REFERENCES

INDIVIDUALS

Robert Holland, AIA – President, AMKEV Consulting PL
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Robert Leicht, Ph.D.
John Messner, Ph.D.
Mila Corkins—Director, Planning, Scheduling, and Management Controls, Walt Disney Imagineering
David Van Wyk – Project Integration Executive, Walt Disney Imagineering

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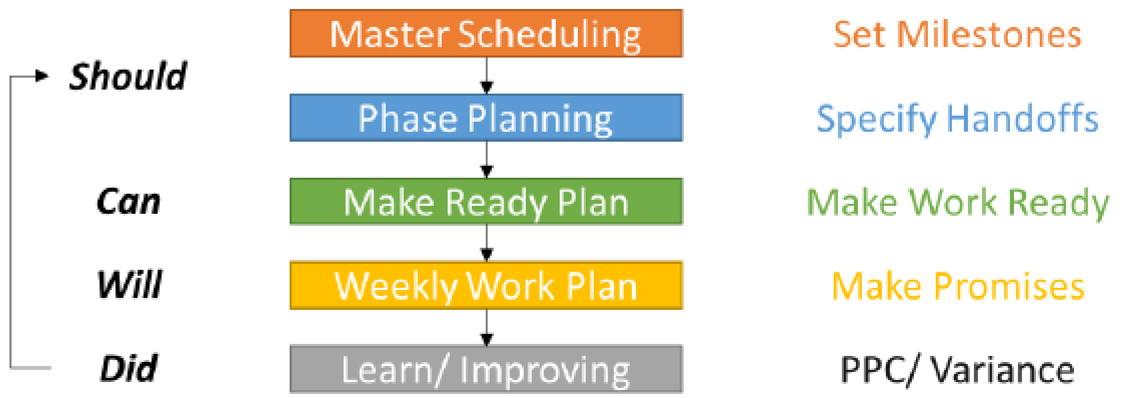
LAST PLANNER SYSTEM (LPS)

[redacted]

OVERVIEW

In a recent study on production in design and construction teams, it was found that an average of 54% of planned work was completed on time. The major reason given for this low percentage was that prerequisite work was not completed in order to begin tasks on time. The Last Planner System is a planning strategy that aims to make teams more productive by completing a high percentage of planned work. According to the Lean Construction Institute, the Last Planner System (LPS) is a "collaborative, commitment-based planning system that integrates should-can-will-did planning with constraint analysis, weekly work planning based upon reliable promises, and learning based upon analysis of PPC (plan percent complete) and reasons for variance." LPS follows a 5-step process built on the Plan-Do-Check-Act cycle that ensures that a team is performing work that needs to be done, when it needs to be done, so that successors can proceed as planned.

THE 5-STEP SYSTEM



MASTER SCHEDULING

The first step of LPS involves Master Scheduling, or the act of setting milestones. Generally this portion of the process is performed similarly to traditional scheduling practice, as milestones are often constrained by substantial completion dates or other deadlines. However, more intermediate milestones are generally specified than in a traditional approach, making the next step oh phase/pull planning more clear.

PHASE PLANNING/ PULL PLANNING

Phase planning, or pull planning, is sometimes thought of as synonymous with LPS. However, phase planning does not represent actual promises or commitments between team members, but rather serves to specify the handoffs that need to be made in order to complete work—it specifies what *should* occur in the phase. Pull Planning is performed in a backwards fashion, working from a milestone. Individual tasks are identified collaboratively with zero or minimal-float durations so that once the process is complete, activities are completed or decisions are made at the last responsible moment. This ensures that downstream activities are pulling the work from earlier activities, and the process flows smoothly. Pull planning is usually used with sticky notes that follow a particular fashion, specifying the work an individual is to complete with the work that needs to be completed immediately prior.

MAKE READY PLANNING

Making work ready is an important part of LPS that ensures that the upcoming work can be completed per the initial plan—it defines what work *can* be completed. The initial step of making work ready involves documenting the handoffs that were specified in the previous step. However, the documentation goes one step farther by allowing space for constraints to be documented. By identifying constraints to the phase plan—what *should* happen—the team can work to resolve those constraints ahead of time before they restrict the actual work being performed.

WEEKLY WORK PLANNING

Weekly planning exists for team members to make commitments to each other once it has been determined that the work has been made ready. The weekly plan defines what work *will* be done by each party. This follows a similar process as phase planning, but is much more detailed for the week ahead. It also involves daily check-in meetings with the team to ensure that work is progressing as planned. A recommendation is for these meetings to take no longer than 15 minutes, and to identify what promises have been fulfilled, and what work will be fulfilled.

LEARNING/ IMPROVING

Perhaps the most important part of LPS is the learning/ improving stage, which defines what *did* happen, and aims to support the lean principle of continuous improvement. On a weekly basis, the promises that were to be completed in the week prior are analyzed to determine the Plan Percent Complete (PPC). A common strategy is to publish the entire team's PPC, but track privately per individual or trade. Publishing the team's PPC on a regular basis allows the team to strive for as high a percentage as possible, but the management team can determine if a particular trade is routinely performing at a low percentage. From here, the PPC can be analyzed to determine what needs to be done for the project to be completed better, and bring the average of 54% to a much higher level.

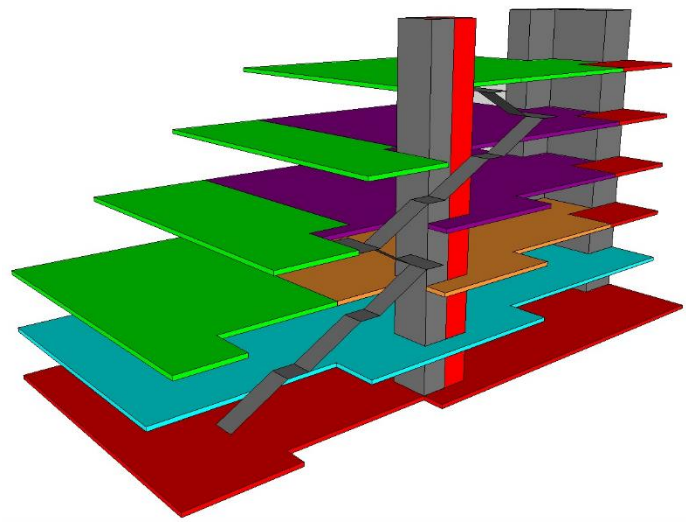
CONCLUSIONS

The Last Planner System is a collaborative way to enhance the planning and scheduling process. With construction having a much lower efficiency than other non-agricultural industries, and only 54% of tasks being completed, LPS has the potential to greatly improve the industry. Through thorough implementation of the 5 steps of LPS, teams can generate more realistic schedules and build chemistry with their trade partners. While often implemented after problems arise through work with consultants, champions of the process can implement the system throughout an entire project to experience clearer understanding of the interactions among team members and develop more useful schedules and planning techniques.

INTEGRATED DESIGN PACKAGES

In order to facilitate focused integration, TBD's management partners devised a plan to develop Integrated Design Packages (IDP) within the larger context of the Growing Power facility. Upon receipt of schematic documents, the team analyzed the facility's program in order to group spaces by their use. The result, shown in the image below, was a facility that was massed into five major IDPs within the facility.

First and foremost, the Growing Power facility is to be used to implement demonstration techniques of vertical farming. As such, the team grouped the three cascading greenhouses, as well as the rooftop greenhouse, into a Growing Space design package, shown in green.
The first floor consists of market-related spaces, such as the public market itself and its support spaces. As such, the team defined a Market IDP, shown in cyan.
The second floor contributes greatly to Growing Power's vision of community involvement, and is made up almost entirely of the gathering space and break-out spaces. TBD defined this level as a Gathering package, shown in orange.
The two floors above the Gathering package housed the administrative and educational spaces, and were also grouped into a package (purple).



Lastly, the facility is to be served by equipment housed in the basement, distributed on each level, and connected by a vertical shaft. The Back of House package was defined to envelop all the facility's support equipment and systems, such as the mechanical and electrical room in the basement. The Back of House package is shown in red.

As the project developed, it became apparent that some designed systems became their own design packages in order to unite the entire facility. The structure and building enclosure, while contained partly in each space, needed to be analyzed on a macro level in order to make them most efficient, and enclose the entire facility, shown to the left.

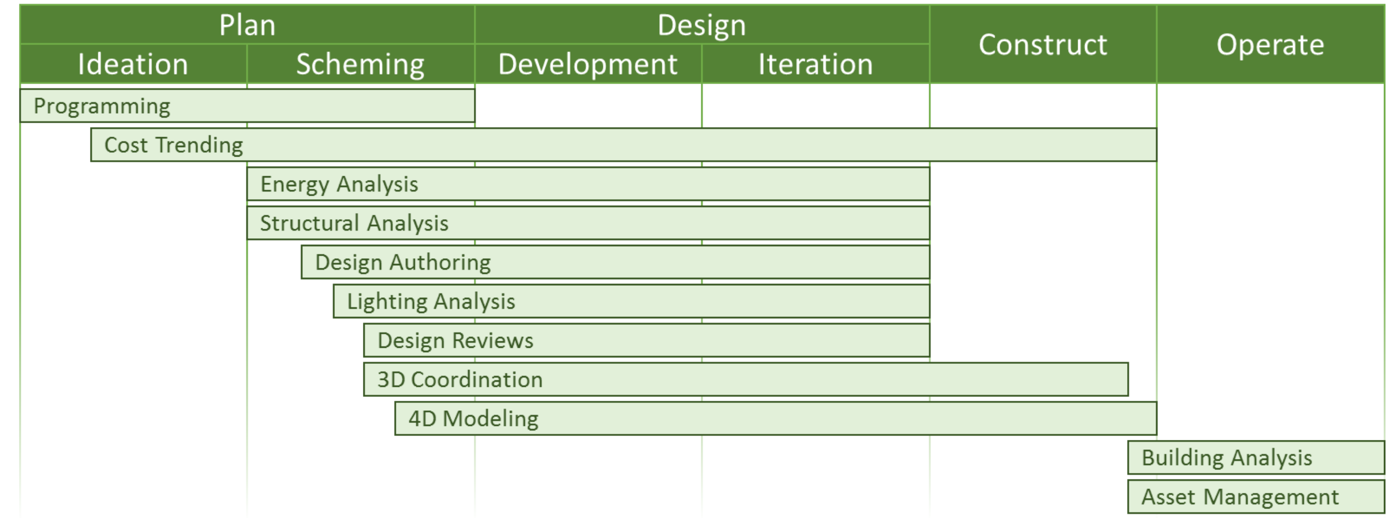
PLANNING THE IMPLEMENTATION OF BIM

As the use of Building Information Modeling was extremely important to the Growing Power facility's development, a plan was put together at the project's outset for the tool's implementation. The process for BIM planning includes defining project goals, determining BIM uses to support the goals, and defining how models are shared and information is extracted from the models. An excerpt of each portion of the process is shown below.

DEFINING BIM GOALS AND USES

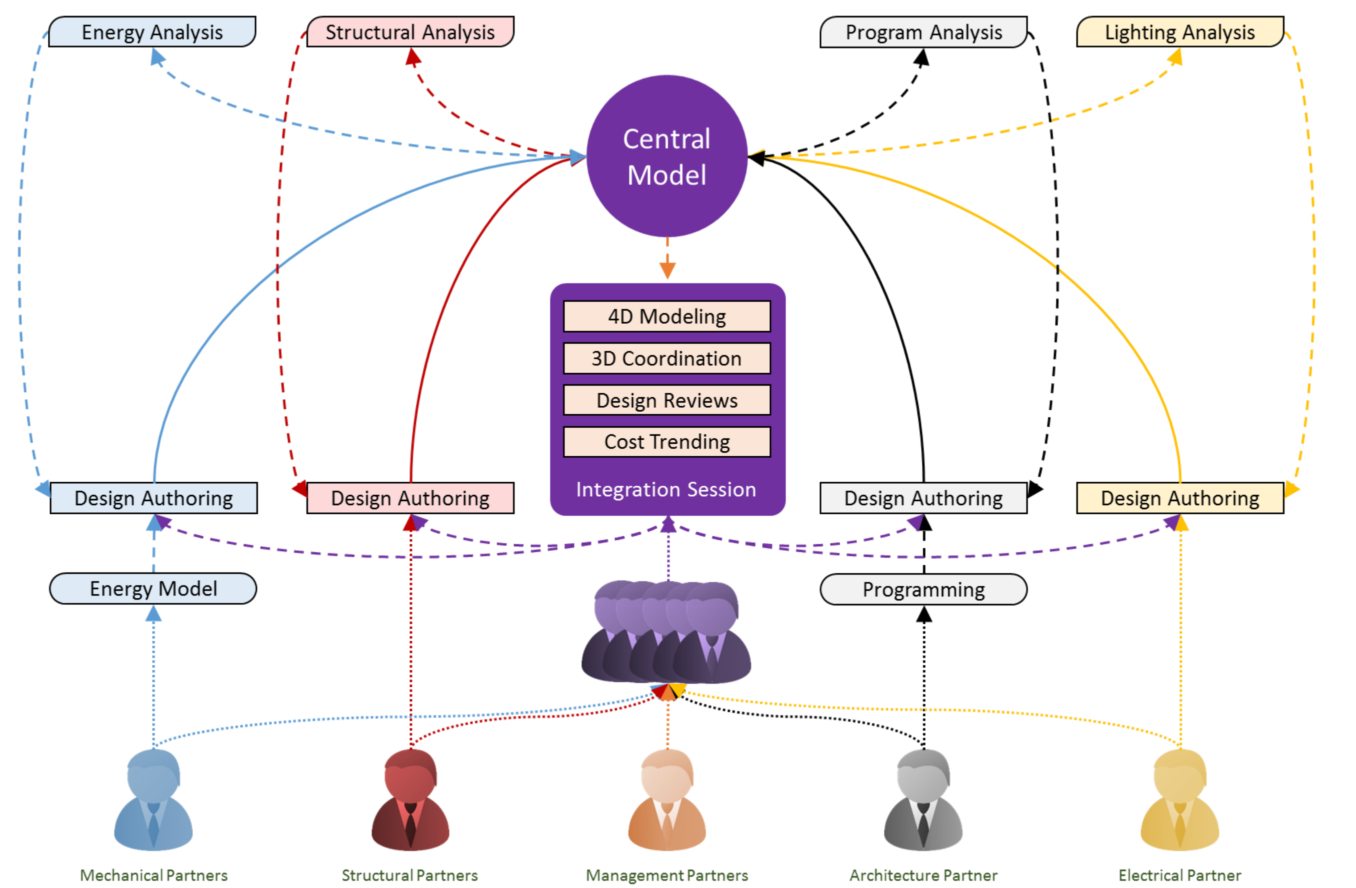
Operate	Construct	Design	Plan
• Allow for an easily maintainable facility • Continuously improve upon prototype	• Minimize field conflicts • Communicate schedule to project stakeholders	• Deliver an efficient, sustainable facility • Ensure mechanical design complies with guidelines • Ensure comfortable (day)lighting in spaces • Ensure structural design complies with guidelines • Review design progress to gather input from team • Ensure project aligns with target value	• Validate and update arch program

Building Information Modeling Use Case Worksheet									
BIM USE	PROJECT VALUE	RESPONSIBLE PARTNER(S)	VALUE TO RESPONSIBLE PARTNER(S)	CAPABILITY RATING			ADDITIONAL RESOURCES REQUIRED	NOTES	PROCEED?
				SCALE 1-3 (1=LOW)					
	HIGH/MED/LOW		HIGH/MED/LOW	RESOURCES	COMPETENCY	EXPERIENCE			YES/ NO/ TBD
Existing Conditions Modeling	Medium	Architectural Partner	High	3	3	3	Topography, utility locations	To be modeled in Infraworks.	TBD
		Construction Partner	High	3	3	3			
		Electrical/ Lighting Partner	Medium	3	2	1			
		Mechanical Partner	Medium	3	2	1			
Cost Estimation	High	Construction Partner	High	2	3	3		Export QTO from Revit.	Yes
		Electrical/ Lighting Partner	High	2	2	1		Apply RSMeans cost data.	
		Mechanical Partner	High	2	2	1			
		Structural Partner	High	2	2	2			
Phase Planning	Medium							N/A to this project.	No
Programming	High	Architectural Partner	High	3	3	3		Analyze schematic documents.	Yes
		Electrical/ Lighting Partner	Medium	3	2	2		Model in Sketchup.	
		Mechanical Partner	High	3	2	2		Review on SMARTBoard.	
		Structural Partner	High	3	2	2			
Site Analysis	Low							Site selected already.	No
Design Reviews	High	Owner	High	1	1	1		To be conducted in immersive	Yes
		Architectural Partner	High	3	3	3		environment (ICON Lab).	
		Construction Partner	High	3	3	3		Revit to RTR (likely Unity).	
		Electrical/ Lighting Partner	High	3	2	2			
		Mechanical Partner	High	3	2	2			
		Structural Partner	High	3	2	2			



DEFINING BIM PROCESS

In order to effectively take advantage of the benefits of BIM, the decided upon uses of the tools must be organized into a process. Shown below is a visualization of TBD's BIM process. For example, the mechanical partner's BIM process began by developing an energy model to analyze potential systems. Once a design was selected, the mechanical partners authored their design in Revit, and continuously synchronized to a shared, central model, which allowed for information to be extracted for data analysis. From there, the cycle was an iterative process, as shown by the loop in the partner's process.



DEFINING BIM INFORMATION EXCHANGES

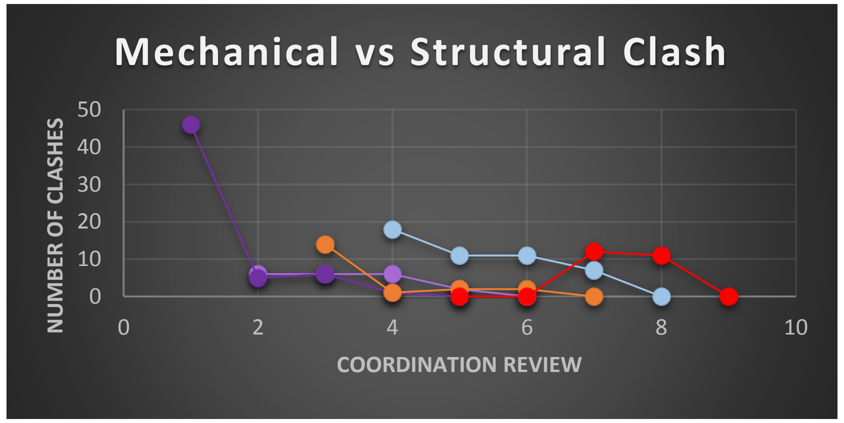
Throughout the design process, key information needed to be extracted from the shared, central model in order to perform various analyses, as displayed on the previous page. Each line type represents different information exchange, whether that be a human resource, direct link, or defined information exchange between BIM software. Below is a key detailing the numerous exchanges that took place throughout TBD's planning and design phases.

Line Type	Involved Design Partner	Information Exchange Description	File Transfer?	Origin	Receiver 1	Receiver 2	File Type
	All	Human resource input	No	N/A	N/A	N/A	N/A
	All	Directly synchronize to central	No	N/A	N/A	N/A	N/A
	Mechanical Partner	Build energy model	No	TRACE	Revit	N/A	Data only
		Extract data for energy analysis	No	Revit	TRACE	N/A	Data only
		Extract data for energy analysis	Yes	Sketchup	IES	N/A	.skp
	Structural Partner	Extract data for structural analysis	Yes	Revit	CAD	RAM	.dxf
		Extract data for structural analysis	Yes	Revit	CAD	SAP2000	.dxf
		Extract data for structural analysis	Yes	Revit	CAD	ETABS	.dxf
	Electrical Partner	Perform daylighting analysis	Yes	Revit	CAD	DAYSIM	.dwg
		Perform lighting system analysis	No	Revit	ElumTools		plugin
		Perform solar site analysis	Yes	Revit	Ecotect		.3ds
	Management Partner	Assemble 4D model	Yes	Revit	Navisworks		.nwc
		Perform 3D coordination	Yes	Revit	Navisworks		.nwc
		Perform design review	Yes	Revit	Navisworks		.nwc
		Perform design review	Yes	Revit	3DS Max	Unity	.3ds
		Analyze cost	Yes	Revit	Excel		.csv
	Architecture Partner	Analyze surrounding site	Yes	Revit	Infraworks		.fbx
		Analyze GIS data	Yes	Civil 3D	Infraworks		.shp
		Programming	Yes	Sketchup	Revit		.dwg

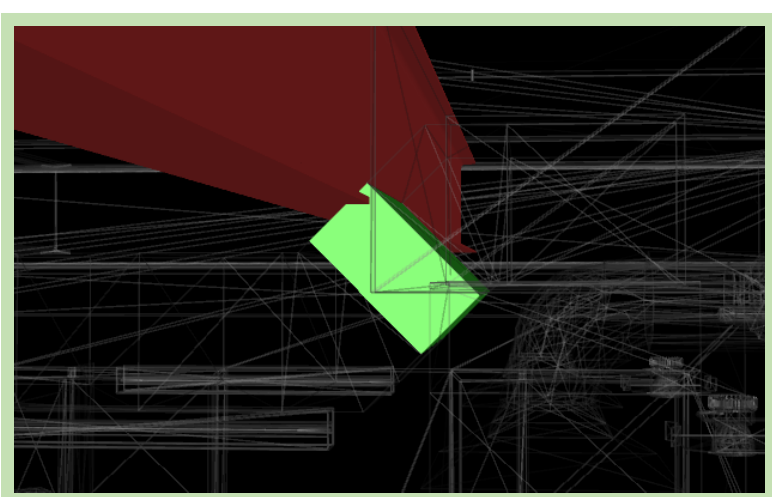
In order to guide the development of TBD's models, the management partners employed the AIA's Model Development Specification, specifically the Level of Development matrix, shown below. Based on a collaborative discussion, the team determined what components needed to be developed to what level of development at what point in time. The matrix was also supplemented by the AIA's LOD specification, to support the team in its understanding of different levels for various components.

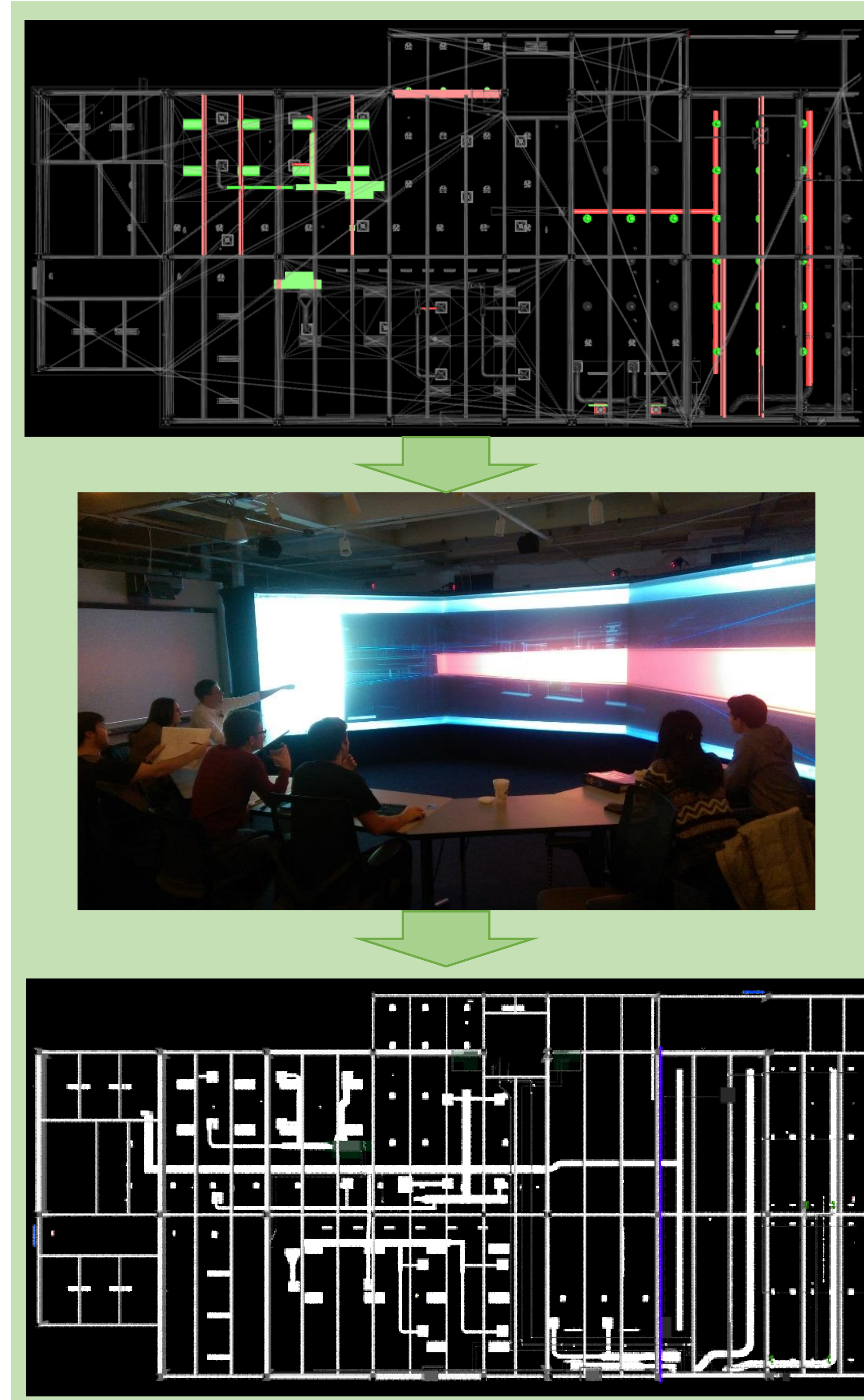
		Design Intent Model				
		Model Element	Scheming		Development	
		Yes/No	LOD	MEA	LOD	MEA
A1010	**Standard Foundations**					
	Wall & Column Foundations	Y	100	SP	200	SP
	Foundation Walls	Y	100	SP	200	SP
	Grade Beams	Y	100	SP	200	SP
	Pile Caps	Y	100	SP	200	SP
	Excavation, Backfill & Compaction	Y	100	SP	200	SP
	Footings & Bases	Y	100	SP	200	SP
	Perimeter Insulation	N				
	Perimeter Drainage	N				
	Anchor Plates/Bolt Patterns	N				
	Means & Methods (Erection/Sequencing/ Shop Standards)	N				
A1020	**Special Foundations**					
	Pile Foundations	Y	100	SP	200	SP
	Grade Beams	Y	100	SP	200	SP
	Caissons	Y	100	SP	200	SP
	Underpinning	N				
	Dewatering	N				
	Raft Foundations	N				
	Pressure Injected Grouting	N				
	Other Special Conditions	N				
	Means & Methods (Erection/Sequencing/ Shop Standards)	N				

COORDINATION



The management team tracked clashes between different technical systems to monitor progress and evaluate the impact of managerial decisions at each collaboration review. After the first coordination review, the high amount of initial clashes signified an opportunity for a better approach to design. To enable the design partners to deliver a more integrated product with less clashes, the management team created coordination views in the discipline specific models, which clearly displayed everyone's technical systems. The change in designing method is reflected by the reduced number of clashes for the remaining duration of design, as indicated in the figure above. Although the change did not completely eliminate all design clashes, it greatly reduced the time and effort required by all parties to resolve clashed through system redesign.



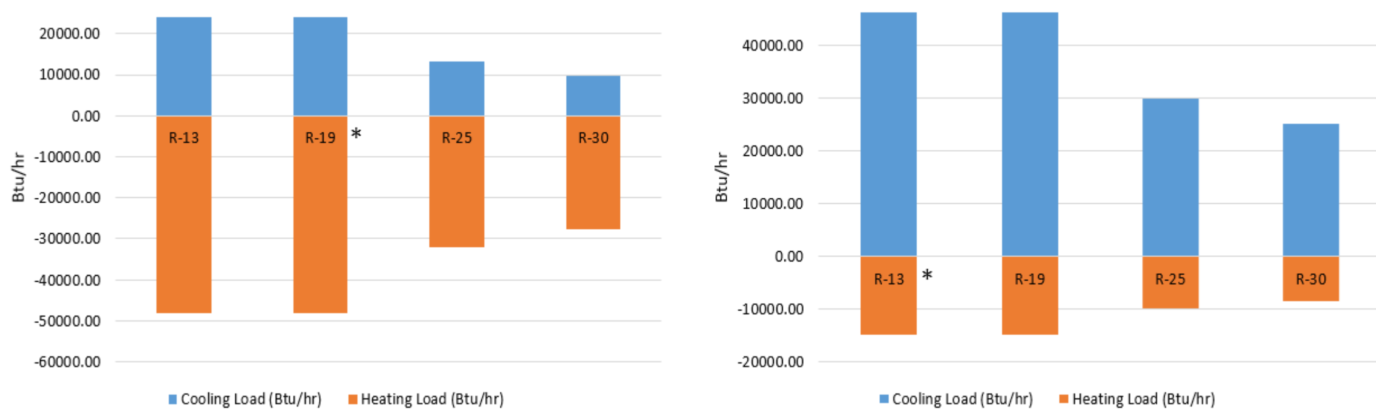


Continuous coordination throughout the design phase of the Growing Power facility enabled the designing partners to develop a facility with minimal clashes. Clashes between the mechanical, electrical, and structural design were identified early in the design process in Navisworks. The clashes, an example of which can be seen to the left, were then discussed in coordination reviews with the entire team. The design teams and construction managers would meet at the planned completion deadlines of the different design packages to conduct an immersive walk through the building, and a coordination review, utilizing a local Semi Immersive Design laboratory, as seen to the left. Clashes identified through the design process were displayed for the team to create group discussions on innovative solutions in a collaborative environment. The team analyzed the potential advantages and disadvantages of the proposed solutions, compromising negative discipline effects for beneficial overall project success. An example of this process would cutting through a steel element to allow piping to remain hidden from the public. The proposed solutions the team agreed upon did not always immediately resolve all clashes, but pushed the project towards the team's clash free goal, while supporting Growing Power's mission.

RAINSCREEN FAÇADE AND GLAZING

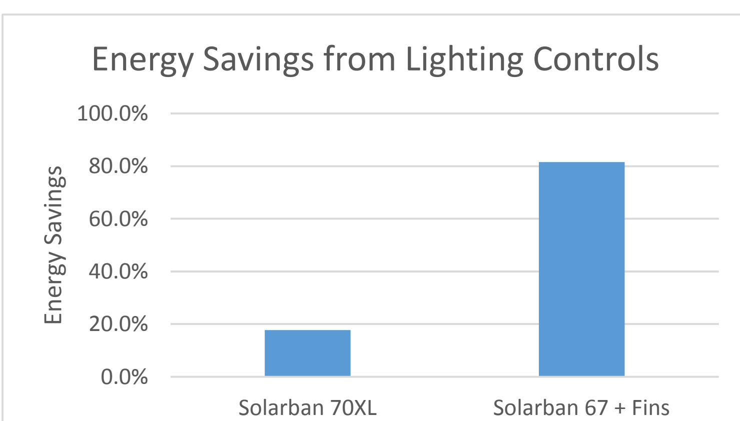
The team oriented design phase of the vertical farming facility, yielded the selection of a terracotta rainscreen façade system to enclose the building. Each discipline partner analyzed the façade system to provide input and suggestions, which led to a constructible, energy efficient system with ample daylighting for occupant comfort, complementing the team goals of sustainability, flexibility, and economy.

Heating and Cooling Demand Changes Affected by Varying Façade R-value in Milwaukee and Miami



ENERGY SAVINGS

The rainscreen façade can be installed with a range of insulation, influence by thermal requirements of specific locations. The mechanical partners analyzed the R-value of different rainscreen assemblies with Trane TRACE 700, to determine if the rainscreen façade could meet the ASHRAE minimum, and identify an optimum insulation value. The figure above displays heating and cooling loads for Milwaukee and Miami, indicating an optimum R-Value of 25, based on the installation cost and energy savings.



Providing adequate daylighting, while maintaining the thermal integrity of the envelope system, is necessary to an energy efficient Growing Power facility. Daylighting studies, performed with Daysim, analyzed different glazing types to determined optimum characteristics (ELEC REFERENCE). By specifying the use of automating lighting controls, the daylighting study indicates a substantial energy savings when using Solarban 67 glazing and shading fins to reduce direct sunlight, compared to standard glazing types.

The study also indicated a reduced need of automated shading, which contributes to energy savings, as well as increases a connection to the exterior site by decreasing blocked views.

	70XL	67 + fins
Shade Up	59.69%	87.30%
Shade Down	40.31%	12.65%

CONSTRUCTABILITY

The specification of the rainscreen alleviated structural dead loads from the façade when compared to traditional masonry façade designs, but still required detailed analysis to confirm its feasible use in the facility design. To ensure safe and proper design of the rainscreen assembly, the structural design partners analyzed appropriate placement of steel stud backup. WHAT ELSE HERE adam/todd

The rainscreen system is a complex assembly that requires diligent effort to install, and price correctly. To ensure the proper installation, the construction team created a virtual mock-up, clearly displaying the assembly pieces, and the order of installation. The visual can be used to indicate to trade contractors, the expectations of the design team. The construction team also conducted a production study to accurately schedule the installation process (Const SD II). The production study, conducted on the installation of a similar rainscreen assembly, provided accurate results to contribute to the reliable scheduling of the vertical farm construction.

Terracotta Panel Size	1 ft x 4 ft

Terracotta Produciton Rate

Date	Completed Area	Unit	No. of Panels	Unit	Crew Size	SF/Crew Mem.	No./Crew Member	Note
10/20/2014	1047.8	SF	262	SF	4	261.95	65.5	First Day Tracking
10/21/2014	237.39	SF	63	SF	4	59.35	15.75	
10/22/2014	231.25	SF	55	SF	4	57.81	13.75	Raining
10/23/2014	227.3	SF	92	SF	5	45.46	18.4	
					Average	54.21	15.97	

Applicable Studs for Exterior Façade - Milwaukee

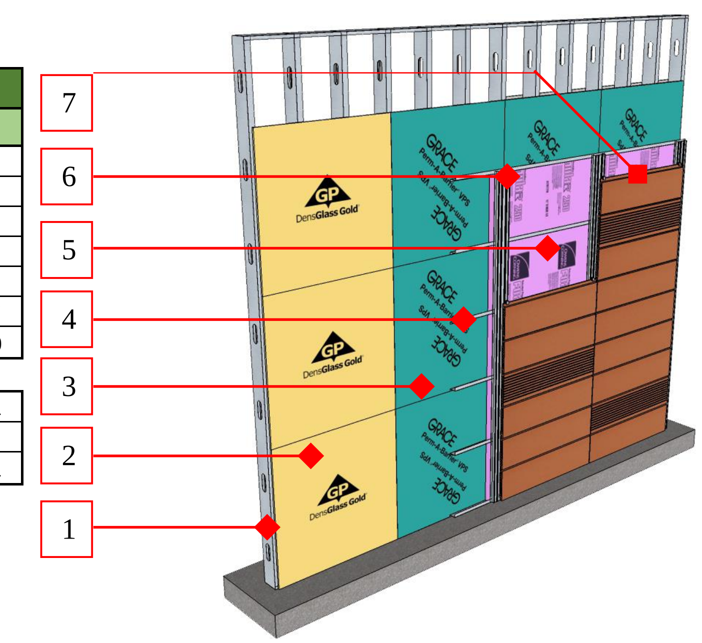
Wall Height	14	ft	
Axial Load	350	plf	
Wall Weight	25	psf	
Axial Load per Stud	*12" o.c.*	350	lbs
	16" o.c.	467	lbs
	24" o.c.	700	lbs
Wind Pressure	36	psf	*Zone 5*

	Clark Dietrich Designation				Actual Values	
Spacing	*Depth*	*Flange Width*	*Minimum Gage*	*Fy*	*Depth*	*Gage*
12	600	137	54	50	6	16
		162	54	50	6	16
		200	43	50	6	18
		250	43	50	6	18
		300	54	50	6	16
	800	137	54	50	8	16
		162	54	50	8	16
		200	54	50	8	16
		250	54	50	8	16
		300	54	50	8	16
16	600	137	68	50	6	14
		162	54	50	6	16
		200	54	50	6	16
		250	54	50	6	16
		300	54	50	6	16
	800	137	54	50	8	16
		162	54	50	8	16
		200	54	50	8	16
		250	54	50	8	16
		300	54	50	8	16
24	600	137	97	50	6	12
		162	68	50	6	14
		200	68	50	6	14
		250	54	50	6	16
		300	54	50	6	16
	800	137	97	50	8	12
		162	68	50	8	14
		200	54	50	8	16
		250	54	50	8	16
		300	54	50	8	16

TC Rain Screen Façade

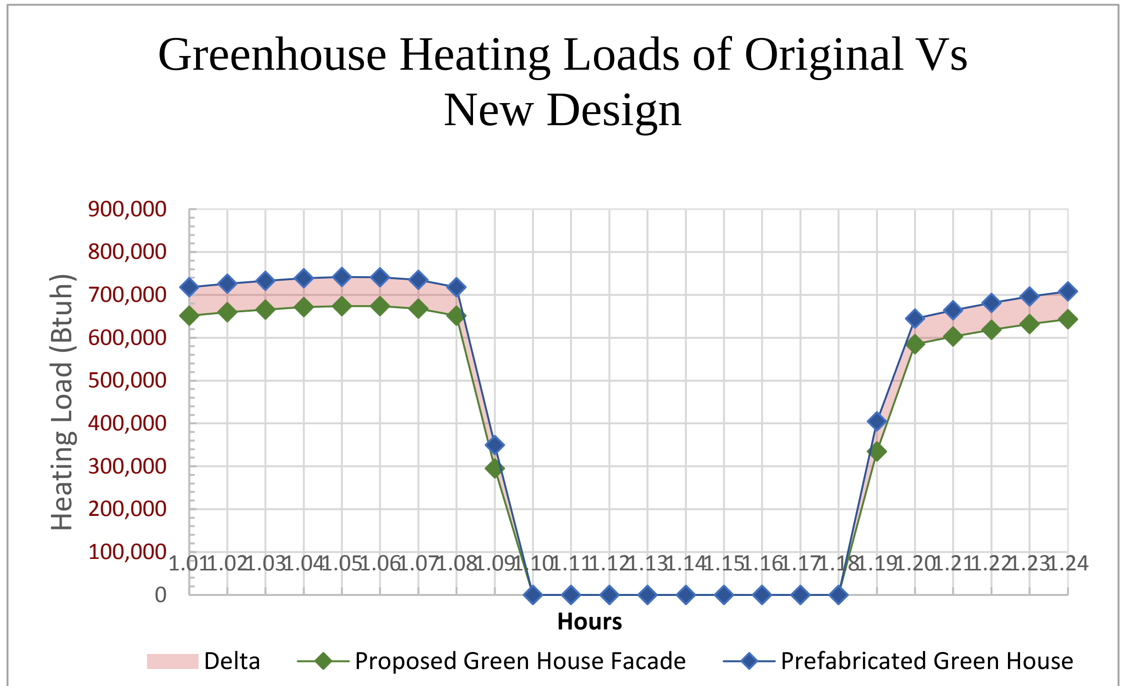
Material	ID	Cost	Qty	Unit	Unit Price	Unit/SF	$/SF
Stud	1	$ 6.21	10	LF	$ 0.62	0.75	$ 0.47
Sheathing	2	$ 19.00	32	SF	$ 0.59	1	$ 0.59
Vapor Barrier	3	$ 175.00	112.5	SF	$ 1.56	1	$ 1.56
Z Strip	4	$ 200.00	192	LF	$ 1.04	0.5	$ 0.52
Insulation	5	$ 32.00	32	SF	$ 1.00	1	$ 1.00
Furring	6	$ 4.49	12	LF	$ 0.37	1	$ 0.37
TC Panel	7	$ 32.00	1	SF	$ 32.00	1	$ 32.00

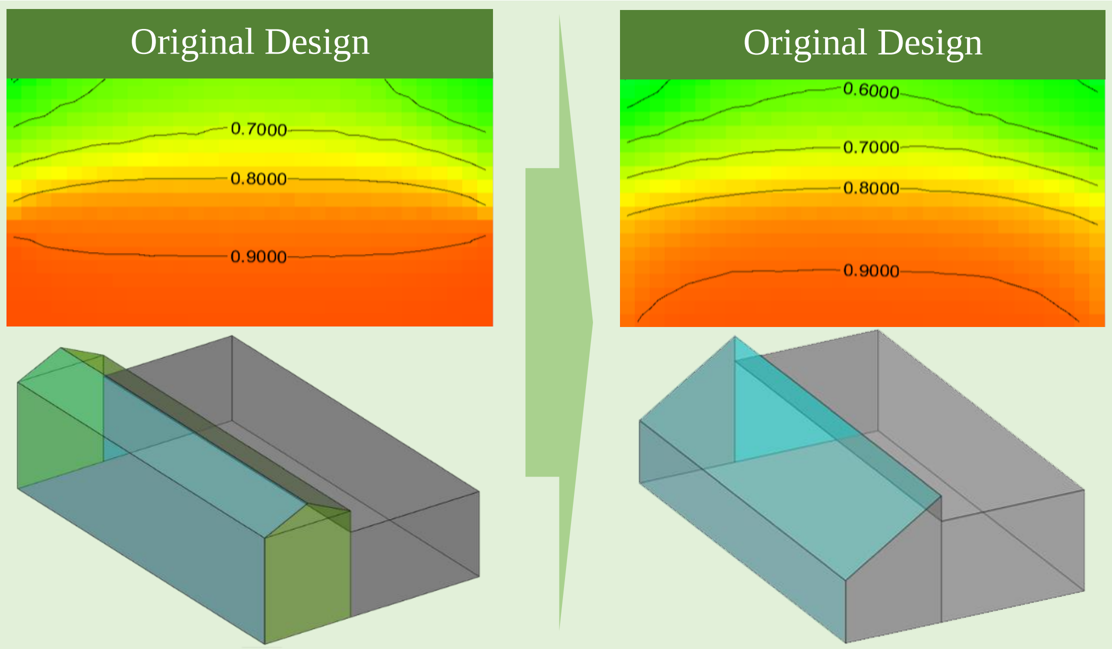
Mat'l	$ 36.51
Inst	$ 2.10
Total	$ 38.61

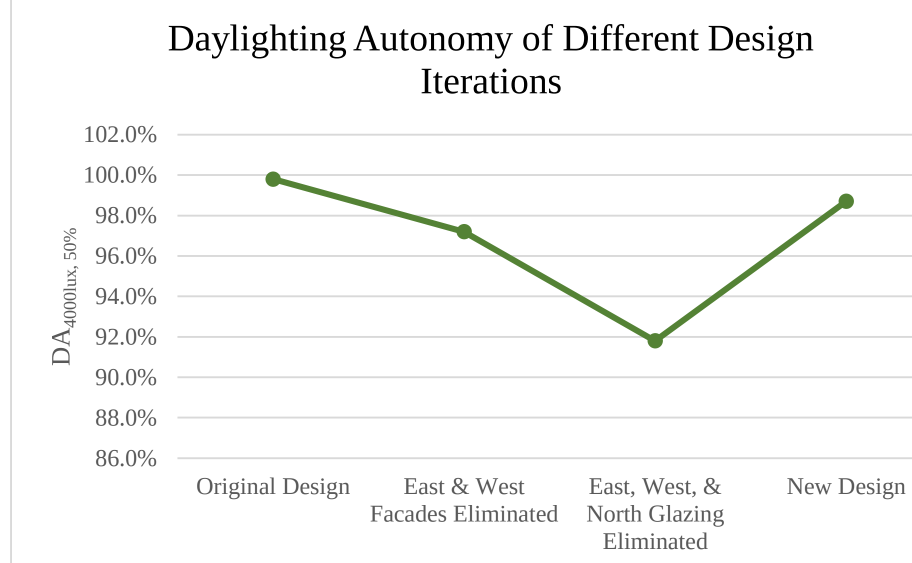


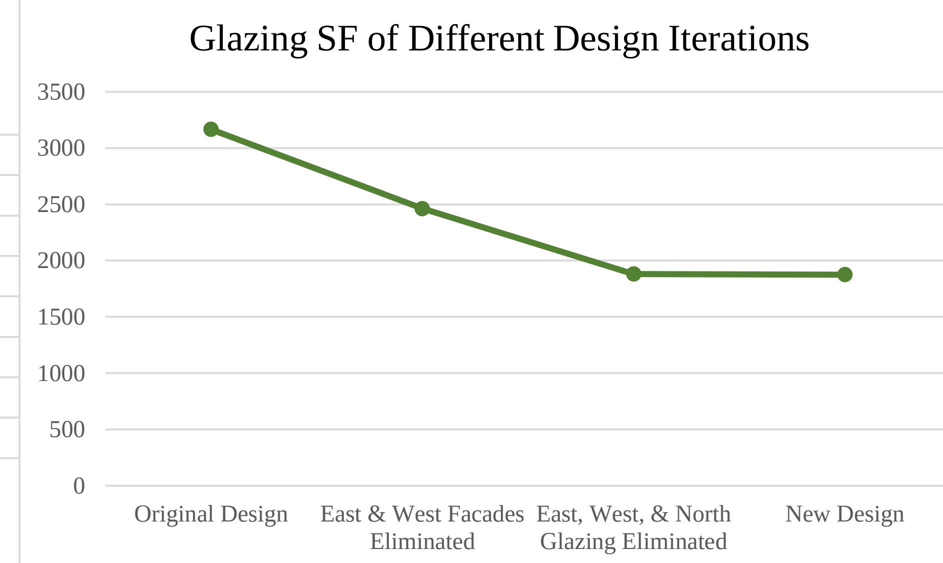
LOWER GREENHOUSE DESIGN

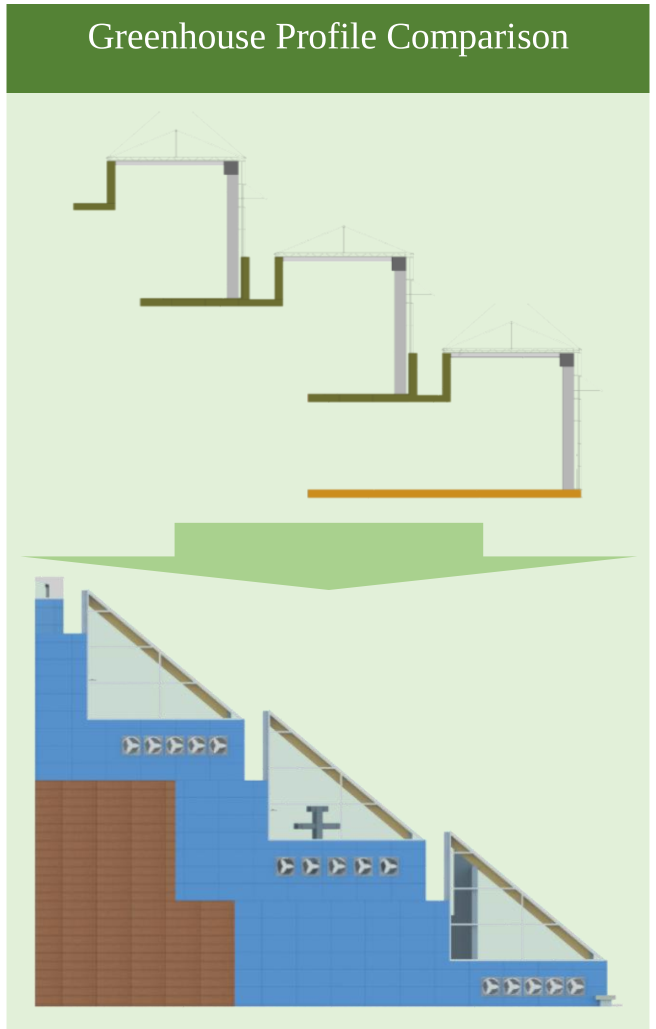
Analysis of the original, pre-manufactured greenhouse design indicated an opportunity for improvement through an integrated design. Analysis through Daysim indicated the elimination of the non-south facing glazing has a minimal impact on the sunlight supplied to the growing spaces, as shown in the daylighting autonomy figure to the right. While the elimination of the excessive glazing has a minimal impact on the daylighting of the space, the reduction of glazing and the addition of the rainscreen facade created a lower heating demand, reflected in the graph below for heating load in January. Redesigning the greenhouse spaces and reducing the amount of glazing in the greenhouses, reduced the cost associated with heating the space, without sacrificing the daylighting necessary to healthy plant life.



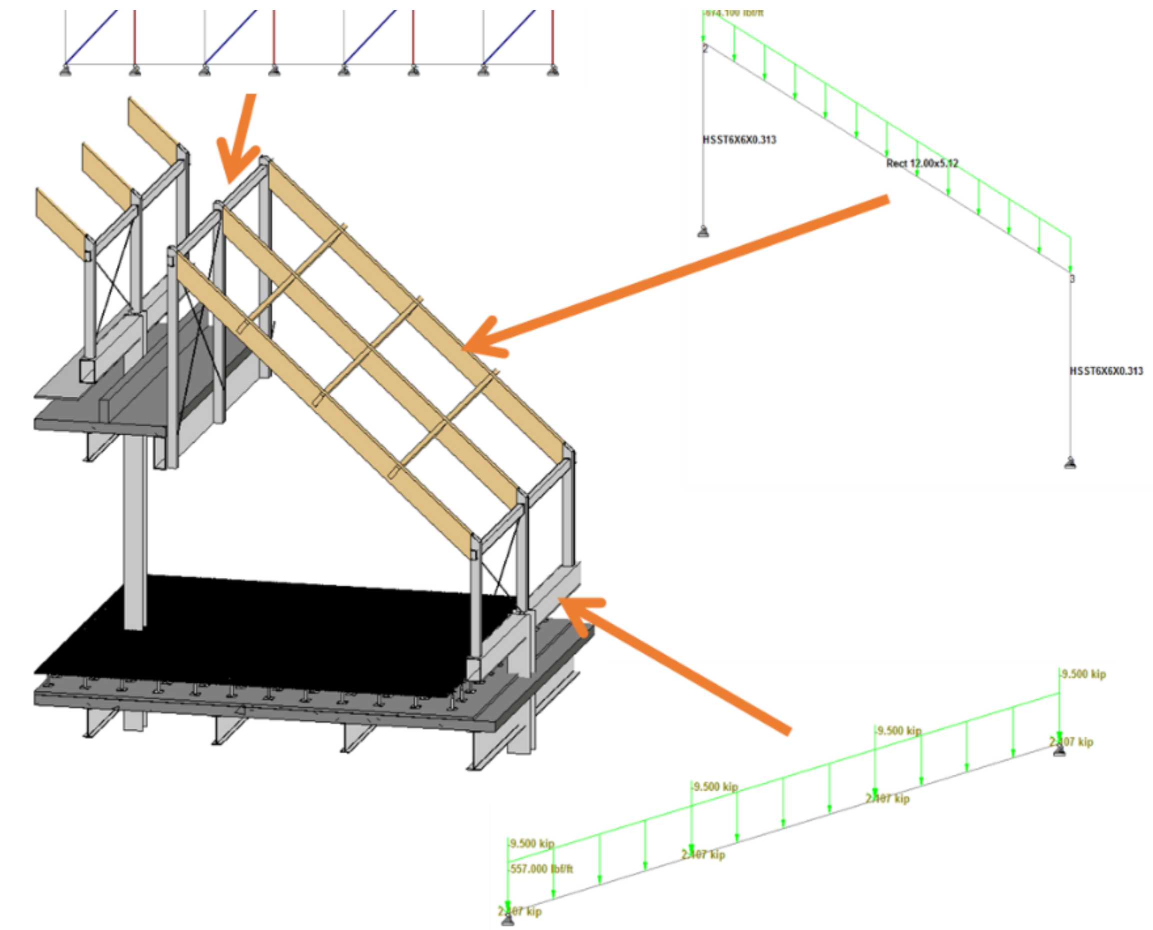








The cascading greenhouse roofs utilizing renewable glulam members framing into HSS components designed to optimize daylighting providing to the plants. As the design is comprised of a number of different parts, several STAAD models were created to analyze the components independently while applying loads from one model to another as appropriate. The structural modeling, combined with a DAYSIM analysis indicated the final design to be beneficial for both structural and electrical design partners.



TOP GREENHOUSE REDESIGN

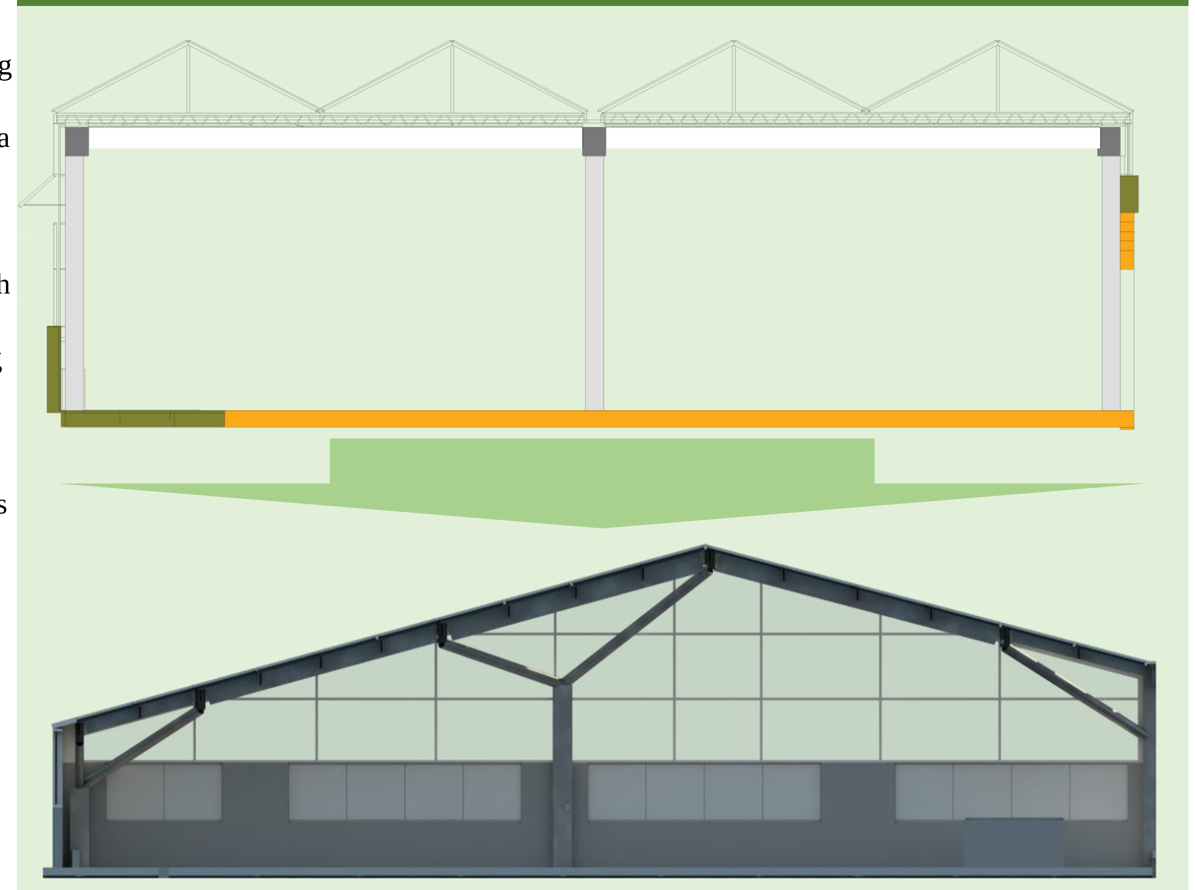
The original, prefabicated greenhouse design on the top of the growing power facility included redundant structural elements and excessive conditioned space. The TBD design team determined this to be an area with the potential for improvement and redesigned the growing space to be more relatable to other locations across the country without sacrificing the sunlight necessary to plant life. The structural, mechanical, and electrical partners determined a 15˚ slope on the south side of the greenhouse roof, limiting the structural height to 30 feet, was an effective angle to reduce conidtioned space without sacrificing daylight. The structual team conducted multiple SAP2000 and RAM SS analyses to determine optimum member dimensions required to create an open floorplan with minimal structural column interference, while simultaneaoulsy comparing member sizes with Daysim analyses by the elctrical partner..

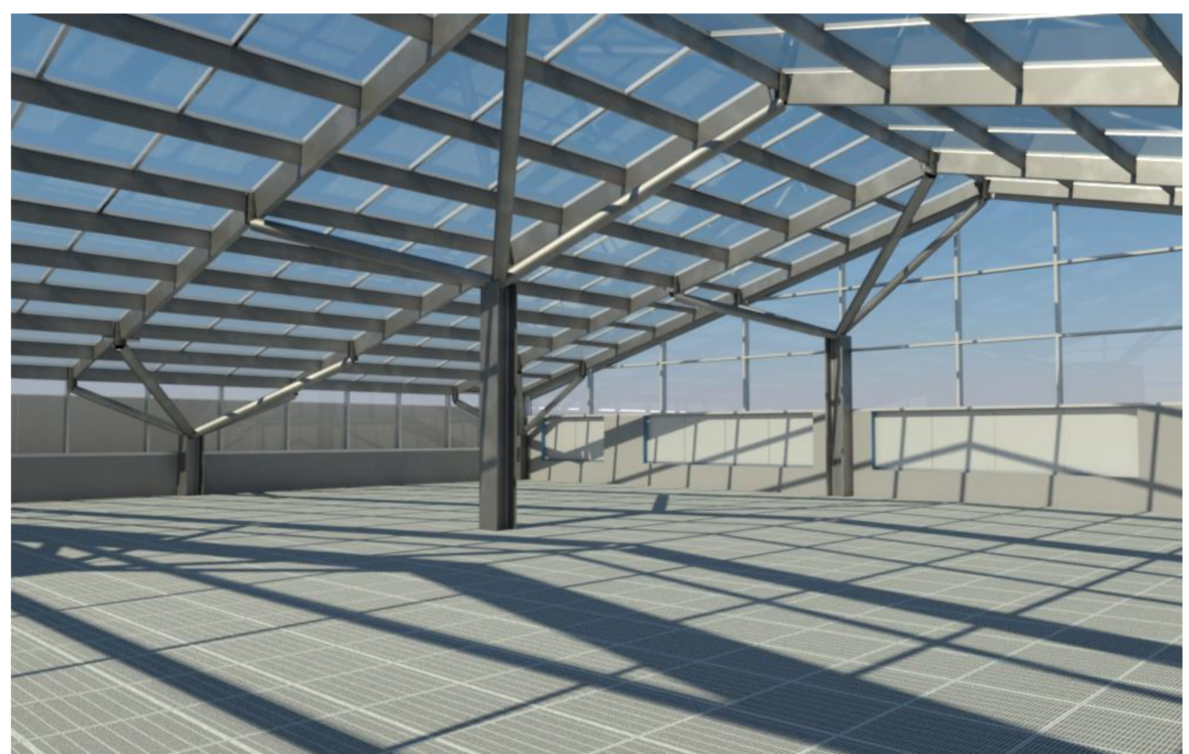
Top Greenhouse Roof Slope Comparison

Start Height	10
Length	73.5

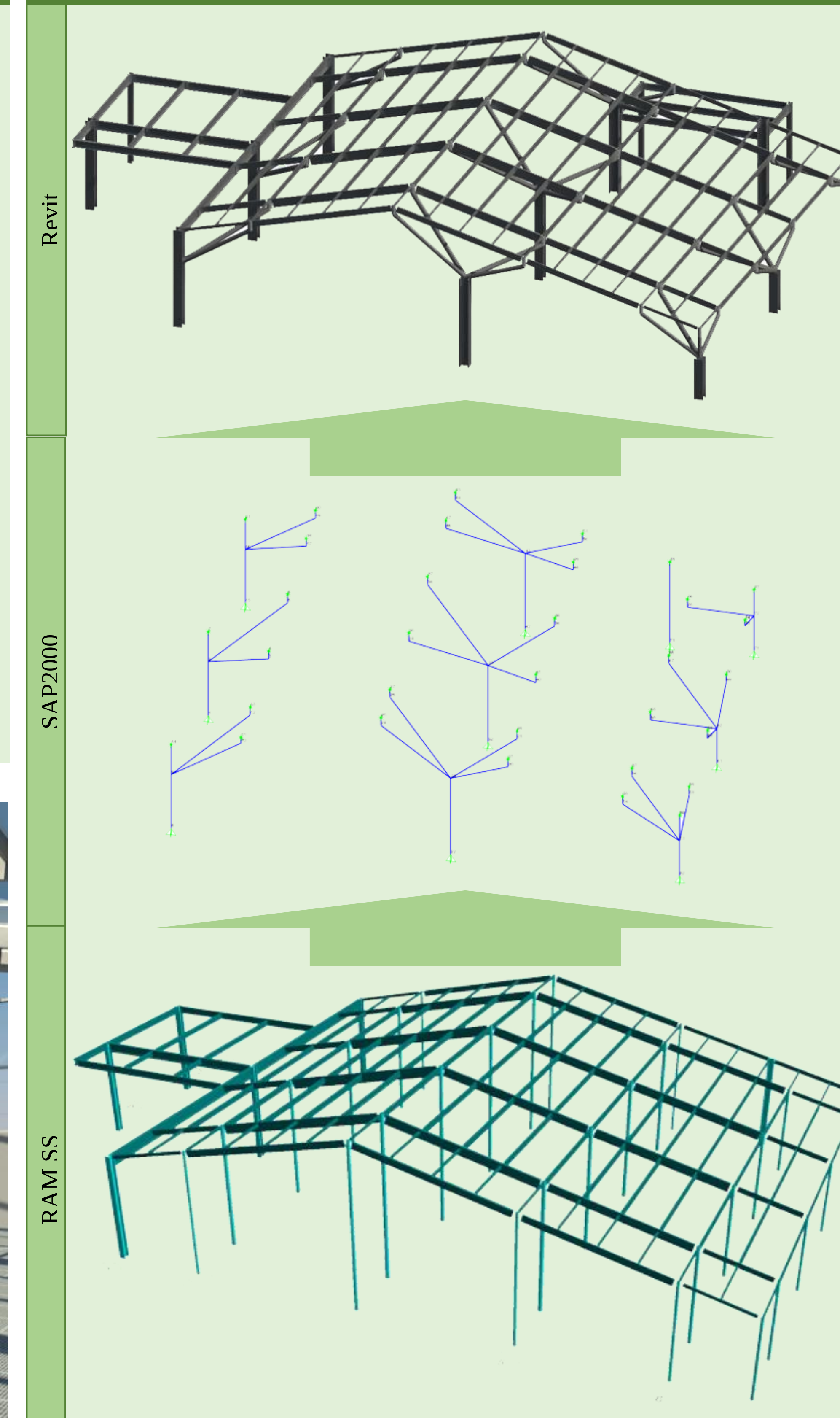
Roof Slope (Degrees)	*Start Height*	*Length*	*Change in Height*	*Total Final Height*
0	10	73.5	0	10
1	10	73.5	1.3	11.3
2	10	73.5	2.6	12.6
3	10	73.5	3.9	13.9
4	10	73.5	5.1	15.1
5	10	73.5	6.4	16.4
6	10	73.5	7.7	17.7
7	10	73.5	9.0	19.0
8	10	73.5	10.3	20.3
9	10	73.5	11.6	21.6
10	10	73.5	13.0	23.0
11	10	73.5	14.3	24.3
12	10	73.5	15.6	25.6
13	10	73.5	17.0	27.0
14	10	73.5	18.3	28.3
15	10	73.5	19.7	29.7
16	10	73.5	21.1	31.1
17	10	73.5	22.5	32.5
18	10	73.5	23.9	33.9
19	10	73.5	25.3	35.3
20	10	73.5	26.8	36.8

Greenhouse Profile Comparison

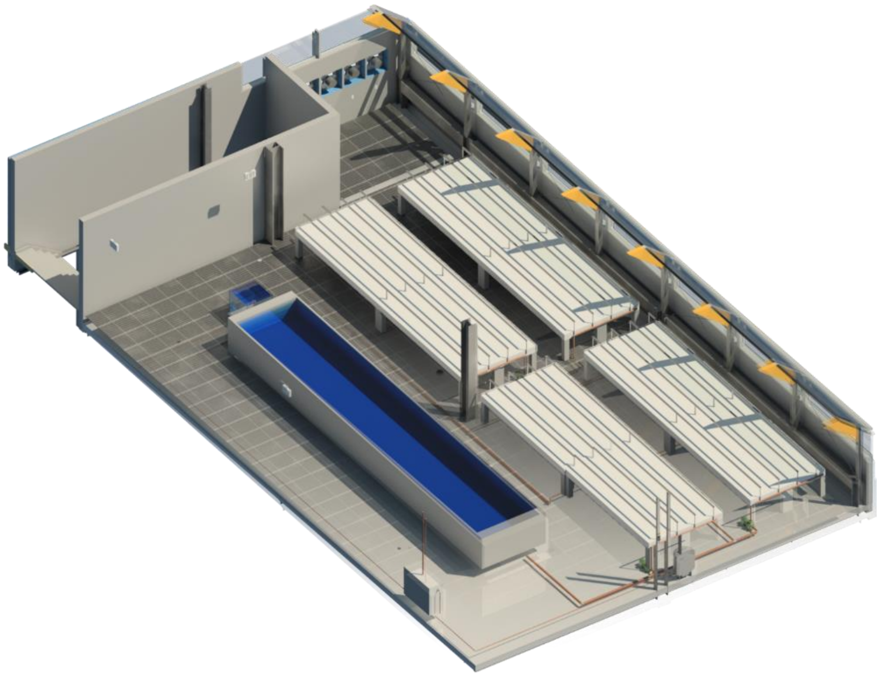




Greenhouse Roof Structure Development



RAISED GRATE FLOOR



COMX Aluminum Raised Floor System

24”x24” raised aluminum panels

1250 lb concentrated load rated - exceeds live load requirements of the space

Corrosion Resistant – Ideal for humid greenhouse spaces

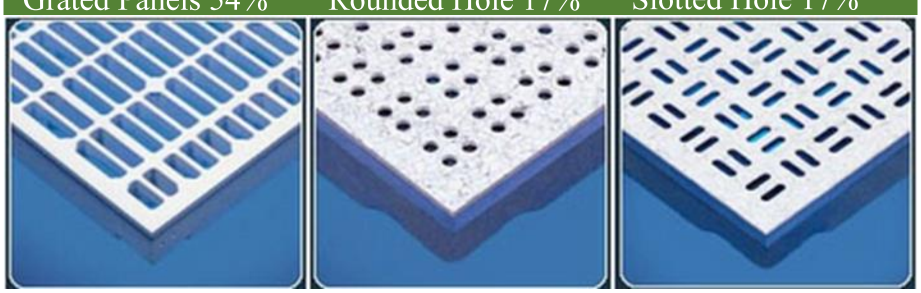
Easy to Install – Lightweight with locking corners for vibration control

Different Options – Flexible to the needs of the owner

The greenhouse flooring system was designed to take advantage of the benefits of a raised, grated flooring system, by placing all piping below aluminum panels. The tile grates are easily removable to allow access to the piping below, enabling Growing Power employees to install caps, or valves on any pipe to supply future growing bed designs. The greenhouse spaces are designed to accommodate everything from traditional growing beds to vertical stacked systems. The raised aluminum floor provides the greenhouse with the flexibility to educate the community about numerous greenhouse growing techniques.

The grated system also contributes to the safety of the community members on educational tours of the vertical farming facility. It is expected that groups of neighbors, students, and children will be traveling though the spaces to learn about sustainable farming methods. Placing all piping under the raised flooring immensely reduces potential tripping hazards and creates a safer environment.

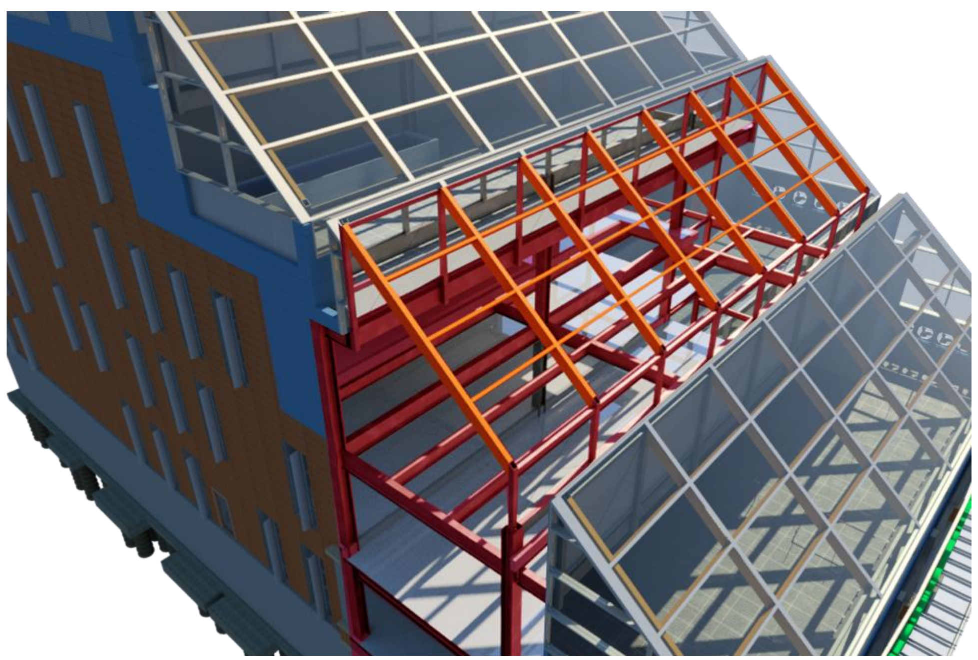
Grated Panels 54% | Rounded Hole 17% | Slotted Hole 17%



AQUAPONICS

The aquaponic system designed by the mechanical partners, allows Growing Power to demonstrate the symbiotic relationship between the fish and plant life as part of their community education program. Correctly sizing the components of the system required the use of equations detailed in the ASHRAE Handbook – HVAC Applications, the product of which is detailed in the table to the left.

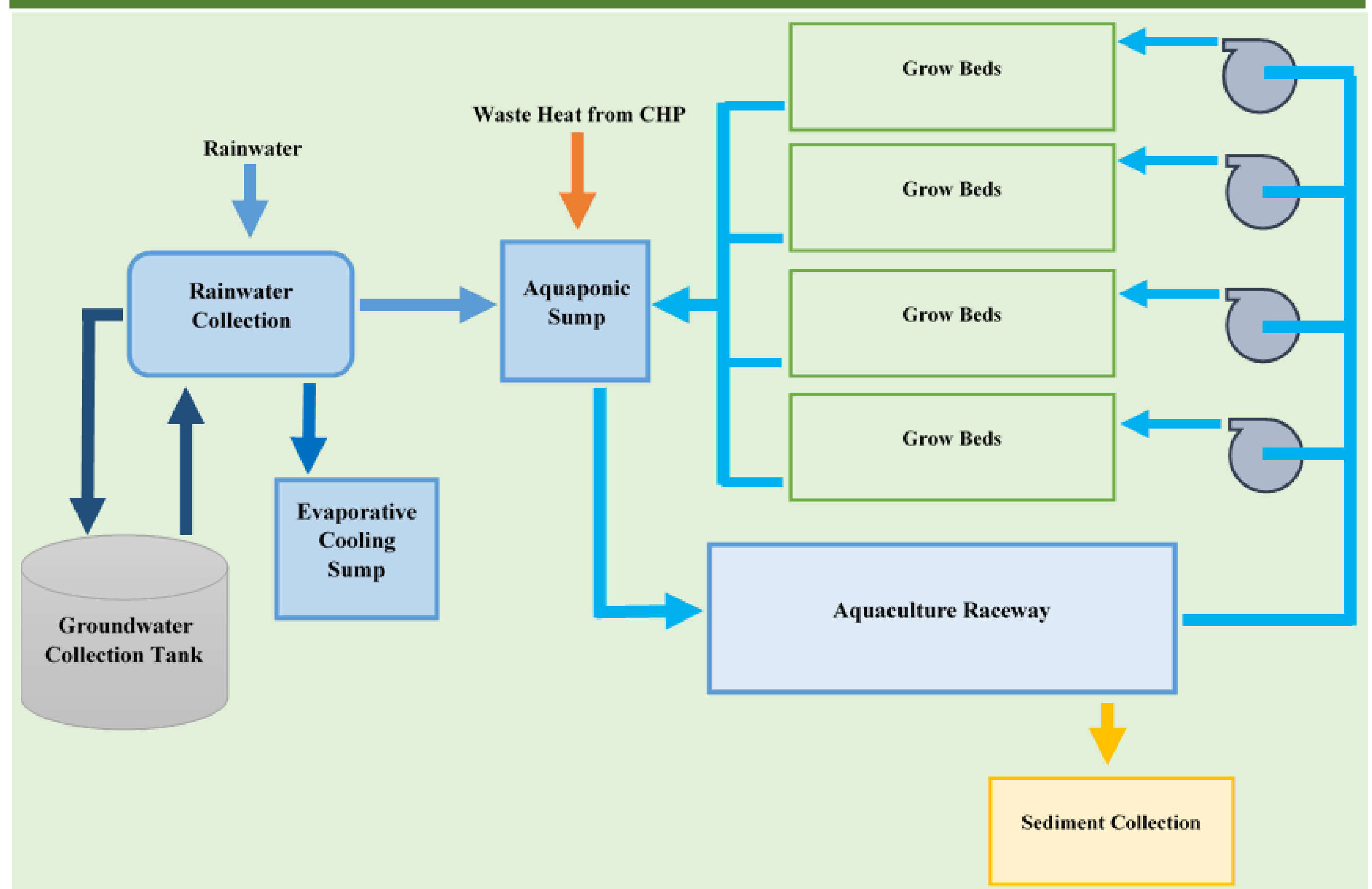
The large components were designed to house enormous amounts of water within the system, which contributed substantial load to be supported by the structural system. The load from the water-filled aquaponic growing beds was so large, it required the use of steel elements, as a concrete alternative created shear excessive shear issues (Struc|5). Steel members were specified to support the growing layout as well as the dropdown in the floor to create space for the necessary piping, and are highlighted in the graphic blow



Growing Place Level	Growing Beds				Aquaculture Raceway *				Aquaponic Sump				Evaporative Cooling Sump		
	Quantity	Length ft	Width ft	Area SF	Length ft	Width ft	Height ft	Volume gallons	Volume gallons	Length ft	Width ft	Height ft	Volume gallons	Diameter ft	Height ft
2	16	4	13	832	40	6.31	3.5	6604	140	2.66	2.66	2.5	16	1.25	2.66
3	16	4	13	832	20	6.25	3.5	6604	140	2.66	2.66	2.5	16	1.25	2.66
4	8	4	13	416	25	5.04	3.5	3302	70	2.1	2.1	2	16	1.25	2.66
5	36	4	13	1872	40	14.13	3.5	14794	300	3.66	3.66	3	56	2	2

*It should be noted that the greenhouse on Level 3 includes two tanks at the size specified due to coordination with the structural system

Aquaponic Growing Bed Schematic



Greenhouse Load Sizing

The required fan and pad sizes were calculated using the equations given in Chapter 52.13 of the 2011 ASHRAE Handbook – HVAC Applications giving the length of pad required. According to Bucklin, et. al., evaporative cooling sumps should be sized to hold 1 to 1.25 gallons per linear foot of pad in order to hold all water that drains to the sump when the system stops. Therefore the evaporative cooling sumps were sized at 1 gallon per linear foot of evaporative pad. See page 4 of Supporting Documents of the Mechanical Report for further evaporative cooling calculations.

Aquaponic sumps are sized to carry 2% of the aquaculture raceway given that the system loses 2% of its water per day. Refer to page 6 of Supporting Documents of the Mechanical Report for further aquaponic system sizing calculations.

Gathering Space Design Coordination

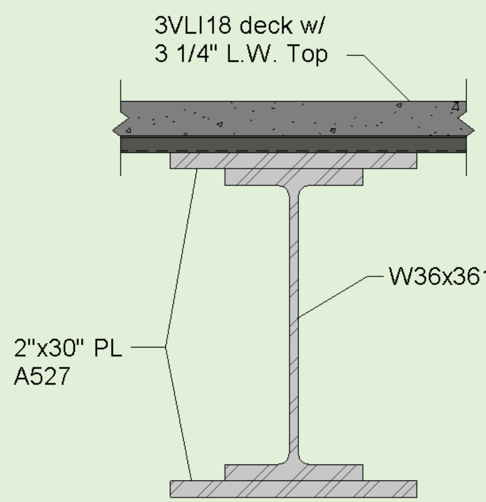
The Gathering Space redesign included the elimination of two structural columns to open the floorplan and allow for better visual connections during presentations. Successful redesign of the space required focus and input from all design partners engaged in the TBD integrated project approach. The resulting Gathering Space provides Growing Power with a space to engage community and industry members in an active learning environment.

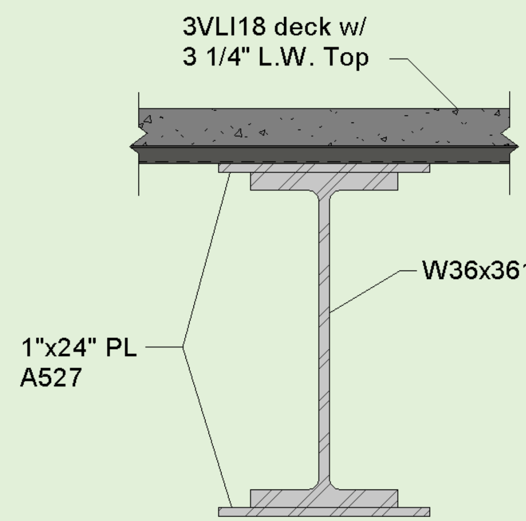
Gathering Space Lighting Scheme

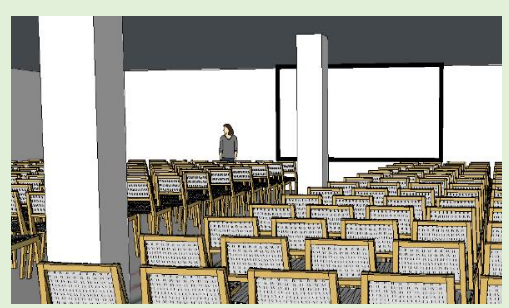
The lighting scheme within the gathering space was planned to work with the linear mechanical scheme to minimize conflicts with structure. ElumTools was used to ensure that the proper illuminance could be achieved in the space with the linear lighting scheme. Information exchanges within Revit were crucial to avoid conflicts between systems before group clash detection took place.

Transfer Element Design Methodology

The structural transfer elements were limited in depth by the plenum depth to avoid impeding upon the gathering space while providing area for MEP systems. As discussed in the Structural Report, the structural partners originally explored the use of typical W-shapes, castellated beams, story trusses, and plate girders, but these options were deemed unfeasible for various reasons. As a result, the structural partners developed the concept of attaching steel plates to W-shapes to achieve the necessary section properties to control deflection, while simultaneously limiting depth of the elements.







Mechanical Systems Layout and Acoustic Analysis

Effective information exchanges between structural, mechanical and electrical design partners were key to the successful execution of the gathering space design. The elimination of the center column line opened up the gathering space, but put additional stress on the mechanical layout. Autodesk Revit was used to coordinate structural, mechanical and electrical systems early on in the project to avoid physical system clashes in the future.

Once the gathering space was designed the mechanical partners performed a reverberation time calculation on the gathering space to insure that the design would be appropriate for the intended uses of the space. An optimum reverberation time of 0.69 seconds was achieved by coordinating appropriate acoustical materials in the ceiling using input from the construction and electrical partners.