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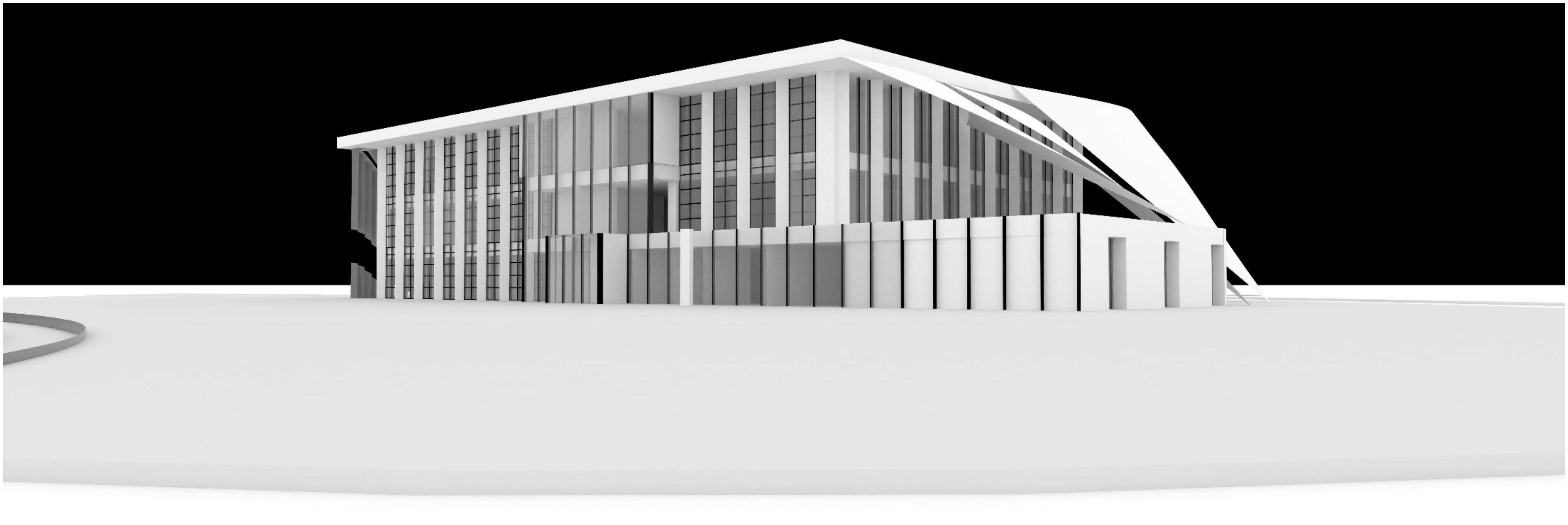


1. Introduction

1.1. Project Introduction

The Project for ASHRAE's 2015 Integrated Sustainable Building Design is to design a Junior College building to meet zero-net energy located in the city of Doha, Qatar while promoting other sustainable design practices. The building site needs to be determined as well as systems to implement to meet zero-net energy, reduce site and building water use as well as maintain comfortable interior spaces relative to natural day lighting, humidity and air temperature. It is crucially important to implement RES in a manner that takes into consideration the life expectancy of the building and the maintenance that goes into the systems needed to attain zero-net energy.

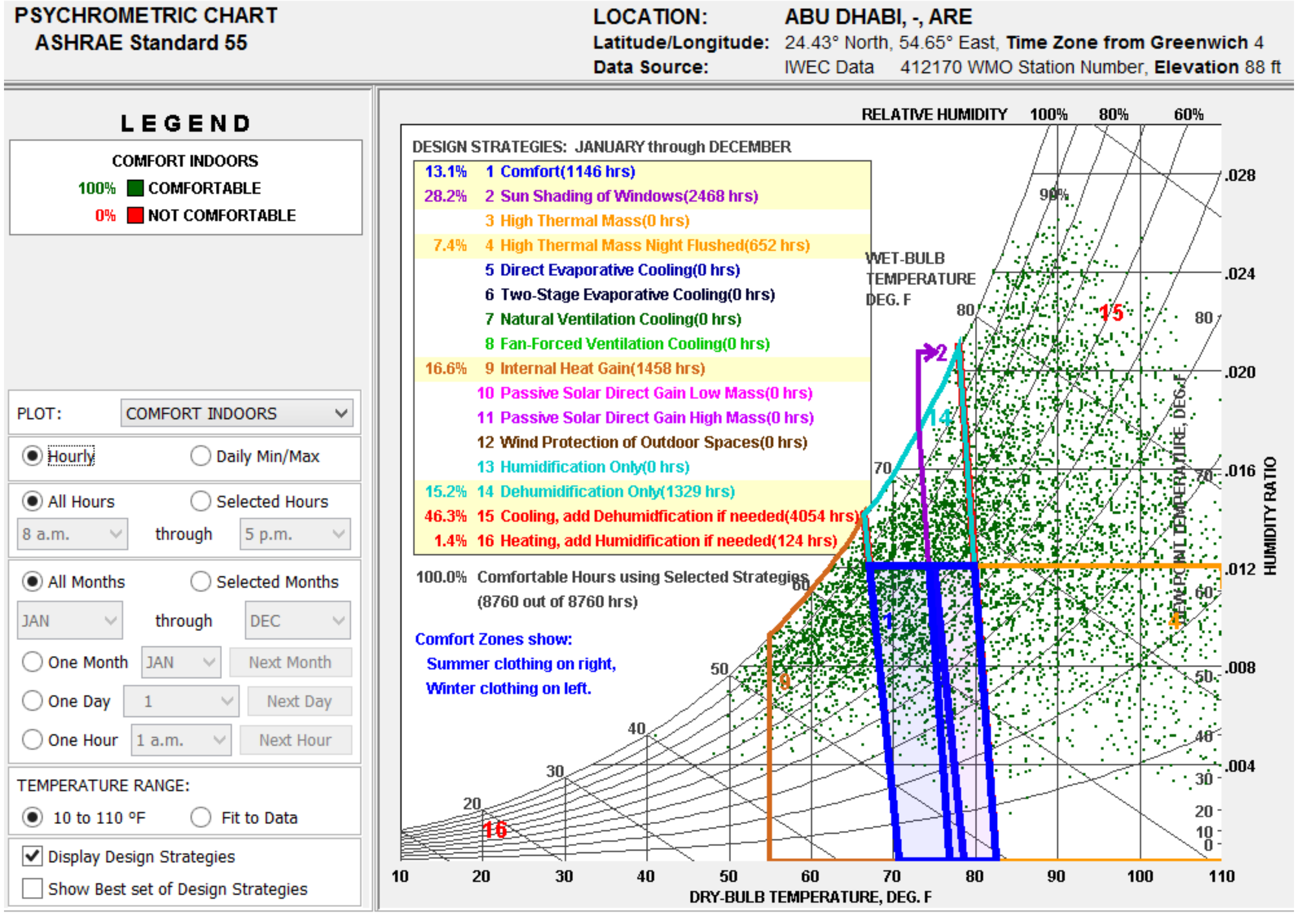
1.2. Design Concept

To achieve the goal of zero-net energy the building has been designed based off the closest similar climate to Doha, Qatar and the owner's project requirements. The climate will be the greatest influence on our design, focusing on passive house design standards will help reduce the heating and cooling need of the buildings HVAC system therefore reducing energy demands. Smart systems will be used to reduce interior and exterior lighting needs as well as air conditioning. The intense sunlight received by Doha will allow for high efficiency PV arrays to be a great renewable energy system with a short payback time and will work with the RES system already being provided by a donor. Shading devices will play a large role in reducing interior solar heat gain while still providing natural lighting to also reduce the need for interior lighting. Horizontal shading on the south façade will shade intense summer sun but act as a light shelf reflecting indirect light into interior spaces. Horizontal shading elements will be used on the east façade helping diffuse early morning light but providing clear views out and indirect sunlight in. New window systems will be used in place of the given windows to maximize the insulation of the building and reduce interior heat gain and the loss of cooled air through thermal bridging and poorly constructed windows. Close attention is going to be given to the construction elements to create a thermal bridgeless wall, floor and ceiling construction to achieve passive house standards and minimize heat gain from the exterior and cool air loss from the interior.

2. Pre-Design Phase

2.1. Pre Design Phase:

1. ASHRAE Standard 15 - 2013
2. ASHRAE Standard 55 - 2013
3. ASHRAE Standard 62.1 - 2013
4. ASHRAE Standard 90.1 - 2013
5. ASHRAE Standard 129 - 2002
6. ASHRAE Standard 154 - 2011
7. ASHRAE Standard 189.1 - 2014
8. Industrial Ventilation, Manual of Recommended Practice.



PSYCHROMETRIC CHART
ASHRAE Standard 55

LOCATION: ABU DHABI, -, ARE
Latitude/Longitude: 24.43° North, 54.65° East, Time Zone from Greenwich 4
Data Source: IWEC Data 412170 WMO Station Number, Elevation 88 ft

LEGEND
COMFORT INDOORS
100% 🟩 COMFORTABLE
0% 🟥 NOT COMFORTABLE

PLOT: COMFORT INDOORS
● Hourly ○ Daily Min/Max
● All Hours ○ Selected Hours
8 a.m. through 5 p.m.
● All Months ○ Selected Months
JAN through DEC
○ One Month JAN Next Month
○ One Day 1 Next Day
○ One Hour 1 a.m. Next Hour
TEMPERATURE RANGE:
● 10 to 110 °F ○ Fit to Data
☑ Display Design Strategies
☐ Show Best set of Design Strategies

DESIGN STRATEGIES: JANUARY through DECEMBER
13.1% 1 Comfort(1146 hrs)
28.2% 2 Sun Shading of Windows(2468 hrs)
3 High Thermal Mass(0 hrs)
7.4% 4 High Thermal Mass Night Flushed(652 hrs)
5 Direct Evaporative Cooling(0 hrs)
6 Two-Stage Evaporative Cooling(0 hrs)
7 Natural Ventilation Cooling(0 hrs)
8 Fan-Forced Ventilation Cooling(0 hrs)
16.6% 9 Internal Heat Gain(1458 hrs)
10 Passive Solar Direct Gain Low Mass(0 hrs)
11 Passive Solar Direct Gain High Mass(0 hrs)
12 Wind Protection of Outdoor Spaces(0 hrs)
13 Humidification Only(0 hrs)
15.2% 14 Dehumidification Only(1329 hrs)
46.3% 15 Cooling, add Dehumidfication if needed(4054 hrs)
1.4% 16 Heating, add Humidification if needed(124 hrs)

100.0% Comfortable Hours using Selected Strategies
(8760 out of 8760 hrs)

Comfort Zones show:
Summer clothing on right,
Winter clothing on left.

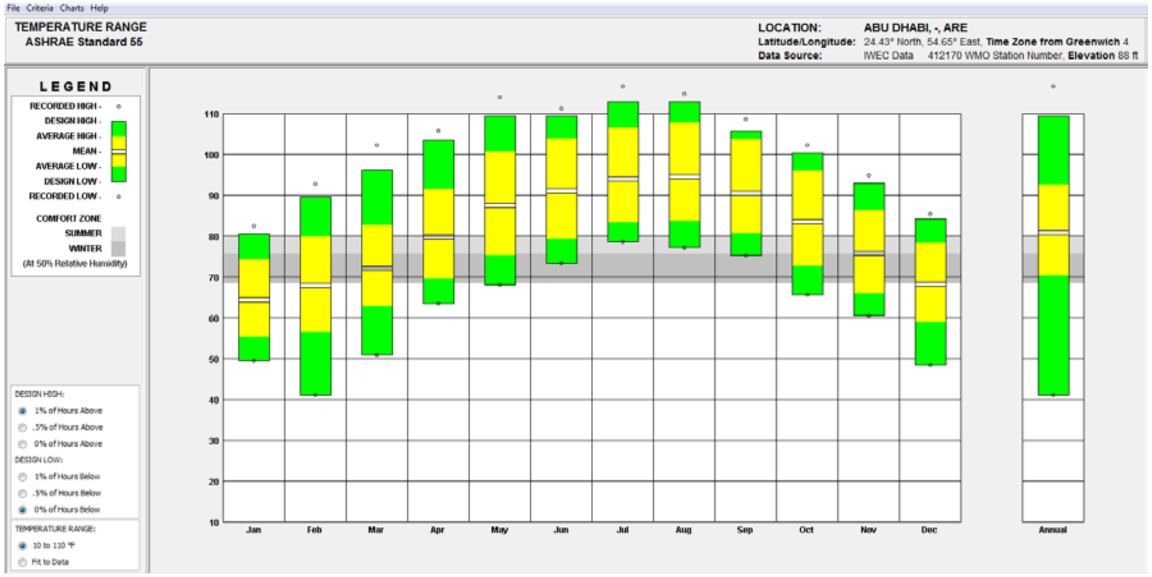
Figure 1 Psychometric Chart

2.2. Climate Analysis

For the location of Doha, Qatar there is no free attainable climate information so in place we are using Abu Dhabi, United Arab Emirates. The climate data of Abu Dhabi was chosen because it resembles a similar altitude; shares the Persian Gulf coast and is located in the same general region as Doha, Qatar at around 185 miles away.

Climate Consultant 5.5 was used to obtain the data that we analyzed and the weather file was downloaded from the Department of Energy's website.

The local climate of Doha, Qatar is hot and humid during the summer and has a significant amount of cooling degree days. From Figure three we can see that the highest relative humidity for Doha is when the temperature is between 60-80 ˚F this happens for 46% of the time. Air conditioning for this building will be important to keep these numbers down in the interior as well as to maintain steady temperatures for specific portions of the -building that require cooling 365 days a year. Psychometric Analysis shows that conventional air conditioning and heating will be important because about 52% of total points (each point roughly represents one hour, 8760 points in total) fall under the heating and A/C region. From Figure two we can see that Doha spends most of its time above normal comfort temperatures with exceptions between November and January. Even the means are well above the summer comfort zone at 20+ degrees Fahrenheit in some areas. Sun shading for windows during summer months will be important as well as evening flushes to cool down interior spaces and lower thermal mass material temperatures to keep interior spaces cooler during the day. During cooler winter months these thermal masses can be used to hold absorbed heat and keep interior spaces warmer.



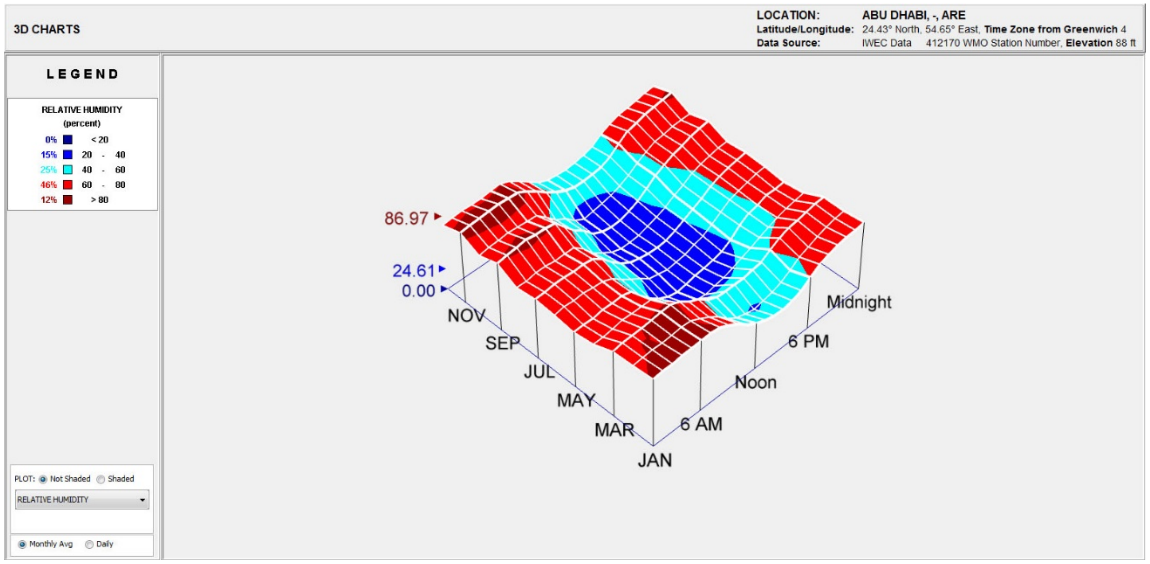
TEMPERATURE RANGE
ASHRAE Standard 55

LOCATION: ABU DHABI, -, ARE
Latitude/Longitude: 24.43° North, 54.65° East, **Time Zone from Greenwich** 4
Data Source: IWEC Data 412170 WMO Station Number, **Elevation** 88 ft

DESIGN HIGH:
● 1% of Hours Above
○ .5% of Hours Above
○ 0% of Hours Above
DESIGN LOW:
○ 1% of Hours Below
○ .5% of Hours Below
● 0% of Hours Below

TEMPERATURE RANGE:
● 10 to 110 °F
○ Fit to Data

Figure 2 Temperature Chart



3D CHARTS

LOCATION: ABU DHABI, -, ARE
Latitude/Longitude: 24.43° North, 54.65° East, **Time Zone from Greenwich** 4
Data Source: IWEC Data 412170 WMO Station Number, **Elevation** 88 ft

RELATIVE HUMIDITY (percent)

0%	■	< 20
15%	■	20 - 40
25%	■	40 - 60
46%	■	60 - 80
12%	■	> 80

PLOT: ● Not Shaded ○ Shaded

RELATIVE HUMIDITY ▾

● Monthly Avg ○ Daily

Figure 3 Relative Humidity

Figure 4 Site Map

2.3. Site Selection

2.3.1. Site Location

Site selection for the Junior College Office and Administration building is in East Doha along the Arabian Gulf. It is a developing area that is along the perimeter of the city, but still has well developed qualities from government buildings that surround it. The Site complies with ASHRAE standard 189.1 5.3.1.1: on a greenfield site that is within a ¼ mile of adequate transit service as well as within ½ a mile of basic services with pedestrian access.

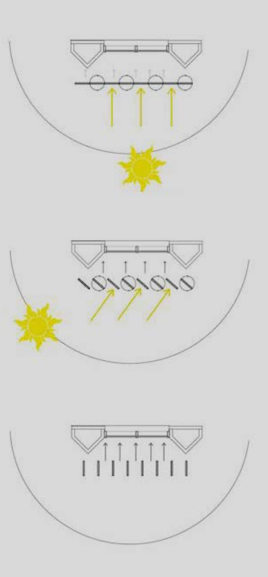
2.3.2. Surrounding Environment

The chosen site in Doha is located on the corner of Al Corniche St. and Al Aqsa St. The Junior College is located in an open lot with one building to the southeast and the Arabian Gulf to the northeast. The lack of surrounding buildings will help the interior daylighting as well as allow for maximum solar gain for our PV array. The surrounding streets are two and three lanes with moderate traffic that will influence our building orientation.

2.3.3. Building Orientation

In such a hot climate it is important to understand the impact the rising and setting sun will have on the building. This is why we chose to orient the library/media center to the east and the carpentry/woodworking and welding shop to the west to minimize solar heat gain on the larger facades. This allows us to take advantage of northern and southern daylighting which will impact our heat gain much less during the year.

2.4. Isolation of the Building from Pollutants in the Soil



The site location is a greenfield site that was cleared for the intent of construction. The soil in Doha, Qatar consists of sand and limestone for the most part. This particular site is near the Arabian Gulf has lithosol soil for 10-30cm over limestone which lies underneath. The soil is not polluted.

3. Design Phase

3.1. Site Hardscape

Parking will be covered with shading elements topped with PV arrays to maximize solar energy gain as well as reduce the Heat Island Effect of the pavement. Walkways and high traffic movement spaces will be shaded with sails to block intense sunlight as building users move between exterior parking areas and the interior of the building. The parking shading elements will also function as a rain collection system maximizing the rain collection area of our building rather than just having a system on the roof.

3.2. Shade

Shading systems will be provided on the South, West and East facades, this excludes the north because the north will receive less than one hour of intense indirect sunlight during the early morning and late afternoon and should not need a shading element for the rest of the day. Transparent sails that block direct sunlight are used on the west façade as a shaded entry way as well as blocking solar heat gain during the later afternoon. The sails will be easily removable for maintenance or if more light is required during winter months. A horizontal shading device is used on the south façade to shade the building during all months of the year while still allowing indirect light to help reduce interior lighting needs. Vertical shading on the east façade will be operable via hand

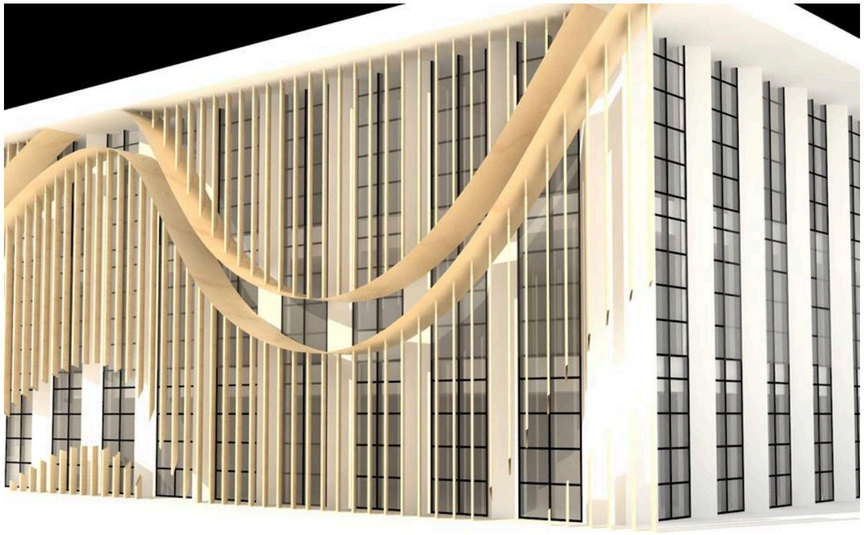


Figure 5 East Shading Device

Figure 6 South and West Shading Devices

cranks to reduce the electricity use. This shading element will be able to completely close or completely open allowing for users to adjust to the amount of light that is right for them. Users will be able to block out the early morning light completely but enjoy the indirect sunlight later in the day, maximizing interior lighting efficiency and reducing solar heat gain.

3.3. Roof System

The roof of the Junior University will be covered in a PV array both provided by the donor as well as extra PV arrays to help produce more sustainable energy. The PV arrays will actually reduce the Heat Island Effect because they will be shading the roof of the building and absorbing the solar energy rather than allowing it to be transferred into the roofing materials. This will in turn help reduce some of the need for our HVAC system. Any non-covered roof area will have an SRI in compliance with ASHRAE standard 189.1, 5.3.5.3 option A, a minimum three-year-aged SRI of 64. The roof will also have evacuated solar heated water tubes to provide the building with hot water year round and help supplement our ground source heat pump during the winter if necessary for hot air.

A stationary PV array will be utilized. By orienting both the roof and parking shade solar panels towards the south sun solar gain will be maximized. Solar panels will reduce the heat island effect of the parking lot, the roof and provide shade for students and faculty as they make their way into the building. Although expensive PV arrays will ultimately lead to a reduced electrical need and will more than likely allow the Junior College to sell excess energy back to Doha.

3.4. Site Water Use

To reduce the need for water on the site and meet ASHRAE Standards 189.1, 5.3.5 native low maintenance plants will be used. Date palm trees, humeira and huwa ghazal will be used because they are all desert plants that require no extra water for maintenance. This will help reduce the heat island effect on the site and provide vegetation to deal with the low amount of rain Doha, Qatar does receive.

3.5. Building Water Use

3.5.1. Toilet Plumbing

Compostable toilets will be used in place of traditional toilets. These toilets use no water to flush saving heavily on water use. The waste is taken down to the basement where a very minimal amount of water is mixed into the compost and the mixture is turned once every two weeks. The compost accumulates for a year where it is then ready to be taken out and brought to a compositing site located in Qatar about half an hour away from the junior college. This plumbing system saves water, energy and gives back to the health of the environment.

3.5.2. Urinal Plumbing

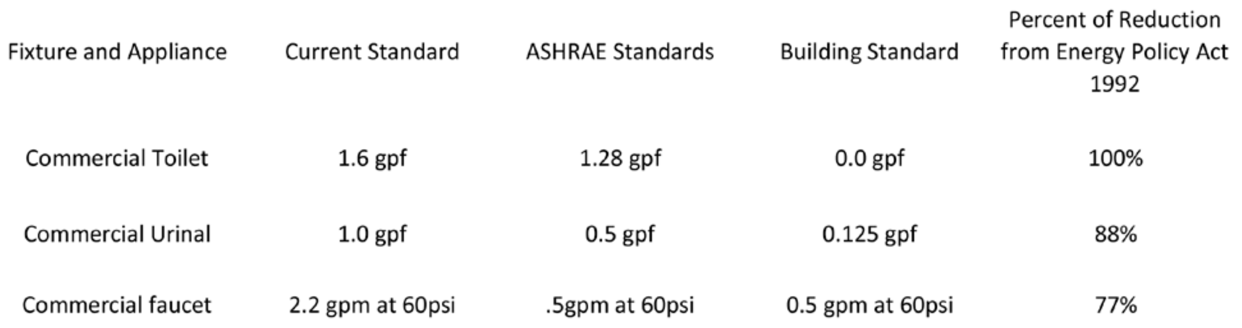
Urinal plumbing water reduction will be done by ZURN’s Z6003AV-ULF. This urinal valve uses only .125 gpf with the current standard being 1.0 gpf according to the EPAct of 1992.

3.5.3. Faucet Plumbing

Commercial faucets consume 2.2 gpm (gallons per minute) at 60 psi. The system chosen is made by Niagara Conservation and consumes 0.5 gpm at 60 psi.

3.5.4. HVAC

The VAV system will not require any water because instead of using a closed loop water system we will be using a closed loop ethylene glycol system which will have a higher startup cost as well as greenhouse gas emissions but will not ever need to be replaced and the ethylene glycol will not freeze at the normal water freeze temperature meaning maintenance will be minimized.



Fixture and Appliance	Current Standard	ASHRAE Standards	Building Standard	Percent of Reduction from Energy Policy Act 1992
Commercial Toilet	1.6 gpf	1.28 gpf	0.0 gpf	100%
Commercial Urinal	1.0 gpf	0.5 gpf	0.125 gpf	88%
Commercial faucet	2.2 gpm at 60psi	.5gpm at 60psi	0.5 gpm at 60psi	77%

Figure 7 Water Use Chart

Water reduction was found to be up to 85% from the implementations of these systems. With filtered gray water being used to flush urinals and act as a backup watering system for on-site agriculture it is believed even more water reduction is possible than preliminary calculations show. The use of Ethylene Glycol in our HVAC system in place of water is one of the majors ways the building was able to reduce it water consumption. This decrease in water consumption will go on to contribute to a reduction in energy necessary to heat/cool and pump water throughout the building.

3.6. Water Consumption Management

3.6.1. Gray Water System

Taking water from sinks, fountains and break rooms the gray water will cycle through Aqua2use GWTS1200 and be used as a post-processed water for flushing urinals as well as water that can be mixed into the composting system that way the use of potable water can be reduced. Figure 8 demonstrates the way water will work through the system and be recycled. This use of water will even further reduce building wide water use because the plumbing fixtures use limited water as is. Filtered gray water will also be used for any agricultural needs on site after. Our rain collection system will be treated with the gray water system as well and will be used for agriculture purposes, urinal flushing and our toilet compost system.

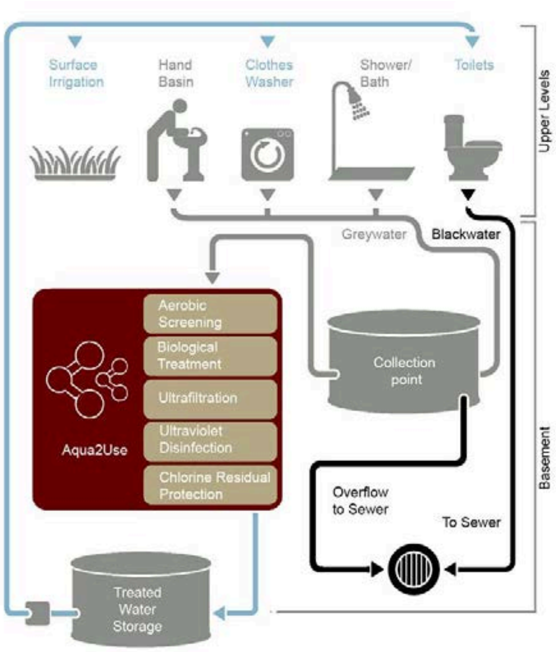


Figure 8 Gray Water System

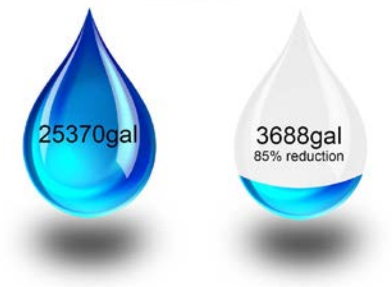
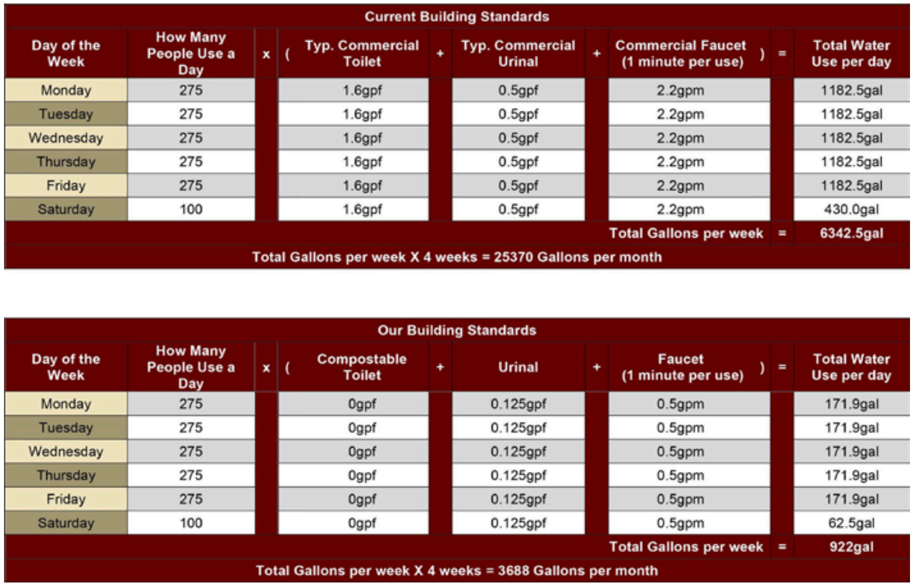


Figure 9 Water Reduction Percentage



Current Building Standards

Day of the Week	How Many People Use a Day	x	(Typ. Commercial Toilet	+	Typ. Commercial Urinal	+	Commercial Faucet (1 minute per use))	=	Total Water Use per day
Monday	275		1.6gpf		0.5gpf		2.2gpm		1182.5gal
Tuesday	275		1.6gpf		0.5gpf		2.2gpm		1182.5gal
Wednesday	275		1.6gpf		0.5gpf		2.2gpm		1182.5gal
Thursday	275		1.6gpf		0.5gpf		2.2gpm		1182.5gal
Friday	275		1.6gpf		0.5gpf		2.2gpm		1182.5gal
Saturday	100		1.6gpf		0.5gpf		2.2gpm		430.0gal
							Total Gallons per week	=	6342.5gal

Total Gallons per week X 4 weeks = 25370 Gallons per month

Our Building Standards

Day of the Week	How Many People Use a Day	x	(Compostable Toilet	+	Urinal	+	Faucet (1 minute per use))	=	Total Water Use per day
Monday	275		0gpf		0.125gpf		0.5gpm		171.9gal
Tuesday	275		0gpf		0.125gpf		0.5gpm		171.9gal
Wednesday	275		0gpf		0.125gpf		0.5gpm		171.9gal
Thursday	275		0gpf		0.125gpf		0.5gpm		171.9gal
Friday	275		0gpf		0.125gpf		0.5gpm		171.9gal
Saturday	100		0gpf		0.125gpf		0.5gpm		62.5gal
							Total Gallons per week	=	922gal

Total Gallons per week X 4 weeks = 3688 Gallons per month

Figure 10 Water Use Calculations

4. Predictions

4.1. HVAC System Selection

4.1.1. A variable air volume system will be used to heat and cool the junior college at a constant temperature allowing the user greater control on the amount of air entering the building.

4.1.2. A closed loop vertical ground source heat pump system will be set into the Doha soil around 450 feet deep. This will provide a constant year round temperature for our water cooling and heating system. During the summer the ethylene glycol will be pumped into the earth to be cooled and then our VAV system will run air over the cooled ethylene glycol chilling the air for building use. During the winter when it is colder outside and the ground is warmer the glycol will be ran through to heat the interior spaces. In the case that more heat is required our evacuated solar water heating tubes can provide hot water for the building to make up for what we cannot get from the ground.

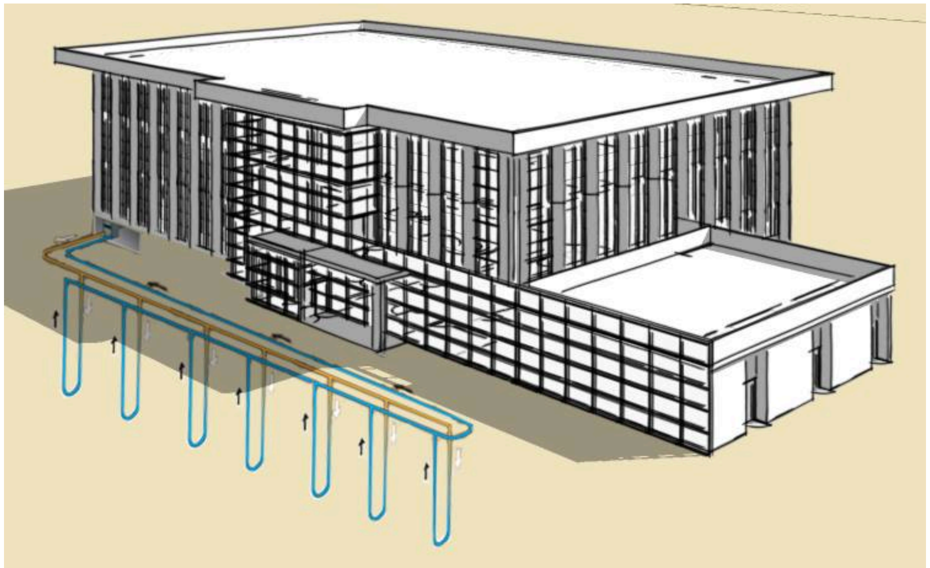
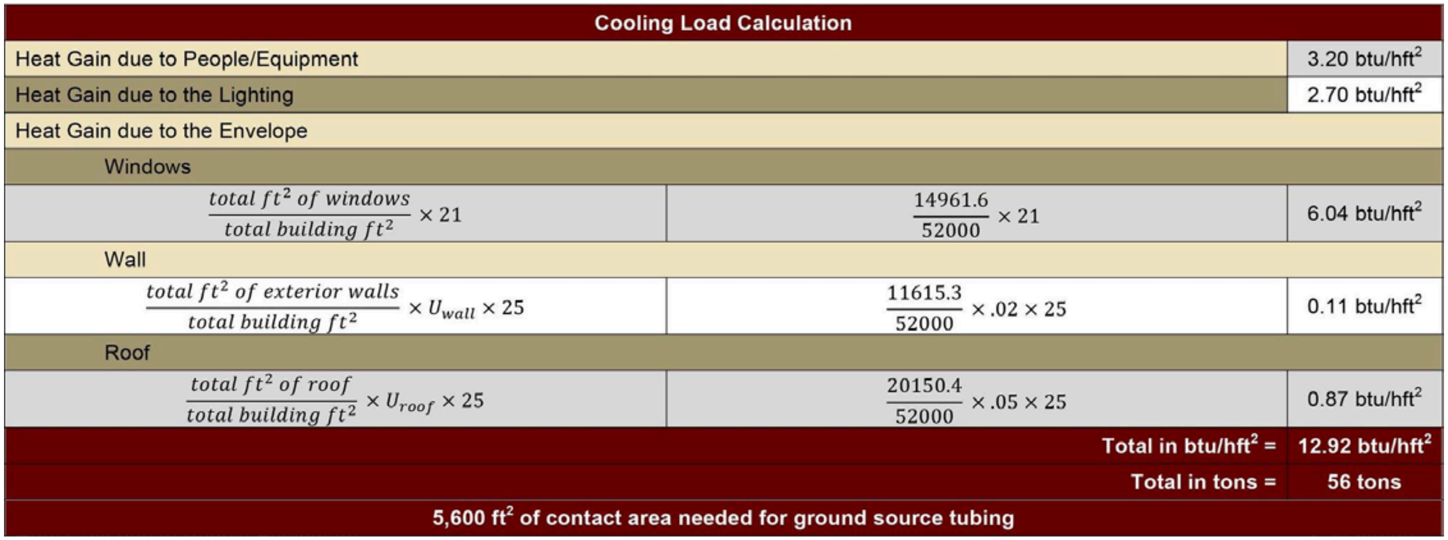


Figure 11 Heat Source Ground Pump

4.2. Cooling Load

The cooling calculations may seem low but a rule of thumb for calculating cooling needs is that every 400sqft requires 1 ton of cooling. This means the roughly 52,000sqft Junior College should require 130 tons of cooling; because of the high R-value of the walls and the PV array on the roof sheltering the building from solar heat gain it is believed that the calculations done are correct. By reducing the buildings heat gain the cooling load in turn is reduced as well. This is done by passive house insulation and efficient window systems.

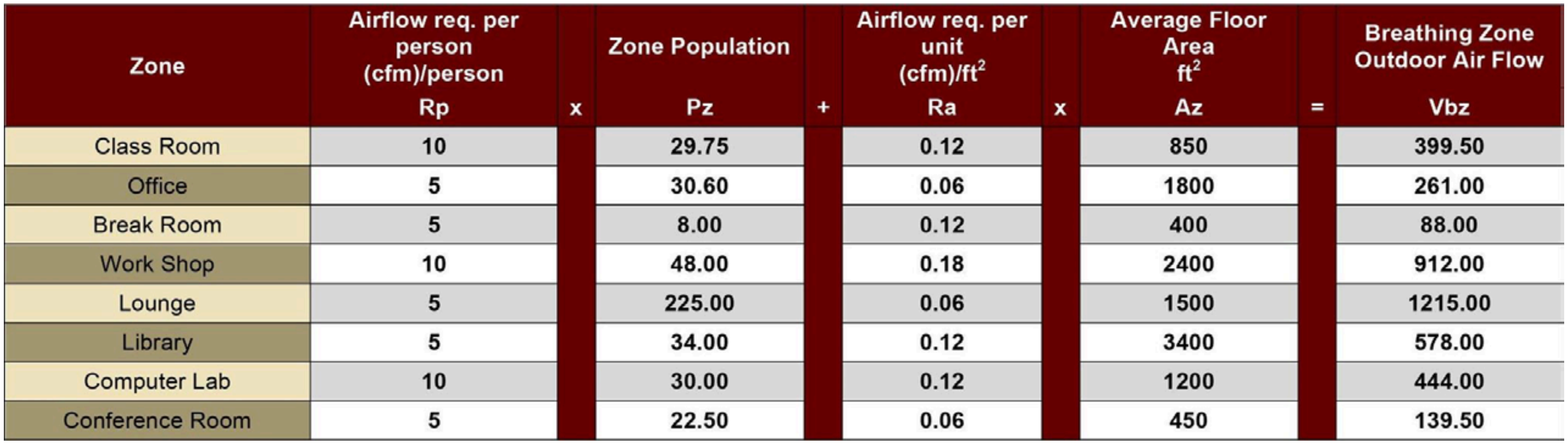


Cooling Load Calculation			
Heat Gain due to People/Equipment			3.20 btu/hft^2
Heat Gain due to the Lighting			2.70 btu/hft^2
Heat Gain due to the Envelope			
Windows			
	$\frac{total\ ft^2\ of\ windows}{total\ building\ ft^2} \times 21$	$\frac{14961.6}{52000} \times 21$	6.04 btu/hft^2
Wall			
	$\frac{total\ ft^2\ of\ exterior\ walls}{total\ building\ ft^2} \times U_{wall} \times 25$	$\frac{11615.3}{52000} \times .02 \times 25$	0.11 btu/hft^2
Roof			
	$\frac{total\ ft^2\ of\ roof}{total\ building\ ft^2} \times U_{roof} \times 25$	$\frac{20150.4}{52000} \times .05 \times 25$	0.87 btu/hft^2
		Total in btu/hft^2 =	12.92 btu/hft^2
		Total in tons =	56 tons
5,600 ft^2 of contact area needed for ground source tubing			

Figure 12 Cooling Load Calculations

4.3. Indoor Air Quality

Indoor air quality calculations were done using ASHRAE Standard 62.1, Minimum Ventilation Rates in Breathing Zone. Using the numbers provided in the table the minimum outdoor airflow was calculated that way the VAV system can provide the proper amount of air to each individual zone reducing unnecessary airflow allowing for a reduction in energy to run the HVAC system.



Zone	Airflow req. per person (cfm)/person Rp	x	Zone Population Pz	+	Airflow req. per unit (cfm)/ft^2 Ra	x	Average Floor Area ft^2 Az	=	Breathing Zone Outdoor Air Flow Vbz
Class Room	10		29.75		0.12		850		399.50
Office	5		30.60		0.06		1800		261.00
Break Room	5		8.00		0.12		400		88.00
Work Shop	10		48.00		0.18		2400		912.00
Lounge	5		225.00		0.06		1500		1215.00
Library	5		34.00		0.12		3400		578.00
Computer Lab	10		30.00		0.12		1200		444.00
Conference Room	5		22.50		0.06		450		139.50

Figure 13 Indoor Air Quality Calculations

4.4. Outdoor Air Delivery Monitoring

Strobic Air Tri-Stack smart system will be used to ventilate our building, specifically the shop spaces which require fume hoods. This system requires little energy in comparison to others and has a short payback period of around 2 years. The smart system makes maintenance easy by telling users what is wrong with the system via an email notification which is also viewable through the touch screen interface that gets installed on the building.

4.5. Filtration and Air Cleaner

Durafil ESB V-Style filters will be used to filter incoming air. With a MERV rating of 16 it exceeds ASHRAE Standard 62.1, 5.8. This is a green air filter that operates at a high level of efficiency reducing HVAC electricity consumption while providing clean air. The filters need to be replaced less lowering maintenance needs and also reducing the carbon footprint by throwing away filters less often.

4.6. Environmental Tobacco Smoke

ASHRAE standard 189.1, 8.3.1.4, Tobacco smoking will not be allowed within 25 feet and No Smoking signage will be posted outside every entrance to the building within 10ft as well as near any air intakes. The building lacks operable windows to maintain lower HVAC costs which means operable windows and tobacco smoke shouldn't be a problem.

4.7. Building Entrances

Building entrances will contain a sequence of mats to help remove exterior debris. The sequence will include a scraper surface, absorption surface and finish surface that is the width of the door to prevent unwanted VOC's in compliance with ASHRAE Standard 189.1, 8.3.1.5. The Scraper surface will be 4ft long and consist of a metal grating allowing for large debris, moisture and dirt to be removed, the interior absorption surface will also be 4ft long and be a rough mat that can absorb water, the finish surface will be a polished concrete flooring which will last longer than other flooring systems and be maintainable.

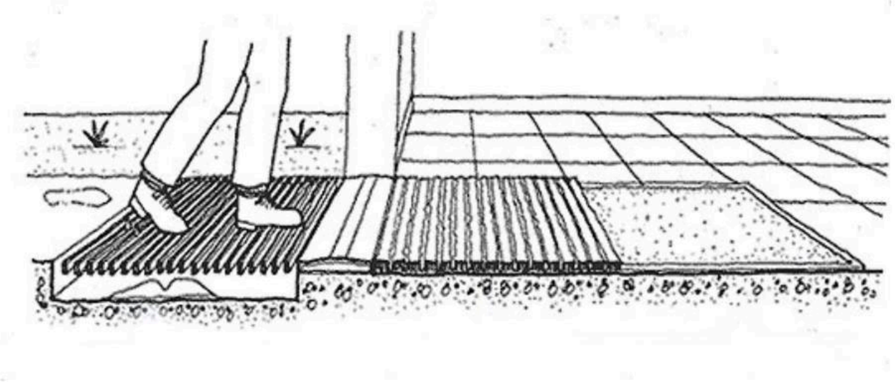
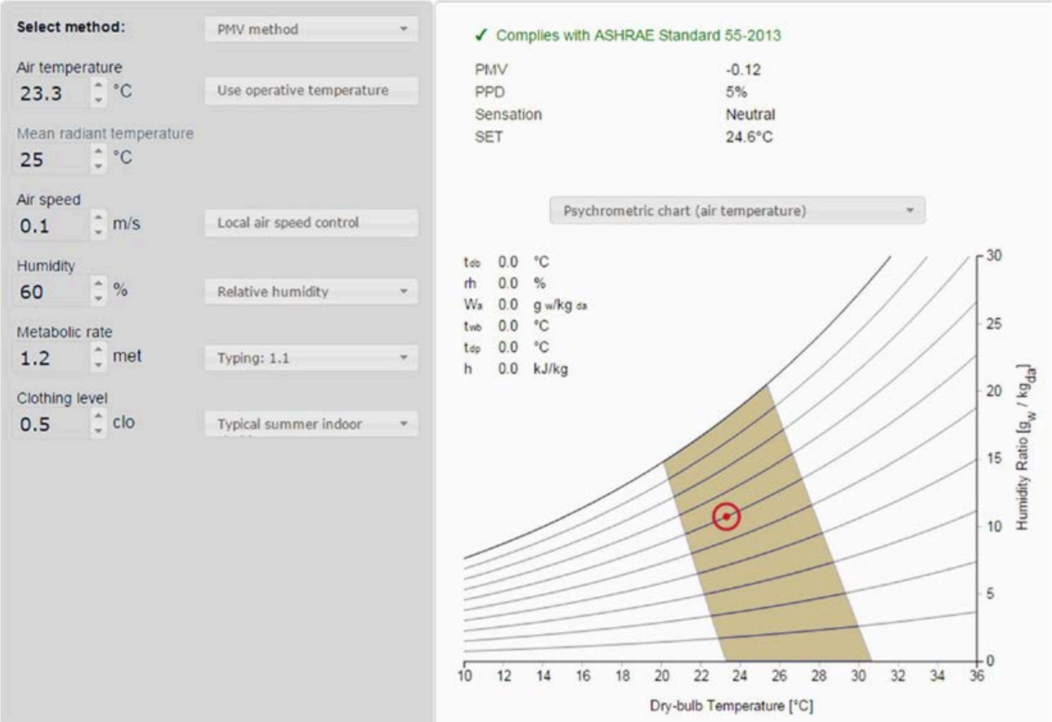


Figure 14 Building Entrance Sequence

4.8. Thermal Environmental Conditions

Berkeley's center for the built environment was used to calculate thermal comfort according to ASHRAE Standard 55. Abu Dhabi's climate consultant figures were put into the system to simulate a similar climate to Doha. Interior air speed was assumed to be low due to the passive house system implemented and the lack of operable windows. 60% humidity was used because 46% of the time the humidity ranges between 60-80% in Abu Dhabi.

4.8.1. Metabolic Rate 1.2 met
4.8.2. Clothing Insulation 0.55 clo
4.8.3. Air Temperature 23.3℃
4.8.4. Radiant Temperature
4.8.5. Air Speed 0.1m/s
4.8.6. Humidity 60%



Select method: PMV method
Air temperature 23.3 °C — Use operative temperature
Mean radiant temperature 25 °C
Air speed 0.1 m/s — Local air speed control
Humidity 60 % — Relative humidity
Metabolic rate 1.2 met — Typing: 1.1
Clothing level 0.5 clo — Typical summer indoor

✓ Complies with ASHRAE Standard 55-2013

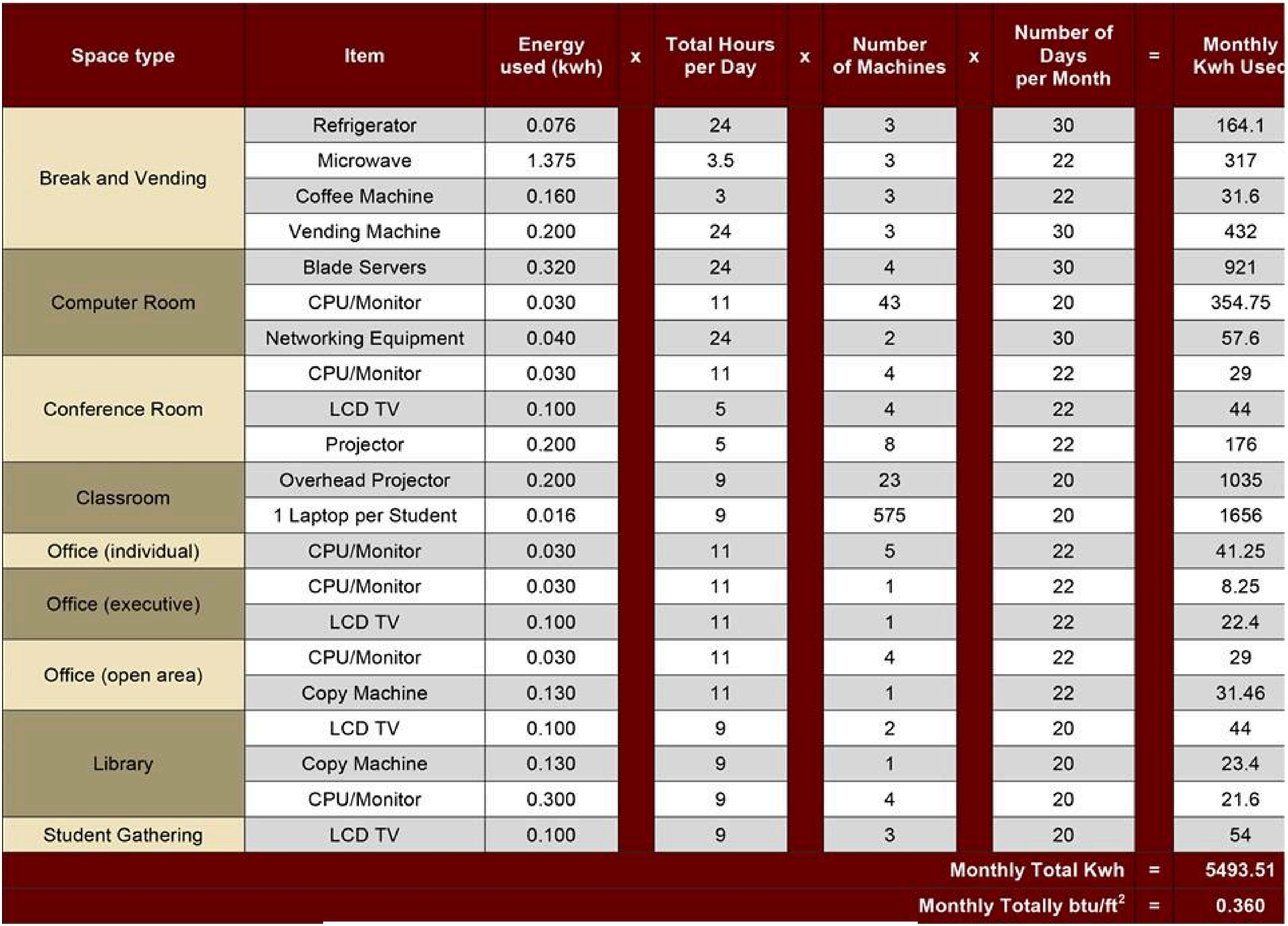
PMV	-0.12
PPD	5%
Sensation	Neutral
SET	24.6°C

Psychrometric chart (air temperature)

Figure 15 Thermal Environment Calculations

4.9. Plug Load Calculations

Plug loads were calculated based on ASHRAE standard 62.1 population density of spaces found in the junior college. The population of people who use the building in a day was found to be 575 people. This number includes students, faculty and other various users. Hours used a day was calculated based on the building days and hours actually used and how often the items would be used in the building. Estimated hours are shown in figure 16.



Space type	Item	Energy used (kwh)	x	Total Hours per Day	x	Number of Machines	x	Number of Days per Month	=	Monthly Kwh Used
Break and Vending	Refrigerator	0.076		24		3		30		164.1
	Microwave	1.375		3.5		3		22		317
	Coffee Machine	0.160		3		3		22		31.6
	Vending Machine	0.200		24		3		30		432
Computer Room	Blade Servers	0.320		24		4		30		921
	CPU/Monitor	0.030		11		43		20		354.75
	Networking Equipment	0.040		24		2		30		57.6
Conference Room	CPU/Monitor	0.030		11		4		22		29
	LCD TV	0.100		5		4		22		44
	Projector	0.200		5		8		22		176
Classroom	Overhead Projector	0.200		9		23		20		1035
	1 Laptop per Student	0.016		9		575		20		1656
Office (individual)	CPU/Monitor	0.030		11		5		22		41.25
Office (executive)	CPU/Monitor	0.030		11		1		22		8.25
	LCD TV	0.100		11		1		22		22.4
Office (open area)	CPU/Monitor	0.030		11		4		22		29
	Copy Machine	0.130		11		1		22		31.46
Library	LCD TV	0.100		9		2		20		44
	Copy Machine	0.130		9		1		20		23.4
	CPU/Monitor	0.300		9		4		20		21.6
Student Gathering	LCD TV	0.100		9		3		20		54
								Monthly Total Kwh	=	5493.51
								Monthly Totally btu/ft^2	=	0.360

Figure 16 Plug Load Calculations

4.10. Lighting systems

4.10.1. Interior Lighting

LED lighting will be used to light interior spaces during hours the building does not receive sufficient sunlight or rooms which do not receive adequate natural sunlight. Although these bulbs have a more significant startup cost their life span expectancy is significantly longer, around 10 years, in comparison to typical bulbs which last a year. LED bulbs also consume much less energy than a typical bulb, coming in at around 4-22 Watts where typical bulbs average 40-150 Watts but produce the same Lumens. This lower energy consumption provided by using LEDs helps meet the zero-net energy goal significantly. Top-lighting will not be used for the third floor or workshop because this would require roof space to be given up for an essential PV array and evacuated solar heating tubes. The air exhaust system will also be located on the roof limiting the space in which top lighting might be located. Doha gets significant sun year round and rooms can be lit well through the glass façade already in place.

4.10.2. Exterior Lighting

Exterior lighting controls will be put in with accordance to ASHRAE Standard 90.1, 9.4.1.4, shutting off outdoor lighting when there is sufficient daylighting and all switches will remember programming for at least 10 hours in the event of a power loss. Exterior lighting will also be powered by LED bulbs to maximize energy efficiency and allow for a variety of intensites by utilizing dimmers so that spaces can be lit differently based off of the need of the space.

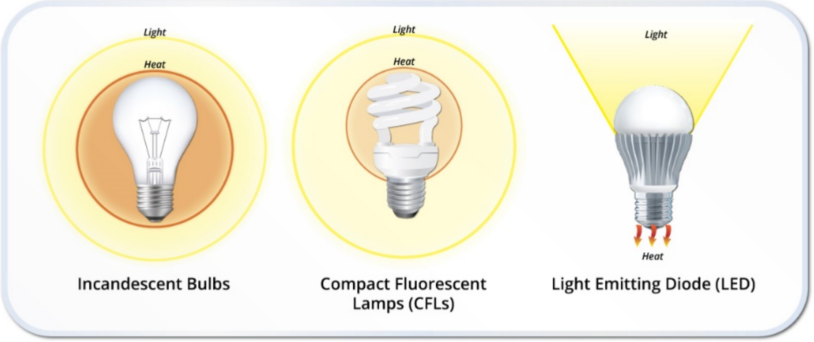


Figure 17 Lighting Diagram

4.11. On-Site Renewable Energy

21,200 sqft of PV arrays will be needed to provide the amount energy the Junior College needs in a year and then some. 5% of this, 530sqft, will be provided by a donor. There will be more PV arrays then actually needed so backup energy can be stored on a generator for days there is limited amount of sunlight. Excess energy will be sold back to the city of Doha. 80% of the PV arrays will be located on the roof of the building while the remaining 20% will be located on the shading devices in the parking lot. This is so that other devices can reside on the roof as well such as the evacuated solar tube heating and the fan exhaust systems.

4.12. Building Energy Consumption

Safira was used to calculate the energy consumption of the buildings. The reason why the energy use per square foot is so low is because strategic lighting strategies are used to reduce the need for interior lights allowing our building to rely on exterior lighting. 60% of the buildings floor area is able to be daylight without the use of interior lighting annually. Cooling loads were reduced dramatically though the implementation of passive house standards. As seen in figure 18 energy reduction in cooling, lighting and heating were able to be dramatically reduced by 46% overall. This allowed for a reasonable amount of PV’s to be installed to make up the energy that is consumed by the Junior College.

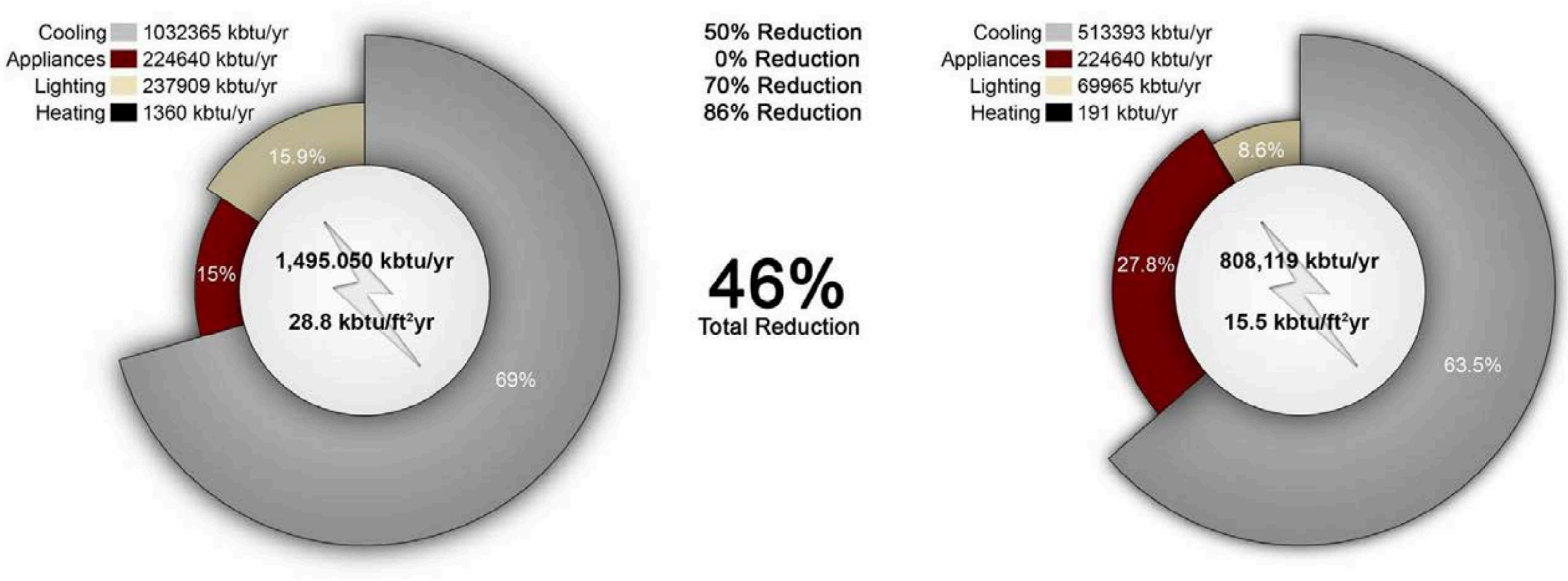


Figure 18 Energy Consumption Comparisons

5. Construction Phase

5.1. Building Construction

5.1.1. Interior Walls

5.1.1.1. Acoustical Control

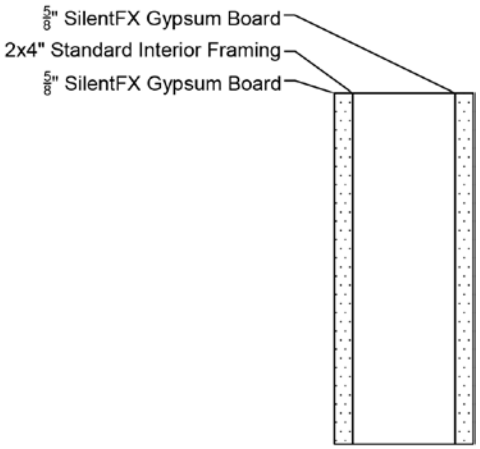


Figure 19 Interior Wall Section

5.1.1.1.1. SilentFX 5/8" Gypsum Board will be used to reduce the noise levels between interior wall as well as exterior noise to the interior spaces. This board is made with Green Glue and M2Tech which has been tested to provide high STC ratings for acoustic management.

5.1.1.1.2. Echo Eliminator sound panels will be used in high need areas where sound proofing is of higher need. These locations include the library, mechanical rooms, workshop and conference rooms. The Echo Eliminator is class A nonflammable and has a Noise Reduction Coefficient of 1.15. It will be placed strategically throughout the interior of rooms that desire noise reduction. This is a cheaper alternative to thickening walls because it requires less material to be effective and is easier to remove and put up rather than constructing thicker walls to reduce noise from adjacent rooms.

Interior walls will be done with standard 2x4" framing with studs 16" on center. The wall will have SilentFX gypsum board on both sides to reduce noise pollution in adjacent rooms. This simple construction will save money but still operate efficiently when it comes to noise reduction. In the case interior walls need more noise reduction Echo Eliminator can be used on interior surfaces to further reduce noise.

5.1.2. Ceiling/Roof Detail

The Ceiling of the 3rd floor of the Junior College will have a ceiling board followed by vapor barrier and batt insulation to keep moisture out of the insulation and help it maintain its best insulation properties. Above this will be metal decking and poured concrete. Above this will be insulation. As seen in Figure 20 by running continuous rigid insulation around the roof and exterior wall construction a thermal bridgeless insulation was created reducing solar heat gain. The insulation on both sides of the concrete renders the thermal mass useless so during the summer the concrete is not allowed an opportunity to heat up and store that heat in the building to be released at night reducing cooling needs.

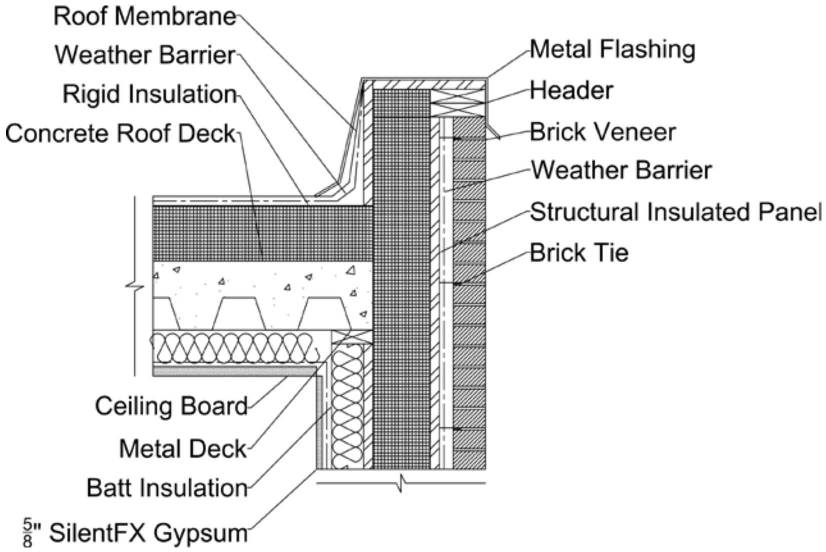


Figure 20 Roof/Ceiling Section

5.1.3. Floor Detail

The construction of the floor is concrete slab on grade. To increase the R value of the floor and reduce thermal bridging of the concrete the decision was made to wrap the underside of the concrete with Rigid insulation reducing the buildings heat gain from the ground up as well as stop thermal bridging between the concrete to the wall as the rigid insulation keeps the concrete from acting as a bridge to outside.

5.1.4. Exterior Wall

Exterior walls will be composed of the tan brick veneer required by the project owner's requirements, there will be a weather barrier behind this to protect from any unwanted rain penetration, then a Structural Insulated Panel which will provide a large portion of the buildings structure and act as the main source of insulation providing an R-value of 34, next is batting insulation acting as a secondary insulator to reduce thermal bridging and interior heat loss followed by 5/8" SilentFX gypsum board to minimize exterior noise to the interior. The purpose of this wall construction is to create a passive house wall with no thermal bridging and excellent insulation properties to reduce heat gain from the exterior and the loss of cool air from the interior.

5.1.5. Window Selection

ClimaGuard windows were selected for their U-value of 0.1 Btu/h*ft^{2}°F. ClimaGuard is a triple glazed window system but still manages to let 74% of light in reducing the need for interior lit spaces during the daytime operating hours. The thermal insulating glass has a high solar heat gain and works well with passive house standards.

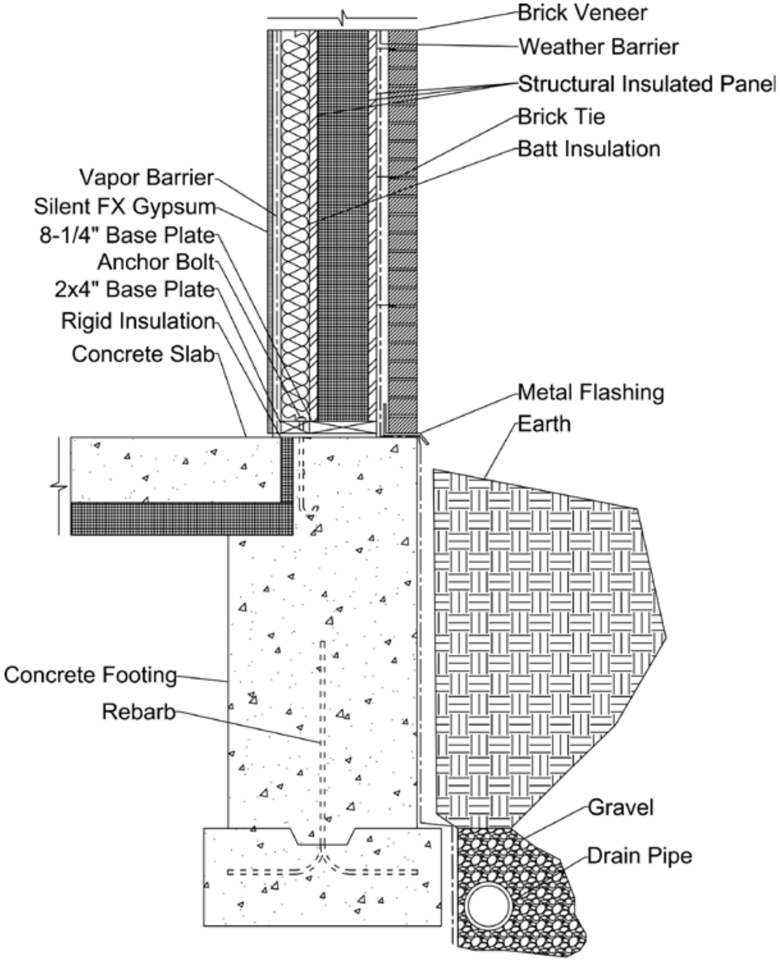


Figure 21 Exterior Wall/Floor Section

5.2. Material Costs

Ekotrope was used to calculate a rough estimate of how much wall construction would cost. Interior walls should cost around $2.08 per square foot consisting of only gypsum board and the interior wall framing construction discussed earlier. Exterior walls will cost around $15.95 per square foot of wall area. This cost is calculated based on wall area that does not consist of window glazing. Exterior façade area that consists solely of glazing is a different cost figure. Building Journal's commercial cost estimator was used to calculate a rough estimate of the total cost for the building materials and the figure of $8,100,000 was determined. This cost does not include high end products used to reduce energy consumption or water use. The average cost per sqft is estimated to be $156.

5.3. Construction Waste Management

To reduce construction waste local materials and machinery will be used in place of importing them from long distances. On site storage units will be provided to separate construction waste and minimize recyclable materials from being thrown away to landfills. Materials will be ordered in as needed bundles to reduce over purchasing materials which creates unnecessary waste and reducing building costs. Storage will be provided for incoming materials as well to reduce damage to the goods prior to their use on the building. Contractors and Architects will work with suppliers to reduce unnecessary material packaging and also possibly have suppliers buy back any unused goods if possibly instead of throwing away the material to a landfill.

5.4. Storage and Collection of Recyclables and Discarded Goods

All break rooms, offices, conference rooms and student and staff lounges will be equipped with 3 sets of bins provided for garbage. These include a recycling bin for plastic, glass and paper goods, a composting bin for materials that can be composted as well as organic produce, and a trash bin for any items that cannot be recycled. The cost of providing separate trash receptacles is minimal in comparison to the impact the products could potentially have on the environment. These three bins will be collected and recyclable goods will be stored on site and collected until given to a processing facility. Compost materials will be given to the composting site in Doha weekly and stored in a bin out of building on the Junior College property. Any trash will be stored in large receptacle and collected once a week by garbage services.

5.5. Construction

5.5.1. Basement

The decision was made to add a basement below the building for the storm water collection system as well as to house the gray water filtration system and the compostable toilet system. Louder functioning mechanics such as the HVAC system will be located in the basement as well. This will allow for easy maintenance as well as hidden mechanical systems from the public.

The control panels to operate as well as monitor building wide systems such as the HVAC system and PV array will be located in the basement for easy access. The generators for excess stored energy from the PV array will also be located in the basement for easy management.

5.5.2. Green Decisions

Throughout the construction process local and regional materials will be used before materials from outside Qatar to reduce carbon emissions from transportation as well as reduce material transportation costs. Renewable materials will be used in place of non-renewable materials where possible. For all wood construction or wood finishes only certified wood will be used. To maintain indoor environmental quality low-emitting adhesives, paints, floors, and chemicals will be used.

Where possible there will be a reuse of materials in the event that the building is deconstructed after its 50 year life expectancy. In the case there is local deconstruction of builds surrounding the site in the city of Doha the reallocation of any materials that are still usable will be used in the Junior College to reduce carbon emissions from harvesting or making of new materials.

5.5.3. Construction Plan

Prior to the construction process a project acceptance representative will be designated to lead and oversee all Acceptance Testing. Construction documents shall indicate who will perform acceptance tests in accordance with ASHRAE Standard 189.1, 10.3.1.1. The acceptance representative will review all construction documents.

Prior to building occupancy the startup and operation of all mechanical and electrical systems shall take place to verify their proper installation and test will be performed to verify they are operating correctly and up to standards. This includes; mechanical systems, lighting systems, automated control systems, water measurement systems, renewable energy systems and any energy measurement devices.

Indoor air quality will need to have a construction management plan mapped out. During construction air conveyance materials will be covered. Prior to building occupancy a post construction flush out will happen when all air filters and HVAC controls are in place. Baseline IAQ testing will take place after the construction has ended and prior to occupancy.

5.6. Plans for Operation

5.6.1. Water Consumption

During operation water consumption and management will be measured to evaluate water use efficiency. The assessment of water use will take place to evaluate actual used amounts in comparison to predicted potable water consumption. This will allow for evaluation and efficiency.

5.6.2. Energy Measurement

Energy measurements shall take place continuously starting prior to acceptance testing. This data will be stored for evaluation. Assessment of the data will be completed after 12 months of occupancy. Ongoing assessments shall take place at a maximum of every three years following the initial assessment. Reports will include hourly load profile for each day, monthly average daily load, monthly and annual energy use, and monthly and annual peak demand. This information will be documented to evaluate energy efficiency.

5.6.3. Maintenance Plan and Service Plan

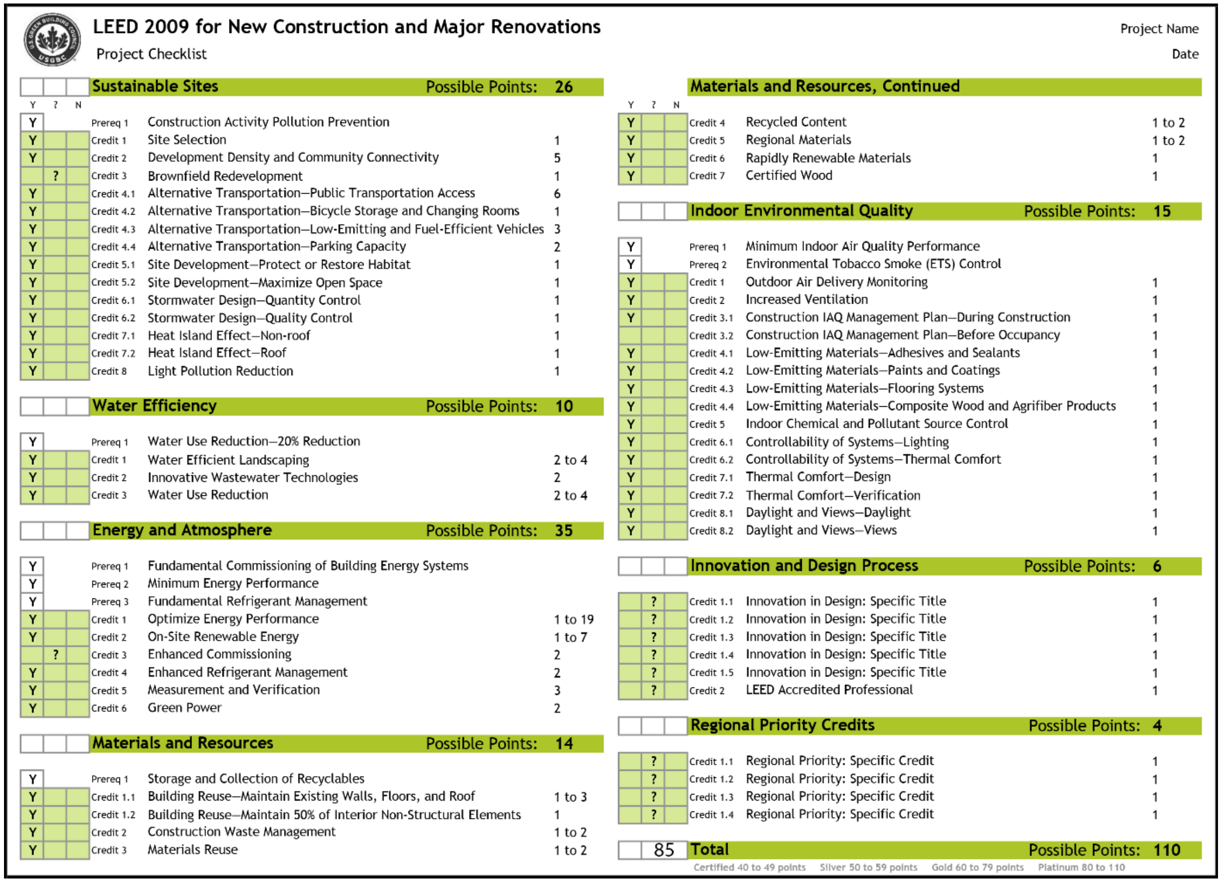
A maintenance plan will be created for the maintenance and operation of mechanical, electrical, plumbing and fire protection systems. Documentation of the plans and procedures will remain on the site at all times in both electronic and hard copy form. The service plan of the building is long term serviceability and should require low maintenance as well as repair needs. Life expectancy of the building is 50 years and has been designed to have little repair needs during this time. Annual tests of systems will be crucial to maintain the systems efficiency throughout life expectancy.

5.6.4. Transportation

Onsite shaded parking for bicycles and vehicles is provided. Public transportation is accessible immediately off site to encourage the use of such transportation. Preferred parking is provided for those who carpool reducing carbon emissions. Handicapped parking is located nearest the entrance of the building to provide accessibility for all building users. A drop-off circulation route was added to encourage carpooling and to reduce the amount of parking needed on site for building users.

5.6.5. LEED Certification

The Junior College in Doha, Qatar received a LEED rating of 85 after locating on a sustainable site, implementing water management systems, Renewable Energy Systems, choosing renewable resources and recyclable products and maximizing indoor air quality.



LEED 2009 for New Construction and Major Renovations

Project Checklist

Project Name

Date

Y	?	N			
			Sustainable Sites	Possible Points:	**26**
Y			Prereq 1	Construction Activity Pollution Prevention	
Y			Credit 1	Site Selection	1
Y			Credit 2	Development Density and Community Connectivity	5
	?		Credit 3	Brownfield Redevelopment	1
Y			Credit 4.1	Alternative Transportation—Public Transportation Access	6
Y			Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Rooms	1
Y			Credit 4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Vehicles	3
Y			Credit 4.4	Alternative Transportation—Parking Capacity	2
Y			Credit 5.1	Site Development—Protect or Restore Habitat	1
Y			Credit 5.2	Site Development—Maximize Open Space	1
Y			Credit 6.1	Stormwater Design—Quantity Control	1
Y			Credit 6.2	Stormwater Design—Quality Control	1
Y			Credit 7.1	Heat Island Effect—Non-roof	1
Y			Credit 7.2	Heat Island Effect—Roof	1
Y			Credit 8	Light Pollution Reduction	1
			Water Efficiency	Possible Points:	**10**
Y			Prereq 1	Water Use Reduction—20% Reduction	
Y			Credit 1	Water Efficient Landscaping	2 to 4
Y			Credit 2	Innovative Wastewater Technologies	2
Y			Credit 3	Water Use Reduction	2 to 4
			Energy and Atmosphere	Possible Points:	**35**
Y			Prereq 1	Fundamental Commissioning of Building Energy Systems	
Y			Prereq 2	Minimum Energy Performance	
Y			Prereq 3	Fundamental Refrigerant Management	
Y			Credit 1	Optimize Energy Performance	1 to 19
Y			Credit 2	On-Site Renewable Energy	1 to 7
	?		Credit 3	Enhanced Commissioning	2
Y			Credit 4	Enhanced Refrigerant Management	2
Y			Credit 5	Measurement and Verification	3
Y			Credit 6	Green Power	2
			Materials and Resources	Possible Points:	**14**
Y			Prereq 1	Storage and Collection of Recyclables	
Y			Credit 1.1	Building Reuse—Maintain Existing Walls, Floors, and Roof	1 to 3
Y			Credit 1.2	Building Reuse—Maintain 50% of Interior Non-Structural Elements	1
Y			Credit 2	Construction Waste Management	1 to 2
Y			Credit 3	Materials Reuse	1 to 2
			Materials and Resources, Continued		
Y			Credit 4	Recycled Content	1 to 2
Y			Credit 5	Regional Materials	1 to 2
Y			Credit 6	Rapidly Renewable Materials	1
Y			Credit 7	Certified Wood	1
			Indoor Environmental Quality	Possible Points:	**15**
Y			Prereq 1	Minimum Indoor Air Quality Performance	
Y			Prereq 2	Environmental Tobacco Smoke (ETS) Control	
Y			Credit 1	Outdoor Air Delivery Monitoring	1
Y			Credit 2	Increased Ventilation	1
Y			Credit 3.1	Construction IAQ Management Plan—During Construction	1
			Credit 3.2	Construction IAQ Management Plan—Before Occupancy	1
Y			Credit 4.1	Low-Emitting Materials—Adhesives and Sealants	1
Y			Credit 4.2	Low-Emitting Materials—Paints and Coatings	1
Y			Credit 4.3	Low-Emitting Materials—Flooring Systems	1
Y			Credit 4.4	Low-Emitting Materials—Composite Wood and Agrifiber Products	1
Y			Credit 5	Indoor Chemical and Pollutant Source Control	1
Y			Credit 6.1	Controllability of Systems—Lighting	1
Y			Credit 6.2	Controllability of Systems—Thermal Comfort	1
Y			Credit 7.1	Thermal Comfort—Design	1
Y			Credit 7.2	Thermal Comfort—Verification	1
Y			Credit 8.1	Daylight and Views—Daylight	1
Y			Credit 8.2	Daylight and Views—Views	1
			Innovation and Design Process	Possible Points:	**6**
	?		Credit 1.1	Innovation in Design: Specific Title	1
	?		Credit 1.2	Innovation in Design: Specific Title	1
	?		Credit 1.3	Innovation in Design: Specific Title	1
	?		Credit 1.4	Innovation in Design: Specific Title	1
	?		Credit 1.5	Innovation in Design: Specific Title	1
	?		Credit 2	LEED Accredited Professional	1
			Regional Priority Credits	Possible Points:	**4**
	?		Credit 1.1	Regional Priority: Specific Credit	1
	?		Credit 1.2	Regional Priority: Specific Credit	1
	?		Credit 1.3	Regional Priority: Specific Credit	1
	?		Credit 1.4	Regional Priority: Specific Credit	1
	85		**Total**	Possible Points:	**110**

Certified 40 to 49 points Silver 50 to 59 points Gold 60 to 79 points Platinum 80 to 110

6. References

(1) ANSI/ASHRAE/USGBC/IES Standard 189.1-2011

(2) ANSI/ASHRAE Standard 55-2004

(3) ANSI/ASHRAE Standard 62.1-2007

(4) ANSI/ASHRAE/IESNA Standard 90.1-2007

(5) Thermal Comfort <http://smap.cbe.berkeley.edu/comforttool>.

(6) Soil Type <http://catnaps.org/islamic/geography.html>.

(7) Air Filter <http://www.camfil.us/>.

(8) Material Cost <http://www.ekotrope.com/products/r-value-calculator/>.

(9) Cost Calculator <http://buildingjournal.com/construction-estimating.html>.

(10) Air Exhaust <http://www.strobicair.com/pdf/SmartSystemBulletin.pdf>.

(11) Site Plants <http://www.floraofqatar.com/halopeplis_perfoliata.htm>.

(12) Carbon Dioxide Sensors <http://www.johnsoncontrols.com/content/us/en/products/building_efficiency/products-and-systems/integrated_hvac_systems/hvac/sensor_product_family/carbon_dioxide.html>.

(13) Plumbing Fixtures <http://www.zurn.com/Pages/ProductDetails.aspx?NodeKey=375815>.

(14) Gray Water System <http://www.sloanvalve.com/News_Press/Sloan_AQUS_Water_Reuse_System.aspx>.

(15) Lighting <http://eartheasy.com/live_energyeff_lighting.htm>.

(16) Climate Consultant <http://www.energy-design-tools.aud.ucla.edu/climate-consultant/request-climate-consultant.php>.