Contents Table of Contents

Appendix A: Decision Matrix

Decision Factors		
Criteria	Wt.	1
Aligns with Owner Philosophy	1	
Design Feasability	1	
Food Output/Energy Used	2	
Adaptability	3	
Initial Cost	4	
Synthesis	5	
Resource Reuse	6	
Emissions	6	
Lifecycle Cost	7	
Durability	8	
Maintenance	8	
Occupant Satisfaction/Functionality	8	
Ease of Constructability	9	
LEED Potential	10	
Weighted Score		0

Located above is an image of the original Decision Matrix developed by Synthesis for the Growing Power Headquarters project. It included 15 design criteria with a scoring of 1-10 for each criteria. The team soon realized this matrix was not efficient or providing a quick decision for the design process and a new matrix needed to be made.

Criteria	Definition
Learning Experience/Environment	A Synthesis goal of developing a building that encorages learning and provides an environment where one can learn efficiently.
Design Adaptability	A Synthesis goal of developing a building that can adapt to its location and the
Self Sustaining Ecosystem	A Synthesis goal of developing a building that can maintain its functionality within the building.
Lifecycle Cost	Cost of system throughout the life of the building/system.
Ease of Constructability	How difficult any system/end product is to construct with regards to its integration into the building.
Durability	How the product/system holds up over time.
Maintenance	Ease and frequency of maintenance for owner and staff.
LEED Potential	Areas in which LEED points could possibly be earned.

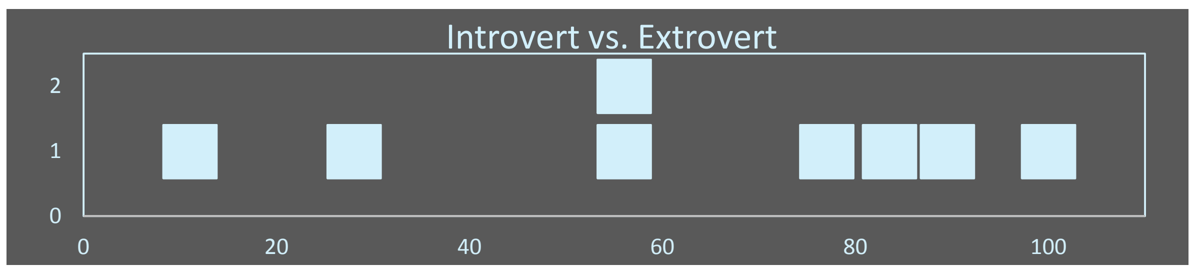
Synthesis developed a Weighted Decision Matrix to verify the selections the team was making were in line with the project goals as well as Growing Power. The matrix uses a simple point system multiplied by the designated criteria weighting to calculate a score for the decision factor. The updated matrix was used for the remainder of the design process. To the left is a table of descriptions to help clarify the design criteria. Each factor is given a separate rating of either "1" for a positive impact, "0" for zero impact, or "-1" for a negative impact for each decision criteria. A decision is made by comparing the proposed alternative factor's weighted score to the existing factor's weighted score, and therefore the higher score is selected.

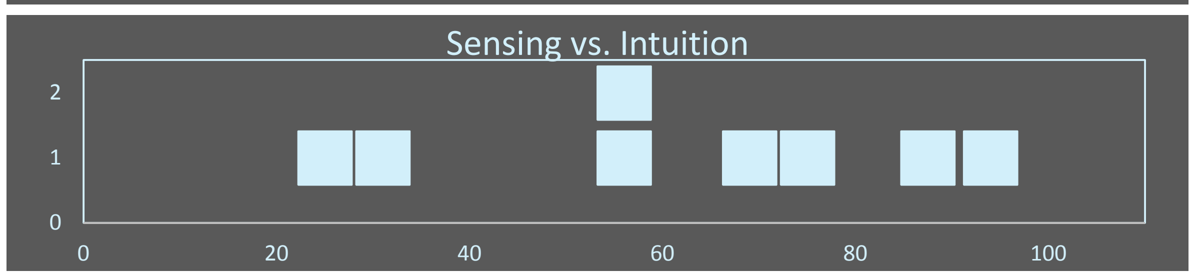
Decision	Reasoning
New Building Layout	This layout aligned more with the systems the design team was wanting to implement in the building.
Raised Floor System with UFAD	The selected system allows for a more efficient air distribution system that is also more adaptable.
Steel Structure	A steel structure can be constructed quicker, allow more natural light into the greenhouses, and adapted to different scenarios.
Modular Greenhouse System	Modular greenhouses allow for Growing Power to be able to more easily expand or retract the building in the future to adapt to other conditions they would like.
Natural HVAC System	This system is more efficient and assists in creating a self-sustaining ecosystem within the building.
Modular Façade	A modular façade allows for a quicker construction and for adaptations similar to the Modular Greenhouse System.
Polypavement	Polypavement is an environment-friendly substitute to asphalt that aligns more with the goals of Growing Power and Synthesis.
GeoPiers with Footings System	The selected system provides a solution to the soil conditions that allows the foundation system to adapt to them rather than attempt to counteract these conditions.

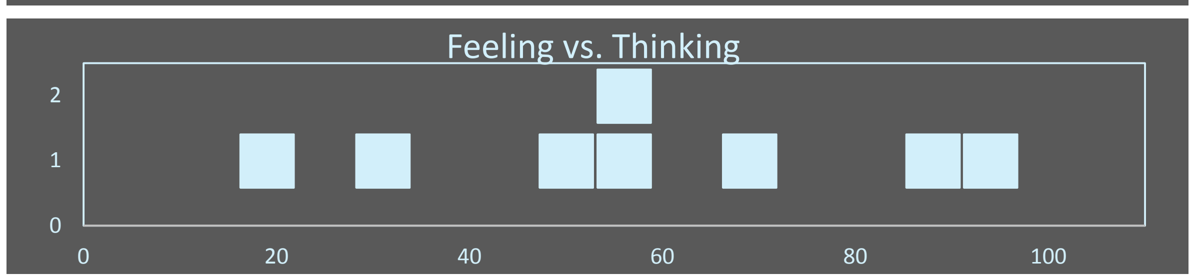
Decision Factors		New Building Layout	Existing Building Layout	Raised Floor System with UFAD	Traditional Floor and Air Distribution System	Concrete Structure	Steel Structure	Natural HVAC System	Traditional HVAC System	Modular Greenhouse System	Non-Modular Greenhouse System	Modular Façade	Non-Modular Façade	Asphalt Paving	Polypavement	GeoPiers with Footings System	Mat Foundation Slab
Criteria	**Wt.**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Learning Experience/Environment	5.0	1	0	1	0	0	1	1	-1	1	0	0	1	0	1	0	0
Design Adaptability	5.0	1	0	1	0	-1	1	1	0	1	-1	1	-1	0	0	1	-1
Self Sustaining Ecosystem	5.0	1	1	1	0	0	0	1	-1	0	0	0	0	0	1	1	0
Lifecycle Cost	4.0	0	0	1	-1	0	1	1	-1	0	0	0	0	0	0	1	0
Ease of Constructability	3.0	1	-1	0	1	-1	1	1	-1	1	-1	1	-1	0	-1	-1	-1
Durability	2.0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
Maintenance	2.0	0	0	-1	0	0	0	0	0	0	0	0	0			0	0
LEED Potential	1.0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0
Weighted Scores		**18**	2	**18**	1	-6	**19**	**23**	-17	**13**	-8	**8**	-3	0	**8**	**11**	-8

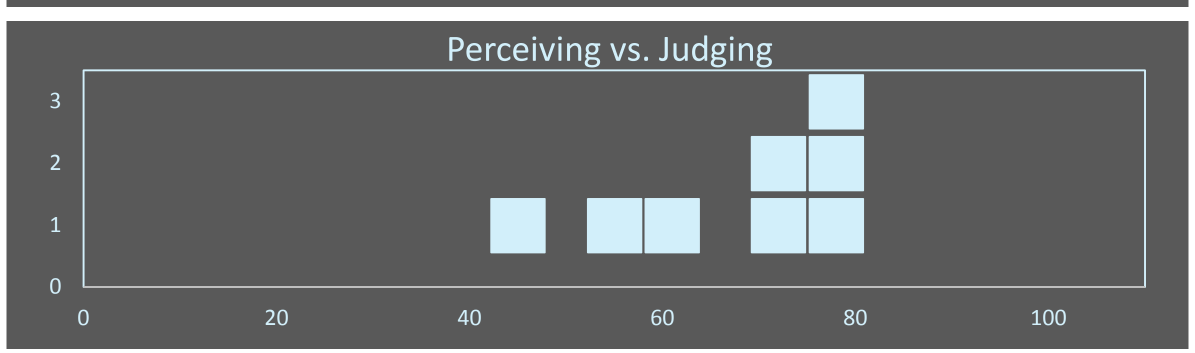
Key Terms:

Advisor – Each has an area of insight that the other lacks
Cohort – Mutually drawn to new experiences
Companion – similar nodes of expression: bear each other's company well
Complement – compatible strengths, but with opposite emphasis
Contrast – can offer a point and counterpoint discussion
Counterpart – perform similar roles in different ways
Enigma – a puzzle: totally foreign in nearly every facet
Neighbor – arrive at the same conclusion by different methods or thought processes
Novelty – intriguingly different: interestingly so
Pal – work and play well together; minimal conflict
Suitemate – each can add to the other's strengths
Tribesman – share a sense of culture, but with different interests and abilities
*All text above on this page came from www.keirsey.com

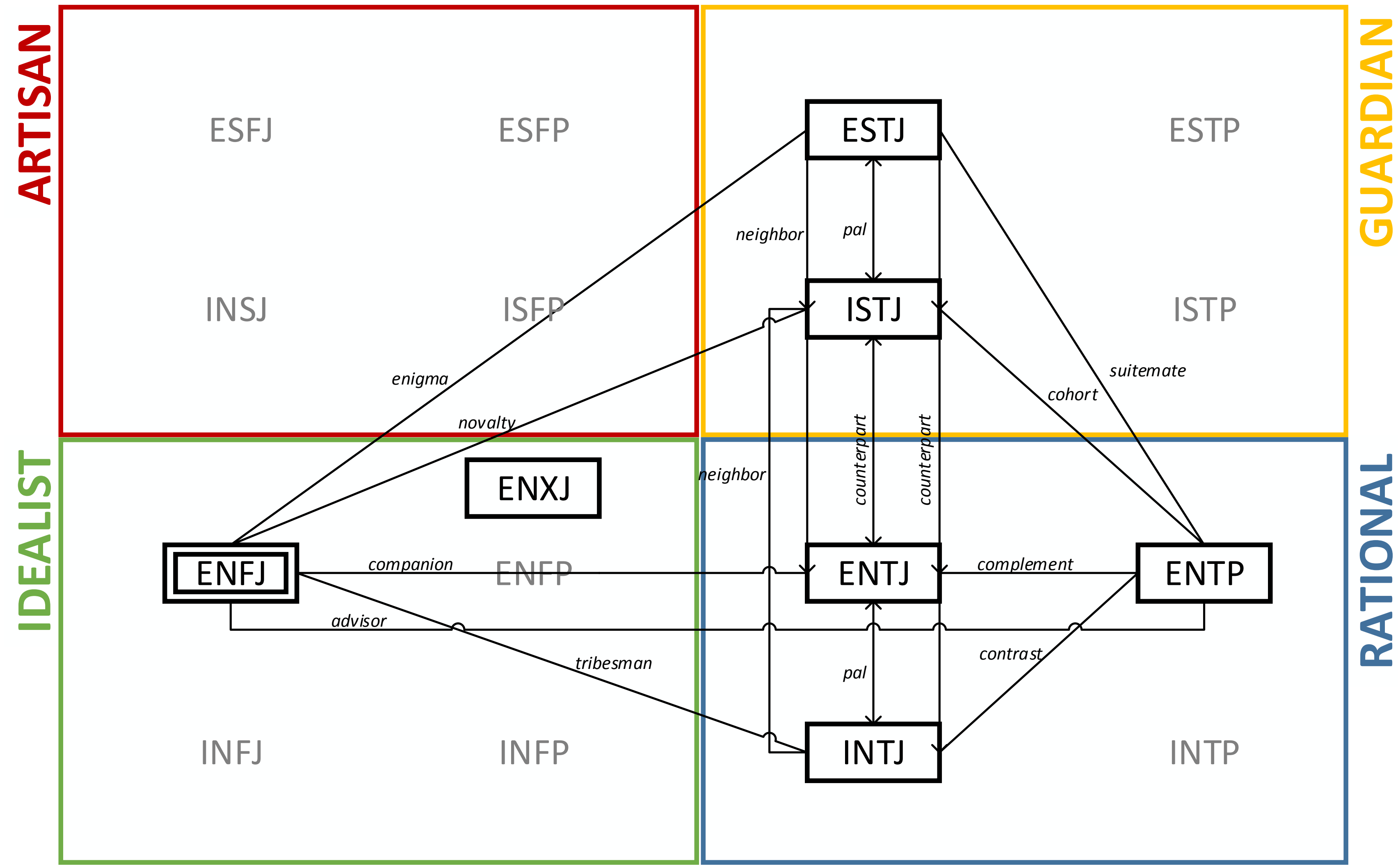








This analysis has been completed in order to understand the members of the team and how they would interact with each other. This also provided the construction engineers with managerial tactics for each group member so that an efficient and healthy work environment could be maintained throughout the process. The illustration of the team personalities and their interaction is meant to show clearly the Synthesis team chemistry and the group culture.



As Concrete Cooperators, **Guardians** speak mostly of their duties and responsibilities, of what they can keep an eye on and take good care of, and they're careful to obey the laws, follow the rules, and respect the rights of others.

As Abstract Cooperators, **Idealists** speak mostly of what they hope for and imagine might be possible for people, and they want to act in good conscience, always trying to reach their goals without compromising their personal code of ethics.

As Concrete Utilitarians, **Artisans** speak mostly about what they see right in front of them, about what they can get their hands on, and they will do whatever works, whatever gives them a quick, effective payoff, even if they have to bend the rules.

As Abstract Utilitarians, **Rationals** speak mostly of what new problems intrigue them and what new solutions they envision, and always pragmatic, they act as efficiently as possible to achieve their objectives, ignoring arbitrary rules and conventions if need be.

*All text above came from www.keirsey.com

Meeting Agenda

Team Collaboration Meeting #6

10/08/2014

4:30pm

Team Office

Topics for Discussion:

Team

- Determine the Team Project Goals
- Provide an overview of Trello and its implication for the design process
- Develop a Decision Matrix to be used for major design decisions
- Determine topics for upcoming Design Progress Presentation

Building

- Review floor plan changes
- Façade material criteria
- Structural system material options
- Code findings for egress requirements
- Classification of spaces that require dropped ceiling and those that could potentially be exposed ceilings
- Needs for the Electrical Design

Greenhouse Spaces

- Overall function/layout of the greenhouses
- Requirements for glazing material – mechanical and lighting
    - Daylight Analysis
- Developments of the Passive Downdraft HVAC System
- Implications of a Raised Floor System – what does it mean?
- What data should be included in the Plant Matrix?

Project Management

- Requests for cost analyses of systems/components?
- Review Square Foot Estimate progress
- Design Schedule updates/progress

Meeting Minutes

Team Collaboration Meeting #6

10/08/2014

4:30pm

Team Office

Action Items:

1. Team is to begin gathering information for upcoming Design Progress Presentation.
2. Further adjustments of new floor plans are to be made in Revit model.
3. Research will begin on possible façade materials.
4. Research glazing, windows in non-greenhouse, passive downdraft HVAC system, and implications of a Raised Floor System.
5. Research will continue to research the function and layout of the greenhouse, the needs for the electrical design, and information needed for the Plant Matrix.
6. A daylighting analysis will be started for glazing types to be used in greenhouses.
7. Research needs to be done to determine the code requirements for enclosing the staircase in the top tier of the building.
8. Cost Analysis of various mechanical systems
9. Design Schedule
10. Team Photographs are scheduled for Wednesday at 3:30 PM

Completed Items:

1. Team decided the locations of having a drop ceiling and an exposed ceiling.
2. The building will have a steel structure.
3. A Square Foot Estimate has been completed for the building.

Appendix D: Adaptability

During design, all teams at Synthesis focused on developing a prototype that is adaptable to other regions and microclimates throughout the country. Therefore, the design of this Vertical Farm allows Growing Power Inc. to implement the building in other regions with minimal engineering changes needed for the building to operate properly.

Considerations for Change				
Integration Topic	Structural	Lighting Electrical	Mechanical	Construction**
Greenhouses	Truss Member Sizes	PAR Transmittance of Glazing	Solar Heat Gain, Cooling and Heating Loads	Cost
	Poly-Carbonate Thickness and Span	Shade Cloth Material	Use of Spraying Water for Crop Cooling in Dry Climates	Labor Force (Union vs. No Union)
	-	-	-	Labor Force (Unskilled)
Enclosure/ Structure	Retaining Wall Size and Reinforcing	Overhang/Aluminum Louvers on East Windows	R-Value of Enclosure	Site Restrictions
	Keeping/Eliminating Geopiers	Add North Facing Windows between Towers	-	Weather
	Foundation Type	Daylight Harvesting Zones	-	Site Trailers and Utilities
Quad-Gen	-	Secure Contract Prior to Selecting Site for Food Wastes from around the Community	Equipment Sizing	-
	-	Developing the Vertical Farm around a Community to share excess power produced with	Location of the Digester	-
	-	-	Amount of Food Waste Provided for Digester	-
Natural HVAC	Knee-Brace in Seismic Regions to Transfer Loads	`-	Use of Forced Air System if not Enough Wind on Site	-
	Reinforcing in Area of High Stress in Seismic Regions	-	Size of Towers/Number of Inlets per Floor	-
	Eccentrically Braced Frame and SidePlate Sizes	-	Number of Chilled Beams	-
	Infill Wall Sizes and Steel in Towers	-	-	-

Design Constants				
Integration Topic	Structural	Lighting Electrical	Mechanical	Construction
Greenhouses	Repeatable 19'-2" Spacing	Angle of the Glazing	Same Cooling and Heating System	Delivery Method
	Gravity Design	Shade System and Deployment	Same Advantages of Closed Greenhouse	Crane
	General Truss Layout	Grow Light Mounting and Deployment	-	-
Enclosure/ Structure	Façade System	Glazing Types, Sizes, and Locations	-	-
	Gravity Design	Space Programming (South and East Facing Rooms)	-	-
	Steel Superstructure/ Uniform Bays	Automated Mechoshade System	-	-
Quad-Gen	-	Same Size Microturbine and Digester	Microturbine and Digester	-
	-	Power Distribution Scheme	Same Schematic	-
	-	Emergency Power Sequence	-	-
Natural HVAC	Deep Girder to Pick up Differing Elevations	Lighting Scheme Remains Same	Under Floor Air Distribution	-
	Implementation of Eccentrically Braced Frames and SidePlates	-	-	-
	Layout of Lateral Elements	-	-	-

*Prior to this prototype building being constructed in other regions, the building needs to be review by design professionals to ensure all local codes and ordinances are met for the specific regions.

**Construction does not apply specifically to each topic but applies to the project as a whole.

Appendix E: Lessons Learned

During the design of the Vertical Farm, all teams at Synthesis faced a multitude of challenges. From these challenges, all members involved in the design process were able to extend their knowledge of how the design process works in the real world. Below is a list of some of the major lessons that were learned by members of Synthesis during the duration of the project. This list consists of aspects of design that were done well and aided in the design process, and lessons that were learned from inefficiency with the design team. Synthesis feels that the lessons learned while designing this Vertical Farm will continue to aid them as they enter their professional careers.

1. Research Prior to Design

   With a design implementing greenhouses on the roofs, an atypical design was going to be needed for the building. Therefore, all members of Synthesis reviewed the original design of the building along with the competition requirements as soon as the information was obtained. While each design team researched the building and systems that were ideal for the Vertical Farm, information was compiled in a shared folder for all members to review. This communication prior to entering the design process allowed for Synthesis to analyze the optimal engineering system for all disciplines, and start a design that work for all involved.

2. File Structure

   With design being an iterative process, Synthesis found that by having a way of organizing files and other information is extremely important. With an organized file structure, maximum efficiency could be achieved throughout all stages of the design process. Previous information and calculations could be easily found by all members of Synthesis with an organized file structure. Time and confusion could be saved by implementing similar file structures for all disciplines on the project.

3. Group Meetings

   It was found that by having regularly scheduled meetings to discuss the status of everybody's work as well as what they planned to get done during the week, an efficient workplace could be developed. With Synthesis putting a large focus on integration and collaboration between all members, major decisions needed to be run by all members effected by a proposed design. These meetings were also a way to ensure that everybody was completing the work needed to finish the project on time. With differing schedules, these meetings gave a place for all members to voice opinions to everybody at Synthesis.

4. Industry Professionals

   Throughout the design process, it was found that the greatest resource for a young engineer is conversations with industry professionals. These conversations helped to develop knowledge on the engineering systems that Synthesis wanted to implement in the design of the Vertical Farm. Industry professionals were more than willing to extend the knowledge that they had learned during their careers to aid in the design of the building. It was extremely helpful for all members at Synthesis to talk to professionals and have them review the designs so that a fully functional design could be developed.

5. BIM Technology

   By using BIM software, information between all team members could easily be transferred through the use of a central model. The use of this software helped eliminate clashes that were occurring between design disciplines earlier in the design process. BIM also was extremely helpful for all team members to create professional visuals. This software was especially helpful in developing details of how all of the systems worked together to create a holistic building. Creating visuals within the BIM software, aided in explaining and educating the rest of the team of the design that each discipline was incorporating.

6. Model Organization

   As design progressed it was found that organization within models was vital to the design process. With standards and typical grids for all models, many issues that come with collaborative design could be eliminated without differing grids in each model. These design grids and lines helped to break the building into portions that were then easily referred to when communicating with other designers at Synthesis. A Revit model with all of the individual designs linked together allowed for all team members to add to the model using the same organization within the models. By synchronizing these designs with one another, conflicts could easily be discussed and solved throughout design.

7. Design Software

   To expedite the design process, all design disciplines at Synthesis implemented the use of design software and technology. With the use of this software, complicated and extensive analyses could be done quicker and results could be given to other disciplines that are effected by the design. However, all technology used during the design process should be used with discretion. Many programs being used were self-taught, therefore a learning curve was experienced during the use of the software. Thus meaning outputs from all computers should be analyzed and verified prior to blindly implementing the design within the building.

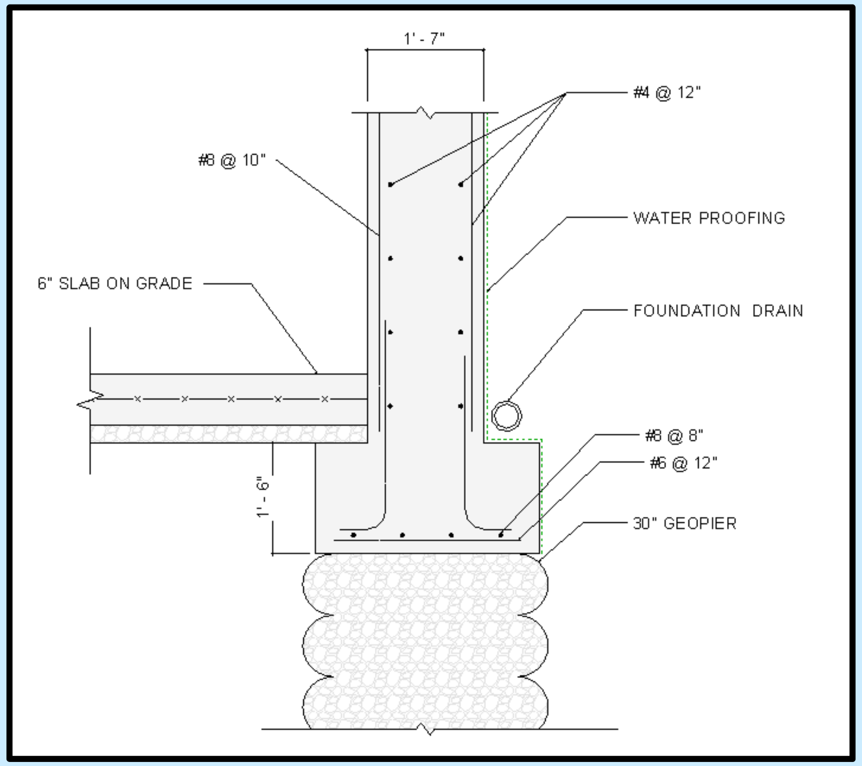
8. Involve All in Changes

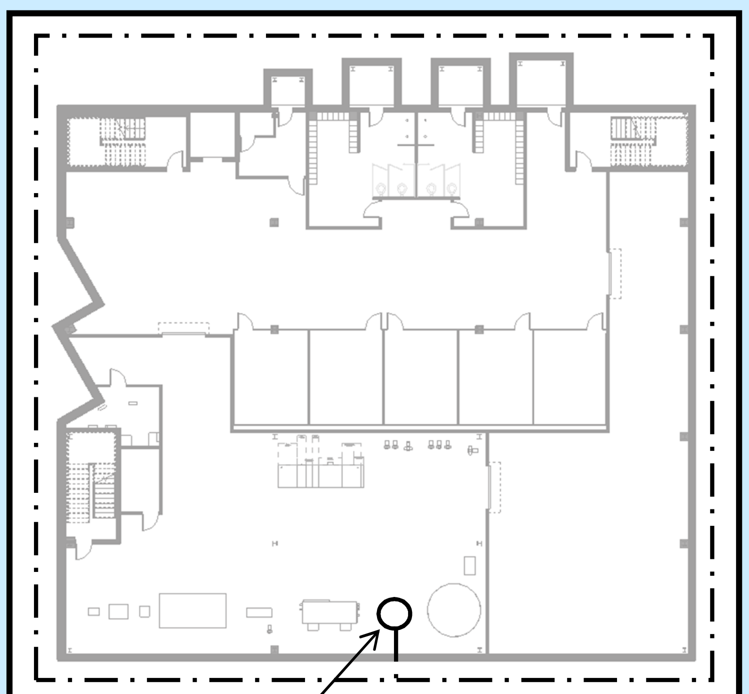
   Throughout the entire design process, it was found that no matter how small a change may seem to an individual option, it may have a huge effect on other options. Therefore, all members should be informed about any changes in a system no matter how small they are. By telling all involved design teams the changes that occur in a specific design, unforeseen clashes and problems can be kept to a minimum. Also, it is of utmost importance to put all design changes into Revit as soon as possible, so that everyone can directly see how the new systems will coordinate with one another.

9. Open to New Designs

   It was found that being open to innovation and changes in design is extremely important for a team to function properly. When working on an integrated project, all members need to keep in mind that what is best for them may greatly hurt the other design teams involved. Therefore, whenever a new system is brought up, all members need to be objective and look at the building as a whole. A specific system may be hurt by the implementation of a design, but if it makes the building function better as a whole then the team that is hurt needs to be willing to take the hit and implement the system to create the best building possible.

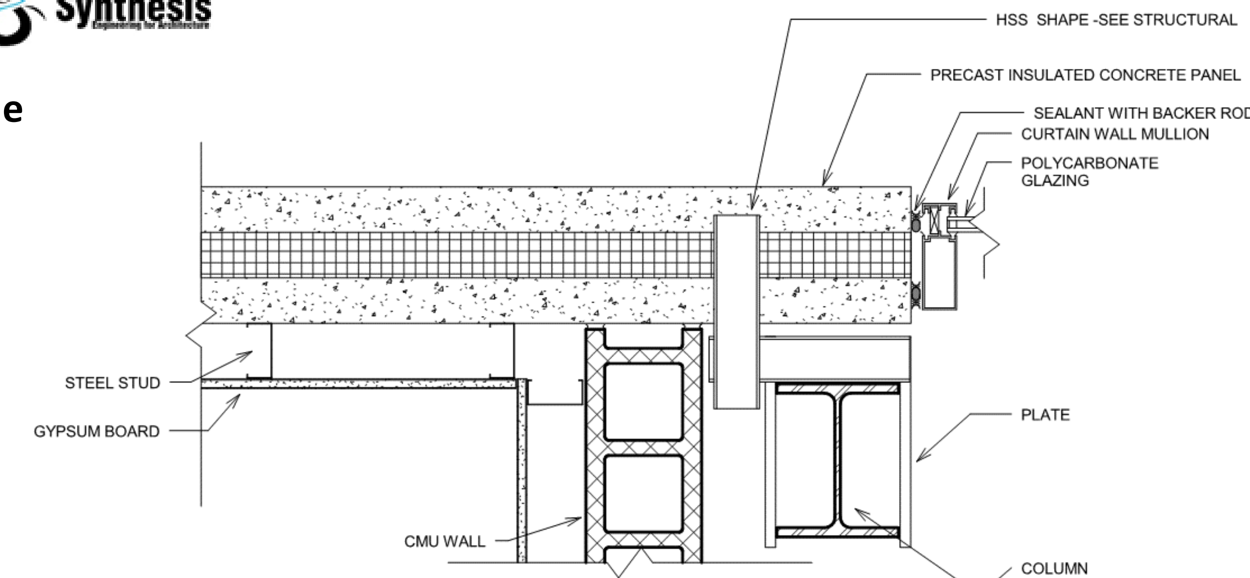
Foundation



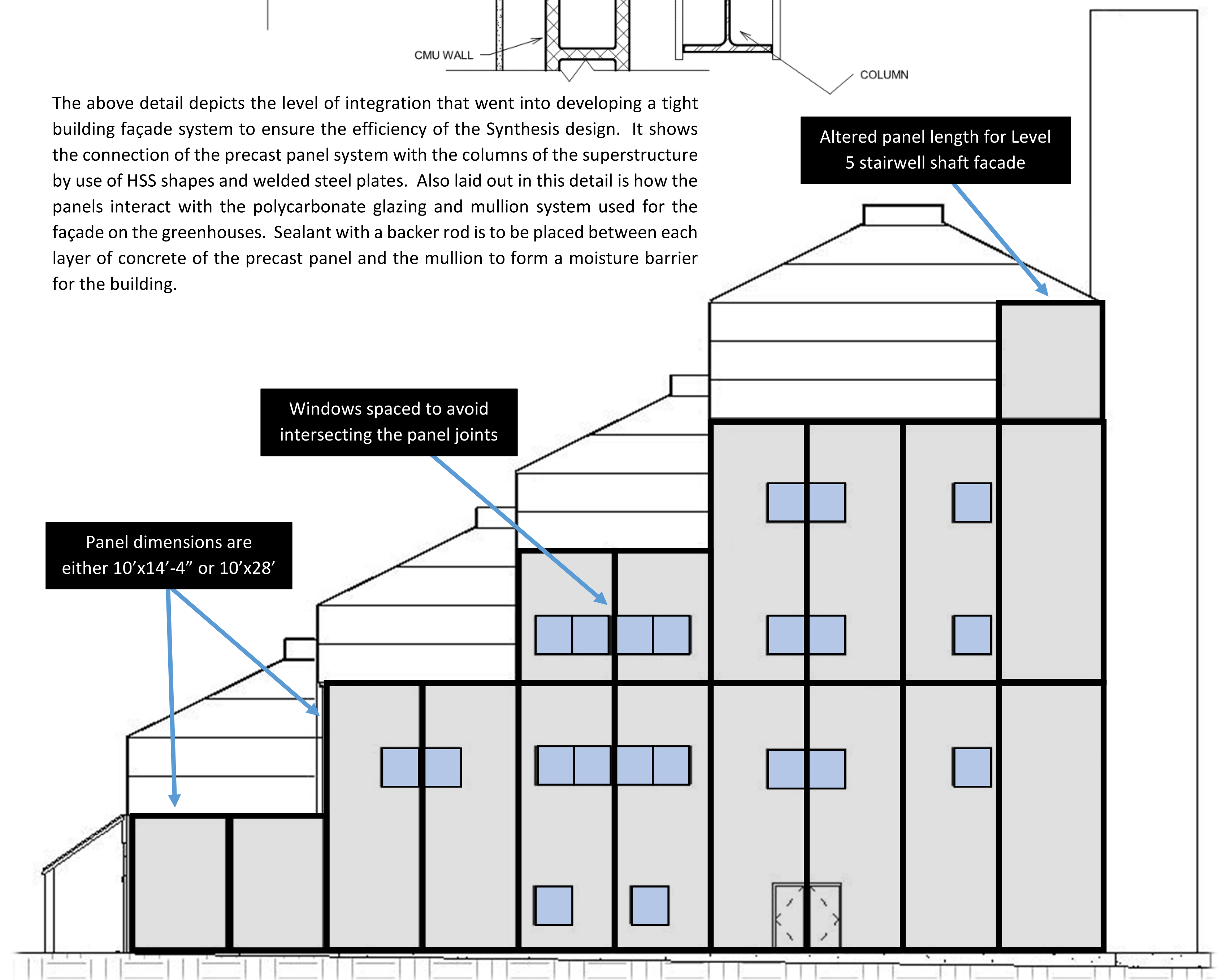


Sump Pump Shaft

Façade



The above detail depicts the level of integration that went into developing a tight building façade system to ensure the efficiency of the Synthesis design. It shows the connection of the precast panel system with the columns of the superstructure by use of HSS shapes and welded steel plates. Also laid out in this detail is how the panels interact with the polycarbonate glazing and mullion system used for the façade on the greenhouses. Sealant with a backer rod is to be placed between each layer of concrete of the precast panel and the mullion to form a moisture barrier for the building.



LEED v4 for BD+C: New Construction and Major Renovation

Project Checklist

Project Name: Growing Power Headquarters

Date:

Y	?	N			
1			Credit	Integrative Process	1

4	1	21		Location and Transportation	16
		16	Credit	LEED for Neighborhood Development Location	16
1			Credit	Sensitive Land Protection	1
		1	Credit	High Priority Site	2
			Credit	Surrounding Density and Diverse Uses	5
1		4	Credit	Access to Quality Transit	5
1			Credit	Bicycle Facilities	1
1			Credit	Reduced Parking Footprint	1
	1		Credit	Green Vehicles	1

6	0	4		Sustainable Sites	10
Y			Prereq	Construction Activity Pollution Prevention	Required
1			Credit	Site Assessment	1
		2	Credit	Site Development - Protect or Restore Habitat	2
1			Credit	Open Space	1
3			Credit	Rainwater Management	3
		2	Credit	Heat Island Reduction	2
1			Credit	Light Pollution Reduction	1

11	0	0		Water Efficiency	11
Y			Prereq	Outdoor Water Use Reduction	Required
Y			Prereq	Indoor Water Use Reduction	Required
Y			Prereq	Building-Level Water Metering	Required
2			Credit	Outdoor Water Use Reduction	2
6			Credit	Indoor Water Use Reduction	6
2			Credit	Cooling Tower Water Use	2
1			Credit	Water Metering	1

31	0	0		Energy and Atmosphere	33
Y			Prereq	Fundamental Commissioning and Verification	Required
Y			Prereq	Minimum Energy Performance	Required
Y			Prereq	Building-Level Energy Metering	Required
Y			Prereq	Fundamental Refrigerant Management	Required
6			Credit	Enhanced Commissioning	6
18			Credit	Optimize Energy Performance	18
1			Credit	Advanced Energy Metering	1
			Credit	Demand Response	2
3			Credit	Renewable Energy Production	3
1			Credit	Enhanced Refrigerant Management	1
2			Credit	Green Power and Carbon Offsets	2

4	6	3		Materials and Resources	13
Y			Prereq	Storage and Collection of Recyclables	Required
Y			Prereq	Construction and Demolition Waste Management Planning	Required
2		3	Credit	Building Life-Cycle Impact Reduction	5
	2		Credit	Building Product Disclosure and Optimization - Environmental Product Declarations	2
	2		Credit	Building Product Disclosure and Optimization - Sourcing of Raw Materials	2
	2		Credit	Building Product Disclosure and Optimization - Material Ingredients	2
2			Credit	Construction and Demolition Waste Management	2

13	1	0		Indoor Environmental Quality	16
Y			Prereq	Minimum Indoor Air Quality Performance	Required
Y			Prereq	Environmental Tobacco Smoke Control	Required
2			Credit	Enhanced Indoor Air Quality Strategies	2
2			Credit	Low-Emitting Materials	3
1			Credit	Construction Indoor Air Quality Management Plan	1
2			Credit	Indoor Air Quality Assessment	2
	1		Credit	Thermal Comfort	1
2			Credit	Interior Lighting	2
2			Credit	Daylight	3
1			Credit	Quality Views	1
1			Credit	Acoustic Performance	1

6	0	0		Innovation	6
5			Credit	Innovation	5
1			Credit	LEED Accredited Professional	1

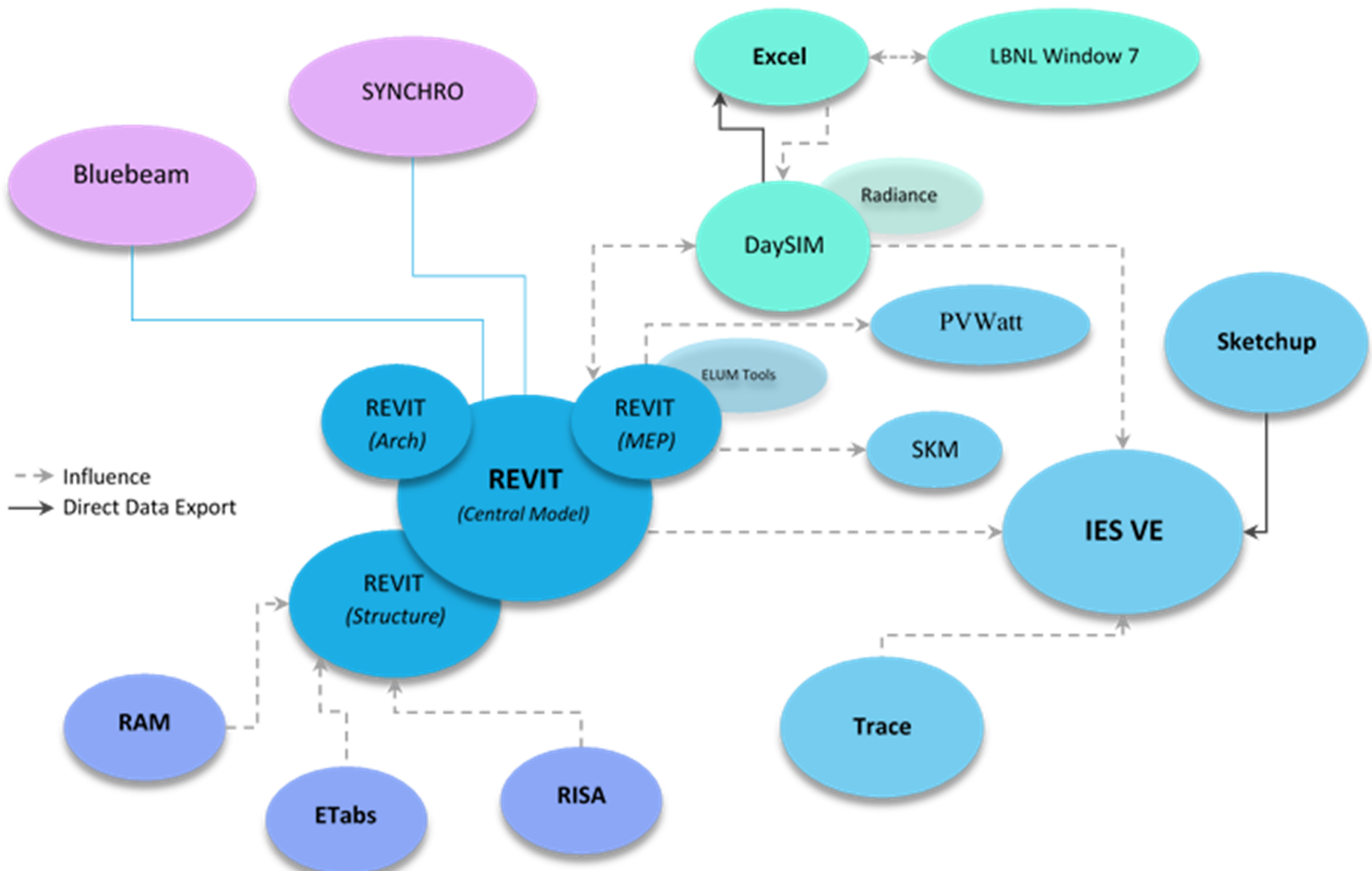
0	0	0		Regional Priority	4
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1

76	8	28	TOTALS	Possible Points:	110

Certified: 40 to 49 points, **Silver:** 50 to 59 points, **Gold:** 60 to 79 points, **Platinum:** 80 to 110

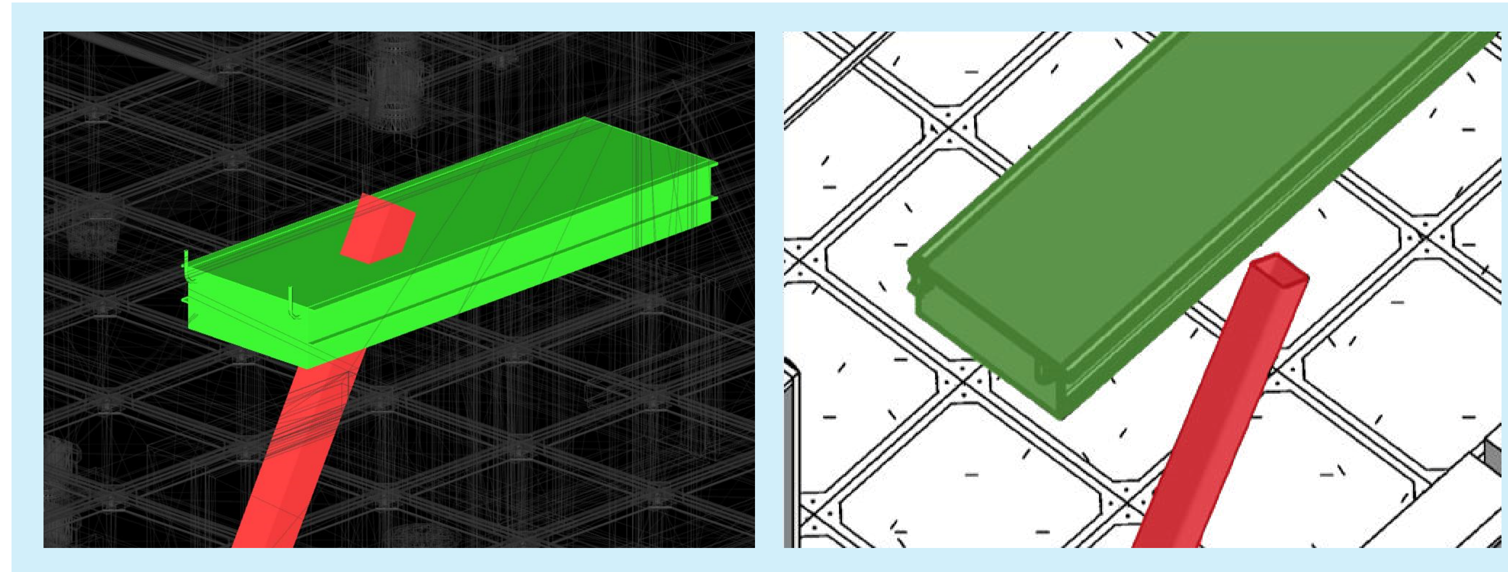
Achieved: Gold

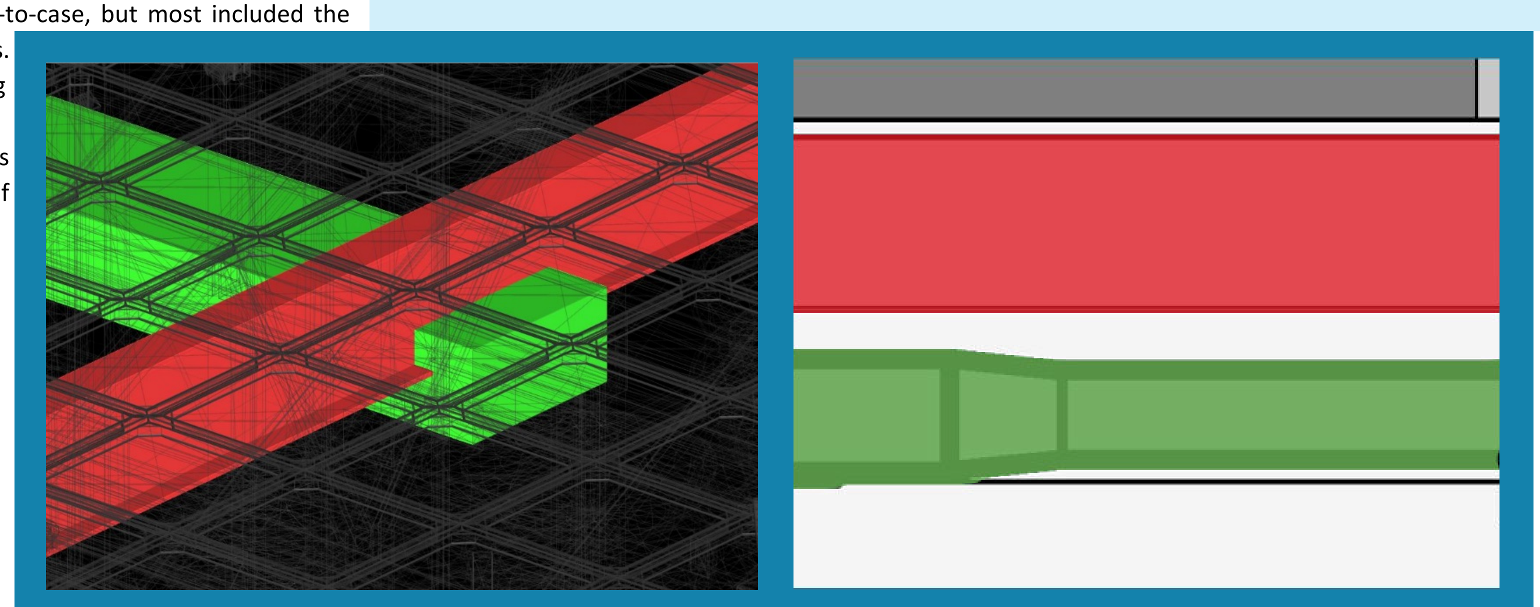
Strive for: Platinum

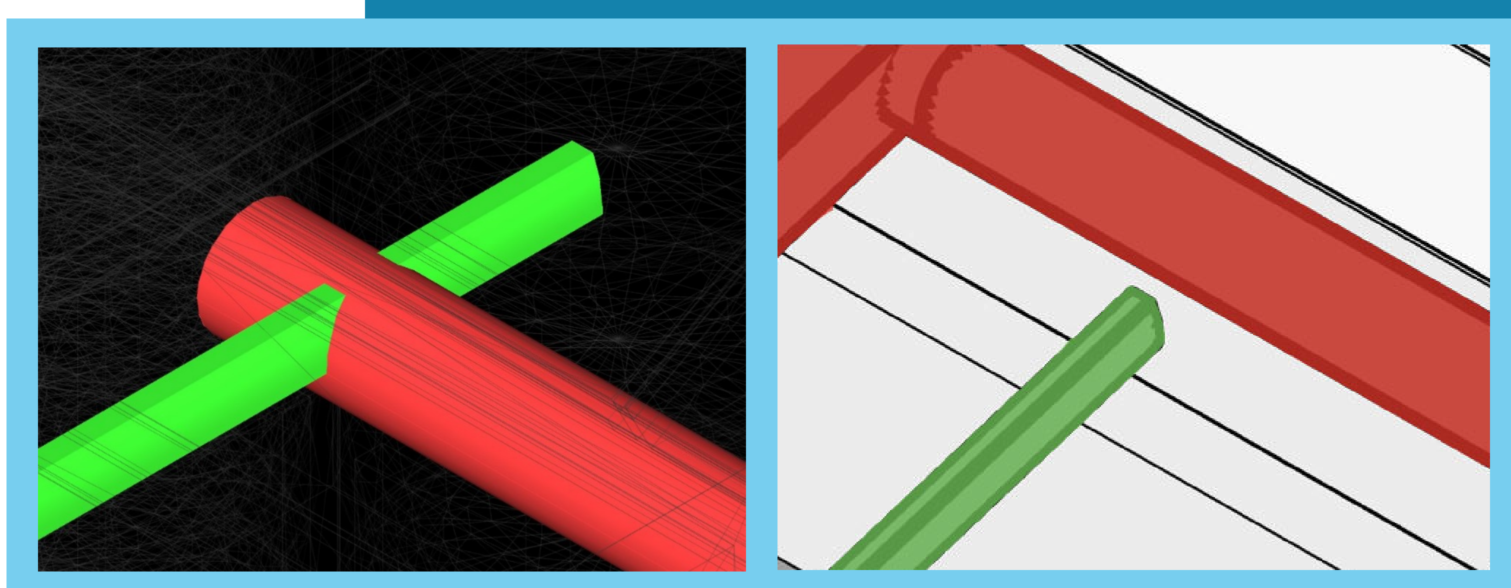

SYNCHRO
Bluebeam
Excel
LBNL Window 7
Radiance
DaySIM
PVWatt
Sketchup
ELUM Tools
REVIT (Arch)
REVIT (MEP)
REVIT (Central Model)
SKM
Influence
Direct Data Export
IES VE
REVIT (Structure)
RAM
Trace
ETabs
RISA

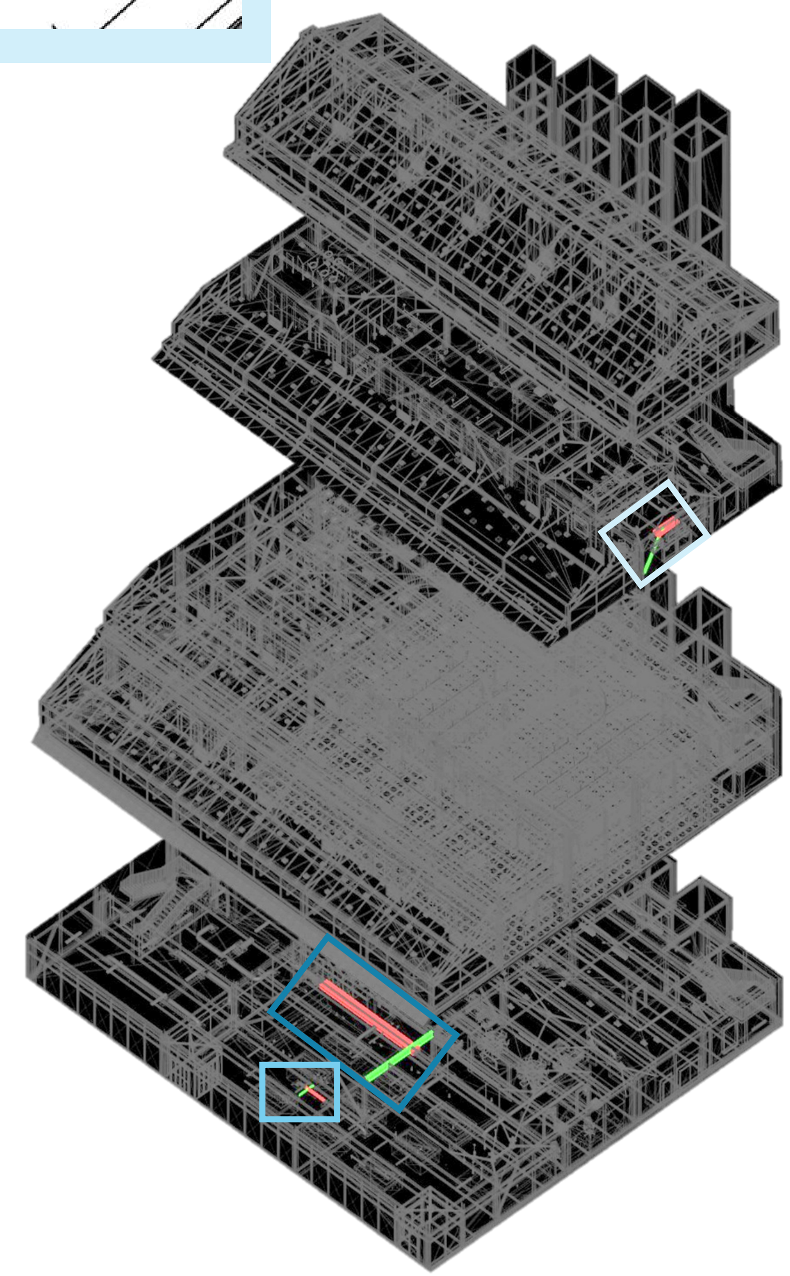
Appendix I: Clash Detection

Synthesis, with the use of Autodesk Navisworks, was able to run clash detection tests on the mechanical, plumbing, electrical, lighting, fire protection, structure, and architecture. When the systems were first tested, several interruptions occurred between components. The test reports were then analyzed and clashes assigned to the appropriate design engineers to be resolved. The clashes were fixed in various ways. One major type of component conflict was the chilled beams intersecting the steel structural system members. An example of this type is represented in the first image to the right, where the chilled beam has a lateral brace puncturing through it. To overcome these clashes, the mechanical engineers were able to relocate the chilled beams to attach below other structural beams in their designated rooms. Another major category of clashes can be seen in the second image on the right, which arose between the structural beams and the rectangular mechanical ductwork. To fixes these issues, the ductwork runs were lowered to a height below the bottom flange of the beams. An example of a third type of clash found in the building design is the bottom image on the right. These clashes developed with the lighting fixtures and the round mechanical ductwork. Solutions varied case-to-case, but most included the ductwork runs shifting to the side of the light fixtures. Overall, discovering and eliminating all clashes during the design phase of this project will save time and money during the building's construction. This allows for the Owner to feel even better about the quality of work put into the project by the design team.

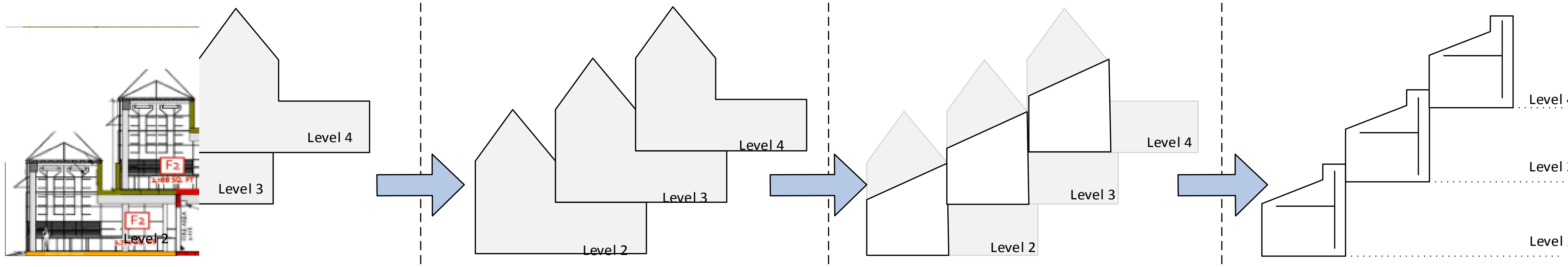






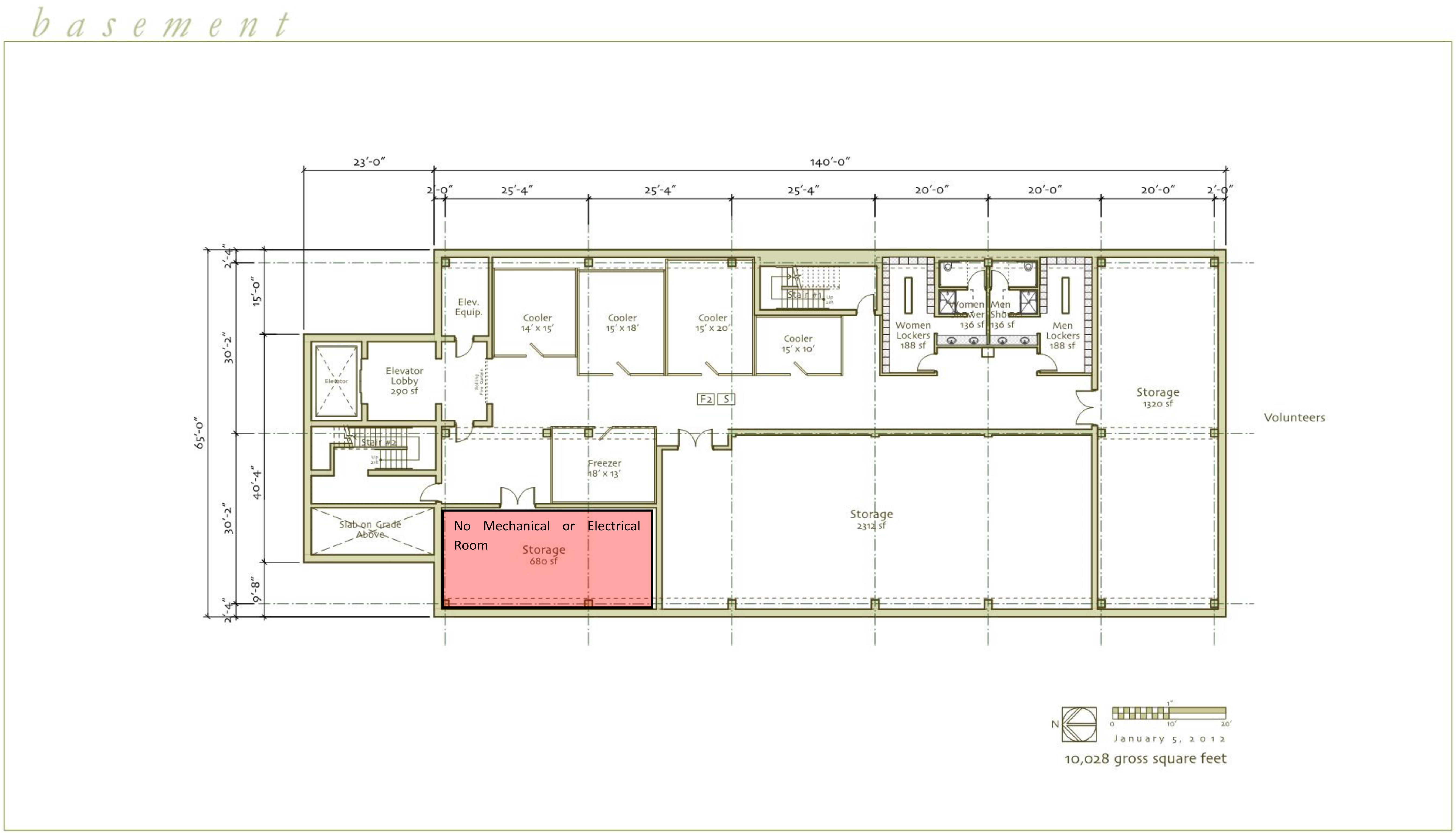


Appendix J: Progression to New Greenhouse Design

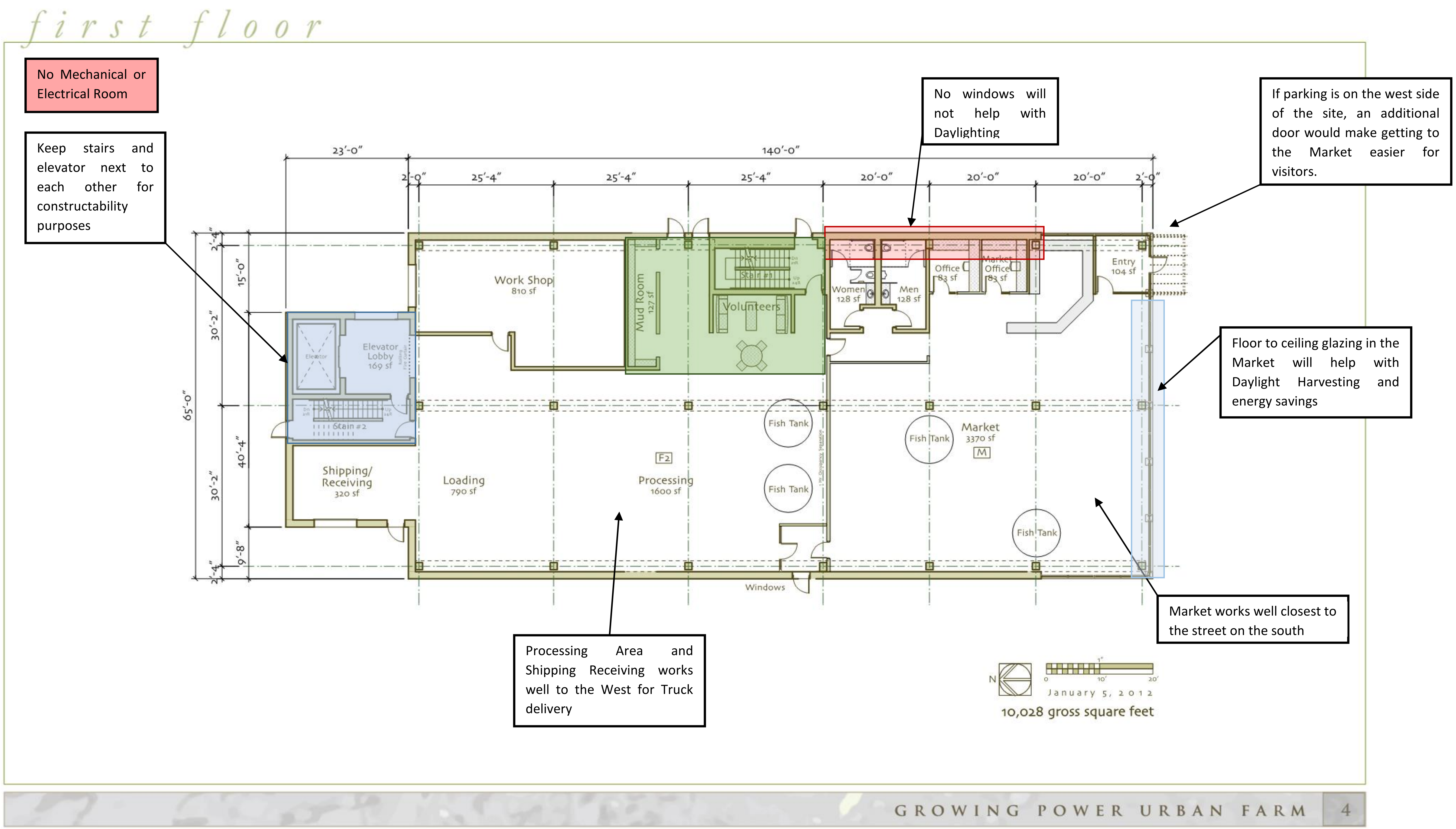


	TKWA Design	Cavity Removal	Eliminate Unused Space	Synthesis Design
Changes that Occured	Original design for the competition provided drawings by TKWA Architects.	Greenhouses were adjusted to remove large gap between each tier.	Transition to a single slope glazing system for smaller, and more adaptable relocation. Overall building width increase to maintain the original area.	Utilize similar single slope design however stagger tiers and coordinate heights by floor in order to decrease shading.
Daylight Delivery	Large glazing area will provide ample daylight to top plants, although the large volume will create shading issues for lower crops.	Similar daylight issues as initial design. The north facing sloped glazing lets in diffuse light. North covered areas in the rear do not receive adequate daylight for sustained plant growth.	Self shading limited between crops. Less depth and more width for higher daylight coverage. Slope optimized incident southern light angle throughout the US.	Module design creates optimum lighting requirements for specific carbon three plants. Minimal structural shading while taking into account mounting of devices and fixtures.
Ventilation	Open loop system, 100% Outside Air	Open loop system, 100% Outside Air	Open loop system, 100% Outside Air	Closed loop heating and cooling system. Lots of benefits including lower loads and increased controllability
Adaptability	Angle of glazing is not optimized	Snow accumulation between greenhouses will become an issue.	Single slope glazing is optimal for multiple locations in the US. Reduced heating and cooling in all climates due to reduced glazing area.	Cooling system, pest control, and carbon dioxide fertilization is sized for Miami. The exact same module can be used anywhere.
Constructability	Tall structure requires concrete and steel system with precast beams. Not ideal. Snow and Rain gutter between greenhouses will cause problems	Similar issues as initial design. Shared walls between greenhouses are difficult to coordinate and construct.	Simple to construct but large top slant poses logistic issues.	Optimal due to consistent and reasonable sized steel and glazing. Allows trusses to be preassembled and trucked to site.
Heating and Cooling	Height of greenhouse will cause stratification resulting in a non-homogenous growing environment	Height of greenhouse will cause stratification resulting in a non-homogenous growing environment. Less glazing than initial design helps.	Less glazing. Reduced stratification resulting in a more homogenous growing enviornment.	Refer to Mechanical Report
Operation Maintenance	Greenhouse is 20' high. This will require a rotational plant system that may have failures and maintenance issues	Similar issues as initial design. Tall growing area will pose problems.	Easier maintenance issues with regards to farming operations. Angled slope is still difficult to maintain	Easier maintenance issues with regards to farming operations. Angled slope is still difficult to maintain
Cost (construction and operation)	Cost of construction will be high due to large floor to ceiling heights	Cost of construction will be high due to large floor to ceiling heights	Reasonable cost due to repeatability	Cost is decreased due to prefabrication offsite and waste is decreased.

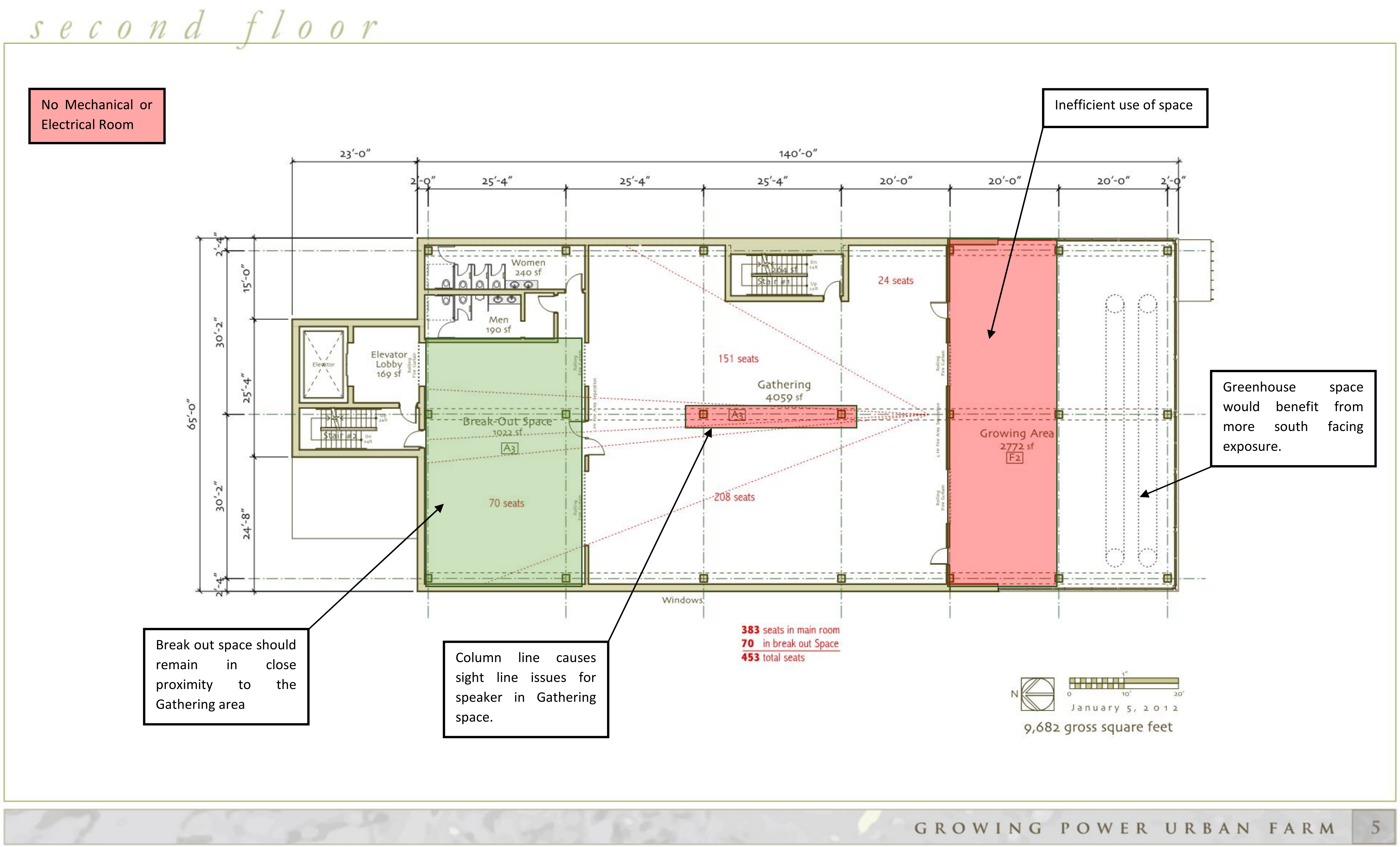
Appendix K: Architectural Optimization – Original Drawings: Basement



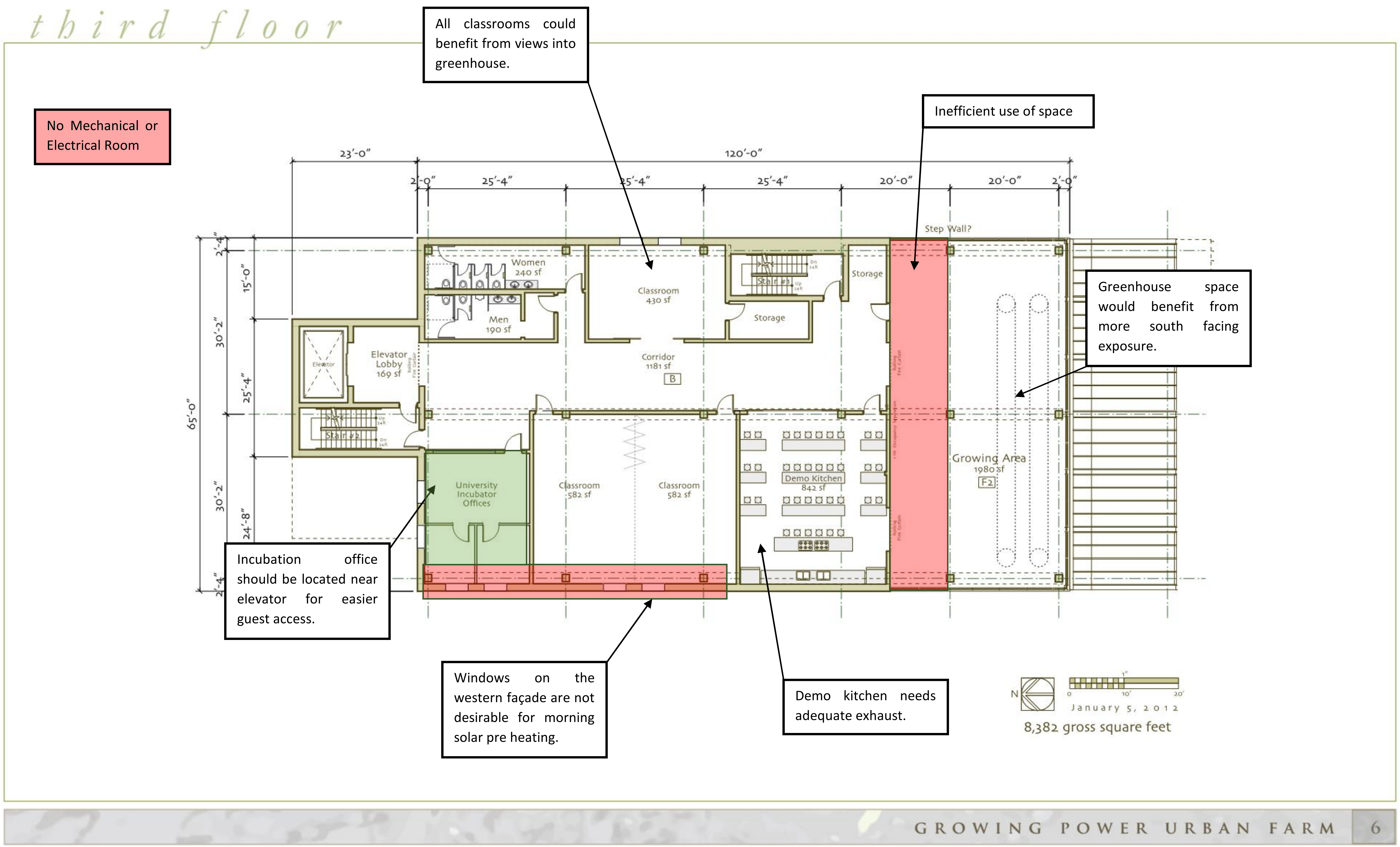
Appendix K: Architectural Optimization – Original Drawings: Level 1



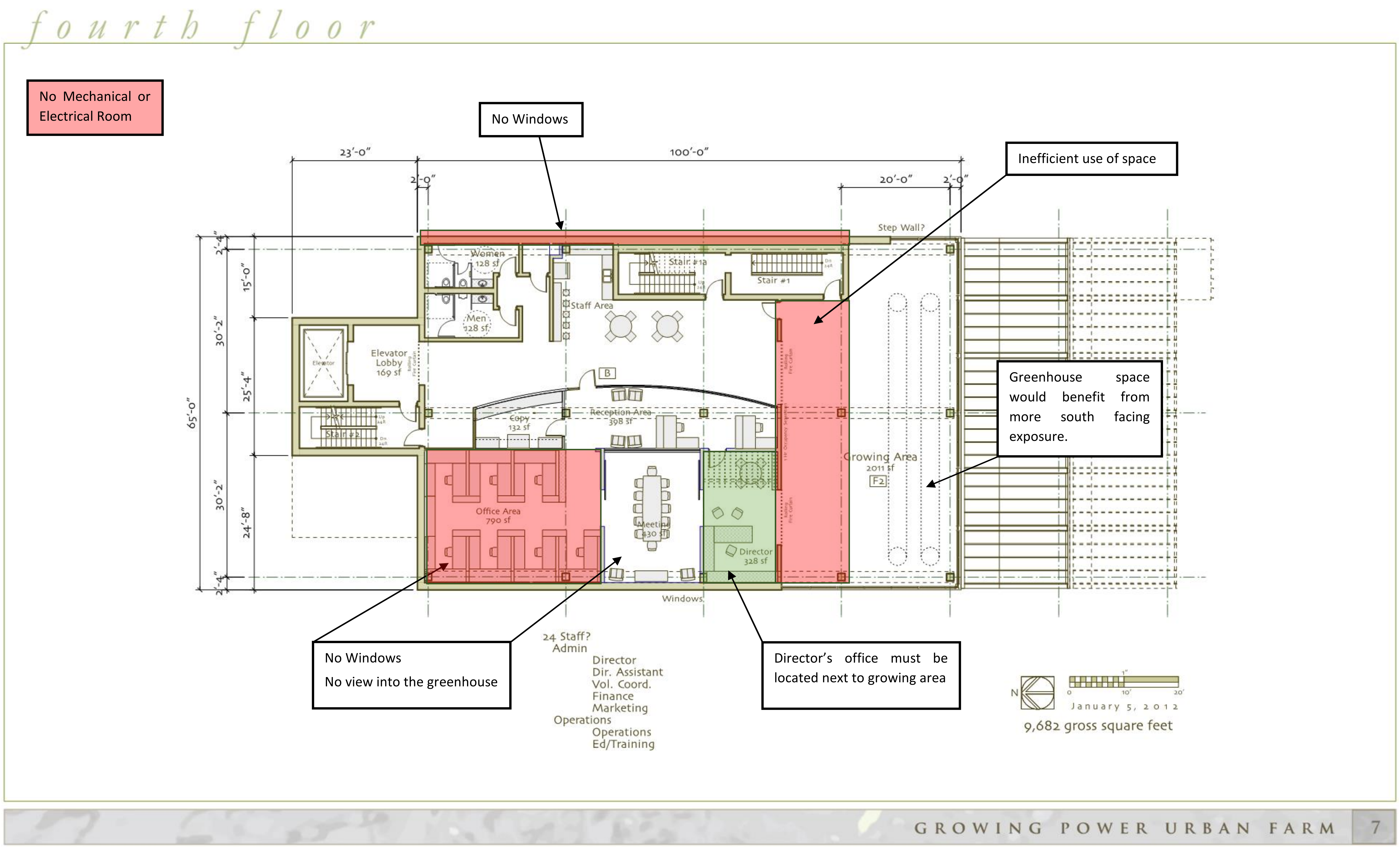
Appendix K: Architectural Optimization – Original Drawings: Level 2



Appendix K: Architectural Optimization – Original Drawings: Level 3



Appendix K: Architectural Optimization – Original Drawings: Level 4



Appendix K: Architectural Optimization – Original Drawings: Level 5