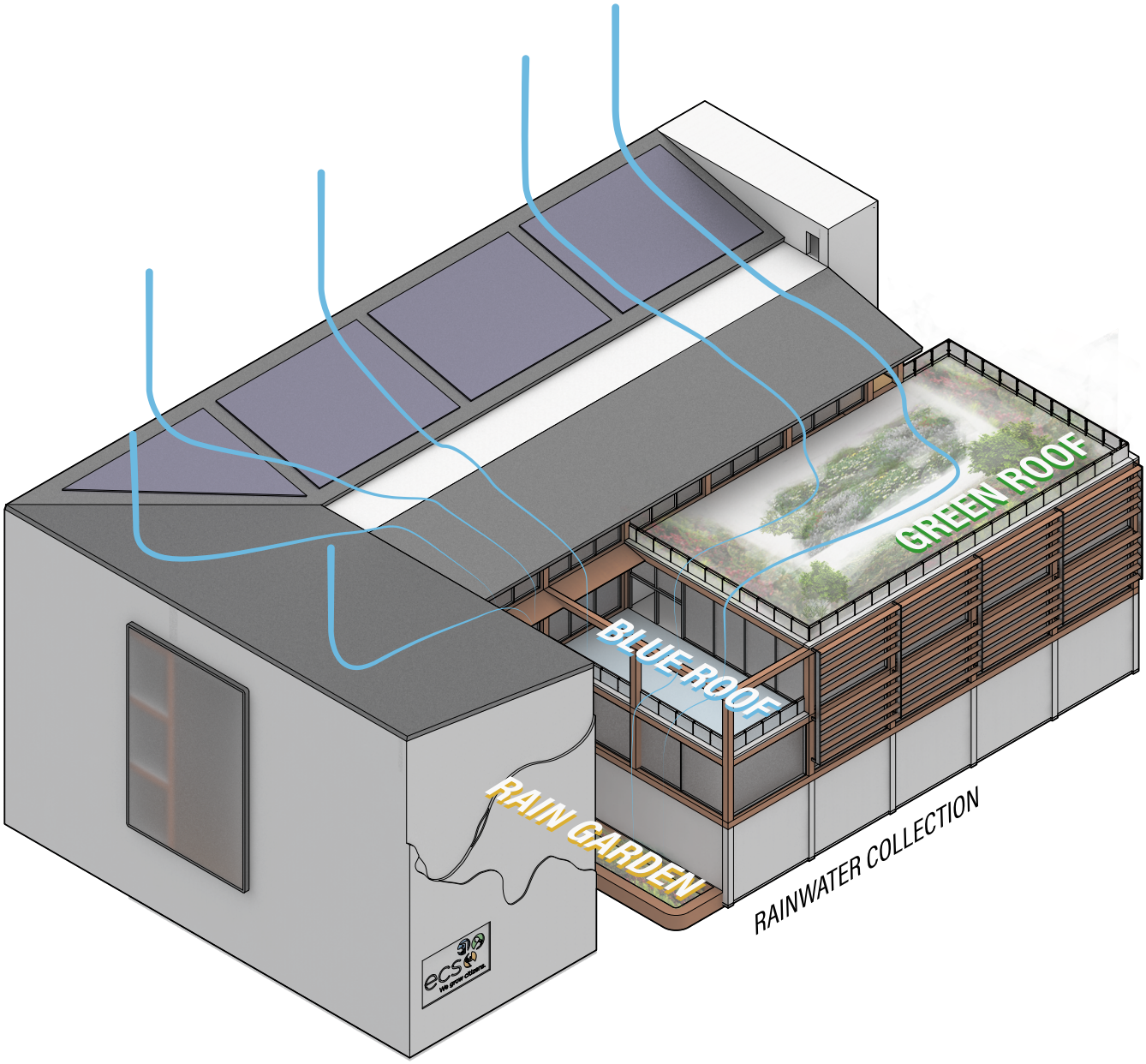
CARRICK, PITTSBURGH, PA

ENVIRONMENTAL CHARTER SCHOOL SYSTEMS REPORT



Daniel Noh and Somin Shim

This report examines how successfully the school design adheres to the environmental charter school values through the building design, if the school meets or exceeds the IECC 2018 requirements, and how passive and active strategies are integrated for high building performance.

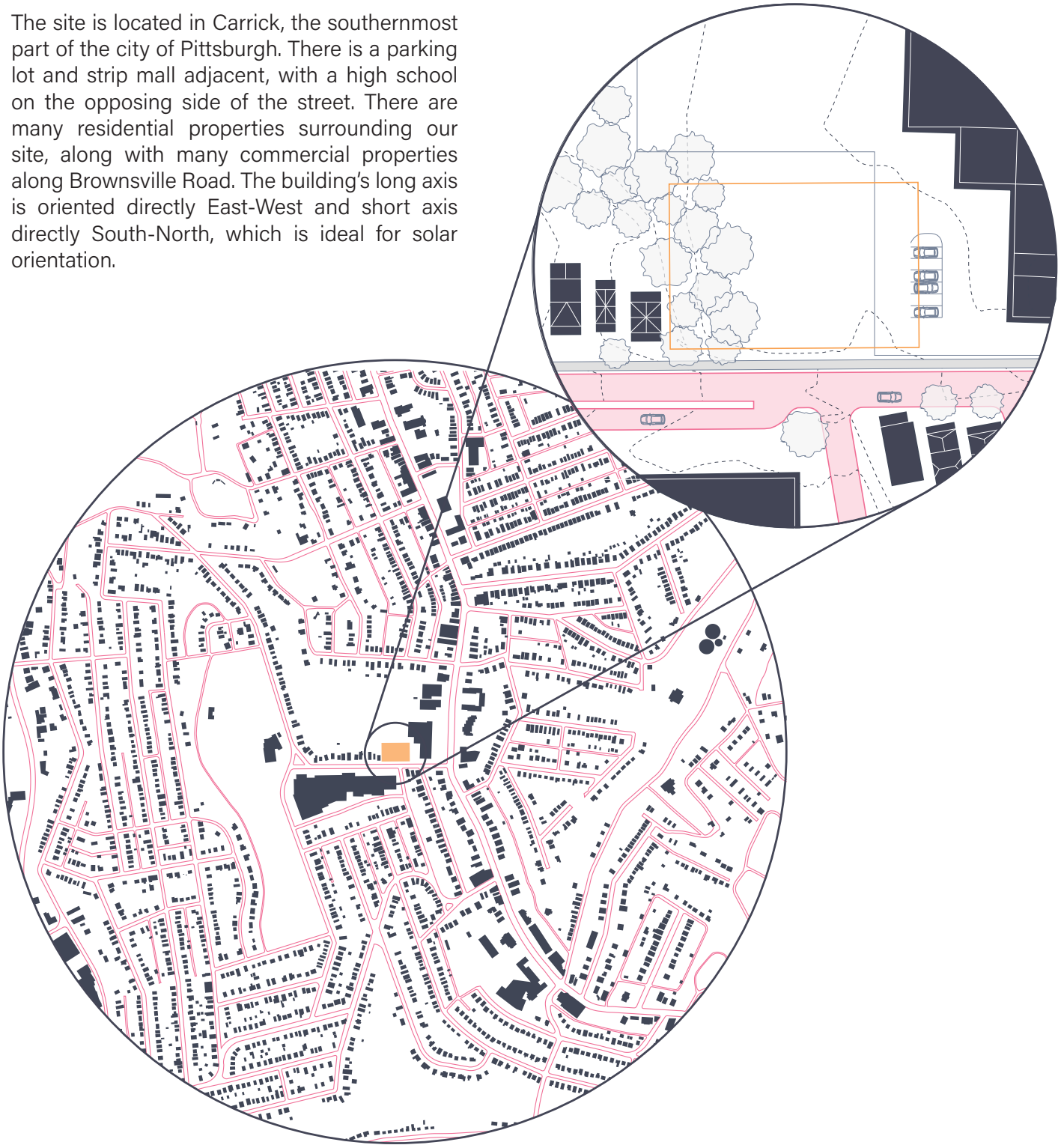
CONTENTS

BUILDING SUMMARY

108 Parkfield Ave
Pittsburgh, PA

Building Description

The site is located in Carrick, the southernmost part of the city of Pittsburgh. There is a parking lot and strip mall adjacent, with a high school on the opposing side of the street. There are many residential properties surrounding our site, along with many commercial properties along Brownsville Road. The building's long axis is oriented directly East-West and short axis directly South-North, which is ideal for solar orientation.



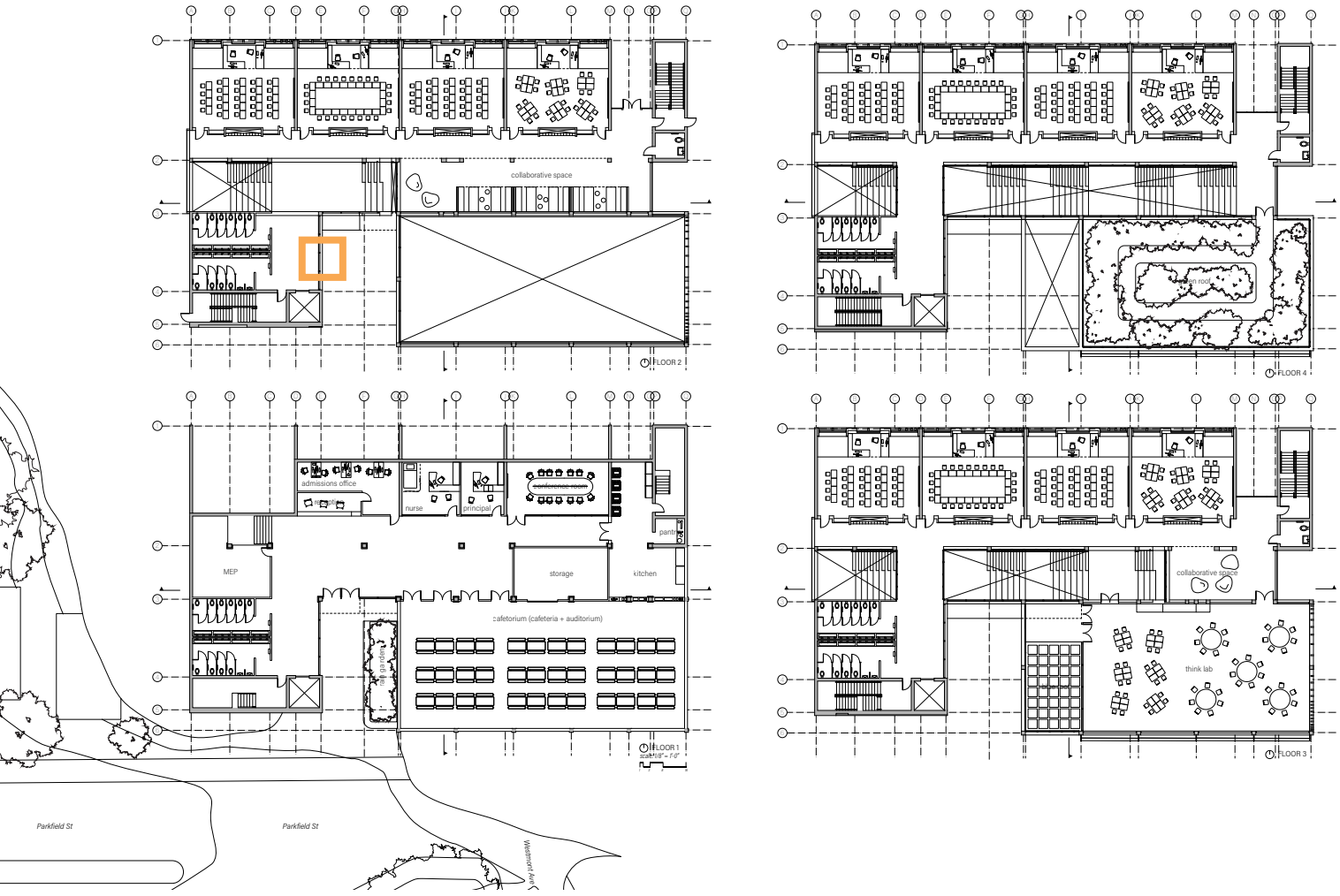
Building Envelope

Initially, during the conceptual design, the walls next to the classrooms as well as the first floor walls were designed to be load-bearing poured concrete. However, after some reconsideration of environmental goals, the structure was modified to be steel studs with concrete cladding with an R-Value of 41.4, which allows for disassembly. Moreover, the classroom floors are held up by cross-laminated timber, which has a smaller environmental footprint than concrete or steel. Also, The wall assemblies would incorporate rock wool, rather than polystyrene or polyisocyanates which release VOCs (volatile organic compounds).

In order to reduce thermal load, one of the Western glass walls, along the entrance, was also modified to be built of the steel stud wall construction instead of glazing.

For thermal comfort, the classrooms were located on the northern side, allowing the classrooms to utilize diffused light. The public spaces were placed on the southern side, allowing more vibrant solar penetration. The southern windows of the thinklab and the multipurpose space were designed with louvers to reduce solar gain and direct glare.

Total Conditioned Floor Area: 45,030 sf
Total Prescribed Occupants: 320 people



Window to Wall Ratios

According to IECC 2018 C402.4.1, the vertical fenestration area cannot be greater than 30% of the above-grade wall area.

Glazing Code

Pittsburgh is in Climate Zone 5. According to IECC 2018 TABLE C402.4, the maximum U-Factor of operable fenestration is 0.45 and fixed fenestration is 0.38. The SHGC requirements are also 0.38 for SEW and 0.51 for N orientation. The window is a non-metal frame, thermally improved, double, low-e glass with a U-Factor of 0.26, SHGC of 0.26, and a VT of 0.51.

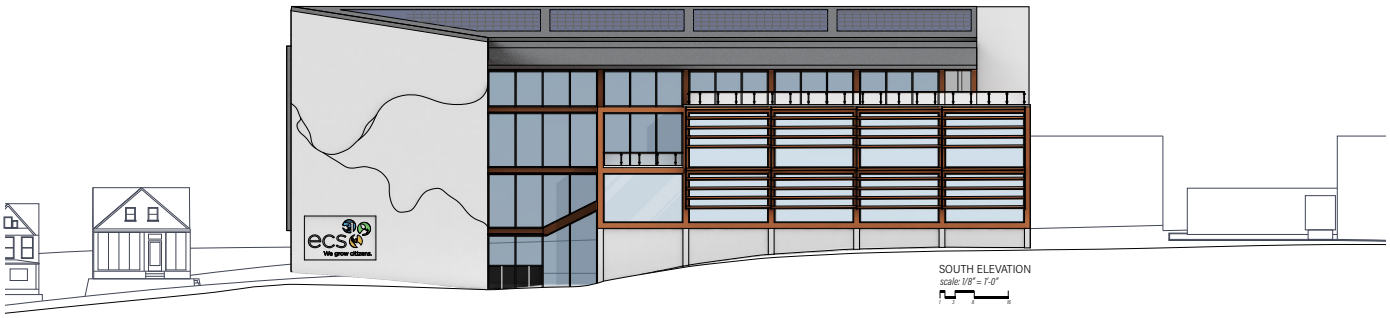
NORTH WWR:
2700/9600 = 0.281

SOUTH WWR:
3850/9650 = 0.400

EAST WWR:
1375/8730 = 0.158

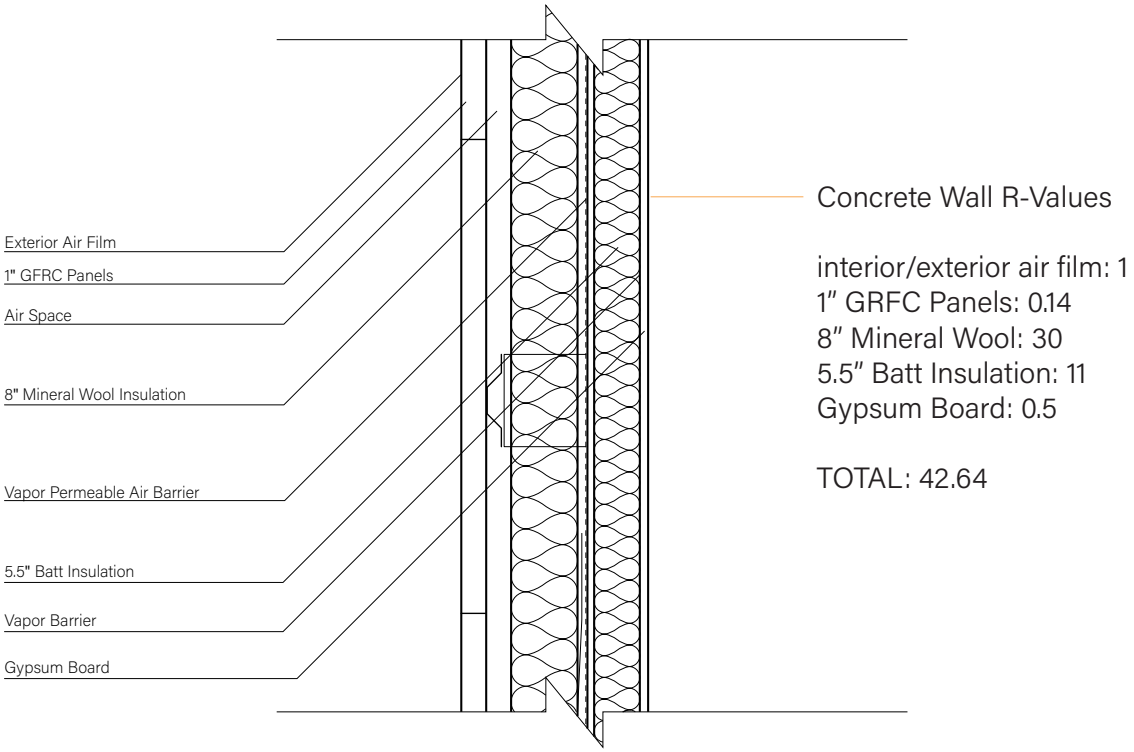
WEST WWR:
2215/9600 = 0.231

TOTAL WWR:
10140/37580 = **27%**



Wall Sections

According to IECC 2018 C402.4.1, the vertical fenestration area cannot be greater than 30% of the above-grade wall area. Also, according tp TABLE C402.1.3, Pittsburgh requires metal framed buildings to have R-13 and R-7.5 continuous insulation. The following wall sections follow the criteria.



Roof R-Values

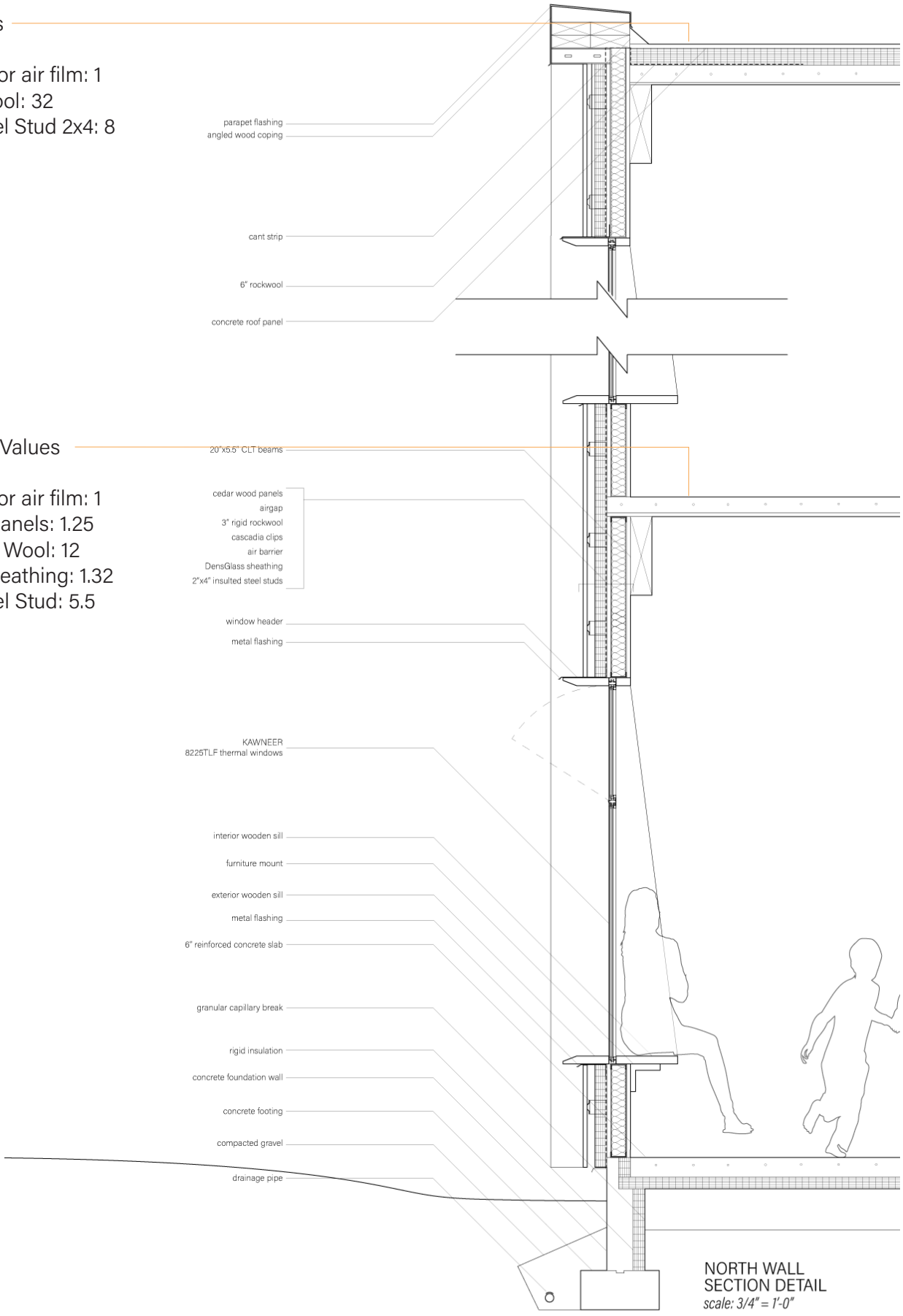
interior/exterior air film: 1
8″ Mineral Wool: 32
Insulated Steel Stud 2x4: 8

TOTAL: 41.00

Wood Wall R-Values

interior/exterior air film: 1
cedar wood panels: 1.25
3″ Rigid Rock Wool: 12
DensGlass sheathing: 1.32
Insulated Steel Stud: 5.5

TOTAL: 21.07



NORTH WALL
SECTION DETAIL
scale: 3/4″ = 1′-0″

LIGHTING

Daylighting

For the classroom floors, the more public spaces, such as the cafeteria/multipurpose space, the thinklab, and the central stairway, are situated on the southern side of the school and the classrooms are located on the northern side of the school. This was done in consideration of using diffused northern light for the major study spaces (classrooms) and more vibrant direct light in communal spaces.

Passive Strategies

For passive strategies, the southern glazing for the communal spaces were also covered by louvers that reduce solar heat gain and diffuse the daylight from being too harsh during the summer. There are also windows on the east and west ends of the central stairway to introduce daylight into the main circulation space.

Active Lighting

The electrical lighting incorporates manual controls with dimmers in each classroom, as well as occupancy sensors. The occupant sensors complies with 2018 IECC 405.2, where the lights turn off within 20 minutes of no occupancy.

In the classrooms, because there are hung ceilings, the electrical lighting is also suspended, rather than mounted or recessed. The chosen luminaire is the Philips Suspended SmartBalance lights (SP480P). This family of lights have an energy efficacy of over 90lm/W which is optimal for lighting fixtures.

Fixture Calculation

ANSI/IES RP-1 = S for <25 (375 lux)

This lighting level was chosen because the classrooms are for the ECS Middle Students and faculty only. The public space for the neighborhood during weekends and holidays are only open on the ground floor, namely the multipurpose/cafeteria space.

Philips Suspended SmartBalance
SP480P LED35S/840 POE ACC-MLO ACL SM1

LMF (LED) at 50K Hours: 0.85
Light Output Ratio: 100% Downwards
Reflectance: Assuming reflectances of ceilings are 0.8, walls are 0.5, and the working plane is 0.3
RCR: Taking the dropped ceiling into consideration, the average height of the ceiling is 10'-6" (10.5), which is also the level where the luminaires would be hung at, the working plane (desk height) is at 2'-8" (2.67), and the classrooms are 34'-9" (34.75) x 28'-8" (28.67).

RCR = 5hrc(L+W)/L*W = 5(10.5-2.67)(34.75+28.67) / (34.75*28.67) **= 2.49**
CU = 1.04
Watts/Luminaire = 32 W
Lumens/Luminaire = 3500 lm

Code Based Calculations

Classrooms are 0.96 W/SF
0.96* 996.28 = 956.43 W
956.43 W / 32 W/luminaire = 29.89 Luminaires

30 Luminaires

Zonal Cavity Method

375 lux = 34.85 fc
(illuminance*area) / (lumens per luminaire*CU*LMF)
= (34.85*996.28) / (3500*1.04*0.85) = 11.22

12 Luminaires

The luminaries needed, calculated by the Zonal Cavity Method, is far less than the code maximum. This, in effect, allows the classrooms to be designed with only 12 luminaires which reduces the carbon emissions of the building. Moreover, using less luminaires also uses less electricity which allows the school to possibly generate excess solar energy from PV panels. This energy can go to help the local district power neighboring buildings, such as Carrick High School.

VENTILATION

Local Air Quality

in Allegheny County, Pennsylvania

Ozone and Particle Pollution Data from American Lung Association (ALA)'s 2019 State of Air Report

Ground-level ozone and particle pollution (PM 2.5) are two major air pollution factors in the United States. Constant exposure to these factors would cause serious respiratory issues on people.

Particle Pollution (PM 2.5)

Average 24 hour exposure

Grade: F

Days of high pollution from 2015-17: 10.5

Average Annual Exposure

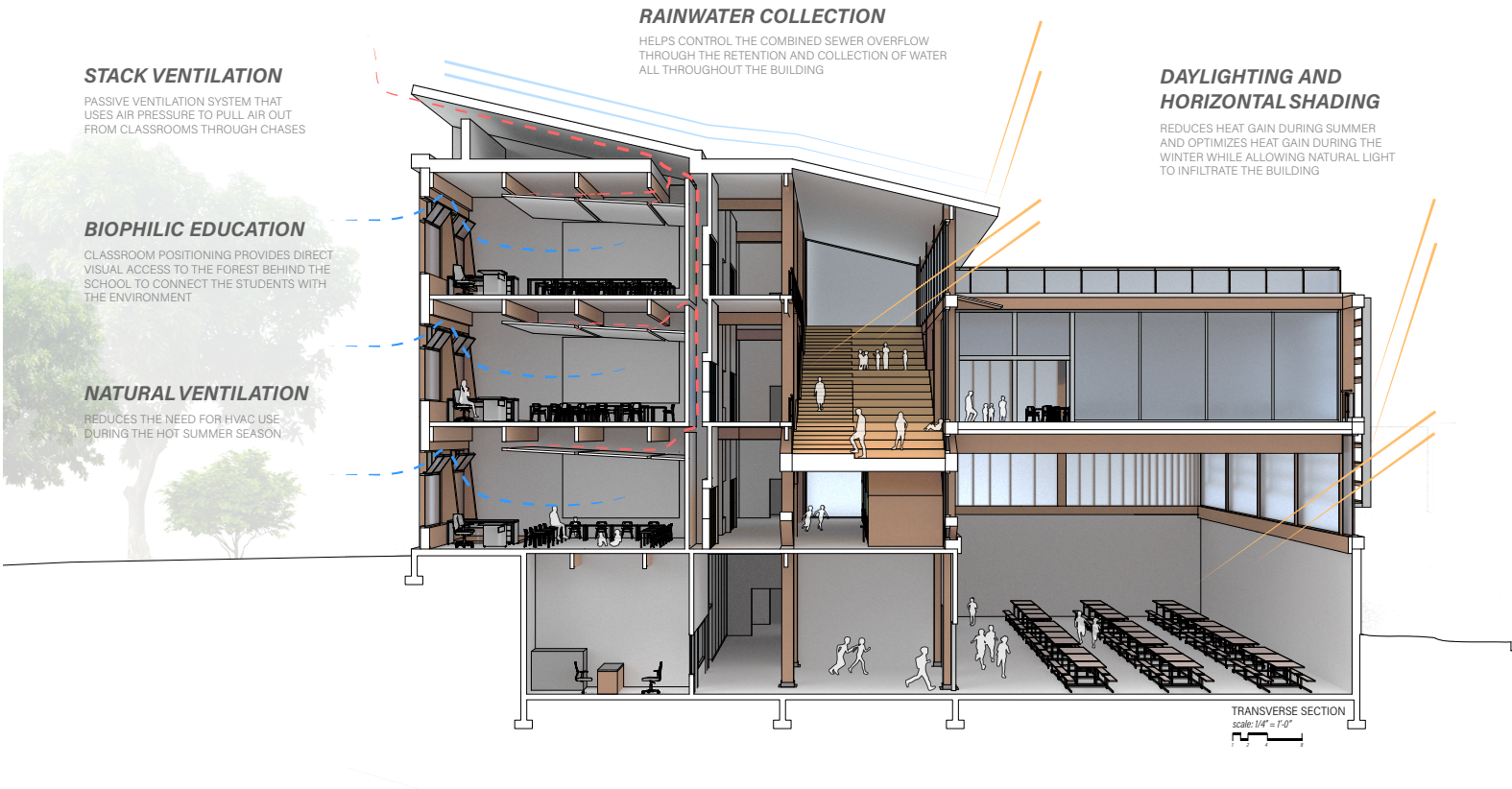
Grade: Fail

Ground Level Ozone

Grade: F

Days of high pollution from 2015-17: 8.3

Average Humidity: 68%



Outside Air Calculation

Area for 1 classroom: 1008 ft2

Occupancy according to IMC Table 403.3.1.1: 35.25people/classroom

CFM based on Occupancy: 352.5 CFM/classroom

CFM based on floor area: 121 CFM

Total CFM for 1 classroom: 473 CFM

Total CFM for 4 classrooms (1 floor): 1,420 CFM
Total CFM for 12 classrooms (3 floors): 5,682 CFM

Duct size of exhaust per floor (1,420 CFM): 16" (Trunk)
Duct size for single classroom (473 CFM): 11.5" (Branch)
*duct sizes are calculated using the friction loss method, assuming 0.1 WC/100ft

Space & Location	Dimensions(ft)	IMC Table 403.3.1.1 Occupancy based on floor area	IMC Table 403.3.1.1 CFM based on occupancy	IMC Table 403.3.1.1 CFM based on floor area	Total CFM
Classroom (1)	**34.75' x 29' =1,007.75 ft²**	35/1000ft² X 1,008 = **35.25 people**	10cfm/person X 35.25 = **352.5 cfm**	0.12/ft² X 1008ft² = **121 cfm**	**473 cfm**

Outside Air Design Considerations

All selected equipment needs to meet MERV 8 or above, ideally around 12, due to bad quality of the local air condition. The IMC Section 402 also requires that the minimum operable area to outdoors (windows, doors, louvers, and other openings) which is naturally ventilated is 4% of the floor area. The calculated minimum openable area would be 5682 sqft * 0.04 = **227 sqft**

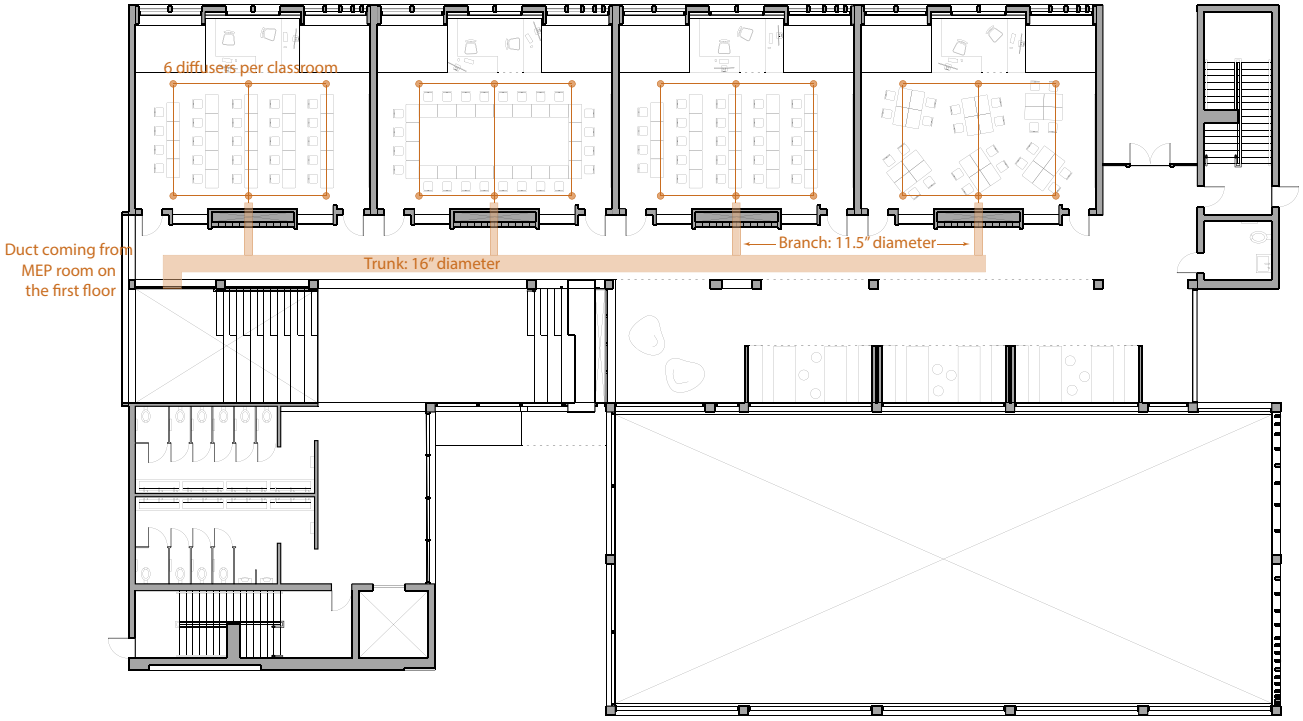
Sustainability Considerations

Choice of outdoor DOAS system is suitable for the local weather condition, which fully conditions the OA as well as dehumidification. Outdoor system is chosen to maximize the indoor area for the students, as well as separating the mechanical noise to meet the comfort level. Separate ventilation system from the heating/cooling allows to save space for equipment as well as energy. High number of OA airflow requires a demand-control system, which would save energy when the space is not in use.

OA Ventilation System and Equipment

For natural ventilation, operable windows are placed on the north side of classrooms. Also, a stack ventilation system is used through all the classrooms to utilize passive ventilation strategy. DOAS (dedicated outdoor air system) is the main mechanical ventilation system, since it allows for smaller ducts and capacity for cooling and heating equipment. Also, the local air condition of high humidity, the integrated dehumidification system further benefits the interior air condition.

Duct Size (Trunk): 16”
Duct Size (Branch): 11.5”



Mechanical System

The design uses DOAS (dedicated outdoor Air System), which is a system that uses the energy contained in the air being exhausted from the building to fully condition the incoming air.
The system is used due to smaller duct size, fully conditioned air, latent energy, and dehumidifier, which are all applicable for Pittsburgh local air quality. In order to save energy, Demand Control Ventilation is used, particularly an occupant sensor system since the building is only occupied at certain times of the year. Furthermore, energy recovery wheel could help to reduce the amount of energy as well as pre-heating OA.

Model Name: Renewaire RD 4XRT
# of units: 2
Type: DOAS
Rooftop Unit
Airflow Range: 1,000 - 4,250 cfm

HEATING AND COOLING

OA Ventilation System and Equipment

For natural ventilation, operable windows are placed on the north side of classrooms. Also, a stack ventilation system is used through all the classrooms to utilize passive ventilation strategy. DOAS (dedicated outdoor air system) is the main mechanical ventilation system, since it allows for smaller ducts and capacity for cooling and heating equipment. Also, the local air condition of high humidity, the integrated dehumidification system further benefits the interior air condition.

CLASSROOM

BLOCK LOADS:		TOTAL ROOM SENS+RA+LATENT =			17,290		ROOM HTG:	8,965
Peak Block Load Occurs		OUTSIDE AIR:		OA Sensible:	-		OA Heating:	-
Month:	7	OA cfm =	0	OA Latent:	-			=====
Hour:	14	FAN HEAT:	0	HP to S. Air	-		**TOT HEATING,btuh=**	**8,965**
		PUMP HEAT:	0	HP to CHW	-		**Heating btuh/sf =**	**8.9**
					=====	**tons**	**sf/ton**	
		TOTAL BLOCK COOLING LOAD, btuh -			**17,290**	**1.4**	**699**	

CLASSROOM FLOOR

BLOCK LOADS:		TOTAL ROOM SENS+RA+LATENT =			87,756		ROOM HTG:	49,135
Peak Block Load Occurs		OUTSIDE AIR:		OA Sensible:	-		OA Heating:	-
Month:	7	OA cfm =	0	OA Latent:	-			=====
Hour:	14	FAN HEAT:	0	HP to S. Air	-		**TOT HEATING,btuh=**	**49,135**
		PUMP HEAT:	0	HP to CHW	-		**Heating btuh/sf =**	**12.3**
					=====	**tons**	**sf/ton**	
		TOTAL BLOCK COOLING LOAD, btuh -			**87,756**	**7.3**	**545**	

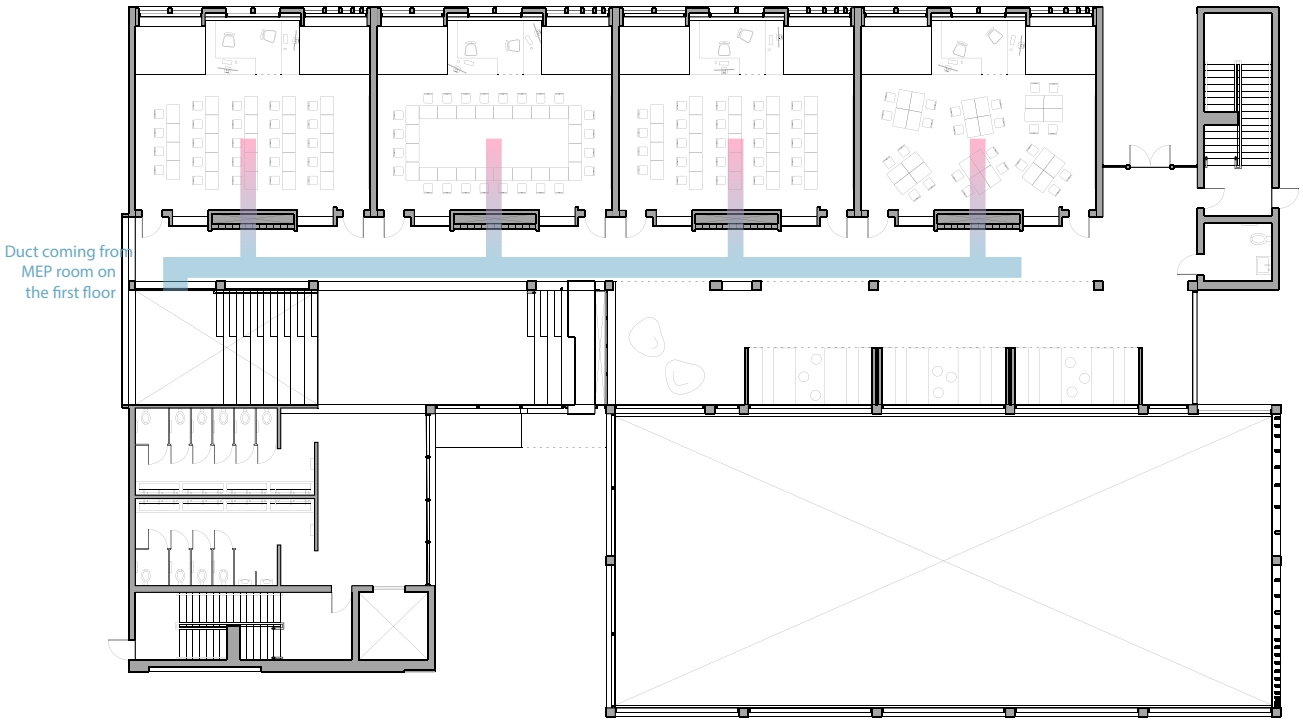
BUILDING BLOCK LOAD

BLOCK LOADS:		TOTAL ROOM SENS+RA+LATENT =			617,045		ROOM HTG:	399,902
Peak Block Load Occurs:		OUTSIDE AIR:		OA Sensible:	-		OA Heating:	-
Month:	7	OA cfm =	0	OA Latent:	-			=====
Hour:	16	FAN HEAT:	0	HP to S. Air:	-		**TOT HEATING,btuh=**	**399,902**
		PUMP HEAT:	0	HP to CHW:	-		**Heating btuh/sf =**	**8.9**
					=====	**tons**	**sf/ton**	
		TOTAL BLOCK COOLING LOAD, btuh -			**617,045**	**51.4**	**876**	

System Layout

The school uses a air-based VRF(variable refrigerant flow) system for distributed cooling and heating air through ducts. The conditioned air is distributed to classrooms by branch duct system, from a single main duct on each floor. The main duct size is calculated according to the required cooling CFM for single classroom floor area, and the branch duct size is calculated from a single classroom cooling CFM. For the VRF equipment, two equipments cover the entire building cooling load.

Duct Size (Trunk): 21”
Duct Size (Branch): 11”



Equipment

Model Name: PURY-P336YSLMU-A
Manufacturer: Mitsubishi Electric
Type: R2-Series
Quantity: 2
Type: OA VRF Heat Pump system with Heat Recovery

Sustainability Considerations

A VRF heat pump system is chosen since it is space-efficient and DOAS ventilation system did not require us to integrate OA with the heating/ cooling system. Air-to air heat pump is used for simultaneous heating and cooling effect. Energy recovery system could be integrated with VRF system for sustainability reason. VRF system allows less fvrequent operation to maintain the desired temperature condition.

WATER SYSTEMS

Code

*2018 International Plumbing Code (IPC) Section 403 is used to calculate the number of water fixtures, classifying the building as Educational Occupancy. According to EPA Portfolio Manager's Median Water Use Intensity, a K-12 school uses 10 gal/sqft.

Water Use Intensity: 10 gal/sqft
Total Building Floor Area: 45,030 sqft
Estimated Water Use: 450,300 gallons of water/year for the entire building.
According EPA chart, about 45% of water is used in school for restrooms

Approximately 202,635 gallons/year might be used in the proposed ECS for restrooms.

Occupants

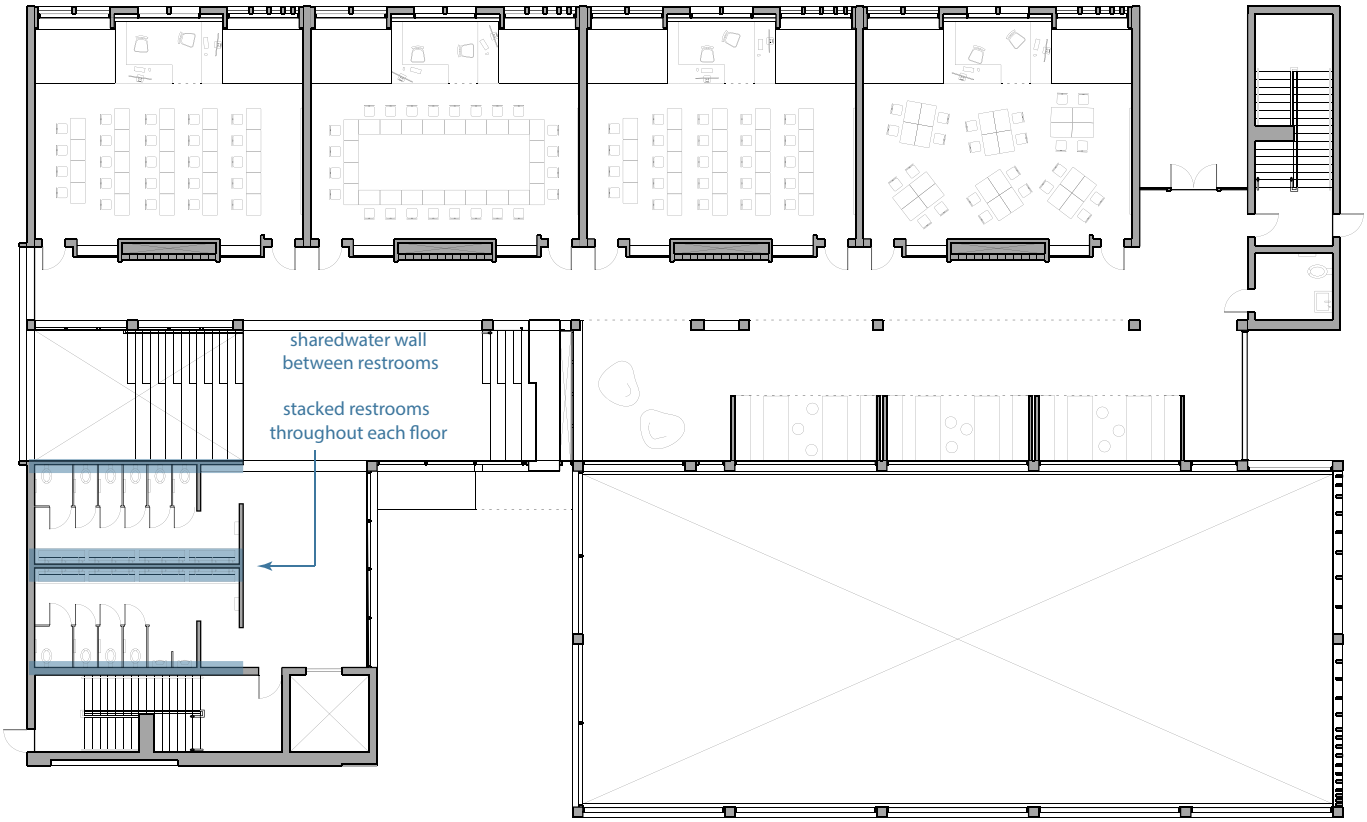
Assumed number of occupants: 288 students + 24 teachers + 8 staffs = 320 people.
The total occupant divided into half by gender.
Female: 160
Male: 160

		Female	Male	Total
Water Closet:	1 per 50	4	4	8
Lavatories:	1 per 50	4	4	8
Drinking Fountain:	1 per 100			4
Other:	1 service sink			1

Total Water Fixtures + Savings

The number of required WCs according to the code seemed too small for the school, since the facilities would be used during a short period of time by a large amount of people, such as recess time. Therefore, we decided to increase the number of water closet fixtures that would be more reasonable.

	Female	Male	Total
Water Closet	24	16	40
Urinals	-	8	8
Faculty WC			3
Drinking Fountain			4
General Sink			35
Kitchen Sink			2
Service Sink			1



We have utilized an efficient layout of plumbing where each set of bathrooms are vertically stacked to minimize the water travel distance from the ground to the floor.

Percent Water Savings

	Total # Fixtures	IPC 2018 value	High efficiency	% saving
WCs	43	1.6 gpf	Commercial Dual flush (1.6/1.0gpf)	0% based on 1.12 gpf avg shown
Urinals	8	1.0 gpf	0.125 gpf	87% below UPC
Sinks	38	2.2 gpm	0.5 gpm	77% below UPC

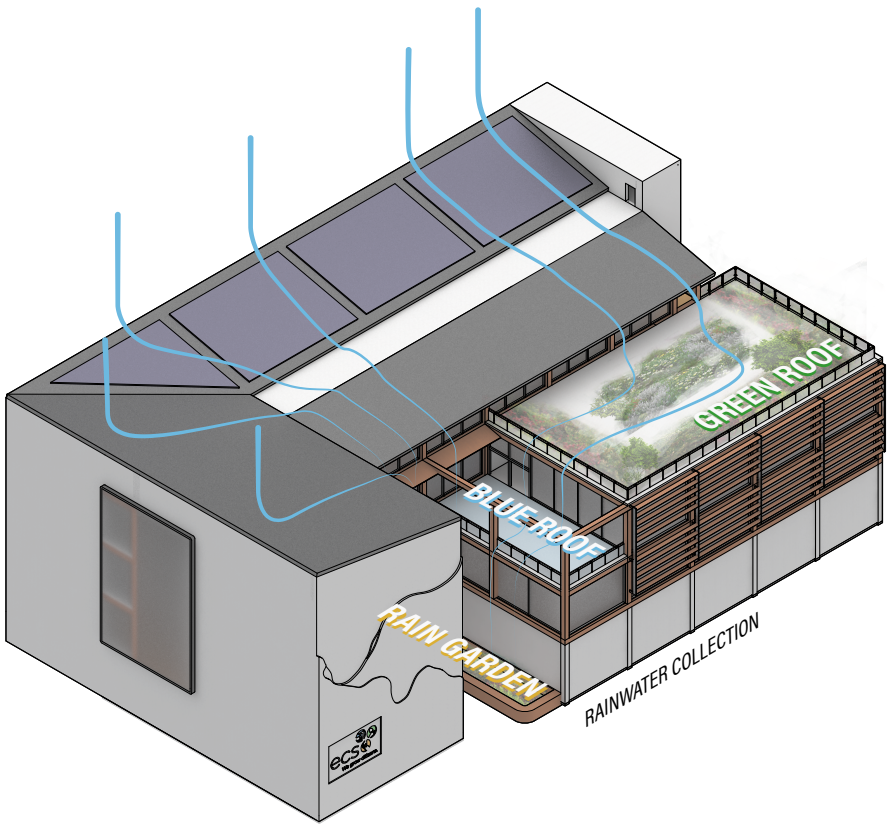
Code Based Fixtures vs High Efficiency Fixtures

	# of uses of water closets	Gallons used by code-based WC	Gallons used by high performance WC	# of uses of urinals	Gallons Used by Code-based Urinals	Gallons Used by High Performance Urinals
Female (160)	0.5 x 160 = 80 uses	1.6 gpf x 80 = 128 gal/day	1.12gpf x 80 = 89.6 gal/day	-	-	-
Male (160)	0.1 x 160 = 16 uses	1.6 gpf x 16 = 25.6 gal/day	1.12 gpf x 16 = 17.9 gal/day	0.4 x 160 = 64	1.0 gpf x 64 =64 gal/day	0.125 gpf x 64= 8 gal/day
Total gallon/day	-	153.6 gal	107.5 gal	-	64gal	8gal
Gallon saved by type of fixture/ day	-	-	46.1 gallons **30% Saving**	-	-	56 Gallons **87.5 % Saving**

*Water savings based on LEED numbers of uses per day compares the gallons

Table 2. Default Fixture Uses, by Occupancy Type

Fixture Type	FTE	Student/Visitor	Retail Customer	Resident
	Uses/Day			
Water Closet				
— Female	3	0.5	0.2	5
— Male	1	0.1	0.1	5
Urinal				
— Female	0	0	0	n/a
— Male	2	0.4	0.1	n/a



Roof Rainwater Capture

According to EPA graph, school generally uses 30% of water supplies for irrigation.
Approximately 148,050 gallons of water used for landscape per year.
The net roof catchment area is (excluding equipment area) 8,530 sqft. 90% runoff efficiency is assumed since the roof has a smooth surface. Assumed average rainfall for Pittsburgh is 38 inches per year.

Month	Avg Monthly rainfall in inches	Avg Gallons of Rainfall/sqft of roof area (Col B x 0.623	Ave Gal Available per Month based on Roof Area in sqft	Collection at 90% efficiency (gallons)	Collection at 90% efficiency in a drought year (50% less rainfall)	Total gallons required for 20 days
January	2.7	1.68	14,330	12,897	6,449	2,310
February	2.4	1.50	12,795	11,516	5,758	2,310
March	3	1.87	15,951	14,356	7,178	2,310
April	3.1	1.93	16,463	14,817	7,409	2,310
May	4	2.50	21,325	19,193	9,597	2,310
June	4.3	2.68	22,680	20,412	10,206	2,310
July	3.8	2.37	20,216	18,194	9,097	2,310
August	3.5	2.18	18,595	16,736	8,368	2,310
September	3.1	1.93	16,463	14,817	7,409	2,310
October	2.3	1.43	12,198	10,978	5,489	2,310
November	3.2	2.00	17,060	15,354	7,677	2,310
December	2.9	1.86	15,866	14,279	7,140	2,310
Total	38.3	23.86	203,526	183,173	91,587	

* *https://www.weather-us.com/en/pennsylvania-usa/pittsburgh-climate#rainfall

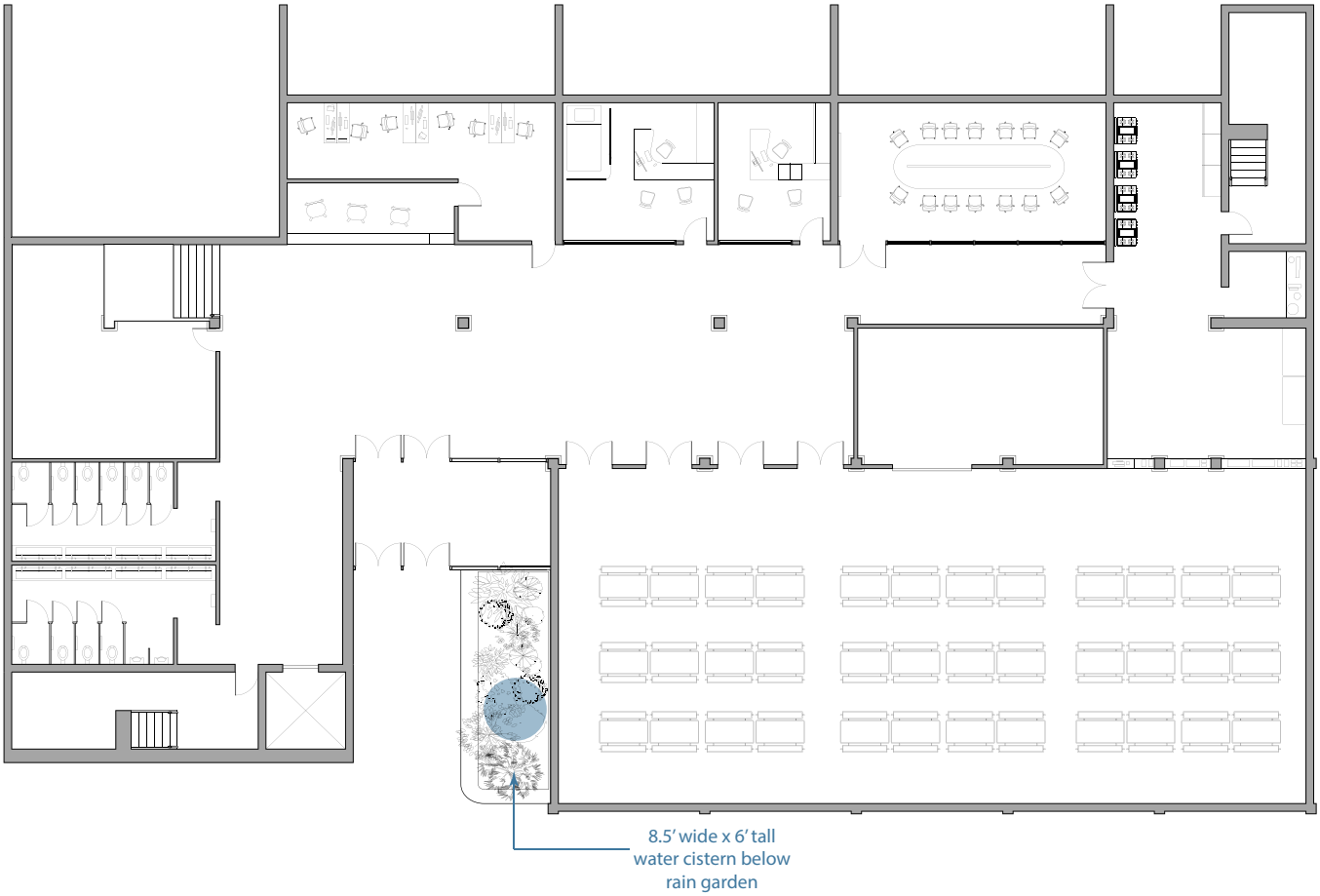
Total Orifinal annual water use at 10 gal/ft2 : 450,300 gallons per year
Monthly total water use: 37,525 gallons per month
Gallons/Day (Code Based Fixtures vs High Efficiency Fixtures): 115.5 gallons/day
Annual use in gal (260 days/ year): 30,030
Total monthly use in gal: 2,503
20-day storage to limit legionella growth : 2,310

Water Cisterns

2,310 gallons x 8.33 lbs/gal = 19,242 lbs of cistern tank.
Approximately 2,500 gallons/month of water would be required for water cistern.

Assuming **6' height** for the water cistern, the width for a cistern that can hold 2,310 gallon is:
V (ft3) = ∏ r2h
7.48 gallons/ ft3, so 2,500gal/7.48 = 335 ft3
335 ft3 = 3.14 x r2 x 6'
r = 4.22'

Approximate dimension of the water cistern is 8.5' wide by 6' high.



Placement

Below-ground placement, under the proposed rain garden on the ground level, adjacent to the main entrance. The rain garden is designed to capture drainage water from the designed green and blue roof. Pavement would need to be removed and replaced with permeable pavement.

Water Heating Equipment

Maximum hourly demand for Junior high school is 1.0 gal/student.
1.0gal/student x 320 occupants = 320 gallons at maximum hour.

According to Consulting Specifying Engineer, 77% of water could be saved by installing high performance fixture for faucet.

320 gallons x 0.23 = 73.6 gallons

Water Heater Type: A.O. Smith - Polaris: BTS 175 200
Number of Units: 2, provides a rated volume of 50 gal/tank and 100 gallon total
Fuel: Natural Gas
Efficiency: 96 %
Size of Equipment: 22" diameter x 63.7" tall

RENEWABLE ENERGY PRODUCTION

PV Panel

The chosen photovoltaic panel is the **SunPower X-Series (X21-345)**

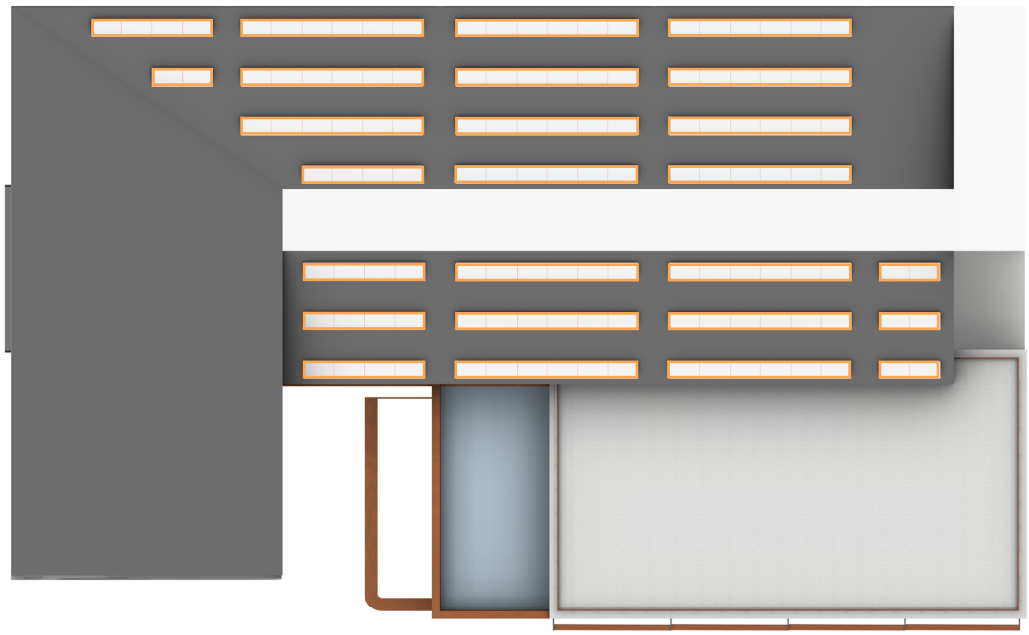
Solar Panel Type:	SunPower X-Series
Number of Panels:	130
Efficiency:	21.5%
Nominal Power:	345 W
Single Panel Size:	61.3″ * 41.2″

Adjustable Frames

The SunPower panels would be situated on adjustable tilt solar panel frames, where during the summer (starting April) the panels would be tilted down to 25 degrees (latitude-15) and during the winter (starting October) the panels would be tilted up to 55 degrees (latitude+15) for optimal solar gain during each season.

PV Panel Placement

The space around the rows of PV panels allow for maintenance of the panels and cleaning of snow. The rows were split into columns due to the extensive length a maintenance person would otherwise have to walk on a roof. The spaces in between the columns would ideally be replaced with stairs to ease the access to the back of the PV panels.



PV Watt

PV Panel * PTC = W
130*345W = **44.86kW**

Due to the adjustable tilt (which changes the panel tilt every April and October), the total kWh/Year results to be **57,417 kWh/Year**

The adjustable tilt is also beneficial to the students of the school as didactic architecture. The adjusting can help students understand that the angle the sun rays hit the ground change over seasons, which can lead to a lesson on the rotation of the Earth.

SUMMER

RESULTS

Print Results

55,044 kWh/Year*

System output may range from 53,052 to 57,175 kWh per year near this location.
Click HERE for more information.

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Value ($)
January	2.60	3,044	113
February	3.44	3,506	130
March	4.30	4,667	174
April	5.35	5,379	200
May	5.57	5,648	210
June	5.79	5,598	208
July	6.13	6,043	225
August	5.88	5,795	216
September	5.39	5,225	194
October	3.85	4,037	150
November	3.14	3,377	126
December	2.39	2,725	101
Annual	4.49	55,044	$ 2,047

WINTER

RESULTS

Print Results

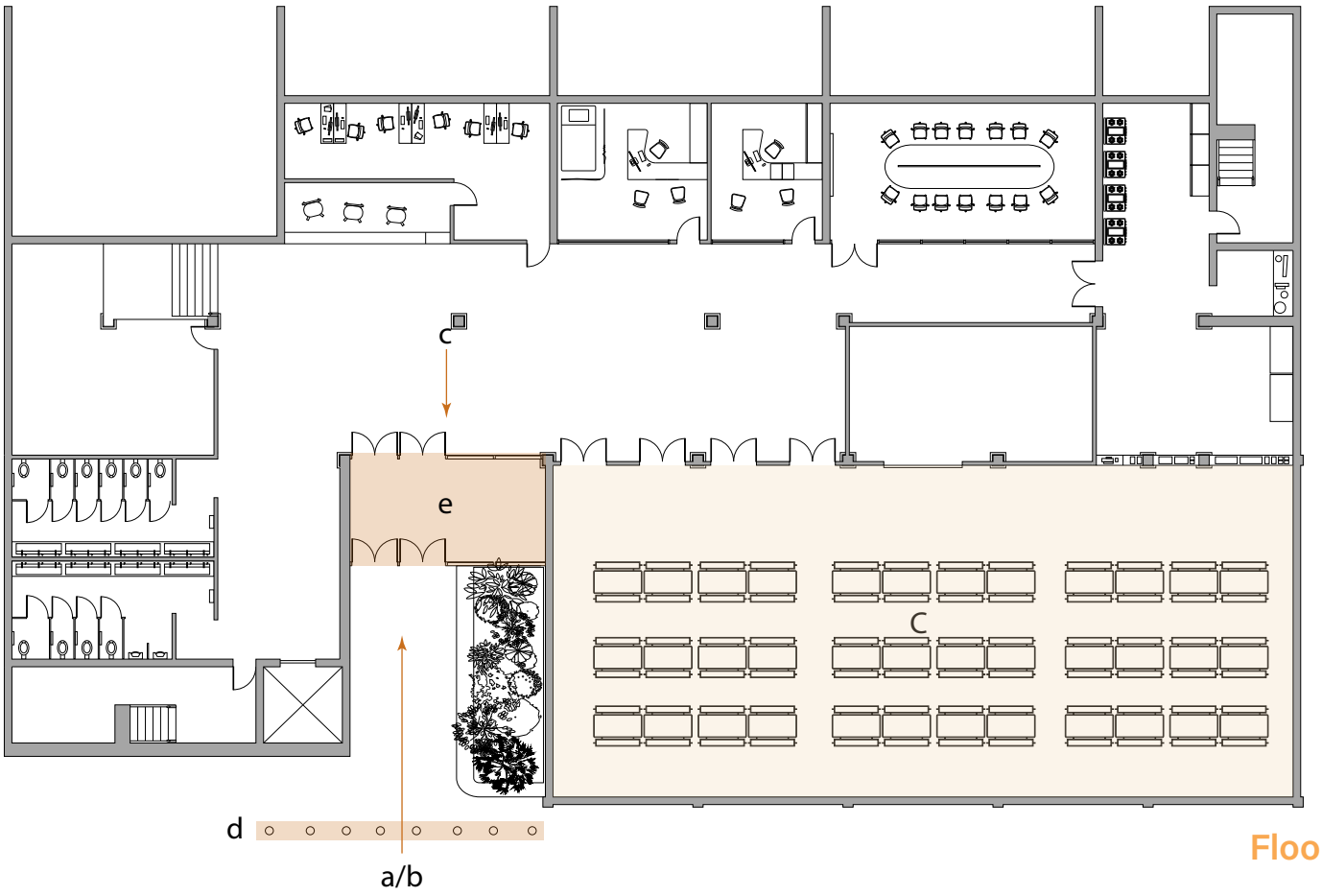
53,007 kWh/Year*

System output may range from 51,088 to 55,059 kWh per year near this location.
Click HERE for more information.

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Value ($)
January	3.09	3,585	133
February	3.85	3,876	144
March	4.33	4,672	174
April	4.87	4,897	182
May	4.61	4,701	175
June	4.60	4,482	167
July	5.00	4,964	185
August	5.18	5,121	190
September	5.28	5,114	190
October	4.16	4,324	161
November	3.74	3,976	148
December	2.93	3,296	123
Annual	4.30	53,008	$ 1,972

SAFETY AND SECURITY

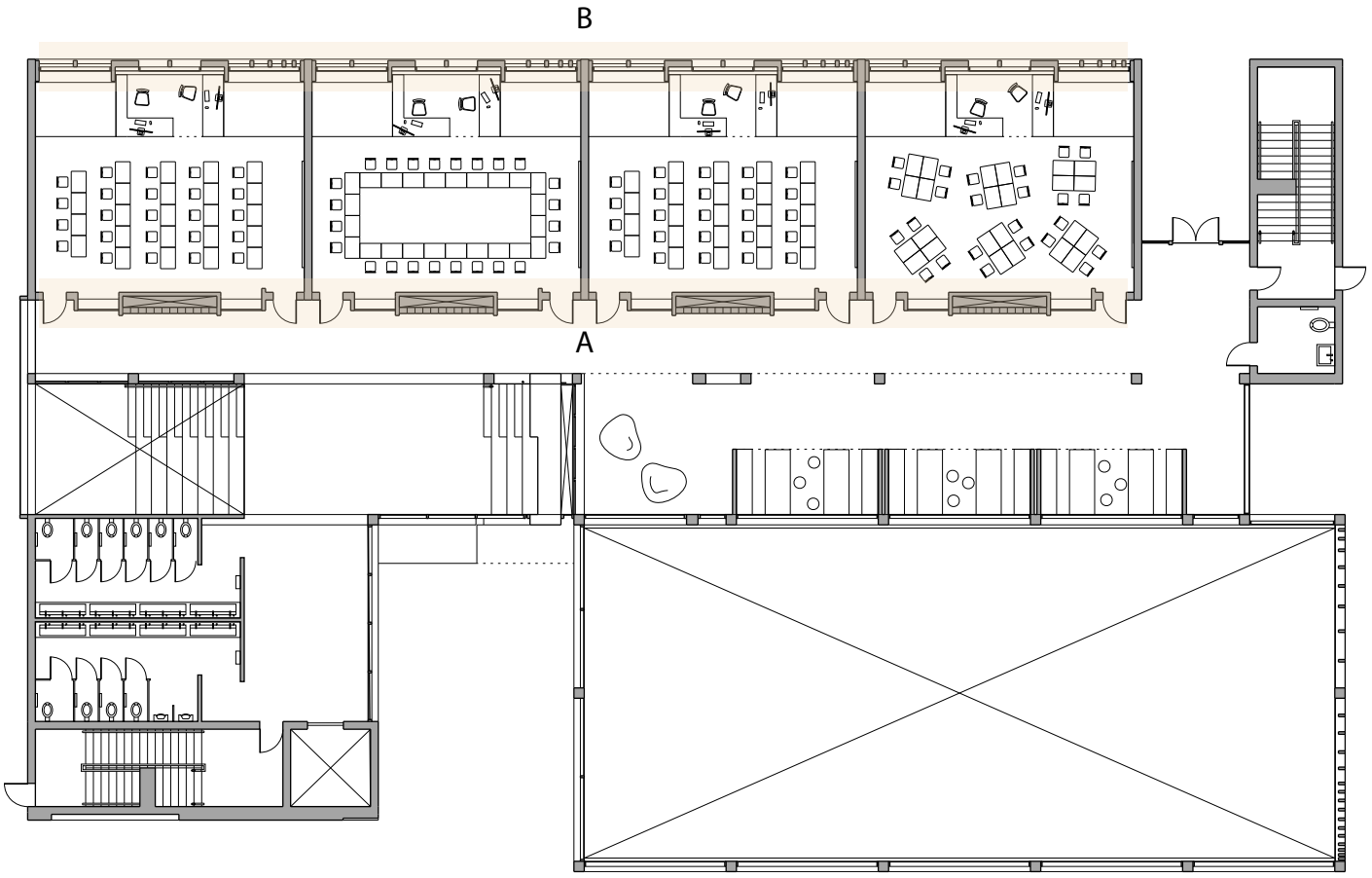
Main Entrance



Floor 1

a. One main point of entry for students and visitors
b. Well marked & clearly identifiable from street or main entry drive
c. Allows clear view from indoors of people entering building▪vegetation or other design features don't block view (low vegetation)
d. Bollards or other devices prevent vehicles from driving into entrance
e. Secure buffer zone (security vestibule) just within main door that allows security screening of visitors

Other Features for Security



Floor 2

A. Ability to lock students behind doors
-Internal wing wall
B. Shield students from large window and clear lines of sight into classrooms
-Exterior shading device
C. Safeguard students when they meet for assemblies and meals