Technical Report 3

Mechanical Systems Existing Conditions

November 10, 2014

NEIU El Centro
Chicago, IL

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Executive Summary

The goal of Technical Report 3 is to analyze the designed mechanical system of NEIU El Centro with regards to design requirements, cost, operation, space requirements and LEED. This report makes references to design considerations and requirements previously analyzed in Technical Reports 1 and 2.

In order for Northeastern Illinois University's (NEIU) El Centro to have a fully equipped and operational mechanical system, $2.4 million dollars was allocated for its installment. The current mechanical design meets and exceeds all of the required ventilation, cooling, and heating loads while also being sustainable. El Centro has multiple sustainable aspects including a PV array, energy efficient mechanical equipment, and low lighting power densities.

El Centro does not utilize a central heating or cooling plant because it is the first building on NEIU's newest campus. There are two identical packaged air handling units (AHU) on the roof that serve all of the cooling and ventilation requirements of the building through VAV boxes for each space. Each air handling unit is served by a separate independent air cooled condensing unit and employ an economizer cycle. Each AHU utilizes electricity for its power consumption and also contain indirect gas fired burners that utilize natural gas.

There are two identical 750 MBH natural gas fired boilers in the first floor mechanical room that serve the buildings hot water system which serves the heating loads of the building. Two hot water pumps serve the radiant finned tubes along the perimeter of the building and the reheat coils in the 71 VAV boxes located throughout the building.

Operational history of the system is unavailable because the building was recently completed in September of 2014. The lost usable space associated with the mechanical system is minimal because the cooling and ventilation equipment is located on the roof, while the hot water plant equipment occupy a mechanical room on the 1st floor.

A LEED v4 analysis was conducted for the mechanical system to see how many points it would be eligible for. This project was initially designed using LEED v3 and aimed to achieve a gold rating. The main sustainability feature of this project is roof-mounted solar photovoltaic panels that will produce about 9% of the buildings energy needs. Some of the other green initiatives taken for this project include low flow plumbing fixtures, high efficiency mechanical equipment, creative lighting, and enhanced commissioning.

Building Overview

Northeastern Illinois University (NEIU) El Centro is a new educational facility that is being built in the northwest side of Chicago, Illinois. It is located along Kennedy Expressway and will be passed by an estimated 400,000 vehicles per day. The building is set to be completed September 2014, in time for Fall Semester classes. It is a 55,000 square foot building with three stories; there is no basement in El Centro. The building will include classrooms, art studios, computer rooms, lecture halls, music studios, wet labs, damp labs, a library, student lounges, resource rooms, administrative space, and offices.

Nearly the entire building is enveloped in a curtain wall façade. The curtain wall features fins that are designed to limit solar gains on the building and to control the amount of natural daylight into the building. The fins will appear gold when driving into the city, and blue when leaving the city, reflecting the school colors as can be seen in the rendering below (courtesy of JGMA). Photovoltaic panels are mounted to the majority of the roof area. Other green initiatives include low flow plumbing fixtures, high-efficiency equipment, and creative lighting that have made this project eligible for a LEED gold rating.

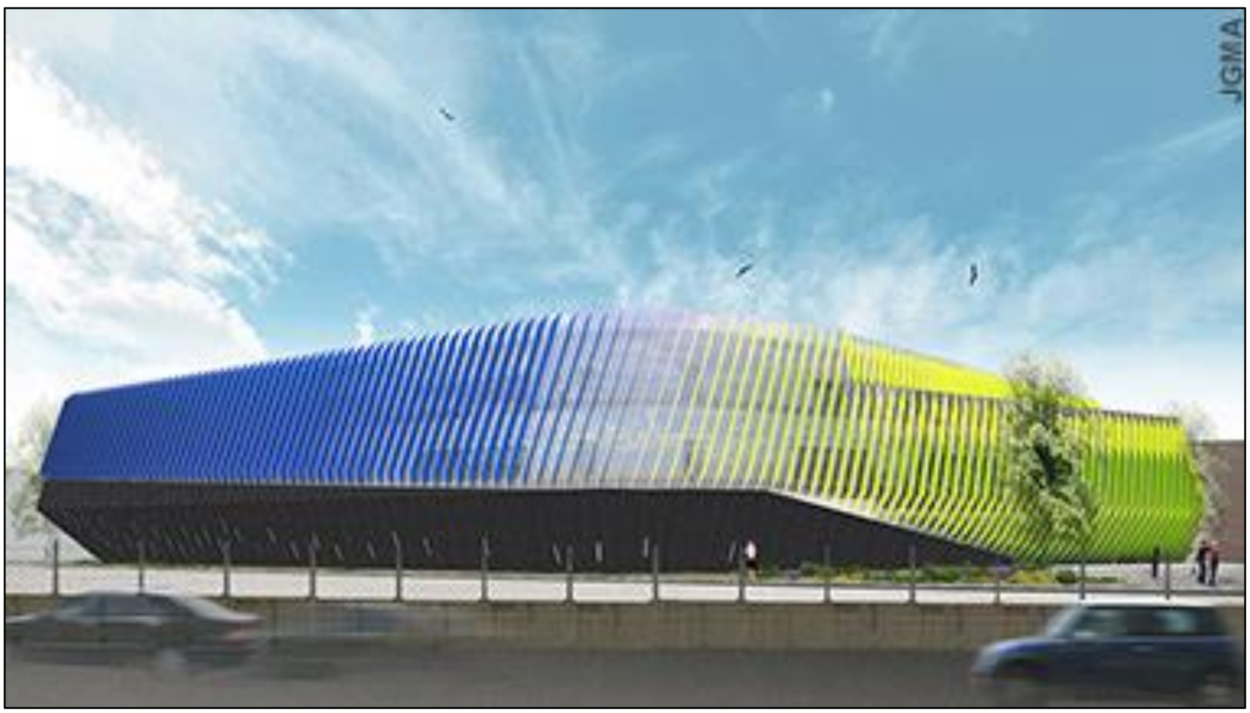

Image 1 – Showing El Centro's curtain wall and unique dual coloring of the fins

Mechanical System Design

Design Objectives

El Centro is the first building to be built on Northeastern Illinois's newest campus. The mechanical HVAC system was designed to exhibit energy efficiency goals outlined in LEED and will aim to achieve a LEED Gold Certification. The design will provide fresh outside air in conformance with building code requirements and thermal comfort based on ASHRAE standards. Heating and cooling will be provided to all occupied spaces. Spaces that have high moisture and/or odor content, such as laboratories and bathrooms, are exhausted to the outside and supplemented with conditioned makeup air. The spaces with large exposure to glass is supplemented with radiant heat from perimeter tubes. Mechanical equipment such as boilers and pumps are located on the first floor in a designated mechanical room and ventilation equipment such as AHU's are located on the roof. All equipment, such as VAV boxes, are located appropriately to achieve LEED required sound levels.

Design Conditions

NEIU El Centro is located on the northwest side of Chicago, Illinois and falls under climate zone 5A. This zone is described as moist and humid and has moderately hot summers and cold winters. Weather data for this area was taken from the 2009 ASHRAE Handbook of Fundamentals for Midway Airport which is located near the site. The design conditions for the building are set points of an indoor air temperature of 75°F for the cooling season and 70°F for the heating season and 50% RH for both seasons. Table 1 below summarizes the design temperatures and set points used in the building.

Heating 99.6%*	Cooling 0.4%*		Dehumidification 0.4%*			Design Set Point		
DB (°F)	DB (°F)	MCWB (°F)	DP (°F)	HR	MCDB (°F)	Cooling DB (°F)	Heating DB (°F)	% RH
-1.6	92.1	74.9	75	134.1	84.3	75	70	50

Table 1 – Design Conditions *(Source: ASHRAE 2009 Handbook of Fundamentals)

Ventilation Requirements

Adequate ventilation is supplied to all spaces through two roof top air handling units (RTU-1 & RTU-2) and variable air volume boxes. Each RTU supplies 12,000 CFM of outside air which exceeds the requirements of ASHRAE 62.1-2013. The supply air entering the building has a 32% ratio of outdoor air to indoor air. Please refer to Technical Report 1 for a detailed calculation of these results. Table 2 summarizes the design outside air CFM and the required outside air CFM for each RTU.

System	Design Total Supply CFM	Design OA CFM	Required OA CFM	AHU OA %
RTU-1	38,000	12,000	7,500	32%
RTU-2	38,000	12,000	7,800	32%

Table 2 – RTU Capacities and Ventilation

Heating & Cooling Requirements

The heating and cooling loads were calculated by developing a Trane TRACE 700 model. Both the heating and cooling loads are achieved by the designed system and the RTU's seem to be a little oversized. This could be due to a multitude of reasons, such as the designer relying on previous experience to adequately size the equipment, or an error in the model created for this report. The difference in heating loads is probably due to the designer using an outdoor air temperature of -10°F design point, well below the -1.6°F required by ASHRAE for Chicago. The loads calculated by the model are summarized below in Table 3. Please see Technical Report 2 for more detail.

	System	Area Served (SF)	Total Supply (CFM)	Heating (MBh)	Cooling (Ton)	Final Size (CFM)	Final Size (MBh)
Model	RTU-1	24,000	20,700	741	93	-	-
	RTU-2	27,800	22,200	810	97	-	-
Design	RTU-1	24,000	21,700	806	93	38,000	1,250
	RTU-2	27,800	27,800	1,013	114	38,000	1,250

Table 3 – Heating and Cooling Loads

Energy Sources

El Centro has two energy sources: electricity and natural gas. Natural gas serves the two 750 MBH hot water boilers in the mechanical room and also serves the indirect gas fired furnaces in both roof top air handling units. El Centro's natural gas needs are served by a pipeline provided by Peoples Gas of Chicago. The following table summarizes the average utility rates for this location.

Fuel Type	Average Rate
Electricity Cost	0.081 $/kWh
Natural Gas Cost	0.795 $/therm

Table 4 – Average Utility Rates

Annual Energy Use

Energy Consumption

The largest consumer of power in the building is the heating plant. This makes sense because the curtain wall enveloping El Centro causes high heating loads during the cold winters of Chicago. The best way to combat this problem is to use glazing with a lower u-value or architecturally reducing the size of the curtain wall. Table 5 and Figure 1 display a breakdown of the total energy usage of the building. Please refer to Technical Report 2 for a more detailed analysis of this energy usage.

Equipment	Electricity Consumption (kWh)	Natural Gas Consumption (kBtu)	Total Building Energy (kBtu/yr)	% of Total Building Energy
Cooling Plant	257,578	-	879,115	21.6
Heating Plant	4,964	1,516,747	1,533,689	37.6
Lights	388,218	-	1,324,987	32.5
Receptacles	99,337	-	338,038	8.3
Total	*750,097*	*1,516,747*	*4,075,829*	*100*

Table 5 – Model Load Analysis Results

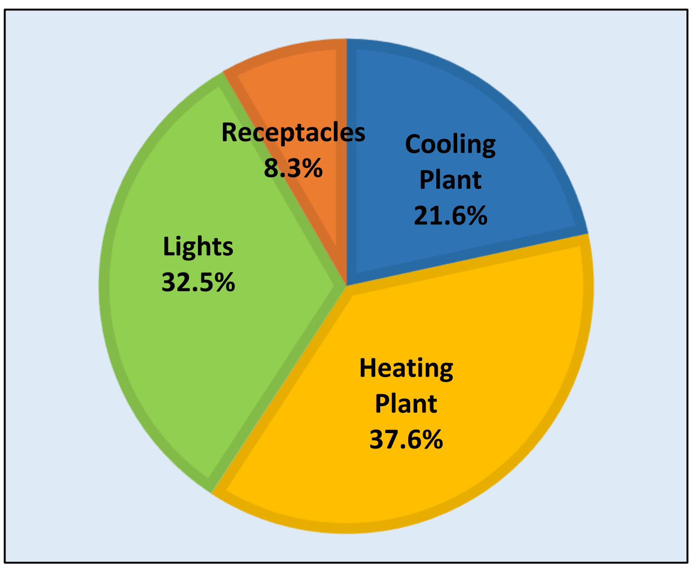

Figure 1 – Pie Chart of Energy Consumption

Energy Costs

The model has predicted a total annual cost of electricity of about $60,000 and the total cost of natural gas to be about $12,000. This results in a total annual cost of $72,000 to heat and power the building. The cost per square foot of the energy is about 1.31 $/SF. An energy analysis was also conducted by the MEP engineer, Primera, using a TRACE model. The energy analysis was conducted to apply for energy efficient LEED credits. Primera estimated that the annual cost of operating the building would be $64,000. These results are summarized in Table 6 below. Since El Centro was recently completed in September 2014, there are not actual utility bills available to compare this data.

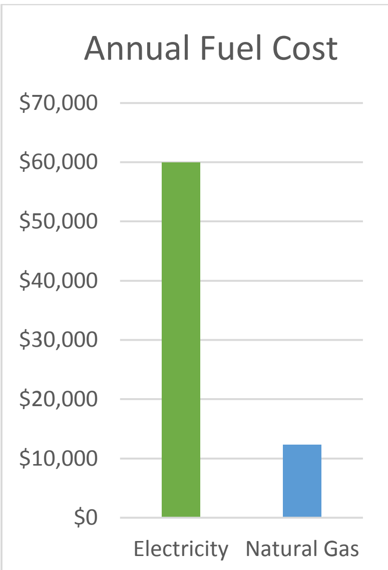

Figure 3 – Annual Fuel Cost

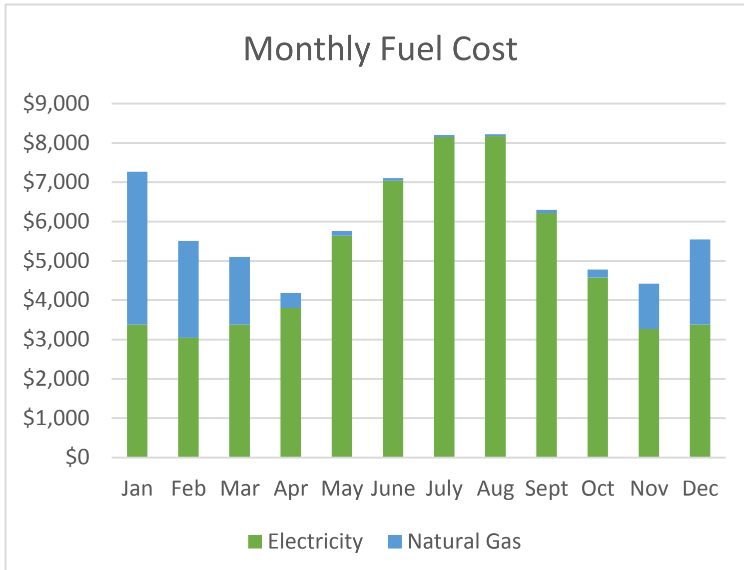

Figure 4 – Monthly Fuel Costs

Analysis	Total Annual Cost	Cost/SF	% Difference From Design
Modeled	$72,000	1.31 $/SF	11%
Designer	$64,000	1.18 $/SF	-

Table 6 – Annual Fuel Cost Comparison

Energy Grants

The following energy grants from the government are projected to be received:

$125,000 for sustainable design and enhanced commissioning.
$275,000 for the 80 kW DC PV array

These grants have not yet been awarded but have been applied for and the project team expects the project to receive them in the near future.

Mechanical System Equipment

Heating Plant

The majority of the heating equipment of El Centro is located in the mechanical room on the first floor because there is no basement.

Boilers

The mechanical room houses two identical 750 MBH natural gas fired hot water boilers. These boilers serve the hot water radiant finned tubes, VAV reheat coils, and a few cabinet unit heaters located throughout the building. Table 7 below summarizes the statistics.

Tag	Fuel Type	Rating (MBH)		Water Temperature (°F)		Flow Rate (GPM)	Min. Thermal Efficiency (%)
		Input	Output	Entering	Leaving		
B-1	NG	750	657	130	150	66	90
B-2	NG	750	657	130	150	66	90

Table 7 – Boiler Operation

Hot Water Pumps

The mechanical room contains two centrifugal, hydronic hot water pumps that serve the boilers. Hot water is pumped to the 71 VAV boxes throughout the building, the hot water radiant finned tubes, and the 10 unit heaters throughout the building. Both pumps are base mounted and end suction. Only one pump will operate at a time and can supply a flow of 100 GPM and a pressure head of 90 feet. Each pump has VFD control and a disconnect switch. See the table below for further properties.

Tag	Flow (GPM)	Head (FT)	Motor		
			HP	RPM	Motor Control
HWP-1	100	90	7.5	1750	VFD
HWP-2	100	90	7.5	1750	VFD

Table 8 – Hot Water Pump Operation

Heating Equipment

Hot water radiant finned tubes run along the length of the curtain wall. They are designed to have a mean water temperature of 140°F. They are made up of copper tubing and aluminum fins. There are also three hot water unit heaters and seven hot water cabinet unit heaters that provide heat for miscellaneous spaces not served by the radiant tubes such as staircases. 71 hot water reheat coils in the VAV boxes are also available to heat the building during the heating season.

Cooling Plant

The cooling equipment of El Centro is located on the roof.

Roof Top Air Handling Units

There are two identical packaged air handling units located on the roof called RTU-1 and RTU-2 respectively. They serve all of the ventilation and cooling requirements of the building year round. They each comprise of: (in order of airflow) return fan, economizer, filter, cooling coil, supply fan, indirect gas fired furnace, sound attenuator, and discharge plenum. RTU-1 and RTU-2 are both served by separate air cooled condensing units, also located on the roof. Each RTU has an indirect natural gas fired burner to allow for reheat and humidity control. Architecturally and mechanically, the building is split up into two distinct zones: A and B. See a simplified floor plan sketch in Figure 5. RTU-1 serves all of the first floor, and zone B on the second floor. RTU-2 serves zone B on the second floor and all of the third floor. Both air handling units use refrigerant R-410A.

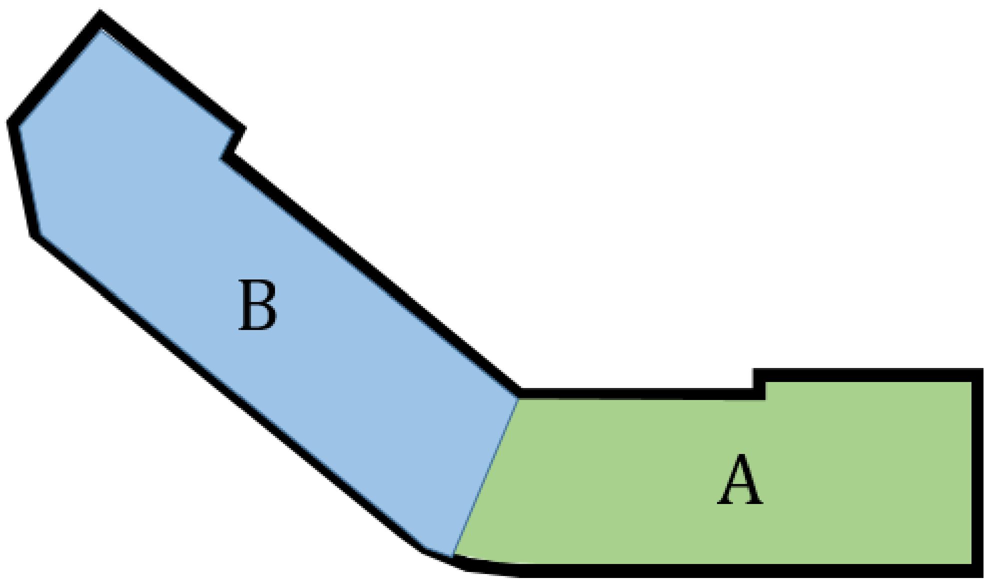

Figure 5 - Simplified Typical Floor Plan Sketch

Tag	Condensing Unit	Capacity (CFM)	Min. OA (CFM)	DX Cooling Coil			Indirect Gas Fired Heating		
				EDB (°F)	LDB (°F)	Refrig.	EDB (°F)	LDB (°F)	Fuel
RTU-1	CU-1	38,000	12,000	79.8	55	R-410A	18.9	55	NG
RTU-2	CU-2	38,000	12,000	79.8	55	R-410A	18.9	55	NG

Table 9 – Air Handling Unit Operation

Air Cooled Condensing Units

Each RTU is served by a separate air cooled condensing unit (CU). Each CU uses refrigerant R410-A which is environmentally friendly. The CU's also employ a hermetic scroll compressor. See Table 10 below for further properties of the condensing units.

Tag	RTU	Condenser E.A.T. (°F)	Fan		Refrig.	Efficiency	
			No. of Fans	CFM		EER (BTUH/W)	IPLV (BTUH/W)
CU-1	RTU-1	95	6	15,600	R-410A	11.3	15.6
CU-2	RTU-2	95	6	15,600	R-410A	11.3	15.6

Table 10 – Air Cooled Condensing Unit Operation

System Operation & Schematics

Air Side

Each RTU has two supply fans and two return fans with separate VFD control for each. The exhaust air, return air, and outside air dampers fluctuate depending on outdoor air temperature and relative humidity. Both RTU's employ an economizer cycle. The minimum volume of outdoor air incorporated is about 33% of the total supply air.

The rooftop air handling units combine the return conditioned air and outdoor air. The mixed air then passes through the filter (prefilter MERV-7 & final filter MERV-13). The differential pressure between the upstream and downstream sides of the filter is measured. Then the air passes over the direct expansion cooling coil served by the air cooled condensing unit. The air then passes through the modulating indirect natural gas fired burner which is used during the heating season. A final supply air temperature and duct static pressure are measured to ensure conditions are met. Please refer to Figure 6 below.

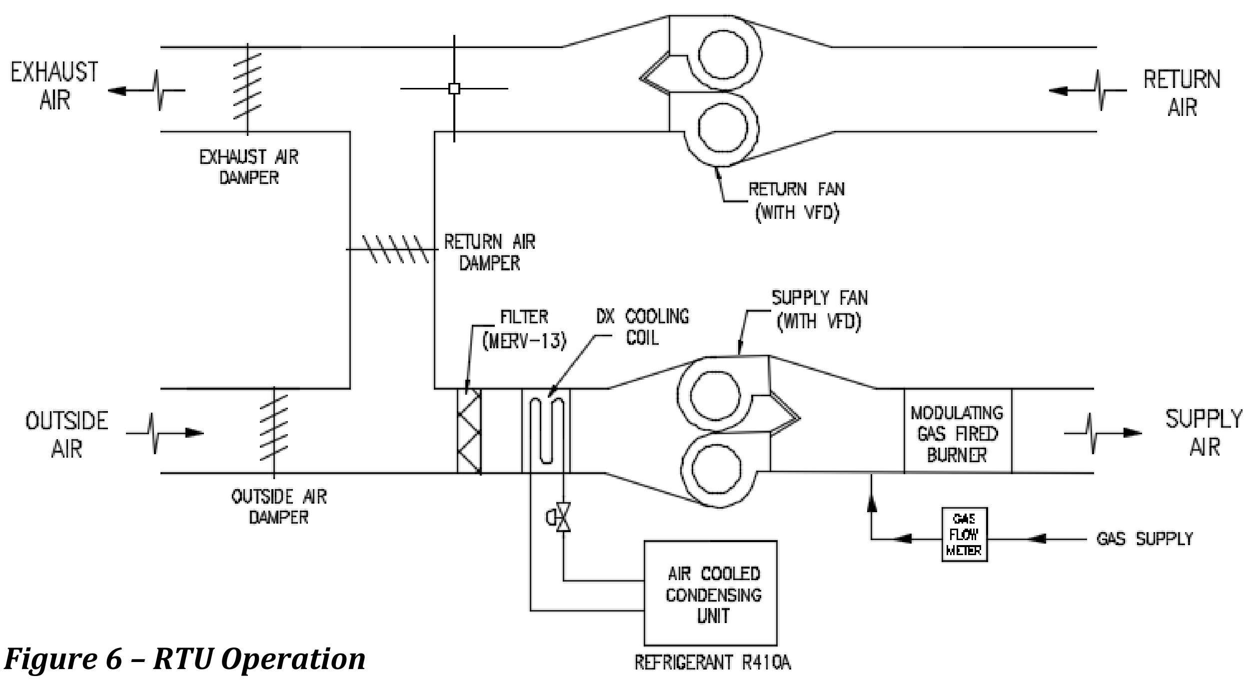

Figure 6 – RTU Operation

Water Side

This facility does not used chilled water.

The mechanical heating hot-water system is comprised of two natural-gas fed boilers capable of providing a combined total of 1500 MBH of sensible heat. The boilers are variable flow condensing type, and the hot water system is variable-primary.

The hot water produced in the boilers will first pass through a 300 gallon buffer tank where excess hot water can be stored. It will then pass through an 84 GPM air-separator and then be distributed to the building via the hot water pumps. The HW pumps operate in a lead/standby mode. Only one pump will operate at any given time. Each pump will have VFD control. The VFD speed for the lead pump will modulate to maintain differential pressure in the hydronic loop as measured by the differential pressure transmitter (DPT).

All of this equipment is located in the mechanical room on the first floor. The hot water system will serve the radiant finned tubes, the 71 VAV reheat coils, and the ten cabinet unit heaters. Refer to Figure 7 for a detailed flow diagram.

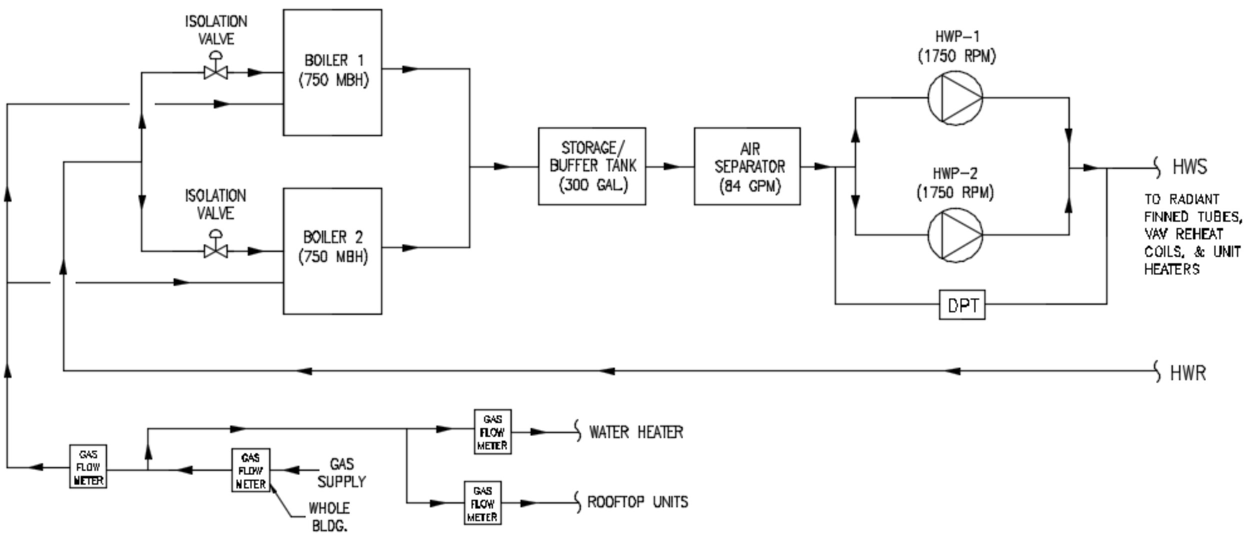

Figure 7 – Hot Water Flow Diagram

Mechanical System Evaluation

Lost Usable Space

The mechanical room on the first floor houses the hot water heating plant and is 650 ft^2. There are mechanical shafts on the 2nd and 3rd floors to allow for the ductwork from the roof top air handling units to enter the building. Each shaft is about 105 ft^2. This results in a total loss of 860 ft^2 or 1.4% of the gross area of the building.

Mechanical System First Cost

The overall project construction cost is approximately $22 million dollars. The HVAC system of the building was estimated to cost $2.4 million dollars, or 38 $/SF. This results in the installing of the mechanical system to be about 11% of the total project cost.

Operation History of System

El Centro was recently completed in September of 2014 so there is currently no data available for actual operating conditions. This page will be updated if this data becomes available later in the year. In the meantime, the following data was generated by the Trane TRACE model in Technical Report 2.

The largest electricity consumption is predicted to occur during the summer months. This is expected because of the high cooling loads required and the roof top air handling units consume electric energy. The highest rates of natural gas consumption occur during the winter months. This is also expected because of the high heating loads associated with the winter and the boilers are fired from natural gas. Figures 8 and 9 below summarize the predicted electric and natural gas consumption of El Centro.

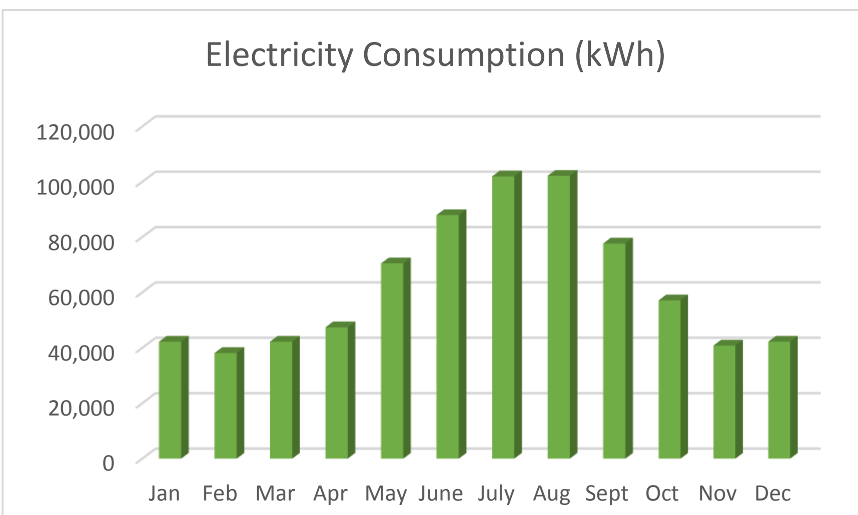

Figure 8 – Predicted Monthly Electricity Consumption

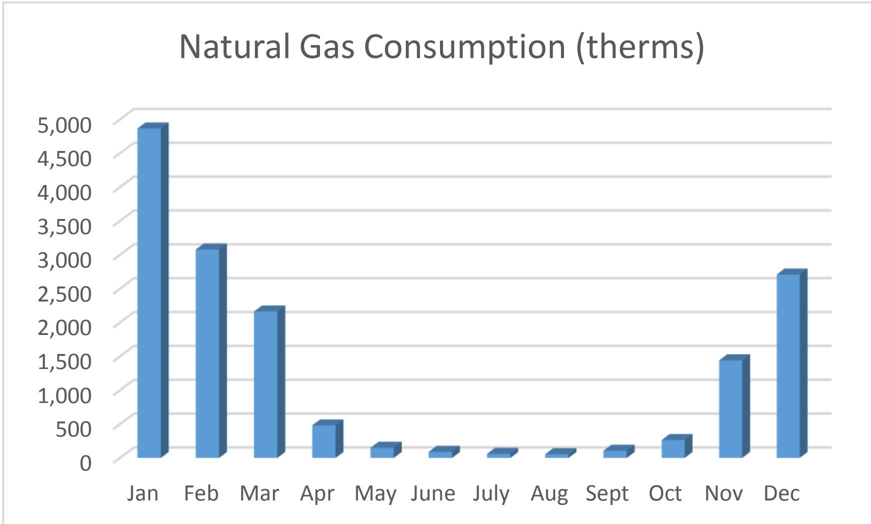

Figure 9 – Predicted Monthly Natural Gas Consumption

LEED Evaluation

El Centro aimed to achieve a LEED Gold Certification. Below is a breakdown of points that the mechanical system is eligible for by the USGBC LEED v4 for Building Design and Construction. This project was designed by the project team using LEED v3 which has some variations from LEED v4.

Energy & Atmosphere Credits (19/35 pts)

✓ EA Prerequisite 1: Fundamental Commissioning and Verification

The purpose of this prerequisite is to verify that the mechanical system is installed and operates as the engineer intended. Proposals were received from three separate third party commissioning agents and one was chosen for this project.

✓ EA Prerequisite 2: Minimum Energy Performance

The purpose of this prerequisite is to reduce environmental and economic harm by unnecessary energy usage and ensure an energy efficient system. The design engineer claims that this project has achieved an energy cost savings of 31.36% using the ASHRAE90.1-2007 Appendix G methodology. A minimum energy cost savings of 5% is required for all new construction projects. Energy efficient measures incorporated into the building design include high efficiency glazing, reduced interior lighting power density, occupancy sensors, and high efficiency HVAC equipment.

✓ EA Prerequisite 3: Building-Level Energy Metering

The purpose of this prerequisite is to ensure that energy usage by the building is tracked. There is a natural gas meter installed where the natural gas supply pipeline enters the building. It is assumed that Commonwealth Edison (ComEd) has installed a meter to track total electricity usage of the building,

✓ EA Prerequisite 4: Fundamental Refrigerant Management

This prerequisite bans chlorofluorocarbon (CFC) based refrigerants from being used in HVAC equipment. The cooling system of the building uses refrigerant R-410A which does not contribute to ozone depletion.

✓ EA Credit 1: Enhanced Commissioning (3/6 pts)

As previously stated, three separate commissioning agencies submitted proposals to the architect and they included enhanced commissioning in their proposals. This would follow Path 1 of this credit and be eligible for 3 points.

✓ EA Credit 2: Optimize Energy Performance (12/20 pts)

This credit is to enhance energy performance beyond that of prerequisite 2. As previously stated, the project was predicted to have an energy cost savings of 31.36% which would make this project eligible to receive 12 points out of the 20 possible.

✓ EA Credit 3: Advanced Energy Metering (1/1 pts)

The purpose of this credit is to ensure that all whole-building energy sources used by the building are being tracked to allow for possible energy savings in the future. As previously stated in prerequisite 3, a natural gas meter is installed and it is assumed that ComEd has installed an electricity meter for the building.

X EA Credit 4: Demand Response (0/2 pts)

EA credit 4 requires that a demand response technology be used to help make energy generation and distribution systems more efficient. This is a new credit for LEED v4 and was not included in v3. Demand response technology cannot be found anywhere in the project documents.

✓ EA Credit 5: Renewable Energy Production (3/3 pts)

A building can receive up to 3 points for using on-site renewable energy. There is a photovoltaic array located on the roof of El Centro that produces solar energy and it is expected to produce about 9% of the buildings energy needs. This will qualify the project for three LEED points according to Table 11.

Percentage renewable energy	Points (except CS)	Points (CS)
1%	1	1
3%	—	2
5%	2	3
10%	3	—

Table 11 – Points for Renewable Energy

X EA Credit 6: Enhanced Refrigerant Management (0/1 pts)

The intent of this credit is to reduce ozone depletion and to comply with the Montreal Protocol. The air cooled condensing units utilize refrigerant R-410A. To comply with this credit: $LCGWP + LCODP \times 10^5 \leq 100$. This project fails to meet this requirement. See Table 12 below for the calculation.

Refrigerant	ODP	GWP	LCODP	LCGWP	LCGWP + LCODP*10^5	Credit?
R-410A	0	1725	0	258.75	258.75	No

Varaibles: Assume Worst Case
Lr = 2% Leakage Rate
Mr = 10% End of Life Refrigerant Loss
Life = 10 year life expectancy
Rc = 5 lbm/ton

Table 12 – EA Credit 6 Calculation

X EA Credit 7: Green Power and Caron Offsets (0/2 pts)

To receive this credit, the building owner must engage in a contract for a minimum of 5 years to be delivered at least 50% of the projects power consumption from green power, carbon offsets, or renewable energy certificates (RECs). Green power delivery could not be found anywhere in the project documents.

Indoor Environmental Quality Credits (4/7 pts)

✓ EQ Prerequisite 1: Minimum Indoor Air Quality Performance

The project complies with this section because it meets the minimum ventilation requirements set forth by ASHRAE 62.1-2013. See Technical Report 1 for a detailed calculation and analysis of the procedure.

✓ EQ Prerequisite 2: Environmental Tobacco Smoke Control

Smoking is prohibited inside of El Centro. Signage will be posted to prohibit smoking within 25 feet of all entries, outdoor air intakes, and operable windows in compliance with this prerequisite.

✓ EQ Prerequisite 3: Minimum Acoustic Performance

This is a new prerequisite that was not included in LEED v3. It requires a maximum background noise level of 40dBA from HVAC systems in classrooms and acoustical treatment for schools located near noisy exterior sources. This project had an acoustical consultant on the design team who ensured that all classrooms are NC 30-35 which is in compliance with this section. The building is also located along the Kennedy Expressway in Northwest Chicago. There is a corridor that runs along the perimeter of the building that "shields" the classrooms from the noisy expressway.

✓ EQ Credit 1: Enhanced Indoor Air Quality Strategies (1/2 pts)

The purpose of this credit is to improve indoor air quality. A CO_2 sensor has been installed within each densely occupied space. Drawings confirming the location of the CO_2 sensors are provided in the project documents allowing the project to be eligible for one point.

X EQ Credit 4: Indoor Air Quality Assessment (0/2 pts)
The purpose of this credit is to establish better indoor air quality (IAQ) after building construction and during occupancy. One method is to flush-out the entire building by supplying a certain amount of total outside air volume. This is a new credit for LEED v4 and nothing was found in the project documents to comply with this section.

✓ EQ Credit 5: Thermal Comfort (1/1 pts)
This project complies with ASHRAE 55-2007 which identifies the range of design for temperature, humidity, and air movement that provide satisfactory thermal comfort for a minimum of 80% of the building occupants. Temperature sensors are set to automatically adjust to winter, summer, and unoccupied conditions.

✓ EQ Credit 9: Acoustical Performance (2/2 pts)
This is a new credit for LEED v4 that sets minimum reverberation times and background noise levels for different spaces. As stated previously, an acoustical consultant was on the project team and responsible for the acoustical performance of the building. The criteria provided by USGBC for this credit seem to be in line with industry standards and guidelines set by ASHRAE so it is probably safe to assume that the project would be eligible for this credit.

Mechanical System Evaluation Summary

The goal for this new construction project is to establish a sustainable building that will be the forefront of Northeastern Illinois University's new campus. El Centro's mechanical system exceeds all of the requirements to adequately heat, cool, and ventilate the building. There is sufficient data to suggest that the project will achieve satisfactory indoor air quality and comfort to most of the occupants.

The overall project cost is $22 million dollars while the mechanical system first cost is expected to have been $2.4 million (38$/SF). Only 1.4% of the gross building area was dedicated to the mechanical system, yet it was 11% of the total project cost. The design utilities minimal occupiable space for the mechanical system. The project team also expects for the building to receive $400,000 in rebates from the government for its impressive sustainable design.

The rooftop air handling units seem to be a bit oversized and exceed the minimum requirements for heating, ventilation, and air conditioning. It seems that smaller air handling units could be appropriate that would consume less energy but the design engineer could have been relying on past experience when sizing the equipment.

El Centro is projected to achieve a LEED Gold Rating but further energy savings could be improved by adding energy recovery devices to extract or reject heat to exhausted air. Optimization of the hot water plant and air handling units control can be studied to further analyze potential energy savings.

The current design achieves the design objectives and requirements set forth by various standards, building codes, and the owner. However, further analysis into other viable design options can be explored to allow El Centro to exceed these minimum requirements. These ideas will be presented further in the Thesis Proposal Report.

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