Technical Report II

Building and Plant Energy Analysis Report

Charles E. Smith Center Renovation

Washington, DC

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Executive Summary

This report was constructed to analyze total load on, and energy consumption of, the Charles E. Smith Center as well as operational costs and pollutant emissions. To do this, a block load model was constructed in order to obtain whole building loads and energy consumption of the building. The simulator used in this report was Trane TRACE 700. This simulator can also be used to construct operational and life cycle costs by including utility rates.

The modeled design loads of this TRACE model were compared with the actual design conditions in the design documents. As a result, it was determined that the computed model resulted in lower cooling loads and higher heating loads than the design documents. When the energy consumption was analyzed, the computed amount was approximately 8.1MMBtu/yr which was slightly higher than the designed consumption but still within 10%. The overall cost/SF was calculated to be $2.44/SF

After calculating the building loads and consumption, the overall emissions of the facility were reviewed. Using the NREL standards for pollutant emissions it was determined that CO2 was largest pollutant.

Design Load Estimation

Modeling Program Selection

For this report, it was recommended to use an energy simulation program to perform block loads and energy estimates. The following programs were considered: EnergyPlus, eQuest, Trace, Hap, IES, and ASHRAE RTSM. Of these programs, Train TRACE was chosen for its familiarity, relative accuracy, ease of user interface, and access to help.

Design Conditions

Climate Data

The outdoor air conditions for the Charles E. Smith Center were taken from the ASHRAE Handbook of Fundamentals for the location of Washington, DC using 0.4% and 99.6% standards. The indoor design air conditions were specified by the owner and given in the design documents. You can view the specific values in Table 1 and Table 2 respectively.

Table 1 – 2009 ASHRAE Outdoor Design Conditions

	Outside Air DB (°F)	Outside Air WB (°F)	Clearness Number	Ground Reflectance
Summer	93.2	75.1	0.85	0.2
Winter	9.6	-	0.85	0.2

Table 2 – Owner Provided Indoor Design Conditions

	Inside Air DB (°F)
Summer	75
Winter	68

Infiltration

For the Charles E. Smith Center, an infiltration rate was assumed to be 0.3 air changes per hour. This was able to be assumed using the knowledge that the Smith Center is newly renovated with tight construction.

Lighting and Miscellaneous Loads

The internal loads were taken from ASHRAE Standard 62.1 and 90.1 and can be seen in Table 3 below. Notice the gym internal loads vary depending on if there is an event in progress. For the purpose of this block load analysis they will be modeled as empty due to the fact that there are not events occurring all day or even every day.

Table 3 – ASHRAE Standard Values

	Lighting (W/SF)	People (BTU/HR)
Office	1.1	200
Locker Room	0.6	545
Classroom	1.4	200
Conference Room	1.3	200
Gym (Seats)	0.4	(varies)
Gym (Court)	2.3	(varies)
Weight Room	0.9	965

Designed vs Computed Results

Table 4 below summarizes the overall design loads and the computed loads from the Trane TRACE model. The design cooling load is slightly larger than the computed load and the designed heating load is slightly less than the computed load. A possible explanation for this could be that the gym was modeled as empty which could lower the cooling load required for such a large area as well as raise the heating load. The airflow for supply and ventilation was considerably less for the designed loads which could also be a result of modeling the gym as empty. This does correlate however since almost the entire first floor is 100% OA because of the types of rooms contained there. This would greatly increase the overall airflow without the gymnasium being considered.

Table 4 – Design vs Computed Block Loads

	Cooling (SF/ton)	Heating (BTUh/SF)	Supply Air (CFM/SF)	Ventilation (CFM/SF)
Design Load	378.8	49.0	0.56	0.63
Modeled Load	328.7	57.3	0.84	0.92

Annual Energy Consumption and Operating Costs

The same Trane TRACE 700 model used for the load computation was also used for the annual energy consumption model. The facility is supplied entirely by electricity except for the four boilers, which are supplied by natural gas.

Annual Energy Consumption

The Charles E. Smith Center relies on electric for its main utility. The cooling towers, chillers, pumps, fans, lights, and miscellaneous space heating and receptacles are all powered using supplied electricity. The only aspect of the facility that does not rely entirely on electricity are the four boilers which use natural gas.

Table 5 below shows the breakdown of the total energy each system uses. As the table shows, approximately 80% of the buildings energy consumption is supplied by electricity. The auxiliary equipment including the supply fans and pumps account for 26% of the buildings total energy consumption. This may be a result of the high amounts of OA being supplied to the first floor because of the high latent loads and exhaust requirements.

The primary heating system with the combined consumption of the electric and gas accounts for the next largest load on the building. This could result from the gym being modeled as empty which would increase the heating load and energy consumption.

The consumed cooling energy is seen as a rather low percentage of the buildings total energy consumption, which is typical for this type of building.

Table 5 – Annual System Energy Consumption

`	Electrical (kWh)	Natural Gas (kBtu)	Total Building Energy (kBtu/yr)	Building Pecent age (%)
Primary Heatin g	58,862	1,793,677	1,994,531	24.3
Primary Coolin g	350,898	-	1,197,369	14.6
Auxiliary	624,453	-	2,130,820	26.0
Lighting	360,920	-	1,231,567	15.0
Receptacle	421,219	-	1,637,325	20.1
			8,191,612	**100**

Annual Operational Cost

To analyze the cost of operation, utility rates were used in conjunction with annual energy consumption. Table 6 shows the fuel costs used in the model. Electricity and natural gas prices were the annual average of the District of Columbia taken from the US Energy and Information Administration as of October 2010.

Table 6 – Energy Rates

	Price	Units
Electric	0.127	$/kWh
Natural Gas	12.99	$/MBtu

Table 7 illustrates the breakdown of the systems and their operational costs. From the table it can be seen that the Auxiliary equipment also has the largest cost associated with it. This correlates with energy consumption of the building.

The cooling, lighting, and receptacle loads all account for about 20% of the total operational cost. These also correlate with the energy consumption. The cooling cost is approximately 40 cents/SF.

The heating cost has been drastically reduced. This does not correlate with the energy consumption as it was the second largest system and now costs the least to operate. This could be a result of natural gas prices differing in comparison with the electric prices, which could greatly reduce the overall cost of the heating system.

Table 7 – Operating Costs

`	Electrical ($/kWh)	Natural Gas ($/MBtu)	Total Utility Cost (kBtu/yr)	Building Pecentage (%)
Primary Heatin g	7,475.47	23,299.86	30,775.33	12.2
Primary Coolin g	44,564.05	-	44,564.05	17.5
Auxiliary	79,305.53	-	79,305.53	31.2
Lighting	45,836.84	-	45,836.84	18.0
Receptacle	53,494.81	-	53,494.81	21.1
			253,976.56	**100**

Cost ($/SF)	**2.44**

Professional Energy Analysis

The Charles E. Smith Center was designed to be LEED Certified and by requirement must have an energy model to prove the desired results. The energy modeling platform chosen was Trane TRACE. There were multiple alternatives modeled for different types of equipment and extents the renovation might choose or not choose to perform. Comparatively, the design model had a slightly less overall energy consumption less than 10%. Both the design model and computed model had the Auxiliary equipment as the highest overall energy consumption equipment.

A life cycle cost was done for the project but actual utility bills were unable to be obtained currently to compare the actual utility cost.

Annual Emmission Rates

The purpose of this section is to determine the approximate pollutant emissions that result from the Charles E. Smith Center facility. These take into consideration both emissions that are generated on site as well as emissions from delivered energy sources like electricity.

The amount of each pollutant emitted from each delivered energy source depends on the location within the country. Figure 1 shows that Washington, DC is in the Eastern Section and Figure 2 shows the type of fuel used to generate the electricity in the Eastern Section. From Figure 2 you can see that most of the fuel used for generating electricity is coal.

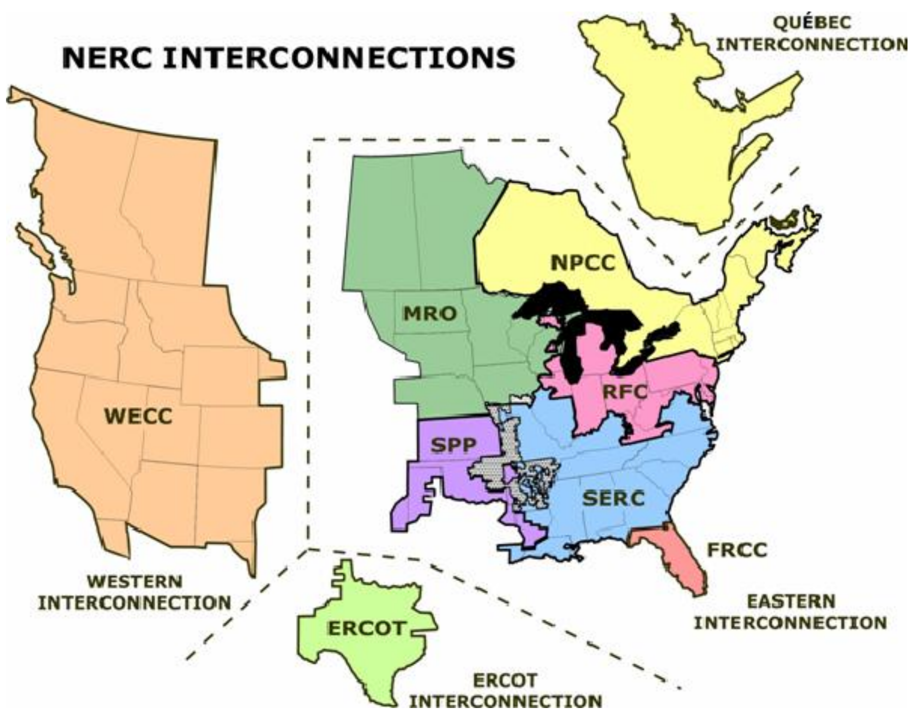

Figure 1 – North American Electrical Grid Interconnections

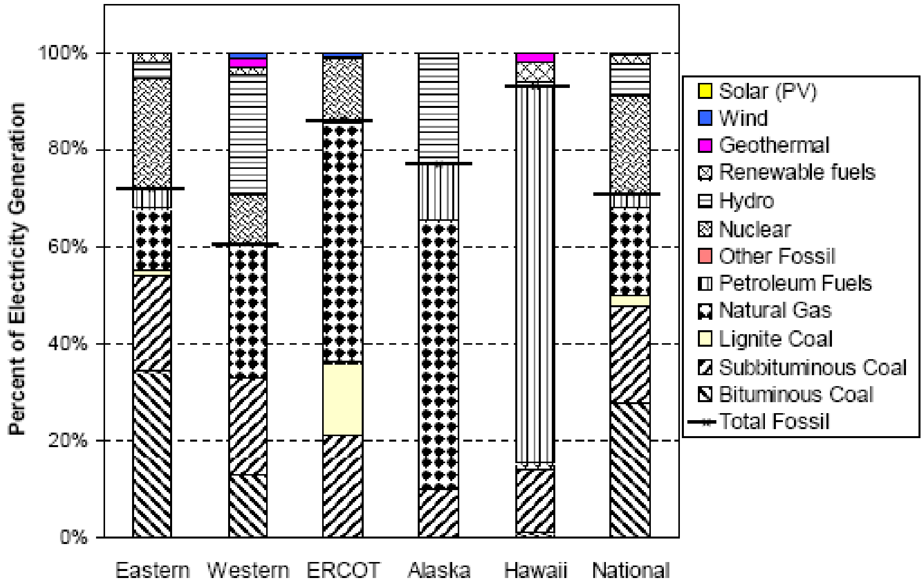

FIGURE 2 – ELECTRICITY GENERATION FUEL MIXTURE

The type and amount of each pollutant generated by electricity for the Charles E. Smith Center can be seen below in Table 8.

TABLE 8 – ELECTRICITY EMITTED POLLUTANTS

	Emission Factors (lb/kwh)	Total Building Electricity (kWh/yr)	Total Pollution (lbs/yr)
CO_{2e}	1.74	1,816,352	3.16×10^6
CO_2	1.64		2.98×10^6
CH_4	3.59×10^{-3}		6520.70
N_2O	3.87×10^{-5}		70.29
NO_X	3.00×10^{-3}		5449.06
SO_X	8.57×10^{-3}		1.56×10^4
CO	8.54×10^{-4}		1551.16
TNMOC	7.26×10^{-5}		131.87
Lead	1.39×10^{-7}		0.25
Mercury	3.36×10^{-8}		0.06
PM10	9.26×10^{-5}		168.19
Solid Waste	0.205		3.72×10^5

The type and amount of each pollutant generated by the natural gas delivered and used at the Charles E. Smith Center can be seen below in Table 9.

TABLE 9 – NATURAL GAS EMITTED POLLUTANTS

`	Delivered Emission Factors (lb/mcf)	Produced Emission Factors (lb/mcf)	Total Building Electricity (mcf/yr)	Total Pollution (mcf/yr)
CO_{2e}	27.80	123	1.793	270.38
CO_2	11.60	122		239.54
CH_4	0.70	2.5×10^{-3}		1.27
N_2O	2.35×10^{-4}	2.5×10^{-3}		4.9×10^{-3}
NO_X	1.64×10^{-2}	0.11		0.23
SO_X	1.22	6.32×10^{-4}		2.19
CO	1.36×10^{-2}	9.33×10^{-2}		0.19
TNMOC/VOC	4.56×10^{-5}	6.13×10^{-3}		1.11×10^{-2}
Lead	2.41×10^{-7}	5×10^{-7}		1.33×10^{-6}
Mercury	5.51×10^{-8}	2.6×10^{-7}		5.65×10^{-7}
PM10	8.17×10^{-4}	8.4×10^{-3}		1.65×10^{-2}
Solid Waste	1.6	-		2.87

From the above tables it can be inferred that CO2 is by far the largest pollutant being emitted by this facility and lead and mercury would be the least emitted.

References

- ANSI/ASHRAE Standard 62.1-2007 Ventilation for Acceptable Indoor Air Quality
- ANSI/ASHRAE Standard 90.1-2007 Energy Standard for Buildings Except Low-Rise Residential Buildings
- 2009 ASHRAE Handbook of Fundamentals
- Charles E. Smith Center Renovation Design Documents
- U.S. Energy Information Administration website, http://www.eia.gov
- NREL Source Energy and Emission Factors for Energy Use in Buildings