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Technical Report Two

Building and Plant Energy & Emissions Analysis

WESTINGHOUSE ELECTRIC CO.
NUCLEAR ENGINEERING
HEADQUARTERS CAMPUS

Pittsburgh, PA

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Executive Summary

The purpose of this report is to design and analyze an energy model of Building 1 of the Westinghouse Nuclear Engineering Campus. Building 1 is an office building with higher than average computational equipment for a typical office building.

To determine the airflows, design loads on the system, and other energy values, a model was created in the Trane Trace analysis program. Room dimensions, occupancies and window areas were all input into the building simulation. This model was designed only as a block model and all input values have been calculated by hand since a Revit model was not available for this analysis.

The Trace model's results were very similar to the figures in the design documents. In terms of accuracy: Cooling was within 7%, Heating within 10%, Air Supply within 12% and Ventilation within 14%, with respect to the design documents.

The Trace model was also used to calculate the building's total energy use which is approximately 7.36 million kWh per year or about 50,800 BTU/SF-YR. A similar building, according to EIA, consumed about 51,500 BTU/SF-YR. Heating was found to be the largest energy user with about 31% of the total. This can be attributed to the building's location, amount of glazing, orientation and other factors.

Overall, there are some minor deviations from design document and EIA figures. However, the model was successful at approximating Building 1's energy use to that of a comparatively similar building.

Design Load Estimation

Energy Modeling Program Selection

For my analysis of Building 1, I chose to model the building in Trane Trace. I chose Trane Trace because of my familiarity with the program as well as its easy user interface. Both of these reasons will allow my energy model to be as accurate as possible.

Assumptions

For effective modeling purposes, the building's spaces and elements were simplified into blocks.

- Chiller plant was modeled as one chiller/cooling tower to simplify the model
- The 4 main AHUs are modeled as one AHU
- The façade was modeled as a CMU wall with brick veneer with same U-value as stated in the Design Documents
- Room heights are approximate since plenum height changes throughout the spaces
- Area temperature setpoints are approximated to be 70°F and 72°F for winter and summer, respectively
- The building's location, for modeling purposes, was assumed to be Pittsburgh, PA
- Lighting and Miscellaneous loads have been approximated. Table 1 below shows these assumed values.

Table 1. Electrical Load Assumptions

Electrical Load Assumptions		
Space Type	Lighting (W/SF)	Miscellaneous (W/SF)
Equipment Room	0.683	9.0
Restrooms	0.683	0.0
Computer Intensive Rooms	0.683	1.0
Server Room	0.683	6.0
Lobby/Corridors/Storage	0.683	0
Offices (including Conf Rooms)	0.683	0.5
Cafeteria	0.683	0.2
Kitchen	0.683	0.5
Locker Room/Fitness	0.683	0.0

The miscellaneous loads are higher than a typical office building because of the extra amount of computational equipment. The office areas have a higher density of computer usage also there is a data center and other computer intensive spaces located in the building.

Design Conditions

The outdoor conditions for the energy model are approximated as Pittsburgh, PA and are listed in Table 2 below.

Table 2. ASHRAE Design Conditions

ASHRAE Design Conditions		
Heating Design Temperature	Cooling Design Temperature	
DBT	DBT	WBT
2 °F	86°F	70°F

Load Sources and Scheduling

Because of the high priority of constant computing in the data center and other spaces, some of the miscellaneous loads are 100% of the time. Other miscellaneous loads are modeled on a schedule typical of a low-rise office building. The people and lighting schedules were modeled as low-rise office as well.

Design Document vs. Computed Load

As seen from Table 3 below, the computed loads and the design documented loads are relatively similar. The computed cooling load is slightly high probably due to the assumptions of the heat gain from the computer processing. The Airflow rates for the main AHU are very similar. The supply rate is within 11% of the documented rate. The Equipment (Mechanical and Electrical Rooms) Rooms' figures are somewhat skewed to that of the design documents. The ventilation rate is rather high from the equipment rooms' high internal load—causing the model to suggest using 100% OA.

Table 3. Load and Ventilation Comparisons

Load and Ventilation Comparisons						
Systems	Cooling (FT^2/TON)		Supply (CFM/FT^2)		Ventilation (CFM/FT^2)	
	Computed	DD	Computed	DD	Computed	DD
Main AHU(s)	443.42	414.80	0.696	0.623	0.219	0.255
Equipment Room AHU(s)	306	304.65	1.77	1.25	1.77	0.125

ANNUAL ENERGY CONSUMPTION AND OPERATING COSTS

The annual energy consumption was calculated using the same model as was used for the load calculations. With the exception of the gas-fired burners of the Main AHUs, the entire building is powered by delivered electrical power.

Annual Energy Consumption

In Table 4 below, energy use for an entire year is compiled and separated into the different types of loads in the building.

Table 4. Annual Energy Consumption

Annual Energy Consumption				
Load	Electricity (kWh)	Natural Gas (kWh)	Total Energy (kWh)	Percent of Total (%)
Heating				
Gas-Fired		49343	49343	0.7
Electric Resistance	2267004		2267004	30.8
Cooling				
Chiller	690820		690820	9.4
Cooling Tower	492072		492072	6.7
Condenser Pump	543487		543487	7.4
Auxiliary				
Supply Fans	107267		107267	1.5
Pumps	401158		401158	5.4
Lighting				
Lighting	1106314		1106314	15.0
Miscellaneous				
Receptacle	1711229		1711229	23.2
		Total	7368694	100

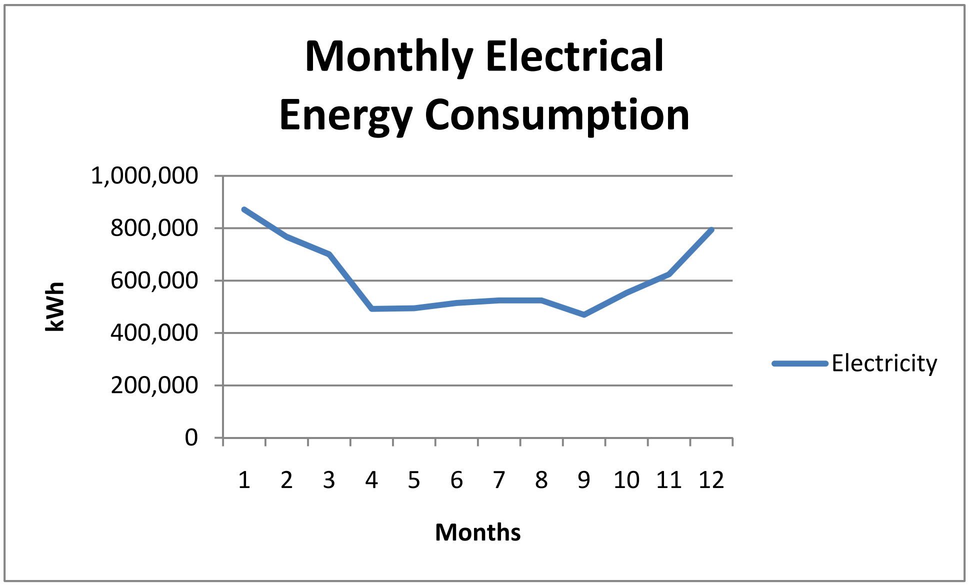
The values in the above table were computed using the energy model with equipment inputs that were taken from the design documents of the building.

From this analysis, it can be determined that the largest energy load in the building is Heating. This is more than likely due to the building's location along with other factors like the amount of glazing area (40% glazing). Also, the building is oriented north-south-- not a preferable orientation for winter solar gain. It should also be noted that the building is on top of a hill with no wind obstructions around it, which may explain a higher need for heating.

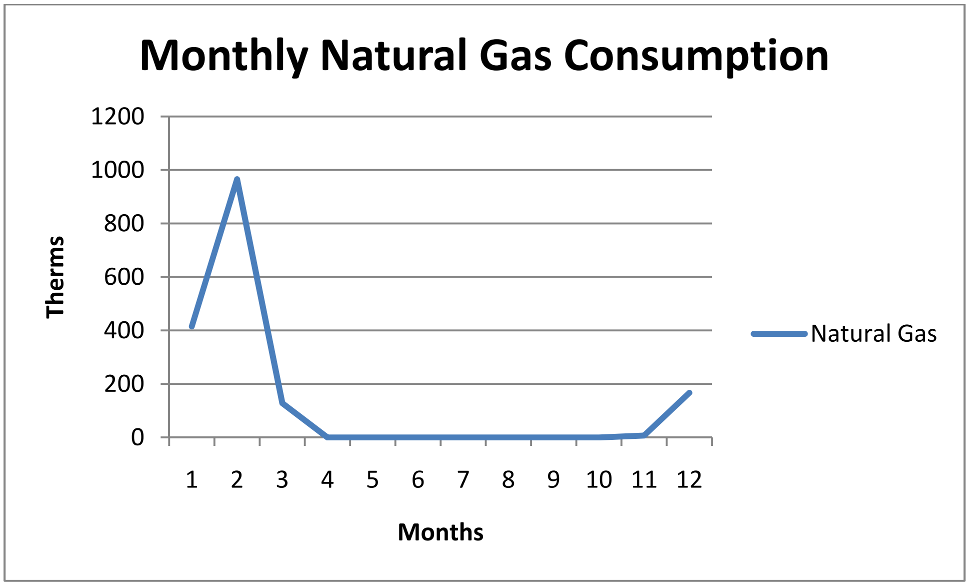
The second largest energy load in the building is the Cooling equipment. This is likely due to the higher amount of computing equipment throughout the building as well as the amount of glazing area.

As seen in Graph 1 and Graph 2 below, the energy usage throughout the year fluctuates with the seasons. The electrical load is peaked during January because of the Heating equipment. The natural gas load is peaked during February again because of Heating needed during the winter months.

Graph 1. Monthly Electrical Energy Consumption



Graph 2. Monthly Natural Gas Consumption



The cost per unit of fuel is listed below in Table 5 for winter and summer months. Due to a lack of information from the project's design team, Duquesne Light and Columbia Gas rates were used. Duquesne Light and Columbia Gas were used because they are the largest utility companies in the Pittsburgh region.

Table 5. Utility Cost Information

Utility Cost Information		
Electricity (cents/kWh)		Natural Gas ($/1000FT³)
On-Peak	Off-Peak	Annual Average
7.44	5.07	5.495

This cost data transposed as cost per month per fuel in Chart 1 and Chart 2 below. As seen in the charts, the cost of natural gas is rather insignificant compared to the cost of delivered electric power. Natural gas is only used for pre-heating; therefore it only accounts for about 0.7% of all energy needs.

Chart 1. Monthly Cost for Natural Gas

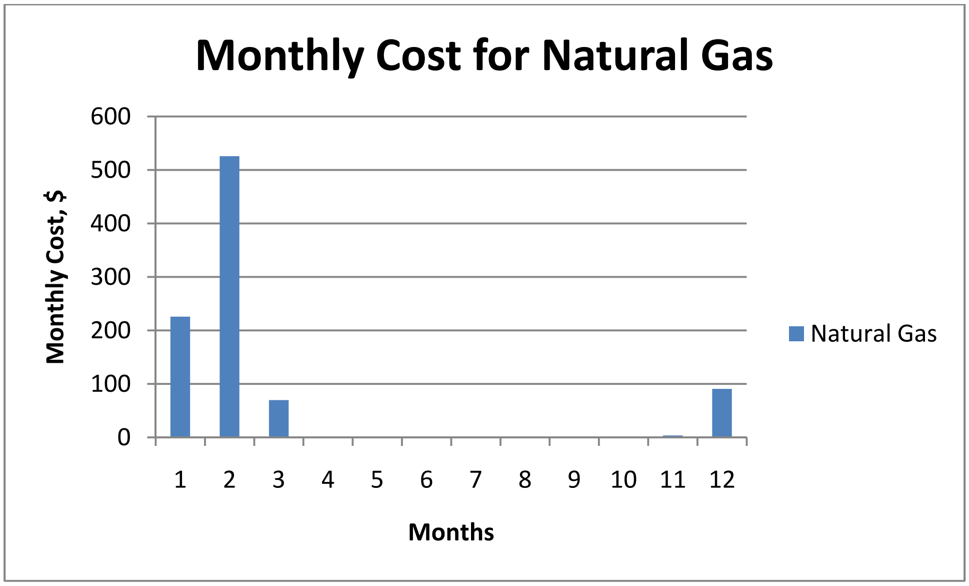
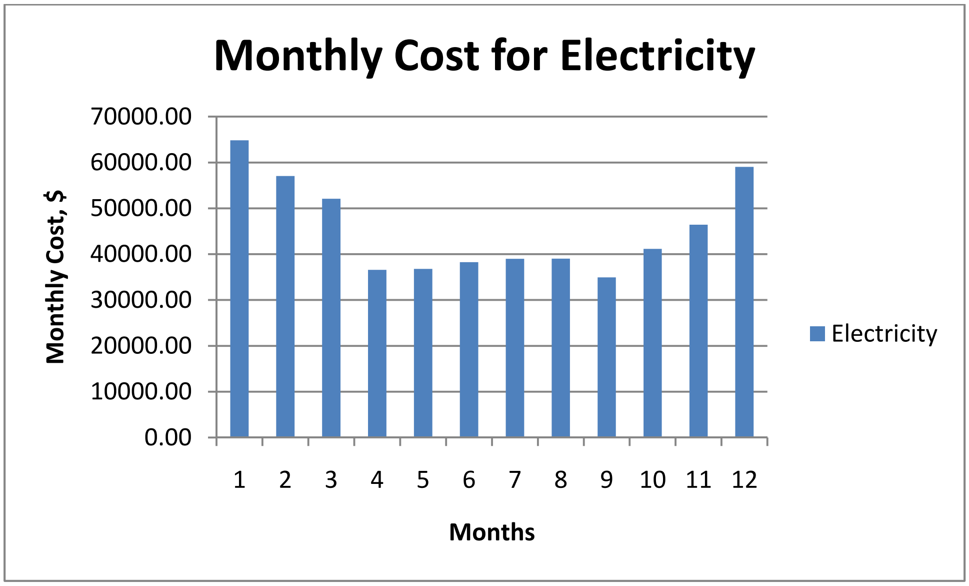


Chart 2. Monthly Cost for Electricity



Cost to Run Systems

The specific costs to each of the systems has been specified in Table 6 below—the purpose being to also to show total energy cost of running the building. It can be seen that the largest cost is the heating the building. The reason for this is from the building's location and other factors like the amount of glazing area. Other possible reasons have been listed in the Annual Energy Consumption section.

The second largest energy cost is cooling the building. This is due again to the building's location, glazing area and amount of computing processing.

With this information, we can conclude that the cost to heat the building is about 35 cents per square foot. The cost to cool the building is about 27 cents per square foot. Typical office buildings of the same size generally cool at about 50 cents per square foot. These lower prices may be attributed to the combination of model inaccuracy and the utility companies in Pittsburgh generally have lower rates than the national average.

Table 6. System Specific Annual Energy Cost

System Specific Annual Energy Cost

Load	Electricity ($)	Natural Gas ($)	Total Energy Cost ($)	Percent of Total (%)
Heating				
Gas-Fired		915.98	915.98	0.2
Electric Resistance	168665		168665	30.9
Cooling				
Chiller	51397		51397	9.4
Cooling Tower	36610		36610	6.7
Condenser Pump	40435		40435	7.4
Auxiliary				
Supply Fans	7980		7980	1.5
Pumps	29846		29846	5.5
Lighting				
Lighting	82309		82309	15.1
Miscellaneous				
Receptacle	127315		127315	23.3
		Total	545472.98	100

Professional Energy Analysis

An energy model was created as part of the design process for this project. Since LEED Certification was the goal of this building, an energy model was required to prove that the building is at least a certain percentage better than the baseline building specified in ASHRAE 90.1. For this report however, repeated attempts to inquiry this information have not been replied to.

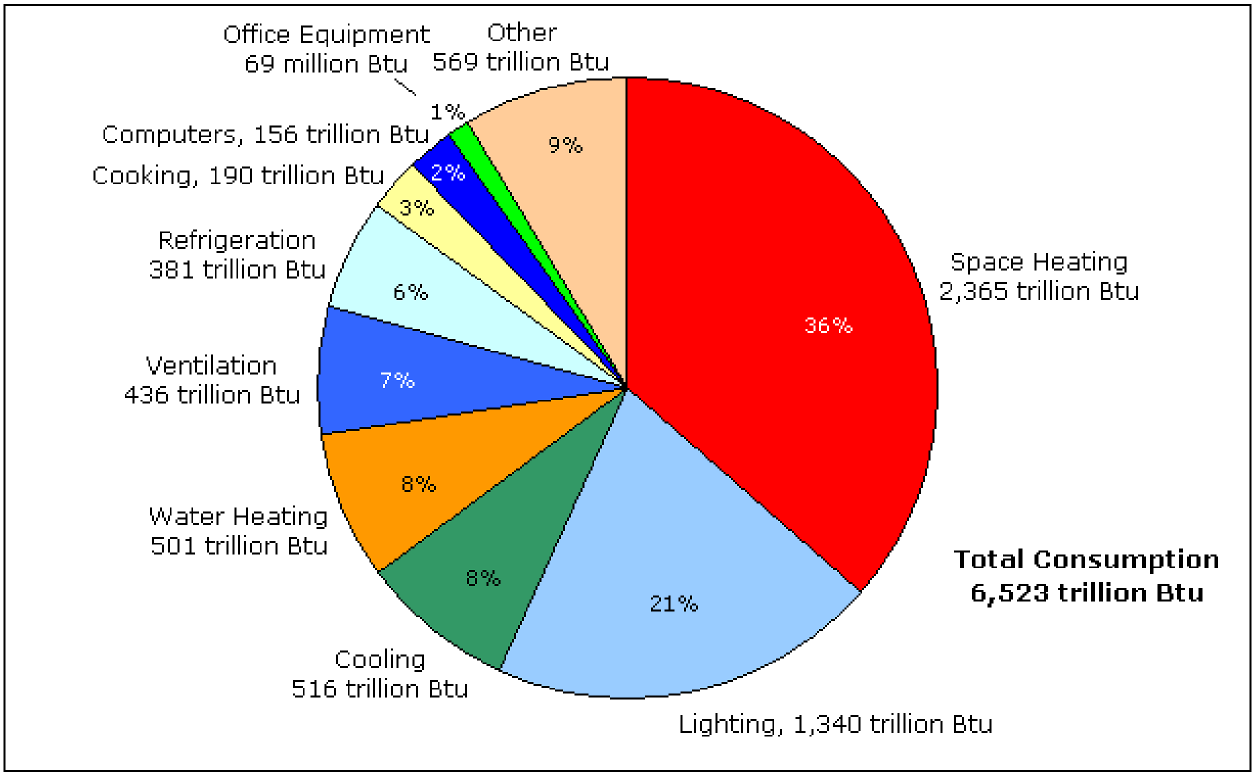
However, comparing the results of this energy model to the design documents have shown to be quite similar. The cooling, ventilation, and supply rates were compared in the Design Document vs. Computed Load section. When comparing the heating, the model's figures are quite similar to the design documents. The design documents estimates the building's heating rate at 14.5 million BTU/HR. The Trace model estimates the heating rate to be 16 million BTU/HR. The difference is about 10%.

Comparison to Energy Information Administration

Comparing the Trace model's figures to the figures provided by Energy Information Administration, the overall energy use is very close. For a typical building of this size, function, year of construction and region the average energy use intensity is about 51500 BTU/SF-YR. The Trace model estimated its intensity to 50861 BTU/SF-YR—or about 98% of the typical intensity.

The EIA has also done research into energy use by system for a commercial building. According to the Chart 3 below, 36% of a building's energy is consumed by space heating (Trace model's space heating was 31.5%). The chart has lighting second with 21% and space cooling at 8%. The Trace model has lighting at 15% and space cooling at 23.5%. The variation in lighting is possibly from the project being LEED Certified and lighting was given major emphasis. The difference in cooling could be attributed to the increase in computer loads.

Chart 3. Energy Consumption for a Typical Commercial Building



Annual Emissions Footprint

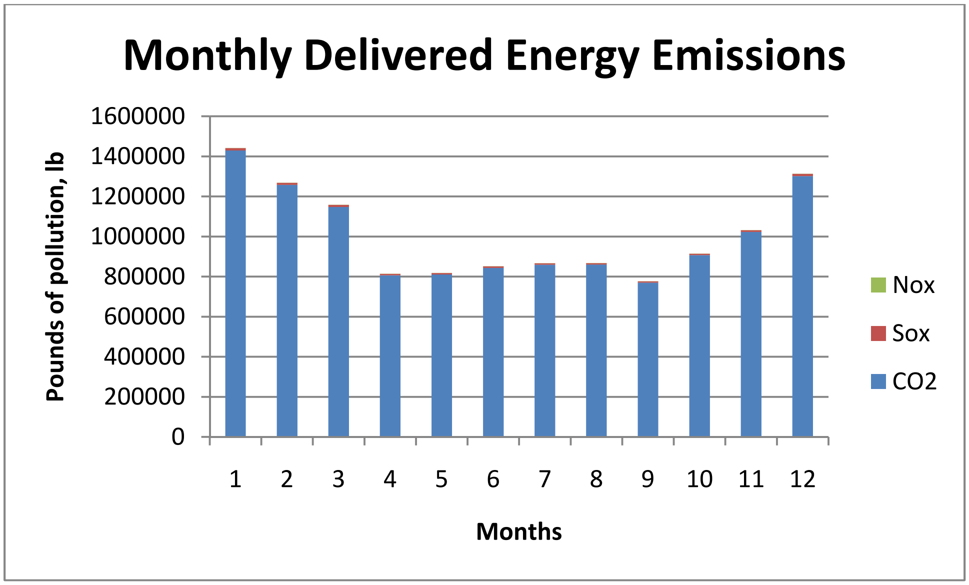
Graph 3 and Graph 4 below show the total emissions associated with delivered electrical energy as well as emissions from on-site combustion systems. As seen from the delivered energy graph, January is the month of peak emissions from electrical usage. This is due to the electrical need for the building’s primary heating elements. On-site emissions are peaked during February. This peaking is also likely from heating needs during winter months. It is unknown why the two do not share the same peak month—possibly because February is colder and more preheating is needed. According to the model results, the building’s total environmental impact is:

8,971,646 lbm CO2/year

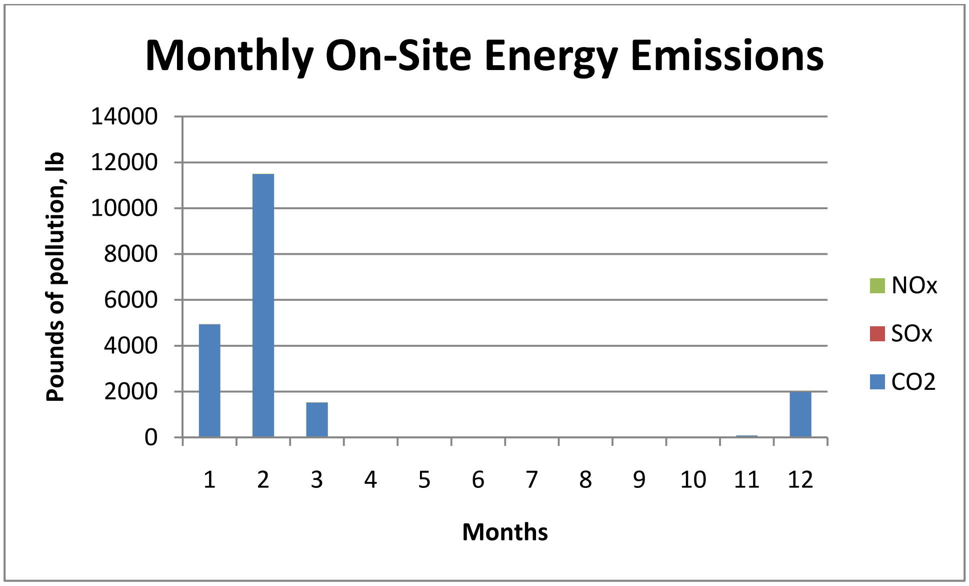
69.363 gm SO2/year

13,942 gm NOX/year

Graph 3. Monthly Delivered Energy Emissions



Graph 4. Monthly On-Site Energy Emissions



Conclusion

Building 1 is a typical low-rise office building with a high amount of computational equipment. After modeling the building with the design document values, the output values of the Trane Trace model are consistent with the description of the building. It is important to remember that the final number is only an approximate energy use, and the cost of energy can widely fluctuate with time especially with de-regulation of power companies in the near future. The overall purpose of this model is more to check that the simulation matched the expected data of a similar building.