APOLLO

Rebecca Bires | Scott Brown | Scott Eckert | Jordan Huey | Helen Leenhouts | Andrew Levy | Jeffrey Loeb | Patrick Vogel

350 Mission

30 Story Mixed-Use High-Rise

4 Story Lobby

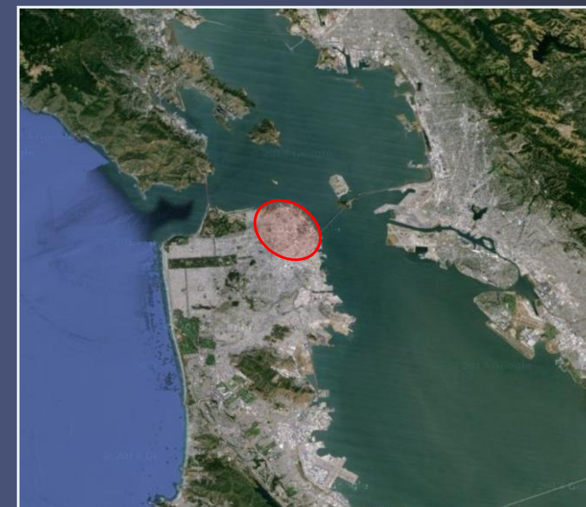
Restaurant

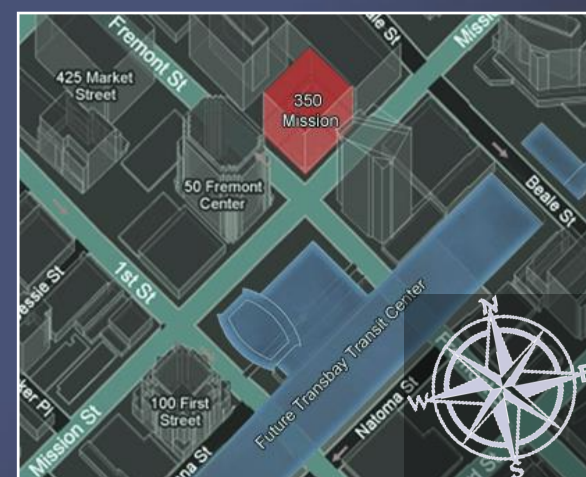
Retail

25 Office Floors

4 Story Underground Parking Garage

San Francisco , CA





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Project Goals

Net-Zero Design

- Producing energy
- Reducing energy load

Seismic Activity Response

- Continuous operation after a design level earthquake
- Half of code allowed drift

High Quality for Occupants

- System performance

Net Zero

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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.

Strategy: buy energy from renewable sources and PV Eco-districts.

Goal: 35%

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

Strategy: use a combined heat-and-power system to generate energy on-site.

Goal: 20%

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

Strategy: use algae bioreactors to offset the carbon emissions of the combined heat-and-power system.

Goal: 50%

Building Overview

Apollo

Price Estimate: $93 million

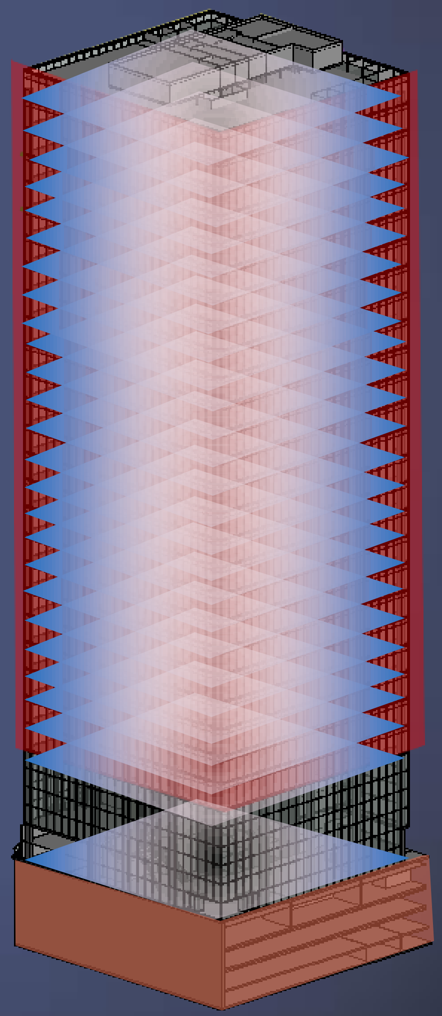
Schedule: 2.5 - 3 years

LEED Certification: Platinum

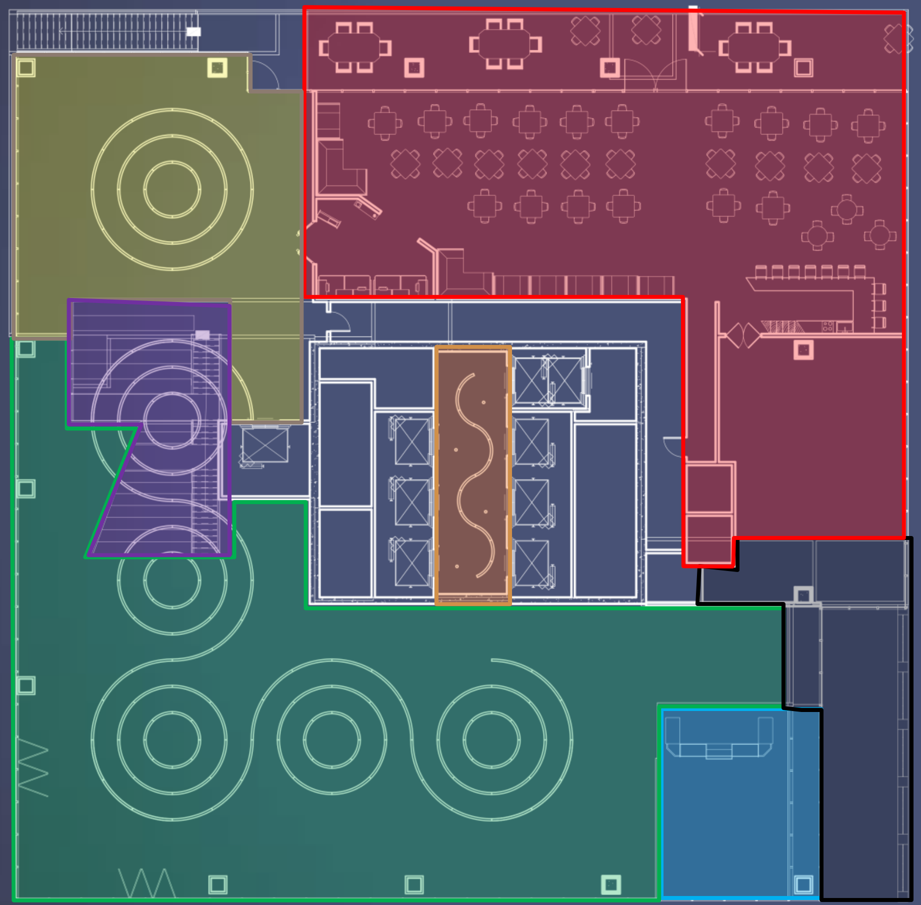
Systems

- Double Façade
- Raised Access Floor System
- Structural Steel System
- Photovoltaic Grid
- Combined Heat and Power

4 Story Parking Garage



Lobby Layout



Street Level
- Lower Lobby
- Retail
- Back of House
- Elevator Lobby

Staircase

Second Level
- Upper Lobby
- Restaurant
- Elevator Lobby

Typical Office Layout

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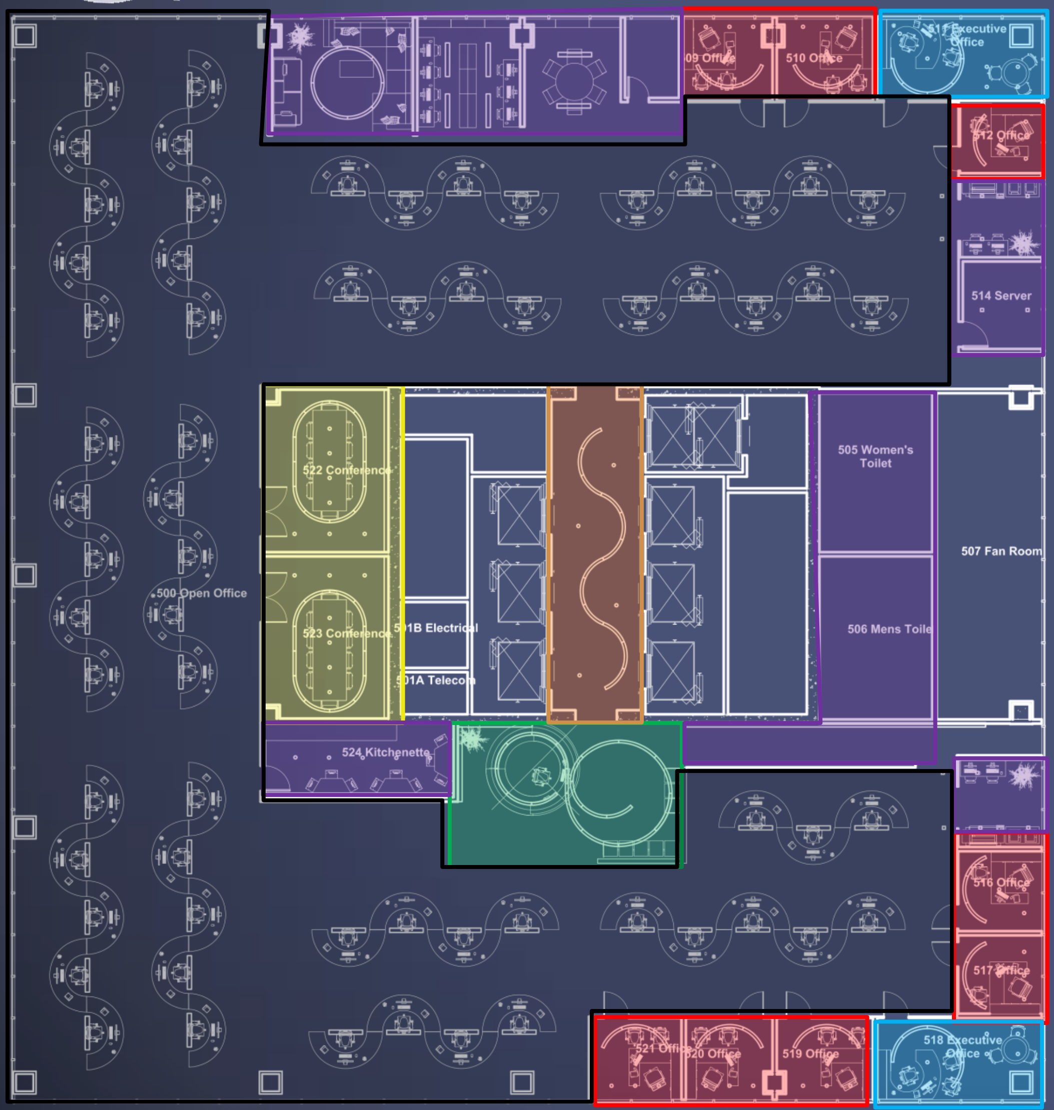


Elevator Lobby

Reception

Executive Offices

Partner Offices

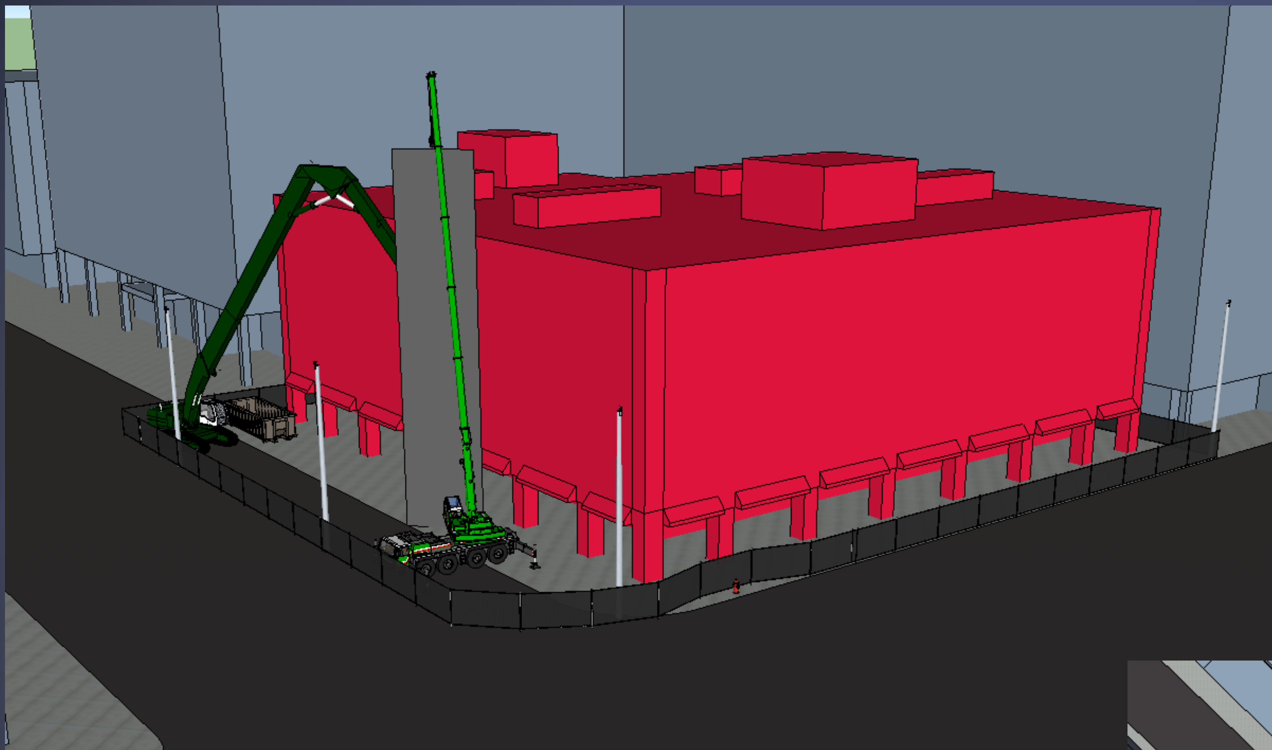
Open Offices

Conference Rooms

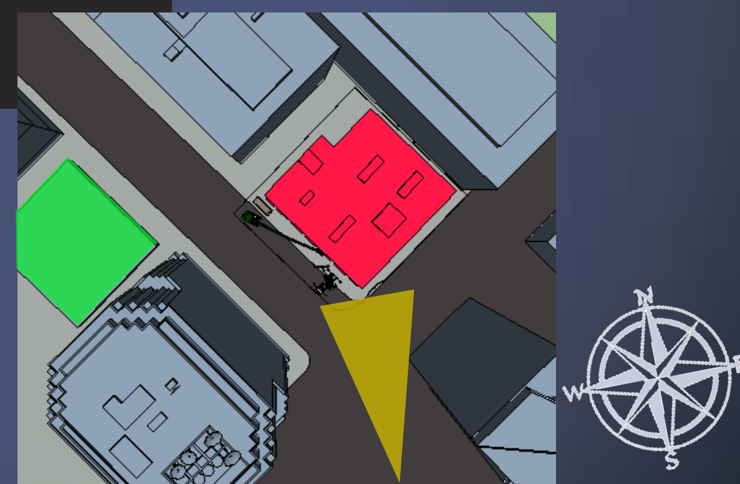
Ancillary Spaces

Project Phasing

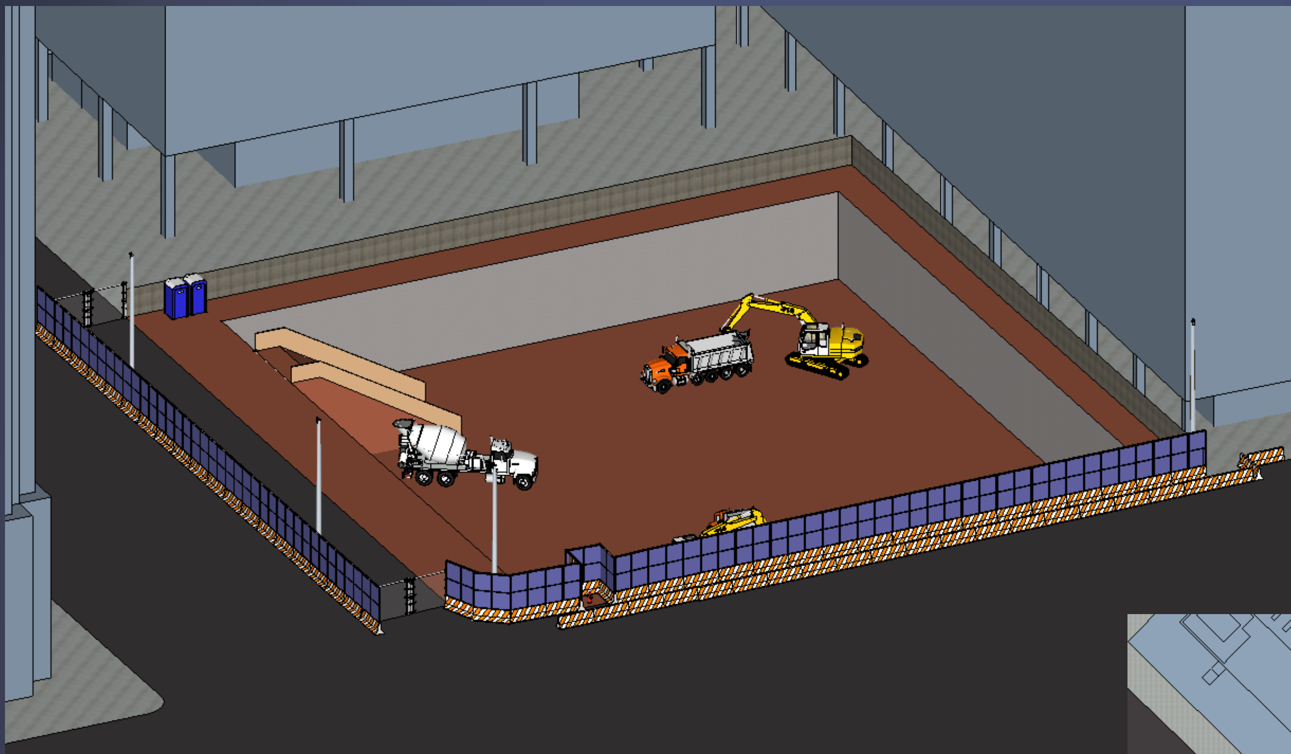
DEMOLITION PHASE



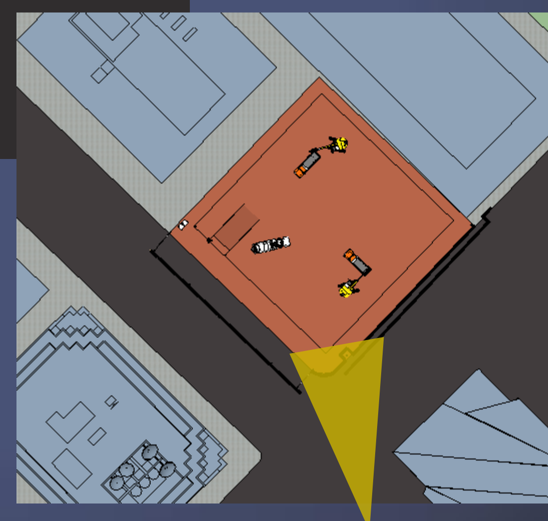
- Electric Bus Lines
- Asbestos Abatement
- Demolition Mat
- Sort & Recycle off-site
- Concrete Reuse
- Off Site Trailer



Excavation Phase



- Construction Fence
- Soil Conditions
- Retaining Wall
- Foundation Mat
- $5 million



ERECTION PHASE

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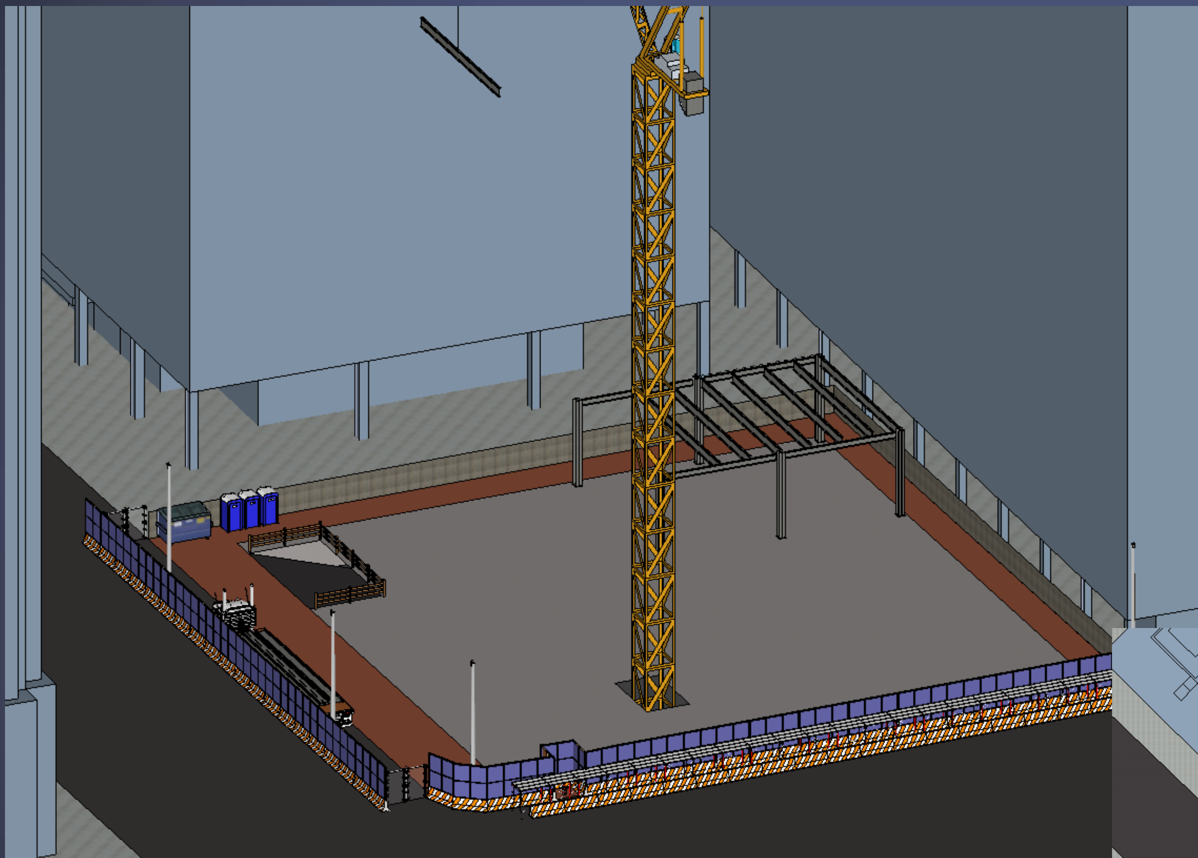
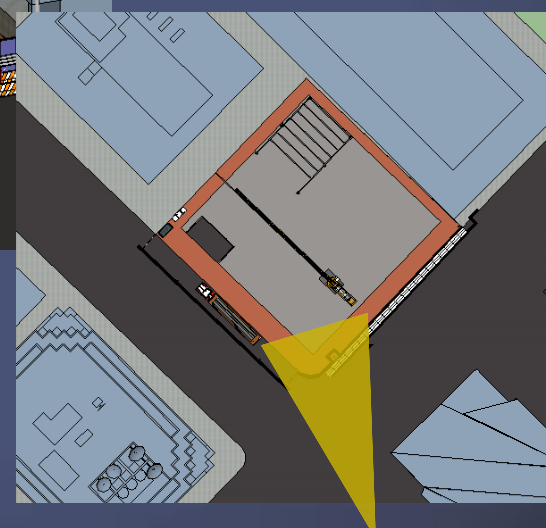


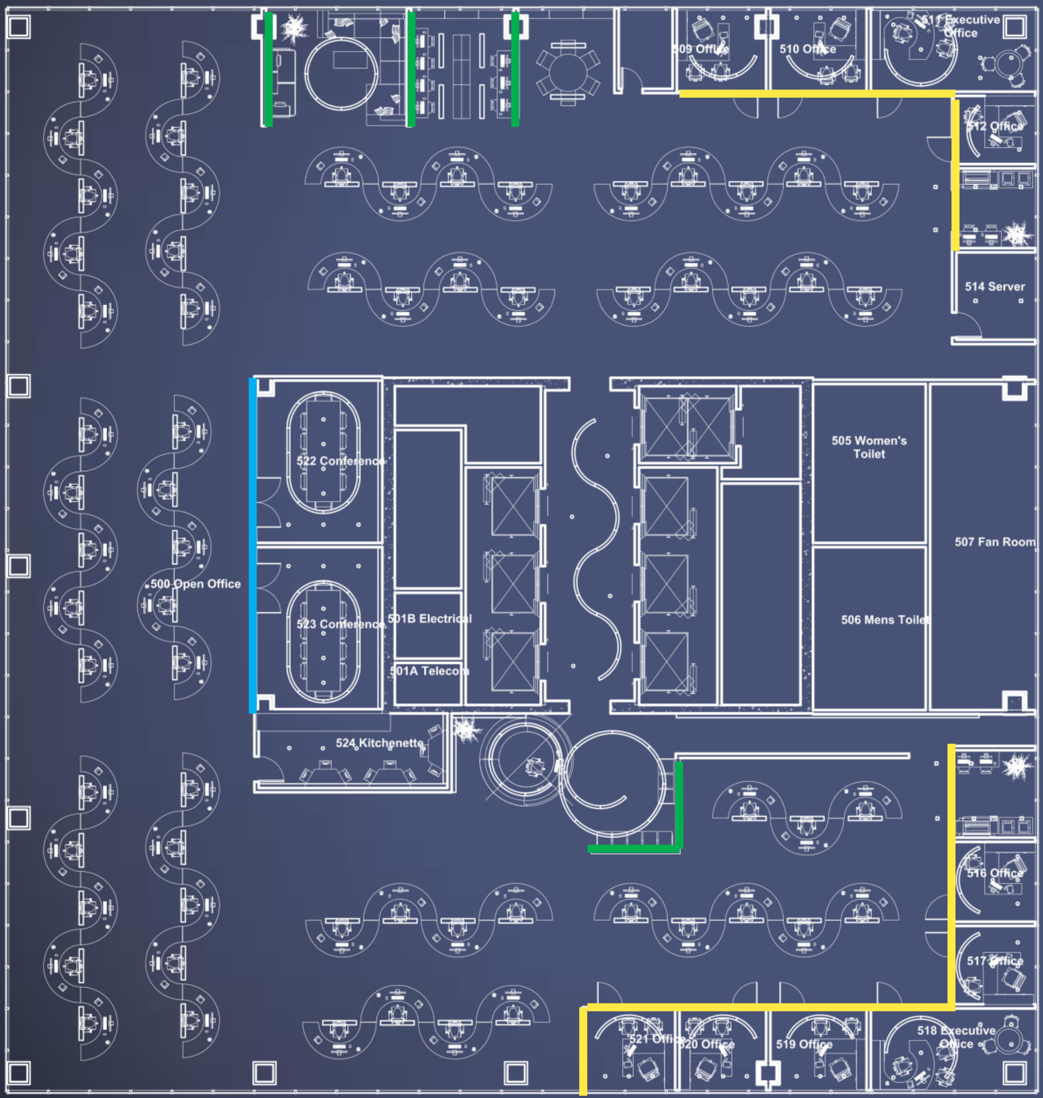
- Office Location
- Crane Location
- Safety
- Electric Bus Lines



SYSTEMS

Daylight

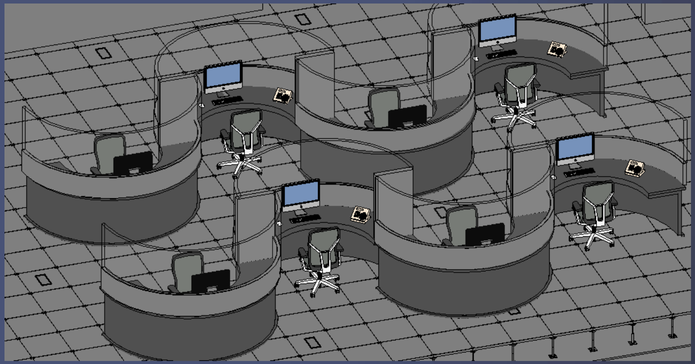
Typical Office Layout



Frosted Glass Walls

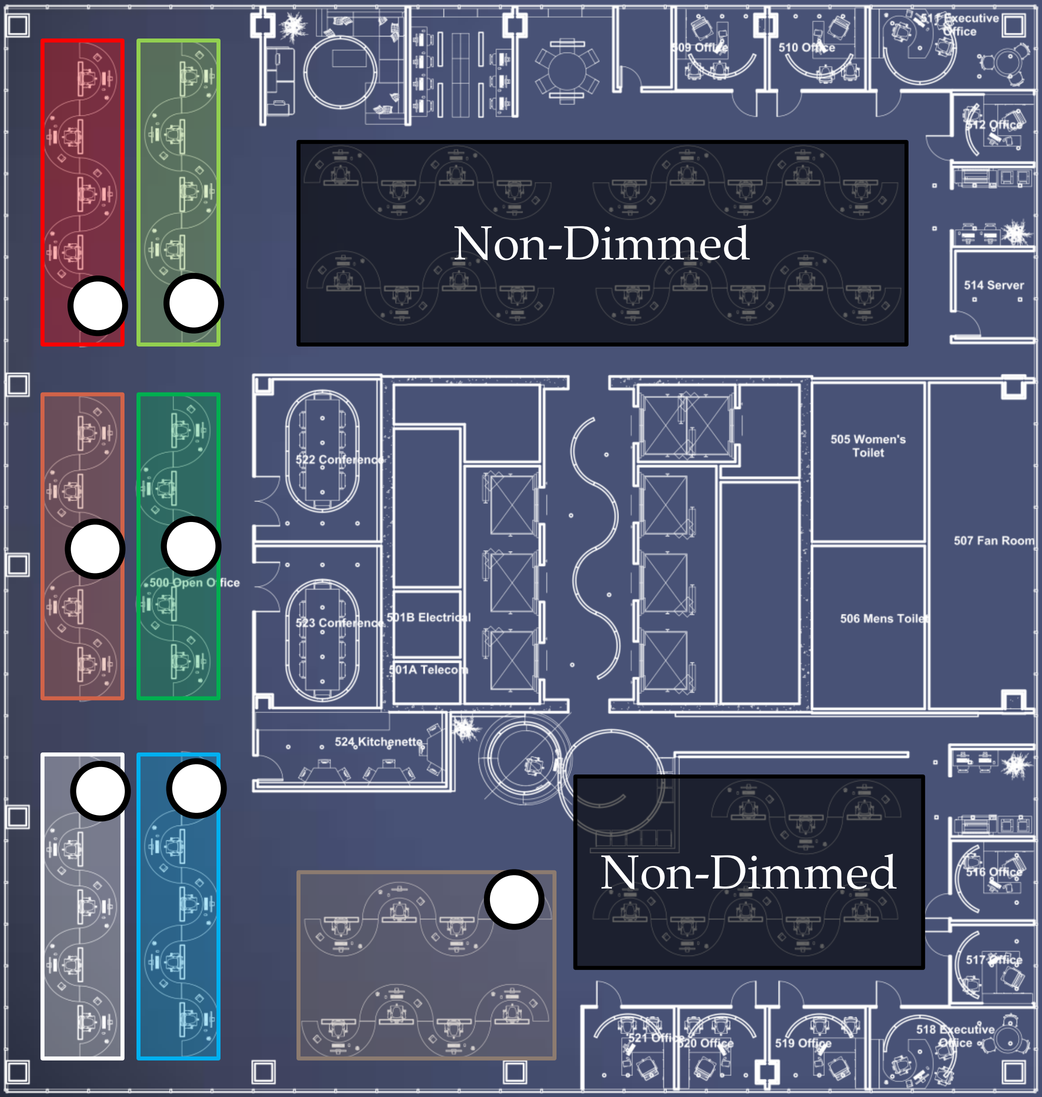
Clear Glass Walls

Half Height Walls



Energy Use Reduction

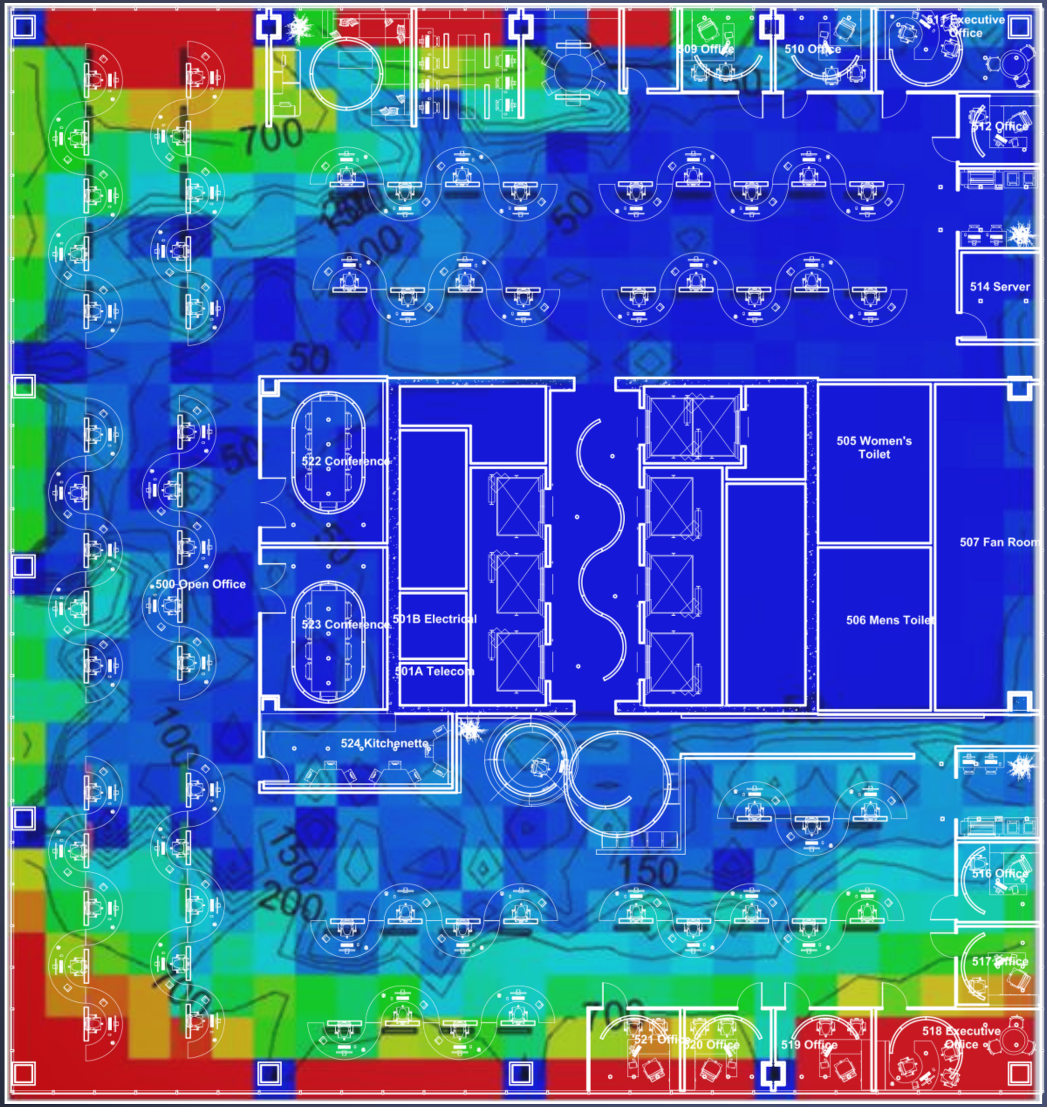
Daylight Harvesting



Vacancy Sensing

Light Level Tuning

Energy Savings



LPD Reduction

0.67 W/ft² out of 0.9 allowable, 36% reduction

191,360 kWhr

Daylight Harvesting

dimming 38 fixtures to an average level of 24%

98,300 kWhr

Light Level Tuning

continually reducing lighting output, until it is too low

24,700 kWhr

Vacancy Sensing

turning off lights in unoccupied spaces

29,000 kWhr

Total
383,814 kWhr

Double Façade

~$13 M

Double Façade

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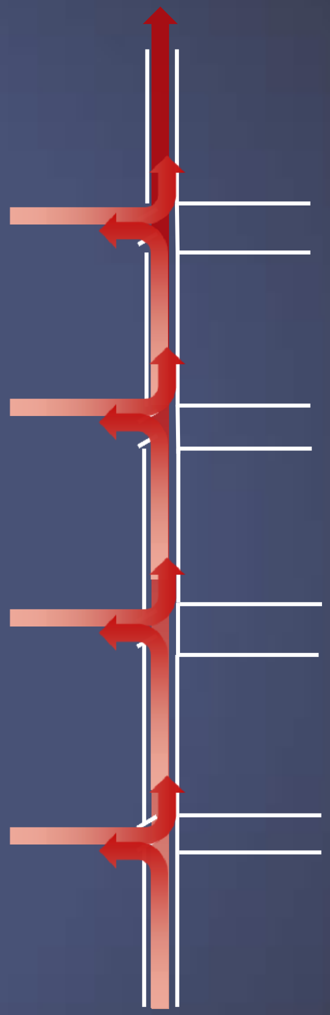
Summer Conditions (>74ºF)	
Window Layer	Action
Outer	Open
Plenum	Opens when plenum >85ºF
Inner	Closed



Double Façade

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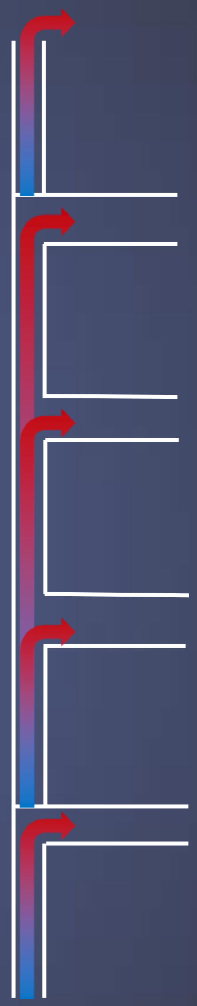
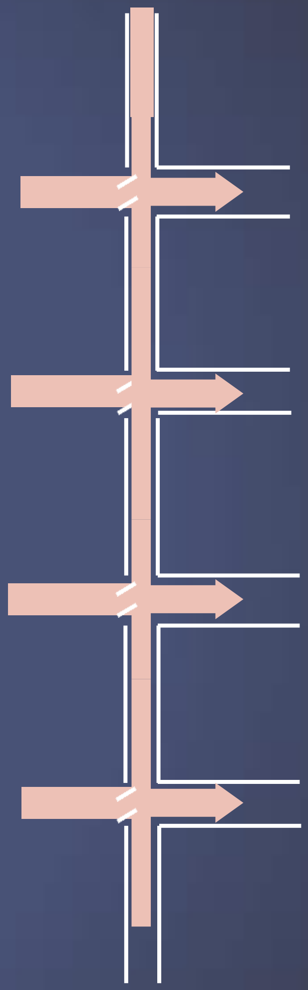
Winter Conditions (0-45 ºF)	
Window Layer	Action
Outer	Closed
Plenum	Opens when plenum >85ºF
Inner	Opens when plenum > 70



Double Façade

APOLLO

Natural Ventilation Conditions (55-74°F)	
Window Layer	Action
Outer	Open
Plenum	Opens when plenum >85°F
Inner	Open



Raised Floor

~ $6 M

RAISED FLOOR

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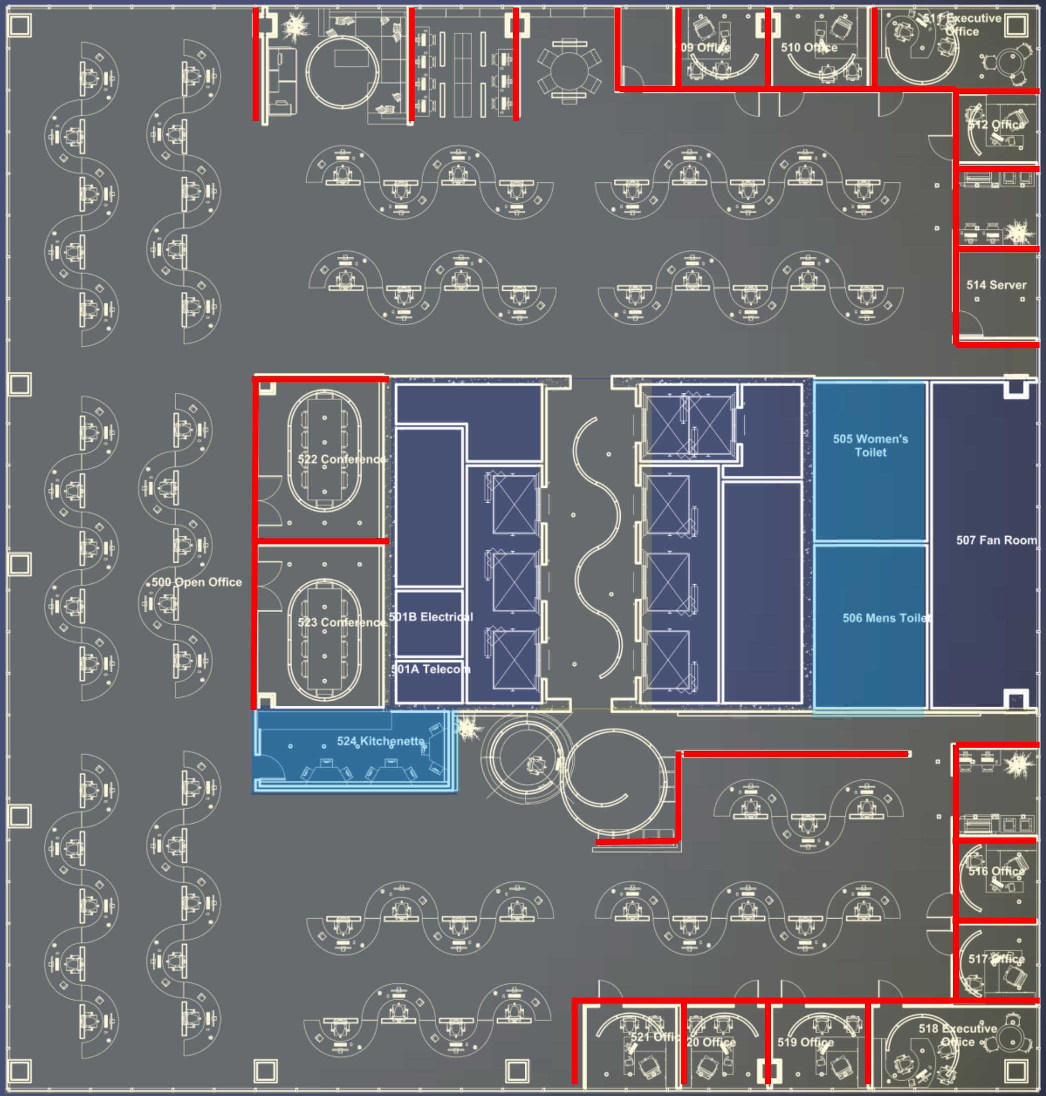
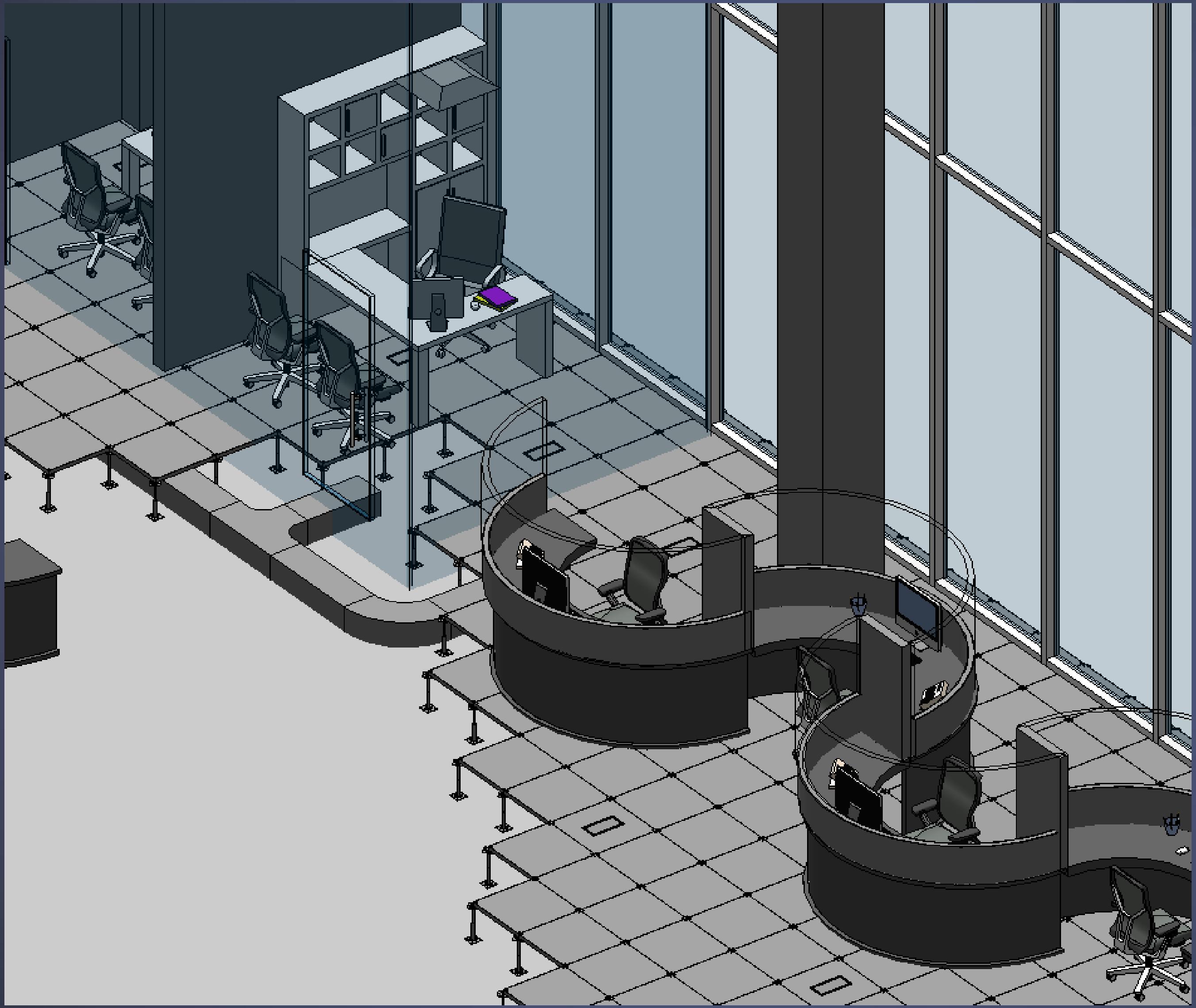
Raised Floor System

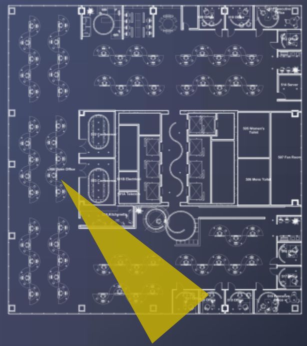
Walls that penetrate the raised floor

Pods



Raised Floor





Gravity Elements

~ $5.5 M

Gravity Elements

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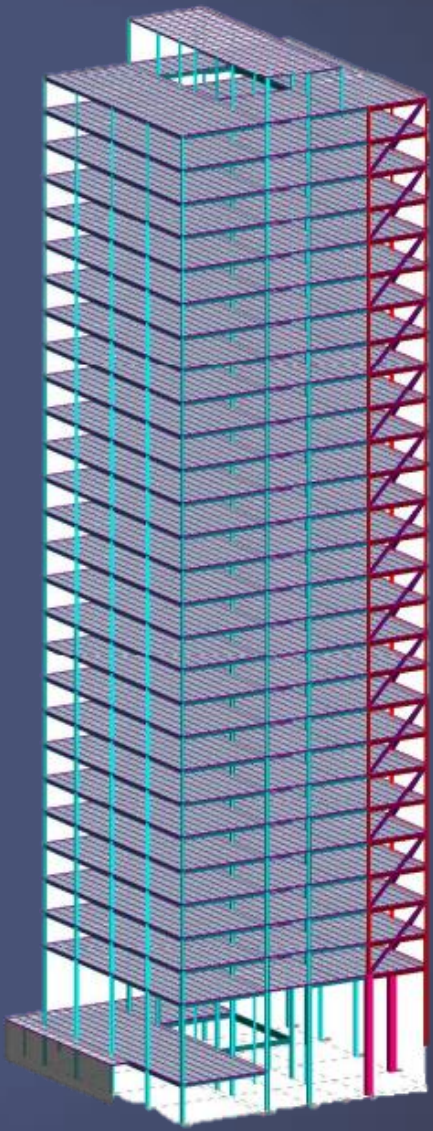
Steel Super-Structure

- Design Considerations:
  - Long span conditions for steel beams
  - Limit excessive beam depths
  - Limit Floor to Floor height increase

- Loads:
  - Live Load: 100 psf
  - Dead load: self weight + 10 psf
  - Partition Load: 20 psf
  - Raised Floor: 10 psf



Gravity Elements

Strategy

- RAM SS was used to design all gravity elements
- Initial RAM model was built for a typical floor with non-composite beams and unreducible loads to determine a worst case beam depth
- Team check-in to discuss beam depths
- RAM model rebuilt to a typical floor with composite beams and reducible loads

Structural Elements

- Beams range from W14 shapes to W36 shapes
- All columns in upper floors are W14 shapes
- Built up columns were designed where W14 had inadequate capacity
- 2VLI20 deck from the Vulcraft Manufacturer's catalog was used with a 4 ½ inch topping thickness of normal weight concrete (2 hour fire rating)

Gravity Elements

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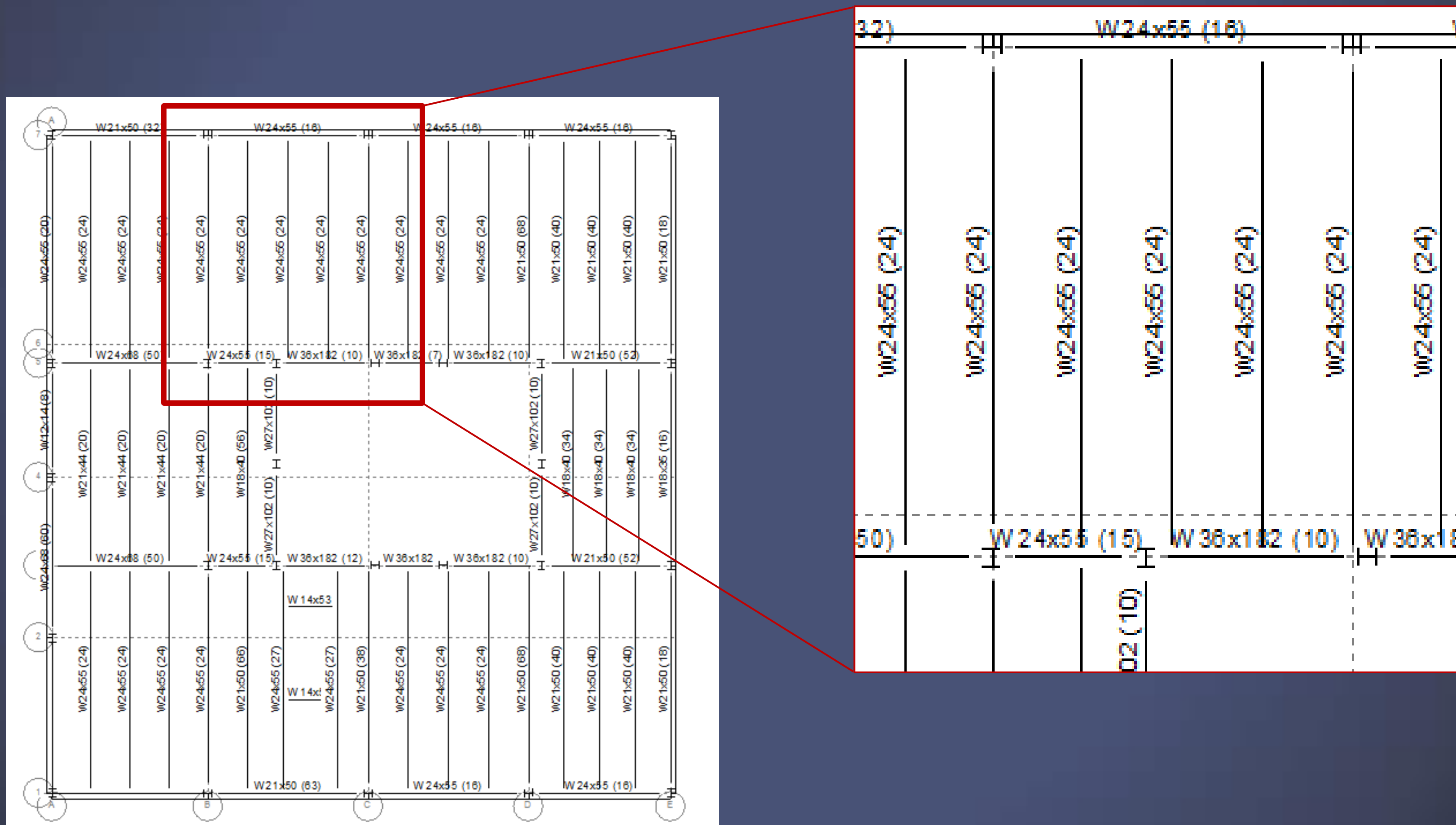
Typical Floor Beam Layout



Gravity Elements

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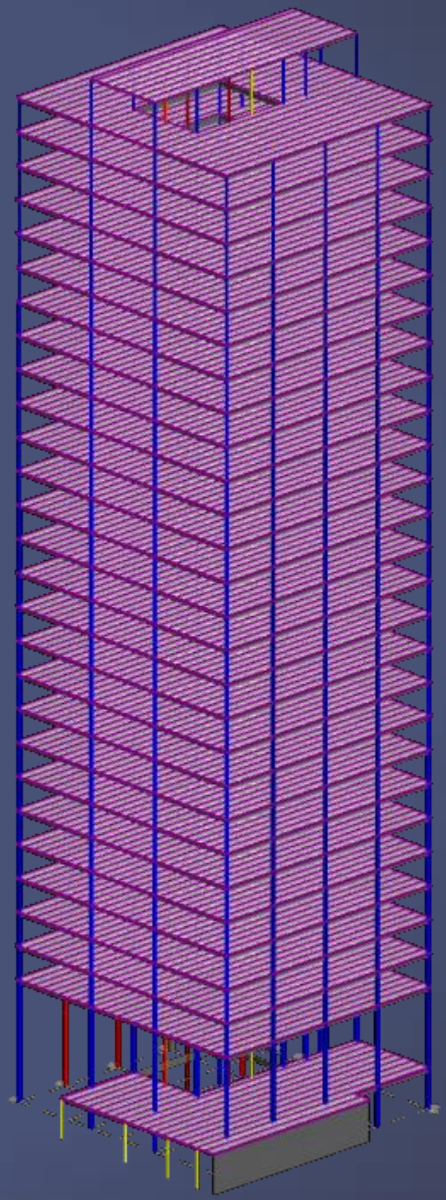
Columns

- Spliced every 2 levels
- W14 shape
- Built-up columns designed in lower levels



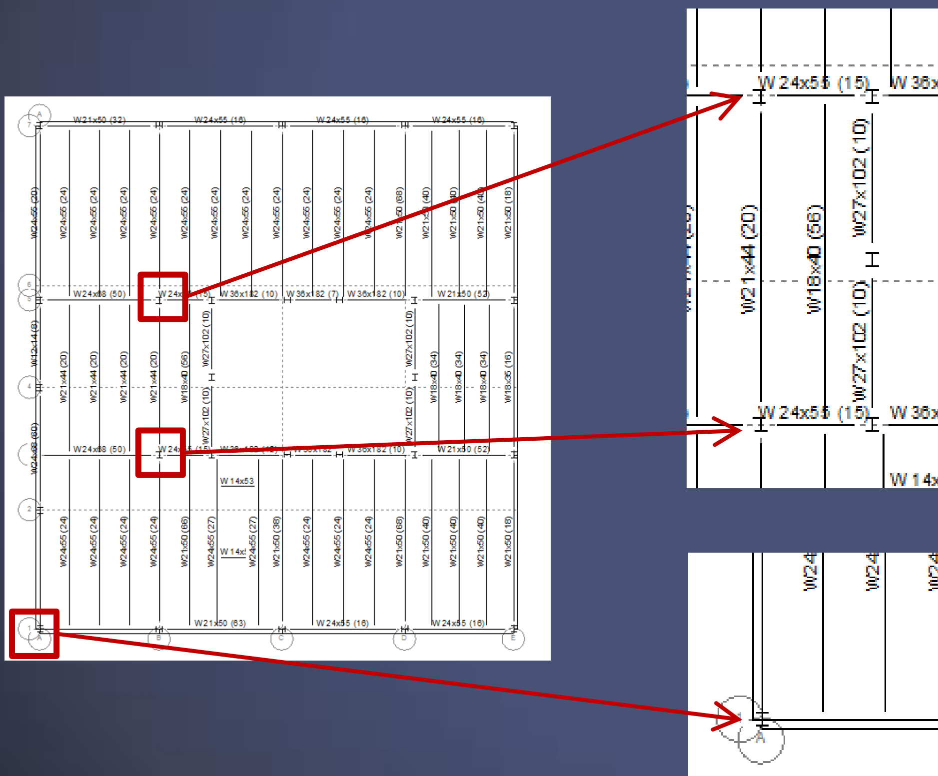
Gravity Elements

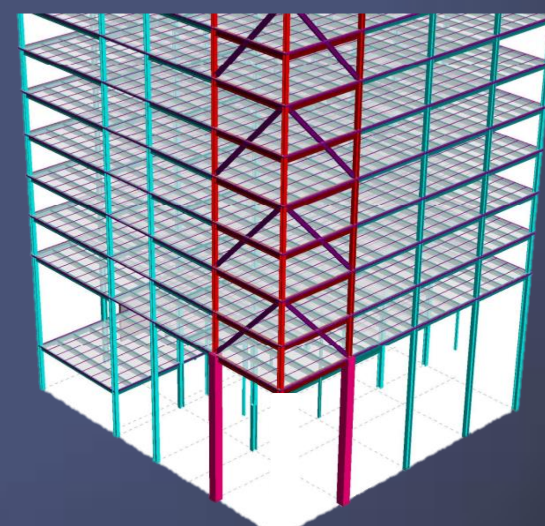
Problems

- Beam depths still excessive
- Cantilever

Solution

- Interior columns added, new spaces created
- Corner column introduced above lobby level, cantilever now only exists at lobby level
- Transfer braces added to cantilevered corner to transfer load away from corner





Lateral Elements

~ $15 M

Lateral Elements

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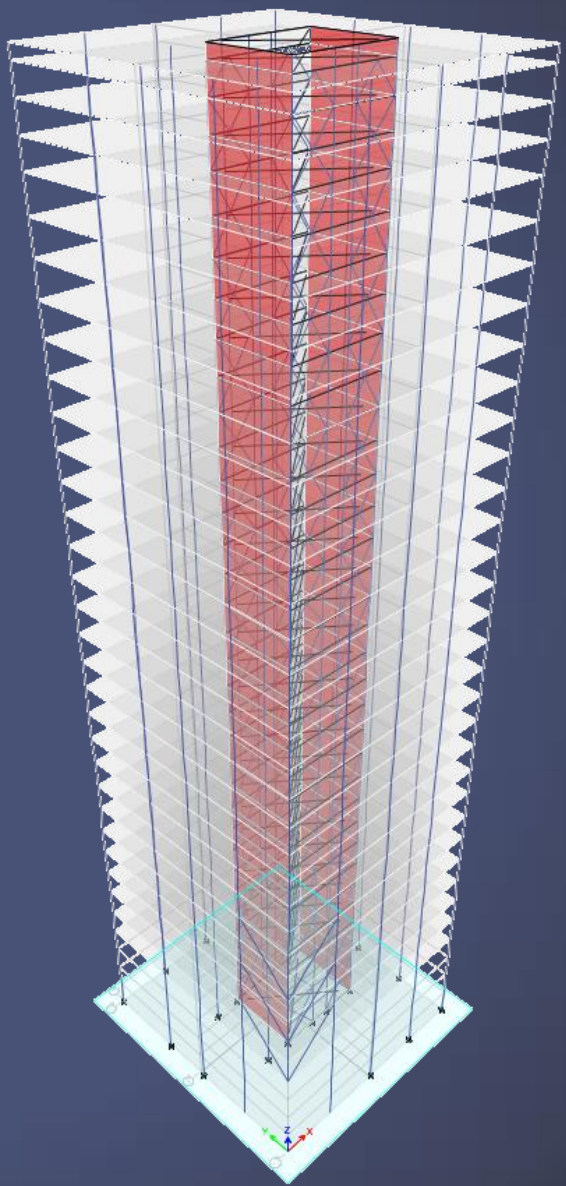
Design considerations:

- Building is to be able to withstand a design level earthquake with near immediate occupancy required after the event.
- The structure is to comply with one half the code allowed drift limit.
- While economy is not explicitly mentioned in the competition guidelines, the design team did consider the cost of different systems.



Lateral Elements

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Initial Strategy:

- Remove concrete structure as the primary LFRS and replace with steel
- Determine the new drift limit for the high rise
- Investigate potential damping systems
- Propose a new LFRS based on investigation and check progress for drift and ease of repair after a seismic event

Initial Lateral Calculations

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Equivalent Lateral Force

- Performed for the estimated design weight in order to determine the approximate forces that the design team would be dealing with

Revised drift limit

- Upon accounting for extra height imposed by the new steel construction and mechanical systems the drift limit was determined to be 41.5 inches at the full height of the building

Level	F_x (kips)	M (kip-ft)
Roof	221.60	85130.23
26	207.66	76835.23
25	195.04	69598.54
24	182.76	62809.38
23	170.82	56455.63
22	159.21	50525.63
21	147.96	45005.28
20	137.05	39883.79
19	126.50	35147.91
18	116.31	30784.84
17	106.49	26781.59
16	97.03	23125.00
15	87.94	19801.73
14	79.24	16798.22
13	70.92	14100.72
12	62.99	11695.24
11	55.46	9567.51
10	48.34	7703.02
9	31.64	6086.94
8	35.37	4707.10
7	29.53	3538.98
6	24.15	2575.59
5	19.22	1797.51
4	14.78	1187.73
3	10.85	728.58
2	7.44	401.59
Lobby	0.00	0.00
	2456.30	**702769.9**

Lateral System Investigation

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After performing the initial calculations and discovering the significant forces on the building, lateral systems and damping were investigated. This investigation included:

- Base Isolation
- Outrigger systems
- Damping systems (primarily viscous fluid damping)
- Steel plate shear walls
- Special braced and moment frames

New Lateral Calculations

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Equivalent Lateral Force

- Performed for the proposed steel structure with estimated lateral members

Increased loads and moments at each floor

Level	F_x (kips)	M (kip-ft)
Roof	258.12	114603.37
30	194.45	83419.72
29	182.84	75695.71
28	171.53	68441.00
27	160.53	61643.12
26	153.02	56465.09
25	142.42	50417.00
24	132.14	44796.41
23	122.19	39590.04
22	115.81	35785.56
21	106.26	31239.88
20	97.05	27078.25
19	88.21	23286.27
18	80.14	19955.64
17	71.98	16842.28
16	64.18	14055.75
15	56.77	11580.62
14	51.01	9640.52
13	44.21	7692.35
12	37.82	6014.15
11	31.87	4588.70
10	26.59	3429.76
9	21.47	2447.39
8	16.82	1665.09
7	12.66	1063.25
6	9.45	652.03
5	6.18	333.92
Restaurant	0.58	10.52
Lobby	0.00	0
	2456.3	**812433.396**

Final Lateral Design

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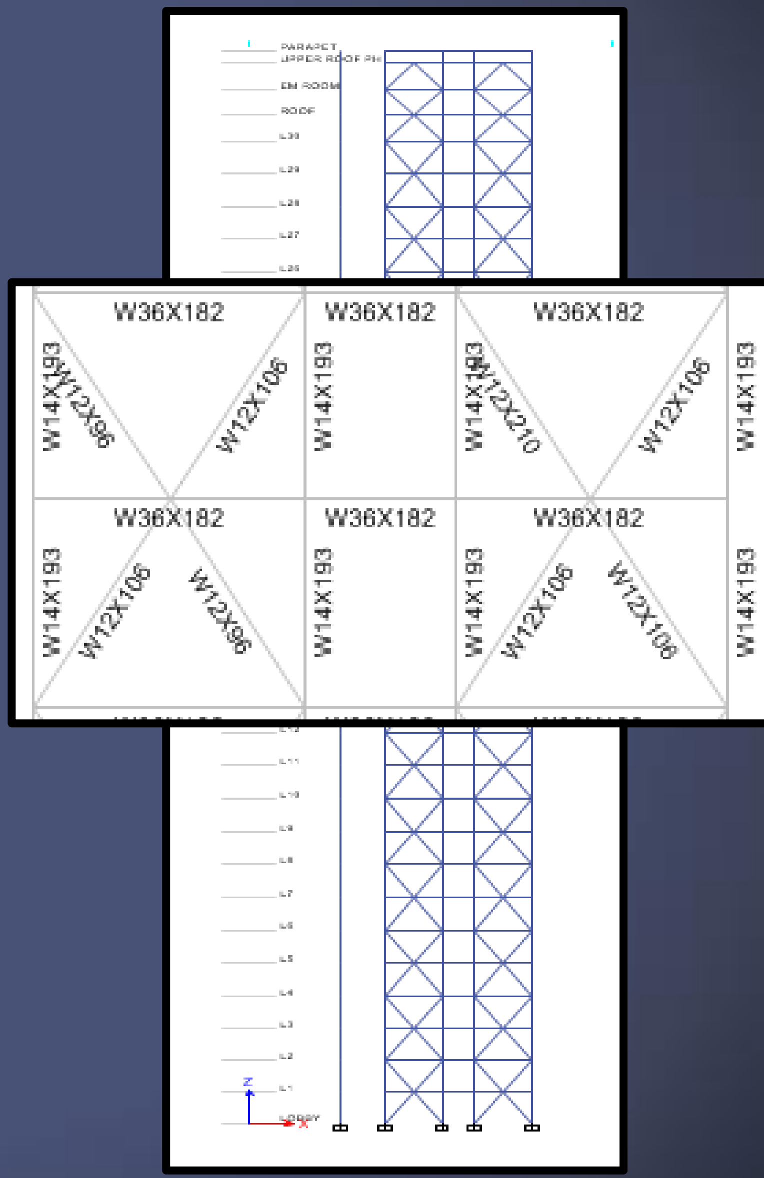
Composed of special concentrically braced frames in the core

- Includes moment frames on the perimeter as required by code although the core alone meets requirements

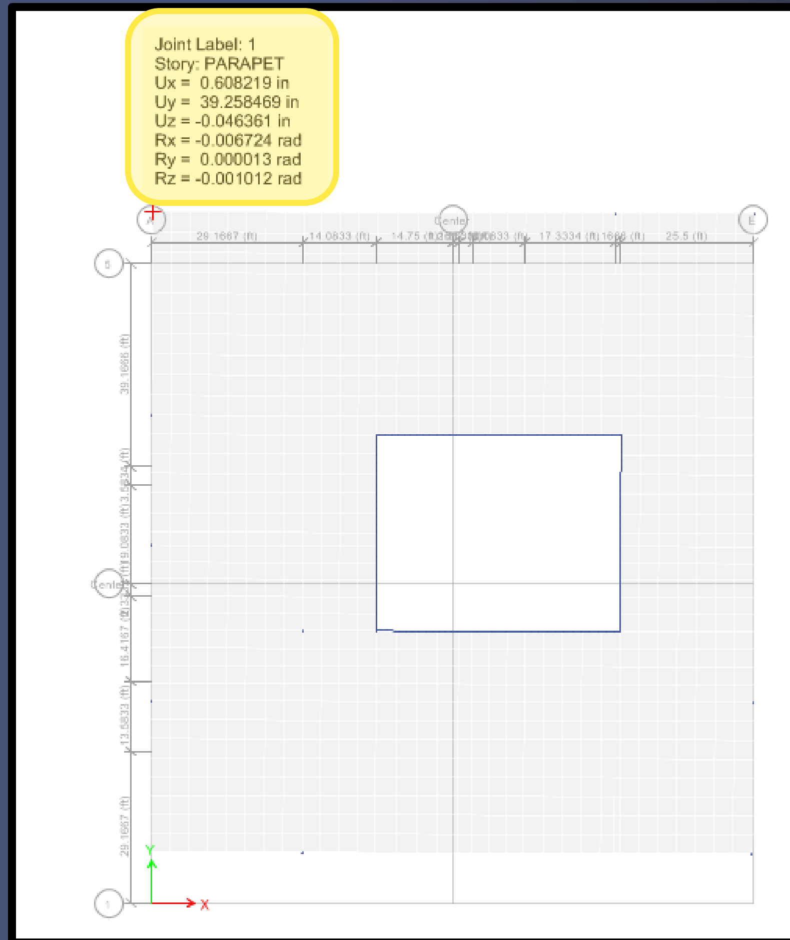
Originally composed of SPSW and braced frames

- SPSW actually proved to be not only stiffer than was needed, but also significantly more expensive than the final design.



Final Lateral Design

- Drift achieved: 39 inches
  - Compare to 41.5 inch requirement
    - Neither over nor under-designed
    - Results in an economic design meeting requirements
- Withstands normal low magnitude seismic events
- Minimal drift during design level events and presents an easily repairable structure.



Photovoltaic

~$510,000

Photovoltaic System

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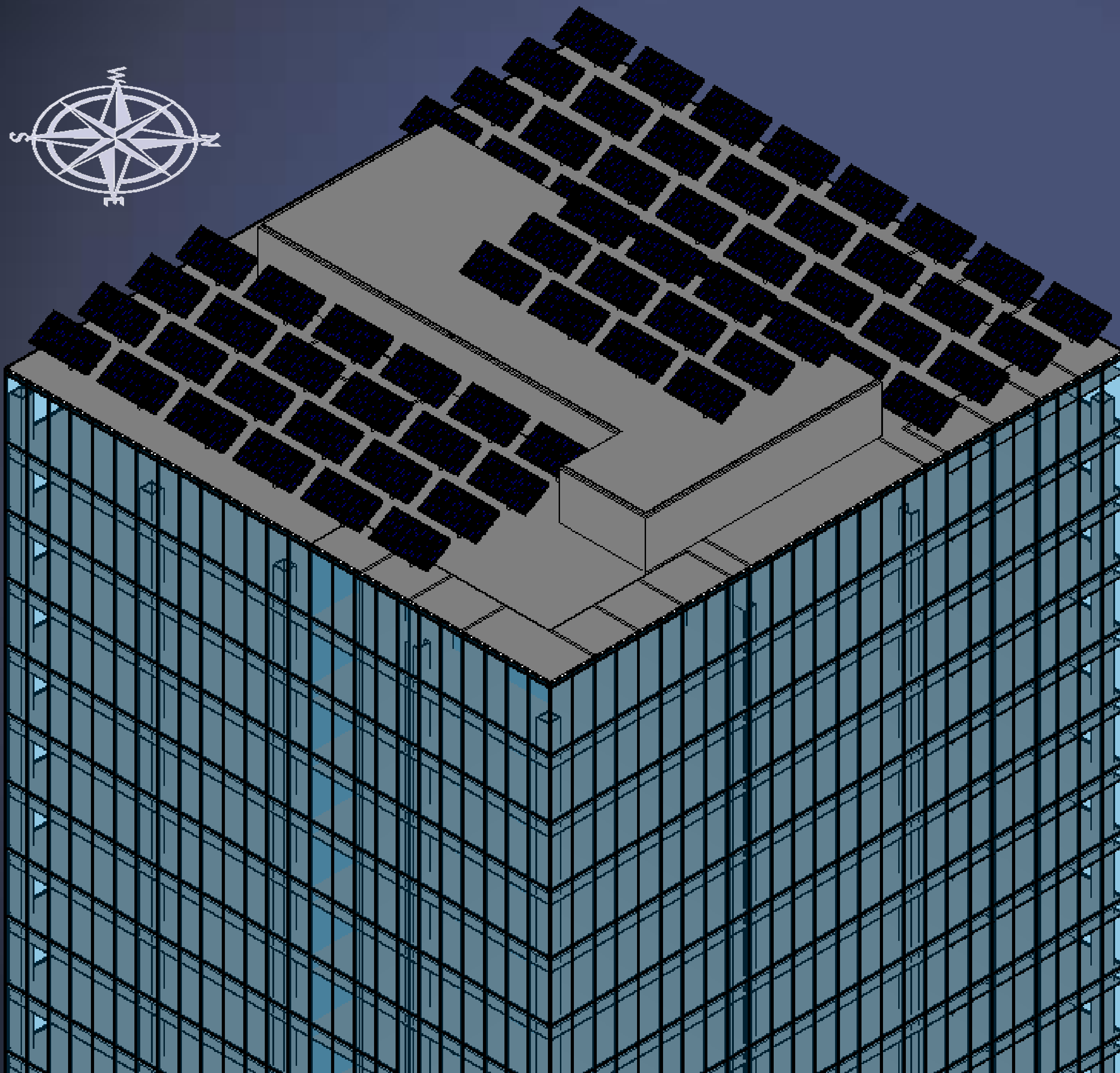

Size

816 Photovoltaic panels mounted on 68 telescoping poles

Distribution

Transformed and fed into a distribution panel in rooftop electrical room

Output

313,250 kBTU per year

Over 3% of total energy use

Combined Heat and Power

~$815,000

Combined Heat and Power

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Feasibility

High Electric Rates:	$0.18/kWh
Desirable Spark Spread:	$0.10/kWh
Future Energy Cost Concerns:	Yes
Reducing Environmental Impact:	Yes

Simple Payback Period (SPP)

Initial System Cost	$815,000
California CHP/Cogeneration Incentives Rebates	$312,000
Capital Cost Post Rebate	$503,000
Annual Operational Savings	$101,400

$$SPP = \frac{\textit{Capital Cost}}{\textit{Annual Savings}} = \frac{503{,}000}{101{,}400} = 5 \text{ years}$$

Combined Heat and Power

Electrical Output

Generation Capacity:	650 kW
Generated Power:	1,014,000 kWh/yr
Electrical Capacity Met:	27%

Thermal Output

Heat Recovery:	1,850 MBtu/hr
Heat Recovery Efficiency:	45%
Heat Capacity Met:	88%

Combined Heat and Power

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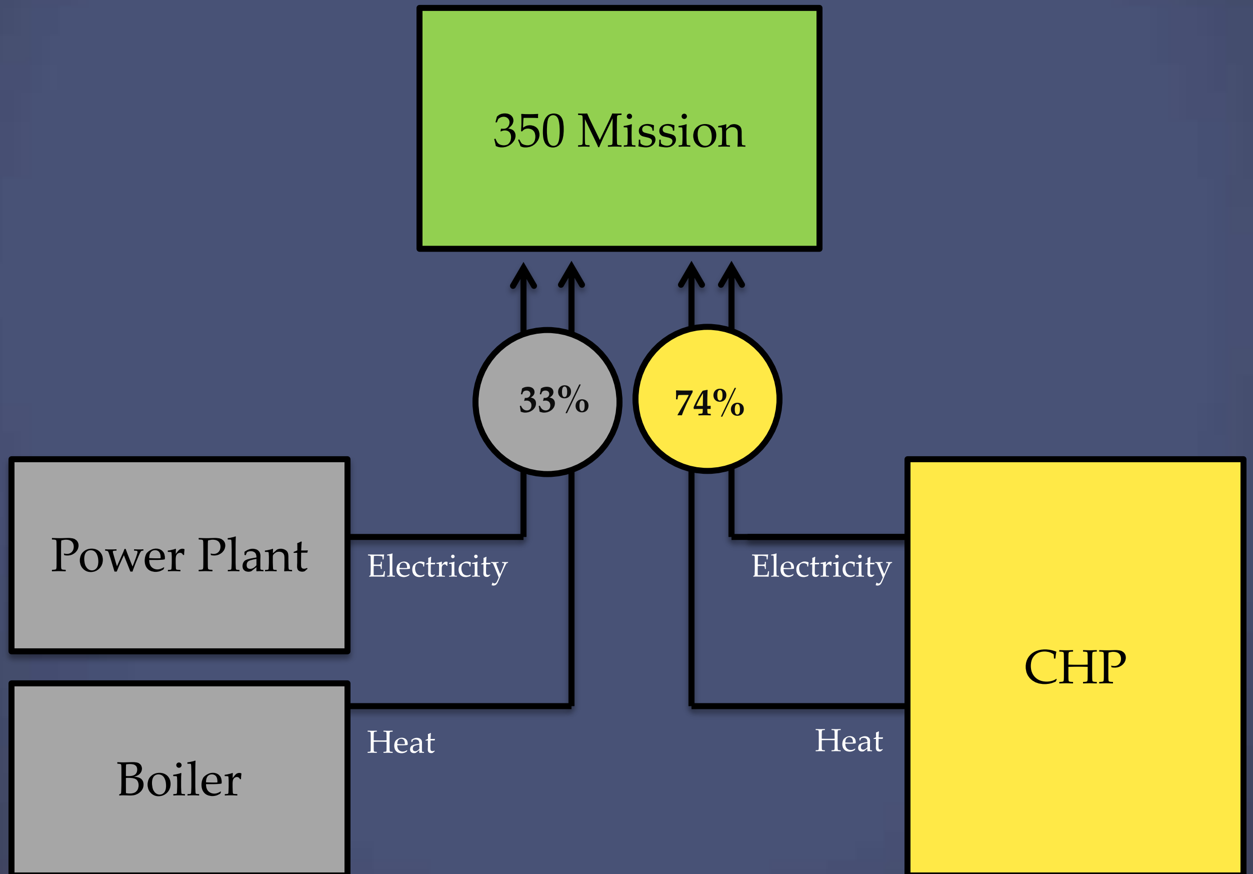
CHP Fuel Savings and Carbon Emission Reduction

Fuel Savings: 625 MCF (5%)
Carbon Reduction: 355,663 lbs. CO_2 (20%)



System Efficiency Model

Algae Bioreactors

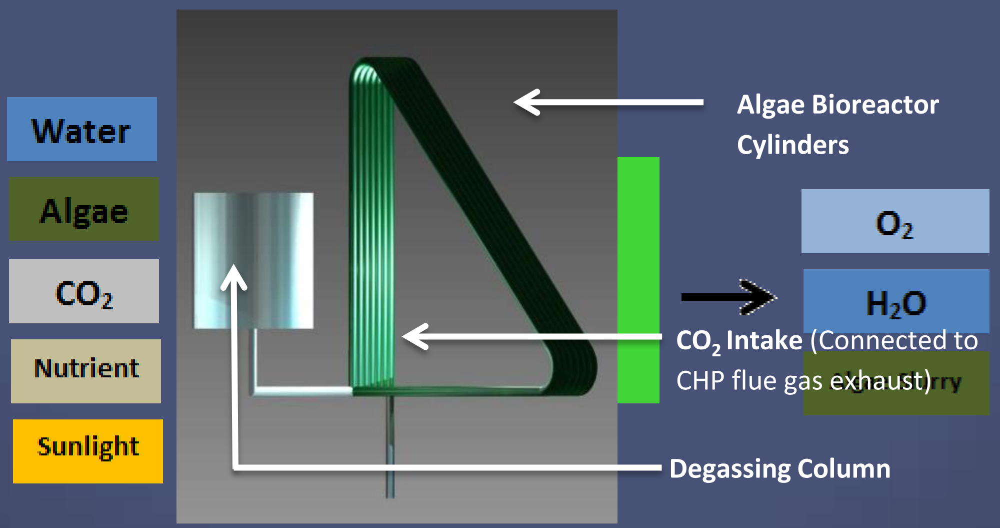
Algae Bioreactors

Carbon Reduction

Yearly Emissions:	1,369,638 lbs. CO_2
Algae Sequestration:	837,503 lbs. CO_2
Percent Reduction:	60%

Photosynthesis Chemical Reaction:

6CO2 + 12H2O + Light → C6H12O6 + 6O2 + 6H2O



RESULTS

Energy Savings

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- Lighting
  1,456,000 kBtu
- Heating
  1,870,000 kBtu
- Cooling
  517,000 kBtu
- Pumps
  38,000 kBtu
- Heat Rejection
  419,000 kBtu
- Fans
  1,240,000 kBtu
- Plug Load
  4,900,000 kBtu

Total
10,440,000 kBtu

Proposed

Baseline

- Lighting
  4,567,000 kBtu
- Heating
  4,625,000 kBtu
- Cooling
  1,550,000 kBtu
- Pumps
  155,000 kBtu
- Heat Rejection
  481,000 kBtu
- Fans
  6,578,000 kBtu
- Plug Load
  4,900,000 kBtu

Total
22,856,000 kBtu

Achievements

	Goal	Achieved
• Building Energy Use Reduction:	30%	54%
• Net-Zero Energy Emissions:	50%	68%
• Net-Zero Source Energy Use:	20%	30%
• Net Off-Site Energy Use:	35%	19%
• Drift Limit:	41.5 in	39 in
• Lifecycle	5 yrs	-
• Schedule Time	2.5 yrs	-

LEED

Project Checklist	Possible Points
Sustainable Sites	21
Water Efficiency	6
Energy and Atmosphere	26
Materials and Resources	8
Indoor Environmental Quality	12
Innovation and Design Process	3
Regional Priority Credits	4
Total	80

APOLLO

350 Mission

An iconic building that sets a precedent for sustainable architecture in San Francisco