Technical Report 2

Energy Model

October 6, 2014

NEIU El Centro
Chicago, IL

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Executive Summary

The purpose of Technical Report 2 is to examine the mechanical systems of NEIU El Centro with load modelling software. A Trane TRACE model was prepared to calculate: the various loads of the building, annual and monthly costs of fuel consumption, and the amount of pollutant emissions produced from fuel consumption. The analysis was conducted using the drawings and documents issued for construction. The results calculated here were also compared to the results calculated by the mechanical engineer.

The TRACE model produced a cooling load of 260 SF/ton and a heating load of 30.8 BTUh/SF. The heating load is relatively high because nearly the entire building façade is made up of a glass curtain wall. The number calculated here is higher than the designers' because the designer used -10°F outside air temperature, which is lower than what ASHRAE recommends. The total supply air calculated was 0.86 CFM/SF and the total ventilation supply air was 0.37 CFM/SF.

The heating plant was determined to use the most energy out of any of the systems in the building. This is most likely due to the high heating loads associated with having glass curtain wall construction in Chicago, which experiences very cold winters. The total annual cost of heating and powering the building was calculated to be about $72,000. This results in a cost per square foot of 1.31 $/SF. An energy analysis, including costs, was also conducted by the mechanical engineer to apply for LEED credits and determined the annual cost of energy to be about $64,000. This is 11% lower than the amount calculated by the TRACE model in this report.

An emission analysis was also conducted to determine the amount of pollutants produced by fuel consumption that will be released into the environment each year. The total annual consumption is about 750,000 kWh of electricity and 1,550 cubic feet of natural gas each year. This will result in millions of pounds of carbon dioxide released into the air and thousands of pounds of solid waste.

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.

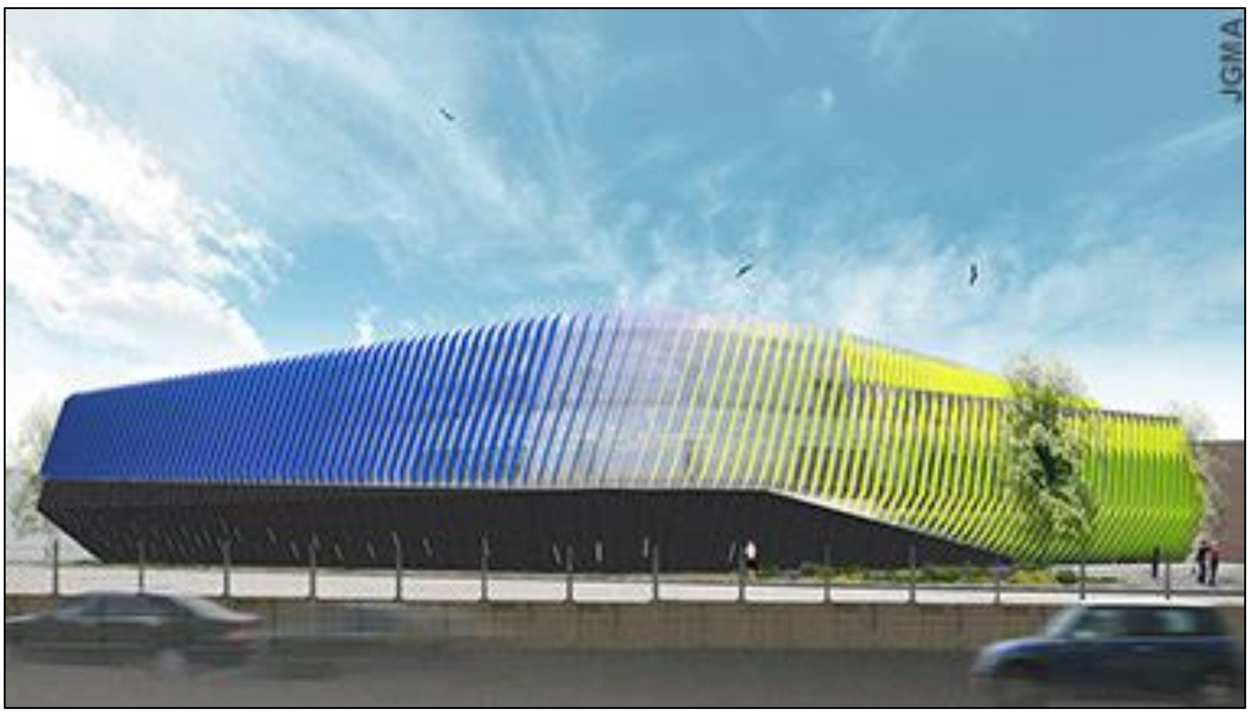
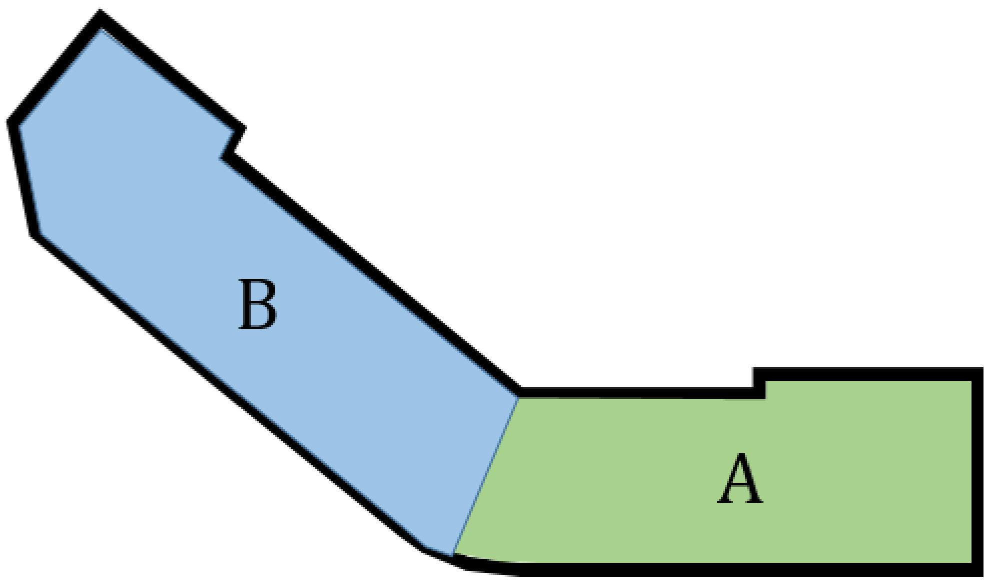


Image 1 – Showing El Centro's curtain wall and unique dual coloring of the fins

Mechanical Systems Overview

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 will 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. Architecturally and mechanically, the building is split up into two distinct zones: A and B. See the simplified floor plan sketch below. 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.



Simplified Typical Floor Plan Sketch

VAV Boxes
El Centro is served by 71 variable air volume boxes. The VAV boxes have reheat coils that are served by two boilers

Boilers
The buildings heating loads are served by two identical 750 MBH natural gas fired hot water boilers. A corridor wraps around the entire perimeter of the building to shield the classrooms from the noisy Kennedy Expressway. This leads to no heating loads in any of the rooms except the corridor. The boilers serve hot water radiant finned tubes that run the length of the perimeter of the building in the corridor. The boilers also serve the heating coils located in all of the VAV boxes in each space. A separate natural gas water heater is used for domestic hot water.

System Design Load Estimation

A model was generated in Trane TRACE 700 to determine the design load energy consumption of NEIU El Centro. Lighting, infiltration, ventilation, occupancy, mechanical equipment, solar gain, envelope, and miscellaneous electrical loads were taken into consideration and utilized in this analysis. Some information was taken directly from the project documents and load models created by the engineer of record, Primera Engineers. Other information was obtained from ASHRAE guidelines and reasonable assumptions. A block load analysis was conducted in this analysis to simplify the model. The results calculated here were compared to the design documents.

Design Conditions

Location

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. Table 1 below summarizes the design temperatures and set points used in the building for heating and cooling calculations.

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)

Building Construction

El Centro is enveloped almost entirely in a curtain wall. Most classrooms and offices do not have exterior walls so that they are shielded from the noisy Kennedy Expressway. They are surrounded by a corridor that runs the perimeter of the building which is enclosed by the curtain wall. The building has solar fins that help limit the amount of direct sunlight into the spaces. Below is a summary of the U-values used in this energy analysis (courtesy of Primera Engineers and JGMA).

Surface	Description	U-Value
Curtain Wall	Glazing	0.29
Solid Wall	CMU, metal studs, Insulation, GWB	0.056
Roof	Metal deck, NWC, PVC membrane	0.033

Table 2 – U-Values

Assumptions

Occupancy & Ventilation

The exact occupancy for some spaces, such as classrooms and offices, were given by the architect, JGMA. For other spaces, the occupancy was calculated on a SF/person basis from ASHRAE 62.1-2013. The minimum outdoor airflows required for each space were taken directly from the design documents.

Lighting & Miscellaneous Loads

The same lighting loads as the design engineer were used and were done on a watt per square foot basis. Miscellaneous loads were included to account for computers and other office equipment located throughout the building. The miscellaneous loads were also done on a watt per square foot basis, reflecting the same method used by the design engineer. Table 3 summarizes the loads used.

Type of Space	Lighting W/SF	Miscellaneous W/SF
Classroom	1.0	0.5
Office	1.0	0.5
Corridor	0.5	-
Storage	0.5	-
Restroom	0.5	-
Lounge	1.0	0.5

Table 3 – Lighting & Miscellaneous Loads

Infiltration

The building is tightly constructed and contains no operable windows. However, the design engineer used 0.4 air changes per hour for any space that had an exterior wall. This may be an overestimation but the same method was applied to this model.

Schedules

El Centro is a university building and will be open 24 hours a day for students who will be studying late. The greatest load is expected to be 8:00 AM to 6:00 PM when classes will be in session. The following schedule reflects the expected occupancy of the building throughout the day and was used in the energy model.

Start Time	End Time	Rate
Midnight	8:00 A.M.	Off-Peak
8:00 A.M.	6:00 P.M.	Peak
6:00 P.M.	9:00 P.M.	Mid-Peak
9:00 P.M.	Midnight	Off-Peak

Table 4 – Occupancy Schedule

System Equipment

The building is served by two roof top air handling units that serve the 71 VAV boxes throughout the spaces. Each RTU is served by a separate air cooled condensing unit. RTU-1 serves zones A and B on the ground floor and zone B on the second floor. RTU-2 serves zone A on the second floor and zones A and B on the third floor. See the mechanical systems overview section at the beginning of this report for reference and for more information about the systems.

Load Results

The results of the TRACE energy model show that the values calculated in this report are relatively close to the designer's values. Table 5 below compares the results modeled for this report against the designer's results.

	System	Cooling (SF/ton)	Heating (Btu/h·SF)	Total Supply Air (CFM/SF)	Ventilation Supply (CFM/SF)
Modeled	RTU-1	260	30.8	0.86	0.37
	RTU-2	285	29.2	0.80	0.36
	Average	**275**	**29.9**	**0.83**	**0.37**
Designed	RTU-1	260	33.5	0.90	0.39
	RTU-2	244	36.5	1.00	0.39
	Average	**251**	**35.2**	**0.96**	**0.39**
	% Difference	*+9.5%*	*-17.8%*	*-15.7%*	*-5.4%*

Table 5 – Model vs. Design Load Analysis Results

Load Results - Conclusion

For reference, the total square footage of El Centro is about 55,000 SF if you want to obtain the total CFM's required for a certain load above. The largest difference appears in the heating requirements of the building. This is probably because the designer used a design outdoor air temperature of -10°F, well below the -1.6°F value obtained in ASHRAE Handbook of Fundamentals. Errors could have occurred in fenestration calculations because they were based off of elevations and floor plans. Simplifications were also made modelling block loads, instead of individual rooms, and errors could have been made. There is also a tilt associated with some of the curtain wall in the building that was not taken into consideration for the load model because of time constraints.

Annual Energy Consumption and Operating Costs

An analysis of NEIU El Centro's annual energy consumption and operating costs was conducted using the same TRACE model. A full year energy simulation was conducted using the same ventilation rates, internal generation and envelope values for the load calculation. To do this, a cooling and heating plant was added to the TRACE model. The cooling plant consists of two separate packaged roof top air handling units which are served by their respective air-cooled condensing units. The heating plant consists of a natural gas fired boiler served by a hot water pump.

Energy Consumption Breakdown

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 6 and Figure 1 display a breakdown of the total energy usage of the building.

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 6 – Model vs. Design Load Analysis Results

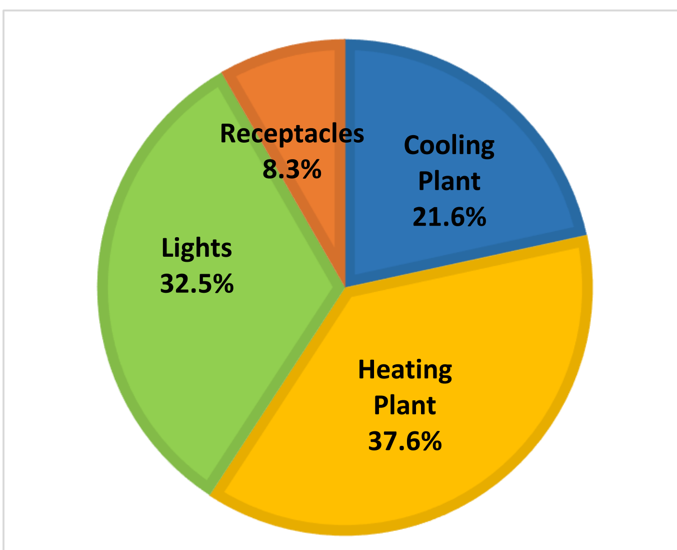


Figure 1 – Pie Chart of Energy Consumption

Monthly Operating Cost Breakdown

The following graph summarize the monthly operating costs of each system. As expected, heating and cooling operating costs vary with the season and mimic the natural gas and electricity consumption graphs below (Figures 3 & 4). Lighting and receptacle loads are fairly consistent throughout the year.

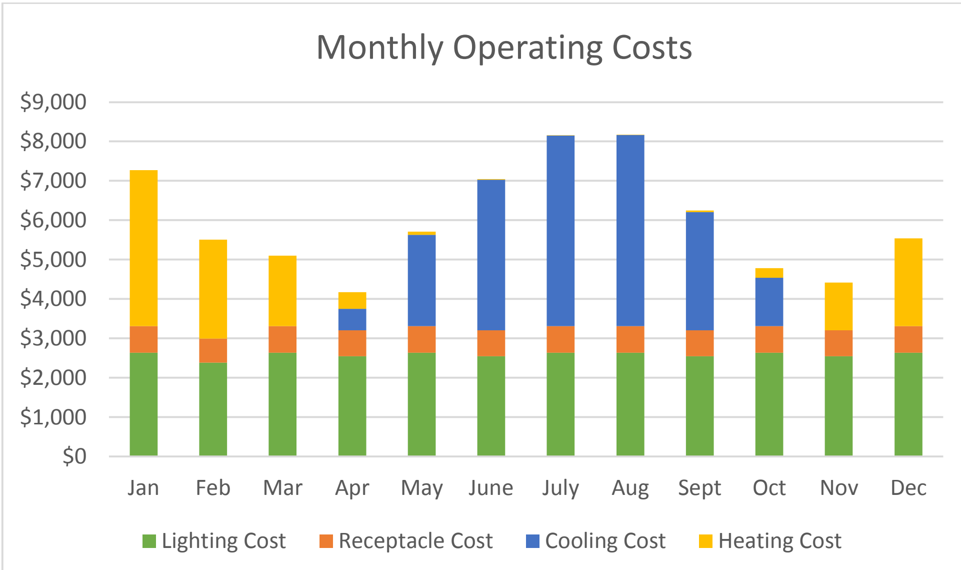


Figure 2 – Monthly System Cost

Monthly Energy Usage by source

The largest electricity consumption occurs 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 3 and 4 below summarize the electric and natural gas consumption of El Centro.

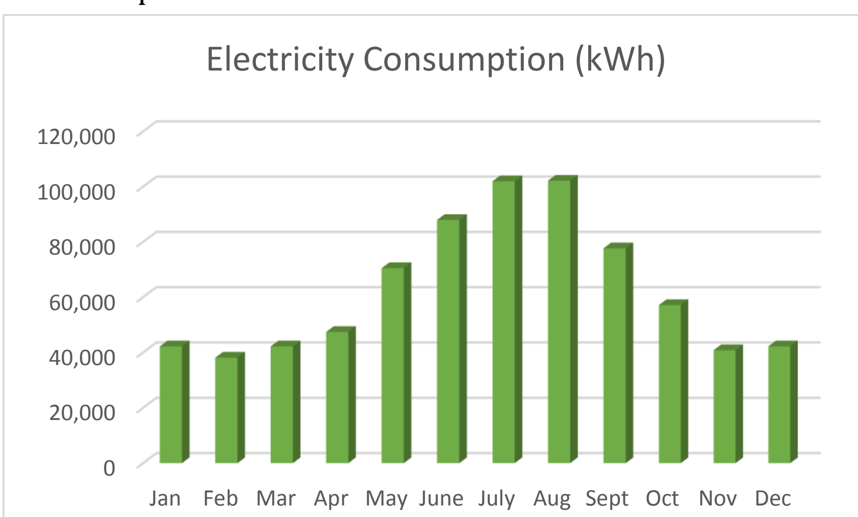


Figure 3 – Monthly Electricity Consumption

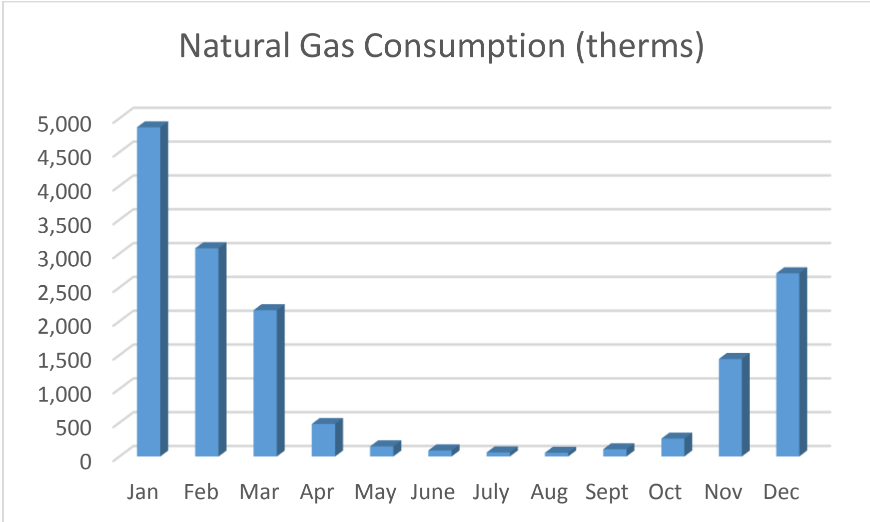


Figure 4 – Monthly Natural Gas Consumption

Annual and Monthly Operating Costs
The cost of electricity in Chicago averages about 0.08 $/kWh. The average cost of natural gas is about 0.80 $/therm. These values were obtained from the energy analysis conducted by Primera Engineers. The figures below summarize the annual and monthly fuel costs associated with El Centro.

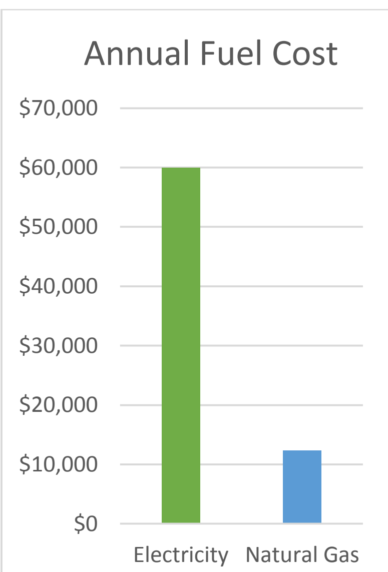


Figure 5 – Annual Fuel Cost

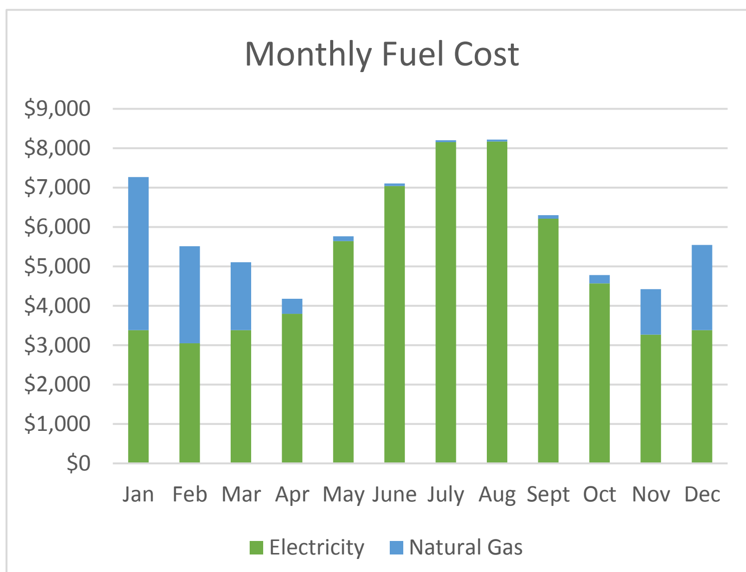


Figure 6 – Monthly Fuel Costs

Annual Costs Conclusion

The total annual cost of electricity is about $60,000 and the total cost of natural gas is about $12,000. This results in a total annual cost of $72,000 to heat and power the building. The cost per square foot 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 the table below. Since El Centro was recently completed in September 2014, there are not actual utility bills available to compare this data.

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

Table 7 – Annual Fuel Cost Comparison

Annual Pollutant Emissions

The environmental impact of El Centro is due mainly to electricity consumption. The data in the table below were calculated using a report from the National Renewable Energy Laboratory entitled *Source Energy and Emission Factors for Energy Use in Buildings.* The total annual electricity consumption of the building is about 750,000 kWh and the total annual natural gas consumption is about 1546 cubic feet. This results in millions of pounds of carbon dioxide released into the atmosphere and thousands of pounds of solid waste each year.

Pollutant	Electricity Rate (lb/kWh)	Natural Gas Rate (lb/MCF)	Emissions due to Electricity (lb/yr)	Emissions due to Natural Gas (lb/yr)	Total Emissions (lb/yr)
CO_{2e}	1.74E+00	1.23E+02	1305171	190158	1495329
CO_2	1.64E+00	1.22E+02	1230161	188612	1418773
CH_4	3.59E-03	2.50E-03	2693	4	2697
N_2O	3.87E-05	2.50E-03	29	4	33
NO_x	3.00E-03	1.11E-03	2250	2	2252
SO_x	8.57E-03	6.32E-04	6428	1	6429
CO	8.54E-04	9.33E-02	641	144	785
TNMOC	7.26E-05	6.13E-03	54	9	64
Lead	1.39E-07	5.00E-07	0	0	0
Mercury	3.36E-08	2.60E-07	0	0	0
PM10	9.26E-05	8.40E-03	69	13	82
Solid Waste	2.05E-01	0.00E+00	153770	0	153770

Table 8 – Annual Emissions due to Fuel Consumption

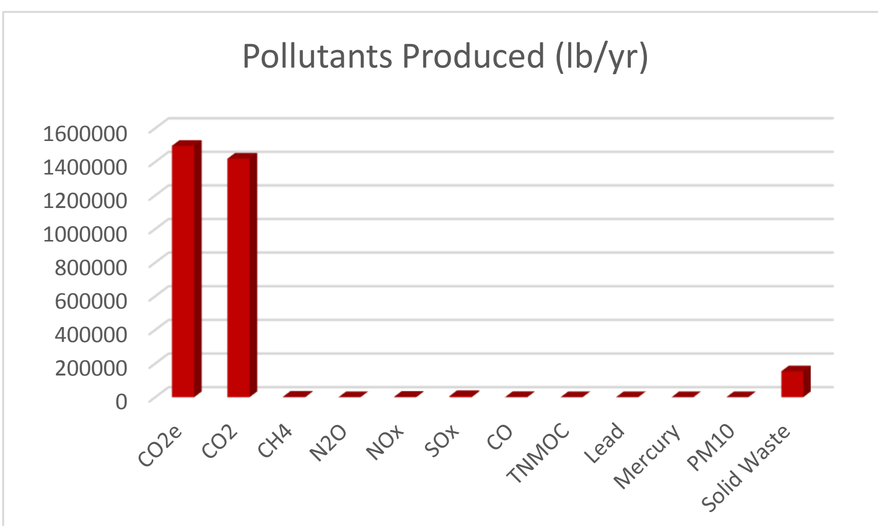


Figure 7 – Bar Graph of Annual Pollutants Produced (lb/yr)

References

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

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

ASHRAE. (2009). *2009 ASHRAE Handbook – Fundamentals.* Atlanta, GA: American Society of Heating, Refrigeration, and Air Conditioning Engineers, Inc.

Primera Engineers Ltd., Construction Documents, John Palasz and Lindsay Bose, Primera Engineers, Chicago, Illinois.

Appendix A

System Checksums

By ACADEMIC

RTU-1 — **Variable Volume Reheat (30% Min Flow Default)**

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 15; Outside Air: OADB/WB/HR: 91 / 73 / 96

Clg Space Peak — Mo/Hr: 8 / 15; OADB: 89

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	0	0	0	0	0
Glass Solar	164,288	0	164,288	15	184,606	37
Glass/Door Cond	34,364	0	34,364	3	28,071	6
Wall Cond	10,450	4,431	14,881	1	10,502	2
Partition/Door	0		0	0	0	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	67,351		67,351	6	24,267	5
Sub Total ==>	276,453	4,431	280,883	25	247,445	49
Internal Loads						
Lights	59,265	14,816	74,081	7	59,265	12
People	326,012	0	326,012	29	181,118	36
Misc	23,232	0	23,232	2	23,232	5
Sub Total ==>	408,509	14,816	423,325	38	263,615	52
Ceiling Load	-7,153	7,153	0	0	-7,205	-1
Ventilation Load	0	0	336,712	30	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	1,118		1,118	0	1,243	0
Exhaust Heat		-16,734	-16,734	-2		
Sup. Fan Heat			84,299	8		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		-44,276	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	678,927	-34,610	1,109,604	100.00	505,098	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 0

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	0	0.00
Glass Solar	0	0	0.00
Glass/Door Cond	-237,539	-237,539	32.26
Wall Cond	-22,694	-31,021	4.21
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	-137,237	-137,237	18.64
Sub Total ==>	-397,469	-405,797	55.11
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-3,659	0	0.00
Ventilation Load	0	-376,935	51.19
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	283,920	283,920	-38.56
Exhaust Heat		11,585	-1.57
OA Preheat Diff.		-205,417	27.90
RA Preheat Diff.		-36,928	5.01
Additional Reheat		-6,791	0.92
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-117,208	-736,363	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	84.0
Ra Plenum	77.4	67.8
Return	77.4	67.8
Ret/OA	83.3	20.4
Fn MtrTD	0.4	0.0
Fn BldTD	0.9	0.0
Fn Frict	2.6	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	20,747	7,112
Terminal	20,747	7,112
Main Fan	20,747	7,112
Sec Fan	0	0
Nom Vent	8,810	4,977
AHU Vent	8,810	4,977
Infil	1,824	1,824
MinStop/Rh	7,112	7,112
Return	22,571	8,936
Exhaust	10,634	6,801
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	42.5	70.0
cfm/ft²	0.86	0.30
cfm/ton	224.37	
ft²/ton	260.34	
Btu/hr·ft²	46.09	-30.81
No. People	724	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	92.5	1,109.6	735.7	20,322	83.3	67.5	78.1	49.2	49.1	52.9
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	92.5	1,109.6								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	24,073		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	15,639	8,444	54
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-269.7	7,112	49.2	84.0
Aux Htg	0.0	0	0.0	0.0
Preheat	-472.1	8,810	0.0	49.2
Reheat	-152.1	7,112	49.2	68.8
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-741.8			

System Checksums

By ACADEMIC

RTU-2 — **Variable Volume Reheat (30% Min Flow Default)**

	COOLING COIL PEAK				**CLG SPACE PEAK**	
Peaked at Time:	Mo/Hr: 7 / 14				Mo/Hr: 8 / 15	
Outside Air:	OADB/WB/HR: 90 / 73 / 99				OADB: 89	
	Space Sens. + Lat.	**Plenum Sens. + Lat**	**Net Total**	**Percent Of Total**	**Space Sensible**	**Percent Of Total**
	Btu/h	Btu/h	Btu/h	(%)	Btu/h	(%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	0	15,373	15,373	1	0	0
Glass Solar	238,722	0	238,722	20	278,892	51
Glass/Door Cond	38,923	0	38,923	3	37,089	7
Wall Cond	3,285	3,829	7,114	1	3,510	1
Partition/Door	0		0	0	0	0
Floor	109		109	0	138	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	52,731		52,731	5	14,275	3
Sub Total ==>	333,770	19,202	352,972	30	333,905	61
Internal Loads						
Lights	61,738	15,435	77,173	7	61,738	11
People	245,700	0	245,700	21	136,500	25
Misc	15,471	0	15,471	1	15,471	3
Sub Total ==>	322,909	15,435	338,344	29	213,709	39
Ceiling Load	-3,853	3,853	0	0	-4,089	-1
Ventilation Load	0	0	413,776	35	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	931		931	0	931	0
Exhaust Heat		-25,096	-25,096	-2		
Sup. Fan Heat			85,546	7		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		-44,931	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	653,758	-31,537	1,166,474	100.00	544,457	100.00

	HEATING COIL PEAK		
	Mo/Hr: Heating Design		
	OADB: 0		
	Space Peak Space Sens	**Coil Peak Tot Sens**	**Percent Of Total**
	Btu/h	Btu/h	(%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-43,868	5.44
Glass Solar	0	0	0.00
Glass/Door Cond	-390,066	-390,066	48.36
Wall Cond	-6,655	-14,114	1.75
Partition/Door	0	0	0.00
Floor	-1,525	-1,525	0.19
Adjacent Floor	0	0	0
Infiltration	-104,079	-104,079	12.90
Sub Total ==>	-502,324	-553,651	68.63
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-24,547	0	0.00
Ventilation Load	0	-428,778	53.15
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	403,924	403,924	-50.07
Exhaust Heat		28,909	-3.58
OA Preheat Diff.		-226,425	28.07
RA Preheat Diff.		-30,647	3.80
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-122,948	-806,667	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.0	84.0
Ra Plenum	78.3	65.4
Return	78.3	65.4
Ret/OA	84.1	15.3
Fn MtrTD	0.4	0.0
Fn BldTD	0.9	0.0
Fn Frict	2.6	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	22,111	7,391
Terminal	22,111	7,391
Main Fan	22,111	7,391
Sec Fan	0	0
Nom Vent	9,890	5,665
AHU Vent	9,890	5,665
Infil	1,414	1,414
MinStop/Rh	7,391	7,391
Return	23,525	8,804
Exhaust	11,304	7,078
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	44.7	76.6
cfm/ft²	0.80	0.27
cfm/ton	227.46	
ft²/ton	285.43	
Btu/hr·ft²	42.04	-29.20
No. People	546	

COOLING COIL SELECTION

	Total Capacity		Sens Cap.	Coil Airflow	Enter DB/WB/HR			Leave DB/WB/HR		
	ton	MBh	MBh	cfm	°F	°F	gr/lb	°F	°F	gr/lb
Main Clg	97.2	1,166.5	765.9	20,623	84.1	67.9	79.1	49.2	48.9	52.3
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	97.2	1,166.5								

AREAS

	Gross Total	Glass ft²	(%)
Floor	27,746		
Part	0		
Int Door	0		
ExFlr	660		
Roof	20,136	0	0
Wall	17,300	13,339	77
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity	Coil Airflow	Ent	Lvg
	MBh	cfm	°F	°F
Main Htg	-280.2	7,391	49.2	84.0
Aux Htg	0.0	0	0.0	0.0
Preheat	-530.0	9,890	0.0	49.2
Reheat	-157.0	7,391	49.2	68.7
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-810.2			

Appendix B

ENERGY CONSUMPTION SUMMARY

By ACADEMIC

	Elect Cons. (kWh)	Gas Cons. (kBtu)	% of Total Building Energy	Total Building Energy (kBtu/yr)	Total Source Energy* (kBtu/yr)
Alternative 1					
Primary heating					
Primary heating		1,516,747	37.2 %	1,516,747	1,596,576
Other Htg Accessories	4,964		0.4 %	16,942	50,831
Heating Subtotal	**4,964**	**1,516,747**	**37.6** %	**1,533,689**	**1,647,407**
Primary cooling					
Cooling Compressor	219,399		18.4 %	748,809	2,246,652
Tower/Cond Fans	37,716		3.2 %	128,726	386,216
Condenser Pump			0.0 %	0	0
Other Clg Accessories	463		0.0 %	1,580	4,741
Cooling Subtotal....	**257,578**		**21.6** %	**879,115**	**2,637,610**
Auxiliary					
Supply Fans			0.0 %	0	0
Pumps			0.0 %	0	0
Stand-alone Base Utilities			0.0 %	0	0
Aux Subtotal....			0.0 %	0	0
Lighting					
Lighting	388,218		32.5 %	1,324,987	3,975,357
Receptacle					
Receptacles	99,337		8.3 %	339,038	1,017,215
Cogeneration					
Cogeneration			0.0 %	0	0
Totals					
Totals**	**750,097**	**1,516,747**	**100.0** %	**4,076,829**	**9,277,590**

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

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

Appendix C

EQUIPMENT ENERGY CONSUMPTION
By ACADEMIC

Alternative: 1 Tech_Report_2

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

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Lights													
Electric (kWh)	32,971.9	29,781.1	32,971.9	31,908.3	32,971.9	31,908.3	32,971.9	32,971.9	31,908.3	32,971.9	31,908.3	32,971.9	388,217.6
Peak (kW)	44.3	44.3	44.3	44.3	44.3	44.3	44.3	44.3	44.3	44.3	44.3	44.3	44.3
Misc. Ld													
Electric (kWh)	8,436.9	7,620.4	8,436.9	8,164.7	8,436.9	8,164.7	8,436.9	8,436.9	8,164.7	8,436.9	8,164.7	8,436.9	99,337.2
Peak (kW)	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3
Cooling Coil Condensate													
Recoverable Water (1000gal)	0.0	0.0	0.0	0.5	10.2	21.2	28.0	27.4	18.0	4.0	0.0	0.0	109.3
Peak (1000gal/Hr)	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.1
Cpl 1: Cooling plant - 001 [Sum of dsn coil capacities=189.7 tons]													
RTU-1 [Clg Nominal Capacity/F.L.Rate=189.7 tons / 197.1 kW] [Orig F.L.Rate=227.6 kW] (Cooling Equipment)**													
Electric (kWh)	0.0	0.0	0.0	5,747.8	24,532.0	40,718.7	51,754.5	51,882.3	31,842.2	12,921.7	0.0	0.0	219,399.1
Peak (kW)	0.0	0.0	0.0	64.7	133.3	170.4	190.2	183.9	152.5	94.9	37.9	0.0	190.2
Condenser fan for Heat Pump [Design Heat Rejection/F.L.Rate=254.4 tons / 30.53 kW]													
Electric (kWh)	0.0	0.0	0.0	1,065.9	4,349.1	6,987.8	8,642.4	8,721.1	5,588.0	2,362.0	0.0	0.0	37,716.3
Peak (kW)	0.0	0.0	0.0	11.6	22.1	27.2	29.3	28.7	25.1	16.6	7.1	0.0	29.3
Cntl panel & interlocks - 0.1 KW [F.L.Rate=0.10 kW] (Misc Accessory Equipment)													
Electric (kWh)	0.0	0.0	0.0	39.5	74.4	72.0	74.4	74.4	72.0	56.3	0.0	0.0	463.0
Peak (kW)	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1
Hpl 1: Boiler [Sum of dsn coil capacities=549.9 mbh]													
Boiler - 001 [Nominal Capacity/F.L.Rate=549.9 mbh / 6.60 Therms] (Heating Equipment)													
Gas (therms)	1,671.2	1,116.8	863.4	328.6	90.6	18.2	5.4	5.8	45.5	236.2	692.4	1,062.0	6,135.9
Peak (therms/Hr)	4.1	3.8	3.6	3.3	1.5	0.5	0.2	0.2	1.2	2.8	3.4	3.6	4.1
Boiler forced draft fan [F.L.Rate=0.55 kW] (Misc Accessory Equipment)													
Electric (kWh)	409.1	369.5	409.1	245.3	60.5	36.3	22.0	25.3	34.6	194.7	384.4	409.1	2,600.0
Peak (kW)	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Cntl panel & interlocks - 0.5 KW [F.L.Rate=0.50 kW] (Misc Accessory Equipment)													
Electric (kWh)	372.0	336.0	372.0	223.0	55.0	33.0	20.0	23.0	31.5	177.0	349.5	372.0	2,364.0
Peak (kW)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Hpl 2: Heat Exchanger [Sum of dsn coil capacities=1,002 mbh]													

EQUIPMENT ENERGY CONSUMPTION
By ACADEMIC

Alternative: 1 Tech_Report_2

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

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Hpl 2: Heat Exchanger [Sum of dsn coil capacities=1,002 mbh]													
Gas-fired heat exchanger - 002 [Nominal Capacity/F.L.Rate=1,002 mbh / 13.01 Therms] (Heating Equipment)													
Gas (therms)	3,195.5	1,961.2	1,299.3	152.4	0.0	0.0	0.0	0.0	0.0	27.6	749.0	1,646.7	9,031.6
Peak (therms/Hr)	5.9	4.0	2.9	0.9	0.0	0.0	0.0	0.0	0.0	0.3	2.2	3.4	5.9

Appendix D

MONTHLY ENERGY CONSUMPTION

By ACADEMIC

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

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Alternative: 1	**Tech_Report_2**												
Electric													
On-Pk Cons. (kWh)	42,190	38,107	42,190	47,394	70,480	87,921	101,922	102,135	77,641	57,120	40,807	42,190	750,098
On-Pk Demand (kW)	57	57	57	133	211	253	275	268	233	167	102	57	275
Off-Pk Demand (kW)	57	57	57	82	110	159	195	194	137	96	57	57	195
Mid-Pk Demand (kW)	57	57	57	65	92	108	130	124	102	67	57	57	130
Gas													
On-Pk Cons. (therms)	2,311	1,411	952	282	90	18	5	6	46	211	617	1,110	7,059
Off-Pk Cons. (therms)	2,119	1,449	1,073	199	0	0	0	0	0	53	762	1,397	7,051
Mid-Pk Cons. (therms)	437	218	138	0	0	0	0	0	0	0	62	202	1,057
On-Pk Demand (therms/hr)	10	8	6	3	2	0	0	0	1	3	4	6	10
Off-Pk Demand (therms/hr)	9	7	5	2	0	0	0	0	0	1	4	6	9
Mid-Pk Demand (therms/hr)	6	4	2	0	0	0	0	0	0	0	1	3	6

Energy Consumption

Building	78,674	Btu/(ft2-year)
Source	179,038	Btu/(ft2-year)
Floor Area	51,819	ft2

Environmental Impact Analysis

CO_2	830,065	lbm/year
SO_2	2,179	gm/year
NOX	919	gm/year

Appendix E

Table 3 Total Emission Factors for Delivered Electricity
(lb of pollutant per kWh of electricity)

Pollutant (lb)	National	Eastern	Western	ERCOT	Alaska	Hawaii
CO_{2e}	1.67E+00	1.74E+00	1.31E+00	1.84E+00	1.71E+00	1.91E+00
CO_2	1.57E+00	1.64E+00	1.22E+00	1.71E+00	1.55E+00	1.83E+00
CH_4	3.71E-03	3.59E-03	3.51E-03	5.30E-03	6.28E-03	2.96E-03
N_2O	3.73E-05	3.87E-05	2.97E-05	4.02E-05	3.05E-05	2.00E-05
NO_X	2.76E-03	3.00E-03	1.95E-03	2.20E-03	1.95E-03	4.32E-03
SO_X	8.36E-03	8.57E-03	6.82E-03	9.70E-03	1.12E-02	8.36E-03
CO	8.05E-04	8.54E-04	5.46E-04	9.07E-04	2.05E-03	7.43E-03
TNMOC	7.13E-05	7.26E-05	6.45E-05	7.44E-05	8.40E-05	1.15E-04
Lead	1.31E-07	1.39E-07	8.95E-08	1.42E-07	6.30E-08	1.32E-07
Mercury	3.05E-08	3.36E-08	1.86E-08	2.79E-08	3.80E-08	1.72E-07
PM10	9.16E-05	9.26E-05	6.99E-05	1.30E-04	1.09E-04	1.79E-04
Solid Waste	1.90E-01	2.05E-01	1.39E-01	1.66E-01	7.89E-02	7.44E-02

Table 8 Emission Factors for On-Site Combustion in a Commercial Boiler
(lb of pollutant per unit of fuel)

Pollutant (lb)	Commercial Boiler					
	Bituminous Coal *	Lignite Coal **	Natural Gas	Residual Fuel Oil	Distillate Fuel Oil	LPG
	1000 lb	1000 lb	1000 ft^3 ***	1000 gal	1000 gal	1000 gal
CO_{2e}	2.74E+03	2.30E+03	1.23E+02	2.56E+04	2.28E+04	1.35E+04
CO_2	2.63E+03	2.30E+03	1.22E+02	2.55E+04	2.28E+04	1.32E+04
CH_4	1.15E-01	2.00E-02	2.50E-03	2.31E-01	2.32E-01	2.17E-01
N_2O	3.68E-01	ND †	2.50E-03	1.18E-01	1.19E-01	9.77E-01
NO_X	5.75E+00	5.97E+00	1.11E-01	6.41E+00	2.15E+01	1.57E+01
SO_X	1.66E+00	1.29E+01	6.32E-04	4.00E+01	3.41E+01	0.00E+00
CO	2.89E+00	4.05E-03	9.33E-02	5.34E+00	5.41E+00	2.17E+00
VOC	ND †	ND †	6.13E-03	3.63E-01	2.17E-01	3.80E-01
Lead	1.79E-03	6.86E-02	5.00E-07	1.51E-06	ND †	ND †
Mercury	6.54E-04	6.54E-04	2.60E-07	1.13E-07	ND †	ND †
PM10	2.00E+00	ND †	8.40E-03	4.64E+00	1.88E+00	4.89E-01

* from the U.S. LCI data module: Bituminous Coal Combustion in an Industrial Boiler (NREL 2005)
** from the U.S. LCI data module: Lignite Coal Combustion in an Industrial Boiler (NREL 2005)
*** Gas volume at 60°F and 14.70 psia.
† no data available