards: W-White, G-Green, B-Black
CT = Conference Table
CH = Chair

NON-RESTRICTED SEMINAR ROOMS

Building	Room	Cap.	Air Cond.	AV Equipment	Writing Boards	Set-up
Aubert	112	16		OH	B (3)	4 CT/17 CH
Little Hall	204	18			B (2)	2 CT/18 CH
Little Hall	212	18		OH	B (2)	1 CT/10 CH/7 TABS
Neville Hall	327	16			B (2)	2 CT/16 CH
Nutting Hall	203	14			B	1 CT/14 CH
Nutting Hall	212	15			B	1 CT/15 CH
Nutting Hall	255	16			B	1 CT/10 CH
Stevens Hall	310	18			B	1 CT/19 CH/1 TABS

Appendix 3: Customer Counts

University of Maine
Daily Customer Counts
Resident Dining

	York	Wells	Hilltop
Sunday, January 31, 2016	1280	936	1943
Monday, February 01, 2016	1657	2606	2639
Tuesday, February 02, 2016	1601	2703	2455
Wednesday, February 03, 2016	2052	2387	2290
Thursday, February 04, 2016	1617	2580	2425
Friday, February 05, 2016	1448	1733	2262
Saturday, February 06, 2016	1217	709	1832
Sunday, February 07, 2016	1233	890	1865
Monday, February 08, 2016	1570	2380	2397
Tuesday, February 09, 2016	1584	2661	2356
Wednesday, February 10, 2016	2128	2420	2195
Thursday, February 11, 2016	1569	2524	2197
Friday, February 12, 2016	1417	1505	2164
Saturday, February 13, 2016	1079	677	1577
Sunday, February 14, 2016	1043	636	1601
Monday, February 15, 2016	1505	2389	2364
Tuesday, February 16, 2016	1731	2545	2281
Wednesday, February 17, 2016	2157	2431	2229
Thursday, February 18, 2016	1530	2442	2332
Friday, February 19, 2016	1387	1597	2165
Saturday, February 20, 2016	1182	668	1684
Sunday, February 21, 2016	1227	797	1929
Monday, February 22, 2016	1555	2591	2505
Tuesday, February 23, 2016	1646	2568	2424
Wednesday, February 24, 2016	2106	2366	2199
Thursday, February 25, 2016	885	1057	3132
Friday, February 26, 2016	1513	1574	2312
Saturday, February 27, 2016	1226	714	1886

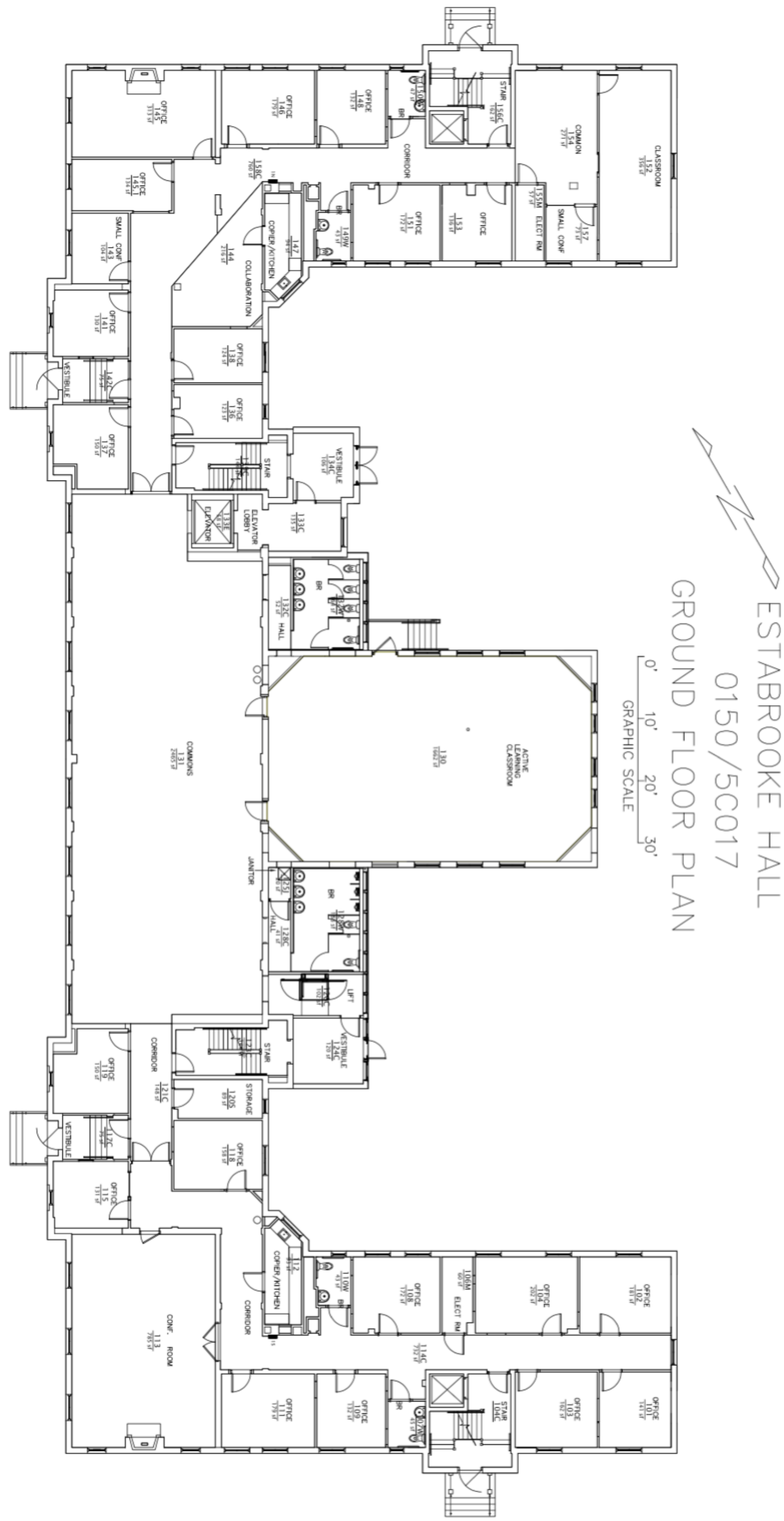
Customer/Square Ft. Ratio	Sq.ft. Dining Space	Building
0.225596309	6672	York
0.200230465	9112	Wells
0.199044175	11060	Hilltop

York Dining Avg. Weekly	
1553.142857	
1511.428571	**York Overall**
1505	1505.178571
1451.142857	

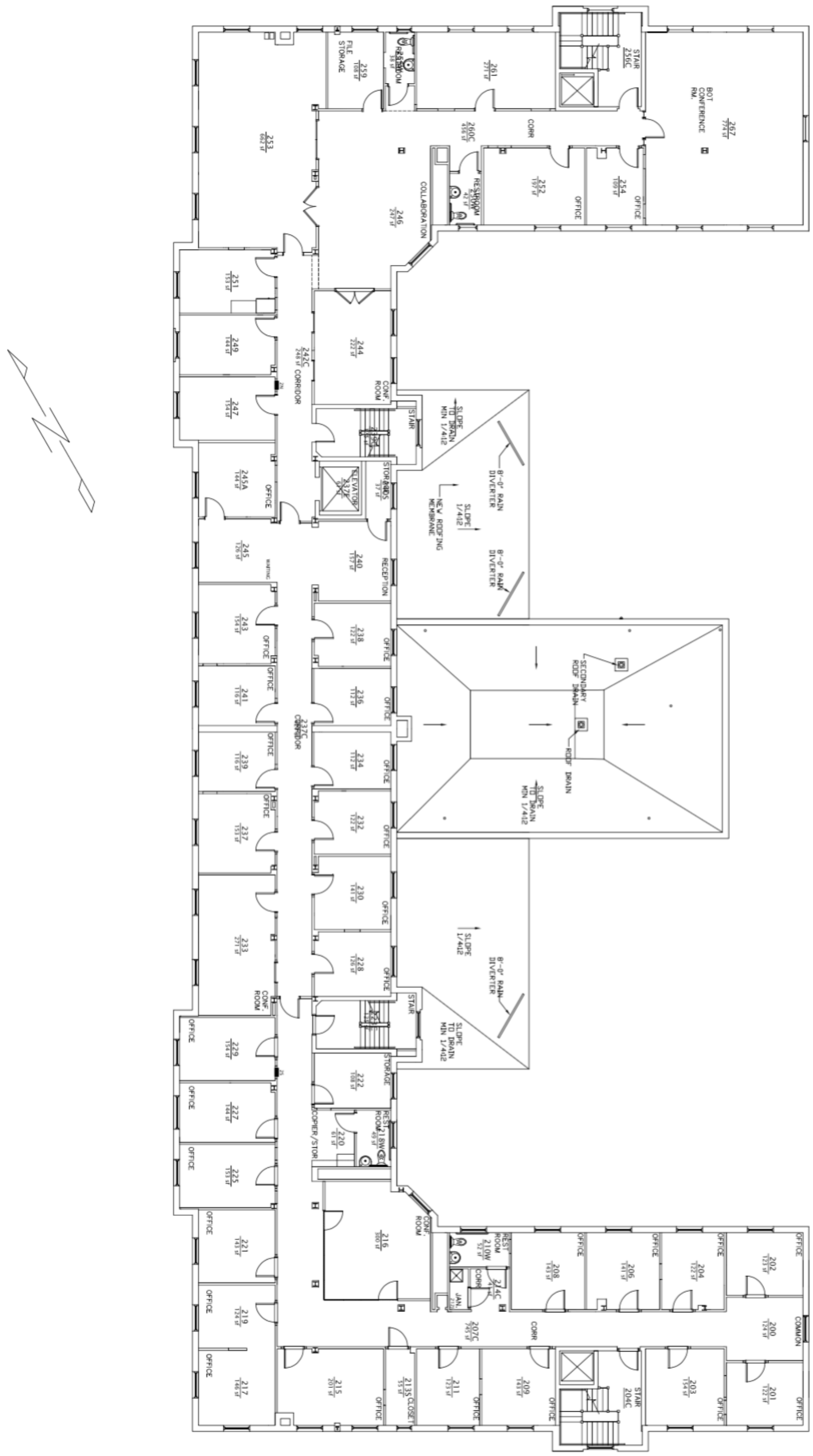
Wells Dining Avg. Weekly	Wells Overall
1950.571429	1824.5
1865.285714	
1815.428571	
1666.714286	

Hilltop Dining Avg. Weekly	Hilltop Overall
2263.714286	2201.428571
2107.285714	
2093.714286	
2341	

Appendix 4: Estabrooke Hall First Floor Plan



Appendix 5: Estabrooke Hall Second Floor Plan

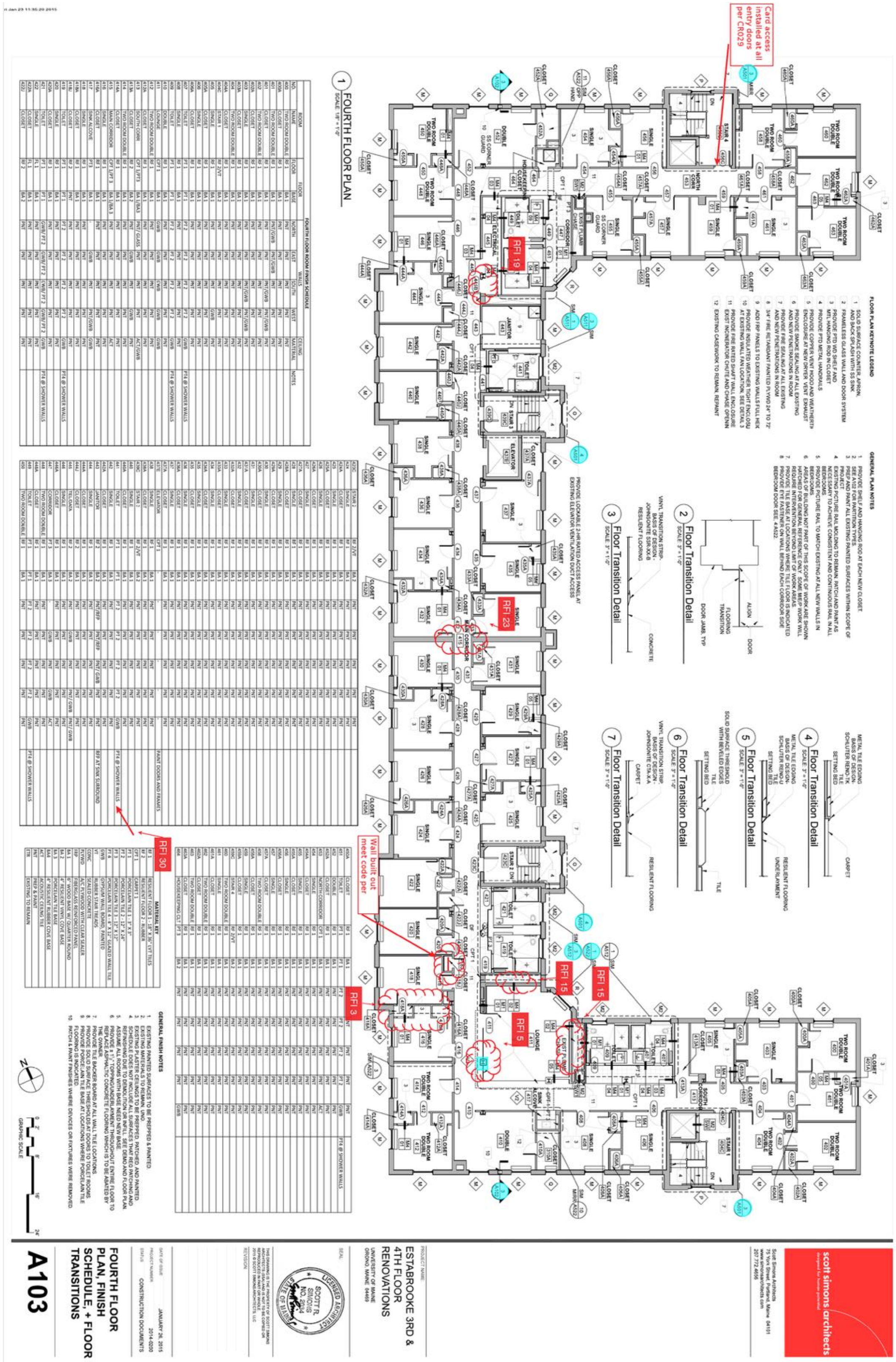


Appendix 6: Estabrooke Hall General Information

Dorm: Estabrooke Hall

	Depth	Length	Width	Height	Space under	Built in Furniture
Bookshelves						
Closets rod to floor				5' 8"		
Closets shelf Dimensions	14"	4' 5"		2' 7"		
Window 4th floor	6 1/2"	3' 11"		4' 9"		
Window 3rd floor	6 1/2"	4'		5' 4"		
Room Dimensions Single		10'	12'	8' 6"		
Room Dimensions Double		16' 11"	11' 10"	8' 6"		
High Single Bed floor to spring					27"	
Loft Bed floor to spring					51"	
Bed Spring			80"	40"		
Matress			80"	40"		
Desk		42"	24"	30"	26"	
Dressers		30"	24"	29 1/2"		

Appendix 7: Estabrooke Hall Floors 3 and 4 Floor Plans


Card access installed at all entry doors per CR029
RFI 19
RFI 23
RFI 30
RFI 15
RFI 5
RFI 3
Wall built out meet code per
FOURTH FLOOR PLAN
Floor Transition Detail
scott simons architects
ESTABROOKE 3RD & 4TH FLOOR RENOVATIONS
FOURTH FLOOR PLAN, FINISH SCHEDULE, + FLOOR TRANSITIONS
A103

Appendix 8: Sally Clark Email

From: Sally Clark <sally.clark@maine.edu>   April 7, 2016 11:14:12 AM
Subject: Re: Average Dorm Room Size
To: **Neal Harrisonbilliat**   View in Browser
Cc: Jennifer Perry <jperry30@maine.edu>

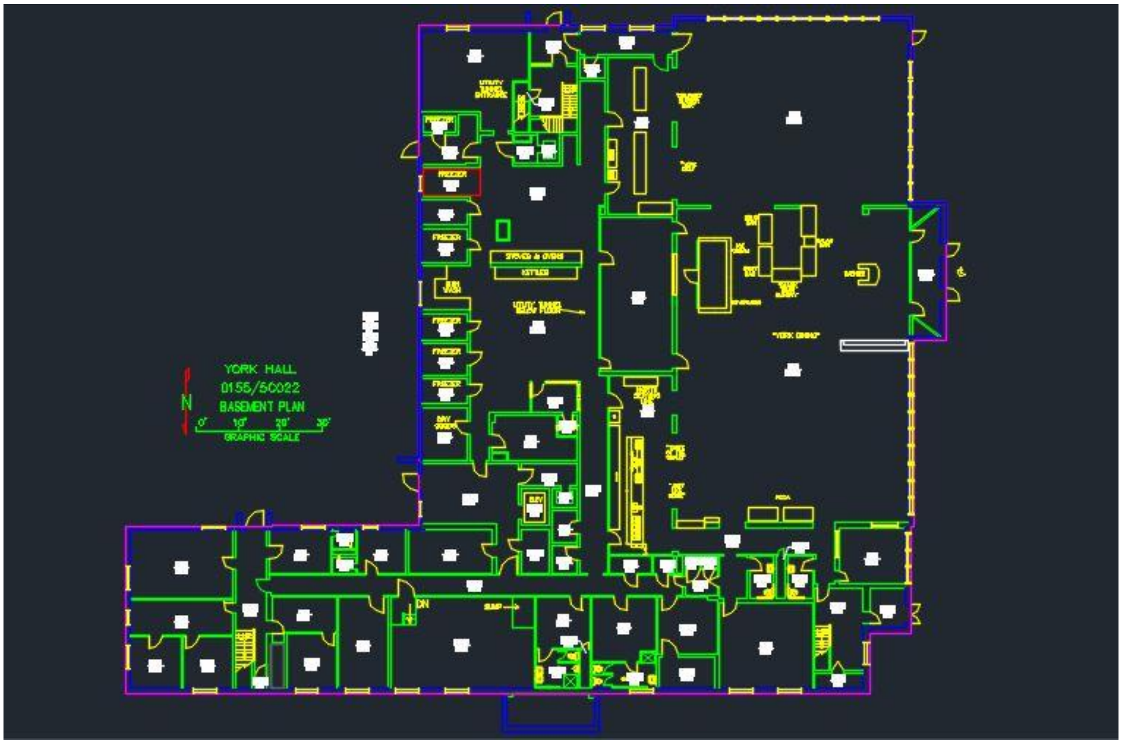
Attachments: Aroostook Hall.pdf / Uploaded File (207K) Estabrooke 3rd Floor with Renovations 2015.pdf / Uploaded File (142K) Oak Hall.pdf / Uploaded File (194K) Aroostook Hall General Information -.pdf / Uploaded File (183K) Estabrooke Hall General Information.pdf / Uploaded File (180K) Oak Hall General Information.pdf / Uploaded File (185K)

Hi Neal,

Attached is the floor plans and specs for Estabrooke Hall (has doubles, regular and deluxe singles), Aroostook Hall (has doubles and small singles), Oak Hall (has regular and small singles). These represent our typical rooms. I hope this helps. Good luck with your thesis!

Sally Clark
Administrative Support Supervisor
Auxiliary Services

Appendix 9: York Dining Floor Plan



Appendix 10: Kenneth on Extended Outages

From: Kenneth Violette Jr <kennethv@maine.edu> April 21, 2016 12:55:44 PM
Subject: Re: Information on Usage of Dining Halls
To: Neal Harrisonbilliat
View in Browser

Neal,
We have a very effective protocol for power outages. Hilltop Commons has a generator so, if that facility losses power, it's operation as normal. York has a generator that will power up all of their walk-in coolers and freezers. If one of our other locations is without power, we have a number of options.

- ship refrigerated/ frozen products to Hilltop/York
-we have 2 refrigerated trucks that can be temperature controlled for refrigerated or frozen product storage
- for a widespread and prolonged power outage, our primary vendor, PFG Northcenter, will supply a refrigerated (diesel) tractor trailer box.

If for some unforeseen reason, we were to loss the ability to keep perishable items at a safe temperature and have to dispose of them, on average, York maintains an inventory of about $20,000 on these items.

Ken

Appendix 11: Buildings on the West Sub

Note: All values pulled from CYME Campus Model

Feeder 1

(D07) LORD HALL - 480V

(D06) WINGATE HALL - 208V

(D05) FERNALD HALL - 208V

(D02) HOLMES HALL - 208V

(D04) ALUMNI HALL - 208V

(D08) AUBERT HALL - 480V

(D15) CORBETT HALL - 480V

(D41) MAHANEY CLUBHOUSE - 208V

(D18) MEMORIAL GYM - 480V

(D14) DUNN HALL - 480V

(D10) OAK HALL - 208V

(D12) WELLS COMMONS - 480V

(D13) HART HALL - 208V

(D09) HANCOCK HALL - 208V

Feeder 2

(C35) SIGMA CHI HERITAGE HOUSE - 240V

(C34) PHI ETA KAPPA - 240V

(C32) DELTA TAU DELTA - 240V

(C24) CHILDREN'S CENTER - 240V

(D16) CROSSLAND HALL - 240V

(D17) ALFOND STADIUM - 480V

(D28) ALFOND ARENA NORTH - 480V

(D28) ALFOND ARENA SOUTH - 480V

Feeder 3

(D01) FOGLER LIBRARY - 600V

(D01) FOGLER LIBRARY OLD - 208V

(D01) FOGLER LIBRARY NEW - 208V

(C10) BALENTINE HALL - 208V

(C09) STODDER HALL - 208V

(C17) ESTABROOKE HALL - 480V

(C22) YORK HALL - 208V

(C21) KENNEBEC HALL - 208V

(C45) YORK VILLAGE BUILDING 1 - 240V

(C47) YORK VILLAGE BUILDING 3 - 240V

(C50) YORK VILLAGE BUILDING 6 - 240V

(C23) AROOSTOOK HALL - 208V

(C62) BUCHANAN ALUMNI HOUSE - 480V

(C20) LENGYEL GYM - 208V

(C19) CHADBOURNE HALL - 208V

(C08) PENOBSCOT HALL - 208V

(C07) CARNEGIE HALL - 208V

(B20) HITCHNER HALL WEST - 480V

(B20) HITCHNER HALL EAST - 480V

(B20) HITCHNER HALL NEW - 480V

(B21) NUTTING HALL - 208V

(C18) DEERING HALL - 600V

(C18) DEERING HALL - 208V

(C11) MERRILL HALL A &B - 240V

(C16) COLVIN HALL - 208V

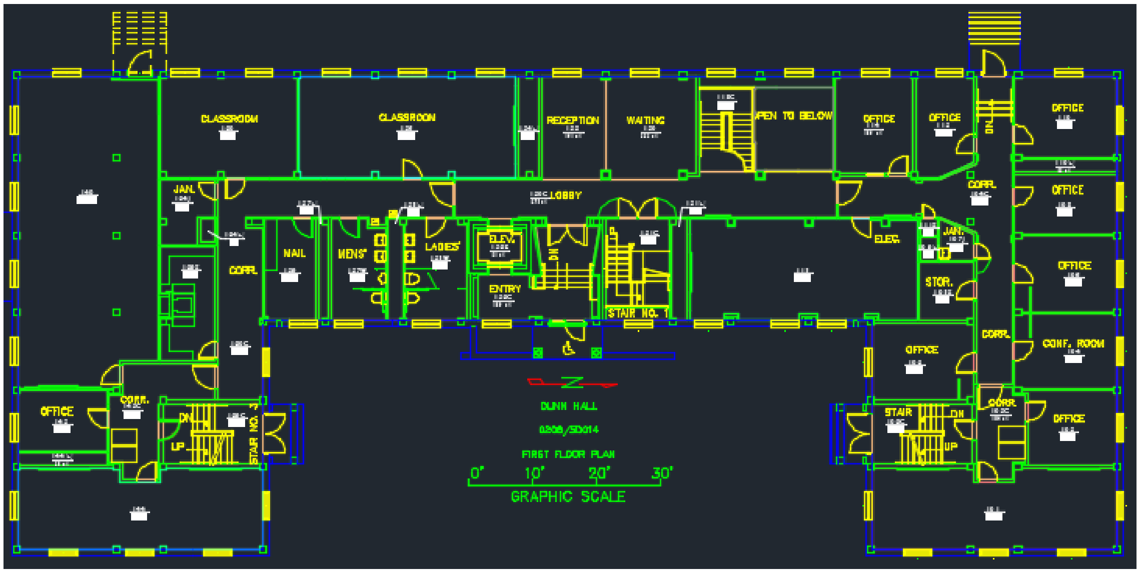
(C12) ROGER CLAPP GREENHOUSES - 240V

(C03) PRESIDENT'S HOUSE - 240V

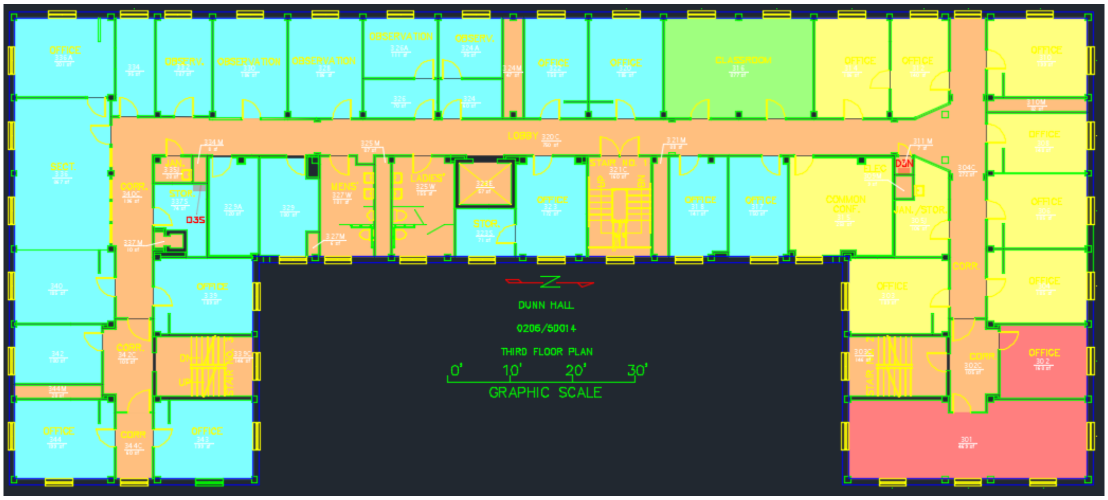
(D03) COBURN HALL - 240V

(C04) WINSLOW HALL - 208V

Appendix 12: Dunn Hall Autocad Floor 1



Appendix 13: Dunn Hall Autocad Floor 3



6.3 Results Obtained

The finished product includes a fully functional, accurate model of the University primary power system as well as load flow analyses based on several random and planned scenarios. Since the Electrical Shop does not have access to the CYME software, the database and study files will be of most significance to Emera, which they will be able to use when making decisions regarding the University and surrounding areas. The model has been scaled to match those of Emera, and will be able to integrate seamlessly with minor adjustments when entered into a larger model.

With the functioning model, several switching scenarios were simulated. The University does not typically use East side feeders to power building that are fed by the West substation in regular operation due to the fact that should an incorrect switch change be made tying East to West, the result could be catastrophic. In the eyes of Emera, the purpose of this model is to investigate the feasibility of powering the entire campus using only the seven East side feeders, effectively eliminating the need for the Steam Plant substation. This scenario was the most heavily investigated. CYME provides the ability to extract any and all of the load flow results that the user chooses. The most important to this project were cables, substation transformers, loads, buses, East breakers and West reclosers. Within these categories CYME is able to calculate power, voltages, currents, and loading percentages. These are the most important to capturing the characteristics of the power system.

Using the analysis capabilities of CYME, it was immediately apparent that the East substation would need significant upgrades in order to perform under heavier loading. At this moment, the East substation operates at 105.5% loading, and the West substation at 93.8%. While these existing conditions do not warrant any immediate concern, the substations will require immediate attention if any new electrical interconnects were to be added in the future. Once the entire load is removed from the West and transferred to the East substation, the loading stands at 178%. This means that several significant and costly improvements will have to be made to the East substation in order for it to support the current and future loads of the University.

Author Biography

Neal T. Harrison-Billiat was born on November 30th 1993 to parents Steven and Ann Harrison-Billiat. Although born in Beverly Westwood Hospital, UK, Neal was raised in Connecticut until the age of 3. At this time, he moved to Rockland, Maine and eventually settled in Appleton, Maine. While in Appleton, Neal attended middle school, and moved on to high school at Camden Hills Regional. Neal graduated from high school with aspirations of becoming an engineer, and set his sights on attending the University of Maine to graduate with an engineering degree. Neal is a member of Alpha Tau Omega, where he served as Chaplain, as well as the President of the engineering fraternity Theta Tau here on campus. Neal is a member of The Order of the Engineer, as well as Tau Alpha Pi. Neal has received numerous scholarships, and paired with working approximately 20 hours a week, will graduate debt free. Upon Graduation, Neal will be working for Woodard and Curran, an environmental consulting agency, with headquarters in Portland, Maine. After school, Neal plans to pursue his Masters, so that in his later years he can teach if so inclined.