# MONGOMERY COLLEGE

## Building and Plant Energy Analysis

**TECHNICAL ASSIGNMENT 2**

**Prepared For:**
Dr. James D. Freihaut, PhD
Department of Architectural Engineering
The Pennsylvania State University

**Prepared By:**
Amy L. Leventry
Mechanical Option
November 3, 2008

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# EXECUTIVE SUMMARY

Recently more now than ever people have become more energy conscience. Another movement within the building industry today is sustainability. Sustainability and the energy crisis go hand in hand. One of the key concepts of “green” buildings is the reduction of energy use and emission. The emission of the building along with the energy use, loads, and cost were all therefore calculated and assessed for this report.

Specifically within the building industry, energy models have become more prevalent to accommodate for the current energy crisis. Energy models create a breakdown of where and how much of the energy and loads of the building are consumed and generated. This detailed breakdown can then be used to improve or create a new heating, ventilation, and air-conditioning system.

The Montgomery College New Science Center is a college laboratory building along with offices and classrooms. This type of building requires special attention towards the heating, ventilation, and air conditioning equipment to maintain safety while minimizing loads and energy of the building as a result minimizing the cost.

In order to aid the design process an energy model was performed for both this report and the actual design of the building. The modeling software IES VE was chosen for its superior modeling capabilities. Overall the software selection was difficult but a success.

The load and energy use of the building came out to be significantly larger than those designed for the building. After further analysis of the problem, it was determined the heat recovery of the building was not simulated correctly. The heating loads were then considerably increased. The loads for the building did not changed but the loads on the equipment increased to account for the energy that would have otherwise been recovered.

The New Science center model for this report uses 8,399,377 kwh of electricity and 70,495 therms of natural gas annually. The operating cost of the building is therefore $8.66/ft$^2$ equaling $1.2 million. The majority of the operating cost is attributed to the direct acting heaters. The selection of a natural gas boiler helped to reduce the energy cost since natural gas is less expensive than electricity per btu.

# ENERGY MODELING PROCEDURE

In order to accomplish energy and load analysis IES VE, an energy and load simulation program, was used. IES VE 5.8.5, Integrated Environmental Solution Virtual Environment was selected based level of accuracy and integration the software can provide. This program allows for a high degree of energy simulation sophistication often necessary with laboratory systems and larger buildings.

When modeling the energy and loads of a building, the more variables taken into account, the more accurate and realistic the results will be. IES VE is one of the most inclusive programs out there today. The amount of information that can be modeled is the reason IES VE was chosen for this energy and load analysis. Some of variable used to calculate the energy and loads of the building include:

- Façade Constructions
  - Wall construction and associated location (R and U values assigned)
  - Window type and associated location (SHGC, Shading Coefficient, R and U values assigned)
  - Roof, floor construction and associated location (R and U values assigned)
  - Interior partitions
  - Ground exposed floors
  - Doors
  - Internal windows
  - Skylights
- Location associated weather files (provides a typical weather file for the location selected on an hour by hour basis)
- Solar files based on the building orientation and location(provide lighting and solar gain values to the model)
- User defined HVAC system
  - Controls used to model flow rate, temperature, etc.
  - System components energy used and generated
- Three dimensional geometry of the building, room adjacency, orientation, and location
- Equipment and occupancy schedules
- Lighting energy used, internal gain created, and illumination of room (Illumination studies were not completed for this report)
- Cost assessment (was not calculated using IES VE for this report)

Room and building usage is vital to conducting energy and load simulations. The type of building will determine the minimum ventilation rate and indirectly affect the internal gains of the room/building. The rooms were grouped together by space type in the Apache HVAC system schematic. This organizes the HVAC system while emphasizing the importance of space type relations over room adjacencies.

The steps below describe the procedure used to conduct the energy and load simulation. The simulation provides the values used in the energy and load evaluation and comparison discussed later in on in this report.

**I. Assigning physical properties of the Building**

**Step 1**

The three dimension building geometry/model is loaded into IES. For this report an Autodesk Revit Model was used. The Revit model can be imported directly into the IES software.

Complications are common and should be dealt with from Revit as opposed to IES due to the limited modeling capability the Model Builder IES provides. Every room was checked with the drawing set to verify location, orientation, and square footage. As expected some of the rooms did not match exactly. Modifications were made to geometry of the model to match the drawing set.

**Step 2**

Select the building location and orientation. This provides the correct weather and solar files for the building. The weather files offer hour by hour outdoor air information for the respective location. The solar files are used to calculate the solar gain and lighting into the building.

IES VE attained permission to use the ASHRAE design weather data of 2005. The ASHRAE percentiles should be entered and a monthly or annual profile should be selected.

To model the Montgomery College New Science Center an annual profile at 99.6% heating and 0.4% cooling was chosen for Baltimore Maryland. The actual New Science Center is to be located in Rockville Maryland. The closest location available through IES VE was chosen in order to model the building as accurate as possible with in the program limitations.

**Step 3**

The wall, roof, floor, window, and partition types/assemblies are known as the construction templates within IES VE. The construction templates are assigned automatically from the Revit model. As mentioned before, numerous complications arise when importing a Revit model into IES VE. The construction templates were altered to meet the construction drawing more accurately and any additional importing errors are corrected.

**II. HVAC system of the Building**

Numerous HVAC systems can be created for any particular model. This allows the several different systems to be calculated for the same building. Only one HVAC system was model, the designed model, was created for this report.

The IES VE Apache HVAC: HVAC Simulation Interface is used to simulate the Montgomery College New Science Center HVAC system. IES VE also provides a generic HVAC system. The Apache HVAC system was there for chosen to model the system as accurate to the drawings as possible.

**Step 4**

Each room is assigned a flow rate specified by the drawing set, by the use of a controller. The controller information requires a proportional bandwidth, maximum change per time set, minimum flow rate, and a maximum flow rate.

> Proportional Bandwidth: 1.00 ˚F
> Maximum Change per Time Set: 0.2
> Minimum Flow Rate: Set at a recommended 1/3rd of the maximum (conservative way to model the minimum air flow to the room)
> Maximum Flow Rate: CFM specified by drawings based on the diffusers

Spaces that are not supplied air are not modeled in the Apache HVAC system. These spaces still apply the space loads to the model, but do not require air to be supplied to the spaces directly and therefore are not used in the Apache HVAC schematic.

**Step 5**

Both exhaust and supply fans are incorporated into the modeled system in order to calculate the fan energy used. The fans modeled do not regulate, model, or simulate the flow rate. The fans can only be used to model the energy used.

The Montgomery College New Science Center HVAC system only utilizes an exhaust and supply fan. No return fan is used and therefore no return fan was modeled. Air is returned to the system but only by the draw of the supply fan.

**Step 6**

System components such as the boilers and chillers are required to be modeled but are not represented visually in the HVAC system. Information for the boilers and chillers is taken off of the drawings.

| | | | |
|---|---|---|---|
| Boilers: | Load: 5220 kbtu/h | Chillers: | Output: 7320 ktbu/h |
| | Efficiency: 87% | | COP at Temperature 1: 5.26 |
| | Use of CHP: No | | Temperature 1: 68 ˚ F |

Fuel is assigned for both the boilers and chillers to track where and how much of the energy is used in the system.

**Step 7**

Heating and cooling coils are modeled in the system. The boilers and chillers are assigned to the respective coils. Both coils require the specification of a maximum duty (kbtu/h). A contact factor must also be entered for the cooling coil.

The maximum duties were determined by the summation of the values found on the drawing set. The contact factor was set at 0.8 (20% bypass) as recommended by the IES manual.

**Step 8**

Finally schedules are created for the occupancy, lights, room equipment, HVAC equipments, etc. These schedules are assigned accordingly to model the actual use of the building and HVAC system. This is a realistic representation of the building as opposed to simulating a building with all of the equipment and system used at all times.

As an example the office schedule are described below. Additional schedules created for the model can be found in Appendix B -Schedules.

Office Schedules:

Most of the office weekly schedules have a different profile for the weekday than the weekend. The offices will be occupied during the week only. Schedules assigned to the lights, people, and equipment will follow the following schedules during the week and will be modeled at zero over the weekend.

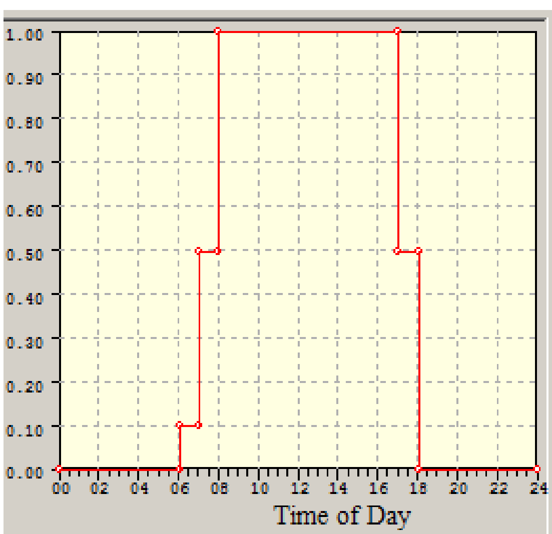



**Figure 1: Lighting Schedule**

This weekly profile represents the lighting schedule of the offices. The profile is progress since not all of the lights will be turned on at one particular time. Realistically all the lights will be off first thing in the morning and as more people enter the building more lights will be turned on until all of the lights are in use. 100% of the light use is estimated once the maximum occupancy has been reached at 8:00 AM.

The occupancy schedule shown above, similar to the lighting schedule is progressive to represent a more realistic progression to maximum occupancy. An estimated 20% decrease in occurs around the typical lunch hour. This schedule is used to represent the internal gain from the occupants that will be applied weekly for the entire year.

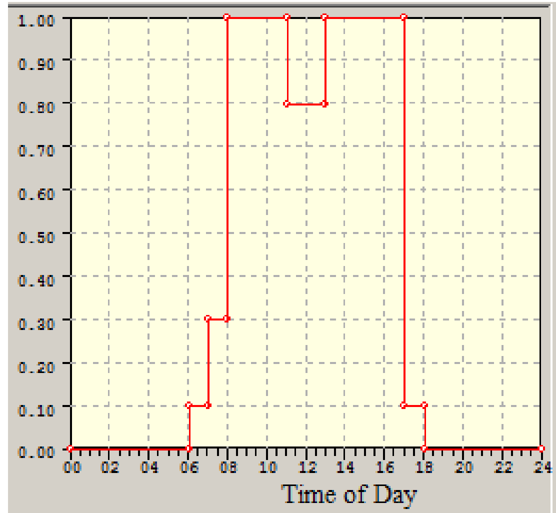



**Figure 2: Occupancy Schedule**

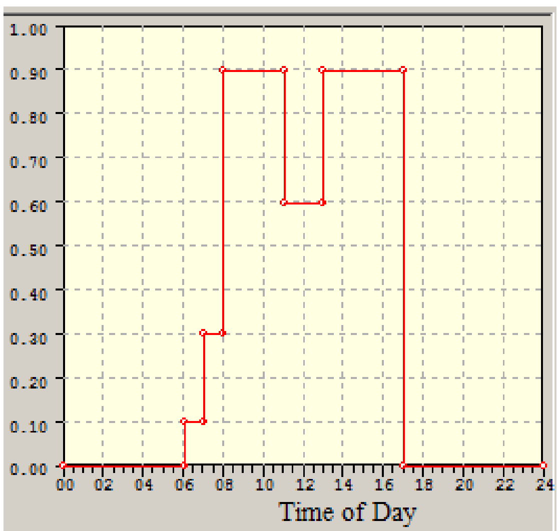



**Figure 3: Office Equipment Schedule**

The office equipment schedule follows the occupancy schedule most similarly. The only deviation is the equipment schedule drops to 60% over lunch assuming that even though some of the occupant will be in the office for lunch will not using the equipment as they would during regular business hours.

The equipment also never reaches 100% assuming that all offices computer, printers, etc. will not be used at the same time.

The cooling schedules for the rooms range from 74 degree F before and after occupancy to 77 degree F during occupancy.

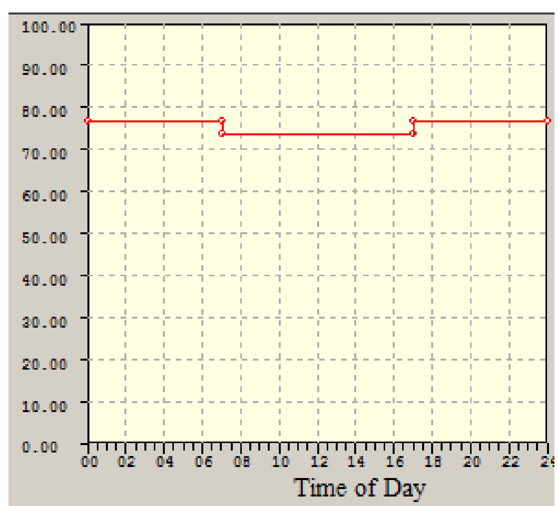



**Figure 4: Cooling Schedule**

The Apache HVAC system for the Montgomery College New Science Center as designed is shown below. The first four groups of rooms are the offices broken down floor by floor. The remaining four groups are the rest of the rooms of the New Science Center broken organized floor by floor in ascending order.

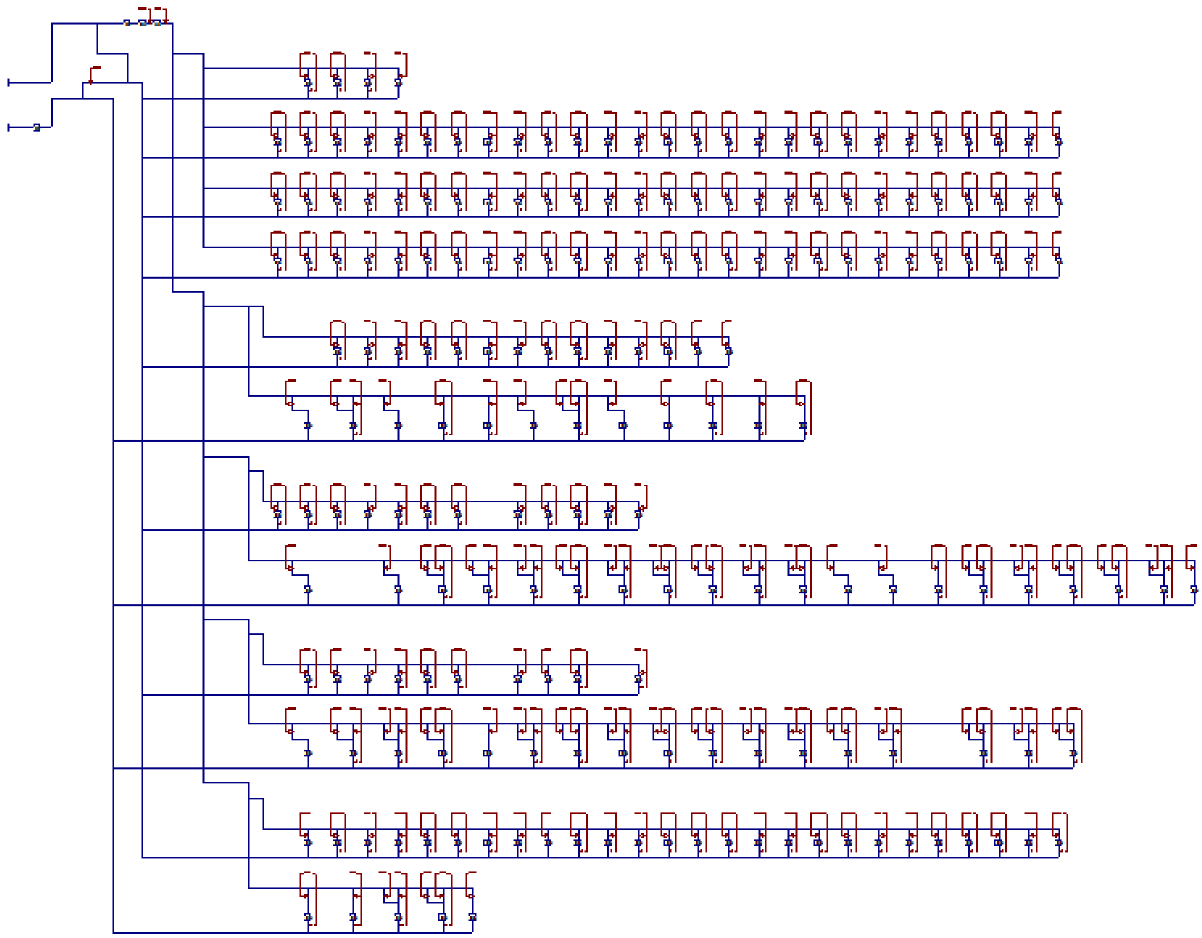


**Figure 5: Apache HVAC System Schematic**

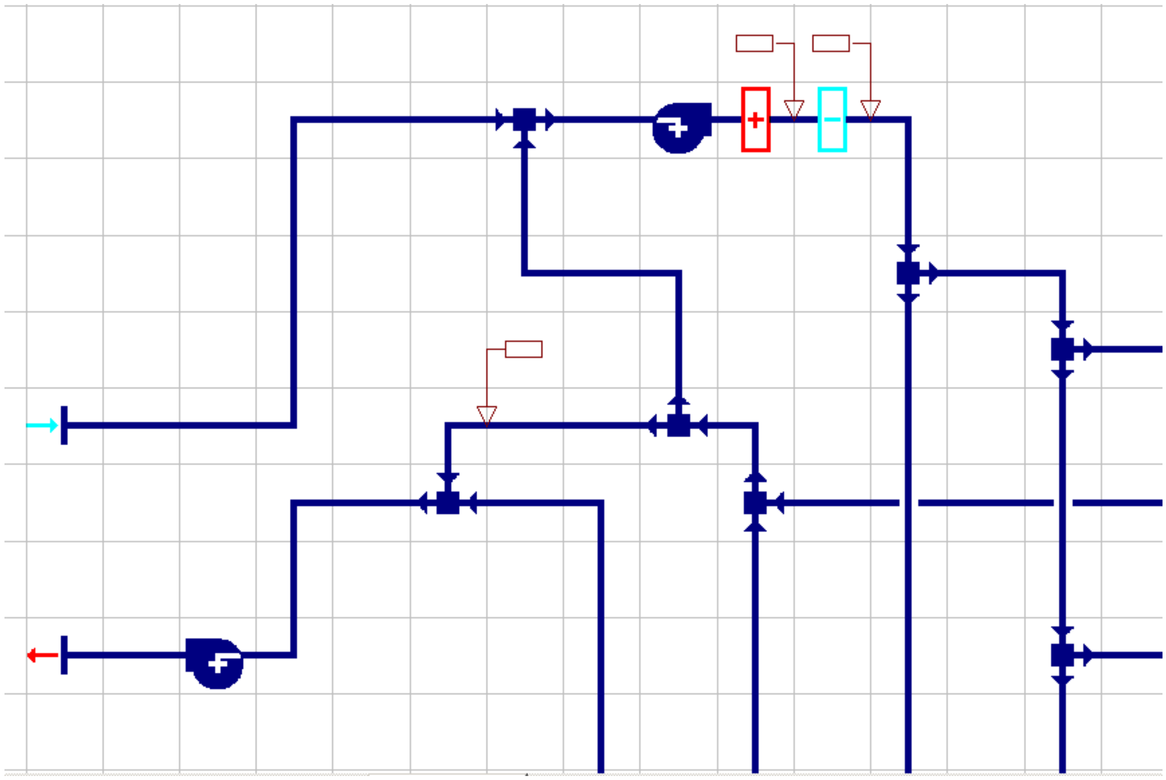


**Figure 6: Enlarged HVAC Schematic – AHU View**

The representative AHU shows one exhaust fan, supply fan, heating coil, and cooling coil. The components of the system were summed and represented by one component within the model. The summation and input data for these components can be found in Appendix D- DESIGN SUMMATIONS.

In general the rooms were modeled as shown, where the control measures the flow rate across the room.

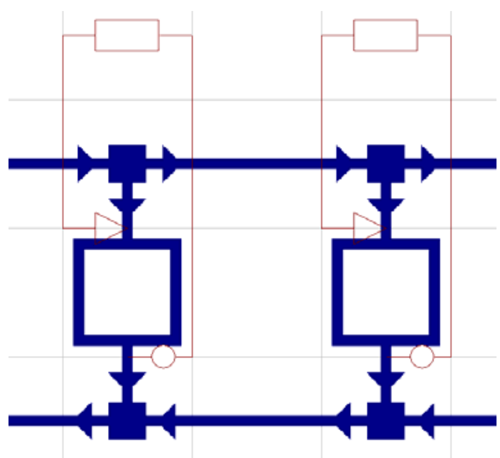


**Figure 7: Enlarged Room Schematic**

# LOAD COMPARISON

Comparing the modeled building to the designed building the loads were found to be significantly greater. No heat was recovered with the modeled system and therefore affected the rest of the calculated loads. The heating coil load increased almost 3,895% and the boiler load increased almost 2,600%. This shows how much the heat recovery can reduce the load of the building. Other increases could be due to control data entry differences. The table below shows the complete breakdown of the system load comparison.

| | Load | Computed MMBTU | Designed MMBTU | % increased |
|---|---|---|---|---|
| Heating | Room heating plant sensible load | 7496.4 | 3772.8 | 99 |
| Heating | Heating coil | 6012 | 154.4 | 3794 |
| Heating | Boiler | 6123.4 | 235.57 | 2499 |
| Heating | Recovered latent heat | 0 | 1597.3 | No recovered heat |
| Cooling | Room cooling plant sensible load | 856.7 | 823.2 | 4 |
| Cooling | Room dehumidification plant load | 27.4 | 17.3 | 58 |
| Cooling | Cooling coils latent load | 4877.5 | 3657.4 | 33 |
| Cooling | Chiller | 19922 | 11866.3 | 68 |
| | Summation | 45315.4 | 22124.3 | 105 |

**Figure 8: Load Comparison – Computed vs. Designed**

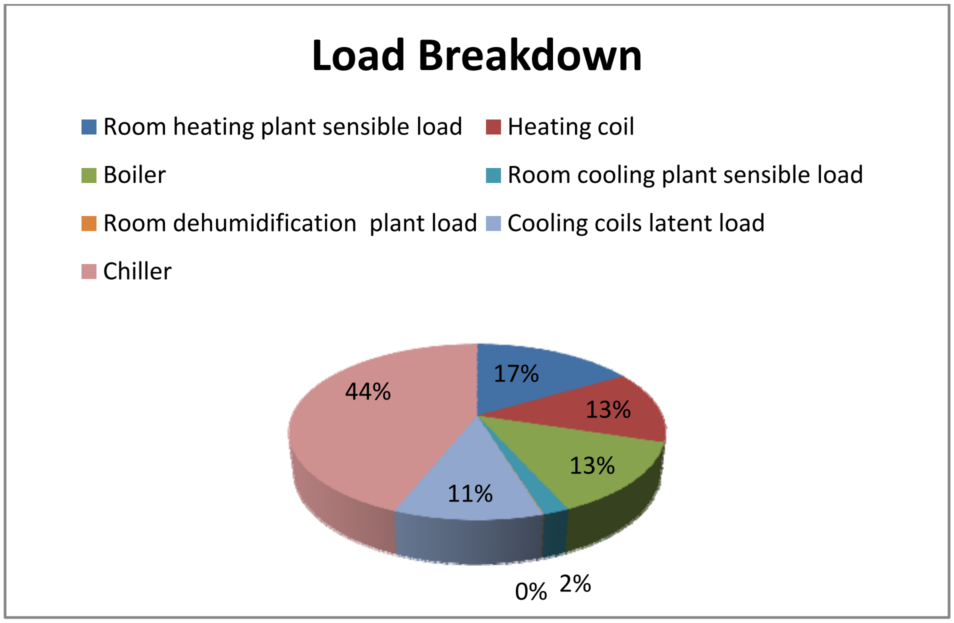



**Figure 9: Load Breakdown**

In conclusion well over the majority of the load goes to the chiller. The New Science Center is an internal load dominated buildings. Looking at Classroom 105 for an example the internal gain was comprised of 85% of the load based on peak values. This type of building results in cooling for most of the year regardless of the fact the building is located in Rockville Maryland, a mixed but predominately cold climate. Due to the fact the building is cooling most of the time, the chiller resulted in the majority of the load for the building.

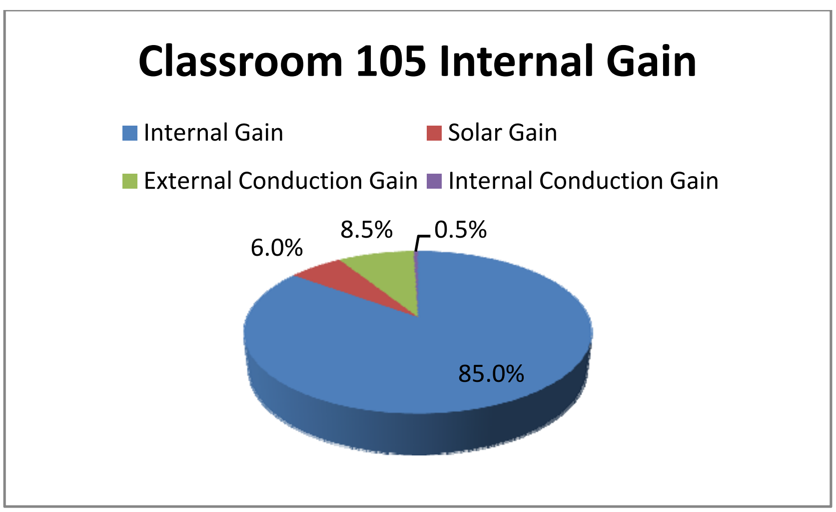



**Figure 10: Classroom 105 Internal Gain**

The loads graphed over time for the entire year to analysis seasonal energy can be found in Appendix E- GRAPHICAL LOADS but will not be analyized for this report.

# ENERGY ANALYSIS

The New Science center consumes 8,645,948 kilowatt hours annually. A complete kilowatt hour breakdown of the total energy use can be found in Appendix A – COMPONENT BREAKDOWN. As expected the energy for the boiler energy increased with the boiler load. In addition, the pump energy increased drastically due to the increased pump power needed for the boiler.

A load and energy month by month breakdown for the model can also be found in the Appendix C – NUMERICAL STUDIES for a more detailed perspective on the energy and loads of the building.

| Energy | Computed MMBTU | Designed MMBTU | % increased |
|---|---|---|---|
| Boilers | 7,047.8 | 271.7 | 2,494 |
| Chillers | 4,422.8 | 2,613.4 | 69 |
| Direct acting heaters | 9,274.5 | 4,272.2 | 117 |
| Fans | 3,614.1 | 2,731.7 | 32 |
| Pumps | 5,142 | 327.6 | 1,470 |
| Lights | 1,432.744 | 1,432.744 | 0 |
| Equipment | 4,773.798 | 4,773.798 | 0 |
| Total System Energy | 29,501.2 | 10,216.6 | 189 |

**Figure 11: Energy Comparison – Computed vs. Designed**

Over all the energy for both the designed and computer values were less than the baseline values, even though the energy was drastically increased due to the lack of energy recovered for the simulated model. This shows the HVAC design combined with the simulated schedules create an excellent system.

Most of the energy went to the direct acting heaters followed by the boilers, pumps, and chillers. The previous load calculations showed the chiller as the dominate load and would therefore be assumed to use the highest percent of energy. This is quite the opposite since the chillers have a COP of 5.26 and boilers are 87% efficient. Although the boilers have a high efficiency they still require over six times the amount of energy as the chillers at equal loads. The pump energy is required regardless of the season and therefore also surpasses the chiller energy.

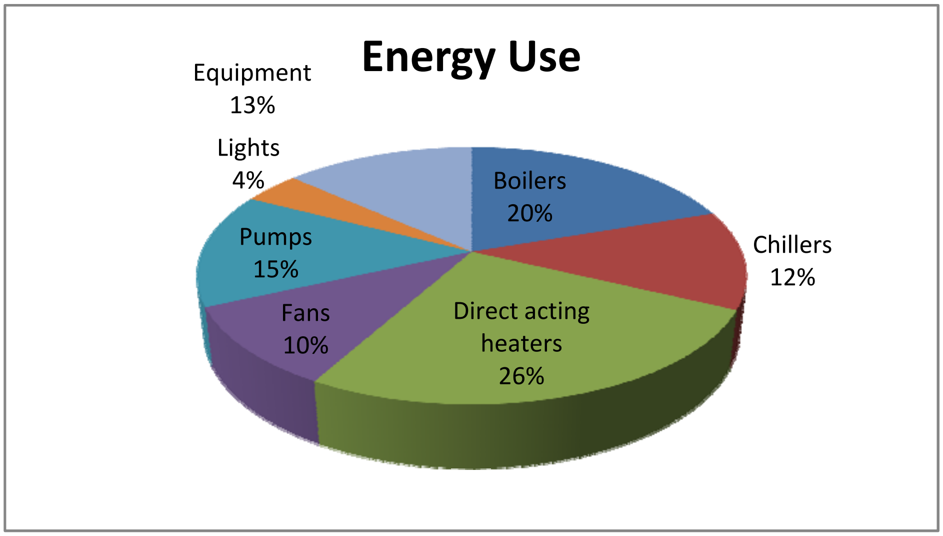



**Figure 11: Energy Use Breakdown**

The energy graphed over time for the entire year to analysis seasonal energy can be found in Appendix F- GRAPHICAL ENERGY but will not be analyized for this report.

# COST ESTIMATE ANALYSIS

**Assumptions based on design reports provided:**

- Natural Gas: $1.54 per therm (2008)
- Electric: $0.1321/kWh (2008 Projected)
- Lighting/plug include all building electrical utilization except fan and pump energy

Compared to other electric rates schemes, this fixed rate requires simple calculations. The simulated energy use was converted from mmbtu to therms and kwh respectively. These values were then used to compute the total energy cost based on the assumptions listed above.

| | mmbtu | therms | $1.54/therm |
|---|---|---|---|
| boilers | 7047.823 | 70495.06 | $108,562.39 |
| **Total Natural Gas** | **7047.823** | **70495.06** | **$108,562.39** |

| | mmbtu | kwh | $0.1321/kwh |
|---|---|---|---|
| chillers | 4422.75 | 1296180.13 | $171,225.40 |
| direct acting heaters | 9274.428 | 2718066.66 | $359,056.61 |
| fan | 3614.103 | 1059189.08 | $139,918.88 |
| pump | 5142.042 | 1506983.82 | $199,072.56 |
| equipment | 4773.798 | 1399062.15 | $184,816.11 |
| Lights | 1432.744 | 419895.84 | $55,468.24 |
| **Total Electric** | **28659.865** | **8399377.68** | **$1,109,557.79** |

| | | | |
|---|---|---|---|
| **Total Energy Cost** | - | - | **$1,218,120.19** |

**Figure 12: Cost Estimation Breakdown**

The Montgomery College New Science Center utilizes all electric systems and a natural gas boiler.   Natural gas is the less expensive of the two energy sources per btu of energy. Therefore, the boiler's energy use must be calculated and modeled separately.

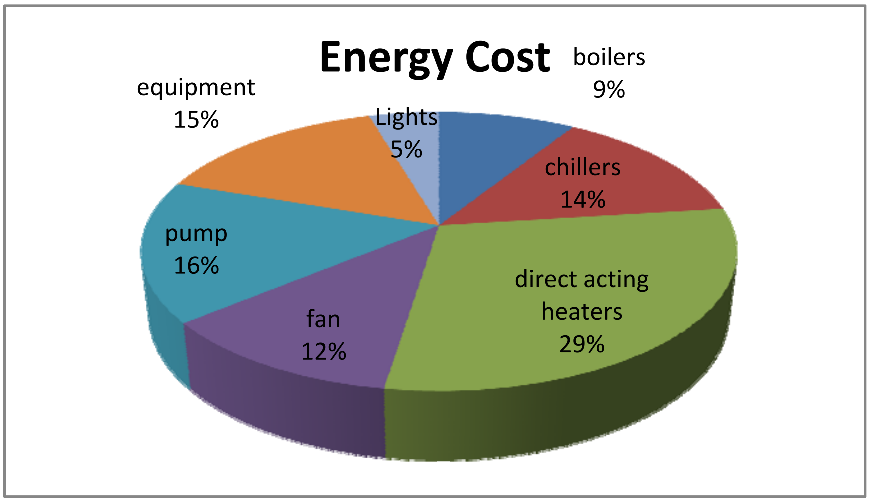



**Figure 13: Energy Cost Breakdown**

The pie graph shows how each system component contributes to the total energy cost taking the source price differences into account.  The boiler consists of 20% of the energy usage but only contributes to 8% of the energy cost.  This is due to the reduced energy price of natural gas.  Based solely on economic the natural gas boiler is a wise design choice over and electric boiler. To analysis the energy use beyond shear economics, see the emission analysis section of the report.

# EMISSIONS

The Montgomery College New Science Center is located in Rockville Maryland and therefore located in the RFC, Eastern Interconnection electric grid. The continental United States is separated up into three main grids of which little energy is transferred.

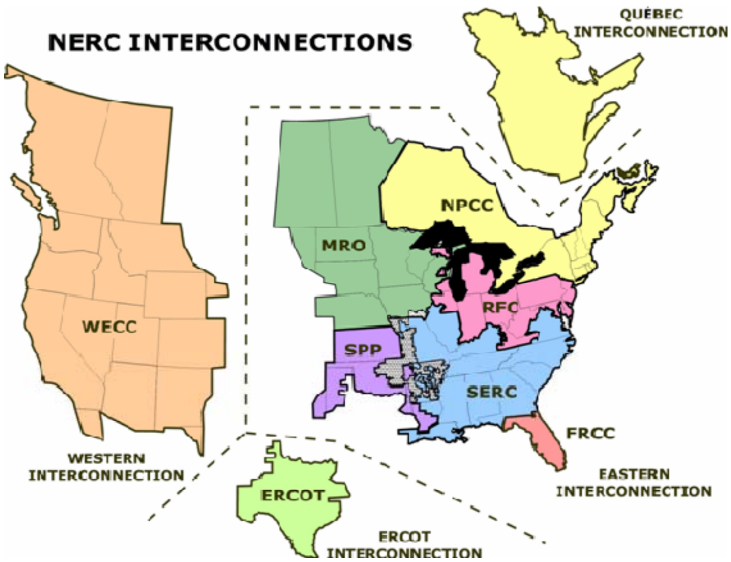



**Figure 14: North American electrical interconnections**

The energy model of the New Science Center revealed 8399377.68 kwh, as discussed earlier. Based on the location of the building the amount of major pollutants in the United States could be calculated.

| Pollutant | Eastern (lb/kwh) | lb of pollutant |
|---|---|---|
| CO2e | 1.7400000 | 14,614,917 |
| CO2 | 1.6400000 | 13,774,979 |
| CH4 | 0.0035900 | 30,154 |
| N2O | 0.0000387 | 325 |
| NOX | 0.0030000 | 25,198 |
| SOX | 0.0085700 | 71,983 |
| CO | 0.0008540 | 7,173 |
| TNMOC | 0.0000726 | 610 |
| Lead | 0.0000001 | 1 |
| Mercury | 0.0000000 | 0 |
| PM10 | 0.0000926 | 778 |
| Solid Waste | 0.2050000 | 1,721,872 |

**Figure 15: New Science Center's Electrical Pollution**

The boiler's use of natural gas for the year must also be taken into account. The boiler uses 7047.823 mmbtu. The calculations for this report were made on the assumption that for every 1010Btu, 1 cubic foot of fuel (Natural gas) is delivered to the building at 60 °F at 14.70 psia.

| Pollutant | Natural Gas | lb of pollutant |
|---|---|---|
| CO2e | 123.00000000 | 937,263 |
| CO2 | 122.00000000 | 929,643 |
| CH4 | 0.00250000 | 19 |
| N2O | 0.00250000 | 19 |
| NOX | 0.11100000 | 846 |
| SOX | 0.00063200 | 5 |
| CO | 0.09330000 | 711 |
| VOC | 0.00613000 | 47 |
| Lead | 0.00000050 | 0 |
| Mercury | 0.00000026 | 0 |
| PM10 | 0.00840000 | 64 |

**Figure 16: New Science Center's Natural Gas Pollution**

# CONCLUSION

The energy model completed very in depth building load and energy calculations. The software itself lacked the user interface that comes standard with most modeling software programs. Many problems arose in the model creation and were solved based on trial and error, and previous experience. Overall the selection of IES VE for the energy and load modeling software was beneficial. As many and difficult the problems were detail of the results cannot be matched by any other program out there today.

Some of the load and energy calculations varied from the designed building values due heat recovery modeling mistakes. If changes were made to account for the heat recovery the model would match the designed data relatively closely.

The direct acting heaters consumed most of the energy for the Montgomery College New Science Center. The direct acting heater also consumed the majority of the energy cost at 29%. After the fuel source was taken into account the boiler energy cost was reduced from the percent of energy used.

The system could improve the amount of emissions created, but could result in a very costly design. A net-zero building would be the optimal design, but is not done with ease.

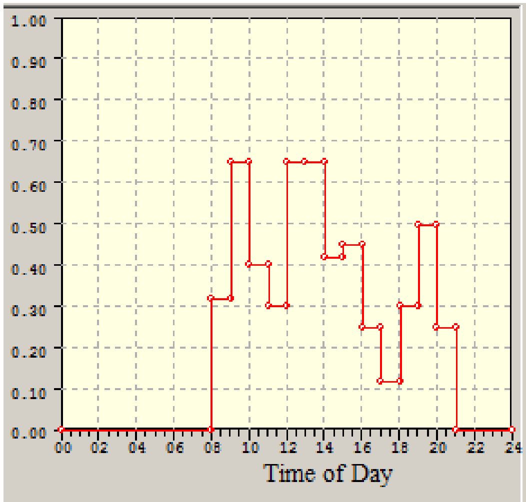
In general the building heating ventilation and air-conditioning system was designed well.

# APPENDIX A – COMPONENT BREAKDOWNS

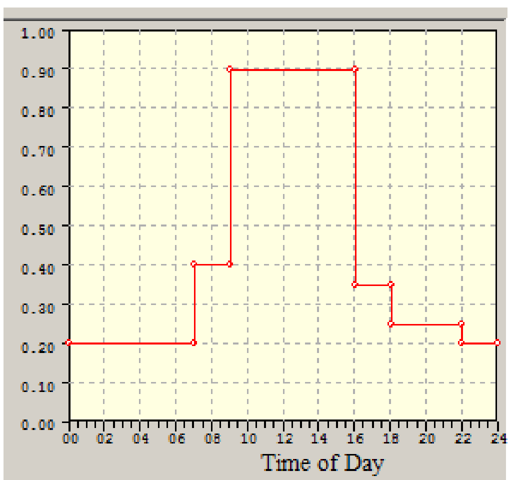
| | Load | Computed MMBTU | Designed MMBTU | % increased |
|---|---|---|---|---|
| Heating | Room heating plant sensible load | 7496.4 | 3772.8 | 199 |
| Heating | Heating coil | 6012 | 154.4 | 3894 |
| Heating | Boiler | 6123.4 | 235.57 | 2599 |
| Heating | Recovered latent heat | 0 | 1597.3 | No recovered heat |
| Cooling | Room cooling plant sensible load | 856.7 | 823.2 | 104 |
| Cooling | Room dehumidification plant load | 27.4 | 17.3 | 158 |
| Cooling | Cooling coils latent load | 4877.5 | 3657.4 | 133 |
| Cooling | Chiller | 19922 | 11866.3 | 168 |
| | Summation | 45315.4 | 22124.3 | 205 |

| Energy | Computed MMBTU | Computed kwh | Designed MMBTU | Designed kwh | % increased |
|---|---|---|---|---|---|
| Boilers | 7047.8 | 2,065,592.03 | 271.7 | 79,630.72 | 2594 |
| Chillers | 4422.8 | 1,296,248.53 | 2613.4 | 765,943.73 | 169 |
| Direct acting heaters | 9274.5 | 2,718,200.47 | 4272.2 | 1,252,110.20 | 217 |
| Fans | 3614.1 | 1,059,232.12 | 2731.7 | 800,615.47 | 132 |
| Pumps | 5142 | 1,507,034.00 | 327.6 | 96,014.07 | 1570 |
| Total System Energy | 29501.2 | 8,646,307.15 | 10216.6 | 2,994,314.19 | 289 |

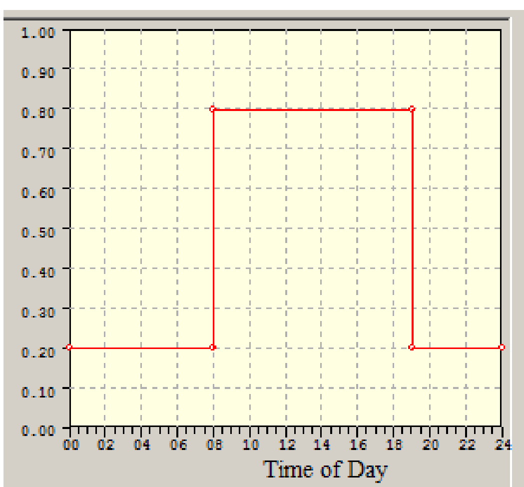
# APPENDIX B - SCHEDULES



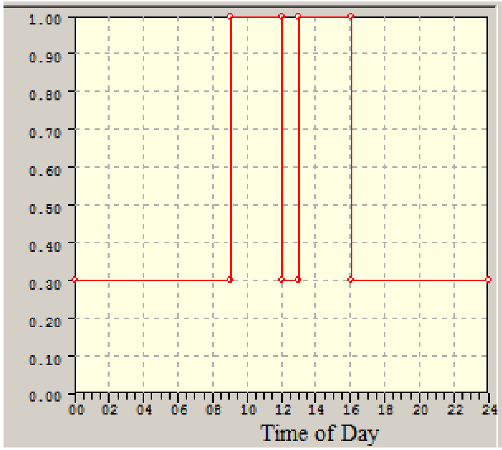

Domestic Hot Water Usage



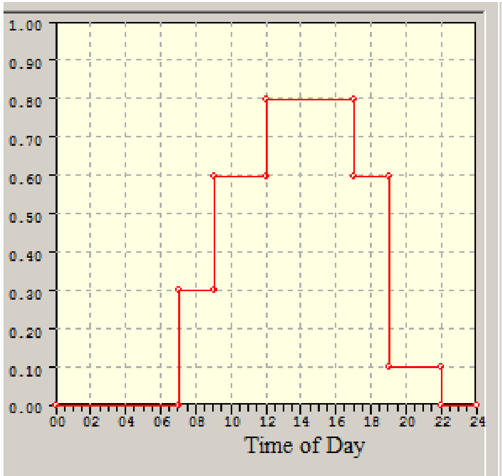

Lab equipment weekdays



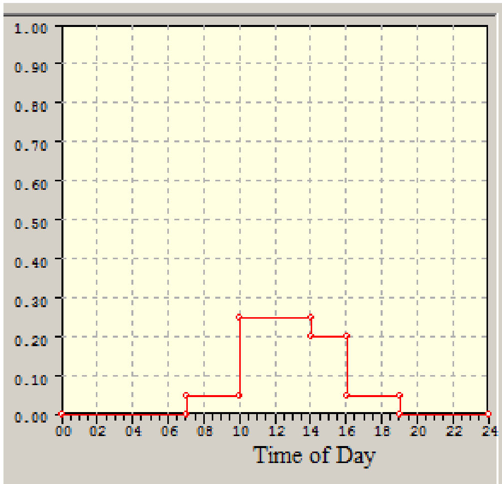

Lab equipment weekends




Lab General and Organic Chemistry




Lab lighting/people/equipment weekdays




Lab lighting/people/equipment weekends

# APPENDIX C – NUMERICAL SUMMARIES

| | Room heating plant sens. load (MMBtu) | ApHVAC heating coils load (MMBtu) | Boilers load (MMBtu) |
|---|---|---|---|
| | amy run1.aps | amy run1.aps | amy run1.aps |
| Date | | | |
| Jan 01-31 | 878.459 | 1445.213 | 1465.615 |
| Feb 01-28 | 734.607 | 995.049 | 1009.926 |
| Mar 01-31 | 766.645 | 754.940 | 766.666 |
| Apr 01-30 | 634.833 | 440.604 | 449.341 |
| May 01-31 | 513.699 | 112.658 | 117.557 |
| Jun 01-30 | 425.786 | 25.678 | 29.056 |
| Jul 01-31 | 405.235 | 0.430 | 3.418 |
| Aug 01-31 | 425.693 | 28.436 | 31.922 |
| Sep 01-30 | 534.568 | 74.198 | 78.766 |
| Oct 01-31 | 617.361 | 278.787 | 286.047 |
| Nov 01-30 | 730.809 | 707.081 | 719.451 |
| Dec 01-31 | 828.688 | 1148.963 | 1165.595 |
| Summed total | 7496.381 | 6012.037 | 6123.361 |

Heating Load Breakdown

| | Room cooling plant sens. load (MMBtu) | Room dehum. plant load (MMBtu) | ApHVAC cooling coils total load (MMBtu) | ApHVAC cooling coils sensible load (MMBtu) | ApHVAC cooling coils latent load (MMBtu) | Chillers load (MMBtu) |
|---|---|---|---|---|---|---|
| | amy run1.aps | amy run1.aps | amy run1.aps | amy run1.aps | amy run1.aps | amy run1.aps |
| Date | | | | | | |
| Jan 01-31 | 51.034 | 2.229 | 730.117 | 730.115 | 0.002 | 912.490 |
| Feb 01-28 | 51.512 | 2.098 | 699.900 | 676.006 | 23.893 | 883.460 |
| Mar 01-31 | 64.694 | 2.392 | 841.179 | 825.136 | 16.042 | 1070.882 |
| Apr 01-30 | 68.307 | 2.296 | 926.441 | 833.886 | 92.555 | 1168.183 |
| May 01-31 | 81.456 | 2.227 | 1627.132 | 1125.041 | 502.092 | 1913.663 |
| Jun 01-30 | 86.167 | 2.295 | 2122.808 | 1301.030 | 821.779 | 2425.704 |
| Jul 01-31 | 93.538 | 2.317 | 2925.459 | 1556.915 | 1368.543 | 3253.665 |
| Aug 01-31 | 89.106 | 2.312 | 2397.651 | 1358.119 | 1039.531 | 2710.664 |
| Sep 01-30 | 80.023 | 2.294 | 1929.367 | 1203.614 | 725.753 | 2211.220 |
| Oct 01-31 | 73.609 | 2.231 | 1216.873 | 938.724 | 278.148 | 1476.549 |
| Nov 01-30 | 60.788 | 2.293 | 729.631 | 723.574 | 6.057 | 945.619 |
| Dec 01-31 | 56.415 | 2.391 | 748.522 | 745.399 | 3.123 | 949.874 |
| Summed total | 856.649 | 27.375 | 16895.078 | 12017.560 | 4877.517 | 19921.973 |

Cooling Load Breakdown

| | ApHVAC heating coils load (MMBtu) | Boilers load (MMBtu) | ApHVAC cooling coils total load (MMBtu) | Chillers load (MMBtu) |
|---|---|---|---|---|
| | amy run1.aps | amy run1.aps | amy run1.aps | amy run1.aps |
| Date | | | | |
| Jan 01-31 | 1445.213 | 1465.615 | 730.117 | 912.490 |
| Feb 01-28 | 995.049 | 1009.926 | 699.900 | 883.460 |
| Mar 01-31 | 754.940 | 766.666 | 841.179 | 1070.882 |
| Apr 01-30 | 440.604 | 449.341 | 926.441 | 1168.183 |
| May 01-31 | 112.658 | 117.557 | 1627.132 | 1913.663 |
| Jun 01-30 | 25.678 | 29.056 | 2122.808 | 2425.704 |
| Jul 01-31 | 0.430 | 3.418 | 2925.459 | 3253.665 |
| Aug 01-31 | 28.436 | 31.922 | 2397.651 | 2710.664 |
| Sep 01-30 | 74.198 | 78.766 | 1929.367 | 2211.220 |
| Oct 01-31 | 278.787 | 286.047 | 1216.873 | 1476.549 |
| Nov 01-30 | 707.081 | 719.451 | 729.631 | 945.619 |
| Dec 01-31 | 1148.963 | 1165.595 | 748.522 | 949.874 |
| Summed total | 6012.037 | 6123.361 | 16895.078 | 19921.973 |

Coil Loads

| | Boilers energy (MMBtu) | Chillers energy (MMBtu) | ApHVAC direct acting heaters energy (MMBtu) | ApHVAC fans energy (MMBtu) | ApHVAC pumps energy (MMBtu) | Ap Sys fans/pumps/ctrl energy (MMBtu) | Total system energy (MMBtu) |
|---|---|---|---|---|---|---|---|
| | montgomery | montgomery | montgomery | montgomery | montgomery | montgomery | montgomery |
| Date | | | | | | | |
| Jan 01-31 | 91.855 | 70.219 | 578.132 | 204.936 | 0.000 | 143.734 | 1088.875 |
| Feb 01-28 | 48.130 | 98.095 | 438.710 | 193.198 | 4.069 | 130.603 | 912.805 |
| Mar 01-31 | 28.325 | 169.007 | 428.979 | 229.849 | 12.717 | 157.984 | 1026.861 |
| Apr 01-30 | 15.961 | 204.380 | 343.675 | 224.412 | 26.726 | 154.382 | 969.535 |
| May 01-31 | 3.262 | 290.608 | 282.618 | 243.920 | 45.461 | 159.883 | 1025.752 |
| Jun 01-30 | 0.708 | 306.102 | 242.544 | 243.554 | 48.124 | 160.764 | 1001.798 |
| Jul 01-31 | 0.054 | 354.218 | 212.291 | 245.453 | 50.595 | 174.974 | 1037.585 |
| Aug 01-31 | 1.149 | 318.338 | 221.777 | 241.797 | 48.691 | 168.705 | 1000.458 |
| Sep 01-30 | 3.167 | 289.762 | 309.993 | 248.096 | 45.200 | 157.118 | 1053.336 |
| Oct 01-31 | 8.729 | 243.130 | 327.664 | 234.572 | 36.076 | 159.033 | 1009.204 |
| Nov 01-30 | 23.084 | 171.611 | 398.080 | 210.085 | 8.897 | 152.266 | 964.024 |
| Dec 01-31 | 47.256 | 97.952 | 487.730 | 211.858 | 1.088 | 146.631 | 992.516 |
| Summed total | 271.680 | 2613.422 | 4272.193 | 2731.729 | 327.643 | 1866.078 | 12082.747 |

| | Boilers energy (MMBtu) | Chillers energy (MMBtu) | ApHVAC direct acting heaters energy (MMBtu) | ApHVAC fans energy (MMBtu) | ApHVAC pumps energy (MMBtu) | Ap Sys fans/pumps/ctrl energy (MMBtu) | Total system energy (MMBtu) |
|---|---|---|---|---|---|---|---|
| | amy run1.aps | amy run1.aps | amy run1.aps | amy run1.aps | amy run1.aps | amy run1.aps | amy run1.aps |
| Date | | | | | | | |
| Jan 01-31 | 1686.352 | 211.755 | 1080.471 | 298.474 | 757.937 | 167.429 | 4202.415 |
| Feb 01-28 | 1162.100 | 206.485 | 905.423 | 273.431 | 657.420 | 150.178 | 3355.036 |
| Mar 01-31 | 882.224 | 251.801 | 948.188 | 322.923 | 679.324 | 176.441 | 3260.898 |
| Apr 01-30 | 517.229 | 272.826 | 786.003 | 296.667 | 535.340 | 174.375 | 2582.438 |
| May 01-31 | 135.541 | 423.953 | 637.897 | 302.965 | 253.324 | 181.247 | 1934.925 |
| Jun 01-30 | 33.685 | 524.734 | 529.318 | 297.695 | 90.327 | 180.733 | 1656.491 |
| Jul 01-31 | 4.183 | 687.453 | 503.966 | 308.518 | 5.433 | 193.278 | 1702.830 |
| Aug 01-31 | 36.989 | 581.032 | 529.108 | 297.823 | 63.331 | 188.524 | 1696.807 |
| Sep 01-30 | 90.924 | 479.541 | 664.269 | 314.127 | 186.767 | 177.545 | 1913.171 |
| Oct 01-31 | 329.408 | 335.215 | 765.437 | 301.819 | 435.166 | 180.408 | 2347.456 |
| Nov 01-30 | 828.008 | 225.108 | 902.839 | 295.152 | 723.809 | 170.749 | 3145.659 |
| Dec 01-31 | 1341.180 | 222.845 | 1021.509 | 304.511 | 753.862 | 167.131 | 3811.035 |
| Summed total | 7047.823 | 4422.750 | 9274.428 | 3614.103 | 5142.042 | 2108.037 | 31609.164 |

System Energy

# APPENDIX D – DESIGN SUMMATIONS

## TOTALS USED FOR ENERGY MODEL CALCULATIONS (DATA TAKEN FROM CONSTRUCTION DOCUMENT SCHEDULES)

| Supply Fan | CFM | S.P. in wg | Q*P |
|---|---|---|---|
| SF- 1A | 33,365 | 6.00 | 200,190.0 |
| SF- 1B | 33,365 | 6.00 | 200,190.0 |
| SF -2A | 33,365 | 6.00 | 200,190.0 |
| SF -2B | 33,365 | 6.00 | 200,190.0 |
| SF -3 | 2,110 | 0.85 | 1,793.5 |
| TOTAL | 135,570 | 5.92 | 802,553.5 |

| Exhaust Fan | CFM | S.P. in wg | Q*P |
|---|---|---|---|
| EF-1A | 24,200 | 5.50 | 133,100.0 |
| EF-1B | 24,200 | 5.50 | 133,100.0 |
| EF-1C | 24,200 | 5.50 | 133,100.0 |
| EF-1D | 24,200 | 5.50 | 133,100.0 |
| EF-2 | 2,900 | 0.75 | 2,175.0 |
| EF-3 | 760 | 0.60 | 456.0 |
| EF-4 | 550 | 0.50 | 275.0 |
| EF-5 | 0 | 0.00 | 0.0 |
| EF-6 | 2,600 | 0.45 | 1,170.0 |
| EF-7 | 77 | 0.10 | 7.7 |
| EF-8 | 77 | 0.10 | 7.7 |
| EF-9 | 77 | 0.10 | 7.7 |
| TOTAL | 103,841 | 5.17 | 536,499.1 |

| Boiler | MBH IN | MBH OUT | Efficiency (%) |
|---|---|---|---|
| B-1 | 3,000 | 2610 | 87 |
| B-2 | 3,000 | 2610 | 87 |
| TOTAL | 6,000 | 5,220 | 87 |

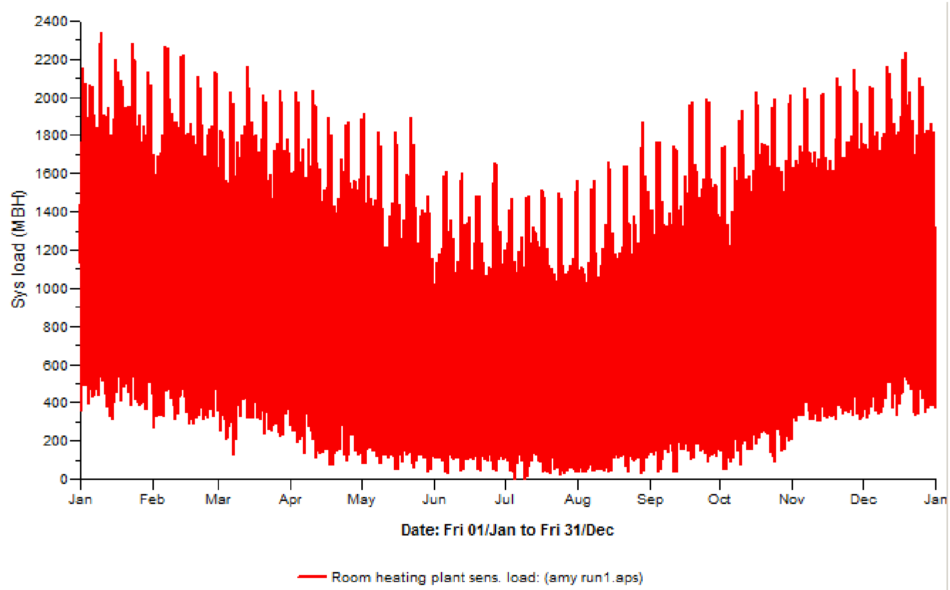
| Heating Coil | MBTH | kbtuh |
|---|---|---|
| HC-1 | 951.5 | 951500 |
| HC-2 | 951.5 | 951500 |
| TOTAL | 1,903 | 1903000 |

| Chiller | Tons | kbtu/h | KW/ton | COP |
|---|---|---|---|---|
| CH-1 | 305 | 3660 | 0.669 | 5.26 |
| CH-2 | 305 | 3660 | 0.669 | 5.26 |
| TOTAL | 610 | 7,320 | 0.669 | 5.26 |

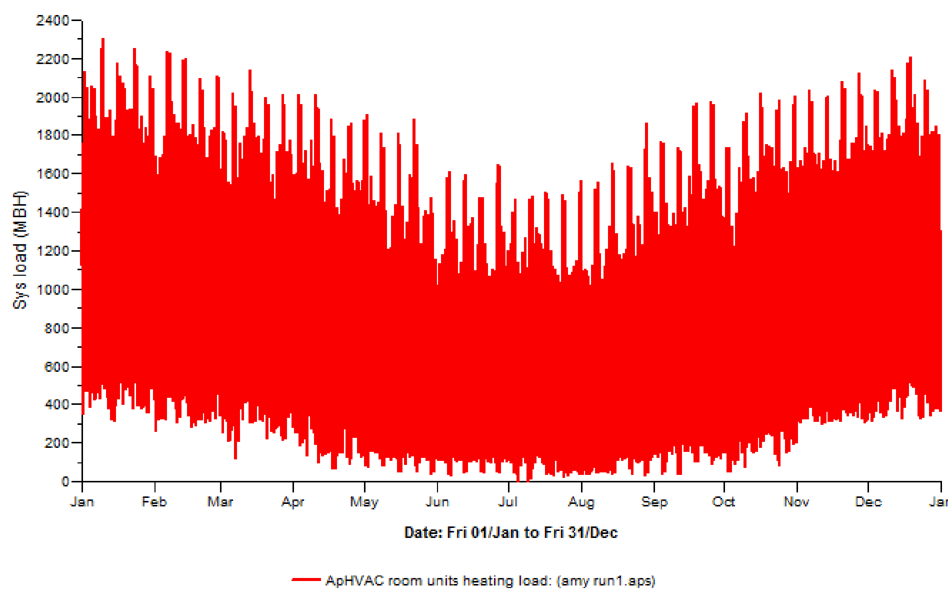
| Cooling Coil | kBTH |
|---|---|
| CC-1 | 4,264.0 |
| CC-2 | 4,264.0 |
| TOTAL | 8,528 |

# APPENDIX E – GRAPHICAL LOADS

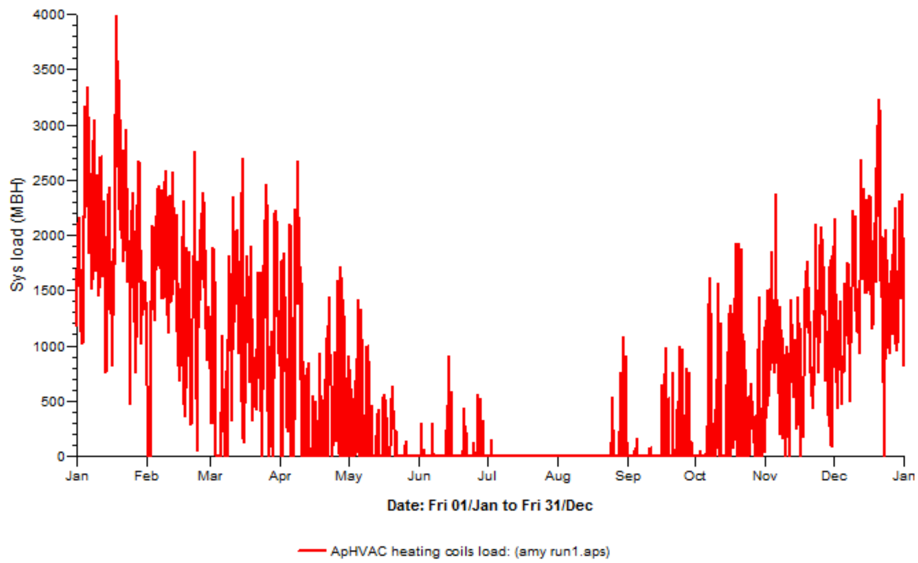
**Heating Loads:**



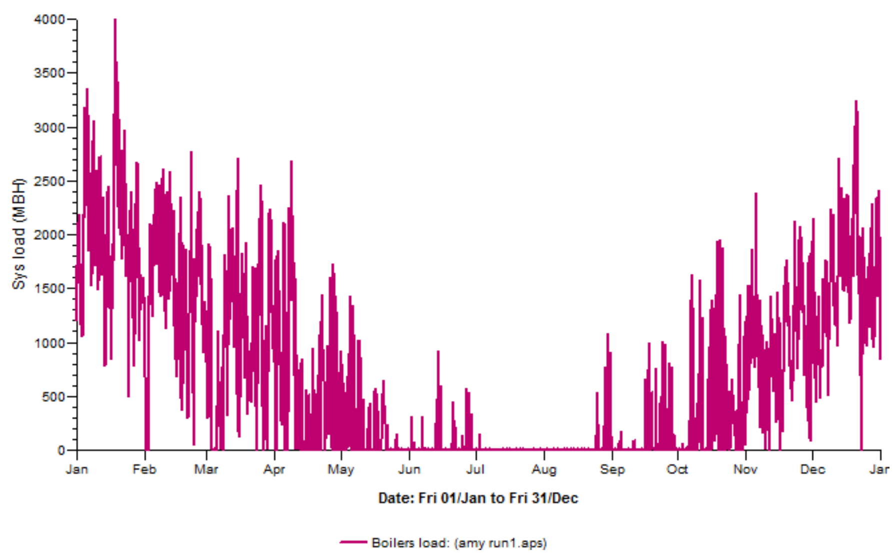

Room Heating Plant Sensible Load




Unit Heating Load

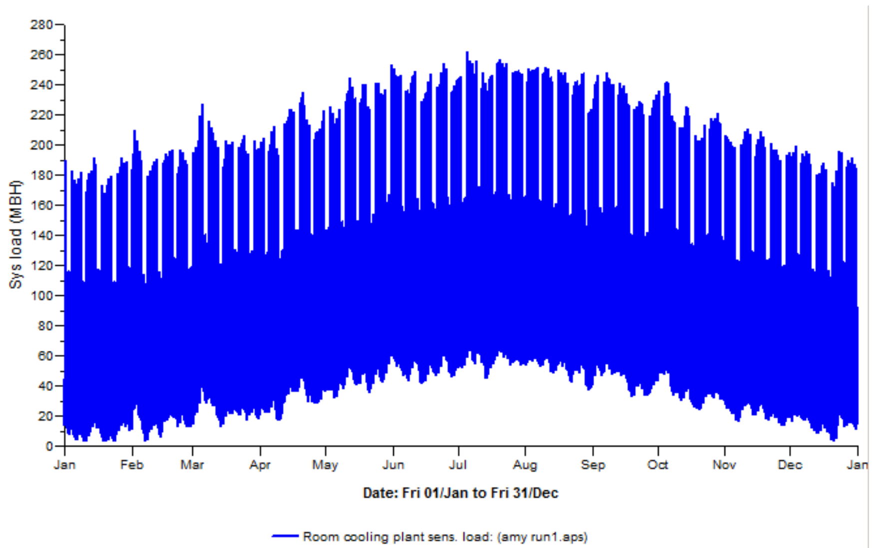



Heating Coil Load

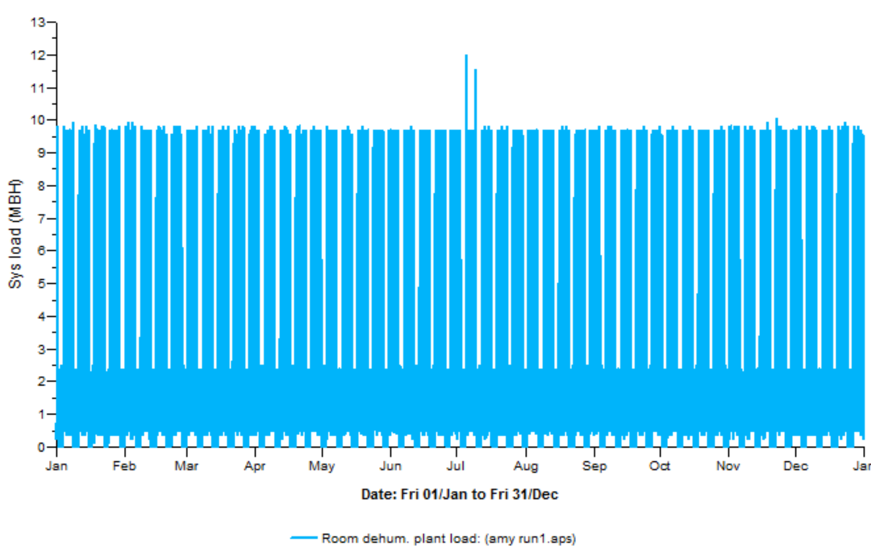



Boiler Load

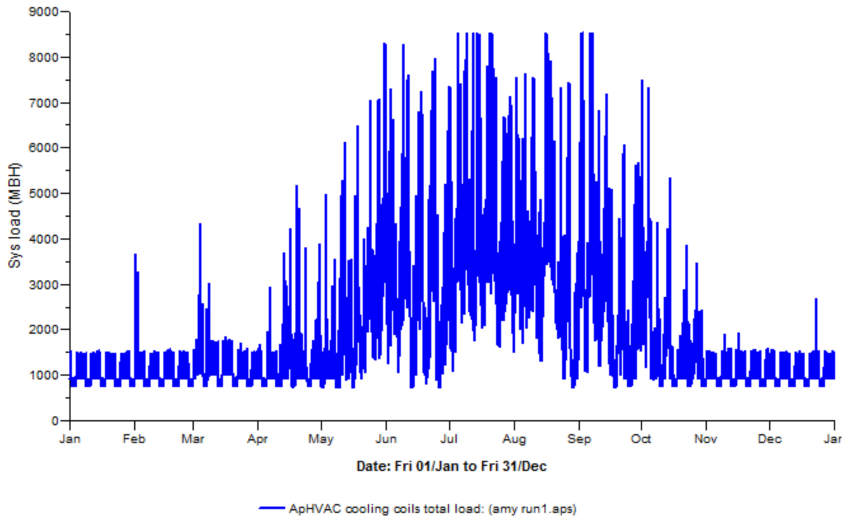
**Cooling Loads:**



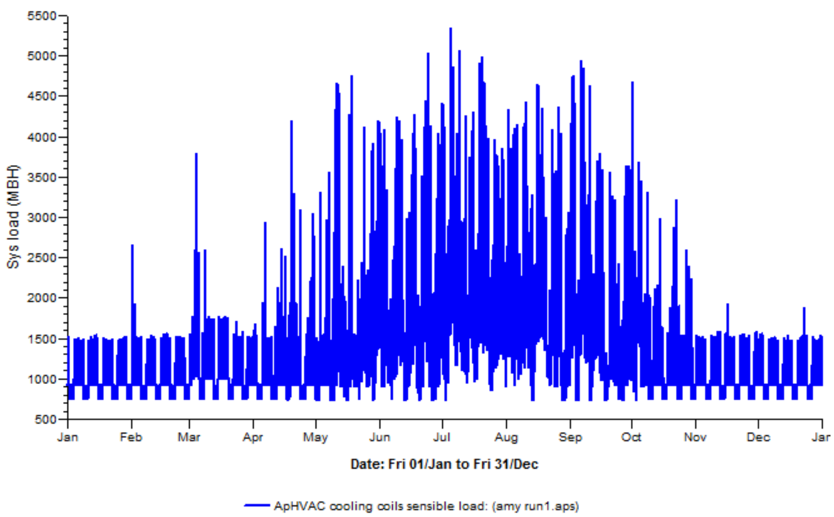

Room Cooling Plant Sensible Load



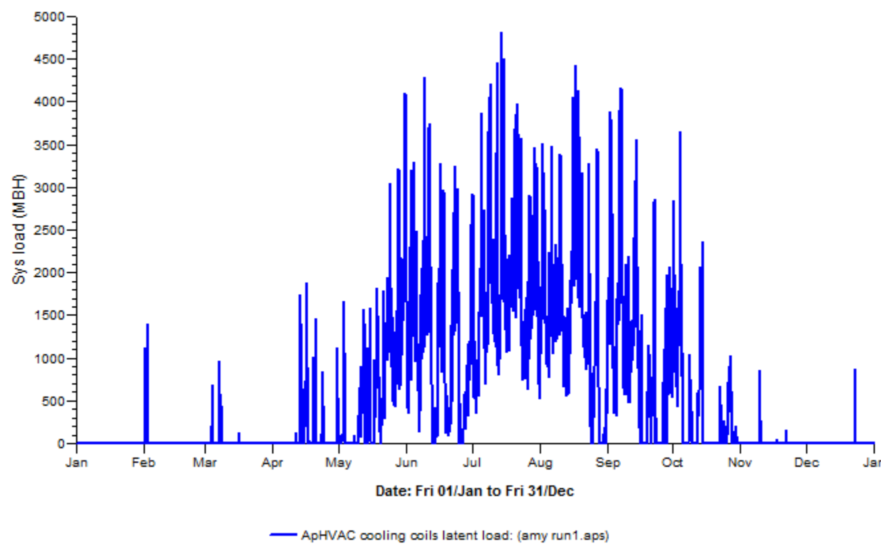

Dehumidification Plant Load



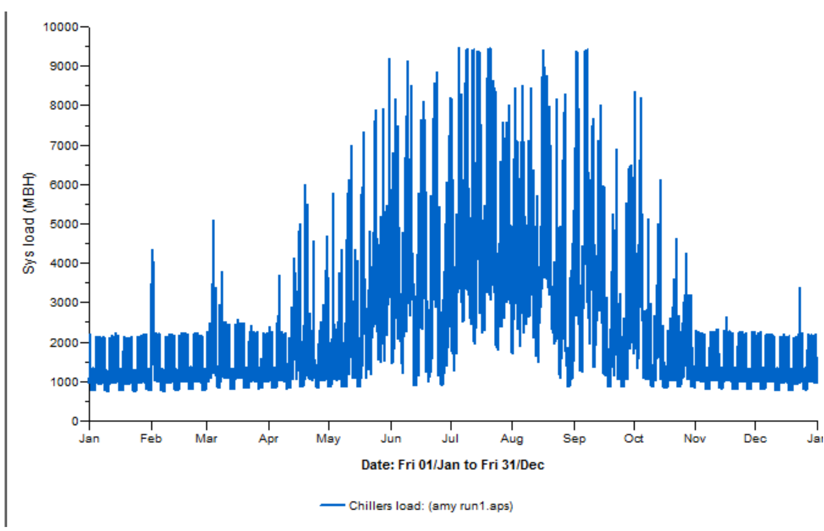

Coiling Cools Total Load




Cooling Coils Sensible Load

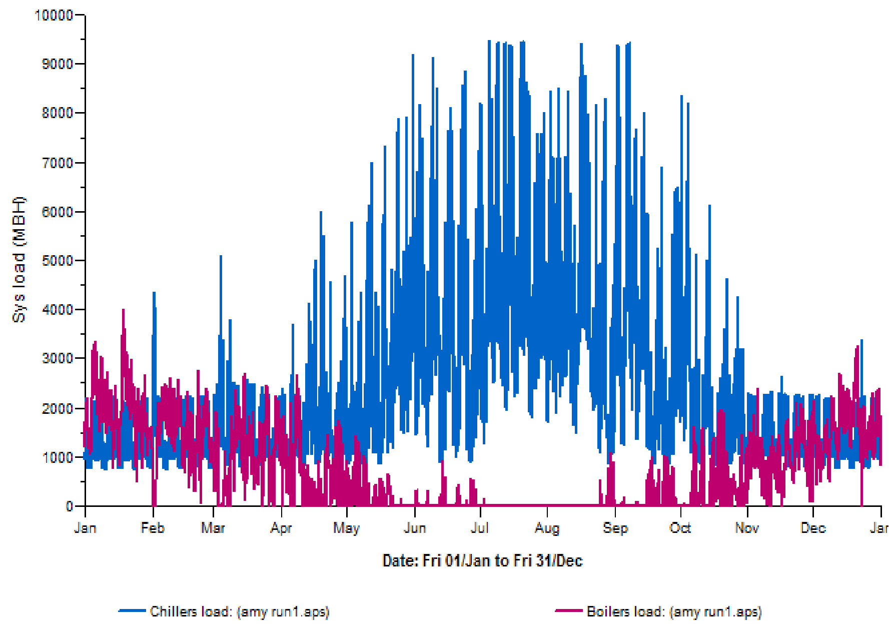



Cooling Coil Latent Load

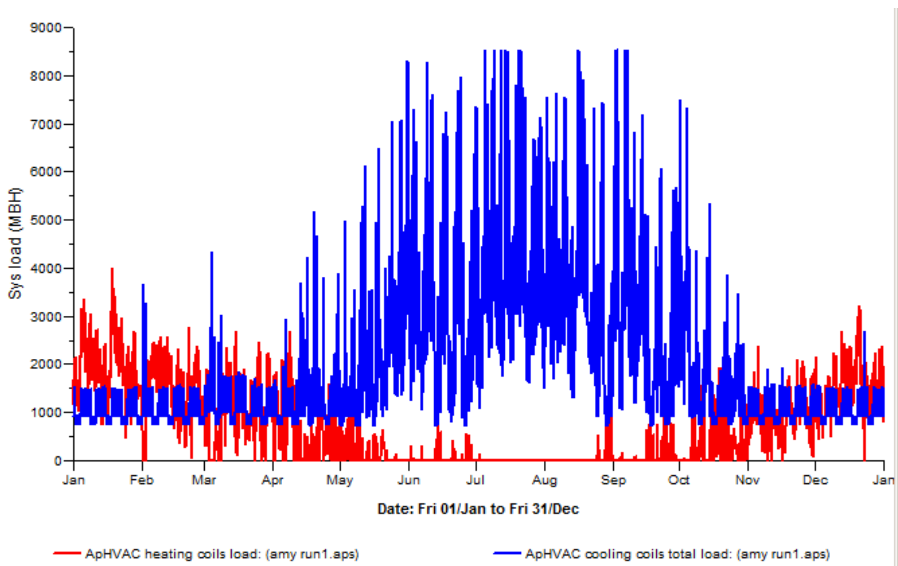



Chiller Loads

**Load Summary:**

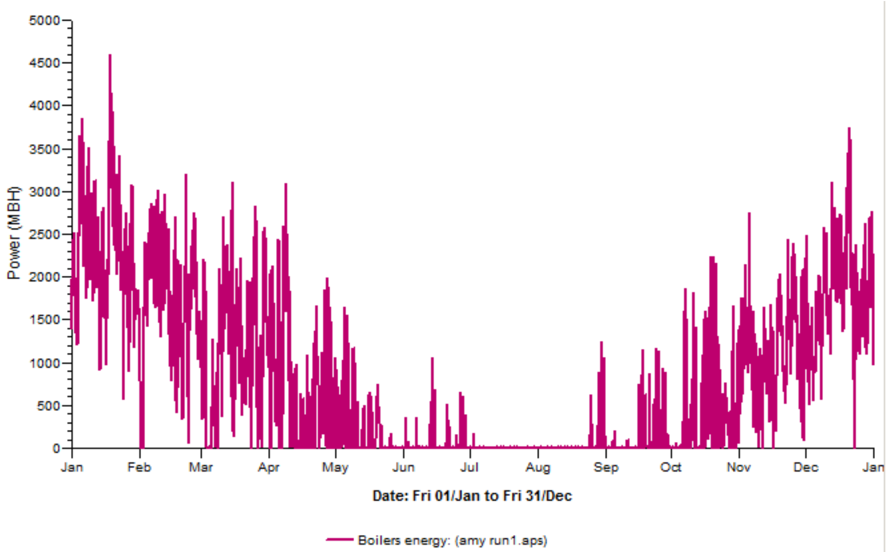



Boiler and Chiller Loads

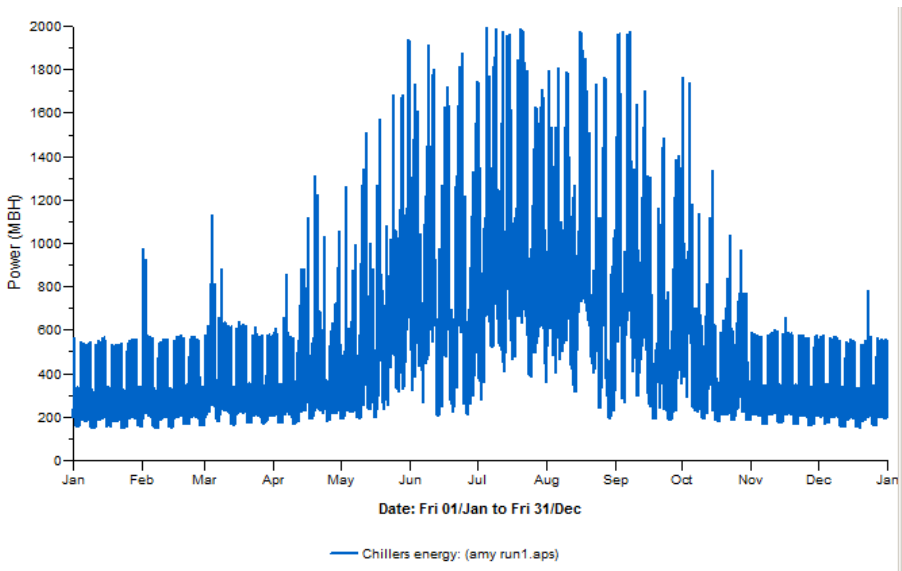



Heating and Cooling Coil Loads

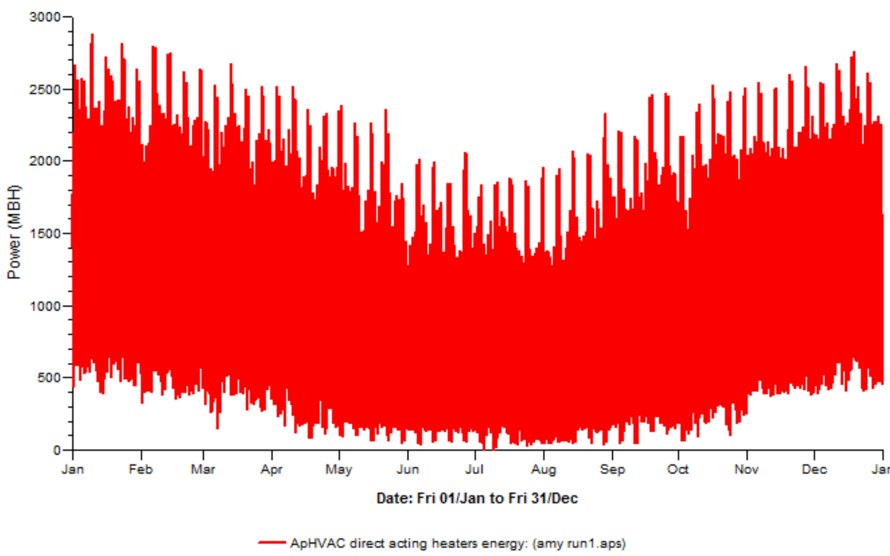
# APPENDIX F – GRAPHICAL ENERGY



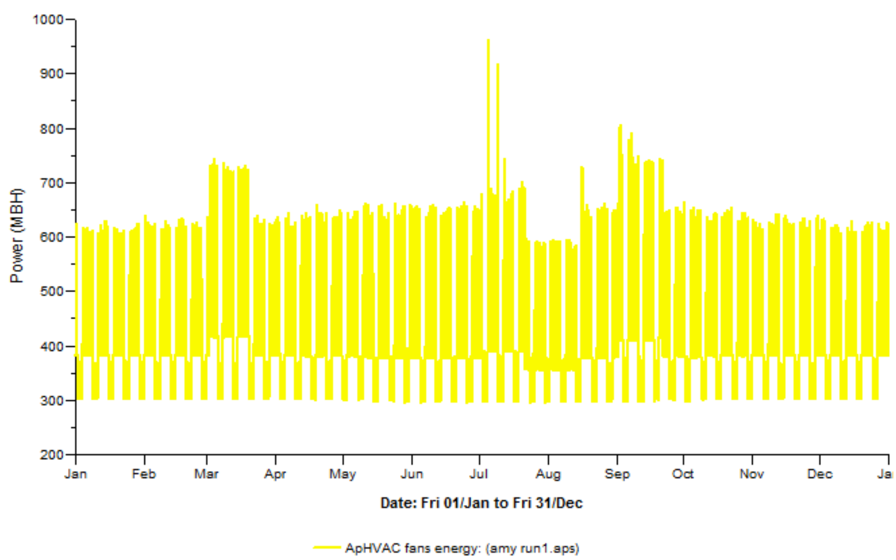

Boiler Energy



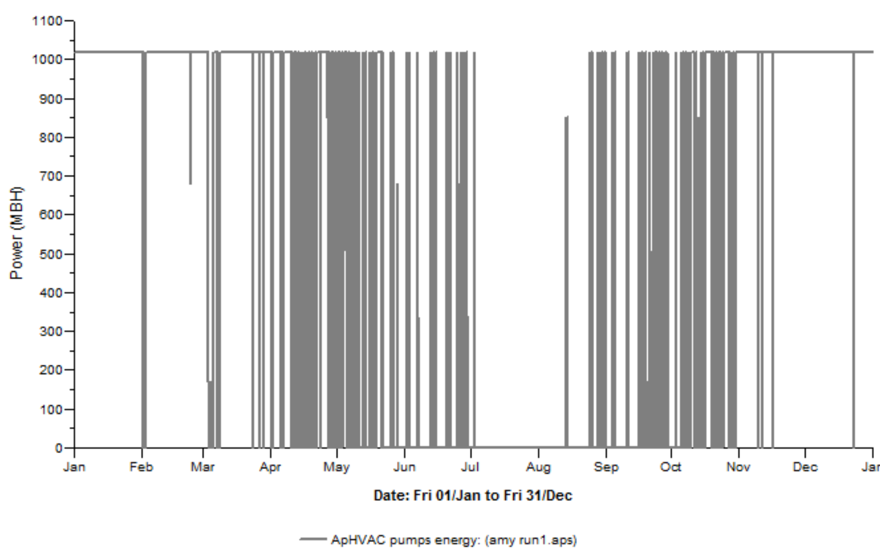

Chiller Energy



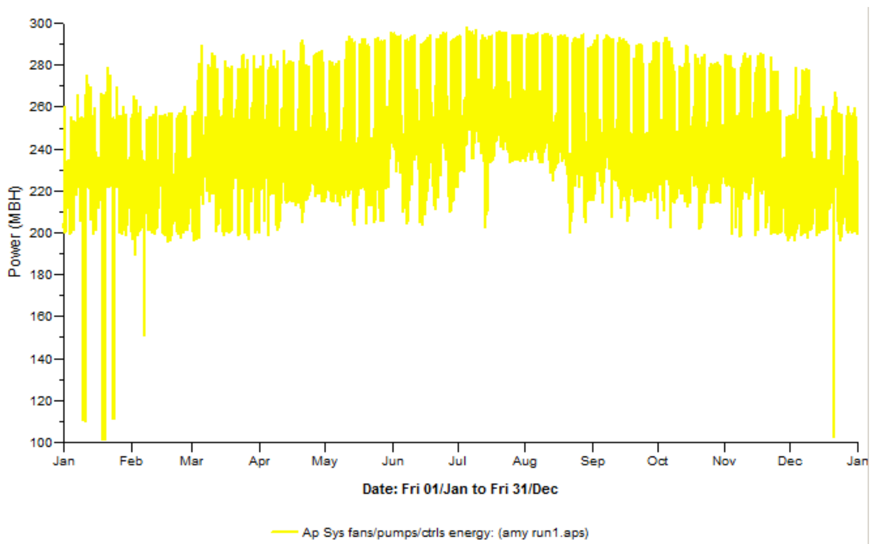

Direct Acting Heater Energy



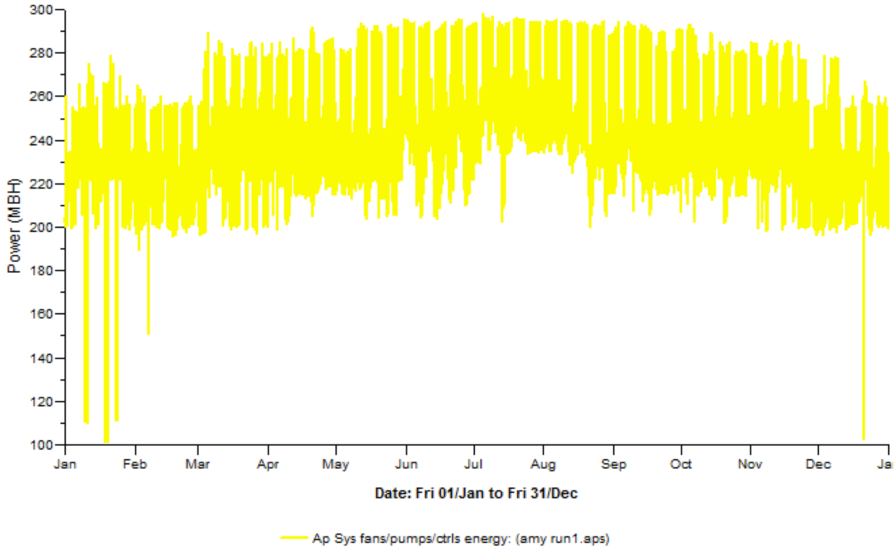

Fan Energy



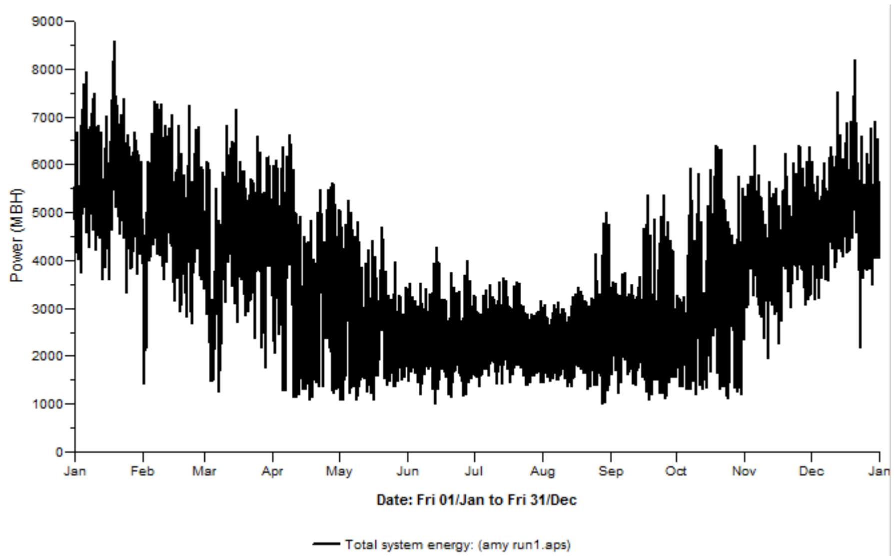

Pump Energy



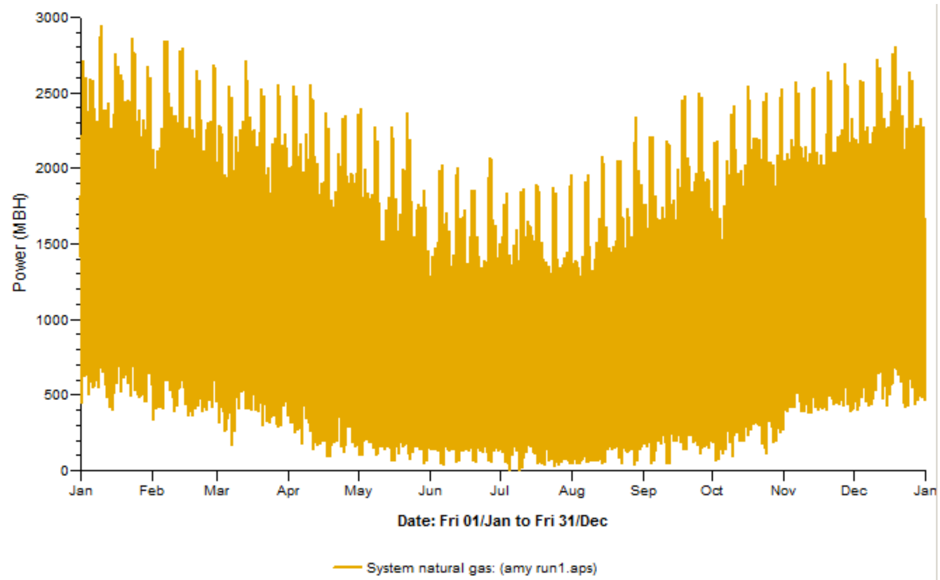

Fans/pumps/controls energy



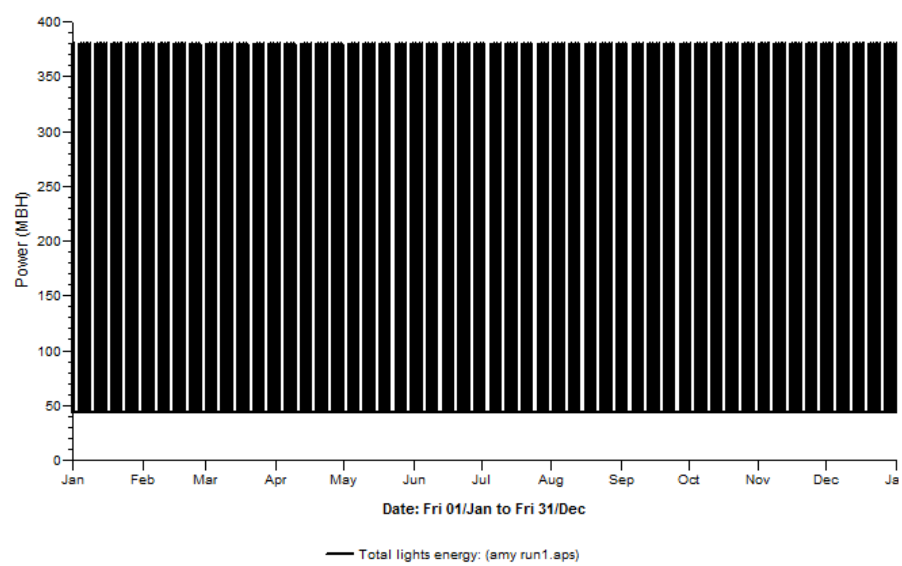

System Electricity



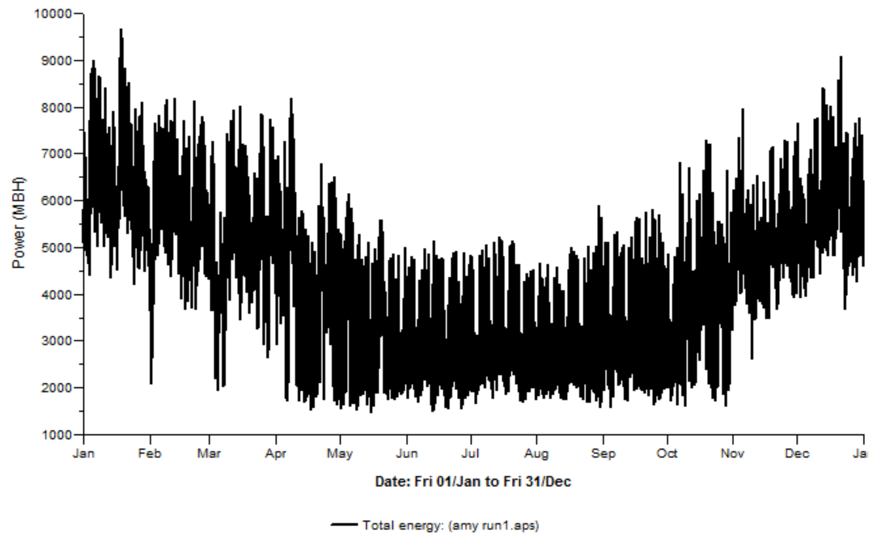

Total System Energy



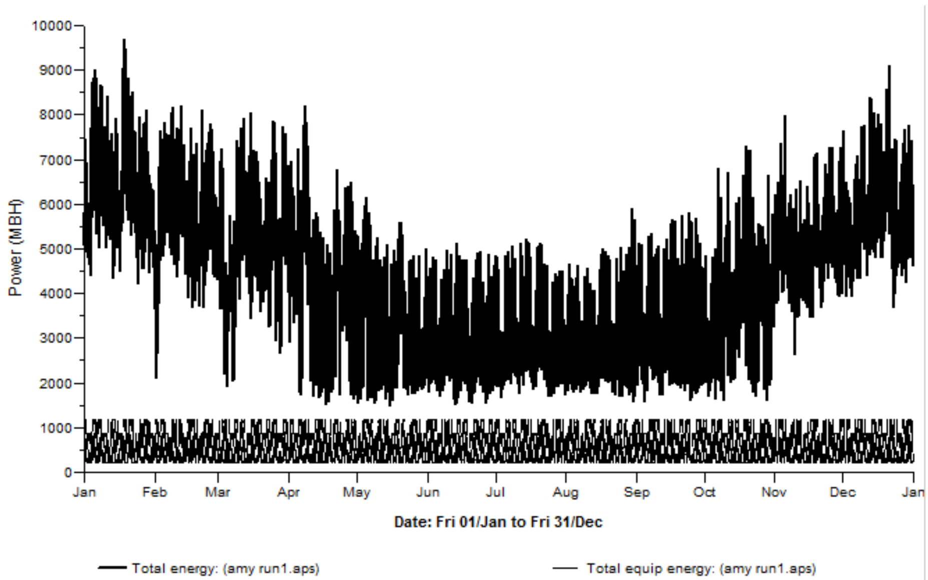

System Natural Gas Energy



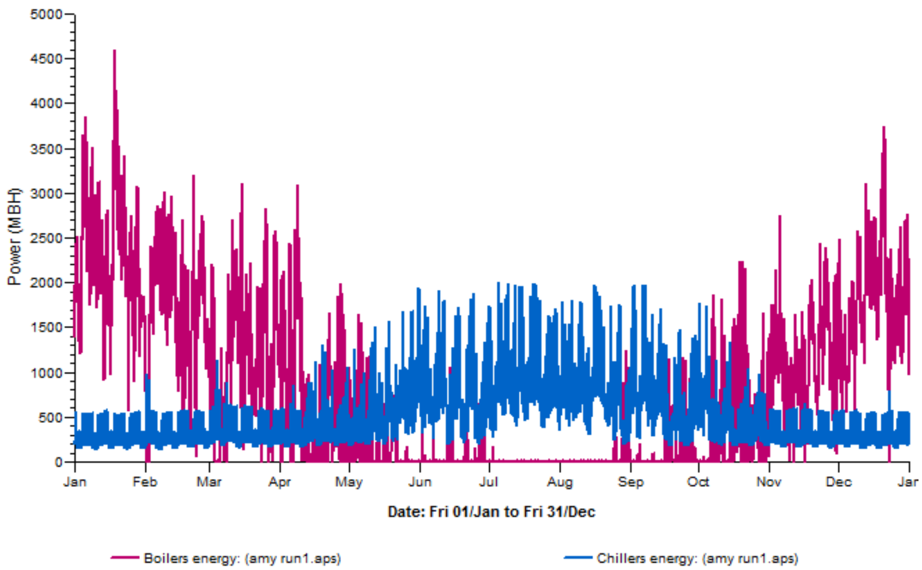

Lights Energy




Total Energy




Total Energy Vs. Equipment Energy




Boiler and Chiller Energy