Technical Report Two

Building and Plant Energy Analysis Report

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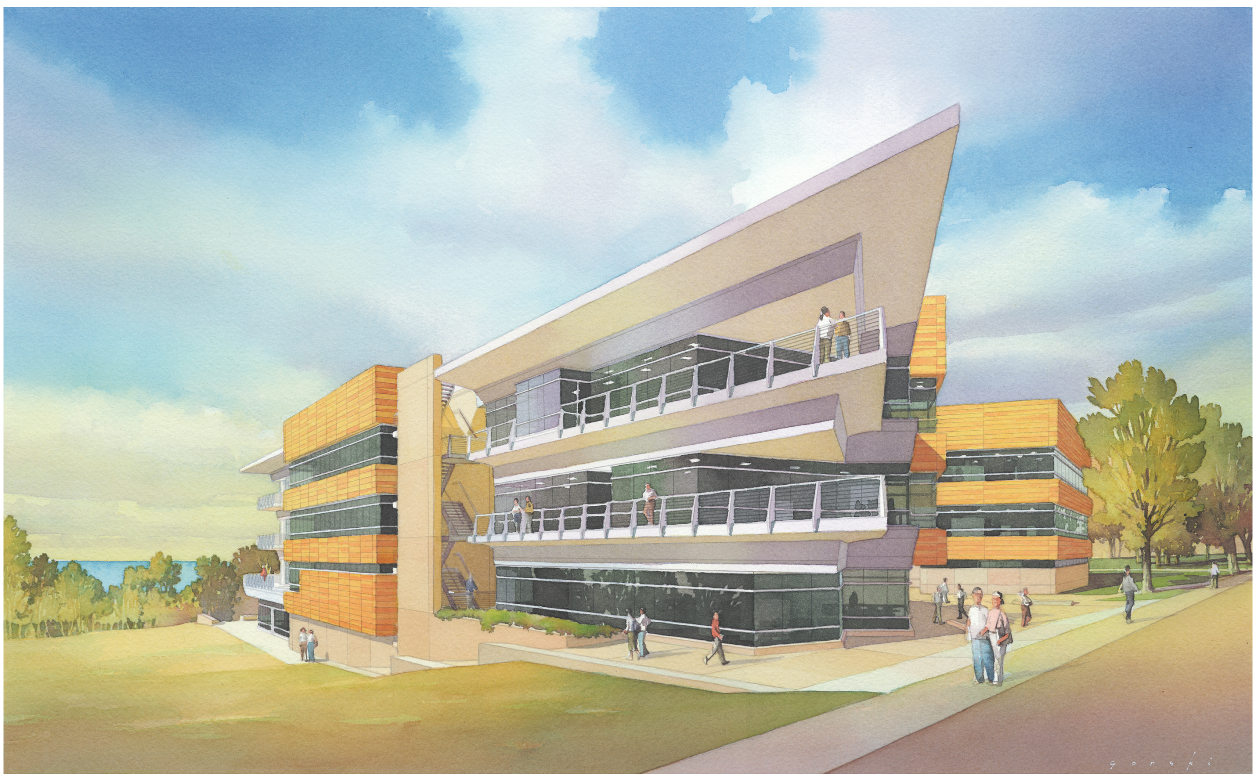

UNIVERSITY OF CALIFORNIA – SAN DIEGO

RADY SCHOOL OF MANAGEMENT

LA JOLLA, CA

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EXECUTIVE SUMMARY

This report is to evaluate building energy consumption, cost of operation, and emissions related to the energy use.

It starts off with a quick overview of the building's use and the main components of the mechanical system are listed with a brief description. Then the report goes on to explain my procedure for creating an energy model with the TRACE 700 program.

There were a few problems with the results of the energy model. Electricity consumption seemed to be about right, as compared to actual consumption data from July '08 to June '09. There was however a problem with the natural gas calculation. For some reason, this number was very low, so I used actual data to calculate operational cost. The process was also complicated by the fact that this building is served by UCSD's central utility plant (CUP), and regular utility data was not available.

Upon evaluation, the operational costs of this building are quite low. It was calculated that the cost of operating the building from July'08 to June '09 was only $\$1.91/ft^2$. This is largely due to cheap and efficient energy being supplied by the CUP. It also has a lot to do with good construction and efficient mechanical systems.

It was determined that operational costs are dominated by electricity consumption, due largely to a relatively high lighting load and cooling load. The most effective way to reduce operational cost would be to use electrical equipment that is more efficient. This would probably prove to be difficult to change much though, due to the fact that the operational cost is already pretty low.

The report then goes on to show the amount of pollution that is created by running this building for a year. This also proved to be a little difficult because exact numbers from the CUP were not known.

Samples of how the energy model was set up are located in the appendix, along with design conditions, construction properties, and some equipment schedules. A list of references is also included.

Mechanical System Overview

PART I

Mechanical System Overview

The UCSD Rady School of management is a roughly 91,000 SF, state-of-the-art, learning facility dedicated to the development of the next generation of science and technology business leaders. This building is home to a combination of learning/research facilities, faculty offices, and student services offices. Some sustainable design principles taken into consideration for this project were: Efficient lighting, recycled materials, and natural ventilation. In addition to these features, they plan on utilizing solar energy with photovoltaic panels that are to be installed in the future.

The mechanical load on the building will be mainly cooling load because of the building's location and usage. Air is distributed to the interior spaces by an over-head VAV system with reheat coils. The VAV system is supplied by three AHU's that are roof mounted to maximize the usable program area.

<u>AHU's</u>

The facility utilizes three roof-mounted air handling units with variable frequency drives. The air handlers supply air at 53^{0}F through the use of chilled-water cooling coils and utilize a minimum of 30% outdoor air. They have also been oversized in order to leave room for future expansion.

AHU-1 has a capacity of 40,000 CFM and serves the northern wing of the building, serving mainly classrooms and faculty offices. The current designed air flow is 33,660 CFM at maximum load with 19,368 CFM of outdoor air required.

AHU-2A and AHU-2B are combined into one system and work together cool the other two remaining wings of the building. These AHU's are similar to AHU-1, but they have a slightly smaller capacity. They can each handle 35,000 CFM, so together the combined system can handle up to 70,000 CFM. The current designed airflow on these air handlers is only 60,610 CFM at maximum load with 22,662 CFM of outdoor air required.

<u>FCU's</u>

There are a total of seven fan coil units located throughout the building. These units are located in rooms with high amounts of heat generation such as, the server room, elevator equipment room, and main electrical room, to help maintain them at the designed temperature. They are also located in the main and intermediate cross connects, which act as hubs for connecting telecommunications equipment. The

FCU's take air in at 80^{O}F, cool it down to 55^{O}F and re-circulate it throughout the room in order to maintain acceptable ambient temperature.

Central Utility Plant (CUP)

The CUP is designed with one 3,000 ton York OT steam turbine driven centrifugal chiller which handles the majority of cooling requirements, as well as, a 2,000 ton York YK electric centrifugal chiller to handle peak loads and off-hour requirements. The combination of a steam and electric chillers is to provide UCSD with maximum energy efficiency and flexibility.

Chilled Water System

Chilled water is supplied by the university's CUP at 42^{O}F and circulated throughout the building by a 445 GPM base-mounted pump, as well as a 50 GPM in-line pump for off-hour loads. The chilled water supplies the 3 rooftop air handlers, as well as the seven fan coil units.

Hot Water System

Hot water is supplied by a Bell & Gossett water-to-water U-tube heat exchanger. The heat exchanger can heat 145 GPM of water from 140^{O}F to 180^{O}F with the use of high temperature water supplied by the CUP at 350^{O}F and 60 GPM. The hot water is then supplied to the building's VAV reheat coils and domestic water heater by a 145 GPM base-mounted pump.

Exhaust Fans

There are a total of 6 roof-mounted exhaust fans in the building to serve the bathrooms, electrical closets, and mechanical room. The fan serving the mechanical room moves between 600 and 2,000 CFM, and all others are designed for 4,000 CFM.

PART II

HVAC Design Load Analysis

To estimate the HVAC design loads, energy consumption, and operating costs for the Rady School of Management, Trane Air Conditioning Economics (TRACE) 700 energy simulation software was used. To ensure an accurate energy model, many pieces of information needed to be gathered from the design documents. This information included:

1.) Room Dimensions – Gathered from architectural drawing set.

2.) Room Areas – Calculated using the room dimensions.

3.) Occupant Load – Gathered from Occupant Load/Exiting Plan drawings.

4.) Building Construction – Gathered from wall sections and other architectural drawings.

5.) Typical U-values – Calculated by referencing wall sections and glazing specifications. Values can be found in Appendix.

6.) Percentage of Glazing – Calculated from building elevations.

7.) Lighting Load – Given on lighting design documents to be an average of .946 W/ft^2 for the entire building.

8.) HVAC Equipment and Operation – Gathered from mechanical design documents.

9.) Outdoor/Indoor Air Conditions – Gathered from design documents and ASHRAE Handbook of Fundamentals 2009. Data can be found in appendix.

In addition to this information, assumptions needed to be made in order to simplify the energy model for block analysis. These assumptions included:

1.) A lighting power density of .946 W/ft^2 was used for the entire building, instead of entering individual densities for each room.

2.) Bathrooms, storage rooms, and other areas that do not significantly contribute to mechanical loads were not included in the calculation.

3.) Since there are no local chillers, an on-site chiller plant was assumed.

4.) Miscellaneous equipment loads for things such as typical office and classroom equipment were assumed to be equal to the values given by TRACE 700.

5.) Sensible load per occupant is 250 BTU/hour and latent load is 200 BTU/hour.

6.) Lighting in most areas was assumed to recessed fluorescents with 80% load to the space.

7.) Infiltration rate is equal to that of average construction.

Using this information, templates were made for each typical room type. Examples of typical templates can be found in Appendix A.

Computed Loads

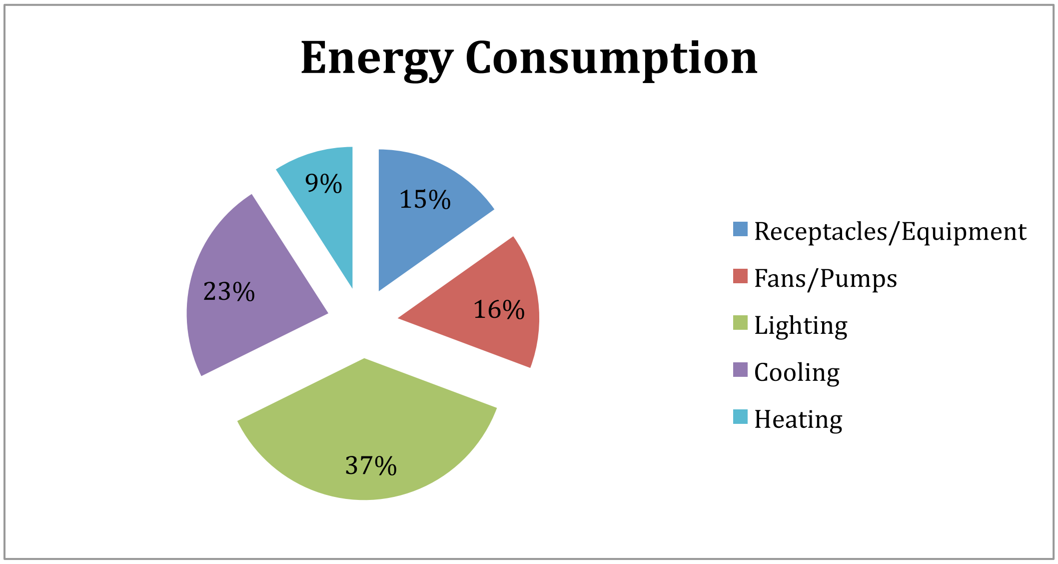
After running the energy simulation, the results were analyzed and compared to the energy model results of the design engineer. The design engineer used EnergyPro 3.1.

Cooling Load

	Calculated	*Design*	*% Diff*
Load (ft^2/ton)	549	812	32%
Supply Air (CFM/ft^2)	1.98	1.47	35%
Ventilation Air (CFM/ft^2)	0.86	0.67	28%

As you can see from the data, the energy simulation did not yield very accurate results. There may be several reasons for this. Since a central utility plant feeds the actual building, it makes it hard to get accurate numbers with TRACE 700. Also, the lighting control system in the building is fairly sophisticated; therefore, the lighting load is most likely an over estimation.

The graph below shows the breakdown of energy consumption throughout the building, according to the simulation.



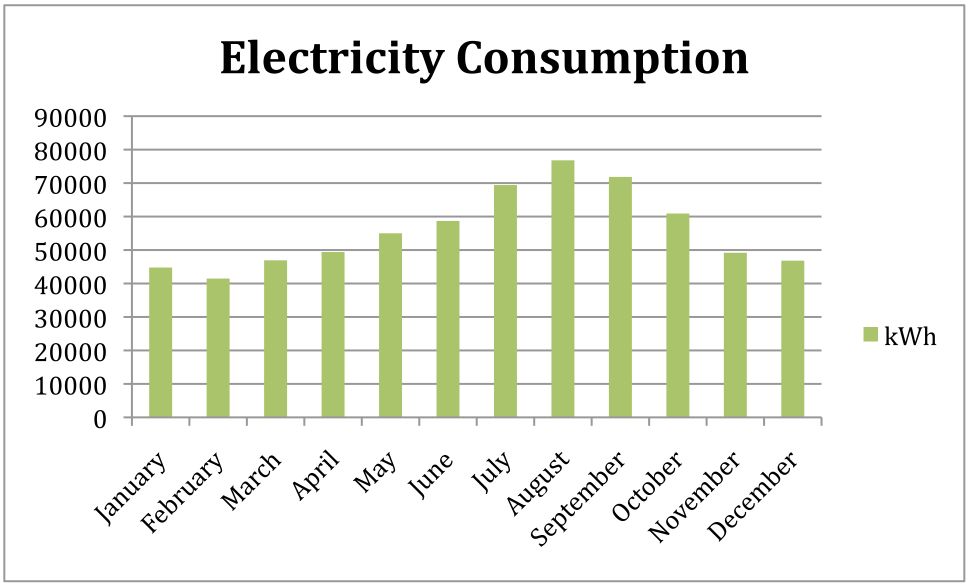
Based on total annual energy use, the simulation was somewhat accurate with an 18% difference between the TRACE model and the design engineer's.

Annual Energy Use	
	kBTU/ft²*yr
Designed	129.47
Calculated	153.14
% Error	18%

Obtaining an accurate estimate for annual operation cost is difficult for this building because it is served by the university's central utility plant and does not pay standard utility rates. Through speaking with the assistant campus energy manager, I was able to obtain rough estimates of utility costs.

Utility Rates	
Electricity	$.08/kWh
Chilled Water	$6/MBTU
Hot Water	$11.5/MBTU
Domestic Water	$5.7/100 ft^3

Below is the monthly energy consumption profile as calculated by TRACE 700. It is fairly similar to actual energy consumption data that I have received, and it seems to have the energy profile you would expect for a building in this climate.

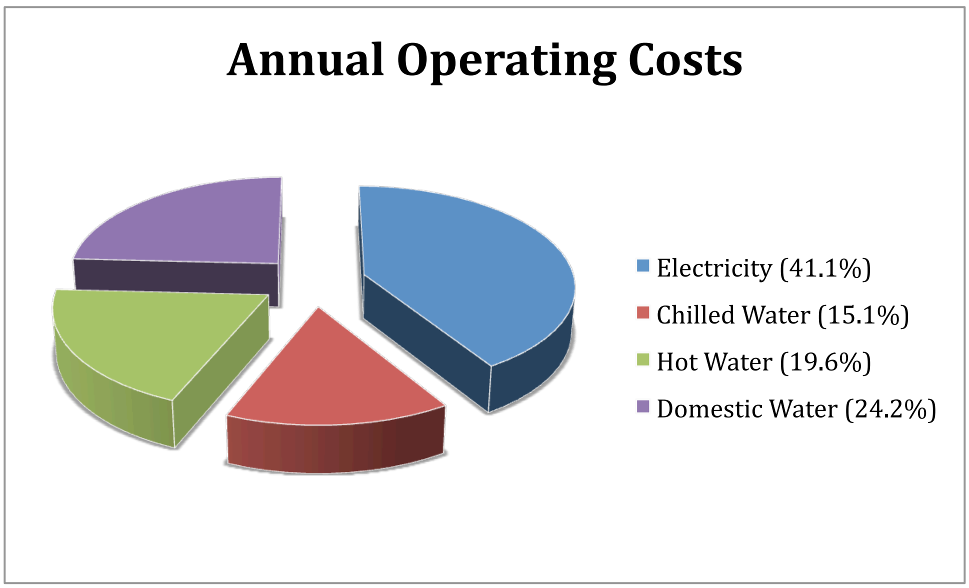


Based on actual electricity consumption data that I have obtained, this is very accurate. Below is a table comparing the actual annual cost of electricity from July '08 to June '09 to the annual cost of electricity calculated from the TRACE 700 model results.

Annual Electricity Costs	
Calculated	$53,701.68
Actual	$50,266.80
% Diff	6.83%

Based on the model, I was not able to calculate what the total annual cost of operation would be, because my utility rates are not given in the standard manner, and my energy model results yielded a very low number for the required amount of therms for heating. I am not sure why the number was so low, but it was off by a magnitude of 10. I will calculate annual operating cost based on actual data I received instead, since using the energy model results will not yield accurate numbers. Below is a breakdown of the actual annual operating cost from July '08 to June '09.

Annual Cost	
Electricity	$50,266.80
Chilled Water	$18,456.00
Hot Water	$23,943.00
Domestic Water	$29,560.20
TOTAL	$122,226.00
TOTAL/ft²	$1.91



As you can see from the figures above, this mechanical system has a very low cost of operation at only $1.91/ft^2. This is most likely due to the fact that the utilities are supplied by the university's central utility plant at a very low cost, and high efficiency. It is also apparent that electricity consumption is the major factor in this building's operational costs. In order to reduce this cost, it seems the best strategy would be to try and use equipment that consumes less electricity. As, for chilled water and hot water, it would probably be difficult to lower these costs much further since they are a necessity to heat/cool the building, and they are already being delivered to the building at such a low cost.

PART III

Emissions Calculation

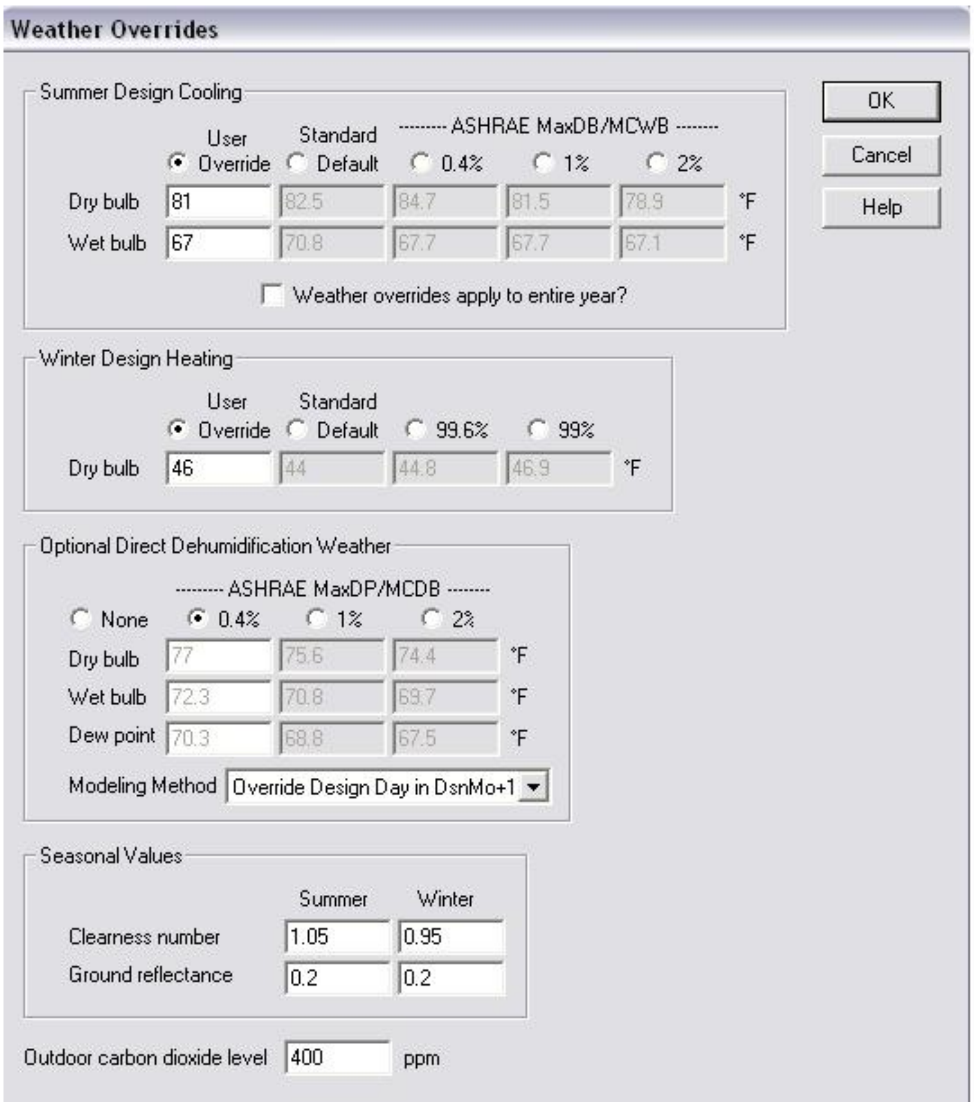
The western region is one of the best regions in term of pollutants produced by electric generation. This is because they use large amount of renewable sources for electric generation in comparison to other regions. Below is a chart detailing how many pounds of pollutants will be created by the building's electricity consumption over a one year time period.

Pollutant	lb/kWh	lbs of Pollutant/year
CO2e	1.31E+00	8.23E+05
CO2	1.22E+00	7.67E+05
CH4	3.51E-03	2.21E+03
N2O	2.97E-05	1.87E+01
NOX	1.95E-03	1.23E+03
SOX	6.82E-03	4.29E+03
CO	5.46E-04	3.43E+02
TNMOC	6.45E-05	4.05E+01
Lead	8.95E-08	5.62E-02
Mercury	1.86E-08	1.17E-02
PM10	6.99E-05	4.39E+01
Solid Waste	1.39E-01	8.73E+04

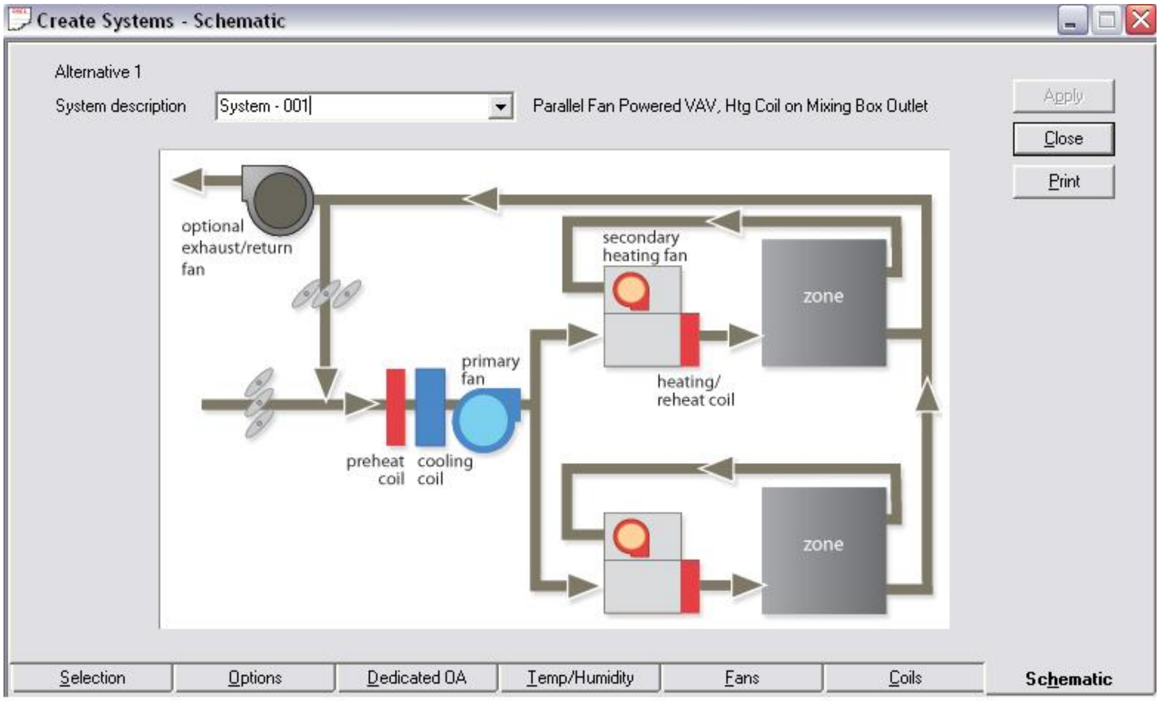
I could not calculate the emissions from the use of natural gas, because I do not know how cubic feet of natural gas the water heater takes, and I also do not know how much is used at the central utility plant.

APPENDIX

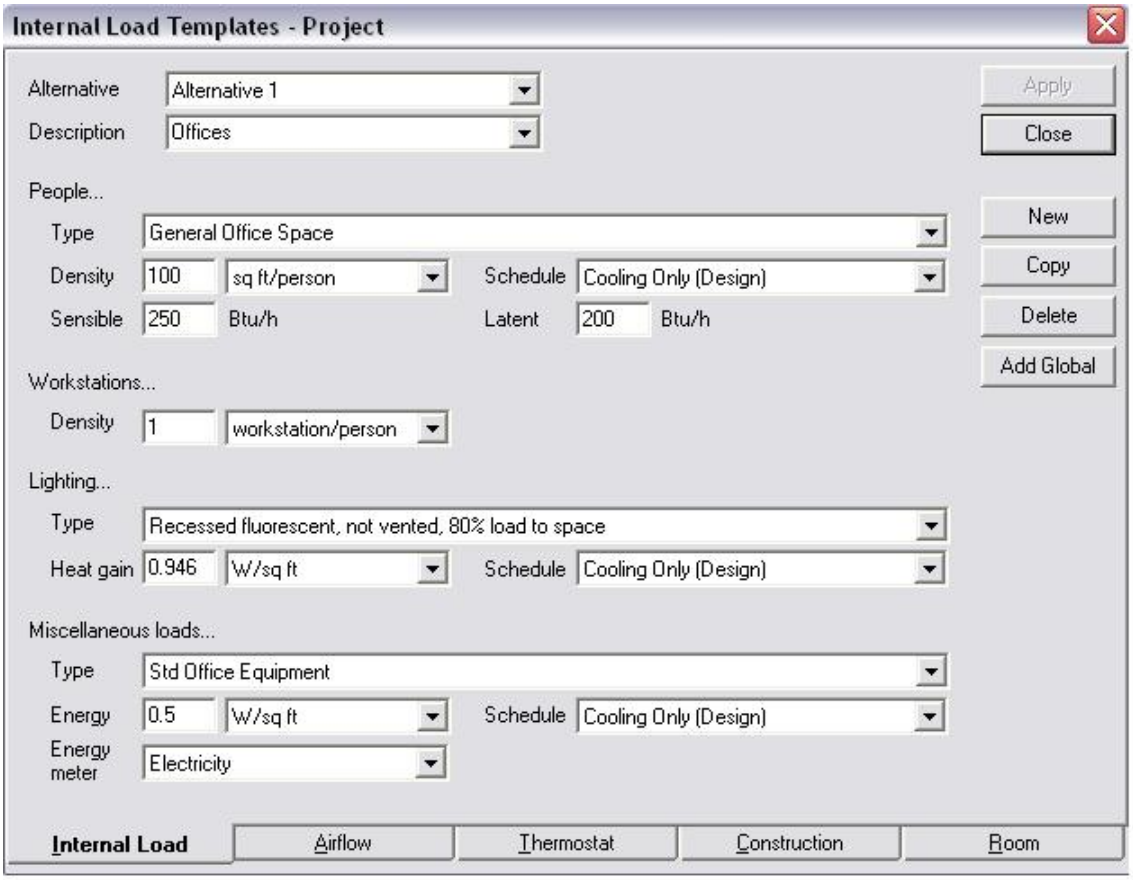
Weather Overrides



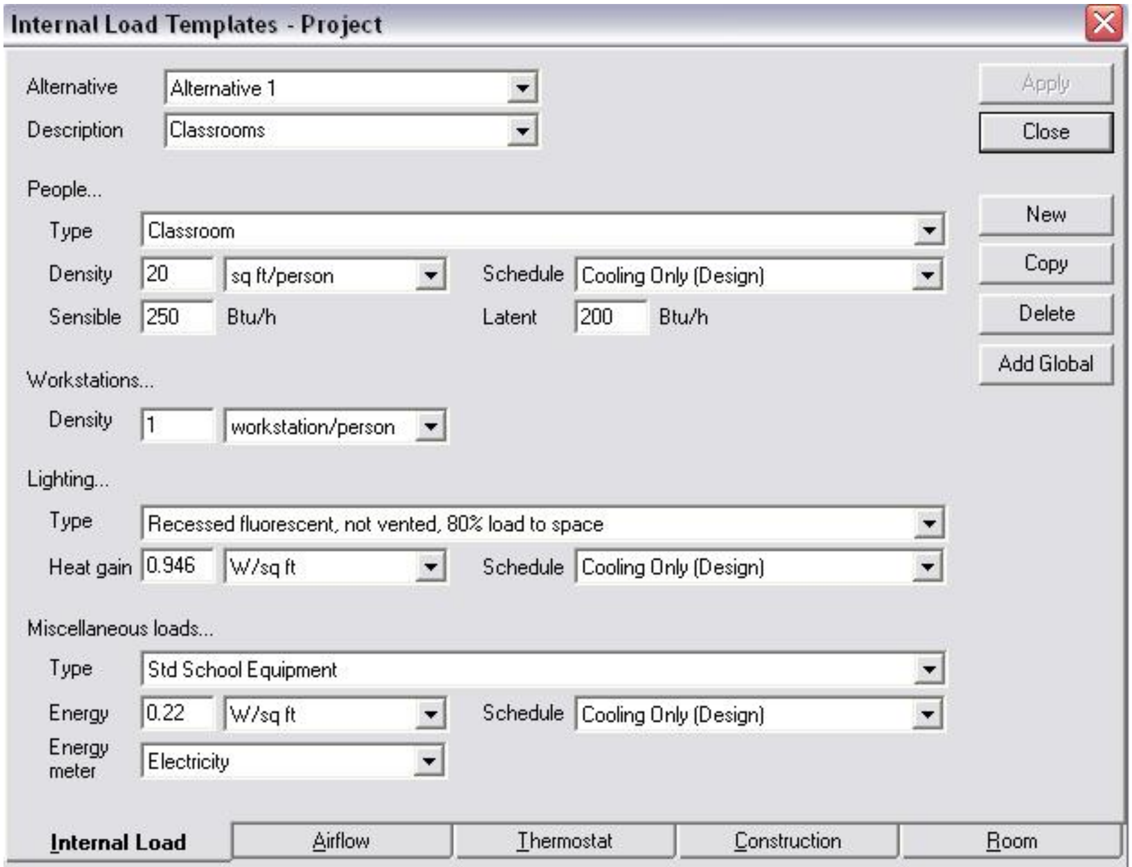
System Schematic



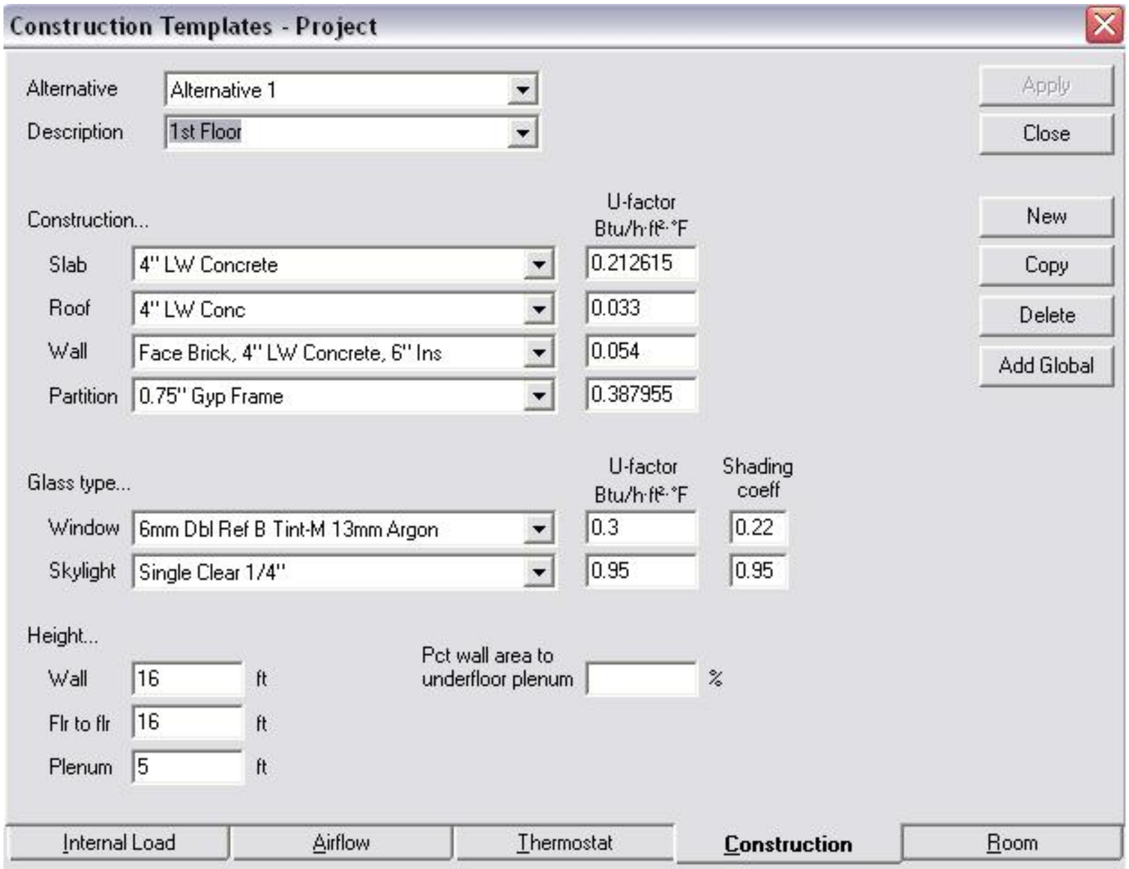
Typical Office Template



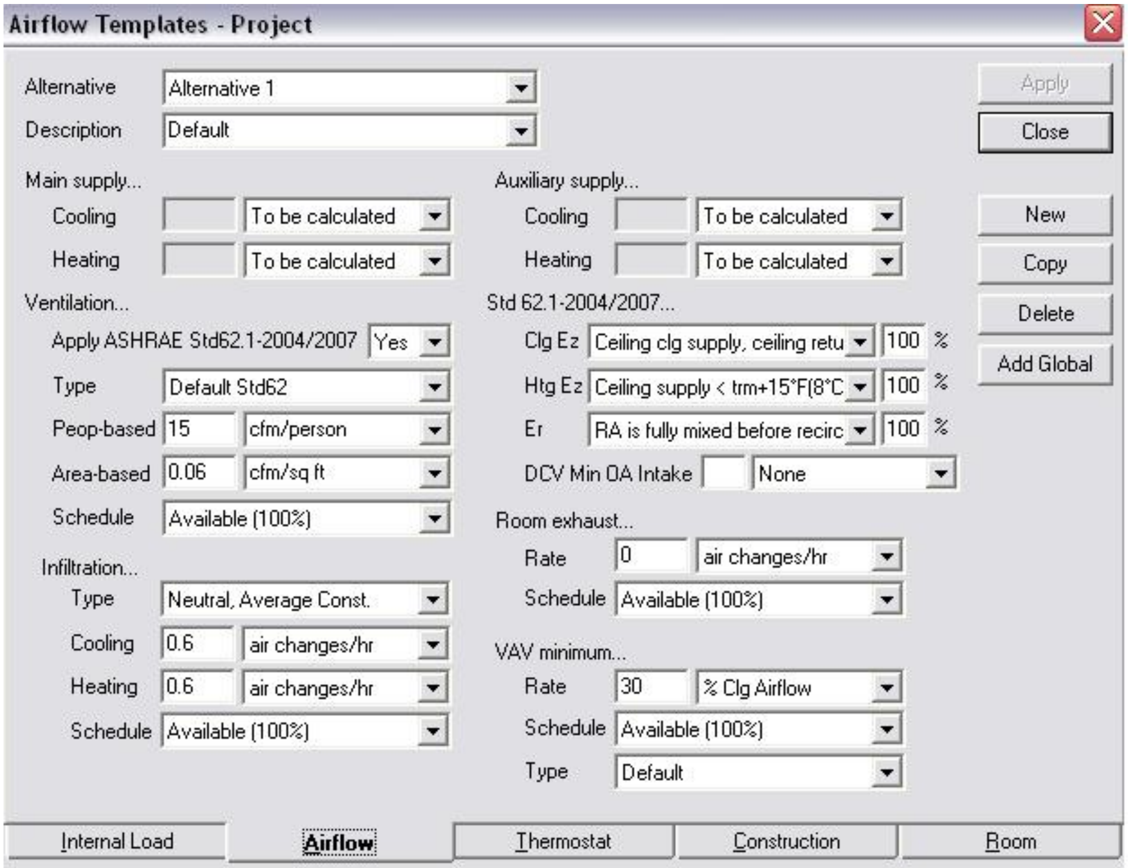
Typical Classroom Template



Typical Construction Template



Airflow Template



	U-value
Roof	0.033
Walls	0.054
Glass	0.3

Typical U-Values

BUILDING DESIGN DATA

OUTDOOR DESIGN TEMPERATURES:

WINTER: 46 °F
SUMMER: 81 °F DB
SUMMER: 67 °F WB

INDOOR DESIGN TEMPERATURES:

DISCHARGE AIR TEMPERATURES:

WINTER: 72 °F OR HIGHER
SUMMER: 75 °F

THERMOSTAT SETPOINT TEMPERATURES:

75 °F (DEADBAND 73 TO 77 °F)
72 °F AND BELOW – HEATING
78 °F AND ABOVE – COOLING

WATER–TO–WATER HEAT EXCHANGER SCHEDULE

UNIT	SYSTEM	LOCATION	TUBE SIDE FLUID TYPE	TUBE SIDE TEMP IN (DEG F)	TUBE SIDE TEMP OUT (DEG F)	TUBE SIDE MAXIMUM PRESSURE DROP (FT)	TUBE SIDE GPM	SHELL SIDE FLUID TYPE	SHELL SIDE TEMP IN (DEG F)	SHELL SIDE TEMP OUT (DEG F)	SHELL SIDE MAXIMUM PRESSURE DROP (FT)	SHELL SIDE GPM	SHELL SIDE MAX. LENGTH (INCHES)	SHELL SIDE DIAMETER (INCHES)	TUBE SIDE OPERATING PRESSURE (PSIG)	SHELL SIDE OPERATING PRESSURE (PSIG)	REMARKS
HE-1	HEATING WATER	MECH ROOM	WATER	140	180	5	145	WATER	350	250	5	60	60	10	400	150	PHASE I BLDG – B&G MODEL HTWU-85-46
HE-2	HEATING WATER	MECH ROOM	WATER	---	---	---	---	---	---	---	---	---	---	---	---	---	FUTURE HEAT EXCHANGER FOR PHASE II BLDG

PUMP SCHEDULE

MS26H1XB

PUMP NO.	SYSTEM	LOCATION	PUMP TYPE	DESIGN CAPACITY GPM	DESIGN HEAD (FEET)	MAXIMUM SHUTOFF HD. FT.	115% CAPACITY HD. FT.	MOTOR HP	MOTOR RPM	PUMP SIZE SUCTION (INCHES)	PUMP SIZE DISCHARGE (INCHES)	ISOLATION TYPE	ISOLATION DEFLECTION (INCHES)	SEAL TYPE	REMARKS
CHWP-1	CHILLED WATER	MECHANICAL ROOM	BASE MOUNTED	445	80	103	73	15	1750	4	3	5	---	MECHANICAL	BASED ON B&G SERIES 1510 MODEL 3A W/VFD CONTROL
CHWP-2	CHILLED WATER	MECHANICAL ROOM	INLINE	50	35	38	33	1	1750	---	---	---	---	MECHANICAL	BASED ON B&G SERIES 60 MODEL 2A W/VFD CONTROL
CHWP-3	CHILLED WATER	MECHANICAL ROOM	BASE MOUNTED	---	---	---	---	20	---	---	---	---	---	---	FUTURE PUMP W/VFD CONTROL – SERVES FUTURE BLDG. ESTIMATED MTR HP
CHWP-4	CHILLED WATER	MECHANICAL ROOM	INLINE	---	---	---	---	1	---	---	---	---	---	---	FUTURE PUMP W/VFD CONTROL – SERVES FUTURE BLDG. ESTIMATED MTR HP
HWP-1	HEATING WATER	MECHANICAL ROOM	BASE MOUNTED	145	60	67	57	5	1750	2.5	2	5	---	MECHANICAL	BASED ON B&G SERIES 1510 MODEL 2BC W/VFD CONTROL
HWP-2	HEATING WATER	MECHANICAL ROOM	BASE MOUNTED	---	---	---	---	7.5	---	---	---	---	---	---	FUTURE PUMP– SERVES FUTURE BLDG. ESTIMATED MTR HP
DWRP-1	DOMESTIC WATER / DWH-1	MECHANICAL ROOM	INLINE	10	20	---	---	1/12	---	---	---	---	---	MECHANICAL	BASED ON B&G MODEL PL-30 – PROVIDE ALL BRONZE CONSTRUCTION
DWRP-2	DOMESTIC WATER / DWH-1	MECHANICAL ROOM	INLINE	---	---	---	---	1/8	---	---	---	---	---	---	FUTURE – ALL BRONZE CONSTRUCTION– SERVES KITCHEN. ESTIMATED MTR HP
DWRP-3	DOMESTIC WATER / DWH-2	MECHANICAL ROOM	INLINE	---	---	---	---	1/8	---	---	---	---	---	---	FUTURE – ALL BRONZE CONSTRUCTION – FUTURE BLDG. ESTIMATED MTR HP

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RegionalGridEmissionFactors2007.pdf