Technical Report Three

Existing Conditions for Mechanical Systems

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Contents

Executive Summary

Oklahoma University Children's Medical Office Building is a 12-story above grade structure that is part of the Oklahoma University Health Services Division. The building under analysis is located in downtown Oklahoma City, Oklahoma and is situated on the university hospital grounds. The building is primarily comprised of office spaces and patient care services similar to a general medical office building. The medical services provided here are only diagnostic doctor care and outpatient care related to routine check-ups. It is important to note that the construction for the building is based on a tenant fit-out plan and not all of the floors are currently occupied.

The purpose of this report is to examine the existing conditions of the mechanical systems designed for construction. In this study, the HVAC and plumbing equipment used within the building as well as the heating and chiller plants that supply it will be analyzed. Additionally, information from the previous two technical reports specifically the energy model data and the buildings compliance with ASHRAE Standard 62.1 will be used.

Building Overview

The OU Children's MOB is a 337,000 square foot newly constructed building on the OU hospital grounds. The cost of the project is approximately $60 million, and was set for completion in the spring of 2009. The architecture of the building incorporates a standard, brick veneer façade separated visually by large spans of aluminum panels and glass curtain walls to give it a modern appearance. The interior floors are repetitive and feature exterior and interior offices, which are divided by a continuous corridor. Offices and spaces are designated by their corresponding medical use.

Mechanical Systems Overview

The general mechanical layout for the building makes use of an air-handling unit on each of the 11 above-grade floors and 1 basement floor. Each air-handling unit is capable of providing approximately 28 tons of cooling. From the air-handling unit, air is distributed to approximately 40 terminal boxes per floor. All terminal boxes present within the building are intended for variable air volume (VAV). The medical office building uses the plenum space above the rooms for air return and circulation by way of the terminal units and transfer ducts. Additionally, each floor is served by the two mechanical rooms; that which houses the floor's air-handling unit and another at the opposite side of the building were approximately 50% of the distributed air is discharged from the building. All exhaust air travels up to the roof to be relieved.

Chilled and heating water is distributed through the building after transfer in the main mechanical room, which is served by a central steam heating plant and a chiller plant both located offsite, but on the hospital campus. Currently, nine of the twelve floors are set to be occupied, leaving three floors with AHUs not yet in operation. Furthermore, egress spaces on the unoccupied floors, parking deck, and stairwells are served by fan coil units.

Mechanical System

Outdoor & Indoor Design Conditions

The design conditions for the building were based on weather data at the nearest weather station, Oklahoma City International Airport, which were taken from the 2009 ASHRAE Handbook of Fundamentals, Appendix A. Additionally these values were based on the 1% and 99% design conditions for cooling and heating, respectively. This data can be seen in Table 1, below.

Table 1. Building Design Conditions

	Summer (1%)	Winter (99%)
	Design Cooling	Design Heating
Outdoor Air Dry Bulb (°F)	96	17
Outdoor Air Wet Bulb (°F)	75	-
Indoor Air Dry Bulb (°F)	75	72
Indoor Air Wet Bulb (°F)	62	60

Essentially, the values in the table mean that during the summer (or cooling season) the temperature exceeds the value in the table only one percent of the hours in a given year while in the winter the temperature exceeds the value 99 percent of the time. It should be noted that the values for the indoor design conditions in building were taken at a relative humidity of 50 percent.

Ventilation

The ventilation rate procedure was computed for the building yielding the results summarized in the table below. A more detailed analysis can be found in Technical Report One. Both ASHRAE Standard 62.1 and Standard 170 were used in the analysis as the building is divided into general commercial office building space as well as space intended for healthcare.

Table 2. Ventilation Rate Results Summarized

Unit/Floor	Capacity [CFM]	Outdoor Air Supplied [CFM]	Outdoor Air Required [CFM]	ASHRAE 62.1 & 170 Compliance
AHU - F0	15000	5680	1115	Yes
AHU - F2	25000	4000	-	-
AHU - F3	25000	4625	2537	Yes
AHU - F4	25000	3650	1692	Yes
AHU - F5	25000	4405	2287	Yes
AHU - F6	25000	4550	2096	Yes
AHU - F7	25000	4710	2097	Yes
AHU - F8	25000	5015	2222	Yes
AHU - F9	25000	4310	1256	Yes
AHU - F10	25000	3800	2510	Yes
AHU - F11	25000	4000	-	-
AHU - F12	25000	4000	-	-

The fourth column in Table 2 represents the calculated ventilation rate based on space type, area, occupant density, and equipment loads. As can be seen, the current outdoor air rate being supplied by each air-handling unit on each floor meets the minimum value that was computed using ASHRAE 62.1 and ASHRAE 170. Therefore, the current conditions of the ventilation are compliant and will not need to be improved. Floors two, eleven, and twelve were neglected from the ventilation calculations since they have yet to be occupied via the tenant fit-out plan.

Heating & Cooling

The information provided in the table below contains the heating and cooling design flow rates that were taken from the construction documents provided as well as the calculated flow rates from the energy model analyzed through Trane TRACE 700.

Upon first glance, it is easy to see that the calculated rates provided by TRACE 700 are nearly double that of the design documents. It is important to note that the model was designed originally as a worst-case scenario when design data from the construction documents could not be found. The error has been narrowed down to two factors present in the model. The first factor is that the lighting load used in the model is 2 watts per square foot. It should be noted that conventional lighting is more around the realm of 1 watt per square foot. The second error is that the conductivity of the glass curtain walls and other glazing was set to be that of single pane clear glazing which factors in very minimal resistance to solar loads.

Since the model was first created, the construction materials used in the energy analysis have been fine tuned to resemble a more realistic building and the loads dropped significantly, thus reducing the heating and cooling air flow rates that are in the range of what was originally designed.

Table 3. Heating & Cooling Design vs. Trace Flow Rates

	Cooling		Heating	
	Designed [CFM]	Calculated [CFM]	Designed [CFM]	Calculated [CFM]
AHU - F0	15000	13008	5680	4031
AHU - F2	25000	-	7500	-
AHU - F3	25000	44879	9200	14735
AHU - F4	25000	45858	10300	14000
AHU - F5	25000	44715	8060	14584
AHU - F6	25000	45789	8600	14883
AHU - F7	25000	45507	7500	14915
AHU - F8	25000	46078	7500	15169
AHU - F9	25000	42239	7500	13506
AHU - F10	25000	39969	7500	13332
AHU - F11	25000	-	7500	-
AHU - F12	25000	-	7500	-

Existing Mechanical Equipment

Air Handling Units

Each floor requires its own air-handling unit to provide air to all the terminal units downstream. Currently, each floor is equipped with an AHU, although not all the floors are occupied. Additionally, it was assumed by the designers that approximately 40 terminal units, which are taken into account and described in greater detail below, would serve the floors currently without tenants in the future.

The role of the twelve air-handling units in the Oklahoma University Children's MOB is to mix the outdoor and return air, condition it, and distribute it throughout each floor. The amount of outside air and return air with respect to total airflow is approximately 20 percent and 80 percent, respectively. The cooling and heating capacities of the air-handling units on each floor are noted in the following table.

Further analysis of the operation of the AHUs with the corresponding mechanical equipment comprising the entire mechanical system will follow.

Table 4. AHU Schedule

Unit/Floor	Capacity	Outdoor Air Supplied	Return Air	Heating (MBH)	Cooling (MBH)
AHU - F0	15000	5680	9320	450.0	580.0
AHU - F2	25000	4000	21000	330.0	852.5
AHU - F3	25000	4625	20375	380.0	846.0
AHU - F4	25000	3650	21350	330.0	813.0
AHU - F5	25000	4405	20595	330.0	873.0
AHU - F6	25000	4550	20450	330.0	852.5
AHU - F7	25000	4710	20290	330.0	852.5
AHU - F8	25000	5015	19985	330.0	852.5
AHU - F9	25000	4310	20690	330.0	852.5
AHU - F10	25000	3800	21200	330.0	852.5
AHU - F11	25000	4000	21000	330.0	852.5
AHU - F12	25000	4000	21000	330.0	852.5
TOTAL	**290000**	**52745**	**237255**	**4130.0**	**9932.0**

Air Terminal Units

The air terminal units present within the medical office building are all single duct variable air volume boxes. There are a total of 454 terminal units used by the air-handling units to deliver air to each space. The units are based off two different series fan powered boxes manufactured by Price. Additionally, each box is equipped with a reheat coil that has ranges between 0.33 GPM all the way up to 7 GPM. The coils are supplied by the main mechanical room, which is in turn supplied with steam and chilled water from the nearby plant.

Hydronic Unit Heaters

The hydronic unit heaters are located in the mechanical and fan rooms on each floor. Each provides heat at approximately 18000 to 34000 BTUs per hour with varying flow rates of 1 to 5 GPM. The mechanical rooms tend to have the greater capacity heaters for the purposes of mitigating mold growth in the space while the fan rooms (which are exhausting air) do not need as great of a thermal offset. The unit heaters require 120 V power.

Packaged Terminal Heat Pumps

Similar to the hydronic unit heaters previously described, the packaged terminal heat pumps are used to provide heat to small spaces not requiring ventilation air. The heat pumps, which are located exclusively in the elevator equipment rooms, however, also provide cooling during the summer months. The heat pumps are fitted with an electric motor requiring 208 V to power to the fans. The larger of the two types of packaged heat pumps used, provide cooling at 14,500 BTUh and heating at 11,600 BTUh.

Fan Coil Units

There are four different types of fan coil units in design of the building. They are located in the stairwells, the elevator machine room, and on the ground floor egress areas to and from the parking deck. The FCUs utilize hydronic piping to provide both heat and cooling when needed. The largest of the FCUs is the one located on the parking deck floor that supplies the corridor and elevator lobby. This fan coil unit is ducted and provides approximately 42000 BTUh for heating and 22000 BTUh for cooling.

System Operation

Airside

The air-handling unit on each floor mixes outdoor air and return air (which is ducted back to the air handling unit from the plenums above each space). A variable speed fan pulls the return air back to air handling unit through normally open dampers. At a minimum, 30 percent of the mixture will be outdoor air; the outdoor and return air dampers control the mixture. After leaving the mixing chamber, the air passes through the mixed air filter. If the differential pressure sensor across the filter senses a drop below the set point, maintenance must be performed.

The mixed air then passes through the variable volume preheat coil, which will be modulated in all modes to maintain a temperature of 52°F. The supply fan, which is controlled by a variable speed drive, carriers the air along based on a occupied-unoccupied basis. Essentially this means that the fan is either on or off depending on whether the building is occupied or unoccupied respectively. However, when in occupied mode, the variable speed drive of the fan modulates to maintain duct static pressure.

Finally, the mixed air passes through the variable volume cooling coils, which are operated to maintain discharge air temperature at 54°F. From here the air travels to the space devices where the air will get delivered. The pressure sensor at the supply outlet determines the AHU supply fan speed in order to maintain duct static pressure.

Waterside

Multiple boilers contained in the heating plant off site feed the mechanical heating water and steam system. The high-pressure steam from the plant passes through a large heat exchanger in the building's main mechanical room and transfers its heat to a mixture of 65% water and 35% propylene glycol. The steam condensate returns to the plant to be reheated. After passing through an air separator, the water mixture is distributed by two 980 GPM hot water pumps to hydronic heating equipment throughout the building, such as the air handlers and VAV terminal boxes.

The high-pressure steam from the plants also heats the domestic hot water. Again in the main mechanical room, steam passes through a double-wall, instantaneous, domestic hot water heater, where heat is exchanged to the domestic water and pumped out the various plumbing systems. Chilled water and domestic cold water come directly from plant to the main mechanical room where the water is pumped to the floors for hydronic cooling or domestic use.

Mechanical System Space

The Oklahoma University Children's Medical Office Building features two mechanical rooms on each floor: one for the air handling unit and equipment and the other for exhausting air. Very little equipment is placed on the roof except for several exhaust fans. The basement floor contains the main mechanical room, which is served by the central plant. Overall, the mechanical spaces only account for roughly five percent of the floor area.

As can be seen in the figure below the cost of the mechanical systems designed for the Children's MOB is a majority leader at approximately $12.7 million or 19% of the total construction cost.

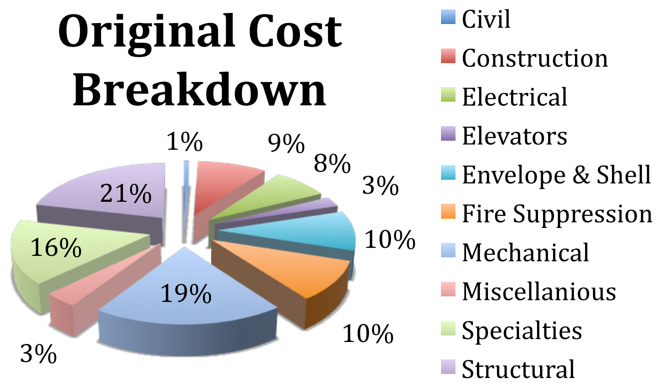

Figure 1. Rough First Cost Comparison

System Energy

The energy consumption associated with Oklahoma University Children's Medical Office Building was evaluated solely by using Trane TRACE 700. Existing energy consumption and utility data were not provided with the construction documents to compare with an energy model; therefore all system energy evaluated is theoretical and not accurate in resembling actual building consumption.

The following figure depicts the energy consumption due to various systems. The largest contributor is lighting, followed by heating and then cooling. Again, the lighting was used set at 2 watts per square, which is large and rarely accurate for new construction buildings. The fact that the heating and cooling energy consumption is large is accurate due to the current systems being used, i.e. one air handling unit per floor, etc.

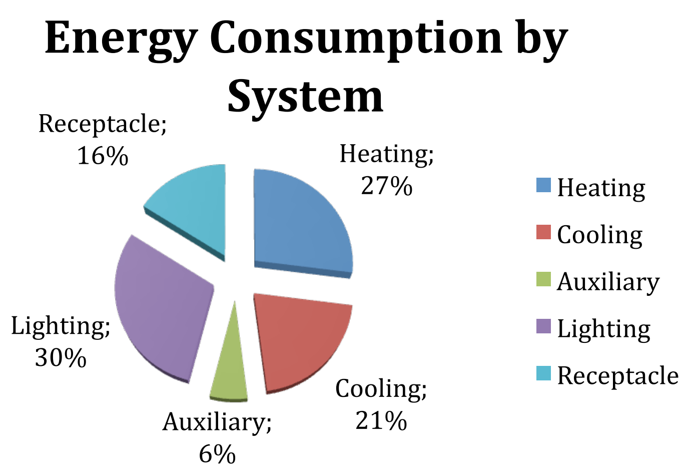

Figure 2. Visual Comparison of System Energy Consumption

LEED Analysis

The Oklahoma University Children's Medical Office Building was constructed between 2006 and 2009. During the time of design of the building the US Green Building Council's LEED accreditation program wasn't universally popular throughout the building engineering industry. Thus, the medical office building did not seek a LEED rating.

Energy and Atmosphere

EA Prerequisite 1: Fundamental Commissioning of the Building Energy Systems
The building was design to be commissioned following construction.

EA Prerequisite 2: Minimum Energy Performance
The building meets minimum energy performance prerequisite. As detailed in Technical Report 1, building adheres to ASHRAE Standard 90.1.

EA Prerequisite 3: Fundamental Refrigerant Management
The building does not make use of any refrigerants. All HVAC equipment is intended to use hydronic cooling and heating.

EA Credit 1: Optimize Energy Performance
Extensive energy data and compliance with said benchmarks not provided. Therefore, there is no indication this credit has been met.

EA Credit 2: On-Site Renewable Energy
The site does not utilize any renewable energy resources.

EA Credit 3: Enhanced Commissioning
The building is to be commission early on in the construction process.

EA Credit 4: Enhanced Refrigerant Management
Refrigerants are not used.

EA Credit 5: Measurement and Verification
Energy consumption data, up to at least one year after construction completion, not provided.

EA Credit 6: Green Power
No renewable energy technologies or net zero pollution methods incorporated.

Indoor Environmental Quality

IEQ Prerequisite 1: Minimum Indoor Air Quality Performance
The building complies with ASHRAE Standard 62.1; therefore, it meets the requirement for this credit.

IEQ Prerequisite 2: Environmental Tobacco Smoke (ETS) Control
The entire building is smoke free, and there are no designated smoking areas within 25 feet of the building.

IEQ Credit 1: Outdoor Air Delivery Monitoring
CO_2 sensors have been provided in densely populated areas as well as naturally ventilated areas within the means of this credit. Airflow monitoring stations are also present at all outdoor air intakes.

IEQ Credit 2: Increased Ventilation
The building does not exceed the minimum ventilation requirements by 30%, therefore, the building cannot achieve this credit.

IEQ Credit 3.1: Construction Indoor Air Quality Management Plan – During Construction
All precautions during construction were taken to protect mechanical equipment from particle accumulation, mold growth, etc. Additionally, MERV-11 filters are used within the AHUs.

IEQ Credit 3.1: Construction Indoor Air Quality Management Plan – Before Occupancy
A building flush out was required by the construction.

IEQ Credit 4.1-4.4: Low-Emitting Materials (ALL)
In order to reduce the quantity of indoor air contaminants that are odorous, irritating and/or harmful to the comfort and well-being of installers and occupants many measures were take when installing low-emitting materials as documented in the specifications for many materials.

IEQ Credit 5: Indoor Chemical and Pollutant Source Control
Ventilation and exhaust air are sufficient in meeting this credit.

IEQ Credit 6.2 & 6.3: Controllability of Systems – Lighting & Thermal Comfort
All windows are inoperable, however, thermostat control is available in all spaces. Lighting control, as well, is provided for 90% of the occupants.

IEQ Credit 7.1 & 7.2: Thermal Comfort – Design & Verification
The building was designed to comply with ASHRAE Standard 55. No verification of thermal comfort was conducted however.

IEQ Credit 8.1 & 8.2: Daylight and Views – Daylight 75% & Views for 90%

Not all spaces receive day lighting or even a view. Does not meet the 75% and 90% criteria.

Overall System Evaluation

The current system in place for the OU Children's Medical Office Building is capable of accounting for the heating and cooling loads characteristic of the building occupants, equipment, and spaces. Additionally, the building meets all requirements for proper indoor air quality and ventilation. However, the building may not run as efficiently as possible, and is dependent upon the central heating and chiller plants used for the entire hospital campus. Thus, improvements may be possible to improve overall building efficiency, reduce energy consumption, and possible even detach the building from the existing plants.

Project Team

- Owner: Oklahoma University Hospital Trust
- Construction Manager: Flintco, Inc.
- Design Architect: Hellmuth, Obata, Kassabaum [HOK]
- Project Architect: Miles Associates
- Structural Engineer: Zahl-Ford, Inc.
- MEP Engineer: ZRDH, P.C.
- Civil Engineer: Smith-Roberts Baldischwiler, Inc.

References

ASHRAE (2010), Standard 62.1-2010, Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., Atlanta, GA, 2009.

ASHRAE (2010), Standard 90.1-2010, Energy Standard for Buildings Except Low-Rise Residential Buildings. American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., Atlanta, GA, 2009

ASHRAE (2009), 2009 ASHRAE Handbook - Fundamentals. Atlanta, GA: American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.

U.S. Green Building Council. LEED 2009 For New Construction and Major Renovations. Washington D.C., 2008

Appendix A

SYSTEM SUMMARY

DESIGN AIRFLOW QUANTITIES
By ACADEMIC

System Description	System Type	Outside Airflow cfm	MAIN SYSTEM Cooling Airflow cfm	Heating Airflow cfm	Return Airflow cfm	Exhaust Airflow cfm	Auxiliary System Supply Airflow cfm	Room Exhaust Airflow cfm
Alternative 1								
AHU-3	Parallel Fan-Powered VAV	0	44,879	14,735	44,879	0	0	0
AHU-0	Parallel Fan-Powered VAV	0	13,008	4,031	13,008	0	0	0
AHU-5	Parallel Fan-Powered VAV	0	44,715	14,584	44,715	0	0	0
AHU-4	Parallel Fan-Powered VAV	0	45,858	14,000	45,858	0	0	0
AHU-6	Parallel Fan-Powered VAV	0	45,789	14,883	45,789	0	0	0
AHU-7	Parallel Fan-Powered VAV	0	45,507	14,915	45,507	0	0	0
AHU-8	Parallel Fan-Powered VAV	0	46,078	15,169	46,078	0	0	0
AHU-9	Parallel Fan-Powered VAV	0	42,239	13,506	42,239	0	0	0
AHU-10	Parallel Fan-Powered VAV	0	39,969	13,332	39,969	0	0	0
Totals		**0**	**388,043**	**118,166**	**388,043**	**0**	**0**	**0**

Note: Airflows on this report are not additive because they are each taken at the time of their respective peaks. To view the balanced system design airflows, see the appropriate Checksums report (Airflows section).

Appendix B

LEED for New Construction and Major Renovations (v2.2)

SUSTAINABLE SITES		POSSIBLE: 14
SSp1	Construction activity pollution prevention	REQUIRED
SSc1	Site selection	1
SSc2	Development density and community connectivity	1
SSc3	Brownfield redevelopment	1
SSc4.1	Alternative transportation - public transportation access	1
SSc4.2	Alternative transportation - bicycle storage and changing rooms	1
SSc4.3	Alternative transportation - low emitting and fuel efficient vehicles	1
SSc4.4	Alternative transportation - parking capacity	1
SSc5.1	Site development - protect or restore habitat	1
SSc5.2	Site development - maximize open space	1
SSc6.1	Stormwater design - quantity control	1
SSc6.2	Stormwater design - quality control	1
SSc7.1	Heat island effect - non-roof	1
SSc7.2	Heat island effect - roof	1
SSc8	Light pollution reduction	1

WATER EFFICIENCY		POSSIBLE: 5
WEc1.1	Water efficient landscaping - reduce by 50%	1
WEc1.2	Water efficient landscaping - no potable water use or no irrigation	1
WEc2	Innovative wastewater technologies	1
WEc3.1	Water use reduction - 20% reduction	1
WEc3.2	Water use reduction - 30% reduction	1

ENERGY & ATMOSPHERE		POSSIBLE: 17
EAp1	Fundamental commissioning of the building energy systems	REQUIRED
EAp2	Minimum energy performance	REQUIRED
EAp3	Fundamental refrigerant Mgmt	REQUIRED
EAc1	Optimize energy performance	10
EAc2	On-site renewable energy	3
EAc3	Enhanced commissioning	1
EAc4	Enhanced refrigerant Mgmt	1
EAc5	Measurement and verification	1
EAc6	Green power	1

MATERIAL & RESOURCES		POSSIBLE: 13
MRp1	Storage and collection of recyclables	REQUIRED
MRc1.1	Building reuse - maintain 75% of existing walls, floors & roof	1
MRc1.2	Building reuse - maintain 95% of existing walls, floors & roof	1
MRc1.3	Building reuse - maintain 50% of interior non-structural elements	1
MRc2.1	Construction waste Mgmt - divert 50% from disposal	1
MRc2.2	Construction waste Mgmt - divert 75% from disposal	1

MATERIAL & RESOURCES		CONTINUED
MRc3.1	Materials reuse - 5%	1
MRc3.2	Materials reuse - 10%	1
MRc4.1	Recycled content - 10% (post-consumer + 1/2 pre-consumer)	1
MRc4.2	Recycled content - 20% (post-consumer + 1/2 pre-consumer)	1
MRc5.1	Regional materials - 10% extracted, processed and manufactured regionally	1
MRc5.2	Regional materials - 20% extracted, processed and manufactured regionally	1
MRc6	Rapidly renewable materials	1
MRc7	Certified wood	1

INDOOR ENVIRONMENTAL QUALITY		POSSIBLE: 15
EQp1	Minimum IAQ performance	REQUIRED
EQp2	Environmental Tobacco Smoke (ETS) control	REQUIRED
EQc1	Outdoor air delivery monitoring	1
EQc2	Increased ventilation	1
EQc3.1	Construction IAQ Mgmt plan - during construction	1
EQc3.2	Construction IAQ Mgmt plan - before occupancy	1
EQc4.1	Low-emitting materials - adhesives and sealants	1
EQc4.2	Low-emitting materials - paints and coatings	1
EQc4.3	Low-emitting materials - carpet systems	1
EQc4.4	Low-emitting materials - composite wood and agrifiber products	1
EQc5	Indoor chemical and pollutant source control	1
EQc6.1	Controllability of systems - lighting	1
EQc6.2	Controllability of systems - thermal comfort	1
EQc7.1	Thermal comfort - design	1
EQc7.2	Thermal comfort - verification	1
EQc8.1	Daylight and views - daylight 75% of spaces	1
EQc8.2	Daylight and views - views for 90% of spaces	1

INNOVATION		POSSIBLE: 5
IDc1	Innovation in design	4
IDc2	LEED Accredited Professional	1

TOTAL	69

40-49 Points	50-59 Points	60-79 Points	80+ Points
CERTIFIED	SILVER	GOLD	PLATINUM