The Ed Roberts Campus

Technical Report 2

Anderson Clemenceau
Mechanical Option

Advisor: Donghyun Rim

October 6, 2014

Contents

Executive Summary

The objective of this report is to model and analyze the loads and energy use of the Ed Roberts Campus. Trane Trace 700 was the software used to model the building and is an industry standard program for energy modeling. About 130 rooms were grouped and entered in the program as 60 different spaces based on load type and usage. These rooms were zoned under their respective air handling units before the program performed calculations on loads and energy use for the entire building.

The model calculated that the Ed Roberts Campus has a total cooling load of 2,777.3 MBh and a total heating load of 1814.5 MBh. This was found to be drastically different than the design cooling and heating loads of 381 MBh and 1051 MBh, respectively. The reasons for these discrepencies are unclear, but can be mostly attributed to difficulty modeling the exact system layout in Trace 700. A model performed by the design engineers was unavailable for comparison.

Trace calculated that the ERC's annual utility costs will amount to $62,168. The largest consumption of energy by any one system was by the cooling equipment which accounted for more than half the energy costs for most months of the year.

Emissions data was not calculated by Trace 700 due to unknown errors in the modeling process. However, by referenecing emissions data published by the electric service company, PG&E, it was estimated that the electric demand of the ERC would account for approximately 541,342.5 Lbs/Yr of CO_2.

Building Overview

The Ed Roberts Campus is a 2-story, 80,000 sq. ft., transit-oriented community center located in downtown Berkeley, California. The campus is connected to a BART Station (Bay Area Rapid Transit) and is designed with a focus on accessibility for people with disabilities. Completed in 2011, the ERC is home to exhibition spaces, meeting spaces, a child development center, a fitness center, vocational training facilities, and offices.

Every square foot of the building is designed far and above the requirements of the Americans with Disabilities Act through a design concept called "Universal Design". Universal Design aims to create environments that are useful for people of all ages and abilities without additional cost. Extra-wide corridors, automatic doors, two-sided elevators are examples of this design ideal. In addition, the ERC's fully accessible connection to the BART station works to connect people directly to airports and bus stations around the city.

Leddy Maytum Stacy Architects

Mechanical Systems Overview

The Ed Roberts Campus combines several system types to heat and cool the building. The building is served by five rooftop air handling units (AHUs):

AHU-1: East Wing – South

AHU-2: B.O.R.P.

AHU-3: West Wing – South

AHU-4: West Wing – North

AHU-5: Covered Court

AHUs 1, 3, and 4 are constant volume units with 100% outdoor air. AHU 2 is a VAV unit with 100% outdoor air that operates in tandem with AHU 1. AHU 5 is a Variable Air Volume (VAV), packaged air cooled DX cooling unit. Each AHU is equipped with a supply fan only. There are also water-source heat pumps for additional heating and cooling to meet the needs of each individual zone within the building.

The building has four roof-mounted fans that serve general exhaust needs (EF-3, EF-4, EF-5, and EF-7) with 1,200 cfm, 1,000 cfm, 800 cfm, and 1,600 cfm respectively. In addition, there are four more roof-mounted fans that serve specific areas. EF-1 serves the BORP with 5,500 cfm of exhaust, EF-2 serves the restrooms with 2,600 cfm, EF-6 serves the garage with 72,000 cfm, and EF-9 serves the BART elevator room with 1,200 cfm. The garbage room has a smaller wall mounted fan that exhausts 350 cfm for that space.

In addition to these air systems, the ERC utilizes a radiant floor system which serves three zones: the entrance lobby, art exhibition space, and covered court area. Altogether, the system provides 115 MBH of cooling (9.6 tons) and 68 MBH of heating (5.6 tons).

Design Load Estimation Procedure

Trane Trace 700 was the sofwater program used to model loads and energy use of the Ed Roberts Campus for this report. To create the model, information was collected from drawings and specifications and entered into the program.

Model Inputs

Climate Conditions

The Ed Roberts Campus is located in Berkeley, CA near the San Francisco Bay area. The closest choice in the Trace 700 weather database was San Francisco (CZ03). This refers to the ASHRAE 90.1 climate zones, investigated in Technical Report 1, and matches with the previously determined zone. Default settings within this climate template were used in the model.

Table 1 - Design Dry Bulb Temperatures

Summer Design Cooling DB (°F)	Summer Design Cooling WB (°F)	Winter Design Heating DB (°F)
74.6	62.6	40

Building Construction

The figure below is a screenshot of the construction materials specified in the templates of the Trace 700 model. These materials are generic choices based on some assumptions from the architectural plans. As a partition schedule was not available during the time of modeling, generic assemblies were chosen based on details and sections throughtout the building. In addition, information about the specific type of glass used for windows in the building was not available so a generic glass type was chosen from Trace.

Table 2- Model Construction Materials

	Construction	U-Factor [Btu/h*ft^2*°F]
Slab	6” LW Concrete	0.534759
Roof	4” LW Concrete	0.213535
Wall	Frame Wall, 6” Ins.	0.046783
Partition	0.75” Gyp Frame	0.387955
	U-Factor [Btu/h*ft^2*°F]	**Shading Coeff.**
Windows	1	.73

Occupancy Loads

In order to calculate building loads the building's approximately 130 rooms had to be entered into the program. Each space was dimensioned, including information about exterior facing walls and the percent of exterior walls that were windows. Once this was completed rooms with similar load characteristics were grouped together in order to simplify the modeling process.

Each room/zone was then classified under load templates in Trace 700 according to use. Templates were established in Trace for offices, meeting rooms, break rooms, lobbies, and applied to the different rooms once they had been entered into the program. Additional lighting loads were entered based on Table 9.5.1 Lighting Power Densities from ASHRAE 90.1. The office and classroom spaces included an additional load for computers and other office equipment.

Ventilation Loads

Trace 700 includes the option to apply ASHRAE Std. 62.1 2007 for the modeling of ventilation air requirements. This option was used in the model of the ERC so that the ventilation templates for different room types could be automatically implemented. While the program references an older version of ASHRAE 62.1, the population and area-based ventilation rates were mostly identical to the most recent edition of the standard.

Equipment

As stated in the mechanical overview, the ERC is served by five Dedicated Outdoor Air AHUs, primarily for ventilation air and latent loads, and zone level Water Source Heat Pumps that cover most of the sensible load. In Trace 700, this type of system can be modeled by Fan Coil Units with Optional Ventilation Coils with special inputs for Dedicated Outdoor Air. One exception is for AHU-5 which contains one Direct Expansion coil and is modeled as a Packaged RTU VAV Reheat with DX and Hot Water.

The heating and cooling coils are all served by two rooftop cooling towers and two boilers in the mechanical room that provide hot and cold water. These pieces of equipment were all modeled in Trace 700 with as much information as could be gathered from the specifications.

Design Load Results

The Trace 700 model was able to successfully calculate load information and energy use data for the Ed Roberts Campus. The results will be compared to design data from the engineers and evaluated for its accuracy.

The following two charts show the monthly load profiles and energy use for equipment in the building. The first chart shows that, for the most part, the building load is somewhat constant throughtout the year. There are jumps in load in the coldest winter months, where heating loads are increased, and in the warmest summer month where cooling load is highest. However, this seems to represent a reasonable profile for a building in a temperate climate.

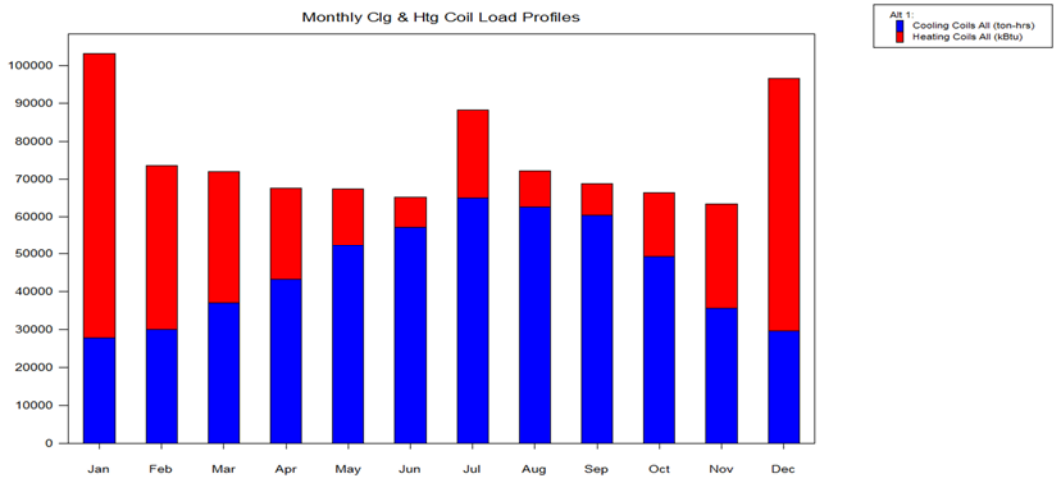


Figure 1 - Monthly Load Profiles

The table below displays the resulting load calculations from the Trace 700 model of the ERC. The results of the model will be compared to listed values in the AHU schedule from the mechanical drawings since an energy model from the MEP engineers is not available.

Table 3 - Heating and Cooling Load Comparison

	Design		Model	
Equipment	**Cooling (MBh)**	**Heating (MBh)**	**Cooling (MBh)**	**Heating (MBh)**
AHU-1	84	295	1,185.1	871.9
AHU-2	59	208	172.4	120.2
AHU-3	38	132	580.1	327.2
AHU-4	65	227	787.1	427.6
AHU-5	135	189	52.6	67.6
Total	381	1051	2,777.3	1814.5

Load Calculation Summary

There are significant differences between the values calculated by the model and the values listed in the design documents, with some model outputs as high as ten times the design load. These differences are likely due to inaccuracies and simplifications made in the modeling process. Trace 700 is also limited in the ways it can model Dedicated Outdoor Air systems like the one in the ERC. Due to differences in load characteristics it was necessary to create different rooms for different uses and occupancies instead of grouping spaces by the mechanical zones as laid out in the drawings. This resulted in Trace adding a Water Source Heat Pump for every room modeled, which is not the case in the actual building, and may have contributed to the inflated loads in the model. Differences in scheduling may have also contributed, as the specifications did not have operation schedules for the building, and in the model some spaces were left at worst-case 100% load. The engineering checks calculated by Trace also indicate problems in the model, such as very high cfm/ft^2 values, that would contribute to high load results, but the exact reasons for this are unclear.

Annual Energy Use

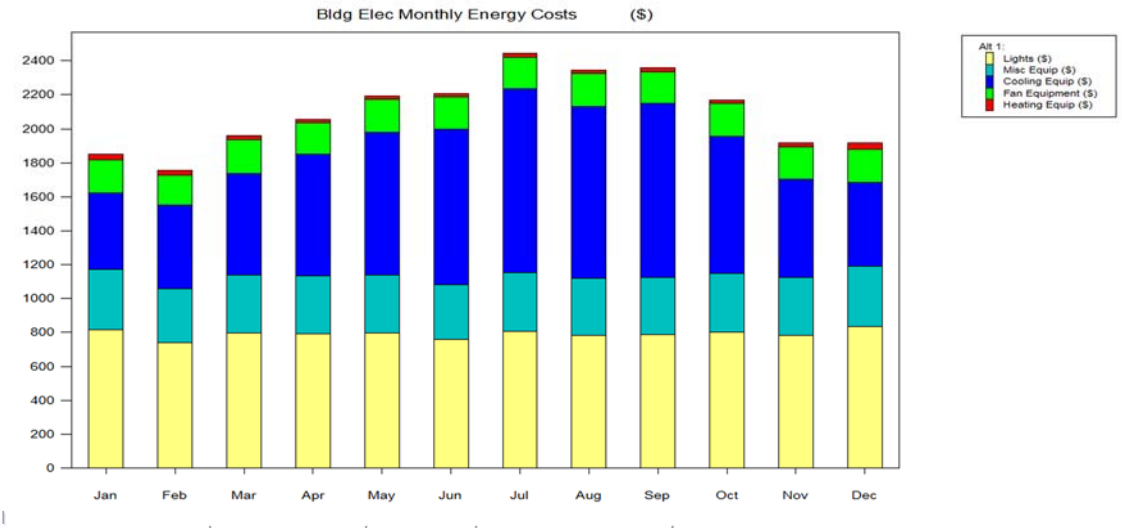
The table below lists the monthly utility cost of the Ed Roberts Campus, according the the Trace 700 model analysis. Utility cost information was gathered from the Pacific Gas and Electric Company website. Information is not available on the actual operational costs of the building but, based on the results in the load section of the report, it can be assumed that these costs may be inflated.

Table 4- Monthly Utility Costs

Month	Utility Cost ($)
January	4,409
February	4,815
March	4,477
April	5,057
May	5,443
June	5,673
July	5,955
August	5,905
September	5,991
October	5,335
November	4,661
December	4,447
Total	62,168

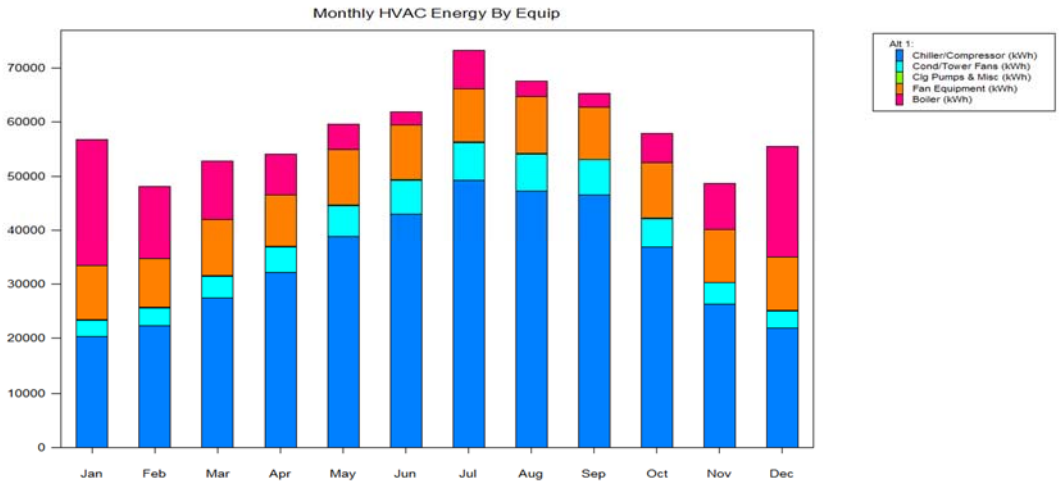
This is equal to 0.94 $/ft^2 based on a building area of 66,166 ft^2, which is the area of conditioned space within the building (not including mechanical and parking garage spaces). The figure below, displaying monthly electricity costs per equipment type, shows that lighting is a constant high demand for electricity use and costs. Standard recessed fluorescent lighting was used in the model, but it is possible that more efficient lighting types could decrease costs dramatically. It should be noted that this figure only includes cost of electricity consumed, and not demand costs.

Figure 2 - Monthly Electric Costs by Equipment Type



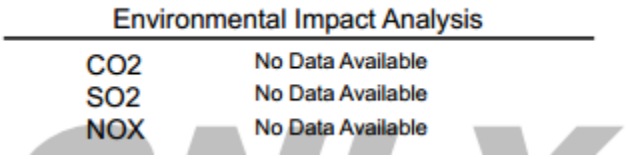
The next chart displays the breakdown of energy use of specific equipment types throughout the building. The energy use of the equipment matches with the load profiles in the previous section with boiler energy spiking in December and January and cooling equipment energy peaking in July. The maximum energy use of the system is just above 70,000 KWh during the month of July.

Figure 3 - Monthly Energy Use by Equipment Type



Due to errors in the Trace 700 model, emissions data was not able to be calculated and was not available in the report. The reasons for this are unclear.

Figure 4- Trace Environmental Analysis



However, based on emissions data published by PG&E, the CO_2 emissions information can be estimated based on the amount of electricity demanded by the ERC. Trace 700 calculated that the building will use 1,313,938 kWh of electricity. At a rate of 412 Lbs-CO_2/MWh, the CO2 emissions attributed to the ERC's electricity use amount to 541,342.5 Lbs/Yr.

Energy Summary

It is clear that the process of modeling the buiding could be improved dramatically. While it is likely these results do not accurately represent energy use of the building, it remains a useful exercise in attempting to understand the building systems and their comparative energy use profiles.

References

ANSI/ASHRAE/IES. 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.

Pacific Gas & Electric Company

Utility Rates and Emissions Data

Leddy Maytum Stacy Architects

Arup San Francisco

Appendix A

TABLE 9.5.1 Lighting Power Densities Using the Building Area Method

Building Area Type[a]	LPD, W/ft^2
Automotive facility	0.80
Convention center	1.01
Courthouse	1.01
Dining: Bar lounge/leisure	101
Dining: Cafeteria/fast food	0.90
Dining: Family	0.95
Dormitory	0.57
Exercise center	0.84
Fire station	0.671
Gymnasium	0.94
Health-care clinic	0.90
Hospital	1.05
Hotel/Motel	0.87
Library	1.19
Manufacturing facility	1.17
Motion picture theater	0.76
Multifamily	0.51
Museum	1.02
Office	0.82
Parking garage	0.21
Penitentiary	0.81
Performing arts theater	1.39
Police station	0.87
Post office	0.87
Religious building	1.00
Retail	1.26
School/university	0.87
Sports arena	0.91
Town hall	0.89
Transportation	0.70
Warehouse	0.66
Workshop	1.19

a. In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply.

Figure 5 - ASHRAE 90.1 Lighting Power Densities

Rate Schedule	Customer Charge	Optional Meter Data Access Charge	Season	Time-of-Use Period	Demand Charge (per kW)		Time-of-Use Period	Total Energy Charge (per kWh)		
					Secondary	Primary	Transmission		Secondary	Primary	Transmission
A-10 (Table A)	$4.59959 per meter per day	$0.98563 per meter per day	Summer		$13.87	$13.10	$9.36		$0.15784	$0.14753	$0.12308
			Winter		$6.46	$6.67	$5.00		$0.11770	$0.11204	$0.09868
A-10 TOU (Table B)	$4.59959 per meter per day		Summer		$13.87	$13.10	$9.36	Peak	$0.17479	$0.16169	$0.13592
								Part-Peak	$0.16711	$0.15621	$0.13092
								Off-Peak	$0.14377	$0.13526	$0.11196
			Winter		$6.46	$6.67	$5.00	Part-Peak	$0.12798	$0.12044	$0.10640
								Off-Peak	$0.10796	$0.10405	$0.09135

Figure 6 - PG&E Utility Rates

PG&E Emissions Factor Summary

Emission Type	Emission Factor			Source
	Year	*Lbs CO_2 /MWh*	*Metric tons CO_2/MWh*	
Historical Emissions	2003	620	0.281	PG&E's third-party-verified GHG inventory submitted to the California Climate Action Registry (CCAR)[2] (2003-2008) or The Climate Registry (TCR) (2009-2011)
	2004	566	0.257	
	2005	489	0.222	
	2006	456	0.207	
	2007	636	0.288	
	2008	641	0.291	
	2009	575	0.261	
	2010	445	0.202	
	2011	393	0.178	
Future Emissions (estimated)	2012[3]	453	0.205	CPUC GHG Calculator, which provides an independent forecast of PG&E's emission factors as part of a model on how the electricity sector
	2013	431	0.196	
	2014	412	0.187	
	2015	391	0.177	
	2016	370	0.168	

Figure 7 - PG&E CO2 Emission Rates

System Checksums

By ACADEMIC

AHU-1 — **Fan Coil**

COOLING COIL PEAK

Peaked at Time: Mo/Hr: 3 / 16
Outside Air: OADB/WB/HR: 61 / 55 / 56

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)
Envelope Loads				
Skylite Solar	0	0	0	0
Skylite Cond	0	0	0	0
Roof Cond	0	213,722	213,722	23
Glass Solar	252,039	0	252,039	27
Glass/Door Cond	-35,865	0	-35,865	-4
Wall Cond	2,163	1,122	3,285	0
Partition/Door	0		0	0
Floor	0		0	0
Adjacent Floor	0	0	0	0
Infiltration	0		0	0
Sub Total ==>	218,338	214,844	433,182	46
Internal Loads				
Lights	63,583	15,896	79,479	8
People	347,744	0	347,744	37
Misc	32,417	0	32,417	3
Sub Total ==>	443,745	15,896	459,640	48
Ceiling Load	27,932	-27,932	0	0
Ventilation Load	78,497	0	78,497	8
Adj Air Trans Heat	0		0	0
Dehumid. Ov Sizing			0	0
Ov/Undr Sizing	0		0	0
Exhaust Heat		-30,206	-30,206	-3
Sup. Fan Heat			7,165	1
Ret. Fan Heat		0	0	0
Duct Heat Pkup		0	0	0
Underflr Sup Ht Pkup			0	0
Supply Air Leakage		0	0	0
Grand Total ==>	768,512	172,602	948,279	100.00

CLG SPACE PEAK

Mo/Hr: Sum of
OADB: Peaks

	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads		
Skylite Solar	0	0
Skylite Cond	0	0
Roof Cond	0	0
Glass Solar	462,008	54
Glass/Door Cond	-44,160	-5
Wall Cond	3,285	0
Partition/Door	0	0
Floor	0	0
Adjacent Floor	0	0
Infiltration	0	0
Sub Total ==>	421,133	50
Internal Loads		
Lights	63,583	7
People	196,564	23
Misc	32,417	4
Sub Total ==>	292,564	34
Ceiling Load	13,820	2
Ventilation Load	122,304	14
Adj Air Trans Heat	0	0
Ov/Undr Sizing	0	0
Exhaust Heat		
OA Preheat Diff.		
RA Preheat Diff.		
Additional Reheat		
Underflr Sup Ht Pkup		
Supply Air Leakage		
Grand Total ==>	849,820	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design
OADB: 40

	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	-173,318	19.88
Glass Solar	0	0	0.00
Glass/Door Cond	-113,120	-113,120	12.97
Wall Cond	-4,158	-6,251	0.72
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	0	0	0.00
Sub Total ==>	-117,278	-292,689	33.57
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	-21,210	0	0.00
Ventilation Load	-178,752	-178,752	20.50
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		22,937	-2.63
OA Preheat Diff.		-423,359	48.56
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-317,240	-871,863	100.00

TEMPERATURES

	Cooling	Heating
SADB	56.2	77.9
Ra Plenum	75.2	69.6
Return	75.2	69.6
Ret/OA	75.2	69.6
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.1	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	48,364	48,364
Terminal	48,364	48,364
Main Fan	48,364	48,364
Sec Fan	0	0
Nom Vent	8,451	8,451
AHU Vent	8,451	8,451
Infil	0	0
MinStop/Rh	0	0
Return	56,816	56,816
Exhaust	8,451	8,451
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	17.5	17.5
cfm/ft²	1.76	1.76
cfm/ton	489.72	
ft²/ton	278.01	
Btu/hr-ft²	43.16	-31.75
No. People	782	

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	79.0	948.3	840.9	48,364	75.3	61.3	58.8	56.1	54.0	58.8
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	19.7	236.8	175.3	8,451	74.2	63.3	70.0	55.6	54.0	59.7
Total	98.8	1,185.1								

AREAS

	Gross Total ft²	Glass ft²	Glass (%)
Floor	27,456		
Part	0		
Int Door	0		
ExFlr	0		
Roof	27,456	0	0
Wall	7,849	3,558	45
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent *F	Lvg *F
Main Htg	-448.5	48,364	69.6	77.9
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	-423.4	8,451	40.0	85.0
Total	-871.9			

Project Name: Ed Roberts Campus
Dataset Name: ERC_EnergyModel.trc

TRACE® 700 v6.3 calculated at 03:14 PM on 10/05/2014
Alternative - 1 System Checksums Report Page 1 of 5

System Checksums

By ACADEMIC

AHU-2 — **Fan Coil**

COOLING COIL PEAK

Peaked at Time: Mo/Hr: 6 / 17
Outside Air: OADB/WB/HR: 69 / 61 / 67

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)
Envelope Loads				
Skylite Solar	0	0	0	0
Skylite Cond	0	0	0	0
Roof Cond	0	87,858	87,858	59
Glass Solar	14,871	0	14,871	10
Glass/Door Cond	-1,672	0	-1,672	-1
Wall Cond	718	84	802	1
Partition/Door	0		0	0
Floor	0		0	0
Adjacent Floor	0	0	0	0
Infiltration	0		0	0
Sub Total ==>	13,917	87,942	101,859	68
Internal Loads				
Lights	15,267	3,817	19,084	13
People	38,820	0	38,820	26
Misc	10,853	0	10,853	7
Sub Total ==>	64,941	3,817	68,757	46
Ceiling Load	20,213	-20,213	0	0
Ventilation Load	-13,587	0	-13,587	-9
Adj Air Trans Heat	0		0	0
Dehumid. Ov Sizing			0	0
Ov/Undr Sizing	0		0	0
Exhaust Heat		-8,634	-8,634	-6
Sup. Fan Heat			890	1
Ret. Fan Heat		0	0	0
Duct Heat Pkup		0	0	0
Underflr Sup Ht Pkup			0	0
Supply Air Leakage		0	0	0
Grand Total ==>	85,483	62,912	149,286	100.00

CLG SPACE PEAK

Mo/Hr: Sum of
OADB: Peaks

	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads		
Skylite Solar	0	0
Skylite Cond	0	0
Roof Cond	0	0
Glass Solar	50,181	46
Glass/Door Cond	-6,906	-6
Wall Cond	310	0
Partition/Door	0	0
Floor	0	0
Adjacent Floor	0	0
Infiltration	0	0
Sub Total ==>	43,585	40
Internal Loads		
Lights	15,267	14
People	21,337	20
Misc	10,853	10
Sub Total ==>	47,457	44
Ceiling Load	5,154	5
Ventilation Load	11,939	11
Adj Air Trans Heat	0	0
Ov/Undr Sizing	0	0
Exhaust Heat		
OA Preheat Diff.		
RA Preheat Diff.		
Additional Reheat		
Underflr Sup Ht Pkup		
Supply Air Leakage		
Grand Total ==>	108,135	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design
OADB: 40

	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	-40,275	33.51
Glass Solar	0	0	0.00
Glass/Door Cond	-22,363	-22,363	18.61
Wall Cond	-1,919	-2,640	2.20
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	0	0	0.00
Sub Total ==>	-24,282	-65,278	54.31
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	-9,034	0	0.00
Ventilation Load	-17,449	-17,449	14.52
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		3,859	-3.21
OA Preheat Diff.		-41,326	34.38
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-50,765	-120,193	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.8	79.6
Ra Plenum	81.4	67.8
Return	81.4	67.8
Ret/OA	81.4	67.8
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.1	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	6,007	6,007
Terminal	6,007	6,007
Main Fan	6,007	6,007
Sec Fan	0	0
Nom Vent	825	825
AHU Vent	825	825
Infil	0	0
MinStop/Rh	0	0
Return	6,832	6,832
Exhaust	825	825
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	13.7	13.7
cfm/ft²	0.89	0.89
cfm/ton	418.14	
ft²/ton	472.26	
Btu/hr·ft²	25.41	-17.71
No. People	84	

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	12.4	149.3	131.2	6,007	81.4	63.4	58.5	55.7	53.7	58.5
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	1.9	23.1	17.1	825	74.2	63.3	70.0	55.6	54.0	59.7
Total	14.4	172.4								

AREAS

	Gross Total ft²	Glass ft²	Glass (%)
Floor	6,785		
Part	0		
Int Door	0		
ExFlr	0		
Roof	6,785	0	0
Wall	2,005	703	35
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-78.9	6,007	67.8	79.6
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	-41.3	825	40.0	85.0
Total	-120.2			

Project Name: Ed Roberts Campus
Dataset Name: ERC_EnergyModel.trc

System Checksums

By ACADEMIC

AHU-3 — **Fan Coil**

COOLING COIL PEAK

Peaked at Time: Mo/Hr: 6 / 18
Outside Air: OADB/WB/HR: 67 / 60 / 68

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)
Envelope Loads				
Skylite Solar	0	0	0	0
Skylite Cond	0	0	0	0
Roof Cond	0	231,601	231,601	45
Glass Solar	155,643	0	155,643	30
Glass/Door Cond	-6,091	0	-6,091	-1
Wall Cond	1,859	978	2,837	1
Partition/Door	0		0	0
Floor	0		0	0
Adjacent Floor	0	0	0	0
Infiltration	0		0	0
Sub Total ==>	151,411	232,579	383,990	74
Internal Loads				
Lights	37,792	9,448	47,241	9
People	114,679	0	114,679	22
Misc	25,160	0	25,160	5
Sub Total ==>	177,631	9,448	187,079	36
Ceiling Load	36,821	-36,821	0	0
Ventilation Load	-40,811	0	-40,811	-8
Adj Air Trans Heat	0		0	0
Dehumid. Ov Sizing			0	0
Ov/Undr Sizing	0		0	0
Exhaust Heat		-18,105	-18,105	-4
Sup. Fan Heat			3,518	1
Ret. Fan Heat		0	0	0
Duct Heat Pkup		0	0	0
Underflr Sup Ht Pkup			0	0
Supply Air Leakage		0	0	0
Grand Total ==>	325,052	187,101	515,671	100.00

CLG SPACE PEAK

Mo/Hr: Sum of
OADB: Peaks

	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads		
Skylite Solar	0	0
Skylite Cond	0	0
Roof Cond	0	0
Glass Solar	243,594	61
Glass/Door Cond	-11,147	-3
Wall Cond	2,466	1
Partition/Door	0	0
Floor	0	0
Adjacent Floor	0	0
Infiltration	0	0
Sub Total ==>	234,913	59
Internal Loads		
Lights	37,792	10
People	65,197	16
Misc	25,160	6
Sub Total ==>	128,149	32
Ceiling Load	24,931	6
Ventilation Load	8,310	2
Adj Air Trans Heat	0	0
Ov/Undr Sizing		
Exhaust Heat	0	0
Grand Total ==>	396,304	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design
OADB: 40

	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	-108,363	33.12
Glass Solar	0	0	0.00
Glass/Door Cond	-60,493	-60,493	18.49
Wall Cond	-1,760	-2,797	0.85
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	0	0	0.00
Sub Total ==>	-62,253	-171,653	52.46
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	-16,645	0	0.00
Ventilation Load	-48,607	-48,607	14.86
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		8,185	-2.50
OA Preheat Diff.		-115,122	35.18
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-127,505	-327,198	100.00

TEMPERATURES

	Cooling	Heating
SADB	57.0	76.8
Ra Plenum	79.1	68.8
Return	79.1	68.8
Ret/OA	79.1	68.8
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.1	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	23,746	23,746
Terminal	23,746	23,746
Main Fan	23,746	23,746
Sec Fan	0	0
Nom Vent	2,298	2,298
AHU Vent	2,298	2,298
Infil	0	0
MinStop/Rh	0	0
Return	26,044	26,044
Exhaust	2,298	2,298
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	9.7	9.7
cfm/ft²	1.45	1.45
cfm/ton	491.23	
ft²/ton	339.68	
Btu/hr·ft²	35.33	-19.93
No. People	259	

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	43.0	515.7	466.9	23,746	79.1	62.7	59.0	56.9	54.3	59.0
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	5.4	64.4	47.7	2,298	74.2	63.3	70.0	55.6	54.0	59.7
Total	48.3	580.1								

AREAS

	Gross Total ft²	Glass ft²	Glass (%)
Floor	16,420		
Part	0		
Int Door	0		
ExFlr	0		
Roof	17,620	0	0
Wall	3,848	1,903	49
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-212.1	23,746	68.8	76.8
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	-115.1	2,298	40.0	85.0
Total	-327.2			

Project Name: Ed Roberts Campus
Dataset Name: ERC_EnergyModel.trc

System Checksums

By ACADEMIC

AHU-4 — **Fan Coil**

COOLING COIL PEAK

Peaked at Time: Mo/Hr: 4 / 17
Outside Air: OADB/WB/HR: 63 / 56 / 57

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)
Envelope Loads				
Skylite Solar	108,978	0	108,978	16
Skylite Cond	0	-9,448	-9,448	-1
Roof Cond	0	112,622	112,622	17
Glass Solar	156,494	0	156,494	23
Glass/Door Cond	-14,465	0	-14,465	-2
Wall Cond	291	122	412	0
Partition/Door	0		0	0
Floor	0		0	0
Adjacent Floor	0	0	0	0
Infiltration	0		0	0
Sub Total ==>	251,297	103,296	354,593	53
Internal Loads				
Lights	28,289	7,072	35,361	5
People	246,634	0	246,634	37
Misc	7,120	0	7,120	1
Sub Total ==>	282,043	7,072	289,116	43
Ceiling Load	10,019	-10,019	0	0
Ventilation Load	38,571	0	38,571	6
Adj Air Trans Heat	0		0	0
Dehumid. Ov Sizing			0	0
Ov/Undr Sizing	0		0	0
Exhaust Heat		-12,555	-12,555	-2
Sup. Fan Heat			4,186	1
Ret. Fan Heat		0	0	0
Duct Heat Pkup		0	0	0
Underflr Sup Ht Pkup			0	0
Supply Air Leakage		0	0	0
Grand Total ==>	581,930	87,795	673,911	100.00

CLG SPACE PEAK

Mo/Hr: Sum of
OADB: Peaks

	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads		
Skylite Solar	165,796	30
Skylite Cond	0	0
Roof Cond	0	0
Glass Solar	155,764	29
Glass/Door Cond	-13,120	-2
Wall Cond	904	0
Partition/Door	0	0
Floor	0	0
Adjacent Floor	0	0
Infiltration	0	0
Sub Total ==>	309,345	57
Internal Loads		
Lights	28,289	5
People	138,208	25
Misc	7,120	1
Sub Total ==>	173,617	32
Ceiling Load	9,365	2
Ventilation Load	51,627	9
Adj Air Trans Heat	0	0
Dehumid. Ov Sizing		
Ov/Undr Sizing	0	0
Exhaust Heat		
Sup. Fan Heat		
Ret. Fan Heat		
Duct Heat Pkup		
Underflr Sup Ht Pkup		
Supply Air Leakage		
Grand Total ==>	543,954	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design
OADB: 40

	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	-25,786	6.03
Roof Cond	0	-66,188	15.48
Glass Solar	0	0	0.00
Glass/Door Cond	-56,863	-56,863	13.30
Wall Cond	-1,002	-1,492	0.35
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	0	0	0.00
Sub Total ==>	-57,865	-150,328	35.16
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	-8,392	0	0.00
Ventilation Load	-85,440	-85,440	19.98
Adj Air Trans Heat	0	0	0
Dehumid. Ov Sizing		0	0.00
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		10,516	-2.46
OA Preheat Diff.		-202,357	47.32
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-151,696	-427,609	100.00

TEMPERATURES

	Cooling	Heating
SADB	54.7	76.8
Ra Plenum	74.8	69.7
Return	74.8	69.7
Ret/OA	74.8	69.7
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.1	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	28,255	28,255
Terminal	28,255	28,255
Main Fan	28,255	28,255
Sec Fan	0	0
Nom Vent	4,039	4,039
AHU Vent	4,039	4,039
Infil	0	0
MinStop/Rh	0	0
Return	32,295	32,295
Exhaust	4,039	4,039
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	14.3	14.3
cfm/ft²	2.49	2.49
cfm/ton	430.76	
ft²/ton	172.66	
Btu/hr-ft²	69.50	-37.76
No. People	540	

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	56.2	673.9	585.4	28,255	74.8	61.1	58.9	54.6	52.8	56.9
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	9.4	113.2	83.8	4,039	74.2	63.3	70.0	55.6	54.0	59.7
Total	65.6	787.1								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	11,325		
Part	0		
Int Door	0		
ExFlr	0		
Roof	11,325	875	8
Wall	2,811	1,789	64
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent *F	Lvg *F
Main Htg	-225.3	28,255	69.7	76.8
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	-202.4	4,039	40.0	85.0
Total	-427.6			

System Checksums

By ACADEMIC

AHU-5 — **System 5 - Packaged RTU VAV Reheat, DX & Hot Water**

COOLING COIL PEAK

Peaked at Time: Mo/Hr: 11 / 8
Outside Air: OADB/WB/HR: 52 / 51 / 55

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)
Envelope Loads				
Skylite Solar	0	0	0	0
Skylite Cond	0	0	0	0
Roof Cond	0	0	0	0
Glass Solar	0	0	0	0
Glass/Door Cond	0	0	0	0
Wall Cond	0	0	0	0
Partition/Door	0		0	0
Floor	0		0	0
Adjacent Floor	0	0	0	0
Infiltration	0		0	0
Sub Total ==>	0	0	0	0
Internal Loads				
Lights	9,358	2,339	11,697	32
People	13,153	0	13,153	36
Misc	7,133	0	7,133	20
Sub Total ==>	29,643	2,339	31,983	89
Ceiling Load	0	0	0	0
Ventilation Load	4,268	0	4,268	12
Adj Air Trans Heat	0		0	0
Dehumid. Ov Sizing			0	0
Ov/Undr Sizing	0		0	0
Exhaust Heat		-449	-449	-1
Sup. Fan Heat			248	1
Ret. Fan Heat		0	0	0
Duct Heat Pkup		0	0	0
Underflr Sup Ht Pkup			0	0
Supply Air Leakage		0	0	0
Grand Total ==>	33,911	1,891	36,049	100.00

CLG SPACE PEAK

Mo/Hr: 5 / 13
OADB: 66

	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads		
Skylite Solar	0	0
Skylite Cond	0	0
Roof Cond	0	0
Glass Solar	0	0
Glass/Door Cond	0	0
Wall Cond	0	0
Partition/Door	0	0
Floor	0	0
Adjacent Floor	0	0
Infiltration	0	0
Sub Total ==>	0	0
Internal Loads		
Lights	9,358	32
People	7,307	25
Misc	7,133	24
Sub Total ==>	23,797	81
Ceiling Load	0	0
Ventilation Load	5,744	19
Adj Air Trans Heat	0	0
Ov/Undr Sizing	0	0
Grand Total ==>	29,542	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design
OADB: 40

	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	0	0	0.00
Wall Cond	0	0	0.00
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0
Infiltration	0	0	0.00
Sub Total ==>	0	0	0.00
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	0	0	0.00
Ventilation Load	-8,395	-8,395	14.46
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		0	0.00
OA Preheat Diff.		-19,884	34.24
RA Preheat Diff.		0	0.00
Additional Reheat		-29,789	51.30
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-8,395	-58,068	100.00

TEMPERATURES

	Cooling	Heating
SADB	56.1	76.5
Ra Plenum	72.0	72.0
Return	73.0	72.0
Ret/OA	73.0	72.0
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.1	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	1,672	1,672
Terminal	1,672	1,672
Main Fan	1,672	1,672
Sec Fan	0	0
Nom Vent	397	397
AHU Vent	397	397
Infil	0	0
MinStop/Rh	1,672	1,672
Return	2,069	2,069
Exhaust	397	397
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	23.7	23.7
cfm/ft²	0.40	0.40
cfm/ton	381.56	
ft²/ton	953.89	
Btu/hr-ft²	12.58	-16.18
No. People	29	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter gr/lb	Leave DB °F	Leave WB °F	Leave gr/lb
Main Clg	3.5	41.5	31.7	1,672	73.0	60.7	59.9	56.0	52.0	51.6
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.9	11.1	8.2	397	74.2	63.3	70.0	55.6	54.0	59.7
Total	4.4	52.6								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	4,180		
Part	0		
Int Door	0		
ExFlr	0		
Roof	0	0	0
Wall	0	0	0
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-47.7	1,672	56.0	76.5
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Reheat	-37.2	1,672	56.0	72.0
Humidif	0.0	0	0.0	0.0
Opt Vent	-19.9	397	40.0	85.0
Total	-67.6			

Project Name: Ed Roberts Campus
Dataset Name: ERC_EnergyModel.trc

TRACE® 700 v6.3 calculated at 03:14 PM on 10/05/2014
Alternative - 1 System Checksums Report Page 5 of 5