Hunter's Point South

Intermediate School & High School

Long Island City, NY

MECHANICAL OPTION

Technical Report Two

Building and Plant Energy

Analysis Report

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Date: 10/19/11

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Executive Summary

The purpose of thesis technical report two is to analyze our building and plant energy consumption using a computer-based method. Hunter's Point South Intermediate School & High School is a new schoolhouse for grades 5 through 12 which is located in Long Island City, New York. Hunter's Point South School was commissioned by the NYC School Construction Authority and designed to the guidelines of the NYC Green Schools Guide. Construction of the schoolhouse began recently on January 10th, 2011 and is expected to be complete on October 7th, 2013.

The program chosen to run this analysis in was Trane TRACE 700, due to program familiarity. Trane TRACE 700 has the capability to perform both load calculations and energy simulations so it was a perfect fit for this assessment. After all the information was input into TRACE, it was calculated that Hunter's Point South School's total heating load is 6,751,800 Btuh and total cooling load is 475.2 tons. As expected, the heating loads were greater than the cooling loads. This was expected because the building site is in New York and is primarily used during the cooling season with little occupancy in the summer. The total heating load was 23% higher when compared to the mechanical engineers' model and the total cooling load was 11% lower. The cooling load was reasonable considering the variation in U-values used for windows between the two models. The total heating load was not too far off but broken down on a zone to zone basis gave some alarming results, especially for AHU-4 which serves the gymnasium. Further explanations for why these differences may have occurred can be read under the Building Load Calculations section.

Energy usage and costs that resulted from the TRACE model were very close to those calculated by the design engineer. The total kWh of electricity used per year was 1,079329, 5% higher than the design engineer's value. Natural gas is used for heating and it was determined that 64,491 therms would be used a year, which is less than one percent off the Energy Cost Budget Method result. The TRACE analysis determined that Hunter's Point South School would have an energy bill of $256,371 a year with an operating cost of $1.67 per square foot. Both of these numbers were only 13% lower than the ones calculated by the design engineer. Finally, the emissions analysis found that Hunter's Point South School would emit approximately 2,084,233 pounds of CO_2 equivalent pollutants.

A lot can be learned from the results found above. Moving forward it will be very helpful to look back at these results to see where the highest costs are being incurred and how to remedy them. Even more can be learned about the assumptions made that gave way to these results.

Building Overview

Hunter's Point South Intermediate School & High School is a public school for grades 5 through 12 serving the PS 287 Queens School district. Hunters Point is a five story school that will house over 1,000 students. It consists of 26 classrooms, 8 special education classrooms, library, gym, assembly space, cafeteria with open terrace seating, kitchen, and support spaces. The building is a part of the Hunter's Point South Project, a redevelopment of the 30 acre Queens area to become a more sustainable, middle income urban community along the waterfront park. This redevelopment in Queens also includes residential housing, apartments, retail space, community/cultural facilities, parking, and a new 11 acre waterfront park.

Mechanical System Overview

Conditioned air is served to Hunter's Point South Intermediate School & High School via the six rooftop air handling units. Units 1, 2, and 3 are variable air volume (VAV) systems that service the classrooms, offices, corridors, and non-public spaces. Units 4, 5, and 6 are constant air volume (CAV) systems that serve the gymnasium, cafeteria/kitchen, and auditorium, respectively. All air handling units have variable frequency drives, wrap around heat pipes for dehumidification, and economizer controls. Preheat coils in the AHU's use a 35% propylene glycol – water mixture while the cooling coil utilizes a 30% propylene glycol – water mixture. This heat-transfer fluid has low toxicity and volatility. It poses little harm to humans in case of a leak.

Four natural gas fired, condensing boilers are used for Hunter's Point South School's heating needs. These boilers are located in the mechanical penthouse's boiler room. Each boiler can produce 1860 MBH worth of 35% propylene glycol – water mixture which is used for the AHU's, perimeter fin tube radiators, unit heaters, and cabinet heaters. All heating hot water and secondary pumps are located in the boiler room along with the hot and chilled water expansion tanks. Two 276 ton air cooled chillers with scroll compressors are also located on the roof. A 30% propylene glycol – water mixture is cooled by the R-410a refrigerant which is used for the AHU's cooling coils.

Cabinet and unit heaters are used to heat the building's entrances, locker rooms/showers, and stairwells. Split heat pumps are utilized in the telecom rooms on each floor, food storage, and elevator machine room. The outdoor section of each heat pump is located on the roof. Fin tubed radiators are used along the perimeter walls to heat the space in conjunction with AHU's. Upblast and mushroom fans are located on the roof where they exhaust air from the science lab's fume hoods and kitchen.

Building Load Calculations

An energy analysis on Hunter's Point South Intermediate School & High School was conducted using Trane TRACE 700. The building's heating loads, cooling loads, and energy usage were calculated using this program and then checked against the Elite Energy Software model created by the mechanical engineers. The assumptions and schedules used to create the Trane TRACE 700 model are outlined below.

Block Load Assumptions

Room areas for each space were taken from the ventilation tables. Added spaces were measured using the building drawings. Heat transfer coefficients and other U-values were found through the specifications or calculated. Finally, window areas, doors, and wall heights were measured from the sections in the building drawings. These were all entered individually in Trane TRACE 700 room by room.

Occupancy Assumptions

The number of occupants for each room of Hunter's Point South School was outlined in the design documents. Because these numbers were given, the occupant density values from ASHRAE Standard 62.1-2007 were not needed and a more accurate model could be created.

Ventilation Assumptions

As outlined in the scope of this assignment, ventilation rates were taken from ventilation tables created by the mechanical engineers. Hunter's Point South School due to its location fell under jurisdiction of the New York State Mechanical Code of 2007. In striving for LEED Silver Certification, ASHRAE Standard 62.1-2007 Procedure 6 was also required to determine minimum ventilation rates. Minimum outside air was calculated using both procedures and then the higher results were taken. These numbers have been inserted into the rooms for the TRACE model. A neutral, average construction was assumed for infiltration.

Lighting and Misc. Equipment Load Assumptions

The lighting and miscellaneous equipment loads were determined on a Watt per square foot basis. The lighting loads were found from the lighting power densities in Table 9.6.1 from ASHRAE Standard 90.1-2007. Lighting fixtures and their corresponding wattages were outlined in the building drawings. For simplicity, the values from Table 9.6.1 were used. A more accurate model could be created using the known lighting fixtures but time did not permit.

The equipment loads in the building were determined through multiple sources. No information was disclosed from the mechanical engineers about the miscellaneous loads assumed when creating their model. Values were determined using the ASHRAE Pocket Guide and knowledge gained through past experience. The gymnasium and exercise room were both assume to have a 700 W load for miscellaneous equipment. This is the equivalent of two computers assumed because the gym will house a scoreboard and the exercise room will have digital equipment. The assumed loads for lighting and equipment are outlined below in Table 1.

Room Type	Lighting Power Densities, W/sf	Misc Loads, W/sf	Workstations
Office	1.1	1	0
Conference/Meeting	1.3	1	0
Classroom	1.4	1	0
Lobby	1.3	0	0
Auditorium	2.6	1	0
Lounge/Break Room	1.2	1.5	0
Dining Area	0.9	0	0
Kitchen	1.2	10	0
Laboratory	1.4	2	1 per person
Restrooms	0.9	0	0
Dressing/Locker	0.6	0	0
Corridor	0.5	0	0
Stairs	0.6	0	0
Storage	0.8	0	0
Elec/Mech/Telecom	1.5	5	0
Gymnasium	1.4	700 W	0
Lifting Area	0.9	700W	0
Library	1.7	1	2
Computer Lab	1.1	0.5	1 per person
Medical	1.4	0.22	0

Table 1 – Internal Loads

Building Construction

Multiple templates were made in TRACE to represent the different facades and glazing of Hunter's Point South School. Below in Table 2 is an outline of the U-values and shading coefficients used for the different components.

	U-Value (Btu/(h-sf-°F))	Shading Coefficient
Exterior Wall	0.056	-
Roof	0.05	-
Floor	0.49	-
Windows:		
Typical Window	0.3	0.438
ITSPS	0.28	0.264
Window w/ perforated steel	0.3	0.291
Typical Door	0.2	-

Table 2 – Building Construction

Weather Data/Design Conditions

The weather data for Long Island City, NY was not in the ASHRAE Handbook of Fundamentals 2009. The closest city to the building's location with weather data in the handbook was New York City, JFK International Airport station. The building site and JFK Airport station are within fifteen miles of one another so the weather is very similar. Below is the weather information in Table 3. A more complete look at the weather data can be seen in Appendix A.

ASHRAE HoF 2009 Chapter 14 Appendix: Climate Data	
JFK Airport, NY	dB Temp
0.4% Cooling	89.7°F
99.6% Heating	12.8°F

Table 3 – Weather for JFK Airport

The room temperatures that Hunter's Point South Intermediate School & High School are maintained at are outlined below in Table 4.

Room Design Temperatures	
Winter	72°F Dry Bulb
Summer	75°F Dry Bulb

Table 4 – Room Design Temperatures

Schedules/Templates

Hunter's Point South School is open all year long. Summer session will have a greatly reduced occupant load. The schedules for people, lighting, and miscellaneous loads were all found in Trane TRACE 700. The schedules used are those that resemble middle schools and high schools with some minor tweaks. Below in Table 5 shows a sample of a typical occupancy schedule. Appendix B has all schedules used.

Months and Days of the Week	Start time	End time	% of Peak
Jan-May and Sept-Dec, Weekdays	Midnight	7:00 AM	0
	7:00 AM	8:00 AM	50
	8:00 AM	11:00 AM	100
	11:00 AM	Noon	80
	Noon	1:00 PM	20
	1:00 PM	3:00 PM	100
	3:00 PM	5:00 PM	30
	5:00 PM	Midnight	0
June-August, Weekdays	Midnight	7:00 AM	0
	7:00 AM	8:00 AM	10
	8:00 AM	3:00 PM	30
	3:00 PM	5:00 PM	10
	5:00 PM	Midnight	0
Jan-Dec, Weekends	Midnight	Midnight	0

Table 5 – Occupancy Schedule for Classrooms

The templates created and used in Trane TRACE 700 may be found in Appendix C.

Systems

For convenience of comparing results, the zones have been broken down similar to the ones in the Elite Software model. The six AHU's were inserted with their corresponding rooms. All other spaces are served by heat pumps or unit/cabinet heaters and were lumped together as "Other" in the results.

Results from Trace Model vs. Elite Software Model

Below in Table 6 are the results for the building loads calculated in TRACE. AHU's 1, 2, and 3 serve the classrooms, offices, corridors, and non-public spaces. AHU's 4, 5, and 6 serve the gymnasium, cafeteria/kitchen, and auditorium, respectively. The stairs and main entrances were modeled as well. "Other" refers to the collection of the restrooms, telecom rooms, electrical closets, and mechanical penthouse. The diversity of the loads created by each different space can be seen through the zones. As expected, the heating load is greater than the cooling load. This is no surprise considering the school is located in New York and is mainly occupied during the heating season with little occupancy for summer session.

	Conditioned Space (sf)	Supply Air per unit area (cfm/sf)		Area per Cooling Capacity (sf/ton)	Cooling Capacity per Area (tons/sf)	Heating Capacity per Area (Btuh/sf)	Total Heating (Btuh)	Total Cooling (tons)
		Cooling	Heating					
AHU-1	30637	0.6	0.37	379.6	0.0026	36.53	1,119,300	80.7
AHU-2	29722	0.89	0.5	274.9	0.0036	51.17	1,521,000	108.1
AHU-3	22567	0.82	0.51	271.9	0.0037	48.89	1,103,300	83.0
AHU-4	12735	1.77	1.77	107.6	0.0093	105.79	1,347,200	118.4
AHU-5	11449	1.34	1.34	208.2	0.0048	85.71	981,300	55
AHU-6	4341	1.34	1.34	144.7	0.0069	118.13	512,800	30
Stairs	1584	n/a	1.1	n/a	n/a	71.21	112,800	n/a
North and South Entrances	668	n/a	0.13	n/a	n/a	8.53	5,700	n/a
Other	4711	n/a	0.17	n/a	n/a	10.27	48,400	n/a
Total Building	118414	0.904	0.710	256.1	0.0040	57.02	6,751,800	475.2

Table 6 –TRACE Loads

Below in Table 7 are the loads calculated by the mechanical engineers in Elite Software.

	Conditioned Space (sf)	Supply Air per unit area (cfm/sf)	Area per Cooling Capacity (sf/ton)	Cooling Capacity per Area (tons/sf)	Heating Capacity per Area (Btuh/sf)	Total Heating (Btuh)	Total Cooling (tons)
AHU-1	28115	0.9801	286.5	0.0035	37.82	1,063,259	98.12
AHU-2	27690	1.0412	232.5	0.0043	48.83	1,351,976	119.1
AHU-3	21646	1.1427	234.6	0.0043	43.36	938,642	92.25
AHU-4	12527	1.4766	113.8	0.0088	70.87	887,731	110.1
AHU-5	9833	1.624	144	0.0069	80.1	787,669	68.27
AHU-6	4341	2.0131	110.7	0.009	84.01	364,697	39.21
Stairs	1080	2.9079	186.3	0.0054	65.47	70,713	5.8
South Entrance	800	0.7225	0	0	31.29	25,034	0
Total Building	106032	1.2022	201	0.005	51.77	5,489,721	532.85

Table 7 –Elite Software Loads

Overall the results do not seem too unreasonable. The total heating load calculated in TRACE is 23% percent higher than the mechanical engineer's model while the total cooling load calculated in TRACE is 11% lower. However, when a closer look is taken zone by zone some discrepancies do occur. Table 8 shows a percent comparison for heating and cooling loads between the two models.

Percent Difference in Trace vs. Elite Software Loads		
	Heating	Cooling
AHU-1	-5%	18%
AHU-2	-13%	9%
AHU-3	-18%	10%
AHU-4	-52%	-8%
AHU-5	-25%	19%
AHU-6	-41%	23%
Stairs	-60%	n/a
Entrances	77%	n/a
Total	-23%	11%

*Note: Negatives mean Trace value is higher than Elite Software value.

Table 8 – Percent Differences in Models

Below is an outline of the differences in the modeling through TRACE and Elite Software as well as an outline of assumptions that may have led to these skewed results for zones.

Assumptions by the Mechanical Engineers:

- For ventilation for the whole building, 20 cfm per person were used for both cooling and heating. This is a valid assumption but no information was found on what was used for corridors.
- The lighting density was generalized for the whole building and was not broken down space by space.
- Occupants were assumed to give off 245 Btuh sensible and 200 Btuh latent loads per person. This assumption was held constant for all spaces. The TRACE model had varied sensible and latent loads for occupants depending on the activity level in the space. This will give a more realistic outcome especially for the gymnasium and weight room.
- No infiltration was assumed for heating and cooling. This would cause there calculated loads to be lower than the TRACE calculated values.
- A U-value 0.5 was used for glazing. This is much higher than the 0.30 value outlined in the specifications. Using a higher U-value will cause more thermal loses and thus increase the heating and cooling loads on the zones.
- A summer dry bulb temperature of 78°F for the rooms was used as opposed to the 75°F used in my TRACE model. Conditioning the rooms at a lower temperature in the summer will require more cooling.
- A discrepancy in floor areas for certain rooms arose between the two models, with the Trace model having a greater total floor area.
- Occupants were added to the locker rooms. This will increase the load on these spaces. No occupants were added in the TRACE model due to the sporadic use of the space. It was assumed that the short duration of occupants' stay would not generate enough loads to the space as to discomfort them. Furthermore, with the time between uses of the locker room there was plenty of time for the space to be reconditioned.
- Stairs and entrances were modeled as being served by AHU's as opposed to unit and cabinet heaters, which is outlined in the drawings.

Though both models are based off the same information, there are differences in how the loads are calculated through each program. I am unfamiliar with how Elite Software works so I cannot expand too much more upon this subject. It should be noted that no two programs will give exactly the same results given the same inputs.

Cooling

Cooling overall was not too far off. Considering the difference in U-values between the two models, the TRACE model would result with lower cooling loads because of the lower U-values used for windows, which it did. 256 sf/ton was calculated in the TRACEmodel for cooling. Checking against the ASHRAE Pocket Guide, the square feet per ton of cooling is just outside the low range of 240 sf/ton. All spaces were modeled in the building for TRACE even those that did not receive cooling. If the area for the spaces that do not receive cooling were taken out, then the sf/ton would fall well in the range outlined in the ASHRAE Pocket Guide.

The only outlier for cooling loads calculated in TRACE was AHU-4, which serves the gymnasium and weight room area. For the gymnasium and exercise room, occupants were modeled as giving off 710 Btuh sensible and 1090 Btuh latent loads. These values were found using the ASHRAE Pocket Guide for the highest degree of activity, athletic. Since the occupants are at a higher level of activity, they will create a much greater load on the space and thus require more cooling. If it is assumed the occupants are at a typical office activity level, like was done in the Elite Software model, then cooling loads will be much lower and will not reflect the actually needed cooling.

Heating

Heating loads overall in TRACE were only above the mechanical engineers’ model by 23%. Considering extra spaces were added to the TRACE model that only required heating, the overall heating load increase is no surprise. There are some alarming differences in the heating loads calculated for the different zones; primarily for AHU-4, AHU-6, the stairs, and entrances.

AHU-4:

The gymnasium’s façade includes the Insulated Translucent Sandwich Panel System (ITSPS). This is a fiberglass system that allows light transmission with a U-value of 0.28. The heating load calculated in TRACE is approximately 50% higher than the one calculated in Elite Software. It is unclear how the gymnasium walls were modeled in Elite Software. If the ITSPS were not taken into account, than the wall U-value of 0.056 would have been used. This would prevent much more thermal loses than the ITSPS would. The TRACE model took into account the ITSPS. The ITSPS comprised of 41% of the gymnasium’s exterior wall area. If the ITSPS was not accounted for in the Elite Software model than the heating loads would be far less. This could be the source of this huge discrepancy.

AHU-6:

The spaces served by this system are all interior rooms. Since no exterior walls or rooms exist, the heating loads should be significantly less as compared to the other zones, which they are for both models. The reason the percent difference may be so great is because the heating loads are both lower so the graver the difference between the two numbers is at a lower value, the percent difference will increase much more. In the future, this zone will have to be given careful attention as to try to understand why there was such a high heating load as well as what assumptions made for the space may need to be reworked.

Stairs:

The heating load calculated in the TRACE model is significantly higher than the one found using Elite Software. The TRACE model accounted for all three stairwells as opposed to only the north and south stairwells which were used for the Elite Software model. The Elite Software model also used a much smaller floor area, approximately 2/3 of the area used in TRACE. The added stairwell did not have any glazing but it did have a large amount of exterior wall which would increase the heating load. Also, the Elite Software model assumed the stairwells were supplied by air handling units when in actuality they are supplied by unit and cabinet heaters. The difference in these systems and how the two programs model them both can produce some difference in the calculated load.

Entrances:

The elite software analysis only modeled the south entrance and neglected the north entrance. This may have been done since the south entrance will see a lot of solar loading and the north will only receive diffuse sunlight. In the TRACE model, both the north and south entrances were taken into account. The Elite Software used a much smaller floor area for the south entrance too. All this information points towards that the entrances modeled in the TRACE model should have a much higher heating load, but from the calculations the opposite has been found. With how little the area the entrances account for and that the only glazing is in the doors, it is unclear how the Elite Software model calculated such a high heating load for this space.

System Energy Consumption and Cost

Trane TRACE 700 was also used to run a full year energy simulation of Hunter's Point South Intermediate School & High School. Systems were added to the model created above and an energy analysis was performed. The results are compared against the values calculated by the design engineer.

Systems

Six VAV systems with baseboard heating were added for the simulation. Fan static pressure and horsepower were found in the design documents and inputted into the VAV systems. All AHU's have economizers and dehumidification wrap around heat pipes. The economizers run based on enthalpy and were added to the VAV systems. The heat pipes could not be added however because there was no viable option in TRACE.

The remaining spaces that were not assigned to the VAV systems use unit and cabinet heaters. A final system was added and modeled as a unit heater. The remaining rooms were added to this.

Plants

The four gas fired, condensing boilers and two air cooled chillers were added under the plants tab. The total loads and efficiencies were inputted from the design documents for all six systems. Pumps were also found in the design documents and they were added along with their horsepower.

Fuel Costs

The following fuel costs were given through the NYPA and used in the design engineers' model. These values can be seen below in Table 9. These same numbers have been used for the economic rates in the TRACE model as well.

Energy Prices	
Type	Price
Electricty (based on NYPA)	$0.0553/kWh
	$21.49/kW
Natural Gas (based on National Grid firm charges)	$1.579/ccf
	$1.542/therms
	$11.65/month

Table 9 – Energy Prices

Results

The results obtained from the TRACE model for the energy simulation were very close to the values calculated by the design engineer. All categories were within an acceptable variance from the design engineer's values and no out liars occurred. Below in Table 10 are the results from the TRACE model energy simulation as compared to the design engineer's results using the Energy Cost Budget Method from ASHRAE Standard 90.1 Section 11.

	Electricty (kWh per year)	Natural Gas (BTU x 10^6 per year)	Electricity Cost per year	Natural Gas Cost per year	Total Cost per year	Cost per Square Foot of Building
TRACE	1,079,329	6449.1	$ 170,668	$ 85,703	$ 256,371	$ 1.67
Design Engineer	1,030,849	6,441	$ 194,745	$ 99,467	$ 294,212	$ 1.91
Difference	-5%	0%	12%	14%	13%	13%

Table 10 – Energy and Cost Comparison

Two factors were not able to be modeled that would further reduce energy costs; occupancy sensors for lights and the wrap around heat pipes for dehumidification. Also note that there would be a little increased load on the building in electricity and pump energy if the wrap around heat pipes were added but a lowering in cooling costs due to these two factors.

The total energy consumption for Hunter's Point South School was broken down so the energy usage could be better understood. Figure 1 shows these results and Figure 2 has the energy consumption breakdown calculated by the design engineer. The auxiliary fraction includes both the pumps and fans in the building. The Misc fraction includes loads such as plug loads, kitchen equipment, and exterior lights. Miscellaneous loads due to computers and internal equipment is included in the Cooling fraction in Figure 1. This is a reason why the Cooling fraction is higher in the TRACE model as opposed to the design engineer's model.

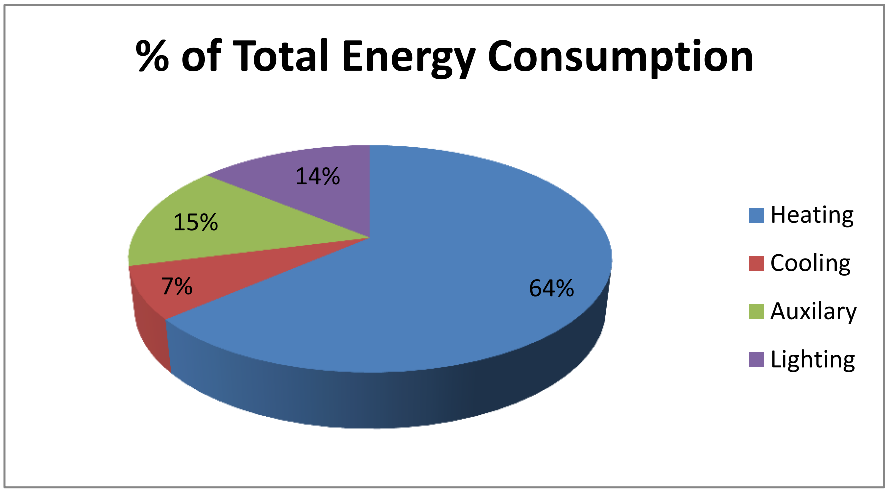

Figure 1 – Energy Consumption TRACE Model

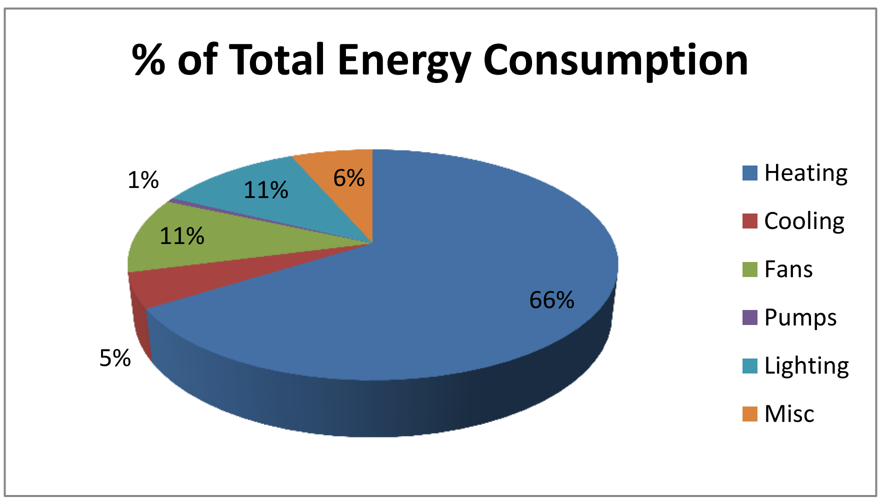

Figure 2 – Energy Consumption Design Engineer's Model

The electricity and natural consumption rates and cost per month were obtained from the TRACE energy simulation. As expected the electricity consumption peaked during the summer while the natural gas consumption peaked during the winter months. This information can be seen in Figures 3 through 6 that follow.

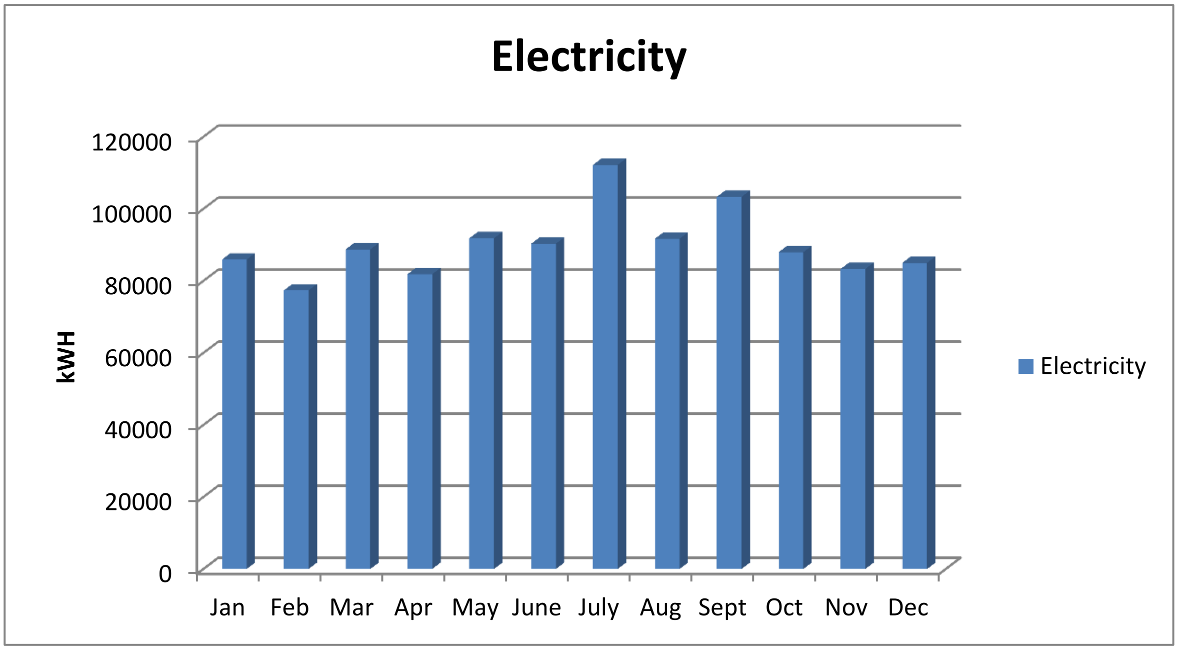

Figure 3 – Electricity Usage per Month

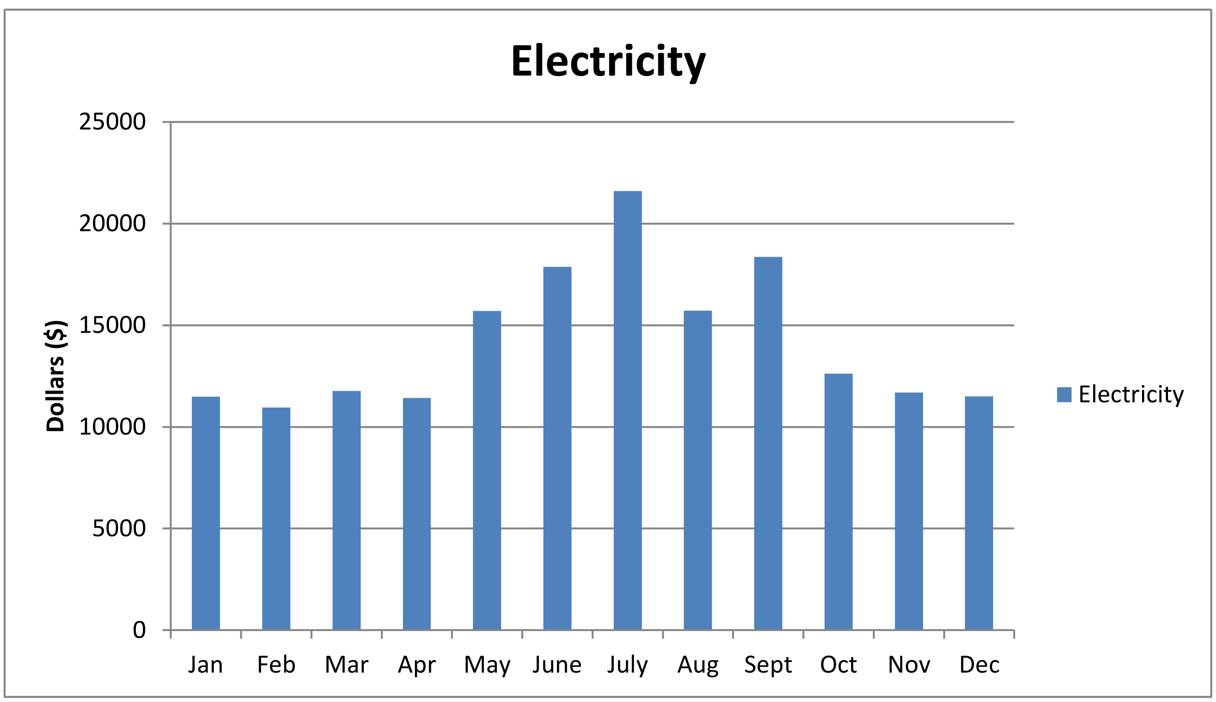

Figure 4 – Electricity Cost per Month

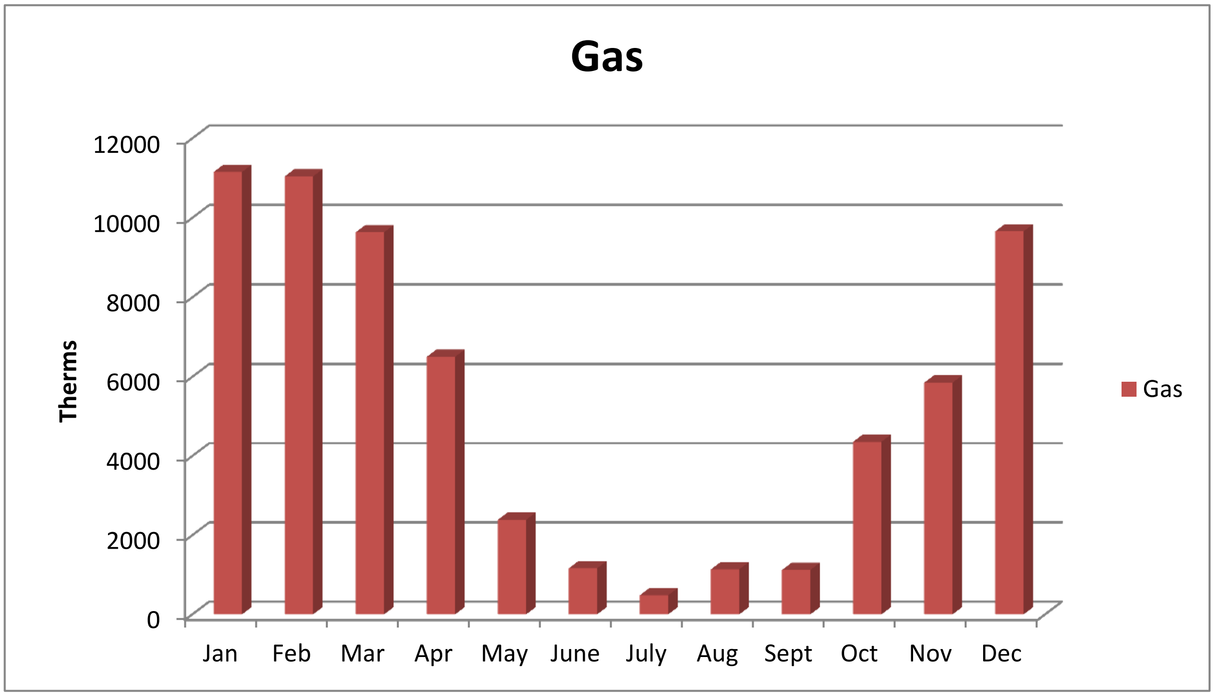

Figure 5 – Natural Gas Usage per Month

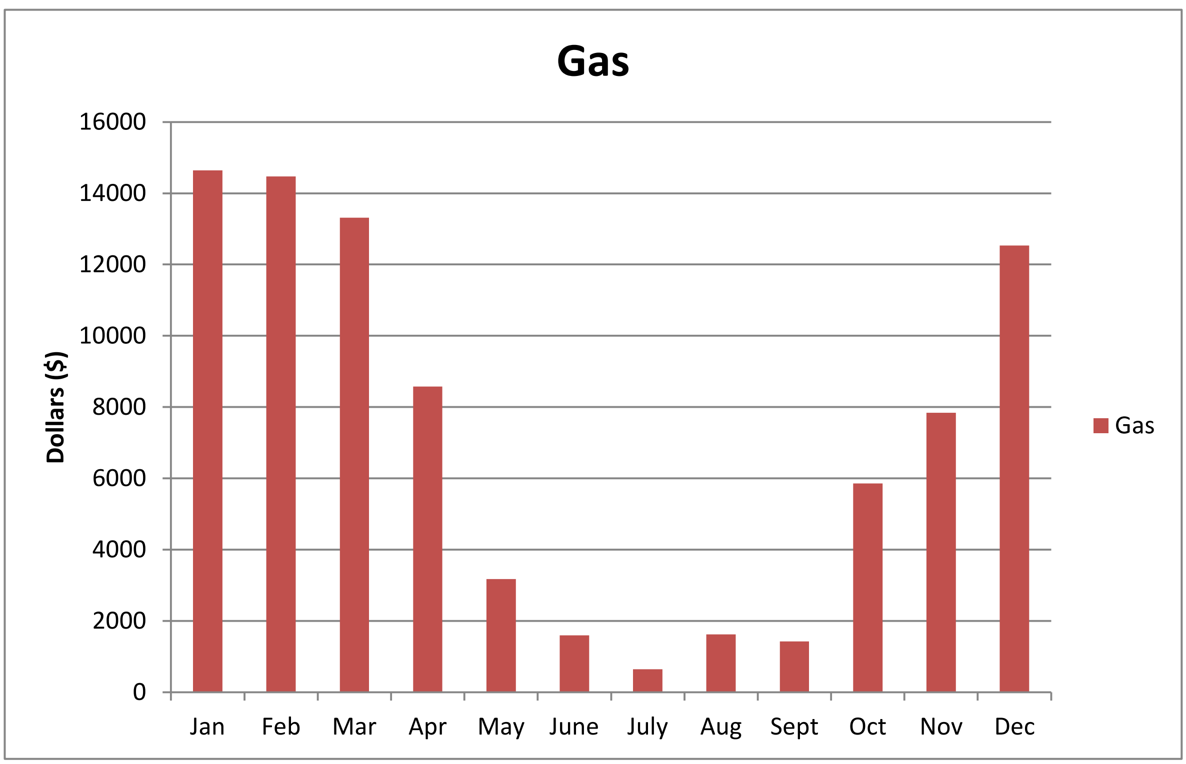

Figure 6 – Natural Gas Cost per Month

Emissions

Hunter's Point South School uses delivered electricity and on-site combustion for power so both must be accounted for when determining total emissions. For on-site combustion, both the pollutants produced by transporting the natural gas to site and the actual combustion process must be taken into account. The pounds of pollutant per kWh of electricity were pulled from Table B10 for New York from the *Source Energy and Emission Factors for Energy Use in Buildings* technical report. The pounds of pollutant per unit of fuel were also taken from this same document for fuel delivered to the building (Table 6) and on-site combustion in commercial boilers (Table 8).

Table 11 below shows the pounds of pollutant per year for each different pollutant due to electricity. The breakdown of pounds of pollutant per year due to shipping the natural gas to site and on-site combustion are shown below in Table 12 and Table 13, respectively.

Pollutant	lb of pollutant per kWh of electricity	lb of pollutant per year due to electricity
CO_{2e}	1.03E+00	1,111,708.87
CO_2	9.61E-01	1,037,235.17
CH_4	2.59E-01	279,546.21
N_2O	1.68E-05	18.13
NO_x	1.72E-03	1,856.45
SO_x	6.23E-03	6,724.22
CO	1.75E-03	1,888.83
TNMOC	6.38E-05	68.86
Lead	5.59E-08	0.06
Mercury	3.99E-08	0.04
PM10	6.87E-05	74.15
Solid Waste	6.18E-02	66,702.53
kWh/year =	1079329	

Table 11 – Pollutants Due to Electricity

Pollutant	lb of pollutant per 1000 cubic ft of natural gas	lb of pollutant per year due transportation to site
CO_{2e}	2.78E+01	179,284.98
CO_2	1.16E+01	74,809.56
CH_4	7.04E-01	4,540.17
N_2O	2.35E-04	1.52
NO_x	1.64E-02	105.77
SO_x	1.22E+00	7,867.90
CO	1.36E-02	87.71
TNMOC	4.56E-05	0.29
Lead	2.41E-07	0.00
Mercury	5.51E-08	0.00
PM10	8.17E-04	5.27
PM-unspecified	1.42E-03	9.16
Solid Waste	1.60E+00	10,318.56
cubic feet of natural gas =		6449100

Table 12 – Pollutants Due to Transportation

Pollutant	lb of pollutant per 1000 cubic ft of natural gas	lb of pollutant per year due to on-site combustion
CO_{2e}	1.23E+02	793,239.30
CO_2	1.22E+02	786,790.20
CH_4	2.50E-03	16.12
N_2O	2.50E-03	16.12
NO_x	1.11E-01	715.85
SO_x	6.32E-04	4.08
CO	9.33E-02	601.70
VOC	6.13E-03	39.53
Lead	5.00E-07	0.00
Mercury	2.60E-07	0.00
PM10	8.40E-03	54.17
cubic feet of natural gas =		6449100

Table 13 – Pollutants Due to On-Site Combustion

Finally, Table 14 has the total pounds of pollutant due to the combined effects of electricity and on-site combustion for Hunter's Point South School. This information can also be seen in Figure 7.

Pollutant	Total Pollutants (lb of pollutant)
CO_{2e}	2,084,233.15
CO_2	1,898,834.93
CH_4	284,102.50
N_2O	35.77
NO_x	2,678.06
SO_x	14,596.20
CO	2,578.23
TNMOC	69.16
VOC	39.53
Lead	0.07
Mercury	0.05
PM10	133.59
PM-unspecified	9.16
Solid Waste	77,021.09

Table 14 – Total Pollutants

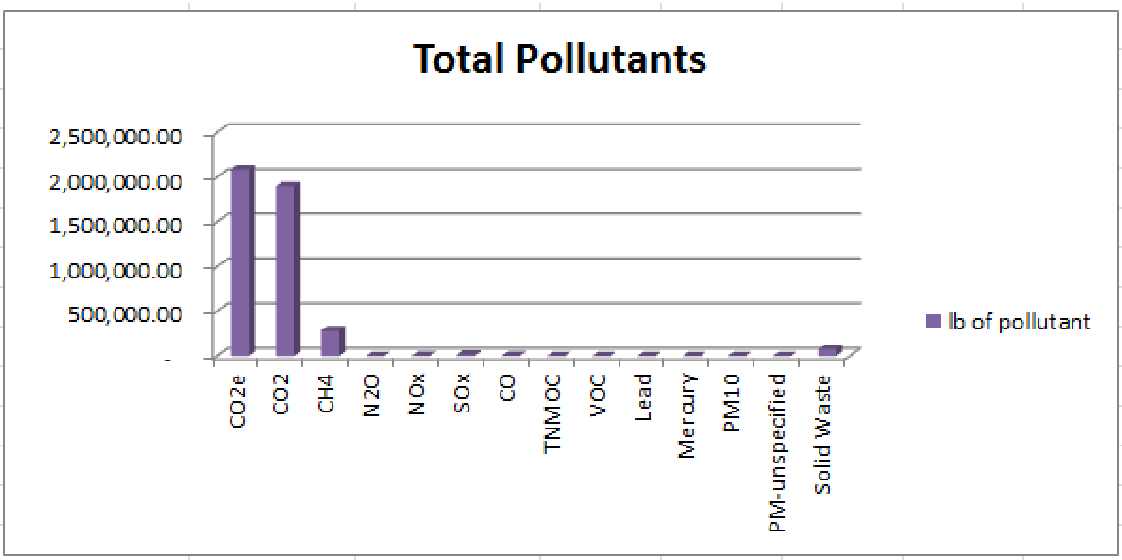

Figure 7 – Total Pollutants Bar Chart

Conclusion

Hunter's Point South Intermediate School & High School contains a multitude of different rooms with varying loads. Through using Trane TRACE 700 building loads and energy simulations have been created. The building loads were accurate for cooling but a bit high overall for heating when compared to the Elite Software model ran by the mechanical engineers. The energy and cost analysis were very close to the design engineer's calculations. In the end, most of the results were fairly reasonable.

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Appendix A- Weather Data

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NEW YORK J F KENNEDY INT'L AR, NY, USA

WMO#: 744860

Lat: 40.66N Long: 73.80W Elev: 23 StdP: 14.68 Time Zone: -5.00 (NAE) Period: 82-06 WBAN: 94789

Annual Heating and Humidification Design Conditions

Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB	
			99.6%			99%			0.4%		1%			
	99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD
1	12.8	17.2	-5.4	4.1	16.0	-1.6	5.1	20.2	31.7	26.2	28.8	27.4	16.7	320

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB	
		0.4%		1%		2%		0.4%		1%		2%			
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD
7	13.4	89.7	73.5	86.5	72.2	83.7	71.4	77.0	84.3	75.8	81.9	74.6	80.2	12.6	230

Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Hours 8 to 4 & 55/69
0.4%			1%			2%			0.4%		1%		2%		
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB	
74.9	130.8	80.5	73.7	125.7	79.0	72.7	121.2	77.9	40.2	84.4	39.1	82.5	38.0	79.7	769

Extreme Annual Design Conditions

Extreme Annual WS			Extreme Max WB	Extreme Annual DB				n-Year Return Period Values of Extreme DB							
				Mean		Standard deviation		n=5 years		n=10 years		n=20 years		n=50 years	
1%	2.5%	5%		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
27.3	24.6	21.4	82.4	7.3	96.1	5.2	3.0	3.6	98.2	0.5	100.0	-2.4	101.7	-6.3	103.8

Monthly Climatic Design Conditions

			Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperatures, Degree-Days and Degree-Hours	Tavg		54.5	33.0	35.1	41.5	50.9	60.3	70.0	75.6	74.8	68.0	57.1	47.7	38.2
	Sd			9.27	7.90	7.73	6.54	6.24	5.92	4.84	4.79	6.03	6.88	7.37	8.67
	HDD50		1813	529	419	281	63	1	0	0	0	0	15	128	377
	HDD65		4828	993	837	729	424	174	21	0	1	37	261	519	832
	CDD50		3439	1	2	17	91	322	601	792	769	541	234	59	10
	CDD65		978	0	0	0	2	30	172	327	305	128	14	0	0
	CDH74		6064	0	0	3	22	193	963	2329	1962	554	38	0	0
	CDH80		1636	0	0	0	4	54	275	707	484	107	5	0	0
Monthly Design Dry Bulb and Mean Coincident Wet Bulb Temperatures	0.4%	DB		55.5	59.2	69.0	77.1	86.5	91.9	95.5	92.6	88.5	79.0	68.2	62.5
		MCWB		51.5	48.0	55.0	60.7	69.1	73.4	76.6	75.0	73.4	66.6	60.7	56.0
	2%	DB		52.0	52.5	60.0	69.6	79.2	87.1	90.2	88.0	82.7	73.4	63.7	56.9
		MCWB		49.1	45.8	50.1	56.3	65.6	71.5	73.6	73.7	70.2	65.5	58.4	52.6
	5%	DB		48.4	49.0	55.4	64.7	74.2	82.7	86.8	84.9	79.5	70.3	61.2	53.2
		MCWB		44.9	44.0	47.4	53.1	63.1	69.3	72.3	72.7	69.4	63.9	57.2	50.1
	10%	DB		45.2	46.2	51.9	60.7	70.4	79.3	83.7	82.3	76.9	67.6	58.8	50.2
		MCWB		41.5	41.9	45.9	51.2	60.8	68.2	71.6	71.7	68.6	61.7	55.1	46.4
Monthly Design Wet Bulb and Mean Coincident Dry Bulb Temperatures	0.4%	WB		53.4	52.2	57.9	63.2	71.6	76.4	79.1	78.6	76.6	70.6	63.9	58.4
		MCDB		54.7	54.6	65.2	72.2	81.7	86.8	89.7	87.3	84.2	74.0	65.9	60.8
	2%	WB		50.0	47.9	52.5	59.0	68.1	74.2	77.2	77.0	74.4	68.4	60.6	54.0
		MCDB		51.3	50.6	56.7	65.9	76.1	82.5	84.9	83.4	78.9	71.7	62.3	55.8
	5%	WB		45.8	45.4	49.9	56.0	65.4	72.3	75.9	75.7	72.8	65.8	58.3	51.0
		MCDB		48.0	48.0	54.0	61.6	72.0	79.1	82.5	81.0	76.3	69.2	60.4	52.9
	10%	WB		42.0	42.5	47.1	53.4	62.9	70.6	74.5	74.7	71.1	63.2	55.9	47.2
		MCDB		44.6	45.7	50.8	57.7	68.1	76.4	80.6	79.6	74.7	66.4	58.3	49.6
Mean Daily Temperature Range		MDBR		12.0	12.7	13.8	14.4	14.4	14.1	13.4	12.9	13.5	13.7	12.7	11.7
	5% DB	MCDBR		14.6	15.7	18.6	20.6	20.8	19.3	16.9	15.1	15.2	15.6	14.4	14.6
		MCWBR		12.7	12.2	11.9	11.2	10.3	8.9	7.6	7.6	7.9	10.2	12.1	13.3
	5% WB	MCDBR		14.4	14.7	17.4	17.5	19.0	16.6	14.3	12.8	12.6	13.5	13.2	13.8
		MCWBR		14.1	13.5	13.2	11.3	10.7	8.9	7.1	7.0	8.2	10.4	13.0	14.5
Clear Sky Solar Irradiance	taub			0.331	0.362	0.401	0.439	0.476	0.534	0.541	0.527	0.418	0.379	0.357	0.328
	taud			2.299	2.147	2.038	1.955	1.890	1.786	1.800	1.822	2.170	2.231	2.246	2.353
	Ebn,noon			259	265	267	265	257	242	238	237	259	257	245	250
	Edh,noon			32	41	49	57	62	69	67	64	43	37	33	29

CDDn Cooling degree-days base n°F, °F-day
CDHn Cooling degree-hours base n°F, °F-hour
DB Dry bulb temperature, °F
DP Dew point temperature, °F
Ebn,noon } Clear sky beam normal and diffuse hori-
Edh,noon } zontal irradiances at solar noon, Btu/h/ft2
Elev Elevation, ft
Enth Enthalpy, Btu/lb
HDDn Heating degree-days base n°F, °F-day
Hours 8/4 & 55/69 Number of hours between 8 a.m. and 4 p.m with DB between 55 and 69 °F
HR Humidity ratio, grains of moisture per lb of dry air

Lat Latitude, °
Long Longitude, °
MCDB Mean coincident dry bulb temperature, °F
MCDBR Mean coincident dry bulb temp. range, °F
MCDP Mean coincident dew point temperature, °F
MCWB Mean coincident wet bulb temperature, °F
MCWBR Mean coincident wet bulb temp. range, °F
MCWS Mean coincident wind speed, mph
MDBR Mean dry bulb temp. range, °F
PCWD Prevailing coincident wind direction, °, 0 = North, 90 = East

Period Years used to calculate the design conditions
Sd Standard deviation of daily average temperature, °F
StdP Standard pressure at station elevation, psi
taub Clear sky optical depth for beam irradiance
taud Clear sky optical depth for diffuse irradiance
Tavg Average temperature, °F
Time Zone Hours ahead or behind UTC, and time zone code
WB Wet bulb temperature, °F
WBAN Weather Bureau Army Navy number
WMO# World Meteorological Organization number
WS Wind speed, mph

Appendix B- Trace Schedules

Occupancy Schedule for Classrooms

Months and Days of the Week	Start time	End time	% of Peak
Jan-May and Sept-Dec, Weekdays	Midnight	7:00 AM	0
	7:00 AM	8:00 AM	50
	8:00 AM	11:00 AM	100
	11:00 AM	Noon	80
	Noon	1:00 PM	20
	1:00 PM	3:00 PM	100
	3:00 PM	5:00 PM	30
	5:00 PM	Midnight	0
June-August, Weekdays	Midnight	7:00 AM	0
	7:00 AM	8:00 AM	10
	8:00 AM	3:00 PM	30
	3:00 PM	5:00 PM	10
	5:00 PM	Midnight	0
Jan-Dec, Weekends	Midnight	Midnight	0

Occupancy Schedule for Cafeteria

Months and Days of the Week	Start time	End time	% of Peak
Jan-May and Sept-Dec, Weekdays	Midnight	7:00 AM	0
	7:00 AM	8:00 AM	0
	8:00 AM	9:00 AM	0
	9:00 AM	11:00 AM	20
	11:00 AM	1:00 PM	100
	1:00 PM	3:00 PM	20
	3:00 PM	5:00 PM	0
	5:00 PM	Midnight	0
June-August, Weekdays	Midnight	7:00 AM	0
	7:00 AM	1:00 PM	10
	1:00 PM	Midnight	0
Jan-Dec, Weekends	Midnight	Midnight	0

Occupancy Schedule for Kitchen

Months and Days of the Week	Start time	End time	% of Peak
Jan-May and Sept-Dec, Weekdays	Midnight	7:00 AM	0
	7:00 AM	8:00 AM	50
	8:00 AM	9:00 AM	50
	9:00 AM	Noon	100
	Noon	1:00 PM	100
	1:00 PM	3:00 PM	100
	3:00 PM	5:00 PM	0
	5:00 PM	Midnight	0
June-August, Weekdays	Midnight	7:00 AM	0
	7:00 AM	1:00 PM	10
	1:00 PM	Midnight	0
Jan-Dec, Weekends	Midnight	Midnight	0

Lighting Schedule for Building

Months and Days of the Week	Start time	End time	% of Peak
Jan-May and Sept-Dec, Weekdays	Midnight	6:00 AM	5
	6:00 AM	8:00 AM	10
	8:00 AM	9:00 AM	80
	9:00 AM	Noon	90
	Noon	1:00 PM	40
	1:00 PM	3:00 PM	90
	3:00 PM	4:00 PM	55
	4:00 PM	8:00 PM	5
	8:00 PM	9:00 PM	30
	9:00 PM	Midnight	5
June-August, Weekdays	Midnight	Midnight	5
Jan-Dec, Weekends	Midnight	Midnight	5

Miscellaneous Equipment Schedule for Educational Facilities

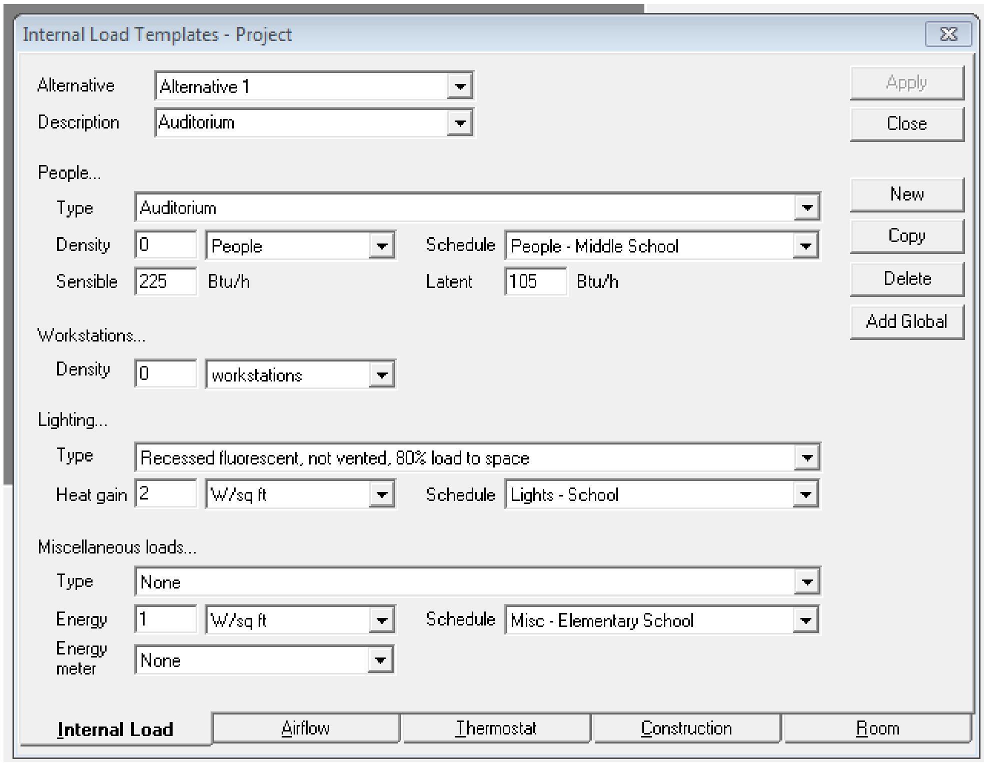
Months and Days of the Week	Start time	End time	% of Peak
Jan-May and Sept-Dec, Weekdays	Midnight	7:00 AM	0
	7:00 AM	8:00 AM	50
	8:00 AM	11:00 AM	100
	11:00 AM	Noon	80
	Noon	1:00 PM	20
	1:00 PM	3:00 PM	100
	3:00 PM	5:00 PM	30
	5:00 PM	Midnight	0
June-August, Weekdays	Midnight	7:00 AM	0
	7:00 AM	8:00 AM	10
	8:00 AM	3:00 PM	30
	3:00 PM	5:00 PM	10
	5:00 PM	Midnight	0
Jan-Dec, Weekends	Midnight	Midnight	0

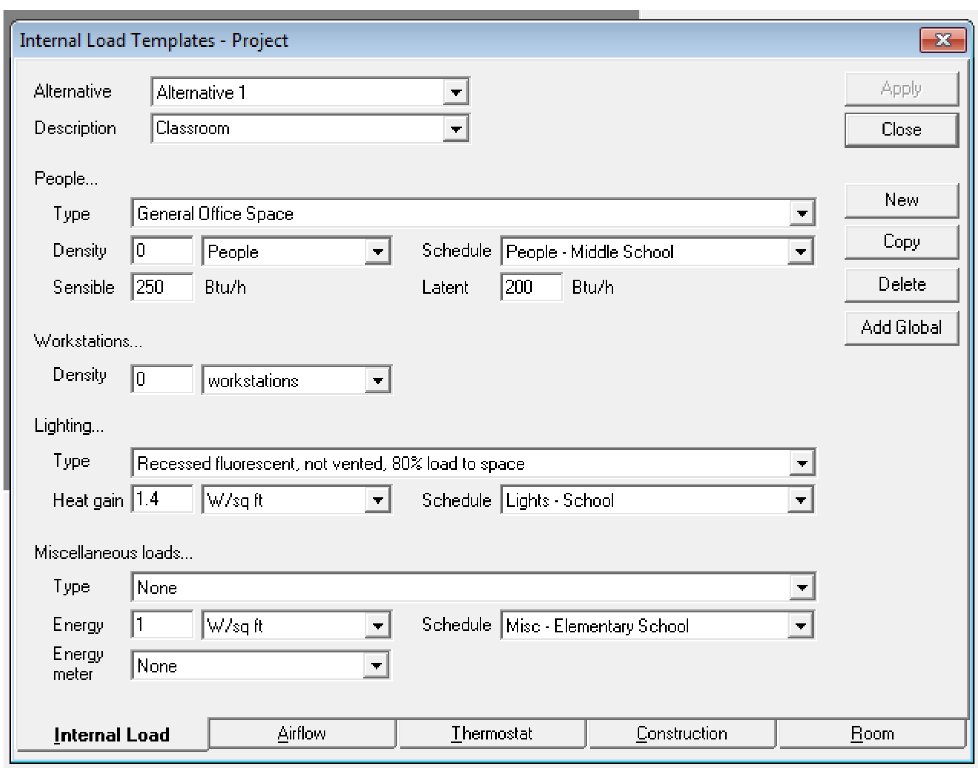
Miscellaneous Equipment Schedule for Kitchen

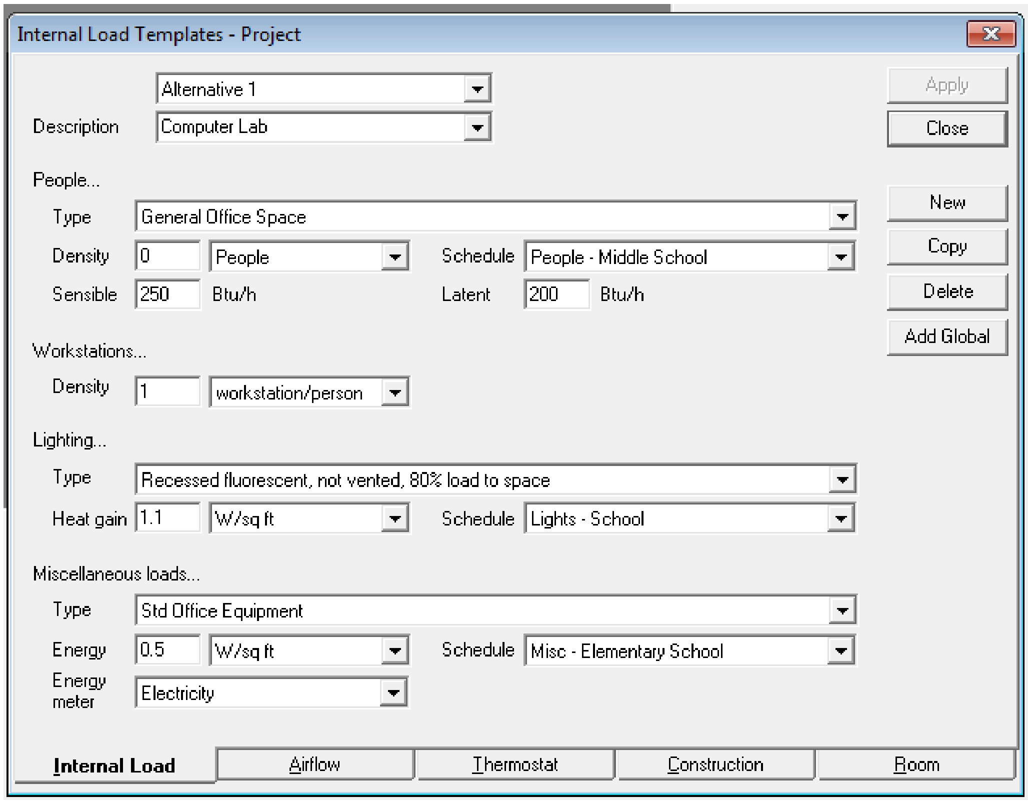
Months and Days of the Week	Start time	End time	% of Peak
Jan-May and Sept-Dec, Weekdays	Midnight	7:00 AM	0
	7:00 AM	8:00 AM	50
	8:00 AM	11:00 AM	100
	11:00 AM	Noon	80
	Noon	1:00 PM	20
	1:00 PM	3:00 PM	100
	3:00 PM	5:00 PM	30
	5:00 PM	Midnight	0
June-August, Weekdays	Midnight	7:00 AM	0
	7:00 AM	8:00 AM	10
	8:00 AM	3:00 PM	30
	3:00 PM	5:00 PM	10
	5:00 PM	Midnight	0
Jan-Dec, Weekends	Midnight	Midnight	0

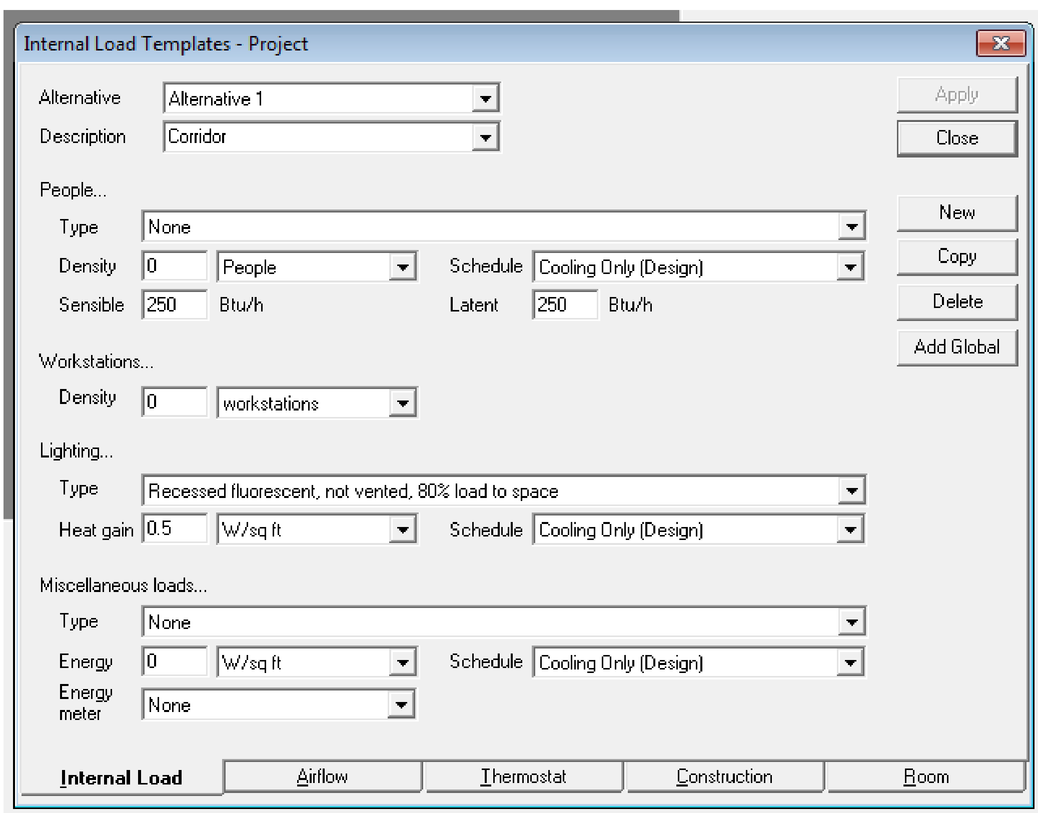
Appendix C – Trace Templates

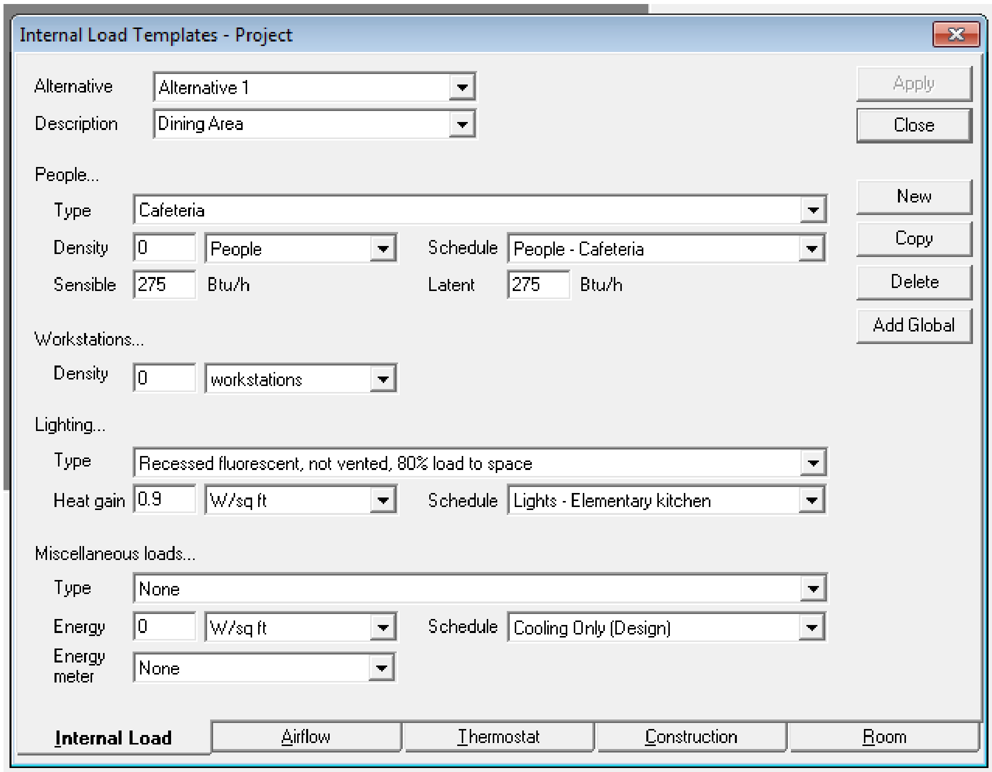
*Note: People density is 0 in templates because they were manually entered in later.

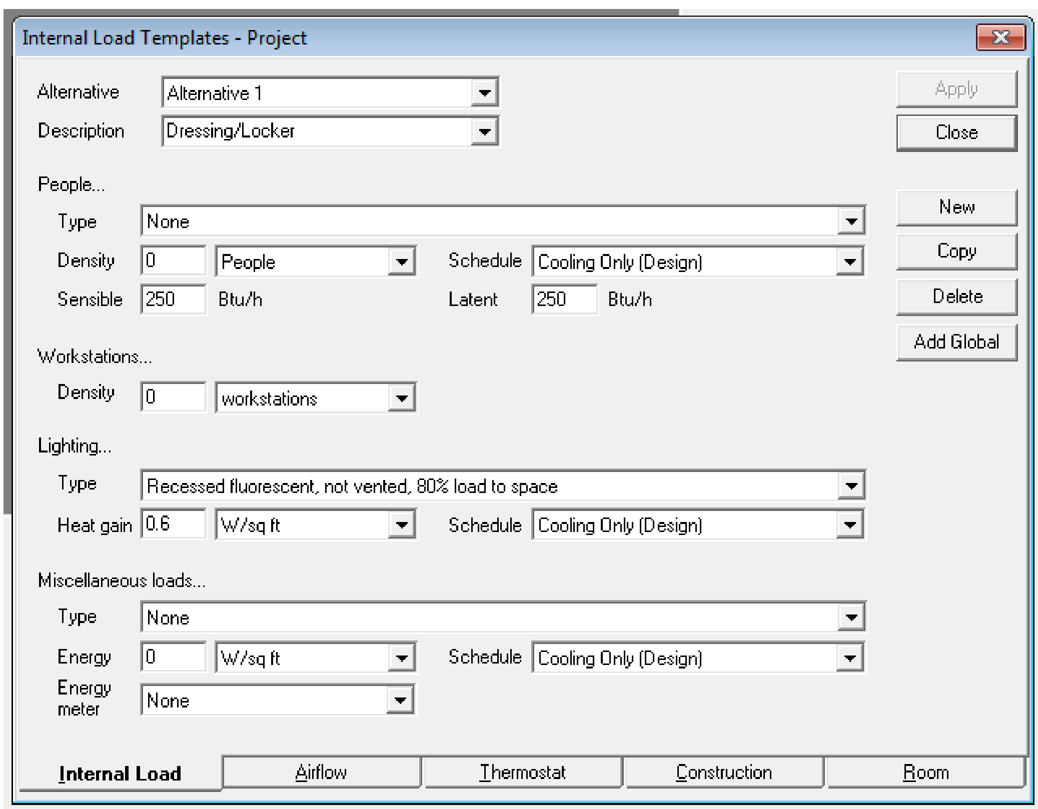


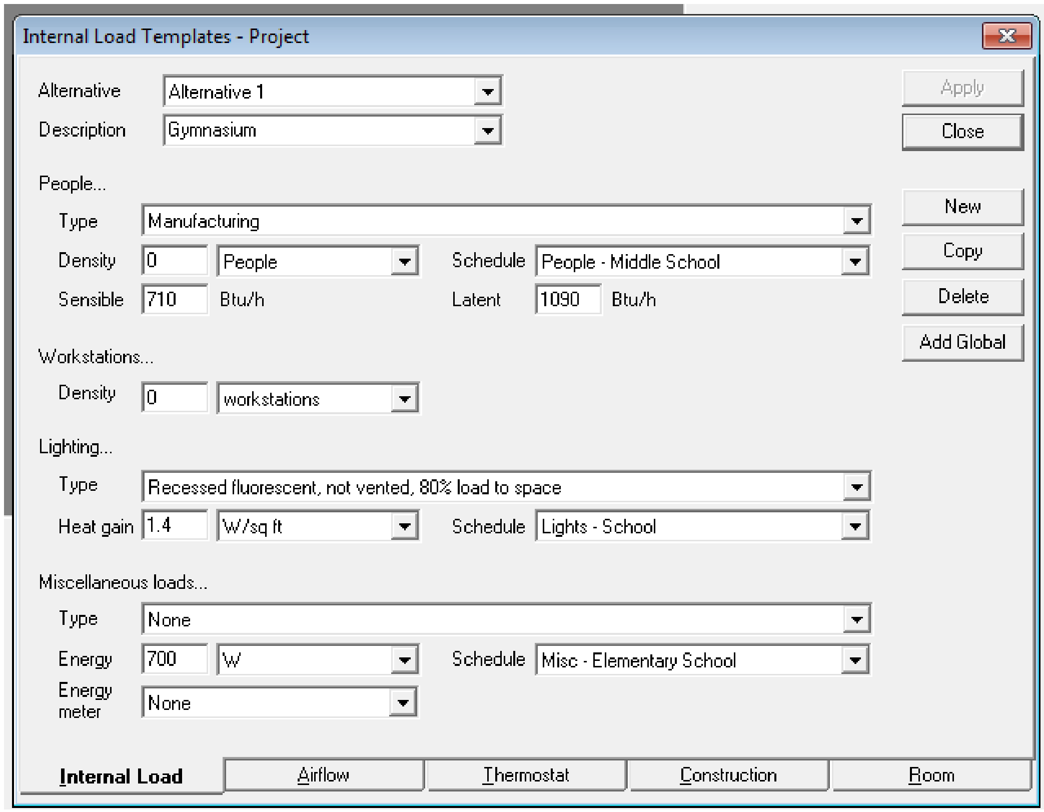


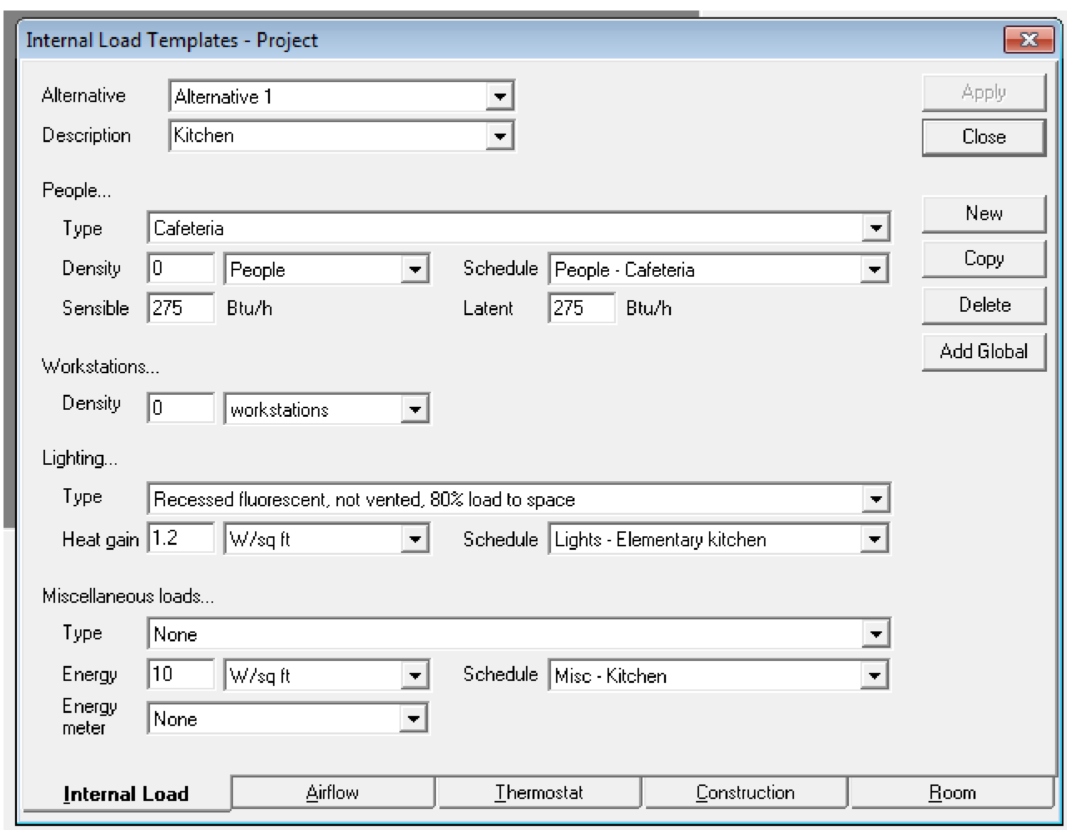

Internal Load Templates - Project
Alternative 1
Description
Computer Lab
Apply
Close
People...
Type
General Office Space
Density
0
People
Schedule
People - Middle School
Sensible
250
Btu/h
Latent
200
Btu/h
New
Copy
Delete
Add Global
Workstations...
Density
1
workstation/person
Lighting...
Type
Recessed fluorescent, not vented, 80% load to space
Heat gain
1.1
W/sq ft
Schedule
Lights - School
Miscellaneous loads...
Type
Std Office Equipment
Energy
0.5
W/sq ft
Schedule
Misc - Elementary School
Energy meter
Electricity
Internal Load
Airflow
Thermostat
Construction
Room

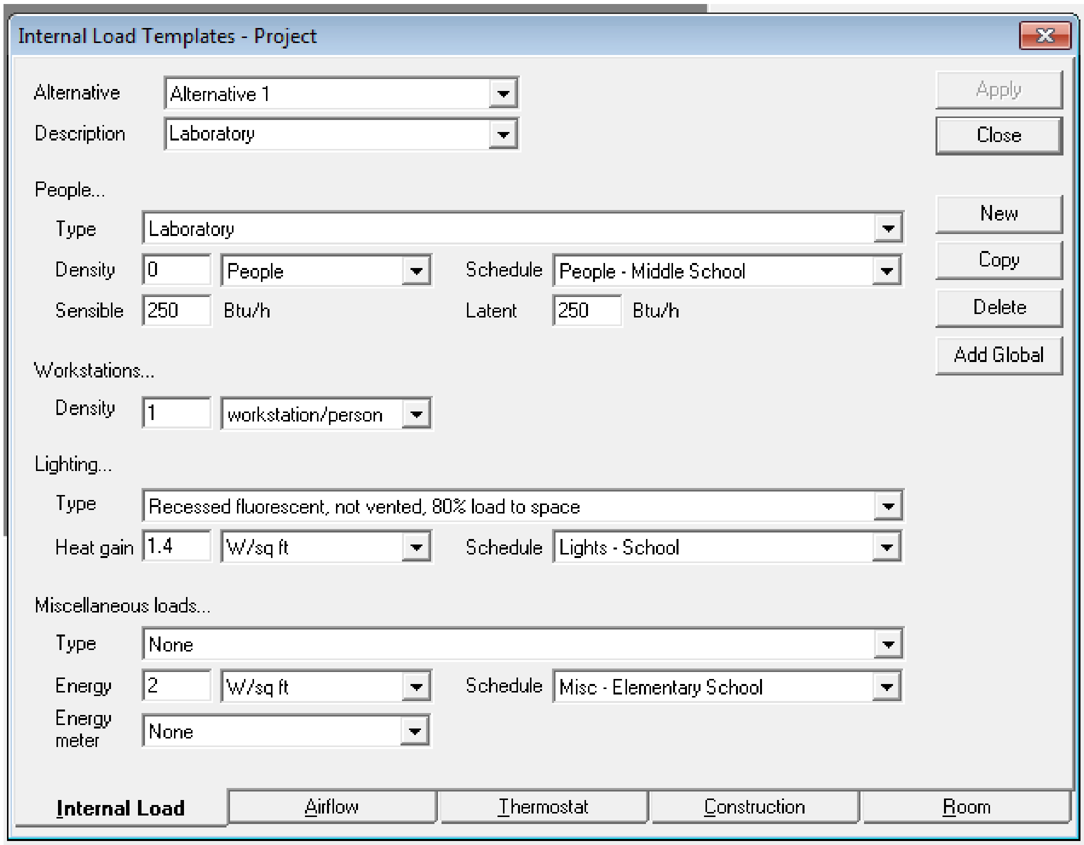

Internal Load Templates - Project
Alternative
Alternative 1
Description
Corridor
Apply
Close
People...
Type
None
Density
0
People
Schedule
Cooling Only (Design)
Sensible
250
Btu/h
Latent
250
Btu/h
New
Copy
Delete
Add Global
Workstations...
Density
0
workstations
Lighting...
Type
Recessed fluorescent, not vented, 80% load to space
Heat gain
0.5
W/sq ft
Schedule
Cooling Only (Design)
Miscellaneous loads...
Type
None
Energy
0
W/sq ft
Schedule
Cooling Only (Design)
Energy meter
None
Internal Load
Airflow
Thermostat
Construction
Room

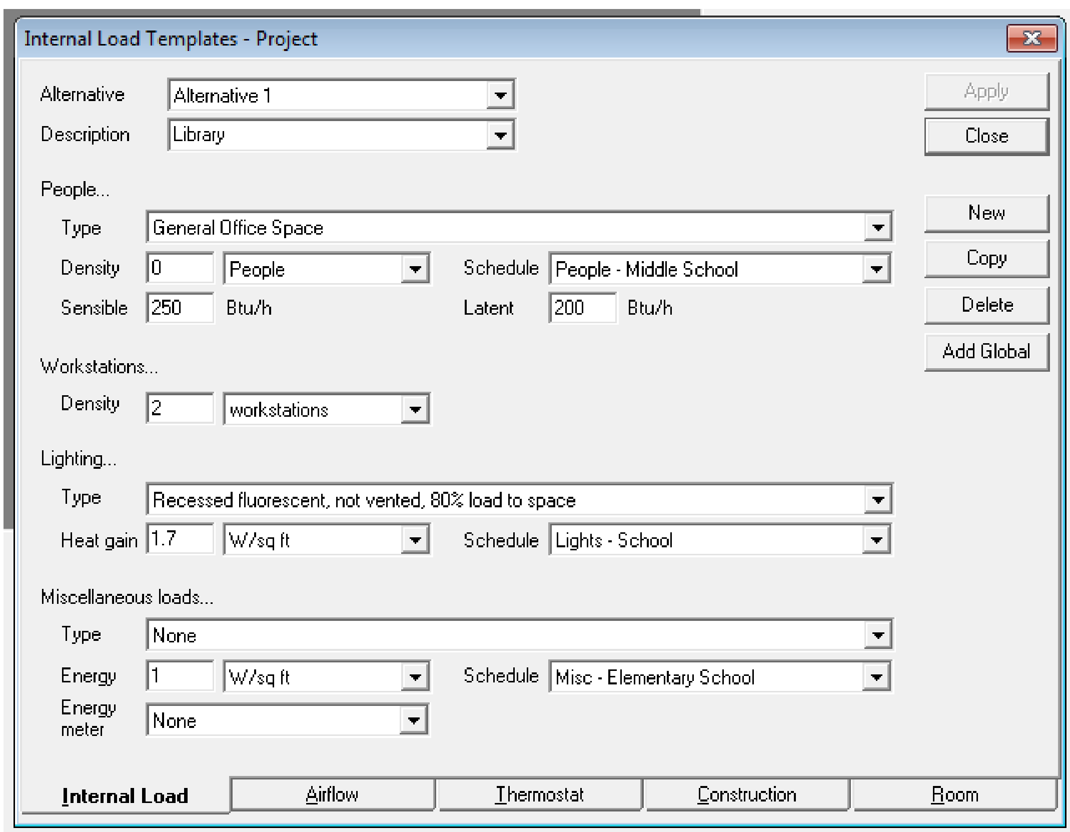

Internal Load Templates - Project
Alternative
Alternative 1
Description
Dining Area
Apply
Close
People...
Type
Cafeteria
Density
0
People
Schedule
People - Cafeteria
Sensible
275
Btu/h
Latent
275
Btu/h
New
Copy
Delete
Add Global
Workstations...
Density
0
workstations
Lighting...
Type
Recessed fluorescent, not vented, 80% load to space
Heat gain
0.9
W/sq ft
Schedule
Lights - Elementary kitchen
Miscellaneous loads...
Type
None
Energy
0
W/sq ft
Schedule
Cooling Only (Design)
Energy meter
None
Internal Load
Airflow
Thermostat
Construction
Room

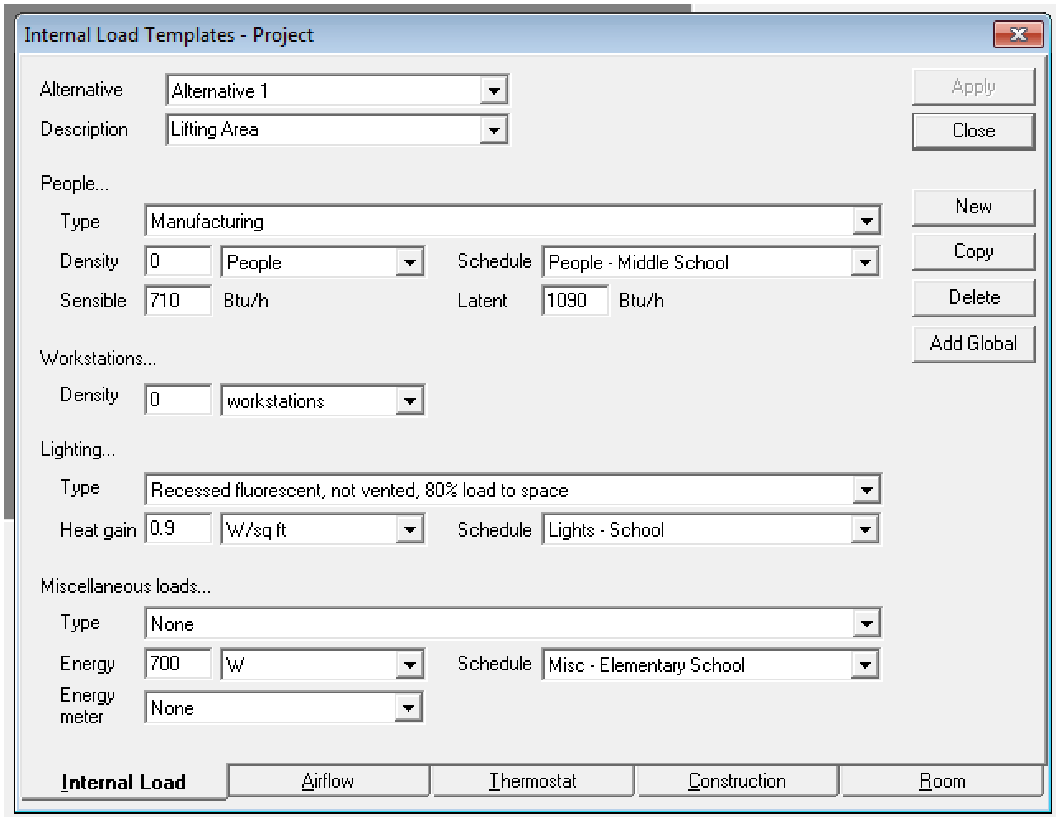

Internal Load Templates - Project
Alternative
Alternative 1
Description
Dressing/Locker
Apply
Close
People...
Type
None
Density
0
People
Schedule
Cooling Only (Design)
Sensible
250
Btu/h
Latent
250
Btu/h
New
Copy
Delete
Add Global
Workstations...
Density
0
workstations
Lighting...
Type
Recessed fluorescent, not vented, 80% load to space
Heat gain
0.6
W/sq ft
Schedule
Cooling Only (Design)
Miscellaneous loads...
Type
None
Energy
0
W/sq ft
Schedule
Cooling Only (Design)
Energy meter
None
Internal Load
Airflow
Thermostat
Construction
Room

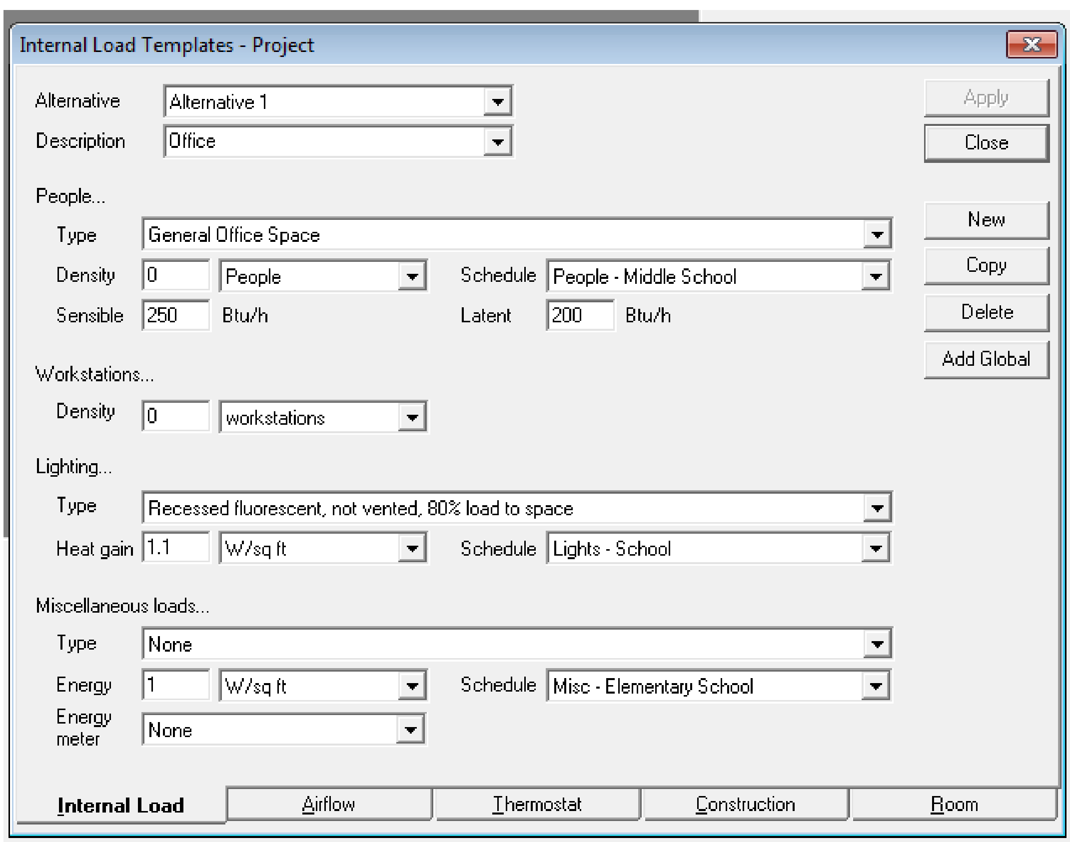

Internal Load Templates - Project
Alternative
Alternative 1
Description
Gymnasium
Apply
Close
People...
Type
Manufacturing
Density
0
People
Schedule
People - Middle School
Sensible
710
Btu/h
Latent
1090
Btu/h
New
Copy
Delete
Add Global
Workstations...
Density
0
workstations
Lighting...
Type
Recessed fluorescent, not vented, 80% load to space
Heat gain
1.4
W/sq ft
Schedule
Lights - School
Miscellaneous loads...
Type
None
Energy
700
W
Schedule
Misc - Elementary School
Energy meter
None
Internal Load
Airflow
Thermostat
Construction
Room

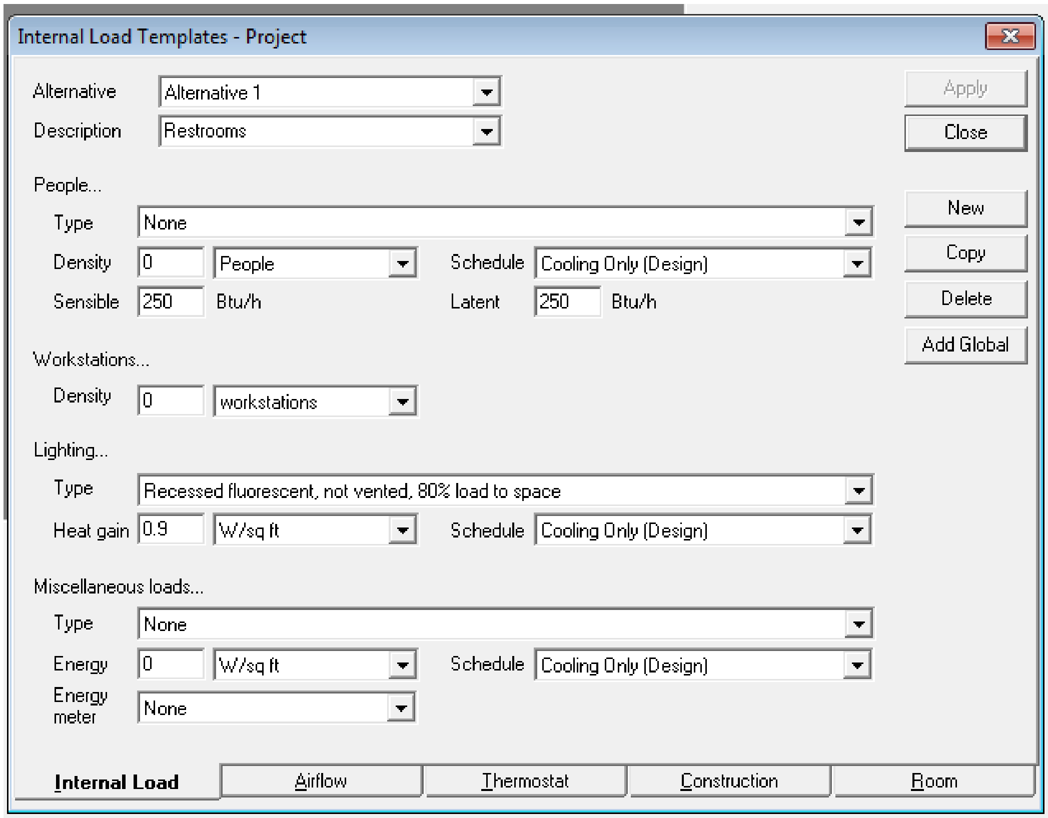

Internal Load Templates - Project
Alternative
Alternative 1
Description
Kitchen
Apply
Close
People...
Type
Cafeteria
Density
0
People
Schedule
People - Cafeteria
Sensible
275
Btu/h
Latent
275
Btu/h
New
Copy
Delete
Add Global
Workstations...
Density
0
workstations
Lighting...
Type
Recessed fluorescent, not vented, 80% load to space
Heat gain
1.2
W/sq ft
Schedule
Lights - Elementary kitchen
Miscellaneous loads...
Type
None
Energy
10
W/sq ft
Schedule
Misc - Kitchen
Energy meter
None
Internal Load
Airflow
Thermostat
Construction
Room

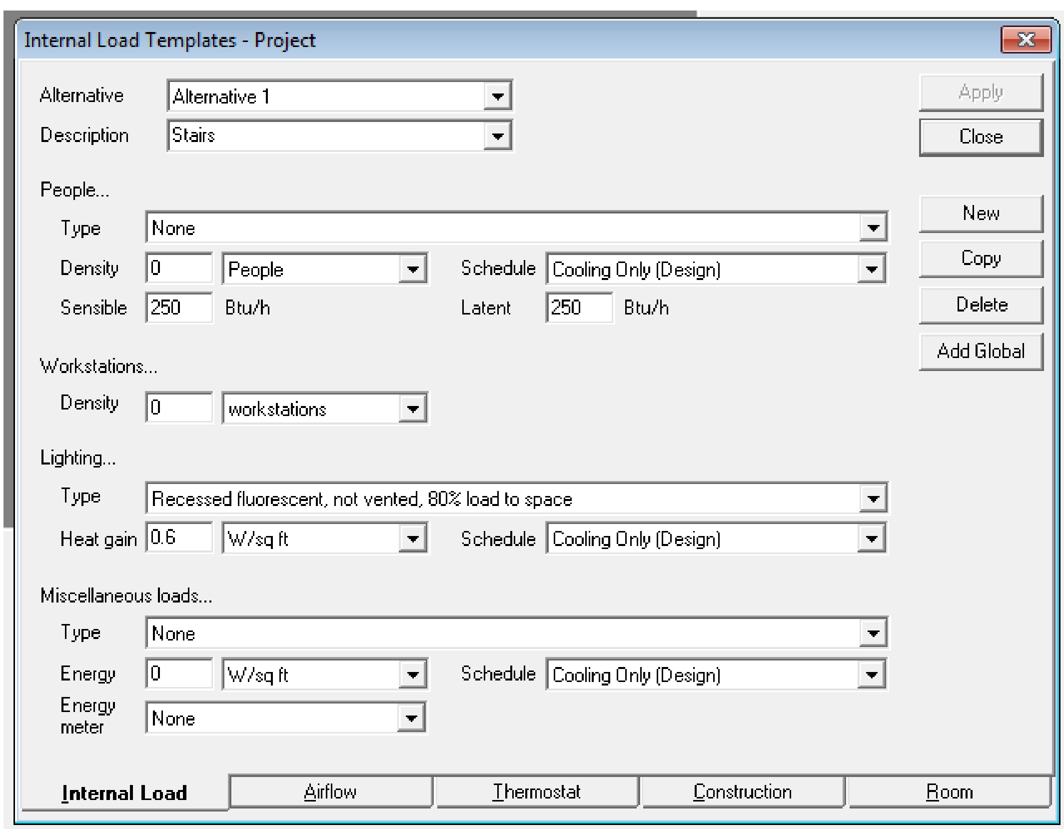

Internal Load Templates - Project
Alternative
Alternative 1
Description
Laboratory
Apply
Close
People...
Type
Laboratory
Density
0
People
Schedule
People - Middle School
Sensible
250
Btu/h
Latent
250
Btu/h
New
Copy
Delete
Add Global
Workstations...
Density
1
workstation/person
Lighting...
Type
Recessed fluorescent, not vented, 80% load to space
Heat gain
1.4
W/sq ft
Schedule
Lights - School
Miscellaneous loads...
Type
None
Energy
2
W/sq ft
Schedule
Misc - Elementary School
Energy meter
None
Internal Load
Airflow
Thermostat
Construction
Room

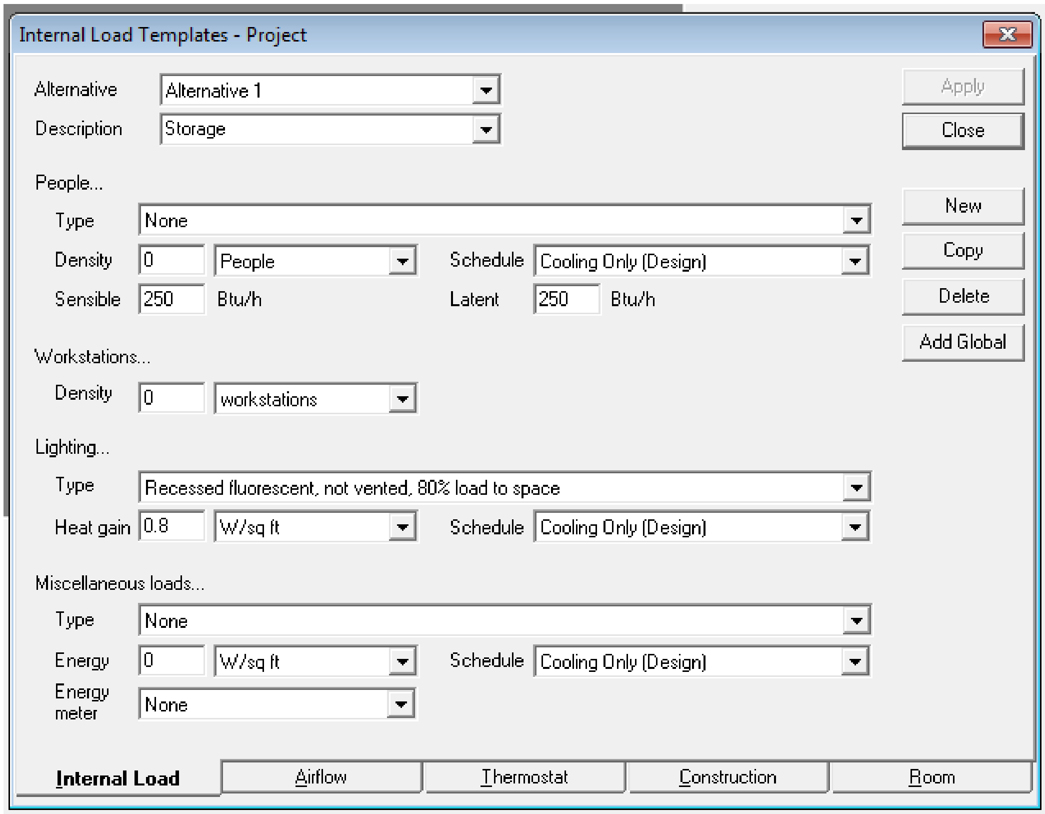

Internal Load Templates - Project
Alternative
Alternative 1
Description
Library
Apply
Close
People...
Type
General Office Space
Density
0
People
Schedule
People - Middle School
Sensible
250
Btu/h
Latent
200
Btu/h
New
Copy
Delete
Add Global
Workstations...
Density
2
workstations
Lighting...
Type
Recessed fluorescent, not vented, 80% load to space
Heat gain
1.7
W/sq ft
Schedule
Lights - School
Miscellaneous loads...
Type
None
Energy
1
W/sq ft
Schedule
Misc - Elementary School
Energy meter
None
Internal Load
Airflow
Thermostat
Construction
Room

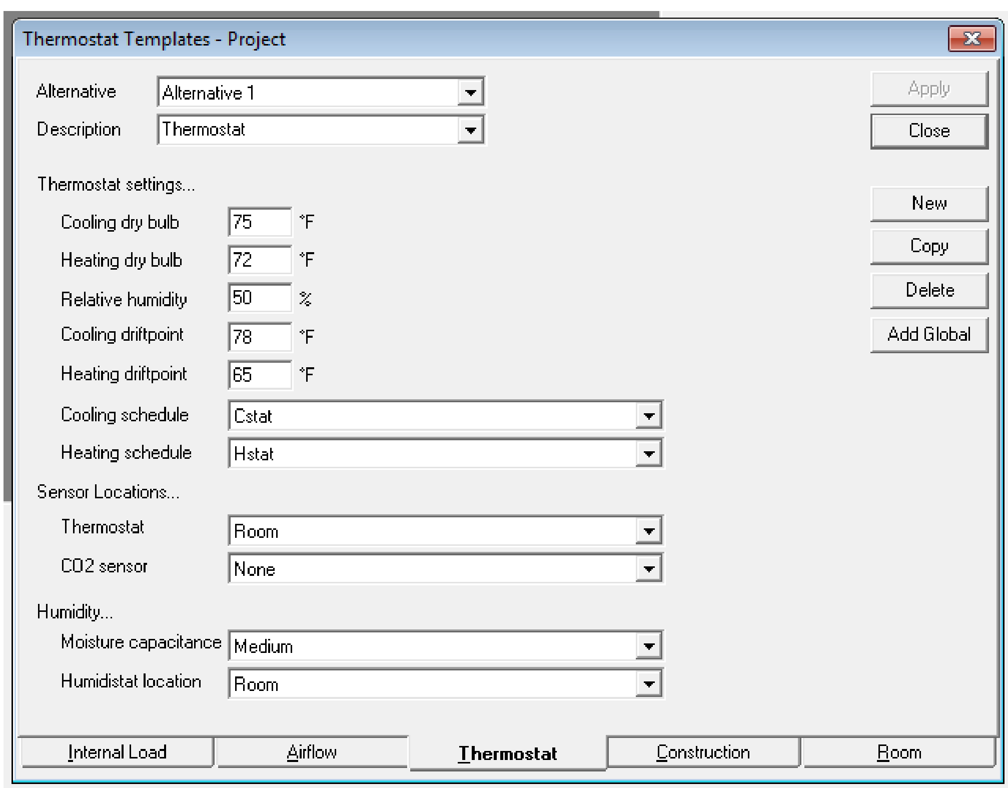

Internal Load Templates - Project
Alternative
Alternative 1
Description
Lifting Area
Apply
Close
People...
Type
Manufacturing
Density
0
People
Schedule
People - Middle School
Sensible
710
Btu/h
Latent
1090
Btu/h
New
Copy
Delete
Add Global
Workstations...
Density
0
workstations
Lighting...
Type
Recessed fluorescent, not vented, 80% load to space
Heat gain
0.9
W/sq ft
Schedule
Lights - School
Miscellaneous loads...
Type
None
Energy
700
W
Schedule
Misc - Elementary School
Energy meter
None
Internal Load
Airflow
Thermostat
Construction
Room


Internal Load Templates - Project
Alternative
Alternative 1
Description
Office
Apply
Close
People...
Type
General Office Space
Density
0
People
Schedule
People - Middle School
Sensible
250
Btu/h
Latent
200
Btu/h
New
Copy
Delete
Add Global
Workstations...
Density
0
workstations
Lighting...
Type
Recessed fluorescent, not vented, 80% load to space
Heat gain
1.1
W/sq ft
Schedule
Lights - School
Miscellaneous loads...
Type
None
Energy
1
W/sq ft
Schedule
Misc - Elementary School
Energy meter
None
Internal Load
Airflow
Thermostat
Construction
Room


Internal Load Templates - Project
Alternative
Alternative 1
Description
Restrooms
Apply
Close
People...
Type
None
Density
0
People
Schedule
Cooling Only (Design)
Sensible
250
Btu/h
Latent
250
Btu/h
New
Copy
Delete
Add Global
Workstations...
Density
0
workstations
Lighting...
Type
Recessed fluorescent, not vented, 80% load to space
Heat gain
0.9
W/sq ft
Schedule
Cooling Only (Design)
Miscellaneous loads...
Type
None
Energy
0
W/sq ft
Schedule
Cooling Only (Design)
Energy meter
None
Internal Load
Airflow
Thermostat
Construction
Room


Internal Load Templates - Project
Alternative
Alternative 1
Description
Stairs
Apply
Close
People...
Type
None
Density
0
People
Schedule
Cooling Only (Design)
Sensible
250
Btu/h
Latent
250
Btu/h
New
Copy
Delete
Add Global
Workstations...
Density
0
workstations
Lighting...
Type
Recessed fluorescent, not vented, 80% load to space
Heat gain
0.6
W/sq ft
Schedule
Cooling Only (Design)
Miscellaneous loads...
Type
None
Energy
0
W/sq ft
Schedule
Cooling Only (Design)
Energy meter
None
Internal Load
Airflow
Thermostat
Construction
Room


Internal Load Templates - Project
Alternative
Alternative 1
Description
Storage
Apply
Close
People...
Type
None
New
Density
0
People
Schedule
Cooling Only (Design)
Copy
Sensible
250
Btu/h
Latent
250
Btu/h
Delete
Add Global
Workstations...
Density
0
workstations
Lighting...
Type
Recessed fluorescent, not vented, 80% load to space
Heat gain
0.8
W/sq ft
Schedule
Cooling Only (Design)
Miscellaneous loads...
Type
None
Energy
0
W/sq ft
Schedule
Cooling Only (Design)
Energy meter
None
Internal Load
Airflow
Thermostat
Construction
Room


Thermostat Templates - Project
Alternative
Alternative 1
Description
Thermostat
Apply
Close
Thermostat settings...
Cooling dry bulb
75
°F
New
Heating dry bulb
72
°F
Copy
Relative humidity
50
%
Delete
Cooling driftpoint
78
°F
Add Global
Heating driftpoint
65
°F
Cooling schedule
Cstat
Heating schedule
Hstat
Sensor Locations...
Thermostat
Room
CO2 sensor
None
Humidity...
Moisture capacitance
Medium
Humidistat location
Room
Internal Load
Airflow
Thermostat
Construction
Room