
AEI Team Number:
05-2014
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Integration Report
2014 Charles Pankow Foundation
Annual AE Student Competition

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EXECUTIVE SUMMARY:

Throughout the design process, our team's approach has been to integrate new and innovative ideas across all disciplines to achieve several key design goals. We wanted to create and iconic building that sets a precedent for sustainable architecture in San Francisco. We were able to accomplish this by meeting and exceeding our driving objectives. Our overall team goals are as follows:

1. **To address the energy efficiency of the building as a whole and achieve a near net-zero design.**

   As a team, we worked together to reduce the overall impact of 350 Mission on the grid. By taking intense measures to reduce energy, and designing multiple on-site energy production systems, we were able to reduce the amount of off-site non-renewable energy consumed by the building by more than 75%.

2. **To analyze potential system choices**

   We conducted a detailed comparison and analysis of various building systems, resulting in our utilization of the following:

   <u>Building Envelope</u> – double façade
   <u>Mechanical</u> - under floor air distribution (UFAD)
   <u>Energy Production</u> - combined heat and power & Photovoltaic
   <u>Carbon Reduction</u> – algae bioreactors fed from CHP system

   Each system was analyzed on both a performance, and life-cycle-cost basis, to ensure that they helped us fulfill our design goal of near-net-zero energy use, and also benefitted the owner in the long-term.

3. **To reduce the impact of a design level seismic event on the integrity of the building through the design and construction of the mechanical, electrical, and structural systems.**

   By utilizing a primarily steel structural system, we were able to reduce the impact of a seismic event and ensure immediate occupancy after a design-level earthquake. Our structural system also restricts the building movement to 39.0 inches, which is less than one half of the code allowable drift of 82 inches, by resisting lateral force with a combination of braced frames connected by deep girders in the core.

   We designed a mechanical and electrical system in the raised access floor that incorporates easily accessible components to facilitate quick assessment of damage and possible repairs. Our electrical distribution system is designed with multiple small points of failure, reducing the probable impact of a seismic event.

In addition to these three main design objectives, we also considered other goals to increase the marketability of the building. We designed an intricate hanging column structure to keep the iconic lobby as open as possible. We have included, in our design, a location to allow future tenants to place a staircase in the office which allows them to create a multi-story workplace. This feature allows the building to adapt to the local market and provide a more versatile source of profits for the owner.

Further, to encourage community acceptance, while also meeting the code, we designed our building to a LEED Platinum level. This demonstrates our commitment to a sustainable building; a benefit to not only the owner and tenants, but the community as a whole.

Introduction:

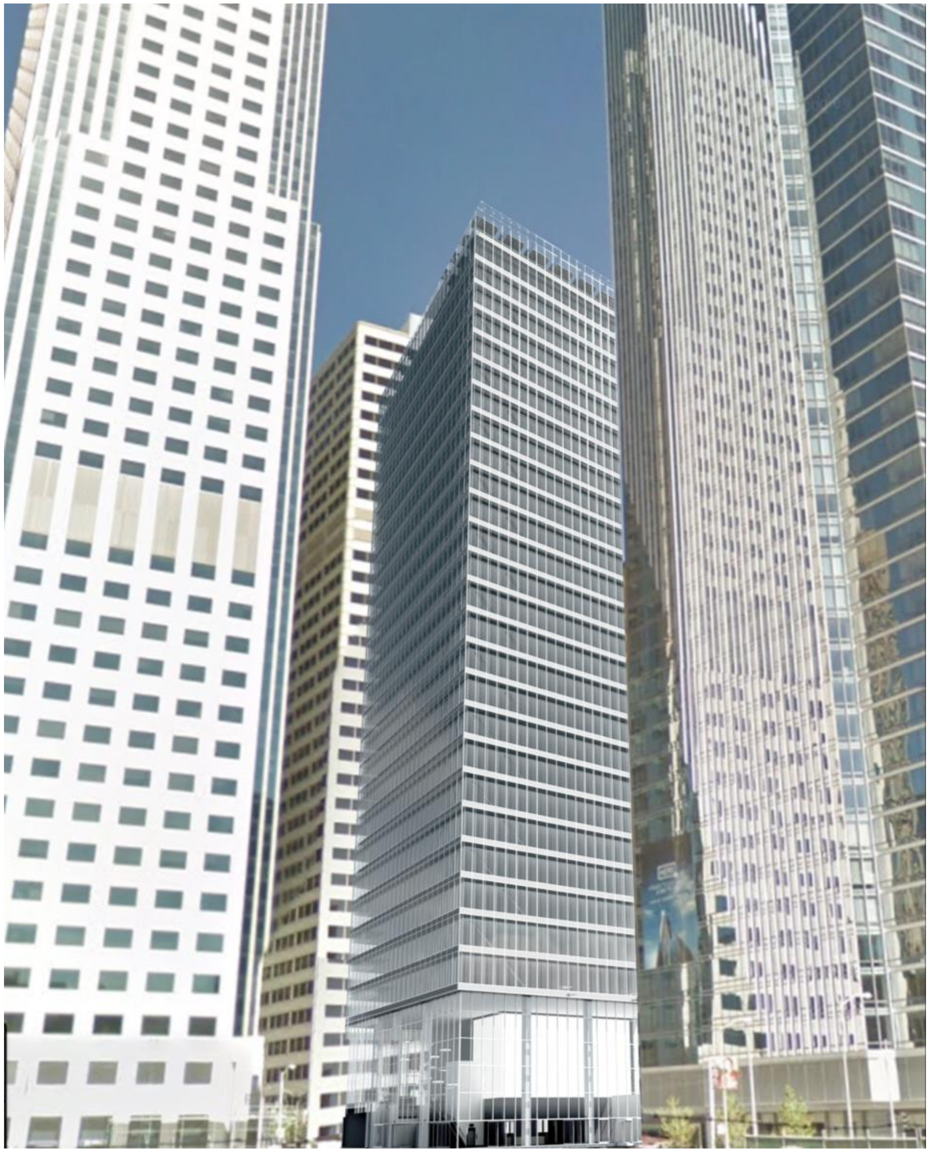
The main goal of the Charles Pankow Foundation Student Competition is to design a building that improves upon the quality, efficiency, and value of large buildings. These ideals are to be developed through new and innovative design ideas via construction, building systems and structural components. These goals can only be achieved through extensive collaboration, communication, and the innovative use of new and unique design methods.

Located at 350 Mission Street, San Francisco, California, across from the future Transbay Terminal, the 30 story mixed use high-rise will be a major focal point for the city in the years to come. It is for this reason that we placed a large emphasis on community, sustainability, and efficiency. By addressing these goals we hope to create an iconic building that sets a precedent for sustainable architecture in the city.

350 Mission will integrate many systems to achieve the primary desired goals of near net-zero energy and near immediate occupancy after a seismic event. By utilizing a steel structural system, a double façade, under floor air distribution, and a combined heat and power system, we were able to provide a safe and sustainable working environment for all occupants.

With such a large building, at over 420,000 square feet, it was vital to incorporate collaboration into all aspects of the building design and construction, in order to create the most efficient possible design.

Over the last few months, our team has designed a near net-zero energy building that is able to remain operable immediately after a design-level earthquake, and acts as a hub for the San Francisco business district community.



PROJECT GOALS:

Before beginning the design process, we outlined our overall goals for the project. While we had many small goals, we focused on two primary design goals, described below.

1. Achieve a near net-zero energy use design.

There are at least eight different definitions of "net-zero energy building" currently in circulation in the United States. Many of these definitions are one-dimensional, and do not accurately represent the real impact that a building has on the environment. As a team, we decided to create our own definition of "net-zero energy use," which we believe is both comprehensive and practical:

> *"A net-zero energy building is a building that consumes no non-renewable energy that is produced off-site."*

Our goal is to design a near net-zero building – that is, to develop a design which will minimize the amount of off-site non-renewable energy that the building uses from the grid.

2. Reduce the drift of the building at full height to less than half of the code allowable drift in accordance with the requirements of the AEI competition. As per ASCE 7-05 building drift for occupancy category III is 1.5% the full height of the building, making the requirement for the competition 0.75%.

3. Ensure immediate occupancy after a design level earthquake. As part of the AEI competition it is imperative that normal business operations are able to be carried out during the repair of the building after a seismic event.

This report details the collaborative strategies our team used in order to achieve these goals.

SYSTEMS SUMMARY:

Underfloor Air Distribution:

- 1,111,144 kWhr saved annually
- Improved Comfort and IAQ
- Modular system provides easy access for maintenance
- Reinforced with seismic bracing to survive earthquake forces

Combined Heat and Power:

- Ten 65 kW microturbines
- 1,014,000 kWhr produced annually
- 20% Carbon Reduction from Simple Heat and Power (SHP)

Photovoltaic System

- 241 photovoltaic panels
- 149,800 kWhr produced annually

Double Façade System:

- Integrated with mechanical system to improve efficiency
- Outer Layer – Clear 6mm glass
- Plenum Layer – Retractable shading blinds and operable vents
- Inner Layer – Based off of PPG SOLARBAD product, U-value - 0.32, ½" argon-filled space, VLT – 64%, SHGC – 0.36

Algae Bioreactors:

- Reduce carbon emissions through CO_2 absorption
- 60% Carbon Reduction of CHP System

Structural System

- Reinforced Concrete Sub-structure
- Steel Super-structure
- Special Braced Frame Lateral Force Resisting System
- 39.0 inches of lateral drift

Collaboration Process:

Our team is comprised of eight architectural engineers who specialize in the construction, electrical, mechanical and structural disciplines. The team was formed to compete in the 2014 ASCE Charles Pankow Foundation Student Competition. Each of the team members has had different experiences in the building industry through various internships with construction companies, structural firms, and MEP firms, as well as experience overseeing construction from the owner's side. This diversity of expertise was a critical piece of our success as a group. These team members have also had experience in working in groups before both in and out of the classroom, which has allowed the team to communicate effectively.

The team held weekly meetings, during which critical design decisions were made. At these group meetings, there was no designated leader because the team felt that an open, horizontal decision-making process was the best way for good decisions to be implemented. Although there was no leader, one of the team members would occasionally act as a mediator if a problem arose. The mediator would be there to help the team come to an agreement. At these weekly meetings, each team reported on their progress to date, and was expected to have a list of non-critical questions/ issues to work through with the other disciplines. If a critical design issue arose between meetings, an emergency meeting was called to work through a specific issue, so as not to hinder the design progress of any system. This meant that each group member needed to be ready and willing to be flexible not only with design, but with meeting availability as well.

Many different software programs were used for design coordination. **Figure A** shows the breakdown of all of the programs which were used by each discipline, and how they led to clash detection, 3D and 4D modeling, mangament purposes, and systems anlyasis.

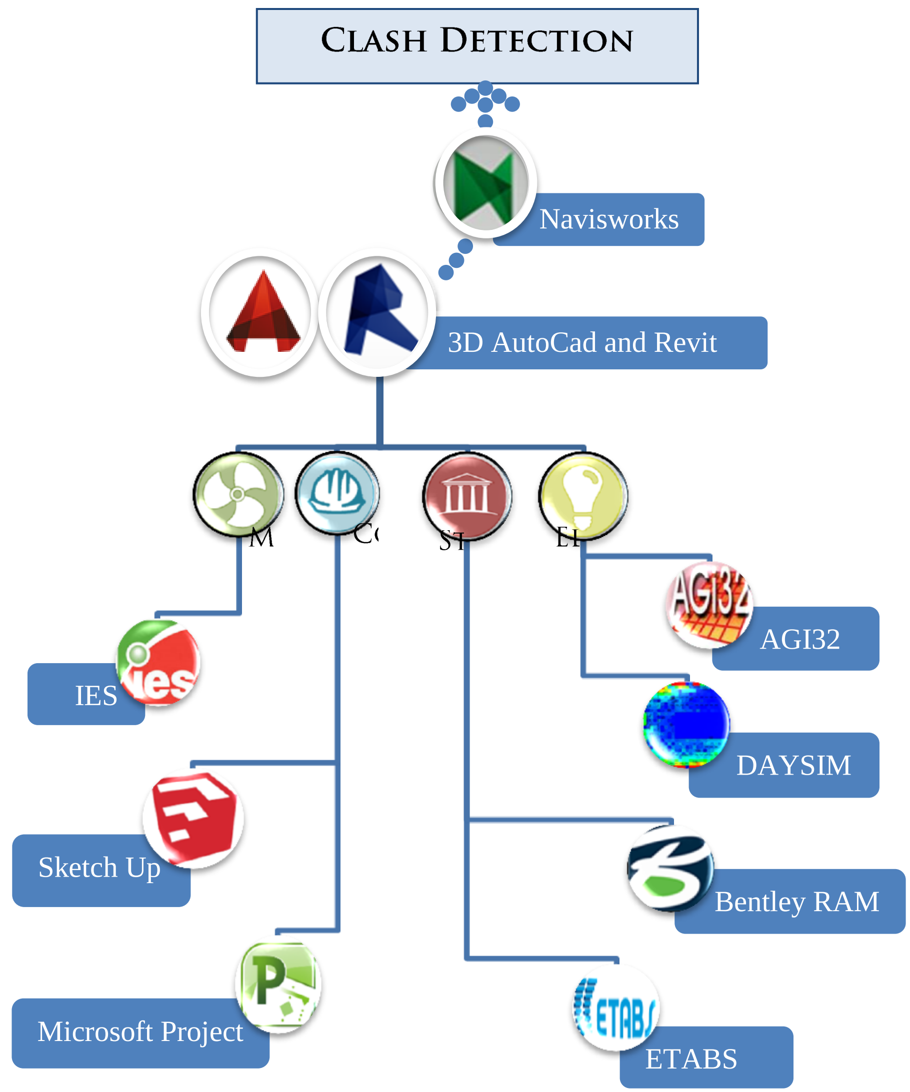


Figure A: Software Process Flow Diagram

To help foster collaboration on this project, multiple forms of communication have been utilized. The team used the university server as a way to store and share files. This server contained all of the meeting minutes (an example of which can be found in Appendix page I-1), reports, models, research and calculations. This server also contained the team's Revit Model which was utilized as an integration tool amongst the different disciplines. The smartphone app GroupMe was utilized to plan extra group meetings, and as a primary form of communication. This app allowed all team members to be involved in the same SMS conversation, ensuring that nobody was uninformed of critical information..

While the programs used made integration much easier, we did run into some problems with consistency between different programs and between programs and hand calculations. For example, we used Integrated Environmental Solutions (IES) for the energy modeling of the building. The most recent version of this software (2013) utilizes ASHRAE 90.1-2007, whereas the reference used for hand calculations was ASHRAE 90.1-2010. This variation in references led to inconsistencies between hand and computer calculations.

Near Net-Zero:

As mentioned in the Project Goals section of this report on page 2, our definition of a "Net-Zero" design was one that eliminates the off-site, non-renewable energy consumed by the building. **Figure B** shows how we achieved a near net-zero design by minimizing the amount of energy our building would need to attain from the grid (non-renewable sources).

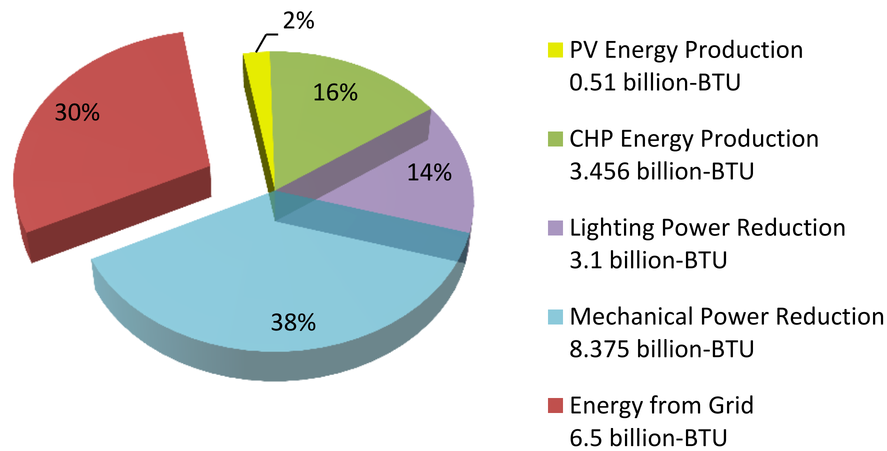


Figure B: Energy Use and Energy Reduction Breakdown

As demonstrated above, our team was able to reduce the amount of off-site, non-renewable energy that the building consumes to 28% of the baseline energy use. This was accomplished by combining innovative power load reductions with on-site energy production. We reduced the energy required by the building to 48%, and we were able to produce an additional 18% of the baseline through the implementation of photovoltaic and combined heat- and power systems, minimizing the required off-site non-renewable energy demand of our building and achieving a near net-zero design.

Load Reduction

As **Figure B** on the previous page demonstrates, the most important strategy to achieve our near-net-zero energy goal was load reduction. Reducing the building load by 54% was a very involved process that required collaboration from every discipline. Our load reduction methods are detailed in the Mechanical and Electrical reports; however, several of the methods are listed below:

Cooling and Heating Loads

under floor air distribution system
double façade
glazing materials

Lighting Loads

daylight harvesting
occupancy sensing
light level tuning
lighting power density reduction
glazing materials

Load reduction was an iterative and multidisciplinary process. Consider glazing materials, for example. A high transmittance glazing material would reduce the lighting load, but increase the cooling load. Our team ran a number of simulations to determine the total building load using various glazing materials in order to find the most optimal solution. Almost all of our energy calculations were performed with IES, which yielded consistent and reliable calculations. **Table 1** on the right provides a breakdown of our calculated energy savings versus the baseline model.

Type	*Baseline Energy Use (b-BTU)*	*Proposed Energy Use (b-BTU)*
Lighting	***4.567***	***1.456***
Heating	***4.625***	***1.870***
Cooling	***1.550***	***0.517***
Pumps	***0.155***	***0.380***
Heat Rejection	***0.481***	***0.419***
Fans	***6.578***	***1.240***
Plug Load	***4.900***	***4.900***
Total	***22.856***	***10.440***

Table 1: b-BTU represents one billion BTUs.

Raised Access Flooring

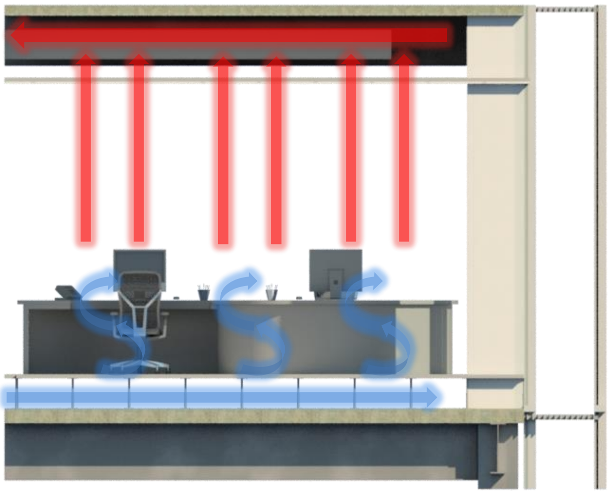


Figure C: Underfloor Air Distribution Schematic

Our primary concern in selecting an air distribution system was to reduce the heating and cooling loads of the building as much as possible. Because of this, our team selected an under floor air distribution system (UFAD), as this configuration increases the effectiveness of cool air, as can be seen in **Figure C**, and generally results in a lower cooling load. As a team, we concluded that a UFAD system would greatly reduce energy costs while also improving indoor air quality (IAQ).

Additionally, our team wanted to create an office layout that was flexible enough to accommodate a variety of potential tenant requirements without requiring expensive retrofits. This combined with the need to have our supply air in the floor, led us to the decision to use a raised access flooring system. The raised access flooring allowed us to design a flexible and efficient means of introducing ventilation and conditioned air into the office areas. In addition, it allowed for the electrical team to conveniently and economically run the wiring under the floor and accommodates customized and flexible receptacle locations.

Prefabricated modular pods for the kitchenette and bathrooms were chosen to cut down on scheduling time. In order to integrate these pods with the floor system, they were designed to be pre-constructed with a raised base to ensure that they are at the same level as the raised access flooring. The weight of these pods is included in our structural design.

The enclosed offices also were coordinated with the under floor system to provide conditioned air. As can be seen in the perspective section in **Figure D**, the partition walls penetrate the raised floor and terminate directly on the slab. A small opening will be created during construction to allow air to pass through the wall via a duct into the under floor system of each office.

Figure D: Raised Access Floor Diagram

Because so many systems and disciplines utilized the raised access flooring, it was vital to perform clash detection to ensure that none of the components interfered with each other. In order to run the clash detection, all of the systems were placed into a single Revit model.

Building Envelope

In addition to reducing the heating and cooling loads with our air distribution system, our team also wanted to choose the building envelope that would maximize energy savings. We ultimately concluded that utilizing a double façade glazing system (DFS) (**Figure E**, and *Appendix page I-9*) on the building's Southeast and Southwest faces would allow for the most savings. The double façade is an integral part of our buildings design. It is incredibly influential in both the mechanical and architectural systems, as well as being a strong structural coordination consideration. While the system was mainly designed for the mechanical system, providing natural ventilation and decreasing the heating and cooling load in their respective seasons, it impacted all of the other disciplines of the design team. The DFS is essentially comprised of three layers:

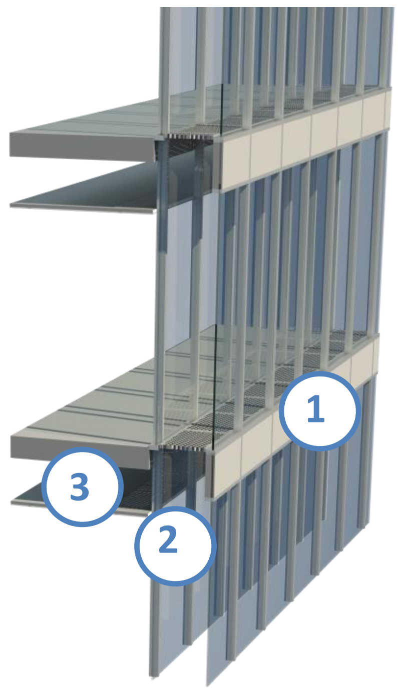


Figure E: Double façade section

1. **Outer Layer** – clear 6mm float glass
2. **Plenum Layer** – operable vents
3. **Inner Layer** – based off of PPG SOLARBAN product. U-value – 0.32, ½" argon-fill space, VLT – 64%, and SHGC – 0.36

From the construction standpoint the DFS posed a scheduling and coordination problem that needed to be addressed early on in the project. This arose from the complexity of the façade system. Since the design decision was addressed early on in the project the construction team was able to plan accordingly and reduce the impact on the overall schedule.

The primary focus of the façade system was to reduce the effects of the external load from the environment, with the main goal of reducing the energy consumption of the building. A DFS on selective sides of the building allowed the mechanical design team to incorporate natural ventilation, manage interior temperatures, and control the amount of solar radiation penetrating the building. All of this was achieved while coordinating with the electrical design team to ensure that an adequate amount of daylight was provided to the office space.

To achieve the electrical design team's desired daylighting levels, they worked with the mechanical team to design a system that could be integrated with the double façade. Shades were chosen as the best method of controlling daylighting into the space. However, there was a debate as to the location of the shades. Originally, the electrical team wanted to place the shades in the plenum because they saw the potential for reduction of space use inside the office. However, there was a concern from the mechanical team that the shades could interfere with cleaning of the double façade. This resulted in a compromise with interior placement of the shades. Also impacting the daylighting in the office space were the floor grates that allowed cleaning access within the plenum. These reduced the direct incidental sunlight on the façade during the summer months.

The mechanical and structural teams also had to work closely to make sure that the weight of the double façade was appropriately accounted for in the structural design. However, because this was done early on in the process, it did not pose much of a problem for the structural team.

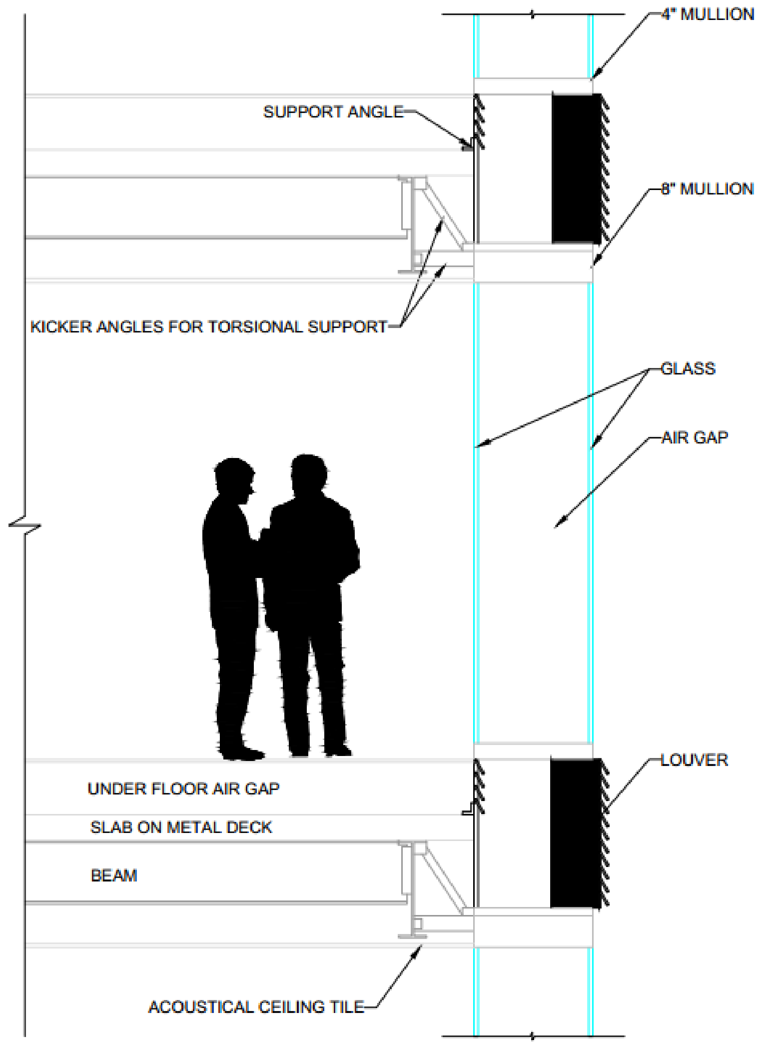


Figure F – Façade Section

In addition, connections had to be considered between the structural, mechanical, and construction disciplines. The double façade had to be designed in such a way as to resist the damage done during an earthquake. This was critical both for immediate occupancy, and for safety to keep glass (or the façade frame) from falling onto the street and sidewalk below. See **Figure F**.

ENERGY PRODUCTION

In order to meet our rigorous near net-zero energy use goal, reducing the load on the building was not enough. We also designed onsite-energy production systems which will ultimately produce over 30% of the building's energy use.

COMBINED HEAT AND POWER (CHP)

After all of the energy reduction methods were considered, our team's next goal was to produce as much on-site energy as possible, in order to meet our near-net-zero energy goal. The decision to design a combined heat-and-power (CHP) system was an easy one, as these systems generate both heat (offsetting the building heating load), and electricity. The CHP system was coordinated between both the mechanical design team and the electrical design team. The mechanical design team's main goal concerning the CHP system was to recover the heat produced by the micro-turbines to be used by the chiller and boilers, which were located in the penthouse region. This posed few problems seeing that the boilers and chiller are within a reasonable distance of the micro-turbines. The real concern came when the electrical team brought up the fact that the building's switchgear was located in the sub-terrain podium section of the building, the parking garage. The main concern of the electrical team was the transmission losses associated with transporting the whole length of the building to the switchgear, and then distributing it back through the building. After much collaboration and research, it was determined that in order to reap the most benefit from the CHP system, it should stay in the penthouse area, close to the boiler and chiller. In order to reduce the transmission losses, the

CHP system does not feed into the switchgear – it is fed into distribution panels which supply the top 15 floors of office space directly.

In addition, the structural team needed to account for the weight of the microturbines in their design of the roof system. The microturbines add a considerable weight because there are 10 of them, meaning the structural team needed to add structural supports to the roofing system.

PHOTOVOLTAIC SYSTEM

To help achieve our near-net-zero energy use goal, our team designed a photovoltaic array on the roof of 350 Mission, shown in **Figure G** below. Our system utilizes a combination of pole mounted, and roof mounted panels, all (except four) oriented southwest, and tilted 10 from the horizontal. Due to the building orientation and site conditions, this configuration yielded a higher energy output than a south facing configuration. See *Appendix page E-11* for details.

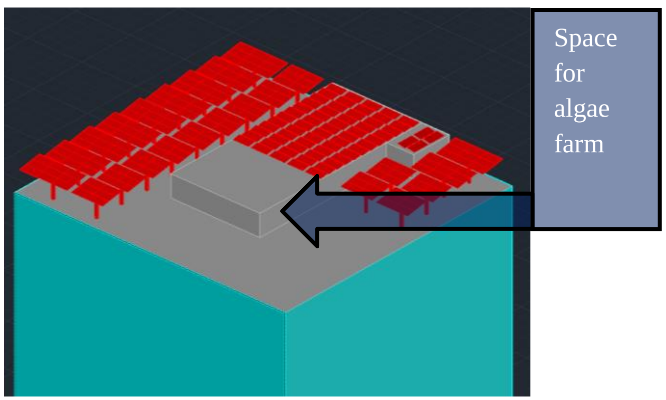


Figure G - Photovoltaic Diagram

Despite the moderate shading conditions, our team determined (using Autodesk's Ecotect Analysis software) that the described photovoltaic array would generate over 149,800 kWhr annually – over 4.5% of our total building energy use. In addition to its contribution to our energy goals, the photovoltaic array would be a rewarding financial investment for the owner, paying for itself in just over 8 years. See the Life-Cycle Cost section of our Integration Report for more details.

BUILDING STRUCTURE & ARCHITECTURE:

STRUCTURAL SYSTEM:

A lot of time was spent very early on in the design process collaborating with all of the disciplines to choose a structural system for 350 Mission. The original design of the structural system for 350 Mission is a reinforced concrete system. We looked at the pros and cons of concrete and steel in order to decide which system would best satisfy our specific design goals.

The overriding deciding factor for choosing a primarily steel structural system, consisting of special moment frames and special brace frames, over a concrete system, consisting of reinforced shear walls, was the design goal of immediate building occupancy after a design-level earthquake. The benefits of a concrete system needed to be sacrificed, because of this decision. These benefits include the higher stiffness that a concrete shear wall provides to a later force resisting system. For the purpose of our project goals stiffness is not necessarily the only criteria. We felt that a more ductile system with added strength would permit us to reach drift results similar to a stiffer system with the increased ability of immediate occupancy. In addition, to truly set a goal of immediate occupancy the structure should be designed the same way that hospitals, fire stations, and police stations are designed. When determining the seismic loads on the structure using Occupancy Category III the loads are higher than if we were to use the traditional Occupancy Category II for a building of this type. The goal of immediate occupancy can be realistically achieved by designing a structure to withstand these higher loads. Table 1-1 from ASCE 7-05 explaining the different occupancy categories can be found on page S-2 of Appendix A in the Structural Design Report.

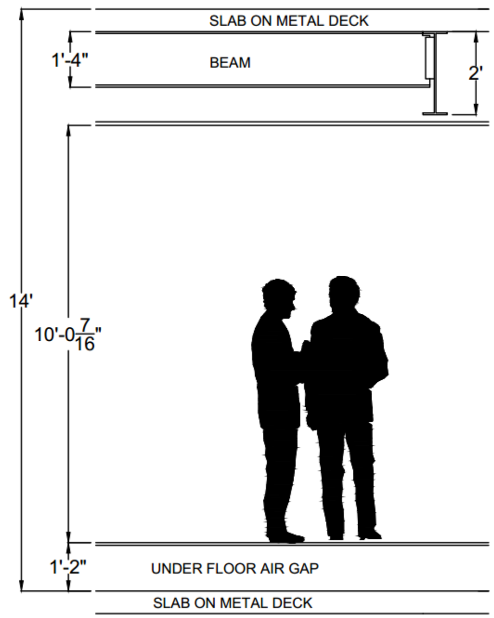


Figure H: Floor-to-floor height diagram

One major impact of this design system was the floor-to-floor height. Steel beams would create a much larger floor depth than a concrete structural system. Therefore, the mechanical and electrical teams, in conjunction with the construction and structural disciplines, sat down and brainstormed ways to minimize the total floor to floor height. The conclusion of this collaboration was that the beam depth would be reduced from a rough estimate of 40 inches to 24 inches, and the total plenum space would be reduced from 20 inches down to 14 inches. Through this collaboration we were able to keep the floor to floor the same as the baseline of 14 feet, as can be seen in **Figure H**. The plenum space was reduced through the use of an underfloor system instead of a traditional plenum. In addition, a creative duct layout was employed to allow the ducts to run between the beams but never have to cross over a beam, removing the need for a ceiling plenum.

Another characteristic of the structural system that impacted the mechanical/electrical teams was the core. Originally, the structural team planned to use a special steel plate shear wall in one of the directions for the core. This meant that cutouts would need to be added at several points on every floor to allow for duct and wiring. Because of these cutouts, the structure would have been weakened to the point where the drift limit of one half code limit would be reasonably unattainable making other options more efficient. Due to this situation, and the inconvenience in design and fabrication of the shear wall with the cutouts, we decided as a team to switch to a system comprised of special braced and moment frames. This allowed for unobstructed openings throughout the core. (Appendix J) However, this did not solve all of our problems. We still ran into some issues with ducts clashing with the larger beams around the core, and several runs of duct had to be rerouted to avoid these beams.

Rooftop Systems

In order to achieve the desired Net-Zero goal the disciplines decided that using photovoltaic panels (PV) on the roof would be a reasonable option. One of the main concerns dealt with coordinating the area for the CHP exhaust. Even though a majority of the exhaust fumes would be taken care of by the bioreactors, there still needed to be means to exhaust any additional combusted fumes. In the end, the electrical design team and the mechanical design team decided that reducing a small portion of the PV panels was necessary to ensure that the exhaust from the natural gas combustions was addressed appropriately. Another potential problem located on the roof area arose when the mechanical team introduced the concept of algae bioreactors to the other disciplines. This again was a main concern with the electrical design team. Since the designated location for the algae bioreactor would be competing for space with the PV panels there had to be a compromise between the two disciplines. In the end it was determined that the reduction in carbon emission that the bioreactors would reduce, outweighed the effect of the PV panels on the overall definition of net zero and energy reduction techniques.

Given that the chiller, boilers, bioreactors, and CHP systems would be located on the roof, there was reason to collaborate with the structural team to ensure that the correct beam and column sizes were calculated to withstand the additional weight of the mechanical equipment.

From a structural standpoint, the mechanical equipment will add a sizable load, more than 20,000 pounds, to the entire building given the equipment's location.

Due to the fact that the structural design team and the mechanical design team were in constant contact, and often had discussions about weight and placement of the mechanical equipment, they were able to take care of this problem early on in the design process. The mechanical equipment was sized by the MEP team and specifications were then passed on to the structural design team. Using this information, the structural team was able to design girders and columns to adequately handle the loads imposed by the equipment. The structural team then returned to discussions with the MEP team to determine placement of the equipment that would satisfy the interests of both parties.

Architecture

As a team, we wanted to create an iconic yet functional building that was designed to be eye-catching from the exterior and flexible on the interior. In order to achieve the desired feel of the building, we wanted to keep the spaces and views as unobstructed as possible. From the exterior perspective, the southern corner of our building is an important one because it is across the intersection from the future site of the Transbay Terminal.

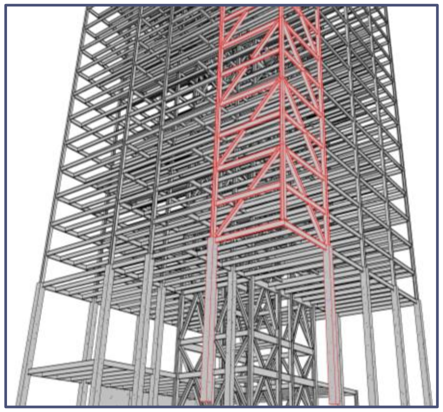


Figure I: Corner bracing to maintain column-free open corner in lobby

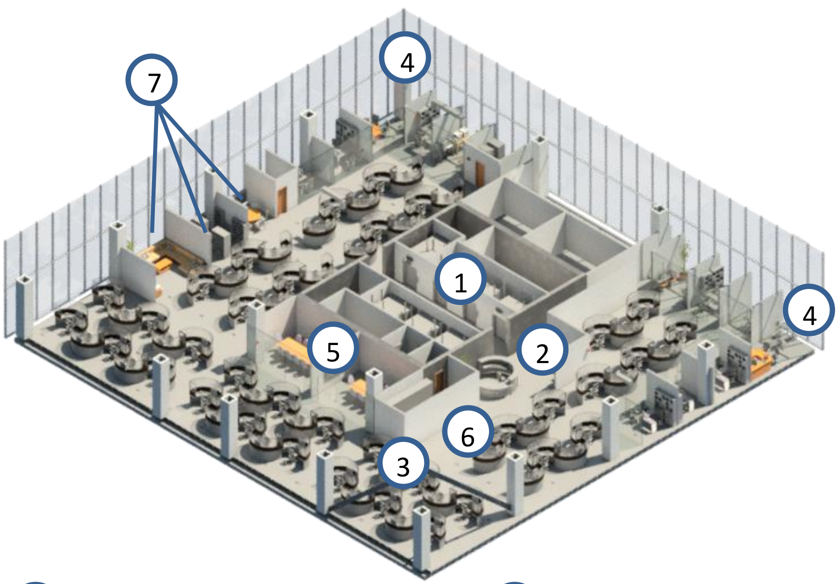
Figure J: The lobby as seen from Mission St. and Fremont St. intersection

To create an eyecatching view of the lobby for the high volume of pedestrian traffic from this transit center, we did not want a corner column to obstruct the view into our 50’ tall lobby. Because of the inclusion of this south corner column in the office floors above, we created a structural design challenge that was solved by hanging that column (see **Figure I**, and **Figure J** left). The transfer braces transfer the loads diagonally away from the southern corner to the adjacent columns. This diagonal bracing also adds an additional means of drawing focus to that corner of the building, with the rhythm of diagonals all drawing the eye from the lobby up the height of the building.

The lobby of our building will serve many functions, including public space, point of entry for the offices above, event space, retail opportunity, and restaurant designated space. Being that the parking garage is entirely underground; the entrance on the street level takes up some of our lobby real estate. In order to maximize the use of the 50’ tall lobby, we utilized the area above the parking garage entrance as a second story of open lobby space. This required a staircase for vertical transportation, and we took advantage of this addition by including seating alongside this staircase as can be seen above in **Figure K**. This improves the quality of public space by giving patrons an area to sit and relax before the work day starts, or to enjoy a coffee from the café located under the stairs.

Figure K: Lobby rendering of staircase

The double façade system our team has chosen to implement for mechanical purposes and daylight contributions created an architectural separation between the lobby and the office space. Since the double façade starts at the 5th floor, the massing of the building appears to be floating above the spacious open lobby. This effect was inspired by the ideas of Bernini and his creation of the Fountain of the Four Rivers in Rome, Italy. In this sculpture, there is a large mass directly over a void, giving an iconic impression to the viewer. This effect is further emphasized by the folding doors on the street level, which effectively opens the lobby space out onto the sidewalk and erases the barrier between the exterior and interior of the building.



1 Elevator Lobby
2 Reception/ Waiting Room
3 Open Office
4 9 Perimeter Offices
5 2 Conference rooms
6 Knockout Location
7 Ancillary Spaces
-Meeting Room
-Library
-Break Room

Figure L: Office Floor Plan

The office floor plan (on left **Figure L**) was another major series of architectural decisions. Our main criterion for this space was flexibility, so the occupants would be able to customize the office to their liking. The two ways we created flexibility in our space was through the inclusion of a designated knockout area and a raised access floor system.

Figure M: Conference Room

The raised access floor system added flexibility to the floor plan. The electrical wiring was placed underneath this floor system, and because they are easily removed, the panels allow ease of access to electricity. This method permits placement of receptacles in the floor in any configuration desired by the patron. Similarly, the ductwork and air distribution system is not space specific and can be altered according to the occupant's desired plan.

As a team, we noticed that maximizing daylight harvesting would lower the overall lighting load on the building significantly, thereby reducing our overall energy use. The perimeter offices were placed along the north and east corners to allow as much natural daylighting as possible to enter the open office plan in the remaining area. In addition, these offices were separated from the open office with glass partitions to allow daylight to penetrate past these spaces. In addition, the conference rooms (previous page, **Figure M**) were placed on the edge of the core not only to allow natural light through the glass partitions, but also to hide structural columns that were included to reduce overall beam depths.

Another issue which was addressed in our coordination meetings was the coordination of the floor knock-out. Each floor of 350 Mission will contain a 10 ½ foot by 17 ½ foot floor knock-out. The purpose of this knock-out is to allow future tenants to have the flexibility of placing a staircase in the office to allow for multiple office floors. For this knock-out to be made possible, coordination amongst all of our team members was conducted so no beams, ductwork, wires, or other services would be located in this area. **Figure N** below shows the results of how each of our team members coordinated with each other to avoid placing their systems in this area. Since there are no beams, ductwork, or wiring running through the knock-out, this also allows for an area inside the building footprint to place the tower crane.

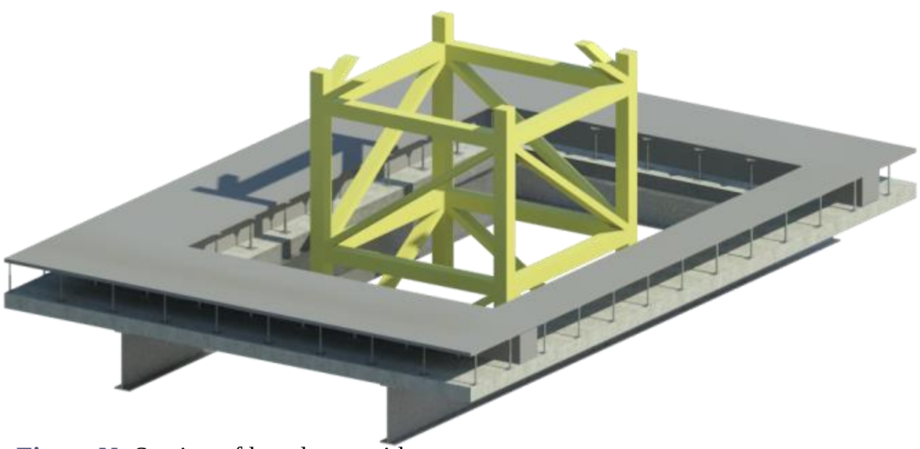


Figure N: Section of knock-out with tower

The knock-out was originally placed in the Northwest end of the building, but was moved to the Southeast end (as can be seen in Appendix #) for the crane. This allows for the crane to be swinging into the site instead of out to the public. A challenge which will need to be addressed is the removal of the crane from the knock-out. Extreme measures will need to be taken to ensure no damage will occur. After removal of the crane, each of the floor knock-outs will have to be filled in.

During the preconstruction process of this project, multiple programs were used for coordination of 350 Mission's systems. Clash detection was used to prevent each of the systems from colliding with one another. Each of the disciplines modeled their systems in Autodesk Revit; the model was then exported into Navisworks and used for clash detection.

Clash Detection:

Multiple clash detection analyses were performed. **Figure O** is an example of one of the clashes found in the Mechanical vs Structural Clash Report (refer to *Appendix H on page I-11* for more clash detection). One of the return ducts clashed with one of the core beams. The purpose of this return is to circulate the air in the elevator lobby. Since this clash was detected early in the design process, an alternative route was established to run the return duct under one of the smaller beam sizes in the core. To obtain this

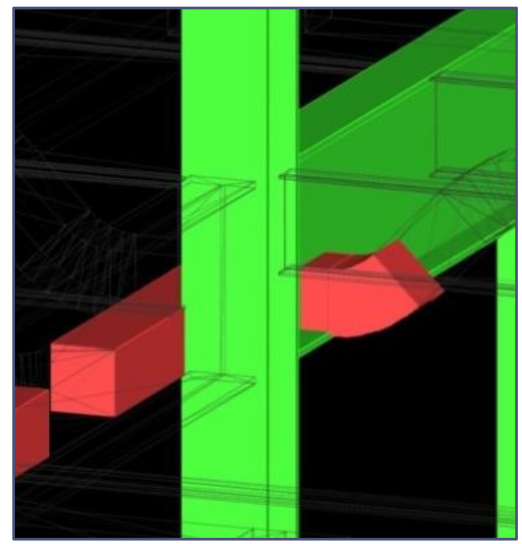


Figure O: Clash Detection Example

solution and others like it, our team would hold coordination meetings where we would analyze all of the clash reports and would communicate on how to resolve the issues. This helped each team member have a better understanding of all of the systems and where these systems are located in the building.

LIFE-CYCLE:

In addition to our energy and structural analysis, our team examined the life-cycle cost of our most important building systems. Collaboration was critical in our life-cycle cost analysis: our construction engineers calculated the cost of each system, and the mechanical and electrical engineers analyzed the payback potential. A detailed analysis of our life-cycle costs can be found in *Appendix D on page I-4*. Below is a summary of our results, displaying the cost of each system, and the return on the investment, at the end of the system's life:

System	Cost	Payback Period (years)	25 Year Return On Investment
Photovoltaic	$218,000	8.1	$456,100
CHP	$503,000	5.0	$1,529,000
RAF/DFS	$2,390,882	12.0	$2,609,266

Table 2: Return on Investment

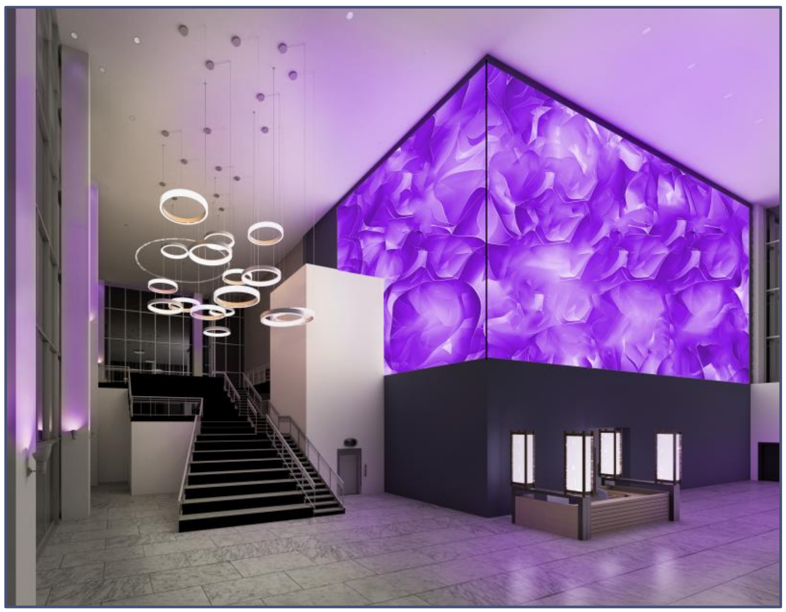
The return on investment calculation in **Table 2** above includes the base cost of each of the building systems, as well as the cost of replacement and maintenance (both the PV system, and CHP system would need to be replaced by the end of the time interval).

LEED:

Our team's primary design goal was to create an iconic building that sets a precedent for sustainable architecture in San Francisco – a building through which the city can facilitate a community of environmentally conscious architects, engineers, city-planners, and citizens. Our team determined that a LEED Platinum certification would increase the publicity of 350 Mission, and help meet this end. A detailed breakdown of our LEED certification can be found in Appendix B. Below is a summary of the LEED points our design qualifies for.

Sustainable Sites:	**21**
Water Efficiency:	**8**
Energy and Atmosphere:	**30**
Materials and Resources:	**8**
Indoor Environmental Quality:	**12**
Innovation and Design Process:	**6**
Regional Priority Credits:	**4**
Total:	**89 points**

LEED Platinum: 80+ points



Conclusion:

Out team created an integrated building design that sets a precedent for sustainable architecture in San Francisco. We used many different collaborative strategies and technologies to efficiently integrate each discipline throughout every stage of the design process. Ultimately, this collaborative effort allowed us to accomplish our three design goals: achieve a near net-zero energy use design, reduce the drift allowance to less than half of the code allowable drift, and ensure immediate occupancy after a design level earthquake.

Through building load reduction and on-site energy production, we reduced our off-site non-renewable energy consumption to 28% of the baseline value, limiting it to only 5.94 billion BTUs annually. The building owner may choose to purchase this off-site energy from renewable sources. This would allow the building to execute a net-zero performance, based on our definition.

Our design restricts the building's lateral movement to 39.0 inches, well under the code allowable drift of 83 inches, and below the competition requirements of half of that (41.5 inches). We were able to accomplish this by implementing a Special Braced Frame core. Immediate Occupancy was achieved by designing the building to a stricter occupancy category of Category III instead of Category II. This is the same category that hospitals, fire stations, and police stations are designed by.

Finally, we specified multiple building systems to minimize the impact of a natural disaster on 350 Mission. The underfloor air distribution system allows for ease of access to repair mechanical and electrical components. The distribution-panel based electrical system further reduces the impact of a natural disaster.

We hope that our design will help lead San Francisco toward a brighter, more sustainable future.