Mechanical Technical Report Three
Mechanical Systems Existing Conditions Evaluation

HITT Contracting Headquarters
2900 Fairview Park Drive, Falls Church, VA

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Executive Summary

This report examines the mechanical system of HITT Contracting Headquarters as it was designed. HITT Contracting Headquarters is a 132,000 square foot three story office building with an additional cellar level below. It is situated next to the Capitol beltway in Falls Church, VA outside of Washington, DC.

The mechanical system consists of seven AAON 50 ton rooftop units that utilize direct expansion cooling and electric resistance heating. These rooftop units provide partially conditioned supply air to VAV boxes throughout the building where the air is conditioned to meet the loads directly sensed by the space. Split system AC units are used to supplement the VAV system in café and fitness areas. Exhaust fans are located in the maintenance and restroom spaces to create negative pressure and directly exhaust contaminants.

This report further develops the analysis in technical reports I and II including:

- ASHRAE 62.1-2007 analysis
- Energy usage analysis

The building passes ASHRAE 62.1-2007 by a margin of +40%. The energy usage analysis demonstrated an estimated annual operating cost of $340,000. It also has a mechanical system first cost of $1,750,000 or $13.18 per square foot. This is on the lower end of typical mechanical system first costs.

In conclusion, the mechanical system of HITT Contracting Headquarters is found to provide a good air distribution system that provides comfort to the occupants while meeting the loads demanded. The system first cost is inexpensive and takes up a minimal amount usable floor space.The downfall of the system is in its abundant energy usage when compared to systems of similar size.

Design Objectives & Requirements

The design team was given with the task to devise a building that included office, conference, storage, plotting & printing, and fitness spaces, all while aiming for LEED silver certification. The design of the mechanical systesm for HITT Contracting Headquarters has few requirements including:

- Occupant controllability of the system
- Minimal use of usable square footage for mechanical systems
- Energy efficiency (LEED requires improvement upon baseline case)
- Meeting ASHRAE 62.1-2004 (LEED credit EQ 1 Minimum IAQ Performance)

Site Factors

The site was chosen due to its proximity to the Washington, DC beltway. HITT Contracting has many of its clients in the Washington, DC metro area and easy access to the beltway is essential to its business. The site was previously unused and directly abuts the Capitol Beltway.

System Description

The HITT Contracting Headquarters has seven (7) 50 Ton AAON air-cooled packaged rooftop units with energy recovery wheels serving the four (4) occupied floors; three above ground and the cellar. Each above ground floor has at total of two (2) units that serve the North and South sections respectively. Parallel, series, and shut-off Variable-Air-Volume (VAV) terminal units control the final supply temperature and flow to individual zones throughout the building. Three (3) split-system air-conditioning units provide air for loads in fitness and café spaces.

Powered Roof Ventilators (PRV) provide exhaust for restroom and locker spaces throughout the building. Additional exhaust for storage and trash rooms is provided by ceiling mounted exhaust fans. Exhaust fans also exist in entry rooms from the parking garage to expel harmful vapors that enter from the parking area.

Design Conditions

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) prescribes outdoor design conditions to be used in HVAC system design. The outdoor and indoor air design conditions for winter and summer and load calculation assumptions are listed in the Tables 1 & 2 below.

Table 1 - ASHRAE Outdoor Air Conditions (99.6% and 0.4%)

Washington, DC	Temperature °F
Winter Dry Bulb	15
Summer Dry Bulb	95
Summer Wet Bulb	76

Table 2 - ASHRAE Indoor Air Conditions

Indoor Design	Temperature °F
Cooling Supply Dry Bulb	78F
Cooling Drift point	90F
Heating Supply Dry Bulb	72F
Heating Drift point	55F
Relative Humidity	50%

Ventilation Requirements

An analysis using ASHRAE 62.1-2007 is shown in table 3 below. ASHRAE 62.1-2007 prescribes the minimum amount of outdoor air to be supplied to building spaces. As noted, the system as designed exceeds the minimum outdoor air requirements in all of the building air systems.

Table 3 – ASHRAE 62.1-2007 Ventilation Calculation

		AHU 1-1	AHU 1-2	AHU 2-1	AHU 2-2	AHU 3-1	AHU 3-2	AHU C-2	AC 3 & 4	AC 2
Total Area	Ft^2	17520	18125	18665	19305	19305	18665	18095	1957	2150
$\sum V_{oz}$	CFM	1851.75	1999	1853	2384.5	2384.25	1853	1615	595	521.5
V_{pz} Total	CFM	22005	21260	21230	22750	22755	21230	27087	3630	3920
V_{ot} Total	CFM	2058	2221	2059	2649	2649	2059	1794	595	522
% over ASHRAE 62.1-2007	%	46	48	46	48	48	46	51	34	34
Design V_{oa}	CFM	4600	4800	4800	4800	4800	4600	5150	3400	3400
Max Z_p		0.16	0.25	0.16	0.16	0.21	0.16	0.22	0.18	0.14

Heating & Cooling Loads

The heating and cooling loads as designed and as modeled in Technical Report II are listed and compared in tables 4 and 5 below expressed in MBH (1000 btu/hr).

Table 4 – Loads: Energy Model vs Designed

Unit Name	Area (Square Feet)	Designed Cooling(MBH)	Model Cooling(MBH)	Designed Heating(MBH)	Model Heating(MBH)	Designed (FT^2/Ton)	Model (FT^2/Ton)
AHU-C-2	26057	746.8	760.1	273.0	128.6	418.70	411.37
AHU-1-1	19165	670.1	625.3	136.5	192.1	343.20	367.79
AHU-1-2	15725	684.1	510.0	273.0	177.8	275.84	370.00
AHU-2-1	19165	670.1	625.3	136.5	192.1	343.20	367.79
AHU-2-2	15725	684.1	471.8	273.0	169.3	275.84	399.96
AHU-3-1	19165	685.2	607.3	273.0	216.3	335.64	378.69
AHU-3-2	15725	677.3	503.7	273.0	192.4	278.61	374.63
AC-2	2450	138.8	127.5	95.6	129.0	211.82	230.59
AC-3	978.5	43.1	61.4	36.1	46.1	272.44	191.24
AC-4	978.5	43.1	61.4	36.1	46.1	272.44	191.24
Totals	135134	5043	4354	1806	1490	321.58	372.46

Table 5 - Cooling Comparison: Energy Model vs Designed

Unit Name	Designed Cooling(Tons)	Modeled Cooling(Tons)	% Difference
AHU-C-2	62.2	63.3	2%
AHU-1-1	55.8	52.1	-7%
AHU-1-2	57.0	42.5	-25%
AHU-2-1	55.8	52.1	-7%
AHU-2-2	57.0	39.3	-31%
AHU-3-1	57.1	50.6	-11%
AHU-3-2	56.4	42.0	-26%
AC-2	11.6	10.6	-8%
AC-3	3.6	5.1	42%
AC-4	3.6	5.1	42%
Totals	420	363	-14%

Energy Rates & Sources

Listed in Tables 6, 7 and 8 below are the energy rates for electric, natural gas, and heating oil for suppliers in the Falls Church, VA area. Currently, HITT Contracting Headquarters only utilizes electric power in all of its building systems.

Table 6 - Dominion Virginia Power Utility Rates

On Peak Demand	14.488	$/kW Demand
Off Peak Demand	2.926	$/kW Demand
On Peak Consumption	0.0404	$/kWh
Off Peak Consumption	0.0272	$/kWh
Customer Charge(Per Month)	119.8	$/Month

Table 7 - Washington Gas Utility Rates

Customer Charge	$16.35	
	Therms	Price/Therm
First	125	$30.21
Next	875	$24.47
Over	1,000	$18.86
Next	29,000	$20.11
Over	30,000	$7.12

Table 8 – Heating Oil Utility Rates

Customer Charge	$21.50
	Price/Gal
Heating Oil	$2.15

Energy Usage

The monthly energy consumption as calculated by Trace 700 is displayed in Figure 1 below. On peak Demand was set to occur between the hours of 10am – 10pm from June to September and 7am-10pm from October to May. This, along with increased demand to satisfy the cooling loads, accounts for the spike in the off-peak demand during the summer months. The annual electricity consumption and the annual electricity cost for HITT Contracting Headquarters were modeled to be 3,769,755 kWh and $340,748 respectively.

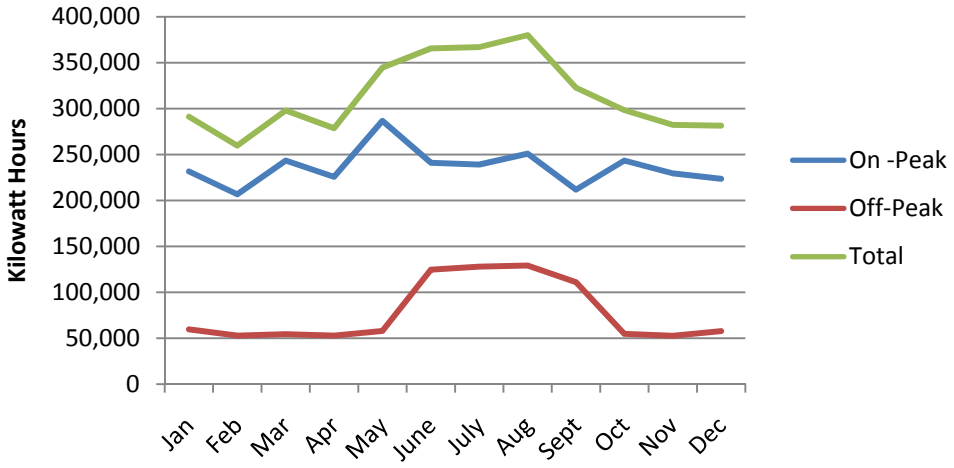

Figure 1 – Modeled Electricity Consumption by Month

Schematics

A schematic of the mechanical systems used in HITT Contracting Headquarters can be found in Figure 2 below. A further breakdown of the system is noted in Figure 3 and displays the design of the air handling units. See the System Operation section for a description of the system operation relating to the schematics shown.

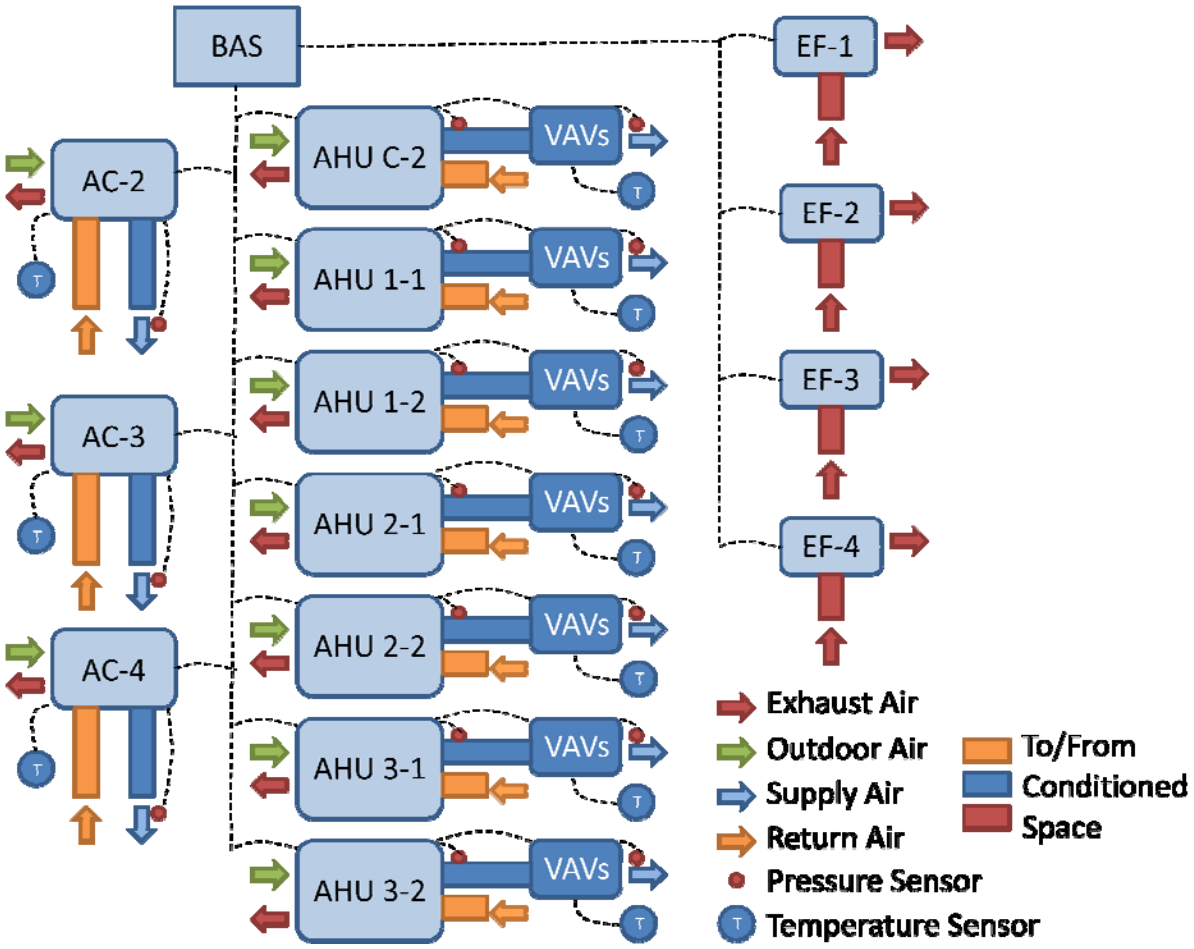

Figure 2 – Schematic of HVAC system

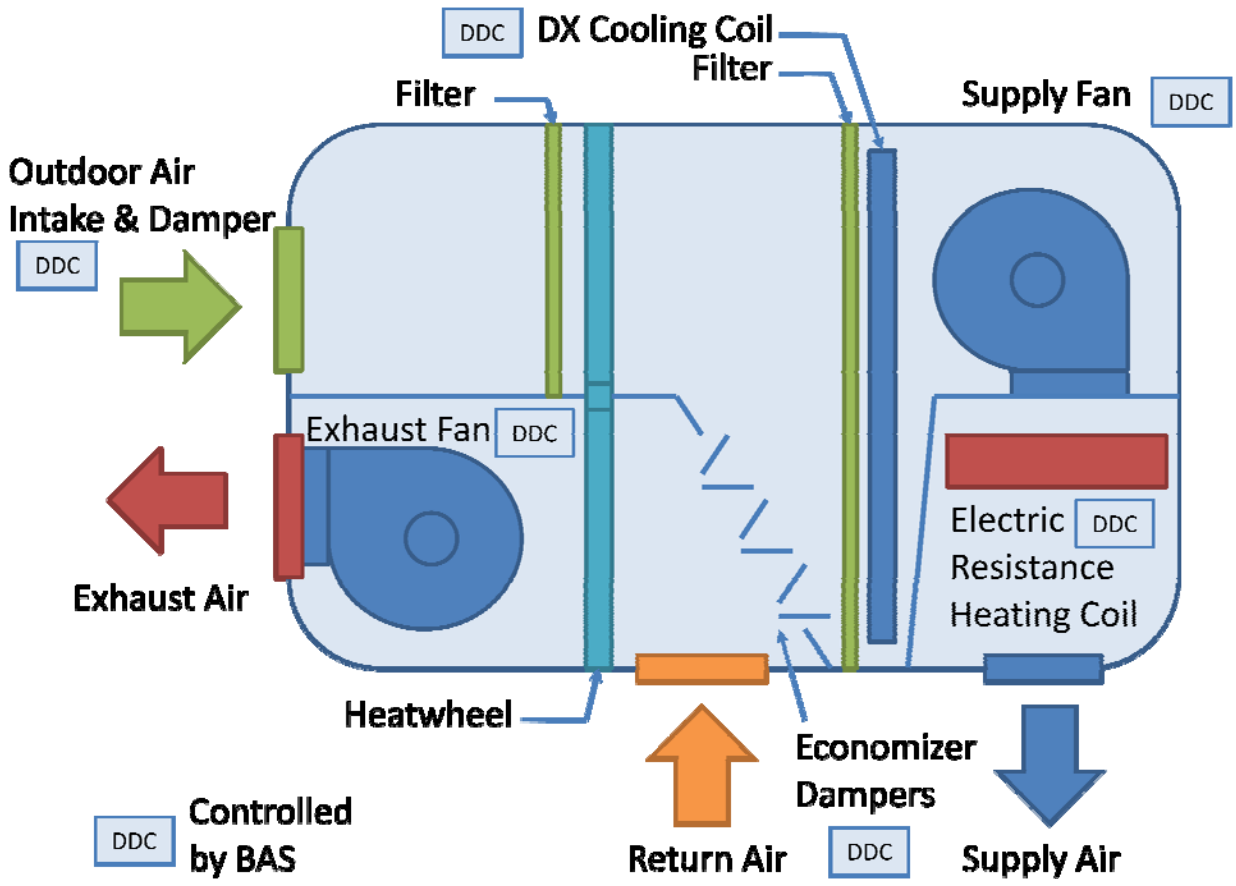

Figure 3 – Schematic of typical AHU

Equipment Schedules

A breakdown of the mechanical equipment for HITT Contracting Headquarters can be found in Appendix A.

System Operation

The mechanical systems in HITT Contracting Headquarters are primarily controlled by a DDC Building Automation System. The Building Automation System (BAS) controls:

- Rooftop units (AHUs)
- Exhaust fans (EF-1, EF-2, EF-3 & EF-4)
- Split system AC units
- Set point for VAV boxes

The AHUs are variable speed and have two main and three transition operating modes that the BAS is designed to manage: Occupied mode, unoccupied mode, startup mode, morning warmup and coastdown mode respectfully. Unoccupied mode has a BAS supply air setpoint of 65°F for heating only. Startup mode is used during the transition from unoccupied mode to morning warmup. Outdoor air dampers are closed while either heating or cooling are used for optimal start. The system then goes into morning warmup mode until the morning warmup setpoint has been achieved. During morning warmup mode the outdoor air damper is no longer closed but the economizer is not in use. Once the morning warmup setpoint has been achieved, the system then switches into occupied mode. During occupied mode the supply air setpoint given by the BAS is 74°F for cooling and 72°F for heating. Coastdown mode provides a transition from occupied mode to unoccupied mode. During coastdown mode, the supply fan remains on, while the outdoor air damper remains open for ventilation, and the mechanical cooling and heating are disabled.

The building exhaust fans EF-1, EF-2, EF-3, and EF-4 are constant speed and are controlled by the BAS and are interlocked with the operation of the AHUs. The split system AC units AC-2, AC-3, and AC-4 operate on a standalone basis with the set point set by users in the space but start and shutdown on command of the BAS.

The Variable Air Volume (VAV) terminal units are controlled by individual Direct Digital Control (DDC) controllers at the terminal unit. The BAS supplies the set point to each of the VAV terminal units via DDC control wiring. The VAV terminal units then compare the output of the temperature sensors (thermostats shown in Figure 2) in the space to maintain the set point by changing supply air rate and engaging electric resistance heating.

See Figure 2 in the Schematics Section for locations of the equipment discussed.

Usable Space Breakdown

The required space for mechanical equipment in HITT Contracting Headquarters had little impact on the usable building square footage. 1.44% of the total building usable square footage is allotted to mechanical systems. The large air handling units that the system uses are located on the roof, freeing up space on the usable floors below. The bulk of the square footage that is taken up by the system is from shaft space for duct connecting the duct systems on each the floor to the air handling units on the roof. This, along with a dropped acoustical tile ceiling, provides ample space on floors one to three. See table 9 below for a total breakdown of the lost usable square footage and per floor. Figure 4 below displays a typical floor with the mechanical shaft areas highlighted in blue.

Table 9 - Lost Usable Square Footage

	Total ft^2	Mech ft^2	% Lost Usable Space
Cellar	20245	1329	6.56%
1st Floor	37500	93	0.25%
2nd Floor	37500	197	0.53%
3rd Floor	37500	288	0.77%
Total	132745	1907	1.44%

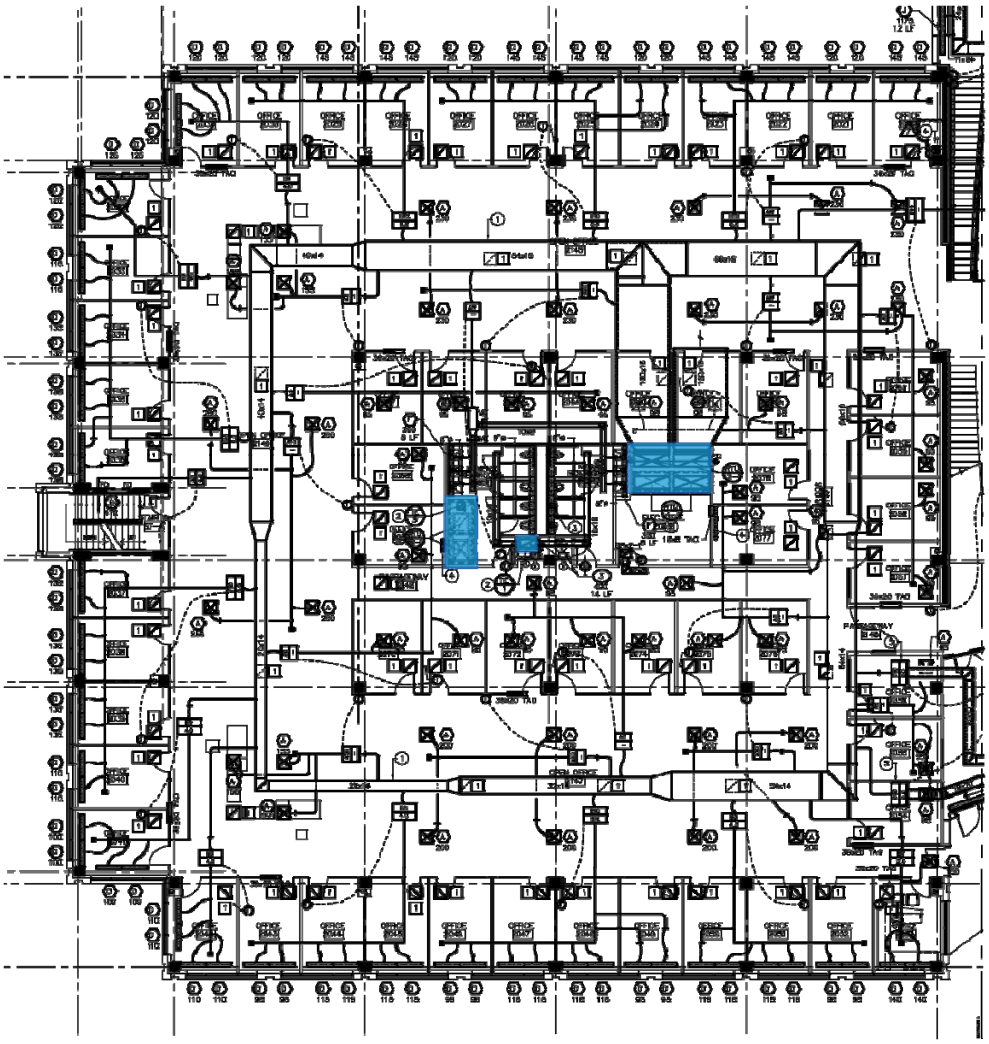

Figure 4 - Typical Floor Mechanical Spaces

Mechanical System Cost

The mechanical systems first cost for HITT Contracting Headquarters is projected to be $1,750,000. When divided by the total building square footage, it comes to $13.18 per square foot. The total cost of the building is $30 million, making the mechanical systems 5.83% of the total building cost. This cost per square foot seems to be on the low end of the typical cost spectrum of $13-25 per square foot.

LEED-NC v2.2 Rating

HITT Contracting Headquarters was designed to achieve a LEED New Construction rating of Silver with 35 points. The LEED points for HITT Contracting Headquarters are as follows: 8 points in site selection, 7 points in energy and atmosphere, 3 points in materials and resources, 10 points in indoor environmental quality, 3 points in innovation & design process.

See Appendix B for a list of the LEED credits achieved.

System Evaluation

The current system designed for HITT Contracting Headquarters provides an excellent level of comfort and indoor air quality for the occupants. Regarding indoor air quality, outdoor air supply rates exceed ASHRAE 62.1-2007 by an average of 47%. ASHRAE 55 comfort requirements are met by achieving the seasonal set points set forth in the sequence of operations. The VAV system also provides user control of their own comfort by making thermostats available to the tenants in many of the spaces.

The overall construction cost for HITT Contracting Headquarters is $30 million dollars, with the mechanical system first cost of $1,750,000. The energy model estimated the annual operating cost to be $340,000. This could be reduced greatly if an alternative energy source is implemented at current prices. Energy usage in HITT Contracting Headquarters as designed is limited to electric power. This is a straightforward method that is easy to maintain and allows for flexibility to alternative energy sources in the future. Alternative energy sources include solar (photovoltaic), natural gas and heating oil. These other sources may provide operating cost savings, especially in heating operation.

The direct expansion rooftop units also require less usable space than a centralized system to heat and cool the space by utilizing unusable roof space. Currently, the mechanical systems only take up 1.44% of the usable square footage, so there isn't much room for improvement. Ductwork and split system units are concealed by the drop acoustical tile ceiling and do not impede on the usable floor space.

In conclusion, there is room for improvement in both the heating and cooling systems. The initial design goals are unknown as to why the only energy source used in HITT Contracting Headquarters is electrical service but it is most likely due to the first cost of the system. The mechanical cost per square foot of $13.18 is on the low end of mechanical first costs. However, the system is easy to maintain and has a DDC system that can be easily used for logging trends and is very flexible. The largest benefit of the system as designed is its very low usable space intrusion of 1.44%. All in all centralized heating and cooling system is distinct possibility for this building and is worth investigating.

References

KTA Group, Inc. 2008. Mechanical Construction Documents. KTA Group, Herndon, VA. 2008.

Noritake Associates. 2008. Architectural Construction Documents. Noritake Associates, Alexandria, VA. 2008.

USGBC. LEED-NC v2.2 Reference Guide. 2006.

Washington Gas.

Appendix A – Equipment Schedules

Rooftop Units AAON RN-050-3											
	Supply Fan					Cooling			Heating		
	Airflow (CFM)	MIN OA (CFM)	SP IN. WG	HP	No.	Cooling (MBH)	EAT (DB/WB)	LAT (DB/WB)	Heating (MBH)	EAT (DB)	Weight (LBS)
RTU-C-2	26400	5150	2.25	25	2	746.8	76.0/63.3	58.1/56.1	273	69.2	8800
RTU-1-1	19850	4600	3.75	20	2	670.1	76.5/63.8	57.4/54.7	136.5	69.2	8800
RTU-1-2	22000	4800	3.00	25	2	684.1	76.5/63.7	58.0/55.5	273	67.7	8800
RTU-2-1	19850	4600	3.75	20	2	670.1	76.5/63.8	57.4/54.7	136.5	69.2	8800
RTU-2-2	22000	4800	3.00	25	2	684.1	76.5/63.7	58.0/55.5	273	67.7	8800
RTU-3-1	18300	4600	3.75	20	2	685.2	76.7/63.9	55.9/53.7	273	67.7	8800
RTU-3-2	20000	4800	3.75	20	2	677.3	76.6/63.8	57.6/54.8	273	67.3	8800

Split System AC Units									
UNIT	Airflow (CFM)	Cooling (MBH)	Heating (MBH)	Weight (LBS)	EAT (DB/WB)	UNIT	EER	Weight (LBS)	Refrigerant
AC-1	850	40.5	39.5	100	85/70	CU-1	13	350	R-410a
AC-2	875	138.8	95.6	1300	79.5/66.9	CU-2	12.6	1100	R-410a
AC-3	1700	86.2	71.7	900	80.1/66.4	CU-3	12.5	900	R-410a
AC-4	1700	86.2	71.7	900	80.1/66.4	CU-4	12.5	900	R-410a

Steam Generator			
	Power (KW)	Steam Capacity (LBS/HR)	Weight (LBS)
SG-1	30	103.5	250

Exhaust Fans					
	Airflow (CFM)	SP IN. WG	Weight (LBS)	Motor	
				HP	RPM
EF-C-1	1085	0.3	40	0.33	974
EF-C-2	150	0.4	40	0.15	1175
EF-C-3	150	0.4	40	0.15	1175
EF-C-4	350	0.4	40	0.18	1007
EF-C-5	150	0.4	40	0.15	1175
EF-C-6	450	0.5	40	0.23	1195
EF-C-7	200	0.5	40	0.21	1390
EF-C-8	350	0.6	40	0.18	1165
EF-C-9	350	0.6	40	0.18	1165
EF-1-1	465	0.3	40	0.42	1075
EF-1-2	465	0.3	40	0.42	1075
EF-2-1	465	0.3	40	0.42	1075
EF-2-2	465	0.3	40	0.42	1075
EF-3-1	465	0.3	40	0.42	1075
EF-3-2	465	0.3	40	0.42	1075
EF-1	2600	0.6	100	0.5	800
EF-2	3000	0.6	100	0.75	850
EF-3	1400	0.65	60	0.33	1250
EF-4	700	0.75	50	0.25	1800

Appendix B - LEED NC v2.2 Checklist

LEED for New Construction v 2.2
Registered Project Checklist

Project Name: HITT Contracting Headquarters

Project Address: 2900 Fairview Park Drive, Falls Church, VA

Yes	?	No		
35			Project Totals (Pre-Certification Estimates)	69 Points
SILVER			**Certified**: 26-32 points **Silver**: 33-38 points **Gold**: 39-51 points **Platinum**: 52-69 points	

Yes	?	No			
8			Sustainable Sites		14 Points
Yes			Prereq 1	**Construction Activity Pollution Prevention**	Required
			Credit 1	**Site Selection**	1
1			Credit 2	**Development Density & Community Connectivity**	1
			Credit 3	**Brownfield Redevelopment**	1
1			Credit 4.1	**Alternative Transportation**, Public Transportation	1
1			Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms	1
1			Credit 4.3	**Alternative Transportation**, Low-Emitting & Fuel Efficient Vehicles	1
			Credit 4.4	**Alternative Transportation**, Parking Capacity	1
			Credit 5.1	**Site Development**, Protect or Restore Habitat	1
			Credit 5.2	**Site Development**, Maximize Open Space	1
1			Credit 6.1	**Stormwater Design**, Quantity Control	1
1			Credit 6.2	**Stormwater Design**, Quality Control	1
			Credit 7.1	**Heat Island Effect**, Non-Roof	1
1			Credit 7.2	**Heat Island Effect**, Roof	1
1			Credit 8	**Light Pollution Reduction**	1

Yes	?	No			
4			Water Efficiency		5 Points
1			Credit 1.1	**Water Efficient Landscaping**, Reduce by 50%	1
1			Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation	1
			Credit 2	**Innovative Wastewater Technologies**	1
1			Credit 3.1	**Water Use Reduction**, 20% Reduction	1
1			Credit 3.2	**Water Use Reduction**, 30% Reduction	1

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LEED for New Construction v 2.2
Registered Project Checklist

Yes	?	No				
7			Energy & Atmosphere			17 Points
Yes			Prereq 1	**Fundamental Commissioning of the Building Energy Systems**		Required
Yes			Prereq 1	**Minimum Energy Performance**		Required
Yes			Prereq 1	**Fundamental Refrigerant Management**		Required
				***Note for EAc1:** All LEED for New Construction projects registered after June 26, 2007 are required to achieve at least two (2) points.		
4			Credit 1	**Optimize Energy Performance**		1 to 10
				10.5% New Buildings or 3.5% Existing Building Renovations		1
				14% New Buildings or 7% Existing Building Renovations		2
				17.5% New Buildings or 10.5% Existing Building Renovations		3
			-->	21% New Buildings or 14% Existing Building Renovations		4
				24.5% New Buildings or 17.5% Existing Building Renovations		5
				28% New Buildings or 21% Existing Building Renovations		6
				31.5% New Buildings or 24.5% Existing Building Renovations		7
				35% New Buildings or 28% Existing Building Renovations		8
				38.5% New Buildings or 31.5% Existing Building Renovations		9
				42% New Buildings or 35% Existing Building Renovations		10
			Credit 2	**On-Site Renewable Energy**		1 to 3
				2.5% Renewable Energy		1
				7.5% Renewable Energy		2
				12.5% Renewable Energy		3
1			Credit 3	**Enhanced Commissioning**		1
1			Credit 4	**Enhanced Refrigerant Management**		1
1			Credit 5	**Measurement & Verification**		1
			Credit 6	**Green Power**		1

LEED for New Construction v 2.2
Registered Project Checklist

Yes	?	No			
3			Materials & Resources		13 Points
Yes			Prereq 1	**Storage & Collection of Recyclables**	Required
			Credit 1.1	**Building Reuse,** Maintain 75% of Existing Walls, Floors & Roof	1
			Credit 1.2	**Building Reuse,** Maintain 95% of Existing Walls, Floors & Roof	1
			Credit 1.3	**Building Reuse,** Maintain 50% of Interior Non-Structural Elements	1
1			Credit 2.1	**Construction Waste Management**, Divert 50% from Disposal	1
			Credit 2.2	**Construction Waste Management**, Divert 75% from Disposal	1
0			Credit 3.1	**Materials Reuse**, 5%	1
			Credit 3.2	**Materials Reuse**, 10%	1
1			Credit 4.1	**Recycled Content**, 10% (post-consumer + 1/2 pre-consumer)	1
			Credit 4.2	**Recycled Content**, 20% (post-consumer + 1/2 pre-consumer)	1
1			Credit 5.1	**Regional Materials**, 10% Extracted, Processed & Manufactured	1
			Credit 5.2	**Regional Materials**, 20% Extracted, Processed & Manufactured	1
			Credit 6	**Rapidly Renewable Materials**	1
			Credit 7	**Certified Wood**	1

Yes	?	No			
10			Indoor Environmental Quality		14 Points
Yes			Prereq 1	**Minimum IAQ Performance**	Required
Yes			Prereq 2	**Environmental Tobacco Smoke (ETS) Control**	Required
1			Credit 1	**Outdoor Air Delivery Monitoring**	1
			Credit 2	**Increased Ventilation**	1
1			Credit 3.1	**Construction IAQ Management Plan,** During Construction	1
1			Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
1			Credit 4.1	**Low-Emiiting Materials**, Adhesives & Sealants	1
1			Credit 4.2	**Low-Emiiting Materials**, Paints & Coatings	1
1			Credit 4.3	**Low-Emiiting Materials**, Carpet Systems	1
			Credit 4.4	**Low-Emiiting Materials**, Composite Wood & Agrifiber Products	1
1			Credit 5	**Indoor Chemical & Pollutant Source Control**	1
			Credit 6.1	**Controllability of Systems**, Lighting	1
1			Credit 6.2	**Controllability of Systems**, Thermal Comfort	1
1			Credit 7.1	**Thermal Comfort,** Design	1
1			Credit 7.2	**Thermal Comfort,** Verification	1
			Credit 8.1	**Daylight & Views,** Daylight 75% of Spaces	1
			Credit 8.2	**Daylight & Views,** Views for 90% of Spaces	1

LEED for New Construction v 2.2
Registered Project Checklist

Yes	?	No			
3			Innovation & Design Process		5 Points
			Credit 1.1	**Innovation in Design:** Provide Specific Title	1
1			Credit 1.2	**Innovation in Design:** Educational Piece TBD	1
1			Credit 1.3	**Innovation in Design:** Green Housekeeping	1
			Credit 1.4	**Innovation in Design:** Provide Specific Title	1
1			Credit 2	**LEED® Accredited Professional**	1

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