ASHRAE STANDARD 90 BUILDING & PLANT ENERGY ANALYSIS REPORT

LANDSCAPE BUILDING

AT

JANELIA FARM

HOWARD HUGHES MEDICAL INSTITUE

ASHBURN, VIRGINIA

PREPARED FOR

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&

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MEHCANICAL OPTION

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EXECUTIVE SUMMARY

This report examines energy use and emissions production of the Landscape Building at Janelia Farm Research Campus using ASHRAE Standard 90.1-2004 Energy Standard for Buildings at design conditions.

The Landscape Building is a 546,436 square foot world-class biomedical research facility owned by Howard Hughes Medical Institute. The facility is built into the side of a large hill overlooking the Potomac River. It is currently beginning its third year of construction in Ashburn, Virginia located 45 minutes outside of Washington, D.C. The building is divided into Zones A through G on three different levels.

The building is supplied air by 15 air handling units which feed into one plenum that serves the entire building. There are 2-50,512 MBH and 2-20,125 MBH (one future) boilers The majority of the load is used for the air handling unit's steam coils. The remaining steam is used at various shell and tube heat exchangers. The chiller plant has seven chillers and seven cooling towers (one back-up) each rated at 1200 tons. The portion of the load that does not go to the air handling units serves various equipment within the building. For example, the data center has air conditioning units that require chilled water.

The Landscape Building is able to achieve a Gold LEED™ rating, but the owner is not applying to be rated. HHMI wanted to be rated Platinum or not at all.

HHMI has asked to keep the mechanical space completely separate from the rest of the building. As a result, almost 50% of the building is dedicated to mechanical systems. All of this space is located in the back of the building buried up to 60ft underground.

The building was modeled using Carrier's Hourly Analysis Program 4.20a (HAP) to compare a calculated design load with the actual design load performed by Burt Hill Kosar Rittelmann. In addition to this, HAP's building simulation provides data on energy usage and emissions production. The emissions data was compared to a series of spreadsheets created by the Energy Information Administration, United States Department of Energy.

The HAP calculations did not come up with numbers similar to those of the original design. This can be attributed to a crucial information not being known and assumptions made during calculation.

LEED™ EVALUATION

BASED ON U.S. GREEN BUILDING COUNCIL'S RATING SYSTEM

The following checklist evaluation is based primarily upon intent of the engineers and architect during design. Howard Hughes Medical Institute expressed a desire to achieve Platinum rating. During the early stages of construction and the end of design, it became clear that the Landscape Building would be a few points shy of Platinum status. Because it was too expensive to gain those points, Howard Hughes decided to no longer go for a LEED™ rating. Few of the credits are documented, but the majority have been carried out during construction. Although not official rated, the Landscape Building is capable of achieving Gold. This is quite impressive considering it is primarily a lab building and the spaces require approximately 90% outdoor air and is not energy efficient.

One interesting system of note is the non-chemical water treatment for the cooling towers. As water is constantly being recirculated in the tower, there is the tendency for scale to occur. This can increase energy use up to 10%. In addition to microbe-induced corrosion, biofilm collecting on surfaces is a source of illness for those in the vicinity. One solution has been to add chemicals that kill the bacteria inhibit scale. The major drawbacks include these dangerous chemicals having adverse effects on inhabitants and the environment. A chemical free option, known as the Dolphin Series is manufactured by Clearwater Systems, LLC from Essex, Connecticut. In this system, and electromagnetic field kills the bacteria and gets rid of scale. "The pulsing electric field induces the coagulation of colloids – very small, electrically charged particles – which creates nucleation sites that encourage calcium carbonate to precipitate as a powder in bulk solution rather than a scale on the surface. The coagulation – precipitation activity also reduces bacteria counts by trapping bacteria within the crystal formation." According to an article in *Environmental Engineering News,* the results and claims include:

- Exceedingly low bacteria counts
- Virtually no biofilm
- Almost no corrosion or scale
- Reduced maintenance
- Extended tower life
- No chemical use

This system accounted for a total of 4 LEED credits; three for "water use reduction" and one credit for "innovation in design.

LEED-NC Version 2.1 Registered Project Checklist
Janelia Farm Research Campus: Landscape Building
Ashburn, VA

Yes	?	No			
10		4	**Sustainable Sites**		**14** Points
Y			Prereq 1	**Erosion & Sedimentation Control**	Required
1			Credit 1	**Site Selection**	1
1			Credit 2	**Development Density**	1
		1	Credit 3	**Brownfield Redevelopment**	1
1			Credit 4.1	**Alternative Transportation**, Public Transportation Access	1
1			Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms	1
		1	Credit 4.3	**Alternative Transportation**, Alternative Fuel Vehicles	1
1			Credit 4.4	**Alternative Transportation**, Parking Capacity and Carpooling	1
1			Credit 5.1	**Reduced Site Disturbance**, Protect or Restore Open Space	1
		1	Credit 5.2	**Reduced Site Disturbance**, Development Footprint	1
1			Credit 6.1	**Stormwater Management**, Rate and Quantity	1
		1	Credit 6.2	**Stormwater Management**, Treatment	1
1			Credit 7.1	**Landscape & Exterior Design to Reduce Heat Islands**, Non-Roof	1
1			Credit 7.2	**Landscape & Exterior Design to Reduce Heat Islands**, Roof	1
1			Credit 8	**Light Pollution Reduction**	1

Yes	?	No			
4	1		**Water Efficiency**		**5** Points
1			Credit 1.1	**Water Efficient Landscaping**, Reduce by 50%	1
	?		Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation	1
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

Yes	?	No			
7	2	2	**Energy & Atmosphere**		**17** Points
Y			Prereq 1	**Fundamental Building Systems Commissioning**	Required
Y			Prereq 2	**Minimum Energy Performance**	Required
Y			Prereq 3	**CFC Reduction in HVAC&R Equipment**	Required
4			Credit 1	**Optimize Energy Performance**	1 to 10
1			Credit 2.1	**Renewable Energy**, 5%	1
	?		Credit 2.2	**Renewable Energy**, 10%	1
	?		Credit 2.3	**Renewable Energy**, 20%	1
1			Credit 3	**Additional Commissioning**	1
1			Credit 4	**Ozone Depletion**	1
		1	Credit 5	**Measurement & Verification**	1
		1	Credit 6	**Green Power**	1

Yes	?	No			
12			**Materials & Resources**		**13** Points
Y			Prereq 1	**Storage & Collection of Recyclables**	Required
1			Credit 1.1	**Building Reuse**, Maintain 75% of Existing Shell	1
1			Credit 1.2	**Building Reuse**, Maintain 100% of Shell	1
1			Credit 1.3	**Building Reuse**, Maintain 100% Shell & 50% Non-Shell	1
1			Credit 2.1	**Construction Waste Management**, Divert 50%	1
1			Credit 2.2	**Construction Waste Management**, Divert 75%	1
1			Credit 3.1	**Resource Reuse**, Specify 5%	1
1			Credit 3.2	**Resource Reuse**, Specify 10%	1
1			Credit 4.1	**Recycled Content**, Specify 5% (post-consumer + ½ post-industrial)	1
1			Credit 4.2	**Recycled Content**, Specify 10% (post-consumer + ½ post-industrial)	1
1			Credit 5.1	**Local/Regional Materials**, 20% Manufactured Locally	1
1			Credit 5.2	**Local/Regional Materials**, of 20% Above, 50% Harvested Locally	1
		1	Credit 6	**Rapidly Renewable Materials**	1
1			Credit 7	**Certified Wood**	1
Yes	?	No			
10	2	3	**Indoor Environmental Quality**		**15** Points
Y			Prereq 1	**Minimum IAQ Performance**	Required
Y			Prereq 2	**Environmental Tobacco Smoke** (ETS) **Control**	Required
1			Credit 1	**Carbon Dioxide** (CO_2) **Monitoring**	1
1			Credit 2	**Ventilation Effectiveness**	1
1			Credit 3.1	**Construction IAQ Management Plan**, During Construction	1
	?		Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
1			Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1
1			Credit 4.2	**Low-Emitting Materials**, Paints	1
1			Credit 4.3	**Low-Emitting Materials**, Carpet	1
1			Credit 4.4	**Low-Emitting Materials**, Composite Wood & Agrifiber	1
1			Credit 5	**Indoor Chemical & Pollutant Source Control**	1
		1	Credit 6.1	**Controllability of Systems**, Perimeter	1
		1	Credit 6.2	**Controllability of Systems**, Non-Perimeter	1
1			Credit 7.1	**Thermal Comfort**, Comply with ASHRAE 55-1992	1
		1	Credit 7.2	**Thermal Comfort**, Permanent Monitoring System	1
1			Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces	1
	?		Credit 8.2	**Daylight & Views**, Views for 90% of Spaces	1
Yes	?	No			
3		2	**Innovation & Design Process**		**5** Points
1			Credit 1.1	**Innovation in Design**: Provide Specific Title	1
1			Credit 1.2	**Innovation in Design**: Provide Specific Title	1
		1	Credit 1.3	**Innovation in Design**: Provide Specific Title	1
		1	Credit 1.4	**Innovation in Design**: Provide Specific Title	1
1			Credit 2	**LEED™ Accredited Professional**	1
Yes	?	No			
46	5	11	**Project Totals** (pre-certification estimates)		**69** Points
			Certified 26-32 points **Silver** 33-38 points **Gold** 39-51 points **Platinum** 52-69 points		

LIGHTING COMPLIANCE

AS OUTLINED IN ASHRAE STANDARD 90.1-2004 SECTION9

Assumptions

The Landscape Building contains approximately 850 individual spaces. It would be beyond the scope of this report to use the Space-by-Space Method outlined in Section 9.6 or ASHRAE Standard 90.1. Instead I have chosen to use the Building Area Method outlined in Section 9.5. The major assumption is that the Building Area Method will give me an accurate evaluation of the interior lighting allowance.

In order to use the Building Area Method, space types had to be determined. To do this, the following assumptions had to be made:

- The majority of the first floor containing auditoriums, galleries, large conference spaces, and office space can be assumed equivalent to a conference center.
- The dinning area falls under the category of dinning: bar lounge/leisure.
- Medical research and laboratory space is equivalent to hospital space.
- All ventilated mechanical and shell space is treated as warehouse space.

There are two feature staircases that divide the building into thirds. Each stair case is an open space from the first to third floors. For the purpose of the lighting analysis, both stair cases have identical lighting fixtures. For the purpose of load calculations, the stairwell is vertical.

The laboratory spaces are all identical with an assortment of supporting rooms. For the purpose of this report, the laboratory spaces have been divided into six equal zones where the difference between support rooms is assumed negligible.

Various zones are two stories high. Within these zones are small service room that are assumed to be two stories high as well for modeling purposes.

Procedure

Step One
Determine the method used for analysis. As discussed above, the Building Area Method is the method chosen.

Step Two
Determine building zones. The Landscape Building is a complex building with many different categories of spaces. The building has been divided in zones according to category which can be found in the following table:

Lighting Power Density	
Building Area Type	**W/SF**
Convention Center	1.2
Dining: Bar Lounge/Leisure	1.3
Hospital	1.2
Office	1.0
Parking	0.3
School/University	1.2
Warehouse	0.8

Fig 1 From Table 9.5.1, ASHRAE 90.1-2004

The above lighting loads are used to determine the lighting allowance for each zone.

Step Three
Determine the lighting load by zone. This is done by taking an inventory of lighting fixtures from the lighting plans provided by the architect. Figure A.1 with the lighting load by zone can be found on page 19.

Step Four
Determine the area of each zone. Areas are calculated by measuring space dimensions from the floor plans. The areas which are of the same classification are grouped together.

Step Five
Calculate the power lighting density by building area type. Divide the lighting power by the square footage. Compare this value to the W/SF column in Table 9.5.1 in ASHRAE Standard 90.1. The calculated value is acceptable if it is less than or equal to the values determined by ASHRAE. Figure A.1 with the power density can be found on page 19.

Discussion

Every space type did not meet ASHRAE standards except "Hospital" and "Parking" that had values of 1.2 W/sf and 0.3 W/sf respectively. The space type with the greatest deviation was office space which had a lighting power density of 2.0 W]sf compared to the allowable 1.0 W/sf. Had the original design complied with ASHRAE Std. 90.1, 9.24% less energy would have been used. Figure A.2 showing the power reduction can be found on page 19.

BUILDING ENVELOPE COMPLIANCE

AS OUTLINED IN ASHRAE STANDARD 90.1-2004 SECTION 5

Assumptions

The Landscape Building has three sides completely underground and one side almost completely glass that is exposed. According to the definitions below, it has been assumed that below grade walls are included in the gross wall area of the building envelope.

- *Building envelope:* the exterior plus the semi-exterior portions of a building. For the purposed of determining building envelope requirements, the classifications are defined as follows:
  a) *building envelope, exterior:* the elements of a building that separate conditioned space from the exterior.
  b) *Building envelope, semi-exterior*: the elements of a building that separate conditioned space from unconditioned space or that enclose semiheated spaces through which thermal energy may be transferred to or from the exterior, or to or from unconditioned spaces, or to or from conditioned spaces.
- *Gross wall area:* the area of the wall measured on the exterior face from the top of the floor to the bottom of the roof.

The building envelope will be sealed, caulked, gasketed, or weather-stripped to minimize air leakage.

Some U-values and shading coefficients were provided by the mechanical engineer. The values not provided were found on the manufacturer's website, these include all solar heat gain coefficients for glazing and assembly U-values. All R-values have been taken from *Mechanical and Electrical Equipment for Buildings,* by Benjamin Stein and John. S. Reynolds.

Procedure

<u>Step One</u>
Determine Compliance Path
Section 5.2.1 outlines two compliance paths; the Prescriptive Building Envelope Option and the Building Trade-Off Option. In order to use the Prescriptive Building Envelope Option, the following provisions must be true:

1) the vertical fenestration area does not exceed 50% of the gross wall area for each space-conditioning category and
2) the skylight fenestration area does not exceed 5% of the gross roof area for each space-conditioning category.

The Landscape Building has a vertical fenestration area which makes up 37% of the gross wall area and a skylight fenestration area that makes up 4.88% of the gross roof area. Therefore the Prescriptive Building Envelope Option is acceptable.

Step Two:
Determine the climate zone.
From Figure B-1: Climate Zone 4A

Step Three:
Determine Compliance. Compare assembly maximum U-values and insulate minimum R-values provided by ASHRAE to actual values. Values were provided by the mechanical engineer when possible. Other values were obtained from product information websites. The green roof was considered in the "Other" category. The table below shows the fenestration area calculation.

Floor	Floor - Floor Height [ft]	Glazing Height	Total Perimeter [ft]	Glazing Parimeter [ft]	Total Area [sf]	Glazing Area [sf]	% Glazing
One	20	15	2,695	1,443	53,900	21,645	0.40
Two	20	12	3,277	1,958	65,540	23,496	0.36
Three	20	12	2,996	1,788	59,920	21,456	0.36
Total	**–**	**–**	**8,968**	**5,189**	**179,360**	**66,597**	**0.37**

Fig. 2

It was found that all but the green roof assembly complied with ASHRAE Standard 90.1 Section 5. One possible explanation could be that there simply is not a category that is applicable for green roofs. One would think that a roof designed to be energy efficient would meet with heat transfer standards. Full results can be found in Figure B.1 on page 20.

DESIGN LOAD & ENERGY ANALYSIS

USING CARRIER'S HOURLY ANALYSIS PROGRAM 4.20A

Assumptions

- The nearest location to the Landscape Building in Ashburn, VA is Washington, D.C. The weather data for Washington is adequate for simulating heating and cooling loads.
- The glass doors have the same U-value and shading coefficient as the windows.
- U-values for unknown doors have been assumed.
- HAP has a maximum depth below grade of 50ft. The back wall of the first floor is greater than 60ft below grade. I am assuming that 50ft below grade is acceptable distance.
- Where the depth below grade changes, the average depth is used in the HAP calculation.
- A space above conditioned space cannot be modeled as below grade in HAP. For all spaces below grade and above conditioned space, I am treated exterior walls as interior. This is as close an approximation that can be made.
- The 900 foot long south wall bordering the parking lot is technically an exterior wall, but it does not have a solar load because it is underground. If modeled in HAP as exterior, it will receive solar loads. Instead the parking lot will be modeled as an unconditioned space with temperature minimums and maximums equivalent to those of the climate.
- The majority of exterior walls are glass. HAP does not have a "glass wall" feature. The window area is as close to the total wall area as possible.
- Occupancy has not been assigned to the day care center. I am assuming ten children and one teacher per room, plus two people in the administrative offices.
- A fan/thermostat schedule was not available from the mechanical engineer. It has been assumed to be the same as the major occupancy schedule: office. "Occupied" status is between 8:00am and 4:00 pm during normal working hours every day of the year. This is because people live at this facility and can work any day. "Unoccupied" status is given to all other times.
- "Medium" building weight has been assumed.
- "Office work" is the assumed activity level.
- No infiltration due to positive pressurized building designed to keep contaminated air from entering.
- No miscellaneous loads lave assumed.
- Equipment loads were provided by the engineer and assumed to be accurate.
- All information provided by the mechanical engineer is accurate as this is the main source of information.

Procedure

Step One
Determine the zones. Twenty-two different zones were created for the lighting allowance calculation. Various zones, such as Zone 15, occur up to three times within the building. The zones have been divided up according to the air handler assigned to that space. AHUs 1 & 2 serve the western most portion of the building on all three levels, while AHUs 3 – 15 serve the remainder of the building.

Step Two
Calculate the space information. HAP 4.20a requires detailed information about the spaces.

- All geometry related information has been taken from architectural drawings.
- U-values have been obtained from the mechanical engineers on the project.
- Occupancies have been taken from the architectural drawings.
- Outside air requirements are derived from Standard 62.1-2004 Table 6-1.
- Equipment load estimates have been taken from Cogeneration Feasibility Study provided by the mechanical engineer.
- Lighting densities calculated in the lighting compliance above are used for each zone.

Step Three
Enter system information.
The Landscape Building is served by 15 identical air handling units; 14 primary and one back up. All 15 air handling units feed into one plenum which then serves the entire building using a primarily variable air volume system. For the purpose of modeling, the system represents the total AHU capacity. Each individual AHU capacity is not represented. The supply temperature is 45.8°F. The supply fan operates at 88.5 BHP.

The boiler plant contains three boilers and room for an addition of a fourth. Two have a capacity of 50,210 MBH and on is 30,125 MBH, a total energy input is 163,181 MBH, and an efficiency of 80%. In general, two boilers run in any combination to meet desired load. The majority of the steam generated by the boilers is used by the air handler steam coils.

There are six w/c centrifugal chillers and one back up that have full load capacity of 1,200 tons. The full load LCHWT and ECWT are 42.0°F and 85.0°F respectively. The full load power is 0.670 kW/ton. The condenser flow rate is 2,400 gpm and pressure drop of 13.0 ft.

Step Four
Enter energy data. Electric service is provided by Dominion Virginia Power. Figure 3 shows the expected rates for the Landscape Building. Natural Gas is provided by Washington Gas. The rates can be seen in Figure 4. All data has been provided by the mechanical engineer and was used in the actual energy analysis.

Electricity Cost Summary	
Energy Charges	
On-peak	$0.05599 per kWh
Off-peak	$0.03166 per kWh
Supply Charge	
On-peak	$1.17150 per kW
Off-peak	$0.6320 per kW

Fig 3

Natural Gas Cost Summary	
Distribution Charge	
Flat Price	$0.570 per therm

Fig 4

Step Five
Perform design load and energy calculation. HAP provides all information necessary for load, energy, and emissions analysis.

Discussion

As can be seen in Figure 5 the load calculated is only 77.5% of the design data. The total energy cost was calculated to be $957,719 where the actual cost has been estimated to be $3,230,762. The calculated value is only 27.9% of the design cost. These differences can be attributed to inputs available and assumptions made during analysis. Given that a significant amount of information was unknown during the calculation process, it is impossible to expect similar results as the design analysis. Also, several large assumptions were made to simplify the building to make the calculation process manageable in size. Although these assumptions were similar to the actual design assumptions, they may be a source of inaccuracy. Full results can be found in Appendix C on page 21.

	Capacity [MBH]	**Supply [cfm]**	**Ventilation [cfm]**	**Cooling [sf/ton]**	**Supply[cfm/sf]**	**Ventilation [cfm/sf]**
HAP Output	31,761	335,969	336,772	168	0.76	0.76
Design Data	44,828	630,000	567,000	Unknown	1.15	1.04

Fig 5

EMISSIONS ANALYSIS

USING CARRIER'S HOURLY ANALYSIS PROGRAM 4.20A

Discussion

Energy mix for Dominion Power could not be obtained. It has been assumed that the data provided by the Energy Information Administration is accurate for Northern Virginia. This data is used in HAP to calculate the emissions report. Detailed results can be found in Appendix E. As shown in Figure 6, the calculation using data provided by the Energy Information Administration and the HAP analysis produced almost identical results. The Landscape Building produces just under 26 million pounds of CO_2 each year. This seems to be an excessively large amount of emissions for just one building and is something to think about next semester.

lbm $Pollutant_j$			
	SO_2	No_x	CO_2
EIA Data	141,537	83,304	25,898,895
HAP Analysis	141,473	83,145	25,893,480

Fig. 6

MECHANICAL SYSTEM FIRST COST

BASED ON BID DOCUMENTS

The Landscape Building is currently under construction and therefore all costs have not yet been finalized. All mechanical costs have been left to the discretion of the construction manager Turner Construction Company. They were able to provide a rough estimate of $10 million or $18.30 per square foot for the first cost of mechanical equipment. While this appears to be excessive, the building will cost an estimated total of $500 million. The mechanical system will represent only 2% of this total. The total cost per square foot is $915/sf. With this perspective, the mechanical cost is much more reasonable.

LOST RENTABLE SPACE DUE TO MECHANICAL SYSTEM

BASED ON ARCHITECTURAL DRAWINGS

While most organizations and companies exist for the purpose of making a profit, Howard Hughes Medical Institute is focused on making progress in the field of medical research and discovery. After years of building facilities on university campuses, HHMI has decided to build their signature building. Knowing precisely how the building should operate, HHMI requested the mechanical spaces be completely separate from laboratory and working spaces of the building. If there is ever a mechanical or electrical maintenance problem, workers do not need to enter the labs or office space. All mechanical and electrical equipment is located along and behind the service corridor at the rear of the building. As seen in the first floor rendering below, the light gray band towards the bottom of the floor plan is the service corridor. All rooms below that corridor are mechanical space and the majority of rooms shaded gray are mechanical space as well.

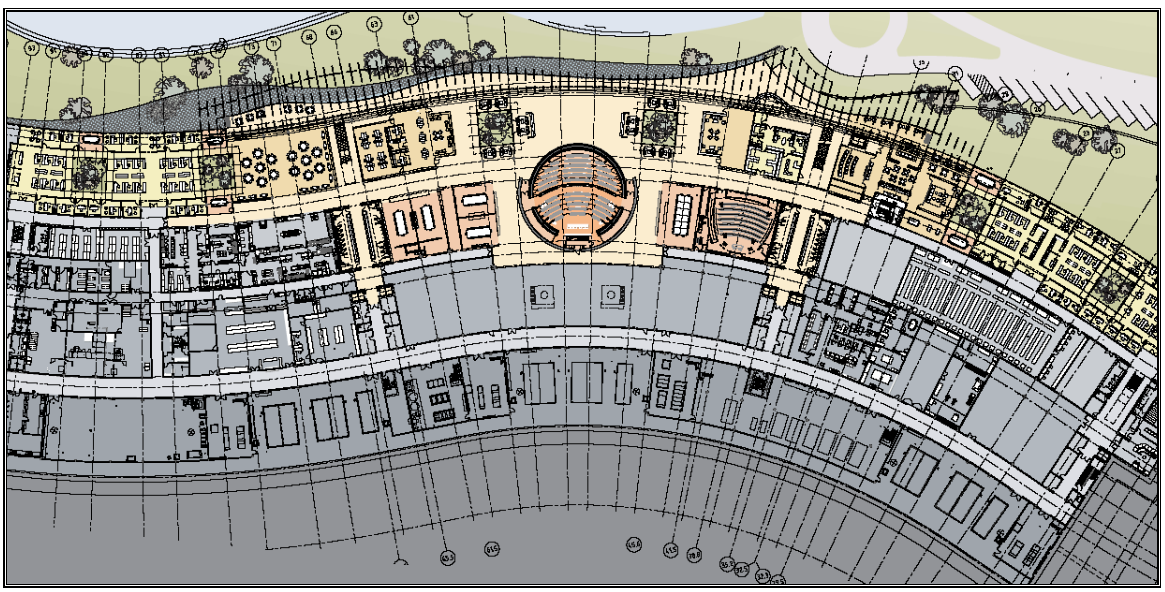

Fig. 7 First Floor Rendering

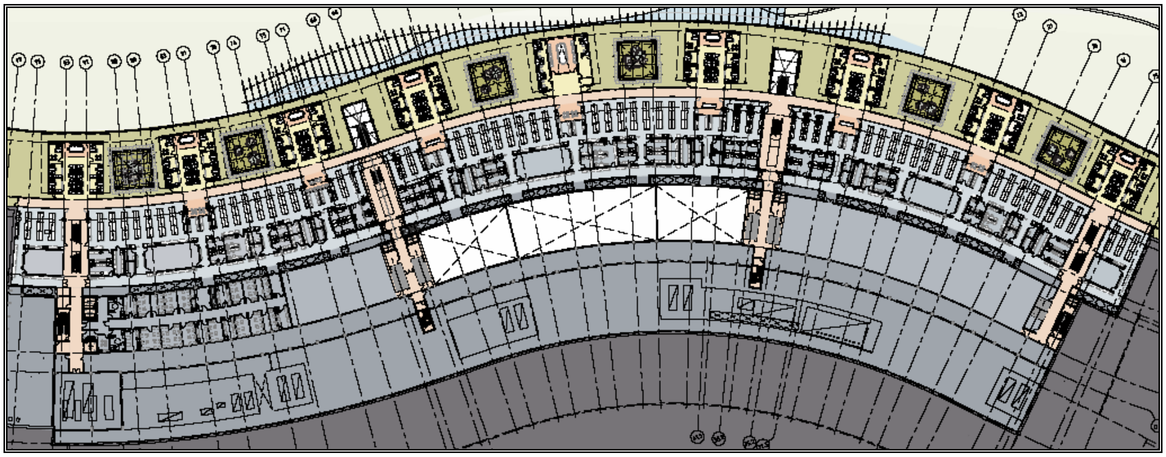

Fig. 8 Second Floor Rendering

The bottom fourth of the second floor is completely dedicated to mechanical systems as shown above. The third floor is almost identical to the second with a service corridor separating equipment rooms fro mlaboratories. Approximately 220,235 square feet of useable space is dedicated to mechanical systems. This is 49.5% of the building's total useable area. Clearly HHMI was more concerned about providing an excellent working environment for the medical experts than the cost of using so much space for systems.

Floor	Mechanical Area [sf]	Total Area [sf]	Percent Lost
First	147,773	240,461	61.5
Second	46,049	122,649	37.5
Third	26,413	82,013	32.2
Total	**220,235**	**445,123**	**49.5**

Fig. 9

Please keep mind that almost 50% of the building area is dedicated mechanical systems while reading the following short anecdote. HHMI was at one point considering using enthalpy and sensible wheels for latent and sensible heat recovery. This could possibly have saved a great deal of money in energy costs considering the building used approximately 90% outdoor air. Later they decided that it would be too expensive to increase the size of the building by adding a room to house the additional equipment.

REFERENCES

DOCUMENTS USED TO OBTAIN INFORMATION

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APPENDIX A

LIGHTING COMPLIANCE

Lighting Power Density by Building Type

Zone	Space Type	Total Lighting Power [W]	Area [sf]	Lighting Power Density [W/sf]	Allowable Power Density [W/sf]	Acceptable
1,3,4,7,10,11,12	Convention Center	199,004	150,860	1.3	1.2	No
2,9	Dining: Bar Lounge/Leisure	22,185	14,392	1.5	1.3	No
15,16,18,19,21,22	Hospital	114,943	92,944	1.2	1.2	Yes
14	Office	4,240	2,092	2.0	1.0	No
23	Parking	15,050	94,900	0.2	0.3	Yes
20	School/University	20,463	10,870	1.9	1.2	No
6,8,13,17	Warehouse	92,593	104,661	0.9	0.8	No

Saved Power

Zone	Space Type	Area [sf]	Allowable Power Density [W/sf]	Total Lighting Power [W]	Saved Power [W]
1,3,4,7,10,11,12	Convention Center	150,860	1.2	181,032	17,972
2,9	Dining: Bar Lounge/Leisure	14,392	1.3	18,710	3,475
15,16,18,19,21,22	Hospital	92,944	1.2	111,533	3,410
14	Office	2,092	1.0	2,092	2,148
23	Parking	94,900	0.3	28,470	0
20	School/University	10,870	1.2	13,044	7,419
6,8,13,17	Warehouse	104,661	0.8	83,729	8,864
			Total Power Saved		**43,288**
			Percent Saved		**9.24%**

Fig. A.1 & Figure A.2

APPENDIX B

BUILDING ENVELOPE COMPLIANCE

		ASHRAE 90.1 - Nonredential		Actual		
Opaque Elements		**Assembly Maximum**	**Insulation Min R-Value**	**Assembly**	**Insulation R-Value**	**Acceptable**
Roofs	Insulation Entirely above Deck	U-0.063	R-15.0ci	U-0.06	R-16.0	Yes
	Attic and Other	U-0.034	R-30.0	U-0.06	R-16.0	No
Walls, Above Grade	Mass	U-0.151	R-5.7ci	U-0.06	R-7.6	Yes
Floors	Mass	U-0.107	R-6.3ci	U-0.13	R-7.6	Yes
Slab-On-Grade Floors	Unheated	F-0.730	NR	U-0.15	NR	Yes
Opaque Doors	Swinging	U-0.700	--	U-0.300	--	Yes
Fenetration		**Assembly Max. U (Fixed/Operable)**	**Assembly Max SHGC (All Orientations/North Oriented)**	**Assembly U (Fixed/Operable)**	**Assembly SHGC (All Orientations/North Oriented)**	
Vertical Glasing, % of Wall	30.1-40.0%	Ufixed - 0.46	$SHGC_{all}$ - 0.25	U_{fixed} - 0.209	$SHGC_{all}$ - 0.23	Yes
			SHGCnorth - 0.25			Yes
ight without Curb, All, % of	2.1 - 5.0%	U_{all} - 0.69	$SHGC_{all}$ - 0.39	U_{all} - 0.5	$SHGC_{all}$ - 0.23	Yes

Fig. B.1

APPENDIX C

BUILDING LOAD CALCULATIONS

	Capacity [MBH]	Supply [cfm]	Ventilation [cfm]	Cooling [sf/ton]	Supply[cfm/sf]	Ventilation [cfm/sf]
HAP Output	31,761	335,969	336,772	168	0.76	0.76
Design Data	44,828	630,000	567,000	Unknown	1.15	1.04

Fig. 5

Annual Coil Loads		
Component	**Load [kBtu]**	**[kBtu/ft^2]**
Cooling Coil Loads	50,130,370	112.908
Heating Coil Loads	3,528,191	7.947
Total	**53,658,561**	**120.855**

Fig. C.1

APPENDIX D

BUILDIN ENERGY UTILIZATION & COST ANALYSIS

Enegy Consumption by Energy Source				
Componenet	**Site Energy [kBtu]**	**Site Energy [kBtu/sf]**	**Source Energy [kBtu]**	**Source Energy [kBtu/sf]**
HVAC Components				
Electric	19,492,598	42.903	69,616,424	156.796
Natural Gas	4,410,237	9.933	4,410,237	9.933
HVAC Sub-Total	**23,902,835**	**53.836**	**74,026,661**	**166.729**
Non-HVAC Components				
Electric	44,527,760	100.289	159,027,728	358.176
Total	**68,430,595**	**154.125**	**233,054,389**	**524.906**

Notes:
1. 'Cooling Coil Loads' is the sum of all air system cooling coil loads.
2. 'Heating Coil Loads' is the sum of all air system heating coil lads.
3. Site Energy is the actual energy consumed.
4. Source Energy is the site energy divided by the electric generating efficiency (28.0%).
5. Source Energy for fuels equals the site energy value.
6. Energy per unit floor area is based on the gross building floor area.

Gross Floor Area: 443,993 sf.
Conditioned Floor Area: 443,993 sf.

Fig D.1

Calculated Annual Costs	
Component	**[$]**
All System Fans	13,200
Cooling	180,206
Heating	25,138
Pumps	6,344
Cooling Tower Fans	86,182
HVAC Sub-Total	**311,070**
Lights	93,700
Electric Equipment	552,949
Non-HVAC Sub-Total	**646,649**
Total	**957,719**

Fig D.2

Annual Cost per SF	
Component	**[$/sf]**
All System Fans	0.030
Cooling	0.406
Heating	0.057
Pumps	0.014
Cooling Tower Fans	0.194
HVAC Sub-Total	**0.701**
Lights	0.211
Electric Equipment	1.245
Non-HVAC Sub-Total	1.456
Total	2.157

Note: Values are calculated using the Gross Floor Area.

Fig. D.3

Component Cost as a % of Total Cost	
Component	**[%]**
All System Fans	1.4
Cooling	18.8
Heating	2.6
Pumps	0.7
Cooling Tower Fans	9.0
HVAC Sub-Total	**32.5**
Lights	9.8
Electric Equipment	57.7
Non-HVAC Sub-Total	67.5
Total	100.0

Fig D.4

Component Cost as a % of Total Cost

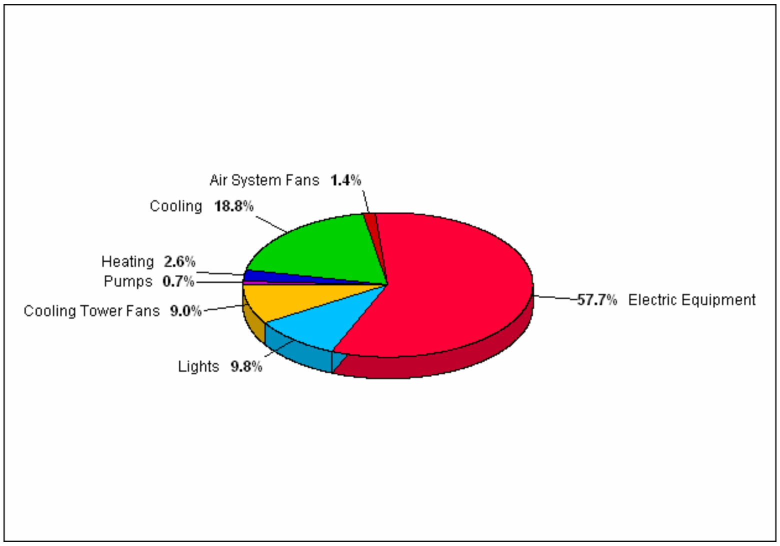

Fig D.5

Monthly Component Cost

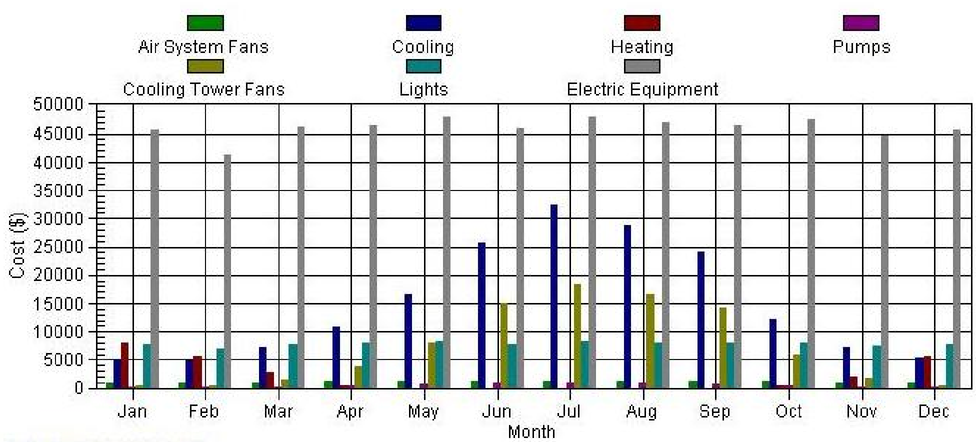

Fig D.6

Annual Costs	
Component	**[$]**
HVAC Components	
Electric	285,031
Natural Gas	25,138
HVAC Sub-Total	310,169
Non-HVAC Components	
Electric	646,647
Total	956,816

Fig D.7

Design Annual Costs	
Component	**[$]**
Electric	3,069,903
Natural Gas	360,858
Total	3,430,761

Fig D.8

Annual Energy Cost

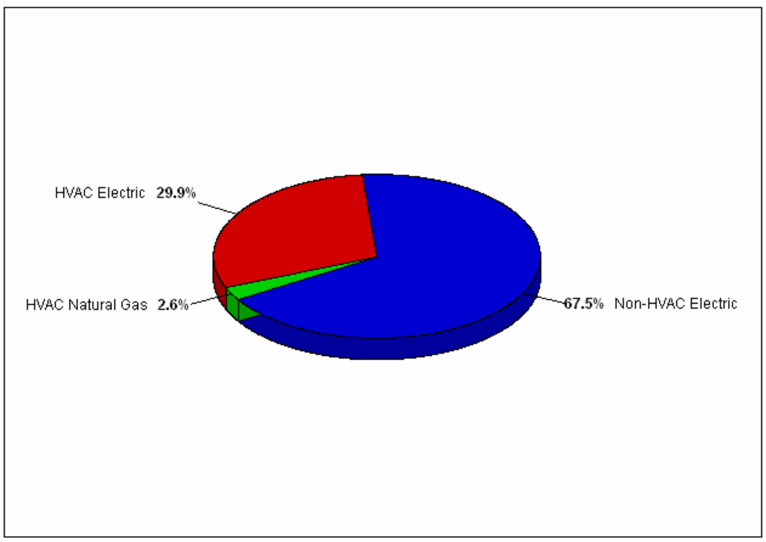

Fig D.9

Monthly Energy Cost

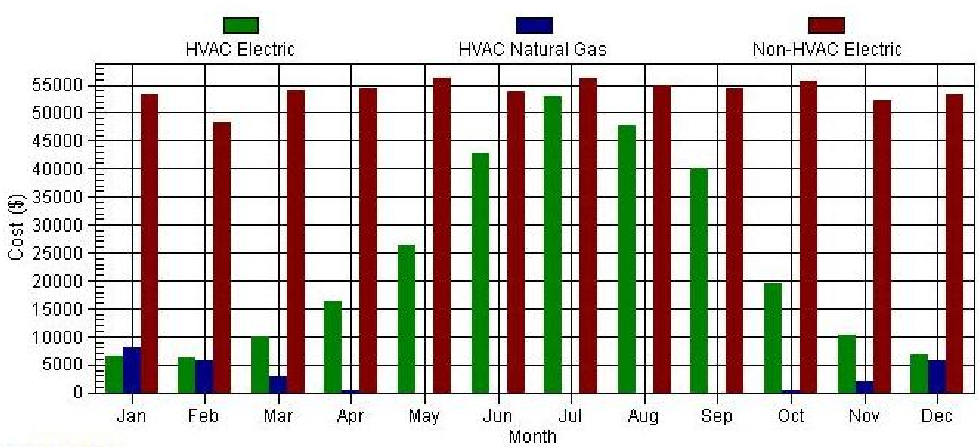

Fig D.10

Annual Energy Consumption	
Component	
HVAC Componeents	
Electric [kWh]	5,712,954
Natural Gas [Therm]	44,102
Non-HVAC Components	
Electric [kWh]	13,050,240
Totals	
Electric [kWh]	18,763,194
Natural Gas [Therm]	44,102

Fig D.11

Annual Cost per Unit Floor Area	
Component	**[$/sf]**
HVAC Componenet	
Electric	0.644
Natural Gas	0.570
HVAC Sub-Total	**0.701**
Non-HVAC Components	
Electric	1.456
Total	**2.157**

Note: Values are calculated using the Gross Floor Area.

Fig D.12

APPENDIX E

EMISSIONS ANALYSIS

Annual Emissions : HAP Analysis	
Compound	
CO_2 [lb]	25,893,480
SO_2 [lb]	141,473
Nox [lb]	83,145

Fig E.1

Estimating Emissions Associated with On-Site Electricity Use U.S. Power Generation Mix

lbm Pollutant$_j$ /kWh U.S.				
Fuel	**% Mix U.S.**	**SO2/kWh**	**NOx/kWh**	**CO2/kWh**
Coal	55.7	7.118E-03	4.126E-03	1.198E+00
Oil	2.8	4.239E-04	7.782E-05	5.805E-02
Nat. Gas	9.3	1.255E-06	2.360E-04	1.247E-01
Nuclear	22.8	0.000E+00	0.000E+00	0.000E+00
Hydro/Wind	9.4	0.000E+00	0.000E+00	0.000E+00
Totals	**100**	**7.543E-03**	**4.440E-03**	**1.380E+00**

Fig E.2

lbm Pollutant$_j$			
	SO_2	**No_x**	**CO_2**
EIA Data	141,537	83,304	25,898,895
HAP Analysis	141,473	83,145	25,893,480

Fig. E.3

Estimating Emissions Associated with On-Site Electricity Use By Building Type

1995 Database of Emissions by Building Type & Climate				
	Thousand BTU/sf-yr	**lbm Pollutant/sf-yr**		
	Total	NOx	SOx	CO2
All Buildings	90.5	0.065383	0.111048	20.32873
Floorspace (sq. ft)				
200,001 to 500,000	114.6	0.082795	0.14062	25.74223
Principal Building Activity				
Health Care	240.4	0.173681	0.294982	54.00029
Climatic Zone				
Zone 4	79.9	0.057725	0.098041	17.94768

Fig E.4

1995 Database of Emissions by Building Type & Climate				
	Thousand BTU/yr	**lbm Pollutant/yr**		
	Total	NOx	SOx	CO2
All Buildings	90.5	29029.77	49304.47	9025812
Floorspace (sq. ft)				
200,001 to 500,000	114.6	36760.35	62434.17	11429371
Principal Building Activity				
Health Care	240.4	77113.34	130970.1	23975749
Climatic Zone				
Zone 4	79.9	25629.6	43529.58	7968645

Fig E.5