Mechanical Systems: Redesign Proposal

Senior Thesis Revised Proposal

Thesis Project Revised Proposal
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Contents

Executive Summary:

Over the past fifteen weeks there has been comprehensive analysis done on the Phoenixville Early Learning Center to determine how it meets codes, compares to other buildings in energy usage, and an in depth review of the schematics of the mechanical system within the building. These previous reports can be found on my website. This report consists of a multifaceted proposal for future study on the Early Learning Center and how building systems would be different if the mechanical system was changed. It should be noted the purpose of these studies is not to imply insufficiency of the current design, however, they are to be evaluated for educational purposes.

In the depth analysis three different systems are brought to the fore front, comparing the current water loop heat pump system with the following systems; geothermal heat pump system with energy recovery ventilator, centralized air handling unit, and variable refrigerant flow (VRF) with energy recovery ventilator. Lifecycle cost analysis, feasibility, operating cost, space utilization, construction cost and energy usage studies will be completed on the previously mentioned systems on a basis to provide educational insight on how the equipment would perform within the building. At the end of the analysis one system will be chosen for recommendation to the board of the Early Learning Center.

Breadth analysis will consist of evaluating facets of various building systems that will be influenced by the change in mechanical systems. The breadths will be as follows, scheduling and cost impacts on construction of a geothermal heat pump system and an electrical load analysis of a VRF system on the building. Along with the specific studies relative to each breadth, lifecycle cost analysis and feasibility studies will also be conducted. In many parts of architecture if one system is changed it could have a profound impact on another system. These feasibility studies will look at not only the main mechanical change, but how other systems are effected.

The tools and methods of which the proposal will be carried out are described to provide an insight as to how the conclusions will be formed. Various tools and methods for calculation may be added at any time during the analysis if it may help the overall final project.

Finally, a schedule of work is provided giving insight as to the length of study and due dates for completion. Due dates will be hard deadlines set by myself to allow the project to stay on track and assure a quality final report and presentation at the end of the semester.

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

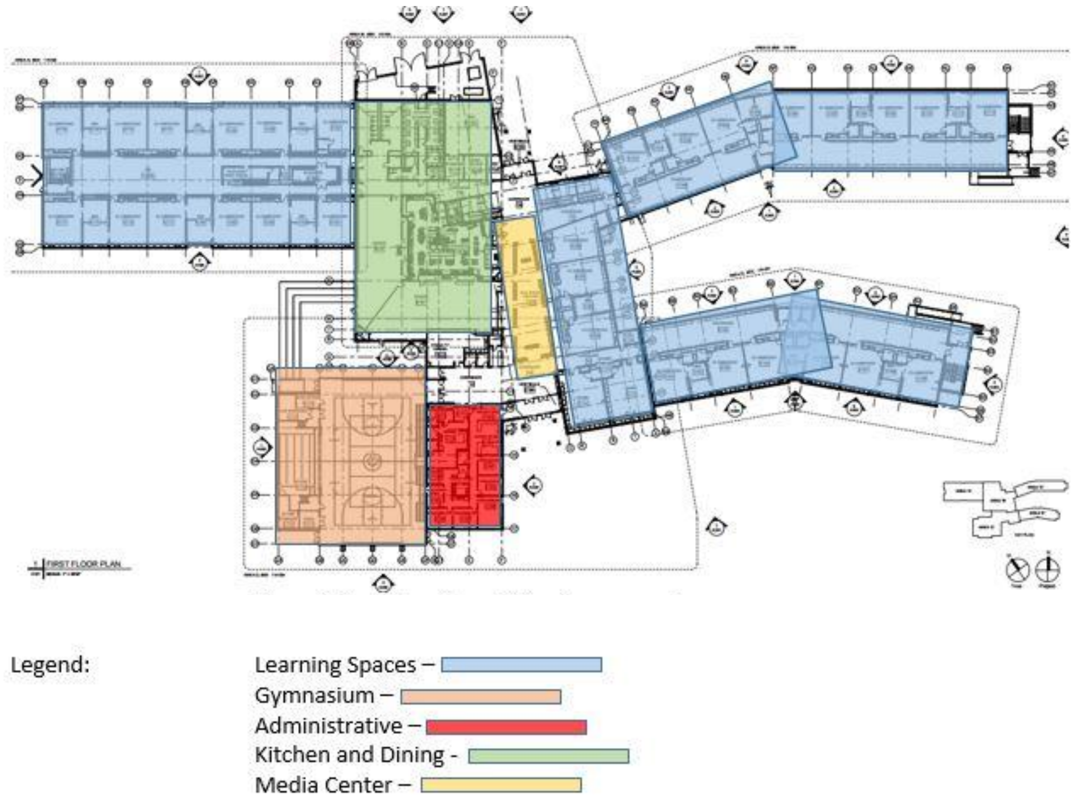

Figure 1: First Floor Plan with Basic Programming

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 loop 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 to save the school district energy, as well as manageable maintenance and the ability 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 bend boarders satisfying LEED points.

When analyzing 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.

Depths Considered

Design alternatives for the Phoenixville Early Learning Center are discussed below. These designs will be compared to the original system from studies of their performance in construction cost, space utilization, operating cost, ease of maintenance, and energy usage. Potential benefits, effects to the design as well as their impact on other systems will be taken into consideration to make a final recommendation for the owners of the Early Learning Center.

Geothermal Heat Pumps with Energy Recovery Ventilator:

An alternate design consideration is geothermal heat pumps combined with the current energy recovery ventilator units. Geothermal heat pumps use the ground as a heat sink in the summer and a heat source in the winter. During summer months heat from the building is put into the ground and the fluid is then cooled from the ground temperature. In the winter months, when the ground is warmer than the outside air, the fluid is heated by the ground and can reduce loads on the heat pumps. This is possible due to stable year-round temperatures roughly twenty feet below the ground. Heat pumps would need to be changed from water loop heat pumps to water to air heat pumps. Existing ERV units would remain to preheat the incoming outdoor air, allowing for even more energy savings. Tonnage and locations of the ERV units will be studied to assure they are compatible with the new system.

Geothermal heat pumps require an area for either vertical or horizontal wells to be drilled. Since there are many surrounding buildings, parking lots, and athletic fields surrounding the Early Learning Center a creative solution will need to be developed to place the wells close enough to the building.

Geothermal heat pumps have a high upfront cost which can be intimidating to owners however, they have a low annual cost, and take advantage of "free" energy which significantly increases their savings. Initial costs and pumping costs will need to be calculated for the analysis as well as a life cycle cost analysis to determine if he system is financially responsible. Reasons for studying geothermal heat pump systems is for further understanding and use in the industry as an energy saving solution to heat and cool buildings.

Centralized Air Handling Unit:

Adding a centralized air handling unit on the roof would provide the heating, cooling and ventilation in one unit. Studying centralized air handling units will aid in future workplace projects for retrofitting of existing buildings where air handling units have been common among older buildings. The advantages of this is the completeness in one unit. Air handlers are relatively easy to monitor and manage, have lower service costs and have a lower first time cost than many other systems. On the other hand, there needs to be large spaces for ductwork within the building and with large runs to the room come more pressure loss, thus, resulting in a stronger fan.

Within the air handler is a mixing box for mixing the return air with the outdoor air, filters to remove particulates in the air then it passes through cooling, humidifying, heating and finally the supply fan. Some air handling units have a preheat coil before the mixing so coils do not freeze in cold winter temperatures.

Adding a large unit on the roof would require structural resizing and analysis. Currently, there is not an area set up for the large load. Beams, joists, and columns effected would need to be resized. Acoustical considerations would also have to be factored into the location and placement of the unit. With classrooms below the roof, dampening strategies on the curb would be mandatory as to not disrupt the learning environment.

Variable Refrigerant Flow with Energy Recovery Ventilator:

Variable Refrigerant Flow (VRF) systems are being integrated in buildings as the technology is becoming more available in American markets. With the increasing use of VRF systems in the United States it would be a benefit to have knowledge of VRF systems. VRF systems start with a compressor, either located in the mechanical room or on the rooftop, and pump refrigeration into the building to the branch controller. The branch controller is the brain of the operation. At the branch controller it sends the appropriate amount of hot or cold refrigerant to the zones that need it. Within the terminal units there may be additional control of the temperature if the fluid is not at the correct temperature.

An advantage of having a VRF system is the high efficiency of heat transfer from refrigerant to room air. VRF systems allow for good zone control since each zone needs to have a terminal unit. Disadvantages of the system include maintenance costs, MERV filters are within the terminal spaces requiring they all need to be changed separately, and the limitation of distance between the outdoor and indoor units. The distance requirement is in place because performance of the system will decrease when the pipe runs are too long.

Breadth:

The following breadth topics relate closely with the mechanical depth topics. The two breadth topics are a result of the change of the air side heating and cooling system to a geothermal heat pump configuration as well as a VRF system and the effects the alterations have on various other building aspects. This analysis will help address the initial and long term impacts as well as cost considerations of the altercations.

Scheduling and Cost Impact on Construction:

Implementation of a geothermal heat pump system will have adverse effects on the schedule and cost impact of construction for the Early Learning Center. Wells will need to be drilled, fitted with pipes, pumps and then refilled all in a concise time schedule. The wells also need a location near the school to bore the holes for the wells. In the breath analysis, the drilling of geothermal wells will be analyzed to consider the impact on the critical path. Factors to be evaluated are number of wells, well orientation (horizontal or vertical), location of wells, depth and length of wells, extra equipment required for digging or installing the wells, lifecycle cost analysis, and construction schedule. Addressing these main points allows for the analysis to address concerns on the feasibility of a geothermal heat pump system. Studying the construction impacts of a geothermal heat pump system allow for the full understanding of the consequences and benefits of choosing a geothermal heat pump system.

VRF Electrical Impacts:

The second breath will examine the impacts of a VRF heating and cooling system on the electrical system of the building. The analysis will include analyzing building loads to determine if the electrical load increases or decreases. Due to the new load, large changes in wire sizing could have a grand impact on cost because conduit sizing will also be effected. Then, a redesign of the electrical system will occur to match the new heating and cooling system. An electrical redesign will provide a basis for electrical comprehension and understanding for future projects.

Tools and Methods:

The various tools and methods that are going to be used to test this proposal for the final report are listed below. All tools and methods are available at Penn State for their use on this project.

Trane Trace 700:

Trane Trace 700 will be used to perform energy modeling to test the various depth systems. These models will be able to be compared to the original system for energy usage and load estimation.

Life Cycle Cost Analysis:

A life cycle cost analysis will be performed for the various designs to determine financial feasibility. Excel spreadsheets will be used in the analysis with data from the energy models and other various sources.

Revit MEP:

Revit MEP will be used to design the VRF system layout and coordinate with other systems. This can provide a good estimation and provide options to any architectural changes that can happen because of the new system.

Proposed Semester Work Plan:

Located in Appendix A is a progress schedule for the spring semester. Major milestones consist of finishing depth analysis, completing breadth studies, completion of the final report and finishing the presentation power point. These deadlines will be hard deadlines set by myself to ensure a smooth flow over work over the semester. It is of the upmost importance to follow these deadlines to ensure the best product to present and write.

Research:

The following is a start to the research I will be conducting on the various systems. Over the next few weeks the sources will be accumulating to provide help on completing the analysis. Currently, I have just scraped the surface in looking at information regarding depths and look forward to continuing the research.

Geothermal Heat Pumps with Energy Recovery Ventilator:

Geothermal heat pumps are becoming a common choice for engineers when selecting systems to reduce energy usage because the systems can take advantage of free cooling or heating. Furthermore, geothermal heat pumps can simultaneously distribute heating and cooling at the same time in different zones. These systems offer an energy savings from other systems of about 25-50 percent depending on the climate of the building. Saving energy saves money and geothermal heat pump systems have become very competitive to schools where they are looking to keep their costs down.

Centralized Air Handling Unit:

Centralized Air Handling Units consist of one modular unit that will heat, cool and distribute air to the building. Benefits include space saving, because there are not secular units spread throughout the building. There does however, need to be a large space either on the roof or behind the building to put the unit. Centralized Air Handling Units are also easy to service, because they are composed of one unit rather than chasing the problem around the building. Units are normally built with access doors making changing of filters and normal maintenance simple. Another positive is since the units are modular, they can be added to and removed if the loads in the building change.

Variable Refrigerant Flow with Energy Recovery Ventilator:

Variable Refrigerant Flow (VRF) systems allow design flexibility for additional units to be added onto the system in case of reconfiguration or building expansion. VRF systems have advanced maintenance and commissioning procedures that allow them to maintain settings and have reduced water treatment issues. Energy Efficiency also plays a large roll in the VRF system selection because there is no duct system to lose heat, which typically loses about 10 percent of the air's heat in ductwork. VRF systems can provide simultaneous heating and cooling between different zones which provides a higher comfort rating for its occupants. Typically, to install VRF systems the initial cost is 5-20 percent higher than typical chilled water sources.

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APPENDIX A: Work Schedule

On the following page is the proposed work schedule for spring semester.

AE Senior Thesis Spring Semester Work Schedule

Project Phase/ Work Plan Description	Break	1/11	1/18	1/25	2/1	2/8	2/15	2/22	2/29	3/7	3/14	3/21	3/28	4/4	4/11	4/18	4/25
Phase 1:		Phase1								[Break]							
Initial Research																	
Update Proposal																	
Aquire Background information																	
Phase 2:					Phase 2												
Geothermal Heat Pump Redesign																	
VRF Assesment																	
Centralized Rooftop Assesment																	
Select Equipment																	
Trane Trace 700 Model																	
Comparison of Alternatives																	
Selection of Recommended System																	
Phase 3:									Phase 3								
Perform Construction Breath																	
Perform Electrical Breath																	
Phase 4:										Phase 4					Presentations	Phase 4	
Write Final Report														Practice Presentation			
Prepare Final Presentation																	
Final Assessment and CPEP Updates																	
Major Milestones																	
Proposal Complete - 1/22			[X]														
Finish Depth Analysis - 2/12						[X]											
Finish Breath Analysis - 3/4									[X]								
Complete Final Report - 3/25												[X]					
Complete Final Presentation - 4/1													[X]				

Notes: Will work during spring break if behind.