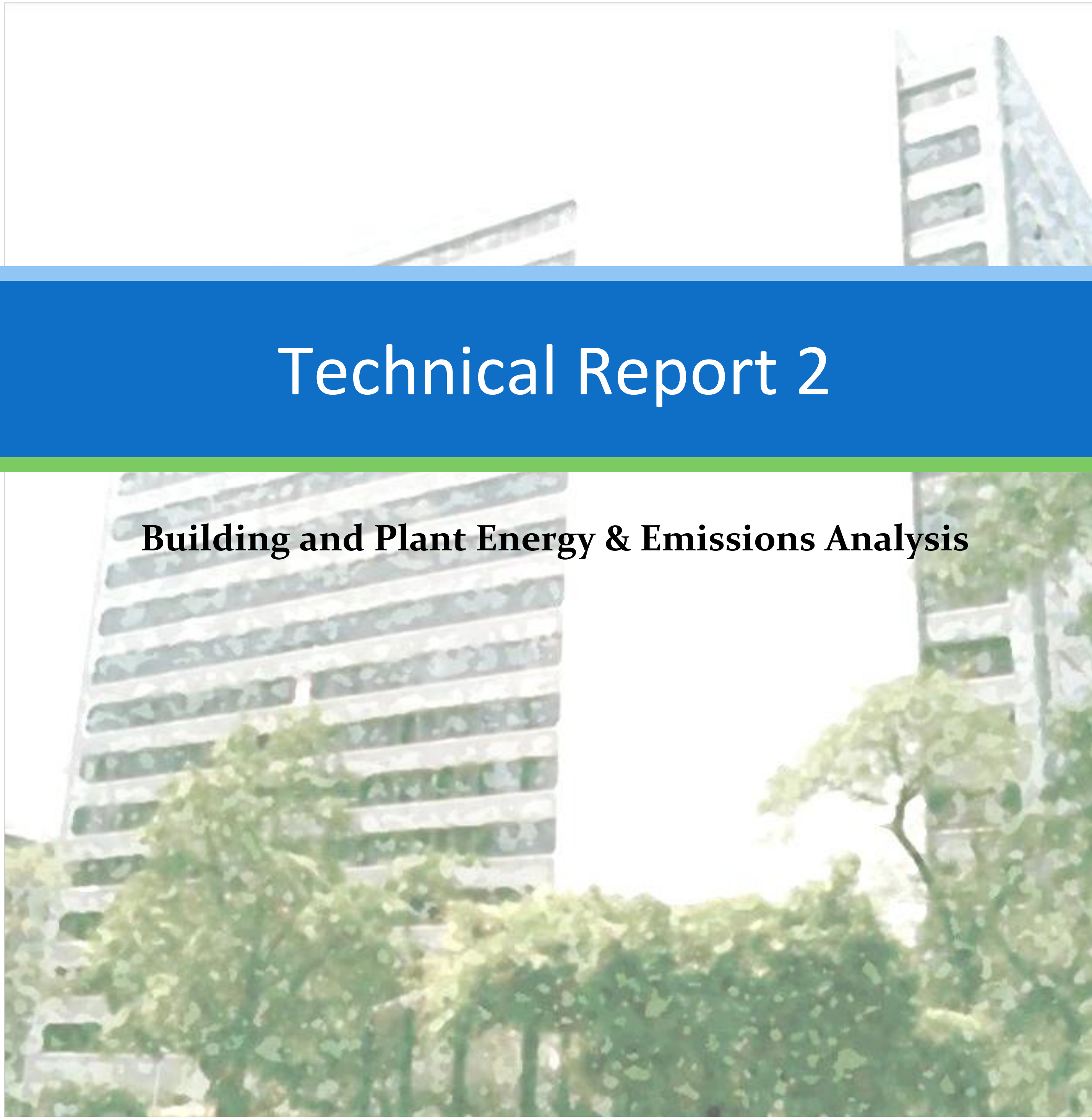

Technical Report 2

Building and Plant Energy & Emissions Analysis

RIVER VUE APARTMENTS, PITTSBURGH, PA

October 19, 2011
Authored by: Laura C. Pica
Adviser: Stephen Treado

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Executive Summary

Buildings are one of the leading users of energy in the United States because of their large mechanical systems and lighting loads. In an age when natural resources are becoming scarce and energy consumption is of international concern, building energy modeling and analysis is a critical component of HVAC system design. Developing simple methods for energy modeling can be helpful in learning how to become a smart mechanical systems designer.

Technical report 2 serves as a summary of energy modeling research and emissions analysis performed on River Vue Apartments. Once Trane TRACE 700 was used to create a simple model of the apartment units, it was found that heating loads dominate the yearly usage of energy and the most influential components of this load is due to mechanical equipment operation, lighting, and people. Ventilation is low compared to supply and exhaust airflows and this could be due to be the addition of operable windows in the apartment units. The design engineer may have assumed occupants would control ventilation individually and therefore place more emphasis on supplying constant volume air to the spaces. Detailed explanation of the modeling process and assumptions made throughout the project follows in this report.

Trane TRACE 700 was also used to investigate monthly and annual electrical, natural gas, and water consumption to understand how efficiently the building operates at normal conditions as well as critical peak operation. As expected, the highest cooling load occurred in July, where hot temperatures and high solar gains exist, and the highest heating load occurred during January and February, where there is lower solar gain and cold outdoor air temperatures. Occupancy schedules were influential in the daily energy usage since River Vue Apartments is a residential facility.

Emissions data was gathered through the energy model as well and it was found that the building will produce roughly 18 million pounds of carbon dioxide annually.

Of course, user experience was a large factor in the model and its outcome. Results may vary if another energy modeling software program is implemented or if time allowed for more detailed model templates.

Introduction

The goal of this technical report is to understand the energy consumption and building loads for River Vue Apartments using an energy simulation program. Trane TRACE was used to model the apartment complex, assign occupancy schedules, room conditions, and create a report documenting the model's expected loads. Building operating costs and equipment operation was further researched, too.

River Vue Apartments, located in Pittsburgh, Pennsylvania, is a renovation project to convert the Old State Office Building into downtown apartment living. During the summer of 2011 the building's interior was completely stripped to allow for new mechanical, electrical, fire protection and other systems to be installed in following months, with an expected substantial completion date in the spring of 2012. It has repetitive residential units on all floors, retail and café area on the first floor, two levels of valet parking for future residents, and bi-level apartment units with balconies on the 15^{th} and 16^{th} floors.

Figure 1 Exterior View of River Vue Apartments

Mechanical System Overview

Due to the simplicity of the complex, River Vue Apartments is served by only one 26,300 CFM air handling unit with an energy recovery wheel located on the roof serving two supply risers and two exhaust risers located in the north-east corner of the building. Two 200 GPM boilers and a 1024 GPM plate heat exchanger are located in the basement mechanical space and a 350 ton cooling tower located behind stainless steel curved panels on the roof serve the plumbing system's risers. The building can be divided into several simple zones requiring ventilation and conditioned air from the air handling unit, including residential apartment units, corridors, lobby/retail space, and the parking garage. Much of the building's ventilation will be provided by operable windows in the façade. Fire protection will be supplied through sprinklers on each floor, which will be new to the building in the current renovation project.

Design Load Estimation

"As-Designed" Document Data:

Contract documents for River Vue Apartments provide a mechanical equipment schedule with energy consumption and equipment sizes as follows. The single make up air handling unit with enthalpy wheel calls for 864,000 BTU/hr which equates to 7,569 MBTU annually. Supply fans provide nearly 72,000 CFM and exhaust fans remove approximately 108,000 CFM for ventilation. The mechanical design data from the River Vue Apartment's mechanical engineer was not available for comparison. No 3-D model or energy model was created for this project by the design team.

Space Zoning

In order to effectively model the annual energy consumption for River Vue Apartments in Pittsburgh, Pennsylvania, Trane TRACE 700, Version 6.2 was used. Peak design heating and cooling loads for the system determined throughout the analysis can be used as a benchmark for potential redesign of the system. The building was divided into five zones per floor, as seen below, to achieve more accurate modeling of solar gains on exterior walls and internal gains.

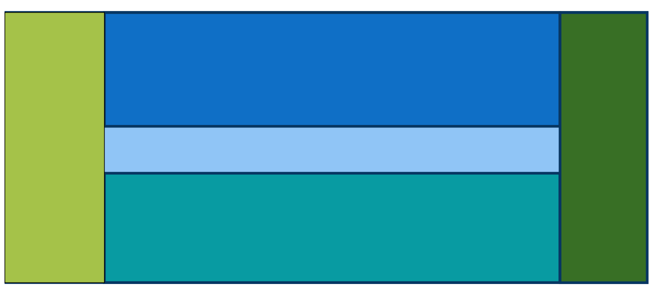


Figure 2: Plan View of River View Apartments

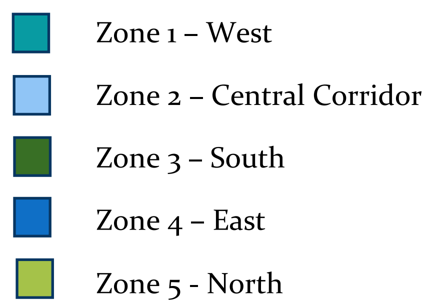


Figure 3: Color Key for Plan View of River View Apartments

The division of zones shown above allows for simple block load analysis to be performed. River Vue Apartments is rotated approximately twenty degrees off true north on its building site. This rotation influences the solar gain seen by each zone and was taken into account in the Trane TRACE model for accuracy.

NOTE: Personal experience with the Trane TRACE 700 program and previous energy analysis projects were factors in the outcome of the energy model's results.

Load Sources

Much of the load for this building comes from its occupants, ventilation, infiltration, lighting and mechanical equipment as well as significant solar gains. Tenants will likely be using the most energy early in the morning and later in the evening during dinner hour since this is a residential facility. The mechanical equipment like boilers, pumps, air handling unit and the generator will be in constant use whereas lighting loads and solar gains will vary throughout the day and year.

Energy Modeling Assumptions

Block load analysis was used for this energy modeling exercise so that calculations could be simplified and the Trane TRACE model had a manageable file size. Time did not allow for a fully expanded energy simulation however, the model's results are accurate within reason for the assumptions listed later in this report.

Schedules used for the energy model were selected from presets available in the Trane TRACE program because they serve as sufficient estimates for occupancy and energy consumption. The schedules define what percentage of a certain energy load is being utilized throughout different times of the day and are listed in Appendix B for reference.

Templates were then created using the Trane TRACE program for each typical space to describe square footage, occupancy, work stations, lighting, and other miscellaneous internal loads. Additionally, templates were established to represent River Vue Apartment's thermostat settings, construction materials, and heat transfer rates. Examples of these templates are provided in Appendix C.

After rooms and zones were established, a system with a cooling tower and water pump as well as a heat exchanger and gas-fired two boilers was created to simulate the system used in River Vue Apartments. Utility rates were applied to fuel consumption in order to identify monthly operational costs.

Construction:

Building construction materials were simplified to include six inch normal weight concrete slab floors, typical exterior metal panel walls and framed interior walls with two inches of insulation. Glazing was assumed to be single-pane bronze windows. These assumptions are close to actual conditions in the contract documentation and serve as helpful simplifications for the modeling process.

Weather Data

Design day weather conditions for Pennsylvania provided by the ASHRAE Handbook of Fundamentals 2009 are as follows:

- Winter Design Dry Bulb Temperature: 61 degrees F (15 degrees Celsius)

- Summer Design Dry Bulb Coincident Temperature: 88 degrees F (31 degrees Celsius)
- Summer Design Wet Bulb Temperature: 86 degrees F (30 degrees Celsius)
- Mean Daily Range of Temperatures: 11 degrees
- Typical Prevailing Winds: West at 6 mph

Indoor and outdoor air conditions for Pittsburgh, Pennsylvania were used in the Trane TRACE model.

Energy Modeling Results& Analysis

As seen in the table below, the energy model from Trane TRACE 700 predicts over 1.4 million cfm of airflow for heating and cooling for River Vue Apartments. This equates to roughly 4.79 cfm per square foot of the building. It can also be seen that the majority of the airflow is dedicated to cooling, heating, and return air whereas outside air and exhaust air are at a minimum. This could pose a potential for the development of poor indoor air quality within the apartment units and could be a basis for a redesign.

Design Airflow					
	OA	**Cooling**	**Heating**	**Return**	**Exhaust**
cfm	186,807	1,412,883	1,412,883	1,439,883	213,837
% TOTAL	4%	30%	30%	31%	5%
cfm/ft^2	0.63	4.79	4.79	4.88	0.72

Table 1: Design Airflow Rates

Average air changes for typical spaces within River Vue Apartments were calculated during the energy simulation and tabulated in the table below. Rooms with highest ventilation include apartment units as well as the fitness room. These results are expected since these spaces will endure high sensible loads from running equipment and high latent loads from occupants.

Air Changes Per Hour	
Apartment Unit North	38
Apartment Unit South	31
Apartment Unit East	31
Apartment Unit West	39
Corridor	25
Mechanical Room	20
Lobby	18
Fitness Room	42

Table 2: Air Changes Per Hour

	Cooling Loads		Heating Loads
	Sensible	**Latent**	
BTU/h	59,001	54,985	18,593,418
TOTAL (MBh)	113.986		18593.418

Table 3: Loads

Heating loads for the building dominate the system according to this energy model. Most times during the year, Pittsburgh's climate is cool and cloudy so it makes sense that more heating is required than cooling overall.

One final analysis was done to examine how the Trane TRACE model compares to what ASHRAE prescribes for typical high rise apartment complexes using the 2005 ASHRAE Pocket Guide for Air Conditioning, Heating, Ventilation, and Refrigeration. The guide gives high, average, and low expected values for various design categories as seen in the table below. Corresponding values from the Trane TRACE model were compared to the average values for each category to understand how the model represents operation.

High Rise Apartment			River Vue Apartments	Reasonable?
occupancy sqft/person			***occupancy sqft/person***	
Lo	Av	Hi	Model	
325	175	100	200	Yes
lights watts/sqft			***lights watts/sqft***	
Lo	Av	Hi	Model	
1	2	4	1	Yes
refrigeration sqft/ton			***refrigeration sqft/ton***	
Lo	Av	Hi	Model	
450	400	350	90	No
supply air rate (east-south-west) cfm/sqft			***supply air rate (east-south-west) cfm/sqft***	
Lo	Av	Hi	Model	
0.8	1.2	1.7	0.63	Yes
supply air rate (north) cfm/sqft			***supply air rate (north)*** *cfm/sqft*	
Lo	Av	Hi	Model	
0.5	0.8	1.3	0.63	Yes

Table 4: System Comparison

It can be seen that assumptions used for the model were almost always conservative compared to typical design values from ASHRAE for high rise apartment complexes. However, most values seen in the model are within reason given the knowledge that many simplifications to space loads, construction materials, occupancy and equipment schedules were made in the modeling process.

Refrigeration is the one category that stands out as being unacceptable and this is most likely due to incorrect system modeling. The cooling system modeled in Trane TRACE consisted of a cooling tower and two circulating pumps because River Vue Apartments uses circulated loops of water and individual heat pump units in each apartment for heating and cooling of the spaces instead of a refrigeration loop. Understanding this data can explain why the model displays lower than expected outputs.

Also note that water consumption from bathroom and kitchen appliances was not figured into the model. All interior spaces were grouped to allow for simple zoning of the building

Energy Model Created by Design Engineer

No energy model was created for this project by the original design team therefore a comparison of model data and ASHRAE design data was made (as described above). River Vue Apartments is an accelerated project with a short schedule and maximum price budget so detailed energy modeling was not of high priority. Choices for schedules and design conditions were consciously made throughout the Trane TRACE energy modeling processto produce the best model possible.

Annual Energy Consumption

Annual energy consumption is a hot topic in today's world, where natural resources are becoming scarce and electricity generation and distribution is increasingly expensive. The United States has several different regions within electricity is generated and distributed. According to the map below, Pittsburgh, Pennsylvania is located in the RFC (Eastern) region.

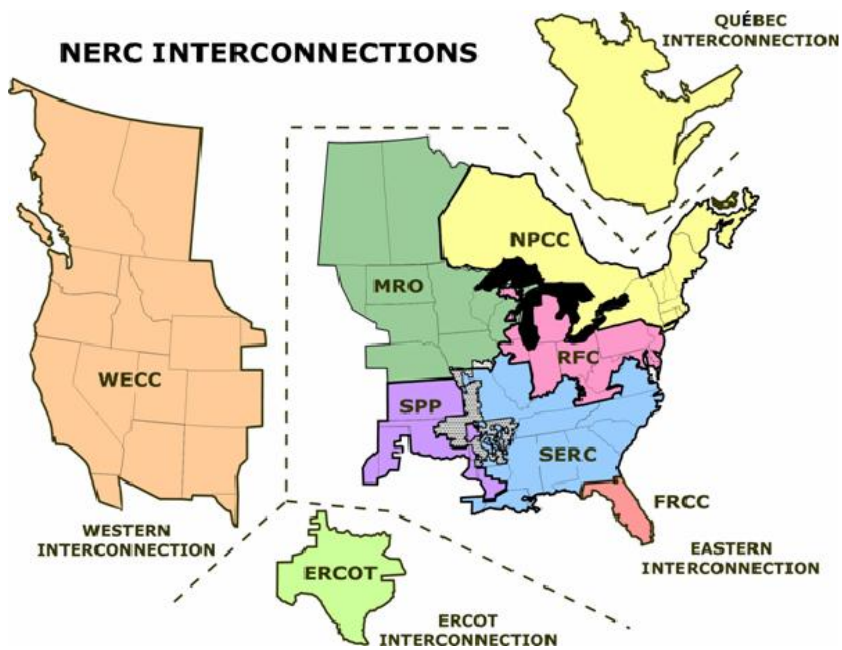


Figure 4: NERC Interconnections map, courtesy of AE 497F

This region is typically known for producing most of its electricity by burning bituminous and subbituminous coal, since it is the natural resource most prevalent in that region. Mechanical equipment like the generator and boilers in this building also consume natural gas for operation.

The energy model created in Trane TRACE was used to estimate the monthly and annual utility usage for River Vue Apartments, based on the cooling and heating systems originally designed for the building. Results say that there will be an annual electric consumption of almost 6 million kWh (combination of on-peak and off-peak usage). The biggest contributor to this usage is the heating and cooling from the mechanical system.

Fuel costs

Annual fuel costs were determined using rate information provided by the service companies' websites as follows:

Electric Company: Duquesne Light

- Coal fired electricity plant
- 8.96 cents per kWh for residential heating service

Natural Gas Company: Columbia Gas of Ohio

- 6.22 cents per hundred cubic feet total rate which breaks down as:
- 5.64 cents per ccf for standard service

  This breaks down as:
  - 2.82 cents per ccf for gross receipts tax
  - 2.89 cents per ccf for transportation cost

Water: Pennsylvania American Water

- $13/month meter fee
- 76.56 cents for the first 16,000 gallons/month in a commercial building
- 58.69 cents for excess usage

Fuel rates from the provider companies listed above were implemented to calculate the total fuel cost for operation of River Vue Apartments as seen below:

Monthly Utility Usage			
Month	Electric (kW)	Gas (therms)	Water (gal)
1	722	36776	16
2	717	35939	13
3	722	26060	17
4	849	15040	104
5	839	4558	263
6	845	1307	411
7	846	46	509
8	844	1717	350
9	839	4782	238
10	842	17417	96
11	749	20845	83
12	726	33222	17
TOTAL	9540	197709	2117
Cost	$ 849.06	$ 148,281.75	$ 1,633.78
TOTAL			$ 150,764.59

Table 5: Monthly Utility Usage

It can be seen that the total cost of fuel is $150,765, which equates to about 56 cents per square foot overall. Note that this cost reflects only the operation of the mechanical equipment and lighting. Appliances and other plug loads were not accounted for because they vary for each occupant. These utility bills will likely be paid for directly by building occupants through their apartment rental fees.

Utility usage per month was graphed to examine which months would see expected peak consumption annually by tenants. High electric and water bills should be expected during the summer months where high natural gas bills should be expected during winter months. This data is expected based on real world experience.

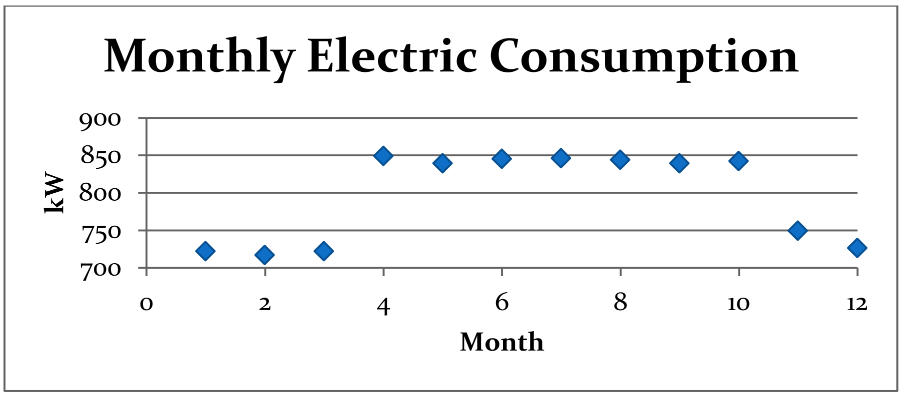


Figure 5: Monthly Electric Consumption Graph

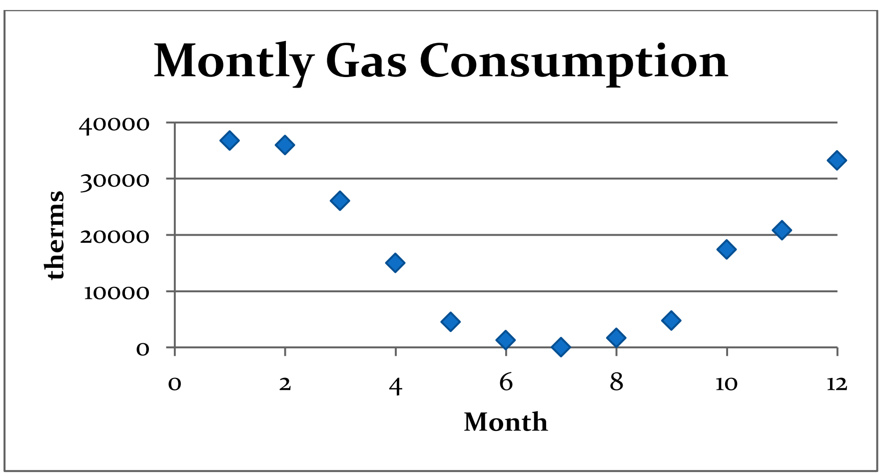


Figure 6: Monthly Natural Gas Consumption Graph

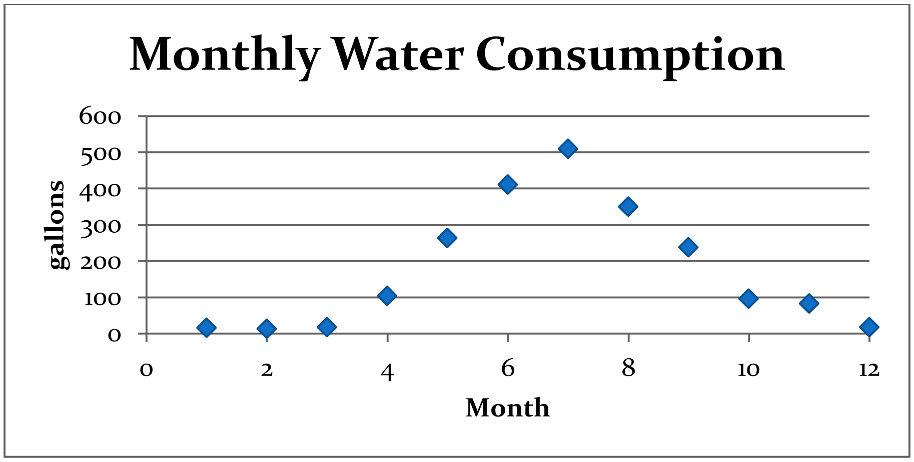


Figure 7: Monthly Water Consumption Graph

Although River Vue Apartments has small appliances like dishwashers and stovetops in each apartment unit, electric, natural gas, and water consumption occurs in bulk through the mechanical equipment. Analysis of air and water flow rates as well as equipment efficiency was done to realize the impact that equipment has on the annual operation of the facility.

Air/water flow rates

The mechanical equipment schedule in the contract documents was used to assess the capacity and flow rates of all equipment. The detailed breakdown is provided in Appendix B, but a summary is provided in the table below. It can be seen that the total BTU/h provided by the existing air handling unit does not meet the demand predicted by the Trane TRACE energy model. This difference could be due to simplifications made in the modeling process; however, it does pose an opportunity for redesign of the air handling unit.

	BTU/hr	Watts	CFM	RPM	GPM	BTU	tons
TOTAL	1,053,600	56175	179750	22604	6162	4000000	350

Table 6: Summary of Equipment Capacities

Equipment performance data

Equipment efficiencies were found in contract documents during research for Technical Report 1. As previously mentioned, the equipment efficiencies all comply with ASHRAE standards. Table 7 acts as a summary of those findings.

Equipment	Size	Specified Equipment Efficiency
Make Up Air Handling Unit	864,000 BTU/h	10 EER
Heat Pump A/C-100	73,000 BTU/h	13.5 EER, 4.7 COP
Heat Pump A/C-103	5,000 BTU/h	
Heat Pump A/C-223	12,900 BTU/h	
Heat Pump A/C-227	11,600 BTU/h	
Heat Pump A/C-1	8,800 BTU/h	
Heat Pump A/C-2	1,900 BTU/h	
Heat Pump A/C-3	18,100 BTU/h	
Heat Pump A/C-4	23,600 BTU/h	
Heat Pump A/C-5	34,700 BTU/h	
Electric Unit Heaters	375-18,700 W	3.5
Boilers	2,000,000 BTU input	91%
Axial Propeller Cooling Tower	350 tons	51.2

Table 7: Equipment Efficiencies

Knowing that the required airflow predicted by the energy model and current design do not match, a larger air handling unit could be selected with the same or better efficiency as listed above.

Operating Costs

Comparison to Utility Bills

No operational data or current utility bills were available for River Vue Apartments since it is a renovation project to convert an office facility to a residential apartment complex. The costs associated with a commercial office building do not correspond to those of a residential facility since the building function is different, therefore old operational data cannot be used. Since the project has an initial substantial completion date of April 2012, operational data may become available later in the development of this senior thesis. If this is the case, data will be provided at that time as a supplement to this report.

Energy Breakdowns

The annual energy usage for River Vue Apartments was divided into several categories to understand the usage of building subsystems like mechanical equipment, lighting, and people loads. As seen by the chart below, most energy is used in heating, cooling, and ventilating the apartment units. The second largest load on the spaces comes from lighting, as expected.

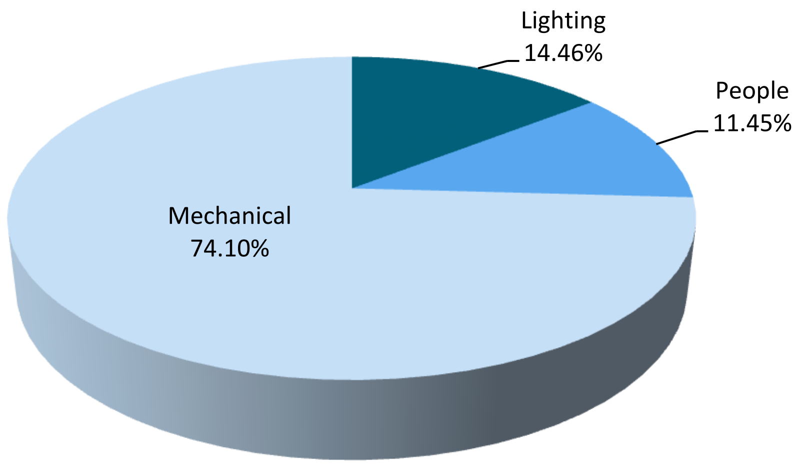


Figure 8: Energy Consumption Breakdown 1

Knowing that the majority of electricity used by River Vue Apartments is consumed by the mechanical and electrical systems, the annual electric consumption can be broken down further into subcategories to understand which building systems consume the most energy. As expected from the energy model, the heating dominates the pie chart below, followed by cooling and lighting.

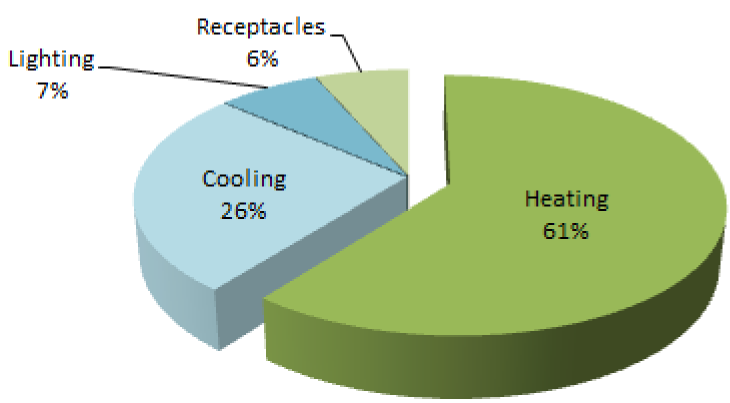


Figure 9: Energy Consumption Breakdown 2

Breakdown of Annual costs

Monthly natural gas, water and electricity usage for River Vue Apartments was plotted together to understand where annual costs would be at a maximum, minimum, and what the average monthly cost would be. As seen in the figure below, the highest cost of operation occurs during January, where natural gas consumption is elevated and the lowest cost occurs in July, where natural gas and water consumption are minimized. The average monthly cost is around $12,700 but it is obvious from the graph below that there are fluctuations each month. It is interesting to note that electric consumption is fairly consistent throughout the year whereas natural gas and water usage change rapidly.

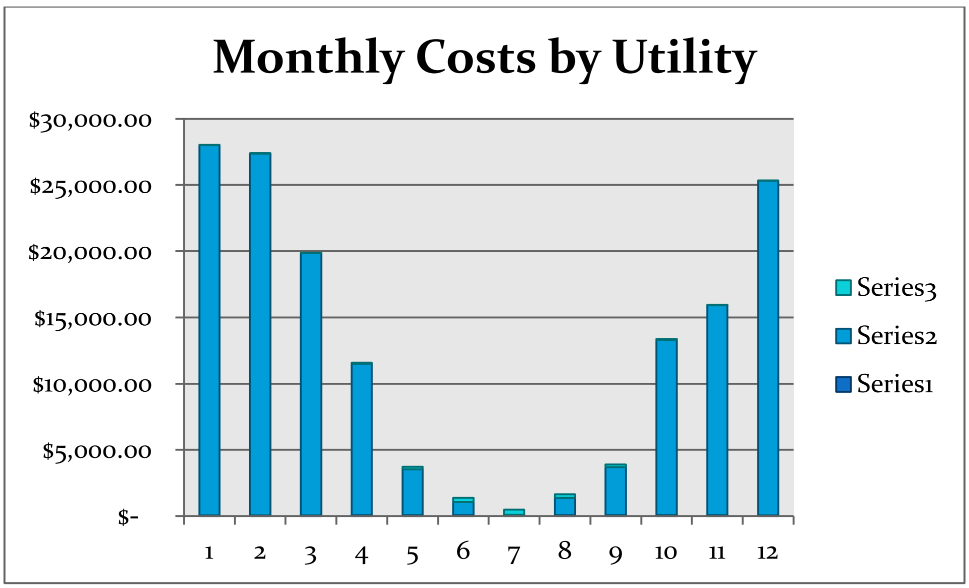


Figure 10: Monthly Costs

Annual Emissions Footprint

Emissions from River Vue Apartments were calculated with the Trane TRACE energy model as follows:

Environmental Impact Analysis		
CO2	18,167,650	lbm/yr
SO2	140,461	gm/yr
NOX	28,223	gm/yr

Table 8: Emissions

It is important to consider emissions today with concerns about the longevity and effectiveness of the Earth's ozone. The two boilers in River Vue Apartments burn natural gas and, when combined with the other mechanical equipment throughout the building, produce over 18 million pounds of carbon dioxide annually as seen in Table 8. From the energy model it is known that this equipment burns nearly 400,000 cubic feet of natural gas each year.

This data seems high compared to a typical commercial boiler, which produces around 1.23 million pounds of carbon dioxide for every 1000 cubic feet of natural gas used annually, according to emissions data from the National Renewable Energy Laboratory's 2007 report on energy and emissions.

Summary of Analyses

Energy and Cost Analysis

The energy model created with Trane TRACE 700 used assumptions and simplifications in order to make the process run quickly, however, the data received from the model is within reason for a high-rise residential apartment building like River Vue Apartments. As expected, most of the load comes from heating and cooling the apartment units as well as supplying power for lighting. Occupants can expect to see high electric and natural gas bills during winter months since peak heating load occurs then. If time allowed, ASHRAE design standards for a high rise apartment building could have been implemented in the Trane TRACE model to create more accurate load calculations.

Suggested Areas for Improvement

After reviewing the model's estimations for annual energy usage and operational costs, several ideas for improvement were generated:

1. Change schedules for lighting and mechanical system operation to operate off peak times by potentially using thermal storage or thermal mass
2. Design air handling unit to operate at peak efficiency more often so that it consumes less energy
3. Implement higher efficiency lighting fixtures to reduce lighting load

Further consideration for improvements will be considered in the development of a redesign proposal as well as breadth studies.

Appendix A –ASHRAE Data

2005 ASHRAE Handbook - Fundamentals (IP)

Design conditions for PHILADELPHIA NE PHILADELP, PA, USA

Station Information

Station name	WMO#	Lat	Long	Elev	StdP	Hours +/- UTC	Time zone code	Period
1a	1b	1c	1d	1e	1f	1g	1h	1i
PHILADELPHIA NE PHILADELP	724085	40.08N	75.02W	98	14.644	-5.00	NAE	8201

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
2	3a	3b	4a	4b	4c	4d	4e	4f	5a	5b	5c	5d	6a	6b
1	11.3	15.7	-3.0	4.7	13.6	1.2	5.9	18.0	24.8	33.1	23.1	31.5	10.1	300

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	8	9a	9b	9c	9d	9e	9f	10a	10b	10c	10d	10e	10f	11a	11b
7	19.0	93.2	75.8	90.4	74.6	88.0	73.5	79.0	88.7	77.1	87.0	75.6	84.4	9.8	300

Dehumidification DP/MCDB and HR									Enthalpy/MCDB					
0.4%			1%			2%			0.4%		1%		2%	
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB
12a	12b	12c	12d	12e	12f	12g	12h	12i	13a	13b	13c	13d	13e	13f
76.1	136.8	83.5	74.2	128.3	81.6	72.8	122.1	80.3	34.6	88.5	32.7	87.1	31.3	84.5

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%		Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
14a	14b	14c	15	16a	16b	16c	16d	17a	17b	17c	17d	17e	17f	17g	17h
21.0	18.7	17.3	88.7	97.7	4.7	2.7	6.5	99.6	0.0	101.2	-3.8	102.7	-7.4	104.7	-12.1

Monthly Design Dry Bulb and Mean Coincident Wet Bulb Temperatures

%	Jan		Feb		Mar		Apr		May		Jun	
	DB	MCWB	DB	MCWB	DB	MCWB	DB	MCWB	DB	MCWB	DB	MCWB
	18a	18b	18c	18d	18e	18f	18g	18h	18i	18j	18k	18l
0.4%	63.8	59.3	66.1	56.2	78.8	64.4	85.5	66.0	90.6	71.6	94.4	74.8
1%	61.2	57.8	62.8	54.5	74.2	61.5	80.7	64.6	88.4	70.9	92.7	74.4
2%	57.6	54.0	59.2	52.5	69.8	58.4	76.4	62.0	86.2	69.9	90.7	74.0

%	Jul		Aug		Sep		Oct		Nov		Dec	
	DB	MCWB	DB	MCWB	DB	MCWB	DB	MCWB	DB	MCWB	DB	MCWB
	18m	18n	18o	18p	18q	18r	18s	18t	18u	18v	18w	18x
0.4%	97.8	78.4	95.3	76.8	91.1	74.8	82.0	68.3	73.7	62.5	66.3	59.8
1%	96.3	77.7	92.9	76.5	88.4	73.2	80.2	67.8	70.9	62.3	63.7	57.6
2%	94.3	76.8	90.9	75.5	85.9	71.8	77.4	66.8	68.3	60.8	61.2	55.5

Monthly Design Wet Bulb and Mean Coincident Dry Bulb Temperatures

%	Jan		Feb		Mar		Apr		May		Jun	
	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB
	19a	19b	19c	19d	19e	19f	19g	19h	19i	19j	19k	19l
0.4%	61.3	63.2	59.3	62.6	65.8	76.7	68.5	80.6	75.7	86.3	79.8	86.7
1%	58.2	60.5	57.1	61.1	63.2	72.2	66.6	77.2	73.9	84.3	77.8	88.4
2%	54.8	57.4	54.0	57.1	60.5	66.9	64.6	74.1	72.1	82.6	76.4	87.1

%	Jul		Aug		Sep		Oct		Nov		Dec	
	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB
	19m	19n	19o	19p	19q	19r	19s	19t	19u	19v	19w	19x
0.4%	82.9	90.3	81.5	89.0	77.6	85.3	72.0	77.5	66.5	70.6	61.8	65.1
1%	80.9	90.7	79.7	88.3	76.3	83.9	70.5	75.9	64.8	68.2	59.4	62.3
2%	79.5	90.3	78.1	87.4	75.2	82.4	69.2	74.5	63.2	66.1	57.2	60.1

Monthly Mean Daily Temperature Range

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
20a	20b	20c	20d	20e	20f	20g	20h	20i	20j	20k	20l
15.0	16.2	18.2	20.0	20.4	20.2	19.0	18.4	18.9	20.0	17.9	15.2

WMO#	World Meteorological Organization number	Lat	Latitude, °	Long	Longitude, °
Elev	Elevation, ft	StdP	Standard pressure at station elevation, psi		
DB	Dry bulb temperature, °F	DP	Dew point temperature, °F	WB	Wet bulb temperature, °F
WS	Wind speed, mph	Enth	Enthalpy, Btu/lb	HR	Humidity ratio, grains of moisture per lb of dry air
MCDB	Mean coincident dry bulb temperature, °F	MCDP	Mean coincident dew point temperature, °F	MCWB	Mean coincident wet bulb temperature, °F
MCWS	Mean coincident wind speed, mph	PCWD	Prevailing coincident wind direction, °, 0 = North, 90 = East		

Appendix B – Schedules

Lighting:

Start Time	End Time	Percentage
Midnight	6 am	5
6 am	7 am	50
7 am	9 am	100
9 am	5 pm	50
5 pm	11 pm	80
11 pm	Midnight	50

Base Utilities:

Start Time	End Time	Percentage
Midnight	9 am	70
9 am	10 am	50
10 am	4 pm	30
4 pm	5 pm	50
5 pm	Midnight	70

Infiltration:

Start Time	End Time	Percentage
Midnight	10 am	100
10 am	6 pm	50
6 pm	Midnight	100

Occupancy:

Start Time	End Time	Percentage
Midnight	7 am	90

7 am	9 am	50
9 am	5 pm	30
5 pm	6 pm	50
6 pm	Midnight	90

Ventilation:

Start Time	End Time	Percentage
Midnight	Midnight	100

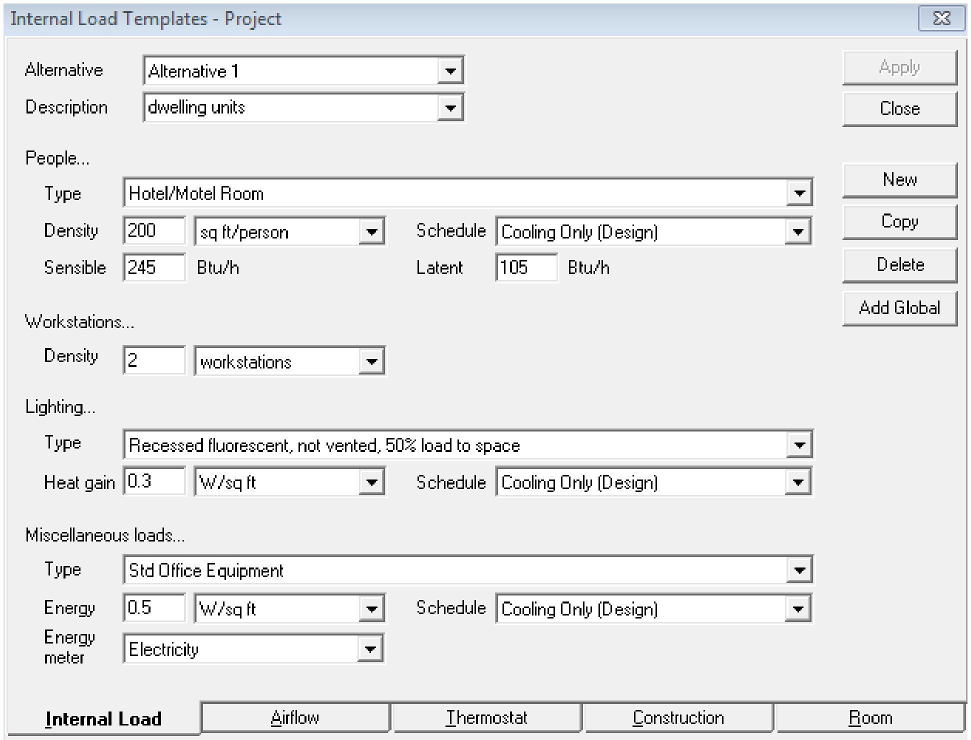
Mechanical Equipment Schedule

Mark	Equipment	BTU/hr	CFM	RPM	GPM
ERU-1	Make Up Air Handling Unit	864,000	26,300		
A/C-100	Heat Pump	73,000			
A/C-103	Heat Pump	5,000			
A/C-223	Heat Pump	12,900			
A/C-227	Heat Pump	11,600			
A/C-1	Heat Pump	8,800			
A/C-2	Heat Pump	1,900			
A/C-3	Heat Pump	18,100			
A/C-4	Heat Pump	23,600			
A/C-5	Heat Pump	34,700			
HE-1	Heat Exchanger				1024
BOILER-1	Boiler			1750	
BOILER-2	Boiler			1750	
CT	Axial Propeller Cooling Tower				
SF-A	Supply Fan		13800	832	
SF-B	Supply Fan		11,000	776	
EF-B19-A	Exhaust Fan		15000	481	
EF-B19-B	Exhaust Fan		15000	481	
EF-114-A	Exhaust Fan		15000	481	
EF-114-B	Exhaust Fan		15000	481	
EF-1700-A	Exhaust Fan		4600	887	
EF-1700-B	Exhaust Fan		3000	1150	

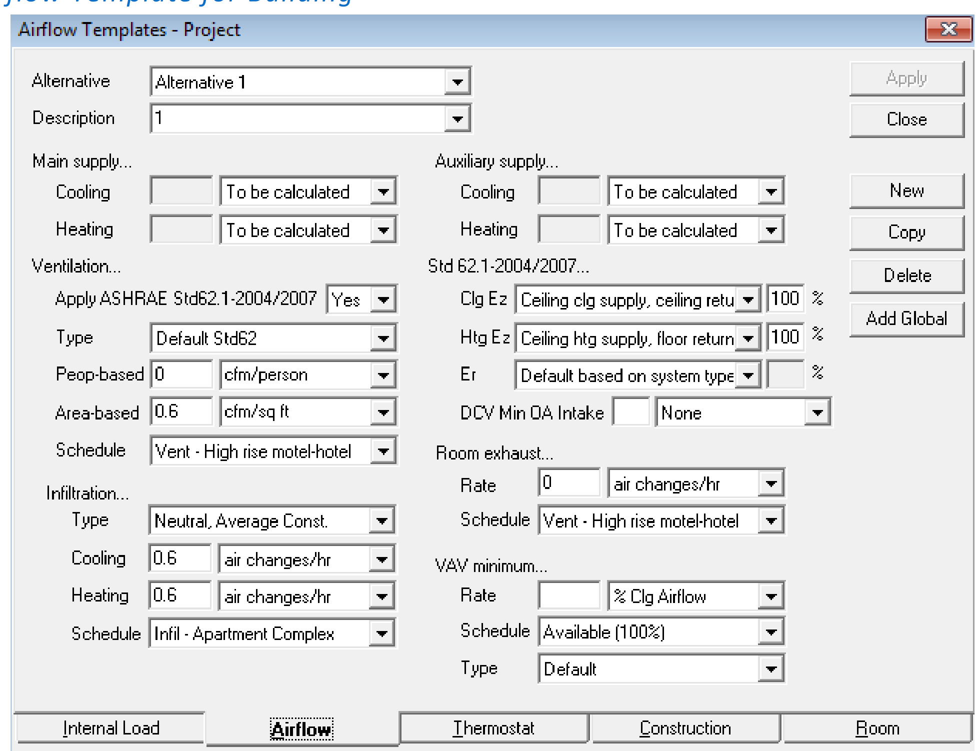
EF-B20	Exhaust Fan		10000	792	
EF-B21	Exhaust Fan		30000	713	
EF-1600-A	Exhaust Fan		150	1300	
EF-1600-B	Exhaust Fan		200	1400	
SF-1600-A	Supply Fan		16000	1160	
SF-1600-B	Supply Fan		31000	1170	
A	Electric Heater				
B	Electric Heater				
C	Electric Heater				
D	Electric Heater				
E	Electric Heater				
F	Electric Heater				
G	Electric Heater				
H	Electric Heater				
CWP-1	Condensing Water Pump			1750	1024
CWP-2	Condensing Water Pump			1750	1024
LWP-1	Loop Water Pump			1750	1030
LWP-2	Loop Water Pump			1750	1030
AS-1	Air Separator				1030
	TOTAL	1,053,600	179750	22604	6162

Appendix C - Trane TRACE Templates

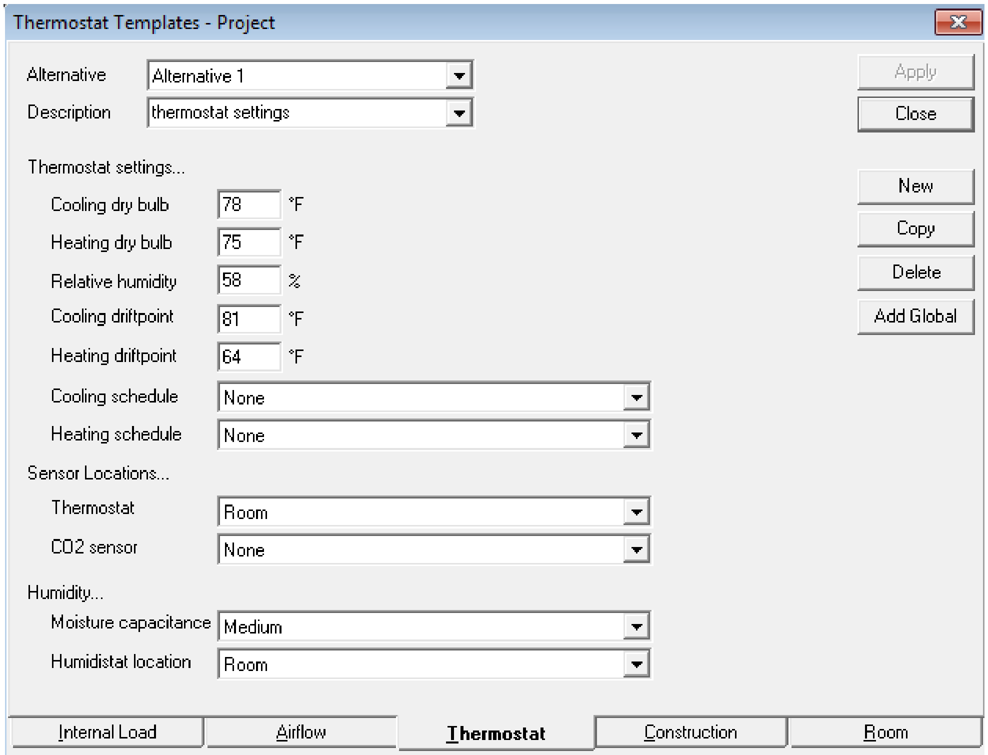
Typical Internal Load Template for Apartment Units



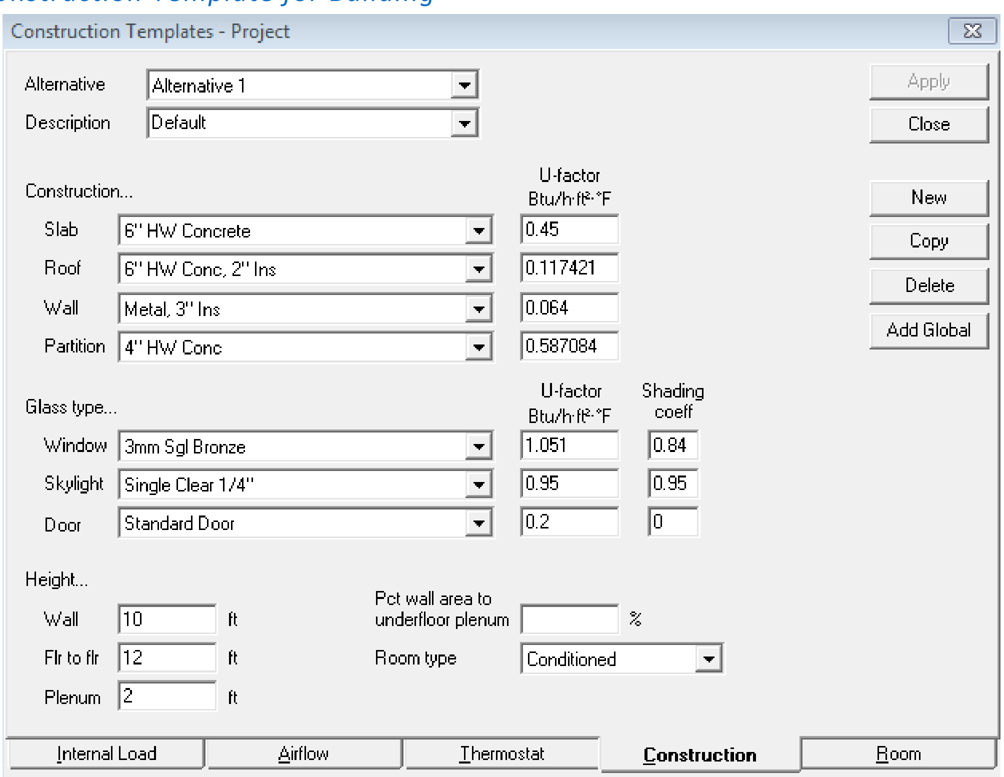
Typical Airflow Template for Building



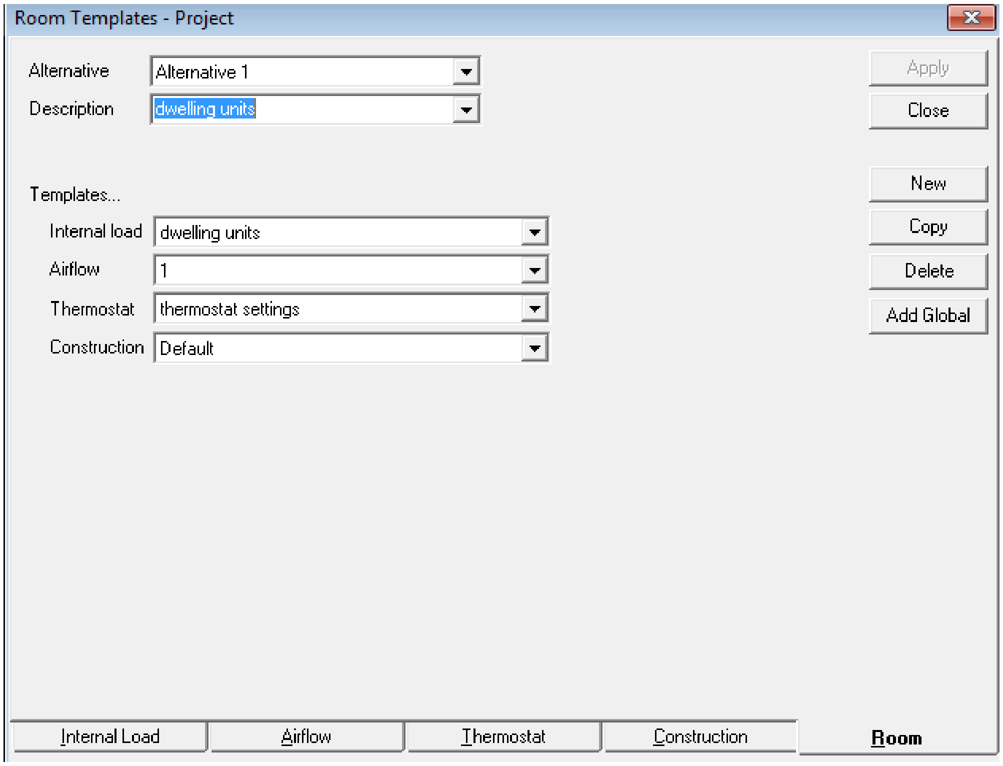
Typical Thermostat Settings for Building



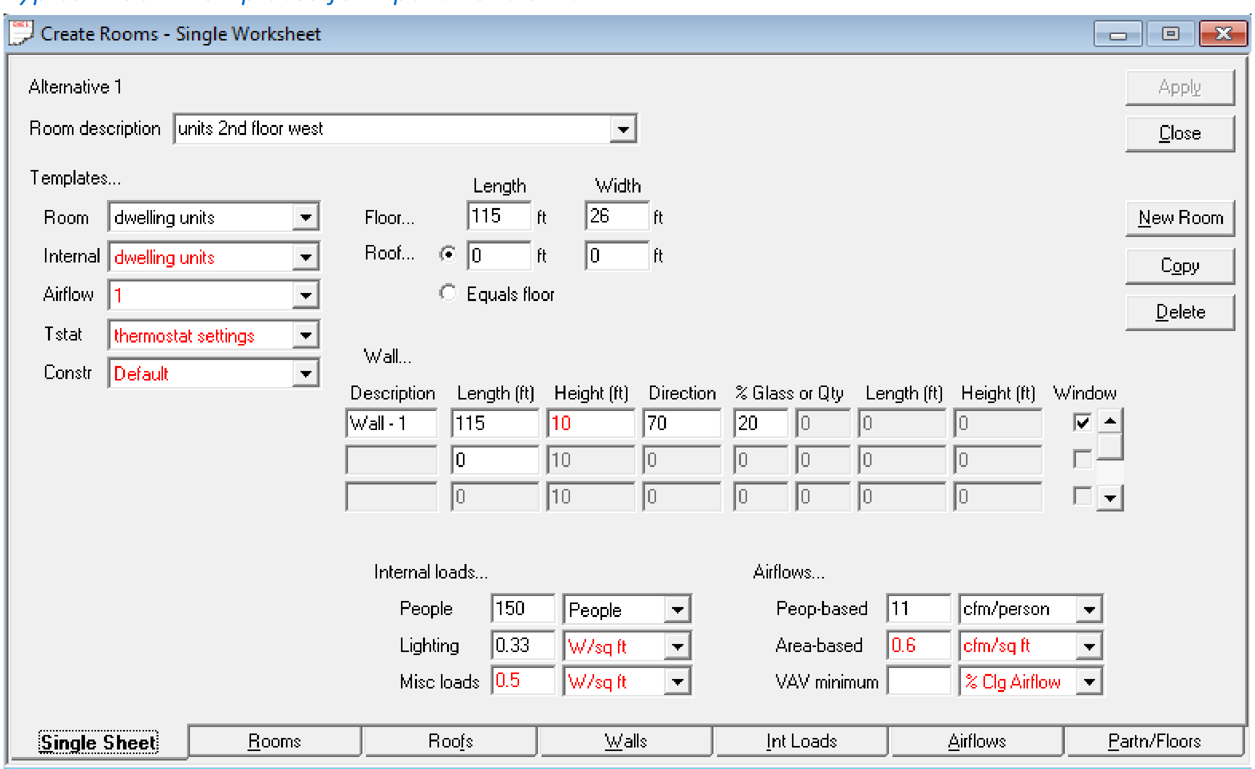
Typical Construction Template for Building

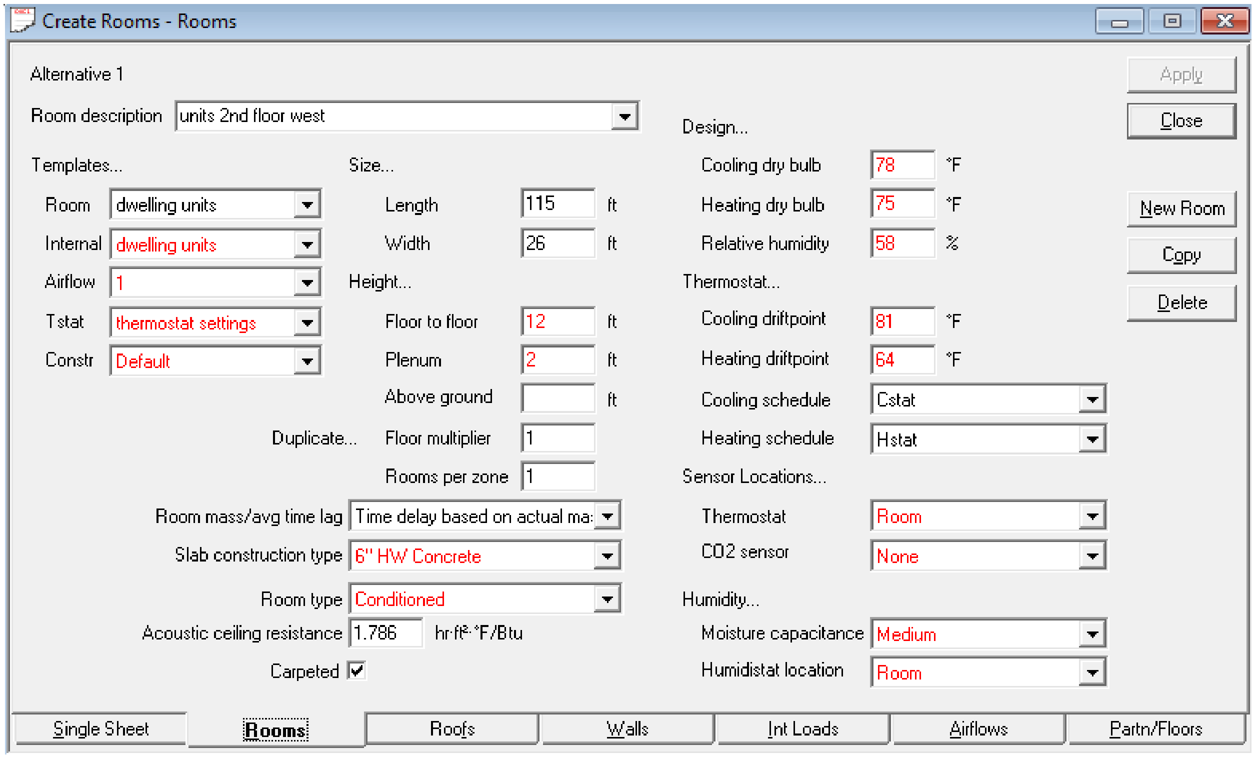


Typical Room Template for Apartment Unit

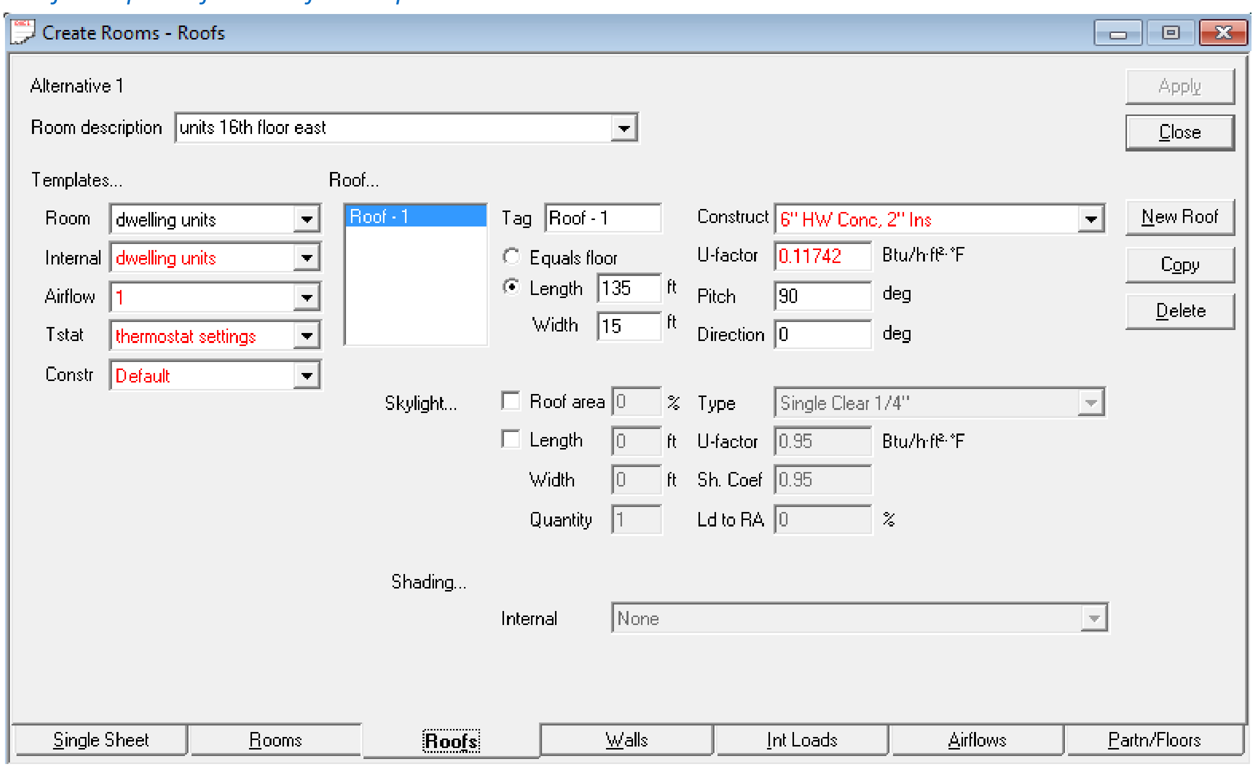


Typical Room Templates for Apartment Unit

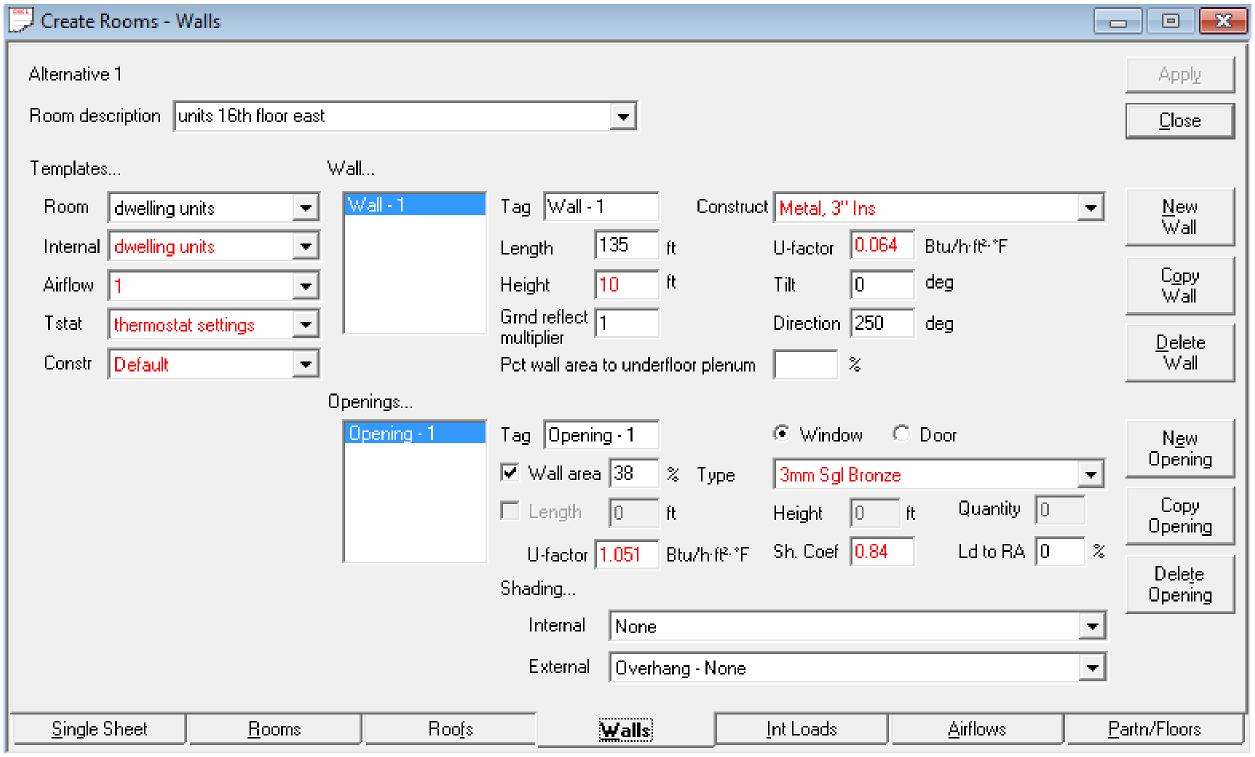




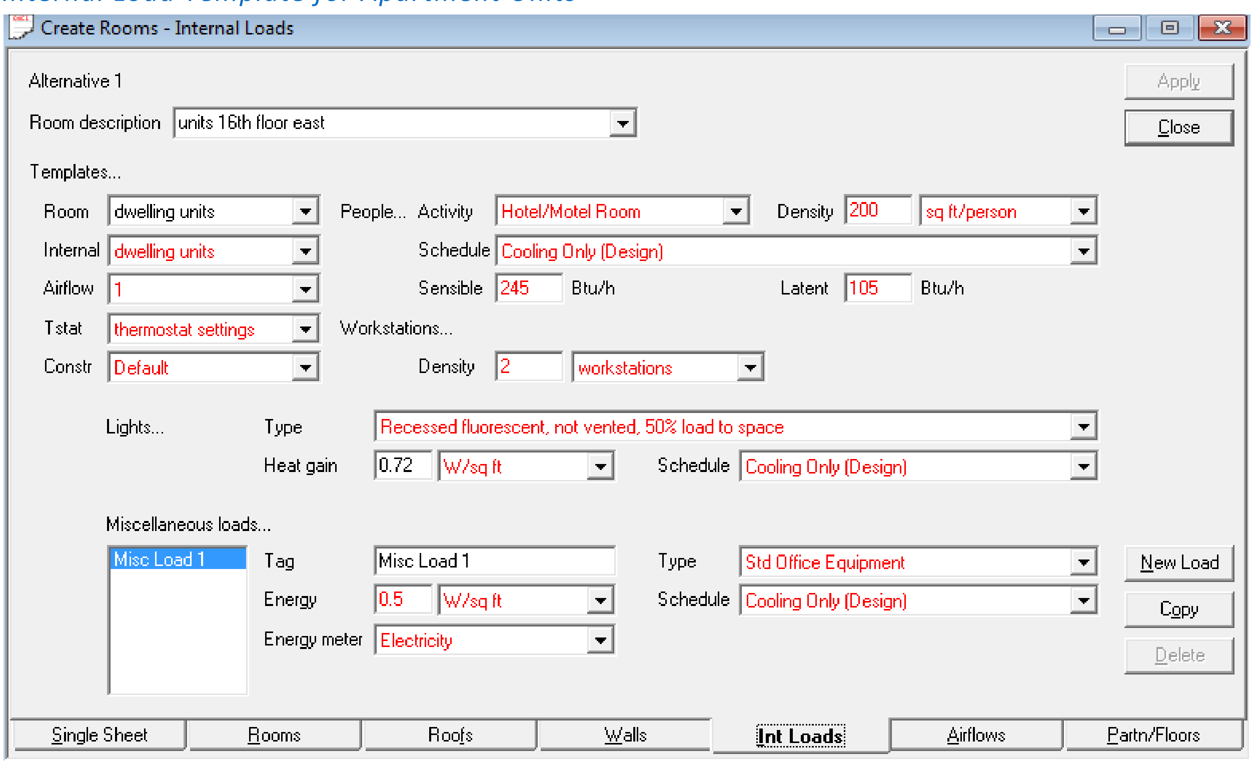
Roof Template for 16th floor Apartment Units



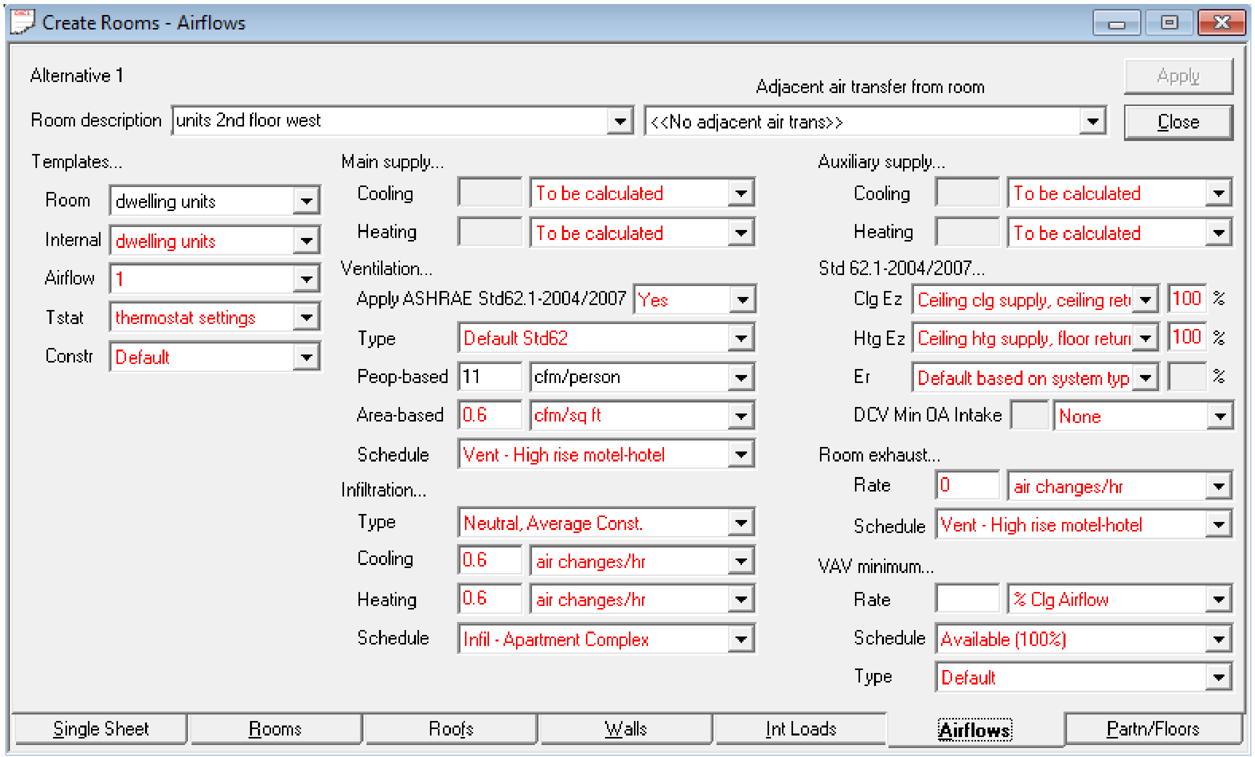
Typical Wall Construction Template



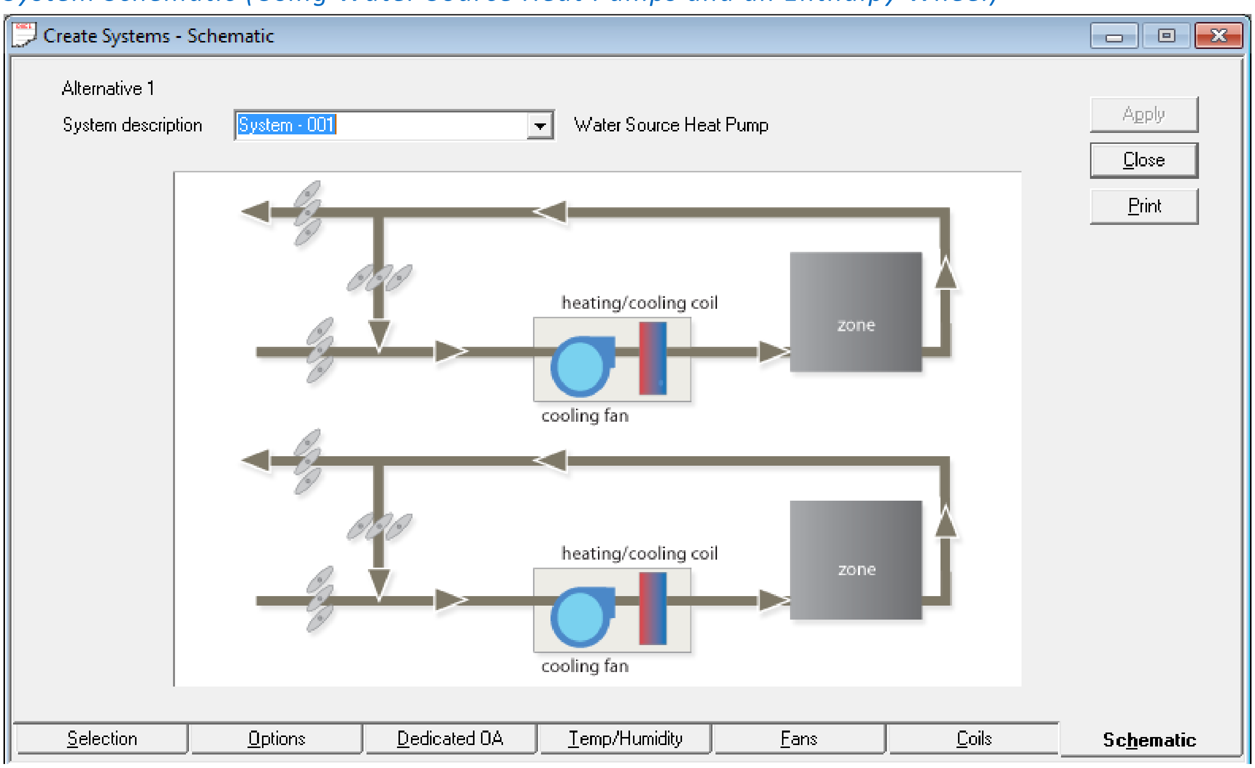
Internal Load Template for Apartment Units



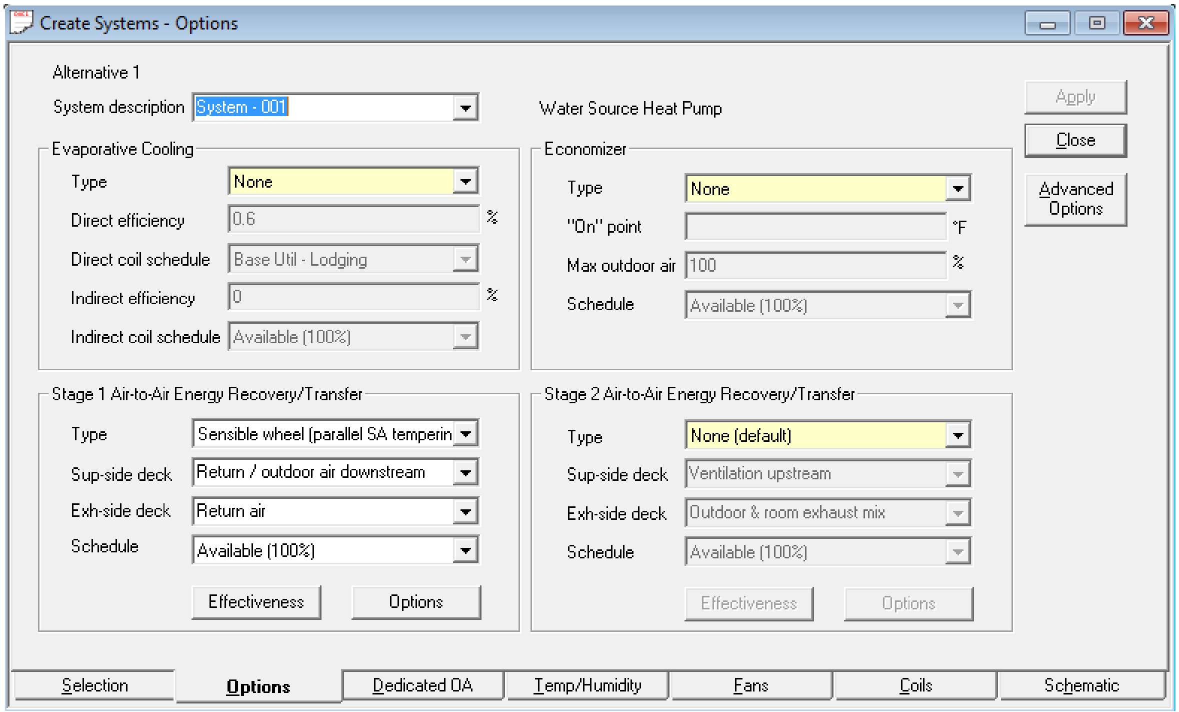
Airflow Template for Apartment Units



System Schematic (Using Water Source Heat Pumps and an Enthalpy Wheel)



System Options Template



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