Building and Plant Energy Analysis

Technical Report Two

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October 13, 2015
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Contents

Executive Summary:

The purpose of this technical assignment is to analyze the Early Learning Center's design loads, annual energy consumption and operating costs.

The basis of this design was centered on the Trane Trace 700 model. One needed to develop skills to understand how the Trace 700 model cohesively performs its calculations and why it returns the results it does.

Data was inputted into the model, as windows, walls and floor areas started to build the foundation for an accurate test. The location was decided as Harrisburg, because according to ASHRAE Standard 90.1 – 2013 in Figure B1-1, the Phoenixville School District is located within zone 5A, where Harrisburg resides, whereas Philadelphia is located in zone 4A. Construction materials were then entered after consulting with Barton Associate's mechanical engineer to verify the U-Values of the wall, slab, windows, and partitions.

Occupancy and ventilation recommendations from ASHRAE Standard 90.1 were enforced in the design and implemented as the minimum. Throughout the classrooms and other rooms, there was equipment, such as projectors or computers, factored into the building load for the room. It was also assumed to have a 1 W/SQFT lighting power density. Power density was based on ASHRAE Standard 92.1 – 2013 Table 9.5.1 Lighting Power Densities Using the Building Area Method, and then decided to raise the level to 1 to stay consistent with Barton Associates' model. Schedules associated with the school primarily run from 8-5pm with after school activities.

When all the rooms were in the building, Energy Recovery Ventilator (ERV) systems were added and rooms were paired up with their proper unit. The cooling tower and boilers were then added to the model as the overall primary heating and cooling systems to serve the ERV units.

After running the results, the model was relatively close to the design loads. The exhaust, total heating and cooling, came out to be very similar in numbers. The one skewed result was the return airflow which was 30,000 CFM under the projected design load.

Energy was then examined in the building looking at what systems use the most energy, how prevalent electricity vs natural gas is, emissions from the building, and annual yearly cost. These values helped provide insight to how the owner will be spending their money in the future and provide a baseline for future modifications.

It was determined the cooling tower used the largest amount of energy. The HVAC system accounted for 70% of the entire energy load, lighting was the other 30%. It was determined the boilers used the natural gas, creating the highest load in the winter for heating. The electricity and water usage rates went up in the summer months to keep the building cool. Overall annual cost for utilities amounted to $81,790.51. Continuing, CO_2 emissions are very high at 1113250 lbm per year. SO_2 and NOX emissions are low compared to CO_2 at 8661 and 1665 gm/ year respectively.

Building Overview:

The Phoenixville Early Learning Center and Elementary school is being built for a progressive school district who is looking to expand and address their growing student population.

Phoenixville Early Learning Center is a 152,000 square foot educational building designed to hold 1,526 occupants.

The building is comprised of two stories above grade and will accommodate grades K-5. There are three wings to the building as well as one large common area and an outdoor

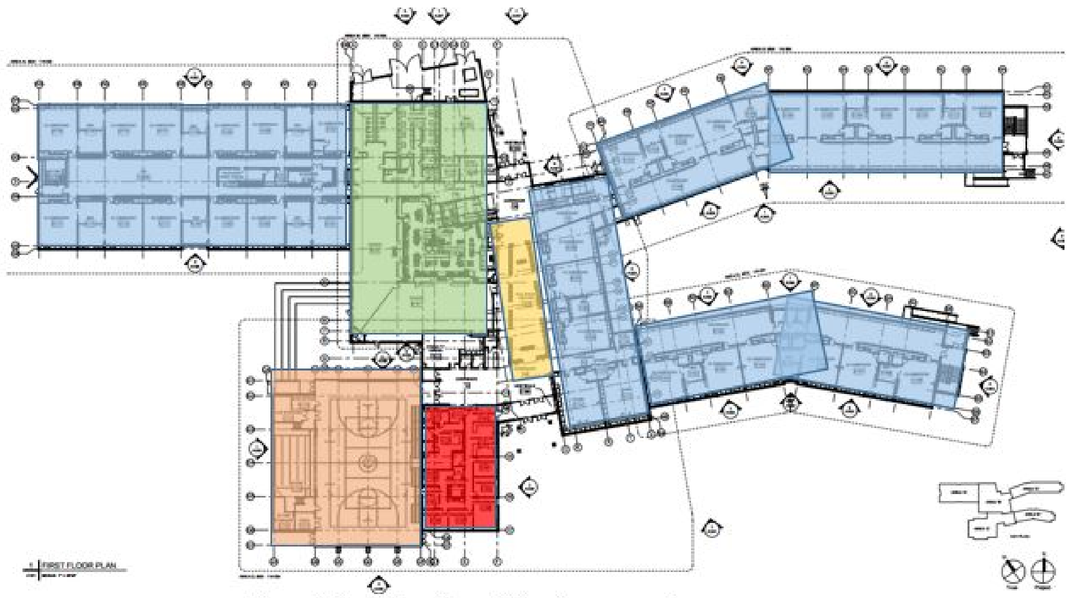

Figure 1: First Floor Plan with basic programming.

Legend:

- Learning Spaces –
- Gymnasium –
- Administrative –
- Kitchen and Dining -
- Media Center –

learning amphitheater. Wings of the building, as shown in figure 1 below, are filled with learning spaces comprised of group learning areas as well as learning studios. Within the large common area there are administration spaces, the learning resource center, support spaces, a media center as well as a full size gymnasium as displayed in figure 1 above.

Mechanical Systems Overview:

To provide an energy efficient and comfortable design the engineers decided to install water source heat pumps, energy recovery capability, condenser water pumps, a cooling tower and a high efficiency boiler plant. Heat pumps are located within small closet areas within close proximity to the space they are serving. Most of the large assembly spaces utilize equipment on the roof or in mechanical rooms. Ventilation is provided by energy recovery ventilator units (ERV) fitted with enthalpy heat wheels which are on the roof and ducted to water source heat pumps. Fans on the rooftop draw air out of the building and exhaust areas such as toilet rooms and locker rooms.

Hot water in the building is distributed via a central hot water plant within the mechanical room. Cold water originates from the roof and is run thru the cooling tower which extracts heat from the condenser loop. Electric trace heating cable is used throughout the building, to prevent piping from freezing in winter months.

Electric unit heaters will also be used in places without ceilings. These spaces using electric unit heaters are “back of house” spaces.

Building Load Estimation

In starting the estimation of load conditions for the Early Learning Center, I resolved to model the building in Trane Trace 700. The mechanical firm on the project, Barton Associates Inc, also used Trace 700 for the basis of calculation for their design loads. Trace 700 has shown to provide a good basis for results when the software is properly used and information is correct. In the next section the methodologies and procedures used for calculating the building loads with trace 700 will be outlined. Design assumptions associated with the model will also be given such as, weather, occupancies, ventilation rates, wall constructions, and lighting and electrical equipment rates. Tasks and assumptions used to create the model will then be compared with Barton Associates’ model to check for repeatability of results.

Model Design Approach

In creation of the Trace 700 model there are steps that can be used to make the model more consistent across the whole building. One of these steps is to use templates for the rooms and specifically detail the airflow, rooms, walls, fenestrations, internal loads, and floor partitions.

Templates were specifically created for classrooms, dining areas, office spaces, the gymnasium, and corridors. When the templates were finished, data for room area, exterior wall length, and fenestrations were inputted into the model. Zones were created in an effort to simplify the model, however, effort was taken to ensure the zones were consistent with the mechanical equipment in the building. Overall, there were 151 zones created that closely followed the rooms of the building. Systems for the building were then chosen based off of the drawings and schedules. Ten Energy Recovery Ventilators (ERV) Units were inputted into the model with enthalpy wheels. As a subzone of the systems, Rooftop Water Source Heat Pumps (RTWSHP) and Water Source Heat Pumps (WSHP) were distributed according to their appropriated ERV units. Then, the rooms were assigned to their system based on which ERV unit serves the area. After all of the rooms were assigned the model was calculated and checked for validity looking at the total number of people, heating and cooling loads as well as airflow. It was determined that the created model resembled the model Barton Associates calculated except for some variances in loads, people, and airflow, but was mostly accurate.

Design Assumptions

Location:

The location for Phoenixville, Pennsylvania where the building is located is in the middle of Harrisburg and Philadelphia. I chose to use Harrisburg because Phoenixville more closely relates to Harrisburg in terms of weather patterns and geography. Furthermore, when referring to Figure B1-1 from ASHRAE Standard 90.1 – 2013, the Phoenixville School District is located within zone 5A, whereas Philadelphia is located in zone 4A. Below is a table showing the heating and cooling try bulb temperatures as well the cooling wet bulb that was used as the basis of design.

Weather Inputs		
Heating (°F)	Cooling (°F)	
DB	DB	MCWB
11	91	74

Table 1: Heating and Cooling Inputs for the Trace Model

Building Construction:

Construction materials were inputted based on the drawings. U-Values for the exterior walls and windows were included in the Trace 700 model. The building is mainly made from a cement wall assembly with double clear 1/4" windows. Note: U-Values were changed after the first report after consulting with the project engineers. The following is a table of U-Values used in the Trace 700 model.

Building Construction			
Type	Description	U-Value (BTU/h*ft^2*°F)	Shading Coefficient
Slab	4" LW Concrete	0.212615	-
Roof	4" LW Concrete, 3" Ins	0.0681057	-
Wall	Frame Wall, 2" Ins	0.111709	-
Partition	0.75" Gyp Frame	0.37955	-
Window	Double Clear 1/4"	0.5	0.4

Table 2: Building Construction U- Values

Load Assumptions

Occupancy and Ventilation Assumptions:

To have accurate results the ASHRAE recommendations for occupancy were used. Looking at ASHRAE recommendations is also how Barton Associates Inc projected the occupancy for the spaces. Therefore, in both models the occupancy values are relatively the same per thousand square feet. The same table referencing the occupancy assumptions was used for ventilation assumptions. ASHRAE Table 6.2.2.1 Minimum Ventilation Rates in

Breathing Zone, from ASHRAE 62.1 – 2013 recommends certain airflow requirements for cfm per person. These values were also used by Barton Associates Inc in their model. Therefore, the created model is designed referencing this ASHRAE table to achieve proper ventilation in the spaces. Proper ventilation is important because it helps your health, influences your mood and your productivity.

Lighting and Equipment Assumptions:

During the lighting input, I consulted ASHRAE Standard 90.1 – 2013 Table 9.5.1 Lighting Power Densities Using the Building Area Method. When analyzing this table the school building should be at a power density of 0.87 W/SF. After comparing with the Barton Associates Inc Trace 700 model it was realized they had used 1 W/SF for their whole building. In turn, 1 W/SF was used for the whole building to be able to compare models more effectively. Upon further investigation 1 W/SF was used to provide a general basis of design and accounted for a safety factor. The equipment to be used within the spaces was determined based on the space. If the room is designated as a classroom the classroom miscellaneous load of .22 W/SF was added into the calculation to account for computers or projectors. Office spaces were assumed to have one main equipment load being the computer. It is important to note, kitchen equipment was not considered in the basis of design because the kitchen equipment uses a separate heating and ventilation system compared to the rest of the building.

Schedules

Schools operate on a regimented schedule of classes and after school activities. The building will be fully occupied from 7:30 until 3:30 every single day excluding the summer months depending on the clients' intended use with the building. However, there are also after-school activities which could last until about 5pm. Therefore, the plan schedule chosen reflects the general 8-5 daily schedule. On the weekends, it is expected there will not be large loads within the building.

System Equipment:

Design Heating and Cooling Loads

After completing the Trace 700 model results could be achieved to examine the model for accuracy and calculated design loads. The results from the model can be compared to the model Barton Associates Inc created. Based upon similar design assumptions they should be relatively similar. The main difference between the models was the creation and arranging of zones. In the model for the report 151 zones were created, whereas, 246 zones for the Barton Associates Inc model. Therefore, the zones created in the model may not exactly represent the Barton Associates Inc model. The table below represents the system design loads for the created model for the Early Learning Center.

Model System Design Loads						
			Airflow (CFM)		Total Capacity (MBh)	
		Sq Ft	Return	Exhaust	Heating	Cooling
ERV -1	NA	27605	16244	10258	418	533
ERV -2	NA	19080	15363	7553	388	508
ERV -3	NA	12808	11944	6196	286	427
ERV -4	NA	23263	10511	7060	252	365
ERV -5	NA	8940	11975	8314	234	525
ERV -6	NA	10980	8100	2351	218	272
ERV -7	NA	6255	3343	0	22	88
ERV -8	NA	6600	3703	90	57	101
ERV -9	NA	9870	4519	84	57	156
ERV -10	NA	24415	14058	6748	273	479
Sum=		149816	99760	48654	2205	3454

Table 3: System Design Loads for Model

The results for the model are within the range of acceptable values. Without a basis for comparison, the model seems reasonable for a building of roughly 150,000 square feet. The table below shows a side by side comparison of the design values labeled as “BA” in white and the model values labeled ”NA” in grey. When looking at this comparison note, ERV – 8 in the design model was not used for an unknown reason, however, was used in the model. Also, looking at square footage for the design and the model is intriguing. The created model is close to the actual square footage of 152,000 square feet, compared to the design model which is about 8000 square feet short. However, despite these differences, the total heating and cooling capacities are relatively similar. The exhaust airflow is also relatively close to the design values. Return airflow is 32,000 CFM under what the design value is, and after some investigation can be attributed to omitting clerestory windows. Since the windows could not be modeled as they would perform, it was determined they should be omitted because they would skew the model. Furthermore, the areas are different for the ERV units because as stated before the zones were arranged differently in the model to provide a simpler layout. Designed zones were adjusted to create an easier model and limit the number of zones to enter into the stadium.

(Table on next page)

Combined Model and Design Results						
			Airflow (CFM)		Total Capacity (MBh)	
		Sq Ft	Return	Exhaust	Heating	Cooling
ERV -1	NA	27605	16244	10258	418	533
	BA	22505	28074	9360	619.2	803.6
ERV -2	NA	19080	15363	7553	388	508
	BA	17142	19056	6434	411	558
ERV -3	NA	12808	11944	6196	286	427
	BA	16286	12803	5987	284	387
ERV -4	NA	23263	10511	7060	252	365
	BA	16251	15294	5985	328	481
ERV -5	NA	8940	11975	8314	234	525
	BA	5308	9394	3775	214	303
ERV -6	NA	10980	8100	2351	218	272
	BA	9303	12458	4813	317	456
ERV -7	NA	6255	3343	0	22	88
	BA	3391	2474	400	47	66
ERV -8	NA	6600	3703	90	57	101
	BA	/	/	/	/	/
ERV -9	NA	9870	4519	84	57	156
	BA	4659	4063	540	70	115
ERV -10	NA	24415	14058	6748	273	479
	BA	26635	22534	6947	404	669
Heating Only	BA	9153	610	610	61	0
Stair WSHP	BA	768	2773	25	45	75
WSHP - 20	BA	2618	1991	0	0	49
WSHP - 89	BA	806	599	48	16	15
Totals	NA	149816	99760	48654	2205	3454
	BA	134825	132123	44924	2816	3977

Table 4: Comparison of Model and Design Loads

Comparison of Results: Calculated Loads versus Design Loads

After analyzing the Phoenixville Early Learning Center and Elementary School using Trane Trace 700 there are points of similarity as well as disparity with the design model and the built model. Error in the built model could be from generalizing parts of the building instead of grouping rooms together to form larger zones. Another possible source would be to add more systems within the model. Barton Associates Inc, included two extra WSHP's and radiant heating that was not analyzed within the built model for ease of design. Expertise was most likely also used in the sizing and final design of the equipment, explaining why most values were under the design values.

Annual Energy Consumption

Fuel Consumption

The figure below shows the Percentage of Total Building Energy usage within the Elementary Learning Center. As on can interpret, the largest consumer of electric within the building is the mechanical system. The cooling tower is the highest contributor to the electricity usage with ERV units being the least. Overall fuel consumption peaks in the summer, because it takes a large amount of energy to cool the building. During the winter, fuel consumption is very high because of the cold temperatures, but electric rates are still high because they need to pump the water through the building.

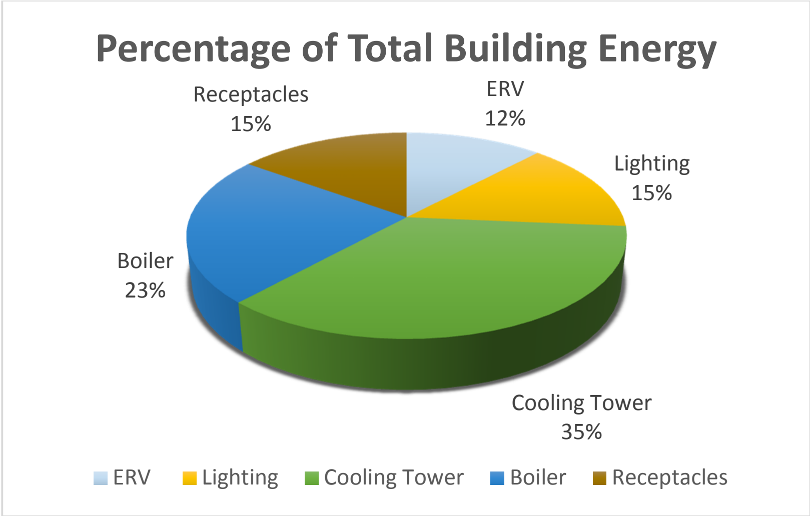

Figure 2: Percentage of Total Building Energy

The fuel consumed was mostly electrical demand with the exception of the heating system. The boiler also requires natural gas in addition to electricity, operating at a rate of about 906,358 kBtu per year. Most of the year the building is in cooling mode because with the occupants the building becomes warm and needs to be cooled down as shown in Figure 3 below.

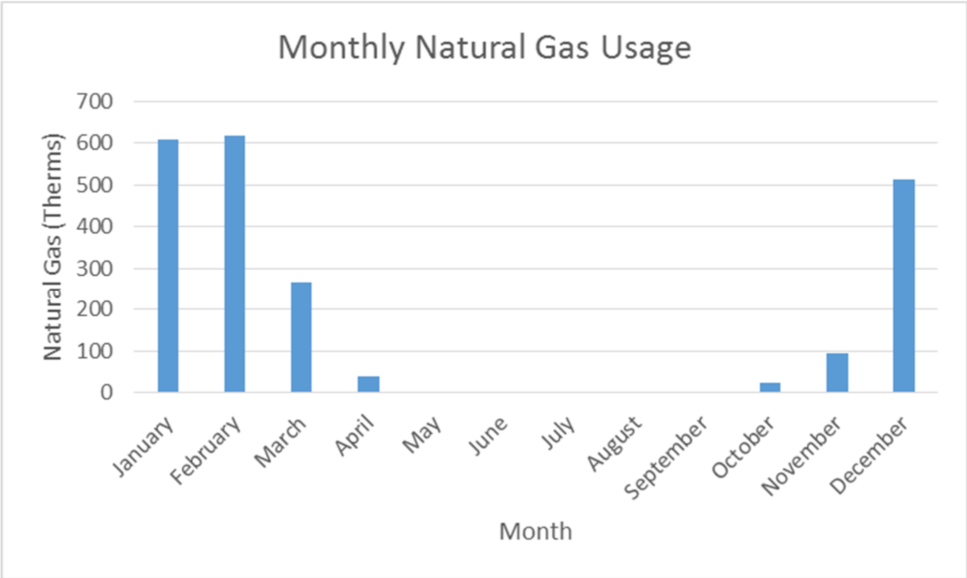

Figure 3: Monthly Natural Gas Usage

Water Consumption

The water consumption is directly related to the electric usage. This is because the electric is needed to pump the water through to all of the WSHP's. The usage is also significantly higher in the summer because of the high temperatures. The water is circulated to the WSHP's to cool the building down. In the table below the monthly water usage is graphed to show when water is in demand.

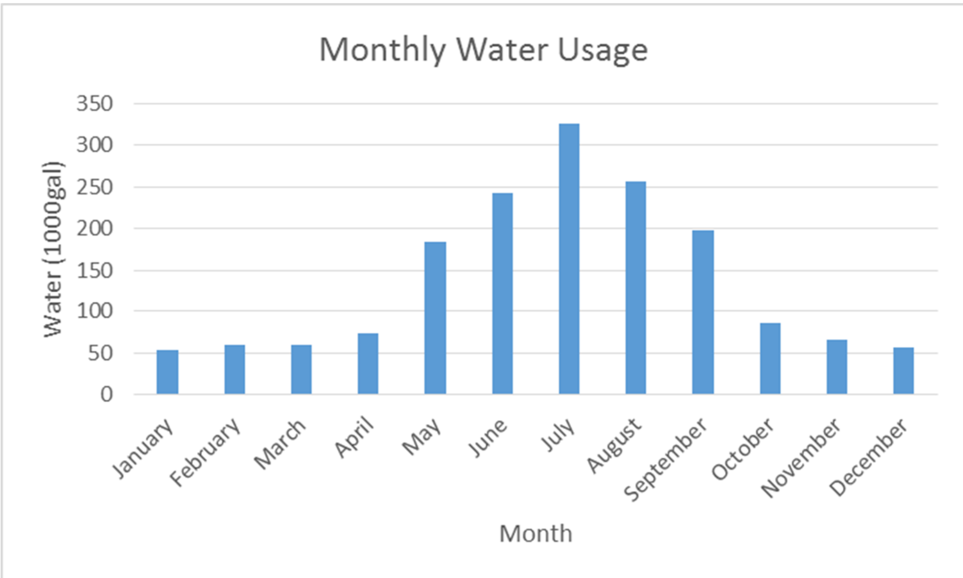

Figure 4: Monthly Water Usage

Energy Rates

Energy rates in the figure below were taken from assumptions and conversations with the mechanical designer. Since the building is not yet built there are no actual rates to reference. The energy rates provided however, are very similar to the current rates at the other elementary schools owned by the Phoenixville Area School District.

Energy Rates		
Source	Rate	Units
Natural Gas	$8.90	/MMBTU
Electric	$0.08	/KWh
Water	$5	/1000 gal

Table 5: Energy Rates assumed for Project.

Annual Operating Cost

After the energy rates were applied to the Trace 700 model, some calculations were performed and solved for the Annual Energy Cost Comparison. When running the energy model in this building, the final cost per year was analyzed at $81,790.51 which with 1500 students equals roughly each family who has a child at the school an extra $55, or $4.58 per day. This seems like a very small amount of yearly cost associated with the annual fuel and electric cost. However, without a benchmark to check the cost, it is difficult to know whether it is in fact correct. Hiring another firm to do a complete life cycle operating and annual cost might be in the best interest to have the time to make the model more specific and use more accurate software.

Annual Fuel Cost ($)	
Electric	73723.92
Natural Gas	8066.59

Table 6: Annual Electric and Natural Gas Cost

Emissions

Emissions given off were primarily because of the natural gas boilers. The model created was able to analyze the CO2, SO2 and NOX being emitted off of the Early Learning Center. With a 90 point Energy Star home the environmental impact of the building is still very large, especially with the CO2 emissions. The table below shows the actual emissions values given off by the building.

Environmental Impact Analysis		
CO2	1113250	lbm/yr
SO2	8661	gm/yr
NOX	1665	gm/yr

Table 7: Emissions Data

Conclusion:

This report covered in depth, the making and calculations of the design loads within the Early Learning Center. The collaboration of systems within the building came together on this report and really addressed the technical aspects of how the heating and cooling systems are run. The energy consumption, cost and emissions were compared to show insight on how the building will operate when it is constructed. Figures provided help show the gaps and the similarities between the calculated loads and the design loads, as well as repeatability of results. A few problems and potential solutions have been addressed within this report and should provide a basis of investigation moving forward.

References:

SCHRADERGROUP architects. Architectural Construction Documents. SCHRADERGROUP architecture, Lancaster, PA

Barton Associates Inc. Mechanical, Electrical and Plumbing Construction Documents. Barton Associates, York, PA

ANSI/AHSRAE Standard 62.1 – 2013, Ventilation for Acceptable Indoor Air Quality. Atlanta, GA: American Society of Heating refrigeration and Air Conditioning Engineers, Inc.

ANSI/ASHRAE/IES Standard 90.1 – 2013, Energy Standard for Buildings Except Low-Rise Residential Buildings. Atlanta, GA: American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.

APPENDIX A:

ASHRAE Standard 62.1 - 2013, Table 6.2.2.1

TABLE 6.2.2.1 Minimum Ventilation Rates in Breathing Zone

(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Notes	Default Values: Occupant Density (see Note 4)	Default Values: Combined Outdoor Air Rate (see Note 5)		Air Class
	cfm/person	L/s·person	cfm/ft²	L/s·m²		#/1000 ft² or #/100 m²	cfm/person	L/s·person	
Correctional Facilities									
Cell	5	2.5	0.12	0.6		25	10	4.9	2
Dayroom	5	2.5	0.06	0.3		30	7	3.5	1
Guard stations	5	2.5	0.06	0.3		15	9	4.5	1
Booking/waiting	7.5	3.8	0.06	0.3		50	9	4.4	2
Educational Facilities									
Daycare (through age 4)	10	5	0.18	0.9		25	17	8.6	2
Daycare sickroom	10	5	0.18	0.9		25	17	8.6	3
Classrooms (ages 5–8)	10	5	0.12	0.6		25	15	7.4	1
Classrooms (age 9 plus)	10	5	0.12	0.6		35	13	6.7	1
Lecture classroom	7.5	3.8	0.06	0.3		65	8	4.3	1
Lecture hall (fixed seats)	7.5	3.8	0.06	0.3		150	8	4.0	1
Art classroom	10	5	0.18	0.9		20	19	9.5	2
Science laboratories	10	5	0.18	0.9		25	17	8.6	2
University/college laboratories	10	5	0.18	0.9		25	17	8.6	2
Wood/metal shop	10	5	0.18	0.9		20	19	9.5	2
Computer lab	10	5	0.12	0.6		25	15	7.4	1
Media center	10	5	0.12	0.6	A	25	15	7.4	1
Music/theater/dance	10	5	0.06	0.3		35	12	5.9	1
Multiuse assembly	7.5	3.8	0.06	0.3		100	8	4.1	1
Food and Beverage Service									
Restaurant dining rooms	7.5	3.8	0.18	0.9		70	10	5.1	2
Cafeteria/fast-food dining	7.5	3.8	0.18	0.9		100	9	4.7	2
Bars, cocktail lounges	7.5	3.8	0.18	0.9		100	9	4.7	2
Kitchen (cooking)	7.5	3.8	0.12	0.6		20	14	7.0	2
General									
Break rooms	5	2.5	0.06	0.3		25	7	3.5	1

GENERAL NOTES FOR TABLE 6.2.2.1

1 **Related requirements:** The rates in this table are based on all other applicable requirements of this standard being met.
2 **Environmental Tobacco Smoke:** This table applies to ETS-free areas. Refer to Section 5.17 for requirements for buildings containing ETS areas and ETS-free areas.
3 **Air density:** Volumetric airflow rates are based on an air density of 0.075 lb_{da}/ft^3 (1.2 kg_{da}/m^3), which corresponds to dry air at a barometric pressure of 1 atm (101.3 kPa) and an air temperature of 70°F (21°C). Rates may be adjusted for actual density but such adjustment is not required for compliance with this standard.
4 **Default occupant density:** The default occupant density shall be used when actual occupant density is not known.
5 **Default combined outdoor air rate (per person):** This rate is based on the default occupant density.
6 **Unlisted occupancies:** If the occupancy category for a proposed space or zone is not listed, the requirements for the listed occupancy category that is most similar in terms of occupant density, activities, and building construction shall be used.

ITEM-SPECIFIC NOTES FOR TABLE 6.2.2.1

A For high-school and college libraries, use values shown for Public Assembly Spaces—Libraries.
B Rate may not be sufficient when stored materials include those having potentially harmful emissions.
C Rate does not allow for humidity control. Additional ventilation or dehumidification may be required to remove moisture. "Deck area" refers to the area surrounding the pool that would be expected to be wetted during normal pool use, i.e., when the pool is occupied. Deck area that is not expected to be wetted shall be designated as a space type (for example, "spectator area").
D Rate does not include special exhaust for stage effects, e.g., dry ice vapors, smoke.
E When combustion equipment is intended to be used on the playing surface or in the space, additional dilution ventilation and/or source control shall be provided.
F Default occupancy for dwelling units shall be two persons for studio and one-bedroom units, with one additional person for each additional bedroom.
G Air from one residential dwelling shall not be recirculated or transferred to any other space outside of that dwelling.

12 ANSI/ASHRAE Standard 62.1-2013

TABLE 6.2.2.1 Minimum Ventilation Rates in Breathing Zone *(Continued)*

(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Notes	Default Values: Occupant Density (see Note 4)	Default Values: Combined Outdoor Air Rate (see Note 5)		Air Class
	cfm/person	L/s·person	cfm/ft^2	L/s·m^2		#/1000 ft^2 or #/100 m^2	cfm/person	L/s·person	
Coffee stations	5	2.5	0.06	0.3		20	8	4	1
Conference/meeting	5	2.5	0.06	0.3		50	6	3.1	1
Corridors	—	—	0.06	0.3		—			1
Occupiable storage rooms for liquids or gels	5	2.5	0.12	0.6	B	2	65	32.5	2
Hotels, Motels, Resorts, Dormitories									
Bedroom/living room	5	2.5	0.06	0.3		10	11	5.5	1
Barracks sleeping areas	5	2.5	0.06	0.3		20	8	4.0	1
Laundry rooms, central	5	2.5	0.12	0.6		10	17	8.5	2
Laundry rooms within dwelling units	5	2.5	0.12	0.6		10	17	8.5	1
Lobbies/prefunction	7.5	3.8	0.06	0.3		30	10	4.8	1
Multipurpose assembly	5	2.5	0.06	0.3		120	6	2.8	1
Office Buildings									
Breakrooms	5	2.5	0.12	0.6		50	7	3.5	1
Main entry lobbies	5	2.5	0.06	0.3		10	11	5.5	1
Occupiable storage rooms for dry materials	5	2.5	0.06	0.3		2	35	17.5	1
Office space	5	2.5	0.06	0.3		5	17	8.5	1
Reception areas	5	2.5	0.06	0.3		30	7	3.5	1
Telephone/data entry	5	2.5	0.06	0.3		60	6	3.0	1
Miscellaneous Spaces									
Bank vaults/safe deposit	5	2.5	0.06	0.3		5	17	8.5	2
Banks or bank lobbies	7.5	3.8	0.06	0.3		15	12	6.0	1
Computer (not printing)	5	2.5	0.06	0.3		4	20	10.0	1

GENERAL NOTES FOR TABLE 6.2.2.1

1 **Related requirements:** The rates in this table are based on all other applicable requirements of this standard being met.

2 **Environmental Tobacco Smoke:** This table applies to ETS-free areas. Refer to Section 5.17 for requirements for buildings containing ETS areas and ETS-free areas.

3 **Air density:** Volumetric airflow rates are based on an air density of 0.075 lb_{da}/ft^3 (1.2 kg_{da}/m^3), which corresponds to dry air at a barometric pressure of 1 atm (101.3 kPa) and an air temperature of 70°F (21°C). Rates may be adjusted for actual density but such adjustment is not required for compliance with this standard.

4 **Default occupant density:** The default occupant density shall be used when actual occupant density is not known.

5 **Default combined outdoor air rate (per person):** This rate is based on the default occupant density.

6 **Unlisted occupancies:** If the occupancy category for a proposed space or zone is not listed, the requirements for the listed occupancy category that is most similar in terms of occupant density, activities, and building construction shall be used.

ITEM-SPECIFIC NOTES FOR TABLE 6.2.2.1

A For high-school and college libraries, use values shown for Public Assembly Spaces—Libraries.

B Rate may not be sufficient when stored materials include those having potentially harmful emissions.

C Rate does not allow for humidity control. Additional ventilation or dehumidification may be required to remove moisture. "Deck area" refers to the area surrounding the pool that would be expected to be wetted during normal pool use, i.e., when the pool is occupied. Deck area that is not expected to be wetted shall be designated as a space type (for example, "spectator area").

D Rate does not include special exhaust for stage effects, e.g., dry ice vapors, smoke.

E When combustion equipment is intended to be used on the playing surface or in the space, additional dilution ventilation and/or source control shall be provided.

F Default occupancy for dwelling units shall be two persons for studio and one-bedroom units, with one additional person for each additional bedroom.

G Air from one residential dwelling shall not be recirculated or transferred to any other space outside of that dwelling.

ASHRAE Standard 90.1 – 2013 Table 9.5.1 Lighting Power Densities Using the Building Area Method

TABLE 9.5.1 Lighting Power Densities Using the Building Area Method

Building Area Type[a]	LPD, W/ft^2
Automotive facility	0.80
Convention center	1.01
Courthouse	1.01
Dining: Bar lounge/leisure	101
Dining: Cafeteria/fast food	0.90
Dining: Family	0.95
Dormitory	0.57
Exercise center	0.84
Fire station	0.671
Gymnasium	0.94
Health-care clinic	0.90
Hospital	1.05
Hotel/Motel	0.87
Library	1.19
Manufacturing facility	1.17
Motion picture theater	0.76
Multifamily	0.51
Museum	1.02
Office	0.82
Parking garage	0.21
Penitentiary	0.81
Performing arts theater	1.39
Police station	0.87
Post office	0.87
Religious building	1.00
Retail	1.26
School/university	0.87
Sports arena	0.91
Town hall	0.89
Transportation	0.70
Warehouse	0.66
Workshop	1.19

a. In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply.

APPENDIX B:

Figure 5: Energy Consumption Summary

Figure 6: Energy Cost Budget

Figure 7: Equipment Energy Consumption

Figure 8: Monthly Energy Consumption

ENERGY CONSUMPTION SUMMARY

By ACADEMIC

	Elect Cons. (kWh)	Gas Cons. (kBtu)	Water Cons. (1000 gals)	% of Total Building Energy	Total Building Energy (kBtu/yr)	Total Source Energy* (kBtu/yr)
Alternative 1						
Primary heating						
Primary heating		906,358		22.4 %	906,358	954,061
Other Htg Accessories	10,988			0.9 %	37,502	112,519
Heating Subtotal	**10,988**	**906,358**		**23.3** %	**943,861**	**1,066,580**
Primary cooling						
Cooling Compressor	304,742			25.7 %	1,040,084	3,120,563
Tower/Cond Fans	113,978		1,649	9.6 %	389,008	1,167,140
Condenser Pump				0.0 %	0	0
Other Clg Accessories	876			0.1 %	2,990	8,970
Cooling Subtotal....	**419,596**		**1,649**	**35.4** %	**1,432,081**	**4,296,673**
Auxiliary						
Supply Fans	142,112			12.0 %	485,030	1,455,234
Pumps				0.0 %	0	0
Stand-alone Base Utilities				0.0 %	0	0
Aux Subtotal....	142,112			12.0 %	485,030	1,455,234
Lighting						
Lighting	171,286			14.4 %	584,599	1,753,973
Receptacle						
Receptacles	177,566			15.0 %	606,034	1,818,283
Cogeneration						
Cogeneration				0.0 %	0	0
Totals						
Totals**	**921,549**	**906,358**	**1,649**	**100.0** %	**4,051,604**	**10,390,742**

* Note: Resource Utilization factors are included in the Total Source Energy value .

** Note: This report can display a maximum of 7 utilities. If additional utilities are used, they will be included in the total.

Energy Cost Budget / PRM Summary

By ACADEMIC

Project Name:	Date: October 13, 2015
City:	Weather Data: Harrisburg, Pennsylvania

Note: The percentage displayed for the "Proposed/ Base %" column of the base case is actually the percentage of the total energy consumption.

* Denotes the base alternative for the ECB study.

		* Alt-1		
		Energy 10^6 Btu/yr	Proposed / Base %	Peak kBtuh
Lighting - Conditioned	Electricity	584.6	14	275
Space Heating	Electricity	37.5	1	9
	Gas	906.4	22	1,767
Space Cooling	Electricity	1,043.1	26	744
Heat Rejection	Electricity	389.0	10	79
Fans - Conditioned	Electricity	485.0	12	121
Receptacles - Conditioned	Electricity	606.0	15	95
Total Building Consumption		**4,051.6**		

		* Alt-1
Total	**Number of hours heating load not met**	496
	Number of hours cooling load not met	349

	* Alt-1	
	Energy 10^6 Btu/yr	Cost/yr $/yr
Electricity	3,145.2	64,968
Gas	906.4	4,532
Total	**4,052**	**69,500**

EQUIPMENT ENERGY CONSUMPTION

By ACADEMIC

Alternative: 1

------- Monthly Consumption -------

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Lights													
Electric (kWh)	17,484.4	15,814.6	18,863.7	16,697.8	18,174.0	5,033.6	4,936.8	5,227.2	16,697.8	18,174.0	17,387.5	16,794.7	171,286.0
Peak (kW)	80.7	80.7	80.7	80.7	80.7	80.7	80.7	80.7	80.7	80.7	80.7	80.7	80.7
Misc. Ld													
Electric (kWh)	13,744.2	12,415.7	13,846.5	13,284.3	13,795.3	12,260.5	12,669.2	12,669.2	13,284.3	13,795.3	13,335.5	13,693.0	158,793.0
Peak (kW)	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3
Energy Recovery Parasitics													
Electric (kWh)	2,172.0	2,013.6	1,952.8	1,456.0	1,043.2	1,232.0	1,612.0	1,218.4	942.0	1,317.6	1,648.8	2,164.8	18,773.2
Peak (kW)	3.6	3.6	3.2	3.2	3.6	3.6	3.6	3.6	3.6	3.2	3.2	3.2	3.6
Cooling Coil Condensate													
Recoverable Water (1000gal)	5.5	5.3	6.2	6.5	12.7	24.7	40.3	26.9	16.5	6.9	6.2	6.1	163.7
Peak (1000gal/Hr)	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.1
Cpl 1: Cooling plant - 001 [Sum of dsn coil capacities=273.3 tons]													
Air-cooled chiller - 001 [Clg Nominal Capacity/F.L.Rate=273.3 tons / 303.1 kW] [Orig F.L.Rate=303.1 kW] (Cooling Equipment)**													
Electric (kWh)	4,872.1	4,609.1	6,205.6	9,208.9	36,402.6	51,832.8	71,635.7	55,050.0	39,919.1	12,237.6	7,468.8	5,299.6	304,741.8
Peak (kW)	21.0	26.7	48.3	73.1	186.9	178.8	214.8	197.9	217.8	101.3	66.3	29.0	217.8
Default Cooling Tower [Design Heat Rejection/F.L.Rate=349.4 tons / 23.06 kW]													
Electric (kWh)	5,864.0	5,280.3	6,129.0	6,612.6	11,410.7	14,774.6	17,156.7	15,192.9	12,254.8	7,115.8	6,250.2	5,936.8	113,978.2
Peak (kW)	8.3	8.3	10.0	13.9	23.1	23.1	23.1	23.1	23.1	16.6	12.2	8.8	23.1
Default Cooling Tower													
Make Up Water (1000gal)	53.0	49.2	60.4	73.3	184.4	242.7	324.7	257.4	197.9	85.7	65.2	55.7	1,649.4
Peak (1000gal/Hr)	0.1	0.2	0.2	0.4	0.8	0.7	0.9	0.8	0.9	0.5	0.3	0.2	0.9
Cntl panel & interlocks - 0.1 KW [F.L.Rate=0.10 kW] (Misc Accessory Equipment)													
Electric (kWh)	74.4	67.2	74.4	72.0	74.4	72.0	74.4	74.4	72.0	74.4	72.0	74.4	876.0
Peak (kW)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Hpl 1: Heating plant - 002 [Sum of dsn coil capacities=2,007 mbh]													
Boiler - 001 [Nominal Capacity/F.L.Rate=2,007 mbh / 24.10 Therms] (Heating Equipment)													
Gas (therms)	2,397.2	2,255.3	1,151.2	281.2	4.4	0.6	0.0	0.0	1.7	268.0	704.7	1,999.2	9,063.6
Peak (therms/Hr)	17.7	17.6	15.2	9.1	0.1	0.0	0.0	0.0	0.1	8.6	13.4	17.2	17.7

EQUIPMENT ENERGY CONSUMPTION
By ACADEMIC

Alternative: 1

------- Monthly Consumption -------

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Hpl 1: Heating plant - 002 [Sum of dsn coil capacities=2,007 mbh]													
Boiler forced draft fan [F.L.Rate=2.01 kW] (Misc Accessory Equipment)													
Electric (kWh)	1,493.6	1,349.1	1,355.1	778.9	240.9	88.3	0.0	0.0	184.7	704.7	1,108.2	1,493.6	8,797.1
Peak (kW)	2.0	2.0	2.0	2.0	2.0	2.0	0.0	0.0	2.0	2.0	2.0	2.0	2.0
Cntl panel & interlocks - 0.5 KW [F.L.Rate=0.50 kW] (Misc Accessory Equipment)													
Electric (kWh)	372.0	336.0	337.5	194.0	60.0	22.0	0.0	0.0	46.0	175.5	276.0	372.0	2,191.0
Peak (kW)	0.5	0.5	0.5	0.5	0.5	0.5	0.0	0.0	0.5	0.5	0.5	0.5	0.5
Sys 1: ERV - 1													
Hydronic in heat pump fan [DsnAirflow/F.L.Rate=15,682 cfm / 5.78 kW] (Main Clg Fan)													
Electric (kWh)	1,282.4	1,165.1	1,326.6	1,058.7	1,001.4	1,077.5	1,107.8	1,127.3	963.9	1,081.6	1,108.4	1,202.9	13,503.4
Peak (kW)	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Sys 10: ERV - 10													
Hydronic in heat pump fan [DsnAirflow/F.L.Rate=14,105 cfm / 5.20 kW] (Main Clg Fan)													
Electric (kWh)	1,884.3	1,695.0	1,836.6	1,530.7	1,504.8	1,557.6	1,651.3	1,615.3	1,450.1	1,588.6	1,624.1	1,833.9	19,772.2
Peak (kW)	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Sys 2: ERV - 2													
Hydronic in heat pump fan [DsnAirflow/F.L.Rate=15,318 cfm / 5.65 kW] (Main Clg Fan)													
Electric (kWh)	1,072.8	1,034.4	1,035.9	885.7	998.0	1,063.3	1,094.5	1,114.2	954.9	927.3	928.0	1,008.1	12,117.0
Peak (kW)	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	4.0	5.7	5.7	5.7
Sys 3: ERV - 3													
Hydronic in heat pump fan [DsnAirflow/F.L.Rate=11,905 cfm / 4.39 kW] (Main Clg Fan)													
Electric (kWh)	889.6	852.5	887.8	717.5	829.8	901.2	909.3	921.6	801.8	775.2	769.4	854.4	10,110.2
Peak (kW)	4.4	4.4	4.4	3.1	4.4	4.4	4.4	4.4	4.4	3.1	4.4	4.4	4.4
Sys 4: ERV - 4													
Hydronic in heat pump fan [DsnAirflow/F.L.Rate=9,776 cfm / 3.60 kW] (Main Clg Fan)													
Electric (kWh)	1,082.0	980.3	1,078.1	884.5	869.4	900.8	935.7	936.4	833.7	920.8	939.4	1,033.1	11,394.2
Peak (kW)	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Sys 5: ERV - 5													

EQUIPMENT ENERGY CONSUMPTION
By ACADEMIC

Alternative: 1

------- Monthly Consumption -------

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Sys 5: ERV - 5													
Hydronic in heat pump fan [DsnAirflow/F.L.Rate=11,974 cfm / 4.41 kW] (Main Clg Fan)													
Electric (kWh)	3,284.5	2,966.7	2,961.6	2,522.7	2,541.6	2,611.0	2,854.4	2,698.0	2,459.6	2,608.4	2,713.1	3,284.5	33,506.1
Peak (kW)	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Sys 6: ERV - 6													
Hydronic in heat pump fan [DsnAirflow/F.L.Rate=7,207 cfm / 2.66 kW] (Main Clg Fan)													
Electric (kWh)	1,393.1	1,291.6	1,365.9	1,336.1	1,459.8	1,485.4	1,609.9	1,535.3	1,417.8	1,381.6	1,346.4	1,363.6	16,986.5
Peak (kW)	2.7	2.7	2.3	2.3	2.7	2.7	2.7	2.7	2.7	2.3	2.3	1.9	2.7
Sys 7: ERV - 7													
Hydronic in heat pump fan [DsnAirflow/F.L.Rate=3,342 cfm / 1.23 kW] (Main Clg Fan)													
Electric (kWh)	654.9	591.5	654.9	633.8	654.9	633.8	654.9	654.9	633.8	654.9	633.8	654.9	7,710.6
Peak (kW)	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Sys 8: ERV - 8													
Hydronic in heat pump fan [DsnAirflow/F.L.Rate=3,586 cfm / 1.32 kW] (Main Clg Fan)													
Electric (kWh)	666.2	601.7	667.3	644.5	683.4	678.9	718.5	702.1	667.1	666.8	645.1	665.6	8,007.0
Peak (kW)	0.9	0.9	0.9	0.9	1.3	1.3	1.3	1.3	1.3	0.9	0.9	0.9	1.3
Sys 9: ERV - 9													
Hydronic in heat pump fan [DsnAirflow/F.L.Rate=3,991 cfm / 1.47 kW] (Main Clg Fan)													
Electric (kWh)	749.4	676.9	750.5	725.1	768.5	763.1	807.8	789.2	750.3	750.0	725.6	748.9	9,005.3
Peak (kW)	1.1	1.1	1.1	1.1	1.5	1.5	1.5	1.5	1.5	1.1	1.1	1.1	1.5

MONTHLY ENERGY CONSUMPTION

By ACADEMIC

------- Monthly Energy Consumption -------

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Alternative: 1													
Electric													
On-Pk Cons. (kWh)	28,817	26,246	31,862	28,849	51,634	46,777	52,751	51,216	50,113	33,627	29,511	27,645	459,049
Off-Pk Cons. (kWh)	30,219	27,495	29,468	30,394	40,879	50,211	67,678	50,310	44,221	31,323	29,469	30,833	462,500
On-Pk Demand (kW)	170	177	189	218	354	346	382	365	385	249	209	178	385
Off-Pk Demand (kW)	159	161	161	166	195	276	344	274	217	161	159	159	344
Gas													
On-Pk Cons. (therms)	608	618	266	38	0	0	0	0	0	23	96	512	2,161
Off-Pk Cons. (therms)	1,789	1,638	886	243	4	1	0	0	2	245	609	1,487	6,903
On-Pk Demand (therms/hr)	6	6	4	2	0	0	0	0	0	1	3	5	6
Off-Pk Demand (therms/hr)	18	18	15	9	0	0	0	0	0	9	13	17	18
Water													
Cons. (1000gal)	53	49	60	73	184	243	325	257	198	86	65	56	1,649

Energy Consumption

Building	27,044	Btu/(ft2-year)
Source	69,357	Btu/(ft2-year)
Floor Area	149,816	ft2

Environmental Impact Analysis

CO_2	1,113,250 lbm/year
SO_2	8,661 gm/year
NOX	1,665 gm/year