CareFirst Cumberland

Cumberland, MD

Final Report

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Mechanical Option

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ABSTRACT

PROJECT TEAM

Owner: CFBC Properties, LLC
General Contractor: Carl Belt, Inc.
Architects: VOA Associates, Inc.
Civil Engineer: SPECS, Consulting Engineers & Surveyors
MEP Engineer: R.G. Vanderweil Engineers, LLP
Structural Engineer: Tadjer Coher Edelson Associates, Inc.

BUILDING INFORMATION

Building name: CareFirst Cumberland
Location : Cumberland, MD
Building occupant: CareFirst of Maryland
Occupancy types: Office
Size: 46,739 SF
Number of stories: 2 Floors above grade
Construction Date: March 2010 - May 2011

ARCHITECTURAL

- ⇒ Designed for the healthcare & insurance office building
- ⇒ Clay brick course with weep and masonry capstone selected by owner
- ⇒ Curtain walls 4 corners of building

MECHANICAL

- ⇒ Cooling Tower on grade level
- ⇒ 30 vertical geothermal wells and 14 future use wells for service mechanical units
- ⇒ 100% outside air roof top unit with ventilation rate of 9000 CFM
- ⇒ Individual Air conditioning unit to supply elevator machine, telecom, and computer room

STRUCTURAL

- ⇒ 4" Normal weight Slab on galvanized steel deck with minimum 3 spans
- ⇒ Typical 24K8 Steel Joist and W27 girder supporting joist
- ⇒ Lateral Braced frames at enclosure staircases
- ⇒ Typical 6' x 6' Spread footing foundation
- ⇒ Roof deck 1.5" Galvanized steel deck over open web steel joist

ELECTRICAL

- ⇒ Main Switchboard rated at 1600 Amps
- ⇒ 80KW/100KVA Emergency Diesel Generator connected to fire pump controller, fire alarm system, and lighting for parking lot
- ⇒ Typical Lighting- 2x2 Recessed Fluorescent with T5HO lamp

http://www.engr.psu.edu/ae/thesis/portfolios/2012/cih5088/Thesis%20abstract.html

ACKNOWLEDGEMENTS

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Dr. William Bahnfleth Faculty Advisor, Penn State University

Moses Ling Mechanical Instructor, Penn State University

Stephen Treado, Mechanical Professor, Penn State University

Executive summary

CareFirst Cumberland currently has the geothermal heat pump system. The primary goal of the existing system was high energy efficiency and lower operating cost. Individual heat pumps serve each zone of the building to condition the space. A ventilation unit consisting of an energy recovery wheel, heating coils, and cooling coils, is located on top of the roof. Conditioned supply air is distributed by the rooftop unit with the minimum ventilation rate and reduces loads on the heat pumps. However, the existing geothermal heat pump system has high initial investment and possibility of operation failure when an underground temperature is too low or too high.

A direct-fired chiller/heater simultaneously operating with radiant panels is designed for an alternative mechanical system to reduce the initial investment and provide thermal comfort to occupants. The direct-fired chiller/heater replaces the existing geothermal system and serves as a central unit to produce hot water and chilled water. Hot water and chilled water produced by the direct-fired chiller/heater are supplied to both the cooling/heating coils in the rooftop unit and the radiant cooling/heating panels.

A main concern of this alternative mechanical system is properly controlling water temperature that enters to and leaves from the radiant cooling panel; temperatures of water lower than the designed dew point cause water vapor to form on the surface of the radiant panel. Temperatures and flow rates of hot water and chilled water are controlled to consistently maintain the comforts of zones. Another concern of this alternative mechanical system is higher operating cost, even if the system has lower initial investment than the existing mechanical system.

In this report, two ways to alleviate those concerns stated above are studied and analyzed: water temperature control for the radiant panels and operating mode controls. Chilled water pumps, hot water pumps, and condensate water pumps that are required for the Chiller/Heater will be installed in the existing mechanical room. The existing geothermal piping system and pumps will be demolished. Economics of the alternative mechanical system was analyzed and compared with that of the existing system.

In addition, a photovoltaic system is designed for on-site generation in order to reduce the operating cost. Even if the PV system is expensive to install, the system will reduce the payback period by making the operating cost even less. The PV system is designed to produce 10% of the total utility cost. Also, the noise exhausted form the equipment requires sound attenuation devices. The noise reduction through the existing partitions is not enough to meet the acoustical requirements of adjusting occupied spaces. Walls with high sound transmission level were selected based on the requirements and applied to the building.

Section One Thesis Background

1.1 Project Background

CareFirst Cumberland is located in Cumberland, MD, which is operated by the CareFirst Blue Cross BlueShield that offers healthcare insurance to residents of Maryland. In March 2010, CareFirst announced plans to expand into Cumberland, MD to provide claims processing and customer service for accounts of 100 or more members. CareFirst suggested the idea for the sustainable energy solution to the VOA Architect. The project team proposed the core design of the geothermal cooling/heating system. The architectural feature of the building remained simplicity using limited color and material on the exterior façade of the wall. With the continuous brick wall and extensive double pane glass around the perimeter area, the building forms a rectangular shape and is directed to four directions. At the middle of the building, a strip of the clay brick wall forms a separation of the space; it is used as a main lobby, elevator core, and breakout room. CareFirst mostly serves as an open office area. A main lobby, conference room, computer room, cafeteria, and exercise room features are located on the first floor of the building. On the second floor, beside an elevator core in the center, all other spaces are served as an open office area. The north end of the building remained undersigned for future tenant expansion.

1.2 Existing Mechanical Systems Summary

The mechanical system of CareFirst Cumberland has features of the geothermal source system with the Dedicated Outdoor Air System (DOAS), which primarily supports the ventilation of the building. Directly below the site parking lot, fifty of the geothermal wells connect into the mechanical piping system for the heat rejection and heat recovery. Ten of the geothermal wells connect as a one branch loop. Three of the geothermal loops use for the existing building load, and rest of the two branches will operate for the future expansion.

An air handling unit located on the rooftop controls outside air intakes. The energy recovery wheel on this rooftop unit operates as a heat exchanger between outdoor air and exhaust air. The main branch of the supply air ductwork enters through the ceiling of the second floor restroom and supply to the heat pumps on the second floor. The ductwork also connects to the first floor through the shaft that is located at the core of the building and supplies ventilation to the heat pumps on the first floor. The supply ductworks connect with the heat pumps located each zones to serve both heating and cooling load in the building. The auxiliary boiler and cooling tower were designed with geothermal heat rejection and heat recovery in case of the set temperature of the geothermal supply water temperature does not meet.

The IT Computer laboratory, elevator machines room and a few of the mechanical and electrical spaces condition with the separated air-conditioned unit, because these rooms are designed as base and heat pumps as tenants. Unconditioned space at the north end side is treated with the electrical heaters to not affect to the interior spaces, which are located right next to the future space.

1.3 Design Condition

The CareFirst Cumberland is classified as nonresidential conditioned space located in Cumberland, MD, corresponding to the cold-humid 4a climate zone determined by Figure 1/Table B-1 located in ASHRAE 90.1.2007.

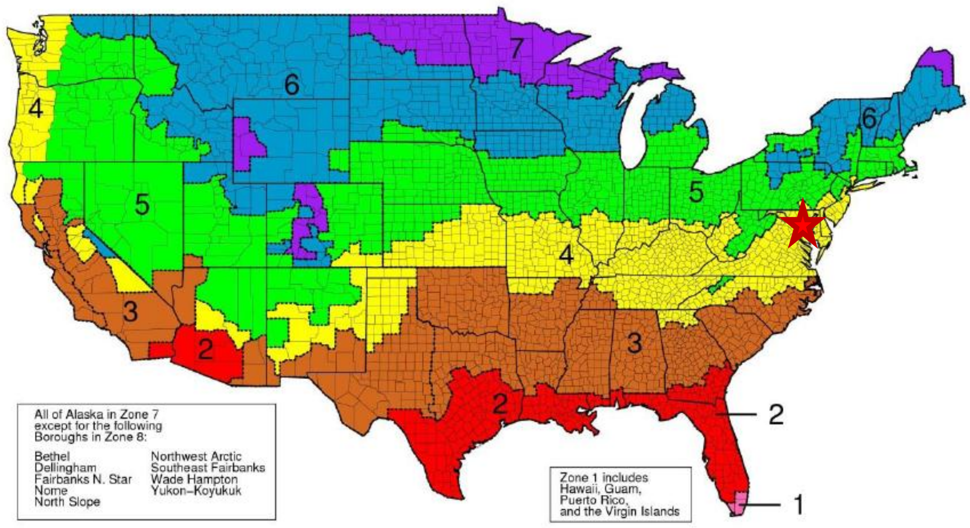


Figure 1 Climate Zone

Since there is no airport weather station in Cumberland, MD, the city of Baltimore, MD weather data used. According to 2009 Fundamentals ASHRAE Handbook, Baltimore located 39.17 N latitude and 76.68W longitude, which is similar to Cumberland, MD, which is 39.65N latitude and 78.76W longitude. The hottest month, which is July, cooling and dehumidification design conditions were selected for critical weather condition of 0.4%, outdoor weather condition is provided in Table-1. ASHRAE weather data is attached in Appendix 1.

	Summer		Winter	
	DB (^{0}F)	RH	DB (^{0}F)	RH
Outdoor Condition	93.9	43	12.9	-
Indoor Desing Condition	75	55	70	50

Table 1 Outdoor Condition

The design condition is designed by Vanderweil Engineers to provide comfort space to the occupants. The given data is used as the set temperature of the thermostat of each zone.

Typical Thermostat Parameter	
Cooling Dry Bulb (^{0}F)	75
Heating Dry Bulb (^{0}F)	70
Relative Humidity %	50$\pm$10
Cooling Drift Point (^{0}F)	80$\pm$3
Heating Drift Point (^{0}F)	60$\pm$3

Table 2 Designed Conditions

1.3.1 Existing Heating/Cooling Loads

The building load and energy Trane Air Conditioning economics 700, known as TRACE 700, is a HVAC design tool that has complete load, system, energy and economic analysis program for comparing energy and economic impact of buildings. This program was created by Trane, which is the HVAC equipment Distribution Company for commercial, industrial and institutional buildings.

Model Design

From the existing design, zones are separated with selected geothermal heat pumps. CareFirst is mainly used as an office building, but there are a few minor uses other than an office area, which are the office, conference, corridor, and lobby. There are more different uses of the space, but the templates are created based on the office building, corridor, and lobby. Some of the general uses of building, such as storage, waiting area, training room and café area are treated as the office area. Each template file with general data of internal load, airflow, thermostat, and construction data is automatically provided by the ASHARE 62.1and input into the model. Existing zones are treated as the room and input data of the space, such as area of the exterior wall and window. Four sided wall direction converts to the angle staring north as 0°. Each wall has an angle direction of 22.5^0, 112.5^0, 202.5^0, and 292.5^0. The area measurement of each room is attached in Appendix 2.

Load Assumptions

The construction documents, specifications, and relevant design calculation of CareFirst Cumberland are supplied by Vanderweil Engineers, LLC. The unknown data of the building is assumed using ASHRAE standards. For the general heat gain in the building from lighting, people, equipment, and solar energy from exterior construction data can be obtained from the ASHRAE Standard 90.1. This data is automatically selected in TRACE 700.

Occupancy Assumptions

The occupancy load of CareFirst is provided by Vanderweil Engineers, LLC. According to ASHRAE 62.1.2007 Table 6-1, the designed occupant density is known, which is in units of number of people per 1000 square feet. To compare with the design load, occupancy load is assumed using data from the ASHRAE Handbook.; the comparison is shown on Table-3. Designed occupancy load is 445 people in the building. With the ASHARE standard, the occupancy load is assumed to be 372 people. In order to design with the critical condition, Vanderweil Engineers over-estimates the occupancy load to be able to condition the space when occupancy in the building exceeds the minimum occupancy load of the building.

Modeled Occupant Density		
	People/1000sf	
Space	Designed	ASHRAE
Lobby	30	10
Office Spaces	7	5
Conference Rooms	50	50
Corridor	0	0
Total	445	372

Table 3- Occupant Density Comparison

Ventilation Assumption

The Vanderweil Engineers, LLC provided the designed ventilation rate of CareFirst Cumberland. According to ASHRAE 62.1.2007 Table 6-1, the minimum ventilation rate is in units of cubic feet per minute per person. Minimum ventilation rate of ASHRAE is lower than the designed, as shown in Table-3. Therefore, CareFirst supplies more air than the ASHRAE standard suggest as minimum ventilation rate. The designed ventilation rate of the building is 9000 CFM.

Modeled Ventilation Rate		
	cfm/person	
Space	Designed	ASHRAE
Lobby	15	11
Office Spaces	20	17
Conference Rooms	20	6
Corridor	0	0

Table 3-Ventilation Rate Comparison

Lighting and Equipment Electrical Load Assumptions

The typical lighting power densities provided in Table 9.6.1 ASHRAE Standard 90.1.2007. Designed lighting density provided and the light loads is calculated. The lighting power density power for designed and ASHARE chart is shown on Table 4. Designed lighting power density is greater than ASHRAE standard, therefore, the light loads of CareFirst is over-estimated. The electrical load is assumed to the 0.5 W/ft^2 for the office area.

Lighting Power Density		
	W/sq. ft.	
Space	Designed	ASHRAE
Lobby	1.5	1.3
Storage	1.3	0.8
Office	1.9	1.1
Post Office	2	1.2
Corridor	1	0.5
Conference	2	1.3
Food Preparation	2	1.2
Exercise Area	2	0.9
Playing Area	2	1.4
Seating Area	1	0.9

Table 4-Lighting Power Density Comparison

Construction

The information of the construction wall of CareFirst is provided in the construction document by the VOA Architecture. The exterior wall of CareFirst is assembled similarly all around perimeter of the building. Therefore, the exterior wall type uniform to face brick, 8" clay tile and 6" insulation. Other structural aspects of the building also are assumed, such as floor slab, on grade is 4" HW Concrete. The SBS modified roof membrane is assembled with ½" roof board, 4" rigid polyisocyanurate insulation, vapor retarde, ½" roof board, and 1 ½" galvanized roof deck. The existing roof system is replaced with 2" HW Concrete, 6" Insulation, due to limited range of the TRACE 700. Typical ¾" gypsum board interior partition and ¼" double glass are used as input data. The height of the exterior wall of each floor is 15', and the floor to ceiling height in the interior is 10'. The structural system and mechanical distribution system are included above the ceiling as well as plenum space for the returned air.

Schedules

CareFirst is specified as a general office building. Between 8am to 6pm on weekdays, the employees or clients of CareFirst are available, as an internal heat gain in the space. The operation of the building is lowered to minimum rate if the occupants are no longer available in the space. A designed schedule can be set to control the operation of the mechanical system.

Results

The result calculated load from the TRACE 700 is overestimated than actual designed load. Calculated cooling load is 153 ton and heating load is 1784 MBh. Comparing to the designed cooling load of the CareFirst results, the calculated designed load is undersized, shown on Table 5.

	Designed	Calculated
Cooling Load, tons	173	153
Heating Load, Mbh	2173	1784

Table 5-Designed vs. Calculated Loads

1.3.2 Existing Energy Consumption

CareFirst primarily uses electrical energy in the building. The building energy is divided to primary heating and cooling, auxiliary, and lighting. The breakdown of the energy used in each section is shown in figure-2.

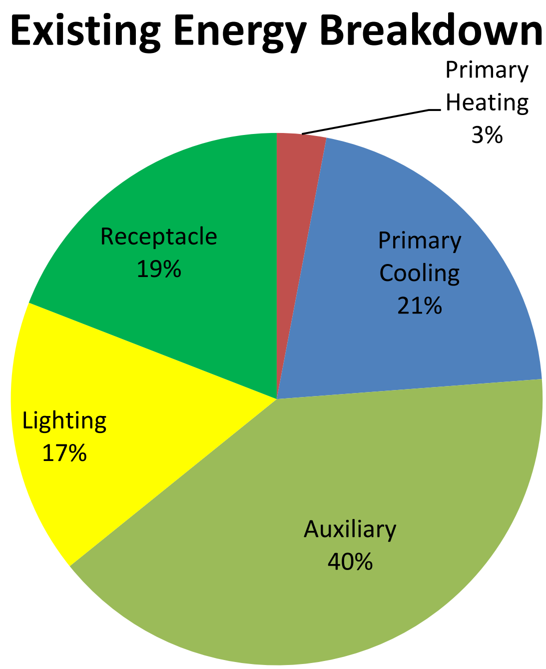


Figure 2 Energy Consumption Breakdowns

The auxiliary boiler operates with natural gas; however, its consumption is fairly low. The designed geothermal system can handle heat rejection and heat recovery and meet the set temperature of geothermal water supply. Trace 700 Report of the monthly energy consumption is shown in Figure-3.

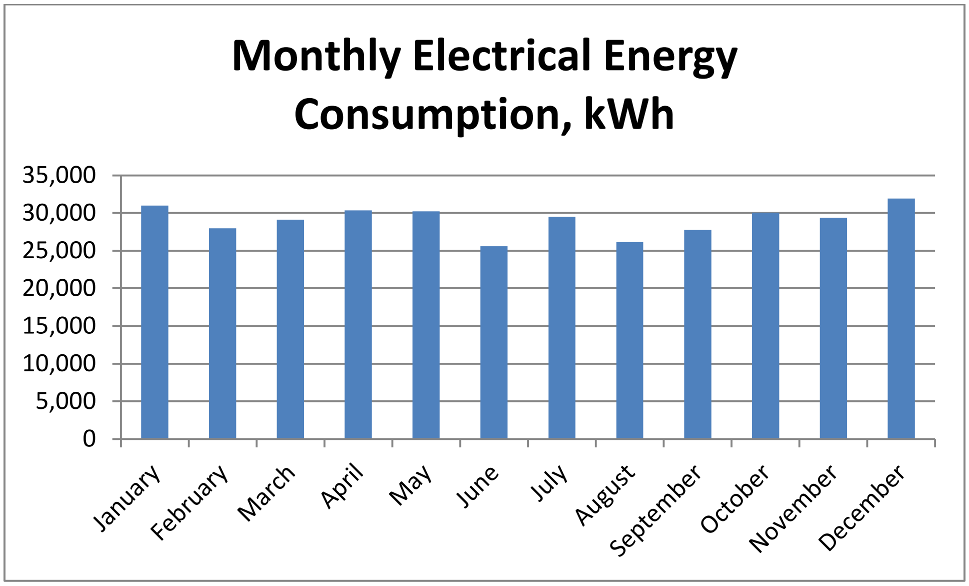


Figure 3- Monthly Electrical Consumption

For the secondary heat rejection, the cooling tower is used, and for the heat recovery, the boiler in mechanical room is used, but as mentioned, the boiler is rarely used in the building. Therefore, the natural gas connection had been disconnected. In December, the peak consumption occurs and lower consumption occurs in June.

1.3.3 Existing Energy Usage Cost

The cost analysis is evaluated by TRACE 700. Monthly utility cost is shown in Figure-4. The highest utility cost was in August and the lowest utility cost was in February. Average monthly utility cost is $3107 and annual utility cost is $ 37,283, which can be calculated to $1.01 per square foot per year.

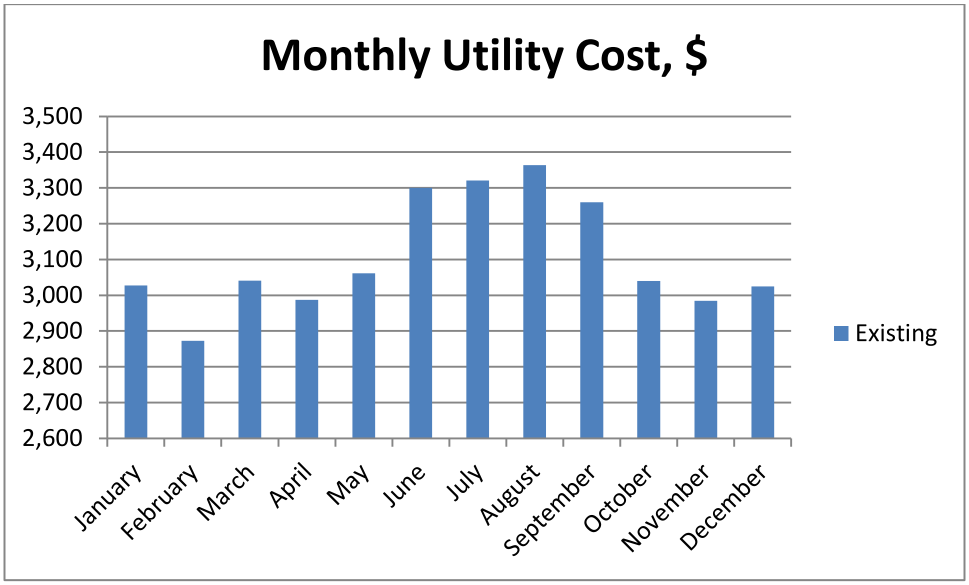


Figure 4~ Monthly Utility Cost

1.3.4 Existing Emissions Rate

By using the RegGridemissionfactors2007.pdf in AE481 mechanical database, the modeled natural gas can be calculated. In the Trace 700 energy model, environmental Impact Analysis has been made for the emission rate below on Table 6. Total CO_2 was calculated to be nearly 16 million pounds annually.

Environmental Impact Analysis	
CO_2 (lbm/year)	10,179,978
SO_2 (gm/year)	91,671
NO_X (gm/year)	17,543

Table 6-Emissions Analysis

1.6 Overall Evaluation

Overall existing mechanical system of the CareFirst Cumberland has expensive initial construction cost and less operation cost. The geothermal heat pump system has an advantage by having both heat rejection and heat gain from the ground, entering water temperature between 35°F to 90 °F. Individual heat pump units are located in each zone to condition the zone. This existing system may attract building owners and engineers because it is a renewable energy, energy efficient and low operating cost. However, initial investment of the system may concern the building owner financially.

1.7 Project Proposal

The existing geothermal heat pump system has high energy efficiency and low operating cost. However, the geothermal heat pump system is not always energy saving way to supply conditioned ventilation to the space. The temperature of supply geothermal water has a range of 35 °F to 90 °F. In the existing system, before geothermal water supplies to the individual heat pumps those serving zones, it is conditioned one more time by the auxiliary boiler and cooling tower. The temperature range is dropped down to 45 °F to 85 °F, and an average of 65 °F -70 °F. With the critical condition, the heat pump system may use more electricity over a period of time to provide the same amount of the heat gain and rejection.

The redesign of the mechanical system will focus on reducing capital cost and providing comfort conditioned space. The proposed redesign is replacing the geothermal system into a single unit, double effect absorption chiller, known as chiller/heater. The chiller/heater unit can provide heating and cooling simultaneously. It has three different operation modes: heating only, cooling only, and simultaneous mode. The operation mode of the chiller/heater holds the building energy consumption. The operation mode of the unit will analyze and compared to the energy consumption of the exiting design. In addition to proposed central plant, the radiant ceiling panel system will be replaced the individual heat pumps in the zones to improve thermal comfort. With the application of the dedicated outdoor air system, the radiant cooling panel and radiant heating panel applied to the ceiling to maintain the designed room temperature and humidity. The minimum required ventilation outdoor air supplies through the DOAS.

SECTION TWO THESIS MECHANICAL DEPTH

2.1 Alternative 2: Gas-Fired Chiller-Heater &DOAS System & Radiant Cooling/Heating Panel

2.1.1 Mechanical System Summary

The proposed mechanical system of CareFirst selects the gas-fired chiller/heater, the DOAS, and radiant ceiling panel. Chilled water and hot water is supply from the chiller/heater to the cooling/heating coil and the radiant cooling/heating panels. Through the energy recovery wheel, the outside air and exhaust air exchange enthalpy, and reduces loads on the coils. The individual unit of radiant panels maintains the set temperature by the convection heat transfer.

2.1.2 Absorption Refrigeration Cycle

Originally, the gas-fired absorption chiller produces chilled water with absorption refrigeration cycle. In the cycle, water is used as the refrigerant while lithium bromide is used as the absorbent. In the absorber, the lithium bromide absorbent absorb the water refrigerant and let water refrigerant dries out. In this process, the water refrigerant is changing phase liquid to gas and can reject the heat. Chilled water piping can be conditioned low as 41°F in the heat rejection process in an absorber. The lithium bromide absorbance is no longer concentrated to absorb more water refrigerant; therefore, diluted absorbent is pumped to the generator to vaporize the water refrigerant. Concentrated lithium bromide absorbent flows back to the absorber and heated water refrigerant moves to condenser to reject heated from heater water refrigerant. Condenser usually obtains heat rejection through a cooling tower, which is heat removal device by using evaporation process of water. Cooled water refrigerant flows back to the absorber to repeat the cycle. The explanation of the absorption refrigeration cycle is listed in Figure-5.

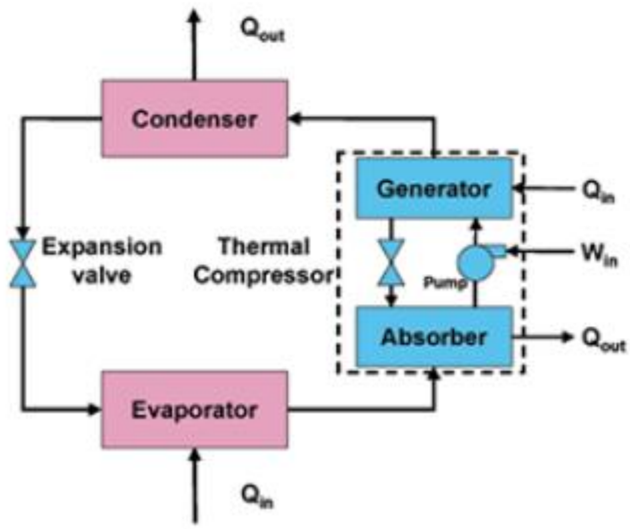


Figure 5- Absorption Refrigerant Cycle

2.1.3 Proposed Alternative System Design Approach

Gas-fired Chiller/Heater mainly operates by natural gas. Some of minor uses of electricity consume by the absorbent pump in the unit. Electrical energy is clean and easy to purchase from a central station, however, compare to natural gas, electricity has higher rate since it is converted energy form from the central station. In the absorption refrigeration cycle, when diluted absorbent heated to vaporize contained water refrigerant, input energy to generation replaced to the gas-fired heater. In this high temperature generation system, hot water supplies to the generator to vaporize the water refrigerant. In the chiller/heater unit, hot water closed piping connects to the gas-fired heater to produce hot water temperature up to 175°F. The operation mode of the chiller/heater will be analyzed further more in this report.

The existing system incorporated DOAS system with the vertical closed-loop geothermal heat pump system. For the proposed distribution air side, the Dedicated Outdoor Air System (DOAS) persists and integrated with the radiant ceiling cooling and heating panels. The selected panel for the alternative system includes radiant panel with center slotted air diffuser. With this slotted air diffuser, the minimum requirement of ventilation can supplied. Instead of supplied air temperature lower to 55°F, temperature can be arranged and resigned with the radiant panel design. The selection of the radiant panel and supplied and returned temperature of water-side and air-side will be analysis further in this report.

2.1.2 Operation System

The proposed alternative of the mechanical system of CareFirst contains three major parts: the Gas-Fired Chiller/Heater, Dedicated Outdoor Air System, and Radiant Ceiling Cooling/Heating Panels. The Gas-Fired Chiller/Heater unit located in the mechanical room and connected to 6-pipes, which are supplied and returned chilled water, hot water, and condensed water. Layout of the equipment in the mechanical room is attached in Appendix-3

In the heating load season, the Chiller/Heater operates in heating mode only and hot water supplies to the radiant heating panel in the perimeter zone. The free cooling of the rooftop air-handling unit supplies conditioned air to the interior zones. In cooling load season, the Chiller/Heater operates in cooling mode only and supplies chilled water to both perimeter and interior zones. Low temperature of the chilled water is designed to supplies to the cooling coil in the RTU to handle dehumidification of the latent loads and avoid condensation issue in the radiant cooling panel. Returned chilled water can supply to the radiant cooling panels in the zone to maintain the set point room temperature. For the radiant heating panels, condensation issue is not applicable, therefore, high temperature hot water supplies the heating panels in the zones first, and then the returned hot water supplies to the heating coil of the RTU. Designed schematic drawing is provided in Appendix-4.

The rooftop air-handling unit supplies ventilation to both of the zones. The rooftop air-handling unit contains energy recovery wheel to pre-condition the outside air before it passes the heating and cooling coils. The rooftop unit mainly operates for the ventilation, however, the energy recovery wheel; the heating and cooling coils can pre-conditioned the supplied air to take part of the heating and cooling load of the building. In the perimeter zone, the selected radiant ceiling panels require to handle both heating and cooling loads. In the interior zone, the radiant ceiling panels only required to handle cooling load in both cooling and heating season due to internal heat gains.

2.2 *Analysis 1:* Radiant Ceiling Panels

2.2.1 Proposed Alternative System-Why Radiant Ceiling Panels?

The proposed alternative system imposed the radiant ceiling panel. The natural circulation of the air movement depends on temperature of the air, which is cold air gravitates toward the floor and hot air inclines to the ceiling. Therefore, ideal radiant system is the radiant cooling panel adapted into installed on the ceiling and radiant heating system embedded into the concrete floor system. However, the proposed alternative has redesigned to reduce first cost of the installation, therefore, if both cooling panel and heating floor system applies to the alternative, the first cost of the alternative increased from the existing geothermal system.

The forced-air heating system eliminated for the proposed alternative system, because it may cost more from duct distribution system. Also, the radiant cooling/heating system is preferred by people with allergies. The ventilation system still remains as the existing designed, therefore, the size of ductwork can remain same. Only change of the ventilation system is replacing connection to the air diffuser, which is applied to the radiant panels.

2.2.2 Proposed Alternative System-Design Approach

For the proposed alternative, the radiant cooling panel system may cause condensation Issue. If the temperature of supplying chilled water through the panels is lower than the dew point temperature of the set point of the zone, condensation form on the surface of the cooling panels. The cooling panel are mounted directly on ceiling and exposed to the space to heat reject and recovery of the zone, therefore, it is hard to have condensation pan and return pipe, because this will lack performance of the panel. Without condensation pan and piping, the associated adverse biological generation may occur, such as moles on the ceiling panel.

The proposed alternative uses a DOAS to remove all of the space latent loads, and rest of the space sensible loads can handle by the cooling panels. The energy recovery wheel in the DOAS can reduce the OA loads on the cooling coil and the cooling coil can reduced the required loads on the cooling panel. This reduces energy demand and consumption as well as reduced the Chiller/Heater size.

For the alternative design approach, the space latent load can be calculated by total cooling load minus total sensible load, however, according to the ASHRAE 62.1, occupant latent load per person with general office activity assume to be 205 Btu/h. The number of occupancy already assume for the existing. In this case, infiltration and other source of the latent loads are negligible. Total latent load of the building is on table-6.

Occupant Latent Load (Btu/h-person)	Number of Occupancy	Total Latent Load (Btu/h)
205	445	91225

Table 6-Total Latent Load

The designed ventilation rate also provided and this will apply same to the proposed alternative. Since the proposed alternative primarily designed for radiant heating/cooling system, the forced-air system can limited to the minimum ventilation of the building. The condition ventilation through the energy wheel and cooling coil can handle part of the building load, and rest of the loads can handle by the radiant cooling panels in the zone.

The total building cooling load calculated to be 153 tons and this can be converted to the 1,836,000 Btu/h. The selected Chiller/Heater has capacity of minimum leaving chilled water temperature of 41°F and maximum 53°F. The temperature of minimum leaving chilled water temperature does matter, because it cannot be lower than 55°F through the cooling panel. However, the supply chilled water must able to satisfy the designed cooling load of the building. Chilled water temperature difference can be selected between 5.5°F and 18.5°F, but must fall within acceptable water pressure drop levels and allowable capacity range.

In order to define the flow capacity of the Chiller/Heater, temperature difference of the entering chilled water and leaving chilled water should be designed. Using an equation given, known data is desired cooling load q and few limits on delta T. The temperature of the cooling panel must higher than a dew point temperature of the space. In a cooling season, designed room condition is set to 75°F DB and 50% RH, and its dew point temperature results to be 55°F as shown in the psychometric chart below. Therefore, the temperature of the entering water must more than 55°F, because the temperature of the entering water to the cooling panel must set to more than 55°F to avoid condensation.

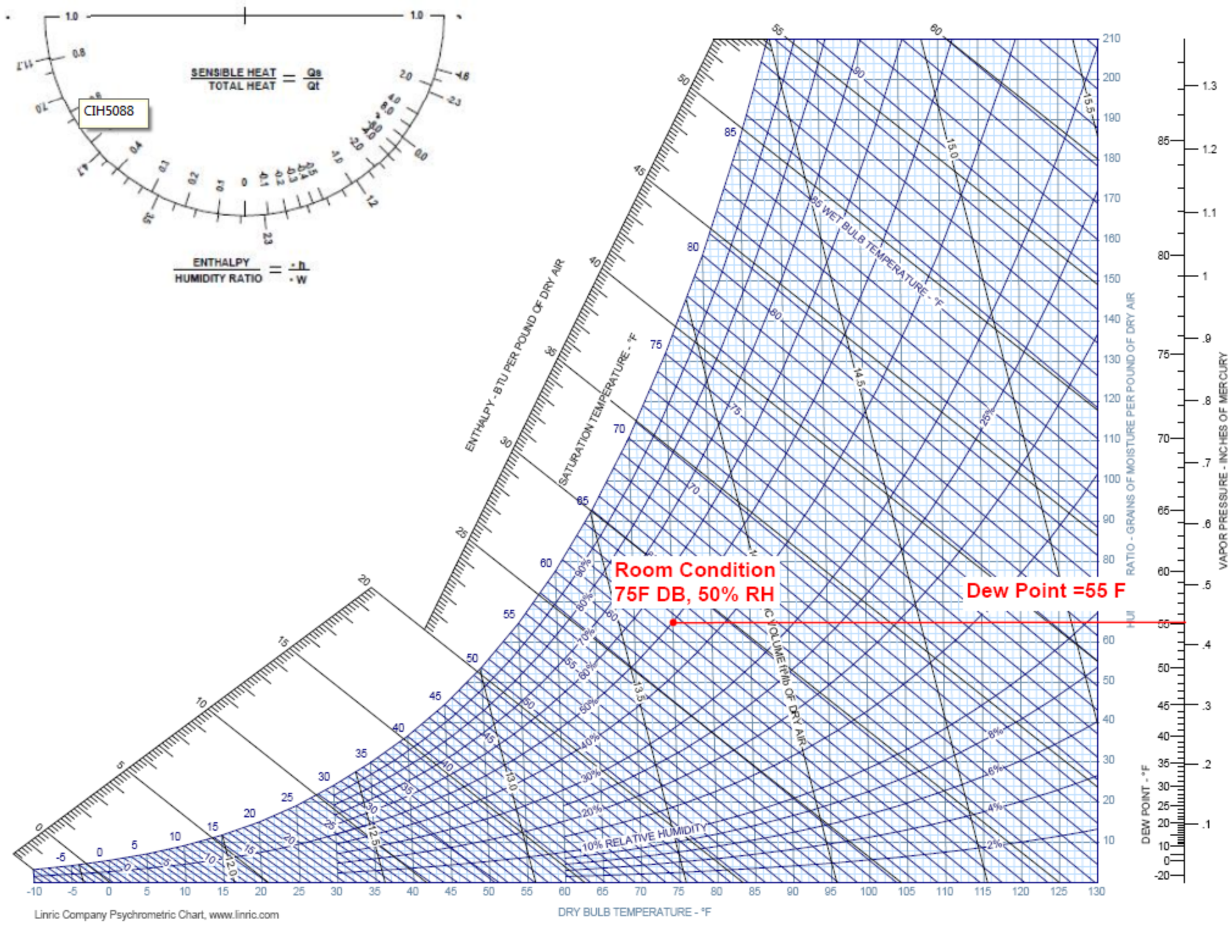


Figure 6~ Dew Point Temperature of the Space

Since the delta T range of the Chiller/Heater is between 5.5°F to 18.5°F, the delta T range between 10.5°F to 15.5 have selected for the GPM calculation. The temperature of the leaving water is also known, which is between 41°F to 53°F. With five different delta T range, the result of calculation is on table-7

ΔT	GPM
15.5	237
14.5	253
13.5	272
12.5	294
11.5	319
10.5	350

Table 7~Chiller/Heater GPM Calculation

With the given leaving water temperature range, the entering water temperature also calculated using GPM, that was calculated by six different delta T. The result above the 55°F automatically eliminated from further calculation.

Now, the leaving chilled water supplies to the cooling coil of the RTU. The RTU contains energy recovery wheel before the OA enters through the cooling coil. The OA and EA exchange heat through the energy recovery wheel, and resulted to be Therefore, the temperature of conditioned OA from the energy recovery wheel is used to calculate the temperature of leaving water of the cooling coil, which is must higher than 55°F. The conditioned air from the energy recovery wheel calculated with critical weather condition in Cumberland and the returned air, shown on table-8. Using this conditioned air, the cooling coil must designed handle the space latent loads.

Energy Recovery Wheel			
	Outside Air	Return Air	Conditioned Air
Dry Bulb, (°F)	93.9	78	85.8
Relative Humidity, (%)	43	60	50
Specific Volume of DB, (ft^3/lba)	14.3	13.8	14.05
Flow rate of Dry Air, (lba/min)	629.4	652.2	
Ratio of Dry Air	0.4911032	0.5088968	

Table 8~ Conditioned Air by Energy Recovery Wheel

The space latent loads assumed, and from the conditioned air, the humidity ratio of the supply air must drop down to 83.4 grain of moisture per pound of dry air. Difference of the humidity ratio required calculation is shown on table-9.

Required Latent Load			
q_lat	0.69	CFM	delta W
91225	0.96	9000	10.6

Table 9~ Required Humidity Ratio

The minimum temperature of supply air must be 61°F or lower. The difference between conditioned air and supply air is now 24.8°F. Besides of the latent load, some of the sensible load can condition by this process. About 15% of the cooling load can be done by the cooling coil in the process of the dehumidification. The required cooling load on the cooling panel is about 1595,000 Btu/h. The total heat rejected is calculated using differences in the enthalpy of the conditioned and supply air, and some of the sensible loads can conditioned by the cooling coil, the calculation is shown on table-10.

Sensible Load_Cooling coil			
q_sen	1.08	CFM	delta_T
241056	1.08	9000	24.8

Table 10~ Designed Sensible Load on Cooling Coil

The total heat reject calculated with using difference of the enthalpy of the conditioned and supply air, which is 307,800 Btu/h, shown on table-11.

Grand Load_Cooling Coil			
q_tot	4.5	CFM	delta_h
307800	4.5	9000	7.6

Table 11~Desinged Total Load on Cooling Coil

Total heat rejection must equal to the heat gain to the chilled water system. The entering chilled water temperature can be varied; therefore, the leaving chilled water temperature calculated with given entering GPM of the chilled water. Range of the selection is shown on table-12.

Cooling Coil_water	
GPM	ΔT
237	2.6
253	2.4
272	2.3
294	2.1
319	1.9
350	1.8

Table 12~ Cooling Coil Capacity

The minimum chilled entering temperature of the cooling panel must exceed 55°F, and the result reduced to three options. The temperature of the leaving chilled water is not below the dew point temperature; therefore, this three option water temperature can be used for selection of the equipment. Designed entering and leaving water temperature is shown on Table-13.

Water-Side Design									
Chiller				Cooling Coil			Cooling Panel		
EWT	LWT	ΔT	GPM	EWT	LWT	ΔT	EWT	LWT	ΔT
68.5	53	15.5	237	53	55.6	2.6	55.6	69.1	13.5
67.5	53	14.5	253	53	55.4	2.4	55.4	68.0	12.6
65.5	53	12.5	294	53	55.1	2.1	55.1	66.0	10.9

Table 13- Water Side Design Selection

2.2.3 Proposed Alternative System- Equipment Selection

With the designed entering and leaving temperature, the radiant cooling panel can selected. The Aritite offers radiant ceiling system with the center slotted air diffuser. The required cooling load on the radiant cooling panel calculated to be 1,595,000 Btu/h. The selection of the cooling panels is listed by heat rejection rate by the area of the cooling panels. The capacity of 72 Btuh/SF is selected for the proposed designed. The total area of the cooling panels will be 22,150 ft^2, which is 50% of the total building area. The layout of the cooling and heating panels of the first and second floor is attached to the Appedix-5.

2.3 *Analysis 2:* Gas-Fired Chiller Heater Operation Mode

2.3.1 Proposed Alternative System-Chiller/Heater

From the previous calculation on the radiant cooling panel selection, the required cooling load of the building is 153 tons. The Chiller/Heater selection procedure guide is provided from the McQuay. Using the given procedure, the required cooling load and heating load is used for the selection of the Chiller/Heater. McQuay Direct Fired Chiller/Heater, DC-14U has 180 tons of cooling capacity and 1,800 MBH of heating capacity. The water entering and leaving temperature is designed based on the required cooling heating load of the building. The designed water temperature of the condensed water, chilled water, and hot water is provided on table-14.

	EWT	LWT	GPM
Cooling Tower			
Condensed Water	85	95	673.8
Chiller/Heater			
Chilled Water	65.5	53	294
Hot Water	127.9	140	294

Table 14- Cooling Tower and Chiller/Heater Capacity

2.3.2 Proposed Alternative System-Operation Mode

The designed cooling and heating load represents peak load of the year. Therefore, the Chiller/Heater does not operate with the peak load. The Chiller/Heater operates in 3 modes: heating only, cooling only, and simultaneous mode. Annual Loads of CareFirst of each month is shown figure-7. In November to February, the operation mode controls the unit as heating only mode. In June to September, the operation mode is changed to the cooling only. Other than heating and cooling load, simultaneous mode operates to produce both the heating and cooling load of the building. However, the simultaneous mode is only little percentage of the annual loads, because, in the heating season, the cooling load of the interior can be controlled with the OA if the temperature of OA is lower than the room temperature and not too cold.

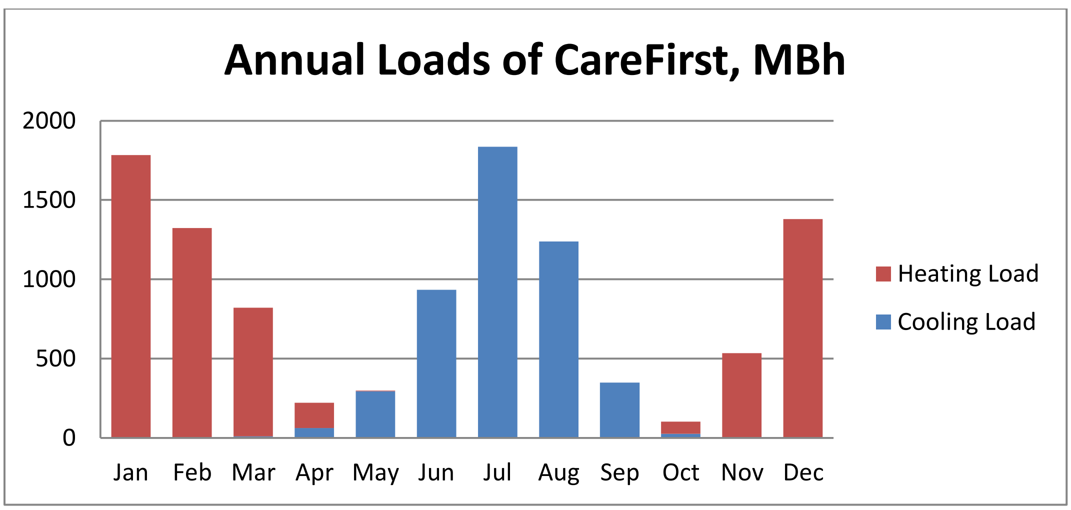


Figure 7- Annual Desired Loads

2.3.3 Proposed Alternative System-Partial Load Operation

The chiller/heater does not always operate in full capacity. Almost 99% of time, the chiller/heater operates in partial load operation. Therefore, the integrated part load value, IPLV is used as the coefficient of performance of the chiller heater. The distributor of the chiller/heater provides the C.O.P in 4 different levels. The table of the C.O.P is shown in table-15.

ARI #560-2000 Performance	
% Load	TSA-DC C.O.P.
100	1
75	1.154
50	1.25
25	1.136

Table 15- Coefficient of Performance of the Chiller/Heater

With the efficiency of the equipment at capacities of 100%, 75%, 50%, and 25%, the integrated part load value is calculated. This value is very important value to consider since it can affect energy consumption and operating cost. Using the following equation, the IPLV of the chiller heater is 1.193. The equation is provide to calculate the IPLV, is shown Figure 8.

IPLV (or NPLV) = 0.01A+0.42B+0.45C+0.12D

Where:

A = COP or EER @ 100% Load

B = COP or EER @ 75% Load

C = COP or EER @ 50% Load

D = COP or EER @ 25% Load

Figure 7- IPLV Formula

With the calculated IPLV, the input energy or energy consumption of the partial load operation of the chiller/heater can be calculated each month. The output of the energy is more than input of energy. Each input and output of energy of the chiller/heater is shown in Figure-8. In July, the energy consumption is the highest of the year, and in October, the energy consumption is the lowest of the year.

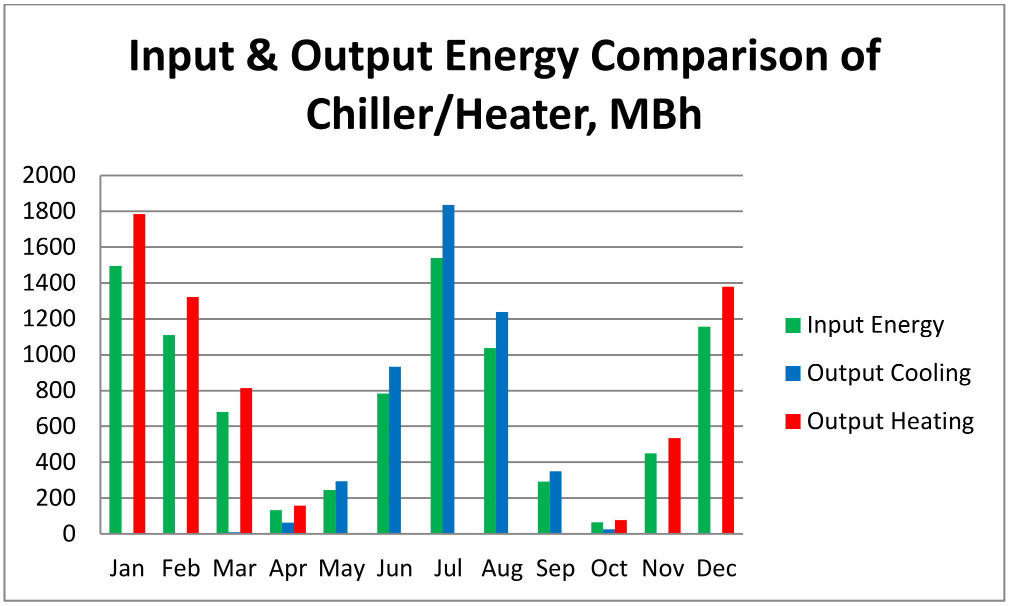


Figure 8- Input vs. Output of Chiller/Heater

In simultaneous mode, both hot water and chilled can produce at the same rate, however, the produced heating and cooling demand does not consume the overflow energy. Therefore, the produced energy is wasted in a simultaneous mode if one of the demand loads is lower than another. Out of twelve months, four months are in a simultaneous mode. The amount of the wasted cooling and heating energy indicated in graph below. Total 738 MBh of the cooling energy produced and not used and 243 MBh of the heating energy produced and not used, is shown on Figure-9.

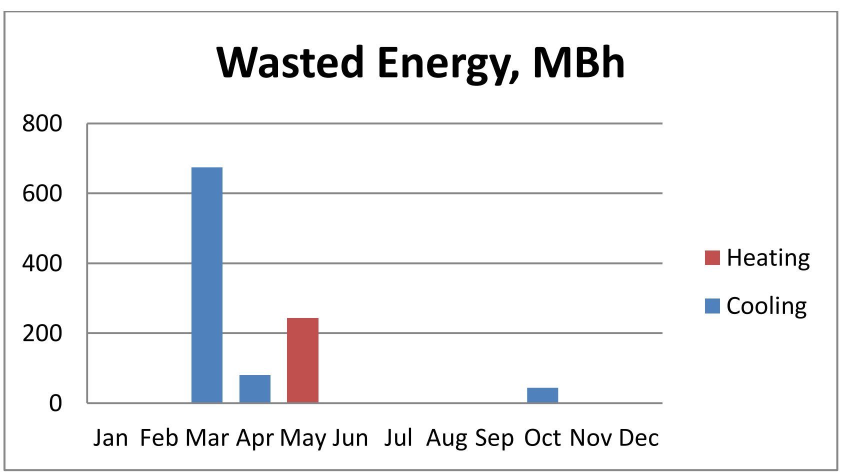


Figure 9- Wasted Energy from Simultaneous Mode

2.3 Energy Consumption Comparison

The proposed alternative mainly used the energy in primary cooling. The breakdown of the each section is shown in figure-10.

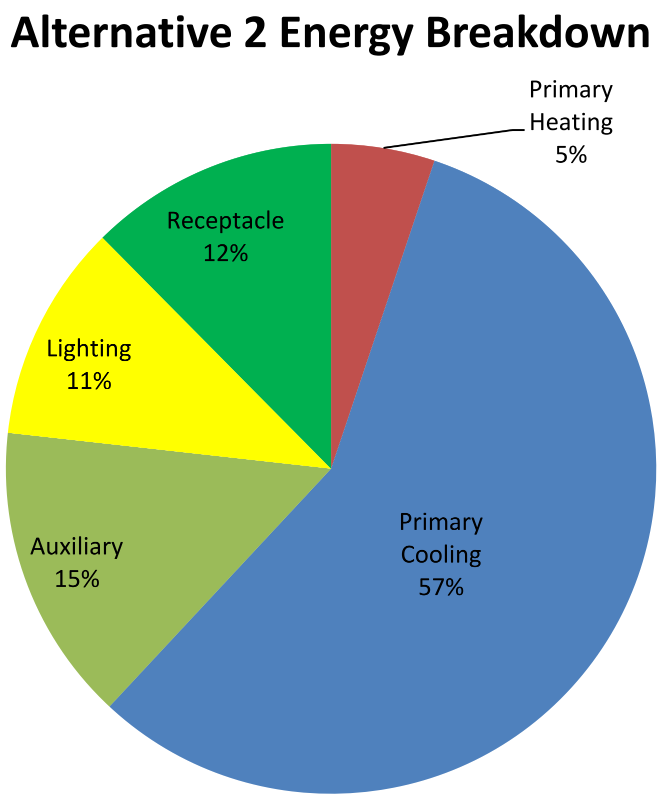


Figure 10- Alternative Energy Consumption Breakdowns

The breakdown of the energy consumption of the existing and proposed alternative is compared in figure below. In the existing system, the auxiliary system consumes most of the building energy and, in the proposed alternative system; the primary cooling consumes most of the building energy. The energy consumption breakdowns of the existing and alternative are compared in Figure-11.

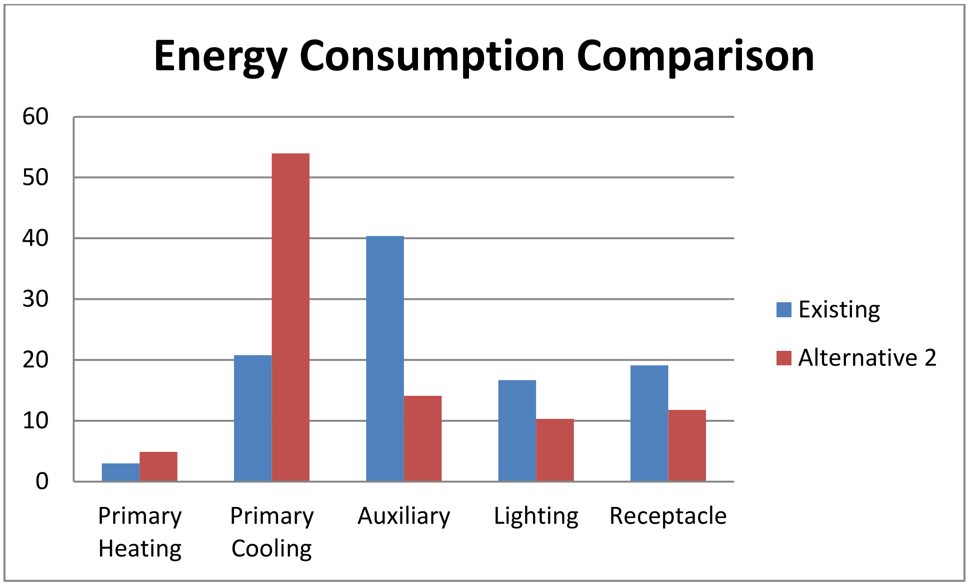


Figure 11~ Energy Consumption Breakdowns

For the existing, the electricity is the primary energy source of the building. Nearly 350,000 kWh of electricity is consumed annually. Compare to the existing, the proposed alternative system consumes 205,750 kWh annually. The monthly electricity consumption is compared in Figure-12

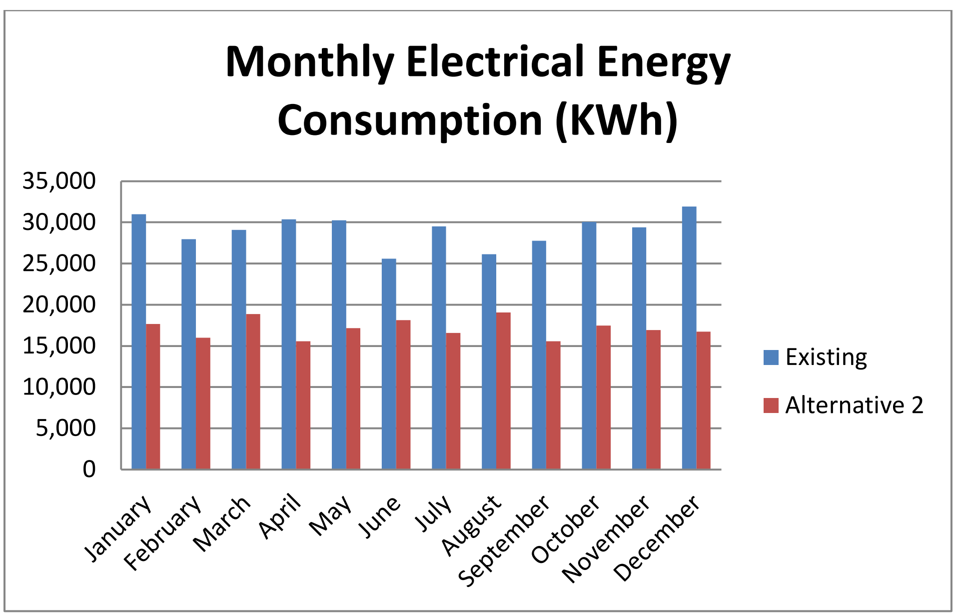


Figure 12~ Monthly Electrical Consumption

The energy consumption of the electricity of the proposed alternative is lower than the existing; however, the natural gas energy consumption of the alternative is primary source of the Chiller/Heater. The auxiliary boiler and cooling tower are designed for the existing system; however, with minimum uses of the boiler, the natural gas utility connection is no longer available. The comparison of the natural gas consumption is shown in Figure-13.

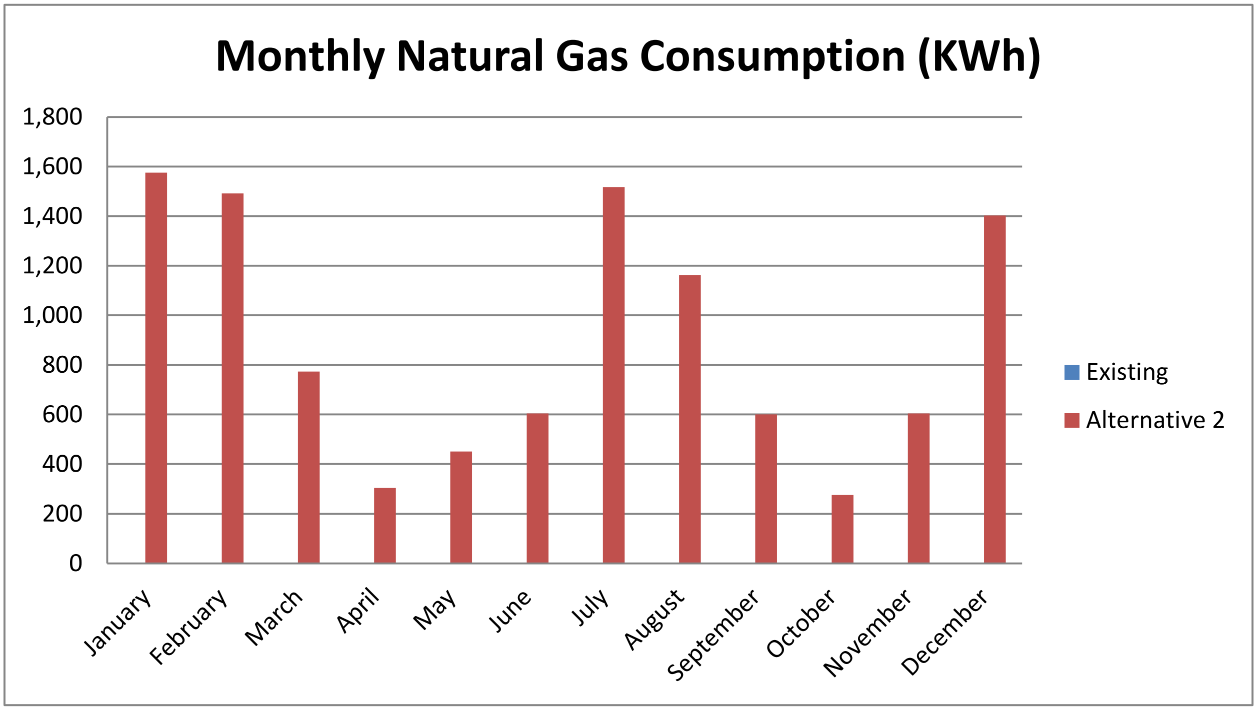


Figure 13- Monthly Natural Gas Consumption

2.4 Economic Consumption Comparison

The first cost of the existing geothermal system is much expensive than the proposed alternative. However, the existing system has lower operating cost. The comparison is shown in Figure-14.

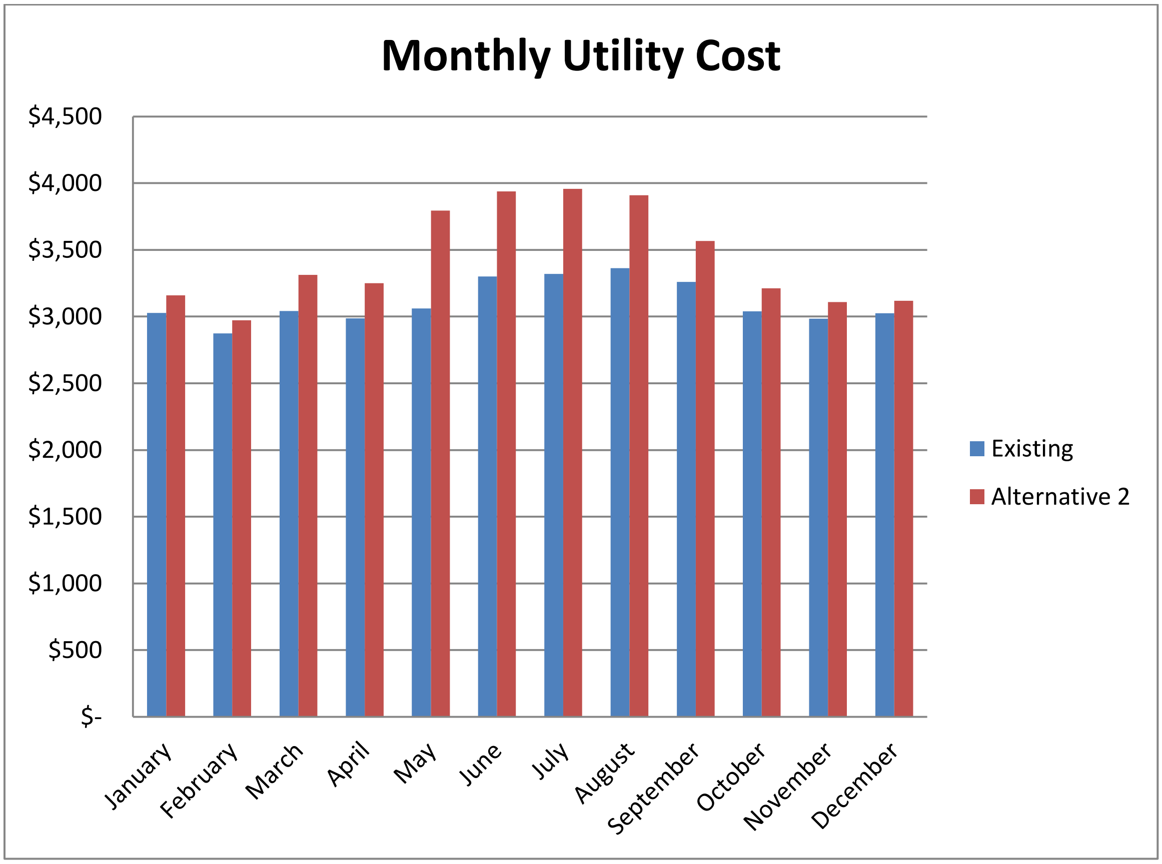


Figure 14- Monthly Utility Cost Comparison

The capital cost of the proposed alternative is almost half of the existing system. The capital cost includes only the equipment and major installation fee. For the existing, the geothermal system and auxiliary boiler are grouped as central plant, and the heat pumps are indicated as distribution systems. For the alternative, the chiller/heater is part of the central plant and the radiant cooling/heating panels are treated as distribution systems. The capital cost comparison is shown in Figure-15.

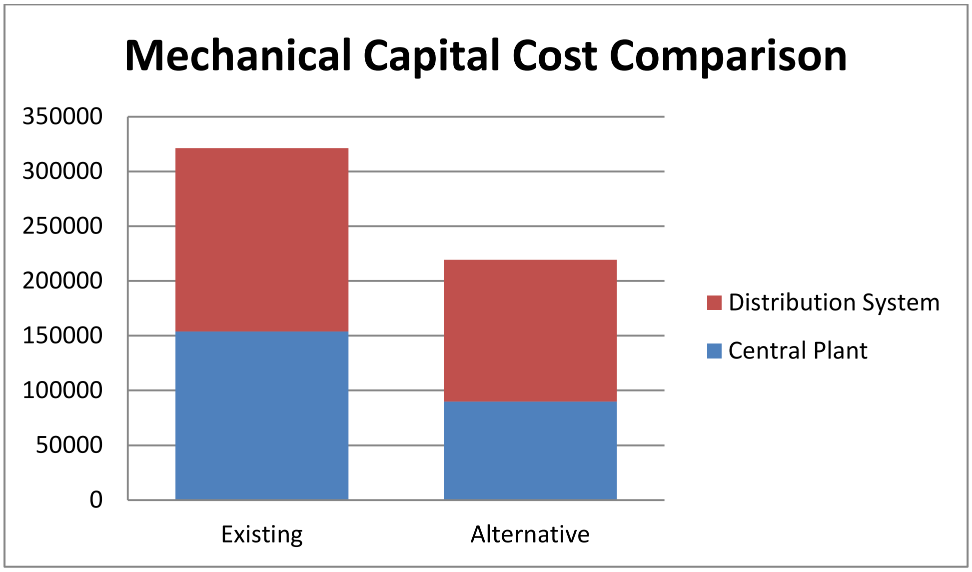


Figure 15~ Initial Investment Comparison

To calculate simple payback, the capital cost and annual operation cost of the existing and alternative must compared. The existing has higher capital cost and lower operation cost. The initial investment of the geothermal compared to the alternative is $102,177 and the operation saving of the existing is $4,022 annually. The simple payback of the existing is calculated to 25.4 years. The summary of the calculation is shown on tTable-15.

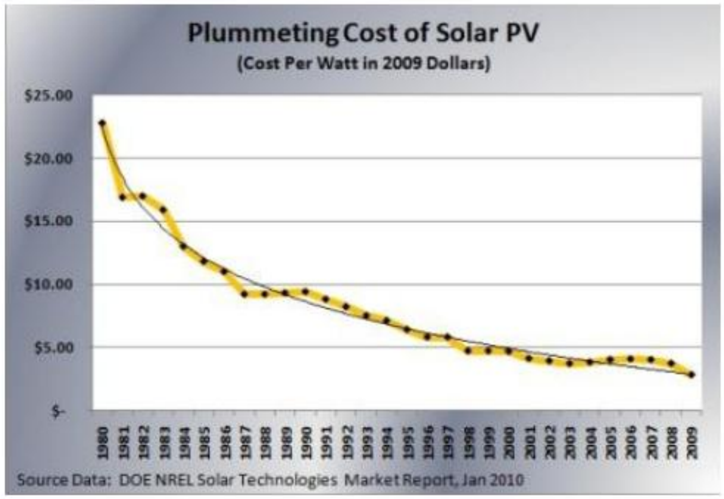
	Capital Cost, $	Operation, $
Existing	321,377	37,283
Alternative 2	219,200	41,305
	Investment	Operation
Saving	102,177	4,022
Simple Payback Period, years	25.4	

Table 15~ Simple Payback Period Summary

Section Three Electrical Breadth

3.1 Photovoltaic System-Background Information

The proposed alternative mechanical system results more energy consumption than the existing system. The sustainable featured application, such as photovoltaic system can obtain site energy generation. Instead of the centralized electricity distribution from the central station, the distributed generation systems produce electricity close to wherever it is used. Photovoltaic system produces clean "green" energy, which is an environmentally friendly technology without production noise or pollution. Infinite amounts of solar energy source are converts into electricity through the selected PV modules. As PV system and efficiency are continued to improve and increasing demand of the production, the retailed priced per watt of crystalline silicon modules decreased, see figure. For the CareFirst Cumberland, on-site energy generation system, PV system application integrated with the proposed mechanical system.



3.2 Photovoltaic System- Site Information

The location of the CareFirst Cumberland is Cumberland, Maryland, which has the latitude of 39.3° N and longitude of 76.6° W, and its elevation is 47m above the sea level. The site is captured from the Google Map and high-lighted in red, shown in figure-16. The available unused roof space of the CareFirst allows the PV panels installation. Also, the building isolated far away from nearby structures, therefore, efficiency of generating electricity remains as designed unless the site has bad weather condition, such as cloudy, rainy or snowy weather.

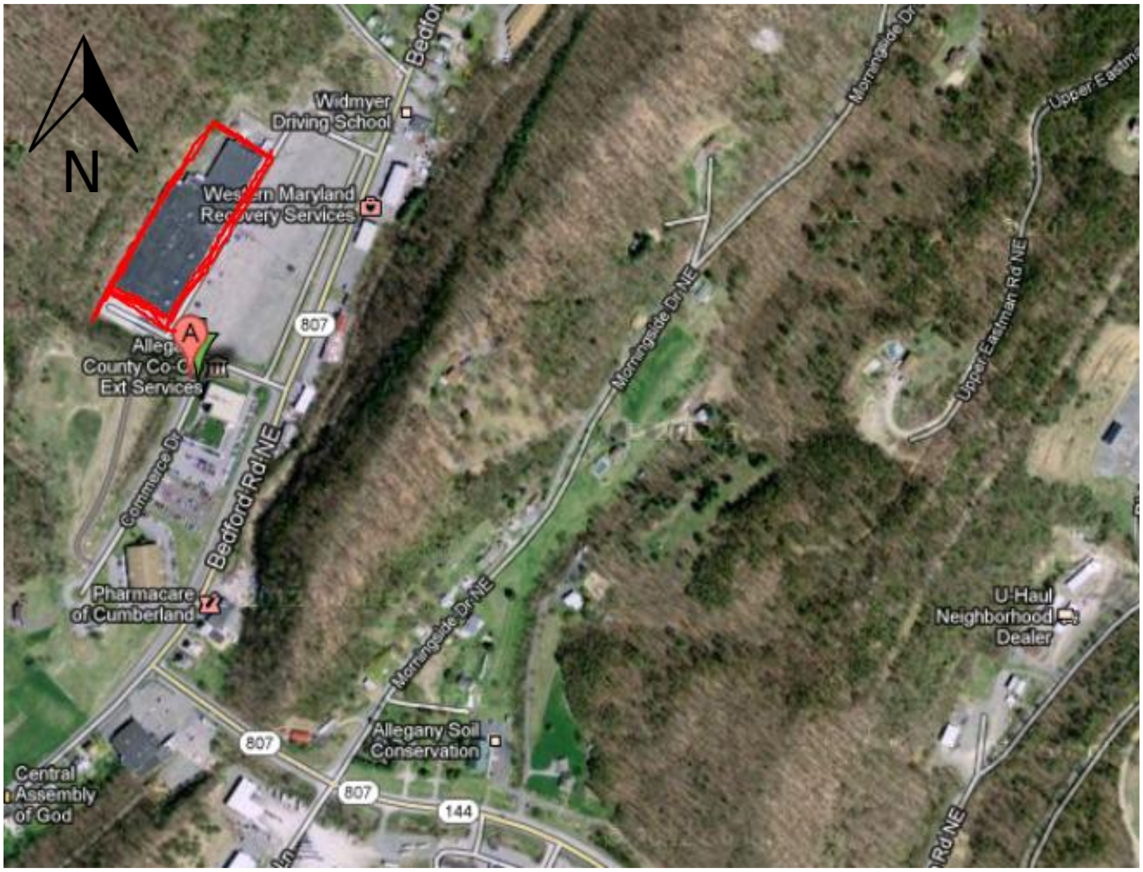


Figure 16- CareFirst Site Surrounding

Using the SAM energy simulation software, on-site electricity generation calculated with the selection of the System, in this case, solar energy system. The weather data information of the Cumberland, Maryland provided with TMY-2, which is long-term weather collection data of typical meteorological year between 1961 and 1990. Annual Direct solar radiation of the Cumberland replaced with the Baltimore. Its global horizontal and direct normal solar radiation is shown in Figure-17 showing that highest solar radiation between 11am to 1pm of a day, shown in figure below. PV system receives the direct normal solar energy of 1429.7 kWh/m^2 annually.

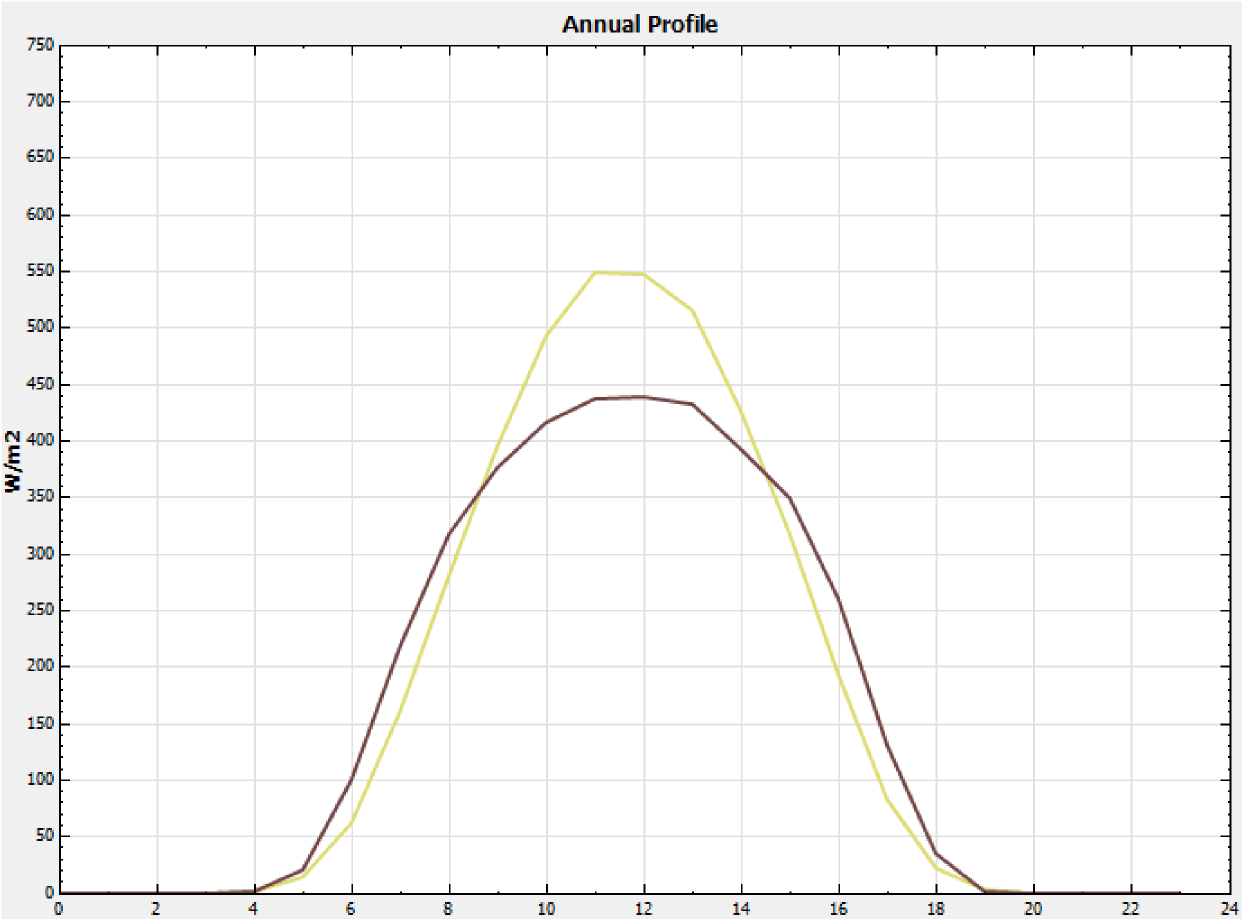


Figure 17-Annual Solar Irradiation

Each month receives a different amount of solar radiation. Between June and July, the Baltimore has highest solar radiation on site about 800W/m^2 and lowest solar radiation between December and January about 400W/m^2, which is almost half of the highest months. The global and direct solar radiation data profiles each month are provided below in Figure-18.

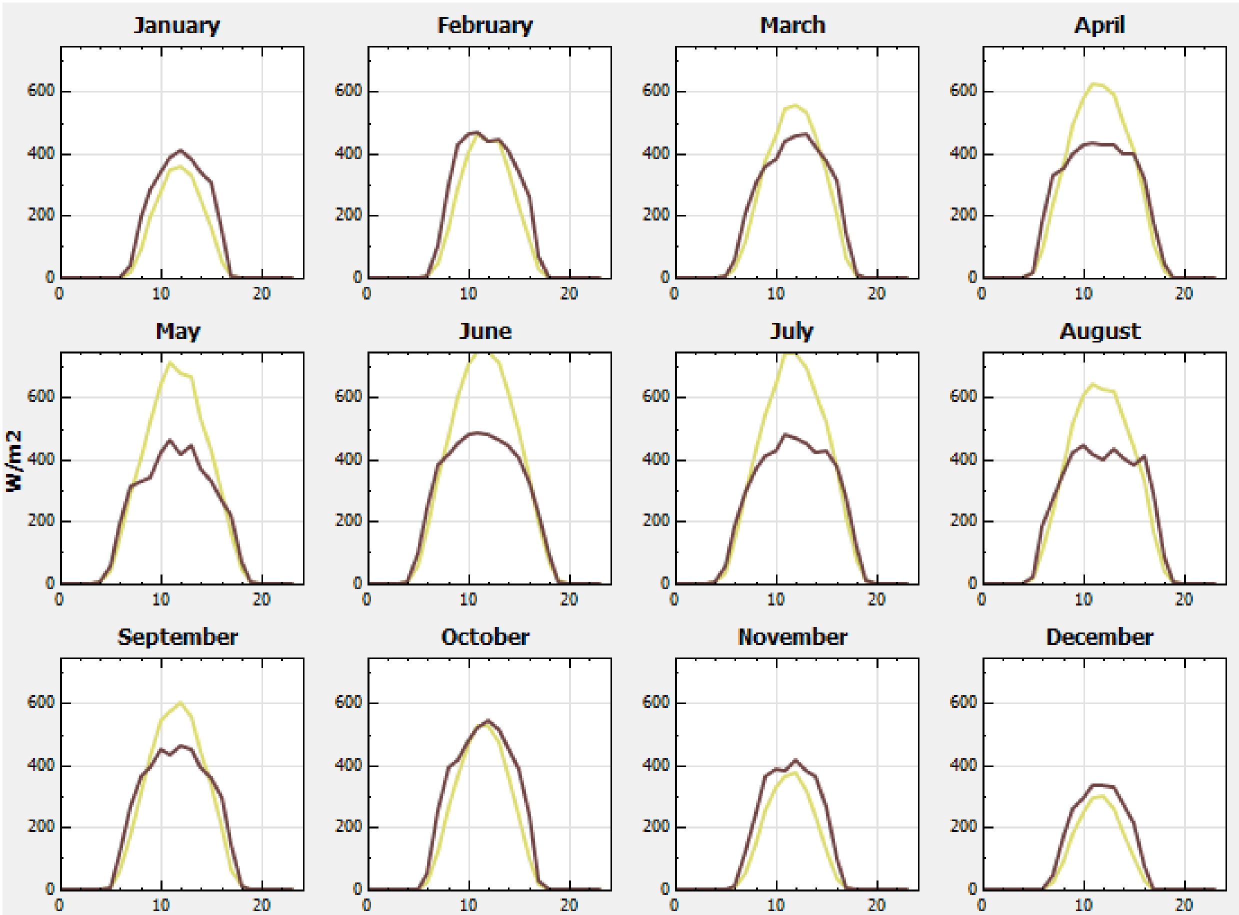


Figure 18-Monthly Solar Irradiation

3.3 Photovoltaic System- Design Approach

The electrical energy consumption of the proposed alternative system is lower than the existing system due to using Natural Gas for the central plant operation. Minimum electrical consumption of the CareFirst is about 15,000 kWh monthly, which can be assumed to be 300kWh daily. Total electrical energy consumption nearly 10 times more than it can be generated in the site, therefore, the partial electrical energy will be designed to generate to reduce cost of the purchased electricity. The electrical consumption of the proposed alternative system changed due to changing major mechanical equipment of the building. However, the general electrical usage, such as lighting and receptacle, remains same with the existing design. The lighting in the site parking lot has reasonable amount of electrical usage, therefore, from panel L4SL, shown below Figure-19, all lighting parking lot electricity will provide by the PV System, on-site electrical generation. In order to supply electricity to the parking lot lighting, about 18 kW of electricity has to be produced. Electricity usage of the parking lot lighting is constant throughout the year. Since the PV array produces DC power, generated DC loads have to invert to the AC power using inverter.

EXISTING PANEL

PANEL: **L4SL** AMP: 100 VOLT: 277/480

PHASE: 3 4 WIRE + GND

MOUNTING: SURFACE MAIN: MLO AIC: 42K AMPS RMS SYM

Branch Circuit Load Description	KVA Load A	KVA Load B	KVA Load C	Trip Poles	Ckt No.	Phase	Ckt. No.	Trip Poles	KVA Load A	KVA Load B	KVA Load C	Branch Circuit Load Description
LTG: ROAD/MONUMENT SIGN	1.75			20/2	1	A	2	20/2	3.38			LTG: PARKING LOT
*		1.50		*	3	B	4	*		3.38		*
LTG: PARKING LOT			1.88	20/2	5	C	6	20/2			3.38	LTG: PARKING LOT
*	1.88			*	7	A	8	*	3.38			*
LTG: PARKING LOT		1.50		20/2	9	B	10	20/2		0.00		SPARE
*			1.50	*	11	C	12	*			0.00	*
SPARE	0.00			20/1	13	A	14	20/1	0.80			LTG: SIGN LETTERS
SPARE		0.00		20/1	15	B	16	20/1		0.20		LTG CONTACTOR
SPARE			0.00	20/1	17	C	18	20/1			0.00	SPARE
SPACE	0.00			/1	19	A	20	/1	0.00			SPACE
SPACE		0.00		/1	21	B	22	/1		0.00		SPACE
SPACE			0.00	/1	23	C	24	/1			0.00	SPACE
SPACE	0.00			/1	25	A	26	/1	0.00			SPACE
SPACE		0.00		/1	27	B	28	/1		0.00		SPACE
SPACE			0.00	/1	29	C	30	/1			0.00	SPACE
	3.63	3.00	3.38	<< PHASE SUB-TOTALS >>					7.55	3.58	3.38	

PHASE A	11.18	kVA
PHASE B	6.58	kVA
PHASE C	6.75	kVA

24.50	kVA TOTAL CONNECTED LOAD
30.63	kVA TOTAL DEMAND LOAD

PROVIDE THE FOLLOWING:
ROUTE CIRCUITS VIA
LIGHTING CONTACTOR

Figure 19-Existing Panel Board

3.4 Photovoltaic System- System Sizing

With a designed electrical load of 18 kW, the Photovoltaic System components can be selected. Before selecting the component, understanding the photovoltaic effect is important. PV cells on modules converts light into electricity by absorbing photon from the solar irradiation. The PV system efficiencies is depend the PV cells, higher efficiencies module has higher first cost and lower efficiencies module has lower first cost. Most widely use PV type is polycrystalline silicon with an efficiency of 11.5 to 14% of solar irradiation. The Polycrystalline silicon type module selected for the proposed PV system. Its maximum power output is rated 244W with +10%

and -5% with the module efficiencies 13.74%. The current-voltage characteristic of the module is showing basic electrical output profile, shown below figure. This represents all possible current-voltage operating points and power output at specified condition of incident solar radiation and cell temperature.

This is used to rate module performance and includes the open-circuit voltage, short-circuit current, maximum power voltage, maximum power current, and maximum power. The I-V curve, which is performance of the module changes with cell temperature and irradiance, is shown in Figure-20. The given condition is based on the illumination of 1 kW/m[6] at spectral distribution of ASTM E892 global spectral Irradiance at a cell temperature of 77°F.

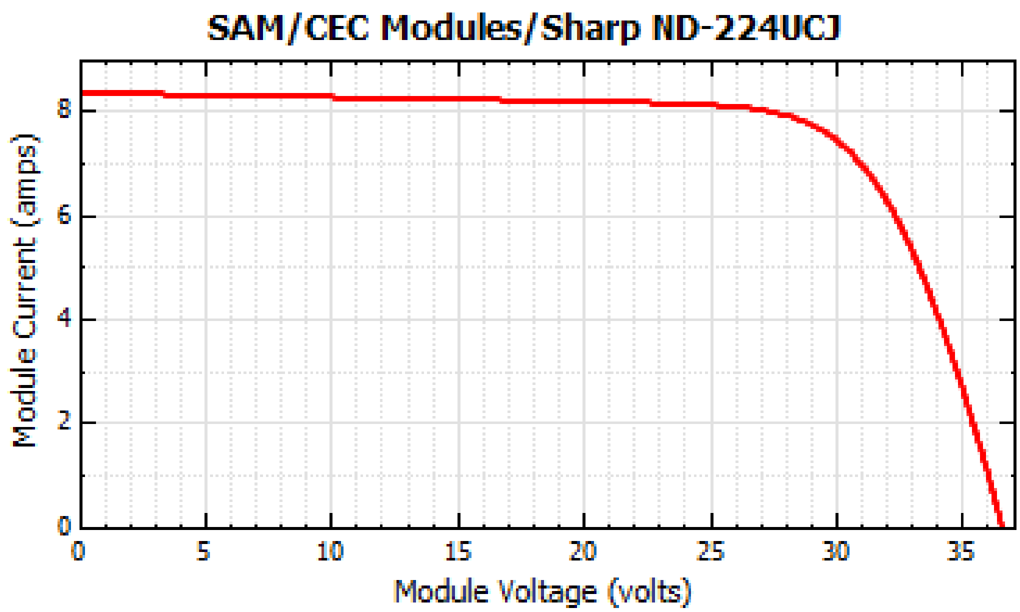


Figure 20 I-V Curve of the Module

Along with the module, the solid-state inverter is selected to produce the AC power from a DC power source. With 10560W of DC power, 9995W of AC power can be invert with an efficiency of 95%. An efficiency level of the inverter is control by percentage of rated output power, see figure-21.

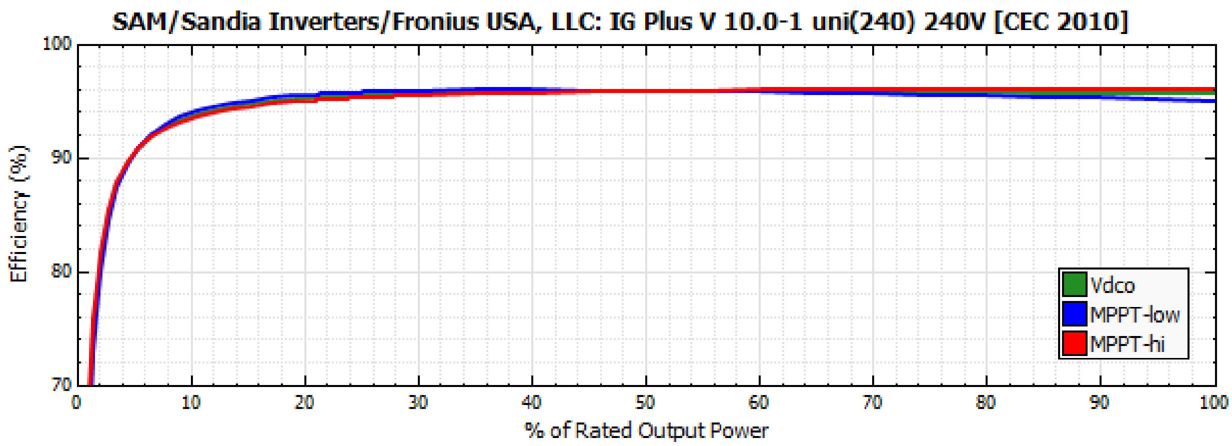


Figure 21-Efficiency Level of the Inverter

Using the SAM software, the desired array size specify by the designed electrical load of the parking lot lighting in the CareFirst. With an input desired power and selection of the module and inverter, the actual layout of the PV system can be calculated. Twelve of the modules per string and six strings are layout in parallel, therefore, total of the 72 modules layout on the roof of the CareFirst with a total area of 1220 ft^2. The actual PV array has capacity of 16.2 kW DC power and converts into 20kW AC power with two selected inverters. Twelve set of the six strings are placed on the roof top of the CareFirst, and the array directed to the South to get most solar irradiation all time. Between the set of modules, the row spacing must be 16.5 feet or above to avoid shading. Layout of the modules is attached in Appendix 6.

3.5 Photovoltaic System- On Site Energy Generation

With the proposed PV system, total 22,612.2 kWh of the electricity generated annually. Monthly generated electricity output also listed in figure-22. Month of July has highest output and month of December has lowest out of the years.

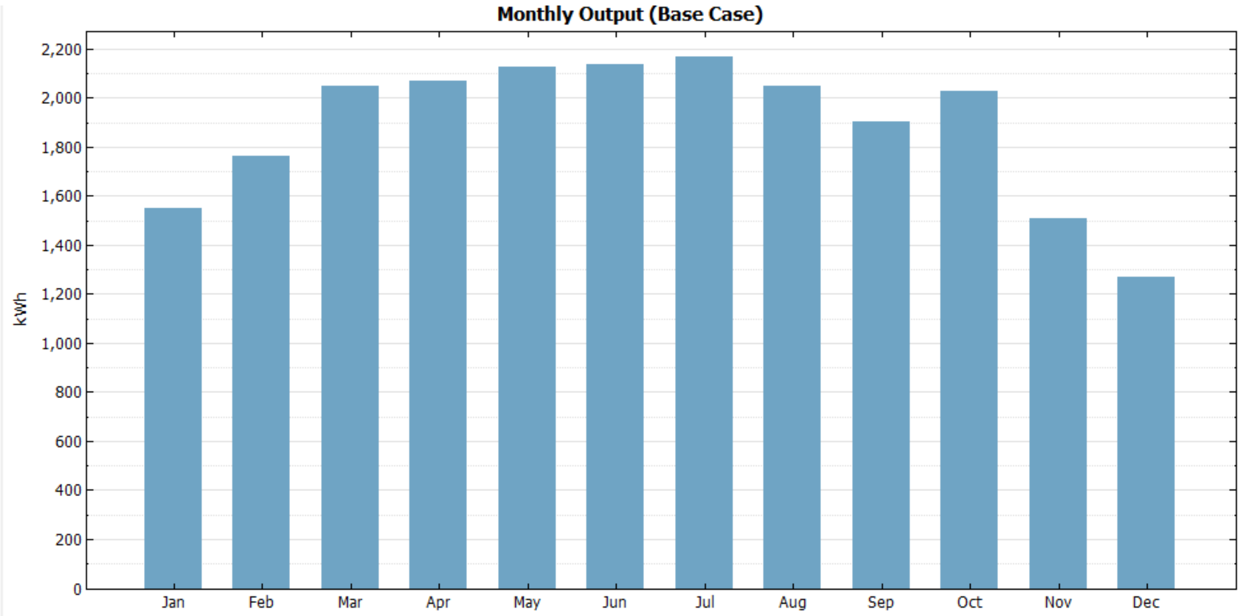


Figure 22-Monthly Electrical Generation

Total electrical consumption of the building is calculated to be 205,754 kWh and total generated electricity of the PV system is 22,612.2 kWh, which is 10% of the total consumption.

3.6 Photovoltaic System- Economics

With the proposed PV system of the CareFirst, $4,453.86 can be reduced from the original electricity bill. Initial investment of the system including rebates from the government costs total $75,611.93 and total installed cost per capacity is $4.68 per W DC power. The payback period calculated to be 17 years, using simple payback period equation below.

$$\text{Payback Period} = \frac{\text{Initial Investment}}{\text{Cash Inflow per Period}}$$

Therefore, after 17 years from now, the proposed PV system can have profit. The first of the system is very expensive, however, beyond the potential financial saving; the PV system produces energy with harming environment.

Section Four Acoustical Breadth

4.1 Mechanical Acoustical System- Analysis Procedure

The proposed mechanical system of the CareFirst replaced some equipment in the mechanical room in the building. The gas-fired chiller/heater and pumps for chilled water, hot water, and condensed water are placed. In the original design of the CareFirst, the conference room is located right next to the mechanical room as shown in figure-23. The partition between conference room and the mechanical will be retreated acoustically.

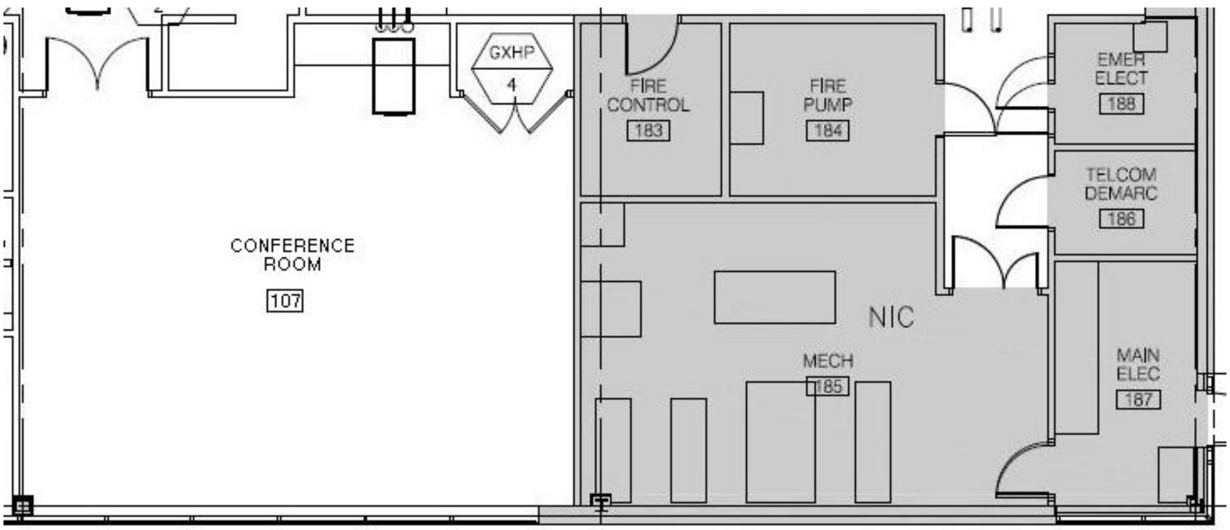


Figure 23-Plan View of the Mech. And Conference Room

4.2 Mechanical Acoustical System- Mechanical Noise Consideration

The noise sources of the mechanical are considered for the acoustical analysis. Major mechanical equipment is main noise source of the mechanical system. These noise levels of the each equipment has individual frequency in Hz, therefore, all noise sources need to combined as a noise source to see that the conference room is comply with minimum masking background noise level NC-35. The calculation of the combining all four noise sources is provided on Table-. Highlighted data below will be used for the acoustical analysis, which represents total sound pressure level of all four sources in each octave band in decibel.

Formula									
OctaveBand Frequencies (Hz)	63	125	250	500	1000	2000	4000	8000	
A-weighted	-26.2	-16	-8.6	-3.2	0	1.2	1	-1.1	
Given Unweighted (dB)									Overall Sound Pressure Level (dB)
Lp_Chilled Water Pump	77	79	68	63	58	55	57	51	81
Lp_Hot Water Pump	68	71	64	61	57	51	53	49	74
Lp_Condensed Water Pump	65	69	62	57	55	49	51	43	71
Lp_Gas-Fired Chiller/Heater	91	85	81	79	77	67	61	63	93
Converted to A-weighted (dBA)									Overall Sound Pressure Level (dB)
Lp_Chilled Water Pump	50.8	63	59.4	59.8	58	56.2	58	49.9	68
Lp_Hot Water Pump	41.8	55	55.4	57.8	57	52.2	54	47.9	64
Lp_Condensed Water Pump	38.8	53	53.4	53.8	55	50.2	52	41.9	61
Lp_Gas-Fired Chiller/Heater	64.8	69	72.4	75.8	77	68.2	62	61.9	81
SPL of all source in each Octave Band (dB)	91	86	81	79	77	67	63	63	
Total SPL of all source (dB)	93								
SPL of all source in each Octave Band (dBA)	65	70	73	76	77	69	64	62	
Total SPL of all source (dBA)	81								

Table 16- Combined Noise Level Calculation

The back ground Noise Level of the conference must remain at NC-35, decibel level of each frequency listed in calculation below. The require transmission loss between the conference room and mechanical room is highlight in Tabel-

OctaveBand Frequencies (Hz)	125	250	500	1000	2000	4000
Noise in Mechanical Room (dB)	86	82	81	80	71	66
Background Noise Level in Conference (NC-35)	52	45	40	36	34	33
Required TL (dB)	34	37	41	44	37	33

Table 17- Required TL Calculation

The transmission loss of the existing partition each frequency can cover some of the require TL, however, it is not enough to comply with the required TL. The existing wall section view is shown in figure below. Its partition assembly includes 5/8” gypsum board both sides, steel channel studs and 1.5” of fire blanket.

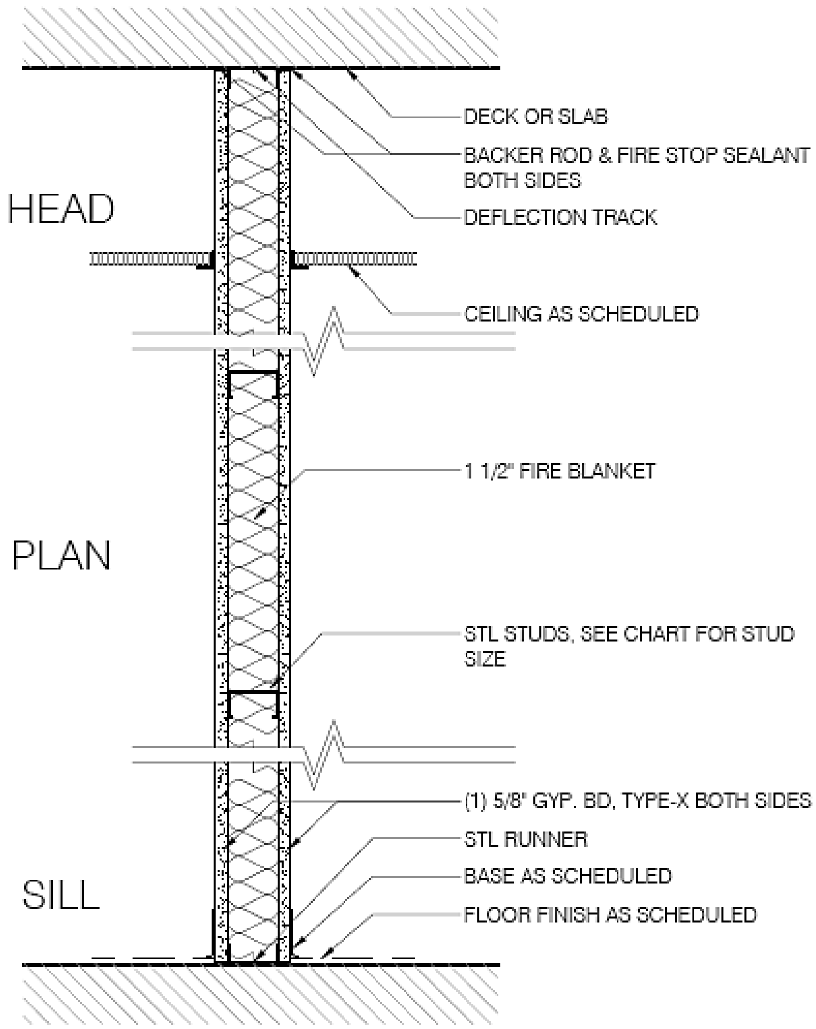


Figure 24- Existing Partition

4.3 Mechanical Acoustical System- Proposed Acoustical System

The proposed partition between must meet the required transmission loss to comply noise criteria of the conference room. The TL data of the proposed partition listed below for the calculation. It is 3 5/8" steel channel studs 24 in o.c. with two layers 5/8" gypsum board both sides (11 lb/ft^2). The proposed partition has enough transmission loss to comply NC-35 in the conference room, the calculation is shown Table-18.

Required TL (dB)	34	37	41	44	37	33
Proposed Partition	34	41	51	54	46	52
Remaining TL (dB)	0	-4	-10	-10	-9	-19

Table 18- Required TL Calculation

Section Five Thesis Conclusion

5.1 Conclusion Mechanical Depth

The direct-fired chiller/heater and the radiant ceiling panel system replaced the existing geothermal system as the proposed alternative. Based on the heating and cooling loads of the building, the chiller/heater and radiant panel system are selected. Within the calculation procedure, the water temperature of the entering and leaving the chiller/heater, cooling coil, and radiant panels are designed. The entering water temperature of the radiant cooling panel must set temperature above the dew point temperature of the space, because it may cause condensation on the surface of the cooling panel.

The operation mode of the chiller/heater is analyzed. The chiller/heater operates in heating only, cooling only, and simultaneous mode. In simultaneous mode, the unit is available to produce hot and chilled water at a same time, however, produced hot and chilled water does not used at same rate, therefore, the over-produced of the hot and chilled water wasted. The chiller/heater can save the area of the mechanical room, instead have the chiller and boiler separately.

Overall, the proposed alternative is less energy efficiency than the existing system. However, the capital cost of the existing is expensive compared to the proposed alternative. The simply payback period of the existing is 25.4 years. Even though the existing system will have payback and saving of the operation cost, the payback period is not reasonable. The proposed alternative may have higher operating cost, however, it has lower capital cost.

5.2 Conclusion Electrical Breadth

To reduce the operation cost of the utility cost of the proposed alternative, the Photovoltaic System is adapted. On-site generation of the PV system connects into the panel of lighting in parking lot. On-site PV system nearly generates 10% of the total electrical consumption of the building. The initial investment of the PV panel is expensive, but it could reduce the 10% of the utility cost annually. The simple payback of the PV system is 17 years. This is not great result of the payback period in my opinion, however, if the owner desires to have green energy generation and reducing operating cost, the proposed PV system can be applied to the building.

5.3 Conclusion Acoustical Breadth

With the proposed mechanical system, the mechanical room has more noise source than the existing system. The partition between the mechanical room and conference room includes 5/8" gypsum board both sides, steel channel studs and 1 ½" of fire blanket. However, this existing partition cannot reduce the noise to comply the background noise level in the conference room. Therefore, the proposed acoustical partition, wall thick of proposed partition is 2" thicker than the existing partition, the some area in conference decreased. The proposed partition, 3 5/8" steel channel studs 24 in o.c. with two layers 5/8" gypsum board sides, can absorb and reduces the noise from the mechanical room to comply with NC-35 in the conference room.

APPENDIX 1: ASHRAE Standard Weather Data

2009 ASHRAE Handbook - Fundamentals (IP)

BALTIMORE BLT-WASHNGTN INT'L, MD, USA

WMO#: 724060

Lat: 39.17N Long: 76.68W Elev: 154 StdP: 14.61 Time Zone: -5.00 (NAE) Period: 82-06 WBAN: 93721

Annual Heating and Humidification Design Conditions

Coldest Month	Heating DB 99.6%	Heating DB 99%	Humidification 99.6% DP	99.6% HR	99.6% MCDB	99% DP	99% HR	99% MCDB	Coldest month WS/MCDB 0.4% WS	0.4% MCDB	1% WS	1% MCDB	MCWS/PCWD to 99.6% DB MCWS	PCWD
1	12.9	17.3	-3.3	4.6	17.8	1.3	5.9	22.1	26.2	31.6	24.2	32.1	8.7	290

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest Month	Hottest Month DB Range	Cooling DB/MCWB 0.4% DB	0.4% MCWB	1% DB	1% MCWB	2% DB	2% MCWB	Evaporation WB/MCDB 0.4% WB	0.4% MCDB	1% WB	1% MCDB	2% WB	2% MCDB	MCWS/PCWD to 0.4% DB MCWS	PCWD
7	18.7	93.9	74.9	91.2	74.2	88.5	73.1	78.1	88.6	76.8	86.5	75.6	84.3	10.2	280

Dehumidification DP/MCDB and HR 0.4% DP	0.4% HR	0.4% MCDB	1% DP	1% HR	1% MCDB	2% DP	2% HR	2% MCDB	Enthalpy/MCDB 0.4% Enth	0.4% MCDB	1% Enth	1% MCDB	2% Enth	2% MCDB	Hours 8 to 4 & 55/69
75.3	133.3	82.1	74.1	127.9	80.8	73.0	123.1	79.8	41.5	89.1	40.2	86.5	39.1	84.5	723

Extreme Annual Design Conditions

Extreme Annual WS 1%	2.5%	5%	Extreme Max WB	Extreme Annual DB Mean Min	Mean Max	Standard deviation Min	Standard deviation Max	n=5 years Min	n=5 years Max	n=10 years Min	n=10 years Max	n=20 years Min	n=20 years Max	n=50 years Min	n=50 years Max
22.4	19.2	17.3	84.6	5.1	98.0	6.3	3.3	0.6	100.3	-3.1	102.2	-6.7	104.0	-11.3	106.4

Monthly Climatic Design Conditions

			Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperatures, Degree-Days and Degree-Hours		Tavg	55.9	33.9	36.9	44.2	54.2	63.6	72.7	77.6	75.7	68.3	56.8	47.3	37.8
		Sd		10.07	8.67	9.29	8.30	7.49	6.31	5.08	5.20	6.95	7.72	8.51	9.29
		HDD50	1726	507	376	231	45	1	0	0	0	0	22	152	392
		HDD65	4567	964	787	649	339	119	12	0	2	45	275	532	843
		CDD50	3861	8	9	50	171	424	680	855	796	550	232	71	15
		CDD65	1228	0	0	4	15	77	242	390	333	145	21	1	0
		CDH74	11317	0	1	42	195	792	2240	3853	2963	1071	148	11	1
		CDH80	4315	0	0	8	57	267	849	1669	1125	317	23	0	0
Monthly Design Dry Bulb and Mean Coincident Wet Bulb Temperatures	0.4%	DB		65.2	69.3	80.0	86.9	90.9	94.6	98.0	96.9	92.6	83.2	75.3	68.5
		MCWB		57.7	56.2	62.2	66.7	71.5	74.5	76.5	75.9	72.8	68.9	63.6	60.2
	2%	DB		59.5	61.4	71.1	79.6	86.8	91.3	94.7	92.6	87.1	78.1	69.8	62.1
		MCWB		54.5	53.5	58.1	63.2	69.3	73.9	75.7	75.0	71.7	66.9	60.2	55.3
	5%	DB		53.0	55.5	64.7	74.1	82.6	88.2	91.8	89.2	83.4	74.0	65.3	56.4
		MCWB		46.8	47.5	54.1	60.3	67.9	73.0	74.9	73.8	70.1	64.3	58.7	51.0
	10%	DB		47.6	50.4	59.4	69.3	78.1	85.1	88.7	86.1	80.2	70.2	61.4	51.6
		MCWB		42.7	44.3	50.1	57.3	65.5	71.8	74.0	72.5	69.0	62.5	55.6	46.1
Monthly Design Wet Bulb and Mean Coincident Dry Bulb Temperatures	0.4%	WB		60.1	60.1	64.6	68.9	74.8	78.8	80.2	79.4	77.0	72.2	66.5	62.1
		MCDB		63.2	66.0	76.5	80.5	86.0	88.3	91.3	90.0	85.0	77.8	70.8	67.1
	2%	WB		55.0	53.7	60.2	65.7	72.1	76.5	78.4	77.5	75.0	69.8	63.5	57.2
		MCDB		58.6	58.7	68.8	75.7	82.8	85.9	89.4	88.0	82.1	75.5	67.9	61.0
	5%	WB		47.9	49.1	55.7	62.4	69.7	75.2	77.2	76.2	73.3	66.6	60.1	52.1
		MCDB		50.9	54.0	62.1	71.4	79.4	84.2	87.6	85.0	79.2	71.9	64.1	55.5
	10%	WB		43.3	45.1	51.5	59.3	67.4	73.7	76.0	74.9	71.7	63.8	56.7	47.0
		MCDB		47.2	50.2	58.5	67.2	75.4	81.7	85.2	82.5	77.2	68.8	60.6	50.6
Mean Daily Temperature Range		MDBR		15.5	16.7	18.4	20.3	20.2	19.6	18.7	18.3	18.6	19.8	18.6	16.0
	5% DB	MCDBR		22.7	24.8	26.8	27.7	26.2	23.2	22.4	21.7	22.1	23.8	23.5	22.7
		MCWBR		17.1	17.3	16.6	14.6	12.2	9.6	8.1	8.3	9.7	13.7	16.1	17.5
	5% WB	MCDBR		20.1	21.3	23.7	24.0	22.7	19.6	19.1	18.6	17.7	19.3	19.6	19.8
		MCWBR		17.2	17.0	16.5	14.0	11.7	9.2	8.2	8.2	9.1	12.5	16.2	17.4
Clear Sky Solar Irradiance		taub		0.319	0.353	0.411	0.417	0.474	0.546	0.552	0.580	0.421	0.370	0.342	0.317
		taud		2.373	2.188	1.997	2.036	1.892	1.746	1.769	1.681	2.164	2.286	2.350	2.446
		Ebn,noon		269	272	266	273	258	239	237	225	261	264	258	262
		Edh,noon		30	40	52	53	62	72	69	74	44	36	31	27

CDDn Cooling degree-days base n°F, °F-day
CDHn Cooling degree-hours base n°F, °F-hour
DB Dry bulb temperature, °F
DP Dew point temperature, °F
Ebn,noon } Clear sky beam normal and diffuse hori-
Edh,noon } zontal irradiances at solar noon, Btu/h/ft2
Elev Elevation, ft
Enth Enthalpy, Btu/lb
HDDn Heating degree-days base n°F, °F-day
Hours 8/4 & 55/69 Number of hours between 8 a.m. and 4 p.m with DB between 55 and 69 °F
HR Humidity ratio, grains of moisture per lb of dry air

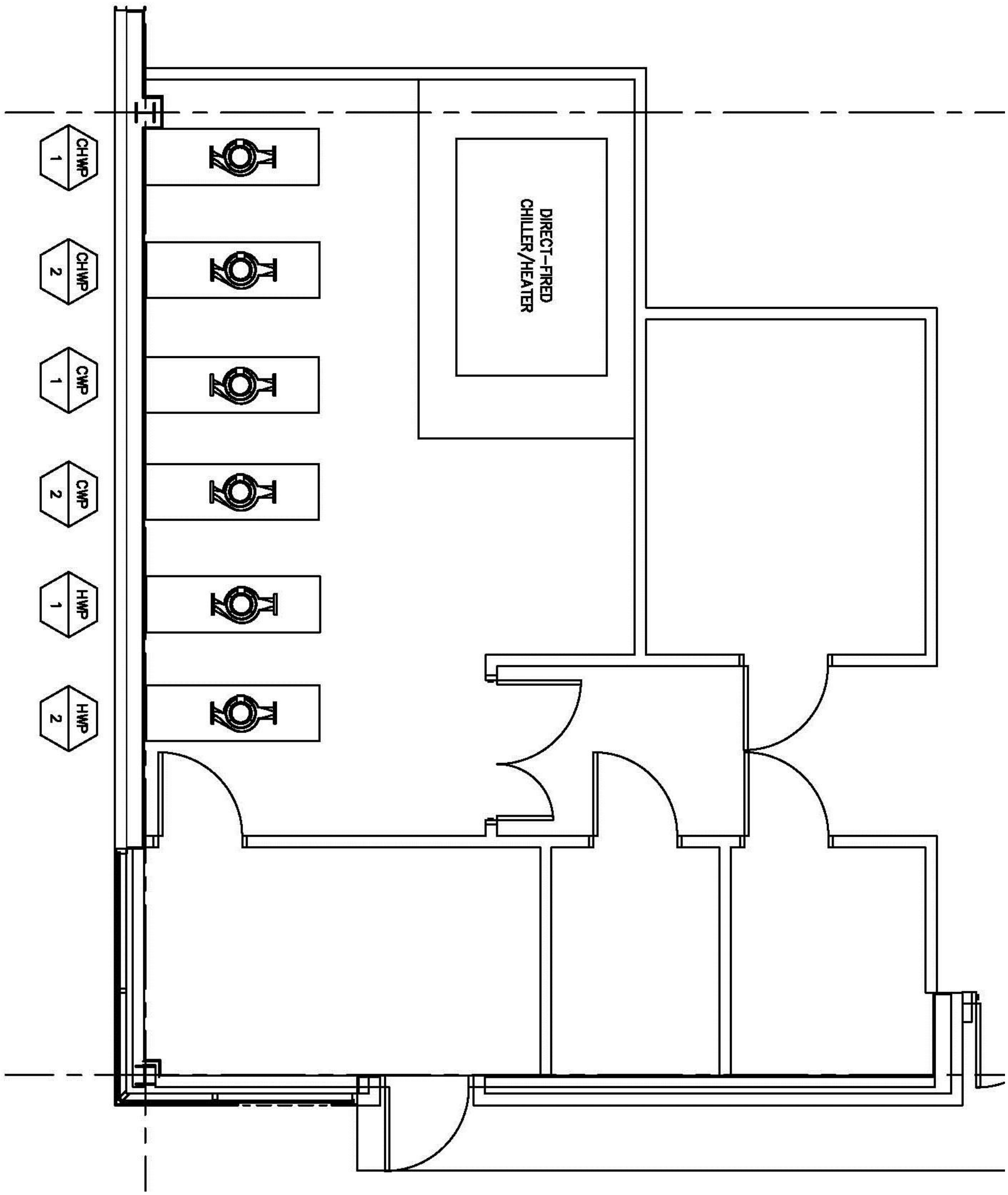
Lat Latitude, °
Long Longitude, °
MCDB Mean coincident dry bulb temperature, °F
MCDBR Mean coincident dry bulb temp. range, °F
MCDP Mean coincident dew point temperature, °F
MCWB Mean coincident wet bulb temperature, °F
MCWBR Mean coincident wet bulb temp. range, °F
MCWS Mean coincident wind speed, mph
MDBR Mean dry bulb temp. range, °F
PCWD Prevailing coincident wind direction, °, 0 = North, 90 = East

Period Years used to calculate the design conditions
Sd Standard deviation of daily average temperature, °F
StdP Standard pressure at station elevation, psi
taub Clear sky optical depth for beam irradiance
taud Clear sky optical depth for diffuse irradiance
Tavg Average temperature, °F
Time Zone Hours ahead or behind UTC, and time zone code
WB Wet bulb temperature, °F
WBAN Weather Bureau Army Navy number
WMO# World Meteorological Organization number
WS Wind speed, mph

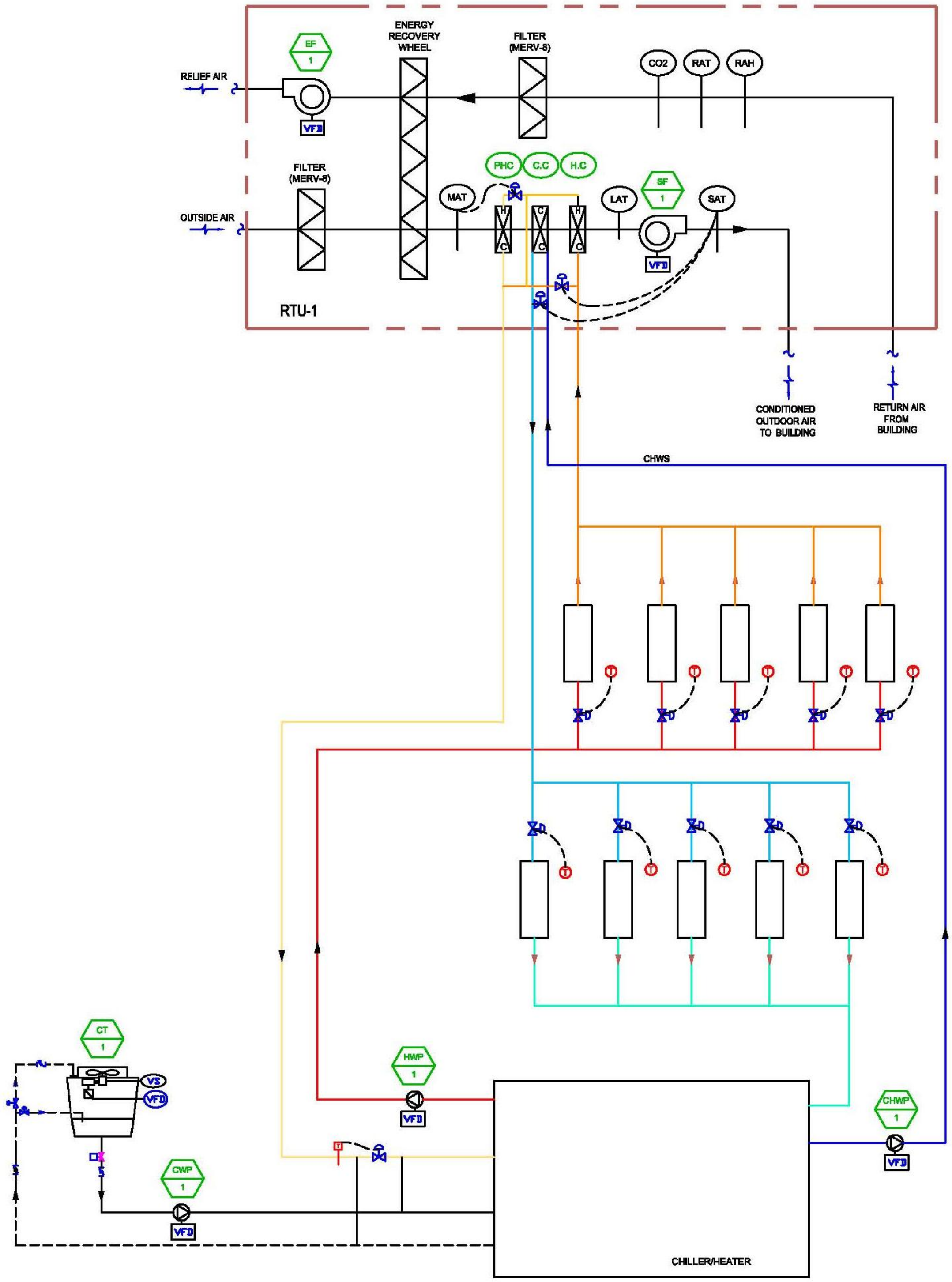
APPENDIX 2: Area Take off

Room	Uses	Floor	Roof	Opening Area (sq. ft)				Extrior Perimeter area(sq. ft)			
1st Floor		Area (sq.ft)	Area (sq.ft)	(NWW)	(SSW)	(SEE)	(NNE)	(NWW)	(SSW)	(SEE)	(NNE)
GXHP-101	Reception	1667		271.542		145.0863					
GXHP-102	Office	855		221				340			
GXHP-103	Office	726		293				485			
GXHP-104	Office	1012									
GXHP-105	Office	533	225	128.98	273.83			101.28	231.405		
GXHP-106	Corridor	1388			29.55				161.894		
GXHP-107	Office	600			311.29				324.948		
GXHP-108	Office	540			215.209	135.779				398.502	
GXHP-109	Office	900									
GXHP-110	Classroom	920				165.14				285.522	
GXHP-111	Classroom	975				235.9				312.025	
GXHP-112	Conference	790				151.33				277.181	
GXHP-113	Conference	800				199.83				262.715	
GXHP-114	Corridor	1295					171.34				151.253
2nd Floor											
GXHP-201	Conference	360		294.23							
GXHP-202	Office	1220	1220								
GXHP-203	Office	1276	1275	514.98				906.644			
GXHP-204	Office	650	650	139.43			337.97				434.479
GXHP-205	Office	1220	1220								0
GXHP-206	Office	870	870				162.32				240.984
GXHP-207	Office	530	530			147.34	293.65			67.417	326.44
GXHP-208	Office	440									
GXHP-209	Office	194									
GXHP-210	Office	900	900								
GXHP-211	Office	1275	1275			525.87				913.847	
GXHP-212	Office	900	900								
GXHP-213	Lobby	1020	1020			149.99				28.7487	
GXHP-214	Office	700	700			267.76				516.019	
GXHP-215	Office	925	925								
GXHP-216	Office	215	215								
GXHP-217	Office	220									
GXHP-218	Office	220									
GXHP-219	Cafeteira	415	415								
GXHP-220	Office	700	700			329.93				463.656	
GXHP-221	Office	925	925								
GXHP-222	Office	110									
GXHP-223	Conference	140									
GXHP-224	Conference	170									
GXHP-225	Office	145									
GXHP-226	Office	750	750		397.84	146.168			473.025	54.0464	
GXHP-227	Office	715	715	147.13	404.87			54.6063	543.105		
GXHP-228	Office	715	715	331.17				444.492			
GXHP-229	Office	1350	1350								
GXHP-230	Office	1230	1230								
GXHP-231	Office	615	615	188.43				483.912			

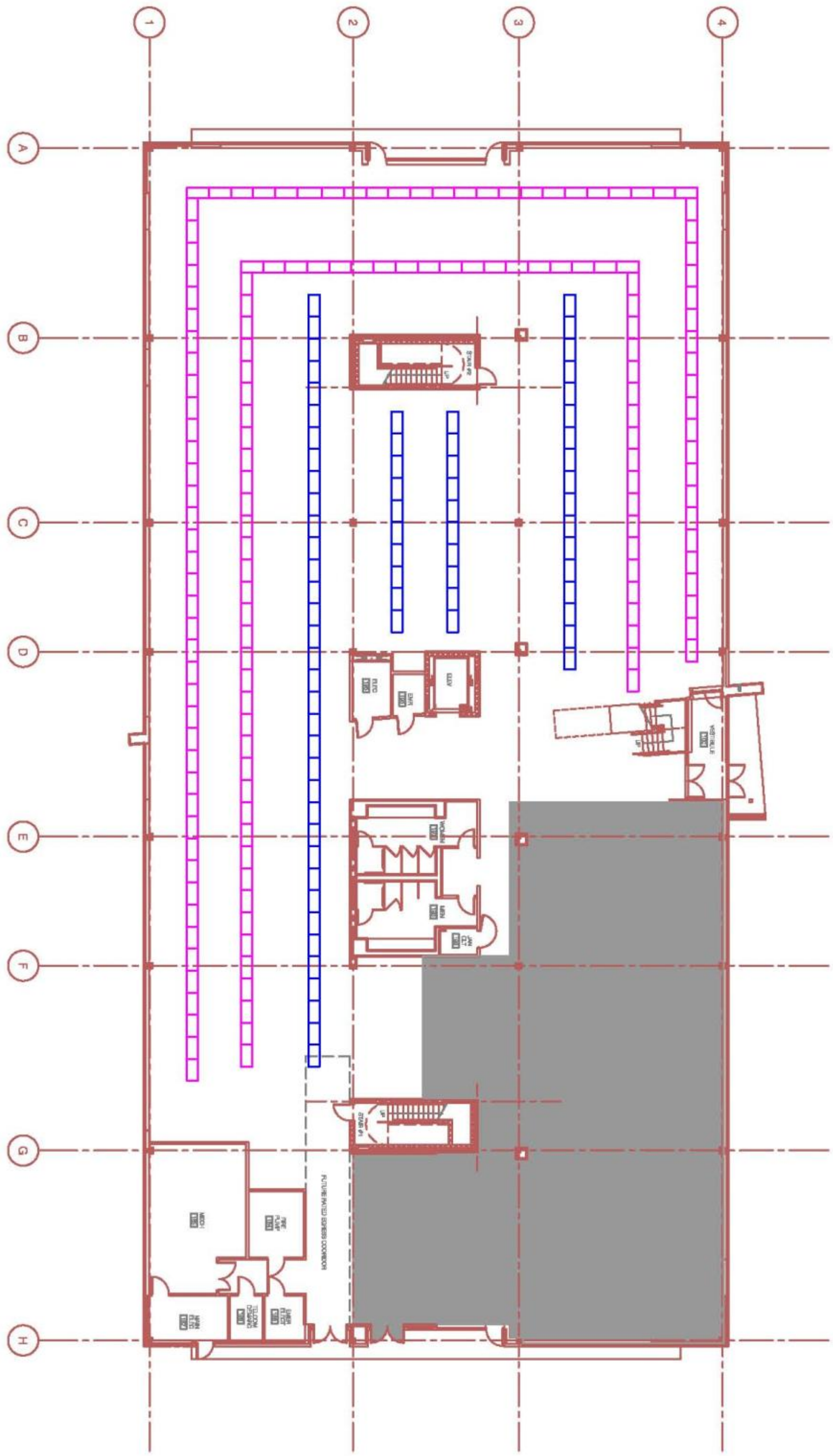
APPENDIX 3: Mechanical Room Layout

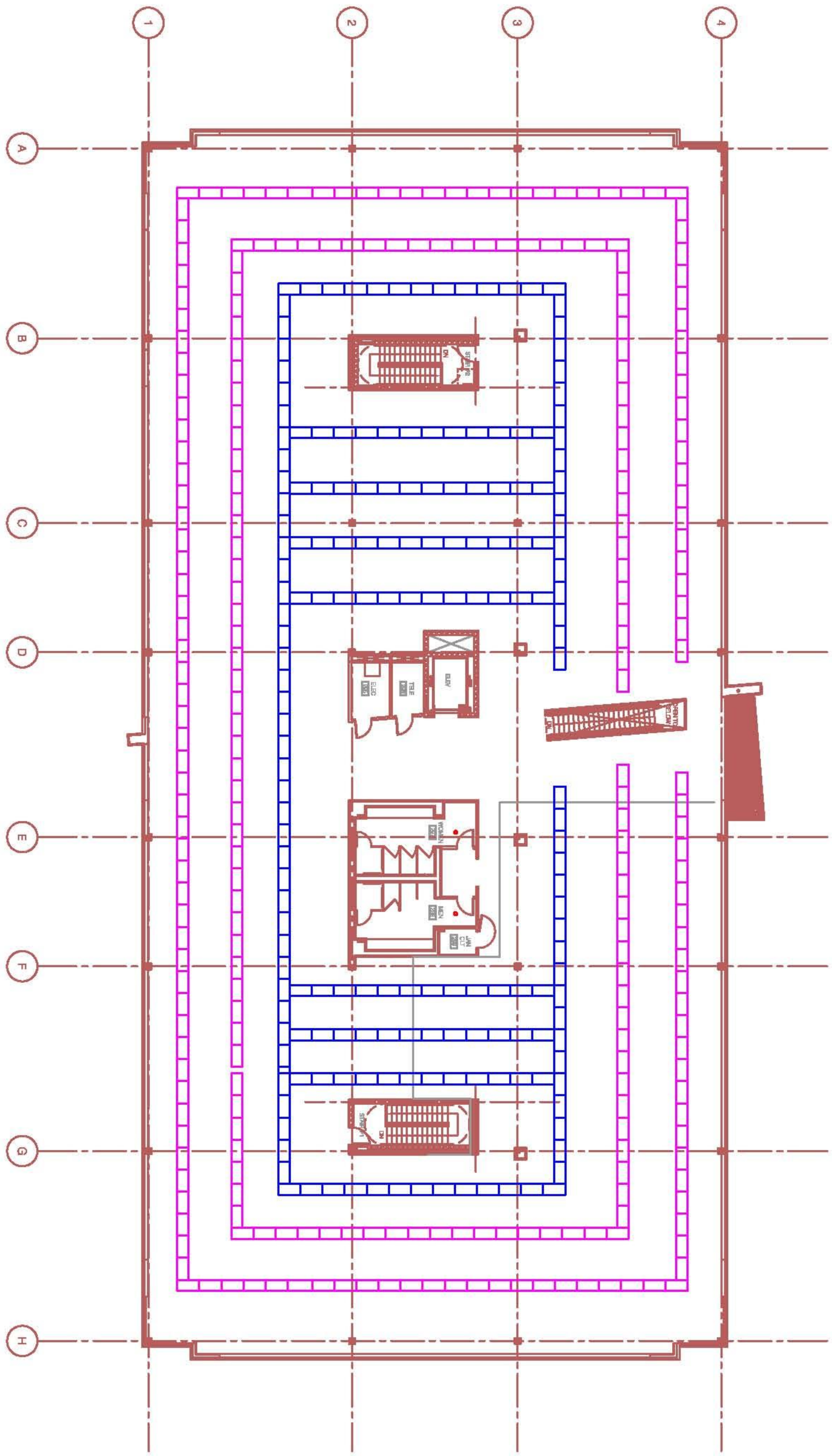


APPENDIX 4: Mechanical Schematic Design

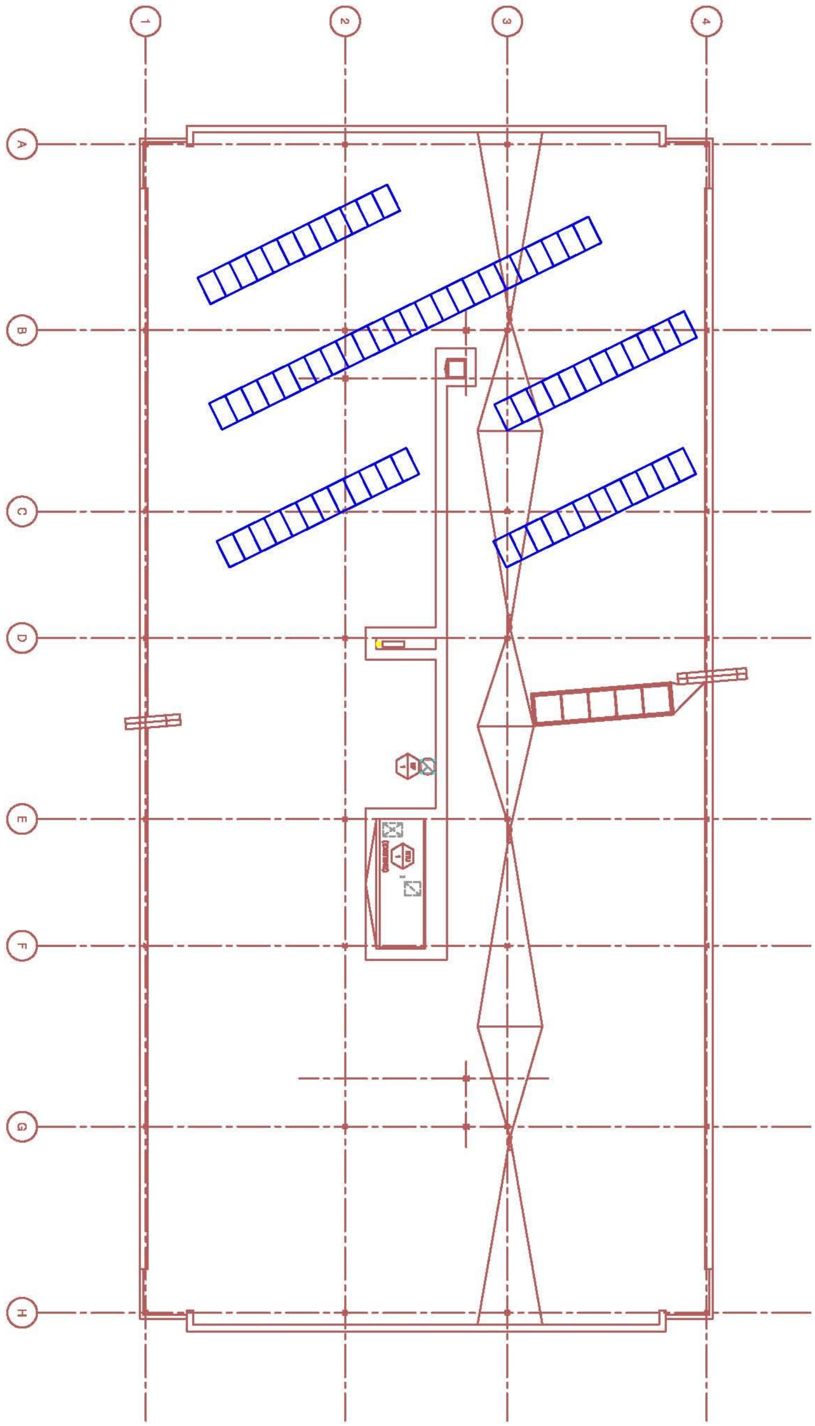


APPENDIX 5: Radiant Ceiling Panel Layout (1st & 2nd Floor)





APPENDIX 5: Photovoltaic System Roof Layout



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