Mechanical Systems: Existing Conditions

Technical Report Three

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Executive Summary:

This report outlines the specifics of the mechanical system within the Phoenixville Early Learning Center and Elementary School. As a new public facility it is important to consider all aspects of thermal comfort, sustainability, as well as ease of maintenance. The mechanical system described in this report touches on each important aspect.

When designing it is important first to understand and list out the design objectives and requirements. The most important criteria to the school district was a workable space, which is on a reduced energy and sustainable footprint. Along with sustainability, ease of maintenance was a high concern to address to reduce downtime and manage the building for years to come.

A variety of energy sources were thought of as possibilities for the building however, natural gas and electric was decided to provide energy. The natural gas will go into providing energy for the boilers to create condensate and heat the air being blown through the water source heat pumps. Electricity will be used in many ways including but not limited to powering mechanical equipment, mechanical controls as well as electric heating. It was determined in the future a possibility of an onsite generation of energy may be possible for their campus considering the proximity of their schools. Utility rates for natural gas are currently at $8.90/ MMBTU and $0.08/ KWhr for electricity. Given these utility rates the average annual cost of utilities based on the current design will be about $107,000 per year.

The report then proceeds to discuss design conditions including indoor and outdoor conditions. Ventilation was addressed in terms of compliance with ASHRAE Standard 62.1, the current design was found to not comply with some spaces within the building. Heating and cooling loads were analyzed to find the heating load for the building is 235 tons and 332 tons of cooling is needed for thermal comfort within the space.

Air-side and water-side components were analyzed in detail to provide insight to the inner workings of each system. Equipment was sketched in a schematic to make understanding of the system easier to comprehend. Finally, mechanical costs, mechanical floor space and a LEED analysis were inspected for compliance and possibilities of better adjustments in future design.

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 learning amphitheater. Wings of the building, as shown in figure 1 below, are filled with learning spaces comprised of group learning

Figure 1: First Floor Plan with Basic Programming

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 location of boilers 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.

Design Objectives and Requirements

The most important requirement for the mechanical system is it needs to be efficient. Efficient meaning able to save the school district energy, as well as maintenance and be able to be paid back within a 30 year time period. It has been discussed and decided not to pursue LEED accreditation which provided more flexibility for the mechanical designers because they did not have to think about checking off LEED points.

When looking at efficiency and maintenance, it is of utmost importance to make the water source heat pumps accessible from the corridors. This was something the architect and mechanical designer worked on early in the process to achieve that goal. The door to the cabinets were put in the hallway for acoustical considerations and were also made large enough for easy access to all critical maintenance areas of the equipment. With this in mind it is possible for maintenance personnel to tear out the unit, even while class is in session, and can replace it with another unit. Extra acoustical batt insulation was put inside the walls near the equipment closets to reduce noise.

Energy Sources and Rates

The two different fuel types used within the Early Learning Center are natural gas and electricity. Both of these services are piped directly from the street from existing infrastructure. Natural gas is primarily to serve the boilers to create hot water for the ERV and Water Source Heat Pumps.

Other possible energy sources which could be of use to investigate would be to provide a power generation on their campus with either steam, coal, nuclear. With the close proximity and sharing of parking, busing circles and campus greenery, there might be a savings of generating some of their own power for all of their buildings, reducing load on PECO and HESS during peak supply times.

Energy Rates

Rates for electrical and natural gas change varying on the time of year and current economic conditions. The electric rates used for the Early Learning Center reflect prices for the Phoenixville Area School District from PECO Billing for distribution charges. It is important to note electric generation charges were not provided. From the information given by the school district, $0.08/KWh and $4.96/KW were utilized for the analysis. The school district also provided rates from Hess Billing for their price of natural gas without including any transmission charges. Rates given by the school district were representative of the commodity price for August and September. Therefore, since the price changes based on season a yearly average would be best represented and $8.9/MMBTU was used for the analysis. It is also important to note, since there are almost 100 water source heat pumps within the building, this is a large amount of water and the school district needs to pay for water usage since it is located on the Borough of Phoenixville water supply. Water use charges were not provided so an assumption of $5/1000 gallon rate was utilized in table 1.

Table 1: Energy Rates assumed for Project.

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

Annual Operating Cost

Operating costs for the systems were calculated using Trane Trace 700 results and simple algebra. In the modeled case the annual utility costs of natural gas and electric were able to be distinguished. The results are shown below in table 2: Annual Electric and Natural Gas Cost.

Table 2: Annual Electric and Natural Gas Cost

Annual Fuel Cost ($)	
Electric	73,723.92
Natural Gas	8,066.59

Based on provided values from the mechanical engineer annual utility costs are able to be compared. Below is table 3, showing the Annual Utility costs of the model and the designed cost.

Table 3: Annual Utility Cost Comparison

Annual Utility Cost ($)		
Modeled	Designed	% Difference
81,790.51	107,572	(23.97)

As shown in the table above, the designed values for annual utility cost is about 24 percent higher than the modeled cost. The difference could be the result of a simplified model and varied assumptions for consumption of different system components such as the lighting or electrical components.

Site, Cost and other factors that influenced design

The main issue of wanting, or not wanting a geothermal system was a main factor that influenced design. There were two distinct groups from the owner; one that did want geothermal pumps and one group that did not want geothermal pumps. After a site analysis, it was determined the geothermal well would need to be placed 400 – 500 feet away from the school because of the Astroturf fields causing the need for a higher head and more pump power which would increase cost. Following a payback period analysis, it was found the geothermal system did not payback within the 30 year time allotment.

In the start of construction it is becoming evident there will be a plethora of RFI's and change orders. This is occurring because of coordination issues with the structural and mechanical systems. The structural system was not designed or modeled in Revit at the time the mechanical system was designed and is leading to a large amount of clashes with different systems.

Design Conditions

Below the design conditions for the outdoor and indoor design conditions are discussed. These design conditions are the basis of temperatures and seasonal fluctuations of what the mechanical system needs to be designed to accommodate.

Outdoor Design Conditions:

The outdoor Conditions for the area of Phoenixville Early Learning Center and Elementary School are a direct reflection of the climate. As previously explained in Technical Report 1, the Early Learning Center is located in climate zone 5A, which designates the location as Cool-Humid with between 5400 and 7200 heating degree days. The specific temperatures used in the design for this building are shown in the table below.

Table 4: Outdoor Design Conditions; Phoenixville, PA

Weather Design Condtions, Phoenixville, PA		
Season	Dry Bulb (°F)	Wet Bulb (°F)
Winter	11	/
Summer	91	74

Indoor Design Conditions:

The indoor Design Requirements were to keep the indoor air temperature and relative humidity levels to consistent states throughout the summer and winter months. During the summer months the temperatures would be higher because the temperature difference coming from the outdoors makes the interior space feel cooler. Similarly, in the winter the indoor temperature is lowered to save energy however, the occupants will still feel warm because they are coming from a cold outside temperature.

Table 5: Indoor Design Set Points

Conditioned Spaces (°F)			
Season	DB	WB	RH
Summer	79	68.2	\
Winter	70	\	30

Ventilation Requirements:

Ventilation Requirements for the Early Learning Center and Elementary school were limited to ASHRAE Standard 62.1, 2012 version. There were no special or specific ventilation requirements for the elementary school. Ventilation control was addressed within the building, since the ERV units supply constant volume they are controlled by occupancy sensors that reduce the volume of air being dispersed into the rooms when there is no one in the rooms.

Table 6: System Ventilation Comparisons

System Ventilation Comparisons and ASHRAE STD 62.1 Compliance					
Unit	Modeled	Designed	% Difference	Required	Compliance
ERV-1	10257	9349	8.86	6085	Yes
ERV-2	7549	6441	14.68	5125	Yes
ERV-3	6191	5992	3.22	5320	Yes
ERV-4	7059	5980	15.29	5290	Yes
ERV-5	8311	3776	54.56	5520	No
ERV-6	2349	4809	51.15	3100	Yes
ERV-7	0	401	100.00	480	No
ERV-8	90	0	100.00	1204	No
ERV-9	84	540	84.45	2356	No
ERV-10	6742	6940	2.86	3090	Yes
Total	48632	44228	9.06	37570	/

From the table above, it is evident the designed ventilation airflows did not meet the ventilation requirements for ASHRAE Standard 62.1 based off of calculations for airflow performed for Technical Report 1: *ASHRAE Standards 62.1 and 90.1 Evaluations*. There could be variances in the areas covered for each ERV. For example, the final design did not use ERV-8. It is also obvious in cases such as ERV-5, and 9 that the spaces must be different from the trace model and the ventilation model.

Heating and Cooling Loads Comparison

Heating Loads

Heating Loads for the Early Learning Center and Elementary School are compared in the table below. Loads from the model and the mechanical engineers were computed using built Trane Trace 700 models. Both models included the different zones from the ERV units and comparatively showed similar results. Heating the water is two 166 ton high efficiency boilers, with one boiler on standby for emergencies.

Table 7: Comparison of Heating Loads

Heating Load Comparison (Tons)			
	Modeled	Designed	% Difference
ERV-1	35	52	33
ERV-2	32	34	6
ERV-3	24	24	0
ERV-4	21	27	22
ERV-5	20	18	18
ERV-6	18	26	31
ERV-7	1.8	4	55
ERV-8	5	/	/
ERV-9	5	6	17
ERV-10	23	34	32
Heating Only	/	5	/
Stair WSHP	/	4	/
WSHP-89	/	1.5	/
Total	184	235	22
/ = signifies the value was not represented			

Cooling Loads

Similar to the heating loads, cooling loads for the elementary school were calculated using Trane Trace 700. Results of the calculations show similar performances of each models. Cooling for the building is derived from the 950 GPM Cooling Tower on the roof. After water is processed through the cooling tower pumps distribute the cooled water throughout the building.

Table 8: Comparison of Cooling Loads

Cooling Load Comparison (Tons)			
	Modeled	Designed	% Difference
ERV-1	44	67	34
ERV-2	42	46	9
ERV-3	36	32	11
ERV-4	30	40	25
ERV-5	44	26	41
ERV-6	23	38	39
ERV-7	7	6	14
ERV-8	8	/	/
ERV-9	13	10	23
ERV-10	40	56	29
WSHP-20	/	4	/
Stair WSHP	/	6	/
WSHP-89	/	2	/
Total	288	332	13
/ = signifies the value was not represented			

Existing Mechanical System

The existing mechanical system is comprised of many systems working simultaneously together. The mechanical system has a main face of a Water source heat pump system fed from Energy Recovery Units which are heated and cooled with a boiler and cooling tower, which also utilizes a flat plate heat exchanger. These components heat and cool water as well as air to provide a sustainable and comfortable working environment for the occupants of the building.

Air-Side Components

Intake air for the Early Learning Center is brought in through the ten Energy Recover Ventilators (ERV) on the roof. ERV units send air through the duct systems to reach terminal Water Source Heat Pump (WSHP) units located in closets in the classrooms as well as seven Rooftop Water Source heat pumps (RTWSHP) on the roof. When the air reaches one of these terminal WSHP units the air is conditioned again to ensure the proper temperature and comfort level for that particular room. This is one of the advantages of having terminal WSHP units because if a room on the south side of the building is experiencing a large solar gain they can lower the temperature on the unit, whereas a classroom on the north side of the building might need to turn the temperature up because they are not receiving the solar gain.

Energy Recovery Ventilator (ERV) – Air is brought into the building through these units which positively pressurize and feed the building. If all WSHP's are indexed to unoccupied mode the ERV unit serving those zones will de-energize and shut down with all dampers closing. ERV units are built with an energy wheel which mixes outdoor air and return air. By mixing the air by use of a rotating energy wheel outdoor air is able to be heated with the excess energy in the return air.

Table 9: Energy Recovery Ventilator Unit Schedule

Major Equipment: Energy Recovery Ventilators				
	OA CFM	EA CFM	OA FAN HP	EA FAN HP
ERV-1	8915	8470	10	10
ERV-2	6480	5845	7.5	5
ERV-3	6155	5945	5	5
ERV-4	6125	5600	5	5
ERV-5	3775	3050	3	1.5
ERV-6	5000	4500	3	3
ERV-7	600	550	1/3	1/3
ERV-8	600	550	1/3	1/3
ERV-9	3870	3870	3	3
ERV-10	4375	4155	5	5

Water Source Heat Pumps (WSHP) – RTWSHP's and terminal WSHP's for the classrooms function the same but vary in size. WSHP's take air and push them through heating and cooling coils. These coils are filled with water as a source to transmit energy which is fed from the boiler and cooling tower (*See Water Side Components).* With the large amount of WSHP's the all tonnages are represented in table 10 below.

Table 10: Water Source Heat Pumps Unit Schedule

Main Units: Water Source Heat Pumps								
		Fan Data					Cooling	
		CFM		ESP	HP	Heating (Tons)	Tons	
Unit	Tonnage	Total	OA				Total	Sense
WSHP-1	3	910	420	0.5	1/3	3.95	2.95	1.88
WSHP-7	4	1370	870	0.5	1/2	5.16	3.85	2.57
WSHP-14	3/4	255	40	0.5	1/8	0.92	0.7	0.5
WSHP-17	1.5	515	345	0.5	1/8	1.98	1.48	1
WSHP-22	2.0	760	155	0.5	1/3	2.75	2.08	1.44
WSHP-46	3.0	1140	420	0.5	1/2	4.07	3.04	2.1
WSHP-73	4.0	1670	490	0.5	1/2	5.51	4.33	3.09
RTWSHP-1	6.0	2430	600	1.25	1	7.45	6.17	5
RTWSHP-2	10.0	4305	600	1.5	5	12.4	8.72	9.29
RTWSHP-3	20.0	6500	2500	0.75	5	27.3	15.58	16.28
RTWSHP-6	15.0	6100	2665	0.87	5	16.88	9.98	10.69
RTWSHP-7	12.5	5500	1100	0.87	3	16.74	9.48	10.06

Fan units – There are several rooftop fans that draw outdoor air into the building for a DOAS system and help push the air to where it needs to go throughout the building.

Table 11: Fan Unit Schedule

Major Units: Fans				
Unit	CFM	ESP	HP(WATTS)	SONES
F-1	5355	1.25	2	15.5
F-2	600	0.8	1/4	8.2
F-3	500	0.5	0.067	7.4
F-4	500	0.5	0.067	7.4

Water-Side Components

The water-side components are crucial to the success of the building's comfort. Water-side components control the temperature of the air that is being blown into the spaces because the air is first blown over the heating and cooling coils. It is imperative these coils be filled with the correct temperature water to provide steady, comfortable air. Temperatures of water are changed through the boiler where the water is heated to a gas state. This gas then condenses and goes to the cooling tower, where the cooling tower can cool the reuse water. Water from the cooling tower and the boiler are sent to ERV's and WSHP's to condition the air before it is delivered to the occupants. Water is constantly circulating and will progress back to either the cooling tower or the boiler to be reconditioned.

Boiler – A boiler heats water by burning natural gas. Water is pushed through multiple fins over the fire converting the water to steam and is pushed to the condensing tank where is cooled back into water and assumes the temperature it will be distributed through the building. Water leaving the boiler is at 140°F.

Table 12: Boiler Schedule

Major Equipment: Boilers						
	Gas Boiler					Boiler Motor HP
	Tons		GPM	LWT	Boiler HP	
Unit	Input	Output				
B-1	166.7	160	190	140	57.4	1.18
B-2	166.7	160	190	140	57.4	1.18
B-3	166.7	160	190	140	57.4	1.18

Cooling Tower – In the cooling tower energy is removed to cool the water. Energy is removed by evaporation. Water enters the cooling tower at 98.8 °F and leaves at 85°F

Table 13: Cooling Tower Schedule

Major Equipment: Cooling Tower						
Unit	Type	GPM	EWT	LWT	Tower WPD (PSI)	Fan HP
CT-1	Induced Draft	950	98.8	85	4.33	25

Plate-Frame Heat Exchanger (HX) – The HX can condense or heat the water depending on the supply and temperature of the water given. In the case of the elementary school it does perform both heating and cooling.

Table 14: Plate-Frame Heat Exchanger

Major Equipment: Plate-Frame Heat Exchanger								
Unit	Cooling Tower				Condenser Water			
	Tons	EWT	LWT	GPM	WPD	EWT	LWT	GPM	WPD
HX-1	541967	85	98.8	950	10.2	101.6	87	900	9.3

Pumps – Pumps control the supply of water to all of the heating coils in the rooftop units, the water source heat pumps and VAV boxes. These pumps are extremely important to the function of transporting liquid.

Table 15: Pump Schedule

Major Equipment: Pumps							
Unit	Service	GPM	FT HD	% EFF	RPM	HP	Impeller Size
P-1	Condenser Water	900	80	84.5	1750	30	9-7/8"
P-2	Condenser Water	900	80	84.5	1750	30	9-7/8"
P-3	Cooling Tower	950	55	82.4	1750	20	8-3/4"
P-4	Cooling Tower	950	55	82.4	1750	20	8-3/4"
P-5	Boiler Circulator	188	20	63	1750	2	5-5/8"
P-6	Boiler Circulator	188	20	63	1750	2	5-5/8"
P-7	Boiler Circulator	188	20	63	1750	2	5-5/8"

Schematic System Diagrams

Air-Side Schematic

In figure 2 below, the schematic diagram for the Air-Side system is shown. Air first flows into the ERV unit to from outside and is conditioned before it is sent down to the WSHP's in the second and first floors. When the air travels down the duct there is a possibility for heat transfer through the duct by conduction, or convection. Before, the air turns to enter the WSHP it must pass through a volume damper. This volume damper controls the amount of air going through each WSHP. Dampers should be balanced at turnover of the building and periodically throughout the lifespan of the building. After passing the volume damper there is a reheat coil within the WSHP to combat the heat transfer that may have occurred on the way to the unit.

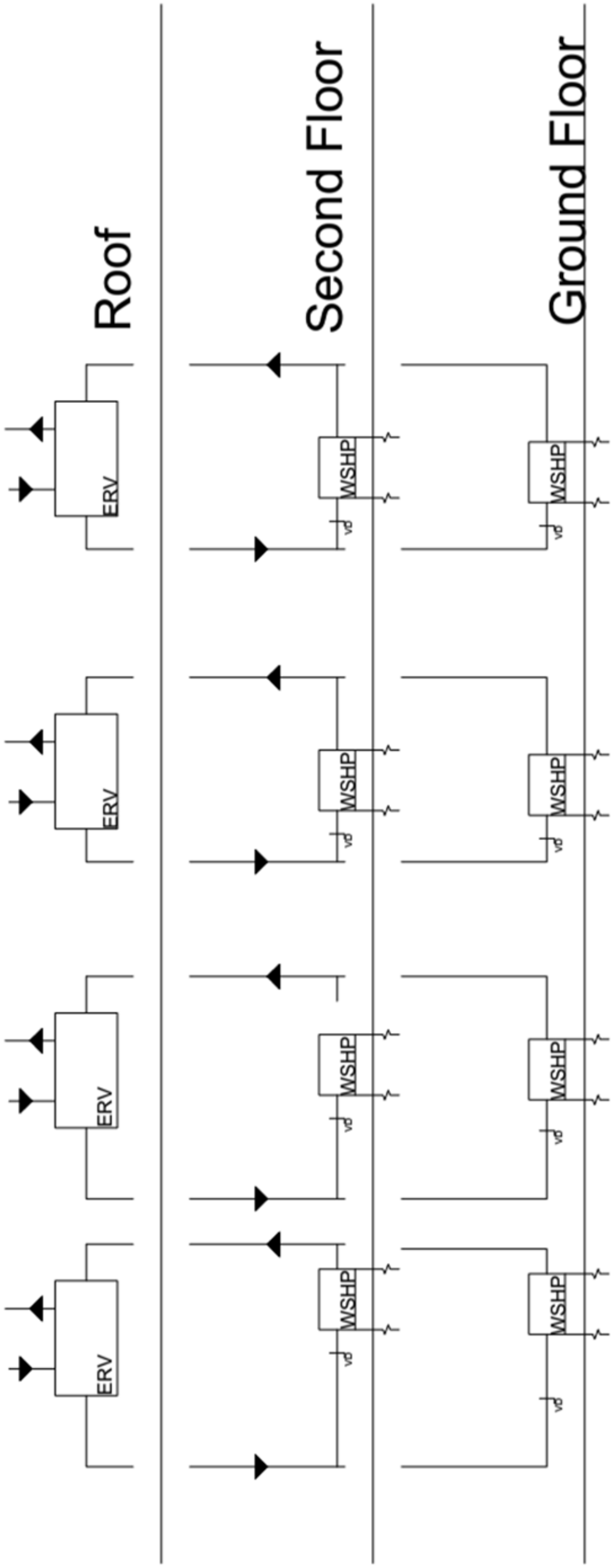

Figure 2: Air-Side Schematic

Water-Side Schematic

In the water-side schematic, figure 3 below, starting at the boilers the water is heated up and passes through the boilers where it encounters the Air Separator, to remove air bubbles from the vapor gas, and then it can go through a series of valves to the expansion tank where excess pressure can be let out. Before going in the Expansion tank there is an automatic air vent to vent excess pressure. Condensate then moves through to the pressure gage where it is determined if it needs to go through the pressure reducing valve and out of the system. Back before the split to the Expansion tank is the suction from the pumps. The condensate will go through a gate valve down into the pump and discharged through to the other side after running through a pressure gauge, monitoring pressure. Condensate is then distributed to the WSHP where it is again run through a temperature gauge. After being run through the unit it goes through a balancing valve and is sent back to the boilers. On the cooling tower side of the loop, it comes out of the cooling tower, with the pressure being monitored and is sent directly to the WSHP. After the condensate is run through the WSHP it is sent back to the cooling tower to lower the temperature again and continuously runs through the loop.

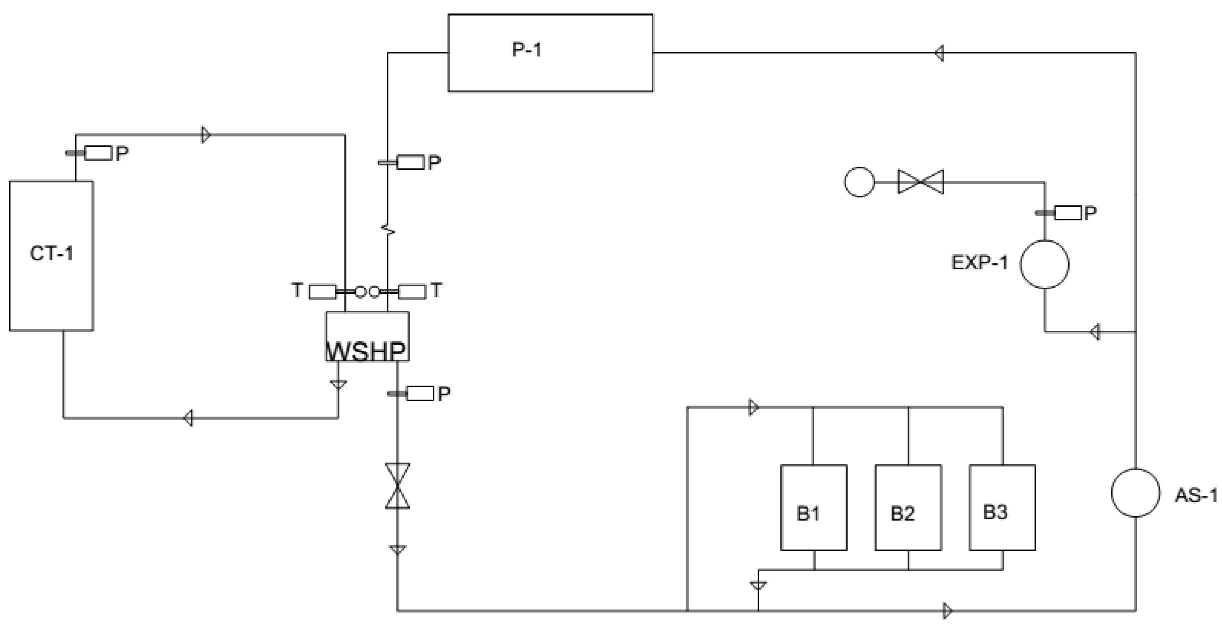

Figure 3: Water-Side Schematic Drawing

Mechanical System Space Considerations

Shown below, table 16 shows the square footage of floor space lost to mechanical equipment and services in each zone of the building.

Table 16: Floor Space Lost to Mechanical Chases

Floor Space Lost											
Zone	1A	1B	1C	1D	1E	2A	2B	2C	2D	2E	Total
Area (SF)	251	72	34	309	159	272	155	21	183	119	1575

Water source heat pumps take up the most space of the 1575 square feet lost. This is because the WSHP units are located into closets in the hallways and are given a large amount of space to be easily accessible. In preliminary designs of the building these spaces were developed and included because it was a requirement of easy maintenance for the client. Square feet vary from area to area due to the types of spaces within the zones as well as what types of areas are located above the zones. It is also important to note there are ten ERV units, seven RTWSHP units, three boilers, and a cooling tower on the roof. By allowing a large amount of equipment on the roof it frees up space within the building to allow for programmable areas.

Mechanical System Costs

Currently the winning bid for construction of the building was 31.1 million dollars. Of the 31.1 million dollar total cost of the building 4.0 million dollars was the base mechanical system bid. At the time of publishing the mechanical contractor has yet to publish a specific itemized list of cost per item. To note, the mechanical bid included alternates such as geothermal heat pumps instead of water source heat pumps which would raise the cost 1.5 million dollars with the cost of each additional geothermal well, beyond the scope, to be 10,000 dollars each.

LEED Comparison

LEED Certification was not pursued on the Early Learning Center project but sustainability and commitment to energy efficiency were a high priority of the clients. For the LEED Analysis and Comparison LEED for Schools – New Construction v2009 will be the basis of comparison. LEED Schools v2009 has been chosen because this project is a school building and most closely relates to the Schools criteria. Only breakdowns of the sections referring to the mechanical systems will be explained.

Energy and Atmosphere

Prerequisite 1 - Fundamental Commissioning of Building Energy Systems: Commissioning will take place after the mechanical systems are in and the building is built. There is a comprehensive section in part three of the specifications which calls for the Testing Adjusting and Balancing of HVAC System.

Prerequisite 2 – Minimum Energy Performance: This prerequisite was met with the whole building Energy simulation in Trane Trace 700. The results from the study were then improved upon ten percent to meet the requirement. The Trane Trace 700 model is fully comprehensive and includes most loads that would be expected to be within the building.

Prerequisite 3 – Fundamental Refrigerant Management: There will be no usage of Chlorofluorocarbons (CFC), in the Early Learning Center.

EA Credit 1 – Optimize Energy Performance: Designs were made with various systems and comparisons to the systems. From the first energy model the engineers decreased the energy usage by about 22 percent awarding the building 6 credits - **6**

EA Credit 2 – On-site Renewable Energy: The Early Learning Center does not have on-site renewable. – **0**

EA Credit 3 – Enhanced Commissioning: Very strict and highly legible specifications have been made in the specifications and the entry level higher. This credit will be completed after completion. – **2**

EA Credit 4 – Enhanced Refrigerant Management: The Early Learning Center and Elementary School will be using an approved amount of R-407C and R-410A based on the equation calculator created by Trane for compliance to the USGBC LEED Credit. – **1**

EA Credit 5 – Measurement and Verification: Programs are in place to keep track of equipment before selling the home therefore, without a concrete after construction management plan we will keep this building at no credits – **0**

EA Credit 6 – Green Power: This credit is not something the owner is pursuing. – **0**

Indoor Environmental Air Quality (IEQ)

IEQ Prerequisite 1 - Minimum Indoor Air Quality Performance: ASHRAE Standard 62.1 has been followed throughout the design to which satisfies the prerequisite.

IEQ Prerequisite 2 – Environmental Tobacco Smoke (ETS) Control: There is to be no smoking on school grounds.

IEQ Prerequisite 3 – Minimum Acoustical Performance: Classrooms were designed with acoustical considerations in mind especially since WSHP's are located right next to the classrooms. Classrooms will be set to the minimum NRC levels.

IEQ Credit 1 - Outdoor Air Delivery Monitoring: The CO2 levels within the Early Learning Center are closely monitored by CO2 sensors. These sensors are within the Variable Frequency Drives to be able to control how much air is going into the space and if there need to be corrections based on the CO2 levels. - **1**

IEQ Credit 2 – Increased Ventilation: According to the comparisons with ASHRAE 62.1, Table 6, the outdoor air ventilation rates are not above 30% of the minimum values. Thus, this the building does not qualify for this credit. – **0**

IEQ Credit 3.1 – Construction Indoor Air Quality Management Plan – During Construction: The building has yet to start construction therefore has yet to address this concern. Standard practice limits the contaminants of air particulates on a construction site, which would make it reasonable the general contractor would be concerned about air quality but it is too add this credit. – **0**

IEQ Credit 3.2 – Construction Indoor Air Quality Management Plan – Before Occupancy: It is common practice to flush the building before construction ends to blow out all contaminants. There has been no communication between the general contractor, mechanical contractor and mechanical designers about this procedure, however, it is assumed it will be done. The credit will wait to be applied because it has not been specifically mentioned. – **0**

IEQ Credit 5 – Indoor Chemical and Pollutant Source Control: Water Source Heat Pumps within the building contain filters to protect against dust and pollutants, however, are only MERV-8 instead of the LEED required MERV-13. The credit cannot therefore be applied. - **0**

IEQ Credit 6.2 – Controllability of Systems – Thermal Comfort: Mechanical designers confirmed the space was compatible with ASHRAE Standard 55 to be within the 50% limits of comfortability for the space. In addition to ASHRAE Standard 55, operable windows have been designed on the exterior of the building to allow users their own personal preferences. – **1**

IEQ Credit 7.1 – Thermal Comfort – Design: The building was designed according to ASHRAE Standard 55 to comply with thermal comfort. An analysis was done to determine the activity zones and projected thermal clo values of the occupants therefore upon the conclusion of the study the temperatures and relative humidity levels in the building were adjusted to fit the occupants and their activity levels. - **1**

IEQ Credit 7.2 – Thermal Comfort – Verification: There has not been conversation about verification within the mechanical or architectural trades. A verification could be performed by asking the teachers their opinions however, the main population group is children and they may give inaccurate results based on their understanding of comfortability in space. – **0**

IEQ Credit 9 – Enhanced Acoustical Performance: Per specifications an STC-26 is specified for the classroom insulation and wall system. The wall system calls out 2" of high density acoustical insulation. As expected higher frequencies are more prone to reverberating through the wall but conversational and low frequency vibrations from equipment should be stopped. – **1**

Overall, the building scored 9 out of 33 possible points in the Energy and Atmosphere category and 4 out of 19 possible points in the Indoor Environmental Quality category. There is a possibility of adding more points in each category if a few next steps are taken to achieve the credits. Most of the credits that did not earn points are intertwined with the construction management and delivery of the project. Proper tracking and maintenance of the construction progress and site can lead to more points in both categories. Another viable option of upgrading the MERV-8 filters to MERV-13 filters can satisfy IEQ Credit 5. If a project goal, of the building, is striving for a LEED Certification it can be done.

Overall System Evaluation

The current systems in place address the needs and requirements set out by the owners in the Phoenixville area school district. Following the commitment to sustainability, the water source heat pump system is efficient at providing energy to such a large building. In the ERV units there are ten cumulative enthalpy wheels which will save the school district money and energy. The benefits of reusing the air and energy compared to exhausting the air into the atmosphere are unparalleled. Controls became a large part of this system with the occupancy sensors. Not only are the sensors for lighting and CO2 monitoring but they can shut down whole energy recovery ventilators if there are no people in the spaces. My critique with shutting down units though might be it will take longer to have the unit start and provide a comfortable environment again in a zone if a class comes back for a field trip or sporting event. The students and professor will be uncomfortable the first 10 – 15 minutes until the unit runs as designed.

Other improvements such as providing chillers instead of one specific cooling tower may provide a difference in energy savings. Having the large tower operate when half of the building is shutting down from occupancy seems counterproductive. Geothermal heat pumps were considered an option however, the location of the wells was going to provide a problem with the distance of pumping the fluid back to the building. Chilled beams may fit logically with central cooling.

References:

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

ANSI/ASHRAE (2013) 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.

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

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

USGBC LEED Reference Guide for Green Building Design and Construction. Washington, DC: U.S. Green Building Council, 2009. Print

APPENDIX A:

The following four pages are the Heating and Cooling Summaries of the design in Trane Trace 700.

SYSTEM SUMMARY
DESIGN COOLING CAPACITIES
By ACADEMIC

Alternative 1

Building Airside Systems and Plant Capacities

Plant	System	Peak Plant Loads: Main Coil ton	Aux Coil ton	Opt Vent Coil ton	Misc Load ton	Stg 1 Desic Cond ton	Stg 2 Desic Cond ton	Base Utility ton	Peak Total ton	Block Plant Loads: Time Of Peak mo/hr	Main Coil ton	Aux Coil ton	Opt Vent Coil ton	Misc Load ton	Stg 1 Desic Cond ton	Stg 2 Desic Cond ton	Base Utility ton	Block Total ton
Unassigned Cooling Loads		331.8	0.0	0.0	0.0	0.0	0.0	0.0	331.8	7/16	304.4	0.0	0.0	0.0	0.0	0.0	0.0	304.4
	ERV-1	67.0	0.0	0.0	0.0	0.0	0.0	0.0	67.0	7/16	59.2	0.0	0.0	0.0	0.0	0.0	0.0	59.2
	ERV-2	46.5	0.0	0.0	0.0	0.0	0.0	0.0	46.5	7/16	44.5	0.0	0.0	0.0	0.0	0.0	0.0	44.5
	Stair WSHP	6.2	0.0	0.0	0.0	0.0	0.0	0.0	6.2	7/16	3.4	0.0	0.0	0.0	0.0	0.0	0.0	3.4
	WSHP-89	1.3	0.0	0.0	0.0	0.0	0.0	0.0	1.3	7/16	1.3	0.0	0.0	0.0	0.0	0.0	0.0	1.3
	ERV-3	32.3	0.0	0.0	0.0	0.0	0.0	0.0	32.3	7/16	29.1	0.0	0.0	0.0	0.0	0.0	0.0	29.1
	ERV-4	40.1	0.0	0.0	0.0	0.0	0.0	0.0	40.1	7/16	40.1	0.0	0.0	0.0	0.0	0.0	0.0	40.1
	WSHP-20	4.1	0.0	0.0	0.0	0.0	0.0	0.0	4.1	7/16	4.1	0.0	0.0	0.0	0.0	0.0	0.0	4.1
	ERV-5	25.3	0.0	0.0	0.0	0.0	0.0	0.0	25.3	7/16	22.6	0.0	0.0	0.0	0.0	0.0	0.0	22.6
	ERV-6	38.1	0.0	0.0	0.0	0.0	0.0	0.0	38.1	7/16	38.1	0.0	0.0	0.0	0.0	0.0	0.0	38.1
	ERV-7	5.6	0.0	0.0	0.0	0.0	0.0	0.0	5.6	7/16	4.7	0.0	0.0	0.0	0.0	0.0	0.0	4.7
	ERV-9	9.6	0.0	0.0	0.0	0.0	0.0	0.0	9.6	7/16	7.1	0.0	0.0	0.0	0.0	0.0	0.0	7.1
	ERV-10	55.8	0.0	0.0	0.0	0.0	0.0	0.0	55.8	7/16	50.4	0.0	0.0	0.0	0.0	0.0	0.0	50.4
Building totals		331.8	0.0	0.0	0.0	0.0	0.0	0.0	331.8		304.4	0.0	0.0	0.0	0.0	0.0	0.0	304.4

Building peak load is 331.8 tons.

Building maximum block load of 304.4 tons occurs in July at hour 16 based on system simulation.

SYSTEM SUMMARY

DESIGN COOLING CAPACITIES

By ACADEMIC

Alternative 1

Building Airside Systems and Plant Capacities

Plant	System	Peak Plant Loads: Main Coil ton	Aux Coil ton	Opt Vent Coil ton	Misc Load ton	Stg 1 Desic Cond ton	Stg 2 Desic Cond ton	Base Utility ton	Peak Total ton	Block Plant Loads: Time Of Peak mo/hr	Main Coil ton	Aux Coil ton	Opt Vent Coil ton	Misc Load ton	Stg 1 Desic Cond ton	Stg 2 Desic Cond ton	Base Utility ton	Block Total ton
Unassigned Cooling Loads		288.2	0.0	0.0	0.0	0.0	0.0	0.0	288.2	9/15	243.3	0.0	0.0	0.0	0.0	0.0	0.0	243.3
	ERV - 1	44.4	0.0	0.0	0.0	0.0	0.0	0.0	44.4	9/15	36.8	0.0	0.0	0.0	0.0	0.0	0.0	36.8
	ERV - 2	42.4	0.0	0.0	0.0	0.0	0.0	0.0	42.4	9/15	33.0	0.0	0.0	0.0	0.0	0.0	0.0	33.0
	ERV - 3	35.6	0.0	0.0	0.0	0.0	0.0	0.0	35.6	9/15	28.6	0.0	0.0	0.0	0.0	0.0	0.0	28.6
	ERV - 4	30.4	0.0	0.0	0.0	0.0	0.0	0.0	30.4	9/15	27.9	0.0	0.0	0.0	0.0	0.0	0.0	27.9
	ERV - 5	43.8	0.0	0.0	0.0	0.0	0.0	0.0	43.8	9/15	41.0	0.0	0.0	0.0	0.0	0.0	0.0	41.0
	ERV - 6	22.7	0.0	0.0	0.0	0.0	0.0	0.0	22.7	9/15	17.9	0.0	0.0	0.0	0.0	0.0	0.0	17.9
	ERV - 7	7.3	0.0	0.0	0.0	0.0	0.0	0.0	7.3	9/15	6.3	0.0	0.0	0.0	0.0	0.0	0.0	6.3
	ERV - 8	8.4	0.0	0.0	0.0	0.0	0.0	0.0	8.4	9/15	7.7	0.0	0.0	0.0	0.0	0.0	0.0	7.7
	ERV - 9	13.1	0.0	0.0	0.0	0.0	0.0	0.0	13.1	9/15	12.0	0.0	0.0	0.0	0.0	0.0	0.0	12.0
	ERV - 10	40.0	0.0	0.0	0.0	0.0	0.0	0.0	40.0	9/15	32.2	0.0	0.0	0.0	0.0	0.0	0.0	32.2
Building totals		288.2	0.0	0.0	0.0	0.0	0.0	0.0	288.2		243.3	0.0	0.0	0.0	0.0	0.0	0.0	243.3

Building peak load is 288.2 tons.

Building maximum block load of 243.3 tons occurs in September at hour 15 based on system simulation.

SYSTEM SUMMARY

DESIGN HEATING CAPACITIES

By ACADEMIC

Alternative 1

System Coil Capacities

System Description	System Type	Main System Btu/h	Aux System Btu/h	Preheat Btu/h	Reheat Btu/h	Humid. Btu/h	Optional Vent Btu/h	Stg 1 Desic Regen Btu/h	Stg 2 Desic Regen Btu/h	Stg 1 Frost Prevention Btu/h	Stg 2 Frost Prevention Btu/h	Heating Totals Btu/h
ERV-1	Incremental Heat Pump	-619,227	0	0	0	0	0	0	0	0	0	-619,227
ERV-2	Incremental Heat Pump	-411,303	0	0	0	0	0	0	0	0	0	-411,303
Heating Only	Radiation (Heating Only)	-60,852	0	0	0	0	0	0	0	0	0	-60,852
Stair WSHP	Incremental Heat Pump	-44,632	0	0	0	0	0	0	0	0	0	-44,632
WSHP-89	Incremental Heat Pump	-16,310	0	0	0	0	0	0	0	0	0	-16,310
ERV-3	Incremental Heat Pump	-284,780	0	0	0	0	0	0	0	0	0	-284,780
ERV-4	Incremental Heat Pump	-328,160	0	0	0	0	0	0	0	0	0	-328,160
WSHP-20	Incremental Heat Pump	0	0	0	0	0	0	0	0	0	0	0
ERV-5	Incremental Heat Pump	-214,186	0	0	0	0	0	0	0	0	0	-214,186
ERV-6	Incremental Heat Pump	-317,289	0	0	0	0	0	0	0	0	0	-317,289
ERV-7	Incremental Heat Pump	-46,879	0	0	0	0	0	0	0	0	0	-46,879
ERV-9	Incremental Heat Pump	-70,808	0	0	0	0	0	0	0	0	0	-70,808
ERV-10	Incremental Heat Pump	-404,843	0	0	0	0	0	0	0	0	0	-404,843
Totals		**-2,819,268**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**-2,819,268**

Building Plant Capacities

Plant	System	Peak Loads												
		Main Coil MBh	Preheat Coil MBh	Reheat Coil MBh	Humid. Coil MBh	Aux Coil MBh	Opt Vent Coil MBh	Misc Load MBh	Stg 1 Desic. Regen. MBh	Stg 2 Desic. Regen. MBh	Stg 1 Frost Prev. MBh	Stg 2 Frost Prev. MBh	Base Utility MBh	Absorption Load MBh
Unassigned Heating Loads		2,819	0	0	0	0	0	0	0	0	0	0	0	0
	ERV-1	619	0	0	0	0	0	0	0	0	0	0	0	0
	ERV-2	411	0	0	0	0	0	0	0	0	0	0	0	0
	Heating Only	61	0	0	0	0	0	0	0	0	0	0	0	0
	Stair WSHP	45	0	0	0	0	0	0	0	0	0	0	0	0
	WSHP-89	16	0	0	0	0	0	0	0	0	0	0	0	0
	ERV-3	285	0	0	0	0	0	0	0	0	0	0	0	0
	ERV-4	328	0	0	0	0	0	0	0	0	0	0	0	0
	ERV-5	214	0	0	0	0	0	0	0	0	0	0	0	0
	ERV-6	317	0	0	0	0	0	0	0	0	0	0	0	0
	ERV-7	47	0	0	0	0	0	0	0	0	0	0	0	0
	ERV-9	71	0	0	0	0	0	0	0	0	0	0	0	0

ERV-10	405	0	0	0	0	0	0	0	0	0	0	0	0

Building peak load is 2,819.3 MBh.

SYSTEM SUMMARY

DESIGN HEATING CAPACITIES

By ACADEMIC

Alternative 1

System Coil Capacities

System Description	System Type	Main System Btu/h	Aux System Btu/h	Preheat Btu/h	Reheat Btu/h	Humid. Btu/h	Optional Vent Btu/h	Stg 1 Desic Regen Btu/h	Stg 2 Desic Regen Btu/h	Stg 1 Frost Prevention Btu/h	Stg 2 Frost Prevention Btu/h	Heating Totals Btu/h
ERV - 1	Incremental Heat Pump	-418,288	0	0	0	0	0	0	0	0	0	-418,288
ERV - 2	Incremental Heat Pump	-388,228	0	0	0	0	0	0	0	0	0	-388,228
ERV - 3	Incremental Heat Pump	-286,076	0	0	0	0	0	0	0	0	0	-286,076
ERV - 4	Incremental Heat Pump	-251,913	0	0	0	0	0	0	0	0	0	-251,913
ERV - 5	Incremental Heat Pump	-234,783	0	0	0	0	0	0	0	0	0	-234,783
ERV - 6	Incremental Heat Pump	-217,864	0	0	0	0	0	0	0	0	0	-217,864
ERV - 7	Incremental Heat Pump	-21,931	0	0	0	0	0	0	0	0	0	-21,931
ERV - 8	Incremental Heat Pump	-57,329	0	0	0	0	0	0	0	0	0	-57,329
ERV - 9	Incremental Heat Pump	-57,548	0	0	0	0	0	0	0	0	0	-57,548
ERV - 10	Incremental Heat Pump	-273,466	0	0	0	0	0	0	0	0	0	-273,466
Totals		**-2,207,426**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**-2,207,426**

Building Plant Capacities

Plant	System	Peak Loads												
		Main Coil MBh	Preheat Coil MBh	Reheat Coil MBh	Humid. Coil MBh	Aux Coil MBh	Opt Vent Coil MBh	Misc Load MBh	Stg 1 Desic. Regen. MBh	Stg 2 Desic. Regen. MBh	Stg 1 Frost Prev. MBh	Stg 2 Frost Prev. MBh	Base Utility MBh	Absorption Load MBh
Unassigned Heating Loads		2,207	0	0	0	0	0	0	0	0	0	0	0	0
	ERV - 1	418	0	0	0	0	0	0	0	0	0	0	0	0
	ERV - 2	388	0	0	0	0	0	0	0	0	0	0	0	0
	ERV - 3	286	0	0	0	0	0	0	0	0	0	0	0	0
	ERV - 4	252	0	0	0	0	0	0	0	0	0	0	0	0
	ERV - 5	235	0	0	0	0	0	0	0	0	0	0	0	0
	ERV - 6	218	0	0	0	0	0	0	0	0	0	0	0	0
	ERV - 7	22	0	0	0	0	0	0	0	0	0	0	0	0
	ERV - 8	57	0	0	0	0	0	0	0	0	0	0	0	0
	ERV - 9	58	0	0	0	0	0	0	0	0	0	0	0	0
	ERV - 10	273	0	0	0	0	0	0	0	0	0	0	0	0

Building peak load is 2,207.4 MBh.