AEI Team Number:
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Mechanical Report

2014 Charles Pankow Foundation
Annual AE Student Competition

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EXECUTIVE SUMMARY:

The main goal of the Charles Pankow Foundation Design Competition is to design a building that improves upon the quality, efficiency, and value of tall 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 original design methods.

The following report summarizes the strategies, rationale, and steps the mechanical team took when designing the mechanical systems for San Francisco's 350 Mission Street Project. The report also contains several appendices which outline the necessary design conditions, calculations, and sizing methods, along with construction documents summarizing system layouts and schedules.

The subsequent paragraphs summarize the main design concepts that the mechanical team implemented in conjunction with all the other disciplines to create an efficient and high quality building for San Francisco's business district.

A decision was made by the mechanical team to condition the building via a Chiller/Boiler plant located in 350 Mission's penthouse. The cooling will be handled by two absorption chiller. The two 450 ton absorption chillers will be driven by hot exhaust produced by a series of ten 65 kW electrical generating microturbines. The condensed water loop will be cooled via a two cell Evapco 700 Ton cooling tower. Any useful heat that is not used by the absorption chiller will be passed through a heat exchanger to satisfy the Domestic Hot Water (DHW) load of the building during these cooling periods. During the heating season the hot exhaust from the microturbines will pass through a heat exchanger to produce space hot water, in conjunction with three 750 MBH natural gas fired boilers.

The air side distribution for the Office spaces will be supplied via an Underfloor Air Distribution System (UFAD). It was decided by the mechanical team that two AHUs will be located on each floor to supply conditioned air to the core and peripheral underfloor plenums.

In order to take advantage of the temperate climate of San Francisco and control solar variables, a façade study was conducted. The mechanical team determined that a Double Façade System (DFS) would be beneficial to maintaining desired indoor temperatures and conditions. The DFS will accomplish this goal through passive conditioning methods such as natural ventilation and by means of a conditioned thermal layer in the heating months. Along with passive strategies the DFS will be integrated with control logic in order to maximize its efficiency.

Near immediate occupancy after a catastrophic event was a main design challenges presented in the competition. In order to satisfy this requirement the mechanical team in conjunction with the structural team researched seismic design options and construction methods utilized in industry.

The owner expressed a great desire for the building to be high-performance. This, inevitably, required the team to look into LEED certification. After analyzing our system, it was determined that our proposed design contributed 41 out of 89 points, resulting in a LEED certification of Platinum.

Lastly, algae bioreactors will be incorporated with the CHP system in order to reduce the carbon emissions from the natural gas combusted in the microturbines. The CO_2, along with other gasses and nutrients, will facilitate algae growth which can be used for research, biofuels, and other beneficial byproducts. This tactic of reducing carbon emissions is proposed to be a joint venture between the owner of 350 Mission and CAL-COM, who partner with Berkeley University, a local higher education facility that researches algae and its benefits.

SITE OVERVIEW:

Figure A: Trans Bay Transit Center Tower [1]

The 350 Mission Project is located in San Francisco's Business District, five blocks off the Bay. 350 Mission is at the corner of Fremont St. and Mission St. which can be seen in **Figure A** to the right. When analyzing the site, it was crucial to understand the sun path and how the surrounding buildings would affect the project site. As one of the shorter buildings in the immediate vicinity, the design team recognized the need to analyze the presence of direct light onto the sight, both for illumination and energy harvesting. One major concern was the future Trans Bay Transit Center Tower, which can be seen in **Figure A**, alongside 350 Mission. The massive structure will have a significant effect on the project site and consequently the design heat loads, cooling loads, and lighting design. As can be seen in **Figure A**, the Trans Bay Transit Center, as well as other surrounding buildings, do cast shadows on 350 Mission Street. It is because of this environmental impact that it is imperative the electrical design team and the mechanical design team collaborate to ensure that all the design goals and comfort goals are met and satisfied.

DESIGN STRATEGY:

Before beginning any sort of calculations, the mechanical team, as well as the other disciplines, sat down and took the time to focus their efforts.

DESIGN CONDITIONS

Before choosing any systems, the mechanical team addressed several design considerations. First, a climate zone of 3C was chosen based on Table B-1 of ASHRAE Standard 90.1-2007. Along with this climate zone, the temperature in San Francisco ranges from 32^{0}F in January to 95^{0}F in July, with the majority of the days between 50^{0}F and 59^{0}F. There is an annual mean wind speed of 14.9ft/s from E of N -76.1^0. In addition, San Francisco experiences an average rainfall of 23.8", with the wettest month being February with 4.61" of rainfall, and the driest month being July with 0.00" of rainfall.

From Table D-1 of the Standard, the data in **Table 1** was obtained:

Table 1: San Francisco, CA Climatic Data

			Cooling Design Temp		**No. Hrs. 8am-4pm**
HDD65	**CDD50**	**Heating Design Temp 99.6%**	**Dry-Bulb 99.6%**	**Wet-Bulb 1.0%**	**$55<T_{db}<69$**
3016	2883	37	78	62	1796

From this data, we were able to see that roughly 62% of the hours in a year between the times of 8 a.m. and 4 p.m. are within the temperature range that allow for natural ventilation benefits, which can be seen in the last column in **Table 1**. This information was vital in our decision to design a building that is not only capable of natural ventilation, but relies on it as a major source of energy savings. *(Appendix A: Design Conditions).*

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1. Taken from http://transbaycenter.org/

Mechanical Design Goals and Procedure

Before designing any systems, the mechanical team, along with the other disciplines, sat down and outlined the main goals/objectives of the project. From this discussion, the mechanical team was able to develop its main design goals. The mechanical design goals for the 350 Mission Project are as follows:

1) Develop a habitable space where the health, safety, and productivity of the occupants are of utmost importance.
    - Enhance the indoor air quality (IAQ) through building and mechanical systems. (UFAD)
    - Reduce energy consumption by taking advantage of the naturally temperate climate.
    - Provide localized thermal comfort through floor diffusers.
2) Ancillary to the above objective, the design team plans to meet the main objective while using as minimal energy as possible, with the hopes of meeting the requirements of a near net-zero building. (Definition for net-zero found below in section “Defining Net-Zero”)
    - Reduce the Building energy consumption by 50% as compared to ASHRAE Standard 90.1-2007 baseline.
    - Reduce the strain on San Francisco’s power grid by utilizing a CHP system.
    - Incorporate natural ventilation
    - Reduce the carbon emissions of the building by 50%
3) Minimize down time during a catastrophic event such as an earthquake or power outage.
4) Ensure that all mechanical related systems/structures are coordinated with appropriate disciplines.
5) Obtain LEED Certification by implementing new and innovative technologies
    - Obtain LEED Platinum for project
    - Reduce potable water use by implementing rainwater harvesting
6) Provide flexible office layouts to allow for future alterations in tenant spaces.

When first looking at how to *reduce* the amount of energy consumption of the building, the team constructed **Figure B**. **Figure B** focuses on the main aspects that control the design of a net-zero building. We focused the most amount of effort on aspects of the building that have the longest life, i.e. the building site and orientation. These design elements cannot be easily changed in the future, so it was imperative that they be as innovative and efficient as possible when first built. For example, as solar panel technology improves, new solar panels can be bought to replace more outdated versions, keeping the efficiency of the building high. However, the building façade is unlikely to be upgraded in the near future. Therefore, it is imperative that we spend the most time making the “bottom of the pyramid” as efficient as possible. This way in the future, the building owner will not be fighting against the inefficiency of the building mass itself like so many older building do today. It was through this reasoning that the design team strongly focused first on site/location, then façade, then MEP systems, and lastly alternative energy sources.

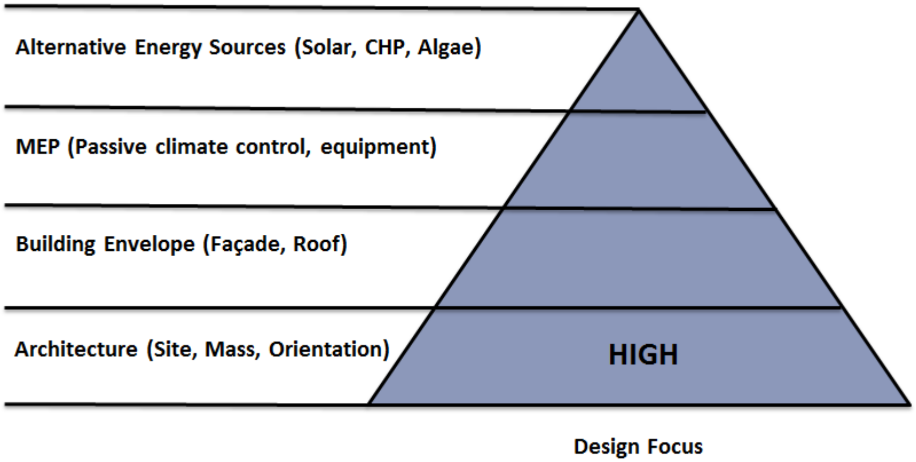

Figure B: Project Design Triangle

DEFINING NET-ZERO:

There is no one set definition when it comes to defining a Net-Zero Buildings. Rather, according to Whole Building Design Guide (WBDG)[2], there are five separate definitions. The five ways to define net-zero are as follows:

- Net-Zero Site Energy
- Net-Zero Source Energy
- Net-Zero Energy Costs
- Net-Zero Energy Emissions
- Net-Off-Site Energy Use

When attempting to decide which definition was the best for our 350 Mission building, all disciplines came to the conclusion that one definition was not the most logical, financial, or environmentally feasible way of approaching this problem. It was decided that in order to maximize the sustainability and overall quality of the building, three of the five definitions should be explored. The three definitions that the team decided on were as follows:

- **Net Off-Site Energy Use (ZEB)** - 100% of the energy purchased comes from renewable energy sources, even if the energy is generated off the site.

- **Net-Zero Source Energy Use (ZNE)** - The building generates the same amount of energy that it consumes.

- **Net-Zero Energy Emissions (ZEE) –** A building with zero net carbon emissions.

As stated above, the team felt that focusing on reaching a certain percentage of each definition would be more financially feasible and environmentally sustainable than attempting to fully satisfy one definition.

Our ultimate goal was to achieve:

30% of the buildings energy from off-site renewable sources
20% of annual electricity demand produced on site
50% reduction in carbon emissions during building operations

These goals reflect data taken from PG&E's website and researched case studies such as the 201 Mission Street project. **Table 2** below shows that we were able to exceed or meet our expectations in all three goals. The strategies used to achieve these goals will be further explained through the selected systems further on in the report.

Table 2: Net-Zero Energy

Net-Zero Energy

	Goal	Achieved
Net Off-Site Energy Use	30%	30%
Net-Zero Source Energy Use	20%	27%
Net-Zero Energy Emissions	50%	68%

ABSORPTION CHILLER:

When needed, 350 Mission's cooling load will be satisfied via two 450 Ton double effect absorption chillers. The absorption cycle will be powered via the hot exhaust generated by the ten 65kW microturbines. The absorption chillers will also have the ability to drive the absorption cycle via a direct-firing option in the event that the microturbines are unable to meet the desired load. By utilizing an absorption chiller over a traditional electrically driven chiller, the design team will eliminate the need for any CFC refrigerants to produce chilled water. In place of the refrigerant an absorption process relies on a lithium bromide solution.

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2. Taken from http://www.wbdg.org/resources/netzeroenergybuildings.php

COMBINED HEAT AND POWER (CHP):

The CHP system was first considered because of the high electricity rates in San Francisco, roughly $0.18/kWh, as compared to a state average of $0.13kWh. Additionally a cogeneration system will add a layer of redundancy in case of a catastrophic event. By having a CHP system the building has the ability to be completely independent from San Francisco's electric grid.

In order to determine whether CHP would be a viable design option for the 350 Mission Project, the mechanical design team conducted a CHP feasibility study. The feasibility study was based off of the qualifying form found on the EPA government website. In order for the facility in question to be a good candidate for CHP, it had to satisfy at least 3 of the questions imposed by the qualifying form. The following questions were applicable based upon the needs of 350 Mission:

- Do you pay more than $.07/ kWh?
    - San Francisco electricity is $0.18/kWh
- Are you concerned about the impact of current or future energy costs on your business?
    - Life-cycle costs are a considerable factor
- Are you concerned about power reliability?
    - Immediate occupancy is desired even after power outage
- Are you interested in reducing your facility's impact on the environment?
    - Net-zero energy is a driving design goal
- Is your facility located in a deregulated market?
    - San Francisco is in a newly deregulated market

Another method of determining if a CHP system would be a good choice for the building is to analyze the "spark spread", or the price difference in generating electricity compared to purchasing electricity from the grid. The spark spread for San Francisco was calculated to be $.10/kWh as seen in **Table 3**. Further analysis of the CHP system's feasibility and projected payback period can be found in *Appendix B: Combined Heat and Power*.

GOVERNING EQUATION:

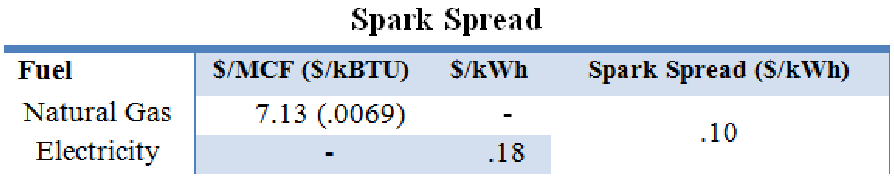
Spark spread = Power Price – [Natural Gas Price * Heat Rate]

*Heat Rate taken at 29% efficient (3.412/.29 = 11.765)

Gas Conversion:

$$= \frac{\$7.13}{MCF} * \frac{1\ MCF}{1000\ CF} * \frac{1\ CF}{1020\ BTU} * \frac{1000\ BTU}{1\ kBTU}$$

Table 3: Spark Spread



Spark Spread

Fuel	$/MCF ($/kBTU)	$/kWh	Spark Spread ($/kWh)
Natural Gas	7.13 (.0069)	-	.10
Electricity	-	.18	

The CHP system will be comprised of ten 65kW Capstone microturbine resulting in a max plant capacity of 650 kW. Microturbines were chosen for their flexible staging capabilities. The ability to stage the microturbines will result in a more efficient CHP plant. Depending on the amount of needed heating or cooling, the turbines can be staged in order to achieve the most efficient mode of supplying electricity and chilled/hot water. The CHP system was sized based off the calculated cooling load, which was determined to have a larger designed capacity than the calculated heating load. **Table 4** on the next page shows the resulting CHP capacity and efficiencies associated with each process.

Table 4: CHP Calculation / Efficiencies

CHP System Capacity

Production Method	Efficiency	Resulting Capacity
Electricity	29%	650 kW
Heat Recovery	45%	1850 MBTU/hr
Overall	74%	-

*Electrical efficiency obtained from Capstone C65 Microturbine Performance Specification
* Heat Recovery efficiency obtained from case studies (201 Mission St.)

Based upon the values calculated above the CHP system will be able to supply 88% of the building's annual space hot water demand and 27% of the building total annual electrical demand. Further supporting calculations can be found in *Appendix B: Calculations.*

BUILDING ENVELOPE:

One of the main design focuses of the competition's project was the building's enclosure. After running a solar study with Integrated Environmental Solutions Virtual Environment (IES VE), the mechanical team decided that a double façade system (DFS) would allow for substantial energy savings. The DFS is to be located on the Southwest and Southeast walls of the high rise. It will begin on the fifth story, directly above the Main Lobby space, and extend the height of the building. The Northeast and Northwest walls will be glazed with a traditional double paned curtain wall system. The DFS assembly can be seen in **Figure C.**

In order to take full advantage of the DFS, control logic was integrated within the IES VE model. The following logic is located on the following page. By applying vent controls to the façade system, the mechanical team was able to accurately model and analyze the effects of natural ventilation. The controls are integrated with vents located on the external glazing layers, within the plenum, and vents located on the inner glazing layer. The vents are positioned such that the naturally ventilated air enters the floor plenum. The control logic for the DFS windows was split into three different schemes. The three schemes are outer, plenum, and inner which can be seen in **Figure D** on the next page. In the cooling season the façade can either be opened up to breathe, or partially closed to vent hot air away from the building. In the heating months the façade closes and creates a thermal barrier/artificial environment around the building. This will prevent/retard conditioned air from escaping the occupied space.

DOUBLE FAÇADE CONSTRUCTION:

1. **Outer Layer** – Clear 6mm 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

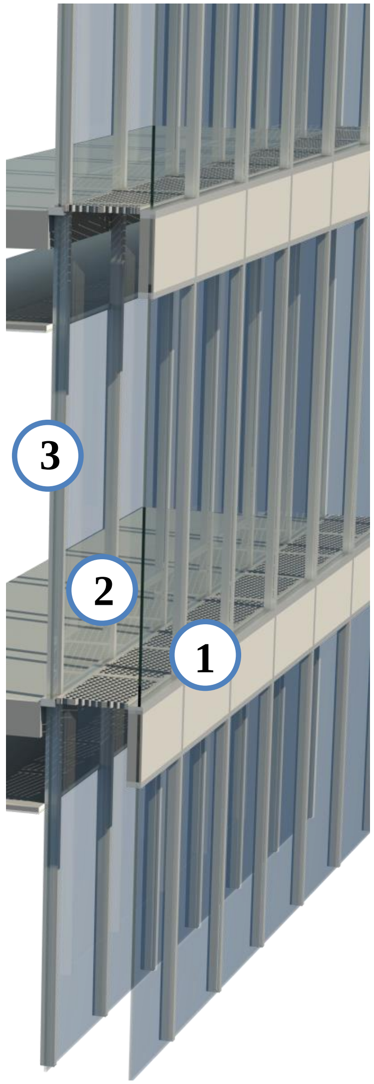


Figure C: Double Façade System

Summer Conditions (>74°F)

Window Layer	Action
Outer	Open
Plenum Vents	Opens when plenum >85°F
Inner	Closed

Natural Ventilation Conditions (55-73°F)

Window Layer	Action
Outer	Open
Plenum Vents	Opens when plenum >85°F
Inner	Open

Winter Conditions (0-45 °F)

Window Layer	Action
Outer	Closed
Plenum Vents	Opens when plenum >85°F
Inner	Closed

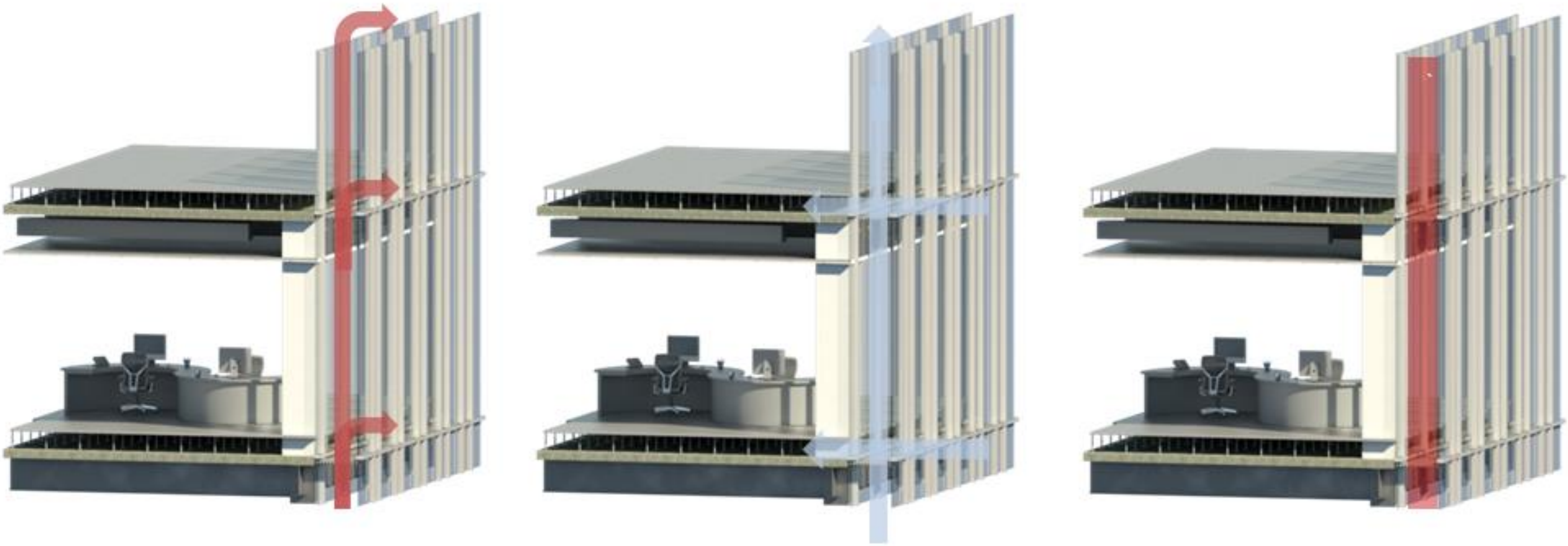


Figure D: Double Façade System Control Scheme

IMMEDIATE OCCUPANCY:

Seismic precautions had to be addressed when designing both the HVAC and fire suppression systems. Piping, a critical component of the infrastructure, can be severely damaged during an earthquake. If this piping gets damaged there is no way to suppress potential fires, which can be just as detrimental as the seismic movements itself. In order to prevent the piping systems from failing during a severe seismic event several method were researched. These precautions were vital towards increasing the possibility of immediate occupancy after a seismic event.

Some simple design and installation strategies can have a large impact on the performance and preservation of piping systems during an earthquake. One such strategy is to provide adequate clearance between pipes and structural members, floors, walls, ceiling, or any other object that could cause potential damage upon impact. In addition, properly anchoring and isolating equipment and piping are vital to decrease differential movement, sliding, and overturning. Correct pipe hangers and sway bracing also minimize the potential for pullout. Finally, using appropriate couplings such as Victaulic couplings, which are specially designed to resist earthquake accelerations, help to minimize movement in the piping system. These couplings were tested, and had no leakage when pressurized to 200 psi after being subjected to accelerations 50% greater than the Northridge, California earthquake in 1994. This earthquake has one of the largest accelerations ever recorded in an urban area at 16.7 m/s^2. Another design method to prevent the fire suppression system from failing is seismic expansion joints. These joints, as seen in **Figure E**, allow movement in all directions without putting additional stress on the suppression system. This is especially important because in an emergency situation such as an earthquake, there is a high potential for fires to start due to various damage. To allow for immediate occupancy, these fires cannot be allowed to spread and damage equipment or the structure, making a working fire suppression system vital.

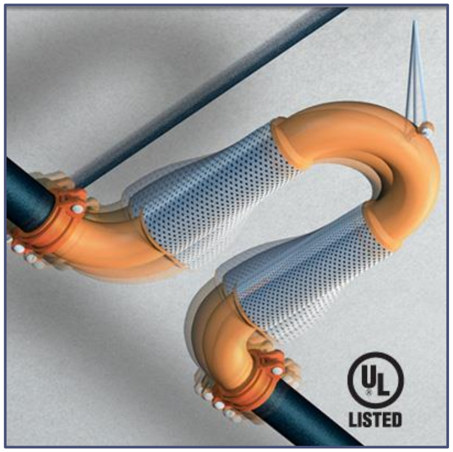


Figure E: FireLoop Seismic Expansion Joint[3]

In addition to the layout of the piping system and selection of correct components, the type of fire suppression system chosen was also key. We spent a lot of time as a team discussing which strategy would be ideal. While a traditional water system would be the cheapest option, it creates a large issue with the immediate occupancy goal. When the sprinklers go off, any electronics in the space, as well as drywall and other finishes, have the potential to be ruined. Therefore, we turned to a gaseous fire suppression system. While the gas for such a system is expensive, we reasoned that it would be vastly offset by the cost of repairs and replacements in the event of a fire. In addition, the gaseous system allows for a faster return to occupancy for the space, a major overall goal of the project. The layout of the fire suppression system can be found on drawing *M107*.

The duct system was designed in a similar fashion for immediate occupancy and reduction of damage. It is vital that all ducts be securely mounted to the appropriate supporting surfaces, with more bracing than would normally be required. For long runs of duct, both longitudinal and transverse bracing will be utilized to ensure that none of the duct becomes disconnected. In addition, the raised access flooring system allows for ease of access to duct for any repairs that may be necessary after a seismic event. All of these considerations combine to produce an overall duct system that is conducive to the flexibility required in a seismically active region.

3. Taken from http://www.metrafire.com/

CARBON EMISSIONS:

By incorporating a CHP system into 350 Mission, we were able to see a 20% reduction in CO_2 emissions and a yearly savings of 620 MCF of natural gas. The 20% reduction correlates to fuel and electricity that would have been produced by less efficient means, such as gas for boilers and electricity produced at power plants, i.e. Simple Heat and Power (SHP). This was calculated by using the "Fuel and carbon dioxide emissions savings calculations methodology for CHP system" as prescribed by the EPA. *(See Appendix B: Calculations)*. Even though the incorporation of a CHP system displaces 20% CO_2 emissions from the start, the emissions produced by the CHP were still of concern. When burned, natural gas, one of the cleanest fossil fuel, gives off mainly carbon dioxide. The average emission rates in the United States from natural gas can be found in **Table 5**.

Table 5: Natural Gas Emissions

Natural Gas Emissions

Pollutant	**Quantity (lbs/MMBtu)**
Carbon Dioxide (CO_2)	117
Sulfur Dioxide (SO_2)	.001
Nitrogen Oxides	.092

*Data taken from www.naturalgas.org

Even though natural gas is one of the cleanest fuels when it comes to emissions such as $C0_2$, it still needs to be addressed. In order to combat this pollution, the mechanical design team has decided to integrate algae bioreactors with the CHP system.

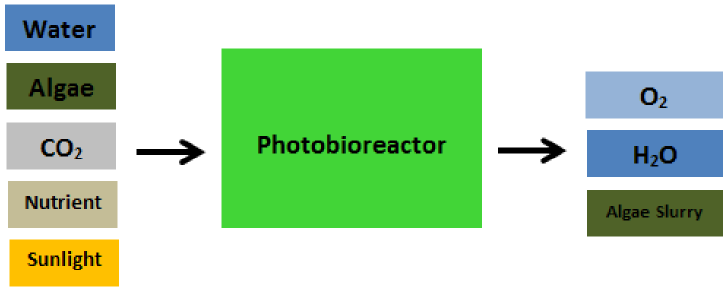
ALGAE BIOREACTORS

Algae bioreactors or photobioreactors (PBR) are used to deliberately grow algae. There are many reasons for cultivating algae such as reducing greenhouse gas emissions and the synthesizing of biofuels. The main concern of 350 Mission, as stated in the above section and in our near net-zero definition, is the reduction of CO_2 emissions produced on-site. **Figure F** below illustrates the typical inputs and output of an algae photobioreactor and the benefits that result from this particular setup.

Photosynthesis Chemical Reaction:

$6CO_2 + 12H_2O + \text{Light} \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$

Figure F: Bioreactor Inputs and Outputs

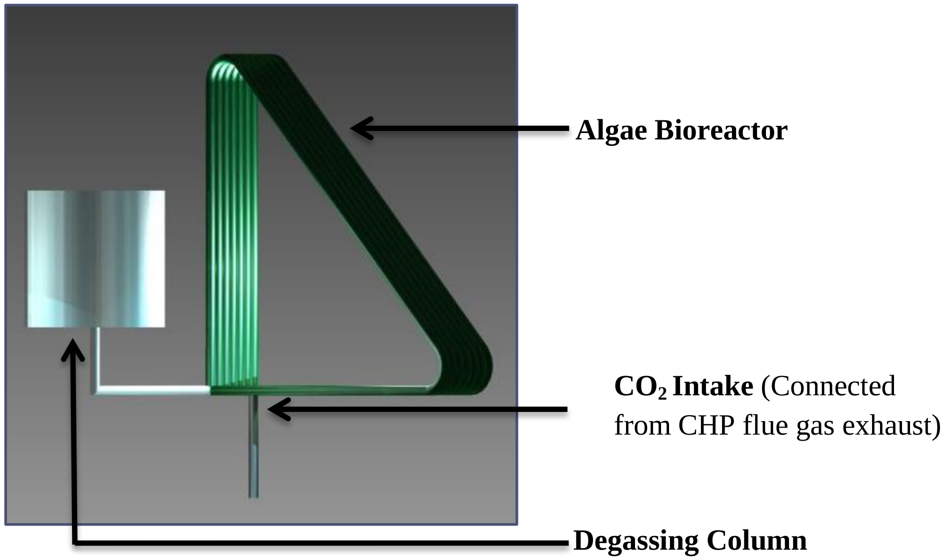


As seen in the chemical equation above, when CO_2 and solar radiation are introduced to an algae infused water sources; the byproducts are simply plant biomass ($C_6H_{12}O_6$, Glucose), oxygen, and water. This process not only reduces the carbon emissions, but also allows for the creation of biofuel, animal feed and many other useful products. In essence the "would be" harmful CO_2 is being used twice before potentially being introduced into the atmosphere.

In order to utilize this carbon reducing method, it was decided that partnering with a local research instituted would be the most feasible and economical solution. The reason for this decision was mainly due to the small CHP infrastructure and the substantial start-up cost associated with algae bioreactors. After researching potential routes, it was determined that a research facility by the name of Cal-CAB (California Center for Algae Biotechnology) would be a viable candidate to undertake this project. Cal-CAB is unique in that it partners with a variety of universities, one being Berkeley University of California, located directly across the bay. It was decided that 350 Mission would allow the research department at Berkeley to use an allotted space in the Penthouse area. It is through this partnership that both parties, Berkeley and 350 Mission, would benefit.

It was calculated that the CHP system would produce 685 tons of CO_2 yearly (approx. 2 tons daily). The CO_2 sequestration capacity is based off of a myriad of factors. Some of the dominating factors are algae type, culture time, solar exposure, and temperature. Given that this system will be used for research purposes, it is difficult to accurately determine the exact amount of CO_2 that will be captured. Based upon researched case studies from many sources including MIT's algae bioreactor system and a study done at the Institute of Systems Biology and Ecology, it was determine that typical CO_2 sequestration ranges between 50% and 75%. These percentages are based off of the factors listed above and seasonal effects, i.e. summer month and winter months solar exposure. Based upon the researched information, the mechanical team believes that the algae system will be able to capture 60% of the CO_2 emitted by the CHP system. A typical algae bioreactor setup can be found in **Figure G.**

Figure G: Algae Bioreactor System Diagram



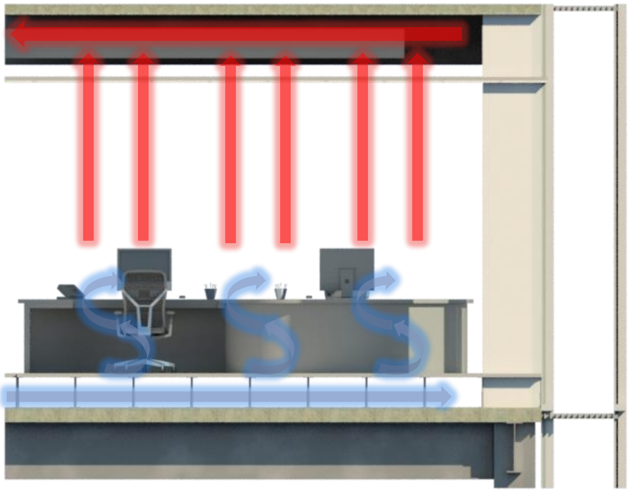
AIR-SIDE DISTRIBUTION SYSTEM:

The air-side distribution for the office space will be achieved through an Underfloor Air Distribution System (UFAD), which will be supplied via two AHUs located in the fan room *(See Drawing M-108 for schedule and sizes).* Some of the main reason for choosing this system derived from our main goals that we set early on in the project.

UFAD systems are exceptionally well suited for an office environment due to their versatile nature. The floor diffusers and floor panels can easily be swapped into different locations. This hits on a secondary goal, that is, creating flexible office layouts that allows for future alterations in the event of new tenants. With this system we are able to localize where the conditioning is taking place, resulting in greater satisfaction of occupant thermal comfort and control.

Another benefit is that by introducing the air at the floor level is that the Indoor Air Quality (IAQ) of the occupied zone is greatly improves. The system supply air is no longer mixing with contaminated air from the stratified zone. Rather the supply air is forcing the contaminants out through the return duct system via thermal buoyancy. This is demonstrated in **Figure H.**

Figure H: Displacement Ventilation Concept

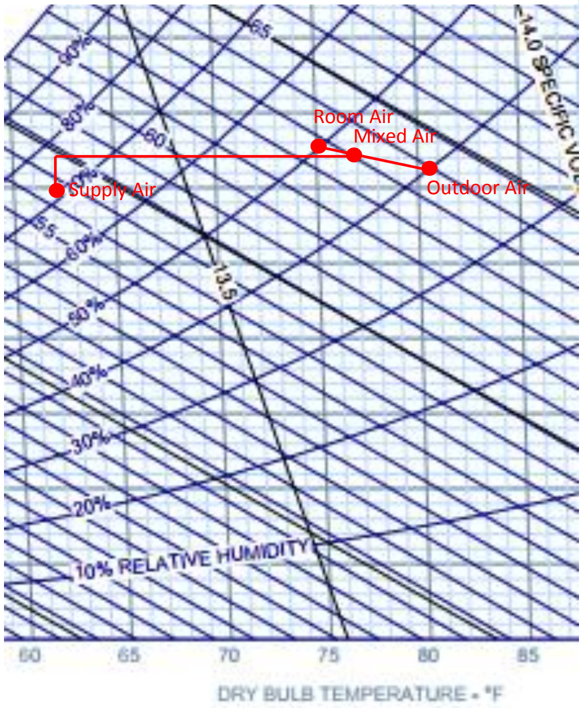


Raised Access Floors (RAF) also allows for data and electrical cables to remain unseen and allow for easy re-routing of cables.

Along with the flexibility of the UFAD system, there can also be substantial energy savings. The location of air dispersal allows for a higher supply temperature at 62^{0}F, as opposed to the traditional 55^{0}F. This difference is attributed to the fact that the air does not need to fall down to the location of the occupant, but is instead supplied where they are seated. Therefore, the design does not need to account for as great an effect from mixing between the time the air enters the room and the time it is felt by the occupant. This causes a decrease in the level of conditioning required.

In addition to the air quality improvements, the phenomenon of “short cycling,” wherein air supplied at the ceiling is immediately pulled into the return duct before it is fully mixed into the room, is eliminated. By supplying air at the floor and placing our returns in the ceiling, we force the air to travel through the occupied zone before it is exhausted. This means that the amount of supplied air will not be as great, because the air is being utilized more efficiently.

Figure I: Psychometric Chart Cut



In order to determine if the proposed system would provide a comfortable space it was vital that both the sensible and latent loads were addressed. The sensible load was satisfied first. After obtaining the needed airflow for the sensible load it was determined via a psychometric analysis that additional steps had to be taken to ensure the latent load was satisfied. This was achieved through the utilization of and enthalpy wheel. The psychometric chart in **Figure I** and equations demonstrate that the sensible and latent loads will be fulfilled. Additional calculations and information concerning the enthalpy wheel can be found in *Appendix C.*

GOVERNING EQUATIONS:

$$Q_{sensible} = 1.08*CFM*\triangle T$$

$$Q_{Latent} = .68*CFM*\triangle w$$

*Note additional supporting calculation found in *Appendix C.*

VENTILATION AND ZONES:

The zoning of 350 Mission was determined by the space’s operational category. **Figure J** outlines the zoning plan. This resulted in 6 separate zoning categories each with a dedicated AHU.

🟦 Zone 1: Lobby and Retail

The interactive public Lobby and Retail were zoned separately due to the fact that they can be entirely open to the environment.

🟧 Zone 2: Podium

It was decided that all the ancillary spaces in the garage area would be placed in a separate zone. While the majority of the Garage space will be exhausted via an independent system

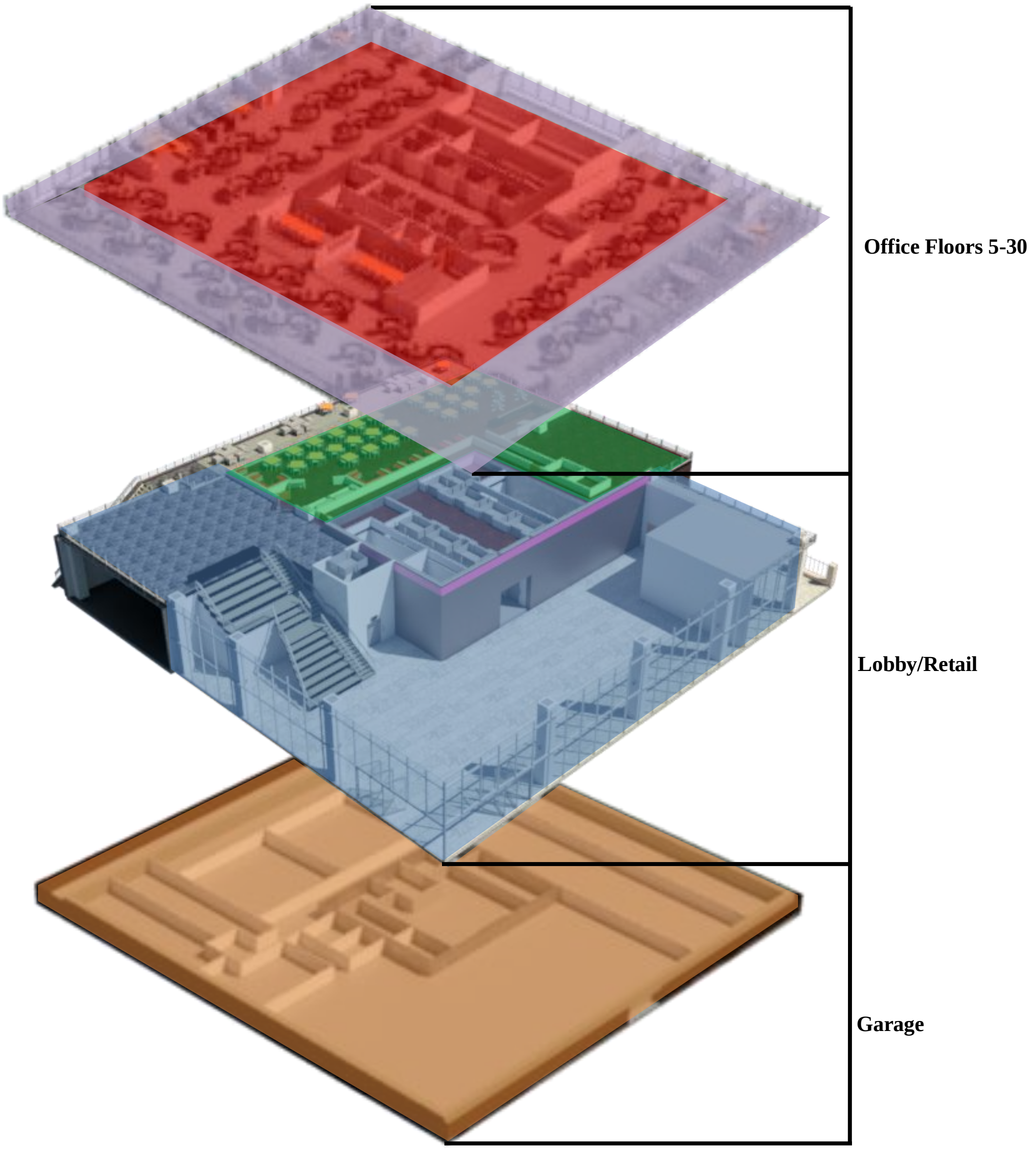
🟩 Zone 3: Restaurant

The Restaurant was assigned its own zone because of the special requirements associated with the kitchen area and exhaust requirements.

🟥🟪 Zone 4 & 5: Office Floors

Each office floor will be broken up into two separate zones, core and peripheral. This zoning scheme was chosen because of constant loads due to occupants, lighting, and equipment found in the core zone, and variable loads due to changing sun position and weather in the peripheral zone. The peripheral zone will extend 10 feet in from the perimeter of the building. This will allow for greater occupant thermal comfort throughout the year.

Figure J: Zoning Scheme



VENTILATION AND EXHAUST CALCULATIONS

Ventilation requirements were calculated via the Ventilation Rate Procedure found in ASHRAE Standard 62.1-2007. **Table 6** displays a summary of the typical required outside air per zone. A more detailed report of ventilation and exhaust requirements can be found in *Appendix D: Ventilation Calculations*.

Table 6: ASHRAE Standard 62.1 – 2007 Ventilation Requirements per Zone

Zone Minimum Ventilation Requirements

Zone	Air-side System	Floor Area	Minimum OA (CFM)
Zone 1: Lobby and Retail	UFAD	9,400	1120
Zone 2: Sub-terrain	VAV	5,250	311
Zone 4: Restaurant	VAV	4,700	3800
Zone 5: Typical Office Core	UFAD	9,000	670
Zone 6: Typical Office Peripheral	UFAD	4,400	320
Garage Exhaust	Exhaust	44,600	33,450

OVERALL ENERGY SAVINGS:

Table 7 outlines the savings of the proposed system compared against an ASHRAE Standard 90.1-2007 baseline energy model, modeled in IES.

Table 7: Energy Consumption Comparison

350 Mission Energy Consumption vs. ASHRAE 90.1-2007 Baseline

End Use	Proposed (kBtu)	Baseline (kBtu)
Internal Lighting	1,456,000	4,567,000
Space Heating	1,870,000	4,625,000
Space Cooling	517,000	1,551,000
Pumps	38,000	155,000
Heat Rejection	419,000	481,000
Fans Interior	1,239,000	2,920,000
Plug Load	4,910,000	4,909,000
Total	**10,447,000**	**21,933,000**
	52% Savings	

WATER USE REDUCTION:

There are two major water reduction techniques we employed as a team. The first approach we took was to reduce the demand for water by choosing more efficient units. The second was to employ a rainwater collection system to be used where non-potable water is sufficient.

DEMAND REDUCTION

In researching bathroom units, we found that the more traditional choices often consumed more water than was absolutely necessary and by choosing more efficient units, we could significantly reduce our water consumption. As can be seen in **Table 8,** by switching to more efficient units alone we were able to reduce water use by 26%. Calculations can be seen *in Appendix G: Water Usage.*

We chose not to change to a more efficient model of urinal in the men's bathroom. While there are flushless urinals that would not use any water at all, they are known to have complaints of a bad smell. Because one of our goals is to provide a comfortable, not only efficient, work environment we chose to use a traditional urinal to ensure the satisfaction of all occupants.

Table 8: Water Demand Reduction

Water Demand Reduction

	Gallons/year
Baseline	609,045
Proposed	451,725
Reduction	**26%**

RAINWATER COLLECTION:

Toilets and urinals use water that never actually comes in contact with, and certainly is not consumed by, a person and therefore can use non-potable water. As can be seen in **Table 9,** 350 Mission Street uses a significant amount of water each year that does not need to be potable. *Appendix G: Water Usage* shows the annual and monthly use of each type of unit as well as the floor each unit is on and the calculations of water use.

A great source of water for use in systems that can use non-potable water is a rainwater collection system. This system collects the rain water from runoff on the 15,990 sq ft roof and stores it for later use throughout the building. As can be seen in **Table 9,** the total amount of rainfall for the year is 189,774 gallons as can be seen in *Appendix G: Water Usage*. This means that rainwater collection can meet about 56% of the annual non-potable demand.

The rainwater collection tank is sized based on the month with the greatest amount of rainfall, in this case February, leading to a 40,000 tank. This way, the building is also able to utilize the maximum amount of rainwater.

Table 9: Non-Potable Water Use

Non-Potable Water Demand

	Use (Gal/unit)	Units	Gal/ month	Total Yearly Gal	
Toilets	2,850	158	21,850	262,200	
Urinals	1,425	52	6,175	74,100	
Total			28,025	**336,300**	
	July (min)	**Feb (max)**		**Annual**	**% of Demand**
Rainfall (in)	0.00	4.61			
Collection Capacity (Gal)	0.00	36,759		**189,774**	**56%**

LEED 2009 NEW CONSTRUCTION: *(APPENDIX I)*

WATER EFFICIENCY 6/10

WE Credit 2: Innovative Wastewater Technologies	2 Points
WE Credit 3: Water Use Reduction	4 Points

ENERGY & ATMOSPHERE 26/35

EA Credit 1: Optimize Energy Performance – 54% reduction	19 Points
EA Credit 4: Enhanced Refrigerant Management	2 Points
EA Credit 5: Measurement and Verification	3 Points
EA Credit 6: Green Power – 35% from renewable sources	2 Points

INDOOR ENVIRONMENTAL QUALITY 4/15

IEQ Credit 1: Outdoor Air Delivery Monitoring	1 Point
IEQ Credit 6.2: Controllability of Systems - Thermal Comfort	1 Point
IEQ Credit 7.1: Thermal Comfort – Design	1 Point
IEQ Credit 7.2: Thermal Comfort – Verification	1 Point

INNOVATION IN DESIGN 5/6

ID Credit 1: Innovation in Design	5 Points

Innovation in Design: Cogeneration, Algae Bioreactors

Exemplary Performance: EA Credit 1, WE Credit 3

TOTAL 41 POINTS

CONCLUSION:

At the beginning of the project the team set out to create an office building space where the safety and wellbeing of the occupants was a strong focus, along with the main goal of making 350 Mission as near net-zero as possible. It was through a variety of systems and processes that we were able to achieve and even exceed our goals. The resulting design achieved the following:

- A **healthy, safe, and comfortable environment** for the occupants
- A **sustainable designed systems** with **reduced energy consumption**
- **Reduced building emissions**
- **Adaptable floor plan**

By incorporating an Underfloor Air Distribution system, IAQ of the office spaces was improved and, concurrently the energy consumption of the air-side mechanical system was lowered. Aside from the previously mentioned benefits, the UFAD system allows for space flexibility and future renovations. Through the use of natural ventilation the team was able to capitalize on San Francisco’s mild climate, which allowed for substantial energy savings. *(Appendix H: Energy Use)*

The utilization of absorption chillers and the CHP system were two integral parts to achieving our goal of reduced energy consumption. By maximizing the effects of each unit of energy we were able to use a smaller amount of fuel efficiently. By incorporating the CHP system we were also able to reduce the carbon footprint of 350 Mission. Carbon emissions were further reduced by the introduction of the algae bioreactors.

Although it was not a requirement for the competition, our team felt strongly that water use reduction went hand-in-hand with energy savings. Therefore, we spent some time looking at various ways to reduce water demand and were able to achieve an overall reduction of 57% by more efficient fixtures and rainwater collection.

Table 10: Overall Savings Summary

Overall Savings Summary

	Baseline	Proposed	% Reduction
Energy Savings (kBtu)	**21,900,000**	**10,500,000**	**52%**
Carbon Emissions (lbs CO_2)	**1,751,500**	**558,400**	**68%**
Water Use (Gals)	**609,045**	**261,951**	**57%**

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