STANFORD
UNIVERSITY

DESIGN LAYOUT FOR TOMMYMENG'S SUSTAINABLE EXHIBITION CENTER


DESIGN IDEAS &
INSPIRATIONS

As the course project for CEE220B, I plan to design a Sustainable Built Environment Learning and Exhibition Center. When I come up with this idea, the first thing I need to consider is the location of the exhibition center. I am Chinese and I have been lived in Beijing for more than 23 years. I am so familiar with this city and the long-time living experience can help and provide detailed information for my deign.

The proposed site is located right next to the Beijing Botanic Garden, and it's next to the road so it's easy to access to as shown in the figure above. There's no high-rise or even low-rise in the surrounding area so it's easy for the building to capture sunlight and utilize it efficiently. The location is also flat enough, so we do not need to care much about the topography influence.

The overall sustainability goal that I want to achieve through my design is to be environmentally friendly. This design is supposed to be cost-effective for construction and maintaining, have less impact on the environment and surrounding society, use less energy during operation, and be educational and meaningful as well. In order to fulfill the requirement, I come up with the following strategies:

1.Utilizing Natural Light

I can use some glasses, windows, and curtain walls in order to utilize the natural light. If we can increase the utilization of natural light, the usage of electricity and even heating can be reduced in a certain amount.

2. Green Decoration and Water Coverage

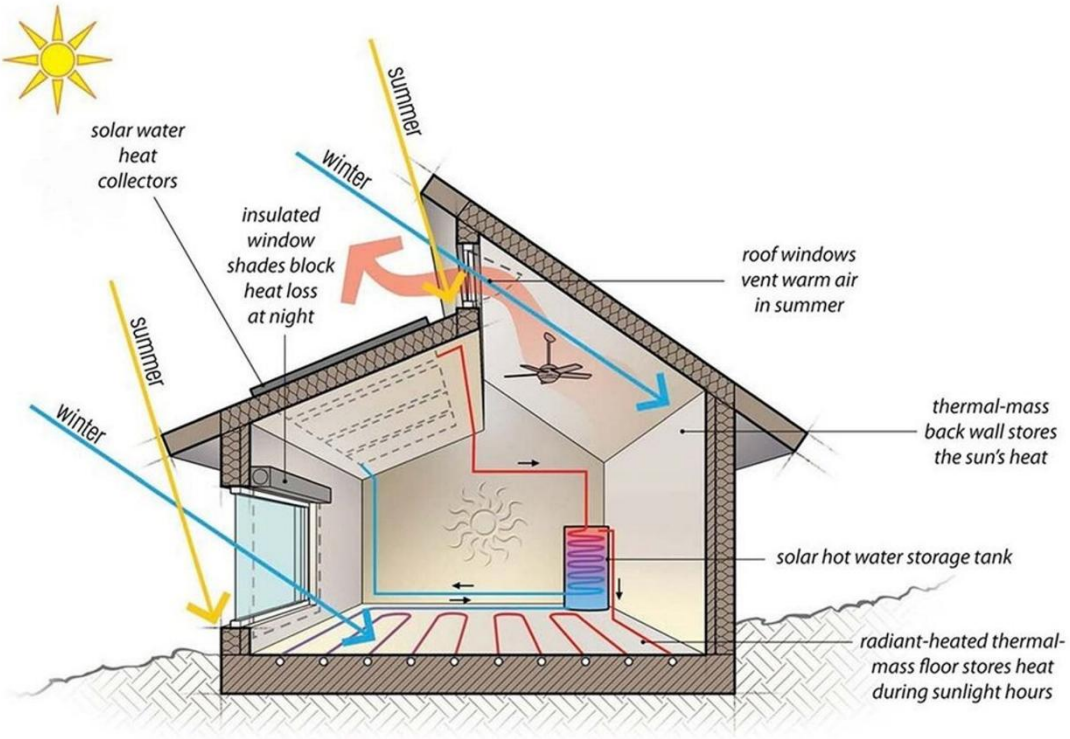

DESIGN
STRATEGIES

At this stage, I start to make my ideas more concrete, so the following are four main goals that are supposed to be accomplished through the life cycle of my Sustainable Built Environment Learning & Exhibition Center at Beijing.

Goal 1: Increase the energy efficiency during operation and maintenance to increase sustainability.

- **Measure:** I would consider the Energy Use Intensity (EUI) as a measurement. Energy use intensity (EUI) is an indicator of the energy efficiency of a building's design and operations. It is used in a number of different ways including to set a target for energy performance before beginning design, to benchmark a building's designed or operational performance against others of the same building type, or to evaluate compliance against energy code requirements.
  EUI is expressed as energy per square foot per year. It is calculated by dividing the total energy consumed by the building in one year by the total gross floor area of the building. To calculate EUI, energy used for one year must be converted from kilowatt hours of electricity or terms of natural gas to kBtu or GJ.

- **Targets:**
  minimally acceptable value: Reduce by about 30% EUI compared with the average EUI for similar Entertainment/Public Facilities in Beijing or China.
  desired / target value: Reduce by around 60% EUI compared with the average EUI for similar Entertainment/Public Facilities in Beijing or China



- **Strategies:**
  - Utilizing natural light as much as possible.
  - Apply positive solar heating design, such as installing Solar PV panels and heat exchangers, which transfer heat between two systems.
  - Apply passive solar heating design.
  - Passive solar heating is the use of the sun's natural ability to heat up spaces. Mid-afternoon sun shining through windows can heat up a house, and it is doubly efficient if the floors contain concrete floor pads and the ceiling contains insulation, which both store heat during the day to keep the home warm at night.

Goal 2: Reduce total carbon emission to be environmental-friendly.

- **Measure:** The overall carbon emission (kg CO2 per sq.ft) after applying a cradle-to-grave life cycle assessment(LCA).

- **Targets:**
  minimally acceptable value: Reduce the carbon emissions by around 15% compared with other buildings with similar functionality and location.
  desired / target value: Reduce the carbon emissions by around 30% compared with other buildings with similar functionality and location.

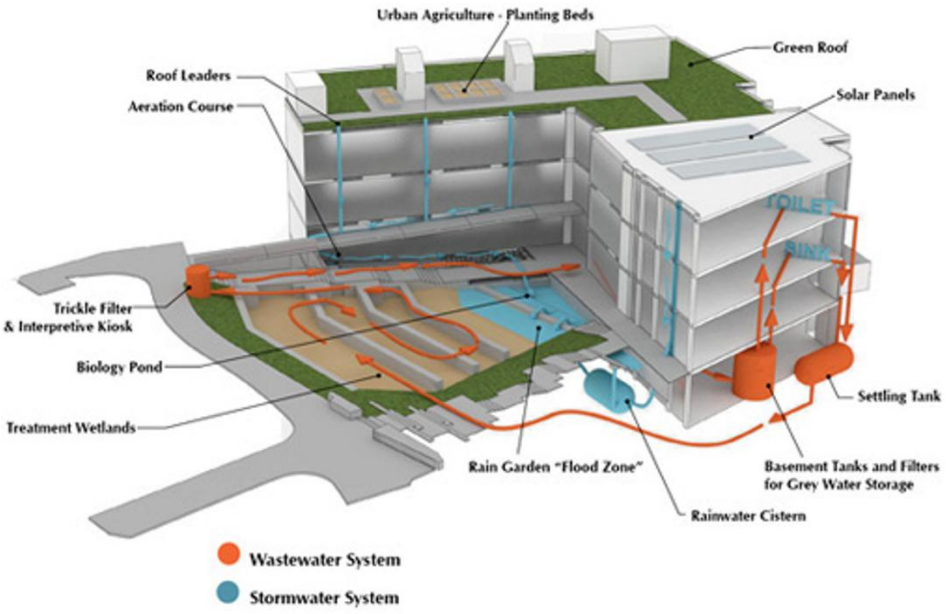
- **Strategies:**
  - Using environmental-friendly materials such as timber.
  - Using as much reusable materials as possible considering the grave stage.
  - Considering the availability of materials to decrease the energy usage for transportation.

Goal 3: Providing a Natural and Ecological Greenfield Design.

- **Measure:** the percentage of greenfield footprint compared with the total footprint (% sq. ft/sq. ft)

- **Targets:**
  minimally acceptable value: 30% greenfield ratio
  desired / target value: 60% greenfield ratio

- **Strategies:**
  - Utilizing roof planting and decorate the building with all kinds of plants, such as Boston ivy.
  - Constructing a garden or greenfield at the middle of the center.
  - Corporate with the National Botanical Garden, which is 15 km away from the site, as the resource for plant exhibition.

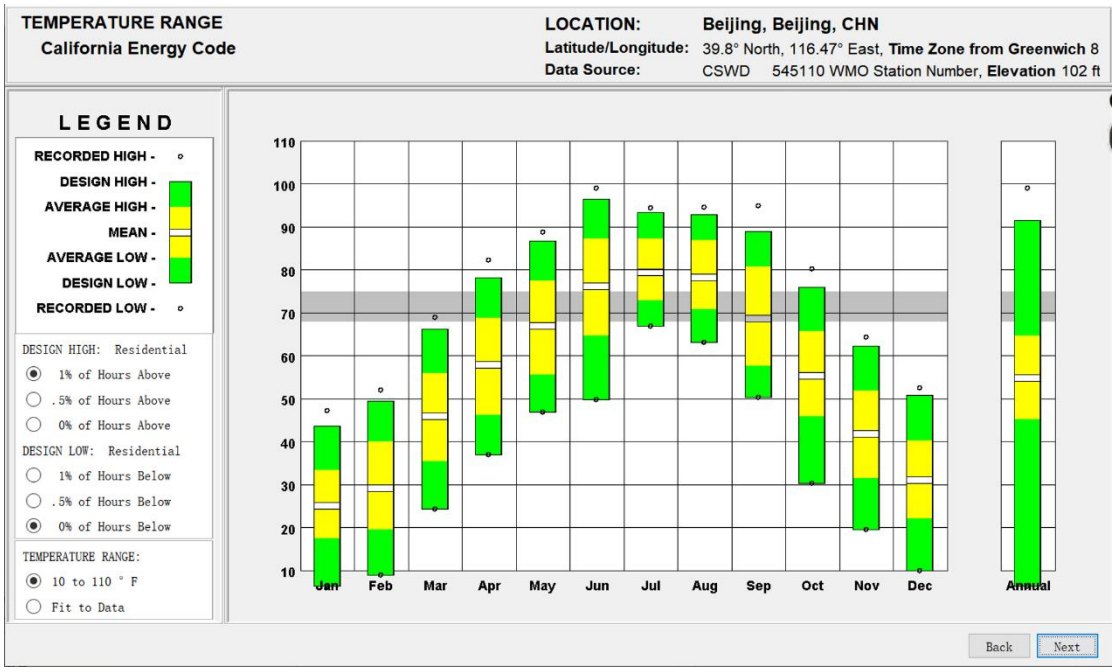


Goal 4: Obtaining natural water resources and reuse them.

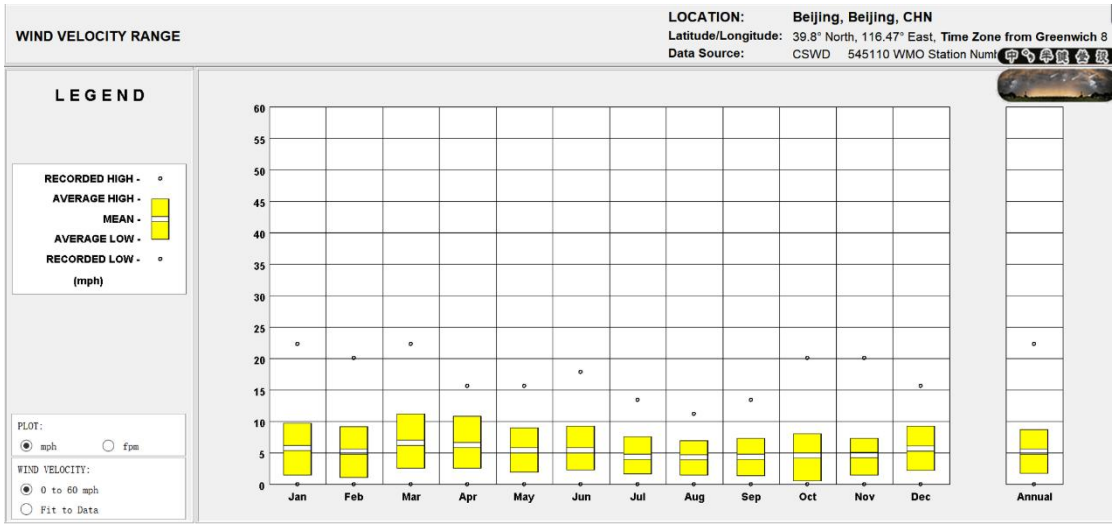
- **Measure:** The percentage of reused water resources and natural resources over the total water usage.
- **Targets:**
  minimally acceptable value: 50%
  desired / target value: 80%
- **Strategies:**
  - Applying a rainfall collection and purification system to collect natural water resources.
  - Designing a water recycle system for the entire building.

SITE GEOGRAPHICAL ANALYSIS

To have more detailed information for the design of my center, a site analysis is applied for the chosen location. Here are some results of importance:

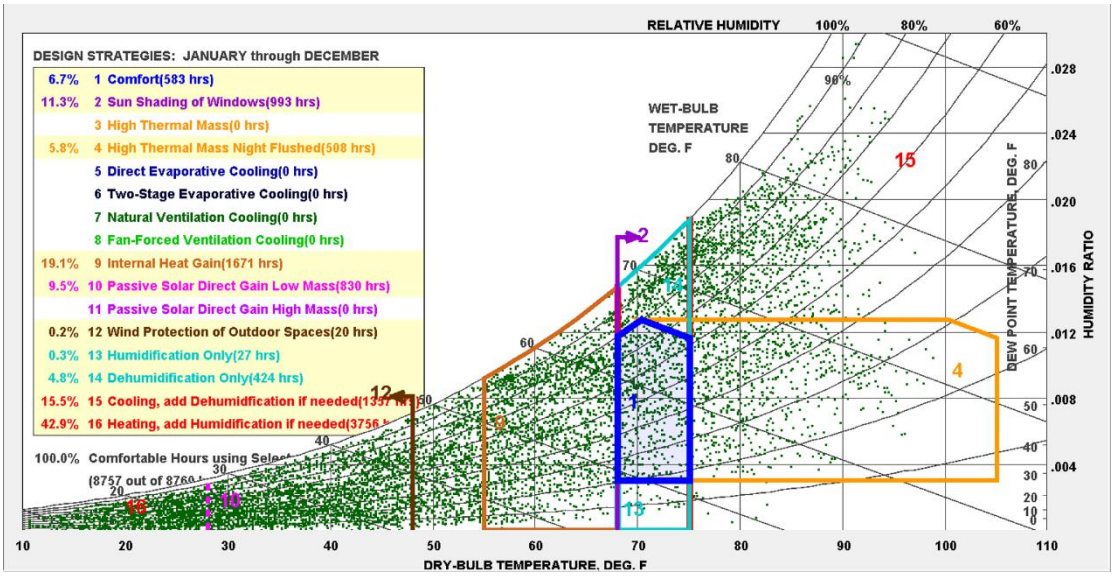


Climate Consultant 6.0 is applied to do a thorough research on the local climate. In the temperature range figure above, we can find that Beijing is pretty cold in winter (15°F -9.4°C mean in Jan) and hot in summer (80°F 26.7°C mean in July). Thus I need to design a powerful and efficient HVAC system to make the temperature more comfortable. This will be introduced in detail in the following HVAC section.

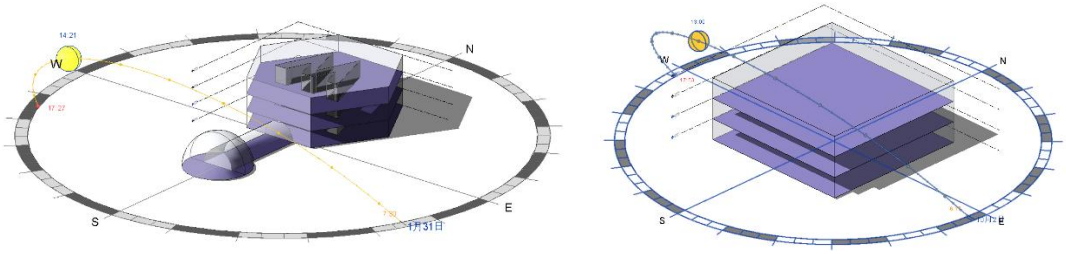


In the wind velocity range figure, it's obvious that there is little wind in Beijing. This is quite reasonable, since Beijing is a city surrounded by mountains in West, North, and East. Thus, we cannot consider the wind power generation in searching for our energy resources.

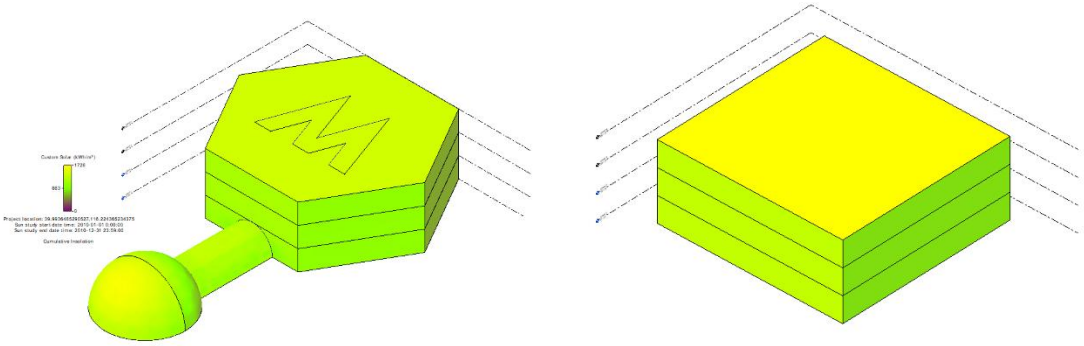
In the psychrometric chart, we find that the place is 6.7% naturally comfortable. Plenty strategies, (993 hours of sun shading of windows, 1357 hours of cooling and dehumidification, 3756 hours of heating and humidification…) are applied. Since Beijing is cold in winter and hot in summer, we need 15.5% of active cooling and 42.9% of active heating. This might be a serious problem need to be solved when designing the HVAC system.



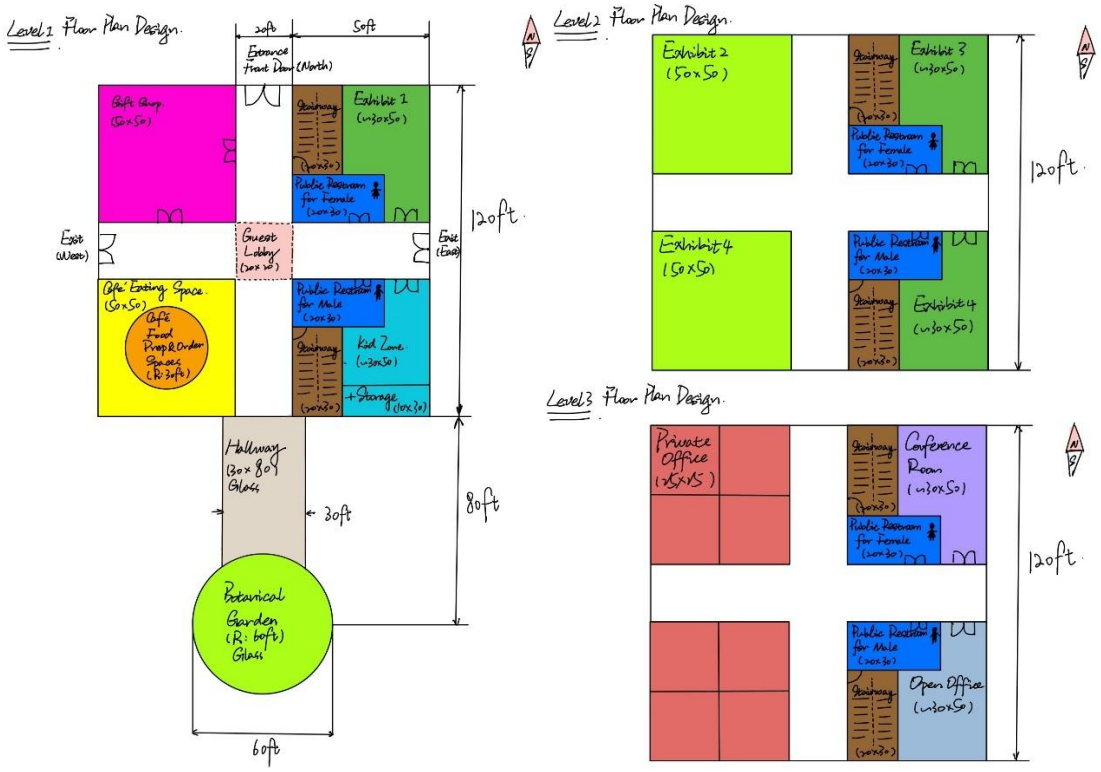
I come up with two alternative designs for the building massing as shown below. Design alternative1 has an overall mass floor area of 36923SF, and design alternative2 has an overall mass floor area of 36288SF.



I applied solar analysis for both alternatives, and the result is shown below:



SCHEMATIC DESIGN

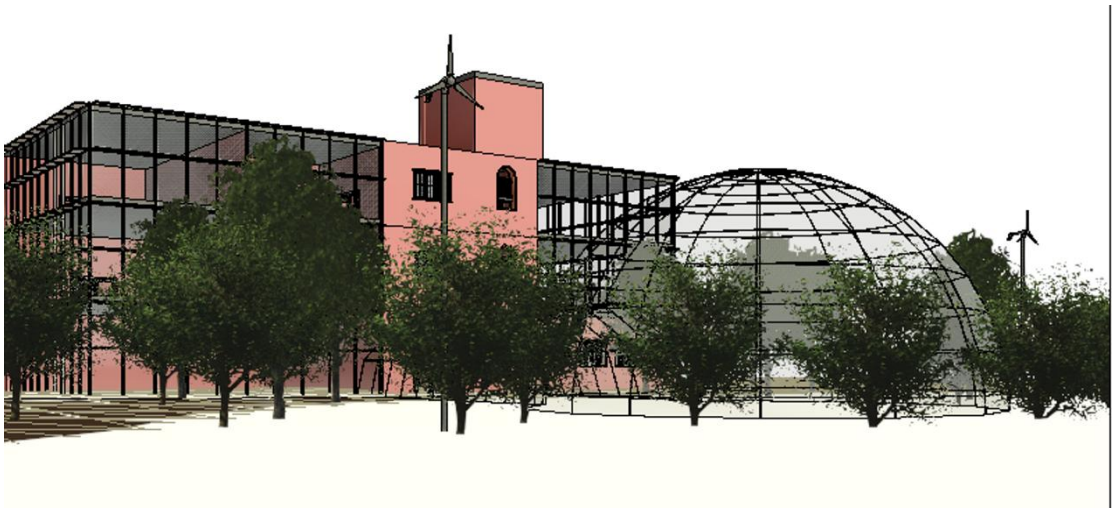


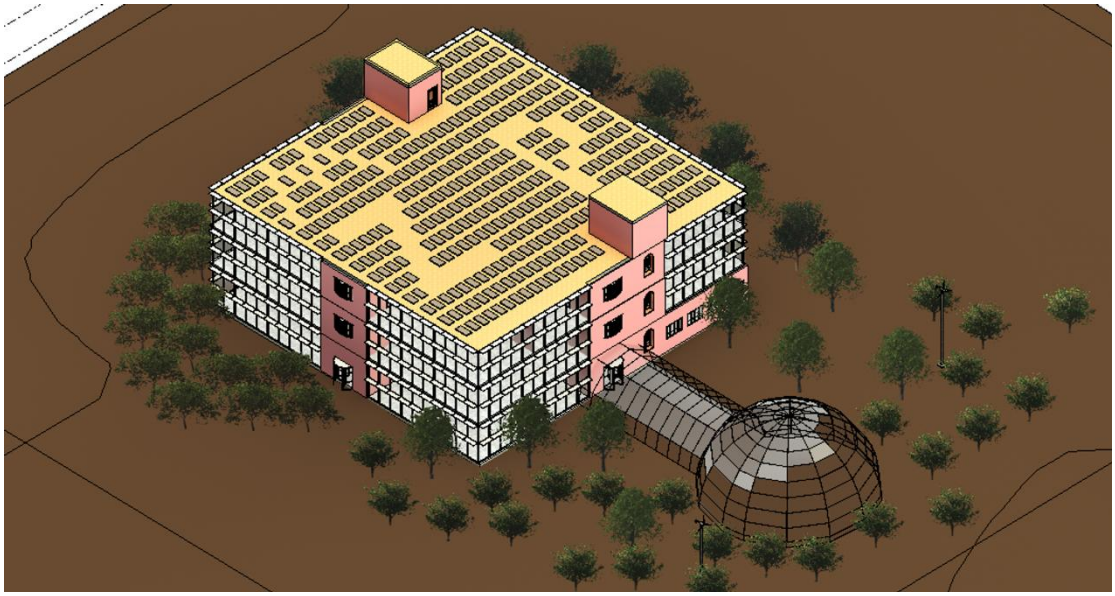
The figure above shows the drafted schematic design for my center that was drawn by myself. Different colors represent alternative functionalities. Since this is an exhibition center, exhibition rooms, offices and conference rooms are necessary. I also designed gift shop and a Café to enhance the customer experience here at my center. The following table demonstrates the function of all rooms, their area, and carrying capacity.

<Space Schedule>

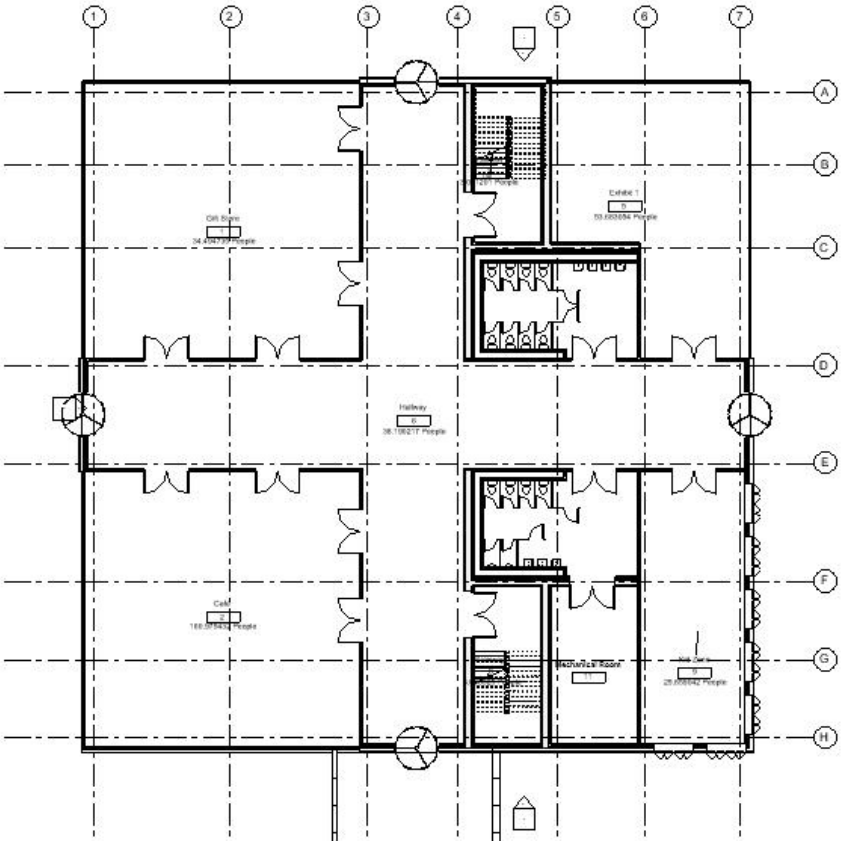
A	B	C	D	E	F
Number	Name	Area	Space Type	Area per Person	Number of People
1	Gift Store	2475 SF	Department Stor	72 SF	34.5
2	Cafe	2475 SF	Dining Area - Lo	15 SF	160.9
3	Stairway	378 SF	Stairway	108 SF	3.5
4	Public Restroom for	576 SF	Restrooms	108 SF	5.4
5	Exhibit 1	1480 SF	General Exhibitio	27 SF	55.0
6	Hallway	4272 SF	Corridor/Transiti	108 SF	39.7
7	Public Restrooms fo	576 SF	Restrooms	108 SF	5.4
8	Stairway	378 SF	Stairway	108 SF	3.5
9	Kid Zone	1452 SF	Playing Area Gy	36 SF	40.5
10	Exhibit 2	2475 SF	General Exhibitio	27 SF	92.0
11	Exhibition 4	2441 SF	General Exhibitio	27 SF	90.7
12	Stairway	378 SF	Stairway	108 SF	3.5
13	Public Restroom for	576 SF	Restrooms	108 SF	5.4
14	Exhibition3	1468 SF	General Exhibitio	27 SF	54.6
15	Public Restroom for	576 SF	Restrooms	108 SF	5.4
16	Stairway	378 SF	Stairway	108 SF	3.5
17	Exhibition 5	1468 SF	General Exhibitio	27 SF	54.6
18	Hallway	4272 SF	Corridor/Transiti	108 SF	39.7
19	Private Office 1	1232 SF	Office - Enclosed	215 SF	5.7
20	Private Office 2	607 SF	Office - Enclosed	215 SF	2.8
21	Private Office 3	601 SF	Office - Enclosed	215 SF	2.8
22	Stairway	382 SF	Stairway	108 SF	3.5
23	Public Restroom for	576 SF	Restrooms	108 SF	5.4

ARCHITECTURAL DESIGN

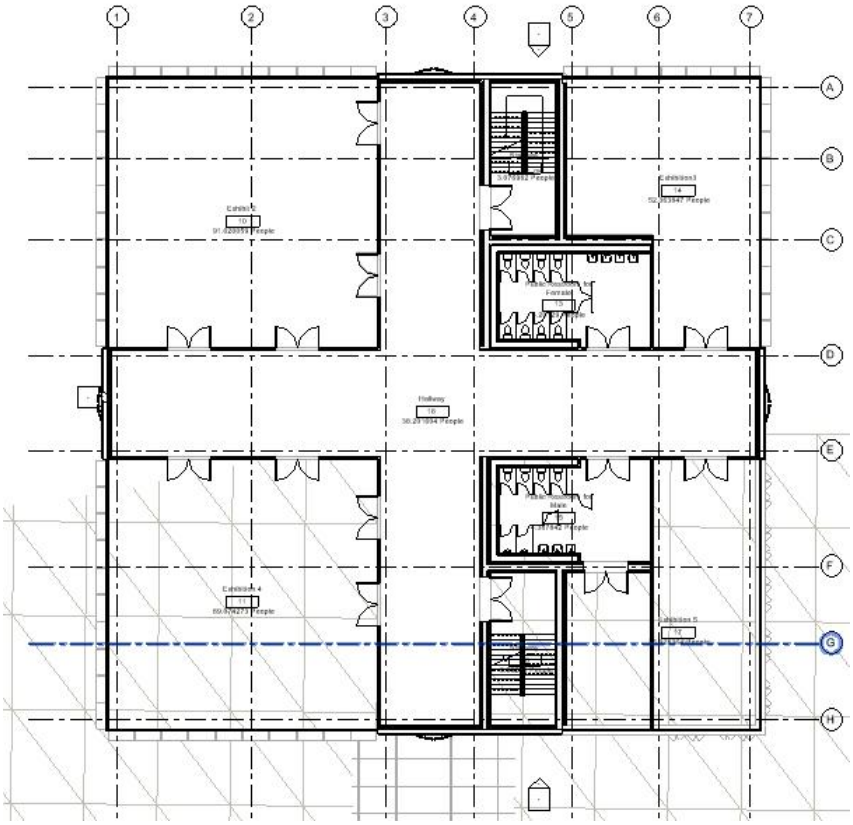




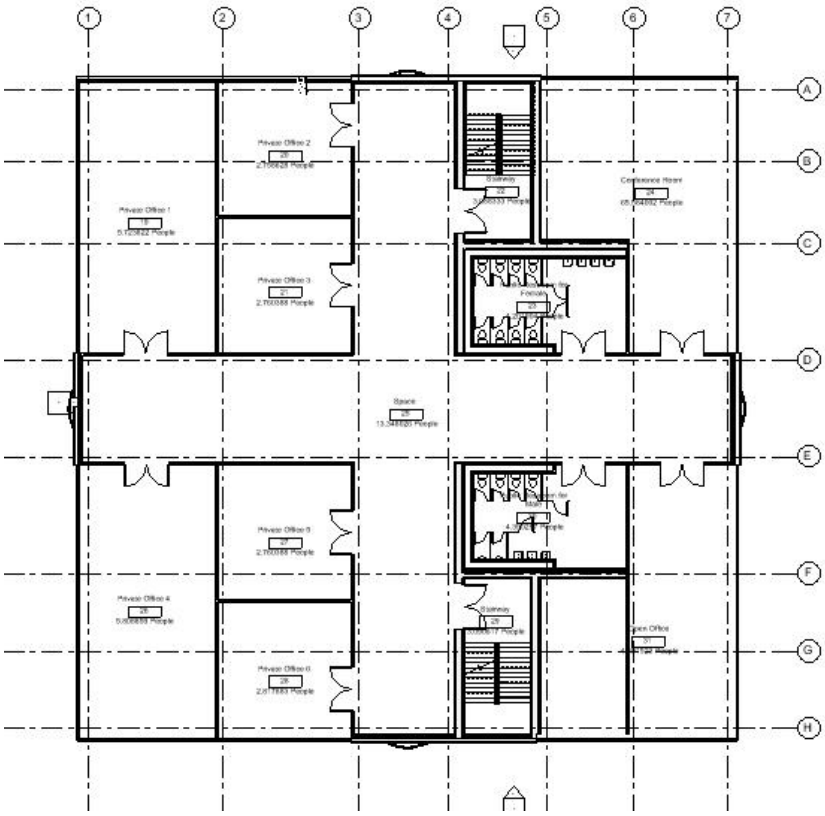
The figures above show the overview of the architectural design for my building. There is a huge semi-sphere made of glass in the southern side of the building, which is designed as a botanic garden to show the idea of environmentally friendly to all.



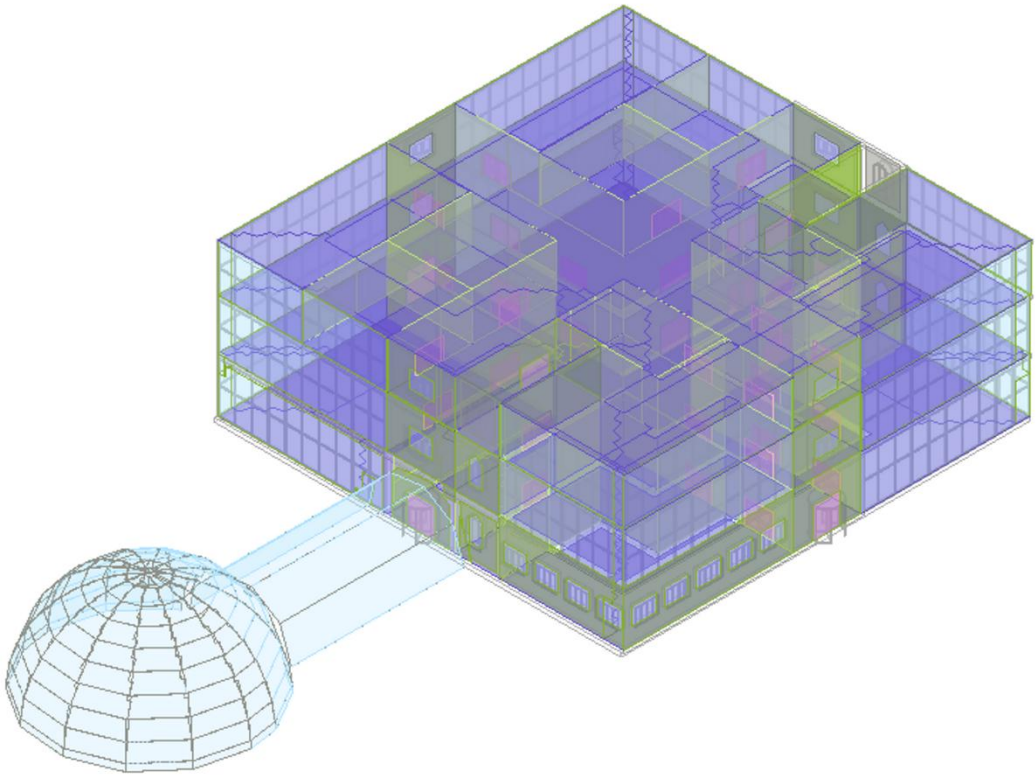
Floor Plan View for Level 1



Floor Plan View for Level 2

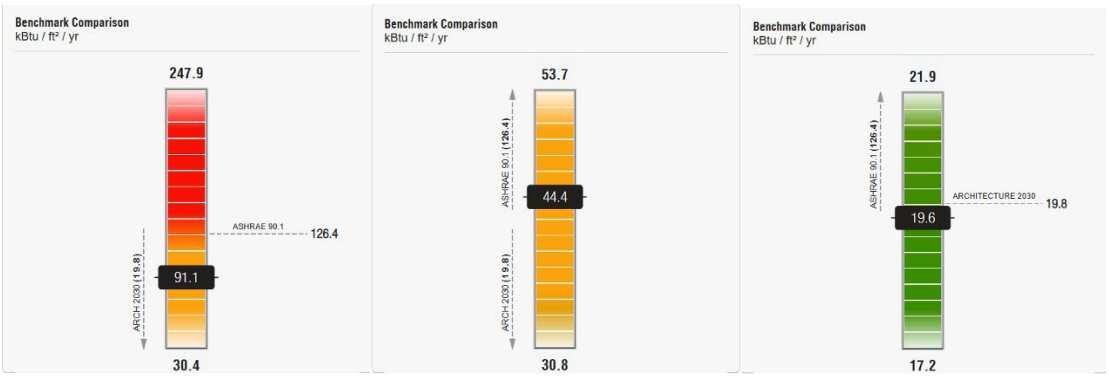


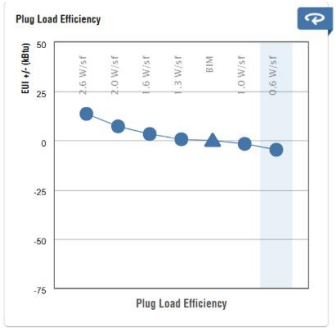
Floor Plan View for Level 3

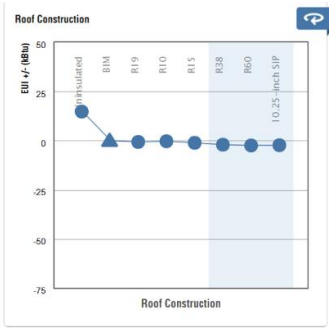


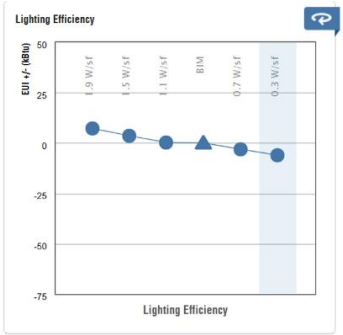
Energy Model Analysis for my Center

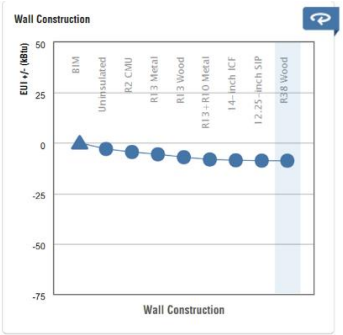
Since energy-efficient is one of the main considerations, I hope to figure out how much energy my model consumes. Thus I built up the energy model and ran the analysis on Insight. As shown below, the resulted EUI is 91.1 kBtu/ft2/yr, which is lower than the ASHRAE 90.1 (126.4 kBtu/ft2/yr). I then modified several factors for my energy design as shown below, and the resulted EUI could be reduced to 44.4 kBtu/ft2/yr, and finally to 19.6 kBtu/ft2/yr, which is less than the ARCHITECTURE 2030 (19.8 kBtu/ft2/yr). The energy conservation of the model is ideal with the adoption of these strategies.

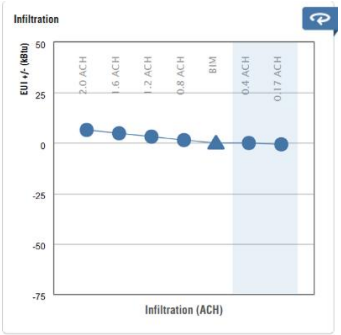


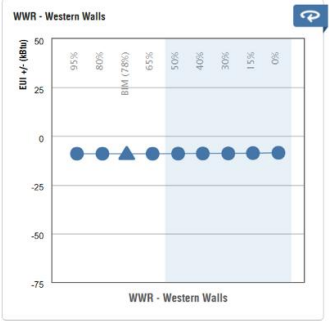


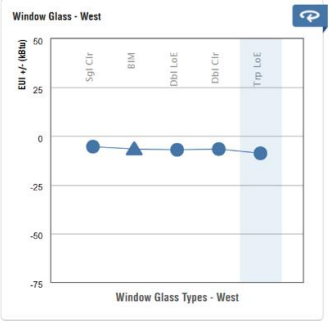


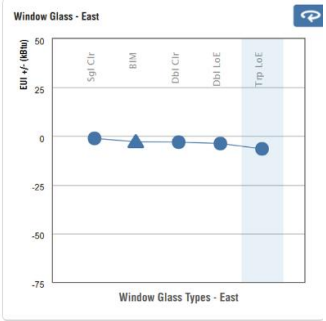


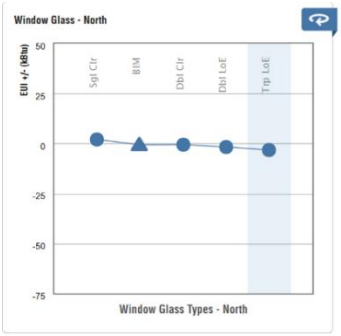


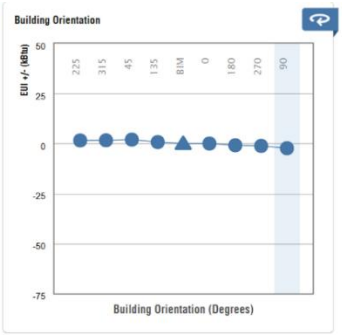








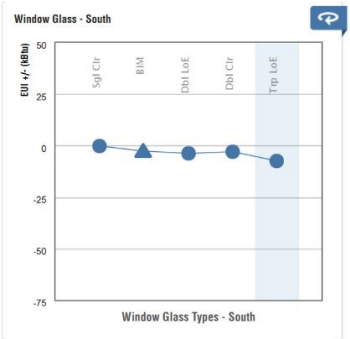


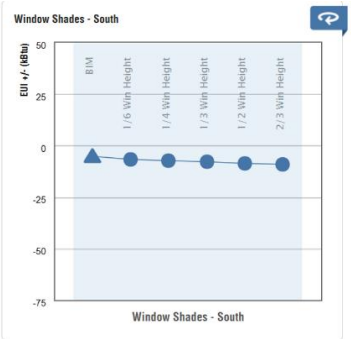


WWR - Eastern Walls

Window-Wall-Ratio (glazing area / gross wall area) interacts with window properties to impact daylighting, heating & cooling.

Current Setting:
95% - 0%

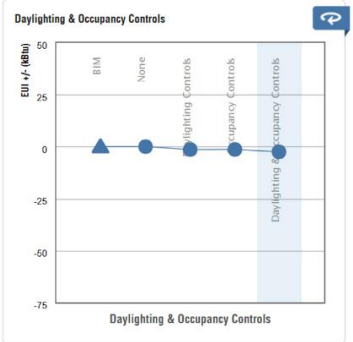




Window Shades - West

Shades can reduce HVAC energy use. The impact depends on other factors, such as window size and solar heat gain properties.

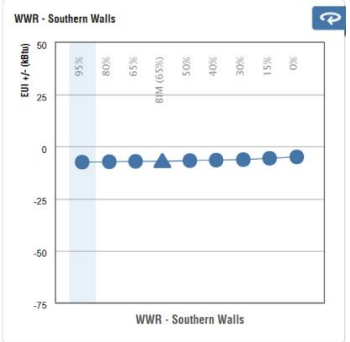
Current Setting:
BIM - 2/3 Win Height



Window Shades - East

Shades can reduce HVAC energy use. The impact depends on other factors, such as window size and solar heat gain properties.

Current Setting:
BIM - 2/3 Win Height



WWR - Northern Walls

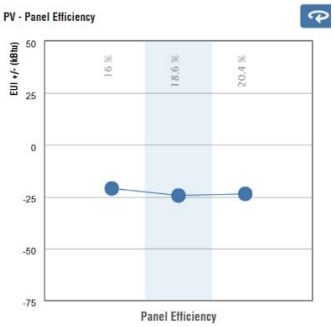
Window-Wall-Ratio (glazing area / gross wall area) interacts with window properties to impact daylighting, heating & cooling.

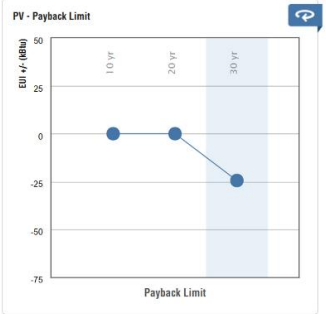
Current Setting:
95% - 0%

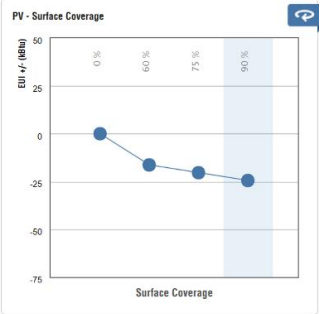
Window Shades - North

Shades can reduce HVAC energy use. The impact depends on other factors, such as window size and solar heat gain properties.

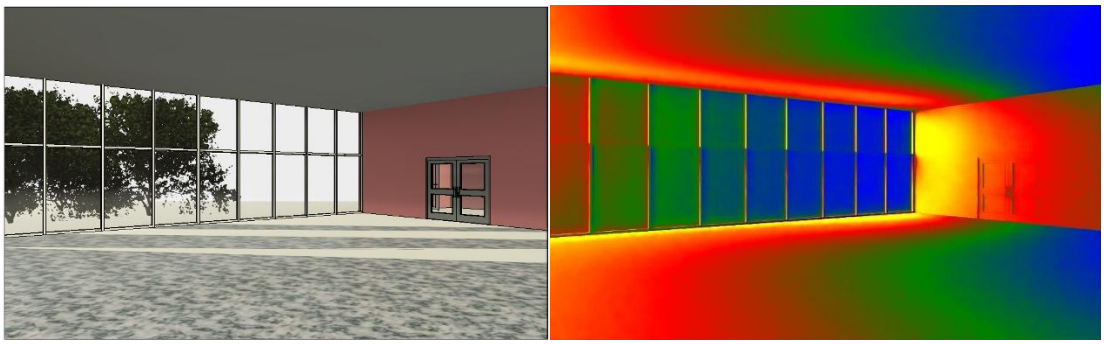
Current Setting:
BIM - 2/3 Win Height



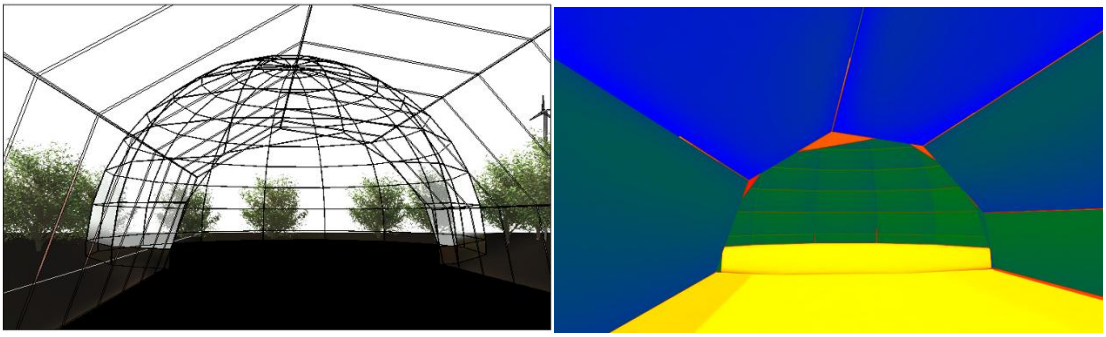




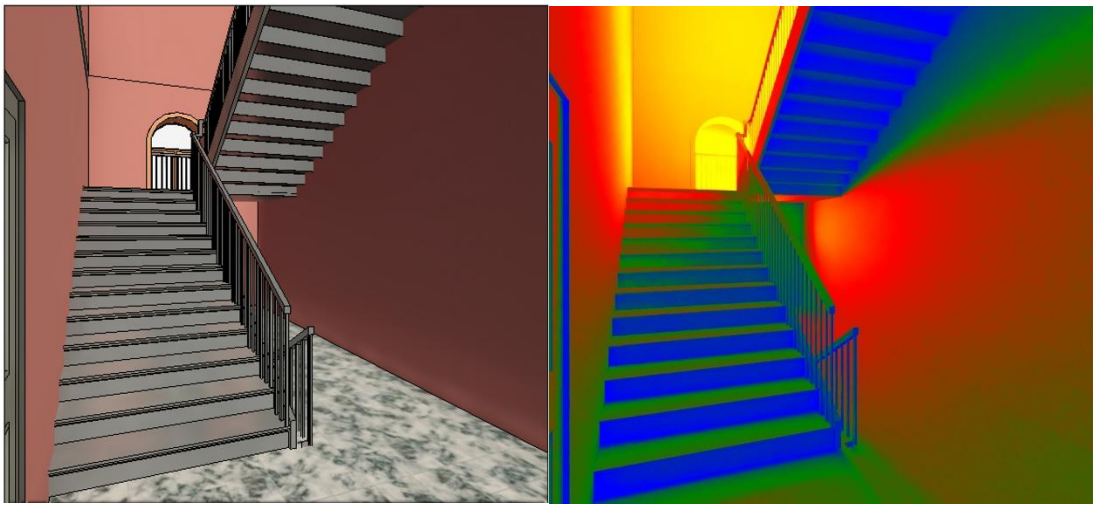
As consideration for the lighting design, I hope to utilize daylight as much as possible to reduce the usage of electricity. Thus I applied a large number of curtain walls and exterior windows in my architectural design. In order to check the actual effect, I applied the daylighting rendering tool in Revit, and the results are shown below:



Daylighting for Gift Store at 1st Floor

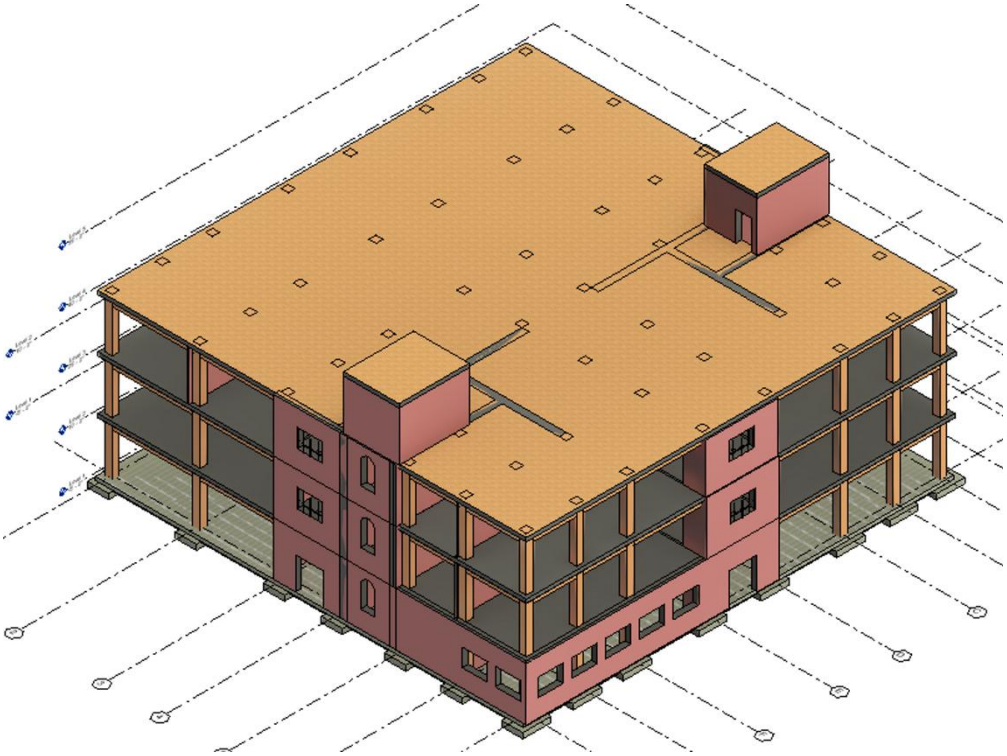


Daylighting for Botanical Garden at 1st floor

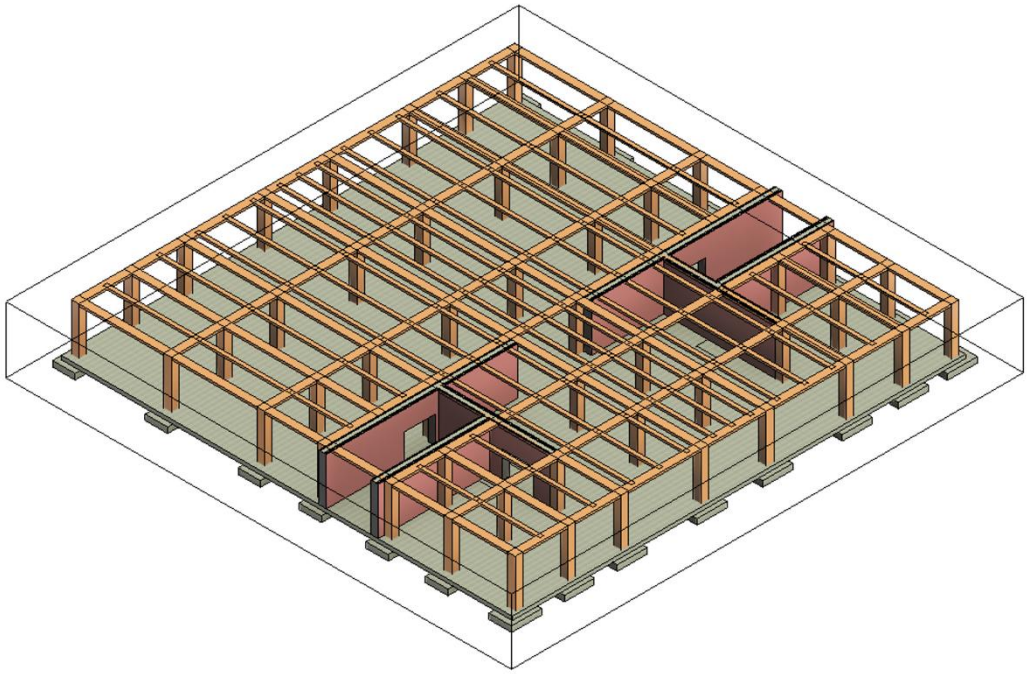


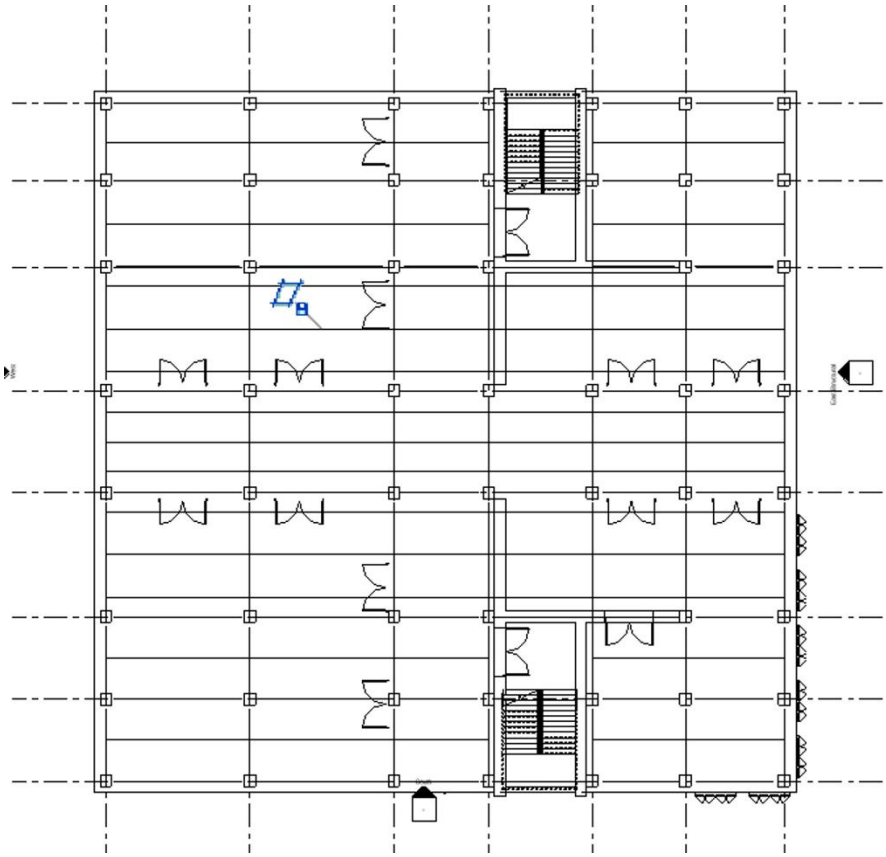
Daylighting for Stairway at 3rd floor

STRUCTURAL DESIGN

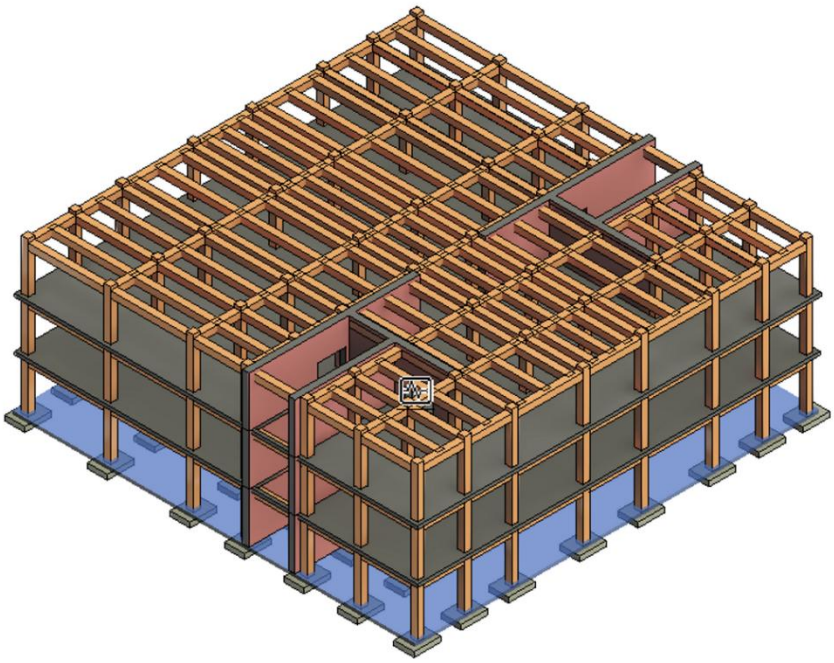


At the preliminary design stage, I hope to come up with a mass timber structure. It is not only qualified to provide enough strength and support, but also sustainable and aesthetic for my center. Thus, for the structural columns system here and the structural beams system below, I choose timber columns and timber beams to meet the design. I choose 24×24 timber column here, since it is strong enough to support the large span and does not affect the appearance as well. The beams have a -1’ excursion to be adjacent to the floor and support it. I also utilized shear walls around the stairways.



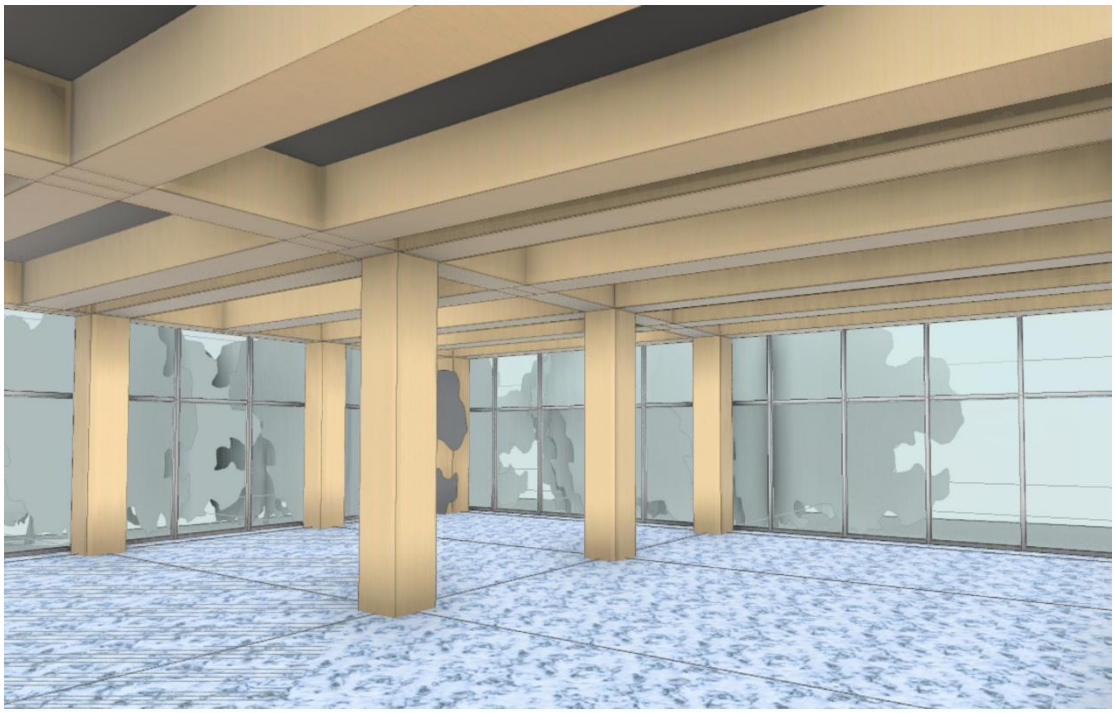


I also put timber beam system in my design, which consist of 24×24 timber with 7’ 4” span in the two sides and 5’ in the middle. In order to decrease the high stress on the field, I use 96” ×72” ×18” shallow foundation in my building. The distribution of my foundation is shown as below:



The following are a group of figures that demonstrate the coordination of my structural system with my previous architectural design. Enough space is maintained below the structural system for the following plumbing system design.

Hallway on 1st Floor

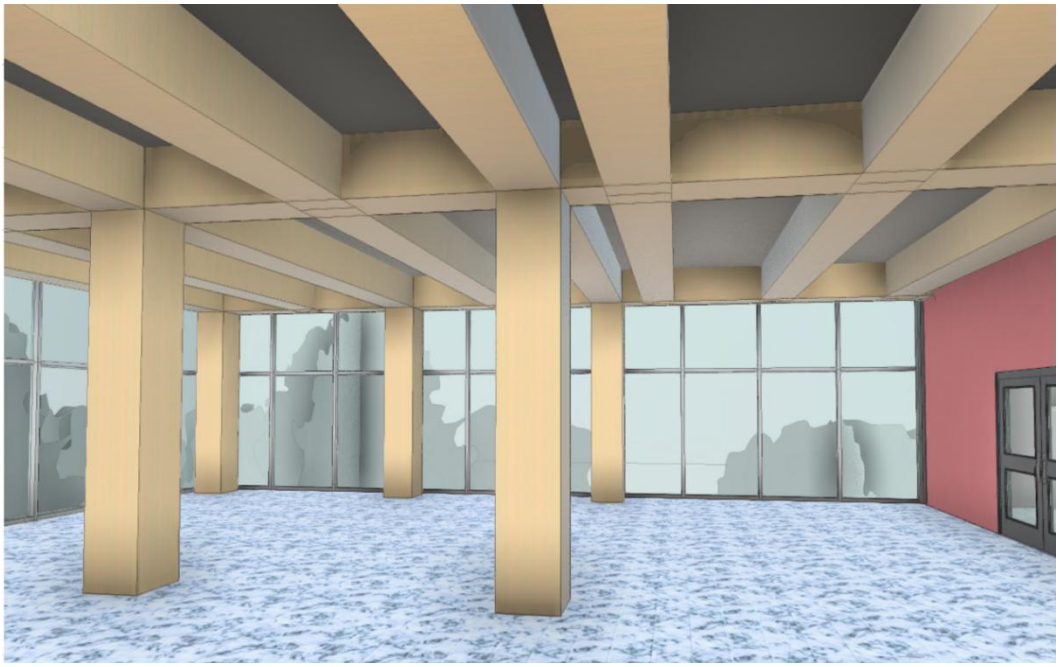


Gift Shop at 1st Floor

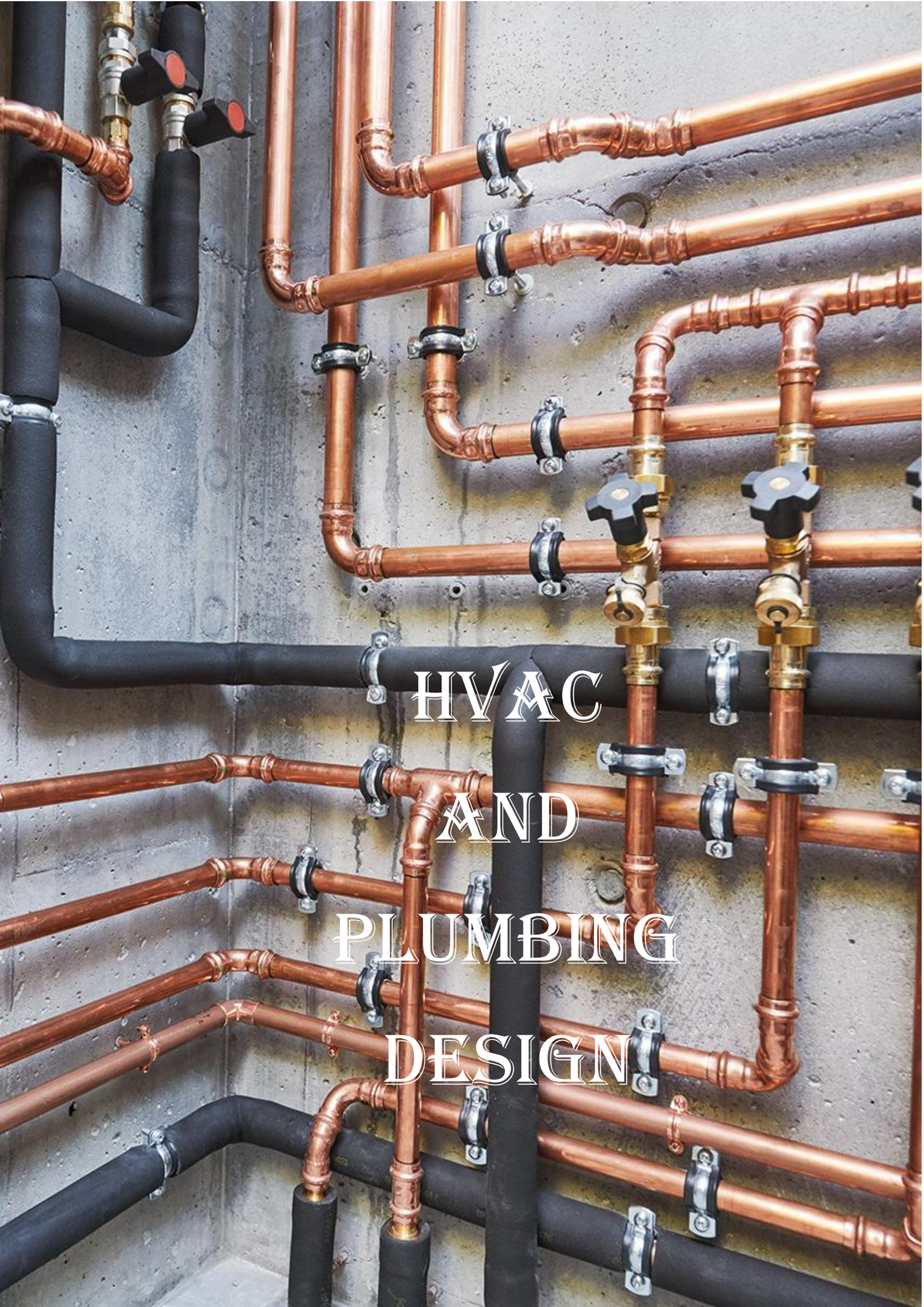
I need to make sure that there are no beams in my stairways that might block the way of tourists, so carefully design is necessary in advance.

Stairway at 2nd Floor

Since there are a lot of exhibition rooms in my center, there should not be too much columns in the middle, which might affect the visiting experience of my tourists.



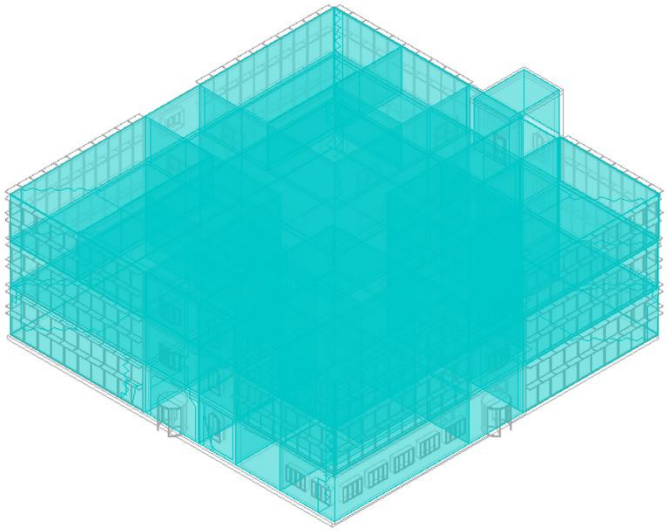
Exhibition at 2nd Floor



HVAC AND PLUMBING DESIGN

In previous section, geographic and climate analysis are applied to my site, and I can further design my HVAC system based on the weather conditions on my site. At this point, let's jump into some details for the overall HVAC strategies. For internal loads, most of the rooms are for regular function and purpose (ex: exhibition, restroom, office, meeting/conference room, cafe…), so the internal load is low (or normal) and we do not need much for this part. For external loads, as mentioned before, since the temperature here in Beijing is relatively extreme, the external load is high and need further strategies to reduce it.

Regardless of what strategy you use for heating and cooling, I still need to provide adequate ventilation to meet the minimum fresh air levels required. As mentioned before, I can use a few natural ventilations throughout the year, so the ventilation will need to be supplied mechanically by my HVAC system.

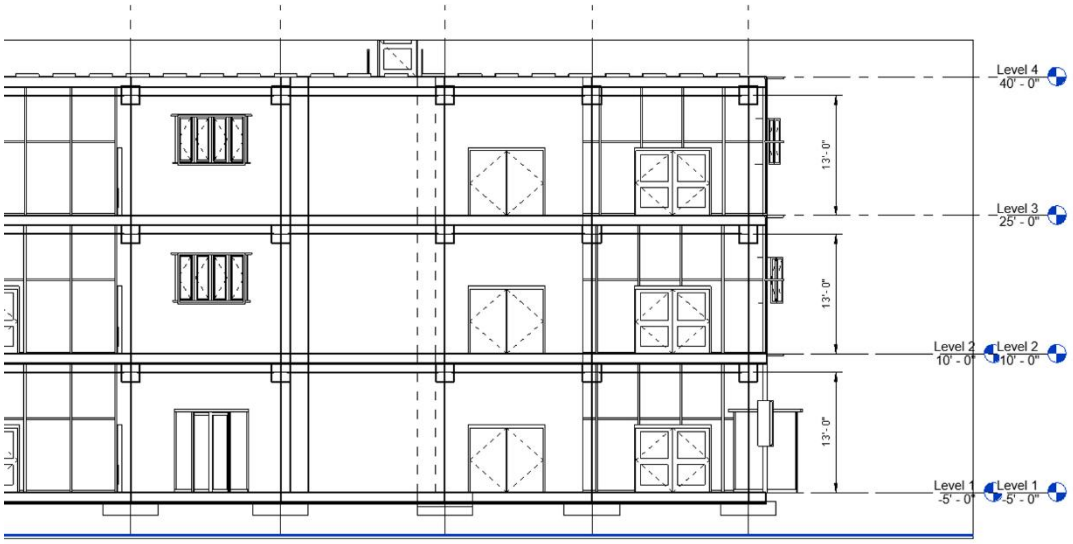


Strategies for Heating System

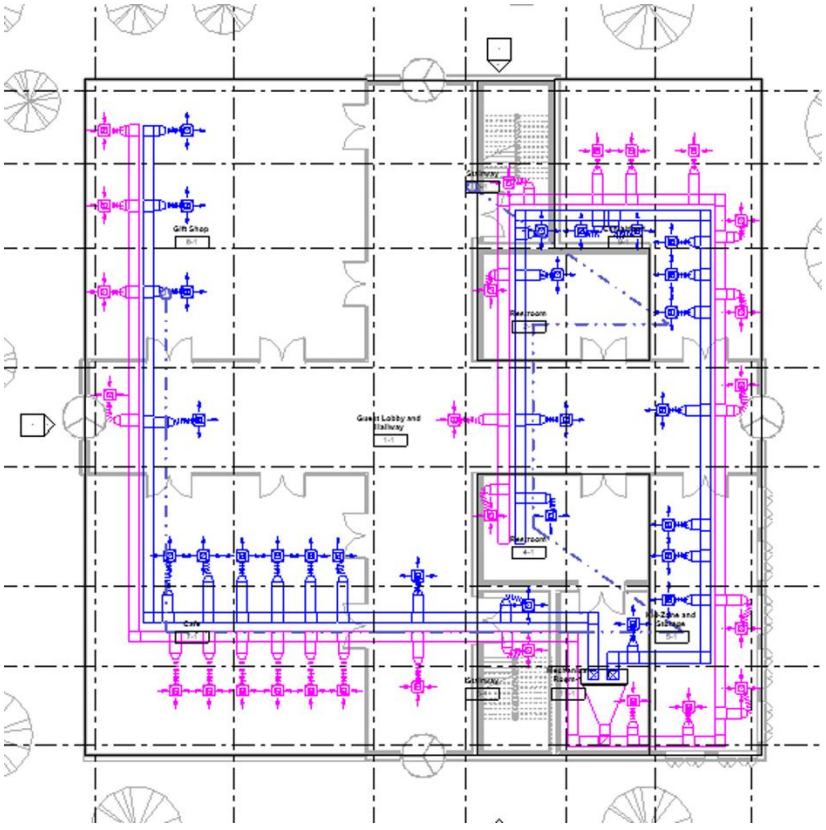
My center has a huge amount of curtain walls all around the main building. This passive design feature could possibly capture pretty much natural heat and meet part of my heating requirements during the warming months. My center also has shading systems on my curtain wall to prevent excess unwanted heat gain during the cooling months. As mentioned before, the water resource here in Beijing is limited, so I choose air-based ducted heating system for my center.

Strategies for Cooling System

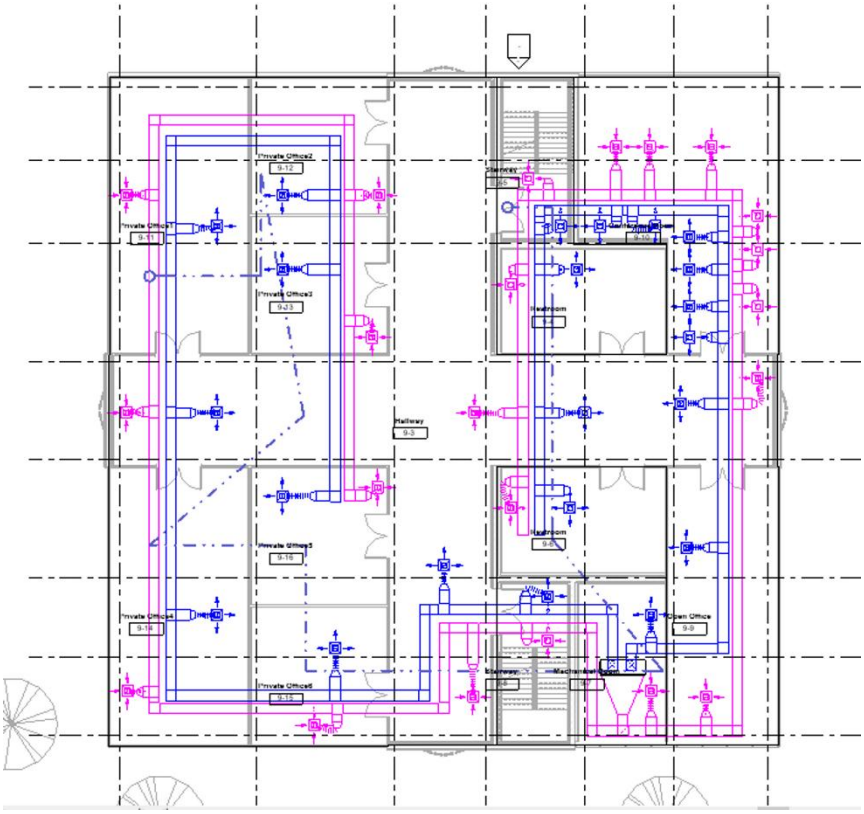
We have the same shading system that can shield my building from the solar heat using passive design features to reduce the cooling load during the cooling months. It is not applicable to use natural ventilation, air movement, or water features (evaporation) to provide some of the cooling naturally, according to the local climate situation.



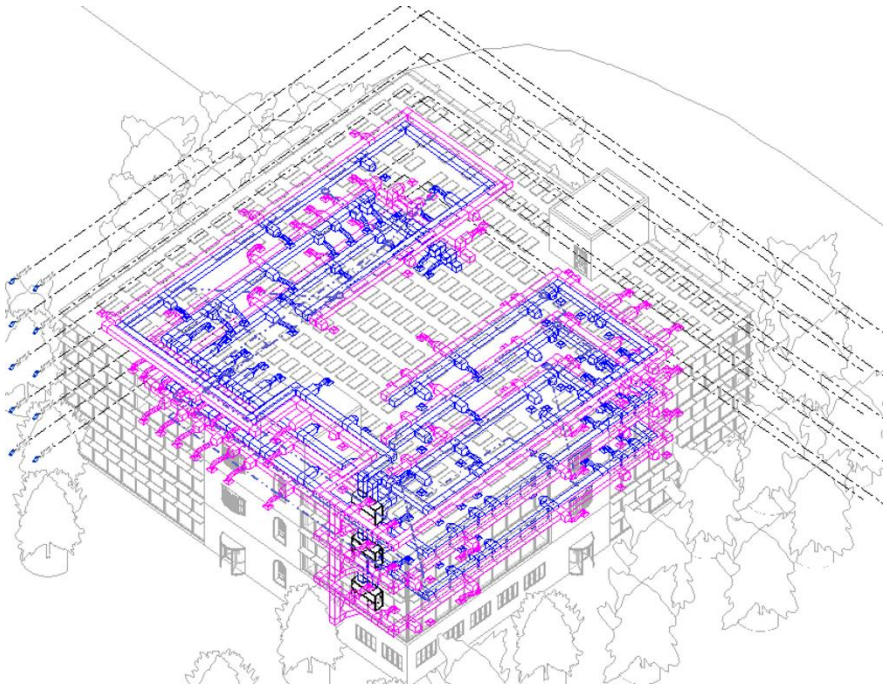
As shown in the figure above, the lower bound of the beams is 13’ above the floor level. Thus, the ducts should not be higher than this. I would leave 24” for the maximum height of the ducts, so the height of the air diffusers is also set as 11’ above the floor. I would consider using the ceiling, and its height as also set as 11’. The size of the ducts is all set to be 22” ×22”. I tried my best to apply the duct sizing tool to determine the exact size, but there always exist some errors. Thus, I use this approximate size in my model. The following as some figures that show my mechanical system：



Mechanical Arrangement on 1st Floor

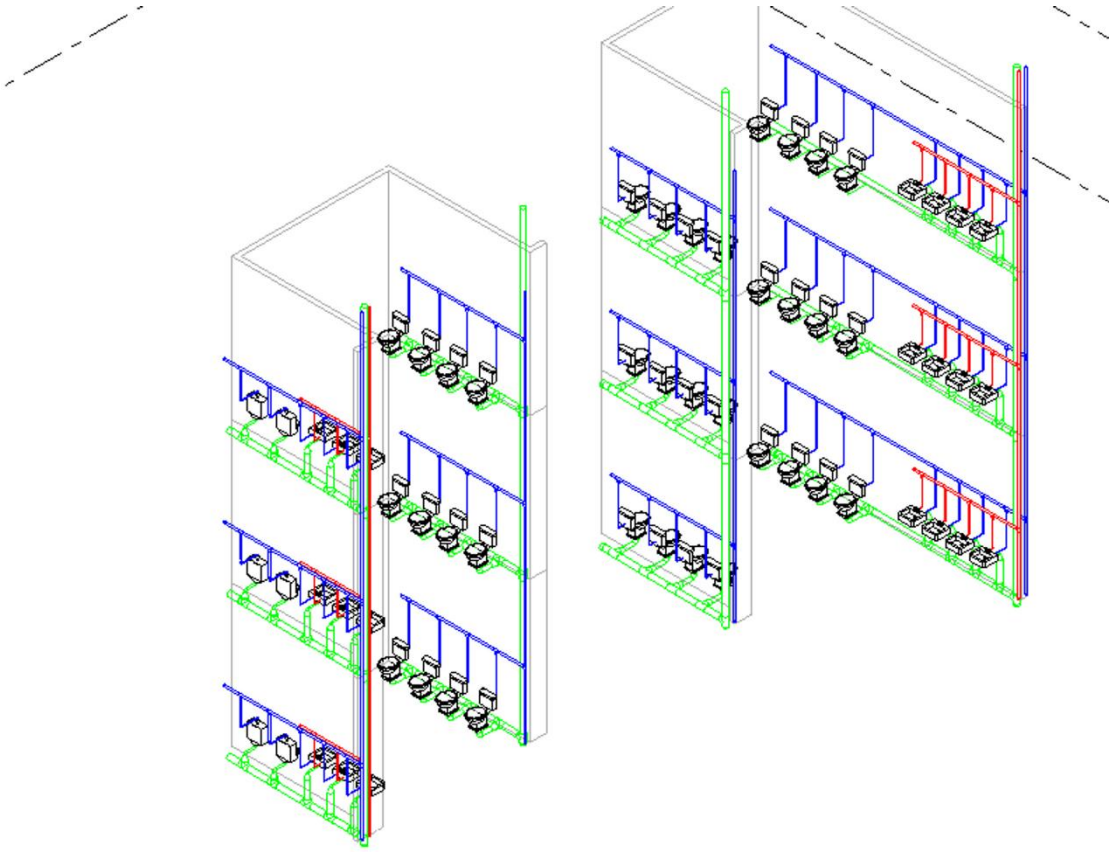


Mechanical Arrangement on 3rd Floor

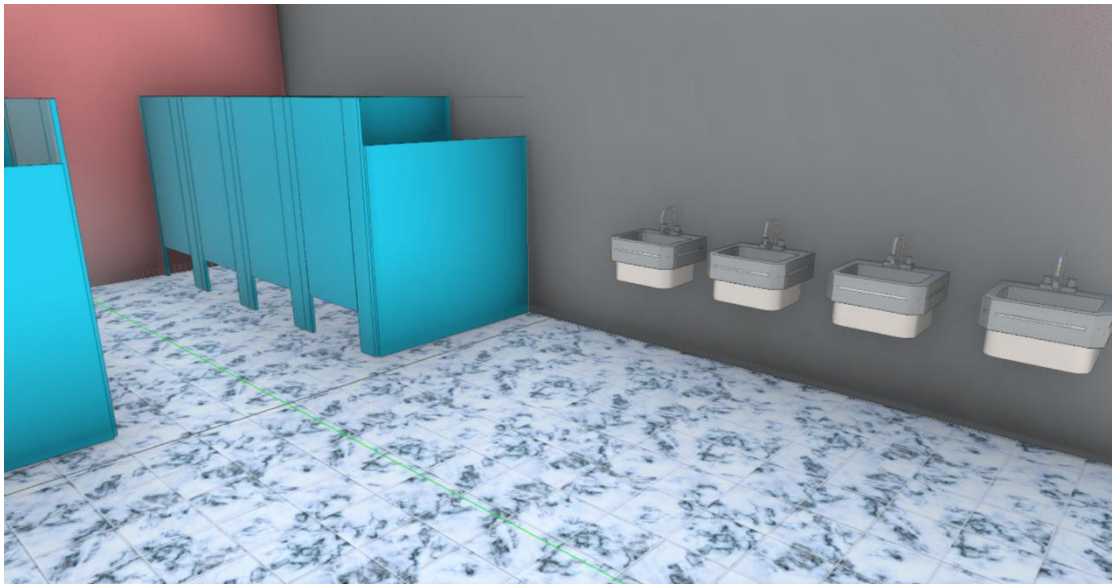


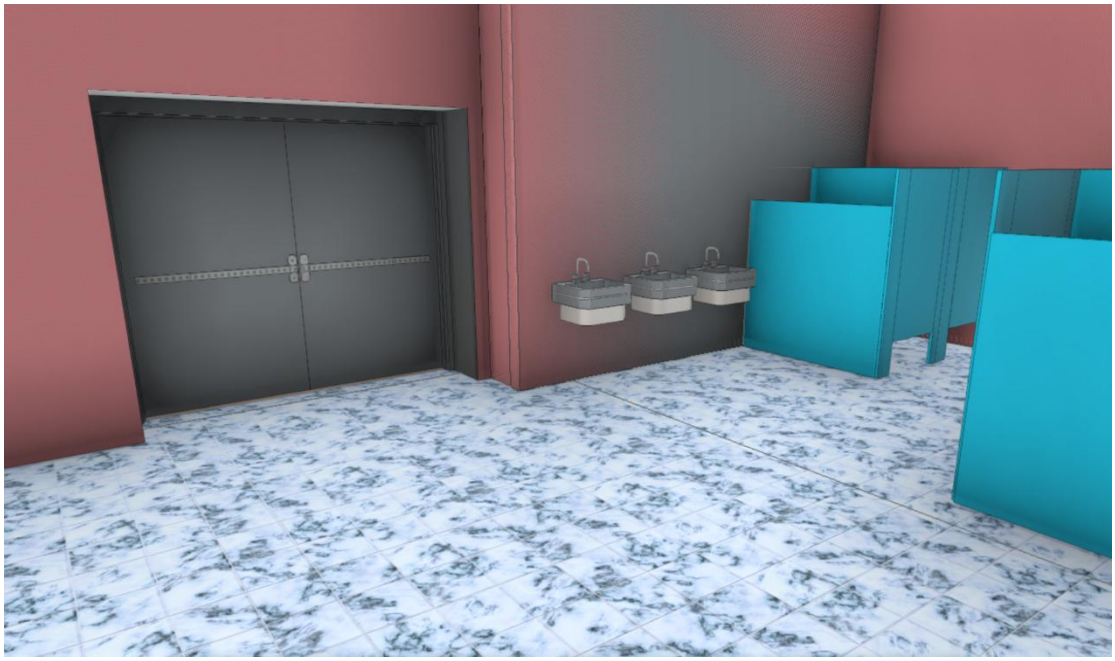
Mechanical Arrangement for Entire Model

An impeccable plumbing system is also designed for my center as shown in the figure below. I have two public restrooms for both male and female on all three floors, and those restrooms are big enough with qualified capacity.

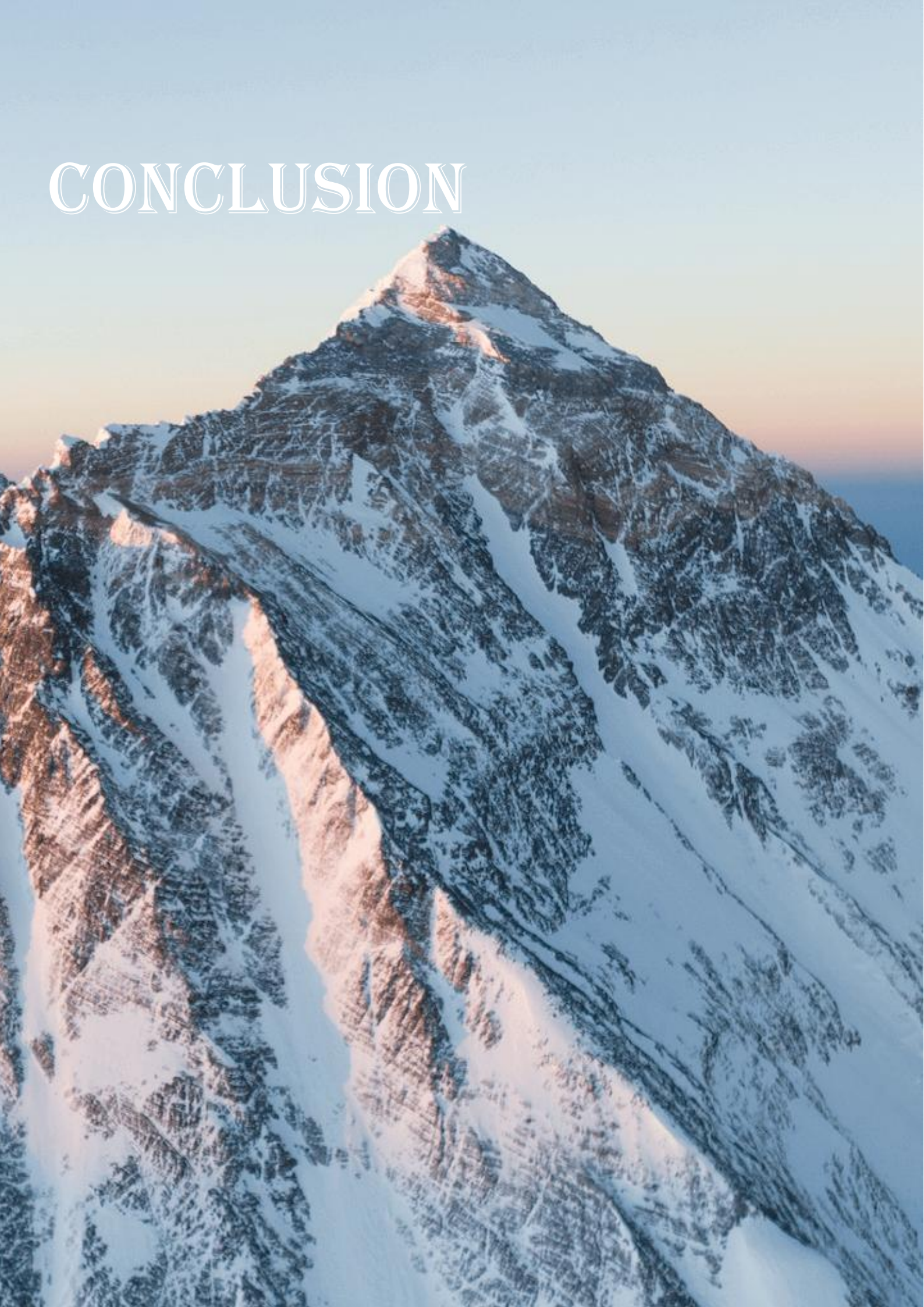


The following figures demonstrate what the restroom look like in reality:





CONCLUSION



Your Big Successes

- Even if I have learned some fundamental skillsets before, it's my first time to design a project all by my own at a higher level.
- I came up with several design strategies at the early stage, and I was finally able to realize most of them. I hope that my building can be energy-efficient, so I installed hundreds of solar panels on the roof of my center. I hope to express the idea of environmentally friendly, so I also designed the botanical garden.
- In the HVAC design, the space is limit and it's difficult to make the arrangement for the ducts. However, I hope to leave enough spaces for my rooms so that the customer experience will not be influenced. Thus, I tried my best to make sure that all the supply and demand ducts are in the same plane.
- For the structural design, I used mass timber structures, which has low carbon emissions and can provide enough strength at the same time.
- My center is located right next to the Fragrant Hills Park and the Beijing Botanical Garden. I designed a large scale of curtain wall, which cover almost 80% of the surrounding surfaces. Tourists and visitors can enjoy an unforgettable scenery while going through the exhibitions or enjoying meals at the Café.
- The main building of my center is a cuboid, and the shape of all my rooms and materials are regular and common, so it has a high constructability and the labor cost can be further reduced.

Your Big Challenges

- The tight schedule might be one of the challenges. Since I am supposed to finish all the stuff in ten weeks, and I have two other courses this quarter with tons of loading, sometimes I need to stay up late in order to get everything done.
- It is unique to design a semi-spheric massing as the botanical garden, but it also brings some difficulties. It is hard to be considered at the structural design, and I can not have any plumbing system for ventilation there. When doing the energy model analysis, it's also a big problem to be considered.
- Some of the energy analysis results cannot be perfectly utilized. Even if the Insight analysis tool provided a lot of improvement recommendations to minimize the energy consumption, not all of them can be directly applied to my model.
- There is still a long way to go if my design can finally come true. I need to further complete and perfect my design: adding more elements and equipment, editing on the existing system, and analyzing my structural model. The regulations are super strict for construction plans in Beijing, so more detailed information is necessary.

Lessons Learned

During my undergraduate study, I took a Revit course at NCTU, in which I learned some basic functions and built a specific model under guidance. Thus, at the beginning of this class, I was confident about myself and believed that they are almost the same. However, the content and arrangement of this course is far more than I expected.

It is the first time in my life that I enjoy the happiness and satisfaction of design and possession. This is my own center, and it was me who came up with the fundamental ideas, applied useful strategies, designed the exquisite architecture and structure, and endowed powerful functionalities.

Acknowledgement

I hope to express my gratefulness to Professor Glenn Katz and all the TAs. Professor Glenn carefully and patiently prepared all those fantastic course recordings, helpful resources, as well as the straightforward kick-off sessions. Even if this is an online course. I feel like I am taking this course in person, and I can easily understand and comprehend the basic concepts and examples that Professor Glenn is trying to demonstrate. In addition, Professor Glenn would always provide patient and powerful help whenever I encountered difficulties in my project. We would work on the problems and hinders together, and I learned a lot through this process. We are supposed to have our check-in sessions for each module, and they are also meaningful to me. TAs are all nice and willing to help on our projects. Sometimes they would even provide some ideas or recommendations that are nor originally considered by myself. I also hope to thank to all my classmates, who continuously shared their ideas and ongoing process, so that I can have enough confidence and courage to keep moving on.

Thanks to you all!

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03.21.2023